REPORT

July 2013

PLATREEF RESOURCES (PTY) LTD

Alternative Strategies and Scenarios

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1.0 INTRODUCTION

Platreef Resources (Pty) Ltd (Platreef) is currently undertaking an investigation to assess the feasibility of developing an underground platinum mine on the farms Turfspruit 241KR, Macalacaskop 243KR and Rietfontein 2KS in the Limpopo Province. Platreef holds prospecting rights for these farms which are located approximately 5 to 10 km North West of Mokopane (Figure 1).

Golder Associates Africa (Pty) Ltd (Golder) has been appointed to develop an Integrated Waste Management Plan (IWMP) and to undertake a Waste Management Licence Application process in terms of the National Environmental Management Waste Act, 2008 (Act 59 of 2008).

Based on the waste inventory developed by Golder in consultation with Platreef, this report develops alternative strategies which could be implemented for each identified waste stream. The report contemplates the waste streams and their projected volumes in order to establish a sense of the feasibility on the appropriate scale.

The waste inventory developed by Golder is based on calculations done according to figures received for similar mining operations in South Africa and estimated numbers for workers on the mine. This however leaves room for uncertainty with regards to the exact figures. In the first waste inventory submitted to Platreef, Golder based calculations on a 3 million tpa mining output scenario, however due to recent changes in the mine plan, the waste inventory has been adjusted to fit a 4 million tpa output scenario. The projected waste inventory is included in Table 1 below:

Table 1: Waste Inventory (based on 4 million tpa scenario)

Waste Type	Source	Classification	Estimated Quantity	Waste Management Facility/Solution
Shaft Area				
Explosive contaminated waste, and explosives packaging	Blasting areas	Hazardous	17 tpa	Engineered detonating yard
Waste rock	Shaft excavations/ mine development	Could vary from general to hazardous, but in terms of the required design standards it could be reasonably accepted that non-hazardous designs supported by Source Pathway Receptor Modelling would suffice for authorisation applications	1780 000 tons total from bulk mine shaft sinking phase. 360 000 tpa from Year 1 onwards	Re-use options will be explored in part, and unusable portions to be disposed on on-site waste rock dump
Concentrator				
Explosive bags	Concentrator stores	Hazardous	4.7 tpa	Take back agreement/on-site or off-site disposal
Dry reagent Bags from flotation unit	Concentrator stores	Hazardous	21 tpa	Take-back agreement/re-use

Waste Type	Source	Classification	Estimated Quantity	Waste Management Facility/Solution
Lab waste	Laboratory	Hazardous	73 tpa	On-site/off-site H:H disposal
Tailings and residue from water treatment plant	Concentrator process	Hazardous	3.81 million tpa (dry)	On-site tailings disposal facility
Sewage Treatment Plant				
Domestic wastewater	Ablutions facilities and change houses	Bio-hazardous	164 ML/a at peak construction phase population to 50 ML/a in operation	On-site sewage treatment plant (STP), with potential re-use of sewage effluent
Sewage residue (sludge and screenings)	STP in shaft area	Bio-hazardous	21 tpa at peak construction phase population to 6.3 tpa in operation	Composting/ Incineration/ On-site/off-site disposal facility
Medical Centre				
General medical waste (including sanitary waste)	Medical station in the shaft area	Hazardous	8.7 tpa	Destruction On-site/off-site H:H disposal
Mine-Wide				
Domestic waste	Mine wide bins and storage facilities	General	1240 tpa	Separation (for recycling) On-site/off-site landfill
Packaging	New equipment & consumables brought on site	General	17 000 tpa	Recycling
Office waste	Offices in shaft and concentrator areas	General	1.04 tpa	Recycling and take-back agreement
Electronic waste	Offices	Hazardous	31 tpa	Recycling On-site/off-site H:H disposal
Wood and garden waste	transport and storage crates in stores	General	Approx. 1 300 tpa	Recycling Donate to community Composting
Rubber (Tyres and conveyor belts)	Vehicle and Equipment maintenance	General	51 tpa	Recycling On-site re-use applications
Scrap metal/steel (ferrous and non-ferrous)	Equipment and vehicle maintenance workshops	Ranging from general to hazardous	2 600 tpa	Recycling

Waste Type	Source	Classification	Estimated Quantity	Waste Management Facility/Solution
Used oil and grease	Equipment and vehicle maintenance workshops	Hazardous	22 tpa	Recycling On-site or off-site H:H disposal
Oil contaminated PPE/Rags	Mine wide	Hazardous	33 tpa	On-site or off-site H:H disposal or Incineration
Hydrocarbon contaminated soil	Mine wide, mostly at workshops	Hazardous	20 tpa	Spillage prevention plan, Bioremediation, Thermal Desorption, On-site/off-site H:H disposal
Used paint	Stores	Hazardous	40 m^3/a	Reduction Donate to community Take-back agreement
Used Batteries (Lead acid from mining vehicles and small NiCd from offices)	Workshops and designated bins mine wide	Hazardous	2.3 tpa	Take back agreement Recycling On-site/off-site H:H disposal
Crushed fluorescent tubes (traces of Hg)	Mine wide lighting, stored at designated hazardous storage area at shaft	Hazardous	1.1 tpa	Avoidance/reduction Recycling On-site/off-site H:H disposal

Most of these wastes will be produced both during the exploration/testing phase and the operational phase, with an estimated 150 and 3 500 personnel respectively. However it is expected that the wastes will be produced in different quantities relating to the size of the operation and number of people on site in each phase and any further, future expansion.

2.0 BACKGROUND

Platreef Resources (Pty) Ltd engages in exploration and production of precious and base metals such as platinum and nickel. The company was incorporated in 1988 and is based in Mokopane, South Africa. Platreef Resources (Pty) Ltd operates as a subsidiary of Ivanplats Limited. Ivanplats holds a 90% interest in the Platreef Project. Itochu, together with ITC Platinum, holds an effective 10% indirect interest in the Platreef Project.

The Platreef Project includes a recently discovered underground deposit of thick PGE-nickel-copper-gold mineralisation, in the northern limb of the Bushveld Complex. PGE-nickel-copper-gold mineralisation in the northern limb is primarily hosted within the Platreef, a mineralised sequence which is traced more than 30 km along strike. The Platreef Project is situated in the southern sector of the Platreef on three contiguous properties, Turfspruit, Macalacaskop and Rietfontein. The northern most property, Turfspruit, is contiguous with and along strike from Anglo Platinum Limited's Mogalakwena group of properties and mining operations.

The Platreef Project Area is located in the Mogalakwena Local Municipality of the Waterberg District Municipal Area. The study and surrounding area is situated in the catchment area of the Mogalakwena River and consist of the quaternary catchments A61F and A61G. The area of the two farms falls on 1:50 000 map sheets 2428BB (Tinmyne) and 2429AA (Potgietersrus) as seen on.

The prospecting rights area is located in the upper end of the Mogalakwena Catchment in a broad SE – NW trending valley. The project area lies within a water scarce region.

The study area is peri-urban and lies to the north west of Mokopane (Figure 1). The main roads to Groblersbridge (N11) and Marken traverse the area.

Extensive portions of the prospecting rights area are developed. The village of Ga-Magongwe is located in the northern boundary area on Turfspruit with Ga-Kgabadi in the west. Large parts of Macalacaskop are built up with the communities of Lekwlakala, Madika and Maroelereng. Recent expansion of the villages is evident.

The Tshamahanzi village is situated on the north eastern portion of the Platreef project area on the boundary between the farms Turfspruit 241 KR and Rietfontein 2KS. The portion of the Tshamahanzi village situated on Rietfontein 2KS is also the only village on this farm.

The existing N11 (main road to Groblersbrug) is currently positioned on the western side of the Tshamahanzi village and will be rerouted to pass the village on the north eastern side.

2.1 Context

Platreef Resources (Pty) Ltd (Platreef) has not yet commenced mining and in this context this report sets an ideal in respect of managing waste streams that assumingly will be generated. In setting an ideal IWMP, the following objectives need to be met:

- As a minimum, comply, but to ideally exceed waste related legislative requirements; and
- Establish an overall Integrated Waste Management Plan towards waste management optimisation and continuous improvement.

An underpinning philosophy to the IWMP is the waste management hierarchy (Figure 2) to assess waste management options through which waste, which is normally regarded as fit for grave, could find application as a resource which implies that it moves back to the cradle part its life-cycle. The waste management hierarchy as depicted below is from the South African National Waste Management Strategy of November 2011. It is structured as an upside down pyramid to indicate that the bulk of waste should be handled higher up the waste management hierarchy and that as little waste should reach the final option as possible.

The waste management hierarchy is an arrangement of waste management options, arrangement in descending order of priority. The waste management hierarchy should be applied in making decisions on how to manage waste.

Avoidance aims for goods to be designed in a manner that minimises their waste components. A reduction in the quantity and toxicity of waste generated during the production process is included in this step.

Re-use of an article removes it from the waste stream to be used in a similar or different function, without changing its form or properties.

Recycling involves the separation of articles from the waste stream and processing them as products or raw materials.

Recovery involves reclaiming particular components or materials, or using the waste as a fuel.

As a last resort, waste enters the lowest level of the waste management hierarchy to be treated and/or disposed of, depending on the best practice for that particular waste stream.

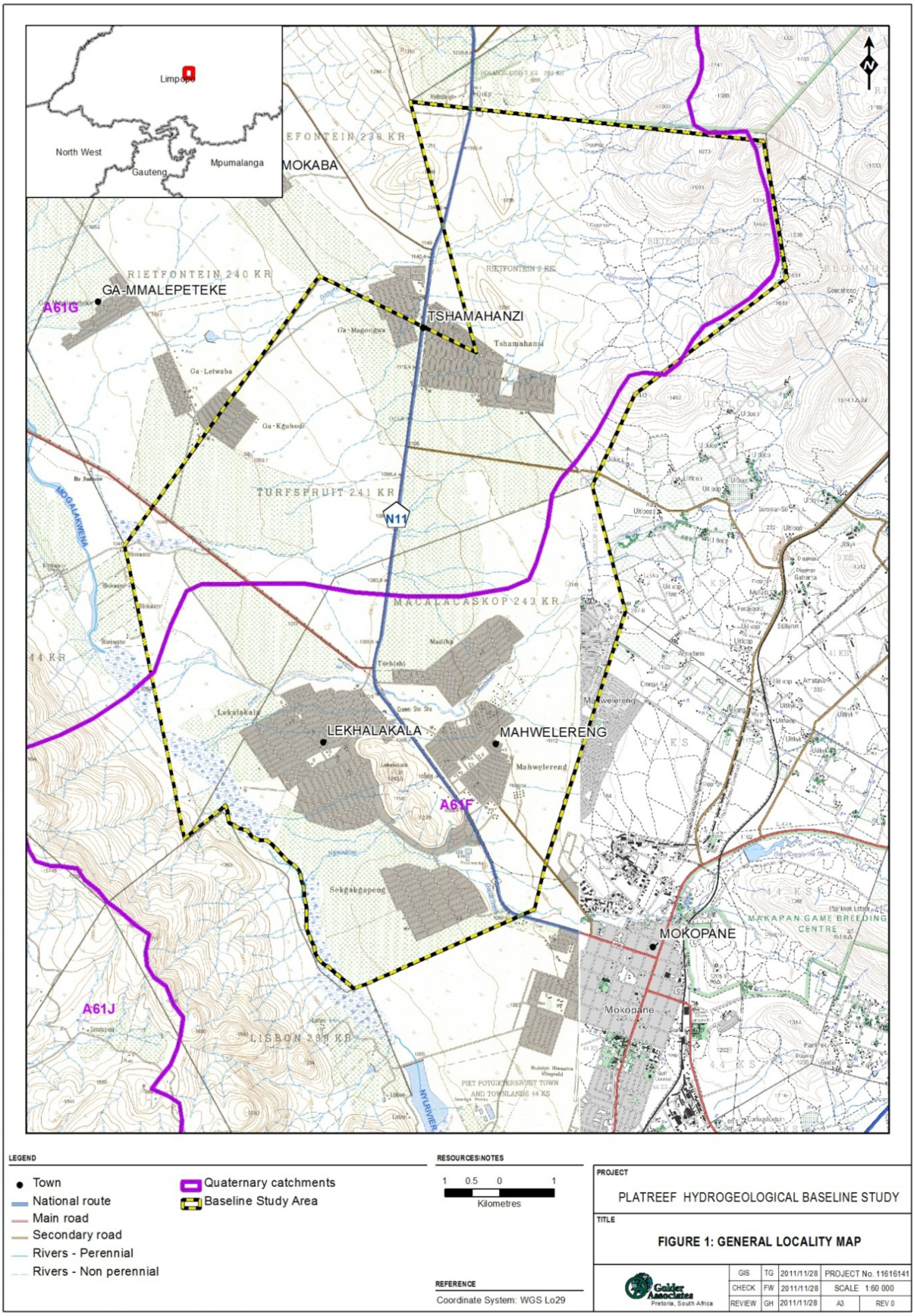

Figure 1: Locality map

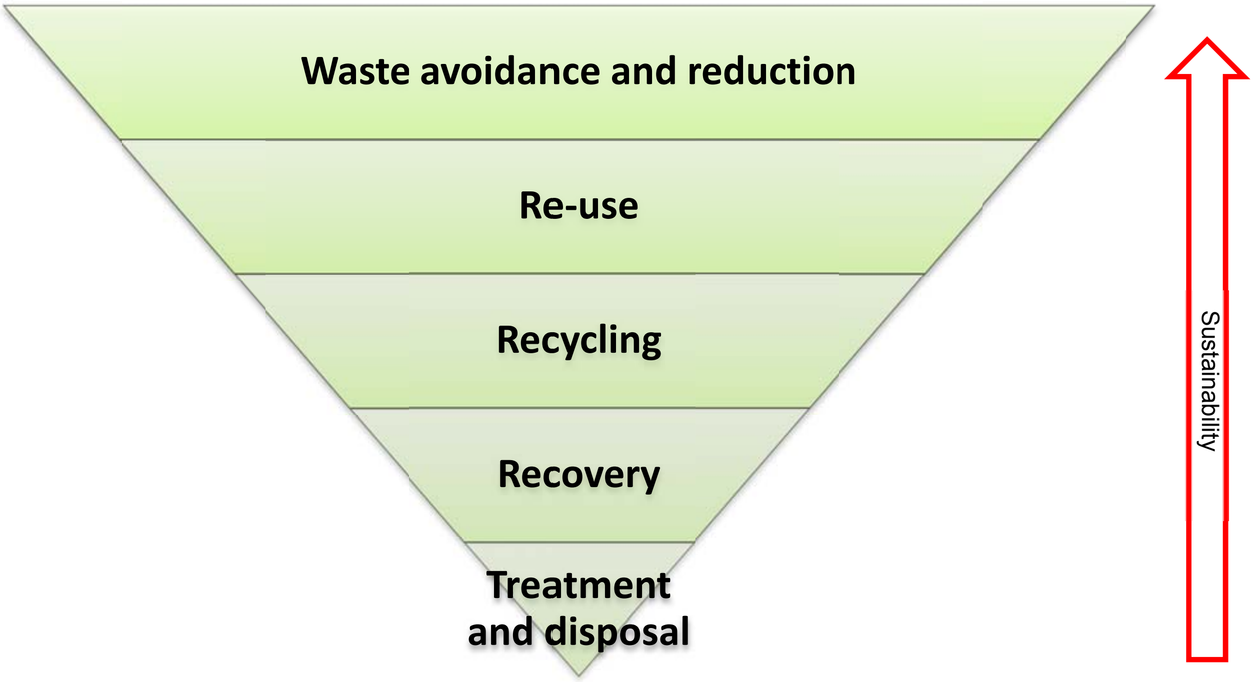

Figure 2: Waste management hierarchy[1]

3.0 OBJECTIVES

The objective of this report is to identify alternative management strategies for each of the listed waste streams and to evaluate the potential effectiveness of each strategy for the different phases of the mine's operation.

It seeks to advise Platreef in terms of best waste management planning options, for each waste stream. It also evaluates the option of establishing an on-site landfill as an alternative to sending waste off-site for disposal.

4.0 METHODOLOGY

For each identified waste stream (Section 7.0), a number of alternative strategies were identified to enable Platreef to reach the set goal, objectives and targets. This was done by means of the following:

- A review of various journals and online sources to obtain additional information for the assessment; and
- Various communications with Regulatory Authorities.

The various alternatives identified were evaluated as follows:

- A scoring matrix was undertaken to evaluate the various management options by means of a trade-off study using criteria which included aspects such as:
  - Legal requirements;
  - Typical unit cost;
  - Environmental risk;
  - Public sensitivity;

[1] National Waste Management Strategy; Department of Environmental Affairs; November 2011

   - Operational aspects; and
   - Sustainability.
- In the scoring matrix, the different scoring criteria were weighted, based on the level of control/ manageability in respect of affecting Platreef Resources' financial and operational feasibility; and
- The various identified waste management options/strategies were differentiated for chronological implementation in accordance with the waste management hierarchy. The dominant intent of such an approach is one of emphasis (and not preference) to identify which hierarchical option will present the larger benefits in going forward.

5.0 APPROACH

The IWMP which will result from this project is to contain elements that relate to the control of generation, storage, collection, transfer and transport, processing and disposal of waste in a manner that is in accordance with legislative requirements and best principles of public health, economics, engineering, aesthetics, and environmental considerations (Figure 3).

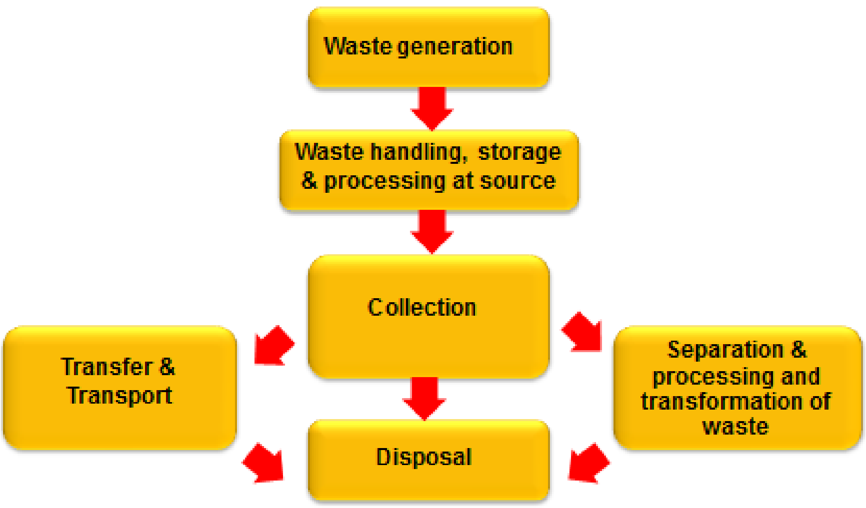

Figure 3: Elements of the IWMP

6.0 ASSUMPTIONS

- The waste inventory is based on what is expected in relation to similar mining operations in South Africa, however due to unique situations, there may be deviations in the accuracy of projected waste volumes;
- Waste volumes as in the waste inventory are based on the assumed staff numbers and operational aspects which have been alluded to by Platreef, however there are expected to be some variability due to uncertainty of these aspects;
- The bulk shaft sinking or construction phase, estimated to last 6 years, will produce a different waste stream to the mine wide operational phase, in both size and quantity. Wastes expected during construction or operation phase (or both) are listed here below:
   - Waste rock (both);
   - Dry reagent bags (operation phase);
   - Tailings (operation phase);

- Residue from water treatment plant (operation phase);
- Domestic waste water (operation phase);
- Domestic waste (both);
- Packaging waste – equipment/ supplies & consumables (both);
- Office waste (both, mainly operation phase);
- Garden waste (both);
- Sewage sludge and screenings (operation phase);
- Pallets (both);
- Medical waste (both);
- Explosives packaging (construction phase);
- Laboratory waste (both);
- Electronic waste (both);
- Waste tyres (both);
- Conveyor belts (operation phase);
- Scrap metal and equipment (both);
- Used lube oil and grease (both);
- Oil contaminated rags and PPE (both);
- Hydrocarbon contaminated soil (both);
- Used paint and tins (both);
- Used batteries (both); and
- Fluorescent tubes (both).

Wastes from construction and operation phase as listed above, have been investigated for alternative management strategies and are described in the investigation results section below. Preferred strategies will be taken forward in the integrated waste management planning process.

7.0 GENERAL LANDFILL TRADE-OFF ASSESSMENT

Golder has suggested the option of constructing an onsite landfill as a potentially feasible option in the long term. This has been considered against a number of alternative off-site disposal options, by means of a trade-off assessment. An alternative to constructing an on-site landfill would be to find an off-site landfill which offers security in terms of availability to receive waste, legal compliance and safe disposal certificates. Such off-site disposal would require removal and transport services from a private service provider, while on-site landfilling could be done by Platreef staff. A list of alternative disposal options with geographic locations and distances from Platreef have been listed below, while a map can be found in APPENDIX A:

- Disposal at the Mogalakwena Municipal class 2: Portion 80 of farm Piet Potgietersrust 44 KS; 4 km from Platreef;
- Constructing a Platreef owned cell alongside the Mogalakwena Municipal Landfill; same location as above;

- Transporting to the nearest available privately owned landfill; AAMM private landfill GCB$^-$: Zwartfontein 818LR; 3 km from Platreef; and
- Transporting to the nearest available alternative municipal landfill:
  - Roedtan GCB$^-$: Portion 95 of farm Byzonderheid 607 KS; 59.3 km;
  - Weltevreden Polokwane GMB$^-$: Portion 4 of the farm Weltevreden 746 LS; 79.7 km; and
  - Rebone GSB$^-$: Farm Steil Loop 403LR; 91.3 km.

Expected volumes

It is noted that for the construction phase 2014 – 2020, there will be 150 staff working over 3 shifts. During this time it is expected that 672 tpa of general waste will be generated. The amount of garden waste produced is unrelated to the number of staff on-site and it may even be more during the construction phase due to land clearing for mine facilities, this will be a non-routine amount and depends on the existing vegetation at the intended mine location.

During the operational phase, an estimate of roughly 900 tpa of domestic waste will be produced while roughly 1 000 tpa of garden and wood waste is expected at the Platreef mine. 20% of domestic waste and 80% of garden waste is anticipated to be recycled, the latter through composting. In addition, 80% of packaging is expected to be recycled with 20% going to landfill. Table 2 summarises inputs to landfill

Table 2: Waste volume assumption

Type	Annual m^3/yr	Recycled %	Landfilled m^3/yr
Bulk Shaft Phase			
Packaging	3 500	80	700
Domestic waste	150	80	30
Wood and garden waste	2 700	80	540
Total	**6 350**	**-**	**1 270**
Operational Phase			
Packaging	3 500	80	700
Domestic waste	2 400	80	480
Wood and garden waste	2 700	80	540
Total	**8 600**	**-**	**1 720**

Expected costs

The cost per ton for landfill at the existing landfill sites has not become available to the consultants, however the municipal average in South Africa is R 80 per ton, therefore it can be assumed that the cost per ton for disposal at these landfills will also be in the range of R 80 per ton. Therefore disposal of general waste is expected to cost R 101 600 per year during the construction phase (6 years) and R 137 600 per year during operation, excluding inflationary price increases.

Golder was able to find a local waste management company in Mokopane called Nieuwco. Their services include on-site waste services, collection, transport and the sorting out of recyclables, while the remainder will be disposed to the local landfill. The costs for general waste management services have been priced below:

- Daily servicing of general waste bins: R 3 500 per month;
- Monthly rental of 6 m^3 domestic waste skip: R 800 per skip; and

- Removal of 6 m^3 domestic waste skip within 10 km of disposal site: R 350 per skip removed.

Waste management infrastructure (Recycling)

This assessment has made reasonable assumptions for recycling as achievable by Platreef. Platreef will require some waste management infrastructure irrespective of how they decide to manage and where they decide to dispose of waste. Platreef will require bins for the collection of various wastes; a very practical option is purchasing wheelie bins with a capacity of 240 litres. These can be bought in various colours, labelled and demarcated as desired. Some options for the purchase of these bins are listed below:

- 240 litre wheelie bins delivered to site at R 580 each, price varies according to bin colour (Otto Waste Systems, Isando);
- 240 litre Bins at R 700 each (delivered to site), plus R 70 for signage (Nieuwco); and
- 240 litre bins at R 500 each (Plasticland, Johannesburg – excluding transport).

