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THE UPGRADE OF DISTRICT ROAD D1841, D1842 & D1884

Stormwater Management Plan

March 2016

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QUALITY VERIFICATION

This Report has been prepared under the controls established by a Quality Management System that meets the requirements of ISO9001: 2008:

VERIFICATION	CAPACITY	NAME	SIGNATURE	DATE
Checked by	Project Manager L. Reitz	L. Reitz	[signature]	31 March 2016
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1 INTRODUCTION

1.1 Background

Royal HaskoningDHV have been appointed by the Province of KwaZulu-Natal: Department of Transport (hereafter referred to as KZN: DOT) to undertake the engineering specialist studies, preliminary design, detailed design and the construction supervision for the upgrade of gravel District Roads D1841, D1842 and D1884 which totals approximately 32,1 km in length.

The upgrade of District Roads D1841, D1842 and D1884 comprises the relocation of services, the provision of surface and road prism drainage structures, the construction of bulk earthworks required for the horizontal and vertical alignment of the existing road formation and the construction of road layerworks and surfacing, including the associated ancillary works for the construction of the access roads of these district roads to neighbouring communities. The required roadworks start at km 0,0 in Ndumo Town at the intersection of Main Road 435 and continues through the towns of Mbadleni, Khume, Magwandu and terminates at eKhuhlehleni totalling a length of approximately 32,1 km.

This portion (km 0, 0 to km 32, 1) of existing gravel road will be upgraded to a Classs 3 single carriageway 7, 5 m wide surfaced road with 1,0m wide surfaced shoulders including adequate stormwater drainage facilities provided.

The one major structure which crosses the UMsunduze River is located at km 10, 4 along the new proposed alignment of D1841 and consists of 4 box cells with dimensions 4,8m x 4,8m.

1.2 Site locality and description

Figure 1 shows the locality plan for the upgrade of District Roads D1841, D1842 and D1884 which is located in the uMkhanyakude District Municipality within the Jozini Local Municipality.

District Roads D1841, D1842 and D1884 comprise a portion of the Ndumo to eKuhlehleni roads upgrade corridor project. By upgrading these roads which forms the link between the eKuhlehleni Pass and Ndumo via eManyiseni, provision of an important east to west desire line is achieved in combination with the eKuhlehleni Pass. This route will give access to the markets in Big Bend and Ndumo as well as serving as an important tourist route. To achieve an improved, more direct route between eManyiseni and Ndumo a re-alignment is proposed. This 6km long realignment will result in a 5km reduction in distance.

Currently, this Ndumo to eKuhlehleni road upgrade corridor link passes through a combination of flat, rolling and mountainous topography.

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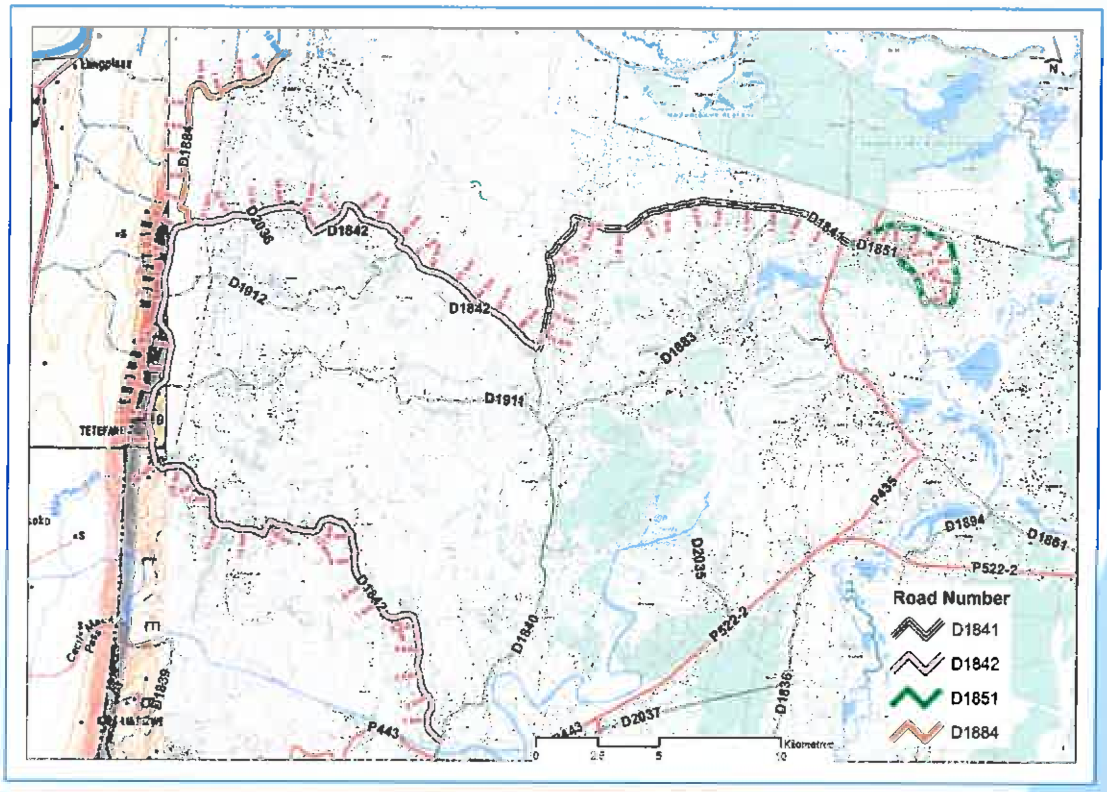

