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THE SOUTH AFRICAN NATIONAL ROADS AGENCY SOC LIMITED

PROJECT NRA R.101-080-2019/1

THE IMPROVEMENT OF NATIONAL ROAD R101 SECTION 8 FROM BELA BELA (KM 0.0) TO MODIMOLLE (KM 26.8)

FINAL PRELIMINARY DESIGN REPORT

NOVEMBER 2020 **BOOK 1 of 2**

PREPARED FOR:

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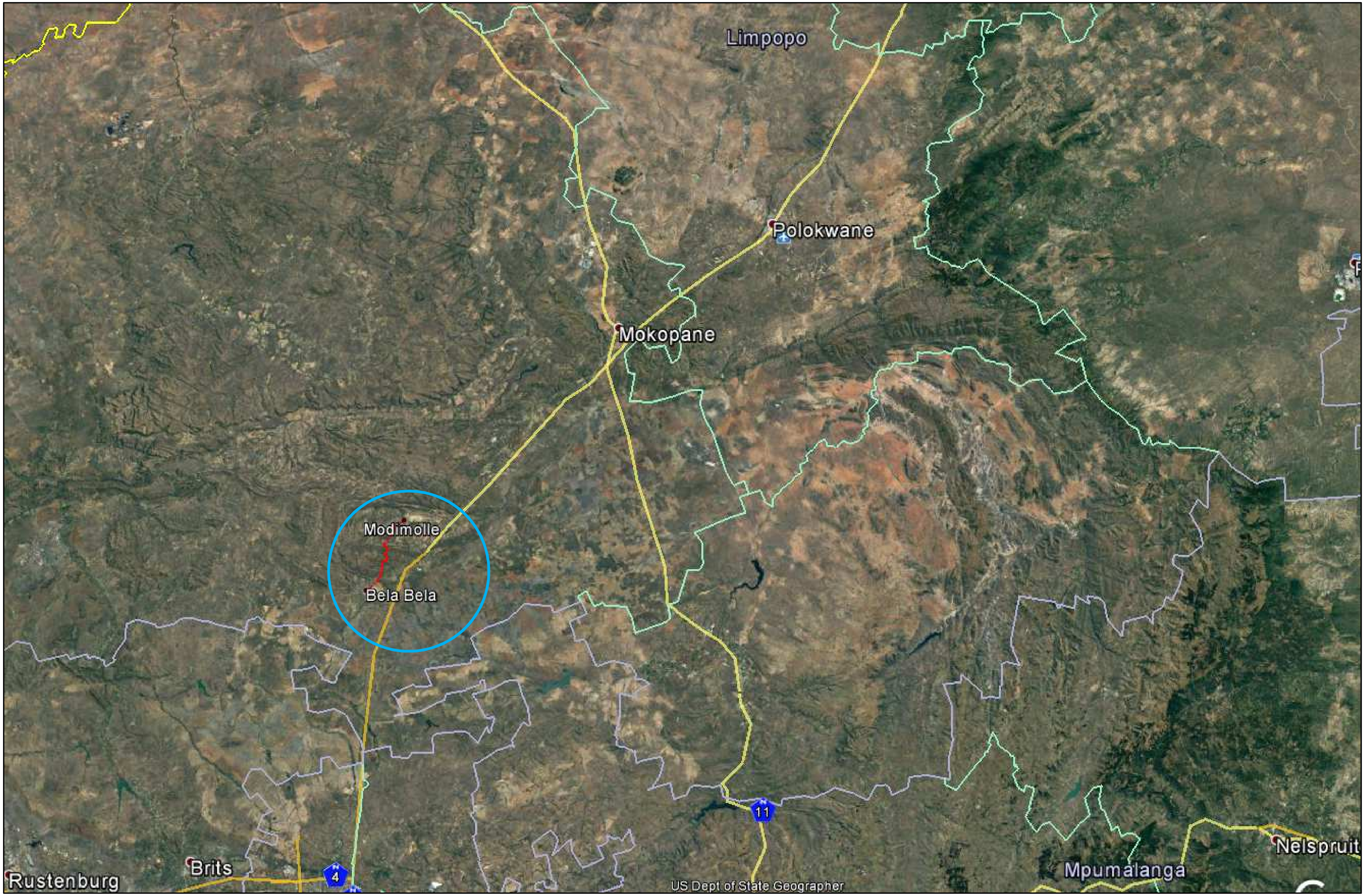
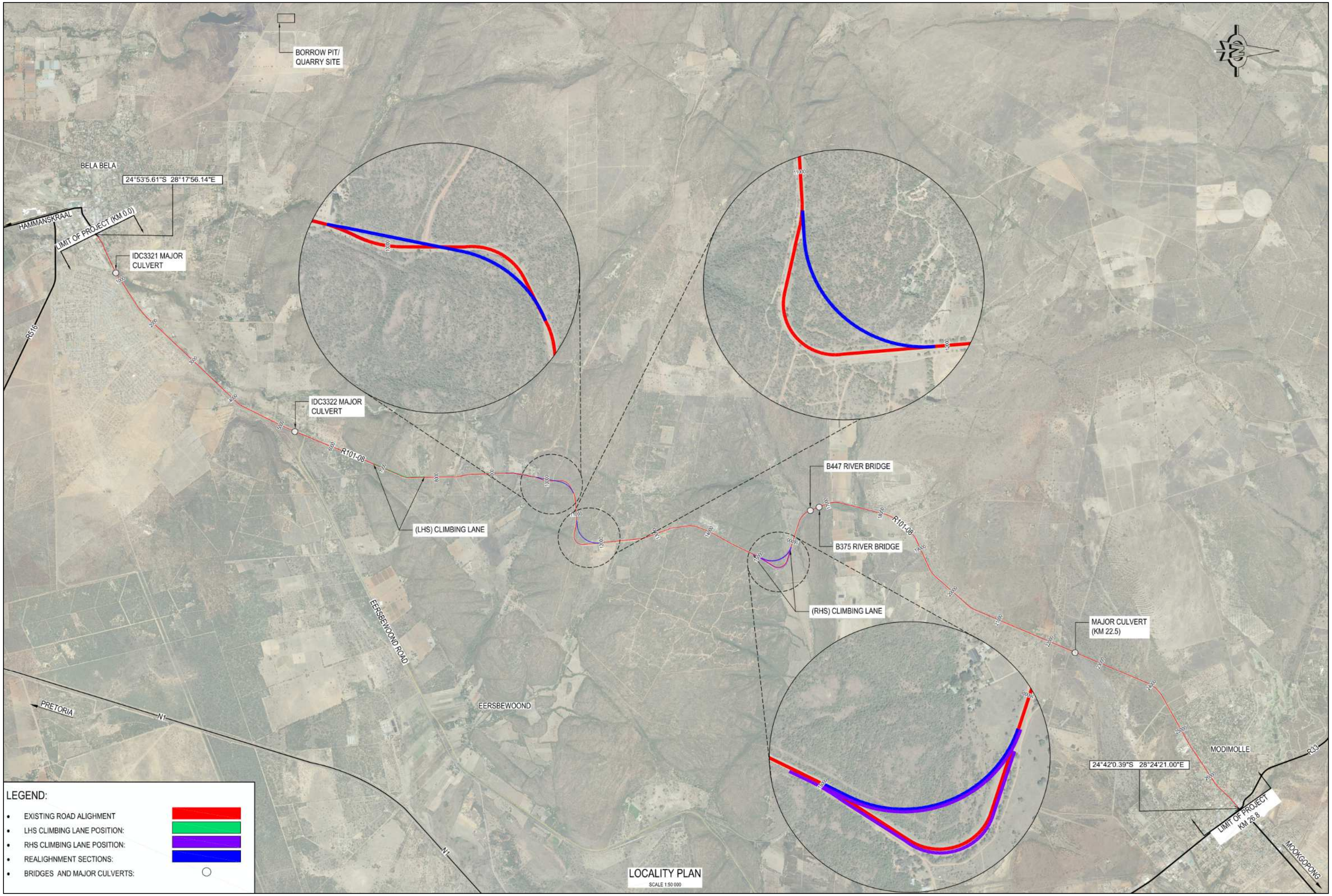


Locality Plan – General Location of Road R101 Section 8 (km 0.0 to km 26.8)



Layout Plan – Road R101 Section 8 (km 0.0 to km 26.8)

EXECUTIVE SUMMARY

INTRODUCTION

BVi Consulting Engineers Western Cape (Pty) Ltd was appointed by the S*outh African National Roads Agency SOC Limited (SANRAL)* to provide *Consulting Engineering Services for the Improvement of National Road R101 Section 8 from Bela Bela (km 0.0) to Modimolle (km 26.8)*. The contract was awarded on the 2nd of August 2018 followed by a handover meeting on 4th of September 2018.

National Road R101 Section 8 is situated within two Local Municipalities (Bela Bela and Modimolle-Mookgophong), both of which fall under the Waterberg District Municipality in the Limpopo Province. The project extends from Bela Bela at the intersection with Voortrekker Road (km 0.0) to Modimolle at the intersection with Road R33 (km 26.8).

The general objective of this project is to successfully and optimally complete improvement of the road section. The aim of this improvement is to:

- Relieve traffic congestion to acceptable level of service by providing suitable cross sections;
- Improve road geometry (alignment) to provide better road safety;
- Provide non-motorised transport (NMT) and pedestrian facilities;
- Provide adequate pavement capacity for a 20-year design period; and
- Widen and lift bridges and other structures where required for hydraulic and traffic capacity.

EXISTING ROAD INFORMATION AND CLASSIFICATION

Road R101-8 consists of a two lane, single carriageway road with gravel shoulders along most of the route. The road has an average surfaced width of 7.0 m. Climbing/passing lanes are provided from km 6.2 to km 7.5 (LHS) and km 14.4 to km 15.7 (RHS). Road R101-8 has an average road reserve width of approximately 35 meters.

In both Bela Bela (km 0.00 to km 0.10) and Modimolle (km 26.40 to km 26.80), the road widens to a four lane undivided single carriageway. A section in Modimolle (km 25.20 to km 26.40) consists of 3 lanes.

Road R101-8 is defined as a mobility road, connecting development centres over long distances. It also connects other collector roads and can therefore be classified as a Class 2 rural major arterial in accordance with *TRH 26 (COTO, 2012)*.

Furthermore, according to *Table 1* of *TRH4,* Road R101-8 falls within the interurban collector and rural roads category and can therefore be classified as ***a Category B Road***. This road category is seen as strategically important and is expected to deliver a good Level of Service (LOS) to its users.

TRAFFIC

Historic Traffic

Traffic data collected in 2015 is summarised in *Table 1* below. The data shows that the section from km 0.00 to km 2.22 and that from km 2.22 to km 5.44 have the same traffic volumes whereas the section from km 5.44 to km 24.83 shows a notable reduction in ADT volumes.

Table 1: Traffic summary (2015)

SEGMENT NO	FROM – TO (km – km)	SURVEYED	ADT (VEH/DAY)	ADTT (TRUCKS/DAY)	DIRECTIONAL SPLIT (ADT)	%HEAVY VEHICLE
1	0.00 – 2.22	2015-02-17	6 576	599	51 : 49	9.1%
2	2.22 – 5.44	2015-02-17	6 576	599	51 : 49	9.1%
3	5.44 – 26.80	2015-03-05	4 307	228	52 : 48	5.3%

7-day classified electronic traffic counts were conducted at three locations along Road R101-8 from 24 October 2018 to 1 November 2018. This data was used to determine the current traffic composition, speeds and the traffic variations on the route and is summarised in *Table 2*.

Table 2: 7-day traffic count summary (2018)

NO	LOCATION KM	STATION NAME	SEGMENT (km – km)	ADT (VEH/DAY)	ADTT (TRUCKS/DAY)	DIRECTIONAL SPLIT (ADT)	%HEAVY VEHICLE
1	3.03	1426	2.22 – 5.44	7 488	1 054	49 : 51	14.1%
2	6.70	1427	5.44 – 26.80	4 788	402	49 : 51	8.4%
3	23.40	1428	5.44 – 26.80	4 431	398	49 : 51	9.0%

The data shows that traffic volumes from station 1427 and 1428 are of the same order of magnitude with station 1427 volumes being higher. Data gathered from station 1427 was therefore used for the analysis of the uniform section from km 5.44 to km 26.80.

Growth Rates

Based on the available information above, high, medium and low growth rates were proposed for analysis. The growth rates are as follows:

- Low – 1.0% per year;
- Medium – 2.5% per year; and
- High – 4.0% per year.

Level of Service

The Highway Traffic Model (HTM) was used for the capacity and level of service determination along Road R101-8. Analysis of the existing road was conducted for the normal day peak hour and the 30th highest hour.

Table 3: Input Traffic Data for HTM Analysis

UNIFORM SECTIONS	AADT	MEDIUM GROWTH RATE %	NORMAL DAY PEAK HOUR				30TH HIGHEST HOUR			
			Q / AADT	PHF	%DIR	%HV	Q / AADT	PHF	%DIR	%HV
(0.00–5.44)	7 488	2.5%	0.08	0.95	60%	14%	0.17	0.95	60%	14%
(5.44–26.80)	4 788	2.5%	0.08	0.95	60%	10%	0.17	0.95	60%	10%

According to the Highway Traffic Model notes (Van As, 2014) the recommended level of service acceptable on a Class 2 roadway should be LOS B and LOS C for the normal day peak hour and the 30th highest hourly volume (HHV), respectively. A number of factors, however, need to be considered in conjunction with this recommendation:

- The historical traffic data on Road R101-8 is inadequate to provide projected growth rates with high level of confidence;
- Capital expenditure needs to consider alternative applications that may provide a better return in light of the traffic growth uncertainty mentioned above; and
- The 30th HHV values should be based on a full year`s traffic data which is not available for Road R101-8.

In light of the above, it was recommended that the normal day peak hour acceptable LOS be used as a guide to inform conclusions going forward. The 30th HHV will be analysed, however the results will be used as a secondary input towards conclusions.

HTM results: Existing road

The HTM analysis for the existing road is summarised in *Table 4.*

Table 4: Summary of HTM results on existing road layout

FROM – TO (km – km)	PEAK VOLUME	GROWTH RATE (%)	YEAR					
			2018	2023	2028	2033	2038	2043
0.0 to 5.44	Normal	1%	D	D	D	D	D	E
		2.5%	D	D	D	E	E	F
		4%	D	D	E	F	F	F
	30th HHV	1%	F	F	F	F	F	F
		2.5%	F	F	F	F	F	F
		4%	F	F	F	F	F	F
5.44 to 26.80	Normal	1%	B	C	C	C	C	C
		2.5%	B	C	C	C	D	D
		4%	B	C	C	D	E	F
	30th HHV	1%	E	E	E	E	E	F
		2.5%	E	E	F	F	F	F
		4%	E	E	F	F	F	F

Note: The poorest acceptable level of service for the normal day peak hour is LOS B for Class 2 road.

The results show that the first section from km 0.00 to km 5.44 was already due for upgrade in 2018 with the normal day peak hour at LOS D (30th HHV at LOS F). The section from km 5.44 and km 26.80 will be due for upgrade in 2033 for the normal peak hour at 2.5% Growth rate and is already due in 2018 for 30th HHV.

Proposed cross section improvements

In order to alleviate the serviceability problem indicated in Table 4, three initial upgrade options were identified and analysed during the Assessment Stage. The initial upgrade options are as follows:

- Cross section option 1: Adding 3.0 m wide shoulders for the entire route, except at existing climbing lanes. Where climbing lanes are present a 1.0m wide shoulder is proposed;
- Cross section option 2:
  - Two lanes per direction from km 0.00 to km 5.44 (Klein Kariba intersection)
  - Three lanes alternating passing/climbing lanes from km 5.44 to km 26.80; and
- Cross section option 3 – Two lanes per direction with 1.0 m shoulders for the entire route

HTM results: Proposed cross section improvements

A 2.5% growth rate was established as the most reasonable growth rate and was used to analyse all three options. The LOS outcome for the respective options is summarised in Table 5.

Table 5: Summary of HTM analysis for 30th HHV using 2.5% growth rate

IMPROVEMENT OPTIONS	UNIFORM SECTION km 0.00-km 5.44		UNIFORM SECTION km 5.44-km 26.8	
	NORMAL DAY PEAK	30TH HHV	NORMAL DAY PEAK	30TH HHV
Option 1 - add 3m shoulders throughout	LOS F (2018)	LOS F (2018)	LOS D (2033)	LOS D (2018)
Option 2 - 4 lanes up to km 5.44 and 3 lanes to km 26.8	LOS A (2043)	LOS C (2043)	LOS C (2043)	LOS D (2028)
Option 3 - 4 lanes throughout	LOS A (2043)	LOS C (2043)	LOS A (2043)	LOS A (2043)

The analyses of the proposed cross section improvements showed the following:

- Option 1 does not provide adequate level of service for the section from km 0.00 to km 5.44 for both normal day peak hour and 30th HHV;
- Option 1 does however provide adequate level of service along the section from km 5.44 to km 26.80 during the normal day peak hour with a decreased LOS beyond 2033 centred at the following segments:
  - Segment 1: km 10.00 to km 12.00;
  - Segment 2: km 16.00 to km 18.00; and
  - Segment 3: km 24.00 to km 26.00.
    - Segment 1 and 2 coincide with areas having sub-standard geometric alignment (horizontal sharp curves) and the realignment of these curves will improve the LOS;
    - Segment 3 is located in Modimolle urban section which currently has 3 lane configuration, therefore an addition lane on the LHS will improve the LOS along this section;
- Option 2 provides adequate level of service along the section from km 0.00 to km 5.44 over the design period up to 2043;

- Option 2 further provides adequate level of service along the section from km 5.44 to km 26.80 during the normal day peak hour over the design period with a decreased level of service centred along km 10.00 to km 11.00.
  - The above segment coincides with an area having sub-standard geometric alignment (horizontal sharp curves).
- It should be noted that research indicate that a 3-lane alternating climbing/passing lane (included in Option 2) could be more dangerous than the conventional 2-lane configuration due to the following reasons:
  - Areas of conflict are introduced at the merge of the two lanes; and
  - The configuration leads to platooning and excessive speeding on the 2-lane sections.
- Option 3 (4 lanes throughout) is adequate for the urban sections from km 0.00 to km 5.44 and km 24.00 to km 26.8, however it provides significant surplus capacity for the section from km 5.44 to km 24.00.

Conclusion

Based on the outcome of the LOS analysis above, it was clear that none of the proposed cross section improvement strategies meet all the design requirements. It was therefore necessary to develop a fourth hybrid cross section that consists of the following:

- **Cross section 4.1:**
  - Section from km 0.00 to km 5.44: A 4-lane urban configuration with kerbed median;
  - Section from km 5.44 to km 24.00: A 2-lane cross section with 3 m surfaced shoulders and existing climbing lanes; and
  - Section from km 24.00 to km 26.80: a 4 lane configuration with kerbed sidewalks.
- **Cross section 4.2**
  - Section from km 0.00 to km 5.44: A 4-lane urban configuration with kerbed median;
  - Section from km 5.44 to km 24.00: A 2-lane cross section with 3 m surfaced shoulders, existing climbing lanes; and additional climbing lanes at specific sections; and
  - Section from km 24.00 to km 26.80: a 4-lane urban configuration with kerbed sidewalks.

ECONOMIC ANALYSIS AND VIABILITY

The proposed hybrid cross-sections were analysed for cost and economic viability using the rates from recently completed projects.The analysis further evaluated the viability of using a Cape seal or asphalt wearing course along urban sections. These scenarios were evaluated over a 20-year period at an 8% discount rate.

The following costs, net present value and internal rate of return (IRR) values were derived from the HDM4 analysis.

Table 6: Economic Internal Rate of Return comparison for the four rehabilitation options

	BASE	CROSS SECTION 4.1		CROSS SECTION 4.2	
		CAPE SEAL THROUGHOUT	ASPHALT IN URBAN SECTIONS	CAPE SEAL THROUGHOUT	ASPHALT IN URBAN SECTIONS
Road Agency Cost	R 25.192 m.	R 391.865 mil.	R 397.101 mil.	R 520.726 mil.	R 525.962 mil.
Capital Cost	R 0.000 m.	R 275.410 m.	R 280.646 m.	R 404.534 m.	R 409.550 m.
Net Present Value	R 0.000 m.	R 192.735 m.	R 202.104 m.	R 94.934 m.	R 104.303 m.
Internal Rate of Return	0%	13.4%	13.6%	10.1%	10.2%

The analysis shows that Cross section 4.1 using Cape seal surfacing for rural section (km 5.44 to km 24.00) and asphalt surfacing for urban sections has the highest economic internal rate of return (IRR). Furthermore, it can be concluded that cross section 4.2 has a lower IRR.

It is therefore recommended that Cross section 4.1 (with asphalt in urban and Cape seal in rural) be carried into the Detail Design and implemented for improvement of Road R101-8.

GEOMETRIC EVALUATION AND DESIGN

Road R101-8 is generally a rural arterial with a current posted speed of 100 km/h. An iterative process of assessing the existing road alignment and the improvement options was conducted during the Assessment and Preliminary Design stages. Options of improve sub-standard curves to suit a design speed of either 80 km/h, 90 km/h or 100 km/h were evaluated for both horizontal and vertical alignments.

Horizontal Alignment

A detailed evaluation of the existing horizontal alignment was conducted to identify any sub-standard curves in terms of curve radii and super elevation as specified in the *SANRAL Geometric Design Manual*. The existing horizontal alignment consists of a total of 32 curves.

Eleven existing horizontal curves were identified to be sub-standard and require curve radius improvement. Seven of these sub-standard curves are located along proposed major horizontal realignment areas (Area 1, 2 and 3). These realignment improvements fall outside the road reserve and will require land acquisition. The remaining four sub-standard curves require minor radius improvement which will be accommodated within the road reserve.

The assessment further showed that the majority of remaining curves along Road R101-8 have acceptable curve radii and will be improved in terms of super elevation.

After detailed assessment of the three design speed criteria and discussion with SANRAL geometric design Specialist, it was agreed that the improvement of horizontal curves to suit a 100 km/h design speed with 8% superelevation and 390 m minimum radii is the most suitable criteria.

Vertical Alignment

The existing vertical alignment was also assessed to identify any sub-standard crest and sag curves as per the *SANRAL Geometric Design Manual*. The following curves were found to be sub-standard (excluding the sag curves along the proposed horizontal major realignment):

- A total of 12 crest curves were found to have a K value less than 30;
- 6 crest curves with K value between 30 and 45; and
- A total of 6 sag curves were found to have K values of less than 30.

After detailed assessment of the three design speed criteria and discussion with SANRAL geometric design Specialist, it was agreed that the vertical alignment should be improved to a corresponding design speed of 90 km/h (Crest curve K=45 and sag curve K=40).

Material Volumes and Land to Acquire for Major Horizontal Realignment

Cut and fill volumes were extracted from the design models generated for the horizontal alignment of 100 km/h and 90 km/h design speeds and are summarised in *Table 7*. Cross section 4.1: A 2-lane cross section with 3 m surfaced shoulders and existing climbing lanes for the section from km 5.44 to km 24.00 was used for the analysis. It follows that the cut volume generated from the horizontal major realignment improvement to suit a 100 km/h design speed is approximately 58 000 m^3 (±30%) higher than that of the realignment improvement to suit 90 km/h design speed. Cut volumes for the two horizontal realignment options are similar at Area 1 and Area 2.

Realignment will generate significant quantities of material which can be utilised for the construction LSSG layer.

Table 7: Cut and fill volumes and land required along Major Realignment areas

AREA	100 KM/H DESIGN SPEED			90 KM/H DESIGN SPEED		
	CUT VOLUME (m^3)	FILL VOLUME (m^3)	LAND REQUIRED (m^2)	CUT VOLUME (m^3)	FILL VOLUME (m^3)	LAND REQUIRED (m^2)
Area 1	41 741.58	2 090.20	14 560	39 496.30	671.71	1 446
Area 2	120 036.65	29 582.04	50 674	112 022.98	1 044.80	13 957
Area 3	87 165.82	5 855.45	50 048	39 733.96	952.93	11 684
Total	**248 944.05**	**37 527.69**	**115 282**	**191 253.24**	**2 669.44**	**27 087**

PAVEMENT EVALUATION

Visual Assessment and Mechanical Survey

The findings from the evaluation and analysis of pavement information indicate the following:

- In terms of visual condition, Road R101-8 can be classified as fair to poor with the sections from km 2.3 to km 5.5, km 18.5 to km 19.0 and km 23.5 to km 26.3 being the most distressed with structural failures such as rutting, crocodile cracking, undulation and pumping;

- Riding quality and rut depth measurements (2017) indicate that most of the road is classified as sound with localised warning and severe areas;
- Maximum deflection measurements (2018) along the northbound lane show that the sections from km 2.3 to km 5.5, km 18.5 to km 19.0 and km 23.5 to km 26.3 are classified as severe and therefore have low structural capacity;
- Along the southbound lane maximum deflection for the sections from km 2.5 to km 5.5 and km 11.6 to km 26.8 are classified as warning to severe;
- Deflection bowl parameters indicate the origin of distress to be from the upper and middle layers;
- Uniforms sections from the respective measurements indicate poor correlation; and
- From the deflection measurements it is evident that the pavement requires some structural improvement for a 20-year structural design period.

Pavement Design Traffic

Estimated future traffic loading for a 20-year design period was calculated using low, medium and high ADTT growth rates of 1%, 2.5% and 4%, respectively, as guided by the historical traffic data and *SAPEM, 2014 Chapter 10 Table 17*. An E80 per heavy vehicle (E80/HV) of 1.8 and an E80/HV growth rate of 2% were used as recommended in *SAPEM, 2014 Chapter 10.*

This analysis showed that for a 20-year design period, the first section of road (km 0.00 to km 5.44) is classified as an ES30 pavement class for all growth rates, whereas the second section from km 5.44 to km 26.80 is classified as ES10 pavement class for all growth rates. The 2.5% growth rate was considered to be the most reasonable growth rate and was used for the pavement capacity analysis.

Materials Investigations

Results from the materials investigation indicated a high variation in the existing pavement structure along Road 101-8, which could be due to previous road maintenance. The existing pavement structures generally consist of 150 mm G5 base, 200 mm G6 subbase, 250 mm G6 selected, and G9 subgrade layers.

The DCP measurements were analysed using *Rubicon Toolbox* and the analysis was assessed againts an ES30 pavement class for the section from km 0.00 to km 5.44 and ES10 pavement class for section from km 5.44 to km 26.80. The outcome showed that the upper ±300 mm of existing pavement structure is structurally inadequate for the estimated design traffic loading. The latter was confirmed to correspond with the FWD measurements.

Existing Pavement Capacity

Using the material investigation results, existing pavement structural capacity was estimated according to *South African Mechanistic Empirical Pavement Design Method (SAMPDM)* on *Rubicon Toolbox* software. The analysis showed Road R101-8 to have estimated remaining capacity of 2.1 million E80`s along the northbound lane and 3.3 million E80`s along the Southbound lane. For both lanes the base layer is the critical layer.

PAVEMENT DESIGN

Rehabilitation Pavement Design

Three pavement rehabilitation alternatives were identified and evaluated for the rural section from km 5.44 to km 24.00 utilising the existing pavement structure:

- Pavement rehabilitation 1: Using a 250 mm G7 USSG and 200 mm G4 subbase for shoulder widening, adding 100 mm of G2 to the existing base material and cement stabilising to a 250 mm C4 base across the lane and shoulder and construct Cape seal;
- Pavement rehabilitation 2: Using a 200 mm G7 USSG for shoulder widening, adding a 100 mm G2 to the existing base material and cement stabilising to a 250 mm C4 subbase across the lane and shoulder, construction of a 150 mm G1 base and Cape seal; and
- Pavement rehabilitation 3: Reuse existing base material for shoulder USSG, adding 50 mm G2 to the existing subbase and cement stabilising to a 250 mm C4 subbase across the lane and shoulder, construction of a 150 mm G1 base and Cape seal.

Table 8: Capacities for rehabilitation pavement structures (km 5.44 to km 24.00)

REHABILITATION 1		REHABILITATION 2		REHABILITATION 3	
		Cape Seal (S4)			
		150 G1 Base	E = 600MPa		
Cape Seal (S4)		250 C4 (EG5) Subbase	E = 1500MPa (E = 300MPa)		
250 C4 (EG5) Base	E = 1500MPa (E = 300MPa)	150 mm DE-G5 reconstructed		Cape Seal (S4)	
				150 G1 Base	E = 600MPa
200 DE-G6 Subbase	E = 200MPa	200 DE-G6 USSG	E = 200MPa	250 C4 (EG5) Subbase	E = 1500MPa (E = 300MPa)
250 DE-G6 USSG	E = 140MPa	250 DE-G6 LSSG	E = 140MPa	250 DE-G6 USSG	E = 140MPa
Roadbed (G9)	E = 80MPa	Roadbed (>G9)	E = 80MPa	Roadbed (G9)	E = 80MPa
Traffic load	421 E80/day/lane	421 E80/day/lane		421 E80/day/lane	
Capacity	2.2 MESA	6.1 MESA		5.1 MESA	
Design life	13 Years	28.5 Years		25.25 years	

- Pavement rehabilitation 1 does not provide adequate structural capacity for the 20-year design period, and
- Pavement rehabilitation 2 and 3 provide adequate capacity for the improvement and addition of surfaced shoulders along the section from km 5.44 to km 24.00 over the 20-year design period.

Practicality and Traffic Accommodation

The construction practicality and traffic accommodation were further investigated for pavement rehabilitation 2 and 3. The outcome showed that pavement rehabilitation 2 allow two way traffic accommodation during construction at all times. Due to the reuse of existing base material for shoulder USSG, pavement rehabilitation 3 will require stop and go (half width) traffic accommodation.

<u>New Pavement Structures</u>

Pavement designs for new lanes in Bela Bela urban section (km 0.00 to km 5.44) as well as the sections along realignment areas were also identified and investigated. The proposed pavement structure for the realignment areas will be used for the additional lanes in Modimolle due to the same pavement class. *Rubicon Toolbox* was used to evaluate the pavement designs with moduli as guided by *Theyse and Muthen, 2000*. The pavement designs and their structural capacities are illustrated in *Table 9.*

Table 9: Capacities for new pavement structures (Bela Bela urban and realignment)

LAYER	PAVEMENT STRUCTURE BELA BELA SECTION km 0.00 TO km 5.44 (ES30)		LAYER	PAVEMENT STRUCTURE: MAJOR REALIGNMENT AND MODIMOLLE NEW LANE (ES10)	
Surfacing	50 AC	E = 3500 MPa	Surfacing	S4 or 50 AC	E = 3500 MPa
Base	150 G1	E = 600 MPa	Base	150 G1	E = 600 MPa
Upper subbase	150 C3 (EG4)	E = 1800 MPa (E=300 MPa)	Upper subbase	125 C3 (EG4)	E = 1800 MPa (E=300 MPa)
Lower subbase	150 C3 (EG4)	E = 1800 MPa (E=300 MPa)	Lower subbase	125 C3 (EG4)	E = 1800 MPa (E=300 MPa)
USSG	150 G7	E = 130 MPa	USSG	150 G7	E = 130 MPa
Subgrade	Road bed (>G9)	E = 80 MPa	Subgrade	Road bed (>G9)	E = 80 MPa
Traffic load	1108 E80/day/lane		**Traffic load**	421 E80/day/lane	
Capacity	13.41 million standard axles		**Capacity**	6.4 million standard axles	
Design life	25.00 years		**Design life**	33.75 years	

The proposed design structures summarised in *Table 9* for the respective sections provide adequate structural capacities.

<u>STRUCTURES</u>

<u>Bridge B375: Modderloop River Bridge</u>

The bridge is situated at km 16.83 along Road R101-8 and crosses the Modderloop River. The deck is made up of 5 x 12.75 m simply supported solid concrete spans with an average thickness of 625 mm, reinforced with mild steel bars (R-bars). The main reinforcement of the deck consists of 25 mm diameter R-bars at 115 mm spacing positioned perpendicularly to the support lines of the sub-structure.

A visual assessment of the bridge revealed the following defects:

- Non-standard parapets;

- Major siltation within the bridge openings;
- Exposed reinforcement and concrete spall to parapets;
- Concrete spall to the edge of the deck; and
- Debris and vegetation within the deck joints.

A preliminary analysis and the resultant load effects of the ultimate moment show that the structural capacity of the deck, without the structural ballustrade, is inadequate due to the balustrade acting as a structural member. No top reinforcement is present in the top slab at the obtuse corner where a significant hogging moment occurs, which could lead to severe bending cracks due to the localised uplift of the deck.

Results from the hydraulic analysis shows that the existing structure does not comply with design freeboard requirements for the 1:14.5-year return period and it is recommended that the drainage capacity of the bridge be increased.

Structural testing was carried out on the bridge and a summary of the results are as follows:

- Minimum parapet concrete core strength of 33 MPa;
- Minimum deck concrete core strength of 34 MPa;
- Minimum abutment concrete core strength of 18 MPa;
- Minimum pier concrete core strength of 22 MPa; and
- Maximum carbonation depth of 95 mm.

Initial indications suggest that the options to be considered in the bridge report include the following:

- **Option 1 - Rehabilitation Only**: Repair spalling and apply a protective coating to all substructures. Clear siltation, provide gabion mattresses below the deck, strengthen the existing balustrades and provide new expansion joints. The cost estimate for this option is approximately **R4.00 million**.
- **Option 2 - New Deck:** Demolish the existing bridge deck and construct a new deck at a raised level and extend the existing sub-structure to accommodate the design flood peak. The deck will also be widened on both sides and the parapet replaced with a *SANRAL* standard F-shaped parapet. A protective coating will be applied to all substructures and new elastomeric bearing will be provided. The cost estimate for this option is approximately **R12.40 million**.
- **Option 3 - Raise Existing Deck:** Jack the existing bridge deck and extend the existing sub-structure to accommodate the design flood peak. Apply protective coating to substructures and replace bearing system and expansion joints. The deck will also be widened on both sides and the parapet replaced with a *SANRAL* standard F-shaped parapet. The existing deck will require strengthening due to the demolition of the structural balustrade. The cost estimate for this option is approximately **R13.09 million**.
- **Option 4 - New Bridge:** Demolish the existing structure and replace it with a new structure with less interference with the natural flow of the river. This will entail longer spans and a substantially raised deck. The cost estimate for this option is approximately **R20.78 million**.

The *Drainage Manual 6th Edition* states that the clearing of siltation to increase the hydraulic capacity of an existing structure is not recommended, therefore Option 1 is not recommended. **Option 2** is the preliminary preferred option as it is the most cost-effective solution to bring the existing structure up to current standards. This will be fully investigated and motivated in the bridge report.

Bridge B447: Groot Nyl River Bridge

Bridge B447 is situated at km 17.62 along Road R101-8 and crosses the Groot Nyl River. The deck consists of three 6.7 m simply supported solid concrete spans with an average thickness of 650 mm, reinforced with mild steel bars (R-bars). It was later extended by an additional span of 7.6 m to the southern side of the existing bridge and the sub-structure was widened by approximately 3 m on each side. The main reinforcement of the original deck consists of 25 mm diameter R-bars at 110 mm spacing, whereas the widened sections consist of 25 mm diameter R-bars at 115 mm spacing.

A visual assessment of the bridge revealed the following defects:

- Damaged balustrades possibly due to vehicle collision;
- Major siltation within the bridge openings; and
- Spalled concrete to top of mass concrete pier.

A preliminary structural capacity analysis of the deck shows that the structural capacity of the deck is adequate.

Results from the hydrological and hydraulic analysis shows that the existing structure does not comply with the design freeboard requirements (20-year flood) and it is recommended that the drainage capacity of the bridge be increased.

Structural testing was carried out on the bridge and a summary of the results are as follows:

- Minimum deck concrete core strength of 33 MPa;
- Minimum abutment and piers concrete core strength of 23 MPa;
- Maximum deck carbonation depth of 30 mm; and
- Maximum pier and abutment carbonation depth of 60 mm.

Initial indications suggest that the options to be considered include the following:

- **Option 1 - Rehabilitation Only**: Repair spalling and apply a protective coating to all substructures. Clear siltation, provide gabion mattresses below the deck, replace the existing balustrades with *SANRAL* standard F-shaped parapets, replace the bearing system, and provide new expansion joints. The cost estimate for this option is approximately **R3.67 million**.
- **Option 2 - Raise Existing Deck:** Jack the existing bridge deck and extend the existing sub-structure to accommodate the design flood peak. Apply protective coating to substructures and replace bearing system and expansion joints. The deck will also be widened on both sides and the parapet

replaced with a *SANRAL* standard F-shaped parapet. The cost estimate for this option is approximately **R6.48 million**.

- **Option 3 – Add Additional Spans:** Repair concrete spalling and provide protective coating to all substructures. Replace the bearing system, expansion joints and balustrades with *SANRAL* standard F-shaped parapets. Widening of the existing deck and substructures, adding additional deck spans and new abutments. The cost estimate for this option is approximately **R9.36 million**.
- **Option 4 - New Bridge:** Demolish the existing structure and replace it with a new structure. The cost estimate for this option is approximately **R9.42 million**.

The *Drainage Manual 6th Edition* states that the clearing of siltation to increase the hydraulic capacity of an existing structure is not recommended, therefore Option 1 is not recommended. The *SANRAL* Code of Procedure for the Planning and Design of Highway and Road Structures in South Africa states in Section 1.3.2 (ii) that, if the cost of remedial works exceeds approximately 67% of the cost of reconstructing the structure, consideration should be given to effecting the latter option.

The minimum estimated cost of remedial work is 69% of the estimated structure replacement cost for this structure. The original structure was constructed in 1936 and approaching the end of its original design-life, while also having been widened and extended in 1966. Taking all of this into consideration, **Option 4** is the preliminary preferred option. This will be fully investigated and motivated in the bridge report.

<u>Major Culvert IDC3321</u>

This culvert provides access across a tributary system situated at km 0.82. The structure consists of an in-situ portal frame culvert with 9 cells, propped cantilever walls and a continuous top slab. Each cell has an internal width of 900 mm and internal height of 600 mm. The culvert has an overall length of 13.0 m and overall width of 12.4 m.

A visual assessment of the culvert revealed the following defects:

- Damaged wing walls;
- Spalling to internal walls and top slab; and
- No guardrails.

Results from the final hydraulic analysis show that the existing structure does not comply with design freeboard requirements (20-year flood) and it is recommended that the drainage capacity of the culvert be increased.

Concrete tests on the existing structure was conducted and the results are summarised below:

- Minimum concrete core strength of 20 MPa; and
- Maximum deck carbonation depth of 50 mm.

Initial indications suggest that the existing culvert is under capacity and would require several additional cells to accommodate the peak design flood. In addition, the road cross-section at this location will be substantially widened to accommodate a 4-lane urban cross section. It is therefore foreseen that the existing structure will be replaced by a new major culvert of a suitable size to accommodate the peak design flood. This will be fully investigated and motivated in the major culvert report. The cost estimate for this option is approximately **R4.77 million**.

Major Culvert: IDC3322

The culvert provides access across a tributary system situated at km 5.19 along Road R101-8. The structure consists of an in-situ portal frame with 2 cells and a pipe culvert.

A visual assessment of the cilvert revealed the following defects:

- Severely damaged wing walls; and
- Spalling to internal walls and top slab.

Results from the hydraulic analysis show that the existing structure does not comply with design freeboard requirements (10.9-year flood) and it is recommended that the drainage capacity of the culvert be increased.

Core samples of the culvert concrete were used to determine the compressive strength of key structural components as well as the level of carbonation. The results of these tests are summarised below:

- Minimum concrete core strength of 15 MPa; and
- Maximum deck carbonation depth of 30 mm.

The information gathered, tests conducted, and calculations completed during the preliminary design stage will be utilized to develop proposals for the redevelopment of Major Culvert IDC3322. These options will be discussed in the major culvert report to be issued as part of the detail design stage.

Initial indications suggest that the existing culvert is under capacity and would require several additional cells to accommodate the peak design flood. In addition, the road cross-section at this location will be substantially widened to accommodate a dual carriageway. It is therefore foreseen that the existing structure will be replaced by a new major culvert of a suitable size to accommodate the peak design flood. This will be fully investigated and motivated in the major culvert report. The cost estimate for this option is approximately **R2.70 million**.

Major Culvert: km 22.5

The structure situated at km 22.5 is a major culvert which provides access across a tributary system. As-built drawings for the structure were not available and it is not listed on *SANRAL*'s Bridge Management System. The structure is an in-situ portal frame culvert with 2 cells, propped cantilever walls and a continuous top slab. Each cell has an internal width of 1.9 m and internal height of 1.2 m. The culvert has an overall length of 17 m.

A visual assessment of the culvert revealed the following defects:

- Severely damaged wing walls;
- Spalling to internal walls;
- Scour behind wing walls and evidence of overtopping; and
- No number plates.

Results from the final hydraulic analysis showed that the existing structure does not comply with design freeboard requirements (11.4-year flood) and it is recommended that the drainage capacity of the culvert be increased.

Concrete tests on the existing structure were conducted and the results are summarised below:

- Minimum concrete core strength of 18 MPa; and
- Maximum deck carbonation depth of 105 mm.

The information gathered, tests conducted, and calculations completed during the preliminary design stage will be utilized to develop proposals for the redevelopment of Major Culvert at km 22.5. These options will be discussed in the major culvert report to be issued as part of the detail design stage.

Initial indications suggest that the existing culvert is severely under capacity and would require several additional cells to accommodate the peak design flood. It is therefore foreseen that the existing structure will be replaced by a new major culvert of a suitable size to accommodate the peak design flood. This will be fully investigated and motivated in the major culvert report. The cost estimate for this option is approximately **R2.71 million**.

<u>ROAD PRISM DRAINAGE</u>

A total of 54 minor culverts were identified along Road R101-8. During the visual assessment it was observed that most in- and outlets were blocked. This was mostly due to recent clearing and shaping of the shoulders and road prism, done by the RRM Contractor. Other culverts were noted where the barrels were blocked with silt and/or debris.

The majority of culvert head walls and wing walls along Road R101-8 were constructed in concrete and are in a fair to warning condition. The assessment showed that a number of culverts had no in- or outlet structures or missing wing walls. A total of six pipe culverts were found to be misaligned. The assessment also revealed that four box culverts were extended using Ø900 mm pipes.

The cross section improvements will require extension of all culvert structures and construction of new side drains. As a result new in- and outlet structures will be constructed. Misaligned culverts will be rehabilitated and damaged pipes will be replaced. Damaged or missing danger plates will be replaced.

The section through Modimolle appears to have a piped storm water system situated on the left side of the road with drainage effected through catch pits and kerb inlets. The section from km 25.35 to km 26.80 includes a cast in-situ concrete lined drain between the traffic lanes and parking bays. The condition of these drains is poor to very poor.

ENVIRONMENTAL, OHS RISK ASSESSMENT

Environmental screening assessment revealed the following:

- The proposed road improvements will traverse through an area that is fairly sensitive in terms of ecological importance and will be subject to a Basic Assessment and will require certain specialist studies;
- The majority of the length of Road R101-8 passes through areas classified as Critical Biodiversity Areas (CBAs) or Ecological Support Areas (ESAs);
- Large sections of Road R101-8 pass through vegetation types classified as Vulnerable or Endangered;
- The six proposed borrow pits are situated in areas classified as being a Vulnerable vegetation type;
- No Critically Endangered faunal species were identified that would likely be impacted by the proposed road works;
- Proposed widening and lifting of the existing bridges for capacity improvement will include the altering of the watercourse banks and thus will require a Water Use License;
- The Great Nyl River (km 17.62) is situated in an area classified as a CBA, however based on the desktop review this area appears to be invaded by alien vegetation;
- In terms of heritage, the southern end of Road R101-8 falls within areas classified as 'Moderate'and 'High' in terms of heritage resources; and
- The proposed development will thus require a heritage assessment and possibly a field assessment.

The findings and recommendations from the design OHS risk assessment are summarised as follows:

- That all work be constantly monitored with particular emphasis on interaction between local community and other industrial activities;
- Two-way traffic accommodation must be maintained at all times, therefore temporary concrete barriers must be installed to separate the traffic from construction works;
- Current high risk accident areas (sub-standard horizontal curves) should be upgraded to a suitable design speed to mitigate future accidents risks;
- All remedial works relating to Modderloop River Bridge and Groot Nyl River Bridge to be completed to a specific safe system of work relating to the work at height and working near water environment; and
- All remedial works to culverts to consider working in confined spaces as a minimum in the respective safe systems of work.

CONSTRUCTION MATERIALS

Material Sources

Six potential borrow areas were identified as part of the geological desktop study, however as indicated these sources may not be approved for use and will require application to the Department of Minerals and Energy. These borrow areas should provide up to G5-quality material, which is ideal for the construction of middle and lower pavement layers. Quality and extent of these sources must however be proven.

The realignments at the three problematic areas will provide more than enough material to be used for lower layers. The geological desktop study showed that the material along these areas should provide up to G7-quality material but will require testing to prove quality.

The following ASPASA accredited commercial sources are available near the project:

- Vergenoeg mining company (Pty) Ltd – Pretoria (±80 km);
- Afrimat -Infrasors - Marble Hall (±110 km);
- PPC Aggregates Mooiplaas – Pretoria (±120 km); and
- Afrisam Ferro Quarry, Bergtuin – Pretoria (±100 km).

Rooiberg quarry situated in Mookgophong (±42 km from the project road) is not listed as an accredited ASPASA source.

Water Sources

It is proposed that water required for construction purposes be procured from the Bela Bela and/or Modimolle Local Municipalities.

Bituminous Products

Several asphalt producers are available that can provide asphalt for the project should this be required. These include:

- National Asphalt – Pretoria (±90 km);
- Rooiberg Asphalt – Pretoria (±90 km);
- Rooiberg Asphalt – Mookgophong (Naboomspruit);
- Much Asphalt – Polokwane (±150 km); and
- Polokwane Surfacing – Polokwane (±150 km).

COST ESTIMATE

A cost estimate for the realignment improvements to suit a 100 km/h design speed was prepared using rates from recently completed projects and is summarised in *Table 10*. The cost estimate was based on the following:

- Cross section 4.1:
  - o Section from km 0.00 to km 5.44: A 4-lane configuration with median and sidewalks;
  - o Section from km 5.44 to km 24.00: A 2-lane cross section with 3 m surfaced shoulders, existing climbing lanes and geometric realignments; and
  - o Section from km 24.00 to km 26.80: A 4-lane configuration with kerbed sidewalks.
- Pavement rehabilitation 2: A 200 mm G7 USSG for shoulder widening, adding a 100 mm G2 to the existing base material and cement stabilising to a 250 mm C4 subbase across the lane and shoulder, construction of a 150 mm G1 base and Cape seal; and
- Structures solution option 2: lifting of bridges and reconstructing major culverts to increase hydraulic capacity.

