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Tshipi Borwa Mine

Stormwater Management and Water Balance for EMPr

SLR Project No.: 710.20029.00011

Report No.: 1

July 2017

Tshipi E' Ntle Manganese Mining (Pty) Ltd

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DOCUMENT INFORMATION

Title	Tshipi Borwa Mine - Stormwater Management and Water Balance for EMPr
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Client	Tshipi E' Ntle Manganese Mining (Pty) Ltd
Date last printed	2017/07/17 01:32:00 PM
Date last saved	2017/07/14 05:58:00 PM
Comments	
Keywords	Stormwater, Water Balance, Tshipi
Project Number	710.20029.00011
Report Number	1
Revision Number	
Status	Final
Issue Date	July 2017

TSHIPI BORWA MINE - STORMWATER MANAGEMENT AND WATER BALANCE FOR EMPR

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ACRONYMS AND ABBREVIATIONS

Below a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	**Definition**
BPG	Best Practice Guidelines
DDF	Depth Duration Frequency
EMPr	Environmental Management Program report
GN 704	Government Notice 704
ROM	Run Of Mine
WR2005	Water Resources of South Africa 2005 Study
WRD	Waste Rock Dump

TSHIPI BORWA MINE - STORMWATER MANAGEMENT AND WATER BALANCE FOR EMPR

1 INTRODUCTION

1.1 BACKGROUND

SLR Consulting (Africa) (Pty) Ltd (SLR), an independent firm of environmental consultants, has been appointed by Tshipi E' Ntle Manganese (Pty) Ltd (Tshipi) to develop a conceptual stormwater management plan and basic water balance to support an update to the Environmental Management Program (EMPr) for the mine.

1.2 PROJECT DESCRIPTION

Tshipi operates the open cast manganese Tshipi Borwa Mine located on the farms Mamatwan 331 (mining right and surface use areas) and Moab 700 (surface use area), in the John Taolo Gaetsewe District Municipality and Joe Morolong Local Municipality in the Northern Cape Province.

The mine holds a mining right (NC/30/5/1/2/2/0206MR) and an Environmental Management Programme (EMPr) issued and approved by the Department of Minerals and Energy (currently the Department of Mineral Resources), an environmental authorisation (NC/KGA/KATHU/37/2008) issued by the Department of Tourism, Environment and Conservation (currently the Department of Environment and Nature Conservation) and an Integrated Water Use License (10/D41K/AGJ/1735) issued by the Department of Water Affairs (currently the Department of Water and Sanitation).

The site layout is presented in Figure 1-1 and Figure 1-2. The changes to Tshipi's approved layout to be addressed by the updated EMPr include the following:

- An increase in the number, position, volume and layout of waste rock dumps.
- Change to the design, capacity and position of the sewage treatment plant.
- Change to the stormwater management system.
- Change to the potable water storage facilities capacity and position.
- Change to the position of the office, plant, workshop and related infrastructure.
- Change to the number, position, volume and layout (footprint) of the ore stockpiles.
- Change to the design of the railway line and an increase in length.
- The establishment of an additional temporary run-off-mine (ROM) stockpile area.
- The establishment of a tyre bays.
- The establishment of additional weighbridges.
- The establishment of an additional topsoil stockpile area (No. 2).
- Change in the position of the secondary crushing and screening plant.

The EMPr also considers additional proposed facilities including the expansion of the approved topsoil stockpile area (No.1), expansion of topsoil stockpile No.2, the change in the position of the approved 78Ml stormwater dam and establishment of a clean and dirty water separation system. In addition to this, Tshipi is proposing on mining the barrier pillar between the Tshipi Borwa Mine and South 32 (Mamatwan Mine).

1.3 ENVIRONMENTAL LEGISLATION

Government Notice 704 (Government Gazette 20118 of June 1999) (hereafter referred to as GN 704), was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. The four main principle conditions of GN 704 applicable to this project are:

- *Condition 4* which defines the area in which, mine workings or associated structures may be located, with reference to a watercourse and associated flooding. Any residue deposit, dam, reservoir together with any associated structure or any other facility should be situated outside the 1:100 year flood-line. Any underground or opencast mining, prospecting or any other operation or activity should be situated or undertaken outside of the 1:50 year flood-line. Where the flood-line is less than 100 metres away from the watercourse, then a minimum watercourse buffer distance of 100 metres is required for infrastructure and activities.

- *Condition 5* which indicates that no residue or substance which causes or is likely to cause pollution of a water resource may be used in the construction of any dams, impoundments or embankments or any other infrastructure which may cause pollution of a water resource.

- *Condition 6* which describes the capacity requirements of clean and dirty water systems. Clean and dirty water systems must be kept separate and must be designed, constructed, maintained and operated to ensure conveyance of flows of a 1:50 year recurrence event. Clean and dirty water systems should not spill into each other more frequently than once in 50 years. Any dirty water dams should have a minimum freeboard of 0.8m above full supply level.

- *Condition 7* which describes the measures which must be taken to protect water resources. All dirty water or substances which may cause pollution should be prevented from entering a water resource (by spillage, seepage, erosion etc) and ensure that water used in any process is recycled as far as practicable.

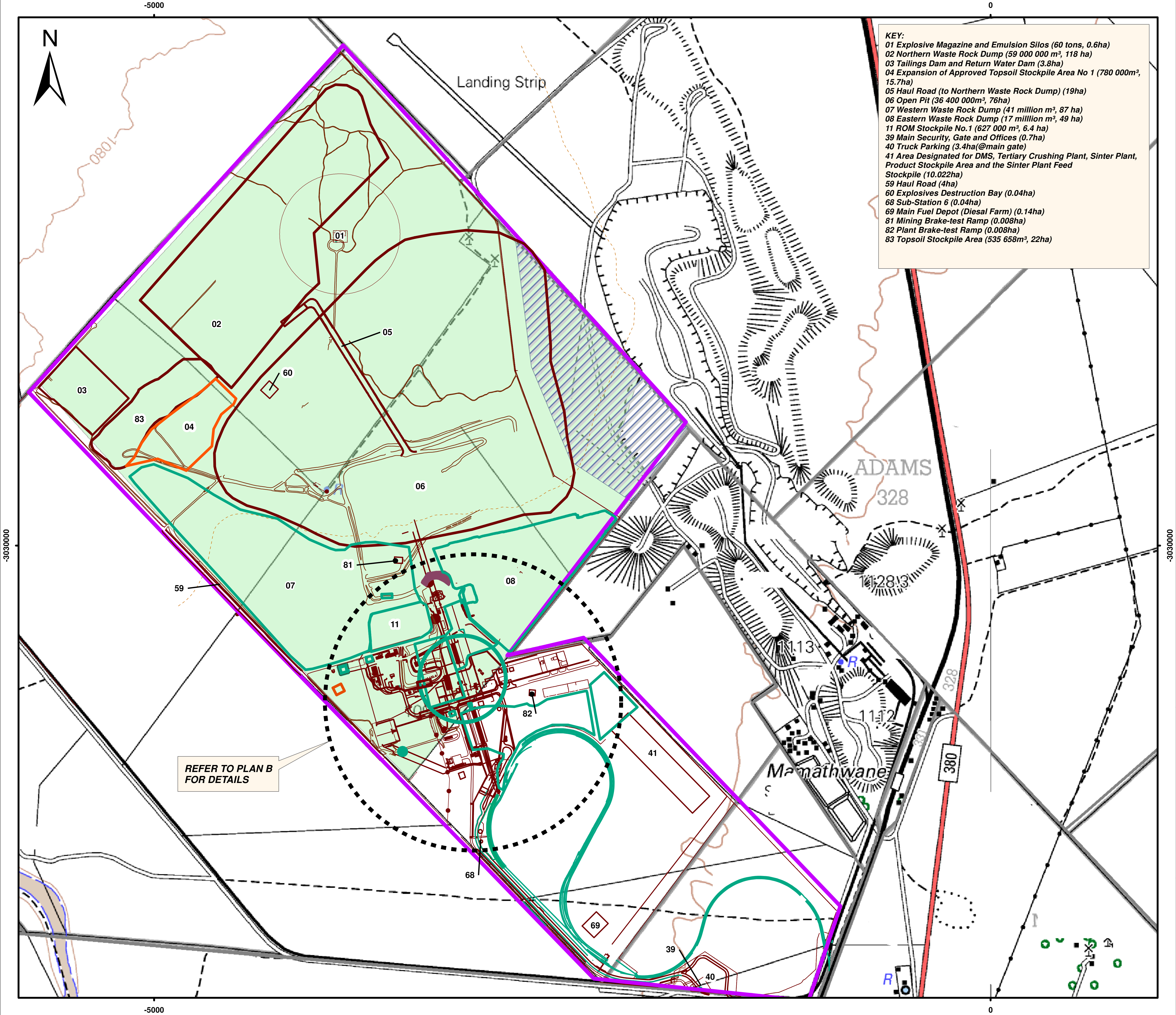
In addition to GN 704, Department of Water and Sanitation (then Department of Water and Forestry), has developed several Best Practice Guidelines (BPGs) for the mining industry including:

- BPG G1: Stormwater Management.
- BPG A4: Pollution Control Dams.
- BPG G2: Water and Salt Balances.