Figure 1: Locality plan

2 OBJECTIVE

The primary objective of this report is to outline the Stormwater Management Plan for District Roads D1841, D1842 and D1884 from km 0,0 to km 32,1. These objectives include the following:

- Protecting all life and property from damages by floods and in case of malfunctioning stormwater systems
- Protecting the water resources in the catchment areas from pollution and siltation.
- Protecting and enhancing the watercourses locally and downstream.
- Conserving the natural flora and fauna in the environment.
- Preventing soil erosion by wind and water.
- Sustainability of stormwater management systems

This report has been prepared to provide details of the analysis to ensure that adequate drainage measures are implemented to promote the dissipation of stormwater run-off, during and after construction.

2.1 Environmental Concern

Poor storm water management can result in storm water becoming contaminated. This can also result in flooding, erosion and damage to the environment and public property. Soil erosion through poor storm water management can result in loss of valuable topsoil, damage to public property through slope destabilisation, collapsing of banks and in extreme cases, mudslides. Erosion can also result in silt depositions in watercourses and wetlands adding to the existing silt problem.

Exposed soils are vulnerable to erosion by wind and water. Soil erosion is more likely to occur in summer months due to higher rainfall and temperatures causing shrinkage and collapse of soils. Soils are particularly vulnerable to erosion during construction as they are exposed to the elements while changes in surface run off patterns occure due to construction activities.

3 METHODOLOGY

3.1 Introduction

The main aim of a proposed stormwater system is to conserve the natural drainage system surrounding the road alignment.

A stormwater system includes any and all measures provided to accommodate and transport the stormwater runoff out of the system.

The existing stormwater system consists of natural water ways, including streams, rivers and seasonal wetlands. The system includes existing devices constructed to control the stormwater. The existing gravel road has drainage structures that forms part of this stormwater system.

The management of stormwater runoff has been planned to mitigate against the effects of increased water runoff from hardened areas and to control the movement of sand and silt.

Roads and associated embankments have been designed to ensure free surface drainage.

The proposed stormwater system will be dependent on factors such as the topography (natural and artificial slopes), the zoning of the site and the natural soil conditions.

Silt and trash traps will need to be provided within the stormwater system to ensure that the water quality is not compromised. Open ditches, drains and channels should be used instead of pipes, where conditions permit. To prevent erosion of the channels, where the flow velocities are high, an appropriate lining should be provided to protect these channels. Types of lining include natural vegetation, stone pitching and reinforced concrete linings.

The proposed development should not adversely impact the environment within its footprint and the surrounding areas by means of erosion and sediment deposition. The frequency of flooding and the runoff volume will increase unless adequate provisions are made to maintain the current natural rate of stormwater attenuation and infiltration in the catchment areas.

The proposed storm water system will have mitigation measures against road drainage and also cross drainage, with the aim of eliminating blockage and to reduce erosion. Gabion structures have been designed in such a way that water velocities are reduced as much as possible.

