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Title	Design Report: Wet Waste Storage Facility in Cable Tunnel of V-14

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REVISIONS

This document has been revised in accordance with the following schedule:

Rev. No.	Date approved	Nature of Revision	Prepared
1.0	See title page	First issue	WJ Jarvis

1 EXECUTIVE SUMMARY

The design of the conversion of the Cable Tunnel in V-14 to a Wet Waste Storage Facility has been completed. The design shows that the area can be used provided that certain mass limits are applied to the drums stored in the area. The User Requirements Specifications [1] have been met.

2 INTRODUCTION

2.1 Purpose

This document describes the design process followed to verify that the Cable Tunnel can be used to store waste identified by the Waste Segregation and Repacking Facility.

2.2 Scope

This document only describes the design and verification of the height of the bund wall, the loading capacity of the slab, and the modification of the transfer route from Pelstore to the Cable Tunnel floor.

3 REFERENCES

Document Title	Document No.	Rev
[1] User Requirement Specification for the Wet Waste Storage Facility in the Cable Tunnel	NLM-SPE-00041	1.0
[2] Email from Patrick Dyasi dated 2022-08-24		
[3] Concrete Details to Slab at 1353,5 Level	7371-14-010-C07600	11
[4] Basis of structural design and actions for buildings and industrial structures - Part 1: Basis of structural design	SANS 10160-1: 2019	1.3
[5] Drawing: Wet Waste Storage Facility General Layout	NNDD-V-14-C-L1-0001	1.0
[6] Concrete floors - Part 2: Finishes to concrete floors	SANS 10109-2: 2013	3.1
[7] Drawing: Uncharacterised Waste Storage Area Layout and Detail	NNDD-V-14-C-L1-0003	1.0
[8] Drawing: 210-Litre Drum Storage Layout and Detail	NNDD-V-14-C-L1-0005	1.0
[9] Drawing: Characterised Waste Area Layout and Details	NNDD-V-14-C-L1-0002	1.0
[10] Drawing: General Drum Storage Layout and Details	NNDD-V-14-C-L1-0004	1.0
[11] Drawing: General Ramp for Pallet Jack	NNDD-V-14-C-L1-0007	1.0
[12] Drawing: Trench Cover	NNDD-V-14-C-L1-0006	1.0

Document Title	Document No.	Rev
[13] Drawing: Air Lock Room Layout	NNDD-V-14-C-L2-0001	1.0

4 DEFINITIONS AND ABBREVIATIONS

4.1 Definitions

Term	Definition
Pelindaba	Pelindaba is the name for the area that NECSA site is located
Pelstore	The waste storage facility found in the Building V-14.
V-14	A building located on the Pelindaba East site.
Cable Tunnel	A floor of Building V-14 located at an elevation of 1353.5 meters above sea-level.

4.2 Abbreviations

Term	Definition
NECSA	South African Nuclear Energy Corporation
WSRF	Waste Segregation and Repacking Facility
WWSF	Wet Waste Storage Facility

4.3 Variables

Term	Definition
A	Area
b	width
B	Edge point
c	cover thickness
dv	Vessel storage volume
f	factor
f	strength (stress)
g	gravity
h	height
I	Moment of inertia
l	length
M	Moment
n	Number of
P	Point Load
Q	Line Load
t	thickness

Term	Definition
V	Volume
V	Shear
w	width
y	distance from centroid to edge
γ	Loading Factor
θ	Stress/Area Load
ρ	density
φ	factor

4.4 Subscripts

Term	Definition
100	Representing 100-Litre Drum
160	Representing 160-Litre Drum
210	Representing 210-Litre Drum
allow	Allowable load
applied	An applied load
applied	Applied to the area/point
b	bending
bund	Bund wall
c5	Characterised 5-litre containers
containers	5-Litre Containers
eff	Effective
frame	The frame used for storing 5-Litre containers
layers	The number of layers per frame
liquid	The amount of liquid
LL	Live Load
max	maximum
pallet	referring to pallet
rupture	The percentage of containers that rupture
s	screed
safety	Safety factor
tot	Total
uc5	Uncharacterised 5-litre containers
x	x axis
y	yield
y	Vertical

5 BACKGROUND INFORMATION

During Pelstore's waste reduction process, drums containing wet or liquid waste are identified using X-Rays. These drums are then separated from the waste reduction process. The Wet Waste Storage Facility (WWSF) will be used to store these drums and the 5-liter containers of characterised and uncharacterised waste from the Waste Segregation and Repacking Facility (WSRF).

The area identified for the WWSF is the Cable Tunnel in the V-14 building on Pelindaba East Site. This area is approximately 3369 m^2 and will be fenced off to maintain security. The area will be split into four storage sections, namely general drum, 210-litre drum, characterised and uncharacterised 5-litre containers [1].

