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GAMSBERG PHASE 2: DESIGN AND ENGINEERING FOR THE TAILINGS STORAGE FACILITY (TSF)

DESIGN CRITERIA FOR TAILINGS AND RETURN PUMP SYSTEMS

Rev	Description	Date
A	Issued in Draft	2 May 2024~~2 April 2024~~

Knight Piésold CONSULTING LEEBA Electrical Project Engineers

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ACRONYMS, ABBREVIATIONS AND UNITS

Below is a list of acronyms and abbreviations:

Acronym / Abbreviation	Definition
CAPEX	Capital expenditure
CCD	Counter current decantation
DTM	Digital terrain model
EPCM	Engineering, procurement and construction management
EPC	Engineering, procurement and construction
ESIA	Environmental and social impact assessment
GA	General arrangement (drawing)
GPS	Global positioning system
HDPE	High-density polyethylene
HGL	Hydraulic grade line
ISO	International standards organisation
LIDAR	Light detection and ranging
LoM	Life of Mine
MAE	Mean annual evaporation
MAOP	Maximum allowable operating pressure
MAP	Mean annual precipitation
MCC	Motor control centre
NPV	Net present value
OPEX	Operational expenditure
PFD	Process flow diagram
PFS	Pre-feasibility study
PS	Pump station
PSD	Particle size distribution
P&ID	Piping and instrumentation diagram
PLC	Programmable logic controller
QA	Quality assurance
QC	Quality control
RFP	Request for proposal
RoR	Rate of Rise
RWD	Return Water Dam
SCADA	Supervisory control and data acquisition
SOQ	Schedule of quantities
TBC	To be confirmed/continued
TSF	Tailings storage facility
VSD	Variable speed drive

Below is a list of nomenclature:

Symbol	Definition	Unit
A	Cross sectional area	m^2
C_{bfree}	Freely settled solids packing volumetric concentration	%
C_{bmax}	Maximum solids packing volumetric concentration	%
C_v	Volumetric solids concentration	% or %v
C_w	Mass solids concentration	% or %m
d	Particle size	µm
d_{50}	Particle size at which 50% of the particles by mass are smaller than d_{50}	µm
D	Internal pipe diameter	m
Ø or OD	Outside diameter of pipe	m
f	Friction factor	
g	Acceleration due to gravity	m/s^2
k	Hydraulic pipe roughness	µm
K	Fluid consistency index	$Pa.s^n$
K_B	Bingham viscosity	Pa.s
L	Length	m
M	Mass flow rate	kg/s
n	Flow behaviour index	
P	Pressure	Pa
Q	Volumetric flow rate	m^3/s
Re	Reynolds number	
S	Relative density	
T	Temperature	°C
V_{dep}	Stationary deposition velocity	m/s
V_m	Mean mixture velocity	m/s
γ	Shear rate	s^{-1}
Γ	Pseudo or bulk shear rate (8V/D)	s^{-1}
ρ	Density	kg/m^3
τ_o	Pipe wall shear stress	Pa
τ_y	Mixture yield stress	Pa
μ_s	Coefficient of sliding friction between solid particle and pipe wall	
μ	Viscosity	Pa.s
μ_w	Viscosity of conveying fluid	Pa.s

Below is a list of subscripts:

Symbol	Definition
b	bed
BP	Bingham plastic
m	mixture (slurry), mass
N	Newtonian
NN	non-Newtonian
s	solids
y	yield
v	volumetric
w	conveying fluid

Below is a list of units:

Unit	Definition
µm	Micron; micro metre
hr	Hour
km	Kilometre (1000 meters)
kPa	Kilopascal
kVA	Kilovolt-amperes
kWh	Kilowatt-hour
ℓ	Litre
ℓ/s	Litres per second
m	Metre
m/s	Metres per seconds
m^2	Square metre
m^3	Cubic metre
m^3/h	Cubic metres/hour
m^3/s	Cubic metres per second
mamsl	Metres above mean sea level
mald	Metre above local datum
Mℓ	Mega litres (million litres)
Mℓ /day	Mega litres per day
mm	Millimetre
Mt	Mega tonnes
Mtpa	Mega tonnes per annum
MW	Megawatt
No.	Number
%m	Solids percentage by mass
%v	Solids percentage by volume
°C	Degrees Celsius
Pa	Pascal
pH	Hydrogen ion exponent, a measure of acidity/alkalinity
rpm	Revolutions per minute
s	Second
t	Tonne (metric)
t/m^3	Tonnes per cubic metre
tpm	Tonnes per months
tph	Tonnes per hour
tpa	Tonnes per annum
V	Volt

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Vedanta Resources Plc is a globally diversified natural resources group with wide ranging interests in aluminum, copper, zinc, lead, silver, iron ore, oil and gas and power. Its operations in Southern Africa, Vedanta Zinc International (VZI), include Black Mountain Mining (SA) and Skorpion Zinc (Namibia). Black Mountain Mining (Pty.) Ltd. (BMM) comprises of The Black Mountain Mine (Deeps and Swartberg Operations) and the Gamsberg Project. Both zinc-lead mines are located near Pofadder in the Northern Cape Province, along the N14 National highway linking Upington to Springbok.

The Gamsberg Project is one of VZI's flagship projects in the journey of realizing their vision to produce 500 Ktpa of finished zinc metal from Gamsberg. It will exploit one of the largest, known, undeveloped zinc ore bodies in the world. The first step was Phase 1 (4 Mtpa Mines & Concentrator) which has been commissioned in September 2018 and is currently in Operation. Phase 1 is currently producing ~ 250 ktpa Zn Metal in Concentrate (MIC).

The current operational zinc Tailings Storage Facility (TSF) for Phase 1 is located approximately 2.5 km to the northwest of the plant site. KP was responsible for the Detailed Design and Construction Quality Supervision of the TSF Phase 1. KP was however not appointed as the Engineer of Record (EoR) for the TSF for the operational phase. KP compiled an updated water balance for the TSF Phase 1 (with available information), which identified the following issues:

- Slurry feed densities were lower than the original design.
- The volume of return water to the plant was lower than design. This was caused by scaling in all the pipelines.
- The decant rate was lower due to scaling in the pipes.

The current Phase 1 TSF will reach its end of life in (2030) and requires a new TSF to be constructed for Phase 2. Knight Piésold (Pty) Ltd (KP) have now been appointed for the Design and Engineering of the TSF for Phase 2 of the project to increase the ore beneficiation capacity with an additional 4 Mtpa. The outcomes from the water balance resulted in several lessons learnt which are to be incorporated into the design for the TSF Phase 2, including:

- Siltation and sedimentation occurring in the return water pipelines and return water dam due to malfunctioning of the silt trap. The silt trap is not functional due to scaling, which caused the valves and sluice gates to become inoperable
- Scaling and choking of the return water pipeline

This document outlines the design criteria to be used for the detailed design tasks of the following systems:

- Proposed Tailings slurry ringfeed pipeline system for the Phase 2 TSF
- Proposed Return decant pump station and pipeline system from the Phase 2 TSF pool to the Phase 2 Return Water Dam (RWD) Silt trap.
- Proposed Return Water Dam (RWD) pump station and pipeline system from the Phase 2 RWD to the tie-in point just outside the RWD.

1.2 REFERENCE DOCUMENTS

Table 1.1 Reference documents

Document title / Description	Document Number
GAMSBERG MINE ZINC TAILINGS RHEOLOGY TESTS Test Work Report (Vietti Slurrytec Report Number: KNP-GAM-6008 R01 Rev 1) 01 December 2022	VST-1
MOUNTAIN MINING (PTY) LIMITED AGGENEYS, RSA, 4 MTPA ZINC MINERAL PROCESSING PLANT AND RELATED INFRASTRUCTURE FOR GAMSBERG PHASE-II MINE EXPANSION PROJECT SCHEDULE-2 TECHNICAL SPECIFICATION FOR DESIGN OF TAILINGS STORAGE FACILITY Contract No. ZI-GAM02-U0400-CTR-CP-0003, Rev.-R0 (July 2022)	BMM-1
GAMSBERG TSF FOR PHASE 1- DETAIL DESIGN AND CONSTRUCTION OPERATIONS, OPERATIONS, MAINTENANCE AND SURVEILLANCE MANUAL, KP Report Number: RI301-00541/03/940/R3, BMM Report Number: ZI-GAM01-U5000-MAN-CL-0940 Rev 3 (December 2018)	KP-1

1.3 SUMMARY DESCRIPTIONS OF THE TAILINGS AND RETURN DECANT PIPELINE SYSTEMS

The following drawings and figures are included at the end of this section showing the layouts of the proposed Tailings slurry ringfeed pipeline system and Return pipeline systems (within KP's scope of work):

- Schematic diagram of Tailings ringfeed system layout (Figure 1.1~~Figure 1.1~~)
- Schematic diagram of Return pipeline systems layout (Figure 1.2~~Figure 1.2~~)
- General Site piping arrangement of proposed Tailings and Return decant pipeline systems (Figure 1.3~~Figure 1.3~~)
- General TSF piping arrangement of proposed Tailings and Return decant pipeline systems (Figure 1.4~~Figure 1.4~~)

All pipe sizes referred within this document and drawings and schematics included are preliminary and would need to be confirmed during finalisation of the design.

A summary description of the proposed Tailings and Return pipeline systems is outlined below.

1.3.1 PROPOSED TAILINGS SLURRY RINGFEED PIPELINE SYSTEM FOR THE PHASE 2 TSF

The tailings pump system consists of a duty and standby pump train, each pump train with its own transfer pipeline extending to the new Phase 2 TSF, and each of the pipelines (one duty and one standby pipeline) consisting of DN300 Std. Schedule steel piping (with 10mm HDPE lining) installed above ground on pipe supports. One of the transfer pipelines extend to the western side of the TSF and the other extend to the eastern side of the TSF, as shown within Figure 1.3~~Figure 1.3~~ and Figure 1.4~~Figure 1.4~~. A crossover valve station (by Onshore Engineering) will be installed just prior to reaching the TSF, to allow the TSF operators to change over the flow between the western and eastern ringfeed pipeline branch systems, where needed. Each ringfeed pipeline branch system consists of the following components:

- **External ringfeed pipeline** (by Onshore Engineering) consisting of DN300 Std. Schedule Steel piping (with 10mm HDPE lining) installed above ground on pipe supports, routed along the largest part of the external perimeter of the TSF, just outside of the solution trench outlining the TSF.
- **Deposition valve stations** (by KP), installed at 407m intervals along the External ringfeed pipeline, to allow
  - tailings to be diverted through offtake riser pipework (DN355 PE100 PN16) leading to a deposition bank along the Internal ringfeed pipeline of the TSF.
  - more operational flexibility and redundancy in the system, when certain internal ringfeed piping need moving, lifting, replacement, unblocking or unscaling.