3.2 Stormwater Design Philosophy

The design methodology used for the stormwater is in accordance with The South African National Roads Agency SOC Limited (SANRAL) Drainage Manual 6th Edition. The stormwater design complies with all the applicable Kwazulu-Natal Department of Transport (KZN DOT) guidelines namely the Standard Specifications, the Drainage Manual and the Standard Drawings.

The Rational Method (SANRAL Drainage Manual 6th Edition) were used to calculate the flood peaks for the stormwater design as the individual catchment areas for the road and minor culvert structures are less than 15 km^2.

The Standard Design Flood Method (SANRAL Drainage Manual 6^{th} Edition) was used for the design of one (1) major structure crossing the uMsunduze River.

These roads have been classified as a Type 3 rural road therefore a design return period of 1:10 shall be used as specified in Figure 5.2 of the SANRAL Drainage Manual 6^{th} Edition.

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3.3 Stormwater Design Considerations

3.3.1 Minor drainage culverts and Structures

Design approach is to allow the storm water to flow through the culverts aligned along the natural watercourse. Natural drainage v-drains and down-chutes for erosion protection works have been designed. Culvert capacity of 1: 10 year storm and 50% blockage has been assessed in sizing of critical pipes.

The proposed upgraded storm water system will consist of pipes ranging in diameter from 600 mm to 1200 mm which will be strategically placed to regularly disperse overland and road surface run-off collected in side drains.

Outlet structures at a culvert or a natural watercourse were designed and equipped with energy dissipaters to reduce velocities to natural flow in order to mitigate the impacts of erosion in addition also protecting the unlined downstream channels against soil erosion.

Each outlet condition has been assessed to control and minimise scour for slope protection works. Larger concrete pipes and portals will be installed on natural water courses, while special attention is given to erosion protection.

3.3.2 Roads

The proposed road was designed and graded to avoid the concentration of water flow along and off the road. Where the flow concentration is unavoidable, measures were incorporated in the road and stormwater system at suitable points.

Unlined meadow drains and concrete lined v-drains were provided along the edge of the road as necessary. These drainage facilities will serve to channel the stormwater to the predetermined discharge positions. Stormwater will either be discharged directly onto the grassland or onto the gabion mattress structures stone pitching, depending on the discharge velocities.

Concrete kerbing and channelling will be provided along the edge of the road as necessary. These drainage facilities will serve to channel the stormwater to the predetermined discharge positions. Stormwater will be discharged directly onto the grassland.

The flow depth along these side drains were designed to satisfy the criteria in Figure 5.2 of the SANRAL Drainage Manual 6th edition. The applicable KZN: DOT standard details for the kerb and channel elements shall be in accordance with SD0701/A.

The applicable KZN: DOT standard details for the entire drainage elements are from SD0406 to SD0702/A. Table 1 below outlines the options adopted for use as side drain outlets.

Table 1: Options adopted for use as side drain outlets

Discharge Type	Standard Detail Name	Condition for use
Drop inlet and grid inlet	SD 0702/A	Deep fill > 3 m
Kerb and Channel drains	SD 0701/A	Shallow fill < 3 m
Side drain outlets	SD 0603/1	Shallow fill < 3 m
1,5 m / 2,4 m v-drain grid inlet	SD 0602/B	In cuttings
2,5 m Meadow drain	SD 0601/1	Flat terrain
1,5 m concrete/grass v-drain	SD 0601/2	Deep cuttings > 5 m
0,75 m concrete v-drain	SD 0601/3	Shallow cuttings < 5 m
1,5 m concrete v-drain	SD 0601/4	Shallow cuttings < 5 m
1,5 m / 2,4 m v-drain	SD 0603/1	Shallow fill < 3 m
Side drain and grid inlet	SD 0602/B	In cuttings

Side drains will be designed to the extent that it has sufficient capacity to collect and convey water from the cut slopes, road surface and general up-sloping terrain. However, if this is not possible catchwater banks will be constructed to reduce the flows towards these side drains.

All the grid inlets will lead to cross-road drainage pipes. Other stormwater drainage pipes will be installed at high fills to prevent the ponding of water.

Scour on high fill banks (height greater than 3 m) shall be prevented by using kerb and channel side drains to collect water and discharge it at predetermined positions via appropriate inlets.

Subsoil pipe systems will be installed in cut situations to collect any groundwater from the cut banks. The subsoil system will either discharge water onto the fill banks, stormwater manholes, outlet and inlet field structures and road side inlets.