6 REQUIREMENTS AND GENERAL DESIGN INFORMATION

The requirements for the design are split into general and area requirements

6.1 General Requirements

The requirements of the general area design are listed below:

Table 1: General Requirements for the WWSF

Requirement Number	Requirement Description	Reference
[R1]	Each Section must be fenced off from each other	[1] 6.1
[R2]	Approximate number of drums to be stored: 16000	[1] Table 6-1
[R3]	Approximate number of characterised 5-litre containers to be stored: 11000	[1] Table 6-1
[R4]	Approximate number of uncharacterised 5-litre containers to be stored: 112	[1] Table 6-1
[R5]	Storage and configuration layout based on loading capacity of the cable tunnel floor	[1] 6.2.1 & 6.2.2
[R6]	Modification of existing access between the cable tunnel and Pelstore floor for transport of drums between facilities.	[1] 6.2.3
[R7]	Bund walls are required around each section. The bund wall must be able to contain the liquid of 50% of the total containers/drums in their respective areas.	[1] 6.5
[R8]	Holes in the existing floor are to be sealed or closed	[1] 6.5
[R9]	Floors must be easily cleaned. The materials of construction used must be acid and oil resistant	[1] 6.5 & 6.6
[R10]	There shall be 500mm spacings between rows of drums or shelves to enable inspections	[1] 6.7

6.2 Drum Storage Area

The requirements in Table 2 only apply to the drum storage area:

Table 2: Requirements for the Drum Storage Area

Requirement Number	Requirement Description	Reference
[R11]	A 2-metre-wide main passage	[1] 6.4.1
[R12]	Drums are stacked four to a pallet. Pallets should be stacked two tiers high depending on floor loading capacity and roof height.	[1] 6.4.1

Table 3 describes the drums that can be stored in the WWSF.

Table 3: General Information on the Drums to be Stored in the WWSF ([1] Table 6-2)

Drum Type	Diameter [mm]	Lid Diameter [mm]	Height [mm]	Maximum Mass [kg]
100 L Plastic Buksie (Red)	503.9	523	582	140
100 L Plastic Barrel (Blue)	490.2	N/A	573	140
100 L Metal Medical (Red)	496.6	522	573	140
100 L Metal (Black)	460.3	488	672	140
160 L Metal (Red)	498.2	524	837	160
210 L Metal (Yellow)	573	608	890	300

The maximum amount of liquid in any drum is 50% of the drums volume [2].

6.3 Requirements for Characterised 5-Litre Container Storage Area

The requirements in Table 4 only apply to the characterised 5-litre container storage area:

Table 4: Requirements for the Characterised 5-Litre Container Storage Area

Requirement Number	Requirement Description	Reference
[R13]	The containers shall be laid out with no more than 3 containers deep.	[1] 6.4.2
[R14]	The containers shall not be able to slip	[1] 6.4.2
[R15]	The shelves shall be compartmentalised with spacers for precise positioning	[1] 6.4.2
[R16]	The height between shelves shall be a minimum of 400mm	[1] 6.4.2

The containers have a maximum mass of 5kg.

6.4 Requirements for Uncharacterised 5-Litre Container Storage Area

The requirements in Table 5 only apply to the uncharacterised 5-litre container storage area:

Table 5: Requirements for the Uncharacterised 5-Litre Container Storage Area

Requirement Number	Requirement Description	Reference
[R17]	Access for the geometrically safe trolleys and cages	[1] 6.4.2

7 DESIGN CALCULATIONS

The following sections illustrates the design calculations performed to conform to the requirements. The general proposed layout of the areas is shown in Drawing NNDD-V-14-C-L1-0001 [5].

7.1 Bund Wall Height

The bund wall height for each section is determined by the amount of liquid spilled in an accident scenario. The method for calculating the height of the bund wall was to find the total volume of potentially spilled liquid for each area and divide that by the effective area of each area. The effective area accounts for space occupied by containers.

7.1.1 Bund Wall

The bund wall will be constructed of commercial steel. Different sized angle irons or flat bars will be used for the wall. This will be easiest to install, seal and maintain.

7.1.2 Drum Storage Area

There are two sections to the drum storage area. The first section is the area where only 210-litre drums can be stored. The second area is a general drum storage area.

7.1.2.1 210-Litre Storage Area

This area can only contain 210-litre drums and is described in Drawing NNDD-V-14-C-L1-0005 [8]. Table 6 illustrates the summarised calculations. The full calculations can be seen in APPENDIX A. The calculations show that the bund wall height is required to be at least 214 mm.

