Eskom	Standard	Technology

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1. Introduction

This document outlines the design of substation on-terrace drainage design. Substation on-terrace drainage are designed to efficiently collect and discharge surface water that could potentially damage substation components such as foundations, electrical equipment and access roads; subsequently causing electrical failure or loss of life.

2. Supporting clauses

2.1 Scope

This standard sets out the minimum requirements for Eskom substation on-terrace drainage design and construction. It is limited specifically to the design of on-terrace drainage systems and is based on the principle of storm water collection, detention and discharge through a network of subsoil drains and concrete pipes. This document excludes oil drainage and containment.

2.1.1 Purpose

Due to the uniqueness, complexities and dynamic demands arising in Substation on-terrace drainage design, there is much ambiguity with regards to the design approach. This document will standardise Eskom Substations on-terrace drainage designs, ensuring that all drainage designs are approached according to South African codes and legislation. It will serve as a guideline for terrace drainage design and construction with the intention of achieving a standard approach that can be adopted in all substation on -terrace drainage designs.

This Drainage standard presents clear and concise technical requirements, policies, and processes to enable design professionals to prepare designs and specifications necessary for the development of drainage projects within Eskom. This document is not to be considered complete or as a substitute for the requirements of the Drainage Codes, or other applicable laws. Should any conflicts arise between the information contained in this document and the Drainage Codes, the information contained within the Drainage Codes shall govern.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions.

2.2 Normative/informative references

2.2.1 Normative

[1] ISO 9001 Quality Management Systems.

[2] SLDG 15 – 1, Substation Layout Drainage Guide 2011.

[3] Eskom H.V Yard Civil Work standard 054/390 series drawings

2.2.2 Informative

[4] Constitution of the Republic of South Africa Act No 108 of 1996

[5] National Water Act (NWA) Act No 36 of 1998

[6] Environmental Conservation Act (Act No 73 of 1989)

[7] National Roads Act (Act No 54 of 1971)

[8] National Building regulations and Building Standards Act (Act No 103 of 1997)

[9] Conservation of Agricultural Resources Act No 43 of 1983

[10] SANRAL Drainage Manual 6th Edition ISBN 978-0-620-55428-2

[11] Guideline for Human Settlement Planning and Design-Volume 1 and 2 ISBN 0-7988-5498-7

[12] SANS 1200 LD - Manhole design

[13] SANS 2001-DP5 – Construction works Part DP5: Stormwater Drainage

[14] SANS 10120 – 2 LE: Stormwater drainage

[15] SANS 10120 – 3 LE: Guidance for design Section LE: Stormwater drainage

[16] SANS 10120 – 4 LE: Typical Schedules of Quantities

[17] The South African Guidelines for Sustainable Drainage Systems, WRC Report No. TT 558/13, 2013

[18] 240-102393009: Standard for substation flood analysis design

2.3 Definitions

2.3.1 General

Definition	Description
Catchment	A geographical area in which a drainage network is designed for.
Manhole	A structure designed and constructed to provide access to the water collection system for cleaning and maintenance purposes.
Return period	Is also known as a recurrence interval, which is an estimate of the probability of an event such as a flood discharge flow to occur. It is used for risk analysis and is measured statistically based on historical data over an extended period of time. It is usually denoted as the average Recurrence Interval.
Runoff	Is the rate of discharge of precipitation on the catchment area. This is the portion that reaches a stream or drain.
Stormwater	Water discharged from a catchment area after a flood or heavy rain.
Terrace	A raised, or dropped open flat area designed to be the substation yard.

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

The following table is a list of all the abbreviations used in this document.

Abbreviation	Description
DWA	Department of Water Affairs
SANRAL	South African National Roads Agency SOC Limited
SANS	South African National Standard
SLDG	Substation Layout Design Guidelines

2.5 Roles and responsibilities

All designers and contractors associated with the design and construction of substation.

2.6 Process for monitoring

Monitoring and Maintenance is to be done by the owner of the drainage infrastructure.