If Platreef opts for the 2 bin separation system, it is recommended that an on-site materials recovery facility (MRF) is constructed for the consolidation of waste for transportation and the separation of recyclables. This should be placed in a centralised location that is close to the on-site landfill (if constructed) in order to minimise transport costs. A MRF can be a simple building structure and often just a concrete slab with roofed area for the sorting and bailing of waste. A MRF can be operated by a waste management contractor or Platreef staff.

7.1 On-site landfill

The option to build an on-site landfill is subject to feasibility and trade-off study as this option will require significant capital expenditure for the establishment and licensing of the site. It is assumed to have a higher start-up cost but lower operating cost than the option of transporting waste to other off-site waste disposal facilities. It has been noted that the other mines in the area have established their own on-site landfills, indicating that it has been the most feasible option in other local cases:

A cost estimate for an on-site landfill would include;

- Licensing cost - currently being undertaken by Golder;
- Cost of constructing a facility – relative to the size of the waste stream expected. Costing for a total 36 year lifespan landfill has been estimated as roughly R 48.5 million. This cost will be expressed in phased development of a landfill which is roughly estimated at R 8.13 million for the Bulk Shaft construction phase and R 6.73 million for each 5 year period of mine wide operation subsequently;
- Machinery for transport, placement and compaction (trucks/tractors and a bulldozer); and
- Labour or contractors.

If Platreef decides to construct a landfill; they have the option to build a landfill with sufficient capacity for the full life of mine, or to build landfill cells in a phased approach, creating capacity for 5 years at a time, with the option to close or extend the landfill after each period. This would assist Platreef to spread the capital expenditure and the risks associated with the mining industry. It is suggested that the cells are developed as part of the long-term landfill footprint.

Due to the short timeframe until shaft sinking commences and the licensing required with full scale facilities it is suggested that Platreef initially provides a single cell landfill not exceeding 50 m^2 (and total capacity of only about 50 tons at 3 m height) which will have the objective of remaining below the licensing threshold and providing airspace until licensing is resolved. In effect, the temporary cell will act as not much more than one month’s storage from which trucks will be filled for transport to temporarily arranged landfill off site.

Table 3: Landfill costing

Landfill Costing							
36 year :	R 48.5 million		Linear phased development cost assumption; no inflation; assumes cells merged to single square cell; 15 m ultimate waste height; 1:20 Industrial cover only				
	Bulk Shaft	**Mine Wide Operation**					
Cell No.	1	2	3	4	5	6	7
Cell Life	0-6 years	7-11 years	12-16 years	17-21 years	22-26 years	27-31 years	32-36 years
Incremental Cost, mR	8.1	6.73	6.73	6.73	6.73	6.73	6.73
Simple Cumulative Cost, mR	8.1	14.9	21.6	28.3	35.1	41.8	48.53
Landfill Area (15 m Height), m^2	400	2 025	4 225	5 625	7 225	9 025	12 100

Table 3 presents a phased development of landfill cost for cells development on an approximate 5 year cycle. The incremental cost for a cell in the operational phase is approximately R 1.35 m per year. In reality a larger part of the CAPEX loading will occur in the earlier years. The cell height development is assumed to be 15 m and as cells are developed, they are merged at some stage to reach this height. Approximate area requirements are also shown.

7.2 Mogalakwena Municipal Landfill

The most obvious off-site disposal option is the Mogalakwena Municipal Landfill situated on the South-Eastern border of the town of Mokopane, as it is the nearest public sector landfill. This site was licensed in 1994, according to the license conditions the site may accept all general waste types but no hazardous wastes such as:

- Any medical and pharmaceutical waste;
- Acids and alkalis;
- Asbestos;
- Any petroleum products; and
- Chrome, Copper, Nickel, Lead, Arsenic and various other heavy metals and chemical bonds.

According to liaison with a local municipal official, the site life will only be for two or three more years until capacity has been reached. At that stage the municipality will either have to extend the site and apply for a new license, or find alternative landfills for the disposal of their waste, these alternative landfills are listed in section 7.5.

This option poses a risk to the Platreef project, as there is no guarantee that the Mogalakwena municipal landfill will be able to accept waste from Platreef for the duration of the mining project. If Platreef decides to use this as the primary disposal option, Platreef should ensure there is a guaranteed secondary option to fall back on in the event that the Mokopane landfill is no longer able to receive waste from Platreef.

7.3 Platreef owned cell at the Mogalakwena Landfill

It has been proposed that Platreef could sponsor the establishment of a new cell at the existing Mogalakwena landfill that would be dedicated for the disposal of waste from Platreef. Much like constructing an on-site landfill, this option will require a new license application and incur similar start-up costs for the construction. The potential benefits include:

- Loss of operational and long-term liability;
- No requirement for operational staff and equipment; and
- A relatively close disposal option, that provides design disposal capacity for the life of the mine.

The risks and draw-backs associated with this option include:

- Platreef would likely need to prepare a total cell capacity for 30 years usage bringing more of cost up front than would be required for on-site landfill;
- The operator (municipality or private) could dispose of waste other than that planned for from Platreef, namely municipal waste from the surrounding settlements, thus filling the cell before the expected date;
- The operator may not adhere to license conditions and thus disqualify the use of the landfill;
- Increased transport cost due to greater distance (relative to on-site); and
- Site establishment, licensing and operating costs will be the same as for an on-site landfill, but transport costs will be higher.

As for an on-site landfill, Platreef could opt to construct an off-site Platreef owned landfill in a phased approach, with cells having a life span of 5 years at a time. This would help to spread the cost and risks over an extended period. This strategy would have to be discussed with the relevant municipal officials and legal agreements would have to be signed to ensure security of access to Platreef. In this case, significant additional costs for site selection including EIA would be incurred.

7.4 Alternative privately owned landfill

There is a privately owned landfill belonging to a nearby platinum mine; Anglo American Mogalakwena Mine (AAMM) roughly 3 km away. AAMM had a previous landfill which has reached capacity and the new landfill to be commissioned in 2014 will have space for general waste, bioremediation of hydrocarbon contaminated soil and temporary storage of hazardous wastes before it is removed to Holfontein by a waste contractor.

As an alternative option, Platreef could establish a mutually beneficial relationship with AAMM for the management of certain waste types; namely domestic waste for landfill and hydrocarbon contaminated soil for inclusion in their bioremediation process.

It is expected that AAMM will charge Platreef premium prices for the use of their waste management facilities, as they may not have catered for the extra waste stream in their original planning. This option may also be reliant on the relations between Anglo-American and Platreef.

7.5 Alternative municipal landfills

In the event that other nearby off-site disposal options become unavailable; i.e. Mogalakwena landfill is over capacity and AAMM declines to offer disposal services; Platreef may need to seek off-site disposal further away. There are a number of alternative municipal landfills in the area which may serve as alternative disposal options in the event of unfeasibility of an on-site landfill. These landfills include:

- Roedtan waste disposal site, 59.3 km from Platreef;
- Weltevreden landfill Polokwane, 79.7 km from Platreef; and

- Rebone waste disposal site, 91.3 km from Platreef.

In such cases the estimated cost of disposal does not vary from R 80, but the cost of transport increases significantly due to the increased distances.

7.6 Trade-off Assessment

On-site landfill might average as R 1.35 million capital expenditure, CAPEX per year. Off-site disposal may result in similar CAPEX costs but will also result in higher operating costs, OPEX such as tipping fees and transportation costs. Since off-site disposal is more exposed to risk, even higher costs might be expected to result over time. The general cost of waste disposal is expected to rise considerably over the life of mine.

Taking some typical potential off-site costs, in addition to anticipated higher CAPEX of off-site facilities, Table 4 describes considerable potential off-site OPEX costs of disposal. These costs assume that the same percentage recycling is achieved as was applied for on site assessment.

Table 4: Off-site OPEX estimations

	Bulk Shaft Phase	Operation Phase
Transport (R 6/m^3/km) 80 km	R 610 000/yr	R 826 000/yr
Tipping Fee R 80/m^3	R 102 000/yr	R 138 000/yr

There are various factors which favour different options and, these factors have been utilized to generate a ranking in the table below. The ranking provides some indication of which factors promote which of the available options. Criteria against which each option was scored were:

- Capital Expenditure;
- Operating Expenditure and transport;
- Lifespan;
- Ease of implementation; and
- Sustainability.

Scoring applied for the favourability of each option against each criteria, is as follows:

- 1: unfavourable;
- 3: Neutral; and
- 5: Favourable.

Table 5: Trade-off Assessment

Alternative	Capex	Opex/ Transport	Lifespan	Ease of Implementation	Sustainability	Total
On-site landfill	5	5	5	1	5	21
Mokopane landfill	5	3	1	3	1	13
Platreef cell at Mokopane landfill	3	3	3	3	3	15

Alternative	Capex	Opex/ Transport	Lifespan	Ease of Implementation	Sustainability	Total
Nearest Private Landfill (3 km)	3	5	3	1	3	15
Nearest Alternative Municipal Landfill:	3	1	3	3	3	13
-Rebone (59.3 km)	1	1	3	3	3	11
-Weltevreden (79.7 km)	1	1	3	3	3	11
-Roedtan (91.3 km)	1	1	3	3	3	11

According to the scoring matrix above, the most favourable option is for Platreef to establish an on-site landfill, while the second most favourable option would either be to negotiate the use of the Anglo American landfill which is roughly 3 km away or to establish a new, dedicated cell at Mokopane landfill, while the fourth most favourable option is to send waste to one of the three municipal landfills, alternative to the Mokopane landfill.

8.0 HAZARDOUS LANDFILL TRADE-OFF ASSESSMENT

A combined volume of over 240 tpa of hazardous waste is also expected during mine operation. Types of hazardous waste expected include:

- Explosive waste, shaft sinking phase, 17 tpa;
- Dry reagent bags, operational phase, 21 tpa;
- Lab waste (samples and chemicals – mixed hazard ratings) throughout mine life, 73 tpa;
- Incinerator ash, if implemented, throughout mine life, 4.4 tpa;
- Medical waste, throughout mine life 8.7 tpa;
- Used oil and grease, throughout mine life, 22 tpa;
- Oil contaminated rags and PPE, throughout mine life, 33 tpa;
- Hydrocarbon contaminated soil, throughout mine life, 20 tpa;
- Used paint, throughout mine life, 40 m^3/a;
- Used batteries, throughout mine life, 2.3 tpa; and
- Fluorescent tubes, throughout mine life, 1.1 tpa.

These figures total over 240 tpa. A separate cell for hazardous waste would be required at an on-site landfill in the event that Platreef prefers this option to transporting hazardous waste to the nearest off-site disposal option. The nearest fully licensed H:H landfill is:

- Holfontein H:H: Portion 23 & 24 of the farm Holfontein 71IR; 283 km from Platreef.

9.0 INVESTIGATION RESULTS

Desktop studies were undertaken to identify potential alternative strategies for the priority waste streams expected to occur at the Platreef operations.

9.1 Waste rock

During the mining process, waste rock is generated due to sinking of shafts, drilling and extraction of rocks. Waste rock is the largest source of waste generated in mines, and while it may not necessarily be a hazardous waste, it does require proper disposal.

9.1.1 Re-use

The waste rock generated by mines, due to the reduction of particle size, undergoes a large increase in volume. This means that if it were attempted, it would not be possible to return all of this waste back into underground mined-out areas. The remaining rock is usually detrimental to the environment. This makes reuse or recycling of this waste rock highly desirable.

In many situations, much of the waste rock is not hazardous to public health, and can be reused for various purposes. Uncontaminated waste rock has been used in various building or decorative applications, in road making, for railroad banks, river embankments, dikes and dams. Waste rock and tailings have also been used to make materials such as cement, bricks, concrete and glass, depending on the make-up of the rock.

There are a number of limitations to the reuse possibilities of waste rock. First and foremost, the rock must be tested to make sure that it is safe for reuse. Metals such as lead and other toxic elements can inhibit plant life and degrade water quality. This is also the case with sulphidic rock, which is prevalent in South Africa, which causes acidic drainage when it comes into contact with water and oxygen. It is thus important to select the correct rock sections, where available, for reuse purposes.

Waste rock, and especially tailings, is likely to include an excess of fines which makes reuse as concrete limited. In such a situation, slag waste may be found to have enough coarse content, and can be selected to be used for this purpose.

Waste rock could be re-used in an application to mitigate noise and visual impacts, through the construction of a berm on the perimeter of the site. This berm should be at least 5 m high and have stable side slopes. This re-use option must take cognisance of the chemistry of the waste rock and its potential to pollute a water resource and the need to control run off from such construction. The information for water quality management and run off management will come out of the geo-chemical analysis and hydrology studies respectively.

It has been noted that a potential off-site demand or available repository for the Platreef waste rock may exist with the neighbouring Anglo mine. Although the details of this have not become clear at this point, Platreef should investigate this option with a duty of care approach, meaning that it may be done under environmentally compliant circumstances only.

9.1.2 Recycling

It is not uncommon for mines to backfill marginal or uneconomic grade ore. Under certain circumstances, the backfill may even be mined in future years should recovery of this ore become economical. This method of waste rock management may also have the added advantage of increasing the stability of the ground, as is discussed under section 9.1.3.

9.1.3 Disposal

Backfilling

Backfilling is the act of sending used rock (or tailings) back into the mined-out part(s) of the mine, which are no longer in use. Material which has not been mined may also be sent into the mine voids, such as slag. This is called infilling, and is also a method of disposal.

Due to volume increase from milling and other operations, a maximum of about 50% of the mined ore can be backfilled. Therefore only in the unlikely event of a greater than 50% ore grade can there be no leftover waste rock. However, backfilling can cause a huge reduction in waste rock to be disposed of. In addition to being a method of waste disposal, backfill has the following advantages:

- It may improve ground stability;
- It provides support for further mining, and increases mining safety;
- It is an alternative to surface disposal, and thus decreases above ground surface disturbance;
- It minimises the mining footprint; and
- It may improve ventilation.

There are a number of ways in which backfilling may be accomplished. Each of these methods is discussed briefly below[2]:

- Dry backfill – dry backfilling is the simplest method, and is used where structural backfill is not required. In this system, unclassified sand, rock, tailings and/or slag is transported underground by dropping it into a stope;
- Cemented backfill – this method entails mixing waste rock or coarse tailings with cement or fly ash slurry to improve the bond strength between rock fragments. The mixed slurry may be placed in voids as is or a slurry can be percolated through rock after it has been placed;
- Hydraulic backfill – This method makes use of slurried tailings or sand deposits mined at the surface, which are dewatered to approximately 65 – 70% solids. Hereafter, it is passed through a hydrocyclone where the coarse fraction is collected and pumped to the stope through a series of pipes. This backfill may be cemented or uncemented; and
- Paste backfill – This is a high density slurry which has a higher content of fines in order to allow it to be pumped. Whole mineral tailings are often used to make paste backfill. Paste backfill is more expensive to pump but results in a denser fill and thus more efficient use of space.

Backfilling may require additional tunnel operations to move the material, as well as possible creation of open spaces to temporarily manage the wastes before backfilling, which may result in an increase in immediate disposal costs. Also, as with reuse purposes, it is important to make sure that the rock that is backfilled will not result in leachate formation which may find its way to underground water sources.

Disposal on rock heaps

In general, the formation of waste rock heaps is inevitable due to the volume of rock retrieved from underground. Delivery of the waste rock to the heap is done by conveyor or trucks. These heaps are monitored regularly for stability. Surface run-off is collected and may be treated in the water treatment plant or discharged into the return water dam.

Waste rock heaps, although their hazard potential may not remain for as long as the tailings facilities require proper design to ensure stability and to minimise erosion, seepage and dust emissions. Progressive reclamation can also reduce erosion and dust emissions.

Other disposal considerations

Waste rock and tailings are infrequently disposed of together, but occasionally where backfilling is involved. Waste rock on its own may be used as erosion protection on the walls of the tailings facility, especially in cases of centreline and upstream tailings wall raises or crushed and graded as part of tailings berm construction.

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[2] European Commission. *Management of Tailings and Waste-Rock in Mining Activities.* 2009

Selective rock management may also be a great advantage. Sulphidic waste rock produces AMD and requires special management, especially after closure of the mine, to prevent acid water formation. Separation of sulphidic and non-sulphidic rock types is practiced to make management easier. Non-sulphidic rock may be used as a protective layer above sulphidic rock in deposition and rehabilitation, with a possible clay layer placed between these rock layers to further protect the core sulphide rock from rain seepage and to reduce oxygen supply. Non-sulphidic rock may be useful as a construction material. Separation of these rock types to optimize reuse can result in a cost saving potential for the mine.

9.1.4 Trade-off Assessment

None of the above options is a complete solution for the entire waste rock volume expected to be generated at Platreef. For this reason all possible management measures should be implemented as far as possible starting from the highest levels of the waste hierarchy, all the way through to disposal; with disposal volumes being reduced by the other strategies as far as possible. This preference for the waste hierarchy is reflected in Table 6 and Table 7.

9.2 Reagent bags

Dry reagent will be used in concentrators to aid in the separation of platinum from other mined rock. One example of this reagent is called xanthate. Dry reagents will only be used when the concentrator is online, i.e. during the operational phase. These reagents are expected to be delivered to the mine in heavy duty bags made of plastic or fabric. The mechanical process of opening the bags results in the complete destruction of bag integrity thus eliminating the option for bag re-use. Platreef will investigate opportunities for bulk delivery of reagents to reduce use and resulting disposal of bags.

Xanthates, as a particular example decompose in the presence of water to form a number of different compounds, some of which pose a health risk, are explosive and are flammable. Both solid and liquid xanthates pose high occupational risks. In addition to inhalation and ingestion hazards, skin contact and absorption of xanthate into the skin may lead to irritation, eye damage, nausea, vomiting and even blood contamination. Xanthates are spontaneously combustible. Explosive carbon disulphide is present from the time of manufacture, and increases with decomposition over time, making xanthate more dangerous with the passage of time. For safety purposes, xanthate bags should be resealed and stored in clearly defined areas. Where a take-back agreement is in place, empty xanthate bags must be sealed and temporarily stored in clearly marked areas before being removed by the contractor. Empty bags must be disposed of as hazardous waste.

Procedure

A safe handling, transport and management procedure should be developed with the particulars of the process for specific wastes within each category, noting the importance of tailoring disposal to each waste as emphasized by the example above. This tailored management for each waste should include health and safety considerations and form part of the IWMP.

Take-back agreement

It is suggested that Platreef include a take back agreement into contracts with dry reagent suppliers. In this way, vehicles delivering dry reagent will collect used containers/bags from previously delivered reagent. This will encourage the suppliers of the bags to improve their packaging strategy, by means of using bulk packaging, or finding downstream uses for the bags.

Re-use

In some cases reagents may be delivered in more rigid containers. Empty plywood/reconstituted particle boards used to transport/hold the dry reagent may be reused by the supplier for the same purpose, recycled or disposed as general waste. If such boards are to be recycled, any metal attachments such as reinforcements on the corners should be removed prior to transportation to the recycling facility.

Disposal

Floor sweepings of reagents must be separated from other wastes and disposed of immediately as hazardous waste. Specific procedures apply but, by example spilt solid xanthate may be dissolved in high pH water and reused if possible.

9.3 Cement bags

During the Bulk Shaft Phase of the mine, it is expected that large volumes of concrete will be used in the construction of various site buildings and other on-site infrastructure. Cement is generally packaged in 50 kg heavy duty, multi-layer paper bags, which fall under the category of packaging waste. The way in which bags are opened destroys the integrity of the bag, thus ruling out the possibility of re-use of the bags. A bulk cement plant would permit bulk delivery but will not completely displace the use of bagged cement.

9.3.1 Minimisation

Platreef will be acquiring the services of construction and building contractors for the establishment of the mine site. The supply of concrete will most likely be included in the construction contracts. A take-back agreement for cement bags under the supply contractors will prevent the cement bag waste from becoming a liability to Platreef.

Another way to minimise the production of waste cement bags is to buy the cement in bulk. This can be done either through the acquisition of ready mixed cement delivered to site, ready for application, in cement mixing trucks or establishment of a modular cement mixing plant on site, particularly during the main construction phase. In this way cement bags brought onto site are reduced along with the risk of cement bags being left for Platreef to clean up at a later stage.

9.3.2 Recycling

The paper used as cement bags can be recycled into high quality cardboard through a selected recycling or waste management contractor. If the waste is being transported over long distances, it should be compressed or bailed in order to maximise transport efficiency.

9.3.3 Composting

It has been reported that in some instances cement bags can be used in composting. This is despite the small volumes of cement still in the bags. Cement bags with small volumes of cement are compostable, but they do not add value or nutrients to the compost material. This would be a disposal technique rather than a value adding strategy. Furthermore, addition of paper to composting operations needs to be strictly controlled, as paper may bind when wet and inhibit the composting process.

9.3.4 Energy recovery

Cement bags are highly combustible and can be co-combusted in cement kilns. Since cement bags originally come from cement factories, the return of cement bags to the cement factory for incineration in the kiln can become part of a take-back agreement. This should be coordinated through the construction contractor, when transport can potentially be combined with the return of bagged cement delivery vehicles.

9.3.5 Disposal

Concrete is classified as an inert waste and thus it can be disposed to a general landfill. Since the bags are made of paper and cement is inert, the entire cement packaging body can be disposed without treatment to a general landfill. If the waste is being transported over long distances, it should be compressed or bailed in order to maximise transport efficiency.

9.4 Tailings

The tailings of a mine originate from the concentrator, where valuable ore is separated from unwanted rock using chemical separation techniques such as flotation. At this point, the ore and waste rock are in a finely ground form (for platinum likely smaller than 100 µm sized particles). The unwanted rock, or tailings, has no more ore value and needs to be managed as a waste material. The management of these tailings will only be required once the concentrator has been commissioned.

9.4.1 Re-use

Tailings have infrequently been used together with waste rock for reuse as a building aggregate or in cement-making. Since tailings have a much smaller particle size distribution than waste rock, the potential use of tailings is more limited. Also, tailings may have trace elements of chemicals used in the concentration process. The tailings will thus have to be tested and classified so that reuse possibilities may be investigated. Reuse of tailings will result in a smaller required tailings storage facility which is a cost benefit.

Backfilling

Backfilling has been described in section 9.1.3. Note that this method of disposal is only feasible where the tailings are not reactive or will not result in leaching to underground water sources. This limits the application of tailings as backfill to cases where the tailings material has been chemically tested and delisted as potentially hazardous and a method of placing fines is developed appropriate to the fines physical properties. Platinum tailings fines may require cementitious binding for such placement to be effective, to prevent shifting or migration of fines. Environmental and legal barriers are often met when attempting to use tailings for backfilling.

9.4.2 Disposal

Disposal of tailings on a tailings storage facility

It is very common for tailings to be disposed of on a tailings storage facility. Once mining processing has completed, this facility must be rehabilitated, which is a major cost factor in mine closure.

Tailings are generally thickened to a solids content of 25% to over 50% by mass to improve the rate of drying and consolidation of the tailings after it has been deposited on to the tailings storage facility. This also reduces the length of time required before the tailings facility can be considered environmentally safe and stable after closure of the mine. The extent of thickening of the tailings also determines the beach angle of the tailings facility. The smaller the pool (and larger the beach area), the sooner the tailings will stabilise and the smaller the volume of water which will be lost to evaporation.