Table 6: Bund Wall Height Calculation Key Values for the 210-litre Drums Area

Variable	Value	Unit	Comment
n_{210}	1088		Number of 210 litre drums
dv_{210}	230	dm^3	Volume of the 210-litre drum
A_{eff}	322.34	m^2	Effective Area
$f_{rupture}$	0.5		Percentage of drums that rupture
$f_{percent\_liquid}$	0.5		Percentage of each drum that is liquid
φ_{safety}	1.1		Safety factor for overflow
V_{liquid}	68.67	m^3	Volume of liquid that should be contained in the bund
h_{bund}	214	mm	Required height of the bund

7.1.2.2 General Drum Storage Area

This area can store 100-litre, 160-litre and 210-litre drums. The layout of this area can be found in Drawing NNDD-V-14-C-L1-0004 [10]. The bund wall calculation assumes that all drums are 160-litre drums stacked in two layers as this is most conservative.

Table 7 illustrates the summarised calculations. The full calculations can be seen in APPENDIX A. The calculations show that the bund wall height is required to be at least 684.5 mm.

Table 7: Bund Wall Height Calculation Key Values for the General Drums Area

Variable	Value	Unit	Comment
n_{160}	14688		Number of 160 litre drums
dv_{160}	163	dm^3	Volume of the 160-litre drum
A_{eff}	962.90	m^2	Effective Area
$f_{rupture}$	0.5		Percentage of drums that rupture
$f_{percent\_liquid}$	0.5		Percentage of each drum that is liquid
φ_{safety}	1.1		Safety factor for overflow
V_{liquid}	659.05	m^3	Volume of liquid that should be contained in the bund
h_{bund}	684.44	mm	Required height of the bund

7.1.3 Characterised 5-litre Container Storage Area

Table 8 illustrates the summarised calculations for the Characterised 5-Litre Container Area. The layout of this area can be found in Drawing NNDD-V-14-C-L1-0002 [9]. The full calculations can be seen in APPENDIX A. The calculations show that the bund wall height is required to be 93.8 mm.

Table 8: Bund Wall Height Calculations Key Values for the Characterised 5-Litre Containers Area

Variable	Value	Unit	Comment
n_{c5}	12096		Number of 5 litre containers
dv_{c5}	5	dm^3	Volume of the 5-litre Container
A_{eff}	354.8	m^2	Effective Area
$f_{rupture}$	0.5		Percentage of containers that rupture
φ_{safety}	1.1		Safety factor for overflow
V_{c5}	33.26	m^3	Volume of liquid that should be contained in the bund
h_{c5bund}	93.75	mm	Required height of the bund

7.1.4 Uncharacterised 5-litre Container Storage Area

Table 9 illustrates the summarised calculations for the Uncharacterised 5-Litre Container Area. The layout of this area can be found in Drawing NNDD-V-14-C-L1-0003 [7]. The full calculations can be seen in APPENDIX A. The calculations show that the bund wall height is required to be 5.3 mm.

Table 9: Bund Wall Height Calculations Key Values for the Uncharacterised 5-Litre Containers Area

Variable	Value	Unit	Comment
n_{uc5}	112		Number of 5 litre containers
dv_{c5}	5	dm^3	Volume of the 5-litre Container
A_{eff}	58.24	m^2	Effective Area
$f_{rupture}$	0.5		Percentage of containers that rupture
φ_{safety}	1.1		Safety factor for overflow
V_{uc5}	0.31	m^3	Volume of liquid that should be contained in the bund
$h_{uc5bund}$	5.29	mm	Required height of the bund

7.2 Loading on the Floor

The allowable load of the floor was defined by Drawing 7371-14-010-C07600[3]. This is the original structural drawing of the area. The allowable loads are defined in Table 10.

A live load factor, γ_{LL}, of 1.6 was applied in accordance with SANS 10160-1[4].

Table 10: Allowable Loads on the Cable Tunnel Slab

Variable	Value	Unit	Comment
θ_{allow}	5	kPa	Allowable Area Load
P_{allow}	20	kN	Allowable Point Load on the Egg-Crate Opening Cover

7.2.1 Drum Storage Area

The loading calculations are split into the three types of drums found in the WWSF, namely 100, 160 and 210 litre drums. The complete calculations can be found in APPENDIX B.

7.2.1.1 100-Litre Drums

A fully loaded pallet, a pallet and four maximum mass drums, will exceed the allowable area loading of the floor, therefore the mass of the four drums on the pallet must be limited. Two situations were considered, namely, a single pallet or two pallets stacked. The summarised calculation is shown in Table 11.