1.4 SCOPE OF WORK AND REPORT STRUCTURE

The scope of work and report structure is as follows:

- Site Setting and Design Inputs – Section 2 presents relevant information which has been used to develop the stormwater management and water balance including climate, storm intensities, surface water receptors, topography, waste classification, and current stormwater management.
- Conceptual Stormwater Management Plan – Section 3 presents the recommended stormwater management measures to manage flood risks to the operation and minimise risks of polluting any water resources, including clean and dirty water catchment delineation, estimation of peak flows, channel routing and sizing, and sizing of stormwater containment facilities.
- Site Wide Water Balance – Section 6 presents the water balance for the operation during average wet and dry seasons in order to inform estimates on re-use rates, makeup water requirements and requirements for discharge (if any).



Legend

- Surface Use Area
- Approved Mining Right Area
- Mine Infrastructure (no changes to approved infrastructure layout)
- Changes to Approved Layout (already implemented)
- Proposed Changes to Approved Layout
- Barrier Pillar

0 500 1 000 Meters

Scale: 1:22 000 @ A3
Projection: Transverse Mercator
Datum: WGS1984, Lo23

Tshipi é Ntle Manganese Mining (Pty) Ltd

Figure 1-1

New Infrastructure Layout - Site Wide

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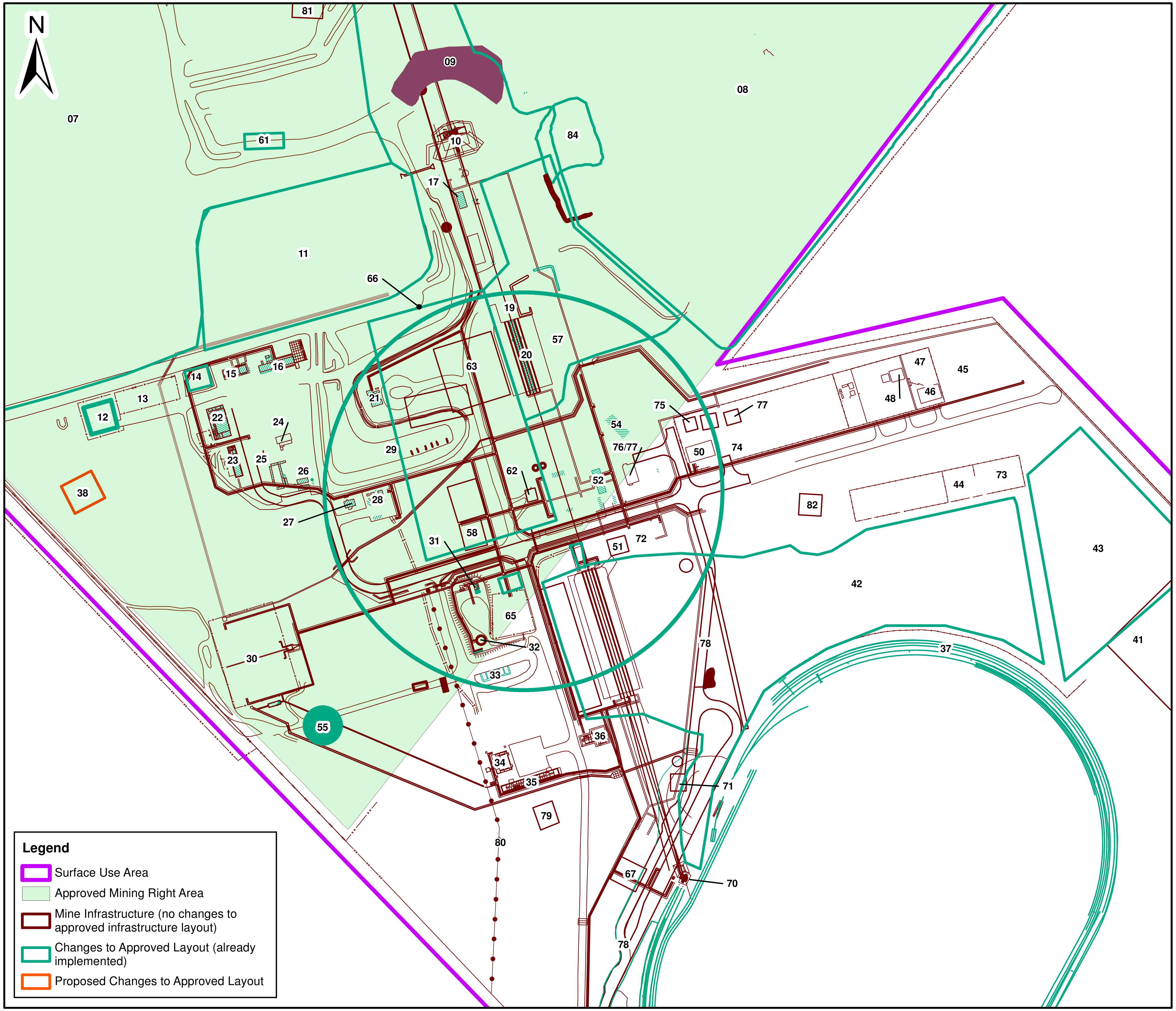

KEY:
07 Western Waste Rock Dump (41 milllion m³, 87 ha)
08 Eastern Waste Rock Dump (17 million m³, 49 ha)
09 ROM Pad (73 000 m³,16 ha)
10 Primary Crusher (±.0.7ha)
11ROM Stockpile No1 (627 000 m³, 7.6 ha)
12 Workshop Dirty Water Collection Dam (4Ml, 0.2 ha)
13 Spares Yard (0.4ha)
14 Mining Equipment Tyre Bay (0.001ha)
15 Boiler Shop (0.06ha)
16 Mining Equipment Service Bay (0.07ha)
17 Sub-station No. 4 (0.08ha))
19 Crushed ROM Conveyor (2.1ha)
20 Crushed ROM Stockpile (1.7ha)
21 Mining Shift Change Building (0.05ha)
22 Mining Equipment Workshop (0.14ha)
23 LDV Workshop (0.06ha)
24 Wash Bay (0.04ha)
25 Mining Office No.1 (0.1ha)
26 Mining Training Rooms (0.04ha)
27 Sub-station No.3 (0.04ha)
28 Mining Office No.2 (0.3ha)
29 Mining Mobile Equipment Hardpark (1ha)
30 Dirty Water Dams (24Ml, 1.2 ha)
31 Fire Water Tank (Approximately 0.01 ha and 653 m³), Elevated Potable Water Storage Tank (Approximately 0.02 ha and 75 m³), Sedibeng meter and RO plant
32 Potable Water Reservoir (2 000m³, 0.01ha)
33 Ancillary Mobile Equipment Hardpark (0.06ha)
34 Change House and Laundry (0.06ha)
35 Main Admin Offices and Clinic (0.12ha) and Ambulance Bay
36 Laboratory (0.08ha)
37 Railway Line (101ha)
38 Stormwater Dam (78ML,5ha)
40 Road Truck and Vehicle Parking Bay(3.4ha)
41 Sinter Plant, Including Feed and Product Stockpiles (future) (10ha)
42 Product Stockpile Area No. 2 (940 500 m³, 17 ha)
43 Topsoil Stockpile Area No.2 (290 000m³, 5.8ha)
44 Engineering and Projects Offices (1.7ha)
45 Salvage Yard and Waste Storing/Sorting/Reclaim Area (0.4ha)
46 Ancillary Equipment Workshop (0.05ha)
47 Ancillary Equipment Diesel Storage and Refueling Area (0.003ha)
48 Plant Production Offices (0.05ha)
50 Mine General Store (0.1ha)
51 Generator Powerhouse Diesel Tanks and Engineering Offices (0.2ha)
52 Plant MCC, Control Room and Offices (0.05ha)
54 General Parking Area (0.1ha)
55 Sewage Treatment Plant (Treatment capacity of 96 m³, ± 0.25 ha)
57 Temporary Mobile Crushing Plant (8.9ha)
58 Thickener (future)
61 ROM Weighbridge (210ton) and Control Room
62 Crushed Ore Weighbridge (80ton) and Control Room
63 Secondary Crushing and Screening Plant
65 Temporary Construction Dam (9 000 m³, 0.24ha)
66 Product Stockpile Area No.1 (434 500 m³ 7.9ha)
67 Satellite Workshop
70 Train Load-Out Station
71 Sub-Station No.5 (0.08ha)
72 Sub-station No.1 (0.04ha)
73 Tyre Bay (0.001ha)
74 Core Stores (0.0612ha)
75 Hazardous Store (0.02ha)
76 Engineering Workshop (0.054ha)
77 Rigging Store (0.05ha)
78 Truck Road
79 Heli-pad
80 11 kVA Overhead Power line
81 Mining Brake-test Ramp
82 Plant Brake-test Ramp
84 Temporary ROM Stockpile Area (20 000 m³, 1ha)

0 100 200 Meters

Scale: 1:6 000 @ A3
Projection: Transverse Mercator
Datum: WGS1984, Lo23

Tshipi é Ntle Manganese Mining (Pty) Ltd

Figure 1-2

New Infrastructure Layout -Plant Area

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2 SITE SETTING AND DESIGN INPUTS

2.1 CLIMATE

The site is located within a semi-arid climatic region of South Africa characterised by seasonal rainfall, hot temperatures in summer, and colder temperatures in winter. Monthly average rainfall was estimated from a 67 year daily rainfall record from Milner rain gauge, located 7km east of the site (Latitude: -27.375, Longitude: 23.042) as presented in Table 2-1. Monthly S-pan evaporation data was obtained from the Water Resources of South Africa manual, (WR2005, 2009), and converted to open water evaporation as presented in Table 2-1. The records show that annual evaporation is much higher than rainfall in this region.