Table 10: Cost estimate

DESCRIPTION	AMOUNT	
SCHEDULE A: PRELIMINARY AND GENERAL	R	54 991 020.00
SCHEDULE B: ROAD WORKS	R	254 759 730.00
SCHEDULE C: STREET LIGHTING	R	12 750 000.00
SCHEDULE D: BRIDGE AND MAJOR CULVERTS	R	31 994 888.00
SCHEDULE E: SMALL CONTRACTOR DEVELOPMENT	R	4 962 000.00
SCHEDULE F: QUALITY	R	-2 800 000.00
SUBTOTAL	**R**	**356 657 638.00**
10%Contingency	R	35 665 763.80
SUBTOTAL	**R**	**392 323 401.80**
Add 15% VAT	R	58 848 510.27
TOTAL	**R**	**451 171 912.07**

CONCLUSIONS

The following conclusions can be drawn from the Preliminary Design stage:

- Road R101-8 can be classified as a Class 2 rural major arterial (km 0.00 to km 25.76) and a Class 4a collector street (km 25.76 to km 26.80). in terms of TRH26 and a Category B road in terms of TRH4;
- Electronic traffic counts indicated two distinct traffic sections, i.e. km 0.00 to km 5.44 and km 5.44 to km 26.80.
- ADT along the two uniform sections are 7 488 and 4 788 vehicles/day, respectively. Similarly, ADTT is 1 054 and 402 vehicles/day;
- Traffic growth rates based on the 2015 and 2018 count data indicate a typical growth rate of 3.0% along Road R101-8, while a medium growth rate of 2.5% was estimated from CTO stations along other sections of Road R101;
- The estimated design traffic loading for a 20-year design life at 2.5% growth rate is 13.30 million E80's for the section from km 0.00 to km 5.44 and 5.02 million E80's for the section from km 5.44 to km 26.80;
- The section from km 0.00 to km 5.44 is classified as ES30 traffic class and the section from km 5.44 to km 26.80 is classified as ES10 traffic class;
- The HTM analysis shows that the section from km 0.0 – km 5.44 was due for capacity improvement in 2018, while the remainder of the road requires improvement in 2033;

- Analysis of results from a road side interview (RSI) indicated that the road upgrade should not have a significant impact on the N1 traffic attraction;
- Cross section option 2 (4 lanes from km 0.00 to km 5.44 and 3 lanes alternating climbing lanes for the section from km 5.44 to km 26.80) was developed further into cross sections 4.1 and 4.2;
- Cross section 4.1 (4 lanes with kerbed median from km 0.00 to km 5.44, 2 lanes with 3 m surfaced shoulders and existing climbing lanes from km 5.44 to km 24.00 and 4 lanes from km 24.00 to km 26.80) was found to be the most viable and suitable cross section;
- Intersections and accesses require improvement to accommodate the proposed cross section upgrade and to improve road safety and capacity;
- Eleven existing horizontal curves were identified as sub-standard in terms of curve radius;
- Of the eleven horizontal sub-standard curves, five are located along major realignment areas from km 9.8 to 10.6, km 11.0 to km 11.7 and km 14.8 to km 15.5;
- The remaining six horizontal sub-standard curves require minor curve radius realignment and falls within the existing roadway;
- Majority of the remaining curves will be improved in terms of the superelevation;
- Traffic counts showed that the rural section has average travelling speeds of 95.1 km/h to 99.14 km/h;
- The realignment to suit an 80 km/h design speed (R=210) does not eliminate safety risks along Road R101-8;
- The realignment of sub-standard curves to suit a 100km/h (8% emax and minimum 390 m radius) was agreed to be the most suitable improvement. This will improve safety and provide adequate capacity as well as uniform alignment along this section of Road R101-8;
- cutting from the major horizontal realignment will generate enough material which can be used for lower layers and stabilised C4 subbase if suitable;
- A total of 18 crest curves and 6 sag curves were found to be sub-standard;
- Majority of the sub-standard vertical curves are located adjacent to the major horizontal realignment areas and will be corrected to suit K value of 45 for crest curves and 40 for sag curves;
- Public transport facilities such as taxi and bus bays are required along town sections;
- Existing sidewalks in Bela Bela and Modimolle are insufficient and need to be extended;
- From the deflection measurements, it is evident that the pavement requires structural improvement for a 20-year design period;
- The materials investigation indicated a high variation in the pavement structure along Road R101-8, which suggests historical maintenance;
- The materials investigation further indicated that the existing pavement structures consist of G5 base, G6 subbase, G6 upper selected and G7 to G9 lower selected material;
- Pavement rehabilitation 2 utilising new G7 material for shoulder USSG, stabilising existing base to construct a C4 subbase, construction of a new G1 base and Cape seal surfacing along rural section provides sufficient structural capacity;
- Pavement rehabilitation 3 utilising the existing base material for shoulder USSG, stabilising existing subbase to C4, constructing a new G1 base and Cape seal surfacing along rural section also provides sufficient structural capacity;
- Pavement rehabilitation 2 allows for two way traffic accommodation at all times whereas pavement rehabilitation 3 will require half width (stop and go) traffic accommodation;

- Two way traffic accommodation is a requirement due to the volume of traffic expected along Road R101-8;
- An HDM4 analysis showed that Cross section 4.1 (4-lane cross section using asphalt from km 0.00 to km 5.44, 2 lanes with 3 m surface shoulders and existing climbing lanes using cape seal from km 5.44 to 24.00 and 4-lanes cross section using asphalt from km 24.00 to km 26.80) provides the highest internal rate of return (IRR) of 13.6%;
- Results from the hydrological and hydraulic analysis show that the existing bridge structures do not comply with the design freeboard requirements (20-year flood) and it is recommended that the drainage capacity of the bridges be increased;
- Similarly, the three major culvert structures also do not comply with the design freeboard requirements (20-year flood);
- Six properties are affected by the realignment and a land acquisition process will be required for the improvements;
- An environmental screening assessment was conducted and the outcome shows that a Basic Assessment will be required;
- Both crushed and bituminous construction materials are available from commercial sources within a 150 km radius of the project; and
- The estimated cost for Cross section 4.1, using pavement rehabilitation 2 and realigning to suit 100 km/h design speed is approximately R 451.2 million (Including VAT).

RECOMMENDATIONS

Based on the investigations conducted and the conclusions reached, the following are recommended:

- All horizontal sub-standard curves be improved to suit a 100 km/h design speed with 8% emax and minimum 390 m radii;
- Road R101-8 be improved in accordance with Cross section 4.1 described as follows:
  - Section from km 0.00 to km 5.44: A 4-lane urban configuration with median and sidewalks;
  - Section from km 5.44 to km 24.00: A 2-lane cross section with 3 m surfaced shoulders, existing climbing lanes and geometric realignments; and
  - Section from km 24.00 to km 26.80: A 4-lane urban configuration with median and sidewalks.
- Pavement rehabilitation 2 be utilised for the section from km 5.44 to km 24.00 as follows:
  - Box cut, rip and compact existing shoulder material for shoulder LSSG, 200 mm G7 USSG for the shoulder, 250 mm C4 subbase across the lane and shoulder, 150 mm G1 base and Cape seal surfacing;
- New pavement structures using asphalt surfacing along urban sections and cape seal along horizontal major realignments be implemented;
- Bridge and major culvert reports be submitted to the Employer for approval and the feedback be included in the detail design;
- Environmental sub-consultant and Road Safety Auditor be appointed;
- Procurement for a geotechnical drilling contractor should proceed;
- Land acquisition process should be finalised; and
- The project should proceed to Detail Design stage.

ISSUE & REVISION RECORD

QUALITY APPROVAL

	Capacity	Name	Signature	Date
Author	Design Engineer	Khutso Nkoana		06/11/2020
Reviewed by	Design Specialist	John Hodgson Pr Eng: 980409		06/11/2020
Approved by Design Centre Leader	Project Director	André Greyling Pr Eng: 20080025		06/11/2020

This report has been prepared in accordance with BVi Consulting Engineers Quality Management System. BVi Consulting Engineers is ISO 9001: 2015 registered and certified by NQA Africa.

REVISION RECORD

Revision Number	Objective	Change	Date
0	Issue to Employers for comments	None	18/12/2019
1	Issue to the Employer for approval	Employer comments included	06/11/2020

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CHAPTER 1 INTRODUCTION

1.1 TERMS OF REFERENCE

BVi Consulting Engineers Western Cape (Pty) Ltd was appointed by the *South African National Roads Agency SOC Limited (SANRAL)* to provide *Consulting Engineering Services for the Improvement of National Road R101 Section 8 from Bela Bela (km 0.0) to Modimolle (km 26.8).* The contract was awarded on the 2nd of August 2018 followed by a hand over meeting on the 4th of September 2018.

The scope of works, as set out in the tender document, is divided into the following distinct stages:

- Project Assessment
- Investigation for Design Development
- Design Development Stage
  - Preliminary Design
  - Detail Design
- Tender Documentation
- Clarification Meeting, Tender Period and Tender Evaluation
- Administration and Monitoring of the Works Contract
- Additional Duties, Special Services and Specialist Advice
- Quality Control: Works Contract
- Close Out

1.2 GENERAL DESCRIPTION OF THE PROJECT

National Road R101 Section 8 is situated within two Local Municipalities (Bela Bela and Modimolle) both situated within the Waterberg District Municipality in the Limpopo Province. The project extends from Bela Bela at the intersection with Voortrekker Road (km 0.0) to Modimolle at the intersection with Road R33 (km 26.8). A locality plan of the project route is included at the front of this report.

Road R101-8 consists of a two lane, single carriageway road with gravel shoulders along most of the route. The road has an average surfaced width of 7.0 m. Within Modimolle, the road widens to four lanes with parking bays and sidewalks in the central business district (CBD). Climbing/passing lanes are provided from km 6.2 to km 7.5 (LHS) and km 14.4 to km 15.7 (RHS).

According to the pavement management system (PMS) information, the road was constructed in 1964 as National Road N1 joining Pretoria and Polokwane. The N1 was however realigned during 1995/1996 under a concession contract at which time this section was renumbered as R101. Road R101 serves as an alternative route to the N1 toll route.

1.3 OBJECTIVES, PURPOSE AND STRATEGIES

1.3.1 General Objectives

The general objective of this project is to successfully and optimally complete *Improvement of National Road R101 Section 8 from Bela Bela (km 0.0) to Modimolle (km 26.8)*. As per the Contract, the aim of this improvement is to:

- Relieve traffic congestion to acceptable level of service;
- Improve road geometry to improve road safety;
- Widen bridges and other structures where required for hydraulic and traffic capacity improvement; and
- Provide adequate pavement capacity for the design period.

1.3.2 Report Purpose

The purpose of this report is to outline the findings from the Project Assessment phase and the Preliminary Design phase in order to provide recommendations to be carried out in the *Detail Design* phase of the project. This report includes the outcome reached at the gateway review meeting held with the Employer.

The following tasks were undertaken during the Preliminary Design:

- A detailed visual assessment of the road and structures;
- Analysis and evaluation of mechanical survey data;
- Analysis of the traffic count data;
- Traffic capacity analysis;
- Preliminary geometric design to improve road alignment;
- Drainage modelling and analysis;
- Preliminary assessment of major structures;
- Materials investigations;
- Pavement structure capacity assessment;
- Pavement and rehabilitation design;
- Access management plan; and
- Economic analysis of proposed alternatives.

1.3.3 Strategy Followed

The strategy followed is based on the procedures described in the *SANRAL Geometric Design Manual*, the *South African Pavement Engineering Manual (SAPEM, 2013)*, *TRH12: 1997* and the *SANRAL Contract Document*. The strategy can be summarised as a systematic approach to investigate, evaluate and analyse the existing road way and to use all available data to complete an economically feasible improvement design.

1.4 SCOPE OF THE INVESTIGATIONS

This report is based on information received from the following sources:

- The MAJV (Topographical survey);
- SANRAL (mechanical survey data and traffic);
- South African Weather Service (Rain and temperature data from 1981 to 2018);
- KBK Engineers (RRM Engineers – accident data);
- TES Trust (Electronic counts);
- Roadlab Laboratories (Falling weight deflectometer (FWD) measurements);
- *Innovative Transport Solution (ITS)* (Traffic and transport investigations and design);
- Cedarland Geotechnical Consult (Geotechnical investigation and design); and
- Roadlab Laboratories (Materials investigation).

1.5 GATEWAY REVIEW FEEDBACK

The following were discussed and agreed during the Preliminary Design Gateway review meeting and further meetings following the gateway review held with the Employer:

- Cross section improvement:
  - An urban 4 lane configuration (3.5 m wide) with 2.8 m kerbed median and 3 m sidewalks is justifiable for the section from km 0.00 to km 5.44 (Klein Kariba intersection) based on the traffic and the potential developments envisaged in the Bela Bela Municipality's SDF;
  - A 2 lane single carriageway (3.7 m lanes) with 3 m surfaced shoulders and localised climbing/passing lanes will provide adequate capacity for the rural section (km 5.44 to km 24.00); and
  - An urban 4 lane configuration (3.5 m wide) with 2.8 m kerbed median and 0.6 m median on the last 300 m for the section from km 24.00 to km 26,80.
- Horizontal realignment:
  - The horizontal sub-standard curves will be improved to a 100 km/h design speed with 8% e_{max} and minimum 390 m curve radius;
  - The vertical sub-standard curves will be improved to a corresponding design speed of 90 km/h with minimum crest curve of K=45 and sag curve of K=40;
- Accesses should be consolidated as much as possible, however, the towns should be treated as urban.

Minutes of Progress meetings 5, 6 and 7 following the Gateway review are included in *Appendix A*.

CHAPTER 2 PHYSIOGRAPHY

2.1 TOPOGRAPHY

The terrain along Road R101-8 can be classified as rolling. The vertical alignment of the road varies from 1 130 m to 1 351 m above mean sea level (amsl).

2.2 CLIMATE

Climate data was received from the *South African Weather Services* for a station situated in Bela Bela and covers the period from 1981 to 2017. The data pertains to the "Warmbad – Towoomba" station, station no. 0589594 1.

2.2.1 Temperature

The project area is characterised by warm, wet summers and cool, dry winters. *Figure 2.1* shows the average minimum and maximum daily temperatures per month. This shows that during winter (June/July), average minimum temperatures drop to almost 0°C. Data also shows that temperatures below freezing point are not uncommon. A minimum (extreme) temperature of - 6°C was measured at this station.

During summer the average daily maximum temperature increases to ±30°C with these temperatures extending from October to March. Average minimum temperatures during the same period range from 14°C to 18°C.

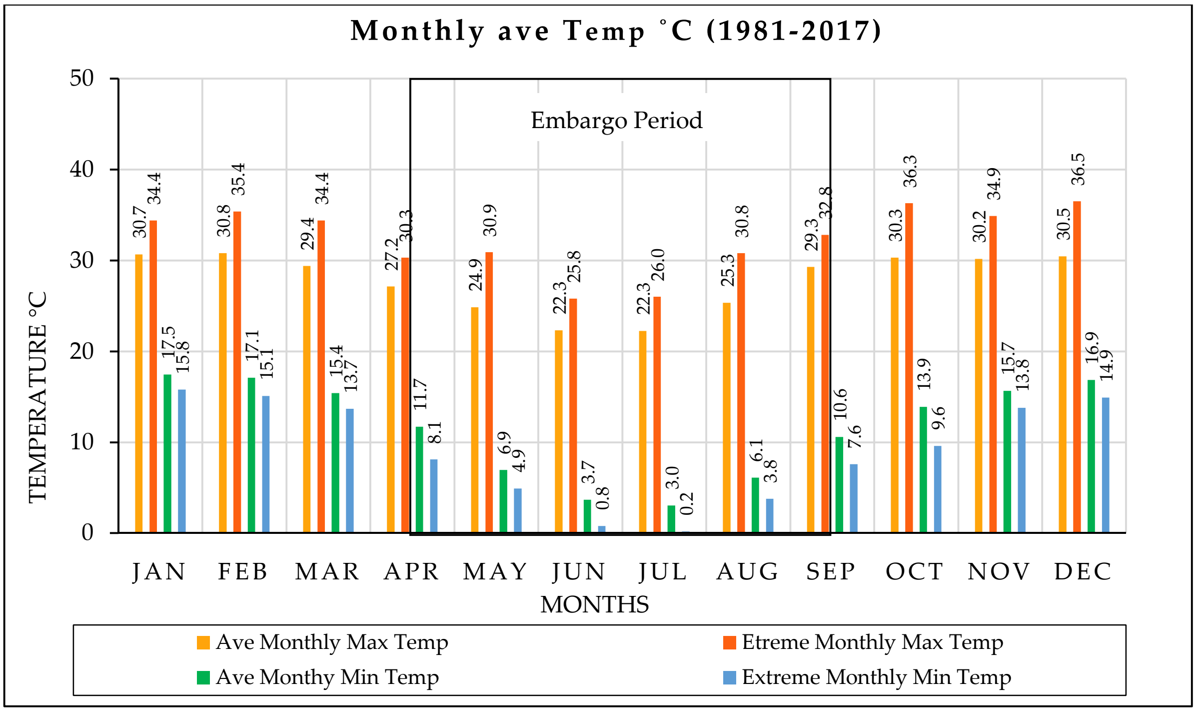

Figure 2.1: Average Monthly Temperature – Bela Bela station 0589594 1

2.2.2 Rainfall

According to the climate data the mean annual precipitation (MAP) for the area is 609 mm. Average monthly rainfall figures are presented in *Figure 2.2*. Also shown is the highest rainfall measured in a single day for the month.

The data shows that most of the rainfall occurs during the summer months from October to April. The average monthly rainfall during this period varies from 60 mm to 126 mm, the latter experienced in January. Winter rainfall is very limited with only ±34 mm occurring from May to September.

Figure 2.2 also shows the number of days per month during which rainfall exceeding 10 mm was recorded.

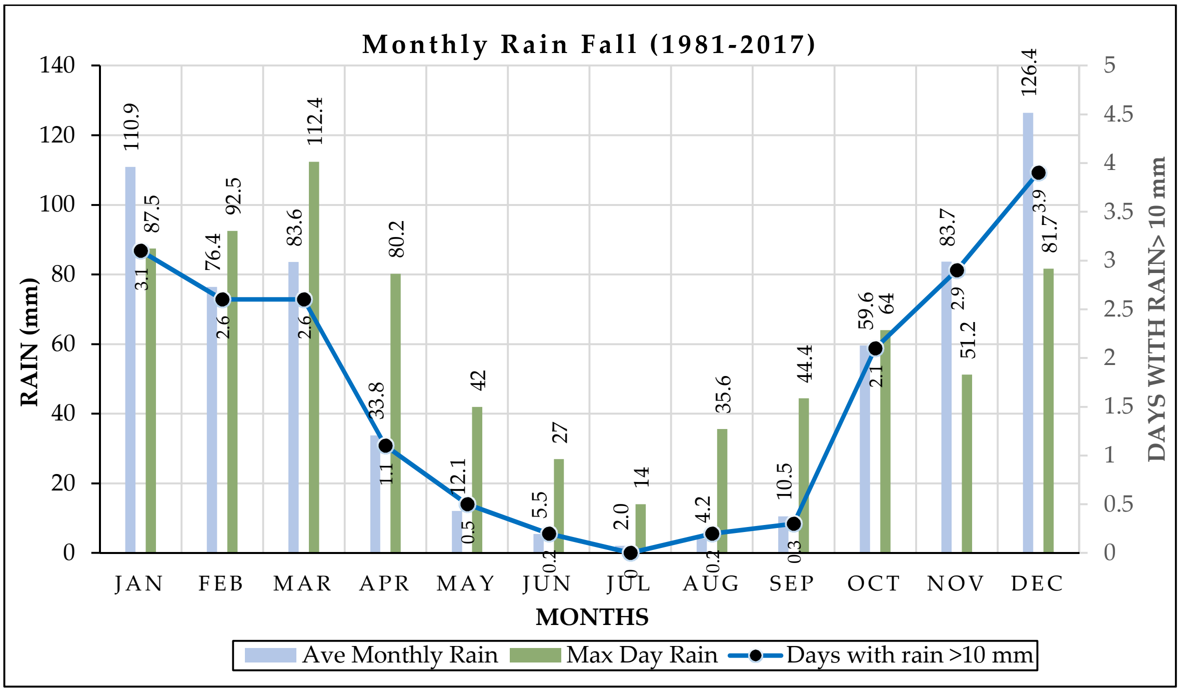

Figure 2.2: Average Monthly Rainfall – Bela Bela station 0589594 1

2.2.3 Classification of Climate

According to the *South African Pavement Engineering Manual (SAPEM), Chapter 10*, the project area falls within a semi-arid, dry region of the country, with the following climatological related indices:

Climatic Region:	Dry Sub-humid (Moderate)
Weinert N-number:	2.5 – 3.5
Thornthwaite's Moisture Index (Im):	-20 to 0

2.2.4 Impact of Climate

The high summer temperatures will impact the choice of bituminous surfacing for the project. Any such surface must be able to handle both the high summer temperatures and the low winter the temperatures without deforming.

Low temperatures and rainfall will impact construction of bituminous surfacing. Allowance will therefore be made in the tender for rain delays. Should a surfacing seal be selected, embargo period from mid-April to mid-September will apply.

2.3 VEGETATION

The area along Road R101-8 is dominated by Central sandy bushveld as well as Waterberg mountain bushveld, which both fall under the Savanna biome. There are various azonal vegetation types occurring within the Bela Bela and Modimolle areas, including azonal forest, alluvial vegetation and inland saline vegetation.

Jacaranda trees were planted on both sides of the road along the first portion of the project (km 0.1 to km 0.3). These were probably planted for shade and decoration purposes.

2.4 REGIONAL GEOLOGY

2.4.1 Background

Regionally the road section under discussion is located on sediments associated with the Nylstroom Subgroup of the Waterberg Group. The Waterberg Group is considered to be between 1 700 and 2 000 million years (Ma) old. It falls within that period of earth's evolution when free atmospheric oxygen was available for the first time in sufficient quantity. This produced oxides of the ferruginous minerals creating suitable conditions for the formation of rock strata with reddish colours.

The main Waterberg Basin evolved as a continental, fault bounded basin, originally extending north and south far beyond its present fault-defined margins. The sequence is presently located between the Melinda fault zone (north) and the Droogekloof thrust fault (south). The presence of this thrust fault explains why the older Waterberg Group is located at a higher level than the younger Karoo sandstones towards the south. These conditions are graphically explained in *Figure 2.3*.

The Figure clearly shows the Karoo beds (2) to the south of Bela Bela followed by the Drooggekloof thrust fault thrusting the Waterberg sandstone (3) and other sedimentary rock upwards.

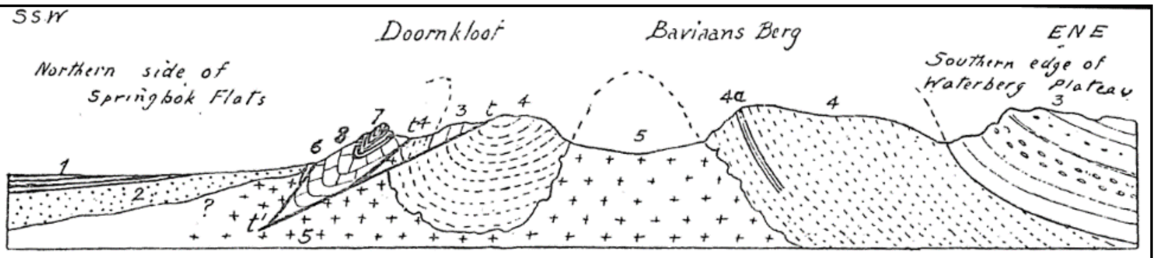

FIG. 20.—Section, 8 miles in length, a little to the west of Warmbaths. 1, Bushveld Amygdaloid; 2, Karroo Beds; 3, Waterberg Sandstones; 4, Felsite; 4*a*, Shales; 5, Red Granite; 6, Pretoria Quartzite; 7, Banded Ironstone; 8, Dolomite; *t*,*t′*, Thrust-planes.

Figure 2.3: Typical Long Section through the Waterberg Group (Alex du Toit in 1926)

2.4.2 Stratigraphy

The regional geology of the area is indicated in *Figure 2.4*. Starting off at the southern extreme of the road section the geology encountered along the route can be described as follows:

2.4.2.1 Clarens Formation

Sandstone of the Clarens Formation, Karoo Supergroup is present from Bela Bela up to Buyskop siding. In the Figure the Clarens Formation is indicated in light salmon and referenced as TR. The sandstone is described as fine grained and of aeolian origin. The deposits reach a maximum thickness of 120 m in the area. Near the base of the deposits it is argillaceous, becoming calcitic towards the top. It is pinkish in colour, but higher up in the sequence white or yellowish. Fossils are scarce in the sequence.

2.4.2.2 Swaershoek Formation

The Swaershoek Formation of the Nylstroom Subgroup, Waterberg Group underlies the road alignment from Buyskop siding up to the farm Modderpoort 454. This Formation is indicated in pale light brown and referenced as Ms *in Figure 2.4*. It constitutes the base of the Waterberg Group and rests un-conformably on the red granites of the Lebowa granite Suite as shown in the Figure. It is composed largely of reddish and brownish, medium grained to coarse grained sandstone with intercalations of siltstone, shale and conglomerate, with flows of lava and greywacke. The maximum thickness in the area is 2 500 m.

2.4.2.3 Alma Formation

The Alma Formation of the Nylstroom Subgroup, Waterberg Group underlies the road alignment from the farm Modderpoort 454 to Modimolle and beyond. In *Figure 2.4* the Alma Formation is indicated in pale light brown hatched light grey and referenced as Mag. It overlies the Swaershoek Formation conformably. The characteristic rock type is green grey greywacke, followed by feldspathic and micaceous sandstone and feldspathic grit with thin, highly altered lava flows. Rocks are well-bedded with cross-bedding in places. Maximum thickness in the area is 3 000 m.

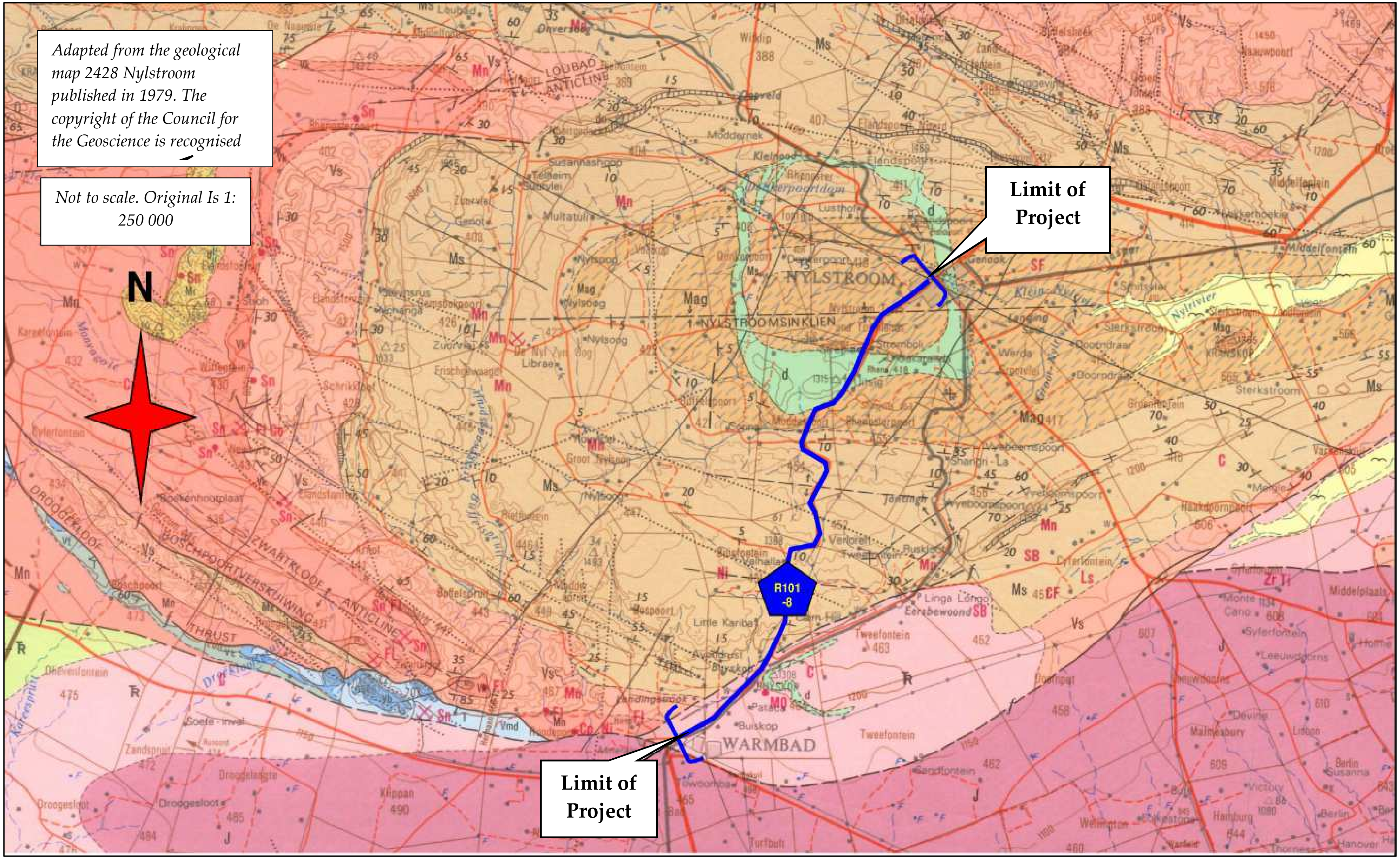

Figure 2.4: Regional Geological Map

2.4.2.4 Diabase

The road alignment traverses intrusive debase on the farms Modderpoort 454 and Renosterpoort 455 just to the south of Modimolle. In the Figure this debase is indicated in light green and referenced as d. Diabase is an intrusive, basic, igneous rock associated with the Bushveld Complex. In an un-weathered state it is dark blue grey to grey green, fine grained and very hard. The main mineral components are pyroxene and plagioclase. As with all basic igneous rocks, debase is subject to chemical weathering, resulting in the formation of active, smectite-rich residual materials containing core-stones of hard rock. Diabase intrusions may also act as aquifers in the given geological scenario.

2.4.3 Structural and Metamorphic History

The geology of the Waterberg Group in this area spans sedimentary deposits dating from the period between 2 500 and 1 200 million years ago, while that of the Clarens sandstone of the Karoo Supergroup dates back to the Jurassic period of 165 million years ago – quite a considerable timespan.

Structurally the important geological features in the area are the Drooggekloof thrust fault to the south which forms the boundary between the Waterberg sediments and the younger Karoo sediments. This thrust fault raised the older Waterberg sediments above the younger Karoo sediments. This topographical feature is clearly visible when passing Buyskop northwards. The second important feature is the presence of the Nylstroom syncline. The trough axis extends east to west and is located just to the south of Modimolle. The net result of the presence of these two features is that after the sharp rise in elevation at Buyskop, the topography gradually reduces again towards Modimolle. This decrease is initially very steep at 45° to 60° towards the northeast, but gradually reduces to 20° to 5° near Modimolle.

2.4.4 In Situ soils

The site is located in an area with a Thornthwaite Moisture Index between -20 and 0 and a Weinert N-value between 2.5 and 3.5. The climate is thus subhumid and residual soils will be the product of chemical decomposition.
Two zones of soil cover can be distinguished, as follows:

2.4.4.1 Transported Soils

Such soil cover is present in the topographically level southern portion of the road section from Bela Bela to Buyskop. The deposits consist of a mixture of sand that has been washed down from the weathering of the Waterberg sandstones to the north and transported sand from the weathering of the Clarens Formation sandstone. However, the nature of these deposits is influenced by the presence of clay derived from the weathering of the Letaba Formation basalt, indicated in purple on *Figure 2.4* and referenced as J. These basalts are located to the south of the Clarens Formation sandstone. The result of the weathering of the basalt is the presence of the highly active clay of the Springbok Flats. Transported clays of this origin extend locally to the area under investigation. The presence of the clay also resulted in the formation of ferricrete or calcrete on the interface of the transported sand overlying the clay.

2.4.4.2 Residual Soils

Residual Sandstone

In the vicinity of Modimolle residual sandstone may be covered by a thick deposit of transported sand. Residual sandstone and to a lesser extent, coarse colluvium, can be associated with the presence of the Waterberg sediments. Such materials consist of gravel to boulder size fragments of sandstone contained in a matrix of sand.

Residual Diabase

Residual debase can be associated with the weathering of the debase intrusion encountered encircling Modimolle. Satellite imagery shows the residual debase to be red brown in colour. Considering the climate of the area, it is expected that the base will weather to red brown clayey sand becoming yellowish, silty sand at depth. Both materials can be regarded as moderately expansive. Especially the yellow silty sand may contain core stones of various sizes.

2.5 SOURCES OF CONSTRUCTION MATERIAL

2.5.1 Crushed Stone Products

A total of four ASPASA accredited commercial sources are situated within a 150 km radius of the project. Details of these sources are provided in *Chapter 15* of this report.

Local material typically consists of rhyolite or felsite. Such materials provide good G1 crushed stone, but is usually not suitable for road stone. The presence of a high quartz content may lead to alkali aggregate reaction in the production of concrete. It is thus important that the crushed stone products be subjected to laboratory testing to determine the physical and chemical properties thereof prior to utilising it for construction.

2.5.2 Natural Gravel

Due to the topography and land use sources of natural gravel are of limited occurrence. Considering the geology, the natural gravels in order preference of quality would originate from rhyolite, Alma greywacke, ferricrete or silcrete, Swaershoek sandstone, debase or basalt.

Several existing excavations have been identified by means of the 1: 50 000 topographical maps and satellite imagery. The references to these excavations do not mean that they are licensed borrow pits or sources of material and merely serves as a starting point to materials procurement. The following areas have been identified:

2.5.2.1 Possible Borrow Area 1

This area is located some 5,2 km to the northwest of Bela Bela at 24° 51′ 13,3″S, 28° 15′ 26,0″E next to the road to Loubad on the farm Roodepoort 467KR. Bedrock consists of rhyolite and the target material is residual rhyolite. It is expected that up to G5-quality gravel can be obtained from this source.

2.5.2.2 Possible Borrow Area 2

This area is located some 450 meters to the northeast of Road R101 at 24° 49′ 59,4″S, 28° 20′ 49,20″E on the farm Buyskop 464KR. Bedrock consists of Swaershoek sandstone and the target material is residual sandstone. It is expected that up to G7-quality gravel can be obtained from this source.

2.5.2.3 Possible Borrow Area 3

This area is located some 4,2 km to the northeast of Road R101 at 24° 50′ 08,2″S, 28° 22′ 32,4″E next to the road to Eersbewoond on the farm Tweefontein 463KR. This is an old borrow pit. Bedrock consists of Letaba basalt and the target material appears to be calcrete. It is expected that up to G7-quality gravel can be obtained from this source.

2.5.2.4 Possible Borrow Area 4

This area is located some 2,5 km to the south of Bela just outside the industrial area at 24° 53′ 57,7″S, 28° 18′ 44,0″E close to Road R516 on the farm Het Bad 465KR. Bedrock consists of Letaba basalt and the target material appears to be residual basalt. It is expected that up to G9-quality gravel can be obtained from this source.

2.5.2.5 Possible Borrow Area 5

This area is located right against Road R101 just outside and south of Modimolle at 24° 42′ 48,8″S, 28° 23′ 05,0″E on the farm Nylstroom Townlands 419KR. The use of the area may be curtailed due to the proximity of residential development. Bedrock consists of Alma greywacke and the target material is residual greywacke. It is expected that up to G6-quality gravel can be obtained from this source.

2.5.2.6 Possible Borrow Area 6

This area is located in vacant land to the south of the Modimolle industrial area some 3,1 km from Road R101 at 24° 43′ 40,2″S, 28° 24′ 21,9″E on the farm Nylstroom Townlands 419KR. The use of the area may be curtailed due to the proximity of residential development. Bedrock consists of Alma greywacke and the target material is residual greywacke. It is expected that up to G6-quality gravel can be obtained from this source.

2.6 ANTICIPATED PROBLEMS

2.6.1 Road Construction

Experience taught that variable roadbed conditions occur between Bela Bela and Buyskop siding. Typically, pockets of expansive clay and collapsible sand follow each other at short intervals. From Buyskop to the occurrence of debase on the farm Modderpoort, bedrock will be present at shallow dept. Although such conditions are favourable for roadbeds, hard excavation may prevail. From Modderpoort up to the northern limit of the project one can expect the presence of deep, loose transported sand.

2.6.2 Founding

The road crosses the Great Nile River on the farm Modderpoort 454KR, but also several non-perennial streams. It is expected that thick deposits of alluvial sand will be present in the course of the Great Nile River. In general terms it is expected that bedrock of sandstone may provide a suitable horizon for founding of bridge and culvert structures, but at the river crossing founding of bridge widening may require piling.

2.6.3 Slope Stabilities

The directions and extent of regional dip of the main set of discontinuities of the sediments of the Waterberg Group are such that major rock slope failures may not be induced as the regional dip generally follows the north-south alignment of the road. However, where the direction of the alignment deviates from north-south, one may expect rock slope failures, especially in the southern cut faces. It is thus sufficient to say that slope failures may occur, but each potential case must be considered on merit.

2.6.4 Materials Sourcing

Sources of construction material are limited in the area. If a programme of materials procurement is not to be implemented, crushed stone and natural aggregates must be obtained from commercial sources.

2.7 LAND USE

The surrounding area mainly consist of agricultural land, estate developments and game farms with a number of small holdings being the prevalent specific use.

CHAPTER 3 EXISTING ROAD INFORMATION

3.1 ROAD CLASSIFICATION

National Road R101 Section 8 generally consists of a two lane single carriageway with gravel shoulders. The road can be classified as follows:

3.1.1 Functional Classification

Classification of Road R101-8 was conducted in accordance with *TRH26*[1] which is the current authority for classification of roads.

- **The size and strategic importance of the trip generators served by the roadway**:
  - National Road R101 is a major rural road situated inland, joining the Provinces of Limpopo and Gauteng. Road R101-8 specifically serves as a link between the towns of Bela Bela and Modimolle. Therefore, it can be defined as a ***Rural Mobility Major Arterial Road***.

- **Rural Functional Classification:**
  - Road R101-8 connects nodes over long distances, the nodes being Bela Bela and Modimolle. The towns of Bela Bela and Modimolle are classified as main towns with populations of over 66 500 and 68 500 (2011 Census), respectively.

- **The travel stage being "through" in nature:**
  - Access is not restricted along this route considering that the road runs through towns and that a number of farm accesses are situated along the road. The fact that this specific section of road allows road users to travel away from their origin or destination, confirms that this road can be classified as "through" in nature.

These characteristics indicate that Road R101 is defined as a mobility road, connecting development centres over long distances. It also connects other collector roads and can therefore be classified as a Class 2 rural major arterial.

3.1.2 TRH4 Road Category

According to *Table 1* of *TRH4,* Road R101 Section 8 falls within the interurban collector and rural roads category and can therefore be classified as **a Category B Road**.

[1] TRH 26 – South African Road Classification and Access Management Manual, Ver. 1.0, Aug 2012

3.2 EXISTING CROSS SECTION AND ROAD RESERVE

Road R101-8 is a single carriageway road with three distinct cross sections. The majority of the road (22.6 km) consists of two 3.5 m lanes with gravel shoulders as shown in *Figure 3.1.* Two climbing lanes are provided at the following locations:

- Northbound, km 6.2 to km 7.5; and
- Southbound, km 14.4 to km 15.7.

A typical cross section of this arrangement is shown in *Figure 3.2*. In both Bela Bela (km 0.0 to km 0.1) and Modimolle (km 26.4 to km 26.8), the road widens to a four lane undivided single carriageway as illustrated in *Figure 3.3*.

A section in Modimolle (km 25.3 to km 26.4) consists of three lanes, two in the southbound and one in the northbound direction. The northbound lane as well as the southbound slow lane are 4.0 m wide, while the southbound fast lane is 3.7 m wide. Turning lanes are also provided at intersections.

Road R101-8 has an average road reserve width of approximately 35 m along the entire project.

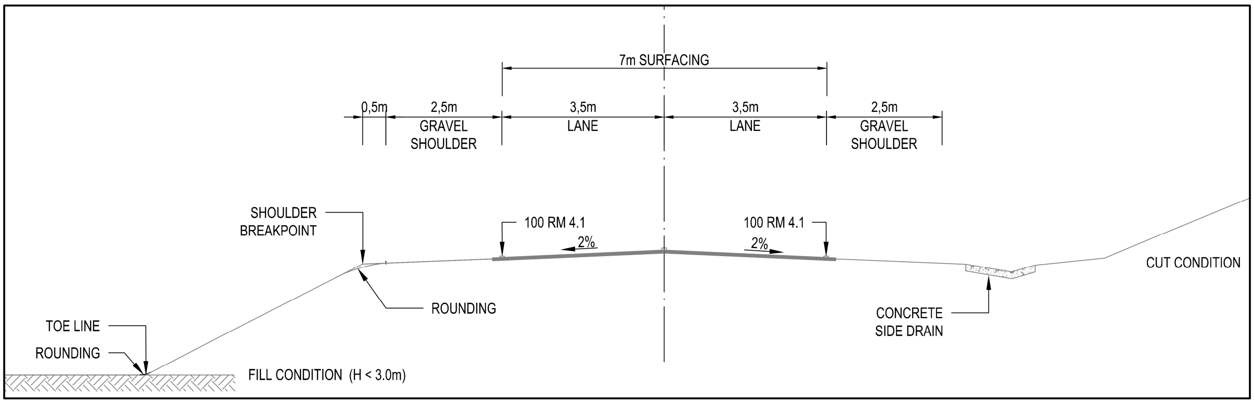

Figure 3.1: Typical cross section along R101 Section 8

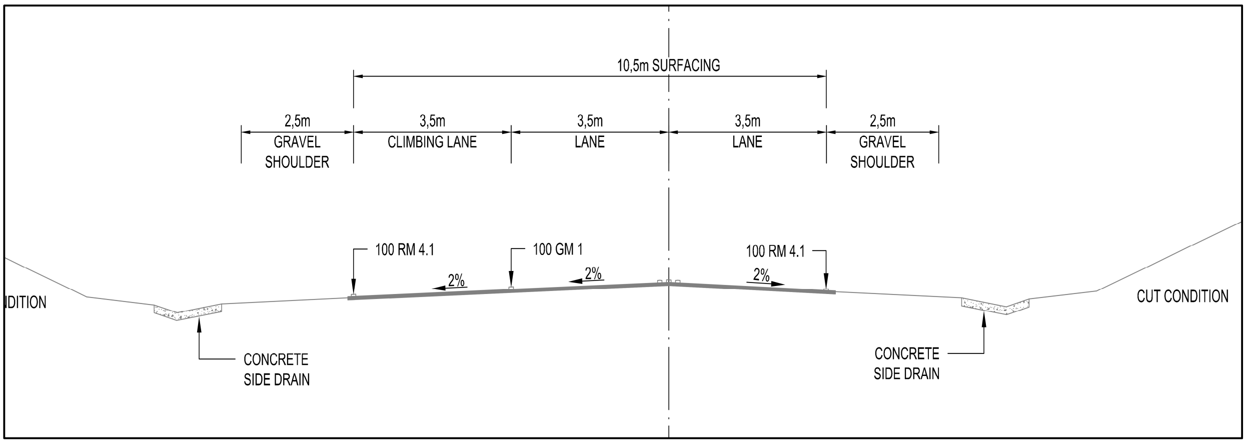

Figure 3.2: Single carriageway cross section with climbing lane

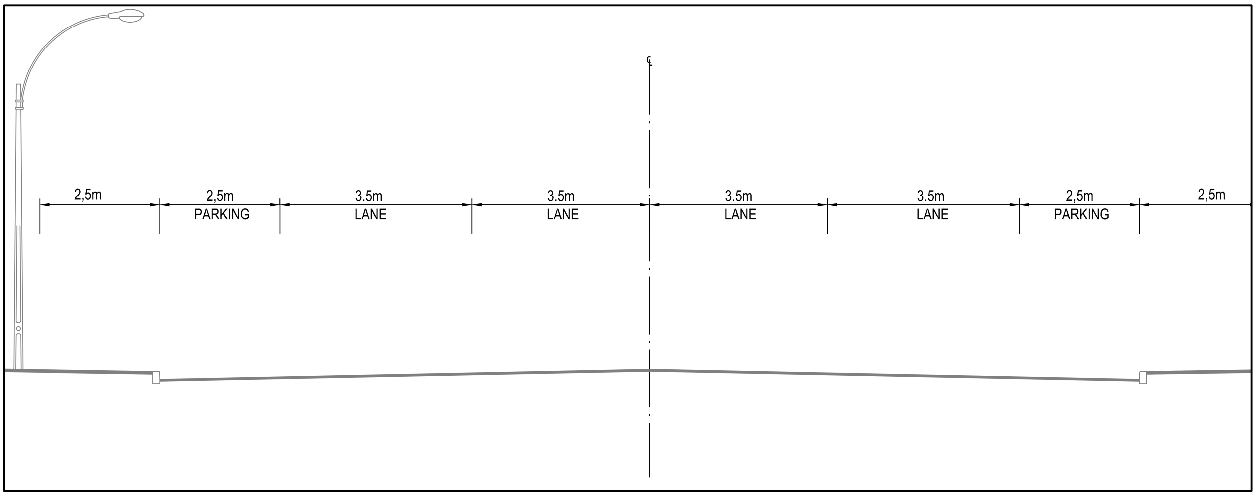

Figure 3.3: Typical existing 4 lane cross section in Modimolle

3.3 PAVEMENT HISTORY

The as-built data provided by SANRAL as shown in *Figure 3.4* indicates that the existing pavement was constructed in 1964 with the following structure:

- Surface: 13.2 mm bitumen rubber single seal
- Base: 125 mm AC
- Subbase: 125 mm G5
- Selected: 100 mm G6

SANRAL
South Africa National Road Agency Limited
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Page Number: PartA, Page 1 of 1
Date Printed: 21 October 2016

Kilometres	5	10	15	20	25	26.81
Traffic Segment speed	60 / 80	100	60			
Traffic Segment ADT	6576	6576	4307		4307	
Segment Reponsibility	N					
Segment Road Type	S2U					
Segment Segment speed	Flexible					
Surface (1964)	13mm S1R(1964)		13mm S1R(1964)		13mm S1R(1964)	
Base	125mm AC (1964)		125mm AC (1964)		125mm AC (1964)	
Subbase	125mm G5 (1964)		125mm G5 (1964)		125mm G5 (1964)	
Selected	100mm G6 (1964)		100mm G6 (1964)		100mm G6 (1964)	
Kilometres	5	10	15	20	25	

Figure 3.4: Pavement as-built information for R101-8

The visual assessment showed an asphalt surfacing along the section from km 0.0 to km 2.3 and similarly for the section from km 25.1 to km 26.8. A 13.2 mm bitumen rubber single seal is present along the remainder of the road (km 5.44 to km 25.1). The materials investigation showed that the base generally consist of gravel material, contrary to the information above.

No information pertaining to the maintenance history along Road R101-8 was available.

CHAPTER 4 TRAFFIC INFORMATION

4.1 INTRODUCTION

The findings from a traffic study carried out by *Innovative Transport Solutions (Pty) Ltd (ITS) are* discussed in this chapter. *ITS* conducted traffic modelling and analysis along Road R101-8 which included the level of service analysis for normal day peak and 30th highest hourly volumes. The purpose of the study was to understand the traffic along Road R101-8 and to identify a suitable configuration to improve the capacity along this road. In addition to this, a road side interview was requested by the Employers to determine if there are any possible attraction of traffic from the N1 Toll Route should Road R101-8 be upgraded. The latter was added following the concerns raised by SANRAL regarding possible loss of toll revenue, should the road section be upgraded to a 4 lane cross section throughout.

4.2 DATA COLLECTION

4.2.1 Sourced 2015 Traffic Data

The SANRAL tender document contained traffic data collected in 2015. The data is summarised in *Table 4.1* below. As indicated in the Table, the sections from km 0.00 to km 2.22 and from km 2.22 to km 5.44 have exactly the same traffic volumes. The road can be divided into two uniform sections from km 0.00 to km 5.44 and km 5.44 to km 26.8.

Table 4.1: 2015 traffic data for Road R101-8

SEGMENT NO	FROM – TO (km – km)	SURVEYED	ADT (VEH/DAY)	ADTT (TRUCKS / DAY)	DIRECTIONAL SPLIT	% HEAVY VEHICLES
1	0.00 –2.22	2015-02-17	6 576	599	51 : 49	9.1%
2	2.22 –5.44	2015-02-17	6 576	599	51 : 49	9.1%
3	5.44 –24.83	2015-03-05	4 307	228	52 : 48	5.3%

4.2.2 Other CTO Data along Road R101

Additional historic traffic information was sourced from the following CTO Stations outside Road R101 Section 8:

- CTO Station 534 (R101- Mokopane to Mookgophong);
- CTO Station 1405 (R101- Mokopane to Mookgophong); and
- CTO Station 1133 (R101- Bela Bela to Hammanskraal).

The locations of these CTO stations are shown in *Figure A2* of a traffic report included in *Appendix B.*

4.2.3 Temporary Electronic Counts, 2018

7-day classified electronic traffic counts were conducted at three locations along Road R101-8 from 24 October 2018 to 1 November 2018. This data was used to determine the current traffic composition, speeds and traffic variations on the route. Refer to *Appendix B* for a map showing the locations of the electronic counts as well as the traffic count data. A summary of the traffic count data is shown in *Table 4.2* below.

Table 4.2: Summary of 7-day electronic counts

NO	LOCATION (km)	STATION NAME	ADT (VEH/DAY)	ADTT TRUCKS/DAY	DIRECTIONAL SPLIT	HEAVY VEHICLE %
1	3.025	1426	7 488	1 054	49 : 51	14.1%
2	6.700	1427	4 788	402	49 : 51	8.4%
3	23.400	1428	4 431	398	49 : 51	9.0%

The data indicates that stations 1427 and 1428 have similar traffic volumes with station 1427 being slightly higher. Data gathered from station 1427 was therefore used for the analysis of the segment from km 5.44 to km 26.80

4.2.4 Site Visit

A site visit was conducted on 18 October 2018. The following noteworthy items were observed:

- No significant capacity constraints were observed along the project section;
- Mile Street in Bela Bela was closed due to construction on the side road close to the intersection. The intersection was temporarily relocated approximately 1.6 km northwards at km 2.40;
- There is a significant number of hitch-hikers in both Bela Bela and Modimolle and there are no formal public transport facilities in place;
- Few bicycles were observed travelling between Bela Bela and Modimolle on Road R101-8;
- A lack of sidewalks in both Bela Bela and Modimolle;
- A strong pedestrian movement into the Bela Bela CBD during the morning peak;
- A hospital and municipal offices are located adjacent to Road R101 in Modimolle with access not directly on Road R101-8; and
- A total of seven schools are situated on both sides of Road R101-8 in Modimolle but none of them have direct access from Road R101-8.