Conventional tailings disposal methods are summarised below:

- Valley storage for sludge – this type of facility maximises the volume of tailings which can be stored for a given wall height, but deposition of fines against the water-retaining containment wall could affect its stability. This facility will also most likely require a final spillway;
- Sludge disposal to a ring containment wall – this facility is located on relatively flat ground and has a central decant area which removes the need for a water-retaining containment wall. This method also minimises land footprint but requires proper closure to prevent on-going seepage;
- Sludge disposal to a series of cells – in this system, disposal is cycled between the cells to allow consolidation of each cell before new tailings is added. Similarly to the ring method, the decant is centralised so no water-retaining containment wall is needed, but proper closure is needed to stop on-going seepage;
- Central thickened discharge, down valley discharge or thickened sludge disposal to a ring containment wall – all of these methods utilise thickened sludge, which increases costs of thickening and pumping. However, these methods minimize the effect of the tailings facility on natural drainage channels, reduce water and process chemical losses, and accelerate the time needed before rehabilitation can take place; and

Table 6: Trade-off Assessment for Waste Rock

Strategy Type	General Notes	Waste Rock													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/ Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals (skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
		Not Required: 5	Yes: 1	Yes: 1	Yes: 1	Low cost: 5	Current practice: 5	Easy: 5	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
		Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
		Required, but complex process: 1	No: 5	No: 5	No: 5	High cost: 1	None to date: 1	Difficult: 1	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
Weighting 1 = (Low) Largely uncontrollable with implications having the potential to detrimentally financial feasibility of operations 3 = (Fair) Although important, it is manageable in respect of affecting Platreef's financial and operational feasibility 5 = (High) Manageable in respect of affecting Platreef's sustained financial and operational activities															
Weighting		1	3	3	3	5	3	1	1	1	1	1	3	5	
Option Score Result Matrix * (Selected Strategy Score cell value is multiplied by Weighting cell value and the results summed to produce each Option score result)															
1. Re-use as building material, road construction, etc.	Only for classified safe-for-use waste rock	3	5	3	3	5	3	1	5	5	3	3	5	5	127
2. Backfilling		3	5	3	3	3	3	3	3	5	3	5	1	5	107
3. Disposal on waste rock heaps	Within mining rights area	3	1	3	3	3	5	5	5	5	3	5	1	3	95

Table 7: Further considerations in support of Table 6 above

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
1. Re-use as building material, road construction, etc.	Should the waste be removed off-site, the downstream application of the waste will require an authorisation in terms of the NEMWA (either to be applied for by Platreef or company Platreef sells the waste to)	Low, depends on cost to separate rock types	Classification is required, otherwise it may pose risks to soil and water quality	Public may be sensitive to using mine wastes, especially in public areas	**Possible income, reduction of disposal costs**	**Value added to waste, rock must be classified beforehand**	Sustainable use of waste reduces the use of natural resources. However, rate of generation vs. rate of disposal required does not make this option sustainable in the long term, unless contractual agreements are entered into with multiple companies	127
2. Backfilling	Approved EMP in terms of MPRDA, Water Use Licence in terms of NWA, Exemption from Regulations GN R.704	Medium	Reactive rock may result in risk of formation of acid mine drainage, although risk is reduced compared to rock heap disposal	Low, although people may perceive underground disposal as a risk to quality of borehole water	Improves ground stability	Cannot be used for all the waste (limited volume), rock must be classified beforehand	Sustainable return of waste to its origin	107
3. Disposal on waste rock heaps	Approved EMP in terms of MPRDA, Water Use Licence in terms of NWA, depending on classification of the waste (i.e. does it have the potential to pollute water resources)	Medium	Dust issues, possible leachate formation	Well-known solution, but large surface disposal facility will be subject to public scrutiny	Ease of implementation	Remediation removes many of the environmental issues	This option is sustainable until the life of the facility has been reached; future expansions to the facility may be restricted by land access/neighbouring communities	95

- Disposal of slurry in a pit or underground – this method has the advantage of reducing or eliminating the need for surface tailing storage areas and can be done using gravity alone. However, the tailings do not dry out quickly, if at all, and it is difficult to recover supernatant. Any supernatant which can be recovered requires additional pumping power to overcome the head.

There is a growing requirement for liners under the tailings facility, even though liners were rarely used in the past. If a liner is not to be used, there must be sufficient justification for this. Where the foundation does not have a very low hydraulic conductivity, a compacted clay or geomembrane liner may be used. A geomembrane liner has a lifetime of maximum 50 to 100 years. It is thus usually used in combination with a clay layer.

Due to the nature of platinum tailings, dust may become an issue. In order to control dust emissions generated from the tailings storage facility, there are a number of options that may be employed. The tailings may be discharged so as to maximise the wetted surface, even though this increases evaporative losses. Gravel may be used to cover the surface of the facility. Chemical dust-suppressants may be sprayed onto the tailings. Other operational methods will be considered in design of the tailings storage facility (TSF) and of the dewatering plant in place before tailings are pumped to the TSF, which may also reduce dusting impact.

9.4.3 Trade-off Assessment

The most preferred option is to re-use tailings in other on-site or off-site applications such as in cementitious and other construction applications. This is subject to the classification of the tailings, which in turn depends of the type of minerals in the rock and the process used in the concentrator.

The next most favourable option is for tailings to be mixed with waste rock and used for backfilling mined out spaces. This adds value to the mine, while reducing the need to dispose of some of the tailings material.

The least favoured option is for tailings to be disposed into the planned TSF, as this requires a large capital outlay, yet does not add any value to the material. This is however a necessary option as the other options do not deal with the entire mass of tailings produced (Table 8 and Table 9).

9.5 Waste water

The proposed Platreef mine is situated in a water scarce setting. At present, the source of potable and process water has not yet been decided due to the fact that the closest river is already over-allocated and the nearby municipality is not over-eager to provide the mine with board water. As a result, it is of extreme importance to use and reuse water very wisely on the mine.

In order to ensure the maximum water usage for the least raw or fresh water utilisation, water reuse and recycling is of utmost importance. To further ensure the maximum water use for the least amount of water treatment, water pinch technology could be utilised for the overall plant. Various options of water conservation are discussed further in this section.

9.5.1 Re-use

Waste water can be reused in a number of processes where clean water is not required. For example, water used for the transportation of ore or water collected from seepage can be reused for milling of ore or for dust suppression. Water utilised for transportation of mine rock or for milling of ore can be reused a number of times in the same application without requiring treatment. Also, water collected from the return water dam or other collection points can also be reused in the plant where pristine water is not required. Reusing water entails using the waste water from a cleaner process as feed water for a process that has lower water quality requirements than that process.

It is the current intention of the mine to re-use all waste water through blending and feeding back into the process. This is a result of water scarcity in the area and insecurity of supply.

9.5.2 Recycling

In the case of waste water, recycling of waste water requires treatment of the water. Treated water can be used for a far wider variety of purposes than wastewater exiting directly from a process. Treatment of wastewater is discussed in further detail under section 9.5.4.

9.5.3 Recovery

Water may be recovered from sludges and other wastes or from stormwater runoff by using drainage and collection systems. This water may not be of a high purity and may thus possibly only be used in applications which can handle the dirtiest of water, or else will require treatment before reuse. Water recovery, however, is very important since it presents a source of water which replaces precious freshwater sources, and which would otherwise go to waste and/or may cause water pollution in the environment.

9.5.4 Treatment

There are different levels of treatment possible for waste water, depending on the required quality of the effluent water. The lower the level of treatment, the lower the cost of treatment will be, but also the fewer the possible reuse opportunities for the water.

The simplest form of treatment is separation of suspended solids from water. Suspended solids, if in high concentrations, can make pumping of the water difficult. Solids content may also result in pipe, pump or valve damage in the long run. Unnecessary suspended solids in water may also reduce effectiveness of processes such as the flotation or concentration process. The suspended solids removal process is thus necessary yet is comparatively simple and cheap.

Solids separation from water is not enough to produce water which is safe for discharge into the environment which requires further treatment such as filtration and possibly membrane treatment or ion exchange to meet discharge Standards. Membrane treatment and ion exchange are expensive technologies to use, but may be necessary to produce clean water safe for discharge if dissolved solids levels need to be adjusted. Since this is the most expensive option available, it is important to reuse and recycle water as much as possible to reduce the volume of water which requires treatment. Due to the high evaporation rate, there is a net influx of water required into the mill boundary. With effective water management within the mill boundary, no water need be discharged to the environment.

9.5.5 Water pinch analysis

Water pinch analysis for a complex facility involves a combination of water re-use, recycle and treatment processes. Water pinch lists the different water quality requirements for different processes and the different water qualities of the various waste streams to reuse all water and to dispose of the solid residuals from water treatment without water wastage. A water quality only slightly above the required quality for a process may be used instead of using clean water. For example, it is preferable to use clean water at bathroom sinks for hand washing, producing grey water, and thereafter using this grey water for flushing producing black water. Treated black water effluent can be reused for irrigation or process water. Water used in cleaner mining operations can also be reused for dust suppression or milling or for transportation of ores.

Water pinch analysis can only be properly done once all the water requirements have been determined for the plant and a detailed water balance developed. This analysis also requires expert opinion to carry out economic analysis of options, to balance potentially higher capital cost for structures used to transport or temporarily store water in reuse and recycle applications with higher operating cost in defining the most effective option. However, in the long term, the costs of conducting pinch analysis and implementing the recommendations for modification to physical plant and operations reduces water usage and ensures the optimal usage of water on the plant at lowest cost.

Table 8: Trade-off Assessment for Tailings

Strategy Type	General Notes	Tailings													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/ Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals (skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
	as noted	Required, but complex process: 1	Yes: 1	Yes: 1	Yes: 1	High cost: 1	None to date: 1	Difficult: 1	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
	as noted	Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
	as noted	Not Required: 5	No: 5	No: 5	No: 5	Low cost: 5	Current practice: 5	Easy: 5	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
Weighting 1 = (Low) Largely uncontrollable with implications having the potential to detrimentally financial feasibility of operations 3 = (Fair) Although important, it is manageable in respect of affecting Platreef's financial and operational feasibility 5 = (High) Manageable in respect of affecting Platreef's sustained financial and operational activities															
Weighting		1	3	3	3	5	3	1	1	1	1	1	3	5	
Option Score Result Matrix * (Selected Strategy Score cell value is multiplied by Weighting cell value and the results summed to produce each Option score result)															
1. Re-use for cement and other construction purposes	Re-use potential subject to classification	3	3	3	3	5	3	5	5	3	5	3	5	3	115
2. Disposal at on-site tailings storage facility	On-site facility	3	3	3	3	1	5	3	3	3	3	1	1	3	81
3. Backfilling	Only if tailings are not reactive or will not result in leaching to underground water sources	1	3	3	3	3	3	3	3	3	3	3	1	5	95

Table 9: Further considerations in support of Table 8 above

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
1. Re-use for cement and other construction purposes	Should the waste be removed off-site, the downstream application of the waste will require an authorisation in terms of the NEMWA	Low, possible form of income	Classification required to determine if it is safe for use	Misperceptions may exist regarding safe use / applications of tailings	**Possible source of income, reduces waste volumes**	Difficult to implement, requires transportation to re-use application	Sustainable use of waste, reduces the use of natural resources. However, rate of generation vs. rate of disposal required does not make this option sustainable in the long term, unless contractual agreements are entered into with multiple companies	115
2. Disposal at on-site tailings storage facility	Approved EMP in terms of MPRDA, Water Use Licence in terms of NWA	Medium, high capital cost	Large footprint required, potential leaching to underground water sources	Well-known solution, but large surface disposal facility will be subject to public scrutiny	Relatively easy to implement	Requires remediation	This option is sustainable until the life of the facility has been reached; future expansions to the facility may be restricted by land access/neighbouring communities	81
3. Backfilling	Approved EMP in terms of MPRDA, Water Use Licence in terms of NWA, Exemption from Regulations GN R.704	Medium, higher operational cost	Classification is required to determine chemical reactivity. Potential leaching to underground water sources	People may perceive underground disposal as a risk to quality of borehole water	Improves ground stability	Requires careful planning and temporary storage areas	There will be large enough voids underground for the sustainable disposal of the waste	95

9.5.6 Disposal

Wastewater is generally unsafe for direct disposal. Wastewater treatment required before this water can be disposed of, produces residuals which will require disposal. Since the specific treatment processes have not yet been chosen, these wastes are not further defined in this report. Tailings or concentrator wastewater treatment residuals are generally of the same characteristics as tailings and usually are co-disposed with tailings.

9.5.7 Trade-off Assessment

Final wastewater treatment for discharge may be required in wet season where captured rainfall exceeds water requirements. However, storage capacity for rainfall is expected to be sufficient to capture and store such water for reuse. All wastewater management methods reduce freshwater use and also minimise the extent of treatment required. It is thus recommended that all of the possible methods of reuse and recycle be considered.

Direct reuse of wastewater is highly desirable since it is the easiest and cheapest to achieve with minimal worker exposure to the water. Where reuse is not possible, wastewater recycling, recovery, and partial treatment can be used, in respective order of importance.

It is highly recommended that the feasibility of a thorough water pinch analysis be investigated to optimise water management throughout the plant, especially considering the scarcity of water in the area (Table 10 and Table 11).

9.6 Domestic waste water

The domestic waste water generated on the mine during the construction and operation phases are very different in terms of volume, and thus require separate management plans. The domestic wastewater volume for the construction phase is approximately 23 m^3/d (8.4 Mℓ/annum) while the volume of wastewater generated in the operation phase is approximately 384 m^3/d (140 Mℓ/annum). It is not feasible to build the first plant and simply add trains for the larger future flow rate. Instead, two separate systems are necessary.

Domestic waste water is a hazardous waste which must be treated to appropriate standards before disposal, reuse or recycling.

9.6.1 Bulk mine construction phase

Treatment and stabilisation

For either of the construction and operation phases, the waste water can be treated on-site or off-site. However, off-site treatment will require piping of the sewage to the nearest sewage treatment works, which is expensive, especially since the nearest plant is a few kilometres away. Furthermore, the additional sewage, especially during the operation phase, will necessitate the existing sewage works to expand in capacity to handle the additional wastewater. Due to these complications and expenses, it is best to treat the sewage on-site.

The volume of sewage generated in the construction is very small and does not justify the construction of an advanced, mechanical treatment plant with high technological skill requirements. According to the Small Water Treatment Works Guidelines drawn up by the Public Works Department of South Africa, the best system to use in this situation is a septic tank system. The treatment steps are described below:

1) Fat, Oil and Grease (FOG) removal: These substances float on the surface of the water and reduce oxygen transfer and other processes necessary for the proper functioning of the microorganisms which break down the waste. This device will require relatively regular operator attention in order to remove accumulated FOG, otherwise it will cease to operate as an FOG remover.

Table 10: Trade-off Assessment for mining wastewater

Strategy Type	General Notes	Mining Wastewater													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/ Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals (skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
	as noted	Required, but complex process: 1	Yes: 1	Yes: 1	Yes: 1	High cost: 1	None to date: 1	Difficult: 1	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
	as noted	Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
	as noted	Not Required: 5	No: 5	No: 5	No: 5	Low cost: 5	Current practice: 5	Easy: 5	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
Weighting 1 = (Low) Largely uncontrollable with implications having the potential to detrimentally financial feasibility of operations 3 = (Fair) Although important, it is manageable in respect of affecting Platreef's financial and operational feasibility 5 = (High) Manageable in respect of affecting Platreef's sustained financial and operational activities															
Weighting		1	3	3	3	5	3	1	1	1	1	1	3	5	
Option Score Result Matrix * (Selected Strategy Score cell value is multiplied by Weighting cell value and the results summed to produce each Option score result)															
1. Wastewater re-use	Reuse is only applicable pending knowledge of required water qualities and wastewater qualities per application	3	5	5	5	5	5	5	5	3	5	5	5	5	151
2. Wastewater recycle	Requires partial or full treatment of wastewater first	3	5	5	5	5	5	1	5	5	5	5	5	5	149

Strategy Type	General Notes	Mining Wastewater													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/ Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals (skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
	as noted	Required, but complex process: 1	Yes: 1	Yes: 1	Yes: 1	High cost: 1	None to date: 1	Difficult: 1	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
	as noted	Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
	as noted	Not Required: 5	No: 5	No: 5	No: 5	Low cost: 5	Current practice: 5	Easy: 5	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
3. Wastewater recovery	Stormwater runoff, spillage and drainage collection will likely already exist, thus this option is generally already implemented	3	5	5	5	3	5	3	5	3	3	5	5	5	137
4. Wastewater partial treatment	Allows limited reuse options, but cheaper than treatment for discharge	1	5	5	5	3	5	3	3	3	3	5	5	3	123
5. Wastewater treatment for discharge (Required)	**Required**, may be used in combination with other options	1	5	5	5	1	5	1	3	3	3	5	5	3	111
7. Water pinch analysis	Requires expert investigations and studies	3	5	5	5	3	3	1	5	3	5	5	5	5	131

Table 11: Further considerations in support of Table 10 above

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
1. Wastewater re-use	Supporting facilities, e.g. dams, pipelines, etc. require a Water Use Licence in terms of the NWA, NEMA authorisation and potentially NEMWA licence	Low, only cost is due to transportation of water from one application to another	Low	Low	Reduces freshwater use	Requires a study of possible reuse options around plant	High, reduces freshwater use	151
2. Wastewater recycle	Supporting facilities, e.g. dams, pipelines, etc. require a Water Use Licence in terms of the NWA, NEMA authorisation and potentially NEMWA licence	Low, only cost is due to transportation of water from treated water to application	Low	Low	Reduces freshwater use	Requires wastewater treatment	High, reduces freshwater use	149
3. Wastewater recovery	Supporting facilities, e.g. dams, pipelines, etc. require a Water Use Licence in terms of the NWA, NEMA authorisation and potentially NEMWA licence	Medium, requires construction of a drainage and collection system	Low, it provides environmental protection	Low	Reduces potential contaminated discharges to the environment, provides additional source of water	A drainage system will likely be required, and can thus simply serve as a source of water	High, provides an alternative source of water, reduces freshwater use	137
4. Wastewater partial treatment	Supporting facilities, e.g. dams, pipelines, etc. require a Water Use Licence in terms of the NWA, NEMA authorisation and potentially NEMWA licence. Water treatment plants require NEMWA authorisation, depending on the treatment capacity of the plant	Medium, requires construction of solids separation process	Low	Low	Not as expensive as full treatment, and produces water which can be reused	Requires some operational attention but reduces risks due to pipeline damage. Also produces a solid waste	Medium, provides relatively clear water to replace freshwater, at relatively low reagent and energy use	123
5. Wastewater treatment for discharge (Required)	Supporting facilities, e.g. dams, pipelines, etc. require a Water Use Licence in terms of the NWA, NEMA authorisation and potentially NEMWA licence. Water treatment plants require NEMWA authorisation, depending on the treatment capacity of the plant. The discharge to the environment requires a WUL in terms of the NWA.	High	Low, trustworthy and functional technology and operators are required	Low	The effluent is of high quality can be reused in high quality applications	Requires high operator attention	Medium, requires reagents and energy, but produces clean water	111
7. Water pinch analysis	Supporting facilities, e.g. dams, pipelines, etc. require a Water Use Licence in terms of the NWA, NEMA authorisation and potentially NEMWA licence	Medium, cost due to transportation and temporary storage of water	Low	Low	Optimises water use on the plant, minimised freshwater use	Requires expert opinion and feasibility investigations	High, minimises freshwater use and minimises reagent and energy costs	131

2) Septic tank: This tank must contain at least 2 compartments with a minimum desludging capacity of 5 years. If this is increased to 6 years this may eliminate operator requirements. The sludge from this plant will be removed and transported via a vacuum tanker to the nearest sewage treatment works. This may refer to the treatment works at the nearest town or the new treatment works to be built on the mine for use in the operation phase.

3) At this point it is optional to install a Rotating Biological Contactor (RBC) and associated humus tank for solids settling. These technologies, if operated well, and where space is limited, eliminate the need for maturation ponds. The RBC is both smaller and more efficient than trickling filters and is able to handle both domestic and industrial sewage.

4) Disinfection: Disinfection may be done by chlorination or ultraviolet (UV) radiation. UV radiation works best where the water to be disinfected has a low turbidity. If this can be guaranteed, it may be preferable to use UV disinfection. Otherwise chlorination is a reliable disinfection method. For very small flows chlorination in the form of sodium or calcium hypochlorite dosing in solution may be used instead of using an automatic gaseous chlorine dosing system.

5) Maturation ponds or reed beds are optional to make sure that the processed water reaches the required discharge standards, and to allow some flexibility in case of process upsets. Reed beds may be used with or without RBC and humus tank. If there is a very large available land area it may be possible to use lined reed beds alone. Disinfection is applied before reed beds.

6) Discharge to river or used for irrigation (or potentially blended to process water).

Due to the effect of the land availability on the choice of technology used, the mine must first determine a suitable site to place the bulk shaft phase septic system and later the mine wide treatment plant. Available area is as important selection criteria, but FOG removal must take place ahead of septic tanks on treatment and with on-site treatment; disinfection is required.

Management/Disposal of residuals

It has been mentioned that the sludge from the septic tank will be sent by tanker to a nearby regional sewage treatment plant or to the future sewage treatment works. The grit is different to the sludge in that it does not biodegrade and is only a nuisance in the treatment plant. This waste will be disposed of as a hazardous waste on a hazardous waste landfill. The collected oil and grease from the FOG remover should be disposed of as hazardous waste.

9.6.2 Mine wide operation phase

Treatment

Due to the small volume of domestic waste water that will be produced at the site in the operation phase, while much greater than produced during bulk shaft construction, and also considering constraints on available land, a package sewage treatment plant (STP) will most likely be used.

Different treatment processes that are available include the following:

- Activated sludge process – Sophisticated process requiring a high degree of operator control. Produces large quantities of sludge but provides high degree of treatment. This process is commonly used in most municipal treatment plants since it is the most advanced and reliable process;
- Extended aeration activated sludge process – This process is adapted for smaller sewage volumes. It is more capable of handling fluctuating loads and concentrations than conventional activated sludge processes, and normally comes in the form of package units. For a smaller volume of sewage, as found on the Platreef mine, this system is more desirable than the activated sludge process. It also provides a high degree of treatment, which is necessary due to the high quality of the South African discharge water quality standards;
- Sequencing Batch Reactor (SBR) process – This process reduces the footprint of a plant generally and carries out the same as activated sludge but using fewer tanks which are sequenced for multiple use,

i.e., aeration and, settling. The process requires an experienced engineering contractor but may prove to be more cost effective;

- Waste stabilisation ponds – This is a natural process with no power/oxygen required, but this process requires a significant land area (not available at this site) and is suited to hot, sunny climates. This process cannot easily be controlled, if at all, and is not as reliable as an active process;
- Oxidation ditch – Requires more power than waste stabilisation ponds, but less land, and is also easier to control than the activated sludge process. This process is not commonly used on the municipal level, and is more suited to very small volumes of sewage in areas where below-quality discharges may be allowed (e.g.: rural areas with few or no rivers/streams), which will not apply to the mine site;
- Reed beds or constructed wetlands – Treatment is by action of soil matrix and the soil/root interface of plants. This treatment system also requires a significant land area (which is not available at the mine site). Reed beds have been described as method for treating sewage in the construction phase. These systems are suited to very small volumes of sewage, and become less economically viable as the feed flow rate increases; and
- Trickling filters – An aerobic process in which bacteria take oxygen from the atmosphere. A bacterial slime layer grows onto the medium and removes pollutants from the sewage as it passes down through the system. This system is relatively simple and uses a small land area, but requires significant pumping which adds to complexity and operating costs. This process has been used very often in the past, and is thus well understood. However, it has largely been taken over by the more modern and more expensive activated sludge process, considered to be more operationally reliable.

The Small Water Treatment Works Guidelines given by the Public Works Department of South Africa, for small sewage plants with a flow rate greater than 100 m^3/day, should be referenced for selection of technology.

The guidelines suggest that treated effluent may be discharged to river or reused for non-potable purposes i.e. landscape or process water.

Stabilisation

The waste water treatment produces volumes of sludge which must managed appropriately. Although it is not a requirement, stabilisation of this sludge allows it to be suitable for a variety of subsequent processes or uses. Different methods of sludge stabilisation include anaerobic digestion, aerobic digestion, thermal and chemical stabilisation. A rule of thumb approach to sludge production is 0.5 kg of sludge per kg of BOD in the influent. For the operational phase, with a population of 3,500 persons, about 260 kg of dry solids would be produced per day. With a moisture content after drying beds of say 60%, approximately 656 kg of sludge would be generated per day.

Aerobic digestion reduces sludge matter consisting of inorganic matter and relatively stable volatile solids. This reduced sludge is of a slightly higher volume than achievable by anaerobic digestion. The difference is that anaerobic digestion provides a valuable by-product – methane gas that contains carbon from the sludge and which can be used to produce electricity or heat energy but which also requires capital investment to utilize the gas.

Thermal stabilisation is a heat process which results in the breaking down of cell structures, coagulating the solids and causing a liquid-solid separation. Chemical stabilisation generally involves lime addition. Lime addition involves adding enough lime to bring the pH above 12, which removes bacterial hazards and destroys odour-forming compounds. Both of these processes are expensive.

For the specific situation at Platreef mine, aerobic digestion may be used since this does not require extensive operator attention and uses a small land footprint. Anaerobic digestion is not recommended as the methane produced will not be sufficient to justify the construction of an energy recovery system, After stabilisation, sludge is usually dewatered using filtration or centrifugation process, or through the use of drying beds. Sludge drying beds are a cheap and reliable option. Sludge from drying beds can be managed as dry cake although at 60% moisture content and the anticipated quantity would be appropriate to blend with waste organics and garden waste with wood chips as input to the composting process.