Table 11: 100-Litre Drums Loading Calculations

Variable	Value	Unit	Comment
m_{100_max}	140	kg	Maximum Mass per Drum
m_{100_pallet}	12	kg	Mass of the Pallet
l_{pallet}	1050	mm	Length of the Square Pallet
n_{100_drums}	4		Number of Drums per Pallet
w_{pallet}	8.91	kN	Factored Maximum Weight of a Pallet
$\theta_{100\_applied\_max}$	8.08	kPa	Factored Maximum Area Load (Not Okay)
$m_{100\_pallet\_1}$	339.2	kg	Factored Maximum 4 Drum Total Weight per Pallet for a Single Layer
$m_{100\_pallet\_2}$	151.6	kg	Factored Maximum 4 Drum Total Weight per Pallet for a Double Layer

7.2.1.2 160-Litre Drums

A fully loaded pallet, a pallet and four maximum mass drums, will exceed the allowable area loading of the floor, therefore the mass of the four drums on the pallet must be limited. Two situations were considered, namely, a single pallet or two pallets stacked. The summarised calculation is shown in Table 12.

Table 12: 160-Litre Drums Loading Calculations

Variable	Value	Unit	Comment
m_{160_max}	160	kg	Maximum Mass per Drum
m_{160_pallet}	12	kg	Mass of the Pallet
l_{pallet}	1050	mm	Length of the Square Pallet
n_{160_drums}	4		Number of Drums per Pallet
w_{pallet}	10.16	kN	Factored Maximum Weight of a Pallet
$\theta_{160\_applied\_max}$	9.28	kPa	Factored Maximum Area Load (Not Okay)
$m_{160\_pallet\_1}$	339.2	kg	Factored Maximum 4 Drum Total Weight per Pallet for a Single Layer
$m_{160\_pallet\_2}$	151.6	kg	Factored Maximum 4 Drum Total Weight per Pallet for a Double Layer

7.2.1.3 210-Litre Drums

A fully loaded pallet, a pallet and four maximum mass drums, will exceed the allowable area loading of the floor, therefore the mass of the four drums on the pallet must be limited. The 210-Litre Drums will only be stored in a single layer. The summarised calculation is shown in Table 13.

Table 13: 210-Litre Drums Loading Calculations

Variable	Value	Unit	Comment
m_{210_max}	300	kg	Maximum Mass per Drum
m_{210_pallet}	12	kg	Mass of the Pallet
l_{pallet}	1360	mm	Length of the Square Pallet
n_{210_drums}	4		Number of Drums per Pallet
w_{pallet}	19.14	kN	Factored Maximum Weight of a Pallet
$\theta_{210\_applied\_max}$	10.35	kPa	Factored Maximum Area Load (Not Okay)
$m_{210\_pallet\_1}$	558.19	kg	Factored Maximum 4 Drum Total Weight per Pallet for a Single Layer

7.2.2 Characterised 5-Litre Container Area

The containers will be stored in shelves which can store 21 containers per layer and be in two layers. This will result in 42 containers applying load to the feet between two racks. The rack feet will act predominately as point loads on the floor. An area load was checked never the less and it was limiting. The summarised calculation is shown in Table 14. The full calculations can be found in APPENDIX C.

Table 14: Characterised 5-Litre Containers Loading Calculations

Variable	Value	Unit	Comment
$n_{containers}$	21		Number of Containers per Layer
n_{layers}	2		Number of Layers
$m_{container}$	5	kg	Maximum Mass of a Container
m_{frame}	70	kg	Mass of the Frame on one Pair of Legs
w_{frame}	650	mm	Width of the Frame
l_{frame}	1270	mm	Length between leg pairs of the Frame
$P_{applied}$	4.12	kN	Point Load Applied
$\theta_{applied}$	4.99	kPa	Area Load Applied

7.2.3 Uncharacterised 5-Litre Container Area

The uncharacterised 5-litre containers are stored in geometrically safe trolleys which results is a far less dense than the characterised 5-litre containers and therefore a check will not be performed.

7.3 Modification of Passage between the Pelstore Floor and WWSF

The modifications required is to:

- Widen the access door to a double door,
- Install a 500 kg crane to lift a drum to the required level

These modifications are shown in Drawing NNDD-V-14-C-L2-0001[13].

7.3.1 Widen of Access Door

The reinforced concrete will need to be cut widen the door. An I-Beam lintel will be installed to maintain the stability of the door and the wall above. A standard Necsa design and drawing will be used.

7.3.2 500 kg Crane

The crane will be designed and installed by a crane manufacturer. This will ensure that the crane is adequate and that it complies with regulations. The crane will be mounted into concrete walls which should be checked once the crane has been designed and drawings are available.

8 FINALISED DESIGN

The final design is based on the results of the design calculations shown in Section 7.

8.1 Bund Walls

The minimum bund wall heights are calculated in Section 7.1. Table 15 shows the selected angle irons and plates for the bund wall and the bolting spacing. Furthermore, this is illustrated in Drawings [7], [8], [9] and [10].