4.2.5 Intersection Traffic Counts

Manual intersection traffic counts were conducted on 25 October 2018 over a period of 12 hours (06:00 to 18:00). These counts differentiated between light and heavy vehicles. Traffic counts were conducted at 14 intersections and the data is summarised in *Figure 4.1*.

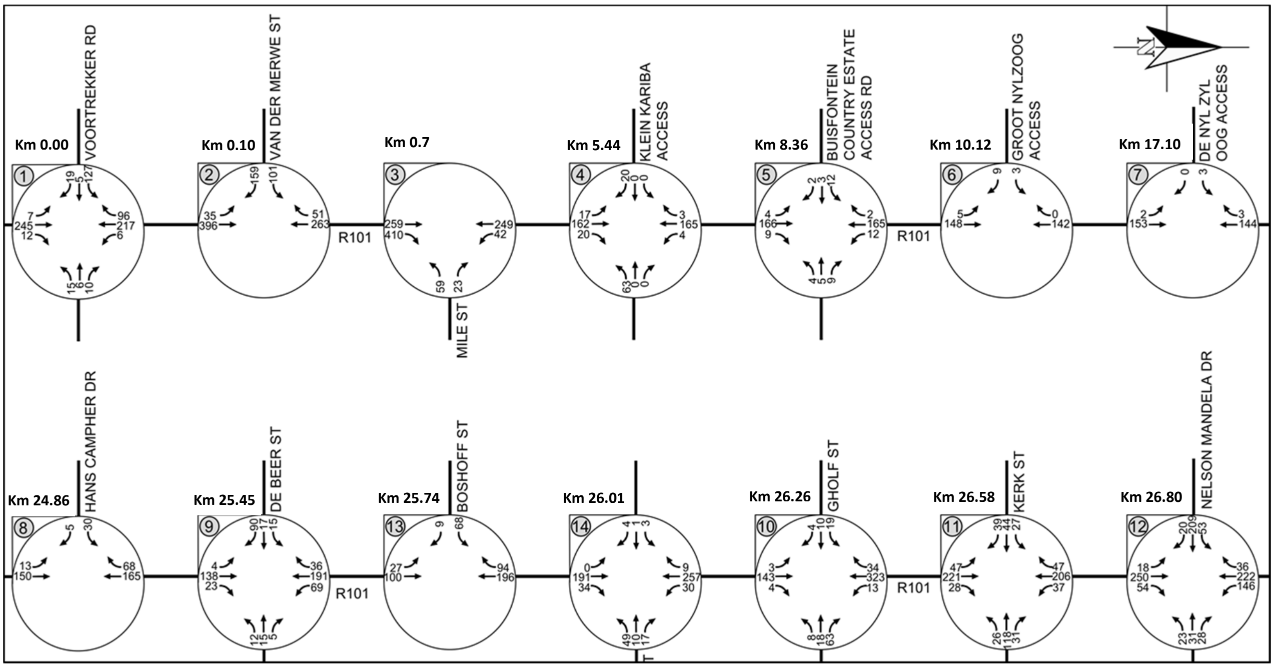


Figure 4.1: Intersection traffic counts along Road R101-8

4.2.6 Pedestrian Counts

Pedestrian counts were conducted at 6 locations using the pedestrian movements illustrated in *Figure 4.2*. The counts were conducted for 12 hours from 06:00 to 18:00.

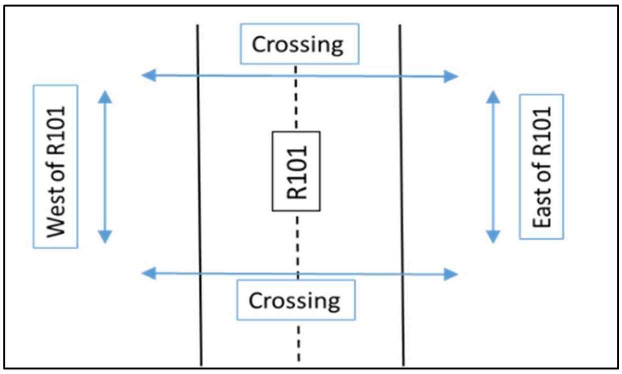


Figure 4.2: Pedestrian movements counted

The total pedestrians counted for the day are shown in *Table 4.3*. These counts were used to identify the need for new pedestrian infrastructure along Road R101-8 within Bela Bela and Modimolle. For more detailed information refer to *Appendix B*.

Table 4.3: Pedestrian volumes per day along Road R101-8

STATION NO	DESCRIPTION	LOCATION (KM)	NORTH / SOUTH			CROSSING R101
			WEST OF R101	EAST OF R101	TOTAL	
P1	Van der Merwe Street	0.100	1251	2510	3761	1232
P2	South of Mile Street	0.800	1190	2333	3523	746

STATION NO	DESCRIPTION	LOCATION (KM)	NORTH / SOUTH			CROSSING R101
			WEST OF R101	EAST OF R101	TOTAL	
P3	Temporary access	2.400	341	244	585	1327
P4	SASSA offices	25.200	154	178	332	158
P5	Boshoff Street	25.670	217	272	489	116
P6	Gholf Street	26.250	422	238	660	191

4.2.7 Accident Data

Accident reports recorded from 2015 to 2018 were provided by *KBK Engineers* and are attached in *Appendix C. KBK Engineers* were appointed by SANRAL in 2015 for the routine road maintenance Manager contract along this section of the road.

Data indicates a total of sixteen (16) accidents recorded during this period, of which ten occurred during the day and six at night. One accident had a fatality while the rest were limited to injuries.

Exact locations were recorded for three accidents, i.e. km 11.6, km 11.8 and km 15.4. These positions coincide with that of two horizontal sharp curves.

Data further indicates that the cause of three accidents was loss of control, one accident was due to collision with an animal, three due to car on car collision and the remaining as unknown.

Seven accidents occurred during weekends (Fridays and Saturdays) and three on Mondays. This correlate to the traffic data indicating that the three days (Monday, Friday and Saturdays) are the most busy days, with Friday having the highest traffic volume.

4.3 TRAFFIC GROWTH

Growth rates were calculated by determining the trend line through historic ADT volume data points. This trend line was extended to the 20-year horizon year (2043). A compound growth rate was calculated in line with the 2043 projected trend line value.

Growth rates for Road R101-8 were also calculated by comparing the 2015 traffic data from the SANRAL tender document with the 7-day electronic counts conducted in 2018. This comparison is summarised in *Table 4.4*, and shown graphically in *Figure 4.3* and *Figure 4.4*. The ADTT graphs are included in the traffic report attached in *Appendix B*.

Table 4.4: Traffic growth rates based on 2015 and 2018 counts

SEGMENT (km – km)	2018 COUNTING STATION	ADT 2015	ADT 2018	ADT ANNUAL GROWTH RATE	ADTT ANNUAL GROWTH RATE
0.00 –5.44	1426	6 576	7 488	3.02%	7.01%
5.44 –26.80	1427	4 307	4 788	2.60%	7.02%

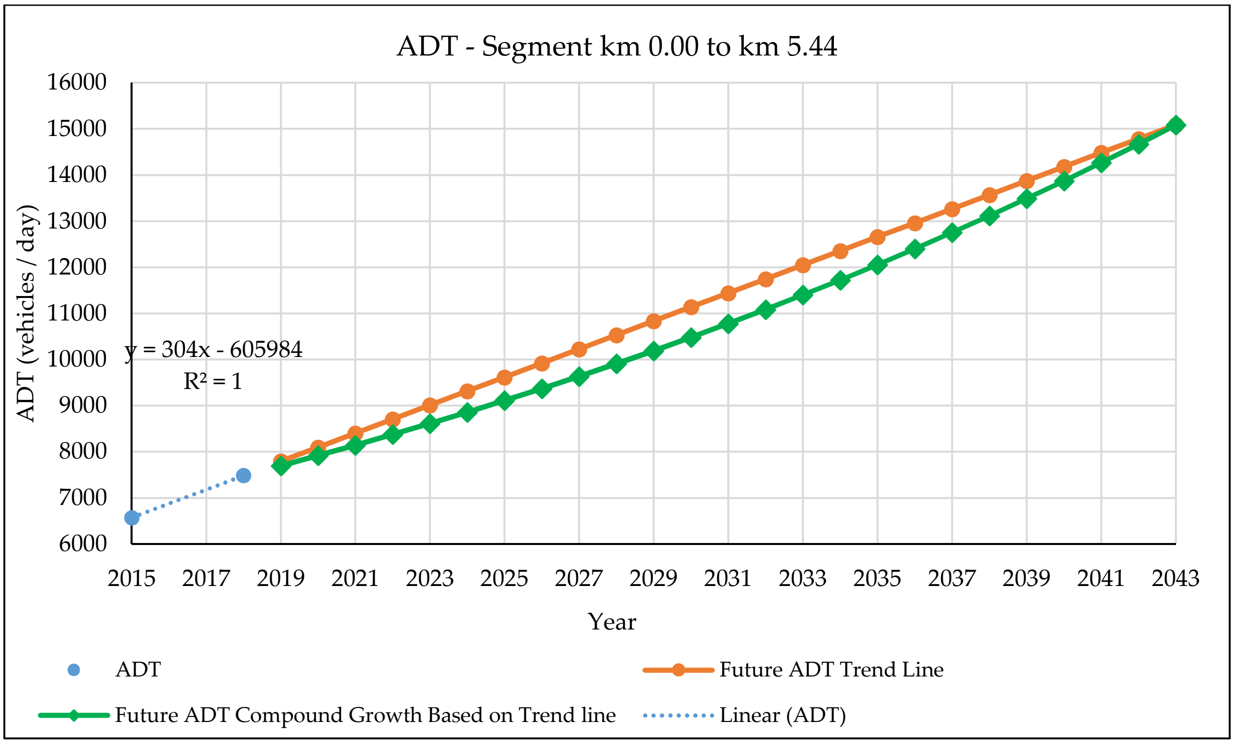


Figure 4.3: ADT Growth Rate for Road R101-8 km 0.00 to km 5.44

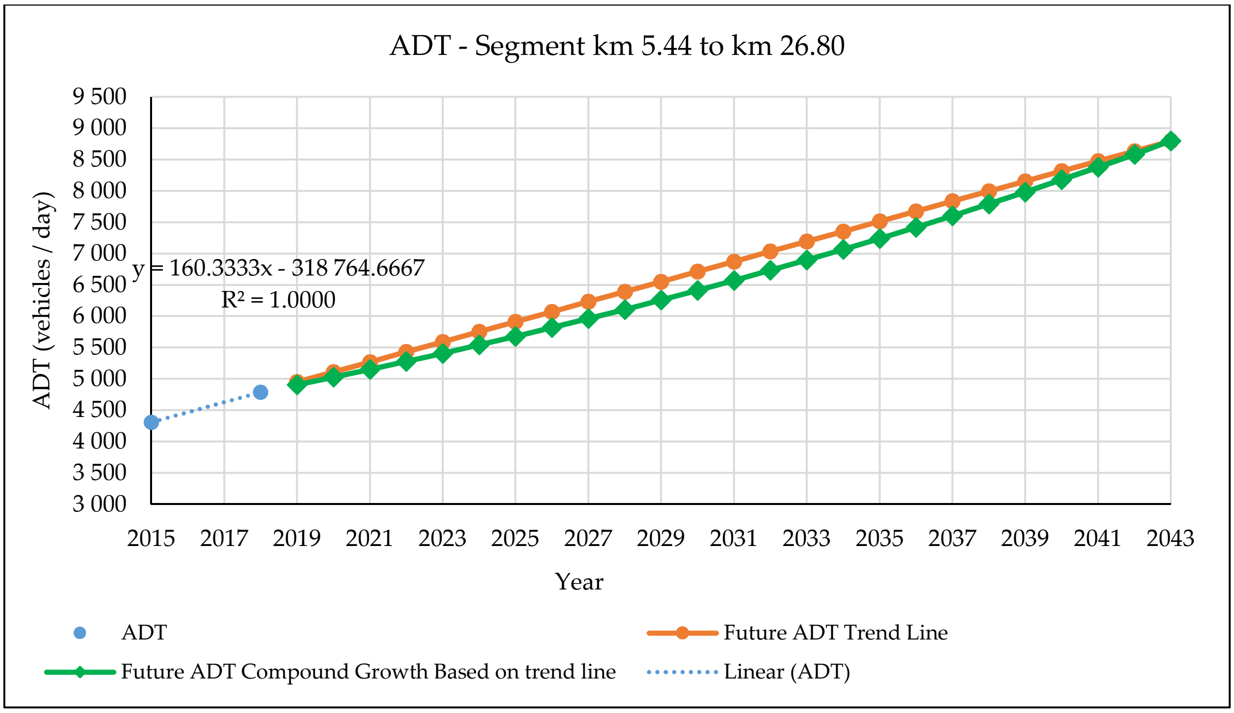


Figure 4.4: ADT Growth Rate for Road R101-8 km 5.44 to km 26.80

The level of confidence for these growth rates are low because only two traffic volume data points are available for the calculation. Growth rates were therefore calculated using available long term data from three selected CTO stations along Road R101 in the region as summarised in *Table 4.5* and shown graphically in *Figure 4.5*, *Figure 4.6* and *Figure 4.7*.

Table 4.5: Traffic Growth Rates for Permanent CTO Stations along Road R101

CTO STATION	CTO LOCATION	ADT		ADTT	
		R^2	ANNUAL GROWTH RATE	R^2	ANNUAL GROWTH RATE
534	On R101 between Mokopane and Mookgopong	0.94	1.35%	0.77	1.16%
1405	On R101 between Mokopane and Mookgopong	0.22	0.63%	0.04	-0.33%
1133	On R101 between Bela Bela and Hammanskraal	0.81	2.51%	0.78	1.79%

Data shows that ADT and ADTT historical growth rates are similar, therefore no separate future growth rate will be estimated for ADT and ADTT.

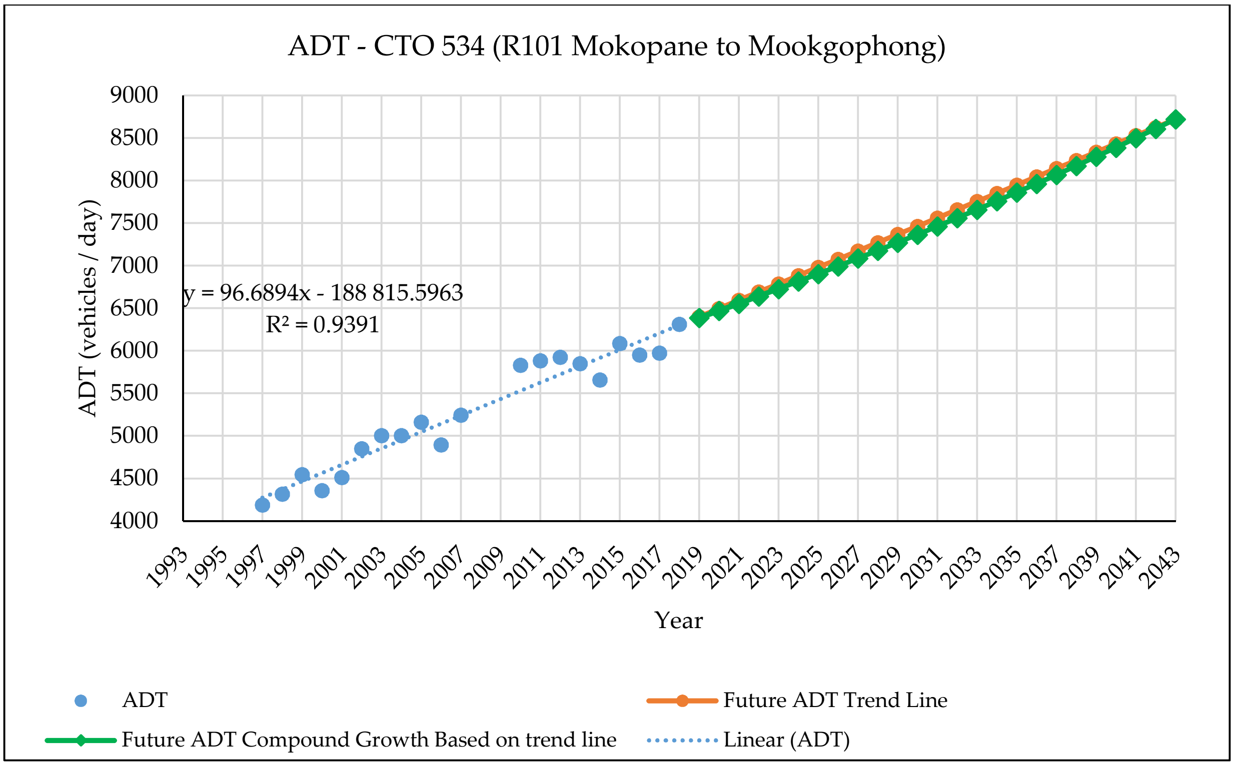


Figure 4.5: ADT Growth Rate – R101 CTO Station 534 (Mokopane to Mookgopong)

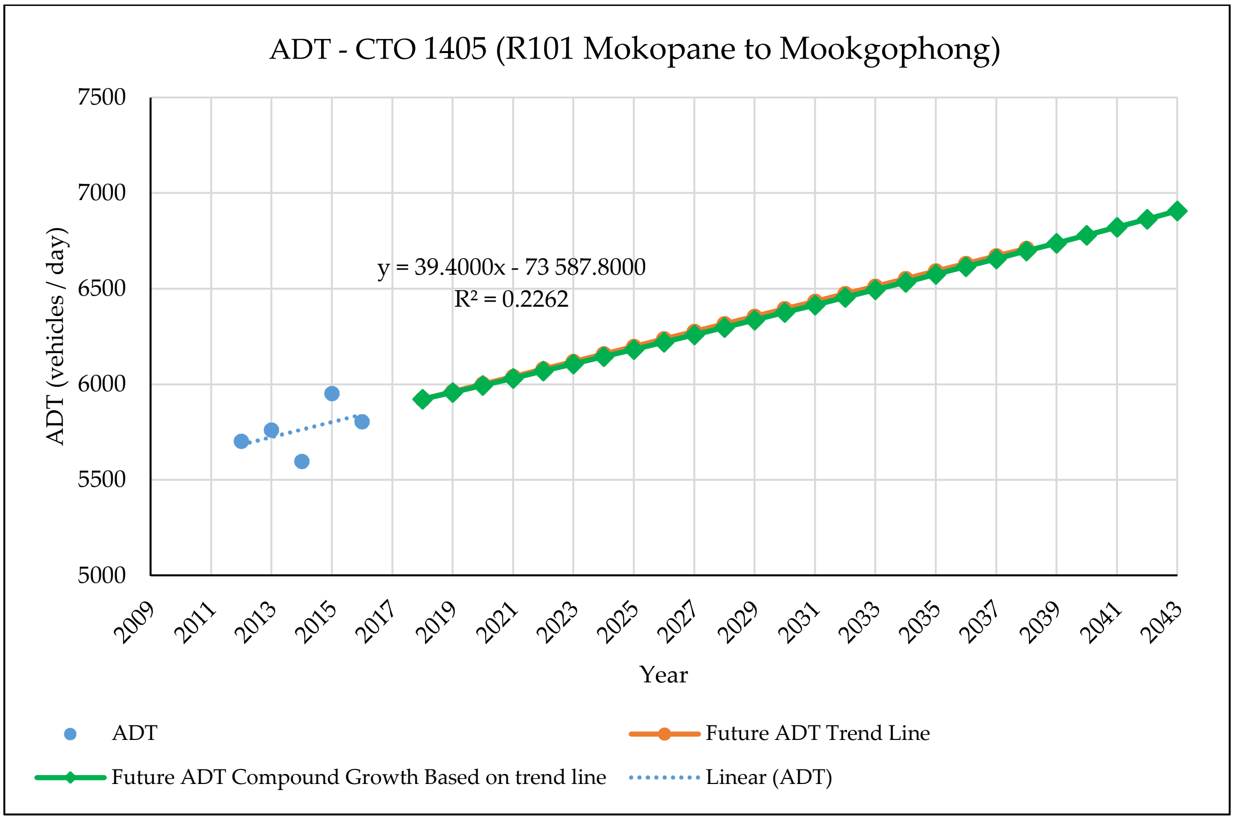


Figure 4.6: ADT Growth Rate – R101 CTO Station 1405 (Mokopane to Mookgopong)

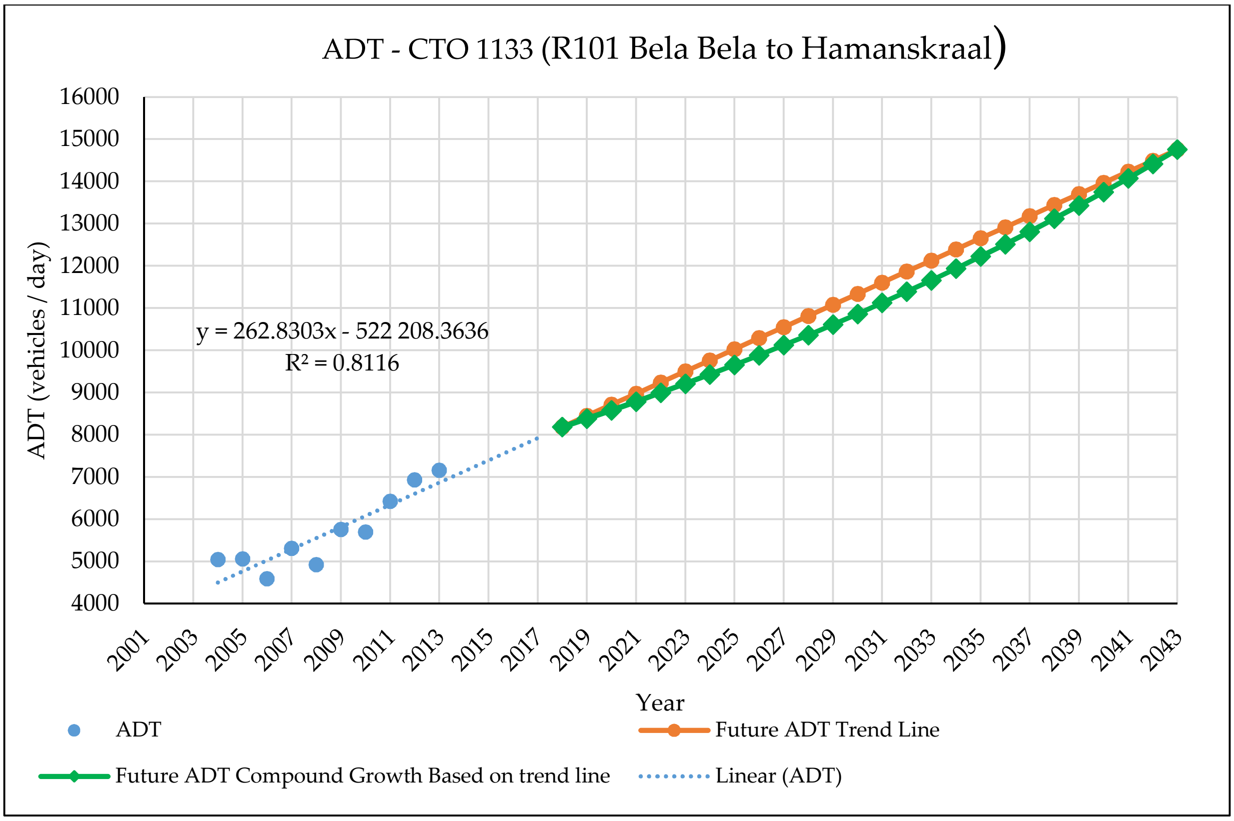


Figure 4.7: ADT Growth Rate –R101 CTO Station 1133 Bela Bela to Hammanskraal

Taking the above historical information into consideration, high, medium and low growth rate scenarios were proposed for the operational analysis. Annual growth rates for ADT and ADTT are as follows:

- Low – 1.0% per year;
- Medium – 2.5% per year; and
- High – 4.0% per year.

4.4 NORMAL DAY PEAK HOUR

The normal day peak hours were identified from the counts as shown in *Table 4.6* and *Table 4.7*.

Table 4.6: Normal Day Peak Hour – Station 1426 at km 3.025

DATE	DAY	PEAK HOUR	VOLUME (VEH/HR)	HEAVY VEHICLES IN PEAK HR	% HEAVY VEHICLES IN PEAK HR	DIRECTIONAL SPLIT
2018/10/24	Wednesday	PM	541	81	15.0%	50.8%
2018/10/25	Thursday	AM	579	88	15.2%	51.3%
2018/10/25	Thursday	PM	604	82	13.6%	51.8%
2018/10/30	Tuesday	AM	562	79	14.1%	50.0%
2018/10/30	Tuesday	PM	583	92	15.8%	51.6%
2018/10/31	Wednesday	AM	547	69	12.6%	51.0%
2018/10/31	Wednesday	PM	592	70	11.8%	51.9%
2018/11/01	Thursday	AM	539	65	12.1%	50.8%
Average			**568**	**78**	**13.8**	**51.2%**
Q / AADT			**568 / 7488 = 0.08**			

Table 4.7: Normal Day Peak Hour – Station 1427 at km 6.700

DATE	DAY	PEAK HOUR	VOLUME (VEH/HR)	HEAVY VEHICLES IN PEAK HR	% HEAVY VEHICLES IN PEAK HR	DIRECTIONAL SPLIT
2018/10/24	Wednesday	PM	333	35	10.5%	52.0%
2018/10/25	Thursday	AM	335	33	9.9%	51.0%
2018/10/25	Thursday	PM	368	35	9.5%	53.5%
2018/10/30	Tuesday	AM	340	31	9.1%	52.1%
2018/10/30	Tuesday	PM	354	35	9.9%	54.8%
2018/10/31	Wednesday	AM	356	22	6.2%	51.4%
2018/10/31	Wednesday	PM	367	35	9.5%	53.4%
2018/11/01	Thursday	AM	336	27	8.0%	50.9%
Average			**349**	**32**	**9.1%**	**52.4%**
Q / AADT			**349 / 4788 = 0.07**			

The following Normal Day Peak Hour values were used in the HTM Model:

- Q / AADT = 0.08
- PHF = 0.95
- Directional split = 60%
- Percentage Heavy Vehicles = 14% and 10%

4.5 30TH HIGHEST HOUR

The Q/AADT factor, also known as the K-factor, was determined from CTO stations in the area. An entire year of data is required to calculate the K factor for the 30th Highest Hour. The K-factors determined are shown in *Table 4.8*.

Table 4.8: K-factor for the 30th Highest Hour – CTO Stations

YEAR	CTO STATION 534 (R101)			CTO STATION 2143 (N1)			CTO STATION 1133 (R101)		
	AADT	30HHV	Q/AADT	AADT	30HHV	Q/AADT	AADT	30HHV	Q/AADT
2011	5883	882	0.15	15454	2446	0.16	22670	2864	0.13
2012	5927	966	0.16	13266	2322	0.18	14994	2387	0.16
2013	5850	938	0.16	14444	2366	0.16	15213	2479	0.16
2014	5660	912	0.16						
2015	6089	1052	0.17						
2016	5953	969	0.16						
2017	5976	1016	0.17						
Average			0.16			0.17			0.15

The following 30th Highest Hour values were used in the HTM Model:

- Q / AADT = 0.17
- PHF = 0.95
- Directional split = 60%
- Percentage Heavy Vehicles = 14% and 10%

4.6 HTM LEVEL OF SERVICE ANALYSIS

The Highway Traffic Model (HTM) was used for the capacity and level of service determination along Road R101-8. The model uses follower density as a general performance measure to warrant road improvements. Analysis was conducted for the normal day peak hour and the 30th highest hour along the existing alignment.

According to the Highway Traffic Model notes (Van As, 2014) the recommended level of service acceptable on a Class 2 roadway should be LOS B and LOS C for the Normal day peak and the 30th highest hourly volume (HHV), respectively. A number of factors, however, need to be considered in conjunction with these guidelines:

- The historical traffic data on Road R101-8 is inadequate to provide projected growth rates with high level of confidence;
- Capital expenditure needs to consider alternative applications that may provide a better return in light of the traffic growth uncertainty mentioned above; and
- The 30th HHV values should be based on a full year`s traffic data which is not available for this project.

In light of the above, it is recommended that the normal day peak hour acceptable LOS be used. It is furthermore recommended that the latter should guide to inform conclusions going forward. The 30th HHV will be analysed, however, the results will be used as a secondary input towards conclusions.

The HTM analyses were conducted in order to evaluate the existing alignment and cross sectional configurations as well as the three initially proposed cross sectional improvements.

4.6.1 HTM Model Input Summary

A "Type 2" analysis was conducted, which analyses each direction with the heaviest directional split and takes the worst LOS. As mentioned previously, the road was divided into two separate uniform sections. The analysis parameters for these segments are shown in *Table 4.9.*

Table 4.9: Input Traffic Data for HTM Analysis

UNIFORM SECTION (km –km)	YEAR	AADT	GROWTH RATE %	NORMAL DAY PEAK HOUR				30TH HIGHEST HOUR			
				Q / AADT	PHF	%DIR	%HV	Q / AADT	PHF	%DIR	%HV
(0.00–5.44)	2018	7 488	2.5%	0.08	0.95	60%	14%	0.17	0.95	60%	14%
(5.44–26.80)	2018	4 788	2.5%	0.08	0.95	60%	10%	0.17	0.95	60%	10%

4.6.2 HTM Results: Existing cross section and alignment

The HTM analysis for existing road was conducted using three growth rate scenarios (1%, 2.5% and 4%). Results from this analysis are summarised in *Table 4.10*. The 2.5% growth rate was found to be the most reasonable growth rate and results for each kilometre are summarised in *Table 4.11*.

The results show that the first section from km 0.00 to km 5.44 (Klein Kariba intersection) was already due for upgrade in 2018 for the normal day peak hour at LOS D (30th HHV at LOS F). The section between km 5.44 and km 26.80 will be due for upgrade in 2033 for the normal peak hour and is already due in 2018 for 30th HHV.

Table 4.10: Summary of HTM results for existing road layout (1%, 2.5% and 4%)

FROM – TO (km – km)	PEAK VOLUME	GROWTH RATE (%)	YEAR					
			2018	2023	2028	2033	2038	2043
0.0 to 5.44	Normal	1%	D	D	D	D	D	E
		2.50%	D	D	D	E	E	F
		4%	D	D	E	F	F	F
	30th HHV	1%	F	F	F	F	F	F
		2.50%	F	F	F	F	F	F
		4%	F	F	F	F	F	F
5.44 to 26.80	Normal	1%	B	C	C	C	C	C
		2.50%	B	C	C	C	D	D
		4%	B	C	C	D	E	F
	30th HHV	1%	E	E	E	E	E	F
		2.50%	E	E	F	F	F	F
		4%	E	E	F	F	F	F

Table 4.11: HTM results using medium growth rate (2.5%) on existing road alignment

SECTION (km – km)	NORMAL DAY @ 2.5% GROWTH RATE							30HHV @ 2.5% GROWTH RATE					
	2018	2023	2028	2033	2038	2043		2018	2023	2028	2033	2038	2043
0 - 1	D	D	E	E	F	F		F	F	F	F	F	F
1 - 2	D	D	E	E	E	F		F	F	F	F	F	F
2 - 3	D	D	E	E	E	F		F	F	F	F	F	F
3 - 4	D	D	E	E	E	F		F	F	F	F	F	F
4 - 5	D	D	E	E	E	F		F	F	F	F	F	F
5 - 6	C	C	D	D	D	E		E	F	F	F	F	F
6 - 7	C	C	C	D	D	D		E	E	F	F	F	F
7 - 8	B	C	C	C	D	D		E	E	F	F	F	F
8 - 9	B	C	C	C	C	D		D	E	E	F	F	F
9 - 10	B	C	C	C	C	D		D	E	E	F	F	F
10 - 11	C	C	C	D	D	D		E	E	F	F	F	F
11 - 12	C	C	C	C	D	D		E	E	F	F	F	F
12 - 13	B	B	C	C	C	D		D	E	E	F	F	F
13 - 14	B	C	C	C	D	D		D	E	E	F	F	F
14 - 15	B	C	C	C	D	D		D	E	E	F	F	F
15 - 16	C	C	C	D	D	D		E	E	F	F	F	F
16 - 17	C	C	C	D	D	D		E	E	F	F	F	F
17 - 18	C	C	C	D	D	D		E	E	F	F	F	F
18 - 19	C	C	C	D	D	D		E	E	F	F	F	F
19 - 20	C	C	C	D	D	E		E	F	F	F	F	F
20-21	C	C	C	D	D	E		E	F	F	F	F	F
21-22	B	C	C	C	D	D		E	E	F	F	F	F
22 - 23	B	B	C	C	D	D		E	E	F	F	F	F
23 - 24	B	B	C	C	D	D		E	E	F	F	F	F
24 - 25	B	C	C	C	D	D		E	F	F	F	F	F
25 - 26	C	C	C	D	D	E		E	F	F	F	F	F
26 - 27	B	B	B	B	C	C		C	D	D	D	D	D

4.6.3 Proposed Cross Section Improvements

In order to alleviate the capacity problem indicated in *Table 4.11,* three initial cross section upgrades were identified and analysed during the Assessment Stage. The upgrade options were as follows:

1. **Cross section option 1:** Adding 3.0 m wide shoulders for the entire route, except at existing climbing lanes. Where climbing lanes are present a 1.0m wide shoulder is proposed;
2. **Cross section option 2:**
   - Two lanes per direction from km 0.00 to km 5.44 (Klein Kariba intersection);
   - Three lanes alternating passing/climbing lanes from km 5.44 to km 26.80; and
3. **Cross section option 3**: Two lanes per direction with 1.0 m shoulders for the entire route.

4.6.4 HTM results: Cross Section Improvement Options

The three cross section options were analysed for capacity and the level of service for each cross section option are shown in *Table 4.12*, *Table 4.13* and *Table 4.14*, respectively. Capacity analyses of the three cross section options are included in each sub section below.

4.6.4.1 HTM Results: Cross section option 1

Option 1 does not provide adequate level of service for the section from km 0.00 to km 5.44 (class 2) for both normal day peak hour and 30^{th} HHV.

The analysis of option 1 along the section from km 5.44 to km 26.80 showed the following:

- Option 1 provides adequate capacity up to 2033 with the segment from km 25.00 to km 26.00 (Modimolle Town) dropping to LOS D.
- Beyond 2033 the following larger segments along the section from km 5.44 to km 26.8 also decrease to LOS D for the normal peak hour and these are as follows:
  - Segment 1: km 9.00 to km 12.00;
  - Segment 2: km 14.00 to km 18.00; and
  - Segment 3: km 24.00 to km 26.00.
    - Segment 1 and 2 coincide with areas having sub-standard horizontal curves and the realignment of these curves will definitely improve the LOS; and
    - Segment 3 is located in Modimolle urban section which has 3 lane configuration, therefore an addition lane on the LHS will improve the LOS along this segment.
- In general, Option 1 does not provide adequate capacity beyond 2033.

Table 4.12: HTM Results for cross section Option 1 at a medium growth rate of 2.5%

SECTION (km – km)	NORMAL DAY-OPTION 1 @ 2.5% GROWTH RATE							30HHV-OPTION 1 @ 2.5% GROWTH RATE					
	2018	2023	2028	2033	2038	2043		2018	2023	2028	2033	2038	2043
0 - 1	C	D	D	E	E	E	US 1	F	F	F	F	F	F
1 - 2	C	D	D	E	E	E		F	F	F	F	F	F
2 - 3	D	D	D	E	E	E		F	F	F	F	F	F
3 - 4	D	D	D	E	E	E		F	F	F	F	F	F
4 - 5	D	D	D	E	E	E		F	F	F	F	F	F
5 - 6	C	C	C	D	D	D		E	E	F	F	F	F
6 - 7	B	C	C	C	D	D	US 2	D	E	E	F	F	F
7 - 8	B	B	C	C	C	C		D	D	E	E	F	F
8 - 9	B	B	C	C	C	C		D	D	E	E	F	F
9 - 10	B	B	C	C	C	D		D	D	E	E	F	F
10 - 11	B	C	C	C	D	D		D	E	E	F	F	F
11 - 12	B	C	C	C	D	D		D	E	E	F	F	F
12 - 13	B	B	C	C	C	C		D	D	E	E	F	F
13 - 14	B	B	C	C	C	C		D	D	E	E	F	F
14 - 15	B	B	C	C	C	D		D	D	E	E	F	F
15 - 16	B	C	C	C	D	E		D	E	E	F	F	F
16 - 17	B	C	C	C	D	D		D	E	E	F	F	F
17 - 18	B	C	C	C	D	D		D	E	E	F	F	F
18 - 19	B	C	C	C	D	D		D	E	E	F	F	F
19 - 20	B	C	C	C	D	D		E	E	E	F	F	F
20-21	B	C	C	C	D	D		E	E	F	F	F	F
21-22	B	B	C	C	C	C		D	E	E	F	F	F
22 - 23	B	B	C	C	C	C		D	D	E	E	F	F
23 - 24	B	B	C	C	C	C		D	D	E	F	F	F
24 - 25	B	C	C	C	D	D		D	E	E	F	F	F
25 - 26	C	C	C	D	D	D		E	E	E	F	F	F
26 - 27	B	B	B	B	C	D		C	C	D	D	D	D

4.6.4.2 HTM results: Cross section Option 2

Cross section option 2 consists of 2 lanes per direction from km 0.00 to km 5.44 and 3-lane alternating passing/climbing lane configuration for the remainder of the road.

It follows from *Table 4.13* that along the section from km 0.00 to km 5.44, option 2 provides adequate capacity (because of the 4 lanes along this section) over the design period up to 2043 for both normal peak hour volume and 30th HHV.

The analysis for the section from km 5.44 to km 26.80 showed the following:

- Option 2 provides adequate LOS along this section for the normal day peak hour over the design period with a decreased LOS centred (beyond 2038) along km 10.00 to km 11.00;
    - o The above segment (km 10.00 to km 11.00) coincides with an area having sub-standard horizontal curves and the realignment of these curve will improve the LOS;

- Option 2 further provides adequate LOS for the section from km 5.44 to km 26.80 up to 2038 with the exception of the segment between km 10.0 and km 12.0 for the 30th HHV. Beyond 2038 the LOS decreases to LOS E with the following segments decreasing to LOS F for the 30th HHV:
  - km 9.0 to km 12.0;
  - km 17.0 to km 18.0; and
  - km 25.0 to km 26.0.
- It was noted that the research indicates a 3-lane alternating climbing/passing lane to be more dangerous than the conventional 2-lane configuration due to the following the reasons:
  - Areas of conflict are introduced at the merge of the two lanes; and
  - The configuration leads to platooning and excessive speeding on the 2-lane sections;
  - Heavy vehicles are more restricted to wheel paths; and
  - Additional signs are required and the cost of road marking and maintenance is high.

Table 4.13: HTM Results for <u>cross section option 2</u> using medium growth rate of 2.5%

SECTION (km – km)	NORMAL DAY-OPTION 2 @ 2.5% RATE							30HHV-OPTION 2 @ 2.5% GROWTH RATE					
	2018	2023	2028	2033	2038	2043		2018	2023	2028	2033	2038	2043
0 - 1	A	A	A	A	A	A	US 1	A	B	B	B	B	C
1 - 2	A	A	A	A	A	A		A	A	B	B	B	C
2 - 3	A	A	A	A	A	A		A	A	B	B	B	C
3 - 4	A	A	A	A	A	A		A	A	B	B	B	C
4 - 5	A	A	A	A	A	A		A	A	B	B	B	C
5 - 6	A	A	A	B	B	B		B	C	C	C	C	D
6 - 7	B	B	B	B	B	C	US 2	C	C	D	D	E	E
7 - 8	A	B	B	B	B	C		C	C	D	D	E	E
8 - 9	B	B	B	B	C	C		C	D	D	D	E	E
9 - 10	B	B	B	C	C	C		D	D	D	E	E	F
10 - 11	B	C	C	C	D	D		D	E	E	F	F	F
11 - 12	B	B	C	C	C	D		D	D	E	E	F	F
12 - 13	B	B	B	B	C	C		C	D	D	D	E	E
13 - 14	B	B	B	B	C	C		C	D	D	E	E	E
14 - 15	A	A	B	B	B	B		C	C	C	D	D	E
15 - 16	B	B	B	B	C	C		C	D	D	D	E	E
16 - 17	B	B	B	B	C	C		C	D	D	E	E	E
17 - 18	B	B	B	C	C	C		D	D	D	E	E	F
18 - 19	B	B	B	B	C	C		C	D	D	E	E	E
19 - 20	B	B	B	B	B	C		C	D	D	D	E	E
20-21	B	B	B	B	C	C		C	D	D	E	E	E
21-22	B	B	B	B	C	C		C	D	D	D	E	E
22 - 23	B	B	B	B	C	C		C	D	D	D	E	E
23 - 24	B	B	B	B	C	C		C	D	D	D	E	E
24 - 25	B	B	B	B	C	C		C	D	D	E	E	E
25 - 26	B	B	B	C	C	C		D	D	D	E	E	F
26 - 27	A	B	B	B	B	C		C	C	C	D	D	D

4.6.4.3 HTM results: Cross section option 3

Cross section option 3 consists of 2 lanes per direction with 1.0 m wide surfaced shoulders for the entire route.

This option provides significant surplus capacity for the section from km 5.44 to km 24.00 and the analysis indicated that it would overcompensate for the expected traffic growth over the design period.

Table 4.14: HTM Results for cross section option 3 using medium growth rate of 2.5%

SECTION (km – km)	NORMAL DAY-OPTION 3 @ 2.5% GROWTH RATE							30HHV-OPTION 3 @ 2.5% GROWTH RATE					
	2018	2023	2028	2033	2038	2043		2018	2023	2028	2033	2038	2043
0 - 1	A	A	A	A	A	A	US 1	A	B	B	B	B	C
1 - 2	A	A	A	A	A	A		A	A	B	B	B	C
2 - 3	A	A	A	A	A	A		A	A	B	B	B	C
3 - 4	A	A	A	A	A	A		A	A	B	B	B	C
4 - 5	A	A	A	A	A	A		A	A	B	B	B	C
5 - 6	A	A	A	A	A	A		A	A	A	A	B	B
6 - 7	A	A	A	A	A	A	US 2	A	A	A	A	A	A
7 - 8	A	A	A	A	A	A		A	A	A	A	A	A
8 - 9	A	A	A	A	A	A		A	A	A	A	A	A
9 - 10	A	A	A	A	A	A		A	A	A	A	A	A
10 - 11	A	A	A	A	A	A		A	A	A	A	A	A
11 - 12	A	A	A	A	A	A		A	A	A	A	A	A
12 - 13	A	A	A	A	A	A		A	A	A	A	A	A
13 - 14	A	A	A	A	A	A		A	A	A	A	A	A
14 - 15	A	A	A	A	A	A		A	A	A	A	A	A
15 - 16	A	A	A	A	A	A		A	A	A	A	A	A
16 - 17	A	A	A	A	A	A		A	A	A	A	A	A
17 - 18	A	A	A	A	A	A		A	A	A	A	A	A
18 - 19	A	A	A	A	A	A		A	A	A	A	A	A
19 - 20	A	A	A	A	A	A		A	A	A	A	A	A
20-21	A	A	A	A	A	A		A	A	A	A	A	A
21-22	A	A	A	A	A	A		A	A	A	A	A	A
22 - 23	A	A	A	A	A	A		A	A	A	A	A	A
23 - 24	A	A	A	A	A	A		A	A	A	A	A	A
24 - 25	A	A	A	A	A	A		A	A	A	A	A	A
25 - 26	A	A	A	A	A	A		A	A	A	A	A	B
26 - 27	A	A	A	A	A	B		B	B	B	B	B	C

4.6.5 Further Analysis and Recommendations

Based on the outcome of the LOS analysis demonstrated above, it is clear that none of the proposed cross sections meet all the design requirements. It was therefore necessary to develop a fourth hybrid cross section that consists of the following:

- **Cross section 4.1:**
  - Section from km 0.00 to km 5.44: A 4-lane urban configuration with kerbed median and sidewalk;
  - Section from km 5.44 to km 24.00: A 2-lane cross section with 3 m surfaced shoulders, existing climbing lanes and geometric realignments of sub-standard curves; and
  - Section from km 24.00 to km 26.80: A 4-lane urban configuration with kerbed median and sidewalks.

- **Cross section 4.2:**
  - Section from km 0.00 to km 5.44: A 4-lane urban configuration with kerbed median and sidewalk;
  - Section from km 5.44 to km 24.00: A 2-lane cross section with 3 m surfaced shoulders, existing climbing lane, additional climbing lanes at specific sections and geometric realignments of sub-standard curves; and
  - Section from: A 4-lane urban configuration with kerbed sidewalks and median.

A 4-lane urban configuration with kerbed median and sidewalk was chosen for the section from km 0.00 to km 5.44 based on the functionality and the required LOS. Furthermore, Bela Bela Municipality's SDF shows potential developments envisaged in along the section from km 0.00 to km 5.44.

A 2-lane configuration with existing climbing lanes and possible additional climbing lanes were selected for the section from km 5.44 to km 24.00 due to the safety concerns of the 3-lane alternating climbing/passing lane configuration. Furthermore, it is envisaged that the realignment of sub-standard curves along this section will improve the LOS to acceptable levels.

A 4-lane urban configuration with kerbed sidewalks was selected for the section from km 24.00 to km 26.80 to allow a left turning opportunity on both sides of the road and to improve the LOS. It should be noted that the majority of this section (km 25.20 to km 26.60) is already a 3-lane configuration.

The cross sections were evaluated in terms of cost and economic viability, the outcome of which is included in the following chapter.

4.6.6 Traffic attraction from N1

Concerns were raised by SANRAL during the progress meeting 2 held on 08 February 2019 regarding possible attraction from the N1 toll road should the full length of Road R101-8 be upgraded to 4 lane configuration. Following the discussions with the SANRAL, a road side interview (RSI) was conducted on 13 March 2019 from 06:30 to 15:00 at km 4.1 (south of the Klein Kariba intersection). A report detailing the findings from this assessment was compiled by *ITS* and is included in *Appendix B*.

The objectives of road side interview were to:

- Estimate total trips that are currently on R101-8 that could have been on National Route N1;
- Estimate current traffic attraction for the N1 and R101 between Bela Bela and Modimolle with the Traffic Attraction Model; and
- Estimate future (after road upgrade) traffic attraction for the N1 and R101 between Bela Bela and Modimolle with the Traffic Attraction Model.

It should be noted that this investigation focused on the localised impact of the proposed road upgrade and not the entire R101 corridor.

A total of 599 vehicles were stopped and drivers interviewed during the road side interview. The findings from these interviews showed that:

- Road R101-8 is used as a commuter route between Bela Bela and Modimolle;
- The prominent origin purpose and destination purpose pair is 59% and were between home and place of work;
- The prominent origin and destination pair was between Bela Bela and Modimolle (53.6%);
- 46% of drivers indicated they use Road R101 on a daily basis;
- Only 19% of drivers thought they could have used the N1 instead and, of the 19% of drivers, 25% indicated they used Road R101 to avoid the tolls on the N1; and
- According to the origin destination analysis, 199 (33%) or 1 out of 3 trips on Road R101 could have been on the N1.

The results from the road side interview were used to determine the estimated attraction of traffic from the N1 toll route should Road 101-8 be improved. The estimated attraction was calculated using the Traffic Attraction Model formula advanced by Ellwood and the findings from the analysis showed that:

- There is no benefit to travel via the N1 between Bela Bela and Modimolle;
- The road improvement should only influence local travel patterns between Bela Bela and Mookgophong slightly;
- The longer distance trip patterns would not be influenced by the proposed upgrade; and

- The proposed road upgrade would not have a significant impact on the N1 traffic attraction.

4.7 CONCLUSION

Based on the traffic growth, capacity analysis, traffic attraction studies and the Employer feedback, the following was concluded:

- None of the three initial proposed cross section options meets all the design requirements;
- It was therefore necessary to develop a fourth hybrid cross sections 4.1 and 4.2 which will be evaluated for cost and economic viability;
- The realignment of sub-standard curves will improve the LOS along the section from km 5.44 to 24.00; and
- The improvement to R101-8 will not have much impact on the N1 traffic attraction.