3.4 Stormwater Management

Stormwater Management encourages the developer, professional teams and contractor to conduct the following aspects:

- Maintaining adequate ground cover at all times and in all areas to negate erosion caused by wind, water and vehicular traffic.
- Preventing the concentration of stormwater flow where the soil is susceptible to erosion.
- Adding devices to reduce the stormwater flows to acceptable levels.
- Ensuring that the development does not increase the stormwater flow above that of which the natural ground can safely accommodate.
- Ensuring that the construction of the stormwater devices is carried out in a safe and aesthetic manner.
- Preventing pollution of water ways and water features.
- Containing soil erosion during construction.
- Avoiding conditions where the embankments may become saturated and unstable.

Poor stormwater management can result in the stormwater becoming contaminated and can also result in erosion, pollution and flooding. These issues are discussed further in the following subitems.

3.4.1 Erosion control

Suitable erosion control measures shall be implemented at stormwater discharge points, exposed areas and high embankments. These measures may include the following options:

- Sand bags on trenches (trench breakers).
- Bunds or grips adjacent to watercourses.
- Technologies similar to Soil Saver on embankments.
- Planting of indigenous vegetation on embankments.
- Minimise clearing and grubbing to necessary sections within the road reserve.
- Excavating borrow pit areas to ensure they are self-draining.
- Over-wetting, saturation and unnecessary runoff during dust control, curing and irrigation activities will be avoided.

Sandbag berms will be placed at regular intervals on all steep slopes and on the trench line before and after backfilling in order to minimise erosion and the discharge of contaminated storm water runoff into water courses.

If there is a scour risk or risks that potholes may form on the existing roads, it can be managed by using suitable gravel to temporarily repair the scouring or potholes.

3.4.2 Pollution

Pollution and or contamination of the surface water and stormwater must be well controlled. This can be achieved by managing activities such as:

- Mixing concrete on wooden boards in a plastic lined and leak-proof area.
- Removing all surplus material from the watercourse.
- Reducing spills of hazardous substances (e.g. Fuel).
- Opening of frequent chutes on long steep grades with unlined drains.
- Ensuring that banks are re-vegetated as soon as construction work is completed.
- Avoid water contamination by construction as well as general traffic.
- Containing the first-flush runoff, collectively or individually.

The stormwater system must be maintained to remove and reduce debris that may pose any pollution risk. The lack of maintenance will lower the transportation of the runoff to the existing watercourses and which may cause flooding.

3.4.3 Flooding

The proposed upgrade will not increase the stormwater runoff significantly as it is existing roads that are being upgraded. Adequate attenuation of flood runoff will be provided as the latter may increase downstream flood damage.

The design of the stormwater system addresses the above issues and was designed as such that the post-development flood risks are not greater than the pre-development flood risks.

4 CALCULATIONS

4.1 Pre-construction

The water catchment areas of concern along District Roads D1841, D1842 and D1884 were divided into one-hundred and ten (110) catchment areas which was then categorised either as overland run-off catchment, road prism run-off catchment or both. The schedule of these catchment areas is listed in Table 2 below.

Table 2: Schedule of catchment areas

Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)	Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)
CR1		0.0023	C33	0.03	0.0016
C1	0.769	0.0044	C34	0.115	0.0059
CR2	0.213	0.0049	C35	0.03	0.0008
C2	2.534	0.0095	C36	0.026	0.0020
CR3	0.337	0.0026	C36A		0.0038
C3	0.401	0.0052	C37	0.025	0.0016
C4	0.677	0.0020	C38	0.041	0.0050
CR4		0.0023	C38A	0.074	0.0063
C5-2	0.57	0.0000	C39	0.016	0.0014
CR5		0.0016	C40	0.015	0.0039
C5	10.880	0.0017	C41		0.0012
CR6		0.0028	C42		0.0007
CR7		0.0019	C43		0.0007