Disposal

Domestic wastewater is unsafe for direct disposal, while treated effluent may be reused. Treatment of domestic wastewater produces solids which need to be managed, as discussed above. Treatment of these solids is further discussed under section 9.9.

9.6.3 Trade-off Assessment

Construction phase

Available options make use of septic tanks with associated grease removal and disinfection. The chosen option is dependent on land availability. A concept-level life-cycle cost comparison will also be needed to determine the feasibility of each option.

Operation phase

For the operation phase it is recommended that the activated sludge process with extended aeration be used. This process is available as a modular plant and is thus easy to set up with a relatively small footprint. It is the most reliable solution in terms of effluent quality and is well-tried and tested. Possible alternatives include the use of trickling filters or SBR systems. Trickling filters are understood to be gradually being phased out nationally due to operational difficulties. However, the alternative processes are well-known and understood, and can be cost-competitive depending on the supplier.

9.7 Domestic waste

Domestic waste is the component of general waste that will be disposed by mine workers into bins on-site, such as food residues, mixed organics, sweepings, mixed recyclables and office waste. These materials will require certain infrastructure to be in place for their collection at various points around the mine. The level of infrastructure required will depend on the strategy chosen by Platreef.

9.7.1 Minimisation

One method that could reduce the production of waste paper is to promote the idea of responsible printing, and making employees accountable for their printing habits through various means such as the use of a printing credit system, printing automatically double sided, incentivization, etc. An incentive such as a competition for the division that reduces its consumption (per capita) the most, could lead to further reduction of paper usage. The purchase of partially recycled paper for printing i.e. 50% recycled would lead to increased awareness of paper wastage issues.

Source separation

It is suggested that Platreef invests in infrastructure to sort general waste at the point of generation in order to reduce the amount of potentially valuable materials that are contaminated by other materials and the amount of waste that is disposed of to landfill. An example is the separation of recyclables such as; tins, glass, plastic, paper and cardboard (the big 5) from wet wastes such as organics. In this way recyclables can be recycled and added back into the value chain, while organics can be added to a composting plant, thus significantly reducing waste to landfill.

There are various methods for the separation of materials. Platreef could provide a duel bins system, which means that two bins will be stationed at every bin location, so that wet waste (organics) and dry waste (recyclables) are separated into one of two bins. After the initial separation into one of two categories, bin contents are taken to a Materials Recovery Facility (MRF) where the recyclables from the dry waste bin are sorted into their respective material groups, sorted and then sold off to a recycling company. The contents of the wet waste bin may be added to a composting plant or landfilled.

It is potentially viable to almost completely separate selected materials from the general waste stream at the source. For this strategy, numerous different bins must be provided at each collection point on site; the number of bins is determined by the number of material categories that match the needs of the recycling contractor most closely. Bins could potentially be provided for: tins, glass, plastic, paper, cardboard, food waste and other waste. If this method is properly implemented with training for staff, it will require only a centralised storage facility, and materials can be transported directly off site by the recycling contractor. This method will require more small bins around the site (bin stations of roughly 5 bins).

A trade-off assessment of these two waste collection options has been presented in the tables in section 9.7.5 below.

9.7.2 Re-use

Cardboard boxes can be re-used for storage of various goods, including the long term storage of files, documents and books, which are being archived. They can be used as waste paper bins or be given to employees and local people for transporting goods amongst other uses. If cardboard becomes contaminated with food or wet waste, it should be removed from re-use and sent to recycling if possible.

9.7.3 Recycling

Following separation of materials at source, materials can be sent to off-site recycling companies in the area. Recyclable material has intrinsic value, which off-sets the cost of transport or disposal of other materials.

An appropriate recycling company should be appointed to remove and recycle as many of the listed recyclable materials as possible. This should be done through a tendering and procurement process.

A waste management and recycling company based in Mokopane has been found. They deal with most waste streams; general and hazardous, recyclable and non-recyclable; details are listed below:

- Nieuwco; Recycling Specialists:
  - Leon van Huyssteen (MD);
  - Cell: 0828023774;
  - Fax : 0866711185;
  - Email: leon@nieuwco.co.za; and
  - www.nieuwco.co.za.

If Platreef decides to separate food waste at source, this can be added to the organic waste stream for composting.

9.7.4 Disposal

The do nothing option would be to dispose of any or all of the above recyclable materials, along with other general waste to a general landfill. This would take valuable airspace in the landfill and forego the opportunity to add value to these materials and to promote economic activity in the local community.

Landfill costs also continue to rise and landfills incur some management and closure liability while the positive value of recycling appears to increase with time.

9.7.5 Trade-off Assessment

It is noted that all of the above mentioned options can and should be implemented in the order of the waste hierarchy. Platreef should seek to reduce waste wherever possible, any waste which is produced after minimisation should be reused or recycled and any remaining waste can then be disposed to landfill.

The main point for consideration is whether Platreef would prefer to have a 2-bin or 5-bin separation system for domestic waste. As mentioned earlier in section 9.7.1, the 2-bin system would require further sorting at a MRF, post collection, while contents of the 5-bin system could be collected, stored and removed by the recycling contractor. The 5-bin system would require a larger initial capital outlay for bins, but requires least landfill airspace and an area for sorted material storage. Prices for bins are listed under section 7.0. It is strongly endorsed that Platreef pursue the total sorting of waste at source, through a 5-bin system, as this would be considered best practice in the industry, it could also promote Platreef as an environmentally responsible mine. It may present some challenges in terms of employee participation, but since Platreef intends to employ educated personnel, this should be a small hurdle that can be overcome through training and awareness.

This option should be considered in consultation with the intended recycling contractor for economic assessment (Table 12 and Table 13).

9.8 Garden waste

It was reported that an estimated 20 793 600 tons of organic waste was produced in South Africa in 2011 approximately 40% of total General Waste produced and includes garden waste, food waste, paper and cardboard, animal carcasses, manure and sewage sludge[3].

It is expected that roughly 1 000 tpa of garden waste will be produced during the full scale operation of the mine. This is due for variation as vegetation may vary according to landscaping plans of the mine. Garden waste can be seen as a potentially valuable resource as it can be used to dilute contaminants in composting (i.e. sewage sludge and remediated soils) while it can also be used in various applications on site, such as slope stabilisation and mine dump rehabilitation.

9.8.1 Composting

Composting is a low impact and high benefit waste treatment option. Composting can be used to treat most kinds of organic waste combined or separately, which could include, food waste, sewage waste, remediated soils etc. The four most common methods of composting are: aerated static pile, windrow, aerated windrow, and in vessel.

Although the principle of composting is very straight forward, the specifics of the mixture of components and various contaminants which will be found in Platreef's organic waste mix will be unique and will require some research and experimentation.

It is essential that the composting process is kept in the aerobic phase, and regular turning is done to keep it from becoming anaerobic. The scale of the composting plant will determine if it is feasible to invest in machinery or manual labour to carry out certain tasks. For this reason a more in depth feasibility study should be conducted if Platreef would like to go ahead with the composting option.

It must be noted that a composting facility would only require a NEMWA Licence if it was built with the capacity to process more than ten tons per month (GN R.718 Section 7, July 2009). Details from specialist studies in the EIA process should reveal if garden waste volumes may exceed the threshold level. However the NEMWA waste license application can be combined with licensing of all the other waste facilities which must be done anyway and this is the recommended process. If Platreef wants to sell any compost or fertilizer products, it would be regulated under the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act (No. 49 of 1996) and would have to be registered with the Department of Agricultural Technical Services.

While garden waste could form the bulk of the composting stream, other organic waste streams should be added to the stream as nutrient sources and for the purpose of treating those wastes and reducing the requirement for landfill.

Garden waste such as vegetation and wood from landscape maintenance activities around the site and wood chips from wood pallets could be incorporated to help with the aeration of the compost and act as a bulking agent. In order to breakdown garden waste such as trees, it is suggested that a chipper or mulching machine is acquired and stored near to the composting facility. An entry level wood chipper could be

[3] National Organic Waste Composting Strategy: Draft Status Quo Report, November 2012, Department of Environmental Affairs

purchased for roughly R 55 000, such as the one in the picture below (Figure 4). Perhaps a second hand chipper would be a preferable option. Food waste and/or sewage sludge are generally needed to add nutrients to the composting mix.

Figure 4: Entry level wood chipper

Beneficial use options of the composted material include general landscaping, once-off high rate applications for rehabilitation of disturbed/degraded soils, continuous high rate applications (cultivation of instant lawn, industrial crops, grain and fruit trees) or use for landfill cover material. All these beneficial use options will be permissible, but application restrictions may apply due to elevated Ni and Cu concentrations in the sewage sludge (Guidelines for the Utilisation and Disposal of Wastewater Sludge, Volume 4), depending on quantities added to compost.

It is expected that composting at Platreef will require an environmental authorisation (EA) which requires a Basic Assessment. This can be done as part of the integrated waste licensing process.

9.8.2 Energy Recovery

Incineration

Garden waste can be used as burning fuel in furnaces, boilers or incinerators. This is highly dependent on the type and location of available or proposed energy recovery facility, as transporting the material long distances will eliminate the feasibility of this use. An on-site incinerator or furnace would be able to use dried organic waste as fuel to increase burning of other materials which don't burn as easily. It is however, not expected that Platreef will construct an on-site furnace, incinerator or boiler. The nature of the garden waste material will also play a significant role in its ability to be used to fuel boilers or furnaces, i.e. moisture content.

Fuel wood

Logs and branches can be donated to labourers or communities for use as fire wood in household applications, which would require stockpiling of wood from landscaping maintenance to be cut and stored and made available to the selected workers or communities.

Platreef should ensure that by providing this wood to workers and communities that it does not cause harm. The remaining garden waste materials could be mulched for composting.

Table 12: Trade-off Assessment of source separation methods for domestic waste

Strategy Type	General Notes	Domestic Waste													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/ Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals (skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
	as noted	Required, but complex process: 1	Yes: 1	Yes: 1	Yes: 1	High cost: 1	None to date: 1	Difficult: 1	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
	as noted	Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
	as noted	Not Required: 5	No: 5	No: 5	No: 5	Low cost: 5	Current practice: 5	Easy: 5	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
Weighting 1 = (Low) Largely uncontrollable with implications having the potential to detrimentally financial feasibility of operations 3 = (Fair) Although important, it is manageable in respect of affecting Platreef's financial and operational feasibility 5 = (High) Manageable in respect of affecting Platreef's sustained financial and operational activities															
Weighting		1	3	3	3	5	3	1	1	1	1	1	3	5	
Option Score Result Matrix * (Selected Strategy Score cell value is multiplied by Weighting cell value and the results summed to produce each Option score result)															
2 bin system	Assumes limited separation at source, with full separation taking place at on-site Material Recovery Facility (MRF)	3	5	3	5	3	5	5	5	5	5	5	3	3	121
5 bin system	Assumes full separation at source	5	5	5	5	3	3	3	5	5	5	5	5	5	137

Table 13: Further considerations in support of table 12 above

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
2 bin system	MRF will require NEMWA license if it exceeds capacity for 100 m^3	MRF can be a cheap simple design, but licensing may require budget	MRF requires larger impact footprint, and additional sorting at MRF may lead to litter	Limited public sensitivity	If service provider does not provide comprehensive service, Platreef could prepare waste for recycling on-site	Platreef Staff or contractor needed to transfer waste from bins to MRF and then to recycler	Simple easy to use system reduces the need for training and risk of failure due to poor use. However, there is the risk that recyclables may report to landfill.	121
5 bin system	None	More bins will require a larger capital outlay, but expenses can be spared on the MRF	Limited environmental risk	Intensive sorting promotes recycling and expresses Platreef's desire to be a green company. Instils responsibility in full work force	If recycler offers full package, this will not be a management liability to Platreef. This system promotes recycling. Greener company image. Less chance of recyclables going to landfill, and diminishing airspace.	Large numbers of bins on site require well organised and demarcated storage points. Purchase and maintenance of these bins will be Platreef's responsibility. Requires training and buy-in from labourers.	More complicated source separation system, requires continuous buy-in from employees, but promotes recycling and reduced waste volumes reporting to landfill.	137

9.8.3 Disposal

If Platreef does not wish to find a downstream use for organic wastes, the do nothing option would be to dispose of garden waste to general landfill. The landfill would be a GCB-[4] according to the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste (2nd Edition, 1998; Department of Water Affairs and Forestry).

However the Draft Waste Classification and Management Regulations, which will change and replace parts of the Department of Water Affairs "Minimum Requirements" regulations (trilogy of documents) and will ban certain materials or substances (e.g. organic waste) from landfills. This will force Platreef to divert organic waste via on-site or off-site composting.

Future looking assessment of regulation supports adoption of organic separation and composting.

9.8.4 Trade-off Assessment

The preferred option for managing garden waste is composting, as this offers a sustainable value adding solution that improves soil quality and can benefit the community.

The second most favourable option is for wood in the form of tree stumps, logs and branches to be donated to labourers and communities as fuel wood. The issue lies in health and safety of those receiving the fuel wood, as unsafe practice can cause danger to health and this could be a liability to Platreef. This option could be used as a supplement for composting and would reduce the need to chip larger wood pieces.

Disposal is the third most favoured option as it can be done close to the source (reducing transport costs), however it is not a sustainable option and offers no benefits to the local community, while requiring additional landfill airspace.

The least favourable option is to use the garden waste as a fuel stock in a cement kiln or boiler, as this will require drying of the material and chipping or crushing, before it is transported off site to the nearest willing recipient (Table 14 and Table 15).

9.9 Sewage sludge and screenings

There is a small volume of sewage that will be treated in the sewage treatment plant. However, sewage treatment works generate sludge which must be managed properly to avoid a hazardous situation.

9.9.1 Recycling

The only useful method of sewage sludge reuse or recycling is as compost. Sewage sludge contains many nutrients and other elements which are essential to plant life, and improves the value of compost as an excellent soil conditioner and good fertiliser. Composting is a biological degradation process as well which requires the presence of the same nutrients and elements to maintain performance. Classification for the suitability of the sewage sludge includes grading in terms of pH, metal content, BOD content, other constituents and general safety assessment which may consider the blended inputs to the composting process.

Composting sterilises and amends sewage sludge in proper mixes while maintaining fertiliser value of contained nutrients. Compost is different to fertilizer in that the most important features are its moisture retaining and humus forming properties. If a composting facility is employed on the Platreef mining site, it will provide a suitable opportunity for composting of the sewage sludge. Only Grade D sewage sludge may be used as a source of compost.

Compost and fertiliser can be used for mine dump rehabilitation and re-vegetation. See section 9.8.1.

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[4] GCB-: General waste; Community landfill; with a negative water Balance.

9.9.2 Treatment

Incineration

The screenings from the inlet works of the sewage treatment plant as well as the sewage sludge may be incinerated. However, an incinerator is not envisioned at the site.

Sludge to be incinerated must be sufficiently dry, or a special type of incinerator may be used which utilises residual heat to dry the sludge prior to incineration. Sewage sludge has a low calorific value in comparison to sources such as oil and coal, but incineration reduces the sludge volume substantially without requiring much energy input. The resulting ash may be suitable for landfilling if organics are suitably reduced and leachable metals within acceptable limits.

In sludge incineration, temperatures must be kept between 675 and 750°C to prevent odours coming from the stack or excessive fly ash formation. Undigested sludge will burn easily without supplementary fuel provided moisture content reduction is employed. Digested sludge has a lower fuel value. No restrictions will apply if sewage sludge alone is combusted (Guidelines for the Utilisation and Disposal of Wastewater Sludge, Volume 5). However, the fly ash and bottom ash from this process may be 20% of original sludge volume and will have to be tested to determine appropriate disposal options.

9.9.3 Disposal

Landfill

Sewage sludge is commonly landfilled. Sludge will also leach in wet conditions; hence deposition to landfill may only be done with digested and dewatered sludge which will not cause odour problems. Lined landfill is required since sewage sludge which is not sterilized, i.e., through composting, may be a source of pathogens.

Incinerator ash from combustion of non-hazardous waste may be disposed of in landfills. The ash may be wetted to suppress dust.

Off-site disposal

Sewage sludge is usually too large a volume to be economically disposed of offsite. However, screenings may be bagged and transported offsite for disposal. However, where screenings and sludge can be co-disposed, onsite disposal becomes a more favourable solution. If untreated, the sewage sludge and screenings would require disposal to lined sanitary or hazardous landfill.

9.9.4 Trade-off assessment

Grit management

Since a landfill will likely already exist on the plant, it is recommended that this be utilised for the disposal of grit.

Sludge management

Recycling of sludge as a component of compost is the most favourable option. It is the only solution which adds value to the sludge. Otherwise, sludge disposal should be to line sanitary landfill.

9.10 Pallets

Pallets will be used at Platreef for the moving and storing of supplies, products and machinery used in the mining operation. It is assumed that wood is the default material of which pallets are made. Once pallets are damaged or at the end of their life the cost for disposal will be a liability to Platreef. There are numerous alternatives to consider. Other containers such as crates and other wood packaging will also be brought onto site and can be managed in the same way as for pallets.

Table 14: Trade-off assessment for Garden Waste

Strategy Type	**General Notes**	**Garden Waste**													
		Environmental authorisations required	**Air**	**Land**	**Water**	**Technology cost and 'provenness'**			**H&S/Exposure on-site/Public & Worker Sensitivity**						**Total**
Strategy Score		**NEMWA, NEMAQA, NWA, MPRDA, EA, etc.**	**Dark smoke & dust particulate**	**Land contamination, sterilisation and aesthetics**	**Impacts making water quality less fit for use**	**Capex/ Opex**	**'Provenness' of practice**	**Ease of implementation**	**Injury risk**	**Chemicals (skin/ inhalation)**	**Physical**	**Public sensitivity**	**Benefits to the community**	**Sustainability**	
	as noted	**Required, but complex process: 1**	**Yes: 1**	**Yes: 1**	**Yes: 1**	**High cost: 1**	**None to date: 1**	**Difficult: 1**	**High: 1**	**High: 1**	**High: 1**	**High: 1**	**Low: 1**	**Low (short-term benefits): 1**	
	as noted	**Required, but not complex process: 3**	**Possible: 3**	**Possible: 3**	**Possible: 3**	**Medium cost: 3**	**Limited cases: 3**	**Neutral: 3**	**Medium: 3**	**Medium: 3**	**Medium: 3**	**Medium: 3**	**Medium: 3**	**Medium (potential for medium to long-term sustainability): 3**	
	as noted	**Not Required: 5**	**No: 5**	**No: 5**	**No: 5**	**Low cost: 5**	**Current practice: 5**	**Easy: 5**	**Low: 5**	**Low: 5**	**Low: 5**	**Low: 5**	**High: 5**	**High (Confident i.t.o. long-term sustainability): 5**	
Weighting **1 = (Low) Largely uncontrollable with implications having the potential to detrimentally financial feasibility of operations** **3 = (Fair) Although important, it is manageable in respect of affecting Platreef's financial and operational feasibility** **5 = (High) Manageable in respect of affecting Platreef's sustained financial and operational activities**															
Weighting		**1**	**3**	**3**	**3**	**5**	**3**	**1**	**1**	**1**	**1**	**1**	**3**	**5**	
Option Score Result Matrix * (Selected Strategy Score cell value is multiplied by Weighting cell value and the results summed to produce each Option score result)															
Composting	On-site recycling	3	3	3	3	3	5	5	5	5	3	5	3	5	117
Incineration	Off-site energy recovery	1	1	1	3	5	3	3	3	1	3	1	1	1	69
Fuel Wood	Off-site energy recovery	5	1	3	5	5	5	1	3	3	3	3	5	3	115
On-site Disposal	Disposal at on-site general waste landfill	3	5	3	5	3	5	5	3	5	5	1	1	1	99
Off-site Disposal	Disposal at off-site facility	3	5	3	5	1	5	5	3	5	5	5	1	1	93

Table 15: Further considerations in support of Table 14 above

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
Composting	NEMWA licence, depending on size of facility	Medium as composting facility is relatively cheap to implement	Depending on trace elements found in the organic waste that is mixed with garden waste	Low, as it may boost Platreef's green image	**Provide employment and compost for land conditioning and rehabilitation**	It requires man power, machinery and transport over short distances	**Highly sustainable as it retains material and resources and adds value to land where it is applied**	117
Incineration	Platreef must ensure that the company accepting the waste has relevant NEMWA & NEMAQA licenses in place	High transport cost for off-site incineration	High risk of air pollution	Generally high due to stringent air quality standards in SA	Could recover energy for other processes	Will require transport and a willing receiver	Low sustainability, as the material is lost and potential yields are low in comparison to inputs	69
Fuel Wood	No licences required, but Platreef to ensure duty of care	Low, as it is assumed waste will be made available to local communities or labourers (minimal to no transport costs)	Medium as burning at low temperatures causes noxious gasses and could be detrimental to health	Could benefit the receiver, but may also be dangerous to the health of the receiver	Could supplement cooking and heating fuel for low income households in the area, thus increasing livelihoods	Will require labourers to cut and stack. Minimal equipment required	Medium, as it improves livelihoods for only as long as it is supplied, this may not perpetuate indefinitely	115
On-site Disposal	Platreef will need to ensure that the landfill has the appropriate licence in terms of the NEMWA. It is important to note that, once the new draft NEMWA regulations are promulgated, there will be restrictions on the quantity of garden waste allowed to be disposed at landfills	Minimal cost of transport to on-site facility, but larger airspace required for landfill	Low risk, dependent on the method of disposal as well as the disposal facility	High public sensitivity associated with on-site landfill	Waste stream is dealt with on site with minimal further processing required	Common practice, but does not reduce the waste stream and requires disposal space	Material is lost and value cannot be recovered	99
Off-site Disposal	Platreef will need to ensure that the landfill has appropriate licence in terms of NEMWA. Platreef must acquire safe disposal certificates, and audit the disposal site to ensure duty of care. It is important to note that, once the new draft NEMWA regulations are promulgated, there will be restrictions on the quantity of garden waste allowed to be disposed at landfills	Medium to high costs associated with transport to off-site facility	Low risk, dependent on the method of disposal as well as the disposal facility	Low public sensitivity, as waste is removed off-site	Waste stream is removed off-site	Common practice, but does not reduce the waste stream and requires disposal space	Material is lost and value cannot be recovered	93

9.10.1 Waste Avoidance/Minimisation

Increased lifespan

If pallets are not broken while they are being used or stored, they can be perpetually used by forklifts for carrying materials from point of storage to point of use. Careful driving and reduced snag points can increase pallet lifespan. In some industries, forklift drivers are incentivised to be more careful with pallets using a points system or economic incentives.

Take-back agreement with suppliers

One way to minimise this waste stream at Platreef is to include a take-back agreement in contracts with suppliers. This would mandate the supplier to take responsibility for the pallets once they have delivered supplies and machinery to the appointed place.

Very often supply trucks return to their origin empty after having delivered a full load to mines, this is seen as an opportunity to cart materials back to suppliers, perhaps at a small extra cost. This should be investigated with suppliers and Platreef's procurement and contracts department. To provide one such example, a company by the name of Quality Pallets and Recycling offers the following services:

- Manufacture of wooden pallets;
- Fixing wooden pallets;
- Buy and sell second hand wooden pallets (collect and tidy); and
- Buy and sell plastic pallets (the use of plastic pallets as a waste avoidance/minimisation strategy is further discussed below).

Plastic pallets

Various types of plastic pallets can provide alternatives to conventional wooden pallets and can essentially minimise pallet waste. The primary advantage of the plastic pallet is its increased durability and hence increased life span. This essentially results in less waste being produced in the form of pallets. Claims are generally made that plastic pallets are 100% recyclable; however, manufacturers and their products do differ. Three potential suppliers of plastic pallets[5], for which prices were obtained, are as follows:

- Fried International Imports:
  - Made from recycled or virgin HDPE in Johannesburg;
  - A large variety of plastic pallets is offered, with various applications and load capabilities; and
  - Prices obtained for a small range of pallets varies from R 225 to R 740 depending on type and load capacities.
- E-Dek:
  - Pallets are made from composite steel and plastic, significantly increasing durability due to the high tensile strength steel framework;
  - 100% recyclable, but recycling not offered or carried out by manufacturer;
  - Prices are relatively high, varying from approximately R 480 to R 950 per pallet (size: 1 200 x 1 000) depending on pallet type and quantity ordered; and
  - Racking loads vary between 800 kg and 2 000 kg.
- Plasti-Furn & Deck:

[5] Golder is not affiliated to these companies, nor does Golder audit the companies to validate legitimacy of services offered

- Pallets are made from 100% recycled plastic;
- Prices vary from R 420 to R 670 per pallet (size: 1 200 x 1 000) depending on pallet type;
- Load capacity dependent on client design specification; and
- Arrangements for maintenance/repair plan or buy-back policy possible.