CHAPTER 5 ECONOMIC EVALUATION AND COST ESTIMATE

5.1 HDM4 ANALYSIS

An evaluation using HDM4 software was conducted to determine the comparative economic and overall performance viability between cross section 4.1 and 4.2. Cross sections are described as follows:

- **Cross section 4.1:**
  - Section from km 0.00 to km 5.44: A 4-lane configuration with kerbed median & sidewalks;
  - Section from km 5.44 to km 24.00: A 2-lane cross section with 3 m surfaced shoulders, existing climbing lanes and geometric realignments; and
  - Section from km 24.00 to km 26.80: a 4 lane urban configuration with kerbed median.
- **Cross section 4.2:**
  - Section from km 0.00 to km 5.44: A 4-lane configuration with kerbed median & sidewalks,
  - Section from km 5.44 to km 24.00: A 2-lane cross section with 3 m surfaced shoulders, existing climbing lanes; additional climbing lanes and geometric realignments; and
  - Section from km 24.00 to km 26.80: a 4 lane urban configuration with kerbed median.

The analysis further evaluated the viability of using a Cape seal or asphalt wearing course along urban sections. These scenarios were evaluated over a 20-year period at an 8% discount rate.

The following economic internal rate of return (IRR) values were derived from the HDM4 analysis, refer *Table 5.1*. Detailed populated HDM4 reports are included in *Appendix K*.

Table 5.1: Economic Internal Rate of Return comparison for the four rehabilitation options

CATEGORY	BASE	CROSS SECTION 4.1		CROSS SECTION 4.2	
		CAPE SEAL THROUGHOUT	ASPHALT IN URBAN SECTIONS	CAPE SEAL THROUGHOUT	ASPHALT IN URBAN SECTIONS
Road Agency Cost	R 25.192 mil.	R 391.865 mil.	R 397.101 mil.	R 520.726 mil.	R 525.962 mil.
Capital Cost	R 0.000 mil.	R 275.410 mil.	R 280.646 mil.	R 404.534 mil.	R 409.550 mil.
Net Present Value	R 0.000 mil.	R 192.735 mil.	R 202.104 mil.	R 94.934 mil.	R 104.303 mil.
Internal Rate of Return	0%	13.4%	13.6%	10.1%	10.2%

5.1.1 Conclusion and Recommendation

The analysis shows that Cross section 4.1 using Cape seal surfacing for rural section (km 5.44 to km 24.00) and asphalt surfacing for urban sections has the highest economic internal rate of return (IRR).

It is therefore recommended that Cross section 4.1 (with asphalt along the urban section and Cape seal along the rural section) be carried into Detail Design and implemented for improvement of Road R101-8.

CHAPTER 6 GEOMETRIC DESIGN

6.1 INTRODUCTION

The improvement of existing road geometry to enhance safety along Road R101-8 is one of the main objectives in this project. Existing road alignment and cross sections were therefore assessed to identify any required improvement.

Road R101-8 is generally a rural arterial with a maximum posted speed of 100 km/h. An iterative process of assessing the existing road alignment and the improvement options was conducted during Assessment and Preliminary Design stages. As part of this process, design speeds of 80 km/h, 90 km/h and 100 km/h were evaluated in details for both horizontal and vertical alignments.

6.2 HORIZONTAL ALIGNMENT

A detailed assessment of the existing horizontal alignment was conducted to identify any sub-standard curves in terms of curve radii and super elevation as guided by the *SANRAL Geometric Design Manual*. Thirty two curves were modelled and assessed as demonstrated in *Table 6.1* below.

Of the thirty two existing horizontal curves, eleven were identified to be sub-standard curves in terms of curve radius. Seven of these sub-standard horizontal curves require major realignment falling outside the road reserve. The other four sub-standard curves require minor adjustment to curve radii which can be accommodated within the road reserve. The assessment further showed that the majority of remaining curves along Road R101-8 have acceptable curve radii and will only be improved in terms of super elevation.

Table 6.1: Horizontal alignment sub-standard curve details for 100 km/h design speed

EXISTING CURVES							
NO.	START STATION	END STATION	LENGTH	RADIUS (m)	EXISTING EMAX (%)	EXISTING DESIGN SPEED (km/h)	COMMENTS
1	118	235	117	736	2.0%	40-50	Urban section 60km/h @ emax=4% will be adequate.
2	694	802	109	768	5.4%	90-100	
3	1427	1845	418	1762	4.0%	120-130	
4	4028	4218	191	638	7.8%	110-100	
5	7321	7456	134	312	3.7%	40-50	Minor radius change within road reserve
6	8259	8364	105	560	4.0%	70-80	Only minor level adjustment needed.
7	8483	8594	111	654	5.8%	80-90	
8	9248	9386	138	619	3.0%	50-60	

EXISTING CURVES							
NO.	**START STATION**	**END STATION**	**LENGTH**	**RADIUS (m)**	**EXISTING EMAX (%)**	**EXISTING DESIGN SPEED (km/h)**	**COMMENTS**
9	9707	9805	98	475	4.3%	60-70	**Area 1 Major Realignment**
10	9887	9984	97	231	5.8%	50-60	
11	10201	10398	197	174	8.3%	50-60	
12	10543	10652	109	282	4.0%	40-50	
13	11024	11118	93	339	4.2%	50-60	**Area 2 Major Realignment**
14	11318	11629	311	157	8.1%	50-60	
15	12669	12755	85	323	3.8%	40-50	Minor radius change with in road reserve
16	13184	13279	95	432	6.5%	80-90	Only minor level adjustment needed.
17	13535	13709	174	328	5.0%	50-60	Minor radius change within road reserve
18	13858	13965	107	1042	5.4%	100-110	Only minor level adjustment needed.
19	14079	14198	118	2211	4.0%	>130	
20	14323	14445	122	1533	6.1%	>130	
21	14907	14983	76	649	6.1%	90-100	**Area 3 Major Realignment**
22	15258	15553	295	157	9.4%	60-70	
23	16262	16649	387	443	7.4%	90-100	Minor adjustment to attain correct superelevation.
24	16965	17163	198	301	6.0%	60-70	Minor radius change within road reserve
25	18021	18237	216	450	7.0%	80-90	Only minor level adjustment needed to attain correct superelevation.
26	18601	18783	182	429	8.6%	90-100	
27	19361	19537	176	420	7.8%	80-90	
28	20337	20495	158	489	6.8%	80-90	
29	23851	24253	402	612	5.6%	90-100	Urban section 60km/h @ emax=4%
30	25139	25266	126	1756	6.0%	>130	
31	26090	26229	138	607	3.6%	70-80	
32	26442	26518	77	722	1.0%	90-100	

The positions of three areas in need of major horizontal realignment are indicated in *Figure 6.1*. Warning signs with posted speeds of 40 km/h were erected along these curves. The accident report showed that three accidents have recently occurred along these areas. In order to improve safety along these areas and Road R101-8 in general, design speeds of 80km/h, 90km/h and 100 km/h were assessed.

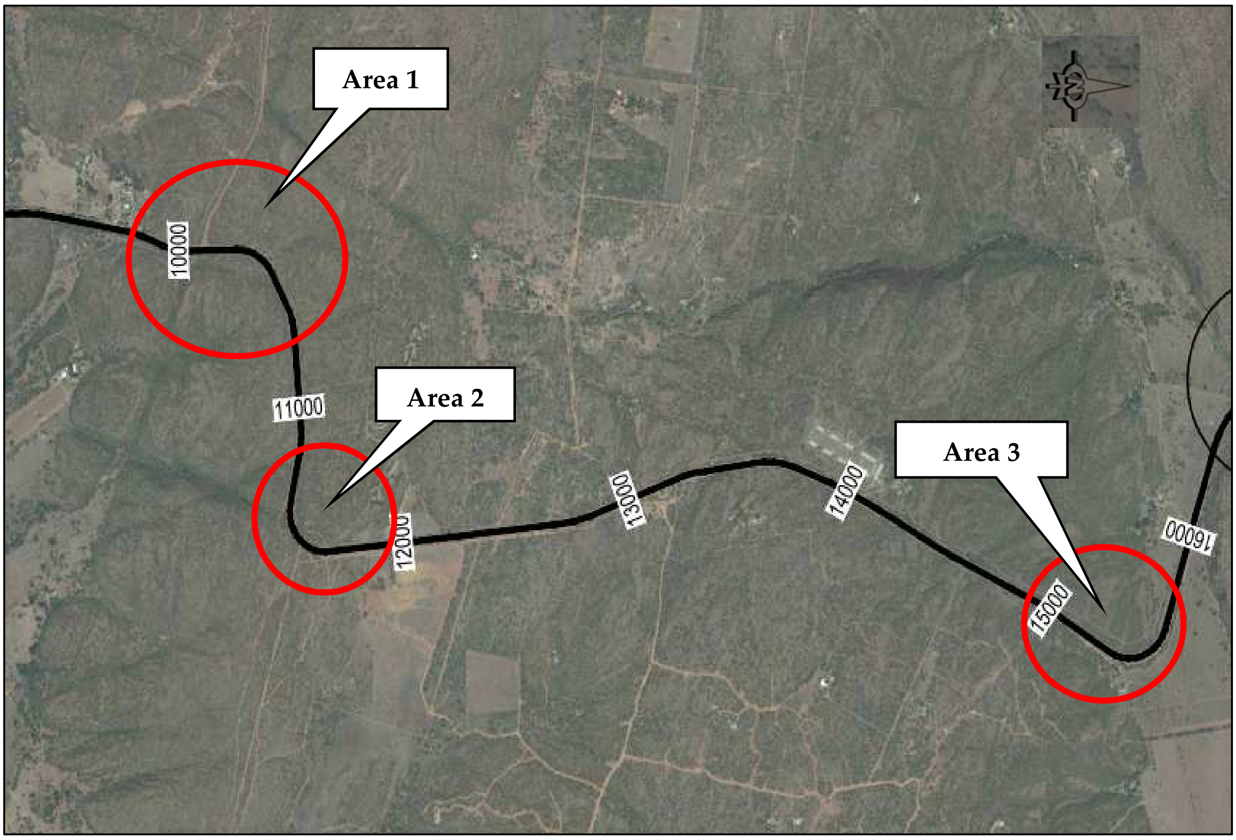


Figure 6.1: Positions of sub-standard horizontal curves (with radii <210 m).

6.2.1 Evaluation of Horizontal Alignment Improvement

The following design criteria for horizontal alignment design summarised in *Table 6.2* and as described in *SANRAL Geometric Design Guideline* were assessed to identify which design speed is the most suitable for the improvement of Road R101-8.

Table 6.2: Horizontal Alignment Design Criteria

DESIGN SPEED	SUPERELEVATION (EMAX)	MINIMUM RADIUS (M)
80 km/h	8%	210 m
90 km/h	8%	300 m
100 km/h	8%	390 m
100 km/h	10%	360 m

The realignment of the design speeds are demonstrated in *Figure 6.2, Figure 6.3 and Figure 6.4.*

It was agreed with the Employer during Progress meeting 6 that the improvement of the horizontal sub-standard curves to suit 80 km/h design speed would not provide adequate capacity and safety. Furthermore it will not be consistent with the rest of the road`s design criteria, therefore, it will not be considered further.

The Employer indicated that they do not prefer a 10% superelevation due to its safety risks along the curves, therefore it was not be considered further.

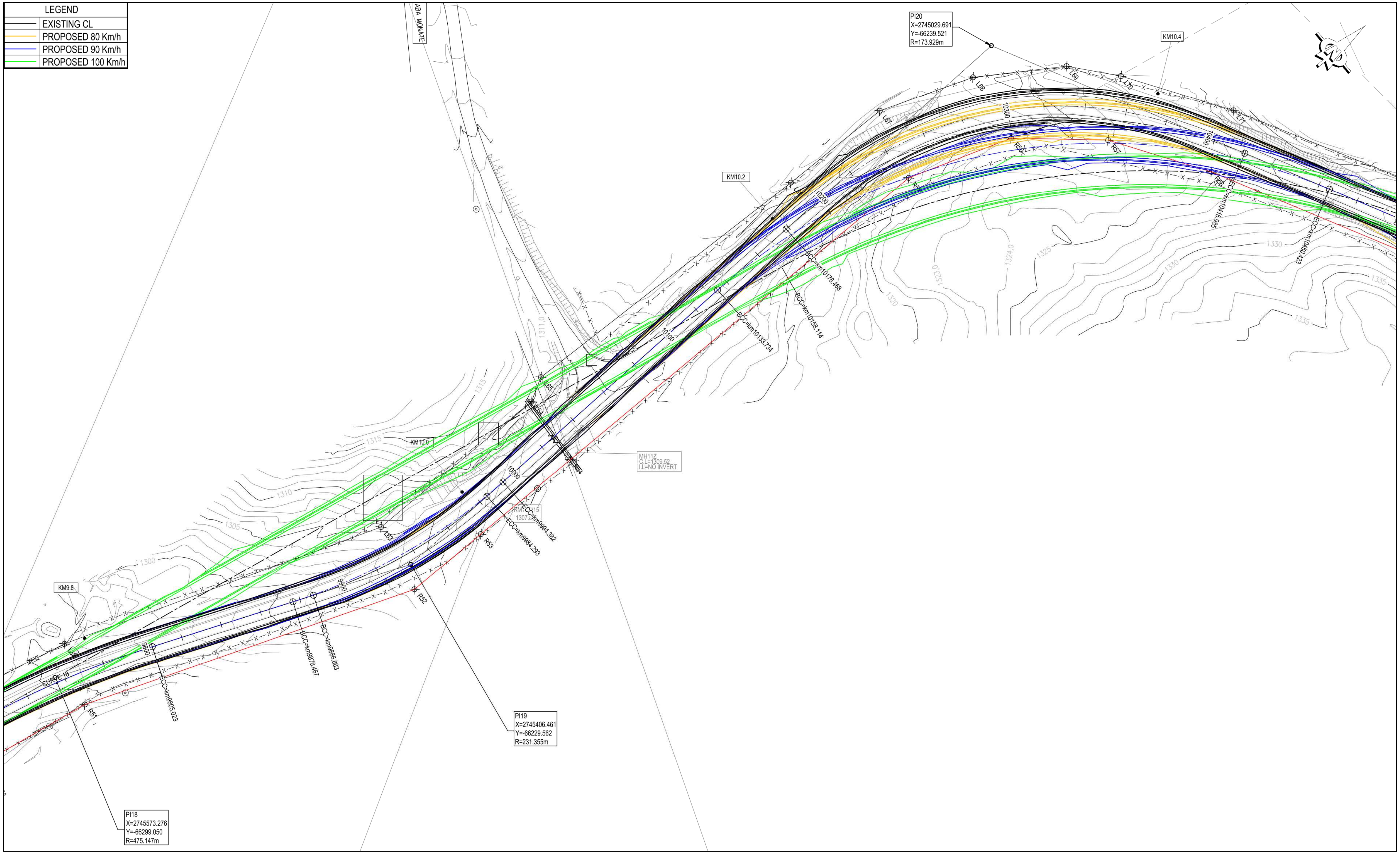


Figure 6.2: Existing and investigated alignments at Area 1 (km 9.80 to km 10.60)

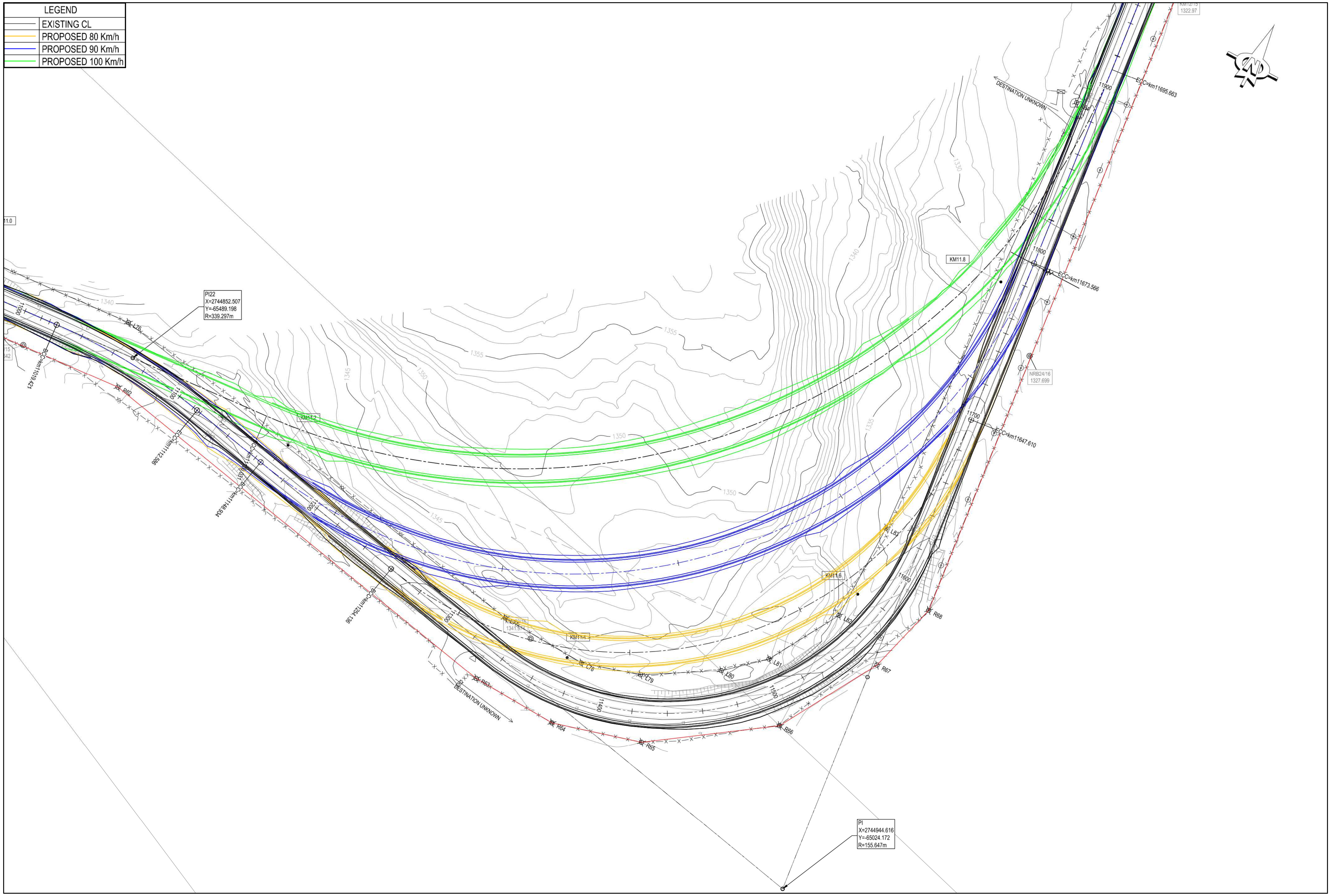


Figure 6.3: Existing and investigated alignments at Area 2 (km 11.00 to km 11.70)

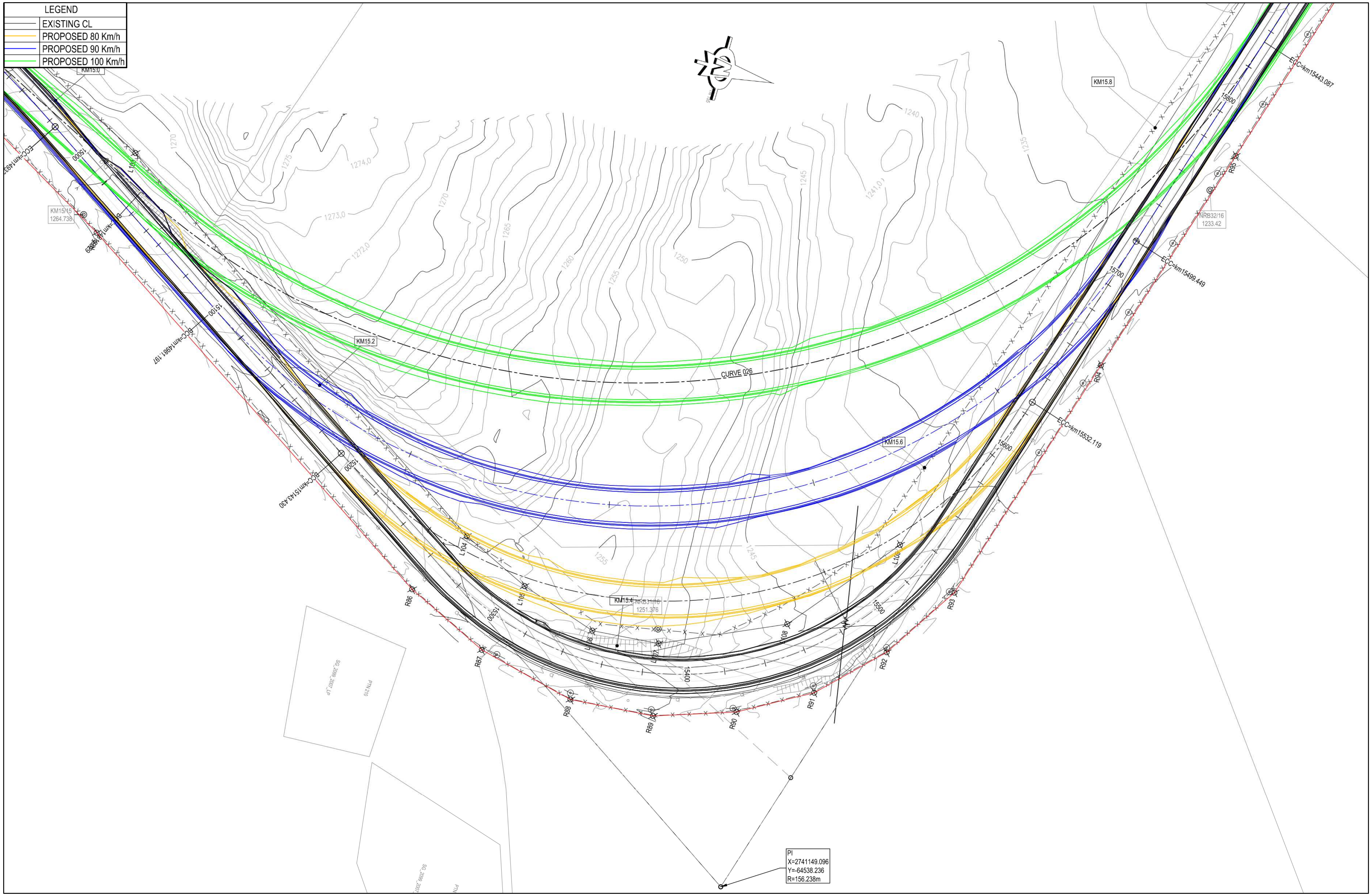


Figure 6.4: Existing and proposed corridors at area 3 (km 14.800 to km 15.500)

As indicated in *Figure 6.2*, three sub-standard curves at Area 1 will need to be merged into a single curve to accommodate the design speed of 100 km/h. For the 90 km/h design speed, only one curve (km 10.201 to km 10.398) requires realignment, however the S-shape along Area 1 will remain a safety concern. Area 2 and 3 require new radii for all criteria.

After a detailed assessment of all criteria and various discussion meeting s with SANRAL geometric design Specialists, it was agreed that the improvement of horizontal curves to suit a 100 km/h design speed with 8% superelevation and minimum 390 m radii is the most suitable criteria. The minutes/notes to the meetings are included in *Appendix A*.

6.3 VERTICAL ALIGNMENT

The existing vertical alignment was assessed to identify sub-standard curves (crests and sags) as per *SANRAL Geometric Design Manual* and this is summarised in *Table 6.3* and *Table 6.4.*

Table 6.3: Existing vertical crest curves

NO.	PVI STATION	A (GRADE CHANGE)	CURVE LENGTH (m)	K VALUE	EXISTING DESIGN SPEED (km/h)	COMMENT
1	127	0.66%	201	305	>130	OK
2	4673	1.62%	73	45	90-100	
3	7215	8.02%	127	16	60-70	Require Improvement
4	7837	4.11%	88	21	70-80	
5	8073	4.44%	62	14	60-70	
6	8569	5.47%	166	30	80-90	
7	9298	2.18%	84	39	80-90	
8	10016	3.28%	82	25	70-80	
9	10419	1.40%	60	43	90-100	HA realignment
10	10836	9.72%	183	19	70-80	Improve
11	11375	9.83%	312	32	80-90	HA realignment
12	12140	1.44%	81	56	100-110	OK
13	12887	4.00%	97	24	70-80	Improve
14	13064	0.33%	92	282	>130	OK
15	13175	1.45%	102	70	100-110	OK
16	13460	2.20%	87	40	80-90	Require Improvement
17	13718	5.11%	161	31	80-90	
18	13997	1.57%	242	154	>130	OK
19	14417	2.72%	45	17	60-70	Require Improvement
20	14454	2.11%	28	13	60-70	
21	14706	8.23%	144	17	70-80	
22	15303	1.83%	77	42	90-100	HA realignment
23	16200	1.57%	87	55	100-110	OK

NO.	PVI STATION	A (GRADE CHANGE)	CURVE LENGTH (m)	K VALUE	EXISTING DESIGN SPEED (km/h)	COMMENT
24	17355	3.68%	93	25	70-80	Improve
25	18271	1.51%	248	164	>130	OK
26	18635	6.32%	229	36	80-90	Improve
27	19576	2.21%	158	72	100-110	OK
28	20162	1.96%	165	84	110-120	Ok
29	20892	5.74%	109	19	70-80	Improve
30	21045	1.65%	128	78	100-120	OK
31	22186	9.98%	240	24	70-80	Improve
32	22537	1.22%	76	63	100-110	OK
33	24407	3.60%	237	66	100-110	OK
34	25093	2.08%	82	39	90-100	Improve
35	25239	0.73%	57	78	110-120	OK
36	25641	0.53%	292	549	>130	OK
37	26498	2.79%	261	93	110-120	OK

Table 6.4: Existing Vertical Sag Curves

NO.	PVI STATION	A (GRADE CHANGE)	CURVE LENGTH (m)	K VALUE	EXISTING DESIGN SPEED (km/h)	COMMENT
1	994	0.35%	142	401	>130	OK
2	3955	1.56%	73	47	>130	
3	5069	0.56%	140	251	90-100	
4	5373	1.71%	222	130	>130	
5	6092	2.49%	318	128	>130	
6	6674	3.63%	569	157	>130	
7	7640	5.83%	282	48	70—80	
8	7953	2.75%	130	47	100-110	
9	8253	1.88%	114	60	110-120	
10	8404	1.42%	102	72	120-130	
11	9054	5.21%	377	72	120-130	
12	9442	2.82%	148	53	100-110	
13	9828	1.78%	89	50	100-110	
14	10153	2.23%	141	63	120-130	HA realignment
15	10538	2.51%	88	35	80-90	
16	11141	9.46%	122	13	40-50	HA realignment
17	11800	4.90%	256	52	100-110	OK
18	12345	4.49%	184	41	90-100	
19	13301	3.77%	51	14	50-60	Require Improvement
20	13590	4.70%	90	19	60-70	

NO.	PVI STATION	A (GRADE CHANGE)	CURVE LENGTH (m)	K VALUE	EXISTING DESIGN SPEED (km/h)	COMMENT
21	14254	3.55%	83	23	70-80	Require Improvement
22	14561	4.54%	87	19	60-70	
23	15011	4.47%	99	22	60-70	HA realignment
24	15612	2.74%	183	67	120-130	OK
25	16687	3.55%	130	37	80-90	
26	16927	1.81%	74	41	90-100	
27	17509	4.49%	70	15	50-60	Improve
28	17735	4.15%	148	36	80-90	OK
29	19073	6.43%	387	60	110-120	
30	19744	1.35%	88	65	120-130	
31	20425	1.52%	91	60	110-120	
32	20690	4.20%	163	39	90-100	
33	23878	8.30%	159	19	60-70	Improve
34	24626	1.74%	89	51	100-110	OK
35	24918	1.95%	122	62	110-120	
36	26004	1.42%	213	150	>130	

A total of 12 crest curves along the existing road were found to have a K value less than 30 and 6 crest curves with K value between 30 and 45. A total of 6 sag curves were found to have K values of less than 30, excluding those along the proposed major horizontal realignment.

6.3.1 Evaluation of Vertical Alignment Improvement

The following design criteria for vertical alignment as described in *SANRAL Geometric Design Guideline* were assessed to identify which one is the most suitable for Road R101-8.

Table 6.5: Vertical alignment design criteria

MINIMUM K-VALUES		
DESIGN SPEED (km/h)	CREST CURVE (0.6 m OBJECT HEIGHT)	SAG CURVE (HEADLIGHT DISTANCE)
80 km/h	30	30
90 km/h	45	40
100 km/h	60	50

It was agreed with the Client during Progress meeting 7 that the improvement of the vertical sub-standard curves to 80 km/h design speed would not be adequate for the preferred corresponding horizontal design speed design speed of 100 km/h.

The design outcome of the vertical alignment indicated that there are four sections with sub-standard vertical curves along the existing roadway, which require deep cuts of more than two meters in order to achieve a design speed of 90 km/h. These sections are located along the following stake values:

- km 7,10 to km 7,36;
- km 7,70 to km 8,00;
- km 12,80 to km 13,60; and
- km 14,00 to km 14,60

The remaining sub-standard vertical curve require minor level adjustment to achieve the improvement to suit a 90 km/h design speed or more.

Following various discussions with SANRAL geometric design Specialists, it was agreed that the vertical sub-standard curves should be improved to a corresponding design speed of 90 km/h as shown in *Table 6.5*.

6.4 MAJOR HORIZONTAL REALIGNMENT VOLUMES AND LAND TO ACQUIRE

Cut and fill volumes were extracted from the design models generated for both 100 km/h and 90 km/h design speeds and are summarised in *Table 6.6*. A 2-lane cross section with 3 m surfaced shoulders and existing climbing lanes was used for the analysis (km 5.44 to km 24.00). It follows that the cut volume generated from the realignment improvement to suit a 100 km/h design speed is approximately 58 000 m^3 (±30%) more than the realignment improvement to suit 90 km/h design speed. Cut volumes for the two realignment options are similar at Area 1 and Area 2.

Realignment to accommodate a 100 km/h horizontal design speeds will generate sufficient quantities of material which is intended to be utilised for construction of the LSSG layer.

Table 6.6: Cut and fill volumes and land required along major horizontal realignment areas

AREA	100 km/h Design Speed			90 km/h Design Speed		
	CUT VOLUME (m^3)	FILL VOLUME (m^3)	LAND REQUIRED (m^3)	CUT VOLUME (m^3)	FILL VOLUME (m^3)	LAND REQUIRED (m^3)
Area 1	41 741.58	20 90.20	14 560	39 496.30	671.71	1 446
Area 2	120 036.65	29 582.04	50 674	112 022.98	1 044.80	13 957
Area 3	87 165.82	58 55.45	50 048	39 733.96	952.93	11 684
Total	**248 944.05**	**37 527.69**	**115 282**	**191 253.24**	**2 669.44**	**27 087**

6.5 DISCUSSION ON FINDINGS

In identifying the optimal solution for improvement, consideration was given to the following:

- With the exception of the sub-standard horizontal curves along the three areas, the remaining rural section meets the requirements for a 90-100 km/h design speed. Improvement of these sub-standard curves to suit a 100km/h design speed will provide Road R101-8 with uniform alignment;
- Traffic counts showed that the rural section has average travelling speeds of 95.1 km/h to 99.14 km/h;
- Cut volumes for the two design speeds are similar at Area 1 and 2 wit; and
- The realignment to suit an 80 km/h design speed does not correct the S-curve at Area 1 and this will pose a safety risk along this area.

It is therefore recommended that the realignment to a 100 km/h design speed along these areas should be carried into Detail Design and implemented for the improvement of Road R101-8.

6.6 DESIGN CROSS SECTION

As indicated in the *Chapter 5*, cross sections 4.1 and 4.2 were evaluated for economic viability using HDM4. The outcome showed that cross section 4.1 has the highest economic internal rate of return and should be implemented for the improvement of R101-8. Cross section 4.1 includes the following:

- o Section from km 0.00 to km 5.44: A 4-lane urban configuration with kerbed median and sidewalks as shown in *Figure 6.5*;
- o Section from km 5.44 to km 24.00: A 2-lane cross section with 3 m surfaced shoulders, existing climbing lanes and geometric realignments as shown in *Figure 6.6*; *Figure 6.7* and *Figure 6.8;* and
- o Section from km 24.00 to km 26.80: A 4-lane urban configuration with kerbed median and sidewalks as illustrated in *Figure 6.9*.

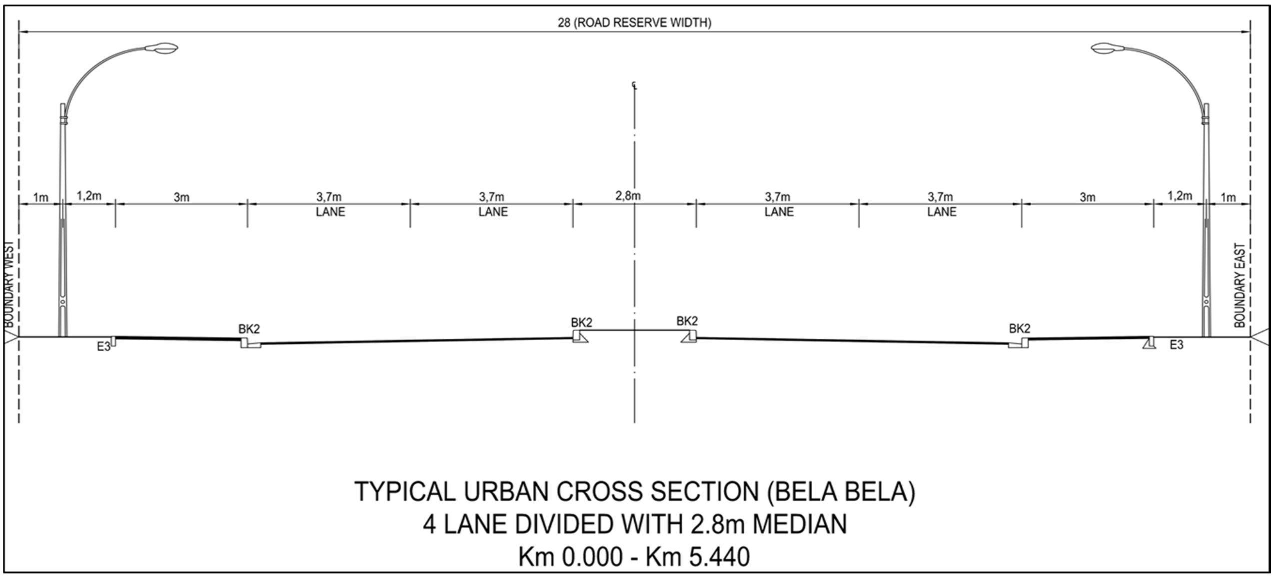


Figure 6.5: 4-lane cross section with raised median for the section from km 0.00 to km 5.44

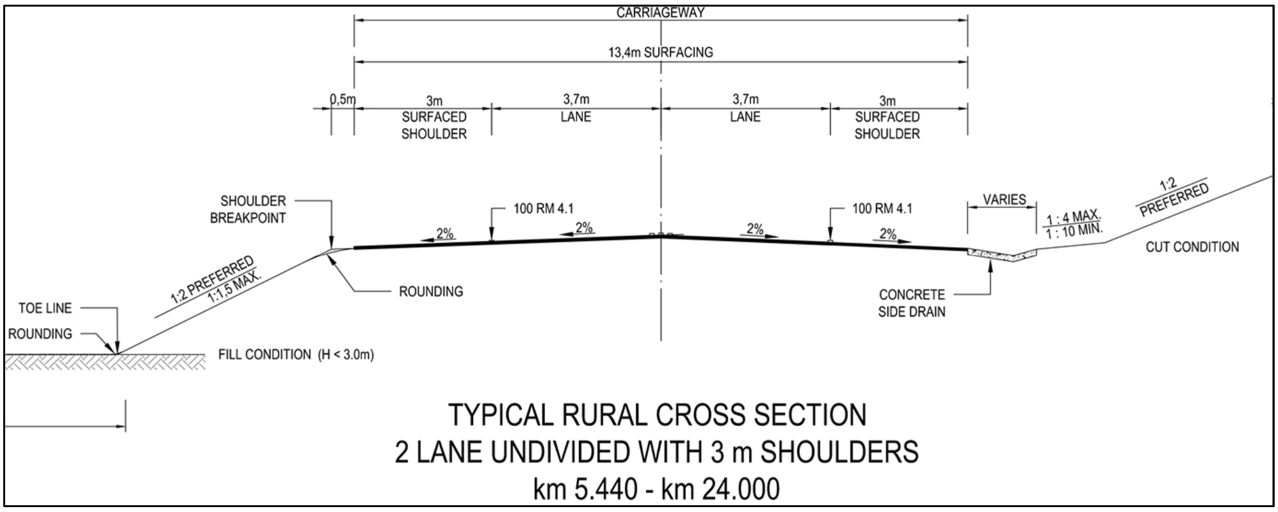


Figure 6.6: 2-lane rural cross-section with 3 m surfaced shoulders (excluding Climbing lanes)

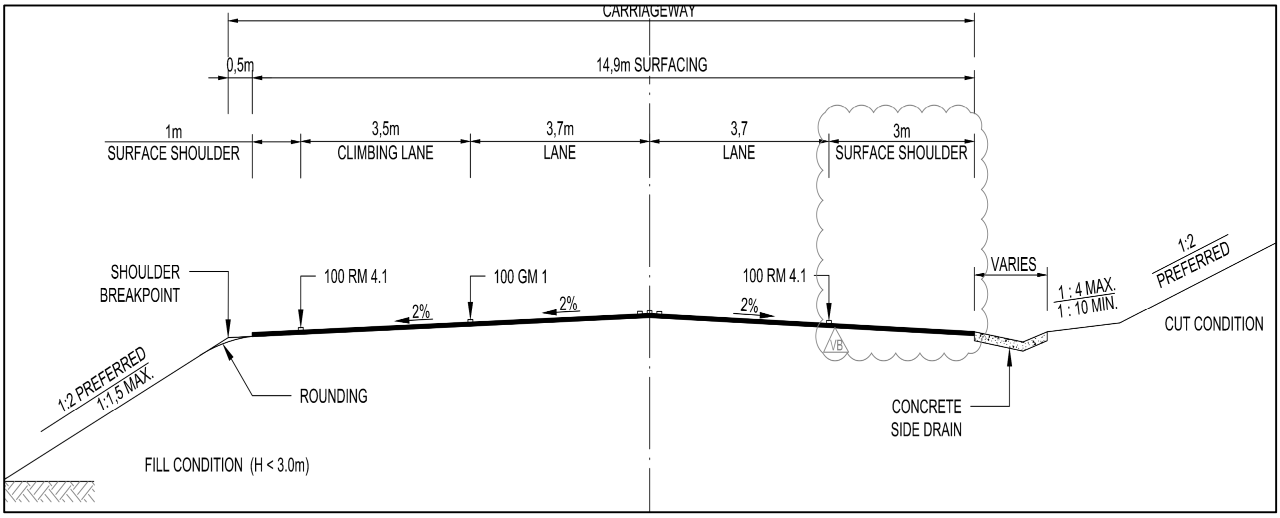


Figure 6.7: 2-lane rural cross-section with climbing lane on the LHS (km 5.80 – km 7.90)

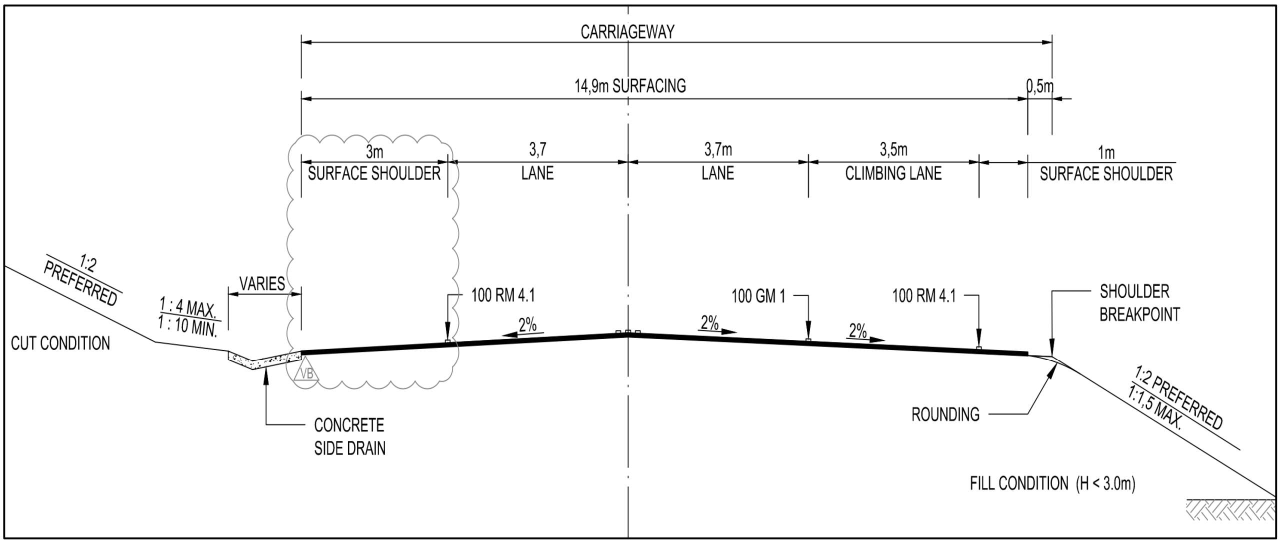


Figure 6.8: 2-lane rural cross-section with climbing lane on the RHS (km 14.40 – 16.20

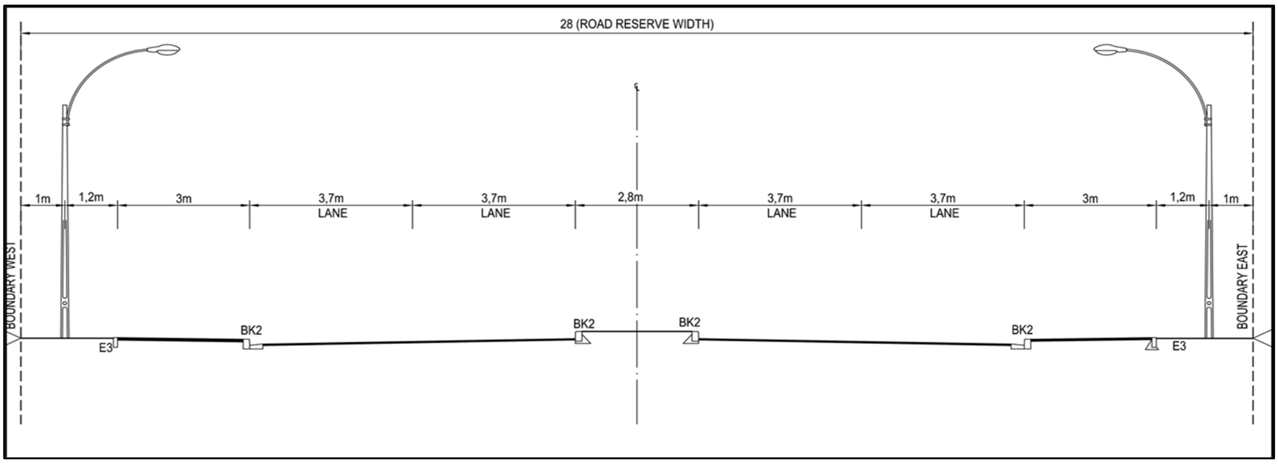


Figure 6.9: 4-lane cross section for the urban section from km 24.00 to km 26.80

CHAPTER 7 EXISTING PAVEMENT EVALUATION

7.1 INTRODUCTION

The purpose of assessing the existing pavement data is to determine the structural and functional condition of the pavement. The following data sets were considered for this purpose:

- Visual condition assessment;
- Mechanical survey measurements (roughness, rut depth and texture);
- Falling weight deflectometer (FWD) measurements; and
- Materials investigation:
  - Test pits profiling;
  - Laboratory material testing; and
  - Dynamic cone Penetrometer (DCP) measurements

These are discussed in detail in the following sections.

7.2 VISUAL ASSESSMENT

A detailed visual assessment of the road was carried out from 8 to 12 October 2018. The purpose of the detailed visual assessment was to evaluate the current condition of the road by identifying the type, degree and extent of all defects/distress visible on the road surface. Structures (bridges and culverts) as well as all road furniture were also evaluated as part of the assessment but is reported on elsewhere in the report. The assessment was conducted in accordance with the guidelines contained in *TMH9 (1992)* and *TRH12 (1997)*. The assessment was carried out at 200 m intervals for each lane separately.

Visually, the road can be divided into four distinct sections:

- Km 0.00 to km 2.30 with an asphalt surface (fair);
- Km 2.30 to km 5.44 with asphalt surface and slurry in localised areas (very poor);
- Km 5.44 to km 25.05 with a 13.2 mm single rubber seal (fair); and
- Km 25.05 to km 26.80 with an asphalt surface (poor).

7.2.1 Visual Assessment Findings – Northbound Lane

Along the asphalt section from km 0.00 to km 2.30 defects including edge breaks, edge drops, rutting and bleeding/flushing were noted. Severe shoving was noted at the intersection with Mile Street (km 0.7) as indicated in *Photo 7.2*.

The section from km 2.30 to km 5.44 is considered the worst in terms of visual condition and distress noted. Defects including rutting (*Photo 7.3*), crocodile cracks (*Photo 7.4*) and failed patches (*Photo 7.5*) were noted. This section has more patches compared to the rest of the road, which is also indicative of the poor condition thereof. Patches are evenly distributed along the length of this section and are generally in fair condition.

The section from km 5.44 to km 25.05 is generally in a fair condition with localised defects such as longitudinal cracks, transverse cracks and flushing (*Photo 7.6*). The surfacing along this section consists of a 13.2 mm rubber seal, which tends to hide some of the structural defects due to its ability to inhibit cracks reflections.

Severe mechanical damage was identified along horizontal curves at km 11.50 and km 15.40 (*Photo 7.8*). The section from km 17.40 to km 18.8 shows both rutting and undulation as shown in *Photo 7.7*.

Distress consisting of evenly distributed block cracks (*Photo 7.10*), classified as severe, as well as rutting were noted along the section from km 25.05 to km 26.80 in Modimolle. Riding quality along this section is considered poor.

The intersection of Road R101-8 with Road R33 as well as the approaches of the slow lanes (±25 m) were surfaced with concrete block paving (*Photo 7.12*). This area is in poor condition with poor riding quality.

7.2.2 Visual Assessment Findings – Southbound Lane

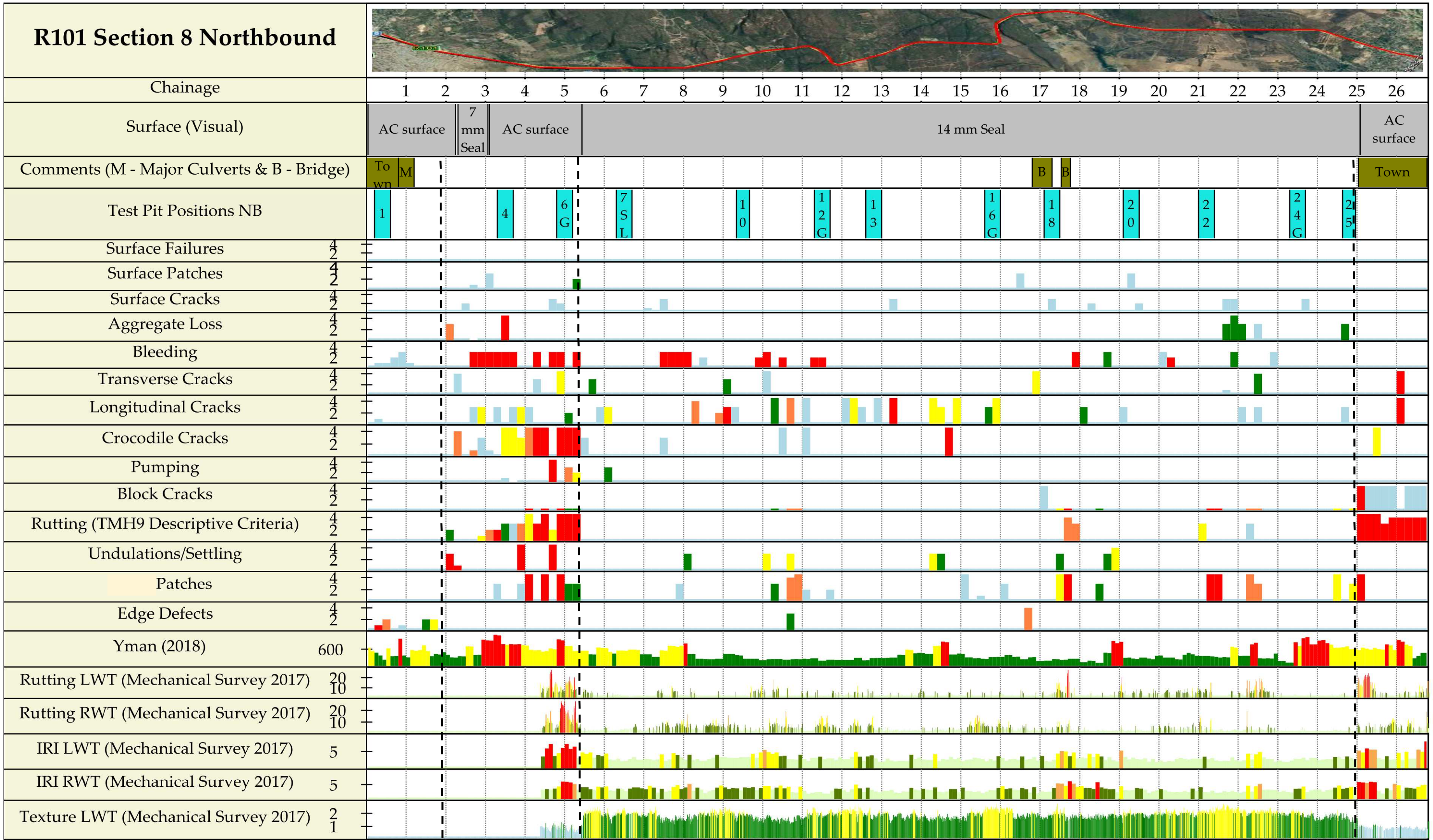
Visually, the southbound lane showed similar distress to that of the northbound lane. Along the first section (km 0.00 to km 2.30) localised bleeding was identified, while the section from km 2.30 to km 5.44 showed severe rutting, crocodile cracks, transverse cracks, longitudinal cracks, patching and undulation.