  Each deposition valve station consists of a DN300 x DN300 steel offtake tee, fitted with DN 300 isolation valves on the downstream longitudinal and transverse legs of the tee as well as relevant DN 300 steel specials and offtake riser pipework (on the transverse side of the tee) that connect into the internal ringfeed pipeline.
- **Internal ringfeed pipeline (with spigot offtakes every 37 m)** consisting of a repeating sequence of pipes consisting of 3 no. of 12-meter long DN355 PE100 PN16 HPDE pipe lengths followed by a DN355 PE100 PN16 HPDE Tee. Each of the spigot offtakes is fitted with a cyclone station installation.
- **Cyclone station installation** consisting of a DN300 to DN125 reducer, DN100 valve, cyclone feed pipe (Approx. 12m length of DN125 PE100 PN10.), Cyclone (CAVEX 250CVX10 or similar), cyclone overflow pipe (DN125 PE100 PN10?)

1.3.2 PROPOSED RETURN WATER DECANT SYSTEM

Return water will be decanted from the pool of the New Phase 2 TSF and transferred to the silt trap for of the New Phase 2 Return Water Dam (RWD), using a **RELOCATABLE LAND-BASED PUMP SYSTEM CONNECTED TO A FLOATING SHALLOW WATER INTAKE DEVICE**.

The decanting system will consist of the following key components:

- A **shallow-water intake device** which will float on the surface of the TSF pool.
- **Suction pipeline and pipe fittings** connecting the shallow-water intake device with the pump unit.
- **Pump Unit:** Dry self-priming pump with an electrical motor mounted on a skid (one duty and one standby pump unit)
- **Delivery pipeline and connecting pipe fittings**, transferring return water to the RWD.

The above key components are elaborated on below:

1.3.2.1 SHALLOW-WATER INTAKE DEVICE

The water will be abstracted from just under the surface of the TSF pool, by the shallow-water intake device. The device is manufactured from ultraviolet resistant polyethylene (or similar material), floatable and capable of drawing the water level down to a depth of 400 mm or less (measured in the vicinity of the water abstraction point) at flows of up to 800 m^3/h. Some known brand products in the industry include: the “Turret” supplied by RBH Mechanical Services in Australia as from 2015, as well as the “Lilly pad” system supplied by Cornell out of South Africa in recent years.

1.3.2.2 SUCTION PIPELINE AND CONNECTING PIPE FITTINGS

The suction pipeline will be made from continuously welded or flanged HDPE pipeline. Based on the site specific hydraulic and operational requirements and constraints, the length of suction pipeline will range from 12 m to 48 m (measured from the intake device to the pump suction inlet) with a maximum vertical suction lift of approximately 5 m (measured vertically from the surface of the TSF pool to the eye of the pump impeller). The density of the HDPE pipe material is comparable to that of water, i.e. 958kg/m^3 for HDPE and 998kg/m^3 for water. The HDPE pipeline (full or empty) will therefore float partially suspended in the water. For operational reasons however, flotation collars will be required to support the pipe where for example, flanged pipe connections are specified. The type of flotation system will be determined during the design phase.

1.3.2.3 PUMP UNIT

The pump unit will consist of a dry self-priming pump with an electric motor mounted on a skid in a duty-standby arrangement and will include the following features:

- An end-suction centrifugal pump with fully automatic vacuum assisted dry priming (using a mechanically driven diaphragm style vacuum pump).
- Run-dry capability (oil-lubricated mechanical seal allowing the pump to run dry for several hours without damaging the seal).

1.3.2.4 DELIVERY PIPELINE AND CONNECTING PIPE FITTINGS

The delivery pipeline will be an above-ground HDPE pipeline from the New Phase 2 Decant Pump station to the new Phase 2 RWD via a silt trap.

1.3.3 PROPOSED RETURN WATER DAM TRANSFER SYSTEM

Water will be abstracted from the pool of the proposed RWD via new pump units and transferred via a two pipeline system (two number of duty pipelines in parallel) from the RWD to the existing process water tank. The Phase 2 RWD is a dual compartment dam and therefore require a duty and standby pump for each compartment.

The proposed Return Water Dam transfer system will consist of the following key components:

- **Suction pipelines and pipe fittings** connecting the intake device with the pump unit.
- **Pump Unit:** Dry self-priming pump with an electrical motor mounted on a skid (one duty and one standby pump unit for each dam compartment).
- **Delivery pipelines and connecting pipe fittings**, transferring return water to the existing Process Water Tank (PWT) (by Onshore Engineering).

1.3.3.1 SUCTION PIPELINES AND CONNECTING PIPE FITTINGS

The suction pipelines will be made from steel pipe. Based on the site specific hydraulic and operational requirements and constraints, the length of suction pipeline will approximately 5m in length (measured from the intake to the pump suction inlet).

1.3.3.2 PUMP UNITS

Each compartment will have a pump unit that will consist of a dry self-priming pump, with an electric motor mounted on a skid in a duty-standby arrangement and will include the following features:

- An end-suction centrifugal pump with fully automatic vacuum assisted dry priming (using a mechanically driven diaphragm style vacuum pump).
- Run-dry capability (oil-lubricated mechanical seal allowing the pump to run dry without damage).

1.3.3.3 DELIVERY PIPELINES AND CONNECTING PIPE FITTINGS

The delivery pipelines will be above-ground HDPE pipelines from the Phase 2 RWD to the existing PWT (by Onshore Engineering).