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Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)
C5-1	2.370	0.0042
C5-1-1	1.100	
CR8	0.081	0.0028
CR9	0.019	0.0020
CR10		0.0026
C5-1-1-1	0.094	0.0031
C5-1-1-2	0.04	0.0009
C5-1-1-3	0.303	0.0037
CR11		0.0017
CR12		0.0006
CR13		0.0020
CR5-1-1-4	0.137	0.0019
C5-1-1-5		0.0024
C6	0.21	0.0038
C7	0.04	0.0022
C8	0.0125	
C9	0.22	0.0070
RIVER 1	60.84	
C10	0.095	0.0056
CR14	0.034	0.0098
C11	0.008	
C12		0.0006
C13		0.0009
C14		0.0032
C15		0.0007
C16	0.06	0.0024
C17	0.017	0.0013
C18	0.028	0.0013
C19	0.023	0.0005
C20	0.029	0.0021
C21	0.0311	0.0046
C22	0.029	0.0029
C23	0.014	0.0030
C24		0.0024
C25		0.0015
C26		0.0007

Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)
C44	0.0066	0.0050
C45		0.0069
C46		0.0044
C47	0.0191	0.0070
C48		0.0019
C49		0.0011
C50	0.0079	0.0023
C51	0.003	0.0030
C52	0.037	0.0023
C53	0.021	0.0017
C54	0.013	0.0008
C55		0.0036
C56	0.0065	0.0009
C57	0.0026	0.0019
C58	0.0158	0.0026
C59	0.082	0.0084
C59A		0.0037
C60	0.0181	0.0016
C61	0.076	0.0034
C62	0.014	0.0006
C63		0.0075
C64	0.015	0.0038
C65	0.0135	0.0079
C66	0.023	0.0033
C67	0.0081	0.0074
C68	0.075	0.0052
C69	0.039	0.0038
C70	0.0195	0.0011
C71	0.021	0.0030
C72	0.008	0.0007
C73	0.0725	0.0041
C74	0.039	0.0024
C75	0.062	0.0051
C76	0.016	0.0002
C77	0.02	0.0019
C78		0.0013

Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)
C27		0.0007
C28		0.0017
C29		0.0086
C30		0.0051
C31		0.0060
C32		0.0013
C33	0.03	0.0016

Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)
C79		0.0040
C80		0.0015
C81		0.0026
C82		0.0023
C83		0.0022
C84		0.0015
C85		0.0024

4.2 Bridge/Culvert

One (1) major structure located in the form of 4No box culverts with a width and depth of 4, 8 m respectively have been designed. This structure is located at chainage km 10, 4 of the proposed alignment with a total length and depth of 21, 2 m and 5, 6 m respectively. The Standard Design Flood Method (SDF) was used which is in accordance with The South African National Roads Agency SOC Limited (SANRAL) Drainage Manual 6th Edition.

The design criterion for this structure is as follows:

- Catchment Area : 60, 84 km²
- Longest Collector : 25, 38 km
- 1085 Height Difference : 320
- Drainage Basin Number : 27
- Basin Mean Annual Precipitation: 890 mm
- 1085 Catchment Slope : 0, 0168 m/m
- Regional Maximum Flood RMF : 1634 m³/s
- Design Return Period QT : 20 years
- Design Peak Flow Rate : 293, 06 m³/s

4.3 Rainfall Return Period and Intensity

A rainfall intensity of 150 mm/hr was used to compute the road prism runoff for a 1:10 year flood with a runoff coefficient (C) of 1, 0.

4.4 Design principles

A 1:10 year flood was used to estimate the peak discharge for the catchment drainage. The depth of sheet flow on the road surface was limited to 6 mm during a 1:5 year storm. An intensity of 150 mm/hr was used to design the cutting side drainage system.

The stormwater drainage systems will be designed based on the following parameters:

- Mean Annual Rainfall – 700 mm
- Site characteristics:
  - Pre-development: $C_{pre\text{-}dev} = 0{,}442$
  - Post-development: $C_{post\text{-}dev} = 0{,}446$
- Design used:
  - Rational Method: $Q = \frac{CIA}{3{,}6}$ (equation 3.8, SANRAL Drainage Manual 6th Edition)
- Time of concentration:
  - Varies for each catchment and is three times the time of concentration i.e. $3T_C$.