Localised transverse and longitudinal cracks were noted from km 5.44 to km 25.05. Similar to the northbound lane, mechanical damage was visible on the surface along sharp curves.

7.2.3 Visual Assessment Summary

Visual assessment data was captured on strip plans using *Rubicon Toolbox* and is illustrated in *Figure 7.1* and *Figure 6.2* for the northbound and southbound lanes, respectively. The following conclusions were made from this assessment:

- The section from km 2.30 to km 5.44 is in a poor to very poor condition;
- The section from km 5.44 to km 25.05 is in a fair condition. The surfacing along this section consists of a 13.2 mm rubber seal, which tends to hide some of the structural defects due to its ability to inhibit cracks reflections, and
- The frequency and extent of patches along Road R101-8 is an indication of underlying problems. These patches probably mask the true condition of the road and will be taken into consideration in the evaluation.



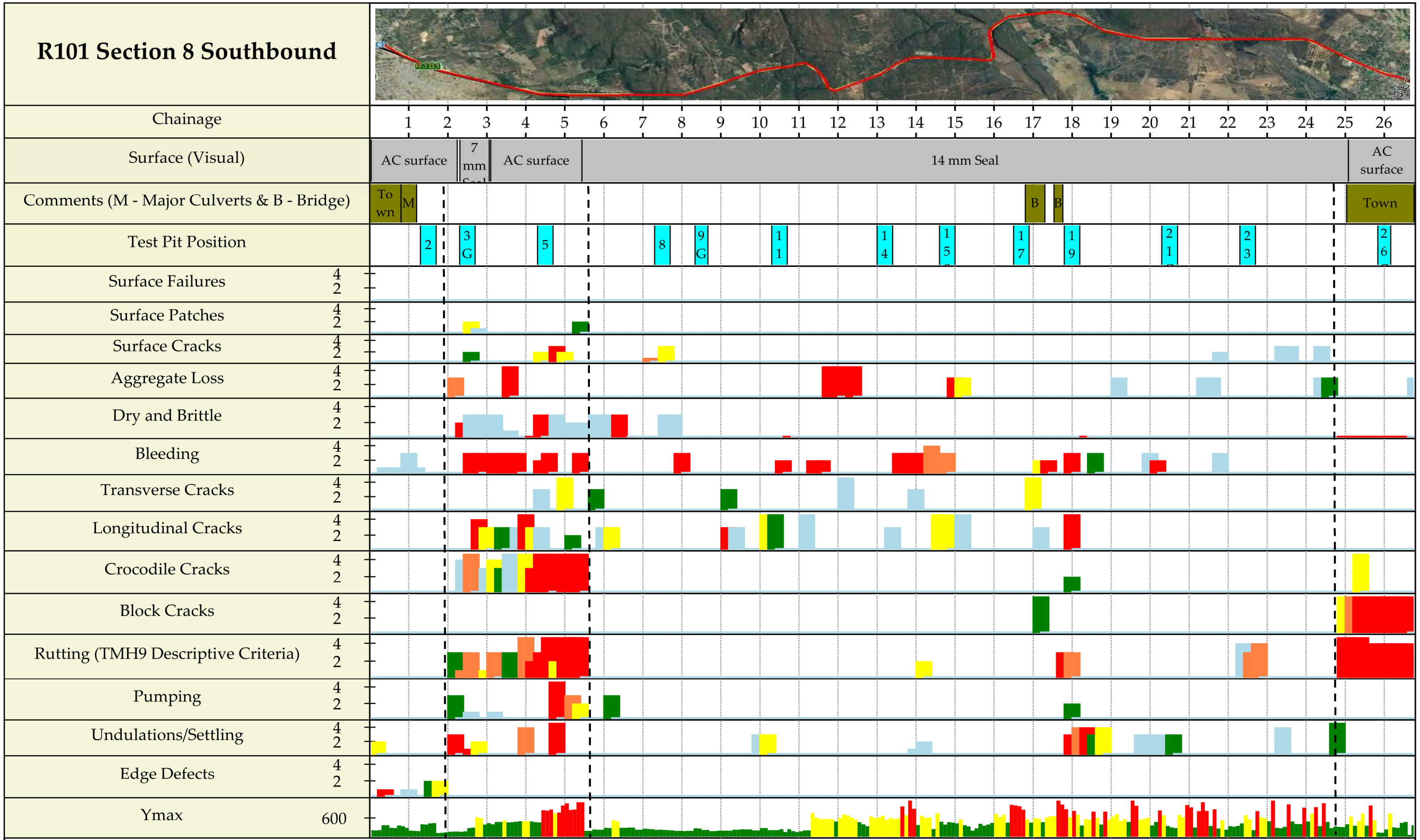
NRA R.101-080-2019/1 KM 0.0 TO KM 26.8

TEST PIT, VISUAL ASSESSMENT, IRI, RUT, TEXTURE and Ymax

1

Rubicon Toolbox: Data Viewer / Ver: 3.1.0 / (Licenced)

Figure 7.1 Visual assessment summary, R101-8 Northbound



NRA R.101-080-2019/1 KM 0.0 TO KM 26.8

TEST PIT, VISUAL ASSESSMENT and Ymax

1

Rubicon Toolbox: Data Viewer / Ver: 3.1.0 / (Licenced)

Figure 7.2: Visual assessment summary, R101-8 Southbound

7.2.4 Photographic Record

Photo 7.1: Typical appearance of first section at km 0.20

Photo 7.2: Shoving at Mile Street intersection (km 0.70)

Photo 7.3: Rutting and typical appearance of the second section at km 4.60

Photo 7.4: Typical crocodile cracks along the second section at km 4.00

Photo 7.5: Patch, rut and crocodile cracks at km 2.40

Photo 7.6: General appearance of section from km 5.44 to km 25.05 with flushing

Photo 7.7: Undulation at km 18.20

Photo 7.8: Mechanical damage on the curve at km 15.40

Photo 7.9: Typical appearance of section in Modimolle showing block and surface cracks

Photo 7.10: Block cracks from km 25.10 to km 26.80

Photo 7.11: Parking bays on the right hand side km 26.60 to km 26.75

Photo 7.12: Concrete block pavers at km 26.80

7.3 MECHANICAL SURVEY

7.3.1 Introduction

To evaluate the functional condition of the existing pavement, mechanical survey data was provided by SANRAL. The data (2017) covered the section from km 4.4 to km 26.8 in the primary direction (northbound) only and included the following measurements:

- Riding quality / Roughness;
- Rut depth; and
- Texture.

For each data set, measurements were compared to the pavement condition criteria specified in *SAPEM* and *TRH12*. The criteria is summarised in *Table 7.1*. The cumulative sum (CUSUM) method was applied to the respective data sets in order to identify uniform sections along the road pavement.

Table 7.1: TRH12 Performance criteria

ROAD CATEGORY	RIDING QUALITY (IRI)		RUT DEPTH (mm)	
	X	Y	X	Y
A	2.9	3.5	10	20
B	**3.5**	**4.2**	**10**	**20**
C	4.2	5.1	10	20

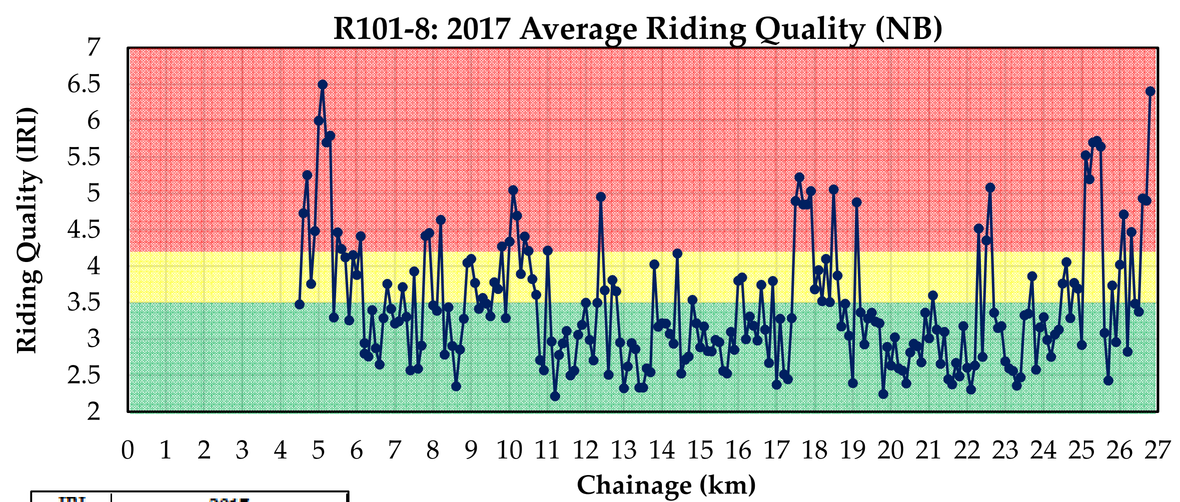
Note: *Values below X are classified as being **sound**, while values between X and Y are classified as **warning** and those above Y as **severe**.*

7.3.2 Riding Quality

Riding quality was measured along the left and right wheel tracks of the northbound lane at 100 m intervals in terms of the International Roughness Index (IRI). *Figure 7.3* shows the average IRI results in terms of the *TRH12* criteria for a Category B road. Uniform sections based on the data is shown in *Figure 7.4*.

The results indicate the following:

- Riding quality along the right wheel track is worse when compared to that along the left wheel track as highlighted in *Figure 7.3;* and
- Average IRI values indicate that 61% of the road is classified as sound, the remaining 20% as warning and 19% as severe;



IRI (m/km)	2017 Left IRI	Right	Average
>4.2	18.2%	19.6%	18.9%
3.5-4.2	10.7%	29.3%	20.0%
<3.5	71.1%	51.1%	61.1%

Figure 7.3: Riding quality data in primary direction (Northbound)

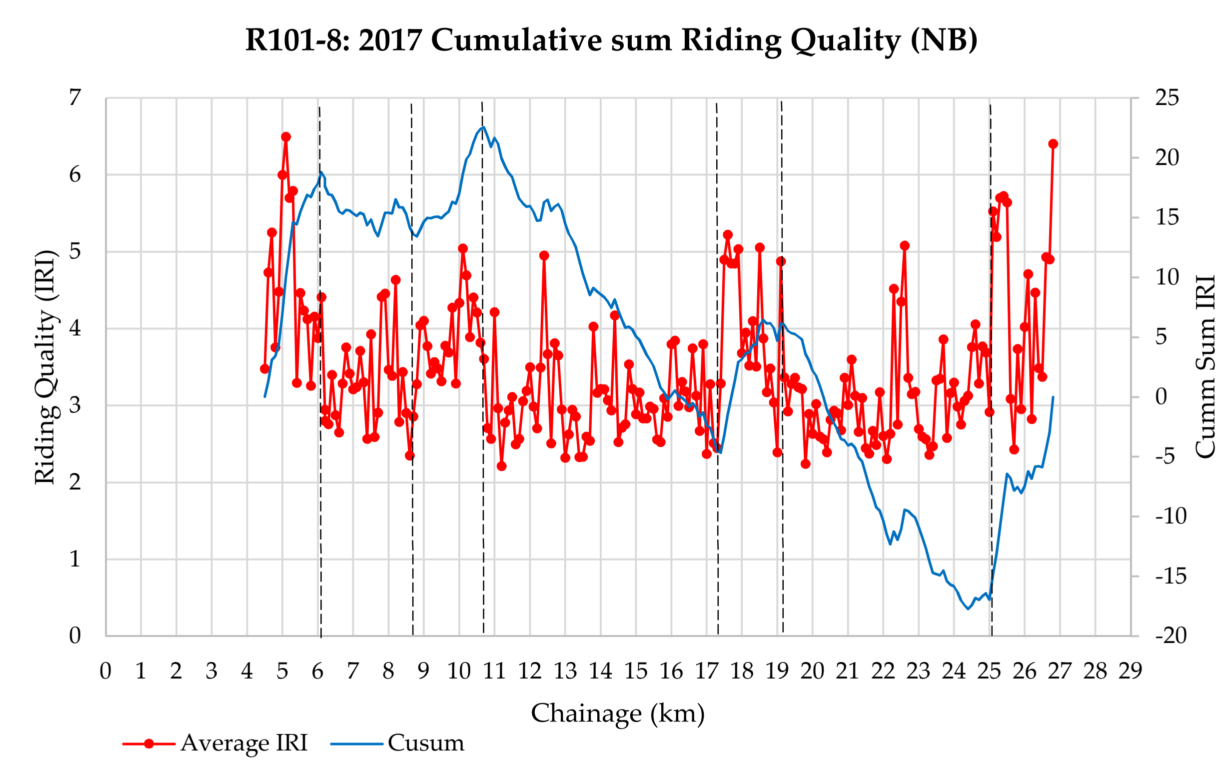


Figure 7.4: Uniform sections based on riding quality measurements

7.3.3 Rut Depth

Rut depth measurements were conducted at 10 m intervals in the northbound direction. This dataset was also analysed using the criteria for a Category B road and is illustrated in *Figure 7.5*.

Figure 7.5 show that rut measurements along the right wheel path are generally higher compared to those along left wheel path. The fact that patch repairs have mostly been carried out along the left wheel path probably explains the lower rut measurements. This does however also indicate possible underlying problems in the pavement.

The following can be concluded from the results:

- In many instances rut depth along the right wheel track is worse when compared to that along the left wheel track, similar to riding quality;
- On average, 94% of the road is classified as sound, 5% as warning and 1% as severe; and
- Based on the cusum analysis using the measurements along the left wheel track, the road can be divided into nine uniform sections.

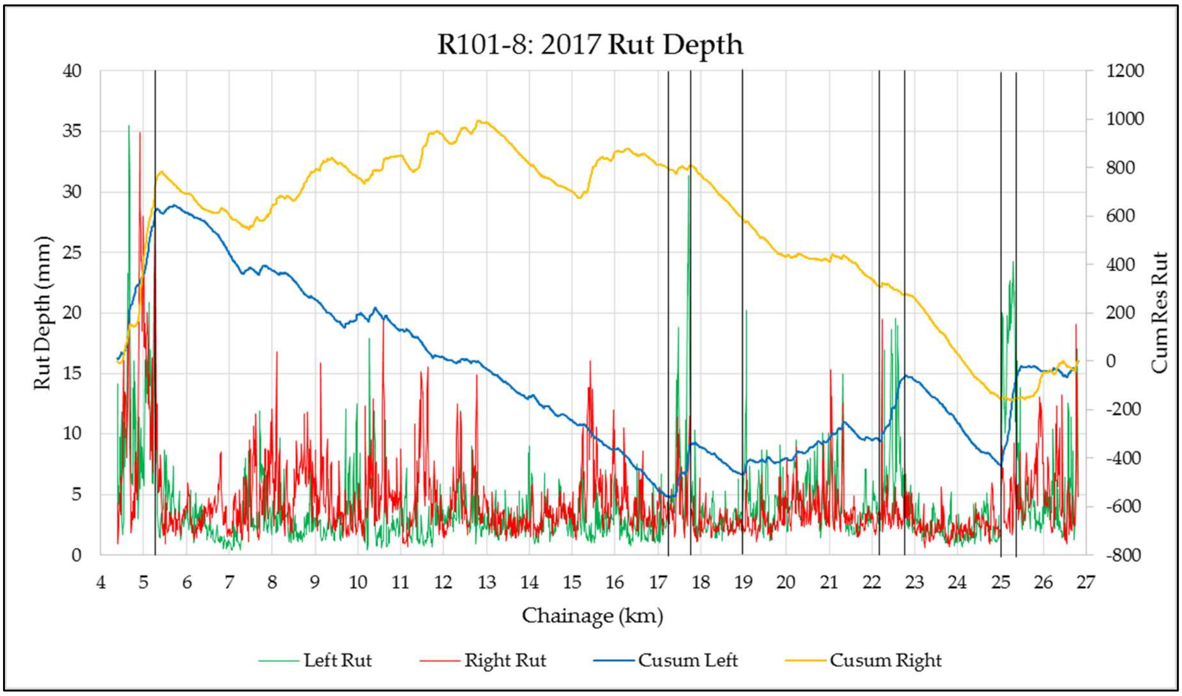


Figure 7.5: Uniform sections based on rut depth measurements

7.3.4 Texture

Texture measurements were conducted at 10 m intervals along the northbound lane and are shown graphically in *Figure 7.6*. The texture data reflects the surface types along Road R101-8 and can be summarised as follows:

- Asphalt sections which typically have lower texture compared to the seal sections, e.g. average texture for asphalt section from km 4.40 to km 5.44 is 0.5 mm compared to 1.5 mm for the seal section km 5.4 to km 25.0;
- Texture varies significantly from km 5.44 (the start of 14 mm seal) to km 25.20 (the start of asphalt section in Modimolle). This is due to varying degrees of bleeding/flushing; and
- Texture is generally classified as adequate (>0.5 mm) to rough (>1.0 mm).

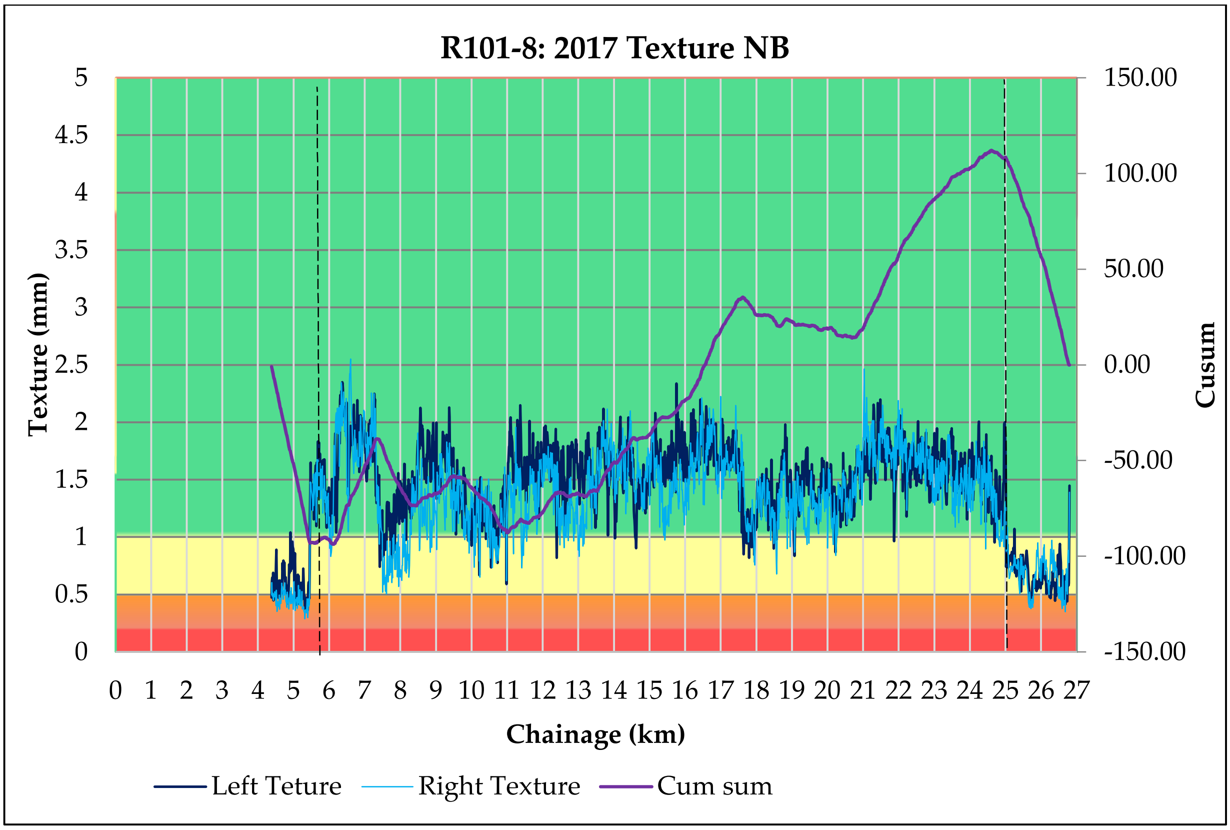


Figure 7.6: Macro texture along R101-8 - Northbound

7.4 DEFLECTION MEASUREMENTS

7.4.1 Introduction

Deflection measurements using the falling weight deflectometer (FWD) were carried out along Road R101-8 during November 2018. These measurements were conducted by *Roadlab Laboratories* at 100 m intervals in both directions. Measurements were also conducted along climbing lanes where present.

As per the specification, three drops were measured at each test position, i.e. two using a 40kN load and one using a 50 kN load. For the purpose of this assessment, data from the second 40 kN drop was analysed.

7.4.2 Condition Criteria

SAPEM stipulates condition rating criteria for deflection measurements, which are summarised in *Table 7-2* below. Based on the findings from the materials investigation, Road R101-8 was assessed in terms of the criteria for a granular base pavement structure.

Table 7.2: SAPEM condition rating criteria

BASE TYPE	STRUCTURAL CONDITION RATING	DEFLECTION BOWL PARAMETERS				
		Ymax (µm)	RoC (m)	BLI (µm)	MLI (µm)	LLI (µm)
Granular base	Severe	> 750	< 100	> 400	> 200	> 100
	Warning	500 – 750	50– 100	200 – 400	100 – 200	50 – 100
	Sound	< 500	> 100	< 200	< 100	< 50
Bituminous base	Severe	> 600	< 100	> 400	> 150	> 80
	Warning	400 – 600	100 – 250	200 – 400	100 – 150	50 – 80
	Sound	< 400	> 250	< 200	< 100	< 50
Cemented base	Severe	> 400	< 80	> 300	> 100	> 80
	Warning	80 – 400	80 – 150	100 – 300	50 – 100	40 – 80
	Sound	< 200	> 150	< 100	< 50	< 40

Notes: Ymax – Maximum deflection; RoC - Radius of curvature; BLI - Base layer index; MLI - Middle layer index; LLI - Lower layer index

7.4.3 FWD Analysis

7.4.3.1 <u>Maximum Deflection (Ymax)</u>

Results of the maximum deflection measurements (Ymax) for the 40 kN load case are presented in *Figure 7.7* and *Figure 7.8* for the northbound and southbound lanes, respectively. Maximum deflection measurements were further used to identify uniform sections along the two lanes using the cumulative sum method.

The following observations were noted from the analysis:

- Measurements indicate poor correlation between the two lanes;
- Northbound lane consists of 12 uniform section whereas the southbound lane consists of 8;
- On average, 48% of the road has maximum deflection above 500 µm, which indicates that 48% of the pavement can be classified as warning and severe;
- FWD measurements further indicate that uniform sections US2, US7 and US11 along the northbound lane are the most distressed with 87% of these sections classified as severe;
- Along the southbound lane two uniform sections (US3 and US5) are the most distressed with warning to severe maximum deflection;
- Uniform section 7 (total of 9 kilometres) in the southbound lane fluctuates between sound, warning and severe conditions. This shows inconsistency of the pavement structure along this section;
- Measurements along the northbound fast lane (km 6.2 to km 7.5) indicate that 31% of the lane can be classified as severe and 38% as warning; and
- In contrast, measurements along the southbound fast lane (km 14.4 to km 15.7) indicate that 68% can be classified as sound and 25% as warning.

R101-8 is a Category B road designed for a 90th percentile, which means only 10% of the road to perform unsatisfactory.

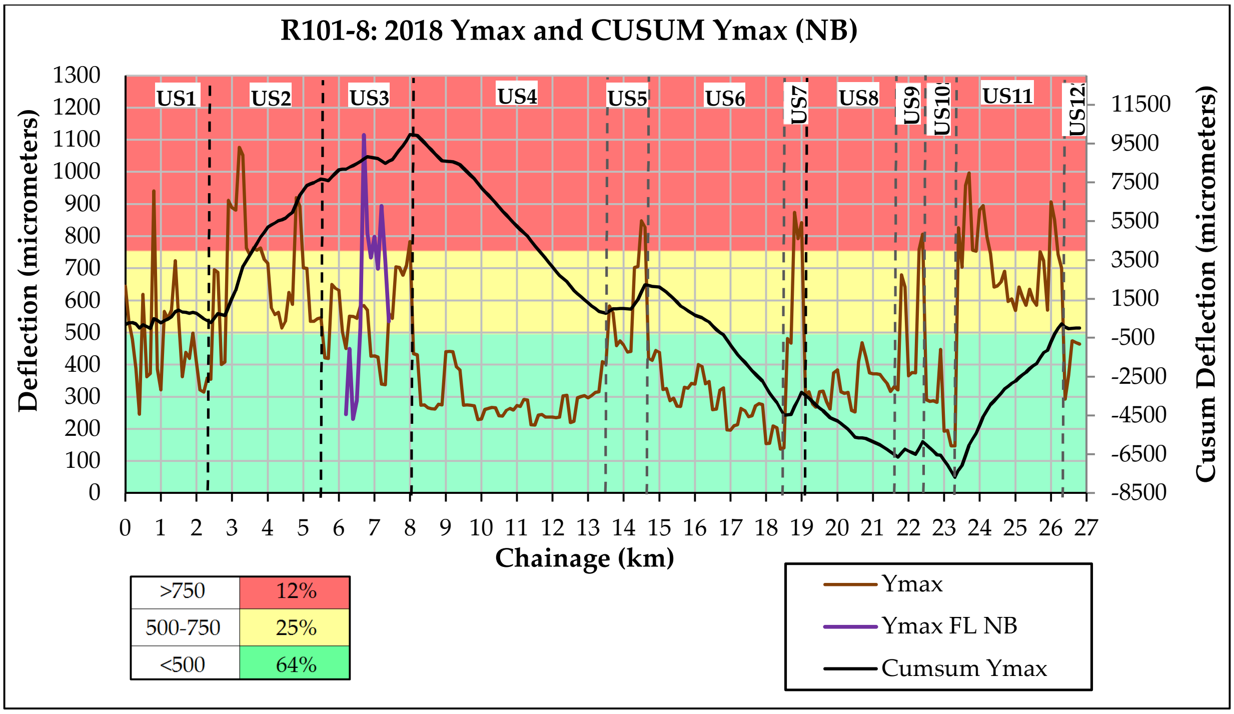


Figure 7.7: Maximum deflection R101-8 Northbound lane

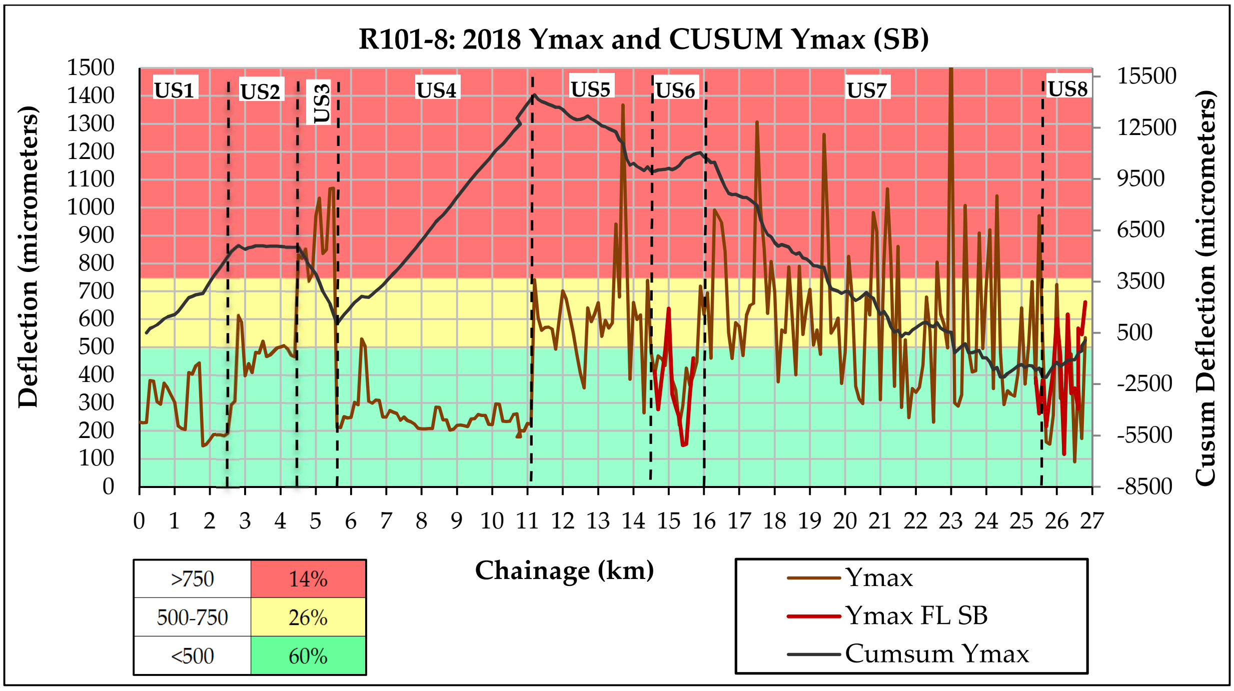


Figure 7.8: Maximum deflection R101-8 Southbound lane

7.4.3.2 Base Layer Index (BLI)

The BLI data for the northbound and southbound lanes are depicted in *Figure 7.9* and *Figure 7.10*, respectively. Included in the Figures are fast lane measurements along climbing lanes as well as the cusum analysis showing uniform sections.

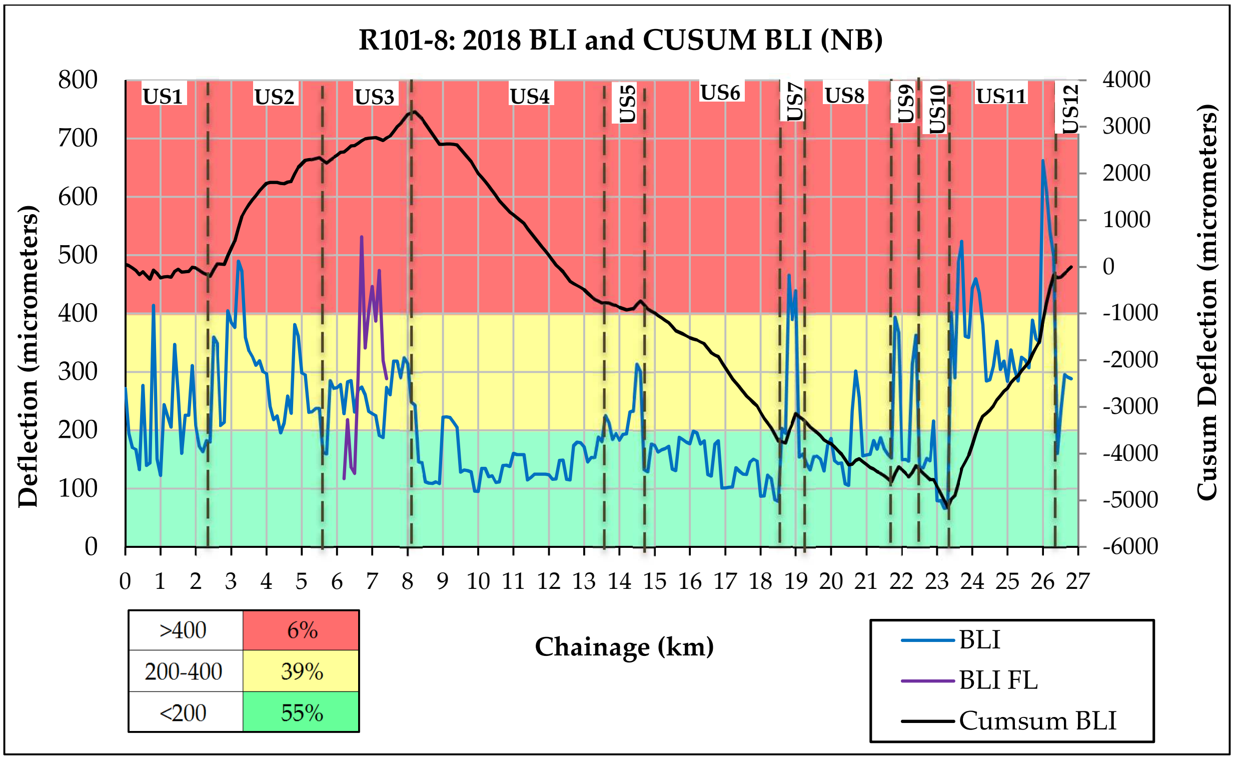


Figure 7.9: BLI and cusum BLI – Northbound lane

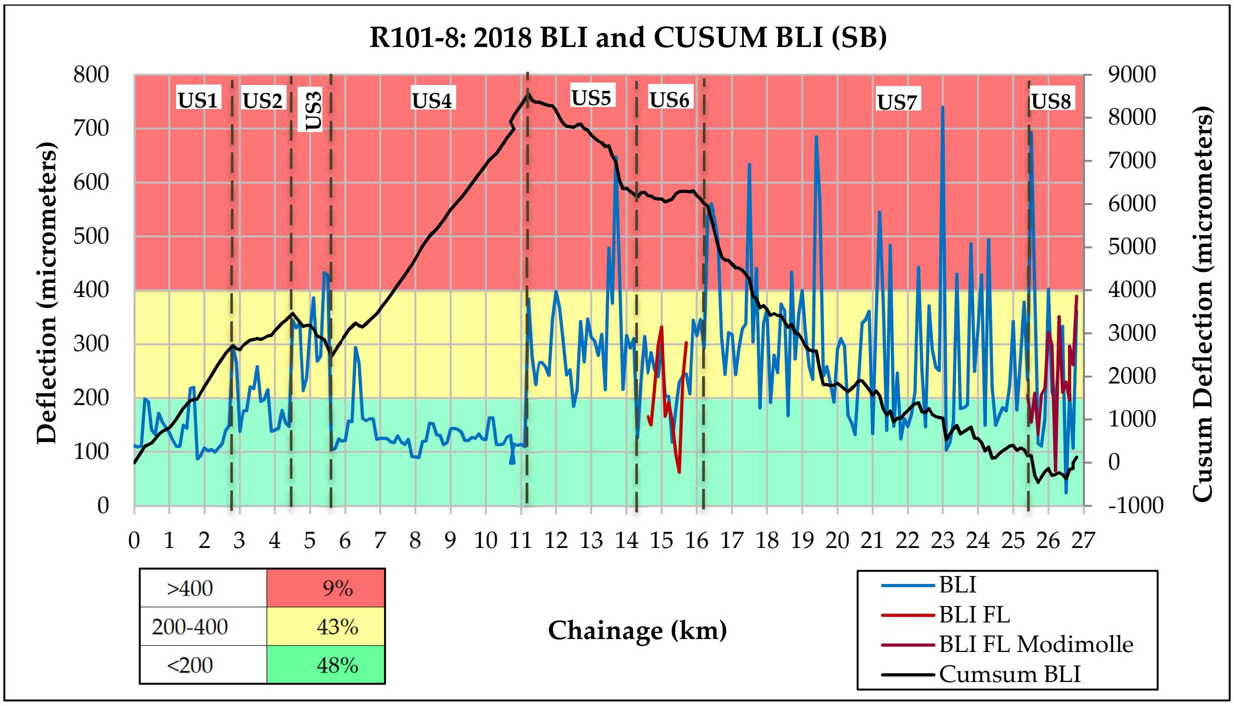


Figure 7.10: BLI and cusum BLI – Southbound lane

The following observations were noted from the analysis:

- Similar to the maximum deflection measurements, BLI showed poor correlation between the northbound and southbound uniform sections;
- Along the northbound lane, 6% of the pavement is classified as severe, 39% as warning and 55% as sound;
- Along the southbound lane 48% of the road is classified as sound, 43% as warning and 9% as severe; and
- The measurements along the fast lane in the northbound direction classify the pavement as severe, whereas in the southbound fast lane measurements classify it as warning.

7.4.3.3 Middle Layer Index (MLI)

MLI data is shown in *Figure 7.11* and *Figure 7.12* for the northbound and southbound lanes, respectively. The following observations were noted from the information:

- MLI measurements in the northbound lane along US4 (km 8.0 to km 13.5), US6 (km15 to km 18.5), US10 (km 22.5 to km 23.5), and US12 (km 26.3 to km 26.8) are generally classified as sound. The remaining sections of the road are classified as warning and severe;
- The southbound lane from km 0.0 to km 2.5, km 5.5 to km 11.0 and km 25.5 to km 26.8 is generally classified as sound with localised warning areas. The remaining sections of the road are classified as warning and severe; and
- Measurements along the northbound fast lane are classified as severe, while that of the southbound are classified as sound to warning.

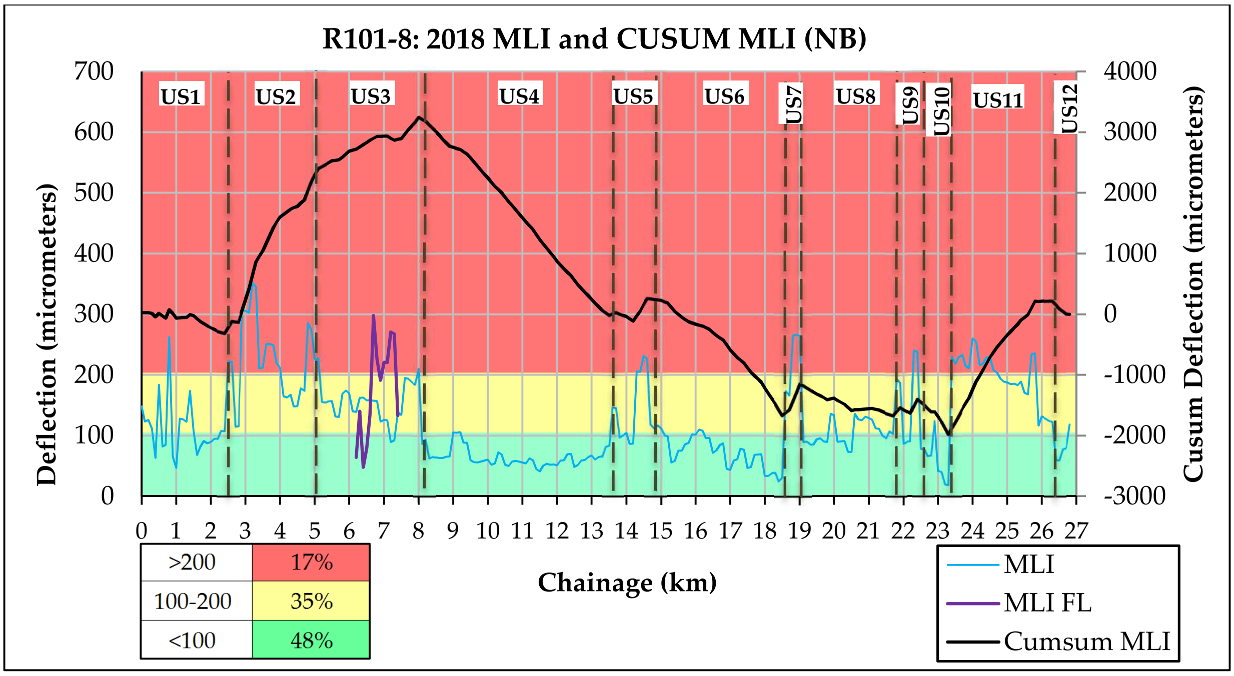


Figure 7.11: MLI and cusum MLI – Northbound lane

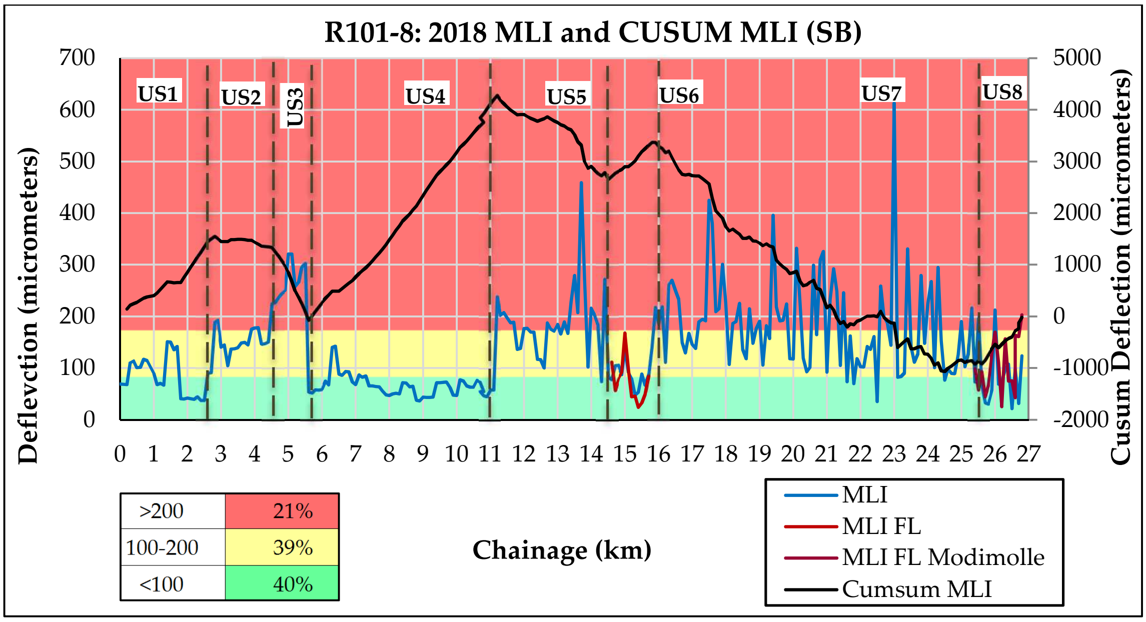


Figure 7.12: MLI and cusum MLI – Southbound lane

7.4.3.4 Lower Layer Index (LLI)

LLI data is shown in *Figure 7.13* and *Figure 7.14* for the northbound and southbound lanes, respectively. The following observations were noted from the information:

- Along the northbound lane, LLI measurements classify the road to have lower layers in sound to warning condition with localized severe areas (US1, US2, US5, US7, and US11);
- Uniform sections US2, US3, and US5 in the southbound lane appear to be the worst with warning to severe lower layers;
- Lower layers in the northbound fast lane are classified as warning, whereas in the southbound direction they are classified as sound.

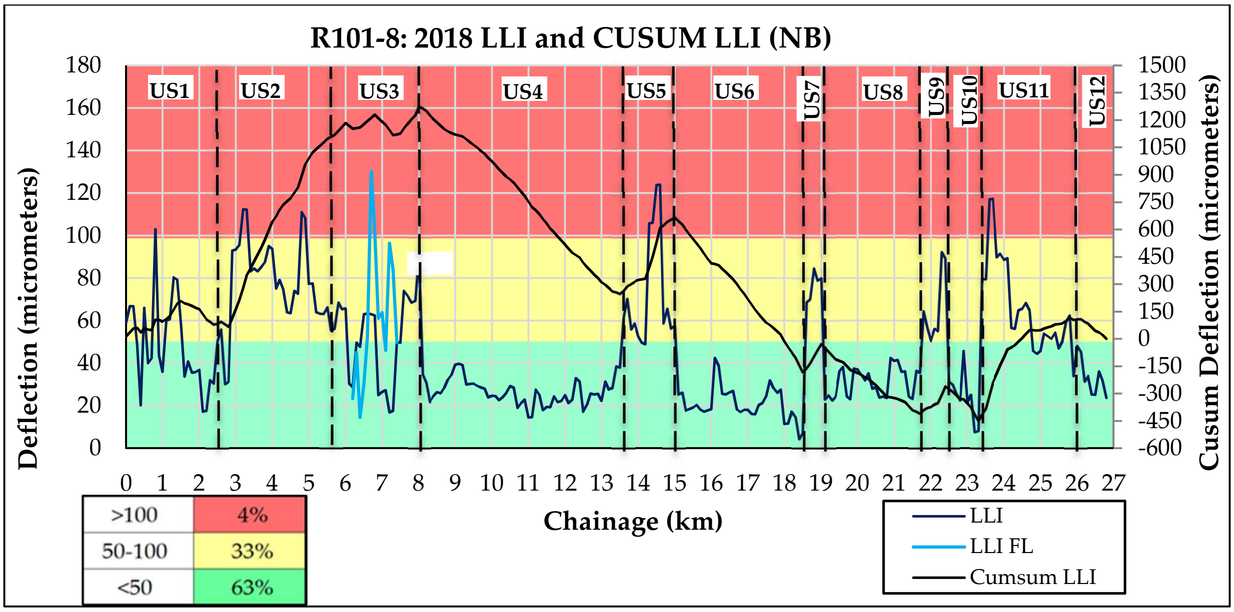


Figure 7.13: LLI and cusum LLI – Northbound

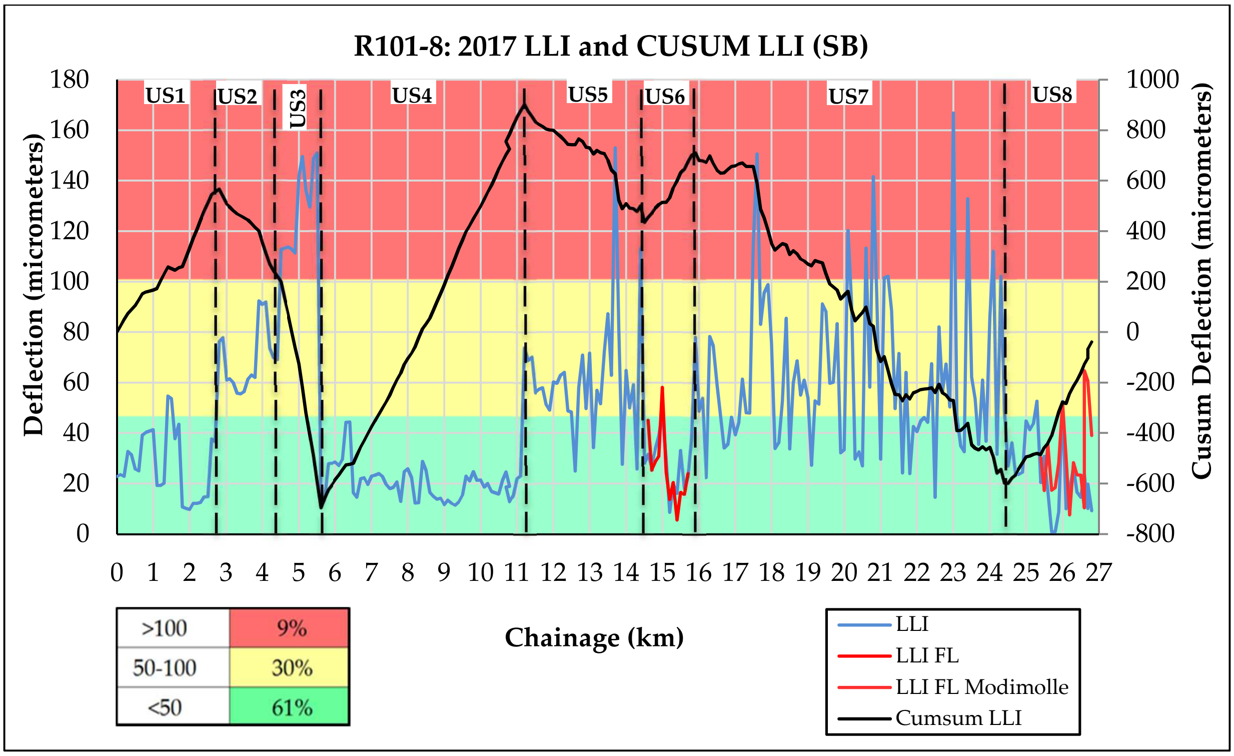


Figure 7.14: LLI and cusum LLI – Southbound lane

7.4.3.5 Summary and Uniform Sections

Deflection bowl parameters provide a good indication of the origin of distress in the pavement. Maximum deflection is indicative of the entire pavement structure. Whereas the BLI is indicative of the reaction of the upper (base & subbase) layers, MLI provides an indication of the middle layers (subbase & USSG) and LLI of the lower layers (LSSG and subgrade).