2.7 Related/supporting documents

The following policies, codes and legislation are used during stormwater design and should be considered in all substation stormwater designs.

- Constitution of the Republic of South Africa Act No 108 of 1996
- National Water Act (NWA) Act No 36 of 1998
- Environmental Conservation Act (Act No 73 of 1989)
- National Roads Act (Act No 54 of 1971)
- National Building regulations and Building Standards Act (Act No 103 of 1997)
- Conservation of Agricultural Resources Act No 43 of 1983
- SANRAL Drainage Manual 6th Edition ISBN 978-0-620-55428-2
- Guideline for Human Settlement Planning and Design-Volume 1 and 2 ISBN 0-7988-5498-7
- Manhole Design SANS 1200 LD
- Substation Layout Design Guidelines (SLDG)
- Eskom H.V Yard Civil Work standard 054/390 series drawings

3. Site drainage infrastructure design standard

3.1 Design

The stormwater management and drainage design specification will discuss the procedure to follow when designing a stormwater management system for substations.

3.1.1 Input Documents

Terrace design is vital as it allows for the creation of a substation platform that ensures substation equipment foundations are laid on competent material that meets the required bearing capacity. The slopes, contours and levels are analysed so that water can be diverted off terrace through the use of berms and cut off drains ensuring that the substation does not flood. Contours show the direction in which water will flow and are used to determine the fall of the terrace that will allow for water to drain off terrace. Preference is given to site topography that allows for gravity drainage using nominally approved falls across the substation.

Foundations, Trenches and Bay Layouts (Electrical) are required so that the actual positions of the foundations for the electrical equipment and the cable trenches are marked so that they do not clash with main pipes and subsoil drains. In drainage design, subsoils must be placed before every cable trench to collect all water that may potentially enter into the trenches. Surface drains or subsoil drains must be constructed over the full length of the site at adequate spacing to fully drain the site taking into consideration the positions of foundations, trenches and specific soil conditions in which they are installed. All drains must be of adequate strength to prevent damage from vehicular or pedestrian traffic in the substation. There must be no standing water that could impact on the operation, inspection and maintenance of the substation during the 1:50 return periods. The foundations, trenches and bay layouts are all referenced to create a single layout. Drainage layouts shall include the following information:

- Survey information, contour layout of existing surfaces
- All existing service and cadastral information
- Manhole numbers, cover levels and invert levels of all branches
- Co-ordinate list of all members
- Pipe diameters, classes and slopes
- Finished road surface contours of all intersections

- Grid positions (y, x) at regular intervals
- Legend for Services
- North point
- Locality plan with sufficient information to uniquely identify the location

3.1.2 Rainfall data

Terrace drainage design takes into consideration the local precipitation that runs off across the surface of the substation. Site drainage must be provided within the substation yard for a design rainfall Average Recurrence Interval (ARI) of 1 in 50 years to maintain a well-drained site, free of ponding and does not allow for any runoff from adjacent land. Rainfall data is usually displayed on a map to show quantity and distribution of rainfall at a specific area over certain periods of time. Reliable weather and climate related data is obtained from South African Weather Service (SAWS) so that substations are designed for resilience to extreme weather events. Mean Annual Precipitation (MAP) is the required parameter obtained through a series of calculations that are associated with rainfall data.

3.1.3 Design methods

There are numerous approaches based on rainfall or run-off data that are used for flood estimation in South Africa. The hydrological method is the preferred method that can be applied to substation drainage. The flood estimation methods that can be used are listed in the SANRAL drainage manual as follows:

- Statistical methods
- Rational methods
- Unit hydrograph method
- Standard design flood (SDF) method
- Soil Conservation Service South Africa (SCS-SA) method
- Empirical methods

The abovementioned methods have been developed based on measured statistical data; or on a deterministic basis; or an empirical relationship. The methods were calibrated for certain regions and flood events but are limited to the size of the catchment areas which they can be applied to.