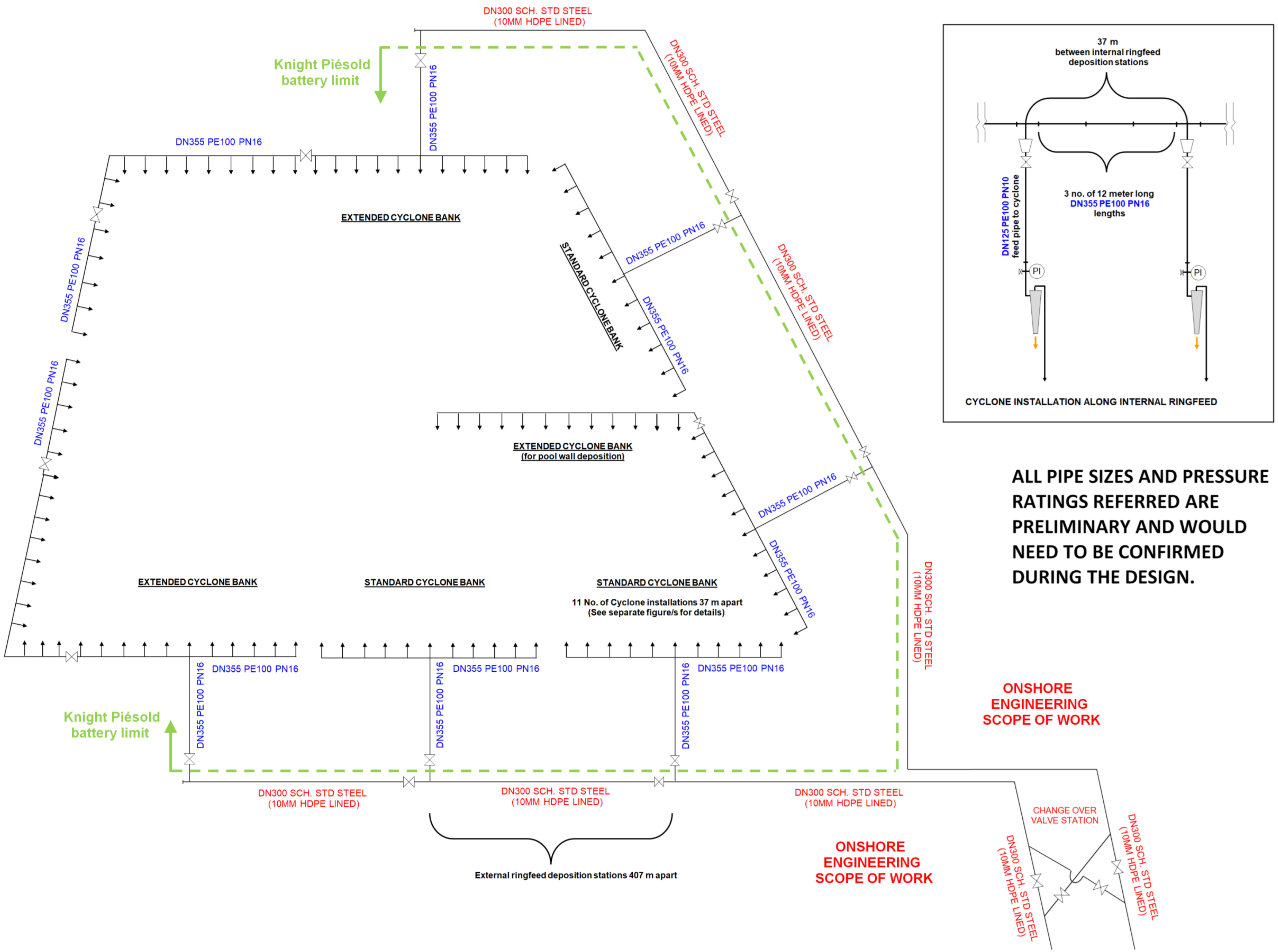

Figure 1.1 Schematic diagram of Tailings ringfeed system layout

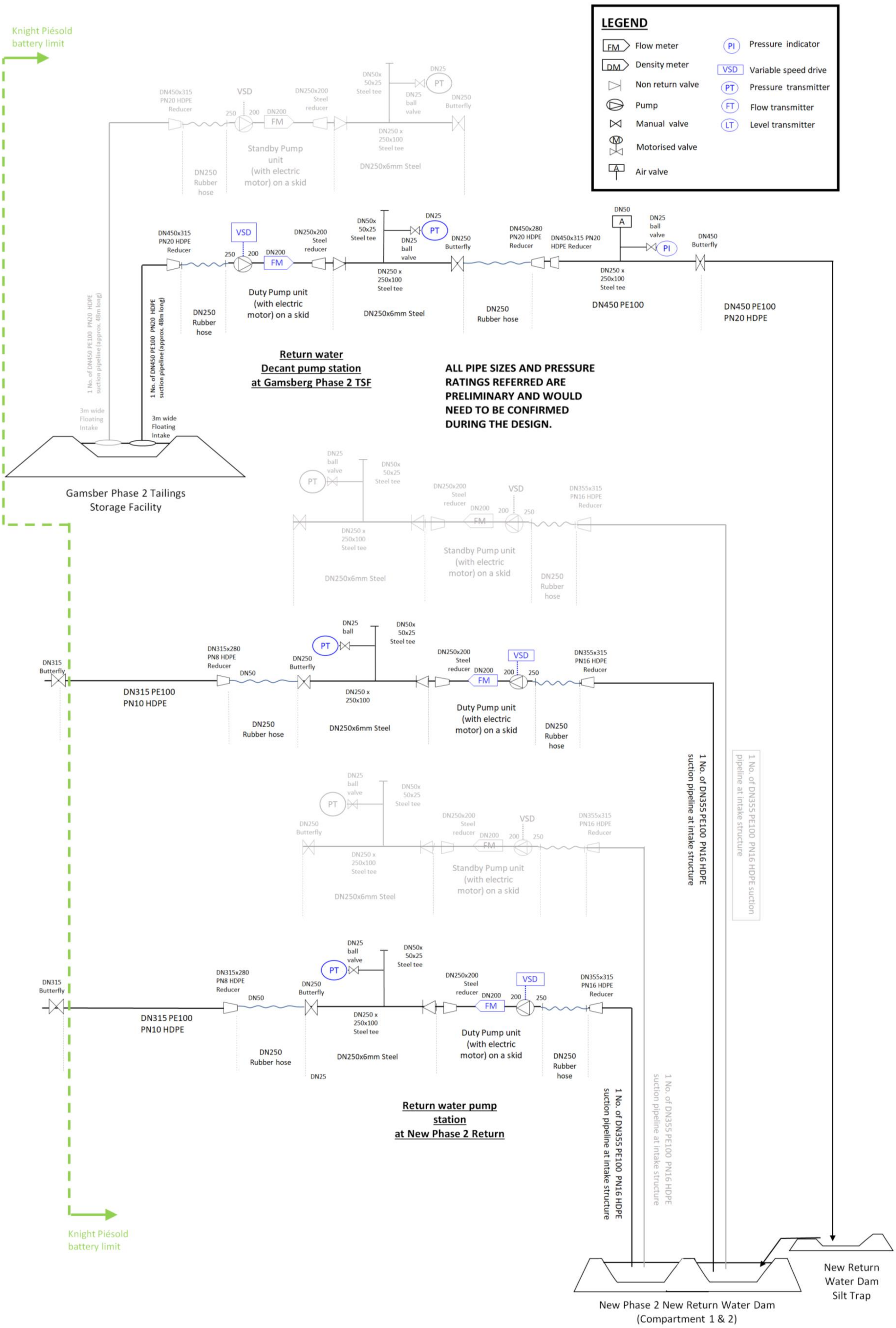

Figure 1.2 Schematic diagram of Return pipeline systems layout

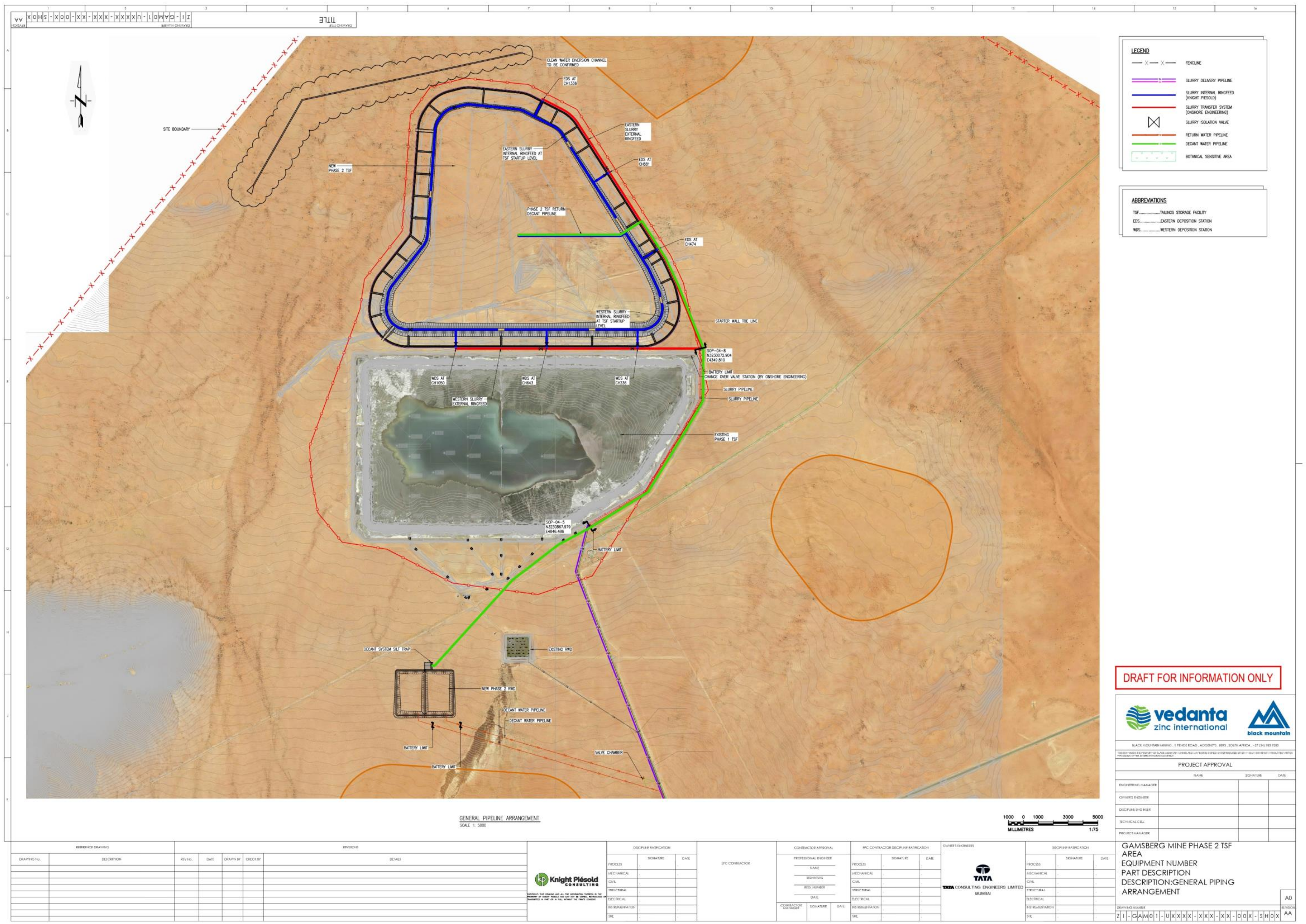

Figure 1.3 General Site piping arrangement of proposed Tailings and Return decant pipeline systems

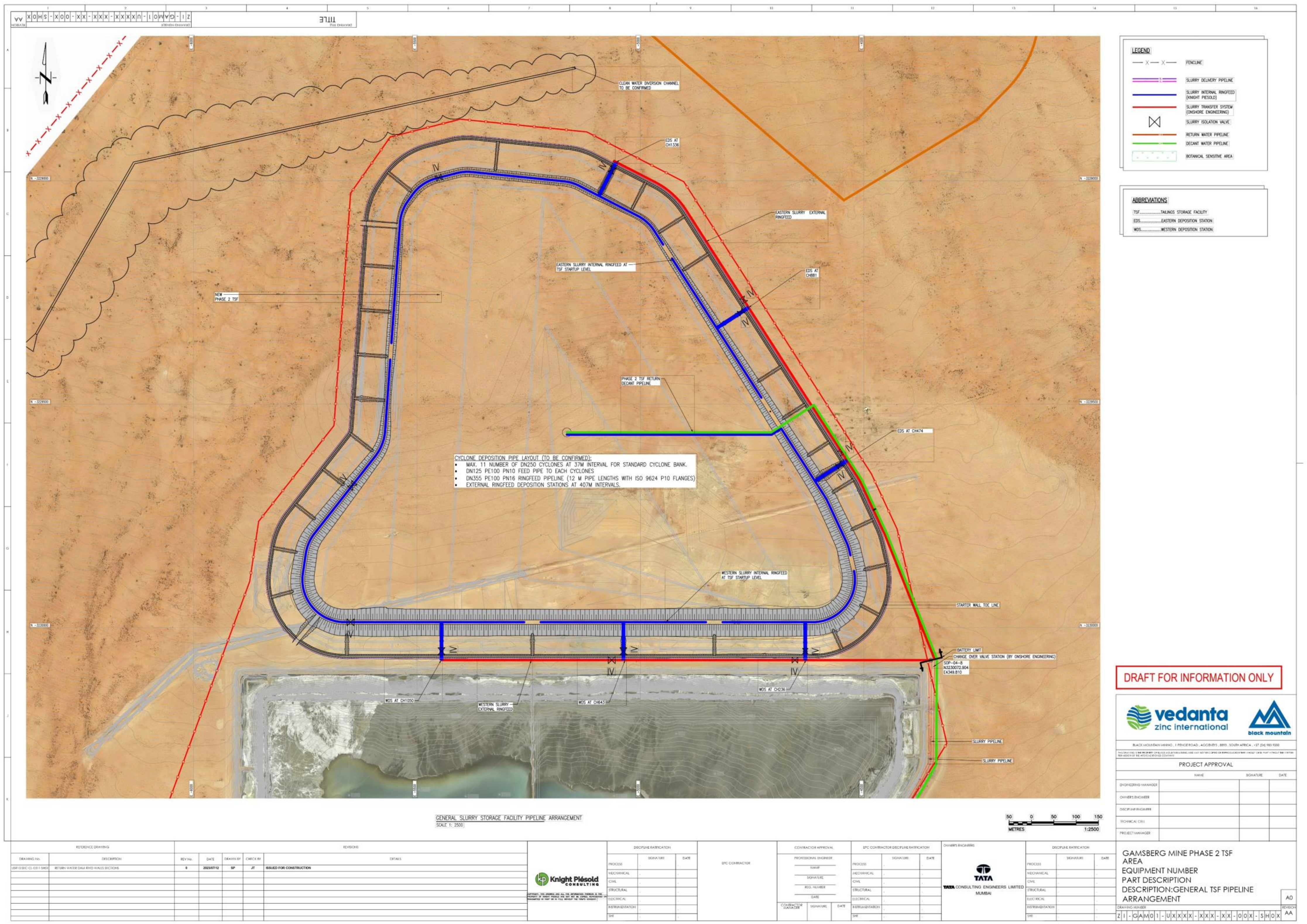

Figure 1.4 General TSF piping arrangement of proposed Tailings and Return decant pipeline systems

1.4 SCOPE OF WORK AND BATTERY LIMITS

KP's scope of work for the proposed Tailings slurry ringfeed pipeline system and Return pipeline systems (within KP's scope of work):

All the civil, structural, mechanical, process, electrical, control and instrumentation engineering designs, detailing, cost estimation, schedule of quantities (for tender purposes) and reporting up to a detailed level of engineering.

Electrical and instrumentation designs will be performed by KP's sub-consultant, Leeba Electrical Engineering. For costing and programming purposes under this proposal a greenfields approach has been assumed, assuming that new pump stations and related electrical infrastructure will be required.

The following battery limits have been assumed for the Mechanical, Civil and Structural scope of work related to the proposed Tailings slurry ringfeed pipeline system and Return pipeline systems (within KP's scope of work):

- **New Tailings slurry ringfeed system - hydraulics**
    - Hydraulics starts just downstream of the changeover valve station
    - Engineering start just outside of external ringfeed pipeline
    - ends at tailings slurry delivery to the new Phase 2 Tailings Storage Facility (TSF).
- **New Return water decant pump station and pipeline system**
    - starts with return water abstraction from the TSF pool, using a movable land-based pump system (or floating barge pump system)
    - ends with delivery of return water, to the proposed silt trap at the proposed Phase 2 Return Water Dam (RWD).
- **Return water dam transfer system**
    - starts at the pool of the proposed Phase 2 RWD
    - ends at the battery limit point indication just downstream of the RWD

The following battery limits have been assumed for the Electrical and Control and Instrumentation scope of work (included within 'KP's scope):

- KP assumes that sufficient bulk power supply (electrical overhead and transformer infrastructure) to the pump station/s will be provided by the mine (or others). The electrical battery limit is fixed at the point of coupling to the relevant LV switchboard incomer at the pump station/s.
- The control and instrumentation battery limit is fixed at the point of coupling to the outgoing terminals of the Remote I/O at the pump station. As such all MCC's are included in KP's scope of work.