Deflection measurements between the respective lanes show very different results, which seems to indicate different pavement structures for these lanes. Unfortunately no information is available on maintenance/rehabilitation actions that may have been carried out along the road, however the deflection measurements as well as profiles from test pits indicate that different repair actions may have been carried out along the respective lanes.

Maximum deflection along the northbound lane indicates that US2 (km 2.3 to km 5.5), US7 (km 18.5 to km 19.0) and US11 (km 23.3 to km 26.3) are classified as severe, indicating that these pavement structures have the lowest structural capacities. Along the southbound lane, US3 (km 4.5 to km 5.5) is classified as severe and US2, US5 and US7 are classified as warning to severe.

The deflection bowl parameters indicate the origin of distress to be generally from the subbase. The 90th percentile values for the respective deflection bowl parameters are summarised in *Table 7.3* for each uniform section. The data shows that the origin of the distress is generally located in the upper and middle layers of pavement structure. It also shows that the road is generally classified as warning to severe based on the 90th percentile parameter values.

Table 7.3: Summary of 90th Percentile Deflection Bowl Parameters per Uniform Sections

NORTHBOUND LANE (KM – KM)					SOUTHBOUND LANE (KM –KM)				
US	Ymax	BLI	MLI	LLI	US	Ymax	BLI	MLI	LLI
0.0-2.3	637	301	166	76	0.0-2.5	406	196	139	43
2.3-5.5	910	384	305	107	2.5-4.5	593	270	189	92
5.5-8.0	703	317	192	71	4.5-5.5	1067	429	321	150
8.0-13.5	407	210	87	35	5.5-11	300	162	86	28
13.5-14.5	719	241	208	108	11-14.5	741	394	262	80
14.5-18.5	414	184	112	57	14.5-16.0	591	309	168	49
18.5-19.0	861	456	267	83	16.0-25.5	971	493	297	102
19.0-21.7	394	206	132	39	25.5-26.8	531	389	119	26
21.7-22.5	772	376	239	90					
22.5-23.5	716	302	220	80					
23.5-26.3	899	528	234	90					
26.3-26.8	472	294	103	34					

7.5 MATERIALS INVESTIGATION

Utilising FWD, mechanical survey, and visual assessment data, a scope for the materials investigation was compiled. Test pit positions were allocated to cover all conditions along Road R101-8. A total of 19 test pits were positioned in the northbound and southbound lanes as well as in gravel shoulders. A summary of the test pit locations is provided in *Table 7-4*.

The field investigation was conducted from the 6th of March 2019 to 16th of March 2019. Test pit profiling showed a high variation in the pavement structure along Road R101-8 which correlates with the FWD measurements. The test pit profile summary is illustrated in *Figure 7.15*. Test pits along the section from km 5.5 to km 26.8 showed a macadam base layer with an average thickness of 80 mm instead of the 125 BTB indicated in as-built information.

Table 7.4: Test pit positions

TEST PIT NO	STAKE VALUE (km)	DIRECTION & POSITION	SURFACE CONDITION
1	0,500	Northbound lane LWT	No Defects
2	1,500	Southbound lane LWT	No Defects
3	2,500	Northbound gravel shoulder	Gravel shoulder
4	3,500	Northbound lane LWT	Crocodile cracks +Rut
5	4,.500	Southbound lane LWT	Crocodile cracks +Rut
6	5,000	SB LWT + gravel shoulder	Surface cracks on LWT
7	6.500	Northbound Slow lane RWT	Climbing lane, no defects
8	7,600	Southbound lane LWT	Minor rut
9	9,500	Northbound lane LWT	Minor rut
10	10,500	Southbound lane LWT	Minor rut
11	11,800	Northbound gravel shoulder	Gravel shoulder

TEST PIT NO	STAKE VALUE (km)	DIRECTION & POSITION	SURFACE CONDITION
12	14,750	Southbound slow lane RWT	Minor rut
13	17,750	Northbound lane RWT	Undulations + bleeding
14	18,000	Southbound lane LWT	Undulations + Rut
15	19,800	Northbound lane LWT	Minor rut
16	20,300	Southbound gravel shoulder	Gravel shoulder
17	23,450	Northbound gravel shoulder	Gravel shoulder
18	25,500	Northbound between FL RWT	Block cracks and rut
19	26,500	Southbound between SL and FL	Crocodile, block cracks & rut

Dynamic cone penetrometer (DCP) measurements were carried out at all test pit positions. These measurements were taken along the surfaced road and along gravel shoulders. The data was analysed using *Rubicon Toolbox* and the outcome is covered in *Chapter 8*.

7.6 CONCLUSIONS

The findings from the evaluation and analysis of pavement information indicate the following:

- In terms of visual condition, Road R101-8 can be classified as fair to poor with the sections from km 2.3 to km 5.5, km 18.5 to km 19.0 and km 23.5 to km 26.3 being the most distressed with structural failures such as rutting, crocodile cracking, undulation and pumping;
- Riding quality and rut depth measurements (2017) indicate that most of the road is classified as sound with localised warning and severe areas;
- Maximum deflection measurements (2018) along the northbound lane show that the sections from km 2.3 to km 5.5, km 18.5 to km 19.0 and km 23.5 to km 26.3 are classified as severe and therefore have low structural capacity;
- Along the southbound lane maximum deflection for the sections from km 2.5 to km 5.5 and km 11.6 to km 26.8 are classified as warning to severe;
- Deflection bowl parameters indicate the origin of distress to be from the upper and middle layers;
- Uniforms sections from the respective measurements indicate poor correlation;
- Test pit profiles indicated variation in the pavement structure which could be due to previous repair or rehabilitation actions; and
- From the deflection measurements it is evident that the pavement requires some structural improvement for a 20-year structural design period.

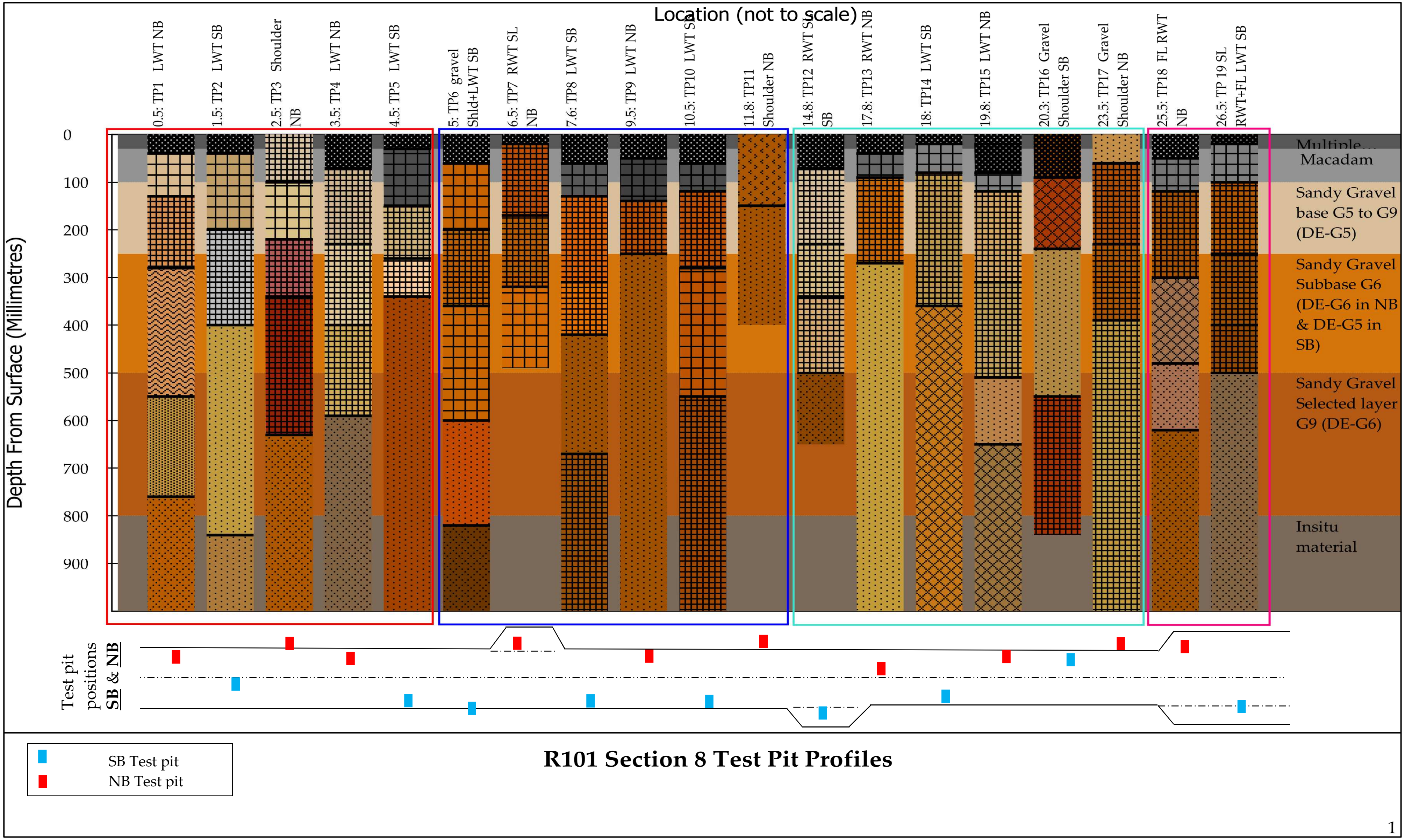


Figure 7.15: Test pit profiles and locations along Road R101-8

CHAPTER 8 STRUTURAL CAPACITY OF EXISTING PAVEMENT

8.1 INTRODUCTION

Pavement traffic loading was estimated for the 20-year design period using 2018 traffic counts. The structural capacity for the existing pavement was evaluated using the *South African Mechanistic-Empirical Design Method (SAMDM).* In addition to this, DCP and surface modulus analyses were conducted to get a holistic understanding of the structural condition of the existing pavement structure.

8.2 PAVEMENT DESIGN TRAFFIC

The traffic count data was used to estimate pavement traffic design loading for a 20-year design period along Road R101-8.

The traffic data between 2015 and 2018 showed an average annual ADT growth rate of 3.02% for the first section from km 0.0 to km 5.44, while that for the second section from km 5.44 to km 26.8 was 2.6%. The level of confidence factor on these growth rates was considered low because only two traffic volume data points were available for the calculation. Growth rates used for the analysis were therefore guided by growth rates from selected number of CTO stations in the region along Road R101. The selected CTO station had long term historical data available.

Estimated future traffic loading for a 20-year design period was calculated using low, medium and high ADTT growth rates of 1%, 2.5% and 4%, respectively, as guided by the historical traffic data and *SAPEM, 2014 Chapter 10 Table 17*. An E80 per heavy vehicle (E80/HV) of 1.8 and an E80/HV growth rate of 2% were used as recommended in *SAPEM, 2014 Chapter 10*.

This analysis showed that for a 20-year design period, the first section of road (km 0.00 to km 5.44) is classified as an ES30 traffic class for all growth rates, whereas the second section (km 5.44 to km 26.80) is classified as ES10 traffic class for all growth rates. The data is summarised in *Table 8.1* and shown graphically in *Figure 8.1.*

The 2.5% growth rate was considered to be the most reasonable growth rate and was used for the pavement capacity analysis.

Table 8.1: Estimated future traffic loading

DESCRIPTION	SECTION 1 (km 0 to km 5.44)	SECTION 2 (km 5.44 to km 26.8)	COMMENT
ADTT for Each lane East and West	527	200	Total for each lane for first and second sections
ADTT growth rate (h)	1.0%		The growth rate between 2015 and 2018 is 3% for first section and 2.6 % for second section
	2.5%		
	4.0%		
Est. Average E80/HV at survey time	1.80		As recommended by SAPEM and as measure at station 1133 along R101
E80/HV growth rate (v)	2.0%		***Table 18 SAPEM Ch 10*** (All heavy)
Combined heavy vehicle growth (h) and E80/HV growth (i)	3.0%		Equation (13) SAPEM Chapter 10 Section 4 =((1+h)(1+Vo)-1)
	4.5%		
	6.1%		
ADE=AADE	949	360	2018 Estimated daily E80 for each lane (AADT*E80/HV)
Years from survey to opening	3.5		Assume to resume in March 2023
AADE for the road at time of Opening ($AADE_0$)	1053	400	Equation (14) SAPEM Chapter 10 Section 4: =(AADEs(1+i)^n)
	1108	421	
	1166	443	
Structural Design Period (Years)	**20**		Design period (End 2043)
Equivalent traffic (ET) after 20 years	**10 658 114**	**4 044 825**	Equation (15) SAPEM Ch.10 Sec. 4. =(365*AADEo*(1+i)^n)/i
	13 339 628	**5 062 478**	
	16 754 900	**6 358 596**	
Pavement Class	**ES30**	**ES10**	Growth rate of 2.5%

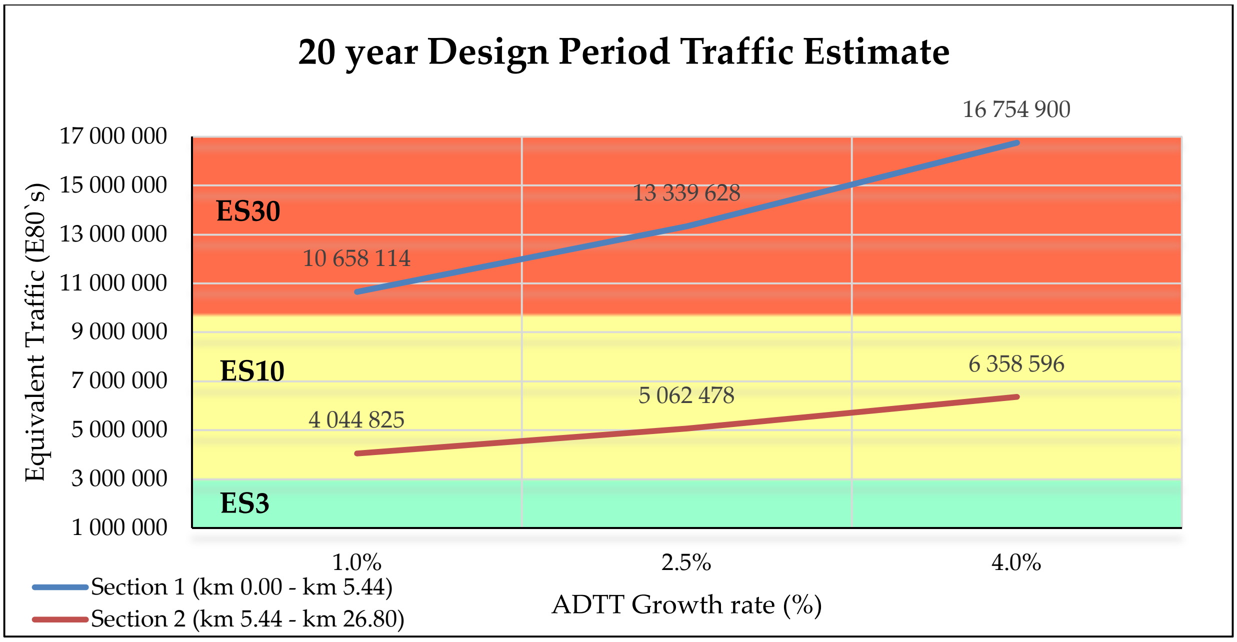


Figure 8.1: Estimated design traffic loading for 20-year design period

8.3 DYNAMIC EQUIVALENT MATERIAL CLASSIFICATION

Due to a high variation in the pavement structure and considering that this project`s aim is to carry out the improvement of pavement capacity, a dynamic equivalent material classification (DEMAC) was conducted using all material investigation results. The classification was done separately for the northbound and southbound lanes. The outcome indicated general pavement structures summarised in *Table 8.2* with the full analysis included in *Appendix D3*. The remaining capacity of existing pavement structures were analysed using the *South African Mechanistic-Empirical Pavement Design Method (SAMPDM)* covered in *Section 8.4*

Table 8.2: Existing pavement structure

NORTHBOUND LANE			SOUTHBOUND LANE		
General pavement structure along northbound lane using average layer thicknesses and DEMAC classification.	Multiple seals/ Asphalt	100 mm multiple seals and or asphalt layer	General pavement structure along southbound lane using average layer thicknesses and DEMAC classification.	Multiple seals/ Asphalt	100 mm multiple seals and or asphalt layer
	Base	150 mm DE-G5 base layer		Base	150 mm DE-G5 base layer
	Subbase	200 mm DE-G6 Subbase layer		Subbase	200 mm DE-G5 Subbase layer
	Subgrade	250 mm DE-G6 selected Subgrade		Subgrade	250 mm DE-G6 selected Subgrade
	In-situ material	In-situ DE-G9 material		In-situ material	In-situ DE-G9 material

8.4 MECHANISTIC ANALYSIS

The existing pavement structural capacity was estimated based on the *South African Mechanistic Empirical Pavement Design Method (SAMPDM)* and was completed using the *Rubicon Toolbox* software. The purpose of this analysis was to determine the remaining pavement life and to establish the critical layers requiring possible rehabilitation.

The existing pavement's structural capacity was estimated using the following information as inputs, to perform a linear-elastic pavement analysis:

- An 80 kN dual wheel axle load setup (350 mm wheel spacing and 750 kPa pressure);
- ADTT of 1054 for the section from km 0.00 to km 5.44 and 400 AADT for the section from km 5.44 to km 26.80;
- A 2.5% growth rate;
- Test pit layer thicknesses for existing layers (see Section 6.3); and
- Stiffness values for existing material derived from DEMAC evaluation.

The outcome of the SAMPDM analysis for the northbound and southbound lanes is illustrated in *Figure 8.2* and shows remaining capacity of 2.1 and 3.3 million E80`s, respectively.

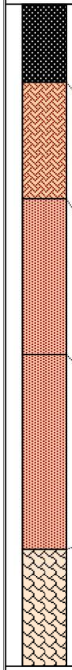
Axle Details: 80 kN Axle, Dual 750 kPa, 350 mm Spacing

Effective Structural Capacity for All Phases = 2.1 million Standard Axles

Time to Exceed Capacity for All Phases: 5.25 Years

Effective Structural Capacity for this Phase Only = 2.1 million Standard Axles

Time to Exceed Capacity for THIS Phase: 5.25 Years



Thickness = 100 Millimetres; Continuously Graded Asphalt Stiffness = 3000 MPa; Poisson = 0.4; Layer Was Not Evaluated	Design Parameter: N/A Position: N/A Basic Axle Capacity: N/A Effective Axle Capacity: N/A Damage not evaluated in this layer
Thickness = 150 Millimetres; G5 material in moderate moisture condition Stiffness = 200 MPa; Poisson = 0.35; Criterion: Granular Materials Cat B Cohesion = 27.7 kPa; Angle of Friction = 38.5	Shear Safety Factor: 1.01 Critical Position: Load Centreline/Middle of Layer Basic Axle Capacity: 2.14 million Effective Axle Capacity: 2.14 million Standard Axles Damage in this Phase from 0.00 to 1.00
Thickness = 200 Millimetres; G6 material in moderate condition Stiffness = 150 MPa; Poisson = 0.35; Criterion: Granular Materials Cat B Cohesion = 23.1 kPa; Angle of Friction = 32.5	Shear Safety Factor: 1.4 Critical Position: Between Loads/Middle of Layer Basic Axle Capacity: 22.15 million Effective Axle Capacity: 22.15 million Standard Axles Damage in this Phase from 0.00 to 0.10
Thickness = 250 Millimetres; G6 material in moderate condition Stiffness = 150 MPa; Poisson = 0.35; Criterion: RSA Subgrade Rut, Cat B No special material properties needed	Vertical Compressive Strain: 290 Microstrain Critical Position: Between Loads/Top of Layer Basic Axle Capacity: >100 million Effective Axle Capacity: > 100 million Standard Axles Damage in this Phase from 0.00 to 0.00
Thickness = Semi-Infinite; Silty sand subgrade, RSA Criterion Stiffness = 80 MPa; Poisson = 0.35; Criterion: RSA Subgrade Rut, Cat B No special material properties needed	Vertical Compressive Strain: 261 Microstrain Critical Position: Between Loads/Top of Layer Basic Axle Capacity: >100 million Effective Axle Capacity: > 100 million Standard Axles Damage in this Phase from 0.00 to 0.00

Load Details:

Setup: 80 kN Axle, Dual 750 kPa, 350 mm Spacing; Daily Count = 1054

Growth Rates: Yr 0 to 5 = 2.5% ; Yr 5 to 10 = 2.5% ; Yr 10 to End = 2.5% ;

Pavement Notes:

R101 Section 8

Existing northbound average structural capacity

1of1

Rubicon Toolbox: LET: Standard Axle Analysis Ver 2 / Ver: 3.1.0 / (Licenced)

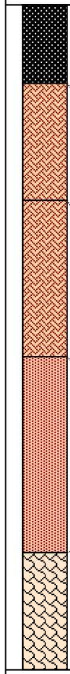
Axle Details: 80 kN Axle, Dual 750 kPa, 350 mm Spacing

Effective Structural Capacity for All Phases = 3.3 million Standard Axles

Time to Exceed Capacity for All Phases: 7.75 Years

Effective Structural Capacity for this Phase Only = 3.3 million Standard Axles

Time to Exceed Capacity for THIS Phase: 7.75 Years



Thickness = 100 Millimetres; Continuously Graded Asphalt Stiffness = 3000 MPa; Poisson = 0.4; Layer Was Not Evaluated	Design Parameter: N/A Position: N/A Basic Axle Capacity: N/A Effective Axle Capacity: N/A Damage not evaluated in this layer
Thickness = 150 Millimetres; G5 material in moderate moisture condition Stiffness = 200 MPa; Poisson = 0.35; Criterion: Granular Materials Cat B Cohesion = 27.7 kPa; Angle of Friction = 38.5	Shear Safety Factor: 1.08 Critical Position: Load Centreline/Middle of Layer Basic Axle Capacity: 3.27 million Effective Axle Capacity: 3.27 million Standard Axles Damage in this Phase from 0.00 to 1.00
Thickness = 200 Millimetres; G5 material in moderate moisture condition Stiffness = 200 MPa; Poisson = 0.35; Criterion: Granular Materials Cat B Cohesion = 27.7 kPa; Angle of Friction = 38.5	Shear Safety Factor: 1.75 Critical Position: Between Loads/Middle of Layer Basic Axle Capacity: >100 million Effective Axle Capacity: > 100 million Standard Axles Damage in this Phase from 0.00 to 0.02
Thickness = 250 Millimetres; G6 material in moderate condition Stiffness = 150 MPa; Poisson = 0.35; Criterion: RSA Subgrade Rut, Cat B No special material properties needed	Vertical Compressive Strain: 290 Microstrain Critical Position: Between Loads/Top of Layer Basic Axle Capacity: >100 million Effective Axle Capacity: > 100 million Standard Axles Damage in this Phase from 0.00 to 0.01
Thickness = Semi-Infinite; Silty sand subgrade, RSA Criterion Stiffness = 80 MPa; Poisson = 0.35; Criterion: RSA Subgrade Rut, Cat B No special material properties needed	Vertical Compressive Strain: 256 Microstrain Critical Position: Between Loads/Top of Layer Basic Axle Capacity: >100 million Effective Axle Capacity: > 100 million Standard Axles Damage in this Phase from 0.00 to 0.00

Load Details:

Setup: 80 kN Axle, Dual 750 kPa, 350 mm Spacing; Daily Count = 1054

Growth Rates: Yr 0 to 5 = 2.5% ; Yr 5 to 10 = 2.5% ; Yr 10 to End = 2.5% ;

Pavement Notes:

R101 Section 8

Existing southbound average structural capacity

1of1

Rubicon Toolbox: LET: Standard Axle Analysis Ver 2 / Ver: 3.1.0 / (Licenced)

Figure 8.2: Linear Elastic pavement analyses for NB and SB lanes

8.5 DYNAMIC CONE PENETROMETER

DCP measurements were analysed using *Rubicon Toolbox* and the outcome is summarised in *Table 8.3* and *Table 8.4* for the northbound and southbound lanes, respectively. The DCP measurements were analysed using *Rubicon Toolbox* and the analysis was evaluated against an ES30 pavement class for the section from km 0.00 to km 5.44 and ES10 pavement class for the section from km 5.44 to km 26.80. The outcome showed that on average the upper 300 mm of existing pavement structure is structurally inadequate for the 20-year design period. The latter corresponds with the findings FWD measurements.

Table 8.3: Dynamic cone penetrometer and uniform sections along the northbound lane

NORTHBOUND LANE				
DCP LOCATION	RUBICON ESTIMATED MESA	REQUIRED IMPROVEMENT THICKNESS	UNIFORM SECTIONS	SUBGRADE STIFFNESS RANGE (MPa)
TP1 @ km 0.5	30	150 mm	US 1 (km 0.0-km 2.3)	408-558
TP 3 @ km 2.5	14.5	300 mm	US 2 (km 2.3-km 5.5)	126
TP 4 @ km 3.5	30	100 mm	US 2 (km 2.3-km 5.5)	193-276
TP 7 @ km 6.5	30	0 mm	US 3 (km 5.5-km 8.0)	
TP 9 @ km 9.5	0.1	600 mm	US 4 (km 8-km 13.5)	84.9
TP 11 @ km 11.8	5.6	0 mm	US 4 (km 8-km 13.5)	
TP 13 @ km 17.8	0.1	700 mm	US 6 (km14.5-km 18.5)	47.5
TP 15 @ km 19.8	5.7	350 mm	US 8 (km 19-km 21.7)	
TP 17 @ km 23.5	7.5	250 mm	US 11 (km 23.5-km 26.3)	133-171
TP 18 @ km 25.5	0.6	250 mm	US 11 (km 23.5-km 26.3)	269-328

Table 8.4: Dynamic cone penetrometer and uniform sections along the southbound lane

SOUTHBOUND LANE				
DCP LOCATION	RUBICON ESTIMATED MESA	REQUIRED IMPROVEMENT THICKNESS	UNIFORM SECTIONS	SUBGRADE STIFFNESS RANGE (MPa)
TP 2 @ km 1.5	0.9	200 mm	US 1(km 0.0-km 2.5)	44-101
TP 5 @ km 4.5	0.5	300 mm	US 2 (km 2.5-km 4.5)	140-237
TP 6 @ km 5.0	0.1	350 mm	US 3 (km 4.5-km 5.5)	47-84
TP 8 @ km 7.6	1.2	300 mm	US 4 (km 5.5-km 11.0)	191-316
TP 10 @ km 10.5	1.5	150 mm	US 4 (km 5.5-km 11.0)	83-137
TP 12 @ km 14.2	19.2	0 mm	US 6 (km 14.5-km 16.0)	-
TP 14 @ km 18.0	1.6	500 mm	US 7 (km 16.0-km 25.5)	561
TP 16 @ km 20.3	6.6	150 mm	US 7 (km 16.0-km 25.5)	243
TP 19 @ km 26.5	0.8	250 mm	US 8 (km 25.5-km 26.8)	273-296

8.6 SURFACE MODULUS

In any pavement structural evaluation, the correct classification and determination of the subgrade strength forms the basis of the analysis and evaluation of the pavement response. The nature of the subgrade stiffness can be evaluated by means of determining the surface modulus[2].

The surface modulus is based on the theory that the load distribution depends on the thickness and stiffness of the pavement layers. Based on these characteristics the stress generated by a load is distributed in a cone shape through the pavement layers. The applied stress will cause deformation of the pavement structure, which can be measured with FWD geophones, spaced at predetermined distances from the applied load centre. Thus, the deformation reading at the load centre can be translated to give information of the stiffness of the top layer, base layer and subgrade combined. As the horizontal distance increases, a point is reached where only the subgrade falls within the zone of influence and the surface moduli thus calculated only reflect the moduli of the subgrade material.

This information is used to produce surface modulus curves, which plot the stiffness on the horizontal axis and the corresponding depth, equal to the distance from the FWD geophone to the load centre, on the vertical axis. The surface modulus at a depth of 600mm to 1200mm typically indicates an estimated stiffness for the subgrade. A surface modulus differential (SMD) was calculated and compared with the benchmark in *Table 8.5* to identify whether the subgrade is categorised as stress softening, linear elastic or stress stiffening.

Table 8.5: Subgrade response benchmarking with surface modulus differentials

RESPONSE CLASSIFICATION	SURFACE MODULUS DIFFERENTIAL RANGES (MPa)
Stress softening	>20
Linear elastic	20 to -20
Stress stiffening	<-20

The sections below elaborate on information obtained from the surface modulus for each lane. Road R101-8 is a category B-road and therefore a 90th percentile was calculated for all surface moduli at each depth.

8.6.1 Northbound Lane

The 90th percentile surface modulus calculated from the FWD measurements for each uniform section in the northbound direction is illustrated in *Figure 8.3*.

[2] Dr. Emile Horak (2007), Surface moduli determined with the falling weight deflectometer used as benchmarking tool, proceeding of the 26th Southern African Transport Conference (SATC 2007), Pretoria.

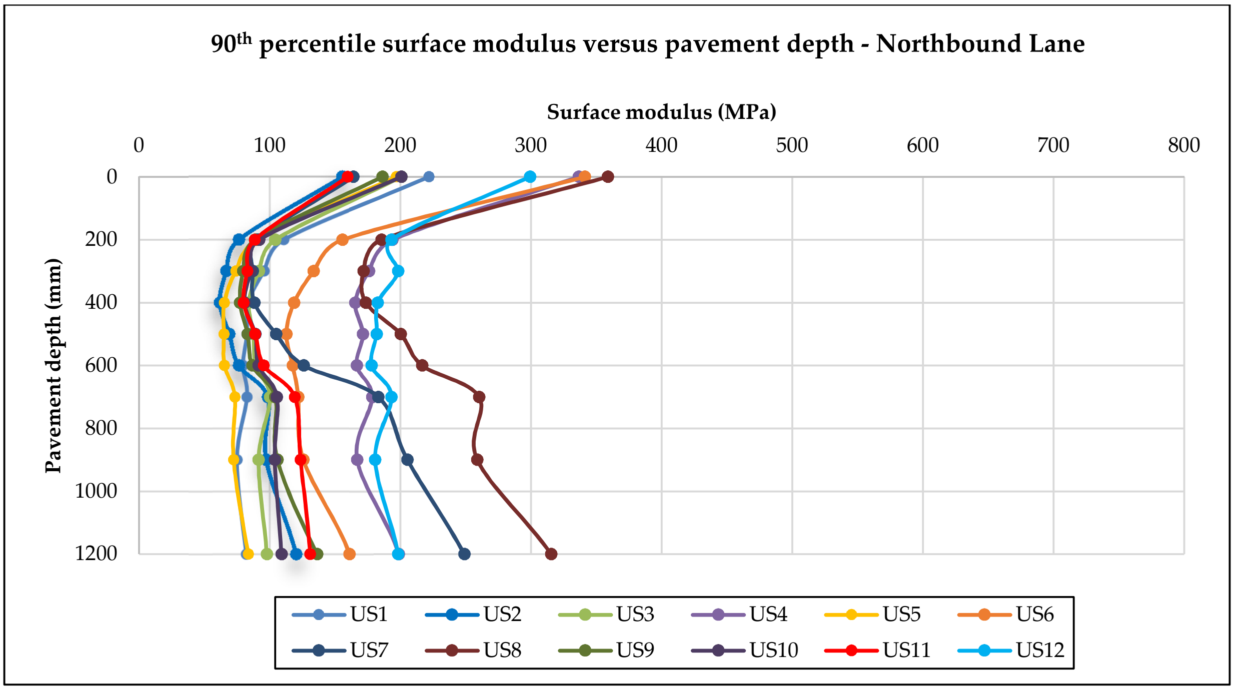


Figure 8.3: The 90th percentile surface modulus for the northbound lane

A surface modulus differential (SMD) was then calculated for all uniform sections to identify the subgrade response. The following can be concluded from this analysis:

- The following uniform sections in the northbound lane have a linear elastic response:
    - Uniform section 1 (km 0.0 to km 2,3) with typical stiffness between 79 MPa and 82 MPa;
    - Uniform section 3 (km 5.5 to km 8.0) with typical stiffness between 89 MPa and 96 MPa;
    - Uniform section 5 (km 13.5 to km 14.5) with typical stiffness between 65 MPa and 84 MPa; and
    - Uniform section 10 (km 22.5 to km 23.5) with typical stiffness between 95 MPa and 109 MPa.
- The remainder of the uniform sections show the subgrade stiffness decreasing rapidly from the depth of 1200 mm to 600 mm. This indicates that the subgrade along these uniform sections experiences stress softening behaviour.

The estimated stiffnesses show that the pavement along the northbound lane of Road R101-8 has good subgrade layers.

8.6.2 Southbound Lane

Similar to the northbound lane, 90th percentile surface moduli and SMD were calculated for the southbound uniform sections. The outcome is that all subgrade stiffness values generally decrease from the depth of 1200 mm to 600 mm. This indicates that the subgrade along the southbound lane exhibits stress softening behaviour. Based on surface modulus, typical stiffnesses for the subgrade along each uniform section are summarised in *Table 8-6*.

Table 8.6: Typical subgrade stiffness based on the surface modulus in the southbound lane

UNIFORM SECTION	90th %TILE @ 600 mm (MPa)	90th % TILE @ 1200 mm(MPa)
US 1 (km 0.0 – km 2.5)	211	300
US 2 (km 2.5 – km 4.5)	96	153
US3 (km 4.5 – km 5.5)	52	74
US4 (km 5.5 – km 11.0)	258	288
US5 (km 11.0 – km 14.5)	109	189
US6 (km 14.5 – km 16.0)	153	182
US7 (km 16.0 – km 25.5)	80	129
US8 (km 25.5 – km 26.8)	249	297

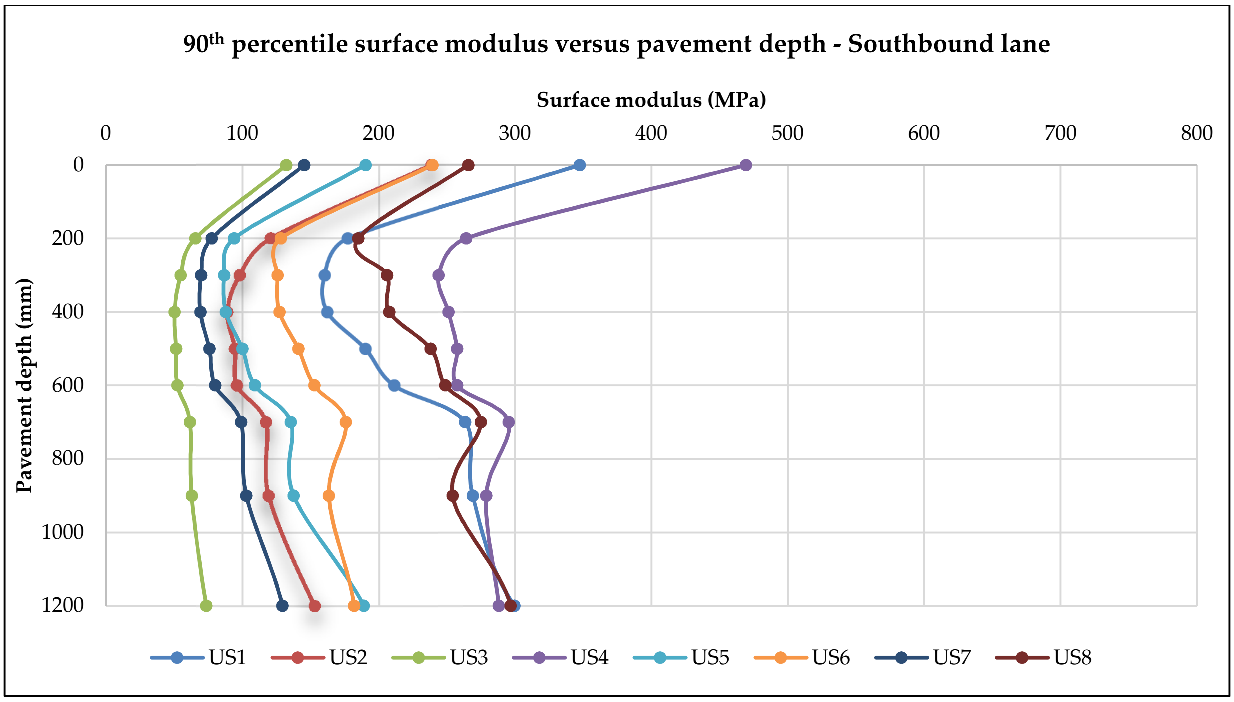


Figure 8.4: The 90th percentile surface modulus for the southbound lane

The estimated stiffness show that the pavement along the southbound lane of Road R101-8 has a good subgrade layers.

8.6.3 Fast Lanes

The surface modulus 90th percentile plot for the fast lanes indicate that the subgrade layers for all sections exhibit stress softening with the northbound fast lane having subgrade layer stiffnesses between 82 and 125 MPa and southbound between 136 MPa and 221 MPa.

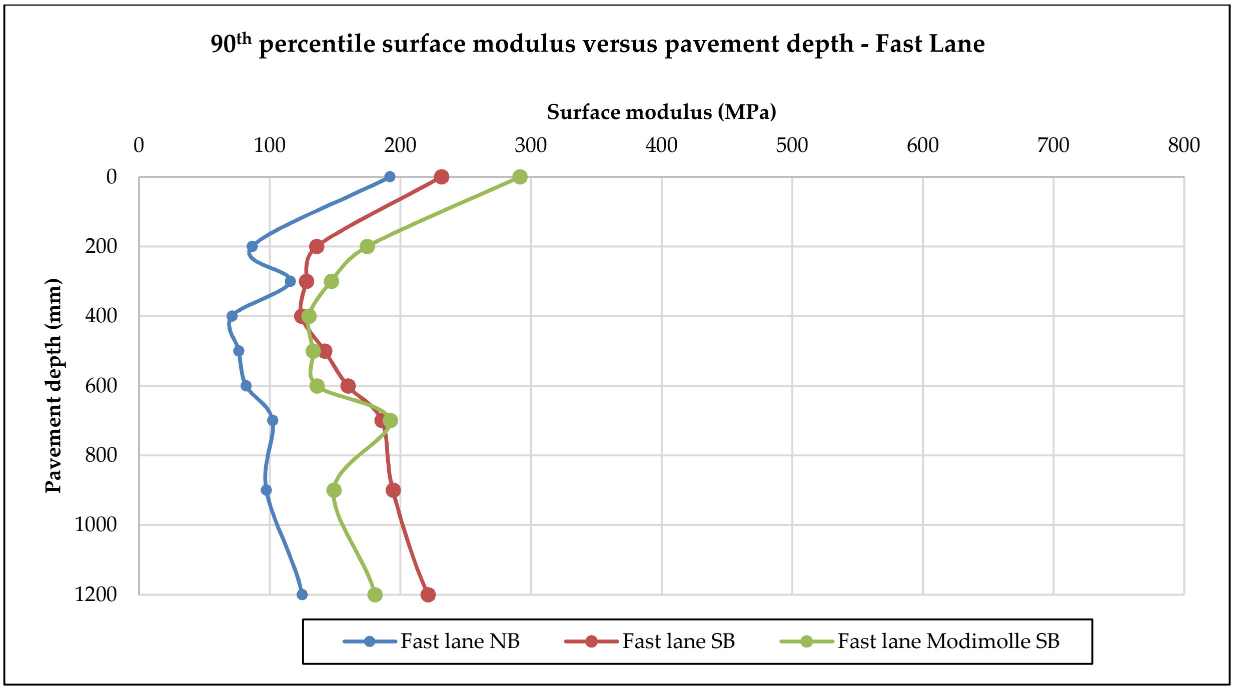


Figure 8.5: The 90th percentile surface modulus for fast lanes NB and SB

8.7 CONCLUSIONS

The following conclusions were drawn from the structural capacity analyses on the existing pavement structure:

- The existing pavement structure is approaching the end of its structural life and will not provide adequate capacity for the 20-year design period;
- The subgrade layer stiffness values derived from the surface modulus using FWD measurements show Road R101-8 to have a sound subgrade;
- The estimated stiffnesses based on material properties are considered reasonable;
- Findings from the mechanistic analysis correspond with that from the DCP analyses indicating the upper ±300 mm of the existing pavement to be structurally inadequate; and
- Rehabilitation/strengthening of existing pavement structure is therefore required to ensure that the pavement has adequate capacity for the 20-year design period.

CHAPTER 9 PAVEMENT DESIGN

9.1 INTRODUCTION

The analysis and evaluation of the existing pavement structure showed that the existing structure is approaching the end of its structural life and will not provide adequate capacity for the 20 year design period. Therefore, rehabilitation/strengthening is required. Three rehabilitation designs to strengthen the existing pavement structure as well as to add new surfaced shoulders were evaluated for the rural section km 5.44 to km 24.00. Furthermore, new pavement structures for additional lanes along urban sections as well as realignment areas were also evaluated.

The *TRH4, 1996* pavement design catalogue was used as the guideline in choosing a suitable pavement structure however, it should be noted that the catalogue contained in *TRH4* was based on lower tyre pressures (520 kPa vs 750 kPa). This results in a decrease in structural capacity when higher tyre pressures are considered.

South African Mechanistic Empirical Pavement Design Method (SAMPDM) was used to evaluate rehabilitation and new pavement designs and these were completed using the *Rubicon Toolbox* software. The following parameters were used in this analysis:

- An 80 kN dual wheel axle load setup (350 mm wheel spacing and 750 kPa pressure);
- ADTT of 1054 for the section from km 0.00 to km 5.44 and 400 for the section from km 5.44 to km 26.80;
- A 2.5% growth rate for the 20 year design period;
- Test pit layer thicknesses for existing layers (see *Figure 7.15*);
- Stiffness values for existing layers were derived from DEMAC evaluation; and
- Stiffness values and material properties for new material as recommended in *Rubicon Toolbox* software.

9.2 REHABILITATION PAVEMENT DESIGN

Three rehabilitation alternatives to improve the existing pavement structure as well as to add surfaced shoulders along rural section (km 5.44 to km 24.00) were identified and investigated:

- <u>Pavement Rehabilitation 1</u>: Using a 250 mm G7 USSG and 200 mm G4 subbase for shoulder widening, adding 100 mm of G2 to the existing base and cement stabilising to a 250 mm C4 base across the lane and shoulder and construct Cape seal as shown in *Figure 9.1*;
- <u>Pavement Rehabilitation 2</u>: Using a 200 mm G7 USSG for shoulder widening, adding a 100 mm G2 to the existing base material and cement stabilising to a 250 mm C4 subbase across the lane and shoulder, construction of a 150 mm G1 base and Cape seal as shown in *Figure 9.2*; and

- Pavement Rehabilitation 3: Reuse existing base material for shoulder USSG, adding 50 mm G2 to the existing subbase and cement stabilising to a 250 mm C4 subbase across the lane and shoulder, construction of a 150 mm G1 base and Cape seal as shown in *Figure 9.3*.

Existing lane pavement structure

100 mm seals and a macadam
150 mm DE-G5 base layer
200 mm DE-G6 Subbase layer
250 mm DE-G6 selected Subgrade
In-situ DE-G9 material
421 E80/day/lane
2.1 MESA
12.5 Years

Pavement Rehabilitation 1

	Lane	Shoulder
	Cape seal	
	Rip and mix existing base material with imported G2 and cement stabilise to a **250 mm C4** subbase layer across lane and shoulder	
	200 mm DE-G6 Subbase layer	200 mm G4 subbase (new)
	250 mm DE-G6 selected Subgrade	250 mm G7 USSG (new)
	In-situ DE-G9 material	Existing road bed(>G9)
Traffic load	421 E80/day/lane	421 E80/day/lane
Capacity	**2.2 MESA**	**2.6 MESA**
Design life	13 Years	14.5 Years

Figure 9.1: Pavement Rehabilitation 1

Existing lane pavement structure

100 mm seals and a macadam
150 mm DE-G5 base layer
200 mm DE-G6 Subbase layer
250 mm DE-G6 selected Subgrade
421 E80/day/lane
2.1 MESA
12.5 Years

Pavement Rehabilitation 2

	Lane	Shoulder
	Cape Seal (S4)	
	150 mm G1 Base (new)	
	250 New C4 Subbase	
	Rework existing base and macadam material and add G5 material where needed to build 150 mm layer.	
	200 mm DE-G6 USSG	200 mm G7 USSG (new)
	250 mm DE-G6 LSSG	Rip and compact 250 mm of existing road bed (>G9)
Traffic load	421 E80/day/lane	421 E80/day/lane
Capacity	6.1 MESA	5.4 MESA
Design life	28.5 Years	22.25 Years

Figure 9.2: Pavement Rehabilitation 2

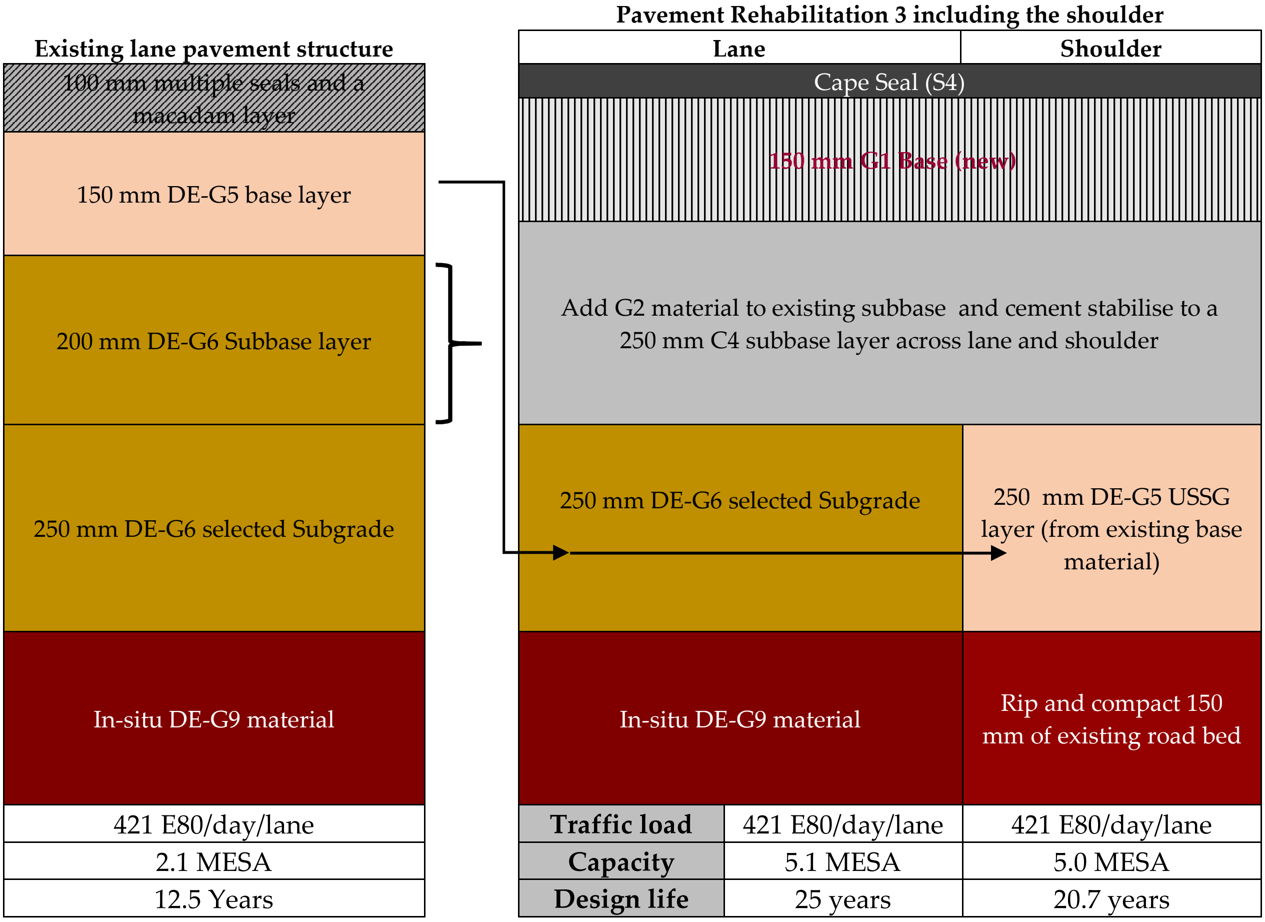


Figure 9.3: Pavement Rehabilitation 3

The evaluation of rehabilitation alternatives showed the following:

- Rehabilitation 1 does not provide adequate structural capacity for the 20-year design period; and
- Pavement Rehabilitations 2 and 3 provide adequate structural capacity for the improvement and addition of surfaced shoulders along the section from km 5.44 to km 24.00 over the 20-year design period;

9.3 NEW PAVEMENT DESIGN

Pavement designs for the new lanes in Bela Bela urban section (km 0.00 to km 5.44) as well as the sections along realignment areas were identified and investigated. The proposed pavement structure for the realignment areas will be used for the additional lanes in Modimolle as the traffic class is the same.