In substation on-terrace drainage design, the rational method is used due to its effectiveness in flood estimations of catchment areas that are smaller than 15 km^2, as suggested in table 3.2 of the SANRAL drainage manual.

3.1.4 Design solution

Terrace drainage is designed based on the principle of storm water flowing through the yard stones on the terrace level. The substation is deliberately divided into numerous effective catchment areas. This allows for adequately designed subsoils to collect run-off water in these “smaller” areas. Run-off water is collected through a series of connected discharge pipes that drain water throughout the entire catchment area. The catchment area is split using a network of storm water pipes and subsoils that intersect to form an intentional square or a rectangular shape that would simplify the effective area calculations. A man-hole is installed at every intersection between the storm water pipe and the subsoil thus completing a closed rectangular shape. The determination of the area that can be drained by the perforated pipes is obtained from the following formula:

$$Q = c.i.A$$

Where:

Q = Peak flow (m^3/s)

c = Run-off coefficient

i = Average rainfall intensity (m/s)

A = Effective area of catchment (m^2)

The run-off coefficient is determined through the stone on a flat compacted terrace as for built up areas, as described in the SLDG. Thus

c = 0.4

When determining the average rainfall intensity (i) for use in the rational method, the following factors need to be considered:

Frequency of occurrence (return period)

Intensity-duration characteristics for a chosen return period

The time of concentration (storm duration)

To obtain the largest possible peak discharge for the given return period using the rational method, the storm rainfall duration is equal to the time required for the whole catchment to contribute to run-off at the outlet, known as the time of concentration (t_c).

A set of equations was developed to calculate the point of precipitation intensity in South Africa. When calculating the intensity (i), the location (inland or coastal), the Mean Annual Precipitation (MAP), the storm duration and the return period are required (Haarhoff & Cassa, 2009).

$$\mathrm{i = (reginal\ factor)\ x\ (MAP\ Factor)\ x\ (frequency\ factor)}$$

Where:

$$\mathrm{regional\ factor\ (inland)} = \frac{217.8}{(1 + 4.164t)^{0.8832}}$$

$$\mathrm{regional\ factor\ (coastal)} = \frac{122.8}{(1 + 4.779t)^{0.7372}}$$

$$\mathrm{MAP\ Factor} = \frac{18.79 + 0.17(\mathrm{MAP})}{100}$$

i = precipitation intensity (mm/hr)

t = storm duration or time of concentration (hr)

MAP = Mean Annual Precipitation (mm/year)

Table 1: The frequency factor based on the return period

Return period (years)	Frequency factor
2	0.47
5	0.64
10	0.81
20	1.00
50	1.30
100	1.60

*Table obtained from Introduction to flood hydrology

The time of concentration of overland flow is obtained from the formula:

$$t_c = \left[\frac{0.87\ \mathrm{x}\ L^2}{1000\ \mathrm{x}\ S}\right]^{0.385}$$

Where:

t_c = Time of concentration for overland flow (hr)

L = The shortest water-course or the overland flow length (km)

S = Slope of the terrain conveying the overland flow

It is important to note that all storm water lines must be placed to avoid any clashes with the equipment foundations, cable trenches or any other service in the yard. Since the construction of the terrace naturally disturbs the run-off characteristics, off terrace drainage should be designed for, through the use of cut-off drains placed on the edges of the terrace or on on-terrace roads to divert run-off water.

Theoretically, application of the above equation (for time of concentration) requires the slope to be calculated using the 1085 method. However, in substations, the slope is usually taken as the slope of the terrace which is determined during the cut and fills process.

3.2 Construction

3.2.1 Subsoils

Surface drains or subsoil drains must be constructed over the full length of the site at adequate spacing to fully drain the site considering the specific soil conditions in which they are installed. Where a roadway's performance may be affected by groundwater, sub-soil drains shall be constructed parallel to the roadway to intercept groundwater. Subsoil drains may also be required to mitigate the effects of groundwater on foundations, retaining walls, drainage structures. All subsoils should be provided with piped systems that are connected by means of manholes. The pipes shall have a stone bedding and geotextile blanket with the perforations or holes in the pipe being laid according to the manufacturer's guidelines. Eskom subsoils must be designed with reference to the H.V Yard Civil Work standard 054/390 series drawings. Figure 1 below is an example of how subsoils are designed according to Eskom standards.