TABLE 2-1: MONTHLY AVERAGE RAINFALL AND EVAPORATION

Month	**Rainfall (mm)**	**WR2005**	**WR2005**
	Milner (393083 W)	**S-Pan Evaporation**	**Open Water Evaporation**
January	59.8	276.9	232.6
February	63.0	209.9	184.8
March	72.3	193.3	170.1
April	39.9	144.1	126.8
May	19.2	114.7	99.8
June	9.1	91.0	77.3
July	1.3	106.0	88.0
August	5.4	153.8	124.5
September	6.4	213.0	172.5
October	19.2	269.7	218.4
November	31.5	248.0	232.9
December	44.5	294.6	244.5
Annual	**372.0**	**2351.0**	**1972.0**

2.2 DESIGN STORM DEPTHS

The design storm data was obtained from the design rainfall software (Smithers and Schulze, 2002), as presented in Table 2-2.

TABLE 2-2: RAINFALL DEPTH DURATION FREQUENCY (DDF)

Storm Duration (m/h/d)	Return Period (years)						
	2	5	10	20	50	100	200
15 m	15.0	21.3	25.7	30.2	36.3	41.2	46.2
30 m	19.8	28.1	34.0	40.0	48.0	54.4	61.1
45 m	23.3	33.1	40.1	47.1	56.6	64.1	71.9
1 hr	26.1	37.2	45.0	52.8	63.5	72.0	80.7
1.5 hr	30.8	43.8	53.0	62.2	74.8	84.7	95.1
2 hr	34.6	49.2	59.5	69.9	84.0	95.2	106.8
4 hr	40.0	56.9	68.8	80.7	97.0	110.0	123.4
6 hr	43.5	61.9	74.9	87.9	105.6	119.7	134.3
8 hr	46.2	65.7	79.5	93.3	112.1	127.1	142.6
10 hr	48.4	68.8	83.3	97.8	117.5	133.1	149.4
12 hr	50.3	71.5	86.5	101.5	122.0	138.3	155.2
16 hr	53.4	75.9	91.9	107.8	129.6	146.9	164.8
20 hr	55.9	79.6	96.2	113.0	135.8	153.9	172.6
24 hr	58.1	82.6	100.0	117.3	141.0	159.8	179.3
1 d	46.7	66.5	80.5	94.5	113.5	128.6	144.3
2 d	56.8	80.8	97.7	114.7	137.9	156.2	175.3
3 d	63.6	90.5	109.5	128.5	154.4	175.0	196.3
4 d	68.2	97.1	117.4	137.8	165.7	187.7	210.6
5 d	72.0	102.5	124.0	145.5	174.9	198.2	222.4
6 d	75.3	107.2	129.6	152.1	182.9	207.2	232.5
7 d	78.2	111.3	134.6	158.0	189.9	215.1	241.4

2.3 SURFACE WATER RECEPTORS

The site is located within the D41K quaternary catchment, which has a total catchment area of 4 216km^2, with a net Mean Annual Runoff of 6.53 million m^3.

The nearest watercourse is the Vlermuisleegte, a non-perennial tributary of the Gamagara, which flows from south-east to north-west approximately 1.6km west of the site. Given the large distance between the mine and this watercourses, the flood-lines have not been mapped.

The entire Moloto catchment which includes D41K is classified as endoreic i.e. catchments with large areas which do not contribute to runoff.

2.4 TOPOGRAPHY

Topography in this area is almost flat, with a gentle slope (1:250) towards the north-west. Small undulations mean that stormwater ponds locally, as opposed to forming sheet flow, which runs off towards a watercourse.

2.5 WASTE CLASSIFICATION

A waste classification study was undertaken by Golders[1] on the waste dump / overburden material which concluded the following:

- The waste material classifies as non-hazardous waste.
- The waste material is not potentially acid generating.
- The waste rock is classified as Type 1 waste on the basis of total Manganese concentrations.
- The concentration of all constituents of concern in leachate is below LCT0, indicating a low risk from seepage.
- The waste rock dumps do not pose a significant risk to water resources.

The above conclusions are used to inform the design principles for stormwater management at the waste rock dumps, as discussed in Section 3.2.

2.6 CURRENT STORMWATER MANAGEMENT

Current stormwater management at the site is as follows:

- Stormwater from the plant area is collected by a series of concrete lined channels and conveyed to the Dirty Water Dam.
- Ground levels at the contractor's area are contoured to convey stormwater to the workshop dirty water collection dam.
- Stormwater and any groundwater inflows in the pit are collected within a drainage sump.

[1] Tshipi e' Ntle Mine – Waste Classification Assessment. Report No. 1541973-301423-1 (Golder Associates, February 2016)

3 CONCEPTUAL STORMWATER MANAGEMENT PLAN

3.1 INTRODUCTION

Mining operations have the potential to impact upon the baseline water quality of an area and, if not managed correctly, stormwater may pose a risk of flooding to project infrastructure. The aim of stormwater management measures is to mitigate these impacts by fulfilling the requirements of the National Water Act (Act 36 of 1998) and more particularly GN 704.

The following definitions from GN 704 are appropriate to the classification of catchments and design of stormwater management measures at the Tshipi Borwa Mine:

- **Clean water system:** includes any dam, other forms of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of unpolluted (clean) water;
- **Dam:** includes any settling dam, slurry dam, evaporation dam, catchment or barrier dam and any other form of impoundment used for the storage of unpolluted water or water containing waste (i.e. dirty water);
- **Dirty area:** means any area at a mine or ***activity*** which causes, has caused or is likely to cause pollution of a water resource;
- **Dirty water system:** This includes any dirty water diversion bunds, channels, pipelines, dirty water dams or other forms of impoundment, and any other structure or facility constructed for the retention or conveyance of water containing waste (i.e. dirty water); and
- **Activity:** means any mining related process on the mine including the operation of washing plants, mineral processing facilities, mineral refineries and extraction plants; the operation and the use of mineral loading and off-loading zones, transport facilities and mineral storage yards, whether situated at the mine or not; in which any substance is stockpiled, stored, accumulated, dumped, disposed of or transported.

In addition to the above, the Department of Water and Sanitation (then Department of Water and Forestry) developed Best Practice Guidelines for the mining industry, which should inform the design and operation of the Tshipi Borwa project.

3.2 DESIGN PRINCIPLES FOR STORMWATER MANAGEMENT

As discussed in Section 1.3, GN 704 requires the following:

- **Capacity:** dirty water systems are to be designed, constructed, maintained and operated so that they are not likely to spill into a clean water system or the environment more frequently than once in 50 years.
- **Conveyance:** all water systems are to be designed, constructed, maintained and operated so that they convey a 1:50 year flood event.
- **Freeboard:** as a minimum, any dirty water dams are to be designed, constructed, maintained and operated to have 0.8m freeboard above full supply level.
- **Collect and Re-Use:** ensure that dirty water is collected and re-used as far as practicable.
- **Diversion:** minimise flow of any surface water or floodwater into mine workings.

Informed by a review of the site setting and existing drainage infrastructure (presented in Section 2), a series of design principles for stormwater management have been developed to ensure compliance with the requirements of GN 704 and BPGs.

The proposed conceptual stormwater management plan for the entire site is presented on , whilst presents more detail around the plant area. The key features include:

- Clean stormwater will be prevented from entering dirty water catchments by creating perimeter berms around dirty water areas and dirty water collection infrastructure (channels and dams).
- Dirty stormwater from the operational areas (crushers, ore stockpiles, load out stations, workshops, stores, contractor's area etc) will be collected by lined drainage channels and conveyed into dirty water containment facilities, either the dirty water dam or workshop dirty water collection dam.
- During significant storm events, the dirty water dam and workshop dirty water collection dam will spill via new channels into a stormwater dam, and this stormwater will be pumped back to the dirty water dam for re-use after the storm event.
- Dirty stormwater and any groundwater collecting within the pit will be collected and pumped to the dirty water dam.
- Runoff from the waste rock dumps will be prevented from entering any surface water receptors by creating perimeter stormwater retention berms to collect runoff and allow it to evaporate and/or infiltrate to ground. Given the waste rock dumps do not pose a significant risk to water resources (Section 2.5), and the low rainfall in this region, this is considered compliant with GN 704.
- Dirty stormwater from the tailings storage facility will be collected within the return water dam and pumped back to the dirty water dam for re-use. Both the tailings storage facility and the return water dam are HDPE lined. Further details of these facilities are presented within Metago's May 2009 Environmental Impact Assessment and Environmental Management Programme report.
- The topsoil stockpile will be revegetated and any runoff from this will be classified as clean.

- Dirty water within the dirty water containment facilities will be re-used at the site for dust suppression, wash down or other non-potable uses where water quality permits.

In order to meet the design principles detailed above, conceptual design details for the proposed stormwater management measures are presented below, along with the specific hydraulic design standards, methodologies, assumptions and input parameters for each measure proposed.

3.3 SIZING OF STORMWATER DAM

The total dirty catchment area draining to the stormwater dam is $0.966km^2$. Runoff coefficients have been estimated using Table 3.7 and 3.8 of the SANRAL Drainage Manual[2], and the new stormwater dam is sized to accommodate runoff generated from a 1:50 year design rainfall (24 hour) event **and** the highest monthly rainfall (March) **less** the corresponding monthly evaporation (March) taking place over the surface area of the dam.

The catchment parameters and recommended design capacity for the stormwater dam are presented in Table 3-1 and Table 3-2. For the purposes of the calculations it is assumed that the dirty water dam and workshop dirty water collection dam are both full, and that these facilities will not contribute to the capacity requirements.