Important aspects when considering plastic pallet options are the recycling and re-use potentials of such pallets. Manufacturers which produce pallets from recycled plastic are providing a "green" option and are more likely to take back damaged or broken units for recycling purposes. This could therefore provide a sustainable option which would produce minimal to zero waste. On the other hand, if plastic is not recycled, the processes to produce the pallets as well as the waste stream produced from broken pallets is not environmentally sustainable.

Aside from the durability and recyclability factors mentioned, some general advantages of plastic pallets may be summarised as follows:

- Plastic pallets are not prone to insect infestation and are easily cleaned, providing a more hygienically friendly option; and
- Plastic pallets are generally lighter in weight when compared to wooden pallets, resulting in reduced transport costs.

Paperboard/Corrugated Pallets

A relatively new and innovative alternative is the use of corrugated pallets. A major supplier of corrugated pallets in South Africa is CX Pallets[6], who cite several advantages of these pallets, including the following:

- They contain no wood and are thus not required to be fumigated or heat treated;
- CX Pallets are lightweight (about 7 kg) resulting in cost-effective transport and easy handling;
- The pallets are robust, produced with heavy duty cardboard, designed with load bearing slats and load tested with 2.7 tons of static load;
- CX Pallets are recyclable as they are made from corrugated paperboard, which may be sold to recyclers. This ensures an environmentally sustainable option; and
- No nails or splinters are present, reducing occupational health and safety risk.

The prices of these pallets are lower than those associated with plastic pallets, with prices ranging from R 136 to R 160 depending on sizes.

Some disadvantages of these pallets include the fact that their load capacities are generally lower than those of plastic pallets and their durability when compared to plastic is unknown. Another factor is their susceptibility to water damage. Although humidity and small amounts of water are not harmful to the pallets, they should avoid standing in static puddles of water for prolonged periods of time.

Wood Pallets

Generally it should be noted that while other pallet materials have several advantages over wood, there are several significant advantages associated with wood pallets themselves. These include the following:

- Wood pallets are in general cheaper than other materials; and
- Reparation of wooden pallets is easier than with other materials.

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[6] Golder is not affiliated to this company, nor does Golder audit the company to validate legitimacy of services offered

9.10.2 Re-use/Recycling

Wood pallet recycling is a blanket term for the business of sorting, refurbishing, dismantling and remanufacturing of pallets for sale, as well as the grinding of wood pallets and pallet components for fibre products. The challenge comes in identifying a feasible use for the pallets, especially if the source is far from a potential market. Recycling options are limited due to various factors, including:

- The presence of rusty nails;
- The wood is often treated/coated with chemicals in its construction stage;
- The pallets are often fumigated (depending on current and prior uses); and
- Wooden pallets are prone to insect infestation.

A potential strategy would be to donate the pallets to a nearby SMME where the material may be used for various recycling processes which could create added industries and jobs. It should be noted that the wood should first be assessed to identify any harmful chemicals that may limit certain recycling strategies. The receiving SMME should be made to sign for the liability associated with the pallets, in order to protect Platreef from any legal action resulting for accidents associated with this material. Some of these recycling options include the following:

- Pallets can be converted to wood chips for composting (providing nails are removed), although the chemical contaminants may significantly affect the use of these chips in such applications as mulches;
- Furniture production (due to the potential chemical contaminants of the wood, outdoor furniture should be considered as the only potential option);
- Fencing (by painting the wood, for example white picket fencing becomes a viable option as any potential chemical contaminants pose a significantly reduced threat in this application);
- Construction of compost storage bins;
- Storage sheds; or
- Bird houses, etc.

Wood chips

The option of converting the pallets to wood chips is a potentially beneficial process, given the various uses of the chips. Platreef could use mulched wood for applications such as composting, landscaping and preventing soil erosion. The major issue affecting this strategy is the presence of nails or chemical contaminants in the wood. Suppliers can be consulted on the types and effects of chemicals used to treat the wood, and this information can be used to guide Platreef on the source of their pallets.

With respect to nails, manual removal can be employed. The best alternative solution to this issue is wood grinders which contain magnets to remove nails and any other metal pieces. Conventional wood chippers are not capable of removing nails, but a “tub grinder” is able to do it. A lower cost tub grinder is the Morbark 950 tub grinder. This machine can be purchased from a supplier in Durban at R 1.7 million (refer to Figure 5 below). Feasibility depends on the volume of waste wood pallets produced as well as the comparative feasibility of other options. It is expected that minimisation and alternative material strategies could eliminate the need for such a large investment as this.

Figure 5: Morbark 950 tub grinder

Community recycling projects

As a whole, the strategy of selling/donating the wood to a nearby community should be further analysed in terms of its feasibility, it would be preferable to donate the material to a registered SMME so that they can sign for any H&S liabilities that may be incurred. While the recycling options have potential economic benefit for community projects, it must first be determined whether the incentives will be sufficient to draw people to the project. Aspects such as start-up funding would need to be looked at in order to train the community and provide the required equipment and direction in terms of how to use the wood. The demand for the pallets in terms of quantity and consistency would also need to be looked at for the strategy to be viable to Platreef.

9.10.3 Energy recovery

Some facilities are able to use wood or charred wood as a fuel stock to supplement other fuels for burning in furnaces, cement kilns or power stations. Wood biomass has an estimated calorific value of 20 MJ/kg[7] which is not much lower that coal (25 MJ/kg).

Platreef could potentially send all wood pallets off-site for incineration with the potential for heat energy recovery at cement kilns or waste to energy power stations. This is however subject to the availability and willingness of receivers of this waste. Cement manufacturers may be more inclined to burn wood pallets in their kilns.

9.10.4 Disposal

Wood pallets could be disposed at a general landfill. This practice would, however, influence the remaining airspace of the facility by introducing more bulky waste. In the event that Platreef develops an on-site landfill, this will become an important consideration. Off-site disposal would require transportation which can be expensive, however delivery trucks which often leave empty could be commissioned to take wood pallets to the nearest off-site landfill for reasonable fee.

Disposal is seen as a loss of a potential resource and all alternatives higher up the waste hierarchy should be explored before disposal is pursued.

[7] National Policy on High Temperature Thermal Waste Treatment and Cement Kiln Alternative Fuel Use; South African Hazardous Waste Profile; DEAT; Dr J. Lauridsen; 2008

9.10.5 Trade-off Assessment

According to the trade-off matrix in the tables below; the most favourable option would be for Platreef to use Paperboard pallets instead of wood pallets. Use of these robust and lightweight pallets, with the easy option of recycling or composting after life might also remove the need for a chipper or grinder for inclusion in recycling or composting.

Due to durability or cost concerns Platreef may resort to the second most favoured material, wood, as it is cheaper than plastic and more easily refurbished. There are also many downstream opportunities for after life wood pallets.

The best option for used/broken pallets is to incorporate a take-back agreement with pallet suppliers. Failing this; the next best option is to send the material off-site for use in community recycling projects. This will however require some involvement from Platreef to validate or initiate SMMEs encouraging locals to develop their own business. This is seen as an opportunity for Platreef to gain favour with the local people and fulfil Corporate Social Responsibility.

Once community recycling opportunities have been exhausted, Platreef should pursue chipping pallets for composting. If this is impractical due to equipment requirements or dangerous chemicals etc., Platreef should dispose of the pallets to either their own on-site landfill or the nearest licensed general landfill.

The last resort is for Platreef to incinerate, as chemical in the wood may cause harm through air emissions or result in not meeting permitting requirements (Table 16 and Table 17).

9.11 Medical waste

The mining operation phase requires a medical facility. The bulk shaft construction phase will require a smaller on-site clinic. Medical waste from these facilities is regarded as Health Care Risk Waste (HCRW) and must be treated before disposal.

According to the Draft HCRW Management Regulations[8], the production of anatomical, genotoxic, infectious, sanitary, sharps and nappy waste, in volumes greater than 150 g but less than 20 kg per day would cause Platreef or the dedicated health care facility to be classified as a minor generator of HCRW, which is the anticipated category for both phases of the mine considered.

It is endorsed that Platreef should acquire the services of a specialised HCRW service provider, as standards for the storage; handling and transport are stringent and require licensing with the relevant authorities. This can be more efficiently done by a specialised contractor.

As a minor generator, Platreef must keep all waste manifest documentation issued and full record of HCRW management from the service provider. Platreef must provide safe storage areas and containers and ensure that the HCRW contractor is registered and licensed.

HCRW must be properly treated in a thermal or chemical treatment facility before safe disposal at an H:H landfill. The most common and proven technology for HCRW destruction in South Africa is incineration, however some service providers use alternative techniques; which may affect the cost of the service.

9.12 Explosives packaging (Construction Phase)

It is understood that explosives will only be used during the shaft sinking or construction phase, as other means of rock drilling and removal will be used during full operation. While the occurrence of waste or expired explosives is unlikely, packaging contaminated with explosives must be managed as hazardous waste.

It has been estimated that explosives contaminated materials will be generated at a rate of 13 t/a during the shaft sinking phase (2014 - 2020).

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[8] National Environmental Management: Waste Act (50/2008): Draft Health Care Risk Waste Management Regulations, Department of Environmental Affairs, 1 June 2012

Table 16: Trade-off Assessment for Pallets

Strategy Type	General Notes	Wood (pallets, crates, etc.)													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals(skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
	as noted	Required, but complex process: 1	Yes: 1	Yes: 1	Yes: 1	High cost: 1	None to date: 1	Difficult: 1	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
	as noted	Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
	as noted	Not Required: 5	No: 5	No: 5	No: 5	Low cost: 5	Current practice: 5	Easy: 5	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
Weighting 1 = (Low) Largely uncontrollable with implications having the potential to detrimentally financial feasibility of operations 3 = (Fair) Although important, it is manageable in respect of affecting Platreef's financial and operational feasibility 5 = (High) Manageable in respect of affecting Platreef's sustained financial and operational activities															
Weighting		1	3	3	3	5	3	1	1	1	1	1	3	5	
Option Score Result Matrix * (Selected Strategy Score cell value is multiplied by Weighting cell value and the results summed to produce each Option score result)															
1. Alternative Materials 1.1 Plastic Pallets	Changing the pallet material to reduce wood waste	5	5	3	5	3	3	5	5	5	5	5	1	3	111
1.2. Paperboard Pallets	Changing the pallet material to reduce wood waste	5	5	5	5	5	3	5	5	5	5	5	1	3	127
1.3. Wood Pallets	Current pallet material	5	5	3	5	5	5	5	3	3	5	5	1	1	113

Strategy Type	General Notes	Wood (pallets, crates, etc.)													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals(skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
	as noted	Required, but complex process: 1	Yes: 1	Yes: 1	Yes: 1	High cost: 1	None to date: 1	Difficult: 1	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
	as noted	Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
	as noted	Not Required: 5	No: 5	No: 5	No: 5	Low cost: 5	Current practice: 5	Easy: 5	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
2. Take-back Strategy	Negotiating with current supplier or finding a supplier who will do this	5	5	5	5	5	3	3	5	5	5	5	1	3	125
3. Wood Chips	On-site wood chipper, chips used for composting or incineration	5	5	5	5	1	1	3	3	5	5	5	1	3	97
4. Community (SMME) Projects	Wood is sold in its whole form or in chips to SMMEs for various recycling initiatives	5	5	5	5	3	3	3	3	5	5	5	5	3	125

Strategy Type	General Notes	Wood (pallets, crates, etc.)													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals(skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
	as noted	Required, but complex process: 1	Yes: 1	Yes: 1	Yes: 1	High cost: 1	None to date: 1	Difficult: 1	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
	as noted	Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
	as noted	Not Required: 5	No: 5	No: 5	No: 5	Low cost: 5	Current practice: 5	Easy: 5	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
5. Incineration with energy recovery	Off-site facility	5	1	3	5	5	5	5	3	3	3	1	1	1	95
6. On-site Landfill Disposal	Disposal at on-site general waste landfill	3	5	3	5	3	5	5	3	5	5	1	1	1	99
7. Off-site Landfill Disposal	Disposal at off-site facility	5	5	3	5	1	5	5	3	5	5	5	1	1	95

Table 17: Further considerations in support of table 16 above

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
1.1. Plastic Pallets	None, other than ensuring duty of care	More expensive than wood pallets, but are more durable, providing an increased lifespan	Plastic must be disposed of or recycled if pallets break	Plastic may be seen as a less environmentally friendly material to use	Longer life due to strength reduces waste quantities by increasing re-usability	If the plastic pallets are not returned to the supplier or sent to appropriate recycling facilities, they provide an undesirable waste stream	Medium-term, longer usable life and recyclability of plastic pallet, provided the material is sent off-site for recycling	111
1.2. Paperboard Pallets	None, other than ensuring duty of care	Inexpensive	Minimal, as pallets are recycled	Minimal sensitivity as paperboard is considered an environmentally friendly option	Low costs, light weight and highly recyclable, containing no nails or chemicals as potential safety hazards	Change in supplier and susceptible to water damage	Medium-term material is recyclable, provided recycler is in place	127
1.3. Wood Pallets	None, other than ensuring duty of care	Inexpensive	Chemicals in wood can be harmful, but generally not a significant environmental risk	Minimal sensitivity if waste pallets are managed responsibly	Low costs	Nails and chemicals used in their production limits their re-use and recycling potential	Low sustainability due to high turnover of pallets	113
2. Take-back Strategy	None, other than ensuring duty of care	Possibly profitable to Platreef if used pallets are sold back to supplier	No risk as pallets are being taken back for off-site recycling or disposal	None associated as waste stream is dealt with responsibly	Possibly profitable to Platreef and waste stream is potentially reduced to zero, requiring zero disposal	Deal must be entered into with current supplier, or a new supplier must be identified who is willing to partake in such a strategy	Medium-term sustainability as pallets go back to the source to be managed by the producer, provided producer is willing to take material back once used/ damaged	125
3. Wood Chips	None, other than ensuring duty of care (composting facility would, however, require a NEMWA licence)	Relatively high capital cost of purchasing chipper which is also able to removes nails	Negligible risk associated with machinery	On-site operations will not affect public, unless wood chips are sold to community (SMMEs) - see below	Usable product, potentially providing economic benefit. Waste stream is diverted from landfill	Type of wood chipper will determine flaws. If nails are removed then only potential flaw is possible chemicals in wood	Medium sustainability due to limited application and downstream use of wood chips	97
4. Community (SMME) Recycling Projects	None, other than ensuring duty of care	No costs involved as wood will be supplied to SMME	No risk as pallets are presumably being re-used or recycled in a responsible manner	Positive public image, viewed as a community outreach project	Good public image and job creation and economic growth in the area. Waste stream is diverted from landfill	There must be a demand for such a project which may be reliant on public training and creating interest and incentives	Creates jobs and adds value to the wood, potential constraint is that there is no SMME willing to accept the waste	125
5. Incineration	Platreef will need to ensure that the off-site facility has appropriate licences in terms of NEMWA and potentially NEMAQA	Costs may be significant in transporting wood to off-site furnace	Potential high risk of air pollution	High public sensitivity is associated with the pollution producing process	Charcoal could be produced for use in electricity generation. Waste stream is diverted from landfill	Pollution production and ultimately ash production, which requires disposal	High transport cost and low value adding, material is lost	95
6. On-site landfill disposal	Platreef will need to ensure that the landfill has appropriate licence in terms of NEMWA	Minimal cost of transport to on-site facility, but larger airspace required for landfill	Low risk, dependent on the method of disposal as well as the disposal facility	High public sensitivity associated with on-site landfill	Waste stream is dealt with on site with minimal further processing required	Common practice, but does not reduce the waste stream and requires disposal space	Material is lost and value cannot be recovered	99

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
7. Off-site landfill disposal	Platreef will need to ensure that the landfill has appropriate licence in terms of NEMWA. Platreef must acquire safe disposal certificates, and audit the disposal site to ensure duty of care	Medium to high costs associated with transport to off-site facility	Low risk, dependent on the method of disposal as well as the disposal facility	Low public sensitivity, as waste is removed off-site	Waste stream is removed off-site	Common practice, but does not reduce the waste stream and requires disposal space	Material is lost and value cannot be recovered	95

9.12.1 Minimisation

To decrease the waste generated and risk associated with storage and transportation of explosives it is essential to ensure that accurate quantities are ordered.

It is understood that all blasting on site will be outsourced to a specialised service provider, who will also supply their own explosives. In many cases the service provider is poorly regulated or contractual terms don't make mention of waste generated during the blasting operations.

It is suggested that a take-back agreement is written into contractual terms with the blasting service provider, thus disallowing them from leaving explosives related waste on site. In this way explosives packaging will never become a waste that Platreef has to manage.

9.12.2 Disposal

In the event that Platreef does become liable for the management of explosives packaging, storage and removal should be as prescribed by the blasting service provider or manufacturer or hazardous waste service provider, and removed by a hazardous waste service provider to a suitably licensed and equipped H:H landfill.

Alternatively the option for on-site detonation of the packaging, is possible and if done correctly will lead to the destruction of all explosive contamination. This must be done safely; out of range of sensitive receptors and by trained and equipped personnel.

9.13 Lab waste

As part of the mining operation, Platreef will construct and operate its own on-site laboratory for the chemical and physical analysis of rock and ore samples brought up from the mine. Once the samples have been processed, they become waste, along with the chemicals used in the tests. Other lab wastes include expired chemicals or the clean-up of chemical spills.

Some forms of laboratory waste are classified as a HCRW[8], this includes "specimens" sent to a laboratory for analysis (biological testing). If the samples are only being chemically tested, the hazard rating will depend on the chemicals used in the test.

Due to its pre-classification, biological lab waste is required to be treated before safe disposal to a H:H landfill. Treatment in this case will mostly consist of chemical neutralisation or thermal destruction, before it is disposed to H:H landfill.

Chemically tested samples and used chemicals should be characterised before disposal. In some instances it is possible to put sample material back into the process. Even though the samples are too small to make mineral recovery significant, this will result in the avoidance of a potentially hazardous waste stream.

9.13.1 Minimisation

Although the production of waste samples is a necessary part of the process; excessive wastage of chemicals is avoidable through proper planning and management of chemical stocks, spillages and stores. In this way, the disposal of unused or expired chemicals can be avoided.

9.13.2 Disposal

Disposal of lab waste should be undertaken by a service provider who is licensed for the handling and transport of hazardous waste. Platreef should capture and keep record of all weigh bills and safe treatment and disposal certificates. This should be kept along with financials for the service provider, so that expenses and level of service received can be easily linked.

9.14 Electronic waste

E-waste is defined as discarded electrical or electronic devices. This generally includes discarded computers, office electronic equipment, mobile phones and other electrical appliances such as televisions, refrigerators, process electrical equipment, electronic components and electrical panel components.

9.14.1 Minimisation

An essential factor in minimising e-waste is to prolong the life of electronic devices. Computers and computer components form a large part of e-waste and various strategies may be implemented to prolong their lives and ultimately reduce waste quantities. Some such strategies for computer related e-waste reduction include the following:

- Computers switched off when not in use;
- Power setting of computers should be suitably managed;
- Upgraded, or only faulty parts replaced as opposed to replacing entire units; and
- Refurbished computers or components should be considered.

Several of these strategies will not only serve the purpose of reducing e-waste, but will also save electricity and hence running costs. Some of these strategies can also be applied to other electronic devices, not only computers.

A take-back (or buy-back) system with suppliers should be implemented in order to promote the refurbishment and further use of all electronics.

9.14.2 Re-use

In cases where computer related electronic equipment is being replaced, but is not broken and could still be used, it is recommended that this electronic equipment be donated to schools, orphanages, libraries or any community amenity that could make use of it. In some cases it may need to be refurbished in order to prolong its lifespan. This could enhance community relations contribute to of Platreef's Corporate Social Responsibility.

9.14.3 Recycling

There are various recyclers who will collect and take e-waste and pay for it, depending on distances, types and quantities of electronics available. Possible recycling companies[9] include the following:

- Sindawonye – are located in Wadeville, Gauteng but offer to collect e-waste further afield. They pay for the e-waste based on an analysis and weighing at their facilities; and
- Blue Platinum Recycling (Bela Bela, Limpopo).

Various other e-waste recyclers and refurbishers are listed on the EWASA website: www.ewasa.org Most of the collectors, recyclers and refurbishers are situated in Gauteng. Subsidiary agreements can be made between waste service providers and recyclers.

9.14.4 Treatment/Disposal

Although e-waste constitutes less than 1% of waste going to landfill countrywide, it contributes almost 20% to the toxicity in those landfills. E-waste contains many poisonous chemicals and heavy metals, as a result any e-waste that has to be disposed of must be safely disposed in a H:H landfill. Options available to Platreef include off-site disposal and on-site disposal at a newly constructed hazardous waste disposal facility, both of which are costly.

Some of the recyclers or refurbishers as mentioned in the section above dismantle e-waste and recover certain components or materials, often the metals. They are also capable of removing the hazardous components, allowing the remainder to be disposed as general waste if they are unable to further recycle it, while the concentrated hazardous materials can then be safely disposed in a reduced volume.

[9] Golder is not affiliated to these companies, nor does Golder audit the companies to validate legitimacy of services offered

9.14.5 Trade-off Assessment

From the trade-off matrix below (Table 18), it is evident that Platreef should pursue selling e-waste to recyclers. This option provides for potential income generation especially if recyclers collect the waste from the mine. Platreef will need to ensure that recyclers manage/dispose/recycle e-waste according to regulatory requirements, through certificates and business registrations.

In addition, prolonging service lives of all electronic equipment through raising awareness of best practices with electronics use will also significantly contribute to managing this waste stream in the long-term.

9.15 Waste Tyres

Waste tyres are an increasingly prominent problem in South Africa, and along with the limited availability and prices of new tyres (with particular reference to mine truck tyres), tyre management strategies are of huge importance. Waste tyres are difficult to dispose of due to several factors including the fact that they are not easily compressed, they do not degrade easily and they can pose a fire risk in storage or landfill. Many successful options and strategies are in use around the world and some even locally in South Africa, though to a lesser extent. These various options have been discussed below and have been prioritised by where they sit in the waste management hierarchy.

It is noted that Platreef is not expected to produce large quantities of waste tyres from mine trucks as the mining method is not intensive on large haul trucks nor are large distances involved. An accurate estimation of waste tyre production can be calculated once the type and number of mine vehicles expected on site is known.

It is not anticipated that Platreef mine site will be responsible for the tyres used in transportation of materials onto or off of the site.

9.15.1 Waste minimisation

Increasing tyre life

There are various methods to increase tyre life. With particular reference to mining truck tyres, the following aspects should be considered:

- Air pressure maintenance should be conducted at a minimum of weekly intervals;
- Mechanical maintenance should be conducted, including checking of alignment and suspension components;
- Tyre and rim inspection should occur regularly by performing walk-rounds to look for cracks or flange damage and check valve hardware;
- Loads on the trucks should be managed, including GVW (gross vehicle weight) adherence and checking load distribution;
- Problem areas such as spills or damaged roads should be dealt with immediately to avoid tyres coming into contact with such areas. Fixing snag points on roads should be prioritised to minimise tyre waste;
- Information to avoid spills and road damage should be readily available, for example via radio communications; and
- Scrap tyres should be analysed to determine common trends in tyre failures or trucks with multiple failures, so as to identify problem areas.