2.0 MECHANICAL AND CIVIL DESIGN CRITERIA - TAILINGS AND RETURN PUMP SYSTEMS

2.1 DUTY POINT DEFINITIONS AND DESIGN FLOWS FOR RETURN WATER DAM TRANSFER PUMP STATION

Duty point definitions are outlined below.

- The **Peak pump head duty point** refers to the pump duty point where the maximum required instantaneous design flow intersects the minimum pipe system curve (determined using a new pipe internal roughness and the minimum static head difference).
- The **Minimum pump head duty point** refers to the pump duty point where the minimum required instantaneous design flow intersects the maximum pipe system curve (determined using the aged pipe internal roughness and the maximum static head difference).
- The **Average pump head duty point** refers to the pump duty point where the average instantaneous flow intersects the average pipe system curve (determined using the average aged pipe internal roughness and the average static head difference).

The design flows for the design are tabled within Table 2.1~~Table 2.1~~ below.

Table 2.1 Design flows for each of the Return water dam transfer systems

Parameter	Value	Source/Notes
Daily design operating flows		
Average daily design flows	## ### m³/day	KP to provide info from the final water balance
Peak daily design flows	12 000 m³/day	Calculated from values below value
Operating hours		
Average operating hours	## hrs/day	To be calculated on receipt of information from water balance
Peak operating hours	24 hrs/day	KP
Instantaneous design flows		
Average instantaneous design flow	## ### m³/hour	To be confirmed from Pump curve data
Maximum required instantaneous design flow (per pipeline)	500 m³/hour	KP value from water balance. Please confirm with Onshore Engineering that this is what they are working to as well, since their calculations seem to show 158 m³/hour per pipeline, meaning 316 m³/hour for the 2 pipes in parallel.

2.2 DUTY POINT DEFINITIONS AND DESIGN FLOWS FOR RETURN WATER DECANT PUMP STATION

Duty point definitions are outlined below.

- The **Peak pump head duty point** refers to the pump duty point where the minimum required instantaneous design flow intersects the maximum pipe system curve (determined using the aged pipe internal roughness and the maximum static head difference).
- The **Minimum pump head duty point** refers to the pump duty point where the maximum required instantaneous design flow intersects the minimum pipe system curve (determined using a new pipe internal roughness and the minimum static head difference).
- The **Average pump head duty point** refers to the pump duty point where the average instantaneous flow intersects the average pipe system curve (determined using the average aged pipe internal roughness and the average static head difference).

The design flows for the design are tabled within Table 2.1~~Table 2.1~~ below.

Table 2.2 Design flow parameters for the Return water decant system

Parameter	Value	Source/Notes
Daily design operating flows		
Average daily design flows	## ### m^3/day F96000	KP to provide info from the final water balance
Peak daily design flows Peak daily design flows	19 200 m^3/day	Calculated from values below value
Operating hours		
Average operating hours	## hrs/day-	To be calculated on receipt of information from water balance
Peak operating hours	24 hrs/day	KP
Instantaneous design flows		
Average instantaneous design flow	#### m^3/hour	To be confirmed from Pump curve data
Maximum required instantaneous design flow	800 m^3/hour	KP water balance required 500 m^3/hr however an additional flow allowance was added to accommodate safety margin for scaling and storm events.

2.3 TAILINGS AND RHEOLOGY

Table 2.3 Tailings throughputs and densities from Process plant

Parameter	Value	Source/Notes
Tailings normal throughput	4 000 000 tpa (or 333 333 tpm)	BMM Design Criteria. Please confirm.
Minimum and Maximum and throughputs (Design operating envelope)	300 000 tpm (Minimum) 366 667 tpm (Maximum)	BMM Design Criteria. Please confirm.
Annual normal operating hours	8030 hpa (91.7% availability)	BMM Design Criteria. Please confirm.
Instantaneous tailings throughputs (Design operating envelope)	448 tph (Minimum) 498 tph (Normal) 548 tph (maximum)	Calculated from the above. Please confirm with Onshore Engineering that this is what they are working to as well, since their calculations seem to show 435 tph.
Tailings metallurgical description	Zinc Tailings	VST-01
Solids SG	3.386 t/m³	VST-01
Mixture temperature	20°C	KP design temperature
Water density	0.9982 t/m³	From literature based on a temperature of 20°C
Slurry mixture density (ρ_m)	1.5 t/m³ (Minimum slurry density) 1.63 t/m³ (Normal slurry density) 1.7 t/m³ (Maximum slurry density)	KP assumed. Please confirm.
Slurry concentration by mass (C_w)	47.44 %m (at Minimum Slurry density) 54.96 %m (at Normal Slurry density) 58.54 %m (at Maximum Slurry density)	Calculated from the above.
Slurry concentration by volume (C_v)	21.02 %v (at Minimum Slurry density) 26.46 %v (at Normal Slurry density) 29.39 %v (at Maximum Slurry density)	Calculated from the above.
Slurry pH	pH of 6.83	VST-01

Table 2.4 Tailings Particle Size Distribution (PSD)

Table 2.5 Tailings Particle Size Distribution (PSD)

Sieve size (mm)	Cumulative % passing	Source/Notes
0.9550	**100.00 (d100)**	VST-01. See Figure 2.1~~Figure 2.1~~ below.
0.2754	98.44	
0.1820	94.77	
0.1107	**85.00 (d85)**	
0.1047	83.67	
0.0912	79.91	
0.0750	**74.16**	
0.0692	71.83	
0.0603	67.71	
0.0457	59.71	
0.0347	52.27	
0.0317	**50.00 (d50)**	
0.0263	45.49	
0.0200	39.28	
0.0132	30.92	
0.0087	23.70	
0.0058	17.61	
0.0033	11.13	
0.0017	5.49	
0.0008	2.12	
0.0003	0.01	
0.1262	**d50 course**	

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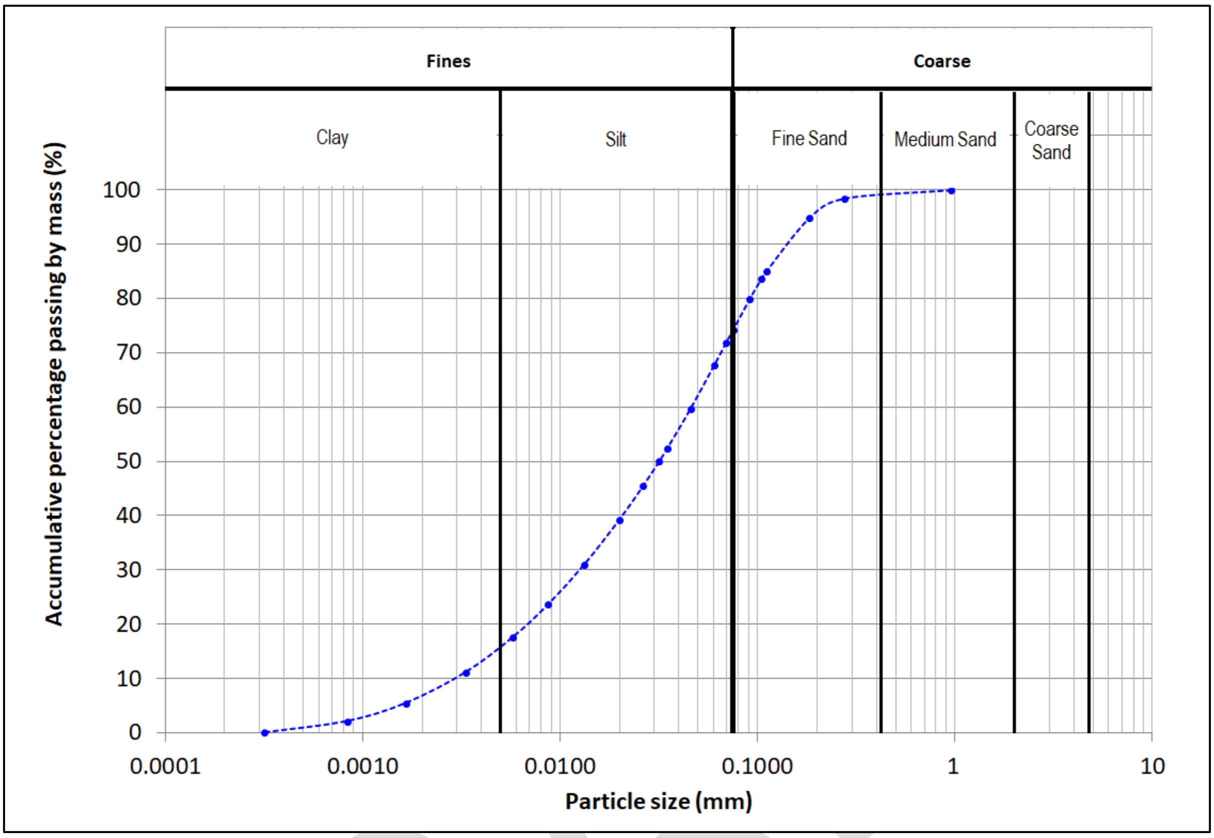

Figure 2.1 Tailings Particle Size Distribution (PSD)

Table 2.6 Tailings slurry rheology and pipeline hydraulic flow behaviour criteria

Parameter	Value		Source/Notes
Bingham plastic model correlation (Note 1)	Bingham Plastic Viscosity (Pa.s)	Bingham Yield Stress (Pa)	Correlation from VST-01.
	$K_{BP} = 3 \times 10^{-6}\ e^{0.1399.Cw}$	$\tau_{yBP} = 6 \times 10^{-5}\ e^{0.1956Cw}$	
Deposition velocity estimation theory	Sanders et al. (2004) equation (Deposition velocity calculations)		KP design standard for the type of tailings
Deposition velocity safety allowance for minimum velocity	0.3 m/s		KP design standard
Slurry flow behavior equations	The following slurry flow behavior equation will be used to calculate the slurry hydraulics: • Wasp equation (Mixed regime slurries under turbulent flow)		Based on current PSD information from VST-01

Note 1: Cw within the equations represents a unitless percentage.

2.4 SITE AND STUDY LEVEL

The key general design criteria for the mechanical and civil definitive feasibility study design tasks under the project are tabled below.