TABLE 3-1: STORMWATER DAM – CATCHMENT PARAMETERS

Catchment	Area (km^2)	1:50 year 24 hour Event		Average Wet Month		
		Runoff Coef.	Rainfall (mm)	Runoff Coef.	Rainfall (mm)	Evaporation (mm)
Plant	0.966	0.30	141	0.15	72	170

TABLE 3-2: STORMWATER DAM – RECOMMENDED DESIGN CAPACITY

Facility	1:50yr Storm Runoff (m^3)	Wet Month Runoff (m^3)	Wet Month Evaporation (m^3)	Design Capacity (m^3)	PCD Footprint (m^2)
Stormwater Dam	42 722	11 564	2 211	52 075	13 000

It is understood that a 78Ml (78 000m^3) stormwater dam has already been approved as part of the previous EIA. This dam has not been established. It is recommended that this dam be moved to the west of the workshop dirty water collection dam and constructed in stages. The initial compartment sized to take the overflow from the workshop dirty water collection dam and the dirty water dam when these are full, thereby satisfying the above capacity requirements (52Ml or 52 075m^3). A secondary compartment can be constructed later if more detailed analysis demonstrates that the additional capacity is required.

[2] South African National Roads Agency Limited - Drainage Manual, Sixth Edition. (SANRAL, 2013)

Legend

- Infrastructure
- Surface Use Area
- Dirty Stormwater Channels
- Stormwater Berms
- Dirty Catchments
- Dirty Water Dams
- Clean Catchments
- Non-Perennial Watercourses
- 0.5m Contours
- 20m Contours

0 0.5 1 2
Kilometers

Projection: Transverse Mecator
Datum: WGS 1984_UTM Zone 34S

Tshipi Borwa Mine

Figure 3-1

Site Wide Stormwater Management

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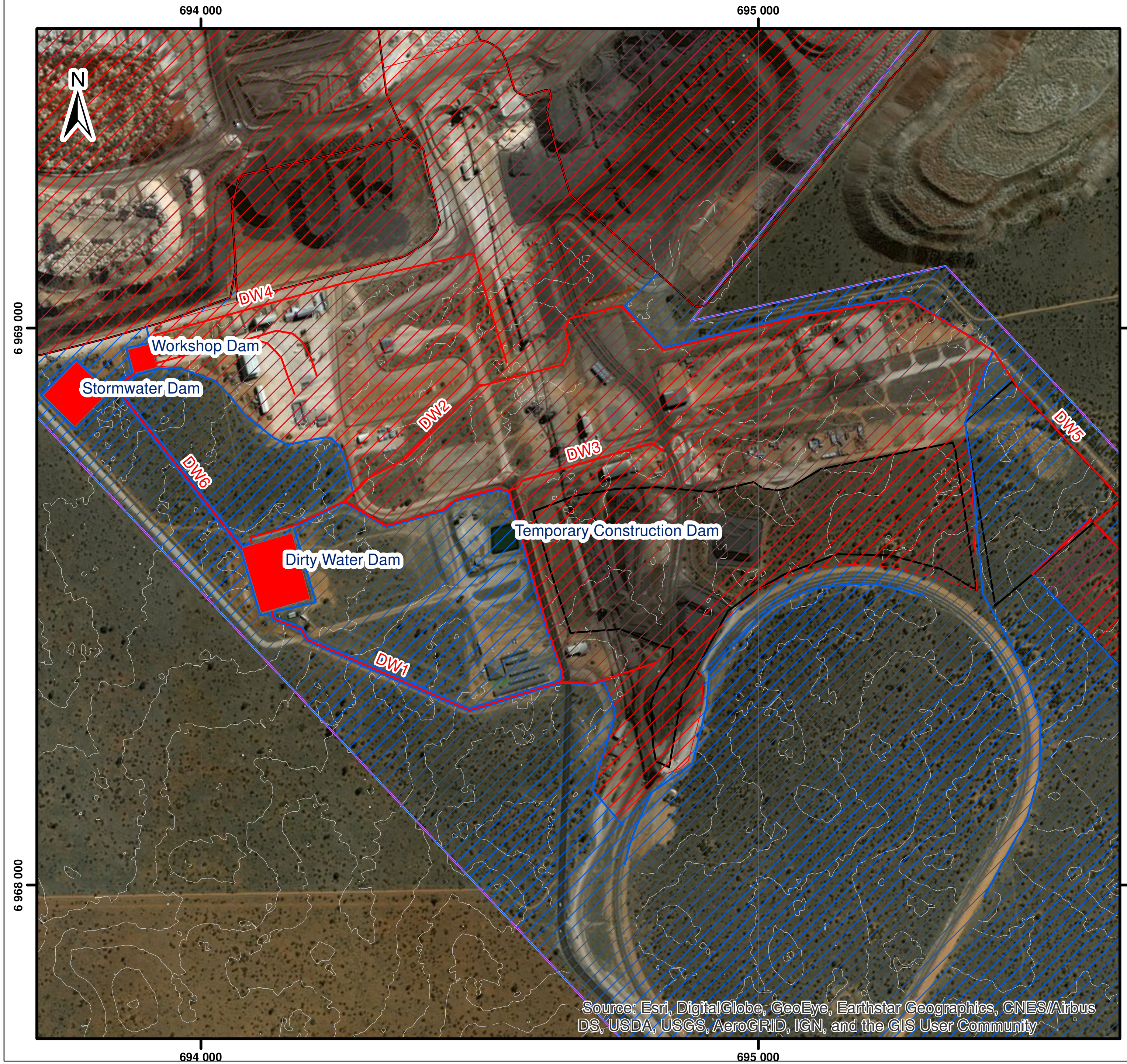

Legend

- Dirty Stormwater Channels
- Stormwater Berms
- Dirty Catchments
- Dirty Water Dams
- Clean Catchments
- Infrastructure
- Surface Use Area
- Non-Perennial Watercourses
- 0.5m Contours
- 20m Contours

0 50 100 200 300 400 500 600

Meters

Projection: Transverse Mecator
Datum: WGS 1984_UTM Zone 34S

Tshipi Borwa Mine

Figure 3-2

Plant Area Stormwater Management

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3.4 SIZING OF DRAINAGE CHANNELS AND BERMS

The 1:50 year rainfall intensities and peak flow estimates for each of the stormwater diversion channels are presented in Table 3-3.

TABLE 3-3: DESIGN FLOW ESTIMATES

Catchment	Area (km^2)	Runoff Coefficient	Time of Concentration (hours)	Rainfall Intensity (mm/hr)	Flow (m^3/s)
ROM, Crusher & Contractors Yard	0.369	0.300	0.910	67.81	2.09
Plant & Stockpiles	0.497	0.300	1.168	58.92	2.44
Sinter Plant	0.102	0.300	0.814	72.42	0.62
Plant & Stockpiles & Sinter Plant	0.597	0.300	1.543	49.19	2.45

In order to accommodate the design flows, the recommended channel sizes are presented in Table 3-4. Figure 3-3 presents a typical cross-section through the channel.

Based on the design drawings, the existing channels at the site are 1.5m wide and 0.6m deep. Comparing the dimensions against the design flows it is concluded that channel DW3 will need to be deepened by 0.2m to accommodate the flows, which should be relatively easy to achieve. It is not considered necessary to extend the concrete lining to the top of the channel, as water will only contact the unlined upper section of the channel during extreme events, in the region of a 1:10 year event. It should be noted that channel DW2 will need to be deepened before the Sinter Plant is constructed to accommodate the increased design flows from this catchment which will be routed via channel DW5 into channel DW2.

The following assumptions were made during the design of the flow diversion channels:

- The channels are sized to take the maximum flow calculated for the downstream end of the contributing catchment and the channel sizing will be uniform along their entire length.
- The longitudinal gradients are based on 0.5m contours provided by Tshipi.
- Clean water will be kept out of the dirty water channels by constructing and maintaining a linear bund alongside the channel with the material excavated from the channel (as shown on Figure 3-3).