Rubicon Toolbox software was used to evaluate the pavement structures with the parameters indicated in the introduction paragraph and the moduli as guided by *Theyse and Muthen, 2000.* The pavement structures and structural capacities are illustrated in *Table 9.1.*

Table 9.1: Pavement structure for new lanes

LAYER	PAVEMENT STRUCTURE BELA BELA KM 0.00 TO KM 5.44 (ES30)		LAYER	PAVEMENT STRUCTURE: REALIGNMENT AND MODIMOLLE NEW LANE (ES10)	
Surfacing	50 AC	E = 3500 MPa	Surfacing	S4 or 50 AC	E = 3500 MPa
Base	150 G1	E = 600 MPa	Base	150 G1	E = 600 MPa
Upper subbase	150 C3 (EG4)	E = 1800 MPa (E=300 MPa)	Upper subbase	125 C3 (EG4)	E = 1800 MPa (E=300 MPa)
Lower subbase	150 C3 (EG4)	E = 1800 MPa (E=300 MPa)	Lower subbase	125 C3 (EG4)	E = 1800 MPa (E=300 MPa)
USSG	150 G7	E = 130 MPa	USSG	150 G7	E = 130 MPa
Subgrade	Road bed (>G9)	E = 80 MPa	Subgrade	Road bed (>G9)	E = 80 MPa
Traffic load	1108 E80/day/lane		**Traffic load**	421 E80/day/lane	
Capacity	13.4 million standard axles		**Capacity**	6.4 million standard axles	
Design life	25.0 years		**Design life**	33.75 years	

*Note: *Stiffness values obtained from Pavement Analysis and Design Software (PADS) based on the South African Mechanistic-Empirical Design method – H.L Theyse, M. Muthen.*

9.4 CONSTRUCTION METHODOLOGY AND TRAFFIC ACCOMMODATION

The sections below illustrate construction methodologies as well as the traffic accommodation for pavement rehabilitation 2 and 3. It was deemed unnecessary to demonstrate the practicality for pavement rehabilitation 1 because it does not provide adequate structural capacity.

9.4.1 Pavement Rehabilitation 2

The construction sequence for rehabilitation option 2 is demonstrated in *Figure 9.4*. Due to the pavement being lifted by approximately 300 mm, this rehabilitation option will improve drainage issues along Road R101-8 and furthermore it will allow the required geometric improvements to be carried out.

Pavement rehabilitation 2 allows for two way traffic accommodation at all times during construction. This is a requirement due to the high traffic volume along Road R101-8.

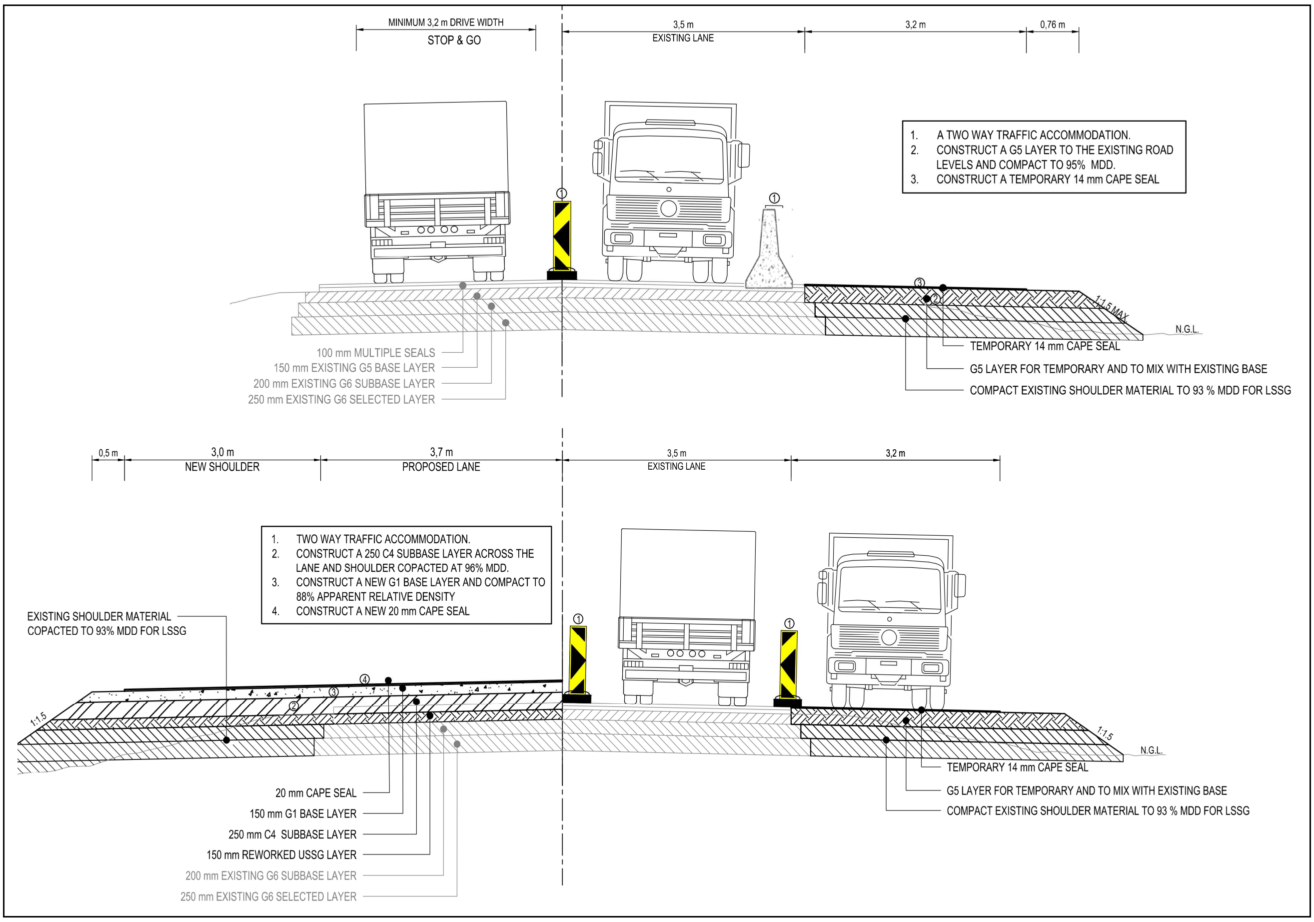


Figure 9.4: Rehabilitation 2: Cement stabilising existing base

9.4.2 Pavement Rehabilitation 3

The construction sequence for this option is demonstrated in *Figure 9.5*. With this option the existing road levels are maintained.

Pavement rehabilitation 3 can only be constructed using half widths (stop and go) traffic accommodation. However, two way traffic accommodation is a requirement due to the volume of traffic using Road R101-8.

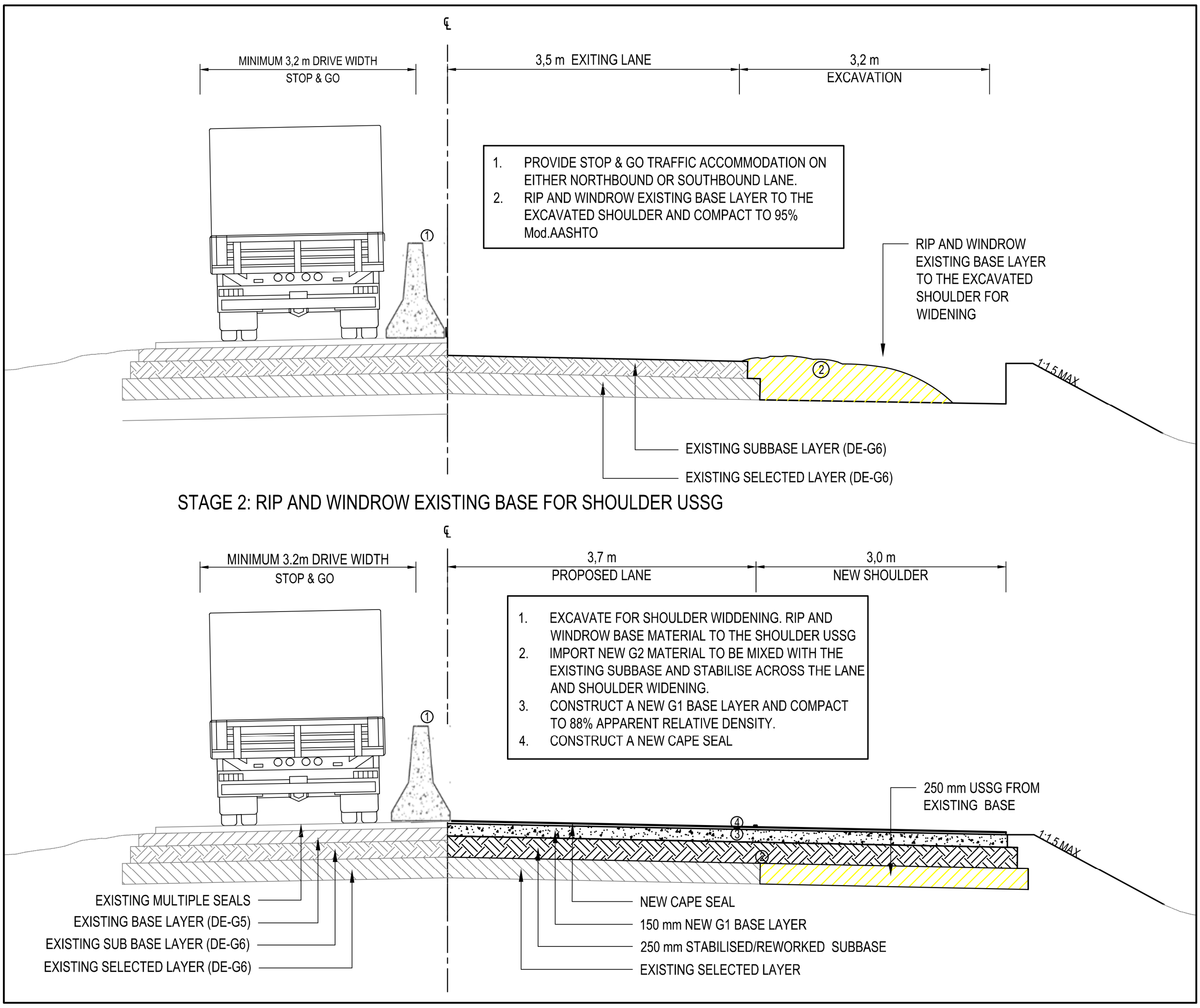


Figure 9.5: Rehabilitation 3: Reuse existing base material for shoulder USSG

9.4.3 New pavement structure

Traffic will be accommodated along the existing road while the new pavement structures along the urban sections and realignment areas are constructed. The construction sequence for the urban section in Bela Bela is demonstrated in *Figure 9.6*.

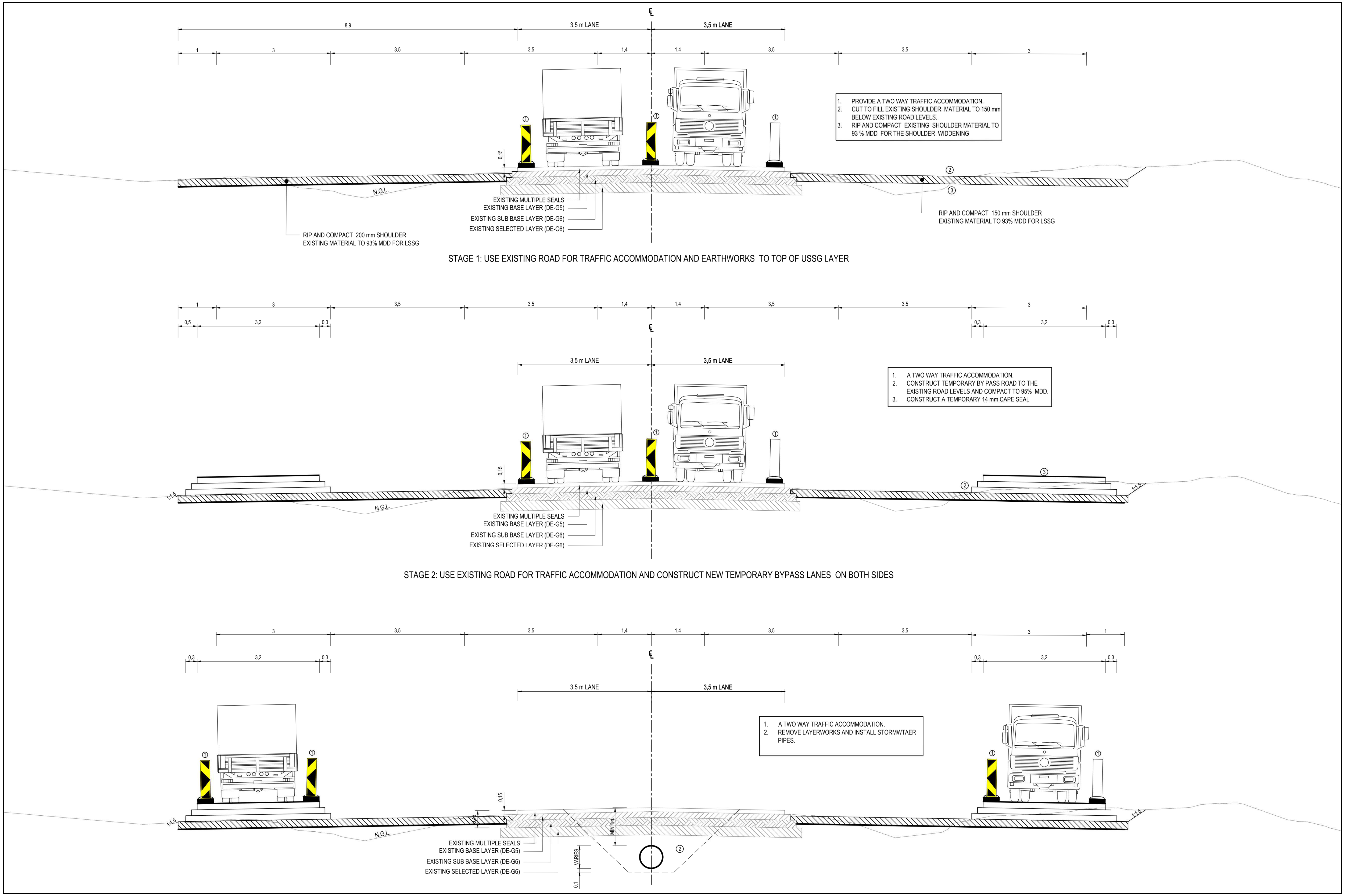


Figure 9.6: Constructing the 4- lane urban cross section with raised kerbs, median and sidewalks

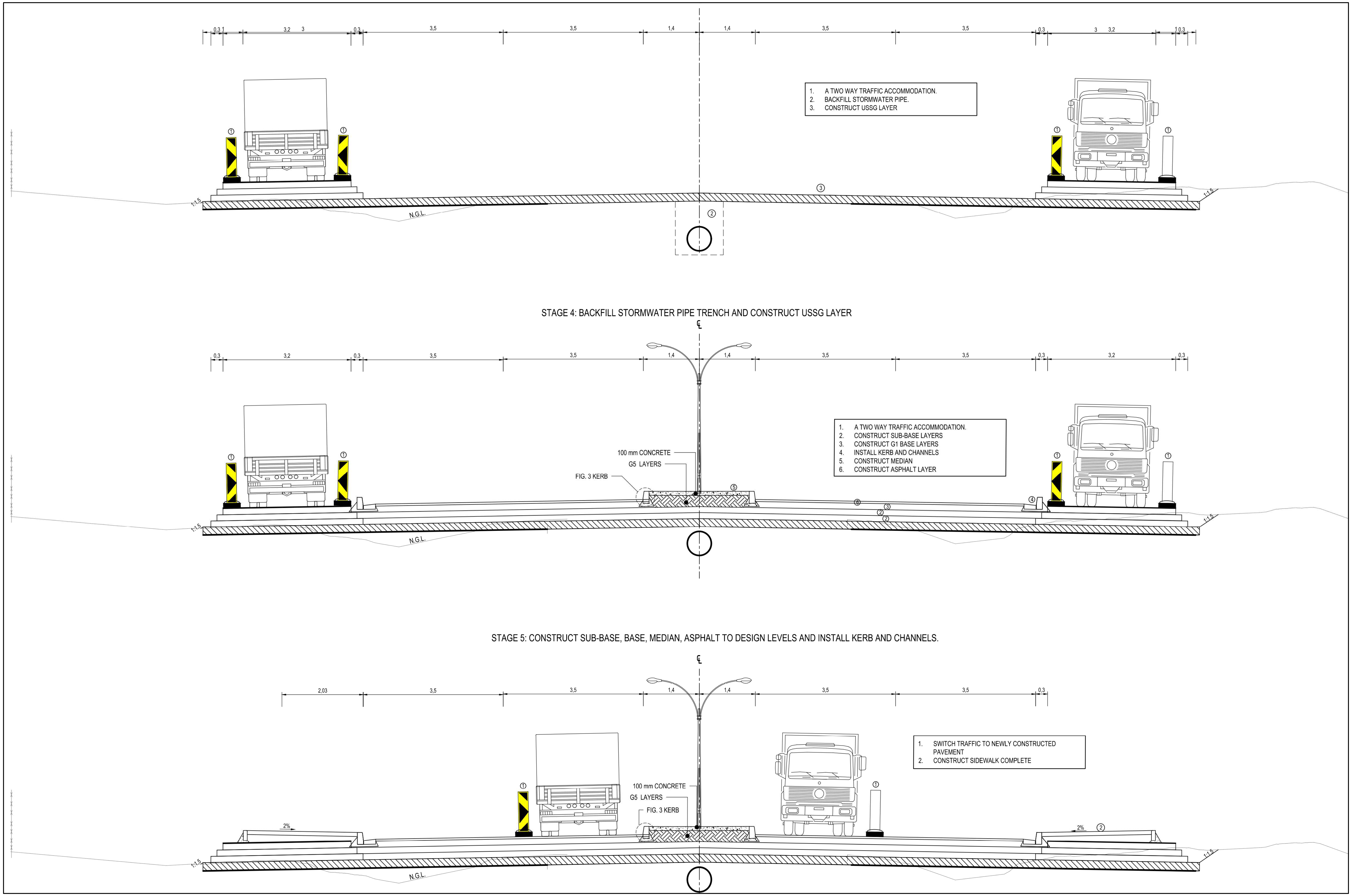


Figure 9.7: Constructing a Four lanes urban cross section with raised kerbs, median and sidewalks

9.5 CONCLUSIONS AND RECOMMENDATIONS

Based on the analyses above pavement rehabilitation options above the following conclusions were reached:

- Pavement rehabilitation 1:
  - Do not have adequate structural capacity for a 20-year design period;
- Pavement rehabilitation 2:
  - Provides adequate structural capacity for the 20-year design period;
  - It will allow the vertical alignment improvements that need to be carried out along Road R101-8;
  - Will utilised the cut material along horizontal realignments areas; and
  - It allows for two way traffic accommodation at all times.
- Pavement rehabilitation 3:
  - Provides adequate structural capacity for the 20-year design period
  - Will require half width (stop and go) traffic accommodation; and

It is therefore recommended that:

- Pavement rehabilitation 2 be implemented to improve the existing capacity and provide surfaced shoulders along rural section (km 5.44 to km 24.00); and
- The proposed pavement structures for new lanes along Bela Bela urban section (km 0.0 to km 5.44), realignment areas and Modimolle urban be accepted for the implementation.

CHAPTER 10 ACCESS MANAGEMENT PLAN

10.1 INTRODUCTION

As part of BVi`s scope, accesses along Road R101-8 were assessed and an access management plan prepared. The complete plan is included in *Appendix E* and summarised below.

Access management can be defined as the systematic control of access on mobility roads and mobility on access streets. It involves the location, spacing, design and operation of driveways and intersections. It also involves the consideration of road reserves, traffic control, pedestrian and public transport facilities and every aspect of the roadside environment *(TRH 26, 2012).*

The purpose of access management is to increase public safety, reduce traffic congestion and improve the appearance and quality of the built environment. By managing accesses, capacity and function can be preserved and a reduction in conflict points can occur. Effective access management also promotes intergovernmental co-operation relating to land development and transportation decisions. Furthermore, access management provides the following benefits:

1. Reduced congestion and better overall traffic flow;
2. A lower potential for crashes as there are fewer places where vehicles cross paths with other vehicles, as well as with pedestrians;
3. Decreased travel times for commuters, truck drivers and others; and
4. Easier movement between properties, improving the sustainability of adjacent neighbourhoods.

10.2 EXISTING ZONING

Maps provided in the *Bela Bela Local Municipality Spatial Development Framework (SDF) 2018* and the *Modimolle Local Municipality Final Integrated Development Plan 2016/2017* were used to determine the existing zoning along Road R101 Section 8. These maps are provided in the access management plan included in *Appendix E.* It must be noted that the zoning of land portions between km 6.1 and km 23.7 could not be identified due to a lack of information and were therefore recorded as “Unknown”.

10.3 FUNCTIONAL CLASSIFICATION AND ACCESS MANAGEMENT

According to the *TRH 26* document, National Road R101 Section 8 can be classified as a Class 2 rural major arterial (km 0.00 to km 25.76) and a Class 4a collector street (km 25.76 to km 26.80). The minimum allowable intersection and access spacing is dependent on the development environment, road classification and type of intersection control.

The primary factor to distinguish between the different types of roadside development environments is development density, measured in square metres of floor space per hectare of land. *Table 10.1* indicates the different types of roadside development environments identified along Road R101-8.

Table 10.1: Development environments along Road R101-8

DEVELOPMENT ENVIRONMENT	EXTENT (km)
Intermediate	km 0.00 – km 2.80 & km 25.76 – km 26.11
Small holdings and businesses	km 2.80 – km 4.80
Rural farmland	km 4.80 – km 23.80
Suburban	km 23.80 – km 25.76
Urban	km 26.11 – km 26.80

Note: Urban (10 000m² GFA/ ha), Suburban (1000 - 3000m² GFA/ ha) & Intermediate (3000 – 10 000m² GFA/ ha)

Table 10.2 indicates the minimum spacing requirements for Class 2 and Class 4 roads in the above-mentioned development environments.

Table 10.2: Intersection and access spacing requirements

ROAD CLASS	DEVELOPMENT ENVIRONMENT	MINIMUM SPACING (m)			
		DRIVEWAYS		SIGNALISED/ PRIORITY CONTROLLED	
		HIGH VOL	LOW VOL	FULL INT.	T-JUNCTION
Class 2	Intermediate	180	90	800	400
	Small holdings & businesses	120	60	-	-
	Rural farmland	500	500	-	-
	Suburban	-	-	800	400
Class 4a	Intermediate	60	25	300	300
	Urban	45	25	225	225

Notes: -Possible signalised intersection spacing may be halved for T-junctions on Class 2 roads (*TRH 26*).
-Spacing of full intersections on a rural Class 2 section is 5km (*TRH 26*).

10.4 REVIEW OF EXISTING ACCESS MANAGEMENT

In addition to the above-mentioned key attributes, all intersections/accesses were also evaluated in terms of sight distances and access spacing. The urban (town) sections were assessed in terms of *Gap Acceptance Sight Distance* and the rural sections were assessed in terms of *Shoulder Sight Distance*. The minimum sight distance requirements, as set out by *TMH 16 Volume 2* and *UTG 1*, are provided in the *Table 10.3*.

Table 10.3: Minimum sight distance requirements

TYPE OF CONTROL	MINIMUM SIGHT DISTANCES (m)	
	Geometric Design Guidelines	*UTG 1*
Signalised or priority controlled	300 m	220 m
No control	80 m – 165 m	160 m – 220 m

It must be noted that for accesses with no control, a maximum shoulder sight distance of 220 m was used. For intersections, a shoulder sight distance of 300 m was used.

The intersections/accesses were assessed in the field between the 5th of November 2019 and the 8th of November 2019. Based on the sight distances and access spacing, the intersections/ accesses were then categorized as either "retain", "re-align/relocate" or "close". *Table 10.4* provides a summary of this evaluation.

Table 10.4: Existing access management

SYMBOL	FUTURE STATUS	MOTIVATION	NO. OF ACCESSES	% CONTRIBUTION
(green circle)	Retain: Formalise bell mouths and add edge beams	Sight distance and/or spacing sufficient.	66	53%
(blue circle)	Re-align/relocate	Staggered intersection	10	8%
(red circle)	To be closed	Accesses deserted, not permitted or closed due to insufficient spacing.	48	39%
TOTAL			**124**	**100%**

All intersections/accesses that require actions are listed in *Table 10.5*.

Table 10.5: Future status of intersections/ accesses

ACCESS NO.	POSITION (KM)	PROPERTY DESCRIPTION.	ACTION REQUIRED
2 (LHS)	km 0.08	Het Bad 465-KR	Close van der Merwe Street intersection, as the intersection spacing of 800 m is not met. Both Voortrekker Road and Mile St intersections are less than 800 m from this intersection.
5 (LHS)	km 0.39	Buiskop 464-KR PTN 28	Close access, as spacing is insufficient. Rather use Voortrekker Rd or Mile St intersection to gain access to Road R101.
6 (LHS)	km 0.70	Buiskop 464-KR PTN 42	Add northern leg to this intersection. Formalise bell mouths and add edge beam.

ACCESS NO.	POSITION (KM)	PROPERTY DESCRIPTION.	ACTION REQUIRED
			Intersection to be used by future Royal Northland township expansion.
7 – 9 & 11 – 15	km 1.24 – km 1.41 & km 1.57 – km 1.88	Buiskop 464-KR PTN 42 & 43	Close accesses as spacing is insufficient. Properties to gain access to Road R101 via the new proposed T-junction at km 1.50 or the full intersection at km 2.82 (urban/ industrial edge).
16	km 2.33	Buiskop 464-KR PTN 34	Close access. Property to use proposed full intersection at km 2.82 to gain access to Road R101.
20	km 3.56	Buiskop 464-KR PTN 137	Close access as spacing is insufficient and only one major access per property is allowed.
24	km 4.31	Buiskop 464-KR PTN 14	Close off access as there are two accesses situated on the same property and spacing between them is insufficient.
26	km 5.43	Farm 849 PTN 0 & Buiskop 464-KR PTN 17	Add turning lanes to this intersection.
28	km 6.15	Buiskop 464-KR PTN 29	Close access as spacing is insufficient and only one major access per property is allowed.
29	km 6.59	Buiskop 464-KR PTN 29	Close off access. It seems the access that was there previously, is deserted.
31	km 7.50	Farm 849 PTN 0	Remove gate to Klein Kariba. Only one major access per property allowed. Use main access at km 5.43.
33	km 7.58	Valencia 449-KR PTN 12	Close access alternative access from road at km 8.30 (access no. 36) is possible.
35	km 8.27	Buisfontein 451-KR PTN 15	Relocate access to side road, as the spacing between accesses no. 35 and 36 is insufficient.
37	km 8.39	Buisfontein 451-KR PTN 14	Relocate access to side road, as the spacing between accesses no. 36 and 37 is insufficient.
38	km 8.71	Buisfontein 451-KR PTN 11	Close access as accesses no. 38 and 40 are situated on the same property and the spacing between these accesses is insufficient.
39	km 8.72	Buisfontein 451-KR PTN 13	Close access as accesses no. 39 and 41 are situated on the same property and the spacing between these accesses is insufficient.

ACCESS NO.	POSITION (KM)	PROPERTY DESCRIPTION.	ACTION REQUIRED
44 (LHS & RHS)	km 9.59	Buisfontein 451-KR PTN 33 (LHS) & PTN 35 (RHS)	Close off accesses on both sides of the R101. These accesses are unused. Also remove the excess gravel on the northern side of Road R101.
46	km 10.05	Cussonia 712-KR PTN 0	Formalise bell mouths. Add 60 m right-turn lane and right-turn refuge lane to this intersection.
47	-	Verloren 787-KR PTN 213	Access needs to be relocated, due to the re-alignment of Road R101. It is suggested that the access be relocated to km 11.00. Formalise bell mouths and add edge beam treatment.
48	km 11.64	Verloren 452-KR PTN 3	Relocate access to km 11.70. Formalise bell mouths and add edge beam treatment.
50	km 12.31	Verloren 787-KR PTN 213	Close access. The earth drain prevents vehicles from accessing Road R101 at this point. It is therefore assumed that this access is unused.
53	km 12.96	Verloren 787-KR PTN 213	Close access as this access is situated on the same property as accesses no. 51 and 52. Access spacing between accesses no. 52 and 53 is also insufficient.
55	km 13.75	Sussensvale 708-KR PTN 51	Close access as the access spacing between accesses no. 55 and 56 is insufficient.
57	km 13.96	Sussensvale 708-KR PTN 51	Close access, as only one major access per property is allowed.
58	-	Verloren 787-KR PTN 213	Access needs to be relocated due to the re-alignment of Road R101. It is suggested that the access be relocated to km 14.60. Add edge beam treatment.
62	km 16.61	Sussensvale 708-KR PTN 35	Add 60 m right-turn lane and right-turn refuge lane to this intersection. Formalise bell mouths and add edge beam treatment.
63	km 16.93	Sussensvale 708-KR PTN 33	Close off access as accesses no. 63 and 64 are situated on the same property.
65	km 17.91	Sussensvale 708-KR PTN 26	Close access as accesses no. 65 and 66 are situated on the same property and the spacing between them is insufficient.
66	km 17.96	Sussensvale 708-KR PTN 26	Relocate access to comply with spacing requirement of major accesses. Formalise bell mouths and add edge beam treatment.

ACCESS NO.	POSITION (KM)	PROPERTY DESCRIPTION.	ACTION REQUIRED
69	km 18.67	Sussensvale 708-KR PTN 26	Close access as spacing is insufficient and only one major access per property is allowed.
72	km 19.62	Rheno 418-KR PTN 28	Relocate access to comply with spacing requirement of major accesses. Formalise bell mouths and add edge beam treatment.
75	km 21.14	Rheno 418-KR PTN 26	Relocate access to comply with spacing requirement of major accesses. Formalise bell mouths and add edge beam treatment.
77	km 21.46	Rheno 418-KR PTN 25	Relocate access to side road, as spacing is insufficient.
79	km 21.63	Streepje 420-KR PTN 2	Close access as spacing is insufficient.
80	km 21.85	Streepje 420-KR PTN 1	Relocate access to comply with spacing requirement of major accesses. Formalise bell mouths and add edge beam treatment.
85	km 24.14	Nylstroom Town and Townlands 419-KR PTN 74	Close access as there are future properties that will be built on both sides of Road R101 and driveways are not permitted.
86	km 24.15	Nylstroom Town and Townlands 419-KR PTN 164	Close access as there are future properties that will be built on both sides of Road R101 and driveways are not permitted.
87 (2x LHS)	km 24.24	Nylstroom Town and Townlands 419-KR PTN 121 ERF 1515 & 1516	Close accesses as driveways off Road R101 are not permitted. These properties are accessible via Bontebok Street.
89 (2x LHS)	km 24.46	Nylstroom Town and Townlands 419-KR PTN 121 ERF 1557	Close accesses as driveways off Road R101 are not permitted. This property is accessible via Olienhout Avenue.
91 (LHS & RHS)	km 24.68	Nylstroom Town and Townlands 419-KR PTN 0 ERF 1029 (LHS) & PTN 106 (RHS)	Close southern access, as access is no longer being used. The main access to this property is situated at km 24.79 (access no. 92). Also closed northern access, as driveways off Road R101 are not permitted. This property is accessible via Emma Street.
93	km 24.76	Nylstroom Town and Townlands 419-KR PTN 0 ERF 1026	Close access as driveways off Road R101 are not permitted. This property is accessible via Emma Street.
98	km 25.25	Nylstroom Town and Townlands 419-KR PTN 51	Close Boshoff St connection to Road R101, as spacing is insufficient. Gain access to Road

ACCESS NO.	POSITION (KM)	PROPERTY DESCRIPTION.	ACTION REQUIRED
			R101 via De Beer St (access no. 95) or Odendaal St (access no. 102).
97	km 25.13	Nylstroom Town and Townlands 419-KR PTN 104	Close accesses as direct property access off Road R101 is not permitted. Discussion with the Nylstroom High School body corporate needed, to determine the use of this access.
99	km 25.32		
100	km 25.41		
101 (LHS)	km 25.52	Nylstroom Town and Townlands 419-KR PTN 74	Close street opposite Colin St. Vehicles can utilise accesses no. 95 (De Beer St) and Odendaal St (access no. 102) to access Road R101.
104 & 105	km 25.87 & km 25.94	Nylstroom Town and Townlands 419-KR PTN 74	Close access. Use main access at km 26.01 (access no. 106) to access Road R101.
107	km 26.03	Nylstroom Town and Townlands 419-KR PTN 0	Close connection to Road R101, as spacing is insufficient. Kroep St will function as a cul-de-sac.
110	km 26.26	Nylstroom Town and Townlands 419-KR PTN 0	Close street. Access to fuel station to be proposed just west of this street at appropriate spacing.

It was agreed during Progress meeting 7 that all affected accesses that need to be consolidated or closed have to be communicated with the affected property owners. A meeting with Municipalities will also be arranged as part of SPLUMA to present and consider their input regarding the access management plan and project scope works in general.

CHAPTER 11 STRUCTURES

11.1 INTRODUCTION

The preliminary road alignment entails the rehabilitation, widening and/or replacement of all bridges and major culverts along Road R101-8. Two bridges and three major culverts are located along the road.

- Modderloop River Bridge B375 at km 16.88;
- Groot Nyl River Bridge B447 at km 17.60;
- Major box culvert IDC3321 at km 0.82;
- Major box culvert IDC3322 at km 5.19; and
- Major box culvert (No number) at km 22.5.

The locations of these structures are included in *Figure 11.1*:

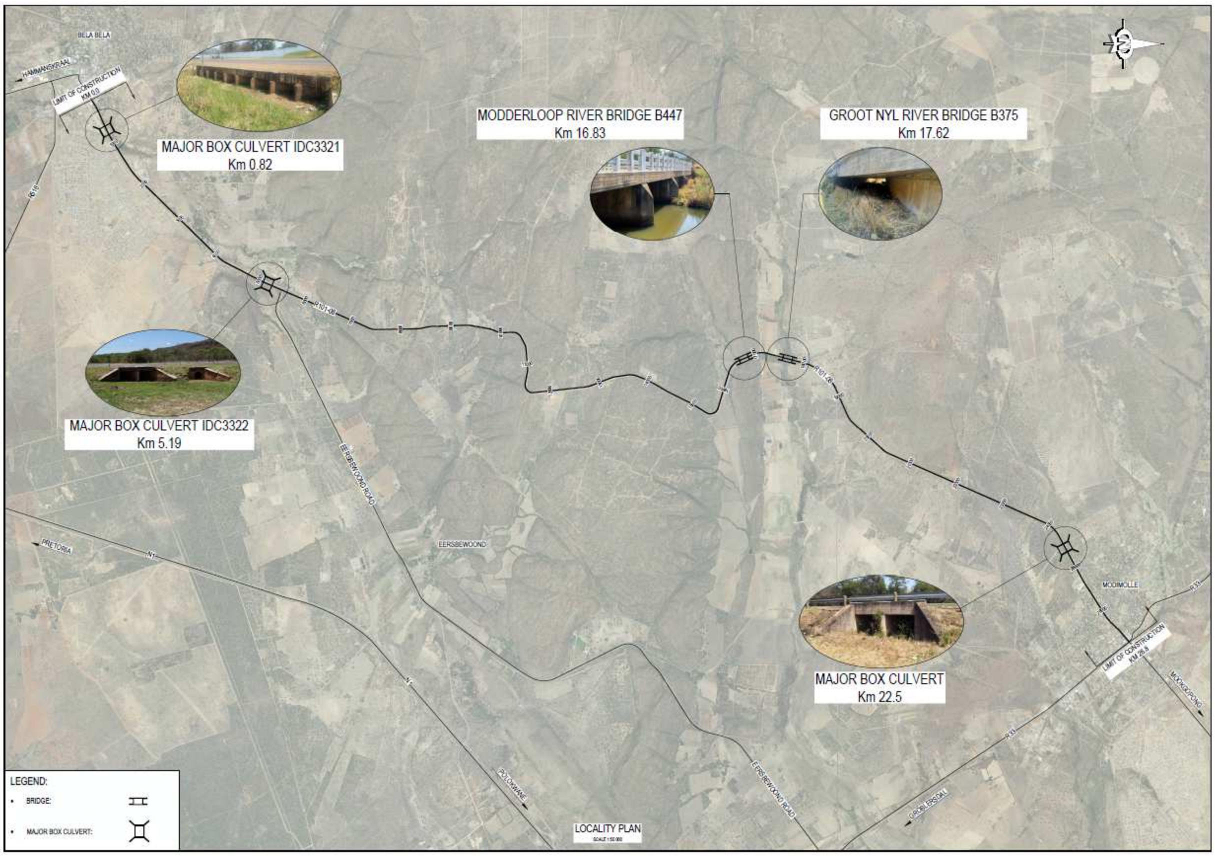


Figure 11.1: Structures locality plan

A detailed visual inspection was carried out for four of the five structures on the 7th of November 2018. All defects were noted and a drafting inspection report containing the recorded defects and remedial measures is attached in *Appendix F1.* A detailed inspection was carried out for the remaining structure on the 27th of August 2019.

Structural surveys and site surveys of the watercourses around each structure were carried out in order to assist with the modelling of existing structures and calculating the hydraulic characteristics.

Geotechnical investigations in the form of boreholes, as recommended in *Appendix H* of the *Code of Procedure for the Planning and Design of Highway and Road Structures in South Africa*, are recommended, but are yet to be carried out. Bridge as-built drawings served as an initial guideline for founding conditions.

The design flood peaks were calculated for each structure, based on the guidelines in the *South African Road Drainage Manual*. Drainage surveys at each structure were utilized to assist with the hydraulic modelling of the design flood peaks through every structure in *HEC-RAS*. Drainage reports were compiled and are attached in *Appendix F2*. These reports were conditionally approved by the *SANRAL* Bridge Network Manager.

A preliminary evaluation of the structural capacity was carried out for Bridge B375 and Bridge B447. These are included in *Appendix F5.* A detailed structural evaluation will be discussed and outlined in the bridge and major culvert reports. Structural testing was carried out to determine the concrete strength and level of carbonation through coring.

Reinforcement scanning was carried out to confirm or determine the reinforcement sizing and spacing within key structural components. In addition to this Basson tests were conducted to determine the characteristics of the water in the area. Test results are attached in *Appendix F4*.

11.2 BRIDGE B375: MODDERLOOP RIVER BRIDGE

11.2.1 Introduction

This bridge is situated at km 16.88 and crosses over Modderloop River at a 59-degree angle of skew. The information gathered from the as-built drawings and the bridge inventory sheets indicates that the original Modderloop River Bridge was replaced by a new bridge in 1963.

The superstructure consists of a 5 x 12.75 m span, simply supported solid reinforced concrete slab with an average thickness of 625 mm. The slab is reinforced with mild steel bars (R-bars). The main reinforcement of the deck consists of 25 mm diameter R-bars at 110 mm spacing positioned perpendicularly to the support lines of the sub-structure. Assessment of the as-built drawings illustrates that the load in the acute corner of the deck is transferred to the solid balustrade which act as a beam running along the edges of the deck.

The sub-structure consists of wall type piers and abutments made up of mass concrete, anchored to mass concrete spread footings bearing on rock. A retaining wall is situated at the structure inlet and redirects the river towards the bridge inlet.

Figure 11.2: Approach to Bridge B375

Figure 11.3: Elevation of parapets

11.2.2 Visual assessment

A detailed visual inspection of the bridge was carried out on the 7th of November 2018. The inspection report attached in *Appendix F1* of this document identifies the following defects:

- Non-standard parapets;
- Major siltation within the bridge openings;
- Exposed reinforcement and concrete spall to parapets;
- Concrete spall to the edge of the deck; and
- Debris and vegetation within the deck joints.

Based on the recorded defects during the visual assessment, the following repair strategies are proposed:

- Demolish existing barriers and replace with F-shape parapets;
- Concrete spall repair to deck;
- Removal of sediment build-up;
- Clearing of vegetation in stream bed obstructing flow through bridge;
- Replace all existing joints with Silicone sealed joints; and
- Install new bridge numbers.

11.2.3 Surveys and testing

A structural survey of Bridge B375 was carried out as well as a site survey of the watercourse, upstream and downstream of the structure. The structural survey was carried out to gather as-built information and verify the dimensions specified in the as-built drawings. This survey was done in accordance with the requirements of *TMH11* – Digital Terrain Model and CAD Drawing Requirements. A 3D structured point cloud is available for Bridge B375. The extent of the site survey of the watercourse is 200 m upstream and downstream and at least 20 m wider than the top of the riverbanks.

Structural testing was carried out on the bridge. Core samples of the bridge concrete were used to determine the compressive strength of key structural components as well as the level of carbonation. Structural scanning was carried out to verify the reinforcement diameters and spacing throughout the bridge. The results of these tests are included in *Appendix F4* and summarised as follows*:*

- A range parapet concrete core strength between 33 and 40.5 MPa;
- A range deck concrete core strength between 34 and 61 MPa;
- Minimum abutment concrete core strength of 18 MPa;
- A range pier concrete core strength between 22 and 34 MPa; and
- Maximum carbonation depth of 95 mm.

11.2.4 Geotechnical Investigations

Based on the guidelines in *Appendix H* of the C*ode of Procedure for the Planning and Design of Highway and Road Structures in South Africa*, it is recommended that 2 exploratory holes be drilled at each base. A hole should be drilled at each side of the bridge foundations, totalling 12 boreholes. Cores at each hole should be logged and profiled.

11.2.5 Structural evaluation

Due to the upgrade of the road and the advanced lifespan of the structures, an estimate of the structural capacity of the bridges is deemed necessary. The structural capacity of the bridge is based on the current *TMH7 Code of practice for the design of highway bridges and culverts in South Africa* loadings.

An estimate of the structural capacity of the deck has been carried out using the following loadings from *TMH7:*

- Normal Loading (NA);
- Abnormal Loading (NB36); and
- Super Loading (NC30x5x40).

With the assumption of a concrete characteristic strength of 30 MPa and dimensions extracted from the as-built drawings and 3D structural survey, the preliminary analysis shows that the deck requires at least 3700 mm^2/m reinforcement for the deck sections spanning between supports. Evaluation of the as-built drawings showed that the deck bottom reinforcement at midspan consists of R25@115mm (4260 mm^2/m). The output of the preliminary analysis is as shown in *Appendix F5*.

However, a large portion of the deck that does not span between supports, due to the large skew angle, and is carried by the balustrades which act as beams. The preliminary analysis and the resultant load effects of the ultimate moment shows that the structural capacity of these deck portions is inadequate if the structural balustrade is removed. Substantial strengthening and temporary supports would be required if the existing deck is retained and widened. No top reinforcement is present in the top slab at the obtuse corner where significant hogging moment occurs, which could lead to severe bending cracks due to the localised uplift of the deck.

Further structural evaluations and calculations will be carried out and discussed in detail in the bridge report, for each option that will be considered.

11.2.6 Drainage capacity

The final hydrological and hydraulic analysis was performed according to the *Drainage Manual (6th edition)* and issued in the drainage report, attached in *Appendix F2*. The Flood runoff was calculated using the SDF method and verified by the Rational 3 method, SCS-SA method, and Empirical method. The backwater heights for the design flood (14.5-year return period), and 29-year return period flood were investigated to verify whether the structure meets freeboard requirements. *Table 11.1* shows the results of the final analysis. An evaluation of the need for erosion protection was also carried out.

The results of the analysis show that the existing bridge has insufficient drainage capacity, and there is a risk of scour occurring. In addition to this, there is potential for debris build-up. As per *Section 8.5.4* in the *Drainage Manual*, excavation of material at bridges is not recommended and due to relatively low flow velocities in the Modderloop River any siltation that is removed is likely to re-occur. It is therefore recommended that the drainage capacity of the structure be increased, and the necessary scour protection be implemented.

The siltation at the structure is also attributed to the erosion of the embankments on the upstream side. It is recommended that the option of gabion protection along the southern and northern embankments on the upstream side of the bridge be investigated, in order to reduce the amount of siltation resulting from erosion.

Table 11.1: B375 Modderloop River Bridge – Hydraulic analysis results

ITEM	VALUE	
	14.5 YEAR RETURN PERIOD	29 YEAR RETURN PERIOD
Catchment area (km^2)	14.48	
Longest watercourse (km)	4.43	
Average slope (m/m)	0.0298	
Runoff (m^3/s)	65	91
Invert level (masl)	1190.79	
Soffit level (masl)	1192.17	
Shoulder break point (masl)	1192.52	
Peak flood level (masl)	1192.48	1192.79
Required level (masl)	1191.99	1192.52

11.2.7 Preliminary Options

The information gathered, tests conducted, and calculations completed during the Preliminary Design Stage will be utilized to develop proposals for the rehabilitation and/or redevelopment of Bridge B375. These options will be discussed in the Bridge Report to be issued as part of the Detail Design Stage. Further detailed calculations will be carried out for each bridge option, supported by detailed cost estimates and drawings illustrating each option. General arrangement drawings will be issued with the Bridge Report, for consideration by the *SANRAL* Bridge Network Manager and *SANRAL* Regional Structures Manager.

Initial indications suggest that the options to be considered include the following, with a high-level costing:

- **Option 1 - Rehabilitation Only**: Repair concrete spalling, apply protective coating, clear siltation, add gabion mattresses below the bridge, strengthen the existing balustrades and provide new asphaltic plug joints. Clearing siltation to the as-built levels does allow for the design flood to pass through the bridge below the required freeboard and SBP levels. This option is generally not preferred, as the *Drainage Manual* does not recommend that siltation be cleared to accommodate the design flood. The bridge shoulders are also limited to 2 m, and the bridge would retain a non-standard balustrade. The cost of this option is in the order of **R4.00 million**.

- **Option 2 - New Deck**: This option entails demolishing the existing bridge deck and constructing a new deck at a raised level and supported on new elastomeric bearings to accommodate the design flood peak. Existing sub-structures will be extended in width and height and a protective coating will be applied. The deck will be widened on both sides and the structural balustrade replaced with a *SANRAL* standard F-shaped parapet. This option satisfies all *SANRAL* standards and will cost in the order of **R12.40 million**.

- **Option 3 - Raising Existing Deck:** Jack the existing bridge deck by 1 m and replacing the bearings system with new elastomeric bearings. Extend existing sub-structures in width and height and apply protective coating. The deck will be widened on both sides and the parapet replaced with a *SANRAL* standard F-shaped parapet. The existing deck will require strengthening due to the demolition of the structural balustrade. This option satisfies all *SANRAL* standards and will cost in the order of **R13.09 million**.

- **Option 4 - New Bridge:** Demolish the existing structure and replace it with a new structure with less interference with the natural flow of the river. This will entail longer spans and a substantially raised road level. This option satisfies all *SANRAL* standards and will cost in the order of **R20.78 million**.

The *Drainage Manual 6th Edition* states that the clearing of siltation to increase the hydraulic capacity of an existing structure is not recommended, therefore Option 1 is not recommended. **Option 2** is the preliminary preferred option as it is the most cost-effective solution to bring the existing structure up to current standards. This will be fully investigated and motivated in the bridge report.

11.3 BRIDGE B447: GROOT NYL RIVER BRIDGE

Bridge B447 crosses the Groot Nyl River at a 0-degree angle of skew at km 17.62 on Road R101-8. Information gathered from the as-built drawings and the bridge inventory sheets indicate that the Groot Nyl River Bridge was originally constructed in 1936 and consisted of three 6.7 m spans. In 1966, the bridge was extended towards the southern end by an additional end span of 7.6 m. During this extension the bridge deck was also widened by 3 m on each side to accommodate the increased traffic flow.

Figure 11.4: West approach to Bridge B447

Figure 11.5: Elevation of parapets

The deck is a simply supported solid concrete slab with an average thickness of 650 mm reinforced with mild steel bars (R-bars). The main reinforcement of the original deck consists of 25 mm diameter R-bars at 110 mm spacing whereas the widening sections consist of 28 mm diameter R-bars at 115 mm spacing. The existing parapets to the deck are the reinforced concrete beam and post type.

The sub-structure are wall type piers and abutments made up of mass concrete, anchored to mass concrete spread footings bearing on rock.

11.3.1 Visual assessment

A detailed visual inspection of the bridge was carried out on the 7th of November 2018. The inspection report is included in *Appendix F1* and identifies the following defects:

- Damaged balustrades possibly due to vehicle collision;
- Major siltation within the bridge openings; and
- Spalled concrete to top of mass concrete pier.