Table 15: Bund Wall Information

Storage Area	Minimum Wall Height [mm]	Section [mm]	Tie-Down Bolt Spacing [mm]
210-litre Drums	214	Plate 240x8	600
General Drums	685	Plate 700x8	600
Characterised 5-Litre	93.8	Angle 100x100x8	600
Uncharacterised 5-Litre	5.3	Angle 50x50x5	400

The 50x50x5 angle is significantly larger than required for the Uncharacterised 5-Litre Area. This is due to minimum end measurements during the bolting process.

8.2 Closure of the Openings in the Slab

The openings in the slab are to be closed. There are 2 types of opening currently, cable trenches running across the slab and rectangular holes.

8.2.1 Trenches

The trenches are all 450mm wide. A steel plate will be used to support 50mm of screed which will be placed over the trench. This will allow sealing of the trench while allowing the trench to continue to operate. This is shown in Drawing NNDD-V-14-C-L1-0006 [12] while the calculations can be found in APPENDIX D. The plate is designed to resist the load of the screed and a live load of 5 kPa, the same load allowed on the slab.

8.2.2 Rectangular Holes

The rectangular holes are found in the northern section of the cable tunnel. They are currently covered using a steel plate welded to an egg-crate grid. This is shown in Drawing 7371-14-010-C07600 [3]. The drawing also states that the covers are designed for a point load of 20 kN. They will only affect the Classified 5-Litre Container Storage area.

The shelves legs will not be placed on the covers. The covers will be filled with screed to ensure that the joints can be sealed to yield an effective bund area. The weight added is checked in APPENDIX D.

8.3 Sealant

A general epoxy sealant is recommended. This epoxy should adhere to SANS 10109-2 [6]. The epoxy should be resistant to acids, bases and oils. The epoxy should be applied according to product instructions.

The epoxy shall be applied to the floor of the area, the columns to the height of the bund wall, and ensure that the bund wall is sealed to the floor.

9 DESIGN REQUIREMENTS CHECK

The design requirements, found in Section 6, are listed below with the outcomes of the design.

Design Requirement	Achieved	Reference	Comment
[R1.]	Yes	Drawing [5]	
[R2.]	No	Section 7.2 and Drawings [8] [10]	15776 Approx. The shortfall was caused by loading and layout limitations
[R3.]	Yes	Drawings [9]	12096 Spaces Supplied
[R4.]	Yes	Drawing [7]	112 Spaces Supplied
[R5.]	Yes	Section 7.2 and Drawings [7] [8] [9] and [10]	
[R6.]	Yes	Section 7.3	
[R7.]	Yes	Section 7.1	
[R8.]	Yes	Section 8.2	
[R9.]	Yes	Section 8.3	
[R10.]	Yes	Drawing [7] [8] [9] and [10]	
[R11.]	Yes	Drawing [5] and [10]	
[R12.]	Yes	Section 7.2	Only the 100 and 160-Litre Drums may be stacked. All pallets have mass limitations expressed in Section 10
[R13.]	Yes	Drawing [5][9][5]	
[R14.]	Yes	Drawing [9]	
[R15.]	Yes	Drawing [9]	
[R16.]	Yes	Drawing [9]	
[R17.]	Yes	Drawings [7] and [11]	

10 PROCEDURAL REQUIREMENTS

Due to the nature of the outcomes of the design check, various procedural requirements shall be implemented. These are listed below:

[PR1.] The maximum mass for four 100-Litre drums on a pallet is 339 kg for a single layer and 151.6 kg (per layer) for a double layer.

[PR2.] The maximum mass for the sum of four 160-Litre drums on a pallet is 339 kg for a single layer and 151.6 kg (per layer) for a double layer.

[PR3.] The maximum weight for the sum of four 210-Litre drums on a pallet is 558.2 kg for a single layer

11 CONCLUSION

The calculations presented show that the Cable Tunnel of V-14 building can be used as a wet waste storage facility with procedural limitations which are described in the previous Section.

This design report is only valid if the limitations set out in Section 10 are implemented in the operational procedures of the facility.

APPENDIX A BUND WALL HEIGHT CALCULATIONS

Bund Wall Calculations for the Drum Storage Area

Number of Drums

$n_{100} := 59 \cdot 144 = 8496$ The 100 and 160 drum types are interchangable

$n_{160} := 36 \cdot 172 = 6192$

$n_{210} := 1088 = 1088$ Found only in the 210-Litre Area

$n := n_{100} + n_{160} + n_{210} = 15776$

$r_{100} := \frac{503.9\ mm}{2}$

$r_{160} := \frac{498.2\ mm}{2}$

$r_{210} := \frac{573\ mm}{2}$

Drum Volumes

$dv_{plastic\_red\_100} := \frac{(503.9\ mm)^2 \cdot \pi}{4} \cdot 582\ mm = 116.0651\ dm^3$