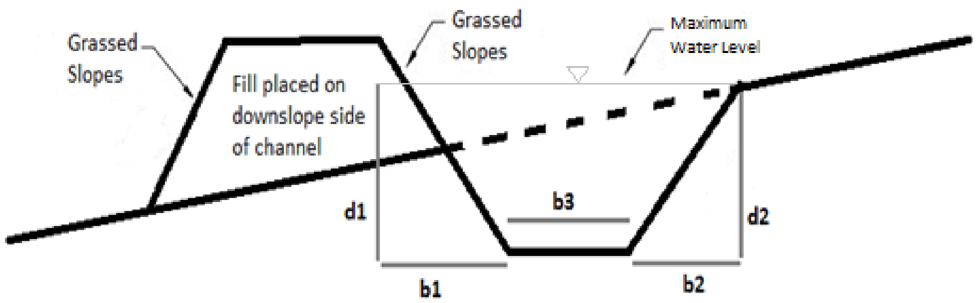

FIGURE 3-3: STORMWATER DIVERSION CHANNEL SIZING

TABLE 3-4: STORMWATER DIVERSION CHANNEL SIZING

Catchment	Total Flow	Drainage Channel	Design Flow		Channel dimension (refer to Fig 3-3)					S	n	A	P	R	V	Q
					b1	d1	b2	d2	b3							
	m³/s		%	m³/s	m	m	m	m	m	m/m		m²	m	m	m/s	m³/s
Plant & Stockpiles	2.4	DW1	25%	0.6	0.6	0.6	0.6	0.6	0.3	0.004	0.025	0.5	2.0	0.3	1.1	0.6
		DW2	25%	0.6	0.6	0.6	0.6	0.6	0.3	0.004	0.025	0.5	2.0	0.3	1.1	0.6
		DW3 Existing	50%	1.2	0.6	0.6	0.6	0.6	0.3	0.004	0.025	0.5	2.0	0.3	1.1	0.6
		DW3 Upgrade	50%	1.2	0.9	0.9	0.9	0.9	0.3	0.004	0.025	1.0	2.7	0.4	1.3	1.3
ROM, Crusher & Contractors Yard	2.1	DW4	100%	2.1	0.9	0.9	0.9	0.9	0.3	0.009	0.025	1.1	2.8	0.4	1.9	2.1
Sinter Plant	0.6	DW5	100%	0.6	0.6	0.6	0.6	0.6	0.3	0.004	0.025	0.5	2.0	0.3	1.1	0.6
Plant & Stockpiles & Sinter Plant	2.4	DW2 Upgraded	50%	1.2	0.8	0.8	0.8	0.8	0.3	0.004	0.025	0.9	2.6	0.4	1.3	1.2
Dirty Water Dam overflow	2.4	DW6	100%	2.4	0.9	0.6	0.9	0.6	1.2	0.009	0.025	1.3	3.4	0.4	1.9	2.4
Workshop Dam overflow	2.1	DW7	100%	2.1	0.6	0.6	0.6	0.6	1.2	0.010	0.025	1.1	2.9	0.4	2.1	2.2

Where practical, the dirty water channels should be lined with a low permeability liner (as is already the case with most of the drainage channels on site) to prevent dirty water from infiltrating through the base of the channels which otherwise might impact upon the quality of the underlying groundwater. Due to the width of the existing channel, this may not be feasible for the existing channel which cross the contractor's area.

A nominal berm height of 0.5m is considered to be sufficient to prevent runoff from clean areas flowing into dirty areas. Given the flat gradients, low rainfall and high evaporation rates, it is expected that any clean stormwater ponding against the berm will either evaporate or infiltrate within a few days of a storm event.

3.5 SIZING OF WASTE ROCK DUMP (WRD) STORMWATER RETENTION BERM

Runoff from the WRDs will collect at the toe of the WRD, and unless managed could potentially migrate off site and reach a surface water receptor. Whilst this is considered unlikely due to the topography, it is recommended that stormwater retention berms are constructed around the perimeter of the WRD to collect dirty stormwater from the WRDs and satisfy the requirements of GN 704.

The side slopes of the WRDs feature horizontal benches 10-30m in width. The width of the side slopes between each bench is typically 30-60m and any runoff from the upper slopes of the WRD will collect on the benches and infiltrate through into the permeable WRD. Runoff from the lowest portion of the side slope will be collected by the perimeter stormwater retention berm which will be created parallel to the toe of WRD. This will be divided into paddocks by smaller berms created at regular intervals perpendicular to the toe of the WRD in order to retain stormwater at the toe of the WRD and prevent conveyance around the perimeter of the WRD. Indicative sizing of the stormwater retention berms is as follows:

- Maximum width of WRD side slope (between benches) = 50m.
- Offset of perimeter stormwater retention berm from toe of WRD = 10m.
- Distance between perpendicular berms creating paddocks = 50m.
- 1:50 year 24 hour rainfall depth = 141mm.
- Runoff coefficient = 0.53.
- Runoff Volume per paddock = 185m^3.
- Maximum Water Depth in paddocks = 0.37m.

Considering the high evaporation and a conservative estimate of infiltration, the number of days it would take to empty the toe paddock is presented below:

- The lowest basic infiltration rate for clay soils (FAO,1988) of 1 mm/hr (24mm/day).
- Mean annual evaporation (1972mm) gives a daily evaporation of 5 mm/d.
- Max water depth in paddocks = 370mm.
- Time to empty (370mm / 29mm/d) = 13 days.

It is recommended that perimeter stormwater berms are created at a nominal 10m from the toe of the WRD with a nominal height of 0.8m, perpendicular berms with a nominal height of 0.5m are to be created every 50m to form a series of paddocks. This will be sufficient to retain dirty runoff and prevent discharge to off-site surface water receptors. During detailed design and construction, the dimensions of the berms / paddock arrangement can be revised according to site constraints whilst still ensuring the volumetric requirements can be accommodated, for example by reducing the offset from 10m to 5m but increasing the height of the berm from 0.8m to 1.2m.

The height of the perimeter stormwater retention berm should include a nominal 0.4m of freeboard above max water levels. Given the arid climate and the fact that the WRDs rarely generate runoff, the stormwater berms / paddock arrangement are not considered to be dams in the context of GN704, and as such, the application of 0.8m freeboard is not considered appropriate.

3.6 LIMITATIONS AND FURTHER WORK

BPG A4[3] requires the capacity of a dirty water containment facility to be estimated by a daily timestep water balance model (not single event) which considers stormwater inflow and resultant storage capacity against the pump out rate, to ensure the capacity of the facility is such that the annual probability of a spillage is no more than 1:50 (2%). The capacity of the approved 78Ml stormwater dam should be confirmed using a daily timestep water balance model as per BPG A4 however, initial estimates of the capacity (presented in section 3.3) suggest that 52Ml would be adequate. Consideration should be given to design a stormwater dam with two compartments, initially a 52Ml compartment could be constructed with a subsequent 26Ml compartment to be deferred and only constructed where more detailed water balance studies confirm that it will be required.

It is understood that the existing dirty water dam is under capacity when considering the expected runoff volumes from the contributing catchment. It is recommended that a spillway is constructed from this facility to convey overflows to the stormwater dam. The invert level of the spillway must be suitable to allow decant from this pond without causing water levels within the dirty water channels to backup and spill upstream of the dirty water dam.

Consideration should be given to incorporating silt traps upstream of the existing dirty water dam and workshop dirty water collection dam, to minimise the silt load to these facilities, which will reduce capacities of the dams and may potentially cause operational problems when re-using water from these facilities (for example silty water may lead to blockages of sprinkler systems at the crushers).

It is recommended that the design parameters for the WRD toe paddocks are revisited and updated to reflect closure plans in particular any reprofiling, topsoiling or revegetation of the WRD prior to closure. Often WRDs will be reprofiled and benches removed creating a larger area of the side slopes that will drain into the toe paddocks. The lower gradients and revegetated surface of the WRD is likely to reduce the runoff coefficients presented above.

[3] Best Practice Guideline A4: Pollution Control Dams

4 SITE WIDE WATER BALANCE

A site wide water balance model has been prepared to understand flows within the Tshipi Borwa Mine's operational water circuit during average dry seasons and average wet seasons during different phases of the project.

The water balance is steady state and no consideration is given to changes in flows resulting from progressive development of infrastructure, variations in climate or changes in production rate, or operational storage.

To demonstrate how variations in groundwater inflows and operational water requirements will impact upon the water balance, the following scenarios were modelled:

- Current average wet and dry seasons.
- Year 10 average wet and dry seasons.
- Life of mine average wet and dry seasons.

The water balance reviews all relevant design work by the wider project team, estimates the typical flows, and volumetric requirements of make-up water or discharge of surplus water (where applicable).

The modelled water balance circuit includes water inflows, losses and transfers for the following aspects of the operation:

- Open Pit;
- Stormwater from various dirty water areas defined in Section 3;
- Process Plant; and
- Various Support Services (offices, laboratory, stores, change house, workshops and load out stations).

4.1 WATER RE-USE HIERARCHY

Priority will be given to reusing dirty water from the open pit, treated sewage effluent, and stormwater (collected within the dirty water dam, workshop dirty water collection dam and stormwater dam) for non-potable uses before abstraction of water from clean water sources i.e. makeup water and potable water from boreholes.

4.2 METHODOLOGY

A spreadsheet model was used to represent the flows within the operational water circuit using information taken from the following sources of information:

- Information collected during a site visit on 14 March 2017.
- Process Flow Simulations Report (SET, May 2017)[4].
- Water Balance – Letter to Dept. Water Affairs (Tshipi, 12 August 2014).
- Tshipi Borwa Groundwater Study (SLR, July 2017).
- Environmental Impact Assessment and Environmental Management Programme for the proposed Ntsimbintle Mining Project (Metago, May 2009).

Water sources (inflows) were taken as:

- Groundwater ingress into the open pit;
- Stormwater collected from dirty catchment and conveyed to the stormwater dam, dirty water dam and workshop dirty water collection dam;
- Direct rainfall into the stormwater dam, tailings facility and return water dam, dirty water dam, workshop dirty water collection dam and temporary construction dam; and
- Makeup water abstraction from:
    - Sedibeng pipeline;
    - On-site raw water storage facility (filled during the wet season); or
    - On-site boreholes.

Water sinks (losses) were taken as:

- Evaporation from the dams and tailings facility;
- Dust suppression;
- Potable water consumption;
- Transfer into an on-site raw water storage facility or discharge to environment (to be treated if required).

4.3 ASSUMPTIONS AND INPUT PARAMETERS

The water balance assumes the following:

- The sinter plant and tailings facility will only become operational towards the end of the mine's life.
- Rainfall related inflows and evaporation related losses for the wet and dry season scenarios were estimated based on: i) average values during the three driest months of the year; and ii) average values during the three wettest months of the year;
- Runoff and evaporation coefficients for each surface were fixed and not influenced by antecedent climatic conditions, likewise all catchment areas are constant;

[4] Process flow simulations to complete the construction of the Tshipi mine process plant – Report for Basic Design. (Simulation Engineering Technologies, May 2016)

- Evaporation from the dams will only occur if there is water in the dam;
- Under normal / average conditions there will be no overflow of stormwater from the dirty water dam or workshop dirty water collection dam into the stormwater dam.
- There will be no inflow of stormwater from the Mamatwan pit, during mining of the barrier pillar; and
- This water balance model is run for only steady state average wet season and average dry season conditions and no consideration is given to storage of water at any aspect of the infrastructure modelled i.e. flow in = flow out.