Table 2.7 Site and environmental

Parameter	Value	Source/Notes
Site location	Gamsberg Mine is situated approximately 113 km NE from Springbok, in the Northern Cape South Africa, along the N14 highway to Upington.	KP
Site temperatures	Maximum recorded ambient temperature = 40.8°C Minimum recorded ambient temperature = - 4°C	BMM-1

Table 2.8 Study level and costing

Parameter	Value	Source/Notes
Study level, Cost accuracy and contingency	• Cost estimation will be performed to a cost accuracy of ±25% predominantly based on factored or in-house rates with some budget quotes (over the phone or written quotes) for major equipment and material from preferred manufacturers. Contingency of 25% of Cost of Works • More accurate cost estimation (cost accuracy of -10% to +15%) will follow from the official tender process.	KP
Estimated life of mine	30+ years	https://vedanta-zincinternational.com/what-we-do/our-operations/
Operating life of TSF	12+ years	BMM-1
Currency for cost estimate	Rand	KP
Exchange rate used in cost estimate	R18.54 = 1 US$	KP
Base date for cost estimate	August 2023	KP
Interest and escalation	8% interest 8% escalation	KP assumed for life cycle costing analysis.
Preliminary and general percentage	30% of Subtotal (for Construction CAPEX cost estimation)	KP
EPCM percentage	12% of Cost of Works	KP
Electricity rate/price (for OPEX cost estimation and life cycle costing analysis)	Rand 1.76 / kWh	KP assumed. BMM to provide a more accurate tariff parameter.
Annual Mech. & Elec. Equipment Maintenance	4% of CAPEX	KP
Annual Civil Infrastructure Maintenance	0.5% of CAPEX	KP

2.5 HYDRAULICS AND PUMPS

Table 2.9 General pipeline hydraulic design criteria

Parameter	Value	Source/Notes
Water density	998.2 kg/m³	From Table 2.3~~Table 2.3~~.
Fluid viscosity (µw)	1.005 × 10^{-3} Pa.s	Literature based on above.
Bulk modulus of elasticity of water	2.2 GPa (water)	Literature based on above.
Pipeline head loss and internal roughness calculation method	Darcy Weisbach & Swamee and Jain	KP design standard
Surge analysis	Detailed surge analysis using the Bentley hammer V8i software package (surge analysis computer software).	KP design standard for study level.
Surge flow scenario/s modelled	Pump trip (with check valve and air valve protection where applicable)	

Table 2.10 TSF cyclone system design criteria

Description	Value/Property	Notes
TSF Construction methodology	Cyclone wall building construction method	KP-1
No of cyclones operating per bank	9 (minimum) 11 (optimum) Spaced at approximately 37 m	KP-1
Pressure required at cyclone feed inlet (at normal feed throughput and slurry density)	120-130 kPa	Preliminary value from KP-1. To be confirmed with cyclone supplier.
	Cyclone underflow requirements	
Cyclone tonnage split required from cyclone coarse underflow (at normal slurry feed density)	35% effective	KP-1
Normal In-situ dry density required from cyclone coarse underflow (at normal slurry feed density)	1.5 t/m³ (in-situ dry density)	KP-1
Normal slurry density required from cyclone coarse underflow (at normal slurry feed density)	2.057 t/m³ (equivalent slurry density)	Equivalent slurry density calculated from the above In-situ dry density.
Preferred cyclone make and model	250 mm mounted on stands Preferred model: CAVEX 250CVX10 or similar	KP -1. To be confirmed.

Table 2.11 Mine water pumps design criteria

Parameter	Value	Source/Notes
Pump type	Surface pump stations: Dry self-prime pumps or End suction pumps Borehole pump stations: Borehole pumps	KP design standard
Maximum required free passage distance between impeller and casing	Pumps capable of pumping mine water with solid spheres (if necessary) of at least 12mm	KP conservative design standard for mine water applications
Casing and impeller material	Suitable for mine water. To be specified by pump supplier.	KP design basis
Strings or rags in fluid	The risk of strings or rags blocking the pumps have been deemed negligible	KP design basis
Minimum Recommended Pump On/Off Cycle time	10 minutes	KP design basis
Drive losses factor	• Straight coupled = 1 • Belt drives and = 1.05 • Gear boxes = 1.04	KP design basis.
Seal losses factor	• Packed glands and mechanical seals = 1 • Expeller seals = 1.05	KP design basis.

2.6 PIPELINE SPECIFICATIONS

Table 2.12 Pipeline design criteria

<table>
<tr><th>Parameter</th><th>Steel pipelines
(up to and including DN150)</th><th>Steel pipelines
(including DN200 and above)</th><th>HDPE pipelines</th><th>Source/Notes</th></tr>
<tr><td>Pipe dimension</td><td>SANS 62 Heavy Class (SANS 62-1:2013)</td><td>ANSI B36.10</td><td>ISO 4427-1:2007</td><td>KP</td></tr>
<tr><td>Pipe material and grade & safe working calculations</td><td>SANS 62 Grade 200 MPa</td><td>SANS 719 Grade B ERW</td><td>ISO 4427, Grade PE100</td><td>KP</td></tr>
<tr><td>Modulus of Elasticity</td><td>200 GPa</td><td>200 GPa</td><td>1.1 GPa</td><td>Literature</td></tr>
<tr><td>Poisson’s ratio</td><td>0.3</td><td>0.3</td><td>0.42</td><td>Literature</td></tr>
<tr><td>Minimum strength of pipe material at 20°C</td><td>Specified Minimum Yield Strength (SMYS)
= 200 MPa</td><td>Specified Minimum Yield Strength (SMYS)
= 241 MPa</td><td>Minimum required strength (MRS) at 20°C and 50 years
= 10 MPa</td><td>Literature</td></tr>
<tr><td>Ultimate hoop stress of pipe material at 50 years and 20°C</td><td>300 MPa</td><td>414 MPa</td><td>12.5 MPa</td><td>Literature</td></tr>
<tr><td>Calculated allowable hoop stresses of pipe material (de-rated for temperatures above 20°C)</td><td>100 MPa
(allowable design stress based on 50% of SMYS)
150 MPa
(allowable surge stress based on 75% of SMYS)</td><td>120 MPa
(allowable design stress based on 50% of SMYS)
180.75 MPa
(allowable surge stress based on 75% of SMYS)</td><td>5.92 MPa
(allowable design stress based on 80% of de-rated MRS)
7.4 MPa
(allowable surge stress based on 100% of de-rated MRS)</td><td>Literature. HDPE is based on a de-rating factor of 0.74 (40°C) and a manufacturers service coefficient of 1.25
(50 year operation)</td></tr>
<tr><td>Under tolerance for pipe wall thickness</td><td colspan="2">-12.5%</td><td>-8.7%</td><td>Literature</td></tr>
<tr><td>Standard pipe length</td><td colspan="2">12 m</td><td>12 m</td><td>For transport purposes.</td></tr>
<tr><td>Standard pipe length end type details</td><td colspan="2">Flanged ends</td><td>Plain ends for butt welding by an approved automatic butt-welding machine in accordance with SANS 0268</td><td>KP</td></tr>
<tr><td>Flange connections
(where applicable)</td><td colspan="2">SABS 1123 Raised Face flanges (Return systems)
SABS 1123 Flat Face flanges (Slurry systems)</td><td>ISO 9624 loose backing flanges</td><td>KP</td></tr>
<tr><td>External coating</td><td colspan="2">Epoxy coating</td><td>No coating</td><td>KP</td></tr>
<tr><td>Pipe internal roughness and wear allowance</td><td colspan="2"><table>
<tr><th>Lining description</th><th>Internal roughness
(See Note 1)</th><th>Internal wear/ corrosion allowances for slurry application (Note 3)</th></tr>
<tr><td>UNLINED</td><td>50 µm (new pipe)
2000 µm (aged & scaled pipe)</td><td>0.4 mm/year
(Slurry transfer pipeline</td></tr>
<tr><td>EPOXY LINED</td><td>50 µm (new pipe)
2000 µm (aged & scaled pipe)</td><td>0.4 mm/year
(Slurry transfer pipeline)</td></tr>
<tr><td>RUBBER LINED AT 65 SHORE HARDNESS</td><td>200 µm (new pipe)
2000 µm (aged & scaled pipe)</td><td>0.4 mm/year
(Slurry pump station piping)</td></tr>
<tr><td>HDPE LINED</td><td>50 µm (new pipe)
2000 µm (aged & scaled pipe)</td><td>See Note 2</td></tr>
</table></td><td><table>
<tr><th>Description</th><th>Internal roughness
(See Note 1)</th><th>Internal wear/ corrosion allowances for slurry application</th></tr>
<tr><td>HDPE</td><td>50 µm
(new pipe)
2000 µm
(aged & scaled pipe)</td><td>See Note 2</td></tr>
</table></td><td>KP design basis for the study.

Note 1: Internal roughness for aged pipes are based on the standard 30 year life.
Note 2: Internal wear has been deemed negligible given the operating conditions, PSD & operating velocity. As a result of this, no wear allowance has been included.
Note 3: KP values based on past experience with similar slurry. BMM to inform KP if data or experience from site show differing values.</td></tr>
<tr><td>Scaling mitigation via flow velocity for Return system designs</td><td colspan="3">Velocities within the delivery pipeline system
will be designed to be above 2.5 m/s
for the peak instantaneous design flow.</td><td>KP. BMM to check with Onshore Engineering whether they have also followed a similar approach for the Return water transfer pipeline.</td></tr>
<tr><td>Scaling thickness for Return systems (operated with above referred scaling mitigation)</td><td colspan="3">0 mm internal scaling for new pipe
6 mm internal scaling for aged pipe</td><td>KP. 6mm scaling for an aged pipe was considered a reasonable scaling allowance for hydraulic calculations considering the
• high aged roughness’s specified of 2000 µm
• scaling mitigation via flow velocity allowances included above
• additional safety margin included into finalising the design flow number for the decant system.</td></tr>
</table>

2.7 GENERIC VALVE SPECIFICATIONS

Table 2.13 Generic specifications for valves on the Tailings slurry ringfeed system (see Note 1)

Application	Diameter	Generic specification
		Ringfeed section (PN 25 and lower)
Slurry manual Isolation valves	DN 50 to 500	Pinch valve; manual operated enclosed valve with hand wheel; flanged
Slurry drain/sample valve (at cyclone station)	DN 25	Ball valve; Stainless Steel 316; with BSPT female threaded ends.

Table 2.14 Generic specifications for Low pressure Mine water valves (and flow meters and pressure gauges) (see Note 1)

Application	Diameter	Generic specification
		Low pressure (PN20 and lower)
Mine water isolation valves	DN 40 and smaller	Ball valve; Stainless Steel 316; with BSPT female threaded ends.
	DN 50 to DN 80	Resilient seal gate valve ; rising spindle, flanged
	DN 100 and bigger	Butterfly valve ; metal seated carbon steel body and disc; with handwheel (right hand); flanged
Mine water non-return valves	DN 50 to DN 600	Silent check valve ; flanged
Mine water air valves	DN 15 to DN 25	Combination non-slam air valve with air release and air vacuum functions ; stainless steel; with BSPT male threaded end; ARI D-040 make or similar approved.
	DN 50 to DN 250	Combination non-slam air valve with air release and air vacuum functions ; stainless steel; with flanged end; ARI D-060 make or similar approved.
Mine water scour valve	DN 40 and smaller	Ball valve ; Stainless Steel 316; with BSPT female threaded ends.
	DN 50 and bigger	Metal seated wedge gate valve ; non-rising spindle; flanged
Mine water flow meter	DN 20 and above	Electromagnetic flowmeter ; flanged; with sensor, remote display and transmitter

Note 1: Finalisation and approval of the valve and flow meter datasheets (including detailed material, lining and coating specifications for the valve and flow meter components) to be performed, in conjunction with the selected valve suppliers, as part of the tender/procurement process. The technical data sheets from the suppliers, to be submitted to the engineer for approval, prior to ordering of any valves and flow meters.