$dv_{blue\_100} := \frac{(490.2\ mm)^2 \cdot \pi}{4} \cdot 573\ mm = 108.1412\ dm^3$

$dv_{metal\_red\_100} := \frac{(496.6\ mm)^2 \cdot \pi}{4} \cdot 573\ mm = 110.9834\ dm^3$

$dv_{black\_100} := \frac{(460.3\ mm)^2 \cdot \pi}{4} \cdot 672\ mm = 111.8256\ dm^3$

$dv_{black\_160} := \frac{(498.2\ mm)^2 \cdot \pi}{4} \cdot 837\ mm = 163.1634\ dm^3$

$dv_{yellow\_210} := \frac{(573\ mm)^2 \cdot \pi}{4} \cdot 890\ mm = 229.5034\ dm^3$

$dv_{100} := \max\left(\left[dv_{plastic\_red\_100}\ dv_{blue\_100}\ dv_{metal\_red\_100}\ dv_{black\_100} \right]\right) = 116.0651\ dm^3$

$dv_{160} := dv_{black\_160} = 163.1634\ dm^3$

$dv_{210} := dv_{yellow\_210} = 229.5034\ dm^3$

Area of the Bunded Storage 210L

$w_1 := 2682\ mm$

$l_1 := 224794\ mm$

Width and Length of the 210-Litre Area

$A_{tot} := w_1 \cdot l_1 = 602.8975\ m^2$ Total Area

$A_{drums} := n_{210} \cdot r_{210}^{\ 2} \cdot \pi = 280.56\ m^2$ Total Area of Drums Bottoms

$A_{eff} := A_{tot} - A_{drums} = 322.34\ m^2$ Effective area. Used drum area as it is more conservtive than pallet volume

Volume of the Liquid to be contained

$f_{rupture} := 0.5$ 50 % of drums rupture

$\varphi_{safety} := 1.1$ 10 % safety factor for the bund wall height

$f_{percent\_liquid} := 0.5$ 50 % of the any one drum is liquid.

$V_{liquid} := \left(dv_{210} \cdot n_{210}\right) \cdot f_{rupture} \cdot \varphi_{safety} \cdot f_{percent\_liquid} = 68.6674\ m^3$

Height of the Bund Wall

$h_{bund} := \frac{V_{liquid}}{A_{eff}} = 213.0305\ mm$ Minimum Bund Wall Height

Area of the Bunded Storage 100L + 160L

$w_1 := 9452\ mm$ $w_2 := 4642\ mm$ Width and length of the Area

$l_1 := 224794\ mm$ $l_2 := 70496\ mm$

$$A_{tot} := w_1 \cdot l_1 + w_2 \cdot l_2 = 2451.9953\ m^2$$

$$A_{drums} := \left(\frac{n_{100} + n_{160}}{2}\right) \cdot r_{100}^{\ 2} \cdot \pi = 1464.57\ m^2$$

Total Area of Drums Bottoms. 100L drum has higher radius, more conservitive.

$$A_{col} := 0.01 \cdot A_{tot} = 24.52\ m^2$$

Assume 1% loss to columns

$$A_{eff} := A_{tot} - A_{drums} - A_{col} = 962.9015\ m^2$$

Effective Area. Bottom of Drums used as it is more conservitive than pallets.

Volume of the Liquid to be contained

$f_{rupture} := 0.5$ 50 % of drums rupture

$\varphi_{safety} := 1.1$ 10 % safety factor for the bund wall height

$f_{percent\_liquid} := 0.5$ 50 % of the any one drum is liquid.

$$V_{liquid} := \left(dv_{160} \cdot n_{100} + dv_{160} \cdot n_{160}\right) \cdot f_{rupture} \cdot \varphi_{safety} \cdot f_{percent\_liquid} = 659.0497\ m^3$$

Height of the Bund Wall

$$h_{bund} := \frac{V_{liquid}}{A_{eff}} = 684.4414\ mm$$

Minimum Bund Wall Height

Characterised Waste 5L

$n_{c5} := 12096$ Maximum number of containers

$dv_{c5} := 5\ dm^3$ Volume per container

$w_{c1} := 3977\ mm$ $w_{c2} := 1977\ mm$ Width of area

$l_{c1} := 73380\ mm$ $l_{c2} := 41295\ mm$ Length of area

$A_{c5} := w_{c1} \cdot l_{c1} + w_{c2} \cdot l_{c2} = 373.47\ m^2$

$A_{c5eff} := 0.95 \cdot A_{c5} = 354.8\ m^2$ Effective area after assuming 5% loss to columns of the racks and building. This is conservitive.