The input parameters used for the water balance are presented in Table 4-1.

TABLE 4-1: WATER BALANCE INPUT PARAMETERS

Parameter	Description	Source
Climate Data	• Average wet month rainfall = 65mm • Average wet month evaporation = 196mm • Average dry month rainfall = 4mm • Average dry month evaporation = 128mm	• Section 2.1
Pit Inflows	• Current: Zero inflows. • Year 10: 477m^3/day • Life of Mine: 609m^3/day	• SLR Groundwater Model, June 2017
Potable Water	• Demand: 2 628m^3/month • RO Plant Brine: 37% of throughput • Consumption Losses: 36.5m^3/month	• SET, May 2016
Sinter Plant and Tailings Facility	• Water in Tailings: 4 526m^3/month • Water Recovery at Thickener (not shown): 118 729m^3/month • Tailings facility footprint: 20ha • Return to Plant: 0m^3/month • Sinter Plant Losses: moisture losses lumpy (5 258m^3/month) & fines (1 788m^3/month) – moisture in ore (6 000m^3/month) = 1 046m^3/month	• Tshipi, 12 August 2014
Dust Suppression	• Sprinkler System: 7 570m^3/month • Dust Suppression Trucks: 20 x 16kl trucks and 10 x 22kl trucks per day • Washdown Water: 10l/s for 12hrs, twice per week.	• SET, May 2016 • Information from Site Visit • Information from Site Visit

Parameter	Description	Source
Dams	• Dirty Water Dam: o Catchment = 496 800m^2 exc. Sinter Plant or 596 900m^2 inc. Sinter. o Footprint = 10 600m^2 o Runoff Coefficient = Wet Season: 13%, Dry Season = 6% • Workshop Dirty Water Collection Dam: o Catchment = 368 700m^2 o Footprint = 1 900m^2 o Runoff Coefficient = Wet Season: 13%, Dry Season = 6% • Stormwater Dam: o Catchment = N/A (overflow from dirty water dam and workshop dirty water collection dam dams only) o Footprint = 13 000m^2 o Runoff Coefficient = N/A • Pit Sump: o Catchment = yr0: 680 541m^2 increasing to 2 437 466m^2 from yr10 onwards. o Footprint = assumed 1% of pit area o Runoff Coefficient = Wet Season: 13%, Dry Season = 6% • Temporary Construction Dam: o Catchment = N/A o Footprint = 2 500m^2	• Stormwater Management Plan – Section 3.

4.4 RESULTS

The water balances for the wet and dry seasons for the modelled scenarios are presented in Figure 4-1 to Figure 4-6 below.