- Stormwater pipe material:
  - For buried pipelines: Class ranges from 50D to 75D prefabricated concrete pipe culverts on Class C bedding.
  - For subsoil drainage: 100 mm internal diameter perforated pipes.
- Stormwater culvert sizes:
  - Pipe sizes: minimum 600 mm diameter to a maximum 1200 mm diameter
  - Box culvert sizes:minimum 600 x 450 Class 200S to a maximum 1800 x 900mm 75S
- Stormwater pipe gradient:
  - Minimum gradient of 2% for all prefabricated concrete pipe culverts.
- Stormwater inlets:
  - For roads: grid and kerb inlets.
- Stormwater manholes:
  - Materials: concrete foundation, 230 mm thick masonry walls.
  - Benching: smooth concrete channel formed to the soffit of the pipe.
- Stormwater headwalls:
  - Materials: concrete foundation, 230 mm thick masonry walls.

From the above design principles it can be seen that there was only a marginal increase in the run off coefficient (c) hence also resulting in a marginal increase in the rate of run off.

Manning's equation was used to compute the v-drain and meadow drain capacity by using a friction coefficient (n) of 0.015.

All the v-drains were designed to retain overland flow and road surface flow within the concrete lined portion of the drain. All the meadow drains are earth lined and are designed to accommodate flow velocities smaller than the scour velocity of gravel but great enough to avoid siltation.

4.5 Hydrology

The difference between the pre and post-development run-off coefficients were minimal which in effect generated minimal differences in the pre and post design peak flow rates. The Design Peak flow Rates per catchment and culverts sized have been specified in Tables 3 and 4 respectively below.

Table 3: Catchment Hydrological calculations

Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)	Design Flow Rate Q10 (m³/s)
CR1		0.0023	
C1	0.769	0.0044	5.77
CR2	0.213	0.0049	0.83
C2	2.534	0.0095	11.93
CR3	0.337	0.0026	0.94
C3	0.401	0.0052	0.94
C4	0.677	0.0020	1.53
CR4		0.0023	
C5-2	0.57	0.0000	1.34
CR5		0.0016	

Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)	Design Flow Rate Q10 (m³/s)
C33	0.03	0.0016	0.27
C34	0.115	0.0050	0.92
C35	0.03	0.0008	0.32
C36	0.026	0.0020	0.33
C36A		0.0038	
C37	0.025	0.0016	0.26
C38	0.041	0.0050	0.53
C38A	0.074	0.0063	0.83
C39	0.016	0.0014	0.17
C40	0.015	0.0039	0.18

Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)	Design Flow Rate Q10 (m³/s)
C5	10.880	0.0017	19.92
CR6		0.0028	
CR7		0.0019	
C5-1	2.370	0.0042	4.61
C5-1-1	1.100		2.15
CR8	0.081	0.0028	0.30
CR9	0.019	0.0020	0.12
CR10		0.0026	
C5-1-1-1	0.094	0.0031	0.37
C5-1-1-2	0.04	0.0009	0.15
C5-1-1-3	0.303	0.0037	0.81
CR11		0.0017	
CR12		0.0006	
CR13		0.0020	
CR5-1-1-4	0.137	0.0019	0.53
C5-1-1-5		0.0024	
C6	0.21	0.0038	0.49
C7	0.04	0.0022	0.17
C8	0.0125		0.07
C9	0.22	0.0070	0.81
RIVER 1	60.84		209.00
C10	0.095	0.0056	0.61
CR14	0.034	0.0098	0.33
C11	0.008		0.06
C12		0.0006	
C13		0.0009	
C14		0.0032	
C15		0.0007	
C16	0.06	0.0024	0.45
C17	0.017	0.0013	0.16
C18	0.028	0.0013	0.2
C19	0.023	0.0005	0.17
C20	0.029	0.0021	0.23

Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)	Design Flow Rate Q10 (m³/s)
C41		0.0012	
C42		0.0007	
C43		0.0007	
C44	0.0066	0.0050	0.12
C45		0.0069	
C46		0.0044	
C47	0.0191	0.0070	0.21
C48		0.0019	
C49		0.0011	
C50	0.0079	0.0023	0.13
C51	0.003	0.0030	
C52	0.037	0.0023	0.39
C53	0.021	0.0017	0.22
C54	0.013	0.0008	0.11
C55		0.0036	
C56	0.0065	0.0009	0.06
C57	0.0026	0.0019	0.06
C58	0.0158	0.0026	0.17
C59	0.082	0.0084	0 54
C59A		0.0037	
C60	0.0181	0.0016	0.21
C61	0.076	0.0034	0.58
C62	0.014	0.0006	0.08
C63		0.0075	
C64	0.015	0.0038	0.11
C65	0.0135	0.0079	0.22
C66	0.023	0.0033	0.17
C67	0.0081	0.0074	0.21
C68	0.075	0.0052	0.6
C69	0.039	0.0038	0.44
C70	0.0195	0.0011	0.19
C71	0.021	0.0030	0.15
C72	0.008	0.0007	0.12