2.8 GENERAL DEFINITIONS FOR MECHANICAL CONTROL AND OPERATING PHILOSOPHY MEASURES

Some of the mechanical operating and control philosophy measures are defined under 2.8.1 to 2.8.2 for general reference purposes and specified for each specific pump system under 2.9. The full detailed Electrical and Control and Instrumentation (EC&I) design criteria is included under section 4.0.

2.8.1 PUMP SPEED CONTROL MEASURES

The following pump speed control measures are defined below for general reference purposes in this document:

General pump speed control definitions:

- **Tank Level Control** is concerned with maintaining the level of the feed tank that supplies the pump/s, (or alternatively the end point tank). The pump is ramped up or down as required to maintain a pre-determined level in the tank. The volumetric flow therefore varies between a maximum and minimum value based on the tank level. The methodology is depicted below within Figure 2.2~~Figure 2.2~~ left for the example of level control on the feed tank.
- **Flow Control** utilises flow control on the local downstream side of the pump/s to maintain the volumetric flow at a constant value, irrespective of tank level (or feed density for slurry). The tank level therefore varies between pre-determined maximum and minimum levels (H&L) during normal operation as a result of maintaining a constant or set flow. See Figure 2.2~~Figure 2.2~~ middle.
- **Pressure Control** utilises pressure control on the local downstream side of the pump/s to maintain the volumetric flow at a constant flow value, or to linearly modulate the volumetric flow (and pressure) within a safe operating envelope (in order to stay within the capacity of the motor). Similar to flow control, the tank level therefore varies between pre-determined maximum and minimum levels (H&L) during normal operation as a result of maintaining a constant flow. See Figure 2.2~~Figure 2.2~~ right.

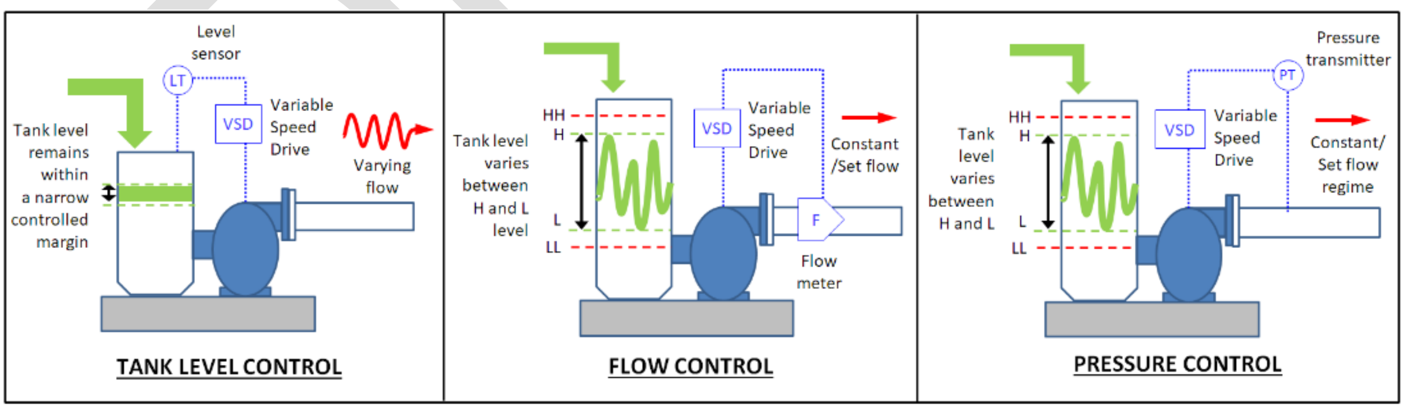

Figure 2.2 Pump speed control methodologies: Tank Level Control (Left) and Flow Control (Middle) and Pressure Control (Right)

2.8.2 ABNORMAL OPERATION PROTECTION MEASURES

Abnormal operation protection measures are defined as follow:

- **Pump dry run protection**
  - Pump dry run protection (by flow instrument and pressure transmitter): The control system monitors the discharge flow and pressure and trips the duty pump should the flow and pressure drop below the dry run limits. The dry run protection is bypassed during pump start-up until the flow is established.
  - Pump dry run protection by the 'motor's under current protection system.

  For the Return Water Dam (RWD) Pumpstations dry run protection will also be performed via the level sensors (duty and standby level sensors) installed within the RWD.

- **Pump dead head protection and pipeline overpressure/burst protection**

  The pump station is equipped with a pressure transmitter on the discharge manifold (or just thereafter). The recorded pressure is compared to the pre-selected set maximum pressure head and, when exceeded, will cause the motor to trip the pump, typically as a result of dead head condition (closed-valve, blocked discharge). The discharge flow is used as a secondary measure allowing a motor trip when the set low-flow is reached for a prolonged period.

- **Spill protection at Process water tank (within the plant)**

  The end point reservoir is equipped with a level sensor to trip the pump should the reservoir reach a set high high level. Should the level instrument fail, a float valve is installed that will mechanically close when the high high level is exceeded.

- **Water hammer protection**

  Water hammer (dynamic state pressure surges) generally occur during sudden pump trips and sudden start-up and shutdown of pumps or inline valves. Surge analysis will be performed as part of the detailed design to mitigate and protect the pump system/s against any undue pressure surges or negative pressures.

- **Scale cleaning or mitigation provision on pipeline**

  No specific descaling infrastructure provision (pigging infrastructure or scale inhibitor systems) has been deemed necessary at this stage. It is assumed that should this become a necessity during the operation of the system it will be dealt with as an operational matter. Certain mitigation measures have however been incorporated within the design allowances included within this document.

- **Secondary spillage containment and Automated leak detection**

  The proposed overland pipelines will be installed within a narrow Secondary Containment Corridor (SCC) with the aim to prevent or limit
  - the spread of slurry or return water spillage
  - contamination of water courses or ground water systems

in the event of a pipeline burst (or leakages through the flanges or in-line valves).

The SCC (consisting of small containment berms and a small v-drains) will be sloped to drain towards small sumps/ponds (located on the low points along the pipeline corridor). Any specific regulatory or client requirements for lining of the SCC to be stipulated by BMM in conjunction with professional advice sought from a registered environmentalist.

Automated leak detection (using two flow meters per pipeline) will not be included for any of the pipeline systems, since it is assumed that leak detection can easily be performed through visual inspection, considering the pipelines are installed above ground.

KP has assumed that where any lining or automated leak detection is specifically required (by any specific regulatory requirements, BMM requirements or environmental requirements) that this will be implemented by BMM as a site run or operational activity.

2.9 SUMMARY OF SPECIFIC MECHANICAL CONTROL AND OPERATING PHILOSOPHY MEASURES

The table below outlines a summary of the key mechanical operating and control philosophy measures proposed for each of the pump systems:

Table 2.15 Key mechanical operating and control philosophy measures proposed

Description	Proposed Return water Decant pump system	Proposed Return Water Dam transfer pump systems
Pump speed control measures to be implemented	• Flow Control (at pump station) Modulating if needed to keep the motor size down.	• Tank Level Control (on End tank)
Secondary control measures to be implemented	• None	• None
Abnormal operation protection measures to be implemented	• Pump dry run protection • Pump dead head protection and pipeline overpressure/burst protection • Water hammer protection • Secondary Containment Corridor	• Pump dry run protection • Pump dead head protection and pipeline overpressure/burst protection • Spill protection at endpoint reservoir • Water hammer protection • Secondary Containment Corridor
SOURCE/NOTES	BMM to confirm	BMM to confirm

To perform the pump speed control measures referred above, variable speed drives (VSD's) will be installed for each of the pumps. The recommendation for 'VSD's relate to the following benefits provided by VSD's:

- VSD's allow for flexibility in pumping volume changes/demands (or duty head point changes) as required by operations or processes. For this application, it is specifically applicable with reference to
  - Pumping to the proposed Process water tank at the plant, which will have limited balancing volume. Regulating the flow to the tank will prevent undue pump on/off cycle times.
- Modulation of control level in end point tanks are made easier by VSD pumps.
- Limiting the flow rate, as per specific end-point demand, is made possible and can also limit the power requirements to within the motor's capability.
- VSD's can compensate for pump-curve anomalies and/or inaccuracies in estimating pipe system curves where applicable.
- VSD's allow for lower pump speeds which extend pump life and saves energy.
- VSD's allow for soft-starts and soft-stops, which save energy and reduces stress on electrical components.
- VSD's allow for more controlled filling of the pipeline during the commissioning of the pipeline.
- VSD's can compensate for impeller or other wear or scaling in the system or design inaccuracies.
- VSD's provide ease of not having to replace impellers should flow requirements change over time.

3.0 KEY INFRASTRUCTURE INFORMATION

3.1 PROPOSED TAILINGS SLURRY RINGFEED SYSTEM

3.1.1 KEY ELEVATIONS

Table 3.1 Key elevations - Proposed Tailings Slurry Ringfeed System

Point description	Parameter	Elevations (mamsl)	Elevations (mamsl)	Source/notes
Battery limit point (just downstream of the Changeover valve station by Onshore Engineering)	Natural ground level	947.700 mamsl		KP Calculation - Level to be confirmed by Onshore Engineering.
	Pipe invert	948.100 mamsl		KP Calculated as NGL + 400mm) - Level to be confirmed by Onshore Engineering.
Proposed New Phase 2 TSF	Crest level	957.000 mamsl – Top of starter wall level (or ringfeed pipe invert)	990.000 mamsl - Top of final wall level (or ringfeed pipe invert)	

3.2 PROPOSED RETURN WATER DECANT SYSTEM

3.2.1 KEY ELEVATIONS

Table 3.2 Key elevations – Proposed Return Water Decant system

Point description	Parameter	Elevations at Startup (mamsl)	Elevations at Final TSF crest level (mamsl)	Source/Notes
Proposed TSF	Bottom of Dam	947.500 mamsl	987.000 mamsl	KP
	Crest level of Dam	957.000 mamsl	990.000 mamsl	KP
	Maximum water level in pond	956.200 mamsl	989.200 mamsl	800mm below crest level
	Lowest contour to decant from	949.500 mamsl	987.000 mamsl	KP
	Minimum water level in pond	949.900 mamsl	987.400 mamsl	400m above lowest contour
New proposed Return Water Dam	Natural ground level	928.100 mamsl		KP
	Highest pipe invert elevation at Return Water Dam	934.100 mamsl		6m above NGL

4.0 ELECTRICAL AND CONTROL AND INSTRUMENTATION DESIGN CRITERIA - TAILINGS AND RETURN PUMP SYSTEMS WITHIN KP SCOPE

4.1 GENERAL

LEEBA has embarked on a project for Gamsberg Zinc Mine that is situated approximately 30km from Black Mountain Mining in the Northern Cape.