$V_{c5} := dv_{c5} \cdot n_{c5} \cdot f_{rupture} \cdot \varphi_{safety} = 33.26\ m^3$

$h_{c5bund} := \dfrac{V_{c5}}{A_{c5eff}} = 93.75\ mm$ Minimum Bund Wall Height

Uncharacterised Waste 5L

$n_{uc5} := 112$ Maximum number of containers

$dv_{uc5} := 5\ dm^3$ Volume per container

$w_{uc1} := 1977\ mm$ Width of area

$l_{uc1} := 31009\ mm$ Length of area

$A_{uc5} := w_{uc1} \cdot l_{uc1} = 61.3\ m^2$

$A_{uc5eff} := 0.95 \cdot A_{uc5} = 58.24\ m^2$ Effective area after assuming 5% loss to racks and columns. This is conservitive.

$V_{uc5} := dv_{uc5} \cdot n_{uc5} \cdot f_{rupture} \cdot \varphi_{safety} = 0.31\ m^3$

$h_{uc5bund} := \dfrac{V_{uc5}}{A_{uc5eff}} = 5.29\ mm$ Minimum Bund Wall Height

APPENDIX B DRUMS LOADING CALCULATIONS

Loading on the Storage Floor

Allowable Loading

$\theta_{allow} := 5\ \text{kPa}$ — Ref Drawing $7371-14-10-C07600$

Know variables

$g := 9.81\ \frac{\text{m}}{\text{s}^2}$ — Gravity

$\gamma_{LL} := 1.6$ — Live load factor from SANS 10160 Series

100 Litre Drum

$m_{100\_max} := 140\ \text{kg}$ — Ref NLM-SPE-00041 R01

$m_{100\_pallet} := 12\ \text{kg}$ — Ref NLM-SPE-00041 R01

$l_{pallet} := 1050\ \text{mm}$ — Pallet Support Length Ref NLM-SPE-00041 R01

$n_{100\_drums} := 4$ — Drums per Pallet Ref NLM-SPE-00041 R01

$w_{pallet} := g \cdot \left(\gamma_{LL} \cdot n_{100\_drums} \cdot m_{100\_max} + m_{100\_pallet}\right) = 8.9075\ \text{kN}$ — Maximum pallet weight

$\theta_{100\_applied\_max} := \frac{w_{pallet}}{l_{pallet}^{2}} = 8.0793\ \text{kPa}$ — Not Okay w.r.t Area Load if all drums are maximum mass.

$m_{100\_Pallet\_1} := \frac{\theta_{allow} \cdot l_{pallet}^{2}}{g \cdot \gamma_{LL}} - m_{100\_pallet} = 339.2041\ \text{kg}$ — Requirement of one layer of drums. The 100 L drums on a pallet cannot have a total mass greater than 339 kg

$m_{100\_Pallet\_2} := \frac{\theta_{allow} \cdot l_{pallet}^{2}}{2 \cdot g \cdot \gamma_{LL}} - 2 \cdot m_{100\_pallet} = 151.6021\ \text{kg}$ — Requirement of two layers of drums. The 100 L drums on a pallet cannot have a total mass greater than 151 kg

160 Litre Drum

$m_{160\_max} := 160\ kg$ Ref NLM-SPE-00041 R01

$m_{160\_pallet} := 12\ kg$ Ref NLM-SPE-00041 R01

$l_{pallet} := 1050\ mm$ Pallet Support Length
Ref NLM-SPE-00041 R01

$n_{160\_drums} := 4$ Drums per Pallet
Ref NLM-SPE-00041 R01

$w_{pallet} := g \cdot \left(\gamma_{LL} \cdot n_{160\_drums} \cdot m_{160\_max} + m_{160\_pallet}\right) = 10.1632\ kN$ Maximum pallet weight

$\theta_{applied} := \frac{w_{pallet}}{l_{pallet}^{2}} = 9.2183\ kPa$ Not Okay w.r.t Area Load if all drums are maximum mass.

$m_{160\_Pallet\_1} := \frac{\theta_{allow} \cdot l_{pallet}^{2}}{g \cdot \gamma_{LL}} - m_{160\_pallet} = 339.2041\ kg$ Requirement of one layer of drums. The 160 L drums on a pallet cannot have a total mass greater than 332 kg

$m_{160\_Pallet\_2} := \frac{\theta_{allow} \cdot l_{pallet}^{2}}{2 \cdot g \cdot \gamma_{LL}} - 2 \cdot m_{160\_pallet} = 151.6021\ kg$ Requirement of two layers of drums. The 160 L drums on a pallet cannot have a total mass greater than 156 kg