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Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)	Design Flow Rate Q10 (m³/s)
C21	0.0311	0.0046	0.61
C22	0.029	0.0029	0.21
C23	0.014	0.0030	0.12
C24		0.0024	
C25		0.0015	
C26		0.0007	
C27		0.0007	
C28		0.0017	
C29		0.0086	
C30		0.0051	
C31		0.0060	
C32		0.0013	
C33	0.03	0.0016	0.27

Catchment Area No.	Overland Catchment Area (km²)	Road Prism Catchment Area (km²)	Design Flow Rate Q10 (m³/s)
C73	0.0725	0.0041	0.6
C74	0.039	0.0024	0.3
C75	0.062	0.0051	0.44
C76	0.016	0.0002	0.12
C77	0.02	0.0019	0.15
C78		0.0013	
C79		0.0040	
C80		0.0015	
C81		0.0026	
C82		0.0023	
C83		0.0022	
C84		0.0015	
C85		0.0024	

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Table 4: Culvert Hydrological calculations

Catchment Area No.	Culvert No.	Design Flow Rate Q10 (m^3/sec)	Proposed culvert size		Catchment Area No.	Culvert No.	Design Flow Rate Q10 (m^3/sec)	Proposed culvert size
	0/1		600 dia		C33	16/3	0.27	600 dia
C1	0/2	5.77	5/1050 dia		C34	16/4	0.92	900 dia
CR2	1/1	0.83	900 dia		C35	16/5	0.32	600 dia
C2	2/1	11.93	5/1,2 x 1,2m		C36	16/6	0.33	600 dia
CR3	2/2	0.94	2/750 dia		C36A	17/1		600 dia
C3	2/3	0.94	2/750 dia		C37	17/2	0.26	600 dia
C4	3/1	1.53	2/900 dia		C38	17/3	0.53	750 dia
	3/2		600		C38A	17/4	0.83	900 dia
C5-2	3/3	1.34	2/900 dia		C39	17/5	0.17	600 dia
	4/1		600		C40	18/1	0.18	600 dia
C5	4/2	19.92	4/1,5m x 1,5m		C41	18/2		600 dia
	4/3		600 dia		C42	18/3		600 dia
	4/4		600 dia		C43	18/4		600 dia
C5-1	4/5	4.61	2/1,2x1,2m		C44	18/5	0.12	600 dia
C5-1-1	5/1	2.15	1/1,2x1,2m		C45	19/1		600 dia
CR8	5/2	0.30	600 dia		C46	19/2		600 dia
CR9	5/3	0.12	600 dia		C47	20/1	0.21	600 dia
CR10	6/1		600 dia		C48	20/2		600 dia
C5-1-1-1	6/2	0.37	750 dia		C49	21/1		600 dia
C5-1-1-2	6/3	0.15	600 dia		C50	21/2	0.13	600 dia
C5-1-1-3	7/1	0.81	900 dia		C51	21/3		600 dia
	7/2		600		C52	22/1	0.39	750 dia
	7/3		600		C53	22/2	0.22	600 dia
	8/1		600		C54	22/3	0.11	600 dia
C5-1-1-4	8/2	0.53	750 dia		C55	22/4		600 dia
	8/3		600 dia		C56	23/1	0.06	600 dia
C6	8/4	0.49	750 dia		C57	23/2	0.06	600 dia
C7	9/1	0.17	600 dia		C58	23/3	0.17	600 dia
C8	9/2	0.07	600 dia		C59	23/4	0.54	750 dia
C9	9/3	0.81	900 dia			24/1		600 dia