Table 18: Trade-off Assessment for E-waste

Strategy Type	General Notes	E-waste													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/ Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals (skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
	as noted	Required, but complex process: 1	Yes: 1	Yes: 1	Yes: 1	High cost: 1	None to date: 1	Difficult: 1	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
	as noted	Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
	as noted	Not Required: 5	No: 5	No: 5	No: 5	Low cost: 5	Current practice: 5	Easy: 5	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
Weighting 1 = (Low) Largely uncontrollable with implications having the potential to detrimentally financial feasibility of operations 3 = (Fair) Although important, it is manageable in respect of affecting Platreef's financial and operational feasibility 5 = (High) Manageable in respect of affecting Platreef's sustained financial and operational activities															
Weighting		1	3	3	3	5	3	1	1	1	1	1	3	5	
Option Score Result Matrix * (Selected Strategy Score cell value is multiplied by Weighting cell value and the results summed to produce each Option score result)															
1. Prolonged life	Promote care and energy saving	5	5	5	5	5	3	3	5	5	5	5	1	3	125
2. Refurbishment	Re-use	5	5	5	5	3	5	3	5	5	5	5	3	3	127
3. Recycling	Off-site recycler: components taken from broken computers	5	5	5	5	3	3	3	5	5	5	5	5	5	137
4. On-site Disposal	Newly constructed on-site H:H landfill	1	5	1	1	1	3	1	3	5	5	1	1	1	59
5. Off-site Disposal	Off-site H:H landfill, such as Holfontein	5	5	1	1	1	3	3	3	5	5	3	1	1	67

Table 19: Further considerations in support of table 18 above

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
1. Prolonged life	None	Minimal costs, simple measures which need to be carried out	No risk	None	Reduced costs as new equipment is required less regularly	Staff using relevant equipment must be educated and agree partake	Limited scope, but can make a significant saving in electronic expenditure and e-waste generation	125
2. Refurbishment	None	Refurbishment remains cheaper than buying new. Old e-waste donated for refurbishment should not incur prices	No risk, provided hazardous components are handled appropriately during refurbishment	Minimal, probable positive publicity if e-waste is donated	Reduced cost of buying new, or reduced waste stream if donated for refurbishment	Refurbished electronics may not meet performance requirements, reliability may be inconsistent	Although refurbished electronics have less functionality than new, they can be used by schools, etc.	127
3. Recycling	Platreef must ensure that recycler has relevant NEMWA licence in place for recycling. Platreef must also acquire safe disposal certificates for hazardous components especially, and audit end destination of the waste to ensure duty of care	**Profitable if recyclers collect and pay**	Only non-recycled e-waste poses a risk	Minimal, seen as a sustainable option	Economic benefits if recycler collects and reduction of waste stream	Finding a recycler and transporting it there	Expensive component materials can be recovered and recycled perpetually	137
4. On-site Disposal	Platreef will need a NEMWA licence for H:H landfill. Note: once the new draft NEMWA regulations are promulgated, hazardous electric or electronic equipment will no longer be allowed to be disposed of at landfills	Minimal transport costs, but high costs associated with H:H facility construction	Hazardous waste detrimental to the environment, though correctly lined H:H facility should mitigate impact.	High sensitivity associated with waste of expensive raw materials and high polluting material.	Waste is safely disposed of.	Transport and safe disposal costs are high and waste stream is not being reduced.	All potential value is lost, and toxicity is added to the landfill	59
5. Off-site Disposal	Platreef must ensure that the H:H disposal site has the relevant NEMWA licence for hazardous waste disposal. Platreef must acquire safe disposal certificates, and audit the disposal site to ensure duty of care. Note: once the new draft NEMWA regulations are promulgated, hazardous electric or electronic equipment will no longer be allowed to be disposed of at landfills	High transport costs	Hazardous waste detrimental to the environment, though correctly lined H:H facility should mitigate impact	High sensitivity associated with waste of expensive raw materials and high polluting material, but mitigated to some extent if off-site	Waste is safely disposed of off-site	Transport and safe disposal costs are high and waste stream is not being reduced	All potential value is lost, and toxicity is added to the landfill	67

In terms of the road design and route planning, several factors can influence tyre life as well as the truck life and running costs. These factors include the following:

- Mine vehicle speeds should be carefully planned and regulated;
- Road surfaces; a smooth road results in less wear on the tyre;
- Road grades can adversely affect tyre life, with steeper and inconsistent grades resulting in more wear on the tyres. With good mine planning, consistent grades of less than 1:10 should be maintained;
- Repeated use of the same path in a road lane can lead to increased wear on tyres due to the formation of ruts in the road; and
- Super-elevation in corners can reduce tyre wear, or else speeds should be reduced in corners.

Coupled with all these factors is the necessity to instil a sense of awareness amongst drivers with regards to maintaining the truck tyres. Proof that such strategies can lead to significant savings may be observed in a case study performed by Anglo American. A global multi-disciplinary team was setup to investigate ways to improve tyre life by 20%. A Tyre Improvement Guideline and Implementation Manual was developed and has been used, achieving more than 50% tyre life improvements. Part of this strategy involves tyre champions, who create operator awareness and ensure optimal road conditions.

9.15.2 Re-use

Re-treading

Although re-treading of tyres has not been a popular strategy in the past with regards to mining truck tyres, increased demands and a limited supply has led to this becoming a viable option. The major concern over this strategy is the issue of safety. This issue is largely dependent on the quality of the re-tread and the methods employed in doing so. The REDISA plan (see section 9.15.6 below) will look to promote re-treading of undamaged tyres, claiming that if done properly a tyre can be re-treaded a number of times[10]. Re-treads should only be used in certain applications including the following[11]:

- Graders and light work loaders, not on large earthmovers; and
- The back inside position, not as steer tyres on haul trucks.

Speed limits will also have to be revised for re-treads and they will need extra maintenance and monitoring to check for tyre pressure, operating temperature and damage.

Even if Platreef's policy is not to use re-treads, Platreef may consider selling their used tyres to re-treaders. This strategy of the re-sale of worn tyres does however carry a certain amount of liability for Platreef. Should this strategy be favourable to Platreef, assurances must be made that Platreef cannot be held responsible for failures from any of the tyres originating from the mine. The re-treaders should thus be prepared to take full responsibility for the condition and reliability of the tyres to be re-treaded.

Civil Engineering/General Use Applications

Mining truck tyres have engineering value owing to the solid structural characteristics associated with their mass and strength. Some of the potential civil engineering and general use applications are as follows:

- Marine applications such as:
  - Artificial reefs;
  - Floating breakwaters; and

[10] Chris Crozier, REDISA, E-mail communication.

[11] MCA Report (Australia)

- Barriers on harbour walls.

- Erosion control;
- Landscaping;
- Retaining walls;
- Used whole in agricultural applications;
- Thermal insulating along household foundations; and
- Road barriers.

Marine applications may not be suitable since they would require long haul transport of the tyres. Other applications may also be limited due to the large size of the mining truck tyres.

Waste tyres may also be used for various building applications in combination with other materials. This usually requires the tyres to undergo a process such as granulation prior to being used. Granulation of waste tyres is discussed in the section on shredding and granulation below.

9.15.3 Recycling

A limited number of recycling options exist for waste tyres, especially with regards to large scale mining truck tyres. Various options are discussed, analysing their suitability and potential in a local context.

Shredding and Granulation

A common strategy, which often forms the first step of many recycling processes of waste tyres, is shredding. Many recycling applications of waste rubber involve this first step as it makes the rubber significantly easier to transport and process or dispose of. The transport of the tyres is made easier and cheaper by significantly reducing the volume when shredding. For this reason, this strategy should be seen as a high priority before considering various other recycling options.

Shredding of the waste tyre would usually take place before granulation. These processes are relatively expensive processes and require the use of specialised machinery, especially with regards to large mining truck tyres. It should however be noted that with the REDISA plan coming into effect, there may be improved incentives and monetary benefits to shred and granulate waste tyres. Some uses for shredded tyres include the following:

- Landfill engineering (as leachate drainage layers); and
- Fill in road embankments.

Smaller granules which may be produced from the shredded tyres have many more uses. The granulation process usually uses one of two processes to produce varying size granules. These two technologies are as follows:

- Ambient Mechanical Granulation. Tyres are passed through a shredder which breaks the tyres into chips; the chips are then fed into a grinder that breaks them into small pieces while removing steel and fibre in the process; and
- Cryogenic Granulation. Using shredded rubber as an input. Liquid nitrogen is used to freeze the rubber at temperatures below -80°C. This makes the rubber brittle and easy to crush into finer pieces, while steel and fibre are easily taken out.

The granules produced may then be sold for use in an increasing number of applications including some of the following:

- Surfacing of sport facilities (synthetic turf);
- Flooring in hospital and industrial buildings;
- Rubberised asphalt for roads and driveways;
- Various moulded rubber products; and
- Mulch in landscape applications.

Rubber granules are also exported for use in these and other applications. Companies in South Africa which are involved with granulation are listed below[12]:

- Gloss Recycling and Chemicals (Johannesburg – Kempton Park);
- ENV&E Rubber (Pietermaritzburg);
- Goswell Industries (Cato Ridge, KZN); and
- SA Tyre Recyclers (Atlantis, WC).

Steel Recovery

Steel recovery from waste tyres is part of tyre processing for rubber reuse. However, a common method of recovery is a major concern where tyres are often illegally burnt to recover the steel. This burning is hazardous to the environment due to the toxic pollutants released into the air. An environmentally sound procedure of recovering the steel wire is the process of de-beading the tyres, generally using specialised machinery. This machinery is expensive for large scale mine truck tyres. The steel extracted from the waste tyres may enter into recycling streams for further re-use. After shredding, steel and rubber recovery off-site are recommended through agreement with an appropriately selected recycler.

9.15.4 Energy Recovery

Incineration

Incineration is an approach concerning the recovery of energy from waste tyres in the form of heat energy. Tyres may be used as fuel (sometimes referred to as tyre derived fuel) as a substitute for fossil fuels in purpose built furnaces of power stations, smelters or paper mills, but most commonly in cement kilns. As can be seen in Figure 6), rubber has a higher calorific value than coal. The incineration process can also yield recyclable by-products including scrap metal, fly ash and steam, however its major drawback is the issue of toxic emissions. The concern in South Africa is that many of the incinerators do not meet international standards and are not using the scrubber process to reduce these toxic emissions[13].

The practise of using waste tyres in cement kilns is not common in South Africa but tyres have been utilised at PPC's Hercules Factory in Pretoria. This practise at the Hercules Factory has been heavily criticised and opposed, mainly due to the hazardous emissions associated with the incineration of the tyres and the opinion that the local cement industry does not meet European standards of best practise[14]. The main benefits include its feasibility (being cheaper than using conventional fuels such as coal), job creation and the reduction of waste tyres. Globally the use of waste tyres in energy recovery such as cement kilns is considered an environmentally sound method of recovery; however the cement industry should meet certain standards. It should be noted that the tyres, especially large-scale mining truck tyres, will need to be cut up or shredded prior to being used in any incineration process.

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[12] Golder is not affiliated to these companies, nor does Golder audit the companies to validate legitimacy of services offered

[13] Dissertation by M.L. Mahlangu

[14] City Press article (http://www.citypress.co.za/SouthAfrica/News/Pollution-row-over-tyres-20100823)

Waste to energy strategies do fall lower on the waste hierarchy than the previously mentioned strategies included in the re-use and recycling sections. The main advantage of incineration is that a certain amount of the energy from the tyres is being recovered, and has a value as opposed to them being sent to a landfill where the energy and value is entirely lost, posing additional concerns of fire hazard in landfill.

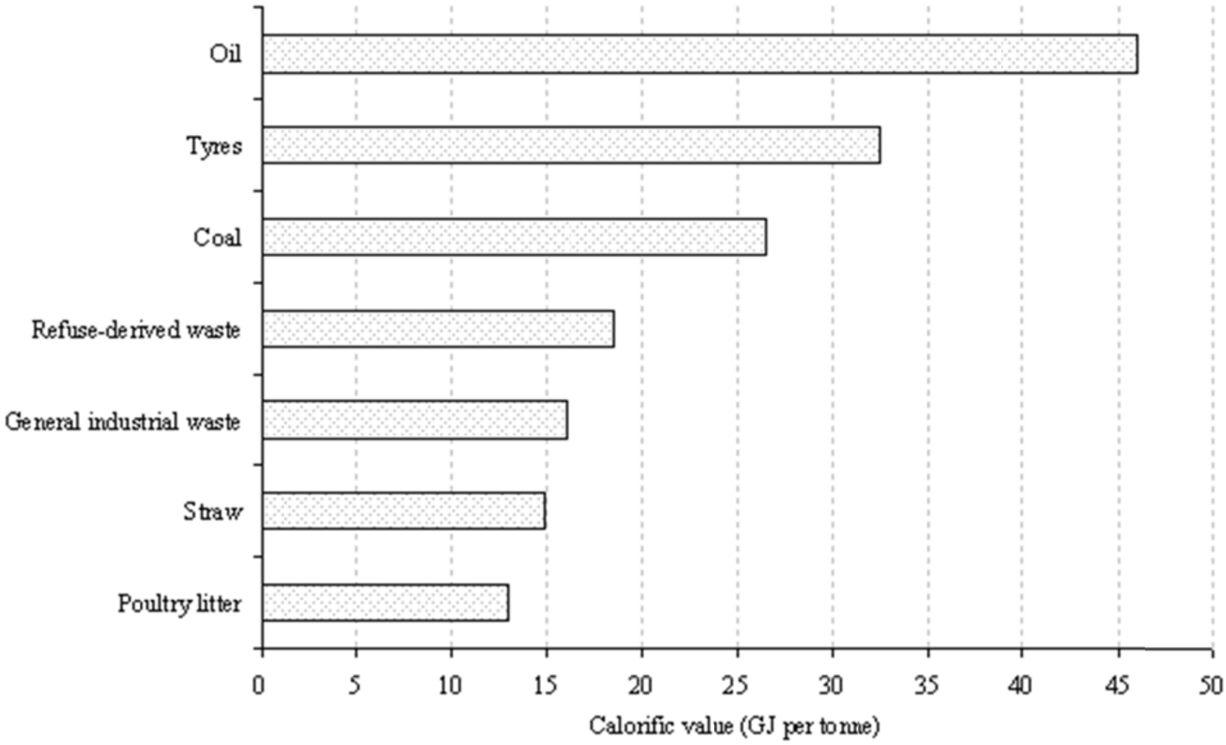

Figure 6: Some calorific values for different sources (Source: Department of Trade and Industry, 1997)[15]

Oil generates the most energy, at over 45 gigajoules per tonne

Tyres generate about 33 gigajoules per tonne

Refuse-derived waste produces 18 gigajoules per tonne

General industrial waste generates 16 gigajoules per tonne

Straw produces 15 gigajoules per tonne

Poultry litter produces 13 gigajoules per tonne

Pyrolysis

Pyrolysis is the thermal degradation of organic carbon based materials. The process uses heat without adding oxygen to recover energy. It should be noted that for tyres to be used in such a process, they are usually required to be broken up or shredded to a certain extent. This makes for easier transport and manageable particle sizes for the process of pyrolysis.

[15] http://www.mfe.govt.nz/publications/waste/devt-regional-waste-recovery-sector/html/figure4-1.html

Like incineration, pyrolysis can handle almost all waste types with correct management, however there are potential advantages including the following[16]:

- It may perform well in controlling the emission of harmful substances such as dioxins with levels substantially lower than regulation values;
- A pyrolysis facility can be self-sustainable in that fuel is only required for start-up operations, and steam/electricity generated is further supplied outside the facility to consumers;
- The plant may not produce waste water effluent from the gas cleaning system, saving not only the environment, but costs as well;
- There may be a reduced quantity of residuals to be sent for landfill disposal. Remaining non-toxic ashes may be used in the building industry;
- Recovered metals are non-oxidised and can therefore be used further; and
- Pyrolysis plants may treat both low and high calorific waste.

Although the specific pyrolysis of tyres is not yet practised in South Africa, pyrolysis as a general way of dealing with waste is increasing due to the increased price of electricity and the increasing need for waste management and controlling the costs involved. While at least one pyrolysis plant does exist in South Africa (located in Wadeville which produces electricity from waste of various calorific levels). Potential pyrolysis plant specifically for waste tyres are further below.

One company who operates in turning rubber to fuel is:

- Innovative Recycling[17], (Pretoria – Newlands).

Prestige Thermal Engineering (PTE) is a local company which is globally renowned for its involvement in the design and fabrication of thermal processing equipment and thermal systems with significant involvement in pyrolysis technology. A brief discussion with PTE yielded the following background information regarding a potential pyrolysis plant in South Africa:

- A feasible plant can process 400 tons of waste per day, generating 7.5 MW;
- The capital expenditure will be in the region of R 300 million, with a 22% return; and
- The pyrolysis option is becoming an increasingly viable option owing to the increasing electricity cost and increasing waste generation.

Another company identified was Ulalo-Doing (South Africa). This is a joint venture between Ulalo, a South African company, and Xinxiang Doing Renewable Energy Equipment Co Ltd, a Chinese manufacturer of renewable energy equipment. This company deals with pyrolysis technology for tyre recycling and is involved in the design, manufacture, installing, training and maintenance of such a plant. The company offers 6, 8 and 10 ton capacity pyrolysis plants and can include a tyre shredder to reduce large-scale mining truck tyres to a suitable size for the plant. The approximate cost of one modular production line is reported as 130 thousand US Dollars (approximately R 1.1 million), including installation, commissioning and staff training at the selected site. However, it is not considered that Platreef will produce a quantity to justify such a plant.

Another viable option involves Anglo American's plans regarding the specific recycling of mining truck tyres. A team from the Anglo SMME funding department have investigated pyrolysis technology. Pyrolysis machinery is apparently available, which is completely developed and produced in South Africa and can be used to turn tyres into fuel and other useful by-products such as carbon black and steel. This means that, although it is an energy intensive process, there is no significant pollution from the proposed plant process.

[16] Adapted from Splianex website, http://www.splainex.com/waste_recycling.htm

[17] Golder is not affiliated to this company, nor does Golder audit the company to validate legitimacy of services offered

A proposal was received by Anglo, and is currently under serious consideration to produce 60 000 litres of product per month requiring capital outlay of R 53 million. If Anglo decides to invest, plant may be operational as early as 2013. The location of the pyrolysis plant has not been finalised, but Anglo will request the SMME to choose a central location to the Anglo mines.

A second initiative is an SMME proposal to Anglo for funding of a mobile tyre processing unit called Mobi-Shred. This would consist of a number of vehicles which carry tyre shredding equipment to mines to shred mining tyres for easier transport to the pyrolysis plant as a separate entity to the pyrolysis business. Mines would pay the shredder for their services, and it is uncertain if the pyrolysis plant would be able to pay mines for their shredded rubber or for the transport of the rubber.

These initiatives may provide a sustainable solution for mining tyres.

Transporting the rubber (raw or shredded) may consider that delivery trucks often leave without a load, creating an opportunity for Platreef to send tyres and other material back to the recycling market. It is suggested that negotiations be undertaken with transport companies, as return journeys are already included in the cost of delivery. For a small extra sum, these companies may be willing to transport used rubber back to industrial areas where downstream processing could take place.

9.15.5 Stockpiling

Although the REDISA plan has not yet come into effect, it is envisioned to be operational within the next two years and to be a solution for mining tyres and even a market for the materials that come from the REDISA plan. For this reason it is recommended that waste mining tyres be stockpiled at Platreef as opposed to being disposed of at least through bulk shaft phase.

9.15.6 Disposal

On-site storage and disposal

A historic practice for the on-site disposal of mining tyres is for them to be buried under waste rock dumps and other waste bodies. This is problematic as tyres tend to “float” to the top of dumps and cause short term and long term instability in the dump material. In instances where mines decide to re-mine or reprocess dump material, they also have to deal with the legacy of buried rubber in the dumps. When a mine closes and has to rehabilitate pits and dumps, often large amounts of material have to be moved and tyres can cause difficulties in this task.

The option of first shredding the tyres before disposal does have advantages and has been discussed in the Shredding and Granulation Section above. This does however mean that the tyres must be shredded on-site as a minimum before disposal and an appropriate storage site must be found. Fire risks must be carefully managed.

REDISA

REDISA is a non-profit company which has been established to implement the Integrated Industry Waste Tyre Management Plan. The plan aims to remove waste tyres of all categories (REDISA claims to have an obligation to start collecting mining truck tyres within 18 months) from the South African environment through subsidising collection and recycling by attaching a value to scrap tyres. The plan targets smaller businesses and individuals who will be responsible for collecting and removing waste tyres from their community and delivering them to a collection point. An integral part of the plan is thus to create jobs in the informal and SMME sectors.

Ultimately a network of collection depots and recyclers will be established. There may be opportunities for Platreef to become a part of the plan.

When asked the question as to what the implications for a mining company are, and whether operations must be in accordance with the REDISA plan as well as what recycling or disposal options there are, Dr Chris Crozier of REDISA gave the following response: “*Mining companies need to work with REDISA. The owner of a registered stockpile must make his arrangements to abate the stockpile. This can be done with or without REDISA, but should make more sense to do in collaboration with REDISA. Technically, in terms of* *the Regulations, they may not add waste tyres to existing stockpiles or dumps and all new waste tyres arising may only be managed via REDISA, but right now we cannot offer a solution. We have had some discussions with some mining groups already to cooperate on solutions for managing OTR tyres. The biggest problem we are working on is how to de-bead and then cut the tyres to manageable size pieces before further processing*".

Different kinds of sites are identified in the REDISA plan, and include the following:

- Transfer site (transporters deliver to an interim site);
- Tyre processing site (tyres prepared for recycling);
- Recycling site;
- Specialist sites for recycling large waste tyres; and
- Combinations of the above.

These sites must be registered, comply with legislation and should also be open to individuals wishing to dispose of their waste tyres. This may link into the previously mentioned potential of creating a tyre processing site and/or recycling site. A specialist site for large tyres would be required and waste tyres from the nearby communities could also be collected and processed.

It is recommended that the REDISA plan be scrutinised by Platreef before deciding whether or not to become involved.

(*It is noted that the REDISA plan which had received approval from the DEA in November 2011 had its approval withdrawn in January 2012 as some amendments had to be made and a legal dispute between REDISA, the DEA and the SATRP had to be resolved. This is seen as a political hiccup and will not stop the ultimate resolution of a plan to deal with South Africa waste tyres. A court ruling on Monday the 17th of September 2012 by the North Gauteng High Court ruled against the SATRP in favour of REDISA making it mandatory for all tyre producers, re-treaders or importers to register and pay levies to REDISA*.)

9.15.7 Trade-off Assessment

Once minimisation has taken place to the greatest practical extent, used tyres should be sent off-site for re-treading as far as possible. The scope for re-treading will not cover all tyres and a fraction of tyres will require further solutions. Recycling through shredding and granulation is the second most favourable waste management option.

Platreef should seek to re-use tyres which cannot be re-treaded or recycled, for on-site engineering uses, such as making barriers or demarcation of certain areas. After this has been exhausted, Platreef should stockpile tyres for future feasible options, at least during the Bulk Shaft Phase. Following the Bulk Shaft Phase it is anticipated that cleaner solutions will present themselves. See Table 20 and Table 21.

9.16 Conveyor belts

It is expected that rubber conveyor belts will be used extensively at the mine for the purpose of transporting minerals from the active mine face, through the process and finally to the point of disposal. Rubber conveyor belts must be replaced routinely due to wear and tear of everyday use.

It is assumed that from the start-up, Platreef will design systems such as conveyor belt specifications, quality of supply/materials and configurations, with the highest efficiency in mind, including the lowest feasible impact on the conveyor belts, in order to reduce the frequency that they must be replaced. This is assumed to be part of the design optimisation and therefore the scope for minimisation, post design, is non-existent. However; the lifespan of the conveyor belts can be increased by controlling the transfer points and other factors as described below:

- The height of the drop, when material is transferred onto the conveyor belt;

- Foreign objects such as concrete, iron, pillars and steel ropes moving through the system;
- Uneven conveyor belt loading;
- Flooding of the belt; and
- Blockages.

It should be noted that used conveyor belts should be rolled up upon removal from operational placement, in order to enable safe storage and transportation.

9.16.1 Re-use

Used and damaged conveyor belts can be reused for a number of different applications on-site and off-site.

Some on-site applications include: creating barriers and boundaries, erosion prevention, ground cover for machinery and equipment laydown areas, landscaping applications, protection layers in blasting zones, shielding in workshops and welding areas, etc. Used conveyor belts can be re-used as a protective covering for the back section of open utility vehicles and flatbed trucks. This simply requires the rubber to be cut into the correct shape and size while seams can be moulded together.

There are various other off-site uses that may be developed, sometimes including benefits to the local communities, such as cricket pitches, gymnasium flooring, playgrounds and sports grounds. Rubber strips can be used in other ways to promote small and informal business ventures such as weaving rubber strips into door mats. The challenge is in finding local people to take the initiative after Platreef has made the offer of the raw material.

These solutions, on their own, however, would not be able to deal with the entire bulk of the used conveyor belt arisings.

A local (Mokopane) waste management company[18], Nieuwco, manages waste conveyor belts through re-use applications and sorting through the conveyor belts to find lengths that can be returned to conveyor belt manufacturers for repair and incorporation into new conveyor belts. Nieuwco may be able to manage the full load of waste conveyor belts from Platreef.