The existing Tailings Storage Facility is nearing capacity, and the new Tailings Storage Facility is being built.

4.1.1 PURPOSE OF DOCUMENT

This document serves to describe the design philosophy and concepts which will be used in the development, selection, and design of the Electrical, Instrumentation and Control System infrastructure for the new TSF. When interfacing with the brown fields, deviations from the parameters will have to be considered.

4.1.2 PROJECT DESCRIPTION

This project involves the new installation of electrical power and control for the Return decant pumps and Return Water Pump Stations.

4.1.3 SCOPE AND AREAS OF DESIGN

The engineering and design of:

- LV Motor Control Centre
- Cabling & Racking
- Pump Control
- Lighting and small power
- Earthing and lightning protection
- Instrumentation and Control

4.1.4 BATTERY LIMITS

- The electrical power battery limit is the terminals of the LV Switchboard in the substation.
- The Control System battery limit is the terminals of the communication module in the RIO panel in the substation.
- Software and System integration is excluded for this scope as it is assumed the mine would want their own technician responsible for the control system to manage this.

4.1.5 REGULATIONS AND SPECIFICATIONS

The electrical system shall generally be designed to meet the requirements of the following regulations and specifications:

Regulations: -

- Mine, Quarries, Works and Machinery Act of Botswana

- RSA Mines Health and Safety Act
- RSA Minerals Act and Regulation
- RSA Occupational Health and Safety Act
- RSA Environmental Protection Act

Specifications: -

- Mine Specifications
- SABS Specifications, Guidelines and Codes of Practice
- International Electrical Commission
- IEEE standards

4.1.6 MAINTAINABILITY

Wherever possible all equipment shall be selected such that

- proven technology
- it is purchased from reputable suppliers
- it has remote supplier support
- It is maintainable without the need for special tools and equipment.
- Strive towards the minimisation of the total cost of ownership of the installation;
- Standardise equipment selection within the plant without compromising the technical solution; and
- Provide a reliable installation to meet the required pumping throughput rate and operational utilisation target.

4.1.7 SAFETY CONSIDERATIONS

While all designs shall take adequate measures to protect the safety of both maintenance personnel as well as other operational personnel, the following shall specifically be applied:

- All safety interlocks shall be hardwired.
- Wherever possible, door and or key interlock schemes shall be employed.
- All equipment shall be designed in a “fail to safe” mode. This means for example, a “fail to open” circuit.
- Provide a safe working environment for personnel and equipment;
- Minimise the environmental impact;

4.1.8 MATERIALS AND EQUIPMENT

Although the site is considered “brown fields” in that it is an existing facility, equipment will be supplied as indicated in the Approved Equipment List.

4.1.9 PROTECTION RATINGS (IP)

All electrical equipment shall generally be designed to meet the following minimum protection ratings unless specifically specified otherwise.

General;

Equipment Location	First Digit (Dust and Contact Protection)	Second Digit (Water Protection)
Outdoors	5	4
Indoor (Conditioned Environments)	2	1
Indoor (Process Environments)	5	5

Equipment Description	IP Rating
Outdoor Motor Control Centres – Doors Closed	IP 54
Indoor Motor Control Centres – Doors Closed	IP 54
Indoor Motor Control Centres – Doors Open	IP 20
VSDs	IP 20 (Min)
Field Isolators	IP 54
RIO Panels	IP65

4.1.10 CABLES

All cables shall be SABS 1339 for MV and SABS 1507 for LV,

XLPECUSPVCSWAPVC for MV and PVCSWAPVC 4 core for LV applications.

Standard flame retardant cable (blue stripe) to be used in general plant areas. Non-halogen (white stripe) to be used in confined security areas and underground only.

Standard BW glands to be used on LV armoured cables unless specified differently for wet areas.

4.1.11 CABLE SUPPORT SYSTEMS

- The cable support systems shall be of a continuous nature and above ground as far as possible. Cable ladder shall be used for all major cable routes with galvanised angle iron for auxiliary routes.
- All racking shall be installed vertically unless specifically allowed in areas that are covered.
- Cable trenching is to be avoided.
- All new cables shall be mounted on heavy duty galvanized cable ladder (OL 75 or equivalent). Individual runs on angle iron sections will be galvanised or coated to structural steel paint specification.
- The existing cable racks will be used where possible. New cable racks will be installed where existing cable racks are full or damaged. The 20% spare capacity may be compromised on existing racks for “Brown Fields” areas only.
- Cables within plant areas may be strapped by means of UV protected PVC straps.

- Power and instrument/control cables will run on separate racks. These will be separated from one another by a distance of at least 300mm. Where this is not feasible, and a single racks is used, 300mm spacing will be maintained between instrumentation and power cabling.

4.1.12 JUNCTION BOXES

- Pratley or CCG or Pratley junction boxes are to be used on all outdoor light fittings and welding socket circuits such that the light fitting or welding socket is not used as a wireway or junction box.
- Pratley or CCG or Pratley junction boxes, as specified, will be used on all instrumentation connections.

4.1.13 VOLTAGE SUPPLIES

The voltages shown below will be used by the Electrical Engineer for the specific functions stated, subject to the confirmation of the electrical design team.

Function	Voltage	Type of System Earthing
MV Distribution	11 000V	Resistively Earthed
Motors above 315 kW	To be advised	
Motors below 315 kW	525V	Resistively earthed
Welding Voltages	525V	Resistively earthed
Portable Equipment	230V AC	Solid earthed
Lighting	400/230	Solidly earthed
UPS Input Power	525/230	Solidly earthed
UPS Output Power	230V	Solid
MCC Control	24V DC	Negative earthed
Analogue control	4-20mA	

4.1.14 PHASE COLOURS

The following cable and wire colouring shall be used:

Characteristic	Function	Colour
3 Phase Power Wiring	First Phase Second Phase Third Phase Neutral	Red White/Yellow Blue Black
1 Phase Power Wiring	Live Neutral	Phase Colour Black
1 phase Small power	Live Neutral	Red Black
Earth		Green, Green with Yellow tracer

4.1.15 CONTAINERISED SUBSTATION DESIGN

Existing Substations will used as far as possible.

New substations will be converted marine containers in accordance with Leeba Specification 00-00-S-0014 and associated data sheet. In general, the following will apply: -

- The substations will be installed on concrete pillar supports 1500mm high with steel stairway access and bottom cable entry.
- It will be airconditioned.
- There will be at least two doors on 12 metre containers and one in 6 metre containers.
- All doors will have emergency crash bars on the inside such the doors can be always opened from the inside in the case of emergency. Doors will be pad lockable from the outside.
- The walls and ceiling will be insulated, and the wooden floor replaced with a steel floor (Vastrap).
- The fire detection system will be room smoke detection only.
- A portioned room will be created to house the RIO panels should it not be integral to the LV Switchboard. The room will have its own access door.

Each substation will have an additional IBR roof fitted that will extend 1000mm over the edges for cooling.

4.2 ELECTRICAL ENGINEERING

4.2.1 VOLT DROPS

Steady State Volt Drop	• Individual feeders to equipment receiving power from busbars connected to transformers with tap change facilities will be sized for a maximum 5 % volt drop • Feeders to Remote Distribution Boards - All feeders to remote distribution boards such as lighting boards, distributed MCC's etc. shall be sized for a maximum 2 % volt drop • Individual branch circuit feeders to equipment, loads and or motors will in general be sized for a maximum 3 % volt drop. • Under no circumstances will the sum of the volt drops of the feeder to a sub-board and any of the associated branch circuits exceed 5%
Motor Starting Volt Drops	The system shall in general be designed to provide for the following percentage of nominal voltages at the motor terminals – Generally no acceleration studies shall be performed. • Motors above ≥ 315 kW shall be determined by the actual torque requirements • Motors < 315 kW – 85% • All motor starting volt drop calculations shall be based on minimum short circuit levels at the particular bus.

4.2.2 LOAD CRITERIA

The maximum demand loading will be calculated as 80% of the motor's nameplate rating. Hence diversity shall be calculated excluding the influence of all loads designated as spare and or standby. The motor efficiency and power factor is taken at 75% of motor full load.

4.2.3 LIGHTING

Lighting levels are to conform to the requirements of the SABS 0114, productivity rating. For the purposes of this document, the following is extracted from the recommendations: -

Area	LUX Level	Emergency LUX Level
General Outdoor Areas	0.3	-
General Plant Areas	160	0.3
Moving Machinery	160	30
General Walkways	50	5

The following lamp types shall be used: -

Area	Lamp Type
General Outdoor Areas	LED
Pumpstations	LED

The total installation shall comply with SABS 0142 parts 1 and 2

- Welding Requirements: 63amp welding plugs of the Ampco (TBA) type shall be used. Welding circuits shall be supplied at 525volts from the 525V MCC by means of an integral earth leakage circuit breaker, with a leakage sensitivity of 30mA.
- All SSOs shall be of the 15amp plug top round pin variety and shall be protected by a 30mA earth leakage circuit breaker.
- Lighting circuits will not be connected to the system via earth leakage protection circuit breakers. A 4-wire system with separate dedicated BCEW (bare copper earth wire) shall be employed.

4.2.4 EARTHING & LIGHTNING PROTECTION

Lightning protection shall be in accordance with the requirements of SANS 10313 and SANS 62305.

4.2.5 PUMP STATION FIRE DETECTION

There is no requirement for fire detection and automatic suppression in the pump stations.

Fire hose reels and hydrants, if required, are to be provided by the mechanical engineer.

4.2.6 LV MOTOR CONTROL CENTRES (MCCS) AND DISTRIBUTION BOARDS (DBS)

- MCCs and power distribution boards are to be metal clad type 4A for control and power. All boards will be front access, back entry.
- All contractors shall be rated for minimum AC3 duty, Type 2 co-ordinated and rated for the designed fault level of 35kA.
- Motor protection shall be Electronic Motor Management relays Allen Bradley E300.
- MCCs shall be supplied as TTA or PTTA as per the provisions of IEC 61439-1.
- VSDs and UPSs can be installed within the MCC where applicable.
- All incomers and busbars shall be rated to the supply the feed breaker.
- All MCCs shall be cable bottom entry.

Incomers:

- Incomers will be equipped with a metering unit that will display voltage, current, maximum demand and consumption as a minimum and a surge protection device.

Fixed speed applications:

- Moulded case circuit breakers, earth leakage and Siemens Pro-V motor protection relay with earth leakage protection.

Variable frequency drives:

- Moulded case circuit breakers and earth leakage. Provided if the VFD trip is intrinsically safe, contactors will be provided for Emergency Stop function.
- VFD Drives may be located in the LV Switchboard or in free standing cabinets.

Soft starters:

- Moulded case circuit breakers, earth leakage, motor protection relay and contactor.