210 Litre Drum

$m_{210\_max} := 300\ kg$ — Ref NLM-SPE-00041 R01

$m_{210\_pallet} := 31\ kg$ — Ref NLM-SPE-00041 R01

$l_{pallet} := 1360\ mm$ — Pallet Support Length
Ref NLM-SPE-00041 R01

$n_{210\_drums} := 4$ — Drums per Pallet
Ref NLM-SPE-00041 R01

$w_{pallet} := g \cdot \left(\gamma_{LL} \cdot n_{210\_drums} \cdot m_{210\_max} + m_{210\_pallet}\right) = 19.1393\ kN$ — Maximum pallet weight

$$\theta_{applied} := \frac{w_{pallet}}{l_{pallet}^{2}} = 10.3478\ kPa$$

Not Okay w.r.t Area Load if all drums are maximum mass.

$$m_{210\_Pallet\_1} := \frac{\theta_{allow} \cdot l_{pallet}^{2}}{g \cdot \gamma_{LL}} - m_{210\_pallet} = 558.1947\ kg$$

Requirement of one layer of drums. The 210 L drums on a pallet cannot have a total mass greater than 539 kg

APPENDIX C SHELVES LOADING CALCULATIONS

Loading of on the Storage Floor

Allowable Loading

$\theta_{allow} := 5\ kPa$ — Ref Drawing 7371 − 14 − 10 − C07600

$P_{allow} := 20\ kN$ — Ref Drawing 7371 − 14 − 10 − C07600

Know variables

$g := 9.81\ \frac{m}{s^2}$ — Gravity

$\gamma_{DL} := 1.2$ — Dead load factor from SANS 10160 Series

$\gamma_{LL} := 1.6$ — Live load factor from SANS 10160 Series

Containers on the Frame

$n_{containers} := 21$ — 21 containers per layers

$n_{layers} := 2$ — Number of layers

$m_{container} := 5\ kg$ — Maximum mass per container

$m_{frame} := 70\ kg$ — Mass allowable per frame legs

$w_{frame} := .65\ m = 0.65\ m$ — Width of Frame

$l_{frame} := \frac{5.080}{4}\ m = 1.27\ m$ — Length of Frame

$P_{applied} := \gamma_{DL} \cdot g \cdot m_{frame} + \gamma_{LL} \cdot g \cdot m_{container} \cdot n_{containers} \cdot n_{layers} = 4.12\ kN$ — Point load applied

Okay

$$\theta_{applied} := \frac{\gamma_{DL} \cdot g \cdot m_{frame} + \gamma_{LL} \cdot g \cdot m_{container} \cdot n_{containers} \cdot n_{layers}}{w_{frame} \cdot l_{frame}} = 4.99\ kPa$$

Area load applied

Okay

APPENDIX D TRENCH AND OPENING COVER CALCULATIONS

Load on the trench cover

$b := 450\ \text{mm}$	Width of the Channels
$l := 1000\ \text{mm}$	Unit length
$t := 8\ \text{mm}$	Thickness of the Plate
$c_s := 50\ \text{mm}$	Screed Depth
$\rho_s := 2000\ \frac{\text{kg}}{\text{m}^3}$	Screed Density
$g := 9.81\ \frac{\text{m}}{\text{s}^2}$	Gravity
$f_y := 355\ \text{MPa}$	Yield Stress 355 Steel
$f_{allow} := 0.9 \cdot f_y = 319.5\ \text{MPa}$	Factored Yield Stress
$I_x := \frac{1}{12} \cdot l \cdot \left(\frac{t}{2}\right)^3 = 5333.33\ \text{mm}^4$	Moment of Inertia
$y := \frac{t}{2} = 4\ \text{mm}$	Distance from centriod to Edge
$Q := 1.2 \cdot \rho_s \cdot c_s \cdot g \cdot l + 1.6 \cdot 5\ \text{kPa} \cdot l = 9.18\ \frac{\text{kN}}{\text{m}}$	Line load on the plate
$B_y := \frac{Q \cdot b \cdot \frac{b}{2}}{b} = 2.06\ \text{kN}$	Reaction on the edge
$M := B_y \cdot \left(\frac{b}{2}\right) - \left(Q \cdot \left(\frac{b}{2}\right) \cdot \left(\frac{b}{4}\right)\right) = 232.3\ \text{N m}$	Moment at the middle of the sheet
$\sigma_b := \frac{M \cdot y}{I_x} = 174.22\ \text{MPa}$	Stress caused by moment
$V := \frac{B_y}{t \cdot l} = 0.26\ \text{MPa}$	Shear stress maximum

Allowable yield stress of 319.5 MPa not exceeded.

Egg Crate Cover Screeding

$P_{allow} := 20\ \mathrm{kN}$	Allowable Point Load on the Cover
$w := 1000\ \mathrm{mm}$	Width of cover
$l := 3000\ \mathrm{mm}$	Length of cover
$d := 50\ \mathrm{mm}$	Depth of Cover
$P := 1.2 \cdot \rho_s \cdot g \cdot w \cdot l \cdot d = 3.53\ \mathrm{kN}$	Load on the cover due to the screed

The screed does not exceed the loading limit.