[18] Golder is not affiliated to this company, nor does Golder audit the company to validate legitimacy of services offered

Table 20: Trade-Off Assessment for Waste Tyres

Strategy Type	General Notes	Waste Tyres													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals (skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
	as noted	Required, but complex process: 1	Yes: 1	Yes: 1	Yes: 1	High cost: 1	None to date: 1	Difficult: 1	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
	as noted	Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
	as noted	Not Required: 5	No: 5	No: 5	No: 5	Low cost: 5	Current practice: 5	Easy: 5	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
Weighting **1 = (Low) Largely uncontrollable with implications having the potential to detrimentally financial feasibility of operations** **3 = (Fair) Although important, it is manageable in respect of affecting Platreef's financial and operational feasibility** **5 = (High) Manageable in respect of affecting Platreef's sustained financial and operational activities**															
Weighting		1	3	3	3	5	3	1	1	1	1	1	3	5	
Option Score Result Matrix * (Selected Strategy Score cell value is multiplied by Weighting cell value and the results summed to produce each Option score result)															
Re-Treading	Re-use option 1	5	5	5	5	5	5	3	5	5	5	5	5	5	153
Engineering uses	Re-use option 2	3	5	3	3	5	3	3	3	5	1	3	5	3	115
Shredding & granulation	Recycling	3	3	5	5	5	5	3	5	5	5	5	5	5	145
Incineration	Off-site Energy Recovery	1	1	3	3	3	3	1	5	1	3	1	1	1	65
Pyrolysis	Off-site Energy Recovery	1	5	5	3	3	3	1	5	3	1	3	5	3	107
Stockpiling	On-site	3	5	1	3	1	5	5	3	3	1	3	1	1	73

Strategy Type	General Notes	Waste Tyres													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals (skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
	as noted	Required, but complex process: 1	Yes: 1	Yes: 1	Yes: 1	High cost: 1	None to date: 1	Difficult: 1	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
	as noted	Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
	as noted	Not Required: 5	No: 5	No: 5	No: 5	Low cost: 5	Current practice: 5	Easy: 5	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
On-site disposal	Disposal will take place at an on-site dedicated facility, potentially co-disposed with waste rock, provided the waste rock will not be used in future	3	5	1	1	3	3	3	3	3	1	3	1	1	69

Table 21: Further considerations in support of table 20 above

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
Re-Treading	Re-treading company must have appropriate authorisations in place for, e.g. storage	Cost of transporting tyres to nearest re-treading company	Reduces waste tyres that need to be managed further down the waste hierarchy, and hence impact footprint	Should the re-treaded tyres be deemed to be "safe", public sensitivity should be low	Reduces tyres that need to be managed further down the waste hierarchy	**Platreef requires the services of a removals company and a contract with a re-treading company. They will only re-tread tyres which have structural integrity**	Tyres can be re-treaded multiple times, assuming it is done correctly. This reduces the demand for the production of new tyres	153
Engineering uses	NEMA general duty of care and NEMWA, pending specific use	Significant costs proportionally related to distance of off-site facilities; limited costs associated with on-site applications	Very limited, depending on specific re-use option	Dependent on specific use, but may be seen as dumping of waste in public areas	Fair benefit in that larger volumes could be employed for general use for off-site engineering	Size of certain tyres may imply transport logistical challenges	Off-site options to address and resolve continuous waste tyre arisings is fair due to the possibility of exploring new off-site application markets	115
Shredding & granulation	NEMWA, depending on processing capacity, whether shredder will be Platreef's or another company's and downstream application of rubber or steel	Shredding machinery is relatively expensive, and if off-site shredding is pursued, transport costs could be fair to significant pending distance travelled furthermore in the case of on-site shredding, transport costs will be reduced based on increased carrying capacity of transport vehicles	Minor risk	Low public sensitivity based on the assumption that shredding will be executed in accordance with best practice	**High benefit, due to reduced transport costs and potential for further recycling**	Specialised machinery required as well as trained employees (unless mobile shredder option becomes available)	Due to the high calorific value of waste tyres, the energy recovery option as a dominant downstream use provides fair weighting subject to the potential constraint of manageable but expensive air abatement equipment	145
Incineration	Platreef needs to verify that NEMWA and NEMAQA authorisations are in place for the incinerator, before sending tyres to an off-site cement kiln or similar process	Significant costs proportionally related to distance of off-site facilities	Potential high risk of air pollution, unless air mitigation is performed in accordance with regulatory requirements, as to be expected from off-site facilities focussing on using alternative energy resources	Despite the fact that off-site facilities operate within the public domain, such facilities normally function at high efficiencies including being equipped with acceptable air abatement equipment. This fact together with Platreef being able to select facilities that manage public relations at an appropriate level makes public sensitivity relatively low	Electricity generated	Advanced skills and expensive abatement equipment normally required for energy recovery and electricity generation will be forming part of the service package provided by an off-site facility; hence relieving Platreef from this requirement	Due to the high calorific value of waste tyres, the off-site energy recovery option provides high weighting based on the assumption that Platreef could opt for downstream facilities using tyres for heat/electricity generation but conforming to air abatement standards. Furthermore, cross-contamination of product is completely eliminated	65
Pyrolysis	NEMWA, NEMAQA, MPRDA	Very high capital cost of plant. Aggravated by low expected volume of tyres	Low risk if the claims about locally proposed pyrolysis technology are accurate. The 'closed' system results in "zero" air pollution	Perceived sensitivity may be high, but if the low minimal pollution claims are accurate there should be little or no public sensitivity	Production of useful materials/fuels such as carbon black. Electricity may also be generated	Plant construction and running required by specialists	Due to complexity of the pyrolysis process, specifically with regards to optimising its operational efficiency, the manageability of this option is low	107

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
Stockpiling	NEMWA, MPRDA	Minimal transport costs involved, saving tyres for future economic use	Potential fire hazard or accumulation of stagnant water	Although for a limited period, the tyres are effectively disposed in an open manner	Potential high economic benefit when REDISA and/or the Anglo initiative come into effect, as there will be an increased demand	Safe storage could lead to large economic gains, though it is reliant on external factors such as REDISA and Anglo's initiative	Due to the extensive footprint required for tyre stockpiling, space will become a significant limiting factor for this option based on the concomitant "General Note" in Table 1. Hence, low manageability	73
On-site disposal	NEMWA, MPRDA, Note: once the new draft NEMWA regulations are promulgated, whole or quartered tyres will not be allowed to be disposed of at landfills	Minimal transport costs involved; however, an appropriate dedicated disposal facility would be required	New best practice facility (in terms of design, construction and operation) will have relatively low impact on environment	Should the new facility be located on site and conform to best practice, public sensitivity will be low	Removes tyre stockpiles which are health and fire hazards	Operations will be in accordance with sanitary landfilling practice which is an established procedure in South Africa and falls within Platreef's ability to manage such a facility	As for stockpiling option above, except that in this application stockpiling becomes permanent hence low weighting	69

9.16.2 Recycling

Waste rubber such as conveyor belts can be sent to a number of rubber recycling companies in South Africa[19], namely:

- Dawhi Rubber Recycling in Germiston;
- Vredestein Recycling in Alberton; and
- Newco Recycling who are setting up premises at Coega in the Eastern Cape.

Of these companies, none are in close proximity to Mokopane, with the closest being Dawhi Rubber Recycling in Germiston. The rubber is generally used to produce products like rubber chips, rubber crumb, rubber brick pavers, rubber roof tiles and rubber floor tiles.

The main drawbacks associated with this recycling option are the low profit margins and high travel costs. It may thus be considered that the recycling of uncontaminated rubber be looked at in combination with waste tyre recycling strategies such as mechanical shredding for use in various applications as discussed in section 9.15.

9.16.3 Energy Recovery & Disposal

If a viable recycling solution is not found, Platreef should consider stockpiling conveyor belts until a time when downstream uses or off-site recycling become more viable. Stockpiling of conveyor belts is similar to stockpiling of tyres; fire risks should be managed through operating procedures, i.e. access control.

Incineration and pyrolysis options would be the same as for tyres, as discussed in section 9.15.4 above, while disposal of rubber conveyor belts would be the same as for tyres, as discussed in section 9.15.5. Due to the bulkiness of conveyor belts and tyres, the cost of transport is an important consideration. Landfill is not recommended due to fire hazard risks.

9.16.4 Trade-off Assessment

All of the alternative strategies should be pursued according to the waste hierarchy as far as possible in order to deal with this waste in the most appropriate manner. Minimisation should be inherent in the site designs, while options for re-use in on-site and off-site applications can avoid costs and liabilities. Nieuwco in Mokopane can undertake off-site re-use and recycling of used conveyor belts. Only once all of the above options have failed, should Platreef consider incineration or disposal. Solutions are being developed and temporary stockpiling should improve options by end of Bulk Shaft Phase.

9.17 Scrap metal

Scrap metal has an intrinsic value and can be sold off to the highest bidder. For this reason it should be managed as a resource which can support other waste management costs.

Platreef will require a storage area for used parts and scrap metal so that it can be stockpiled and either used in another application on-site, or sold off as scrap. For this reason Golder suggests the construction of a storage area which acts as a salvage and scrap yard. A salvage yard is an organised storage of used metal components which may be used again and requires an inventory of all parts in storage. In this way, workshops and units in search of metal components can check in the salvage yard inventory before ordering a new part. This will save on unnecessary purchases. The scrap yard section will store used components which are beyond reuse or repair and will stockpile scrap metal until a volume of scrap is attained that will warrant the services of a large scale scrap dealer who can offer the best prices for Platreef's scrap metals.

According to NEMWA Draft National Norms and Standards for the Storage of Waste (Government Gazette No. 34418, of July 2011) the storage area must have an impermeable floor (section 6.3), such as a concrete slab, while access must be controlled through a barrier (i.e. fence) and signage (section 7). Storage

[19] Golder is not affiliated to these companies, nor does Golder audit the companies to validate legitimacy of services offered

containers must be strong enough to hold the contents and must be covered to prevent water ingress (section 9). All employees working with waste must receive relevant training on handling and storage (section 13.1).

The option for scrap metal salvaging and sale to scrap dealers takes precedence over any other waste management options, as scrap metal is seen as a commodity and should not have to be disposed of.

9.18 Used lube oil and grease

Used lubricating oil and grease is generated in workshops from the maintenance of vehicles and machinery. The projected waste inventory estimates roughly 16.5 tpa of used oil and grease for a mine of this size in operation phase at 3 Mtpa.

Used lubricating oil and grease is classified as a hazardous waste and should be handled, stored and transported accordingly, avoiding spillages and contamination of other material. It is important to properly plan and design the logistics and facilities associated with this hazardous waste to improve management and reduce post construction alterations to the system and facilities.

9.18.1 Avoidance/Minimisation

Brand selection

While the project is still in the planning phase, Platreef engineers should consider what oils and grease to use that will be best suited for their purpose, as well as having the lowest liability post-use.

The oil and grease industries are progressing fast and new brands are often released which have higher lifespans, increased re-use/recycling potential and improved performance and engine protection. It is assumed that Platreef will undertake evaluation during the start-up phase of the project and that workshop managers and engineers will select oil and grease brands with lifespan and end of life issues in mind.

The selection or promotion of certain brands of grease and oil is not seen as part of the scope of this study, but rather that of the planning and design engineers; however there are some known brands of oil and grease which produce less waste, one such example for grease includes:

Castrol Maluballoy 8031 is a synthetic product which can be re-used in the same application up to 5 times before it must be disposed of. When it is beyond re-use, it becomes a “thixotropic gel” which is not grease, but a highly viscous oil and can be disposed of as an oil. This product may have a longer life and produce less wastage than other common brands of grease.

Take-back agreement with suppliers

It is suggested that a take-back agreement be included into contracts with suppliers of grease and oils. In this way, suppliers would collect the used grease and oils for off-site recycling or disposal. Platreef would however need to ensure that the suppliers recycle or dispose of the wastes in a responsible and legally complaint manner. This would require certificates and audit reports.

Used oil has an economic value and Platreef should ensure that they are being reimbursed for their used oil by whoever collects it from site. Used grease however does not have a resale value and thus, it would be highly beneficial for Platreef to include a take-back agreement in the supplier contract. This should be coordinated by the Platreef procurement department. Any grease which can be legitimately disposed as waste oil and processed accordingly in approved facilities should be considered.

9.18.2 Recycling

Oils are highly recyclable. SA research shows that about 40 - 45% of new oil becomes used oil. It is estimated that 50% of oil is destroyed through use. With only 20% being recovered, this means the remaining 30% is disposed of irresponsibly or used indiscriminately as industrial fuel without proper treatment.

The main oil recycling companies[20] in South Africa are FFS oils (Cape Town, Durban, Port Elizabeth) and Oilkol (Johannesburg). The Oilkol facility is based in Chamdor, near Krugersdorp and is the closest to Platreef; it will therefore be most feasible to send used oil to Oilkol for recycling. Other waste management companies offer the service of collecting oil and grease with the purpose of transporting and delivering the oil and grease to recycling depots. Nieuwco in Mokopane offers this service, as do some of the larger companies; namely EnviroServ. Platreef must ensure that best practice is followed by their waste contractors. This can be done through requiring certificates and weigh bills, as well as through regular audits.

Since Platreef is expected to produce large volumes of used oil, it is suggested that Platreef stores used oil in on-site storage tanks which are emptied by Oilkol or a transport contractor on an ad-hoc basis. Platreef could also send smaller loads on a regular basis to bulking points closer to the mine.

Bulking Points have been established to cater for used oil collections in areas not well served by the main Depots. These will assist smaller collectors and reduce transport costs by making up full loads before shipping the oil to processors. Bulking points are located at a number of locations (Table 22):

Table 22: Oil Recycling Bulking Point localities in relatively close proximity to Mokopane

Town	Approximate distance from Mokopane
Burgersfort	178 km
Pretoria	205 km
Middelburg	213 km
Rustenburg	303 km
Nelspruit	359 km

Oilkol only collects used lubricating oil, which is oil that has been contaminated during the process of being used and is no longer fit for the application, e.g. engine oil, gear oil, hydraulic oil, etc. Oilkol does not collect waste oil - any hydrocarbon fluid that has become contaminated prior to its intended use, e.g. crude oil spills, oily sludge at the bottom of storage tanks and oily wastes from refineries – or oil that has been polluted with solvents, cleaning fluids, or other hazardous wastes. Oilkol pays for used lubricating oil; the price depends on the cost incurred for collection and may consider quality.

Oilkol supplies tailor-made, cubic-shaped mini tanks, for the storage of used oil. These containers make maximum use of available space - regardless of whether they are installed in a workshop or outdoors. The containers are available in 1 000 litres. Sealed couplings are used to pump the contents straight into a tanker truck. The collections therefore require no handling of containers, which minimises the possibility of spillage or leakage.

Oilkol collectors will pay for Platreef's used oil and these earnings will pay for the tank. So the more used oil collected, the quicker the tank can be paid off. Containers cost R 1 800 (1 000 litre tank).

9.18.3 Energy Recovery

The calorific value of grease and oil is around 40 GJ/ton. Used oil is sold directly by collectors to approved processors who then filter the oil for reuse or process the oil to low grade industrial heating fuel or use it to fire up cement kilns. Environmentally approved processors have been established in other significant business centres outside of the metropolitan areas to broaden the scope of used oil recycling in South Africa.

9.18.4 Treatment

In South Africa, reprocessing used oil into industrial fuel is commercially attractive. The reprocessed product is sold as a substitute for heavy fuel oil that is derived from crude oil.

[20] Golder is not affiliated to these companies, nor does Golder audit the companies to validate legitimacy of services offered

FFS Refiners Pty Ltd, own and operate several plants in the main centres that buy used oil from environmentally approved collectors. Using a series of treatment steps, they purify and process used lube oil into a low grade low sulphur industrial fuel oil.

Several treatment processes are used in South Africa:

- Mechanical separation of contaminants by filtration and centrifuging;
- Chemical separation to remove unwanted components; and
- Thermal refining to improve the quality of the fuel.

Costs associated with establishment of such reprocessing plants are significantly high. It would be more feasible for Platreef to become indirectly involved in such a strategy by selling waste oil to recyclers.

9.18.4.1 Disposal

The following several disposal options have been evaluated by industry:

- Incineration of used oil at high temperatures, e.g. cement and lime kilns;
- Burning untreated used oil; and
- Blending used oil and fuel oil.

Incineration is most effective at destroying the used oil - but unfortunately it adds the least value. Burning untreated used oil merely dilutes the harmful components into the environment, while using untreated used oil in outdoor applications causes soil and groundwater contamination.

Used oil and grease could be disposed in sealed drums at Holfontein, or at an on-site H:H disposal facility.

9.18.5 Trade-off assessment

Some kinds of used lube oil and grease should be sold off to recycling companies as far as possible, while other types should be included in take-back agreements with suppliers. Remaining oil and grease can be sent to treatment companies who convert it into a fuel oil. Safe disposal of grease as hazardous waste may be required for specific products (Table 23 and Table 24).

9.19 Oil contaminated rags and PPE

Oil contaminated rags and PPE will be generated anywhere that vehicle and machinery maintenance is carried out. This waste is hazardous due to the hydrocarbon contamination found on the fabrics.

9.19.1 Minimisation

It is possible to minimise the liability of generating hydrocarbon contaminated rags through training and awareness of workers who typically generate hydrocarbon contaminated rags. This can be done through signposting in workshop areas and interactions between the waste management officer and relevant workers.

This strategy should be adopted for this waste stream and all other waste streams where possible. Training and awareness for multiple waste streams can be combined to save time and money.

Table 23: Trade-off Assessment for used Grease and Oil

Strategy Type	General Notes	Used Lubrication Oil and Grease													
		Environmental authorisations required	Air	Land	Water	Technology cost and 'provenness'			H&S/Exposure on-site/Public & Worker Sensitivity						Total
Strategy Score		NEMWA, NEMAQA, NWA, MPRDA, EA, etc.	Dark smoke & dust particulate	Land contamination, sterilisation and aesthetics	Impacts making water quality less fit for use	Capex/Opex	'Provenness' of practice	Ease of implementation	Injury risk	Chemicals (skin/ inhalation)	Physical	Public sensitivity	Benefits to the community	Sustainability	
	as noted	Required, but complex process: 1	Yes: 1	Yes: 1	Yes: 1	High cost: 1	None to date: 1	Difficult: 1	High: 1	High: 1	High: 1	High: 1	Low: 1	Low (short-term benefits): 1	
	as noted	Required, but not complex process: 3	Possible: 3	Possible: 3	Possible: 3	Medium cost: 3	Limited cases: 3	Neutral: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium: 3	Medium (potential for medium to long-term sustainability): 3	
	as noted	Not Required: 5	No: 5	No: 5	No: 5	Low cost: 5	Current practice: 5	Easy: 5	Low: 5	Low: 5	Low: 5	Low: 5	High: 5	High (Confident i.t.o. long-term sustainability): 5	
Weighting **1 = (Low) Largely uncontrollable with implications having the potential to detrimentally financial feasibility of operations** **3 = (Fair) Although important, it is manageable in respect of affecting Platreef's financial and operational feasibility** **5 = (High) Manageable in respect of affecting Platreef's sustained financial and operational activities**															
Weighting		1	3	3	3	5	3	1	1	1	1	1	3	5	
Option Score Result Matrix * (Selected Strategy Score cell value is multiplied by Weighting cell value and the results summed to produce each Option score result)															
Take-back agreement	To be written into supplier contracts	5	5	5	5	5	3	3	5	5	5	5	1	5	135
Recycling	Oilkol or Nieuwco	5	5	5	5	5	5	5	5	5	5	5	3	3	139
Energy recovery	Pyrolysis or gasification, on-site or off-site	1	1	1	3	1	3	1	3	3	3	1	3	3	65
Treatment	Treatment into a fuel oil, assumedly off-site	5	5	5	5	5	3	3	5	3	5	5	3	3	129
Disposal	Off-site disposal through licensed contractor	5	5	5	5	3	5	5	5	5	3	5	1	1	111

Table 24: Further considerations in support of table 23 above

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
Take-back agreement	Platreef must ensure that used oil and grease is safely disposed of in accordance with relevant legislation (acquire safe disposal certificates, and audit end destination of the waste to ensure duty of care)	Built into contract, oil has a value	Limited environmental risk, should the waste be appropriately stored, and handled during collection and transport. Platreef to ensure duty of care once the waste leaves the site	Low sensitivity as waste is removed from possible receptors	Liability removed from Platreef, promotes re-use or recycling opportunities	Must be written into contract; Platreef could explore possible remuneration for used oil. Potential for build-up/ accumulation should contractor not remove waste in time	High, promotes recycling entrenched in contract	135
Recycling	Platreef must ensure that recycler has relevant NEMWA licence in place for recycling. Platreef must also acquire safe disposal certificates, and audit end destination of the waste to ensure duty of care	**Can be sold thus is a potential income for the mine**	Limited environmental risk, should the waste be appropriately stored and handled during collection and transport. Platreef to ensure duty of care once the waste leaves the site	Low sensitivity as waste is removed from possible receptors	**Goes back into the value chain. Platreef could gain financially from recycling. Potential to extend benefit to communities in future**	Find the service provider with best credentials and best offer for remuneration. Potential for build-up/ accumulation should contractor not remove waste in time	Medium promotes recycling, but depends on demand	139
Energy recovery	Should facility be on-site, Platreef must obtain licences in terms of the NEMWA and NEMAQA. Should facility be off-site, Platreef must ensure that the company accepting the oil and grease has relevant NEMWA & NEMAQA licenses in place. Platreef must also acquire safe disposal certificates, and audit end destination of the waste to ensure duty of care	High cost if Platreef wants to recover energy on-site, transport cost if it is sent for off-site use	Significant air quality risks and possible water contamination should an on-site facility be established	High sensitivity, should an on-site facility be implemented, due to potential air quality impacts	Could supplement energy requirements for the mine or other fuel stocks for power stations or cement kilns. Potential to extend benefit to communities in future	Subject to feasibility study	Medium, provides alternative energy source, but depends on demand	65
Treatment	Platreef must ensure that facility has relevant NEMWA licence in place for treatment. Platreef must also acquire safe disposal certificates, and audit end destination of the waste to ensure duty of care	Low cost, as this is done by a contractor	Limited environmental risk, should the waste be appropriately stored, and handled during collection and transport. Platreef to ensure duty of care once the waste leaves the site	Low sensitivity as waste is removed from possible receptors	Possible fuel creation. Potential to extend benefit to communities in future	Feasibility study required. Potential for build-up/accumulation should contractor not remove waste in time	Medium, possible fuel creation, but depends on demand	129

Strategy Options	Legal requirement for Platreef	Typical cost	Environmental risk	Public sensitivity	Potential Benefit	Operational aspects and critical factors	Sustainability	Scoring (from Table above)
Disposal	Platreef must ensure that used oil and grease is safely disposed of in accordance with relevant legislation. The disposal site must have NEMWA licence for hazardous waste disposal. Platreef must acquire safe disposal certificates, and audit the disposal site to ensure duty of care	Services of a specialised contractor	Limited environmental risk, should the waste be appropriately stored and handled during collection and transport. Platreef to ensure duty of care once the waste leaves the site	Low sensitivity as waste is removed from possible receptors	None	This should be the last resort, as all intrinsic value of material will be lost	Low, as the oil and grease is lost as a resource, and diminishes landfill airspace	111

9.19.2 Treatment

Hydrocarbon contaminated rags and PPE can be destroyed in an incinerator or furnace. Due to the nature of the contaminants, the burning should take place at a high heat intensity in order to destroy dioxins and furans which would otherwise be emitted at a low burning temperature. For this reason a modern incineration or furnace technology should be adopted.

9.19.3 Disposal

Untreated hydrocarbon contaminated fabrics can be disposed to H:H landfill which requires storage in sealed drums and transportation by a licensed hazardous waste service provider. The nearest H:H landfill will be Holfontein where the waste may be safely disposed for a fee.

9.19.4 Trade-off Assessment

It is noted that each of the above mentioned strategies should be pursued in order of the waste management hierarchy. It is accepted that some contaminated rags and PPE will inevitably be generated, and that failing viable incineration options, Platreef will require the services of a suitably licensed service provider for the removal and safe disposal as hazardous waste.

Platreef must provide sealable bins for the collection and storage of such waste which are conveniently located near to the point of generation and at a bulking point where the selected removals contractor collects the waste.

9.20 Hydrocarbon contaminated soil

Hydrocarbon contaminated soil results from oil and fuel spill events which occur irregularly and/or infrequently as a result of accidents, leaks or negligence. These spills are avoidable, but inevitably they occur at most heavy machinery maintenance areas. The axiom; “prevention is better than cure” rings true for this section.