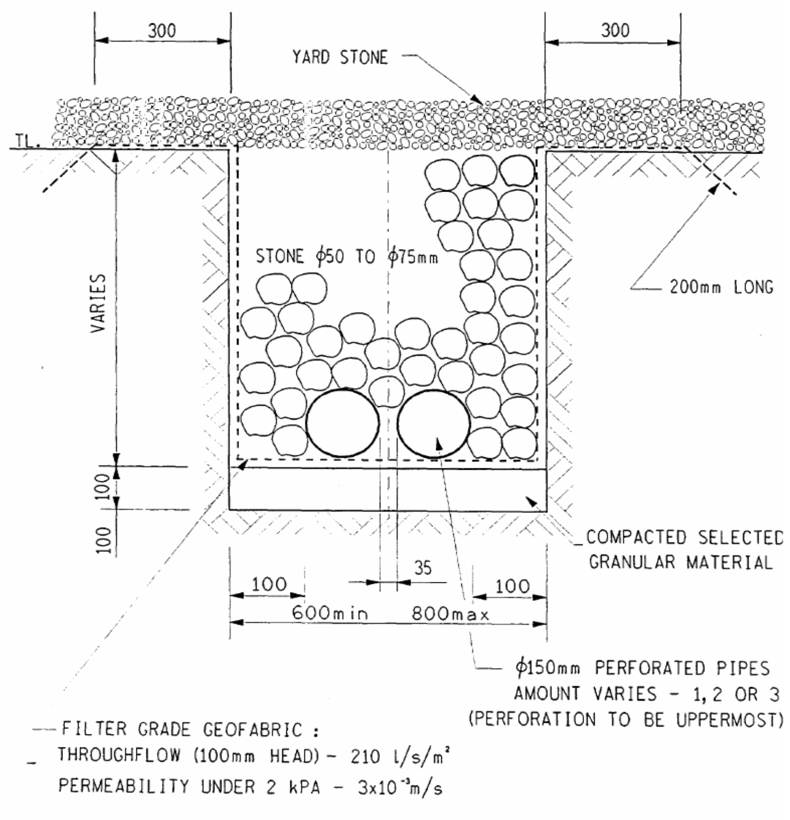


Figure 1: Substation soil drain detail

3.2.2 Concrete pipes

Installation of pipes must be in accordance with SANS 10400 Part R: Stormwater Disposal. According to clause 4.2.2.7, the minimum diameter of pipes shall not be less than 300 mm. Stormwater pipe should be designed to facilitate maintenance and have a sufficient velocity to reduce siltation. Access to pipes for cleaning purposes according to the standard shall be provided at maximum intervals of 40 m. However, substations are closed systems in nature and the probability of solid deposition or debris in the pipes rarely occurs. Hence, for substations a maximum interval of 50 m will be adequate since a manhole is installed in every connection point, change in direction or change in pipe size of the drainage network.

Note: Table 2 below is adopted from CSIR's Guidelines for human settlement planning and design (2000) and as used in SANS 10400 – Part R to provide guidance on the design of stormwater disposal systems. In substation drainage, the absolute minimum gradient shall be used.