Based on the recorded defects during the visual assessment, the following repair strategies are proposed:

- Replace existing barriers with F-shape parapets;
- Repair concrete spalling to top of piers;
- Replace malthoid strips with elastomeric bearing pads;
- Clear vegetation downstream of bridge;
- Remove siltation; and
- Install new bridge numbers.

11.3.2 Surveys and testing

A structural survey of Bridge B447 was carried out as well as a site survey of the watercourse upstream and downsream of the structure. A 3D structured point cloud is available for Bridge B447. The extent of the site survey of the watercourse is 200 m upstream and downstream of the bridge and at least 20 m wider than the top of the riverbanks.

Structural testing was carried out on the bridge. Core samples of the bridge concrete were used to determine the compressive strength of key structural components as well as the level of carbonation. Structural scanning was carried out to verify the reinforcement diameters and spacing throughout the bridge. The results of these tests are included in *Appendix F4* and summary of the results are as follows:

- A deck concrete core strength range between 33 MPa and 63 MPa;
- An abutment and piers concrete core strength ranges between 23 MPa and 47 MPa;
- Maximum deck carbonation depth of 30 mm; and
- Maximum pier and abutment carbonation depth of 60 mm.

11.3.3 Geotechnical Investigation

Based on the guidelines in *Appendix H* of the *Code of Procedure for the Planning and Design of Highway and Road Structures in South Africa*, it is recommended that 2 exploratory holes be drilled at each base. A hole should be drilled at each side of the bridge foundations, totalling 10 boreholes. Cores at each hole should be logged and profiled.

11.3.4 Structural evaluation

Due to the upgrade of the road and the advanced lifespan of the structures, an estimate of the structural capacity of the bridges is deemed necessary. The structural capacity is evaluated based on the current *TMH7 (Code of practice for the design of highway bridges and culverts in South Africa)* loadings.

An estimate of the structural capacity of the deck has been carried out using the following loadings from *TMH7*:

- Normal Loading (NA);
- Abnormal Loading (NB36); and
- Super Loading (NC30x5x40).

With the assumption of a concrete characteristic strength of 33 MPa (as verified during structural testing) and dimensions extracted from the as-built drawings and structural surveys, the preliminary analysis shows that the deck requires a minimum reinforcement of 3630 mm^2 per meter across the deck. Evaluation of the as-built drawings reveals that the original construction of the deck consists of R25@100mm (4905mm^2/m) while the widened sections comprise of R28@115mm (5355mm^2/m). The output of the preliminary analysis is a shown in *Annexure E5*.

The preliminary analysis and the resultant load effects of the ultimate moment and shear shows that the structural capacity of the deck is adequate. Further structural evaluations and calculations will be carried out and discussed in detail in the bridge report, for each option that will be considered.

11.3.5 Drainage capacity

The final hydrological and hydraulic analysis was performed according to the *Drainage Manual (6th edition)*. The Flood runoff was calculated using the SDF method and verified using the Unit-Hydrograph method and Empirical method. The backwater heights for the design flood (20-year return period), and 40-year return period flood were investigated to verify whether the structure meets freeboard requirements. *Table 11.2* shows the results of the final analysis. An evaluation of the need for erosion protection was also carried out.

The results of the analysis show that the existing bridge has insufficient drainage capacity, and there is a risk of scour occurring. In addition to this, there is potential for debris build-up. As per *section 8.5.4* in the *Drainage Manual,* excavation of material at bridges is not recommended and due to relatively low flow velocities in the Groot Nyl River any siltation that is removed is likely to re-occur. It is therefore recommended that the drainage capacity of the existing structure be increased, and the necessary scour protection be implemented.

Table 11.2: Hydraulic analysis results – Bridge B447: Groot Nyl River Bridge (km 17.62)

ITEM	VALUE	
	20 YEAR RETURN PERIOD	40 YEAR RETURN PERIOD
Catchment area (km²)	75.40	
Longest watercourse (km)	13.80	
Average slope (m/m)	0.0206	
Runoff (m³/s)	182	242
Invert level (masl)	1179.74	
Soffit level (masl)	1181.74	
Shoulder break point (masl)	1182.30	
Peak flood level (masl)	1182.92	1183.04
Required level (masl)	1180.94	1182.30

11.3.6 Preliminary Options

The information gathered, tests conducted, and calculations completed during the Preliminary Design Stage will be utilized to develop proposals for the rehabilitation and/or redevelopment of Bridge B447. These options will be discussed in the Bridge Report to be issued as part of the Detail Design Stage. Further detailed calculations will be carried out for each bridge option, supported by cost estimates and drawings illustrating each option. Preliminary General Arrangement drawings will be issued with the Bridge Report, for consideration by the *SANRAL* Bridge Network Manager and *SANRAL* Regional Structures Manager.

Initial indications suggest that the options to be considered include the following:

- **Option 1 - Rehabilitation Only**: This entails repairing concrete spalling, applying a protective coating, clearing siltation, adding gabion mattresses below the bridge, replacing the existing balustrades with standard F-shape parapets, replacing the bearing system with elastomeric bearings and providing new asphaltic plug joints. Clearing siltation to the as-built levels does allow for the design flood to pass through the bridge below the required freeboard and SBP levels. This option is generally not preferred, as the *Drainage Manual* does not recommend that siltation be cleared to accommodate the design flood. The bridge shoulders are also limited to 2 m. The cost of this option is in the order of **R3.67 million**.

- **Option 2 - Raising Existing Deck**: This option entails raising the existing bridge deck through jacking and replacing the bearing system with new elastomeric bearings. Existing sub-structures will be extended in width and height and a protective coating will be applied. The deck will be widened on both sides and the balustrade replaced with a *SANRAL* standard F-shaped parapet. New asphaltic plug joints will be provided. This option satisfies all *SANRAL* standards and will cost in the order of **R6.48 million**.

- **Option 3 – Add Additional Spans:** This option entails adding additional 7.5 m spans at either side of the bridge, providing new asphaltic plug joints and replacing the bearing system with new elastomeric bearings. Existing sub-structures will be extended in width and height and a protective coating will be applied. The deck will be widened on both sides and the balustrades replaced with a *SANRAL* standard F-shaped parapets. This option satisfies all *SANRAL* standards and will cost in the order of **R9.36 million**.

- **Option 4 - New Bridge:** Demolish the existing structure and replace it with a new structure. This option satisfies all *SANRAL* standards and will cost in the order of **R9.42 million**.

The *Drainage Manual 6th Edition* states that the clearing of siltation to increase the hydraulic capacity of an existing structure is not recommended, therefore Option 1 is not recommended. The *SANRAL Code of Procedure for the Planning and Design of Highway and Road Structures in South Africa* states in *Section 1.3.2 (ii)* that, if the cost of remedial works exceeds approximately 67% of the cost of reconstructing the structure, consideration should be given to effecting the latter option.

The minimum estimated cost of remedial work is 69% of the estimated structure replacement cost for this structure. The original structure was constructed in 1936 and approaching the end of its original design-life, while also having been widened and extended in 1966. Taking all of this into consideration, **Option 4** is the preliminary preferred option. This will be fully investigated and motivated in the bridge report.

11.4 MAJOR CULVERT: IDC3321

11.4.1 Introduction

The culvert provides access across a tributary system situated at km 0.82 along Road R101-8. As-built drawings were not available for the structure for confirmation of the culvert parameters as well as the year of construction. However, the 3D structural survey was used to obtain the dimensions of the culvert for the preliminary hydraulic analysis.

Figure 11.6: View of outlet

Figure 11.7: Cell overgrowth

No as-built information was available for this structure and further investigations, with regards to concrete strength, reinforcing steel layouts and design loading, was carried out. Structural inventory information was obtained from the Employer, visual site inspections took place, and surveys were carried out.

It should be noted that immediately downstream of this culvert, the watercourse continues through an existing culvert below a railway line. This structure was also surveyed and forms part of the hydraulic analysis of the proposed options, as it currently acts as a hydraulic control point for this watercourse.

11.4.2 Visual assessment

A detailed visual inspection of the culvert was carried out on the 7th of November 2018, with the following major defects being recorded during this inspection:

- Damaged wingwalls;
- Spalling to internal walls and top slab;
- No guardrails;
- Siltation of the culvert barrel; and
- Debris build-up at the inlet and outlet.

Based on the recorded defects the following repair strategies will be required:

- Reconstruction of the North-Eastern wing wall;
- Patch repair of spalled areas on all faces;
- Installation of new culvert numbers; and
- Clearing waterway of vegetation overgrowth.

11.4.3 Surveys and testing

In order to confirm and attain critical information on this structure, the following surveys have been concluded:

- Topographical survey of the structure (2D and 3D);
- Structural survey in terms of concrete cylinder cores for visual assessment and concrete strength; and
- Concrete cylinder cores for carbonation testing.

11.4.4 Geotechnical Information

Based on the guidelines in Appendix H of the *Code of Procedure for the Planning and Design of Highway and Road Structures in South Africa*, it is recommended that one borehole be drilled at the culvert inlet and one at the culvert outlet.

11.4.5 Structural evaluation

Due to the upgrading of the road, it is crucial to assess the structural capacity due to the added loading and the capacity in accordance with the current *TMH7 Code of practice for the design of highway bridges and culverts in South Africa* loadings.

An estimate of the structural capacity of the culvert will be carried out using the following loadings from *TMH7*:

- Normal Loading (NA);
- Abnormal Loading (NB36); and
- Super Loading (NC30x5x40).

Due to limited information available, testing will be carried out to confirm the existing main reinforcement via scanning or locally exposing the reinforcement. Cores taken have an average compressive strength of 25 MPa.

11.4.6 Drainage capacity

A hydrological and hydraulic analysis indicated a discharge of 140.42 m^3/s for the 20-year design flood event, with the existing hydrological capacity of IDC 3321 and the railway culvert being approximately 20 m^3/s and 32 m^3/s, respectively. Both these culvert capacities are well below the design flood event with IDC 3321 acting as the hydrological control for this watercourse.

As stated in the drainage report, flooding at this structure also produces a complex situation with a depression to the north side of the structure, as well as flooding into the town once overtopping occurs. In order to recommend a viable solution for this culvert, various options will need to be investigated and considered.

11.4.7 Preliminary Options

The information gathered, tests conducted, and calculations completed during the preliminary design stage will be utilized to develop proposals for the rehabilitation and/or redevelopment of major culvert IDC3322. These options will be discussed in the major culvert report to be issued as part of the detail design stage. Further detailed calculations will be carried out for each culvert option, supported by cost estimates and drawings illustrating each option. General arrangement drawings will be issued with the major culvert report, for consideration by the *SANRAL* Bridge Network Manager and *SANRAL* Regional Structures Manager.

Initial indications suggest that the existing culvert is under capacity and would require several additional cells to accommodate the peak design flood. In addition, the road cross-section at this location will be substantially widened to accommodate a dual carriageway. It is therefore foreseen that the existing structure will be replaced by a new major culvert of a suitable size to accommodate the peak design flood. This will be fully investigated and motivated in the major culvert report. The initial high-level cost estimate for the replacement of this structure is **R4.77 million**.

It should be noted that the *SANRAL* road reserve is situated along the left-hand side of the proposed new alignment. This will limit the development and construction of outlet structures and scour protection works and land expropriation or realignment of the existing centreline will be required to fit within the road reserve.

11.5 MAJOR CULVERT: IDC3322

11.5.1 Introduction

Major Culvert IDC3322 provides access across a tributary system at km 5.19 along Road R101-8. No as-built information was available for this structure, therefore additional testing and surveys were carried out.

Figure 11.8: Typical portal cell elevation

Figure 11.9: Typical pipe elevation

The structure consists of an in-situ portal frame and a pipe culvert. Each portal cell has an internal width of 1.4 m and internal height of 1.2 m, with the pipe culvert having an internal diameter of 0.9 m. The culvert has an overall length of 5.4 m and overall width of 17 m.

11.5.2 Visual assessment

During the visual assessment the following defects were recorded:

- Severely damaged wing walls; and

- Spalling to internal walls and top slab.

Based on the recorded defects the following repair strategies will be required:

- Reconstruct outlet structure to connect the in-situ portal and precast pipe (new head wall, wing walls and apron slab);
- Patch repair spalled areas on all faces;
- Install guardrails;
- Install new culvert numbers; and
- Clear waterway of vegetation overgrowth.

11.5.3 Surveys and testing

A structural survey of IDC3322 was carried out as well as a site survey of the watercourse before and after the structure. The structural survey was carried out to gather as-built information and verify the dimensions specified in the as-built drawings. The Structural survey is in accordance with the requirements of TMH11 – Digital Terrain Model and CAD Drawing Requirements. A 3D structured point cloud is available for IDC3322. The extent of the site survey of the watercourse is 200 m upstream and downstream of IDC3322 and at least 20 m wider than the top of the riverbanks.

Structural testing was carried out on the major culvert. Core samples of the culvert concrete were used to determine the compressive strength of key structural components as well as the level of carbonation. The results of these tests are included in *Appendix F4*. A summary of the results are as follows:

- Minimum concrete core strength of 15 MPa; and
- Maximum deck carbonation depth of 30 mm.

11.5.4 Geotechnical Investigations

Based on the guidelines in Appendix H of the *Code of Procedure for the Planning and Design of Highway and Road Structures in South Africa*, it is recommended that one borehole be drilled at the culvert inlet and one at the culvert outlet. Cores at each hole should be logged and profiled.

11.5.5 Structural evaluation

Due to the upgrade of the road and the advanced lifespan of the structures, an estimate of the structural capacity of the culvert is deemed necessary. Moreover, it is crucial to assess the structural capacity based on the current TMH7 (Code of practice for the design of highway bridges and culverts in South Africa) loadings.

An estimate of the structural capacity of the culvert will be carried out using the following loadings from TMH7:

- Normal Loading (NA);
- Abnormal Loading (NB36); and
- Super Loading (NC30x5x40).

The structural survey information as well as the structural testing results will be utilized to assess the current structural capacity of the culvert. A detailed structural assessment of the culvert will be presented in the major culvert report.

11.5.6 Drainage capacity

A detailed hydrological and hydraulic analysis was performed according to the *Drainage Manual (6th addition)*. The Flood runoff was calculated using the SDF method and verified by the Rational 3 method, SCS-SA method, and Empirical method. The backwater heights for the design flood (20-year return period), and 50-year return period flood were investigated to verify whether the structure meets freeboard requirements. *Table 11.3* shows the results of the preliminary analysis. An evaluation of the need for erosion protection was also carried out.

The analysis results show that the existing culvert has insufficient drainage capacity, and there is a risk of scour occurring. It is therefore recommended that the capacity of the structure be increased, and the necessary scour protection be implemented.

Table 11.3: Hydraulic analysis results - IDC3322 (km 5.19)

ITEM	VALUE	
	10.9 YEAR RETURN PERIOD	21.8 YEAR RETURN PERIOD
Catchment area (km^2)	5.88	
Longest watercourse (km)	4.38	
Average slope (m/m)	0.0247	
Runoff (m^3/s)	21.89	32.18
Invert level (masl)	1162.42	
Soffit level (masl)	1163.62	
Shoulder break point (masl)	1164.09	
Peak flood level (masl)	1164.12	1164.16
Required level (masl)	1163.86	1164.09

11.5.7 Preliminary Options

The information gathered, tests conducted, and calculations completed during the preliminary design stage will be utilized to develop proposals for the rehabilitation and/or redevelopment of major culvert IDC3322. These options will be discussed in the major culvert report to be issued as part of the detail design stage. Further detailed calculations will be carried out for each culvert option, supported by cost estimates. Preliminary general arrangement drawings will be issued with the major culvert report, for consideration by the *SANRAL* Bridge Network Manager and *SANRAL* Regional Structures Manager.

Initial indications suggest that the existing culvert is under capacity and would require several additional cells to accommodate the peak design flood. In addition, the road cross-section at this location will be substantially widened to accommodate a dual carriageway. It is therefore foreseen that the existing structure will be replaced by a new major culvert of a suitable size to accommodate the peak design flood. This will be fully investigated and motivated in the major culvert report. The initial high-level cost estimate for the replacement of this structure is **R2.70 million**.

11.6 MAJOR CULVERT: KM 22.5

11.6.1 Introduction

The structure at km 22.5 is a culvert which provides access across a tributary system along the R101. No as-built drawings are available for this structure and it is not listed on SANRAL's Bridge Management System. Further surveys and testing were carried out.

Figure 11.10: Typical portal cell elevation

Figure 11.11: Cracked through wing wall

The structure is an in-situ portal frame culvert with 2 cells, propped cantilever walls and a continuous top slab. Each cell has an internal width of 1.9 m and internal height of 1.2 m. The culvert has an overall length of 17 m.

11.6.2 Visual assessment

A visual inspection of the culvert was carried out on the 27th of August 2019. The following defects were recorded during the inspection:

- Severely damaged wing walls;
- Spalling to internal walls;
- Scour behind wing walls and evidence of overtopping; and
- No number plates.

The following remedial action was recommended:

- Reconstruct inlet and outlet structures;
- Patch repair spalled areas on all faces;
- Install new culvert numbers; and
- Repair scour damage.

11.6.3 Surveys and testing

A structural survey of the major culvert at km 22.5 was carried out as well as a site survey of the watercourse before and after the structure. The structural survey was carried out to gather as-built information and verify the dimensions specified in the as-built drawings. The structural survey is in accordance with the requirements of TMH11 – Digital Terrain Model and CAD Drawing Requirements. A 3D structured point cloud is available for the major culvert at km 22.5. The extent of the site survey of the watercourse is 200 m upstream and downstream of the structure and at least 20 m wider than the top of the riverbanks.

Structural testing was carried out on the culvert. Core samples of the culvert concrete were used to determine the compressive strength of key structural components as well as the level of carbonation. The results of these tests are included in *Appendix F4* summary of the results are as follows:

- Minimum concrete core strength of 18 MPa; and
- Maximum deck carbonation depth of 105 mm.

11.6.4 Geotechnical Investigations

Based on the guidelines in Appendix H of the *Code of Procedure for the Planning and Design of Highway and Road Structures in South Africa*, it is recommended that one borehole be drilled at the culvert inlet and one at the culvert outlet. Cores at each hole should be logged and profiled.

11.6.5 Structural evaluation

Due to the upgrade of the road and the advanced lifespan of the structures, an estimate of the structural capacity of the culvert is deemed necessary. The culvert's structural capacity is assessed based on the current TMH7 (Code of practice for the design of highway bridges and culverts in South Africa) loadings.

An estimate of the structural capacity of the culvert will be carried out using the following loadings from TMH7:

- Normal Loading (NA);

- Abnormal Loading (NB36); and
- Super Loading (NC30x5x40).

The structural survey information as well as the structural testing results will be utilized to assess the current structural capacity of the culvert. A detailed structural assessment of the culvert will be presented in the major culvert report.

11.6.6 Drainage capacity

The final hydrological and hydraulic analysis was performed according to the *Drainage Manual (6th addition)*. The Flood runoff was calculated using the SDF method and verified using Rational 3 method, SCS-SA method, and Empirical method. The backwater heights for the design flood (11.4-year return period), and 22.8-year return period flood were investigated to verify whether the structure meets freeboard requirements. *Table 11.4* shows the results of the preliminary analysis. An evaluation of the need for erosion protection was also carried out.

The analysis results show that the existing culvert has insufficient drainage capacity, and there is a risk of scour occurring. It is therefore recommended that the capacity of the structure be increased, and the necessary scour protection be implemented.

Table 11.4: Hydraulic analysis results – culvert (km 22.5)

ITEM	VALUE	
	11.4 YEAR RETURN PERIOD	22.8 YEAR RETURN PERIOD
Catchment area (km^2)	5.30	
Longest watercourse (km)	2.79	
Average slope (m/m)	0.0306	
Runoff (m^3/s)	28	40
Invert level (masl)	1201.52	
Soffit level (masl)	1202.72	
Shoulder break point (masl)	1203.10	
Backwater level (masl)	1203.40	1203.47
Required freeboard level (masl)	1202.96	1203.10

11.6.7 Preliminary Options

The information gathered, tests conducted, and calculations completed during the preliminary design stage will be utilized to develop proposals for the rehabilitation and/or redevelopment of major culvert at km 22.5. These options will be discussed in the major culvert report to be issued as part of the detail design stage. Further detailed calculations will be carried out for each culvert option, supported by cost estimates. Preliminary general arrangement drawings will be issued with the major culvert report, for consideration by the *SANRAL* Bridge Network Manager and SANRAL Regional Structures Manager.

Initial indications suggest that the existing culvert is severely under capacity and would require a large number of additional cells to accommodate the peak design flood. It is foreseen that the existing structure will be replaced by a new major culvert of a suitable size to accommodate the peak design flood. This will be fully investigated and motivated in the Major Culvert Report. The initial high-level cost estimate for the replacement of this structure is **R2.71 million**.

CHAPTER 12 ROAD PRISM DRAINAGE

12.1 INTRODUCTION

Drainage along Road R101-8 is effected through culverts and bridges. Whereas the previous chapter referred to bridges and major culverts, only minor culverts are discussed in this chapter. Also included here is a discussion on surface drainage.

12.2 MINOR CULVERTS

A detailed assessment report with photos of each criteria is included in *Appendix G*. *Table 12.1* provides a summary of the culverts assessed along the project road.

Table 12.1: Summary of minor culverts

CULVERT TYPE	SIZE	NUMBER OF CULVERTS	PERCENTAGE
Pipe culvert	Ø450 mm	5	9%
	Ø600 mm	19	31%
	Ø900 mm	18	33%
Box culvert	Various	13	22%
Unknown	Covered /buried	2	4%
Total structures		**55**	**100 %**

Culverts were assessed according to the following criteria:

- Inlet waterway condition;
- Inlet head wall and wing wall conditions;
- Barrel condition;
- Outlet head wall and wing wall condition; and
- Outlet waterway condition.

A rating of good, fair or bad was given to each criteria. In addition to the rating, remarks on the defects, damage and functionality were made. Typical photographs showing the condition are included in *Figure 12.1* to *Figure 12.3*.

At the time of the assessment it was observed that most in- and outlets were blocked. This was mostly due to recent clearing and shaping of the shoulders and road prism, done by the RRM Contractor. Examples of these are shown in *Figure 12.1*. Other culverts were noted where the barrels were blocked with silt and/or debris.

The majority of culvert head walls and wing walls along Road R101-8 were constructed in concrete and are in a fair to warning condition. The assessment showed that a number of culverts had no in- or outlet structures or missing wing walls, as demonstrated in *Figure 12.2*. A total of 17 cases were noted. The assessment also revealed that four box culverts were extended using Ø900 mm pipes and six pipe culverts were found to be misaligned, as illustrated in *Figure 12.3*.

Blocked Ø unknown Pipe culvert @ km 16.000	**Blocked Ø unknown Pipe culvert @ km 16.000**
	
Blocked Ø 600 Pipe culvert @ km 14.150	**Blocked Ø 600 Pipe culvert @ km 14.150**
	

Figure 12.1: Blocked inlet and outlet structures due to reshaping of road prism

New outlet head wall for Ø 900 pipe culvert @ km 6.500	Fair condition head wall for Ø 900 pipe culvert @ km 3.900
	
Broken head wall for a Ø 600 Pipe culvert @ km 21.850	**Demolished head wall for Ø 600 Pipe culvert @ km 21.850**
	

Figure 12.2: Typical head wall and wing wall defects

Silted Ø 900 pipe culvert with debris @ km 16.400	Half silted Ø 900 pipe culvert @ km 14.150
	
Ø 900 Pipe culvert @ km 21.850	**Misaligned Ø 600 Pipe culvert @ km 13.900**
	

Figure 12.3: Blocked and misaligned pipe culvert barrels.

A summary of the defects is included in *Table 12.2*.

Table 12.2: Summary of defects and repair methods

FAILURE MODE	REPAIR MODE	NO OF STRUCTURES
Silted and containing debris	Clear silts and debris to spoil	39
Damaged inlet head walls	Reconstruct entire inlet structure	11
Damaged outlet head walls	Reconstruct entire outlet structure	14
Cracked wing wall	Crackseal the structure	3
Misaligned barrel	Realign the barrel	6
Spalling concrete	Repair spall (including honeycombing)	6

12.3 SIDE DRAINS

Earth drains located along the road were recently cleared and shaped by the RRM Contractor. Lined side drains along Road R101-8 consists of either stone pitched drains or concrete lined drains. Stone pitch drains appear to be in a fair condition. Concrete lined drains are generally in good condition and are limited to the following locations:

- Km 6.490 to km 7.250 (Northbound)
- Km 7.480 to km 7.840 (Northbound)
- Km 7.480 to km 7.940 (Southbound)

The section through Modimolle appears to have a piped storm water system situated on the left side of the road with drainage effected through catch pits and kerb inlets. The section from km 25.35 to km 26.80 includes a cast in-situ concrete lined drain between the traffic lanes and parking bays. The condition of these drains is poor to very poor as indicated in *Figure 12.4.*

12.4 RECOMMENDATIONS

The improvement to accommodate a 3.7 m lanes and 3 m surfaced shoulders will require extension of all culvert structures and construction of new side drains. As a result new in- and outlet structures will be constructed. Misaligned culverts will be rehabilitated and damaged pipes will be replaced. Damaged or missing danger plates will be replaced.

Concrete side drain @ km 6.600	Stone pitch drain @ km 10.650
	
Earth drain @ km 11.200	Earth drain @ km 21.850
	
Catch pit in Modimolle @ km 24.880	Kerb inlet in Modimolle @ km 26.800
	
Shattered concrete kerbs in Modimolle @ km 26.700	Catch pit in Modimolle @ km 26.740
	

Figure 12.4: Road side drains (concrete, stone pitching and earth drains)

CHAPTER 13 ROAD FURNITURE

13.1 GUARDRAILS

The current vertical alignment contains no high fills and therefore only sections at bridges, major culverts, and sharp curves received guardrails. Locations of these guardrails together with other details and condition, are summarised in *Table 13.1*.

Table 13.1: Guardrails along Road R101-8

POSITION (km – km)	DIRECTION	LENGTH	CONDITION
15.600 – 16.900	SB (LHS)	306	Miss-aligned
16.700 – 16.950	NB & SB	50	Fair condition
17.740 – 17.840	NB & SB	60	Fair condition
22.450 – 22.550	NB & SB	45	Fair condition
23.580 – 23.700	NB & SB	65	Fair condition

13.2 ROAD SIGNS

Road signs along Road R101-8 are generally in good condition. A number of danger plates situated at culverts were damaged or knocked over during the clearing and shaping recently carried out.

Depending on the final improvement strategy to be adopted, new road signs may be required and where possible existing signs will be removed and re-used. Considerations will also be given to replacement of all road signs to ensure the condition of signs is similar.

13.3 ROAD MARKINGS

The existing road markings appear to comply with the *SANRAL Geometric Design Manual*. Road markings within the town sections are faded.

Road studs are generally only found along the centreline. Road studs along the yellow lines are only present along sections with climbing lanes and next to guardrails.

As part of the improvement of the road section, new road studs will be installed along the project along all lines.

13.4 FENCES AND ACCESSES

Fences along Road R101-8 is generally in good condition with limited damaged sections. Some of the accesses will be moved to concur to the access management plan.

13.5 STREET LIGHTING

There are existing high pressure sodium (HPS) lights installed along the town sections within Bela Bela and Modimolle. These street lights appear to be in fair condition and are functional. The existing street light fittings installed are not consistent throughout each town. In certain parts the lights are in a single arrangement and along other sections lights are in an opposite arrangement.

In Bela Bela the existing street lights only cover the first 700 m of the road and there are no street lights for the rest of the urban section. Within Modimolle overhead lines provide power to the street lights.

Due to the proposed widening improvements, the position of current lights will need to be relocated and new lights provided where pedestrian traffic dictates. The street lighting services will be designed and installed according to all relevant street lighting standards and regulations.

Photo 13.1: Street light fittings in opposite arrangement in Bela Bela

Photo 13.2: Two types of street light fittings installed in Modimolle on the Left hand side

Three lighting options were identified as follows:

1. Light -emitting diode (LED) lighting;
2. High intensity discharge (HID) lighting; and
3. Solar lighting.

The street light luminaires are to be installed on 11.8 m galvanised poles at a mounting height of 10 m. All poles are to comply with the latest SANRAL anti-vandal street light pole requirements, including anti cut v-notches and steel plates within pole to a height of 3 m.

The HID fittings in Option 2 are being phased out by all manufacturers as they switch their focus to the LED industry. Therefore, this Option isn't viable in the long term as replacement of components would become impossible.

The solar solution in Option 3 are approximately double the cost of the LED light fittings from Option 1. The solar solution has two distinct disadvantages namely:

- The batteries and solar panel will need to be replaced every 3 – 7 years; and
- The solar panel requires regular maintenance to maintain good efficiency.

In light of these factors and the advantages and disadvantages listed for each option, we are of the opinion that Option 1 would be the most viable option to take forward. Option 1 would be the most energy efficient solution and require the least maintenance. LED street light fittings will have industry support for future parts and is a 20-year solution. Therefore, Option 1 is considered to be the best value for money.

CHAPTER 14 LAND ACQUISITION

In order to improve the existing road alignment, land acquisition will be required. A summary of all properties affected by the improvement as well as the estimated land areas to be acquired are summarised in *Table 14.1*. Drawings showing affected properties and the required land to be acquired are included in *Appendix I.*

Application process for land acquisition will commence as soon as the preliminary design has been accepted by the Employer. Land acquisition reports with property and owner details have been compiled for each property.

Table 14.1: Affected property to undergo a land acquisition

FARM NAME	MUNICIPALITY	STAKE VALUES (km)	OWNER	TITLE DEED NUMBER	CATEGORY	REQUIRED LAND (m^2)	STATUS
PTN 127 of the farm Tweefontein no. 463-KR	Bela Bela	9.8-10.0	Espach Jan Benjamin Espach Anna Sophia	T33229/1996 PTA	Farms agricultural	6 891	Property Report submitted
PTN 151 of the farm Tweefontein no. 463-KR	Bela Bela	10.3 -10-7	Mechlec Enterprises (Pty) Ltd	T1897/2019	Farms residential	7 669	Property Report submitted
REM of PTN 71 of the farm Tweefontein no. 463-KR	Bela Bela	11.4-11.6	Gedeelte 71 Tweefontein (Pty) Ltd	T56864/1989 PTA	Farms residential	16 145	Property Report submitted
REM of PTN 3 of the farm Verloren no. 452-KR	Bela Bela	11.7 -12.0	TNT Trading 53 CC	T126373/1999 PTA	Farms business & commercial	34 529	Property Report submitted
PTN 45 of the farm Sussensvale no. 708-KR	Modimolle	14.9-15.3	Paradise Sun Farming CC	T59541/1989 PTA	Farms	2 291	Property Report submitted
PTN 46 of the farm Sussensvale no. 708-KR	Modimolle	15.3-16.2	Opperman Adreas Johannes Daniel	T56411/1992 PTA	Farms	47757	Property Report submitted

CHAPTER 15 ENVIRONMENTAL, OHS RISK ASSESSEMENT

15.1 INTRODUCTION

An independent sub-consultant, *Enviroworks (Pty) Ltd* was appointed to conduct a screening assessment for the Preliminary Design. A detailed report is included in *Appendix J*. The report includes site sensitivity assessment, applicable legislation and the recommendations on the way forward. A tender was procured through SANRAL to appoint a Sub-consultant for the environmental subservices for the design and construction stage.

Design risk assessment on the concepts in terms of Occupational Health and Safety was conducted by *SHE Group*. The report is included in *Appendix J*.

15.2 ENVIROMENTAL SCREENING

Based on the sensitivity maps and the Department of Environmental Affairs Screening Tool, the proposed road improvements will traverse through an area that is fairly sensitive in terms of ecological importance and will be subject to a Basic Assessment and will require certain specialist studies.

The majority of the length of Road R101-8 passes through areas classified as Critical Biodiversity Areas (CBAs) or Ecological Support Areas (ESAs). Large sections of Road R101-8 pass through vegetation types classified as Vulnerable or Endangered. The six proposed borrow pits are also situated in areas classified as having a Vulnerable vegetation type. With regards to fauna, no Critically Endangered faunal species were identified that would likely be impacted by the proposed road works.

Road R101-8 crosses two rivers at km 16.80 and km 17.62. Widening of the existing bridges is proposed for capacity improvement. These proposed works will include altering of the watercourse banks and thus will require a Water Use License.

The proposed bridge works on the Great Nyl River (km 17.62) would be situated in an area classified as a CBA, however based on the desktop review this area appears to be invaded by alien vegetation. While still a sensitive area, the bridge works are not deemed a 'no-go' area. The relevant studies will assist in providing proper mitigation measures to reduce construction impacts to acceptable levels.

In terms of heritage, the southern end of Road R101-8 falls within areas classified as 'Moderate'and 'High' sensitivities in terms of heritage resources as indicated in Appendix 5 of the Screening Report. The proposed development will thus require a desktop heritage assessment. Pending the outcome of the desktop assessment a field assessment may be required.

15.3 ENVIRONMENTAL RECOMMENDATIONS

Following the screening assessment the following are recommended:

- An application for Environmental Authorisation will need to be submitted and a Basic Assessment process followed;
- Should any of the borrow pits exceed 4.99 hectares a Mining Permit will be required which would then require a full Scoping and Environmental Impact Assessment and not a Basic Assessment;
- The following specialist studies are recommended to form part of the Basic Assessment process:
  - Aquatic Biodiversity Impact Assessment
  - Botanical Impact Assessment
  - Heritage Impact Assessment and Notice of Intent to Develop
  - Freshwater Study and DWS Section 21 (c) & (i) Water Use Risk Matrix
- The following permits and or licenses will be required:
  - Water Use License
  - Mining Permit
  - Plant Removal Permit
- Borrow pits 1, 5 and 6 should be considered with caution and alternative sites sought out if possible. This is based on the fact that they appear to have intact natural vegetation;
- Vegetation clearing and the development footprint will need to be kept to a minimum, particularly at km 9.00 – km 12.00 and km 15.00 – km 16.00 where road realignments are envisaged; and
- Rehabilitation of the sections of old road along realignment should be undertaken in order to offset the habitat loss incurred by developing the new road sections.

15.4 OHS DESIGN RISK ASSESEMENT

The findings and recommendations from the design risk assessment are summarised as follows:

- That all work be constantly monitored with particular emphasis on interaction between local community and other industrial activities;
- Two-way traffic accommodation must be maintained at all times, therefore temporary concrete barriers must be installed to separate the traffic from construction works;
- Current high risk accident areas (sub-standard horizontal curves) should be upgraded to a 100 km/h design speed to mitigate future accidents risks;
- All remedial works relating to Modderloop River Bridge and Groot Nyl River Bridge to be completed to a specific safe system of work relating to work at height and working near water environment; and
- All remedial works at culverts to consider working in confined spaces as a minimum in the respective safe systems of work.

CHAPTER 16 CONSTRUCTION MATERIAL

16.1 MATERIAL SOURCES

16.1.1 Borrow sources

Possible borrow areas were highlighted in *Chapter 2* of this report, however as indicated these sources may not be approved for use and will require application to the Department of Minerals and Energy. These borrow areas should provide up to G5-quality material, which is ideal for the construction of middle and lower pavement layers. Quality and extent of these sources must however be proven.

The realignments at the three problematic areas will provide more than enough material to be used for lower layers. The geological desktop study showed that material along these areas should provide up to G7-quality material but will require testing to prove quality.

16.1.2 Commercial sources

The following ASPASA accredited commercial sources are available near the project:

- Vergenoeg Mining Company (Pty) Ltd – Pretoria (±80 km);
- Afrimat -Infrasors - Marble Hall (±110 km);
- PPC Aggregates Mooiplaas – Pretoria (±120 km); and
- Afrisam Ferro Quarry, Bergtuin – Pretoria (±100 km).

Rooiberg quarry situated in Mookgophong (±42 km from the project road) is not listed as an accredited ASPASA source.

16.2 WATER SOURCES

It is proposed that water required for construction purposes be procured from the Bela Bela and/or Modimolle Local Municipalities.

16.3 BITUMINOUS PRODUCTS

Several asphalt producers are available that can provide asphalt for the project should this be required. These are as follows:

- National Asphalt – Pretoria (±90 km);
- Rooiberg Asphalt – Pretoria (±90 km);
- Rooiberg Asphalt – Mookgophong (Naboomspruit) (±50 km);
- Much Asphalt – Polokwane (±150 km); and
- Polokwane surfacing – Polokwane (±150 km).

CHAPTER 17 COST ESTIMATE

A cost estimate for the realignment improvements to suit a 100 km/h design speed was prepared using rates from recently completed projects and is summarised in *Table 17.1*. The cost estimate was based on the following:

- **<u>Cross section 4.1:</u>**
  - Section from km 0.00 to km 5.44: A 4-lane configuration with median and sidewalks;
  - Section from km 5.44 to km 24.00: A 2-lane cross section with 3 m surfaced shoulders, existing climbing lanes and geometric realignments; and
  - Section from km 24.00 to km 26.80: A 4-lane configuration with kerbed median and sidewalks.
- Pavement rehabilitation 2: A 200 mm G7 USSG for shoulder widening, adding a 100 mm G2 to the existing base material and cement stabilising to a 250 mm C4 subbase across the lane and shoulder, construction of a 150 mm G1 base and Cape seal; and
- Structures solution option 2: lifting of bridges and reconstructing major culverts to increase hydraulic capacity.

Table 17.1: Cost Estimate

SECTION	DESCRIPTION	AMOUNT (R)	
1200	General requirements and provisions	R	3 150 000.00
1300	Contractor's establishment on site and general obligations	R	49 880 000.00
1400	Housing, offices and laboratory for the engineer's site personnel	R	1 961 020.00
1500	Accommodation of traffic	R	18 287 990.00
1700	Clearing and grubbing	R	321 250.00
1800	Day works	R	879 060.00
2100	Drains	R	1 842 050.00
2200	Prefabricated culverts	R	18 610 000.00
2300	Concrete kerbing, concrete channelling, chutes and downpipes, and concrete linings for open drains	R	14 431 880.00
3100	Borrow materials	R	150 000.00
3200	Selection, stockpiling and breaking down the material from borrow pits, cuttings and existing pavement layers, and placing and compacting the gravel layers	R	3 500 000.00
3300	Mass earthworks	R	32 704 000.00
3400	Pavement layers of gravel material	R	28 215 550.00
3500	Stabilization	R	13 824 500.00
3600	Crushed stone base	R	20 325 000.00
3800	Patching and repairing edge breaks	R	15 487 250.00
3900	Breaking up existing pavement layers	R	2 926 000.00
4100	Prime coat	R	4 500 000.00
4200	Asphalt base and surfacing	R	27 813 500.00
4600	Bituminous single seal with slurry (cape seals)	R	34 825 000.00
4800	Treatment of an existing surface exhibiting certain defects	R	95 000.00
5100	Pitching, stonework and protection against erosion	R	8 510 000.00
5200	Gabions	R	32 400.00
5300	Guide blocks	R	876 000.00

SECTION	DESCRIPTION	AMOUNT (R)
5400	Guardrails	R 1 137 500.00
5500	Fencing	R 991 100.00
5600	Road signs	R 285 000.00
5700	Road markings	R 3 648 200.00
5800	Landscaping and planting plants	R 150 000.00
5900	Finishing the road and road reserve and treating old roads	R 391 500.00
6100	Foundations for structures	R 1 560 000.00
6200	False work, formwork and concrete finish	R 550 000.00
6300	Steel reinforcement for structures	R 8 946 205.00
6400	Concrete for structures	R 10 379 820.00
6600	No-fines concrete, joints, bearings, bolt groups for electrification, parapets and drainage for structures	R 5 202 788.00
8100	Testing materials and workmanship	R -2 800 000.00
G1000	Street lights - installation	R 12 750 000.00
F12 100	Access for bridge rehabilitation	R 4 837 700.00
F12 300	Surface and structural repair of concrete members	R 316 875.00
F12 400	Grouting and crack injection	R 26 500.00
F12 600	Protective coatings and treatments for concrete	R 165 000.00
F12 800	Replacement and repair of ancillary bridge elements	R 10 000.00
D1000	Small contractor development, training and community liaison	R 4 962 000.00
Subtotal A		**R 356 657 638.00**
Add 10% Contingencies		**R 35 665 763.80**
Subtotal B		**R 392 323 401.80**
Add 15% VAT		**R 58 848 510.27**
TOTAL		**R 451 171 912.07**

CHAPTER 18 PROGRAMME

The construction works will be programmed once the scope of work is finalised. The dates in *Table 18.1* below are the requirements from *SANRAL* in terms of the programme for the consulting engineering services and will form the basis for the completion of the work.

Table 18.1: Project Programme

PROJECT STAGE	ORIGINAL STAGE COMPLETION DATE	REVISED/ACTUAL STAGE COMPLETION DATE
Project Hand-over meeting	15 July 2017	September 2018
First Progress meeting	15 August 2017	October 2018
Submissions of draft Assessment Report	01 October 2017	November 2018
Submission of draft Concept Design Report	15 November 2017	Not Applicable
Submission of draft Preliminary Design Report	15 December 2017	December 2019
Submission of Road Safety Audit Report: Stage 3: Detail Design	15 April 2018	December 2020
Submission of draft Detailed Design Report including Structures, Drainage & Geotechnical Reports	15 May 2018	March 2021
Submission of design information to SANRAL's Property Service Provider (PSP) for land acquisition purposes	15 May 2018	August 2020
Submission of Basic Assessment Report or full EIA report	15 March 2018	April 2021
Submission of WULA to approving authority	15 March 2018	April 2021
Submission of EMP's to approving authority	15 March 2018	April 2021
Submission of Draft Tender Documents for the Works and final Detailed Design Reports	15 July 2018	May 2021
Tender Advertisement	15 August 2018	June 2021
Submission of Final Tender Documents for the Works	15 September 2018	June 2021
Clarification Meeting	15 September 2018	June 2021
Tender Closure	15 October 2018	July 2021
Submission of Tender Evaluation Report	15 October 2018	July 2021
Works Contract Handover	01 March 2019	November 2021

CHAPTER 19 CONCLUSIONS AND RECOMMENDATIONS

19.1 CONCLUSIONS

The following conclusions can be drawn from the Preliminary Design stage:

- Road R101-8 can be classified as a Class 2 rural major arterial (km 0.00 to km 25.76) and a Class 4a collector street (km 25.76 to km 26.80). in terms of TRH26 and a Category B road in terms of TRH4;
- Electronic traffic counts indicated two distinct traffic sections, i.e. km 0.00 to km 5.44 and km 5.44 to km 26.80.
- ADT along the two uniform sections are 7 488 and 4 788 vehicles/day, respectively. Similarly, ADTT is 1 054 and 402 vehicles/day;
- Traffic growth rates based on the 2015 and 2018 count data indicate a typical growth rate of 3.0% along Road R101-8, while a medium growth rate of 2.5% was estimated from CTO stations along other sections of Road R101;
- The estimated design traffic loading for a 20-year design life at 2.5% growth rate is 13.30 million E80's for the section from km 0.00 to km 5.44 and 5.02 million E80's for the section from km 5.44 to km 26.80;
- The section from km 0.00 to km 5.44 is classified as ES30 traffic class and the section from km 5.44 to km 26.80 is classified as ES10 traffic class;
- The HTM analysis shows that the section from km 0.0 – km 5.44 was due for capacity improvement in 2018, while the remainder of the road requires improvement in 2033;
- Analysis of results from a road side interview (RSI) indicated that the road upgrade should not have a significant impact on the N1 traffic attraction;
- Cross section option 2 (4 lanes from km 0.00 to km 5.44 and 3 lanes alternating climbing lanes for the section from km 5.44 to km 26.80) was developed further into cross sections 4.1 and 4.2;
- Cross section 4.1 (4 lanes with kerbed median from km 0.00 to km 5.44, 2 lanes with 3 m surfaced shoulders and existing climbing lanes from km 5.44 to km 24.00 and 4 lanes from km 24.00 to km 26.80) was found to be the most viable and suitable cross section;
- Intersections and accesses require improvement to accommodate the proposed cross section upgrade and to improve road safety and capacity;
- Eleven existing horizontal curves were identified as sub-standard in terms of curve radius;
- Of the eleven horizontal sub-standard curves, five are located along major realignment areas from km 9.8 to 10.6, km 11.0 to km 11.7 and km 14.8 to km 15.5;
- The remaining six horizontal sub-standard curves require minor curve radius realignment and falls within the existing roadway;
- Majority of the remaining curves will be improved in terms of the superelevation;
- Traffic counts showed that the rural section has average travelling speeds of 95.1 km/h to 99.14 km/h;

- The realignment to suit an 80 km/h design speed (R=210) does not eliminate safety risks along Road R101-8;
- The realignment of sub-standard curves to suit a 100km/h (8% emax and minimum 390 m radius) was agreed to be the most suitable improvement. This will improve safety and provide adequate capacity as well as uniform alignment along this section of Road R101-8;
- cutting from the major horizontal realignment will generate enough material which can be used for lower layers and stabilised C4 subbase if suitable;
- A total of 18 crest curves and 6 sag curves were found to be sub-standard;
- Majority of the sub-standard vertical curves are located adjacent to the major horizontal realignment areas and will be corrected to suit K value of 45 for crest curves and 40 for sag curves;
- Public transport facilities such as taxi and bus bays are required along town sections;
- Existing sidewalks in Bela Bela and Modimolle are insufficient and need to be extended;
- From the deflection measurements, it is evident that the pavement requires structural improvement for a 20-year design period;
- The materials investigation indicated a high variation in the pavement structure along Road R101-8, which suggests historical maintenance;
- The materials investigation further indicated that the existing pavement structures consist of G5 base, G6 subbase, G6 upper selected and G7 to G9 lower selected material;
- Pavement rehabilitation 2 utilising new G7 material for shoulder USSG, stabilising existing base to construct a C4 subbase, construction of a new G1 base and Cape seal surfacing along rural section provides sufficient structural capacity;
- Pavement rehabilitation 3 utilising the existing base material for shoulder USSG, stabilising existing subbase to C4, constructing a new G1 base and Cape seal surfacing along rural section also provides sufficient structural capacity;
- Pavement rehabilitation 2 allows for two way traffic accommodation at all times whereas pavement rehabilitation 3 will require half width (stop and go) traffic accommodation;
- Two way traffic accommodation is a requirement due to the volume of traffic expected along Road R101-8;
- An HDM4 analysis showed that Cross section 4.1 (4-lane cross section using asphalt from km 0.00 to km 5.44, 2 lanes with 3 m surface shoulders and existing climbing lanes using cape seal from km 5.44 to 24.00 and 4-lanes cross section using asphalt from km 24.00 to km 26.80) provides the highest internal rate of return (IRR) of 13.6%;
- Results from the hydrological and hydraulic analysis show that the existing bridge structures do not comply with the design freeboard requirements (20-year flood) and it is recommended that the drainage capacity of the bridges be increased;
- Similarly, the three major culvert structures also do not comply with the design freeboard requirements (20-year flood);
- Six properties are affected by the realignment and a land acquisition process will be required for the improvements;

- An environmental screening assessment was conducted and the outcome shows that a Basic Assessment will be required;
- Both crushed and bituminous construction materials are available from commercial sources within a 150 km radius of the project; and
- The estimated cost for Cross section 4.1, using pavement rehabilitation 2 and realigning to suit 100 km/h design speed is approximately R 451.2 million (Including VAT).

19.2 RECOMMENDATIONS

Based on the investigations conducted and the conclusions reached, the following are recommended:

- All horizontal sub-standard curves be improved to suit a 100 km/h design speed with 8% emax and minimum 390 m radii;
- Road R101-8 be improved in accordance with Cross section 4.1 described as follows:
  - Section from km 0.00 to km 5.44: A 4-lane urban configuration with median and sidewalks;
  - Section from km 5.44 to km 24.00: A 2-lane cross section with 3 m surfaced shoulders, existing climbing lanes and geometric realignments; and
  - Section from km 24.00 to km 26.80: A 4-lane urban configuration with median and sidewalks.
- Pavement rehabilitation 2 be utilised for the section from km 5.44 to km 24.00 as follows:
  - Box cut, rip and compact existing shoulder material for shoulder LSSG, 200 mm G7 USSG for the shoulder, 250 mm C4 subbase across the lane and shoulder, 150 mm G1 base and Cape seal surfacing;
- New pavement structures using asphalt surfacing along urban sections and cape seal along horizontal major realignments be implemented;
- Bridge and major culvert reports be submitted to the Employer for approval and the feedback be included in the detail design;
- Environmental sub-consultant and Road Safety Auditor be appointed;
- Procurement for a geotechnical drilling contractor should proceed;
- Land acquisition process should be finalised; and
- The project should proceed to Detail Design stage.

APPENDICES

BOOK 2 OF 2