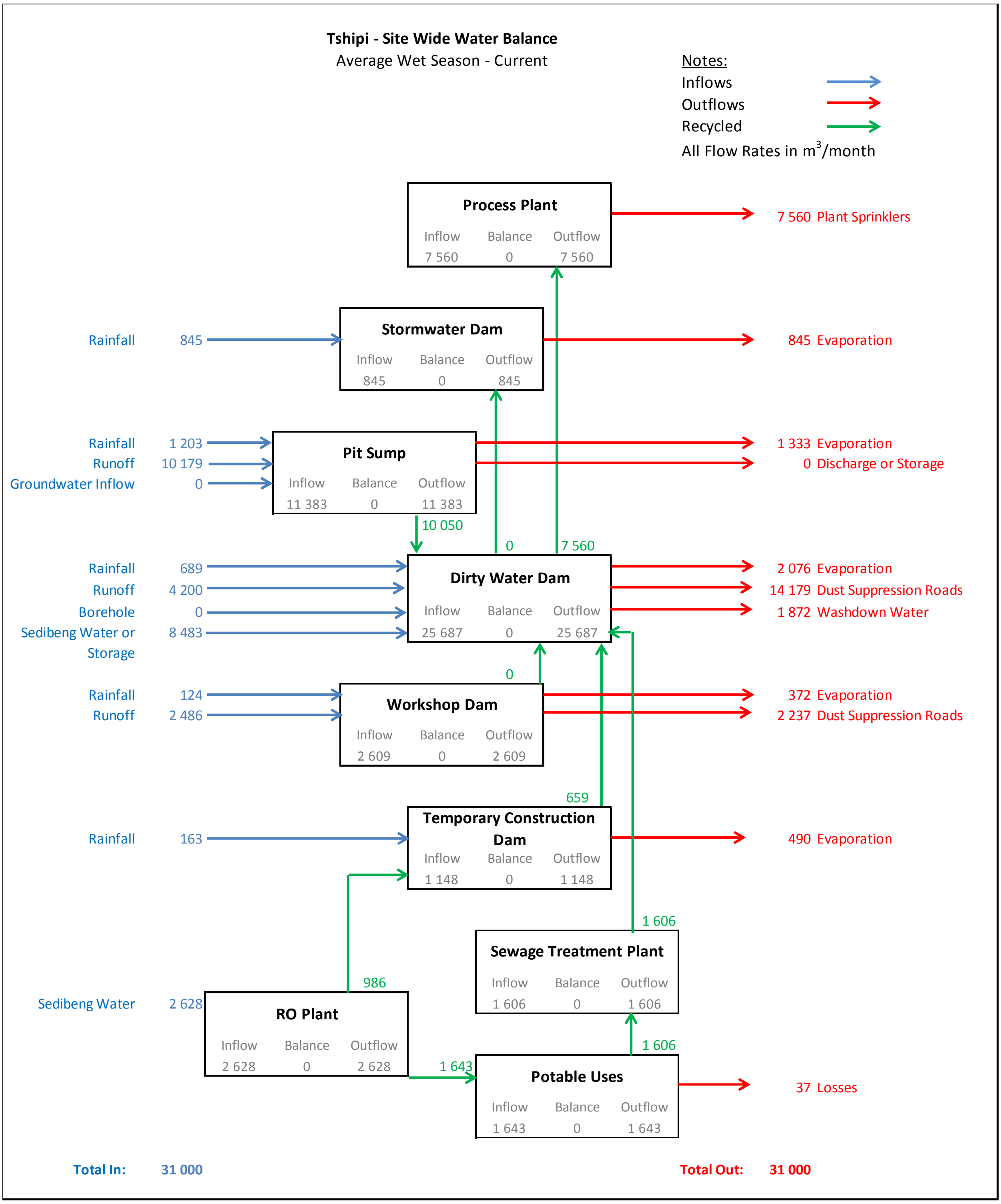

FIGURE 4-1: WATER BALANCE - CURRENT WET SEASON

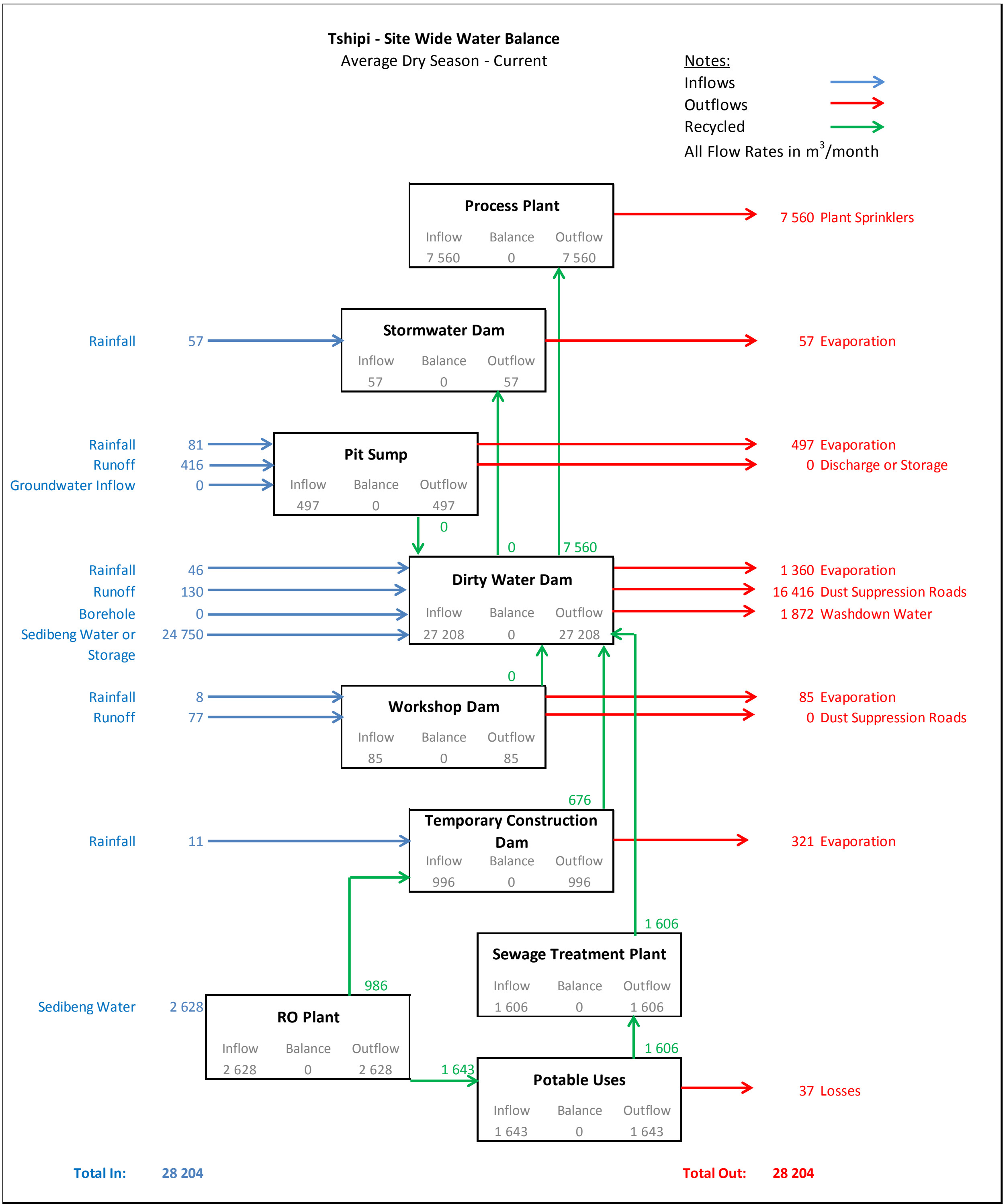

FIGURE 4-2: WATER BALANCE - CURRENT DRY SEASON

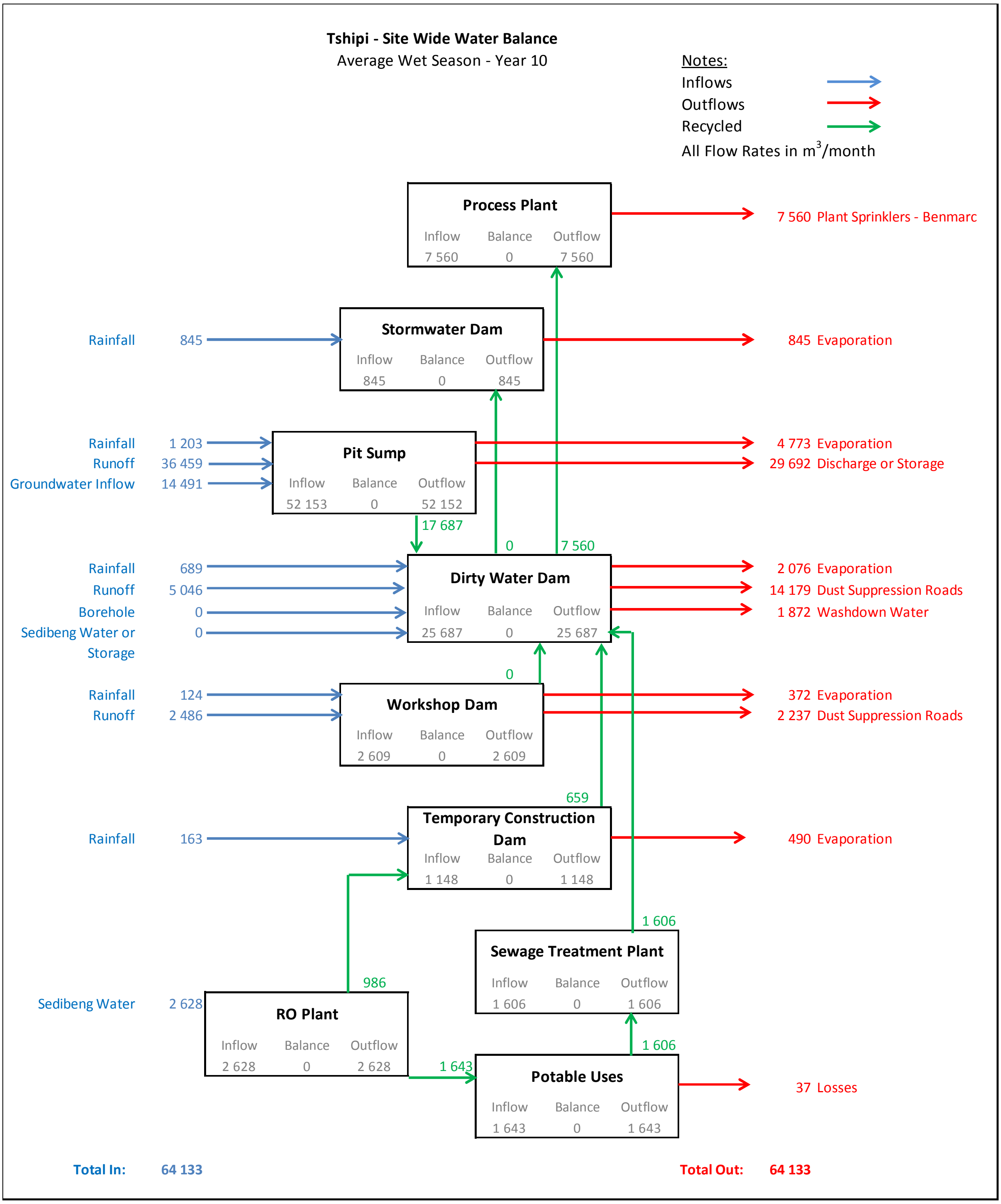

FIGURE 4-3: WATER BALANCE - YEAR 10 WET SEASON

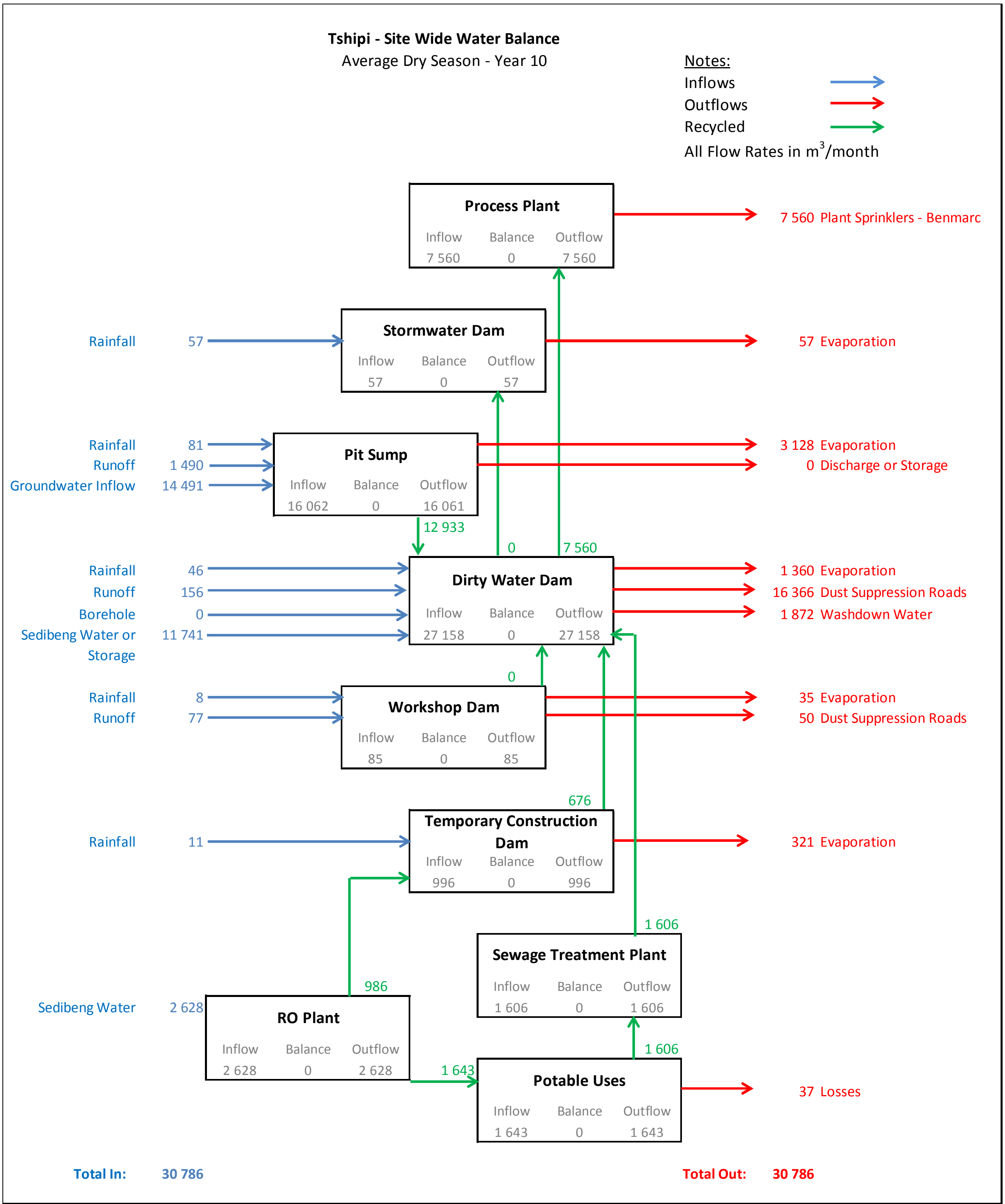

FIGURE 4-4: WATER BALANCE - YEAR 10 DRY SEASON

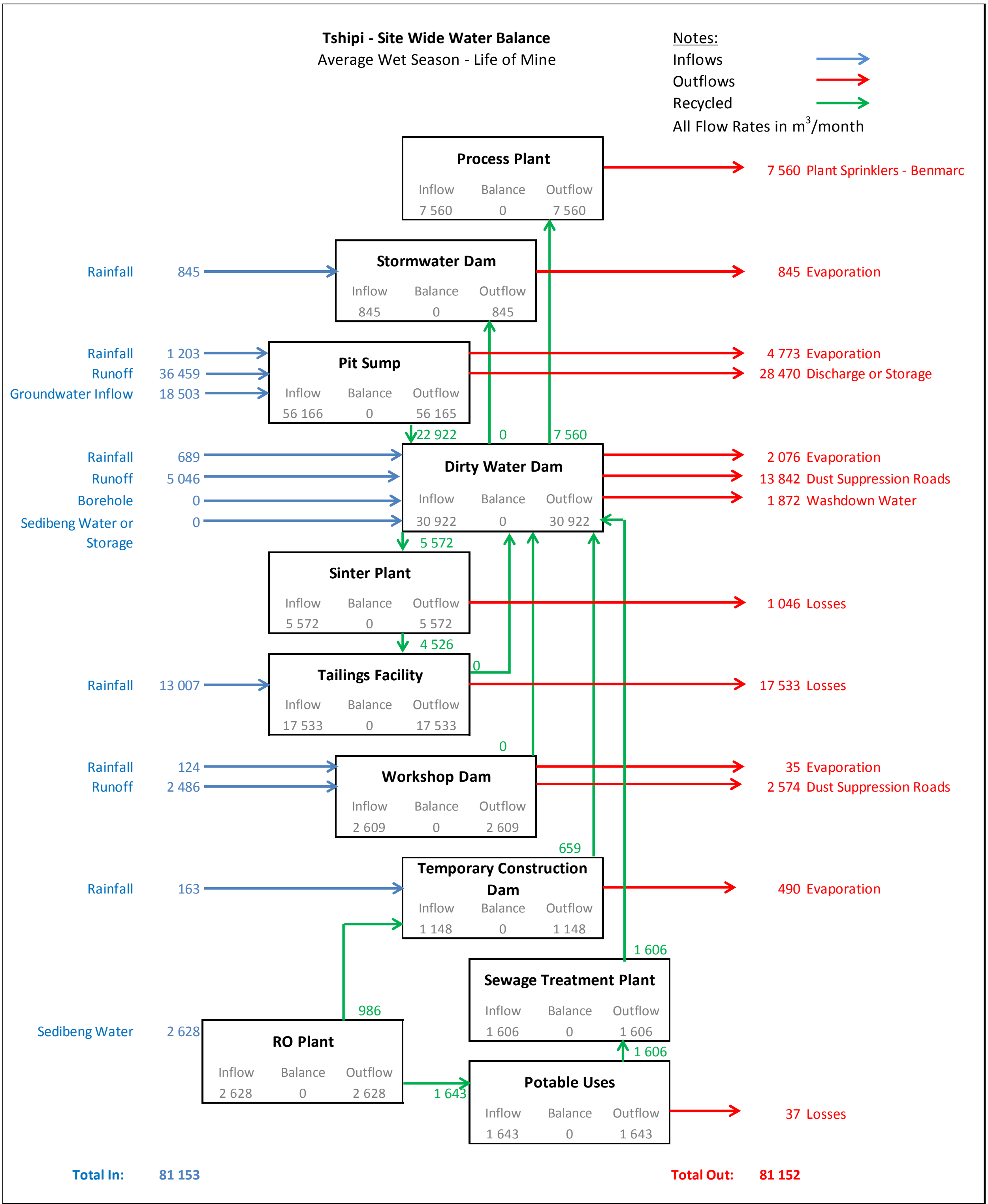

FIGURE 4-5: WATER BALANCE – LIFE OF MINE WET SEASON

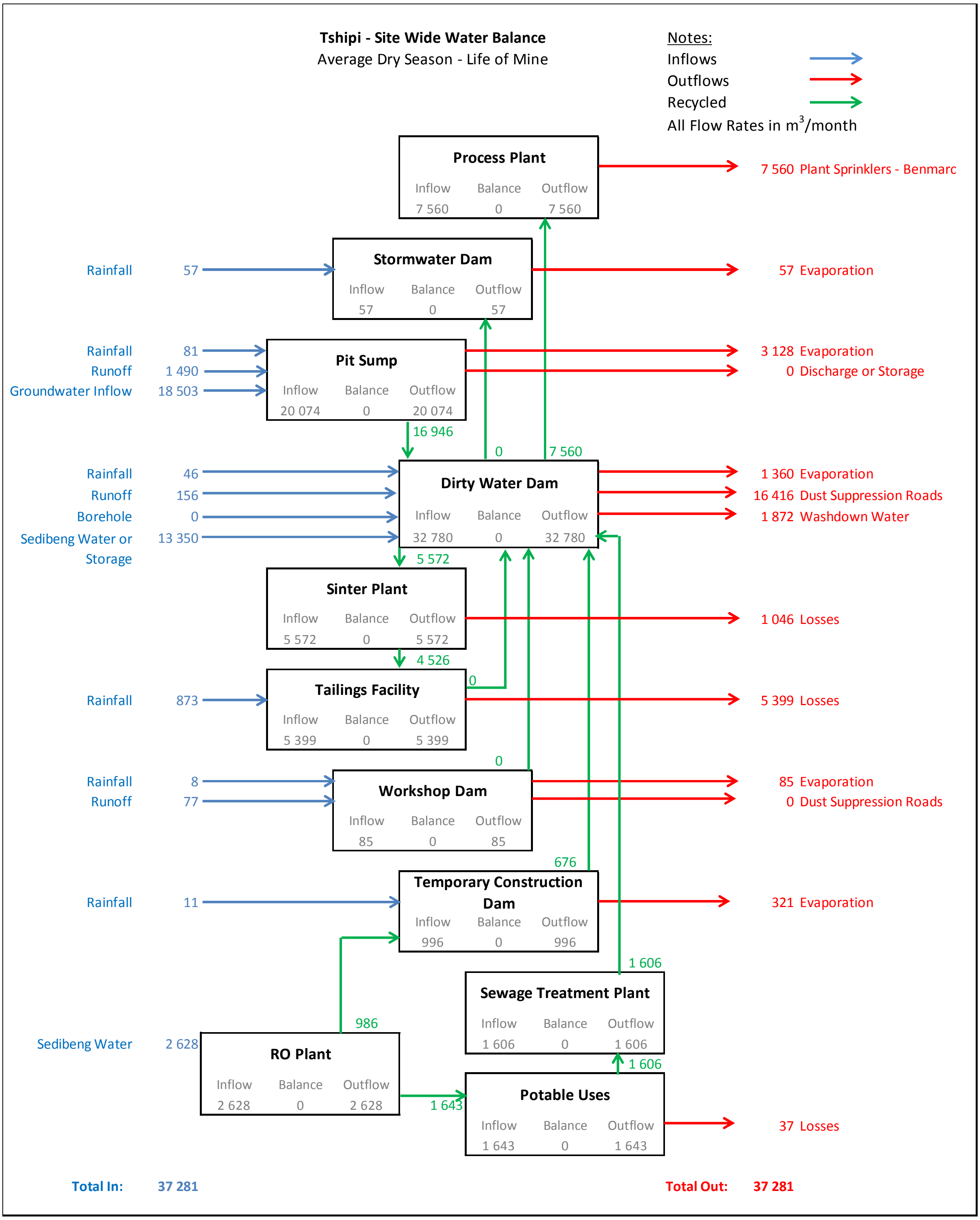

FIGURE 4-6: WATER BALANCE – LIFE OF MINE DRY SEASON

The water balance shows during the current scenario, groundwater inflows are negligible and the mine is reliant on makeup water from Sedibeng with monthly demand estimated to be between 11 111 – 27 378m^3.

Groundwater inflow and stormwater collecting within the open pit becomes a very significant source of water for the mine in future years and from year 10 onwards the mine could be expected to be water positive during the wet season, although there is still expected to be a requirement for makeup water through the dry season.

Consideration should be given to storage of the excess stormwater and groundwater expected during the wet season, to reduce makeup water requirements during the dry season. An option for storage of this water would be to utilise another compartment of the 78Ml stormwater dam not required for stormwater from the plant area, or storage within a suitably designed sump within the base of the pit.

4.5 LIMITATIONS AND FURTHER WORK

Currently, Tshipi are licensed to abstract water from two boreholes at up to 12 612m^3/year per borehole, which would reduce reliance on Sedibeng water. This supply option has not been included in the water balance as further work is required to confirm the sustainable yield of these boreholes and to estimate the cost and benefit of equipping these boreholes to supply water.

As discussed in Section 4.3, this water balance is run on a steady state basis and no consideration is given to storage of water at any aspect of the infrastructure modelled. A dynamic simulation water balance model should be undertaken to improve understanding of the mine's water balance and how it varies in response to climatic variations, improve certainty on the makeup water requirements, and identify water conservation and water demand management measures.

This study makes use of various assumed and estimated parameters, and should be updated whenever additional information becomes available.

Groundwater inflow to the open pit forms a critical part of the mine's water circuit and is the main source of water in later years of mining. Groundwater inflows are based on the available modelled data and it is recommended that measurements of water pumped out of the pit are collected and used to calibrate the water balance model presented herewith.

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RECORD OF REPORT DISTRIBUTION

SLR Reference:	710.20029.00011
Title:	Stormwater Management and Water Balance for EMPr
Site name:	Tshipi Borwa Mine
Report Number:	1
Client:	Tshipi E' Ntle Manganese Mining (Pty) Ltd

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