Table 2: Minimum stormwater pipe gradients

Pipe diameter (mm)	Desirable minimum gradient (1 in ...)	Absolute minimum gradient (1 in ...)
300	80	23000
375	110	300
450	140	400
525	170	500
600	200	600
675	240	700
750	280	800
825	320	900
900	350	1000
1050	440	1250
1200	520	1500

3.2.3 Manholes

A manhole is an opening that is used as an access point for inspection and maintenance operations of stormwater networks. Manholes should be designed to ensure structural integrity during installation and normal service life. They should generally be watertight and strong to support applied loads resulting from substation equipment and vehicles. Manholes are provided at all pipe junctions where there is a change in direction, pipe size and at each intersection or termination on the main stormwater line. Manholes should be designed according to SANS 1200 LD or the Guidelines for Human Settlement Planning and design manual. However, for Eskom substations, manholes are to be constructed with reinforced concrete according to the H.V Yard Civil Work standard 054/390 series drawings 1, 1a, 1b, 2 and 2a as shown in table 3 below.

Table 3: Types of manholes

Type of Manhole	Minimum inlet or outlet pipe diameter (mm)	Depth Range* (m)	Drawing No. (054/390)
Standard manhole	300	0 - 4.0	Detail 1
Standard manhole	300	0 - 8.0	Detail 1b
Manhole locking bar	450	n/a	Detail 1a