Starting methods:-

Use of direct on line	General use
Use of Open Transition Starters – Star Delta	Only by exception
Use of Electronic Reduced Voltage starters	Yes – if required by the electrical system and suited to the load starting requirements
Use of VFD	Only as a consequence where speed control is required, or electrical system constraints dictate
Reactor starts	Only By exception
Use of Liquid Starters	Only By exception
Use of fluid Couplings	Only By exception

4.2.7 MOTORS

Motors are supplied by the mechanical engineer. The electrical designs are based on three phase WEG W22 premium efficiency motors used for all applications.

Large MV drives will be standard motors as far as possible. Special application may require custom built motors.

4.2.8 WELDING SOCKET OUTLETS

Welding sockets will be standard round type with 525V switched four pin plugs, three phase and earth. The sockets will have a locking mechanism such that the power cannot be switched unless the plug is fully inserted and locked into position.

4.2.9 DIP PROOFING

Dip proofing is not required for this installation. The Control system only, will be power by UPS.

4.2.10 LIGHT FITTINGS

Light fittings will be used as follows: -

LED Breakbulk 19W bulkheads will be used for general plant outdoor lighting and LED Tube for indoor lighting.

4.3 CONTROL AND INSTRUMENTATION

4.3.1 PLANT COMMUNICATIONS

Existing plant communication systems will be used.

4.3.2 UPS POWER

All instrument power will be supplied by the existing installed UPS. Power will be supplied via the existing Instrument Power DB (IPDB).

4.3.3 INSTRUMENTATION DESIGN PACKAGES

Instrumentation design package to be used is Dessoft (FDES). An Instrument index and technical datasheets will be produced initially using an Excel spreadsheet, to a format compatible with existing models. This will simplify integration after signoff. The database will be developed as an As Built deliverable.

4.3.4 INSTRUMENTATION TYPES

- The instrument suppliers will be selected from an approved supplier vendor list.
- Standard off-the-shelf instrumentation will be used. Digital switches will be 24V DC and Analogue signals will be 4-20mA driving into a minimum of 500 Ohms.
- All instrument transmitters will be supplied with Field Displays, where possible and will be enclosed in an IP 65 enclosure, with Drip/Shade/Stone Proof covers.
- Air actuated valves will be controlled using 24V DC valve solenoid stations. Modulating Control valves will be connected to their respective stand-alone Controllers using 4-20 mA signals.
- If air is not available, valves will be operated using 24V DC / 220 V AC actuators as the process / size dictates.

4.3.5 INSTRUMENT CABLES

1. Conductors
   Conductors shall be available in the following range:

0.5 mm^2	annealed 0.3 mm copper wire, 7 strands
1.0 mm^2	annealed 0.3 mm copper wire, 14 strands
1.5 mm^2	annealed 0.3 mm copper wire, 19 strands

2. Core insulation
   The core insulation shall be fire resistant, virgin PVC or polyethylene, rated at 105ºC, with a nominal thickness of 1mm.

3. Core identification

   All cores are to be individually alpha-numerically numbered, in contrasting colours, at regular intervals. A stranded, 0.5 mm^2 stranded bare copper communications wire is to be provided. Insulation colour code is to be orange.

4. Lay of twists
   Overlay of pairs/triads is to be in the range 50 mm - 63 mm.

5. Shielding
   100% coverage by a helical aluminium polyester tape shield consisting of a minimum of 0,009 mm aluminium x 0,013 mm polyester. The aluminium is to be in continuous contact with a 1 mm^2, tinned copper drain wire. Individual screening of pairs and triads is required for multi-core cables, complying with the overall screen requirements.

6. Outer sheath
   The outer sheath is to have the following minimum properties:
   - Virgin black PVC;
   - 1 mm nominal thickness;
   - Flame retardant to 90º C;
   - UV resistant; and
   - Oil and acid resistant.

Low Smoke, Zero Halogen (LSZH) requirements will be specified where required.

7. Armouring
   The following armouring may be required, depending upon application.

   - Aluminium polyethylene laminated (APL) with a PVC outer sheath.
   - Galvanised steel wire armour with a PVC outer sheath
   - Double galvanised steel wire armour with a PVC outer sheath

Armouring shall be required for all cables running on exposed cable racks. Cables in enclosed metal trunking or conduit would normally not require armouring. Aluminium polyethylene laminated (APL) with a PVC outer sheath is the preferred armouring for normal applications but in areas where the cables are subject to rodent attack a single or double SWA must be used.

4.3.6 EARTHING

All new earth cables will be connected to the existing earth ring.

4.3.7 REMOTE I/O

The field Remote I/O will be housed in IP65 RIO junction boxes. These enclosures will be manufactured from polycarbonate or mild steel (powder coated see Appendix 1) and have a transparent cover where fused terminals are used. Drip/Shade/Stone covers will be installed with these enclosures.

A 20% spare allowance for signals will be provided in addition to the finalI/O list.

4.3.8 PUMP CONTROL SYSTEM

The Slurry Pump control shall be remotely controlled from the control room using Profbus and Ethernet communication with minimum instrumentation on the following principles: -.

- All safety interlocks will be hard-wired without the facility to override. The interlock will have to be reset before the device can be started.
- All process related interlocks will be by PLC control.
- Local control will be by permit from the control room by radio request. In local status, the field start pushbutton will issue a start request to the control system which in turn will start the motor. In automatic mode, only the control system will start the motor. Stop pushbuttons will function at all times.

In addition to start and stop pushbuttons, the following indication will be communicated to the control room: -

- Motor drive healthy
- Field healthy

Field Isolators are not required. Lockout will be in the substations on the MCC. There will be start request and stop pushbuttons adjacent to the motor.

The following exceptions are made:

- Sump pumps will be independently controlled by level detectors. Run / Stopped monitoring only will be made available on the control panel.

4.3.9 FIELD STOPS

All motor field stop buttons to be latched, twist release pushbuttons.

4.3.10 FIELD STARTS

All field start pushbutton shall be push to make, automatic spring release. Not latching.

4.3.11 VENDOR PACKAGES

The vendor packages will connect to conventional I/O as far as possible, by using the remote I/O panels.

4.4 APPENDIX 1– COLOUR CODING & EQUIPMENT LIST

No.	Description	Proposed Colour
1	Motors	Manufacturers Standard
2	Cable Trays	Galvanised
3	550V Switchgear, MCC & DB	Orange B26
4	Lighting DB's	Orange B26
5	VSD's	Manufacturers Standard
6	Custom Field Junction Boxes	Orange B26
7	Standard Field Junction Boxes	Orange B26
8	Cable Rack Support Steel	Galvanised
9	UPS	Manufacturers Standard
10	Pressurisation Fan Units	Manufacturers Standard
11	Field Stop & start enclosure with Red Stop button	Orange B26
12	RIO/PLC Panels	Orange B26

4.5 APPENDIX 2 - PROPOSED EQUIPMENT MANUFACTURERS

Proposed equipment list		
No.	**Description**	**Manufacturer**
1	Electronic LV Motor Protection Relays	Siemens Pro-V
2	Electronic MV Motor Protection Relays	NA
3	LV Air Circuit Breakers	Schneider ABB
4	Moulded Case Motor Circuit breakers	Schneider ABB Siemens
5	Contactors	Schneider ABB
6	Cables	Aberdare ZEST CBI
7	Variable Frequency Drives & Soft Starters	Siemens WEG ABB
8	Programmable Logic Controllers & HMI	Siemens
9	Uninterruptible Power Supplies	Eaton – Meissner Zest Emmerson
10	Terminals	Phoenix Contact
11	24V DC Power supplies	Phoenix Contact
12	Valves – Control Modulating	CCI, Fisher, Dresser, Arca Controls, Mil Controls LTD, Flowserve
13	Valves – Solenoid and SJVBs	ASCO, Burkert
14	Flow Switches	Endress & Hauser/ IFM
15	Level Switches	Endress & Hauser/ Vega/ KROHNE
16	Level Transmitters	Endress & Hauser/ Vega/ KROHNE
17	Controller	Siemens
18	Panels & Enclosures	Novatech / JB Switchgear
19	Pressure Gauges	Wika/ ASHCROFT
20	Pressure Transmitters	IFM/ ASHCROFT
21	Valves - Solenoid	Festo/Burkett/Hydromatics
22	UPS	Zest / Eaton
23	Power Supplies	Phoenix Contact/ Weidmuller/ Siemens
24	Circuit Breakers	Schneider /Hager/ Siemens
25	Network Switches	Moxa/Siemens/Hirshmann/Cisco
26	Cable Racking	O-Line/Cabstrut/Strutfast

5.0 KEY UNRESOLVED MATTERS

BMM to provide KP with comments and approval of this document, as soon as possible.

Key points requiring confirmation by client, Onshore Engineering and KP:

- A crossover valve station (by Onshore Engineering) will be installed just prior to reaching the TSF on the transfer pipeline system, to allow the TSF operators to change over the flow between the western and eastern ringfeed pipeline branch systems, where needed.
- External ringfeed pipeline (by Onshore Engineering) will be installed consisting of DN300 Std. Schedule Steel piping (with 10mm HDPE lining) installed above ground on pipe supports.
- KP will provide design and drawing details for the deposition stations on the External ringfeed pipeline.

Some of the key outstanding information include:

- KP to provide info from the final water balance for the Average daily design flow (in ## ### m^3/day or m^3/annum) for **Table 2.1**~~**Table 2.1**~~ and **Table 2.2**~~**Table 2.2**~~
- Tailings throughputs, densities etc. for **Table 2.3**~~**Table 2.3**~~ requires confirmation. Please confirm with Onshore Engineering that they are working to KP's instantaneous throughputs listed in **Table 2.3**~~**Table 2.3**~~. Their calculations seem to show a lower number (435 tph).
- BMM to kindly provide a more accurate electricity tariff parameter for **Table 2.8**~~**Table 2.8**~~ where available.
- Please confirm with Onshore Engineering that they are working to the design flow listed under **Table 2.1**~~**Table 2.1**~~ (500 m^3/hour), since their calculations seem to show 158 m^3/hour per pipeline, meaning 316 m^3/hour for the 2 pipes in parallel.
- See **Table 2.12**~~**Table 2.12**~~. Velocities within the return pipelines will be designed to be above 2.5 m/s for the peak instantaneous design flow. BMM to check with Onshore Engineering whether they have also followed a similar approach for the Return water transfer pipeline. Their velocity calculation seem to show a lower number (0.8 m/s).
- Any specific regulatory or client requirements for lining of the Secondary Containment Corridor (SCC) to be stipulated by BMM in conjunction with professional advice sought from a registered environmentalist. KP has assumed that where any lining or automated leak detection is specifically required (by any specific regulatory requirements, BMM requirements or environmental requirements) that this will be implemented by BMM as a site run or operational activity.

6.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

Prepared:

Kobus van Rooyen, Pr.Eng.

Reviewed:

Amal Doorgapershad, Pr.Eng.
Principal Engineer / Regional Manager

Approval that this document adheres to the Knight Piésold Quality System: