ARM (Ltd) Machadodorp Works

2023 $MnSO_4$ Recovery Project

WATER AND SALT BALANCE

Confidential Report

iLEH
3 Herbert Baker St
Sharon Park
1496

e: irene@ileh.co.za
c: 083 447 8377
t: 011 363 2926
f: 086 672 9900

Report No iLEH-EG MACH-WSB 01-23

July 2023

PROJECT DETAILS

PROJECT:	ARM Ltd Machadodorp Works 2023 $MnSO_4$ Recovery Project
Report Title:	Water and Salt Balance
Client:	Envirogistics (Pty) Ltd
Client Contact	Tanja Bekker
Project Number	ILEH-EG MACH-WSB 01-23
Date Submitted	14 July 2023
Author	Irene Lea M. Sc. *Pri. Sci. Nat*

INDEMNITY AND CONDITIONS RELATING TO THIS REPORT

Irene Lea M.Sc. Pr. Sci. Nat

14 July 2023

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS USED

AMW	ARM (Ltd) Machadodorp Works
BH	Borehole
BPG	Best Practice Guideline
DWAF	Former Department of Water Affairs and Forestry
DWS	Department of Water Affairs and Sanitation
EIA	Environmental Impact Assessment
FeCr	Ferrochrome
FeMn	Ferromanganese
iLEH	Irene Lea Environmental and Hydrogeology cc
HDPE	High Density Polyethylene
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MRP	Metal Recovery Plant
NA	Not applicable/available
NWA	National Water Amendment Act (Act 27 of 2014)
RO	Reverse Osmosis
SAS	Scientific Aquatic Services (Pty) Ltd
SWS	Storm Water Solutions (Pty) Ltd
TDS	Total Dissolved Solids (mg/l)
Tph	Tonnes per hour
WCDMP	Water Conservation and Demand Management Plan
WMA	Water Management Area
WRD	Waste Rock Dump
WUL	Water Use License

1 INTRODUCTION

The ARM Machadodorp Works (AMW) is situated approximately 6km southwest of the town of eNtokozweni (Machadodorp). The AMW was constructed in 1971, initially to smelt ferrochrome (FeCr) for export. During 2009, the smelter was converted to implement a system of alternate FeCr and ferromanganese (FeMn) production.

This report presents a water and salt balance for a project that investigates the feasibility of constructing and operating a plant to recover battery grade manganese, referred to as the $MnSO_4$ Recovery Project in this report. The resources earmarked for this project are located at the AMW.

The report is based on the dataset used to complete the latest operational water and salt balance prepared for the Works (iLEH, 2023).

Water monitoring and management at the Works is undertaken according to the operations' approved water use licenses (License No 24079907 and 05/X21F/ACFG/8736). The site is a zero dirty effluent discharge operation. Storm water is captured via concrete channels and is contained in pollution control dams (PCD). The two PCDs, namely Dam 1 and 3, are lined with High Density Polyethylene (HDPE) to prevent contamination to soils and groundwater. The locations of these dams are indicated on Figure 1. Processed water is sourced from captured storm water, runoff and slag dump seepage in the two PCDs for reuse.

Three boreholes are used for groundwater abstraction to supplement process and potable water to the operations. The locations of these boreholes are indicated as production boreholes on Figure 1.

In addition to the groundwater abstraction, AMW also has permission to abstract water from the Leeuwspruit in terms of its water use license (WUL). The surface water is pumped to the River Dam for use at the operations.

AMW obtained a waste license on 11 April 2016 in terms of Section 49(1)(a) of the National Environmental Management: Waste Act, 2008 (Act 59 of 2008) that authorises the construction of a reverse osmosis (RO) water treatment plant and associated lagoons for the storage and treatment brine (License Ref. 12/9/11/L891/6). The RO plant and the associated brine ponds are under construction in the Material Stockpile Area as indicated on Figure 1. Permeate produced at the RO plant will be reused at the operations and a portion of the clean water is earmarked for discharged to a wetland south-east of the AMW (E-Science, 2015).

AMW also obtained a waste license for an H-H waste site for the disposal, recovery and re-use of FeCr and FeMn slag (License No 12/9/11/L368/6/R1) on 20 June 2017. The locations of these slag dumps are indicated on Figure 1.

1.1 Allocated water resources

The WUL allocated water resources available to the AMW are listed in Table 1. These include WUL permitted groundwater and surface water abstraction, water currently in storage in Dam 1, Dam 3 and the River Dam, treated sewage effluent and updated runoff to Dams 1 and 3.

The runoff calculations were prepared by Hydrospatial (2021), the details of which are discussed below. It is shown that 572 220 m^3/a of water resources are available to the works if the typical dry runoff is taken into consideration.

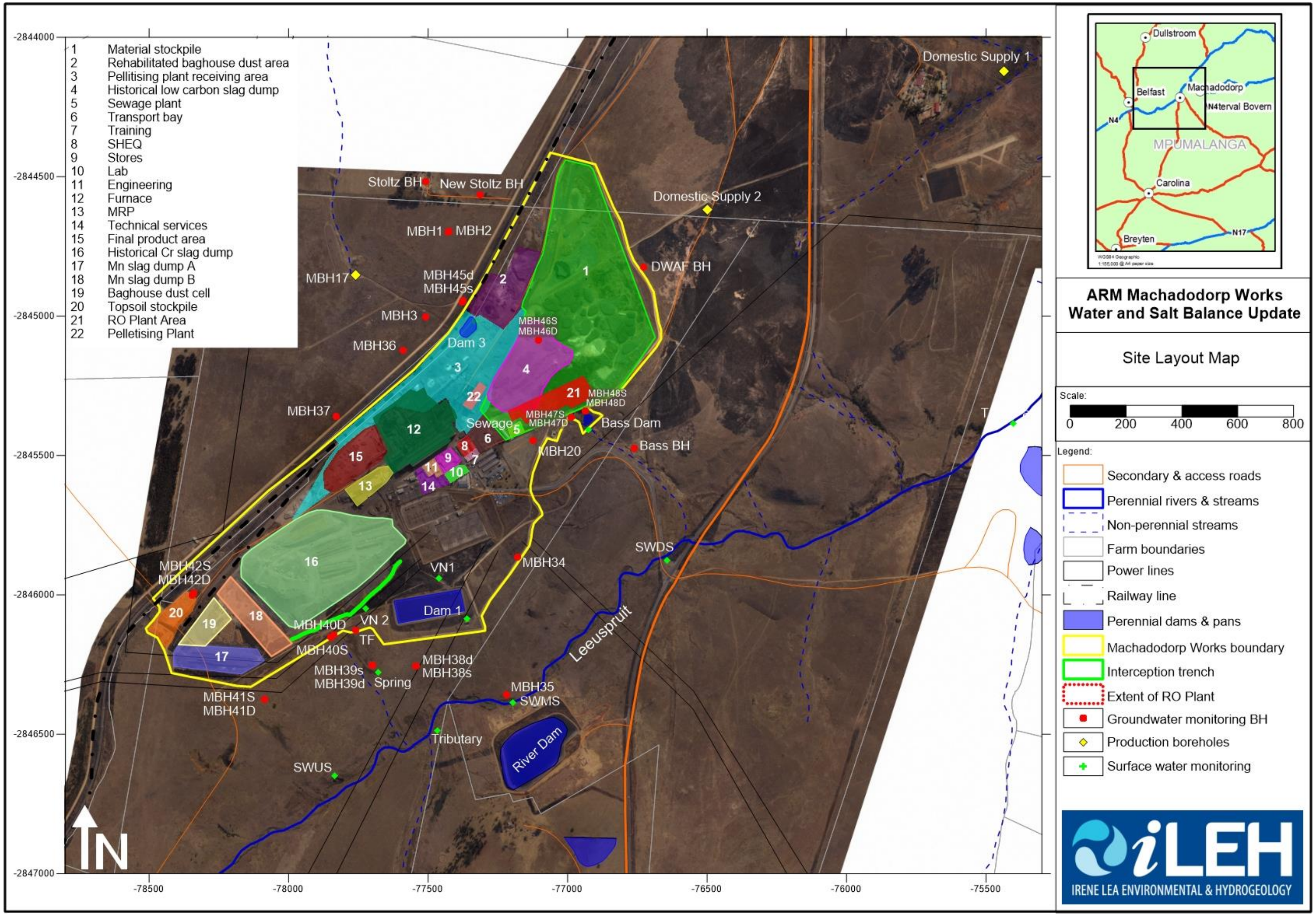

Figure 1 Map indicating the project components

Table 1 Water resources available to the project

Total available resource	Volume (m^3/a)	Comment
Borehole tank	225 000	WUL permitted volume
Leeuwspruit abstraction	195 000	WUL permitted volume
2021 measured volume in dam storage	223 460	Dam 1, Dam 3 and River Dam
Treated sewage water	22 756	2014 to date maximum annual volume
Typical dry runoff to Dam 1 and 3	71 534	Hydrospatial (2021)
Total Resources Available	**737 750**	

1.2 Project description

The information discussed here was summarised from a pre-feasibility study completed for the project by Senet (2023). This information is confidential.

The primary feed for the recovery plant will be ferro manganese slag, which is deposited on the slag dumps at the Machadodorp Works. The existing mill at the Works will be used to process the manganese slag. The slag material will be milled to a size fraction of P80 of 75um. The current design capacity of the mill is 59t/hr. This capacity will however be reduced as part of the $MnSO_4$ Recovery Project to avoid slurry pooling, grinding inefficiencies and slimes generation to a throughput of 30t/hr.

The milled slag will be processed in a two-stage precipitation process. Test work completed yielded encouraging results.

The process plant will consist of the following sections: milling, filtration, pugging, dead burn, leaching, post-leach filtration, jarosite precipitation, thickening and filtration, second fluoride precipitation, thickening and filtration, fluoride recycling, crystallisation, crystal drying and decomposition, product bagging and post-crystallisation gas scrubbing.

1.3 Project water demand

The water demand for the $MnSO_4$ Recovery Project was provided by ARM and is summarised in Table 2. The project required potable quality water, which will be mainly supplied from the RO plant.

Table 2 Project water demand

Project component	Water demand (m^3/hr)
Slag wet milling and filtration initial supply	11.11
Mn extraction from slag Feed 1	5.00
Mn extraction from slag Feed 2	8.00
Leach off gas scrubber	5.00
First precipitation (steam)	1.69
Gas scrubbing and fluoride makeup	5.00
Final scrubbing	5.68
Total water demand	**41.37**

The total water demand for the project is indicated as 268 000m^3/a, which constitutes a 75% use when converted from m^3/hr to m^3/a. The water will be allocated to the project from the WUL allocated resources, as listed in Table 1.

This report will evaluate the additional water demand for this project against the existing water uses at the AMW. The water demand provided in Table 2 is considered the maximum required use. ARM is in the process of assessing several measures to reduce the water demand for the project. In addition, mechanisms are under development to capture water used in the process and making this available for reuse in the project. In this report, the capture of vapour condensate for reuse in the MnSO4 Recovery Project is included. From a conservative perspective, it will be assumed that

50% of the vapour can be recaptured. Measures are underway to increase vapour recapture to 90%. The water and salt balance presented in this report will be re-evaluated when this work has been completed. The future project water demand will however not exceed what is presented in this report. Any future reduction in demand and increase in water reuse efforts will therefore result in a positive impact.

2 PROJECT METHODOLOGY

The spreadsheet-based operational water and salt balances constructed and updated during 2023 (iLEH, 2023) was used as a basis to incorporate the $MnSO_4$ Recovery Project specifications. The spreadsheet allows for reviewing of data and results in graphic and tabular format and monitoring data can be incorporated into the water balance with ease. The spreadsheet-based water and salt balances were constructed in the following manner:

- All available project information was evaluated. This includes the following:
  - The conditions of the approved WUL for the operations (License No 24079907)
  - Dam levels in Dam 1, 3 and River Dam recorded in 2021 were used to calculate the volume of water currently in storage in these dams.
  - Monthly recorded water use volumes for the period March 2022 to February 2023.
  - The water monitoring reports submitted during 2022, completed by SAS and listed in the References at the end of this report.
  - On-site rainfall data for the period January 2003 – February 2023.
  - A report detailing the volume of water to be released to the wetland to replace flow that would be lost by the construction of a cut-off trench and berm (AED, 2014).
  - A spreadsheet detailing the calculation of the volume of water to be released to the wetland.
  - A summary hydrology report (E-Tek, 2011).
  - An application for a water use license for the proposed water treatment plant (E-Science, 2015).
  - A confidential proposal on the design of a water treatment plant and stormwater management upgrade (Proxa, 2016).
  - An updated hydrological study completed by Hydrospatial (2021), which focusses on runoff to Dams 1 and 3 and Bass Dam as well as stream flow in the Leeuwspruit.
  - The project description presented in Senet (2023) and the water balance input data provided by ARM (Environmental BFD, reagents and high level water balance.xls) dated 16 May 2023.
- The conceptual water balance was updated to reflect the operational water management components as well as the $MnSO_4$ Recovery Project. The purpose of the conceptual balance is to improve the understanding of water management at the operations while considering the additional demand for the $MnSO_4$ Recovery Project and to identify and address data gaps.
- The updated conceptual water balance formed the basis for the updated water and salt balances for the operations.
- The $MnSO_4$ Recovery Project will entail several processes, but will be considered as a single water balance component in this report
- Runoff and evaporation volumes were taken from the updated hydrological study (Hydrospatial, 2021). S-pan evaporation rates were converted to lake evaporation following the methodology of the Water Research Commission (2012).
- The salt balance is based on the components of the water balance and on water quality information available from the 2022 monitoring reports listed in the References. Water quality data is not currently available for the $MnSO_4$ Recovery Project. This is discussed below.
- This water and salt balance report was undertaken according to the Department of Water Affairs' Best Practice Guideline G2 (DWAF, 2006).

3 HYDROLOGICAL SETTING

A hydrological study was completed by Hydrospatial (2021) as part of this assessment. The objective of this study was to calculate long-term runoff to the two pollution control dams (PCD), Dam 1 and Dam 3, the Bass Dam as well as long-term streamflow for the Leeuwspruit.

It is noted that the Bass Dam will be rehabilitated during the construction of the Reverse Osmosis (RO) water treatment plant.

3.1 Water management area

The project falls within quaternary catchment X21F of the Elands River, which forms part of the Inkomati Water Management Area. Surface water in this area drains towards to Leeuwspruit, situated southeast of the operation as indicated on Figure 1.

3.2 Climate

3.2.1 Rainfall patterns

AMW is located in a summer rainfall area where 90% of the rainfall occurs between October and April. Rainfall is recorded daily at the smelter. A complete annual on-site rainfall dataset is available for the period 2003 to 2022.

Analysis of the rainfall data indicates that the 18-year AMW rainfall record has a Mean Annual Precipitation (MAP) of 684mm. When combined , the long-term MAP the MAP for the project area is 769mm.

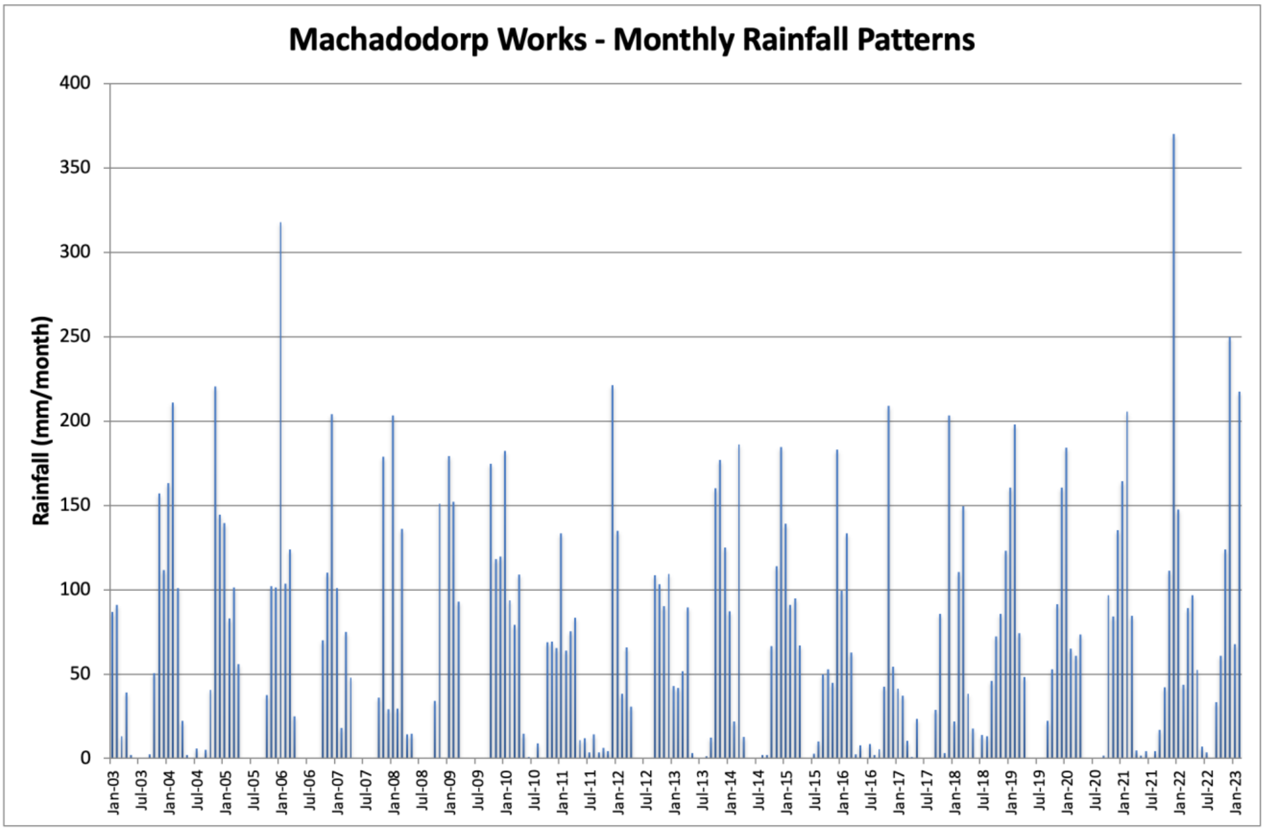

Figure 2 On-site monthly rainfall patterns between 2003 and 2023

The information presented in Figure 2 indicates that recent rainfall intensities are higher compared to the MAP. During 2022, 908mm of rain fell, which is 18% higher than the MAP. During January and February 2023, 285mm of rain fell, which is already 37% of the MAP.

The increased rainfall is incorporated as higher runoff volumes in this report. The typical wet runoff volumes, as calculated by Hydrospatial (2021), were used in the water balance calculations. More details regarding runoff volumes are discussed below.

3.2.2 Evaporation

Evaporation data was obtained from the WR2012 study for quaternary catchment X21F.

According to WR2012, AMW is located in evaporation zone 5A and has a Symon's Pan (S-Pan) Mean Annual Evaporation (MAE) of 1 348 mm (Hydrospatial, 2021). S-Pan evaporation was converted into lake evaporation (evaporation from water bodies such as dams) using recommended evaporation factors published in WR2012. The mean monthly evaporation is indicated in Table 3. Evaporation is highest over the warmer summer months of September to March, and lower over the remaining cooler months of the year.

Table 3 Mean monthly evaporation for the AMW site

Month	S-Pan Evaporation (mm)	Factor	Lake Evaporation (mm)
Oct	128	0.81	104
Nov	128	0.82	105
Dec	145	0.83	121
Jan	152	0.84	128
Feb	130	0.88	115
Mar	128	0.88	113
Apr	97	0.88	85
May	85	0.87	74
Jun	70	0.85	59
Jul	75	0.83	62
Aug	95	0.81	77
Sep	115	0.81	93
Total	**1 348**	**N/A**	**1 135**

3.3 Site runoff calculations

The runoff and stream flow calculations were completed for Dams 1 and 3 and Bass Dam by Hydrospatial (2021). This information is presented as a range of annual runoff types for each of the dams as well as for the anticipated streamflow in the Leeuwspruit. These calculations are presented in Table 4. More detailed information on the calculations presented in the table are contained in Hydrospatial (2021).

Also indicated is the annual streamflow volumes for the Leeuwspruit at the AMW surface water abstraction point.

The availability of water in Dams 1 and 3 depend to a large extent of surface runoff. If the $MnSO_4$ Recovery Project will rely on water supply from these dams, the impact of runoff needs to be considered. This assessment is discussed in more detail below.

Table 4 Range of calculated runoff and stream flow (after Hydrospatial, 2021)

Runoff Type	Dam 1 Annual Runoff (m^3/annum)	Dam 3 Annual Runoff (m^3/annum)	Bass Dam Annual Runoff (m^3/annum)	Annual Streamflow for Leeuwspruit abstraction point (m^3/a)	Comment
Lowest	22 507	5 921	4 870	670 000	Expected to occur on average every 100 years
Extremely low	36 059	10 150	8 831	780 000	Expected to occur on average every 20 years
Typical dry	55 645	15 889	13 867	1 120 000	Expected to occur on average every 3-5 years
Median	71 549	20 868	17 873	1 370 000	Average runoff
Typical wet	97 317	28 647	25 160	1 740 000	Expected to occur on average every 3-5 years
Extremely high	164 434	48 741	43 280	4 070 000	Expected to occur on average every 20 years
Highest	201 418	59 738	53 203	5 300 000	Expected to occur on average every 100 years

The following is concluded from the information presented in Table 4:

- The information presented in Table 3 will be used to complete the water and salt balance calculations presented in this report. Due to the high rainfall intensity measured over the evaluation period, the typical wet runoff volumes will be considered for the three dams.
- The annual runoff volume to Dam 1 can vary between 22 507 and 201 418 m^3, depending on the rainfall conditions and runoff type.
- In comparison, annual runoff to Dam 3 can vary between 5 921 and 59 738 m^3.
- As discussed earlier, the typical wet runoff are expected to occur every 3 – 5 years. Under these conditions, the runoff to Dam 1 is 97 317m^3/a and 28 647m^3/a to Dam 3.
- The annual streamflow in the Leeuwspruit at the abstraction point can vary between 670 000 and 5 300 000m^3.

3.4 Hydrological study recommendations

Hydrospatial (2021) makes the following recommendations based on the outcome of the report as discussed above:

- The runoff entering the dams from the AAMW site should be measured in order to obtain accurate runoff volumes. This will aid in future water balance updates.
- The streamflow at the Leeuwspruit abstraction point should be measured.
- Abstractions from the Leeuwspruit should not exceed the WUL limit of 195 000 m^3/annum (534 m^3/day); and
- There is no specific ecological reserve available for the Leeuwspruit abstraction point, however, the ecological reserve for the Leeuwspruit catchment is 35.1 % of the normal mean annual runoff. 35.1 % of the abstraction point mean annual runoff of 1.64 million m^3 equates to 575 640 m^3/annum. This is the quantity of water that should be allowed to pass downstream in order to meet the ecological reserve.

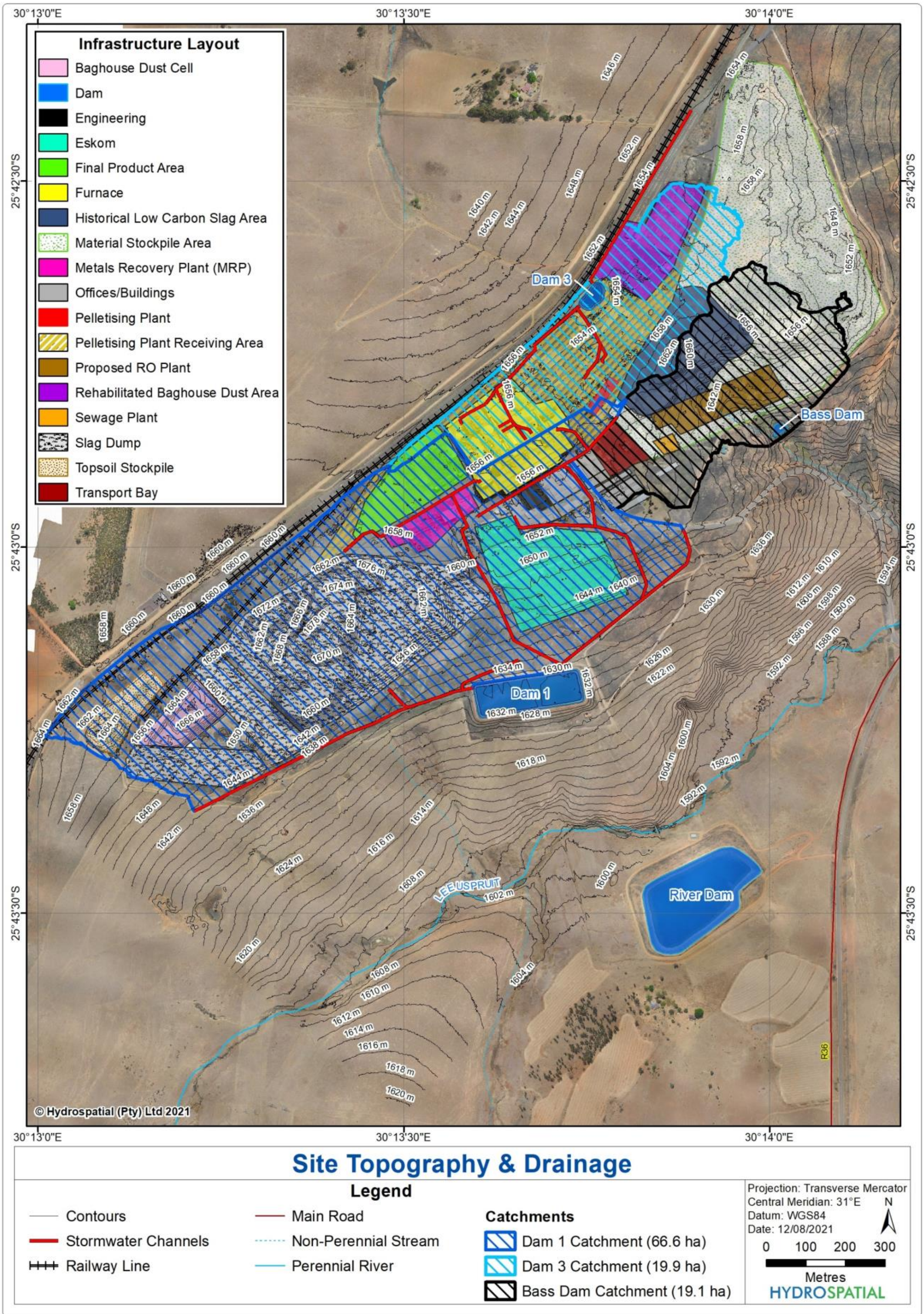

Figure 3 Dam catchments considered in this assessment

4 OBJECTIVES OF THE WATER AND SALT BALANCES

An accurate water and salt balance is an important component to overall water management at the operations. Water and salt balances can assist with identifying data gaps and implementing the required monitoring measures at strategic locations to improve the understanding of water use. A water and salt balance can further be used as an effective water management tool to optimise clean and dirty water use, thus preventing overflow of dams and water wastage. The following objectives are defined, based on the 2006 Department of Water Affairs' Best Practice Guideline G2: Water and Salt Balances (BPG).

- The water and salt balance will provide the necessary information to assist the operations in defining and driving water and waste management strategies.
- The water balance will be used to identify gaps in available data and to guide the monitoring programme. This information will be used to update the water balance as required.
- The water balance will be used to audit and assess water reticulation systems, with the main focus on water usage and the containment of dirty water. This includes identifying and quantifying points of high water consumption or wastage as well as areas of where dam capacities are exceeded. Where such areas are identified, the operations will implement the necessary measures to reduce consumption and/or increase capacity to minimise water wastage.

4.1 Boundaries of the Water Balance

The boundary for the balance is defined by the AMW boundary, as shown in Figure 1.

5 WATER BALANCE COMPONENTS

5.1 Dam storage capacities

The dam and tank storage capacities for the operations shown in Table 5. The dam capacities were confirmed by ARM and updated where new information is available.

Table 5 Dam and tank storage capacities

Dam Name	Area (m^2)	Capacity (m^3)
Dam 1	18 805	99 000
Bass Dam (Dam 2)	870	1 000
Dam 3	2 179	9 000
River Dam	31 400	227 000
Main Storage Tank	Closed tank	1 266
River Tank	Closed tank	148
Borehole Tank	Closed tank	148

5.2 Current Water Use at the Operations

Daily water usage is measured at the operations. The results are recorded in a spreadsheet for management purposes. A summary of the total annual water use volumes for the evaluation period (March 2022 to February 2023) and the maximum measured volume over the period 2014 to 2023 is presented in Table 6 and Figure 4. Also indicated in the table is the dataset used during the previous water balance update (iLEH, 2022).

The information show that to date, very little surface water is abstracted from the Leeuwspruit. The maximum volume abstracted since measurements commenced in 2014 is 25 375 m^3/a, which is 13% of the allocated volume. Over the last two years 5 and 6 m^3/a was abstracted from the river.

In comparison, the maximum volume of groundwater abstracted since 2014 is 54 650m^3/a, which is 24% of the allocated groundwater abstraction volume. During the evaluation period 49 433 m^3/a of groundwater was abstracted, which is slightly more compared to the previous evaluation period.

Measurement of the volume of water pumped from the Main Storage Tank to the MRP and water pumped from Dam 3 to Dam 1 started in 2019. The largest volumes of water are transferred between Dam, the Main Storage Tank and the MRP.

Table 6 AMW 2014 to 2023 Water Usage (m^3/a)

Component	Total annual measured use (m^3/a)		Maximum 2014 to 2023	WUL Limit
	Jul 2020 to Jun 2021	Mar 22 to Feb 23	(m^3/a)	(m^3/a)
Groundwater abstraction	35 647	49 433	54 650	225 000
River Dam to River Tank	0	0	25 374	
Sewage plant	9 241	17 248	22 756	20 805
Dam 1 to Main Storage Tank	97 525	98 574	141 735*	
Surface water abstraction	5	6	15	195 000
Main Storage Tank to MRP	81 989	88 096	100 125*	
Dam 3 to Dam 1	2 345	21 556	30 617	
Dam 1 release	0	90 000	90 000	

* These volumes are considered high, as this water use is likely to reduce significantly in future.

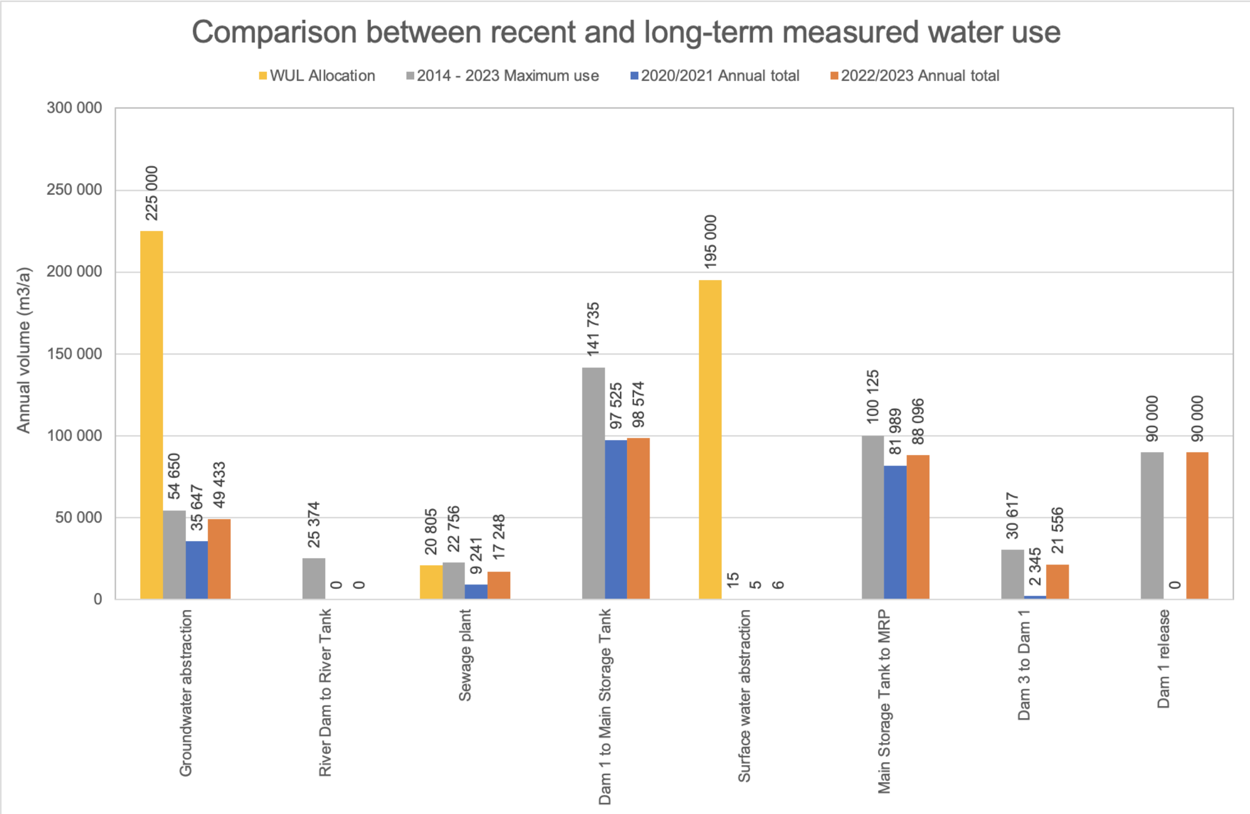

Figure 4 Comparison between recent and long-term measured water use

As discussed earlier, the maximum measured volumes for each component listed in Table 5 will be used to complete the water and salt balance calculations for the project. Figure 4 demonstrates that historically more surface water was used from the PCDs compared to groundwater abstraction. The surface water used constitutes runoff captured and process water used in a closed loop at the Works. Comparatively little surface water is abstracted from the Leeuspruit (indicated as River Dam to River Tank) for use at the operations.

The use over the last two years are consistently less than the maximum historic use.

In order to take a conservative approach to the volume of WUL allocated water available for use in the $MnSO_4$ Recovery Project, the maximum historic volumes will be used. This is also in line with the assumption that with the project production at the AMW will be ramped up. This is expected to increase the operational water demand in addition to the demand for the furnace conversion project. The increased demand is assumed to be in line with the maximum historic use.

It is important that this assumption is tested and the water and salt balance presented in this report is updated as necessary.

5.3 Process and water circuit units

The process units for the water and salt balances were updated to reflect the current status at the AMW and are presented in Figure 5. The inflow and outflow from each process unit are presented in the diagram. The locations of these water balance components are indicated on Figure 1. It is assumed that water for the $MnSO_4$ Recovery Project would be sourced preferentially in the following hierarchy:

RO Plant Product (sourced largely from river water abstraction) ⟶ Groundwater

Clean water flow is indicated in **blue** and dirty water flow in **red** in Figure 5. Dashed lines indicate components that are not currently operational. These are either on care and maintenance or are in the process of implementation.

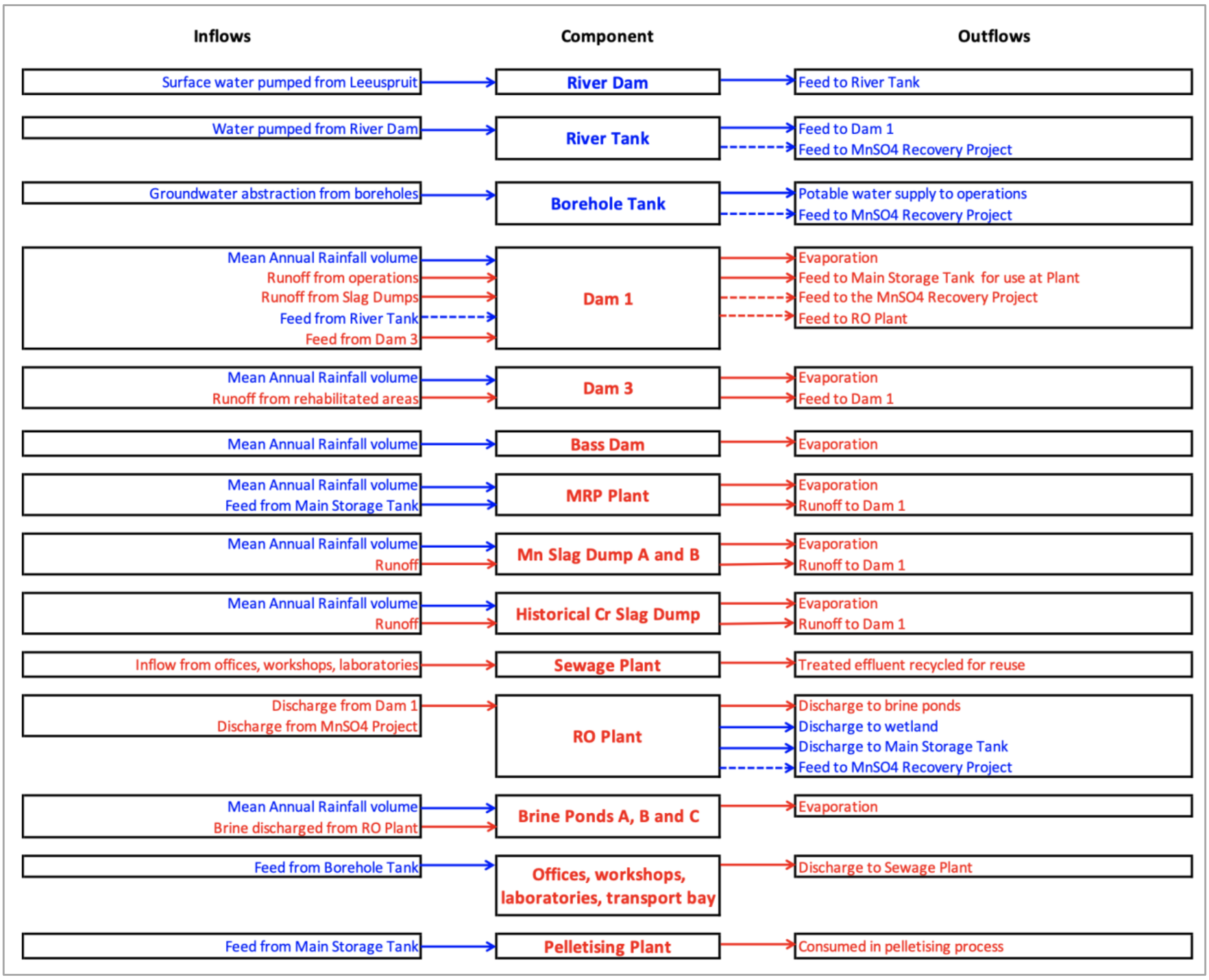

Figure 5 Conceptual water balance process units

The project components for the $MnSO_4$ Recovery Project are indicated conceptually in Figure 6. The project components will however be grouped together and will be presented as a single block in the water balance flow diagram.

Water supplied from existing AMW WUL allocated resources is indicated as a blue arrow.

The project will entail recycling a large component of the water demand, which are indicated with green arrows.

Water that will be discharged from or lost to the project is indicated with orange arrows. This includes vapour loss, discharge to the RO plant, moisture lost in by-products as well as product manufacturing and water consumed in gas scrubbers.

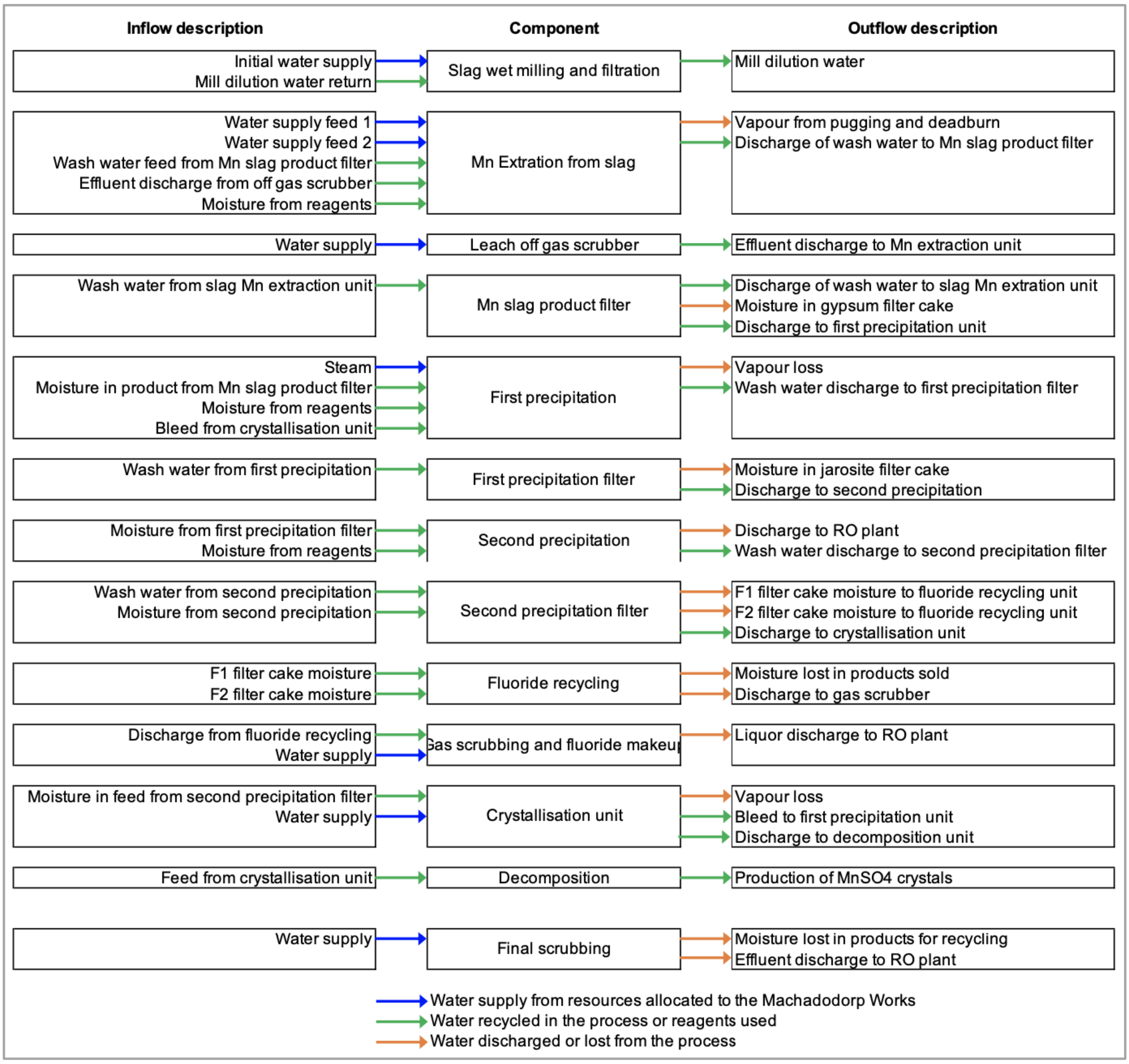

Figure 6 Conceptual water balance for the $MnSO_4$ Recovery Project

6 WATER AND SALT BALANCE CALCULATIONS

The water balance diagram for the operations is presented in Figure 7 as annual volumes. The water balance is based on the discussion above, represents measured and calculated use for the evaluation period (March 2022 to February 2023) and considers water demand and discharge from the $MnSO_4$ Recovery Project.

Input to the water balance, as summarised from the information in this report, is provided in Appendix 1. The water balance calculations are interactive and linked to a master data input sheet. The balance is therefore automatically updated with the new information. The output from the water balance can be viewed with the aid of graphs and tables and data transfer is easily achieved. This allows the water balance to be used as a functional water management tool at the operations. The information presented in the water balance diagram in Figure 7 was calculated as follows:

- The water balance is based on measured use for the period March 2022 to February 2023.
- The water balance incorporates the water demand for the MnSO4 project, as detailed in Table
- Clean water circuits are indicated in blue and dirty water circuits in red.
- The water supply hierarchy for the $MnSO_4$ Recovery Project is incorporated in the water balance. Dirty water will be sourced preferentially from Dam 1 and clean water from the RO Plant permeate.
- Some of the flow circuit components were calculated based on the available dataset and assumptions made. These include:
  - Typical wet runoff for Dams 1 and 3 and Bass Dam, as detailed in Table 3.
  - The incorporation of the RO Plant is based on information presented in E-Science (2015), which is summarised in Table 7. This plant is currently under construction and not yet operational.

Table 7 RO Plant water split (E-Science, 2015)

Component	Volume (m^3/a)
Total permeate (m^3/a)	175 200
Total brine (m^3/a)	8 256
Total inflow (m^3/a)	183 456
Discharge to wetland (m^3/a)	54 581

- The water balance makes provision for direct rainfall, runoff and evaporation from open dams.
- The runoff calculations presented in Hydrospatial (2021) were incorporated in the calculations. As discussed above, the typical wet runoff to Dams 1 and 3 were considered in order to take a conservative approach to the calculations.

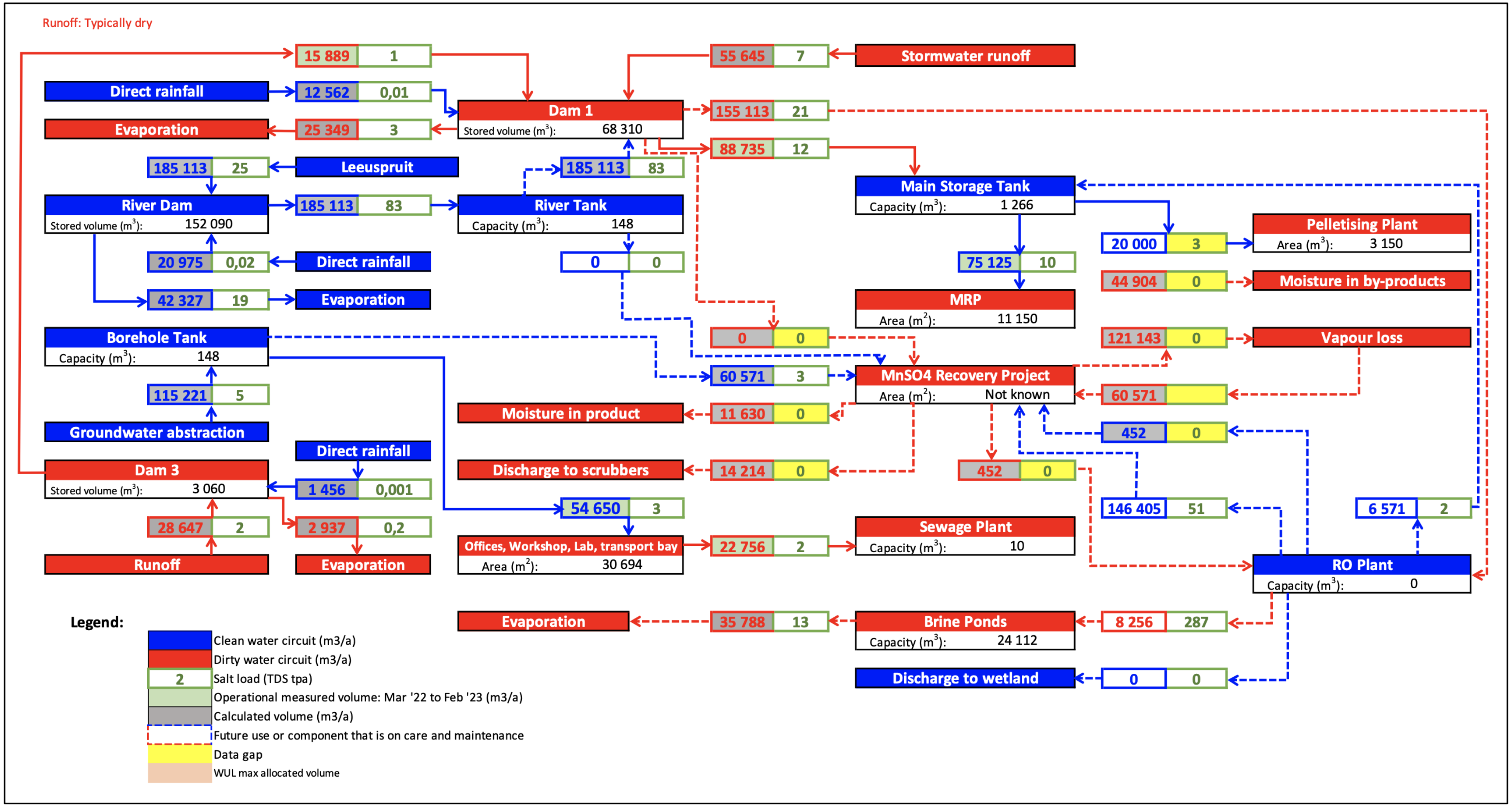

Figure 7 Annual water and salt balance process flow diagram (Unit: m^3/a and tpa)

6.1 Water Balance Interpretation

Summaries of the inflow and outflow volumes from each component evaluated as part of the water balance is presented in Table 8 and Figure 8. The information presented evaluates maximum groundwater use since 2014 and includes the future demand associated with the $MnSO_4$ Recovery Project. In addition, the typical dry weather runoff is considered in the water balance, as it is reported to prevail 70% of the time. This approach was taken to ensure that a conservative approach to future water demand is taken in anticipation of increased water demand with the ramp up of the project.

The Borehole and River Tanks are used to transfer groundwater and surface water to the operations. Inflow into and outflow from these components are therefore assumed to be zero as the water pumped to these tanks are transferred elsewhere for use. The River Dam calculations consider the existing volume of water that is currently stored in this dam. For the purpose of the calculations, it is assumed that 80% of the water stored in the dams could be abstracted and that 20% of the water must remain for practical purposes. Dams that yield a positive water balance due to the storage of water assumed during the assessment include the Main Storage Tank and Dam 3. It is however assumed that water could be taken from storage in the River Dam to reduce the volume of water that needs to be abstracted from the Leeuspruit in order to meet the demand for the $MnSO_4$ Recovery Project, resulting in a negative water balance for this dam for this assessment. This requirement will change with higher rainfall and runoff conditions. The use of typical dry weather runoff used in the calculations is conservative.

A negative water balance is also achieved for the Brine Ponds at the RO plant as it is designed for this purpose.

Provision is made to abstract river water directly for use at the $MnSO_4$ Recovery Project from the River Tank. For the purpose of this update, it was however assumed that the water in Dam 1 would be used preferentially, although it has to be augmented from river water, as indicated.

The information presented in Table 8 indicates that the water demand for the MnSO4 Project can be met with the current WUL allocated water resources, as discussed in more detail below.

6.2 Salt Balance Interpretation

The outcome of the update of the operational salt balance for the operations is summarised in Table 9 and Figure 9. This table compares inflows and outflows for each component evaluated.

The MnSO4 Recovery Project cannot be included in the salt balance calculations, as there is no information on the quality of leachate and other water flowing from the process available. It is noted that the process will not discharge any water.

The difference between inflow and outflow (the balance) is evaluated in terms of compliance with a 8% discrepancy, as prescribed in DWAF (1996) and incorporated in the AMW water and salt balance philosophy.

Table 8 Summarised water balance: Dams, tanks and sewage plant

Inflow (m^3/a)	Component	Outflow (m^3/a)	Balance (m^3/a)	Discrepancy (%)
115 221	Borehole Tank	115 221	0	0%
236 088	River Dam *	227 440	8 648	4%
185 113	River Tank	185 113	0	0%
95 306	Main Storage Tank	95 125	181	0,2%
269 208	Dam 1*	269 197	12	0,004%
30 103	Dam 3*	18 826	11 276	37%
155 565	RO Plant	161 231	-5 666	-4%
8 256	Brine Ponds A B and C	35 788	-27 533	-334%
268 000	MnSO4 Project	192 342	75 658	28%
1 094 859	**TOTAL**	**1 107 941**	**14 450**	1%

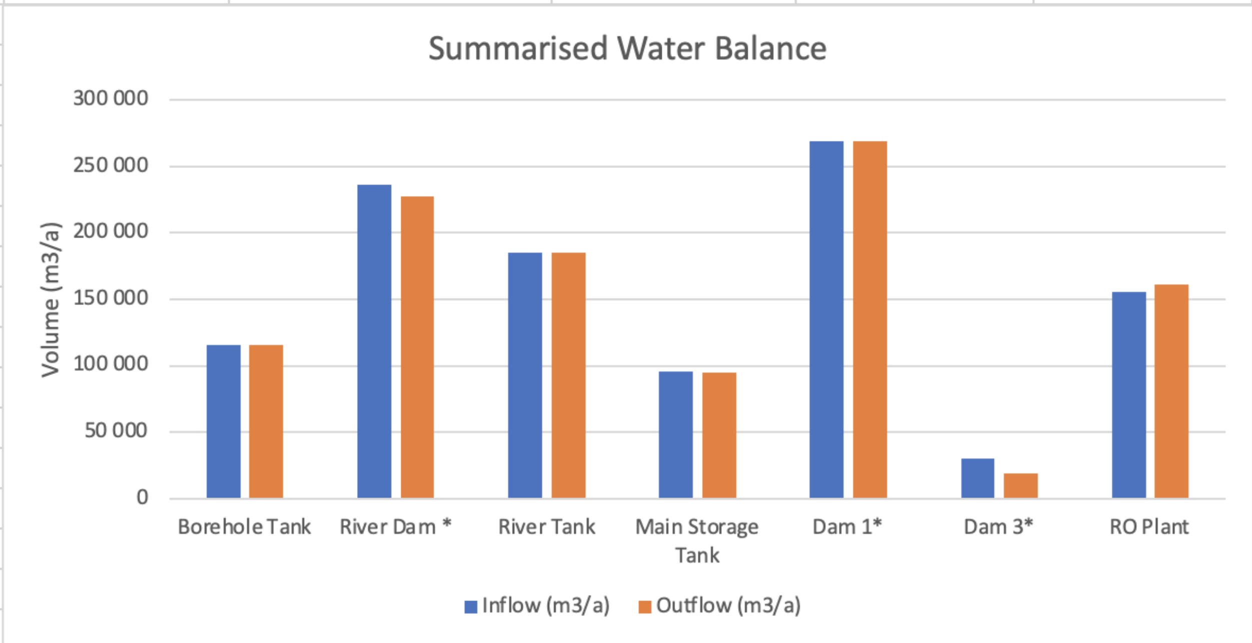

Figure 8 Summarised water balance for dams and tanks

Table 9 Provisional salt balance

Inflow (tpa TDS)	Component	Outflow (tpa TDS)	Balance (tpa TDS)	Discrepancy (%)
5	Borehole Tank	5	0	0%
25	River Dam	102	-77	-308%
83	River Tank	83	0	0%
14	Main Storage Tank	13	1	10%
91	Dam 1	36	55	60%
2	Dam 3	1	1	34%
21	RO Plant	54	-33	-157%
287	Brine Ponds A B and C	13	275	96%
528	**TOTAL**	**306**	**-53**	-10%

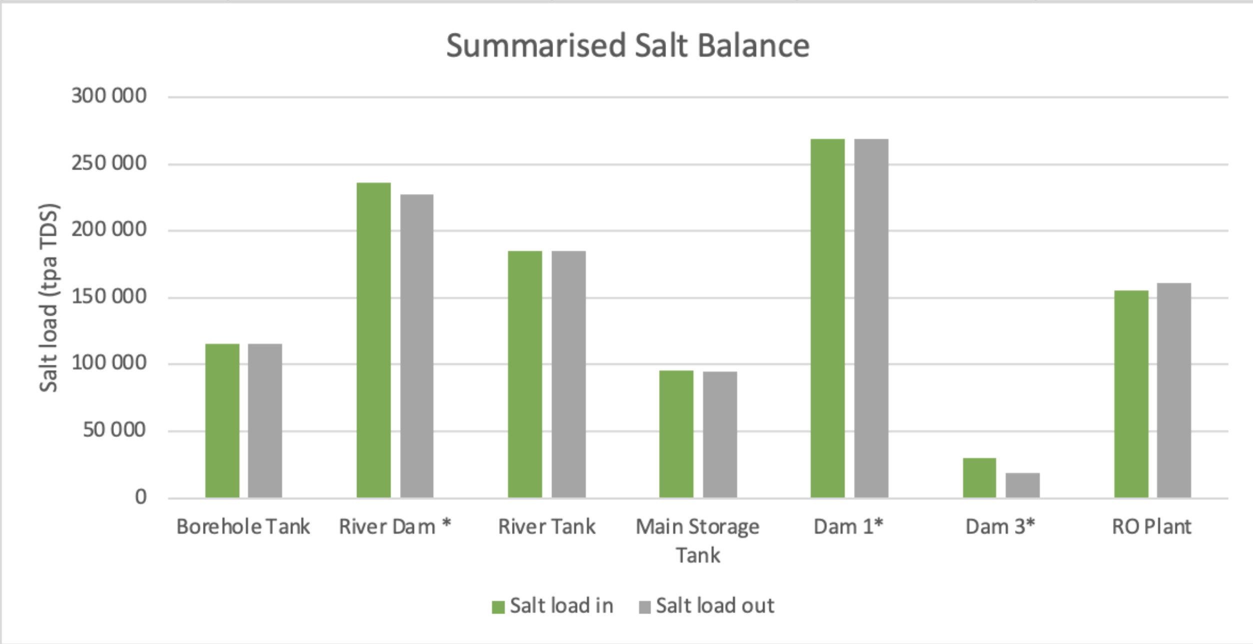

Figure 9 Summarised salt balance for dams and tanks

6.3 Water balance for the $MnSO_4$ Recovery Project

A simplified process flow diagram for the $MnSO_4$ Recovery Project is presented in Figure 10. The total water demand for the project is 268 000m^3/a. This demand will be met through the existing allocated AMW water resources (surface water and groundwater) and return of vapour condensate from the process The surface water will be treated at the RO Plant and will be fed from the River Dam via Dam 1. Several discharges will take place from the project, including vapour loss and moisture entrained in product and by-products, discharge scrubbers and a small discharge to the RO plant.

There are some data gaps in the outflow components to the project. For this reason, there is a 28% discrepancy between inflow and outflow from the project (see Table 8).

Figure 10 Process flow diagram for the $MnSO_4$ Recovery Project

The water balance calculations for the $MnSO_4$ Recovery Project are based on the following:

- The estimation considers the maximum historical operational water use at the AMW, based on data between 2014 and 2023. The feed to the MRP via Dam 1 was however reduced as it is considered an over estimation of future use at the MRP.
- It was assumed that 50% of the vapour generated during the project can be condensated and returned to the project. ARM estimates that this percentage can be improved possibly to 90% recovery. Measures to achieve this are currently being evaluated.
- During calculations, typical dry weather runoff volumes were included. This is considered a conservative approach. A sensitivity analysis of the impact of runoff on water availability for the project is discussed below.
- The project requires potable quality water. The RO plant will therefore be used to generate

good quality water for the project. This water will be sourced mainly from river water through Dam 1. The groundwater component to be supplied to the project is of a sufficient quality and does not need to be treated in the RO Plant.

- The water available in Dam 1 to the project is sourced from the Leeuspruit via the River Dam and River Tank.
- Groundwater will be sourced via the Borehole Tank to the project.

The results of the assessment is summarised in Table 10, which is summarised from Figure 7.

If 50% of the vapour generated in the project can be condensated and returned to the project, around 23% of the water demand for the project can be met through this reuse alone. If this percentage can be increased to 90% of vapour captured, it could contribute 109 028m^3/a of water to the project. This is equivalent to 41% of the water demand for the project. In turn, this will significantly reduce the demand on surface and groundwater for the project.

Based on the outcome of the assessment, it is recommended that 55% of the water demand for the project is sourced from the Leeuspruit. This is equivalent to around 146 800m3/a of water, which is 13% of the typical dry available surface water in the stream after allocation of the ecological reserve (see Table 4). The surface water abstraction volume also represents 75% of the WUL allocated surface water resources to the AMW.

For the purpose of the assessment completed in this report, it is estimated that 23% of the demand can be met through additional groundwater abstraction. This is equivalent to 60 571m^3/a of groundwater, which is co-incidentally the same as the assumed 50% vapour recaptured. This volume of additional groundwater is equivalent to 27% of the WUL allocated volume.

It is recommended that around 29% of the water demand for the project is sourced from groundwater. This is equivalent to 59% of the WUL allocated groundwater resources to the AMW.

At present, it is likely that the discharge to the RO plant from the $MnSO_4$ Recovery Project would be available for reuse. At present, this is a very small volume. The RO design inflow volume is reported to be 183 456 (E-Science, 2015). The volume of effluent discharged from the $MnSO_4$ Recovery Project is very small based on the available dataset. There are however data gaps in this feed.

Table 10 Estimated water resource allocation for the project

Source	Estimated contribution volume (m^3/a)	% use of WUL allocation	% of demand
RO Plant permeate (surface water feed included)	146 857	75%	55%
Groundwater	60 571	27%	23%
Estimated vapour return	60 571	NA	23%
TOTAL	**268 000**		100%

6.4 Impact of runoff availability on the project water demand

As the largest percentage of water will be sourced from the Leeuspruit via Dam 1, the project's sensitivity to runoff availability was tested. In order to do so, the volume of water available from Dam 1 to feed to the $MnSO_4$ Recovery Project was assessed based on the water balance reported above. The volume of groundwater required to meet the project water demand was accordingly adjusted. Some simplifications were made to complete these calculations, but they provide a fair indication of the sensitivity of the project to runoff availability.

The results are presented in Figure 11. It is shown that under the lowest runoff conditions, the project demand will have to be met through 28% from surface water and 49% from groundwater. This constitutes 85% of the allocated groundwater resources to the project. The volume of groundwater required to augment use from surface water gradually decreases to 14% of the total demand for typical wet rainfall conditions.

Under very high rainfall conditions, the total project demand can be met through water contained in Dam 1. Under these conditions care must be however taken to prevent overflow of the dam. It is noted that in February 2023, 90000m^3 of water was released from Dam 1 due to extreme rainfall intensities in the catchment of the dam.

The sensitivity analysis confirms that the water demand for the project can be met during dry and wet periods through supplying water preferentially from Dam 1 and augmenting this water with groundwater, as required.

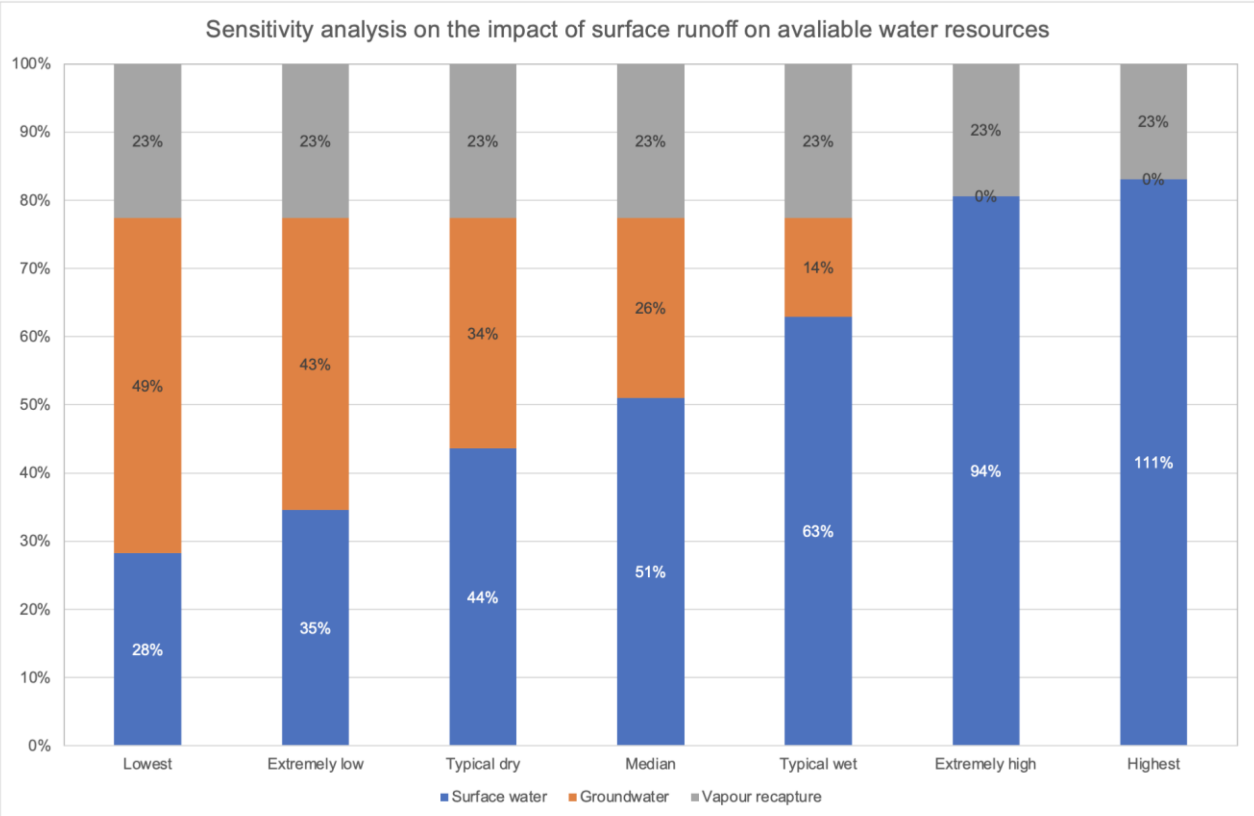

Figure 11 Runoff sensitivity analysis

6.5 Accuracy of the balances

The accuracy of the water balance presented in this report is dependent on the following aspects:

- The rainfall, evaporation and runoff calculations presented by Hydrospatial (2021). As these calculations are linked to the MAP used, inaccuracies have resulted in the current water balance update due to excessive rainfall conditions experienced. The water balance errors for Dams 1 and 3 are however considered adequate within the context of the update.
- The conceptual understanding of the water balance, specifically in terms of demand and supply and how water is transferred between the components during the care and maintenance period.
- The accuracy of flow meters installed on pipelines at the operations.
- The manner in which water will be transferred and re-used at the operations. The report presents the most likely scenario based on the 2022/23 dataset. The water use patterns may change in future. For this reason, it is important to update and improve on the water balance as information regarding water demand and consumption is confirmed through measured data.
- Water stored in dams result in imbalances.
- Evaporation from the RO brine ponds also result in an imbalance.
- Data gaps in understanding water discharge from the $MnSO_4$ Recovery project results in imbalances. These should be addressed. It is noted that no water will be discharged from the process. Many of the components are consumptive uses, like vapour loss.

6.6 Causes of imbalances and addressing the causes of imbalances

AMW has implemented flow meters on all of the main water uses assessed in this update of the water and salt balance. No significant data gaps are therefore applicable to this update.

Imbalances are mainly attributed to two causes:

- The impact of reduced water use patterns during the care and maintenance period. Water use has reduced for some water balance components, which resulted in storage of water in some dams and tanks.
- The effect of high rainfall intensity experienced during the evaluation period. This is specific of relevance to the PCDs used to contain dirty water for reuse at the operations.
- Lack of data for the $MnSO_4$ Project, specifically related to the following:
    - Volume of effluent discharge to the RO plant from scrubbers.
    - Volume of water lost to vapour during the first precipitation stage.

Imbalances are thought to change once the works are operational. At this stage, and updated water and salt balance will be completed and evaluated.

7 WATER AND SALT BALANCE MANAGEMENT PLAN

7.1 Water balance operating philosophy

The water balance operating philosophy provides the principles on which water is managed at the Works. As is discussed earlier, the works are currently on care and maintenance. It is however recommended that the water balance operating philosophy is maintained as far as possible. The following is applicable:

- All dirty water will be collected, contained, and controlled on site.
- In order to achieve this, each dirty water component is contained where possible to ensure that the recycling and re-use of dirty water is optimised.
- Open water dams are operated according to the requirements of GN704, specifically that there is enough storage capacity available at all times to accommodated storm water in such a manner that the system only spills once every 50 years.
- Dirty water containment or conveyance structures need to be lined as to prevent potential pollution via seepage. This is already implemented at the operations.
- A water conveyance infrastructure should be monitored in terms of flow, capacity, and quality throughout the life cycle of operation. Where data gaps occur, the operations should take the necessary steps to implement the necessary measurement and/or monitoring processes. The weirs built in the streams and canals at the operations should be maintained, calibrated and used to monitor water flow volumes. This information will be valuable for both the water and salt balances.
- All spills should be documented and communicated to authorities according to the requirements of the water use licenses.
- Each component of the water balance needs to be operated in such a manner that the combined inflow into the component is equal to or less than the combined outflow plus the storage of the component. This is the case for all components evaluated as part of this water balance.
- No infrastructure may be placed within the 1:50 or 1:100 year flood lines or within the 100m buffer zones of any natural watercourses.

7.2 Ongoing water and salt balance management

The following actions are recommended to manage the water balance for the project:

- Measure the volume of water that is currently in each dam on a monthly basis and record this information in the existing monthly flow meter database maintained at the operations.
- All flow meter and monitoring information used in the water and salt balances must be entered into a central spreadsheet to analyse trends and to undertake statistical analyses. This information must feed into the water and salt balances and must be included in annual updates to be undertaken in future.
- All dams, sumps and pipelines that form part of the water management system must be inspected on a daily basis to determine the available storage volume as well as to detect leaks or overflows.
- If non-compliances are identified, these should be rectified immediately.
- Flow meters should be fitted on all boreholes in use for potable groundwater supply. The volume of groundwater abstracted per day must be recorded and used to update and manage the water balance.
- Groundwater levels should be measured on a quarterly basis in the boreholes used for groundwater abstraction. This information must be used to establish whether the boreholes

are pumped at sustainable rates. If a decline in groundwater levels is observed, the pumping strategy must be adjusted or the alternative water resource, to be identified at the time, must be triggered.

- Flow meters should be installed on pipelines that deliver water to and from all water balance components in order to obtain accurate information for the water balance.
- Include TDS in the analyses of all monitoring points (surface and groundwater). This is not an expensive element to include in the monitoring programme and should therefore not result in significant cost variations.
- The quality of groundwater abstracted as well as the depth to groundwater level must be monitored on a quarterly basis in the water supply boreholes to ensure fitness of use.
- Water quality monitoring must be continued according to the Works' water use license requirements.
- In order to complete the salt balance, only TDS concentrations will be required. It is not necessary to submit water samples for comprehensive analyses for all components listed above. It may be of value to the operations to purchase a hand-held TDS measuring device. Many commercial products are available for this purpose. If a hand-held device is opted for, it is important to regularly calibrate the instrument to ensure accurate readings.
- Rainfall should be measured daily on site to obtain accurate site-specific information with which to interpret monitoring results.
- The operations should re-use dirty water to limit the intake of clean water. In this regard, the Water Conservation and Demand Management Plan (WC/DMP) must be updated and used to improve water management at the works. The water balance forms the basis of the WCDMP.
- The operations' water and salt balances must be updated on an annual basis or if the process units presented in this report changes to ensure that it reflects water management accurately and is used as part of the operations' water management toolkit. Early planning and quick adaption of the water management strategy will be key in ensuring that water is used optimally at the operations and that long-term liabilities associated with water contamination are limited.

8 CONCLUSIONS

It is concluded that the $MnSO_4$ Recovery Project water demand can be met through the existing WUL allocated water resources at the AMW. This assessment includes vapour condensate return generated during the project, which reduces the demand on surface water and groundwater resources for the project.

Under typical dry weather runoff conditions, an estimated 44% of the water demand should be met through surface water (abstraction from the Leeuspruit treated at the RO plant) and 34% through groundwater. This demand does not exceed the WUL allocated surface and groundwater resources.

A sensitivity analysis of the impact of surface runoff under different rainfall conditions indicates that even under extremely dry conditions, the project water demand can be met. Under these conditions, the demand can be met through 28% surface water and 49% groundwater resources without exceeding the WUL conditions.

Under very wet conditions, the project water demand can be met solely from Dam 1, but care must be taken to avoid overtopping of this dam under high rainfall conditions.

9 REFERENCES

DWAF, 2006. Best Practice Guideline G2 – Water and Salt Balances, dated July 2006.

DWS, 2019. Reserve Determination of Water Resources for the Inkomati Catchment, Government Gazette No 42584, dated 19 July 2019.

E-Science, 2015. Brief Water Use License Application Summary Report: Assmang, Machadodorp Works, Mpumalanga Province, Report No 2009/014472/07, dated March 2015

ESS, 2012. Assmang Chrome Machadodorp Works –Contaminated Land Assessment Project – Rehabilitation and Closure Strategy, Report No ASS.RCL. REHAB.11.06.036, dated 29 February 2012.

E-Tek, 2011. Assmang Machadodorp Summary Hydrology Report Revision 0, dated September 2011.

Hydrospatial, 2021. Hydrological study for the ARM Alloys Machadodorp Works, Project Number ILE003, dated October 2021.

iLEH, 2023. ARM Ltd Machadodorp Works – 2023 Operational Water and Salt Balance, Report No iLEH-EG MACH-WSB 01-23, dated May 2023

SAS, 2022a. Water Quality Monitoring - ARM Machadodorp Works Surface, Groundwater and Process Water Quarterly – June 2022 Compliance Monitoring Report, dated October 2022.

SAS, 2022b. Water Quality Monitoring - ARM Machadodorp Works Surface, Groundwater and Process Water Quarterly – August 2022 Compliance Monitoring Report, dated October 2022.

SAS, 2022c. Water Quality Monitoring - ARM Machadodorp Works Surface, Groundwater and Process Water Quarterly – November 2022 Compliance Monitoring Report, dated October 2022.

Senet, 2023. ARM $MnSO_4$ Pre-Feasibility, Project Number SS0894, dated February 2023

SWS, 2016. Machadodorp Smelter Water and Salt Balance Assessment, Storm Water Solutions (Pty) Ltd Reference SWS-2015-28, dated 9 February 2016.

Water Resources of South Africa, 2012 (WR2012). WRC Project No K5/21433/1.

WRC, 2012. Water Resources of South Africa, Water Research Commission Project No K5/2143/1.