Despite all efforts to prevent oil and fuel spills, Platreef must be prepared for the clean-up of spills and the management of contaminated soils and other materials. In instances where spills occur on engineered surfaces like concrete and tarmac (preferable to bare ground spills), an absorption material is used to clean the surface. This material can be in the form of specialised saw dust, dried moss, sand, or other absorbent. Once used, this material becomes contaminated and can be managed in the same way as contaminated soil. Platreef must keep spill clean-up kits in workshops for cleaning up spills.

9.20.1 Minimisation

While the scope for contaminated soil prevention may be small, it is believed that through improved housekeeping and awareness, the amount of contaminated soil produced can be reduced to some extent. This should be done regardless of other management options for hydrocarbon contaminated soils.

A procedure document for the management of oil and fuel, stored in drums and other containers should be developed to assist workers in the prevention of spills.

9.20.2 Treatment

Remediation

There are numerous options for treatment, including bioremediation and phytoremediation, before disposal or downstream use applications need be considered.

Bioremediation and phytoremediation can be done consecutively after each other. Phytoremediation can form part of landfill rehabilitation and re-vegetation if properly designated and appropriately permitted.

Bioremediation is the process of decontaminating polluted soils using bacteria to breakdown contaminants, while phytoremediation uses plants for the same purpose. In the event that certain soils become contaminated by hydrocarbons, there are ways to harness natural services of certain plants in the absorption of such contaminants. Once inside the plant, chemicals can be:

- Stored in the roots, stems or leaves;
- Changed into less harmful chemicals within the plant; and
- Changed into gasses and released into the air.

Microbes around plant roots can also change chemicals into a less harmful state.

Afterwards, plants are harvested for destruction or recycled if metals stored in the plants can be re-used. Usually trees are left for long-term remediation.

The time it takes to fully remediate a site depends on:

- Type and number of plants being used;
- Type and quantities of harmful chemicals present;
- Size and depth of polluted area; and
- Type of soil and conditions present.

Different plants have varying capabilities for the absorption or alteration of various contaminants.

Remediated soils:

Potential uses for remediated soils include:

- Returning to original location as clean soil (pending outcome of soil testing);
- Use as cover material on landfill;
- Use as capping material for closed landfill cells, and re-vegetation of these areas; and
- Combining with other organic wastes in a composting plant.

Remediated soils must be tested for contamination after treatment has been completed. If the soil is below the trigger values it may be introduced back into the environment as clean soil. If it still contains contaminants, it should be safely disposed of or further treated.

One form of combining safe disposal, further treatment and beneficial use, would be to combine it with other organic wastes to form compost, which would be used to rehabilitate and re-vegetate dumps.

Incineration and Thermal Desorption

It is possible to incinerate hydrocarbon contaminated soil; however it will require assistance in the burning process, through pumped air and added fuels. Hydrocarbon contaminated soil is difficult to incinerate due to a high density and therefore it takes a long time for contaminants to be destroyed. Once it has been incinerated the remaining material could be disposed to a general landfill pending classification testing, otherwise the safest disposal option would still be to a hazardous landfill.

Incinerator would require a NEMAQA license with air quality testing, however Platreef has been advised against establishing an on-site incinerator. Alternatively, thermal desorption can be conducted in a modular plant where fuel is required for start-up but is substantially replaced by combustion of removed hydrocarbons during operation stage.

9.20.3 Disposal

Hydrocarbon contaminated soil is classified as hazardous and will thus require disposal at an H:H facility. While still in the hands of Platreef, it must be safely handled, stored (in sealed drums at a waste storage facility) and removed by a licensed service provider for safe disposal with proof in the form of safe disposal certificates.

9.20.4 Trade-off assessment

It is strongly suggested that Platreef develop a comprehensive procedure for the cradle-to-grave management of hydrocarbons. While managing their use, the procedure should also assist in the prevention and mitigation of spills and wastage of oils and fuels.

Minimisation should be done for this waste as far as possible and should be pursued in spite of any post-spillage solutions arranged by Platreef.

The most preferred option for hydrocarbon contaminated soil is treatment by bioremediation. This is a preferred option to incineration and disposal for sustainability reasons. Treatment is higher up the waste management hierarchy than disposal. Bioremediated soil offers other downstream opportunities, such as co-composting with other organic materials that can then be used as rehabilitation material for rock dumps or landfills. Bioremediation can be done on-site on a small scale or off-site in combination with other industries that produce similar waste. This may offer economies of scale and reduced liabilities if another company is paid to carry out the bioremediation.

The ‘do nothing’ option for the management of oil contaminated waste would be to send hydrocarbon contaminated soil to Holfontein. Alternatively Platreef could investigate the option for establishing an on-site H:H cell. The benefit of having an on-site hazardous cell goes hand-in-hand with the volumes of hazardous waste that Platreef will produce. Having an on-site hazardous waste facility could be economically attractive in comparison with off-site disposal costs.

9.21 Used paint and tins

Platreef will use large volumes of paint in the establishment of various site buildings. This will lead to the creation of empty paint tins/buckets often with leftover paint inside. In most instances left over paint is stockpiled on-site for potential use on-site. In some cases where different departments or teams are doing paintwork, they will order the same paint and generate leftover paint. Equipment assembly on site may also employ resin coatings and similar management of residuals may apply. However, whenever an equipment supplier utilises paint or resin the supplier should be made responsible for disposal of residuals.

9.21.1 Minimisation

Once paint has been opened for use, it has a finite shelf life before it solidifies in the tin. One way to avoid this would be to only supply for the need and not in excess. Painting staff should also be proactive about using existing paint for awaiting jobs before the paint dries up.

It is suggested that Platreef centralise their paint supply and storage areas. The mine should keep an inventory of all the types and quantities of paint remaining in their stores so that anyone wishing to use paint at the mine can have fast access to an existing stock of paint rather than ordering new paint and increasing the unused stock. By fine tuning the provision of paint to the different entities at the mine, the production of waste paint can be avoided to a large extent.

In order to deal with the lack of communication between different divisions at the mine, there should be a paint stores manager who keeps record of incoming and outgoing paint supplies, and to coordinate the provision of the correct type and quantity of paint for every job.

One way to minimise the production of used paint tins is to buy paint in bulk containers or drums. In this way fewer paint tins will be generated. This is subject to the amount of paint needed.

The toxicity of wasted paint produced can be minimised through the selection of less harmful paint brands. For example water based paints can be used in place of oil based paints for most applications, making any waste produced non-hazardous. Any thinners used to clean painting equipment will be classified as hazardous, as will any oil based paints.

9.21.2 Reuse/Recycle

In some cases where paint is no longer needed at the mine, this paint could be donated to small businesses, schools or communities for small scale use or for artistic initiatives. There could be a downstream use for the unwanted paint off-site.

Paint tins could find further use as storage containers for small businesses or schools in the community. Alternatively they could be sent to paint manufacturers for refurbishment and reuse.

A solvent recovery plant could become feasible for the separation of paints and solvents. A solvent recovery plant distils solvents from paint leaving only solid paint residue. Recovered solvent from paint is useful wherever white spirit or kerosene is used in the workshop, i.e., parts wash, etc. The dried paint residue which remains after the separation process is a smaller quantity for disposal.

9.21.3 Disposal

According to the NEMWA Waste Classification and Management Regulations (No. 614 of 2012) paint is classified as hazardous and should be disposed of as such. Platreef would have to send paint and tins to Holfontein for safe disposal.

9.21.4 Trade-off Assessment

All of the listed strategies should be pursued and implemented as far as is feasible for Platreef, with disposal as the last resort. Disposal should be done at a licensed H:H landfill and Platreef should keep a record of safe disposal certificates and weigh bills.

9.22 Used vehicle batteries

Batteries used in mine vehicles must be replaced from time to time. This is as a result of loss of integrity of the battery, or general wear and tear from mine use. Once a battery becomes a waste it is a type of E-waste. It has some hazardous components, such as battery acid and heavy metals which, if not removed, cause the entire unit to be classified as a hazardous waste.

9.22.1 Minimisation

Battery life can be extended through appropriate use and regular checks and maintenance. In many mining operations vehicle users are not educated or aware of best practices for the care and preservation of the vehicle they are using. This causes various vehicle components to be damaged and often has a knock on effect. One example is when rough driving caused a damaged alternator which in turn causes a loss of charge to the battery and thus damaging and running the battery flat.

Improved driver care and regular maintenance to vehicles can avoid such run down loss of efficiency. Battery maintenance through topping up water or replacing acid and nodes can extend the battery life significantly.

This option should be pursued as a regular practice in workshops in order to avoid battery waste as well as various other wastes.

Take-back agreement

In many instances battery suppliers are willing to take old batteries and sometimes this even implies a slight rebate on the purchase of new batteries. Battery suppliers or manufacturers are often able to re-use batteries by simply replacing certain components; in other instances refurbishment with the replacement of multiple components is done. Battery suppliers and other electronic companies are also able to dismantle entirely damaged batteries to ensure that hazardous materials are collected and concentrated before safe disposal, while non-hazardous components, such as the plastic shell can be sent to general landfill.

This should be negotiated with all battery suppliers and included into contracts. Assurance must be made that batteries and components are being safely managed and that any waste is managed in a legally acceptable manner.

9.22.2 Re-use/Recycling

If Platreef workshops adopt the practice of routine battery replacement, it may often be possible for used batteries to be re-used by off-site businesses. As mentioned in take-back agreements, certain maintenance or refurbishment activities can enable batteries to re-enter the value chain.

In instances where the battery integrity is compromised and reuse is not safe, many of the components and materials can be recycled, such as the metal components, battery acid and other minor parts. This must be done safely by a licensed company. Such companies are listed under E-waste, section 9.14.

9.22.3 Disposal

If waste batteries are to be disposed of directly, the entire unit is classified as a hazardous waste, however if the batteries are sent to an e-waste management company, they can be dismantled and only the concentrated and greatly reduced hazardous components require H:H disposal while the bulk of the products can be disposed to general landfill.

9.22.4 Trade-off Assessment

Platreef should pursue all of the above mentioned strategies in order of the waste management hierarchy. In terms of the best option for disposal; Platreef will require quotations from waste management and e-waste management companies to compare costs for complete disposal to H:H landfill or dismantling before separated components are disposed appropriately.

9.23 Expired Lithium torch batteries

As part of the underground lighting strategy, miners will wear headlamp torches powered by rechargeable Lithium ion (Li-ion) batteries. These batteries are reusable numerous times, but over time they lose functionality and must be replaced.

9.23.1 Minimisation

It is noted that the turnover of batteries can be reduced through simple yet effective battery use practices. One example is the full activation of all cells within the battery. This is accomplished through the complete run down of the battery before fully charging it up again. This produces longer working times and extended useful life of batteries. Some recharging units run batteries fully flat before commencing with battery recharge.

Careful use may also extend battery life; batteries which are not exposed to moisture or extreme heat tend to have a longer service life.

Careful planning as well as training and awareness will enable Platreef to minimise the turnover rate of these batteries, thus reducing the waste stream.

9.23.2 Recycling

Battery recycling is possible however; it does not make any economic sense to recycle the batteries. Batteries contain only a small fraction of lithium carbonate as a percentage of weight and are inexpensive compared to cobalt or nickel. The average lithium cost associated with Li-ion battery production is less than 3% of the production cost. Therefore battery recycling requires subsidisation.

One company that offers the service of recycling batteries is Uniross[21], situated in Midrand, Gauteng.

9.23.3 Treatment

While lithium batteries are less hazardous than Nickel-cadmium or lead batteries, lithium batteries are potentially explosive and should be managed accordingly. Batteries can be treated through dismantling and recovery of component parts and materials either for recycling or safe disposal. This is done by e-Waste companies. A list of e-Waste companies can be found under section 9.14 or on the EWASA website.

[21] Golder is not affiliated to these companies, nor does Golder audit the companies to validate legitimacy of services offered

9.23.4 Disposal

Expired lithium batteries contain hazardous chemical components and are therefore classified as a hazardous waste. If Platreef wishes to dispose without treating, the entire battery units will be classified as hazardous and should be disposed to an appropriate H:H landfill.

Storage should be done in sealed containers in a hazardous waste storage area that has appropriate access control and signage. Removal and transfer should be done by a licensed service provider.

9.24 Fluorescent tubes

It is expected that lighting within mine wide buildings will be predominantly from fluorescent lighting tubes. This method of lighting is more energy efficient than traditional incandescent bulbs. Life spans of fluorescent tubes vary according to the application and conditions under which they are used. When these tubes are removed from their functional positions by plant maintenance, they will become a hazardous waste stream. The most common practice is for these tubes to be crushed and stored in 210 litre drums and sent to H:H landfill. Fluorescent tubes contain mercury, making it a hazardous material once the glass is broken.

Crushing the tubes reduces the volume of the waste making transport less expensive per unit. The crushing practice requires certain health and safety considerations, as the labourers involved in crushing may be exposed to the mercury gas coming from the crushing process. In some instances companies have arranged to store and transport tubes in protective boxes, in order to avoid the risks associated with crushing.

Crushing and mercury crushing plants are available, but this may not be justified as a feasible investment at Platreef.

9.24.1 Minimisation

In order to minimise the amount of crushed fluorescent tubes that need to be disposed of, Platreef should find ways to prolong the life of these lights.

One way to prolong the life of lighting tubes is to reduce the on/off cycling of lights. Fluorescent tubes and CFLs are sensitive to frequent on/off cycling as it reduces their lifetime significantly. Light fittings in areas where lights are switched on and off regularly should rather use incandescent bulbs. Loose or faulty light fittings or constant shaking and vibrating can result in the flickering of fluorescent lights, causing a reduction in lifespan. In such instances maintenance and monitoring can make a significant improvement.

It is the practice of some maintenance operations to remove and replace all fluorescent tubes in a building at specific intervals, regardless of whether lights are still working or not, this causes a high turnover of fluorescent tubes and could be avoided by only replacing tubes when necessary. This would require intricate contracting with lighting contractors or education of maintenance staff, as well as monitoring of maintenance staff/contractors.

It is suggested that Platreef design buildings for 26 mm fluorescent tubes rather than 38 mm tubes, as they have a longer lifespan and produce less waste by volume. Where possible natural light is a low hanging fruit which can help Platreef reduce electricity usage, lighting requirements and enhance Platreef's green image.

In some instances it may be beneficial to use presence detector lighting systems. These automatically switch off when there is no one in the room.

9.24.2 Recycling

It is possible to recycle fluorescent tubes and CFLs, this entails the separation of materials namely; glass, brass, aluminium, internal coating and mercury, which is then recycled for different purposes. There are currently a small number of facilities in South Africa that are able to recycle fluorescent tubes or CFLs. One such recycling company called "Reclite" collects lamps from drop-off stations at Pick-n-Pay, Woolworths, WESSA & Eurolux lighting. Special negotiations and contracting could enable Platreef to have their fluorescent tubes recycled by Reclite.

9.24.3 Treatment/Disposal

When fluorescent tubes become a waste, they should be crushed into drums and stored at the temporary hazardous waste storage area. The crushing serves to reduce the volume by roughly 80%. This in turn reduces the transportation and disposal costs. Disposal of crushed fluorescent tubes takes will take place at the nearest H:H landfill site; on-site or off-site.

Due to the presence of mercury in the fluorescent tubes, this waste must be treated before disposal, in order to prevent the release of mercury into the environment. Treatment involves the addition of a 50% sodium sulphide – 50% sulphur solution in a 1:10 ratio. The solution is then added to the crushed tubes in a drum. This causes the fixation of the mercury, making it stable and removing the risk of it leaching out.

9.24.4 Trade-off Assessment

Again all of the options should be implemented according to the waste management hierarchy, with the bear minimum amount going to hazardous waste disposal. All minimisation options should be implemented simultaneously.

After all of the minimisation options have been implemented, there will still be a large stream of waste fluorescent tubes which require responsible management, Golder suggests that Platreef pursue the recycling option as far as possible, and use safe disposal as last resort option.

9.25 Refrigerants

Underground mining conditions are strongly influenced by the rock temperature which increases the deeper the mine. The Platreef mine will be relatively shallow in comparison to other mines in the area, but it will still need a certain level of cooling in the underground areas.

Refrigerants used in cooling systems in the mine will include certain gasses which are best suited to heat transfer system under pressure. After a certain period of use, refrigerant gasses become contaminated with impurities. It is unknown what cooling technologies and techniques will be used to cool the mine, and therefore types and volumes of expected waste refrigerant are also unknown.

Since the Montreal Protocol of 1987, certain refrigerant gasses, containing CFC's and other Ozone Depleting Substances (ODS's) have been discontinued in South Africa and therefore it is not expected that Platreef will have any ozone depleting refrigerants. Refrigerants will still be classified as hazardous pending formal delisting. Due to complications associated with disposing of hazardous gasses, Platreef should avoid the option of disposal as far as possible.

9.25.1 Minimisation

It has been found that in some cases it is possible to renew the life of refrigerant gasses through a filtration or purification process. One such system is the Afrox Zugibeast which claims to be an environmentally friendly decontamination system.

Contaminated refrigerant is filtered through a system to take out any deposits and sludge that reduce heat transfer efficiency by building up in the evaporator and condenser.

Take-back agreement

Some suppliers of refrigeration equipment and installations are willing to take back old refrigerants. This is usually only in cases where the supplier or manufacturer has the necessary refrigerant reclamation technologies. Reclamation means that all impurities shall be removed and the refrigerant shall be chemically analysed to verify that it has been purified. One such company which offers to collect used refrigerants is called Airgas Refrigerants Inc.[22] however it is assumed that there will be other suppliers who offer similar take-back and reclamation services as part of a refrigeration contract.

[22] Golder is not affiliated to this company, nor does Golder audit the company to validate legitimacy of services offered.

9.25.2 Recycling

Legislation in South Africa according to SANS 10147 prohibits the venting of refrigerants into the atmosphere. It requires the refrigeration and air conditioning industry to recover and recycle refrigerant.

One company that could assist Platreef to meet these requirements and offers services in recovery and "pump down" (long term storage) cylinders is called A-Gas South Africa (Pty) Ltd[23] and are based in Cape Town. (info.sa@agas.com)

9.25.3 Disposal

To date there has been no legislation pertaining to the disposal of refrigerants; however the SABS 0147 Code of Practice (Refrigerant systems including plants associated with air conditioning systems) has been introduced as a guideline which falls within the scope of the Occupational Health and Safety Amendment Act (No. 181 of 1993).

The code of practice provides guidance on:

- Charging and discharging of refrigerants:
  - Refrigerants must be discharged into an approved container only;
  - No refrigerant shall be discharged into a sewer, river, stream or lake or into the atmosphere, although, ammonia may be discharged to atmosphere with due regard to safety;
  - ODS's used as refrigerants shall not deliberately be vented to the atmosphere by any person who manufactures, maintains, services, repairs or dispose of air-conditioning equipment; and
  - Recovered or recycled refrigerant may be returned to the same system or to other systems owned by the same person without restriction. When the refrigerant changes ownership, however that refrigerant should where possible, be reclaimed.

10.0 CONCLUSIONS AND NEXT STEPS

Golder has identified and evaluated a number of solutions for each priority waste stream, and the preferred options have been highlighted in this report. The trade-off as presented in this report refines the resolution in respect of the different alternatives and does not necessarily eliminate the lesser preferred options but provides focus for going forward on options which in many cases will be co-employed.

In some instances, the cost associated with some of the options is largely prohibitive (e.g. pyrolysis plant, waste tyre shredder, wood chipper, etc.) but if such an option could be used to provide a regional service for waste from other operators in the area, the cost benefit feasibility could become more attractive. Should a contractor/separate company be registered as a JV between operating mines, this approach has a measure of attractiveness that warrants further pursuance.

It is important to understand that the value of the trade-off assessment is central to the weighing of the various options that still require final interpretation and which is still open for debate or work-shopping with Platreef.

In going forward, focus should be given towards ensuring that the implementation of the IWMP successfully achieves its intended objectives. In this respect acquiring baseline data is of importance in order to benchmark progress in respect of achieving targets to be defined through the IWMP process and to be dynamically amended concomitant to the improvement of the system.

Aspects such as economies of scale, extent of managerial control, and impact management, in respect of activities such as storage, re-use, recycling and even treatment as presented for the different waste streams implies that a consolidated facility such as a Material Recovery Storage Treatment and Disposal (MRSTD)

[23] Golder is not affiliated to this company, nor does Golder audit the company to validate legitimacy of services offered.

footprint should take preference over the establishment of individual storage, re-use, recycling, etc. footprints at the various operational areas of the mine.

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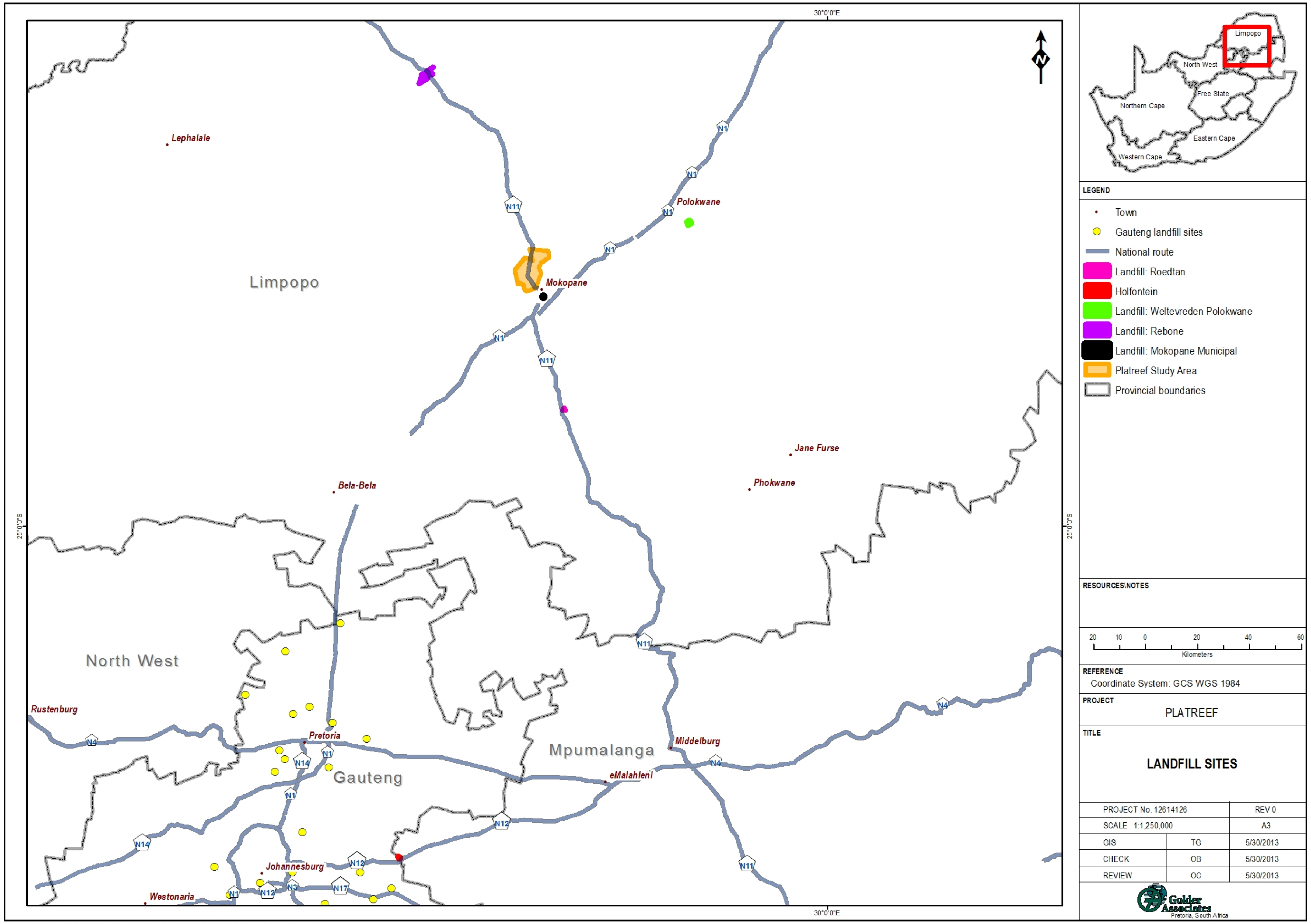
https://afpws.golder.com/sites/12614126amecdevelopiwmpplatreef/reports/3. alt strategies/12614126-12203-3_rep_altstrategies_final_26sep13.docx

APPENDIX A

Alternative Landfill Site Localities



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APPENDIX B

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