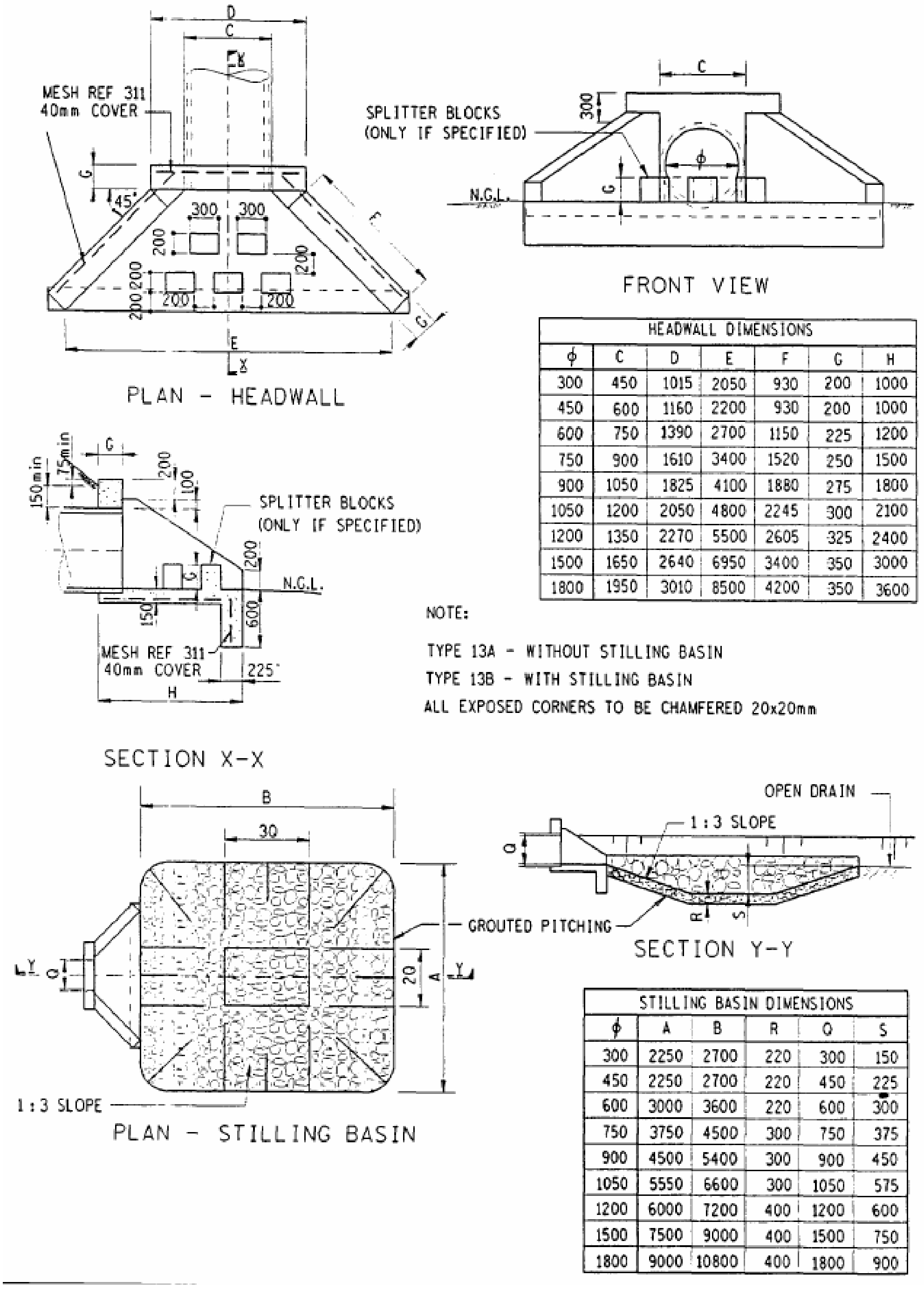
3.2.4 Kerbs and gutters

Kerbs and gutters must be installed along the external edges of all perimeter roads to prevent damage from frequent flooding and run-off to adjacent properties. Kerbs and gutters should ensure that water is released onto natural or man-made water ways without the risk of downstream flooding. Kerbs and gutters are to be designed and constructed according to the H.V Yard Civil Work standard 054/390 series drawings 04 – 08.

3.2.5 Headwalls and stilling basins

Headwalls are provided at positions where the drainage system discharges into the open. The discharge point is usually designed to facilitate maintenance procedures. Where main pipes exceed a diameter of 300 mm, the headwall is designed to prevent unauthorised access. Where drainage falls into a watercourse, provisions must be made to protect the bank from scouring or erosion around the headwall. In situations where the anticipated flow velocity is high, energy dissipators on the apron must be used to prevent erosion of the surface bed. Erosion on or around the discharge point must be considered along with protection measures in the design phase. The designs should follow best practice guides on the erosion around outfalls as per the local Environmental Agency Acts.

Downstream flow creates the risk of scouring, thus consequently putting downstream or outlet structures into risk of damage. When water flows at a high velocity, it possesses potential energy due to its altitude. The potential energy is then converted to kinetic energy due to the flow of water. A stilling basin dissipates the excess kinetic energy associated with water flowing over a spillway through a tunnel or pipe outlet into the downstream channel. The stilling basin is designed to reduce the high flow velocity of water. The reduction of flow velocity results in the reduction of kinetic energy. As the energy of the water drops, its potential to endanger the stability of the bed, banks and the downstream channel reduces. For Eskom substations, headwalls and stilling basins are to be constructed according to the H.V Yard Civil Work standard 054/390 series drawings 13a, 13b as shown in figure 2 below.



HEADWALL DIMENSIONS

ϕ	C	D	E	F	G	H
300	450	1015	2050	930	200	1000
450	600	1160	2200	930	200	1000
600	750	1390	2700	1150	225	1200
750	900	1610	3400	1520	250	1500
900	1050	1825	4100	1880	275	1800
1050	1200	2050	4800	2245	300	2100
1200	1350	2270	5500	2605	325	2400
1500	1650	2640	6950	3400	350	3000
1800	1950	3010	8500	4200	350	3600

STILLING BASIN DIMENSIONS

ϕ	A	B	R	Q	S
300	2250	2700	220	300	150
450	2250	2700	220	450	225
600	3000	3600	220	600	300
750	3750	4500	300	750	375
900	4500	5400	300	900	450
1050	5550	6600	300	1050	575
1200	6000	7200	400	1200	600
1500	7500	9000	400	1500	750
1800	9000	10800	400	1800	900

Figure 2: Headwalls and stilling basins

4. Authorization

This document has been seen and accepted by:

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5. Revisions

Date	Rev	Compiler	Remarks
Nov 2020	1	Bongani Ndlovu	First issue

6. Development team

The following people were involved in the development of this document:

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7. Acknowledgements

- Bongani Ndlovu

8. Bibliography

Haarhoff, J., & Cassa, A. (2009). *Introduction to Flood Hydrology.* Johannesburg.