APPENDIX 1 - WATER AND SALT BALANCE INPUT DATA

Groundwater abstraction	Volume (m^3/a)	Reference/Comment
WUL approved groundwater abstraction volume	225 000	WUL No 24079907, approved 15/10/2008
Borehole collection: 2022/2023 total measured volume	49 433	2022/2023 Total volume pumped to borehole tank
Borehole collection: 2020/2021 total measured volume	42 847	2020/2021 Total Borehole Tank

River water abstraction	Volume (m^3/a)	Reference/Comment
WUL approved river abstraction volume	195 000	WUL No 24079907, approved 15/10/2008
Leeuwspruit: 2022/2023 total measured volume	6	2022/2023 Average volume pumped from river
Leeuwspruit: 2020/2021 total measured volume	2	2020/2021 Total from river

Open dam areas	Area (m^2)	Reference/Comment
River Dam	31 400	Measured from Google Earth
Dam 1	18 805	SWS (2016)
Bass Dam	870	Measured from Google Earth
Dam 3	2 179	SWS (2016)
Brine Ponds A B and C	26 549	Machado operational feedback, 2019

Dam capacities	Capacity (m^3)	Reference/Comment
River Dam	227 000	Machado operational feedback, 2021
Dam 1: Current Volume	99 000	Machado operational feedback, 2021
Dam 1	99 670	Machado operational feedback, 2021
Bass Dam	1 000	Original size: 5000m^3. Silted up. Will be destroyed during construction of RO Plant
Dam 3	9 000	Machado operational feedback, 2021
Sewage Plant	10	Measurement of septic tank
Borehole Tank	148	Machado operational feedback, 2020
River Tank	148	
RO Plant		
Brine Ponds A, B and C	24 112	
Main Storage Tank	1 266	

Volume in storage in dams	Average dam level	Estimated volume in dam
River Dam	0,67	152 090
Dam 1	0,69	68 310
Dam 3	0,34	3 060

Hydrology	Values	Reference/Comment
Rainfall (mm/a)	668	Machado average MAP (October 2003 - October 2021)
Mean Annual Rainfall (m/a)	0,668	As above
Mean Annual S-pan Evaporation (mm/a)	1 348	Hydrospatial (2021) see adjacent calculation
Mean Annual S-pan Evaporation (m/a)	1,348	As above
Mean Annual Lake Evaporation (mm/a)	1 135	Calculated
Mean Annual Lake Evaporation (m/a)	1,135	Calculated
Average dirty water area runoff (m/a)	9,51E-04	SWS (2016)
Average clean water area runoff (m^3/a)	256	SWS (2016)
1:50 year 24-hour peak dirty area runoff (m^3/a)	271 925	SWS (2016)
1:50 year 24-hour peak clean area runoff (m^3/a)	32 850	SWS (2016)

S-pan evaporation conversion

Month	S-Pan Evaporation (mm/month)	Lake Evapporation Factor	Equivalent Lake Evaporation (mm/month)
	Hydrospatial (2021	Source: WRC, 2012	Calculation
January	152	0,84	128
February	130	0,88	114
March	128	0,88	113
April	97	0,88	85
May	85	0,87	74
June	70	0,85	60
July	75	0,83	62
August	95	0,81	77
September	115	0,81	93
October	128	0,81	104
November	128	0,82	105
December	145	0,83	120
TOTAL/AVERAGE	**1 348**	**0,84**	**1 135**

Project component areas	Area (m^2)	Reference/Comment
MPR Plant	11 150	Measured from Google Earth Image
Historical Cr Slag Dump	201 700	
Mn Slag Dump A and B	85 600	
Material Stockpile Area	281 000	
Bag House Dust Area (Rehabilitated)	40 100	
Historical Low Carbon Slag Dump (Rehabilitated)	27 900	
Sewage Plant	1 800	
Transport Bay	10 300	
Training office	1 100	
SHEQ office	2 600	
Stores	4 600	
Laboratory	3 200	
Engineering offices	3 000	
Technical services offices	5 894	
Furnaces	56 500	
Final Product Area	31 100	
Topsoil Stockpile	16 400	
Pelletising Plant	3 150	
RO Water Treatment Plant	21 300	

Total water demand for MnSO4 Recovery Project (m³/a)				Reference/Comment
From	Volume (m³/a)	2022/2023 Average TDS Concentration (kg/m³)	To	
AMW allocated water resources	71 781		Initial supply to slag wet milling and filtration	ARM Spreadsheet Environmental BFD, reagents and high level water balance.xlsx Converted to m3/a by assuming 74% use
	32 305		Water supply feed 1 ton Mn Extraction unit	
	51 688		Water supply feed 2 ton Mn Extraction unit	
	32 305		Water supply to leach off gas scrubber	
	10 919		Steam to first precipitation unit	
	32 305		Water usply to gas scrubbing and fluoride makeup	
	0		Water supply to chrystallisation unit?	
	36 698		Water supply to final scrubbing	
TOTAL WATER DEMAND (m³/a)	268 000			
Total outflow for MnSO4 Recovery Project (m³/a)				**Reference/Comment**
From	Volume (m³/a)	2022/2023 Average TDS Concentration (kg/m³)	To	
Mn Extraction from slag unit	32 305		Vapour loss	ARM Spreadsheet Environmental BFD, reagents and high level water balance.xlsx Converted to m3/a by assuming 74% use
Mn slag product filter	23 493		Moisture loss in by-product (gypsum filter cake)	
First precipitation stage	0		Vapour loss	
First precipitation filter	7 645		Moisture loss in by-product (jarosite filter cake)	
Second precipitation	452		Discharge to RO plant	
Second precipitation filter	0		Moisture loss in by-product (F1 filter cake)	
Second precipitation filter	0		Moisture loss in by-product (F2 filter cake)	
Fluoride recycling	11 630		Moisture in product	
Fluoride recycling	14 214		Discharge to gas scrubber	
Gas scrubbing and fluoride makeup	0		Discharge to RO plant	
Crystallisation unit	88 838		Vapour loss	
Final scrubbing	20 675		Moisture loss in products for recycling	
Final scrubbing	0		Effluent discharge to RO plant?	
TOTAL OPUTFLOW (m³/a)	199 252			

Component				mg/l	kg/m3	mg/l	kg/m3
	01-May-22	01-Aug-22	04-Nov-22	2022/2023 Average		2020/2021 Average	
Dam 1	119	142	143	134	0,134	517	0,517
Dam 3	56	82	21	53	0,053	262	0,262
River Dam						446	0,446
Sewage Plan	92	92	96	93	0,093	425	0,425
Spring	572	594	556	574	0,574	721	0,721
LSDS	136	108	166	137	0,137	162	0,162
LSUS	126	130	142	133	0,133	131	0,131
Bass Dam	384	442	428	418	0,418	384	0,384
Tributary	106	98	122	109	0,109	100	0,100
Stoltz BH	74	46	46	55	0,055	39	0,039
DWAF BH	39	30	44	38	0,038	42	0,042
Seepage abc	203	227	188	206	0,206		
			Average GW	47	0,047	40	0,040
			Average SW	135	0,135	146	0,146
			Rainfall	1	0,001	1	0,001

March 22 to February 23 total annual measured water use (m^3/a)

From	Volume (m^3/a)	2022 Average TDS Concentration (kg/m^3)	To	Reference/Comment
Leeuwspruit	6	0,135	River Dam	Measured volume for Leeuwspruit to River Dam
River Dam	0	0,135	River Tank	Measured volume for River Dam to River Tank
River Tank	0	0,135	Main Storage Tank	All water transferred to Main Storage Tank
Dam 1	98 574	0,134	Main Storage Tank	Measured feed from Dam 1 to the Main Storage Tank
Dam 1		0,134	River Tank	No data, backup option
Dam 1	90 000	0,134	Release to Leeuwspruit	Measured volume release from Dam 1
Inflow	183 456	0,135	RO Plant	E-Science (2015)
Dam 1	55 037	0,134	RO Plant	Assumption: One third of total RO inflow
Main Storage Tank	88 096	0,134	MRP	Measured volume Main Storage Tank to MRP
Discharge from MRP			Dam 1	
Surface runoff	71 549	0,134	Dam 1	Median runoff (Hydrospatial, 2021)
Discharge from Dam 3	21 556	0,053	Dam 1	Measured discharge from Dam 3 to Dam 1
Surface runoff	20 868	0,053	Dam 3	Median runoff (Hydrospatial, 2021)
Surface runoff	17 873	0,418	Bass Dam	Median runoff (Hydrospatial, 2021)
Borehole tank	49 433	0,047	Use at offices, workshop and laboratory	Measured volume: Borehole Collection
Sewage discharge from offices, workshop and laboratory	17 248	0,093	Sewage Plant	Measured volume of treated sewage effluent
Sewage Plant	17 248	0,093	Furnace	Measured volume of treated sewage effluent
RO Plant	55 037	0,350	Main Storage Tank	E-Science (2015)
RO Plant	54 581	0,350	Discharge to wetland	E-Science (2015)
RO Plant	8 256	34,790	Brine Ponds	E-Science (2015): 1,89m^3/hr (assume: 12 hrs/d, 40 hrs/week)

Maximum annual measured water use between 2014 and 2023 (m^3/a)

From	Volume (m^3/a)	2020/2021 Average TDS Concentration (kg/m^3)	To	Reference/Comment
Leeuwspruit	15	0,135	River Dam	Measured volume for Leeuwspruit to River Dam
River Dam	25 374	0,135	River Tank	Measured volume for River Dam to River Tank
River Tank	25 374	0,135	Main Storage Tank	All water transferred to Main Storage Tank
Dam 1	141 735	0,134	Main Storage Tank	Measured feed from Dam 1 to the Main Storage Tank
Dam 1		0,134	River Tank	No data, backup option
Dam 1	90 000	0,134	Release to Leeuwspruit	Measured volume release from Dam 1
Dam 1	0	0,134	RO Plant	Planned future use
Dam 1	63 289	0,134	RO Plant	Assumption/calculation: Assumed to be equivalent to discharges
Main Storage Tank	100 125	0,134	MRP	Measured volume Main Storage Tank to MRP
Main Storage Tank	20 000	0,134	Pellitising Plant	Planned future use (iLEH, 2021)
Discharge from MRP			Dam 1	
Surface runoff	97 317	0,134	Dam 1	Typical wet runoff (Hydrospatial, 2021)
Discharge from Dam 3	30 617	0,053	Dam 1	Measured discharge from Dam 3 to Dam 1
Surface runoff	28 647	0,053	Dam 3	Typical wet runoff (Hydrospatial, 2021)
Surface runoff	25 160	0,418	Bass Dam	Typical wet runoff (Hydrospatial, 2021)
Borehole tank	54 650	0,047	Use at offices, workshop and laboratory	Measured volume: Borehole Collection
Sewage discharge from offices, workshop and laboratory	22 756	0,093	Sewage Plant	Measured volume of treated sewage effluent
Sewage Plant	22 756	0,093	Furnace	Measured volume of treated sewage effluent
RO Plant	0	0,350	Main Storage Tank	Planned future use
RO Plant	6 571	0,350	Main Storage Tank	Volume calculated for IWWMP
RO Plant	0	0,350	Discharge to wetland	Planned future use
RO Plant	54 581	0,350	Discharge to wetland	E-Science (2015)
RO Plant	8 256	0,350	Brine Ponds	E-Science (2015): 1,89m^3/hr (assume: 12 hrs/d, 40 hrs/week)
RO Plant	0	34,790	Brine Ponds	Planned future use