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Catchment Area No.	Culvert No.	Design Flow Rate Q10 (m^3/sec)	Proposed culvert size	Catchment Area No.	Culvert No.	Design Flow Rate Q10 (m^3/sec)	Proposed culvert size
RIVER	10/1	209.00	4/4,8x4,8m	C60	24/2	0.21	600 dia
C10	10/2	0.61	900 dia	C61	24/3	0.58	750 dia
CR14	11/1	0.33	600 dia	C62	25/1	0.08	600 dia
C11	12/1	0.06	600 dia	C63	25/2		600 dia
C12	12/2		600 dia	C64	25/3	0.11	600 dia
C13	12/3		600 dia	C65	26/1	0.22	600 dia
C14	12/4		600 dia	C66	26/2	0.17	600 dia
C15	12/5		600 dia	C67	26/3	0.21	600 dia
C16	12/6	0.45	900 dia	C68	27/1	0.6	750 dia
C17	13/1	0.16	600 dia	C69	27/2	0.44	750 dia
C18	13/2	0.2	600 dia	C70	27/3	0.19	600 dia
C19	13/3	0.17	600 dia	C71	28/1	0.15	600 dia
C20	13/4	0.23	600 dia	C72	28/2	0.12	600 dia
C21	13/5	0.61	900 dia	C73	28/3	0.6	750 dia
C22	14/1	0.21	600 dia	C74	28/4	0.3	600 dia
C23	14/2	0.12	600 dia	C75	28/5	0.44	750 dia
C24	14/3		600 dia	C76	29/1	0.12	600 dia
C25	14/4		600 dia	C77	29/2	0.15	600 dia
C26	14/5		600 dia	C78	29/3		600 dia
C27	15/1		600 dia	C79	29/4		600 dia
C28	15/2		600 dia	C80	29/5		600 dia
C29	15/3		600 dia	C81	30/1		600 dia
C30	15/4		600 dia	C82	30/2		600 dia
C31	16/1		600 dia	C83	30/3		600 dia
C32	16/2		600 dia	C84	30/4		600 dia
C33	16/3	0.27	600 dia	C85	30/5		600 dia

5 CONCLUSION

It is often impossible to make reliable predictions concerning the full extent of erosion protection likely to be required until the road drainage system is fully functioning and the slopes and drainage channels have responded to the new drainage regime.

From the design principles specified in this report, it was seen that there was only a marginal increase in the run off coefficient (C) hence resulting in a marginal increase in the run off rate.

Pipe culverts and box culverts have been designed and strategically placed to ensure that cross and surface drainage is drained to the natural low lying areas, watercourses and valley lines without affecting the designed road.

This roads project upgrade will include new hardened areas such as surfaced roads, taxi bays and pedestrian walkways which will result in reduced infiltration areas, loss of vegetation and evapo-transpiration potential. There will be a slight increase in surface runoff and peak flow rates.

Side drains will be used to channel the stormwater away from the road prism. Gabion boxes and Reno mattresses will be used to retard the velocity of the stormwater and will allow the ground water to recharge and prevent scouring at outlet structures. In addition, stone pitching will be constructed at outlet structures to mitigate the scouring of the natural ground and simultaneously ensure efficient drainage of stormwater run-off from the outlet structures.

Where possible, stormwater will be discharged into the nearest existing natural drainage path via headwalls. Soil erosion and scouring will be prevented by providing gabion boxes, Reno mattresses and/or splitter blocks at the inlet and outlet structures.

Siltation of the stormwater systems will be prevented by ensuring that the drainage facilities are built such that the flow velocity is greater than 0, 25 m/s.

Landscaping and the planting of indigenous plants will be carried out along the footprint of the proposed roads upgrade footprint to ensure the stabilisation of the embankments.

Maintenance of the stormwater system must be carried out on a continuous basis to control and minimise pollution, blockages, siltation and scouring.

The detailed designed drawings and contract document indicates the measures provided in the design to ensure that the Stormwater Management requirements are implemented.

The contractor shall prepare a Stormwater Control Plan that will ensure that all construction methods adopted on site do not cause, or precipitate, soil erosion. The contractor shall take adequate steps to ensure that the requirements of the Stormwater Management Plan are met before, during and after construction. The contractor shall ensure that no construction activity commences before the Stormwater Control measures are in place and approved by the engineer on site.

6 REFERENCES

The Province of KwaZulu-Natal: Department of Transport, 1984. Drainage Manual. 1 Ed. Pietermaritzburg: Geometric Design Section, Provincial Roads Department.

The South African Roads Agency SOC Limited, 2013. Drainage Manual. 6 ed. Pretoria: The South African Roads Agency SOC Limited.