9th International Conference on MANAGING PAVEMENT ASSETS (ICMPA9)

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THE USE OF MEASURED PAVEMENT PERFORMANCE INDICATORS AND TRAFFIC

IN DETERMINING OPTIMUM MAINTENANCE ACTIONS FOR A TOLL ROAD IN SOUTH AFRICA

AND COMPARISON WITH HDM-4 PERFORMANCE PREDICTIONS

Surita Madsen-Leibold

AECOM

PRESENTATION LAYOUT

Presentation Layout

- **Introduction**
  - Project location and nature of the study
- **Road pavement**
  - Structure
  - Maintenance actions
- **Data collection and monitoring**
  - Climate; traffic; pavement performance

Presentation Layout

- **Pavement performance modelling**
- **Comparison of predicted with actual performance**

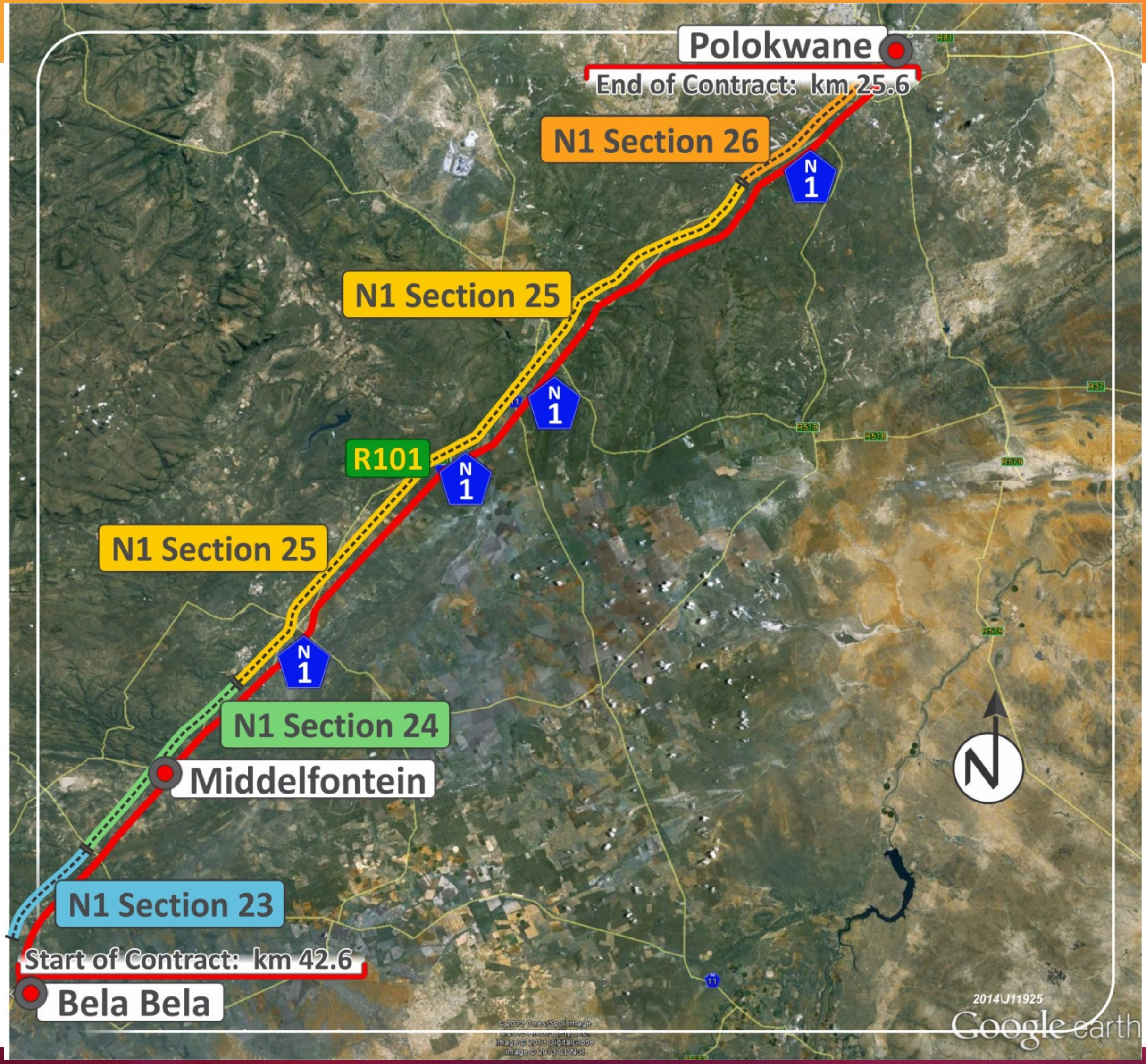
INTRODUCTION

Project locality

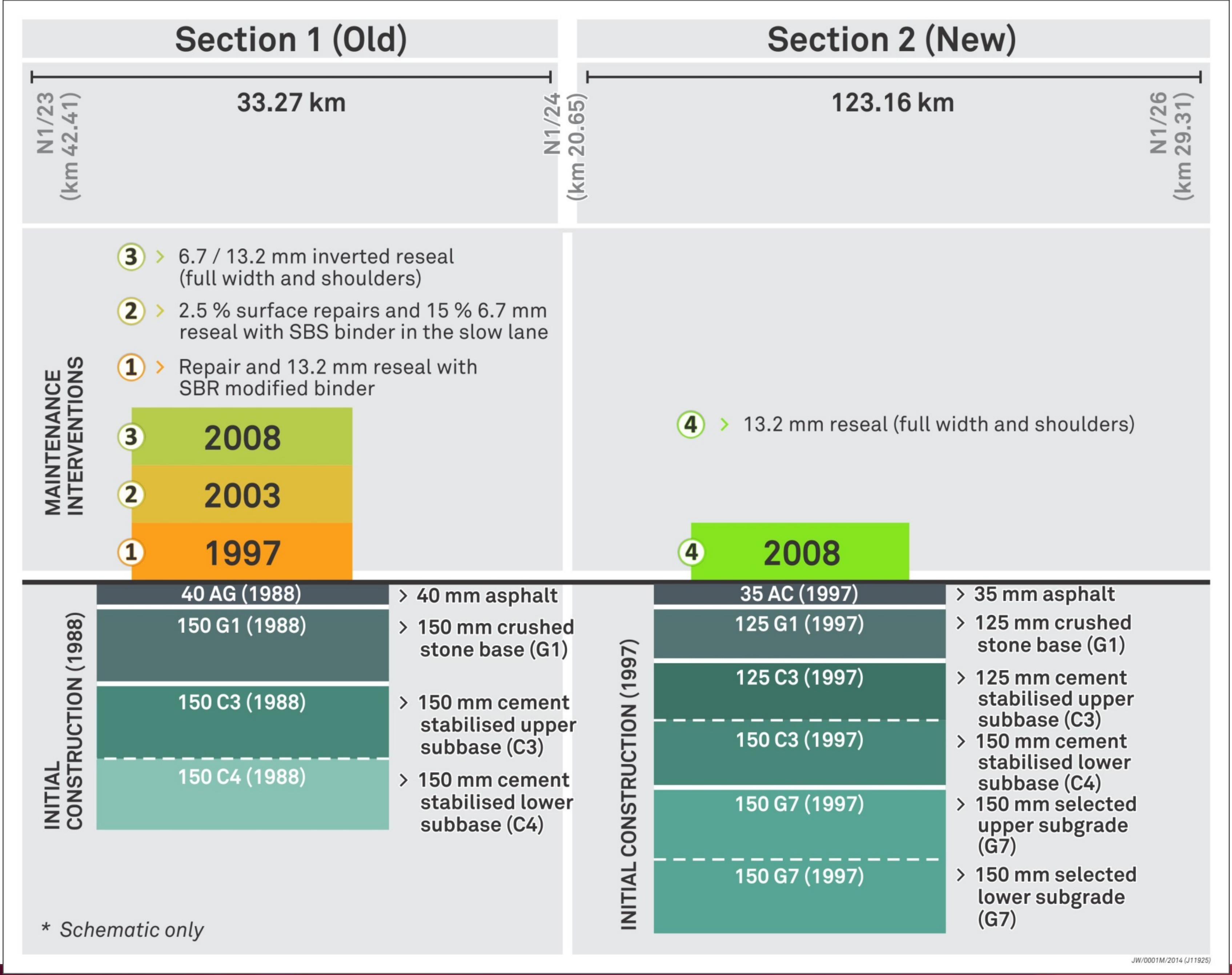
Introduction

- **Significance and nature of the study**
  - First BOT contract in SA
  - Extensive data collected on traffic and pavement performance over last 17 years
  - Data used to determine optimal maintenance actions
  - Data used to compare actual to HDM-4 predicted pavement performance

Project Layout

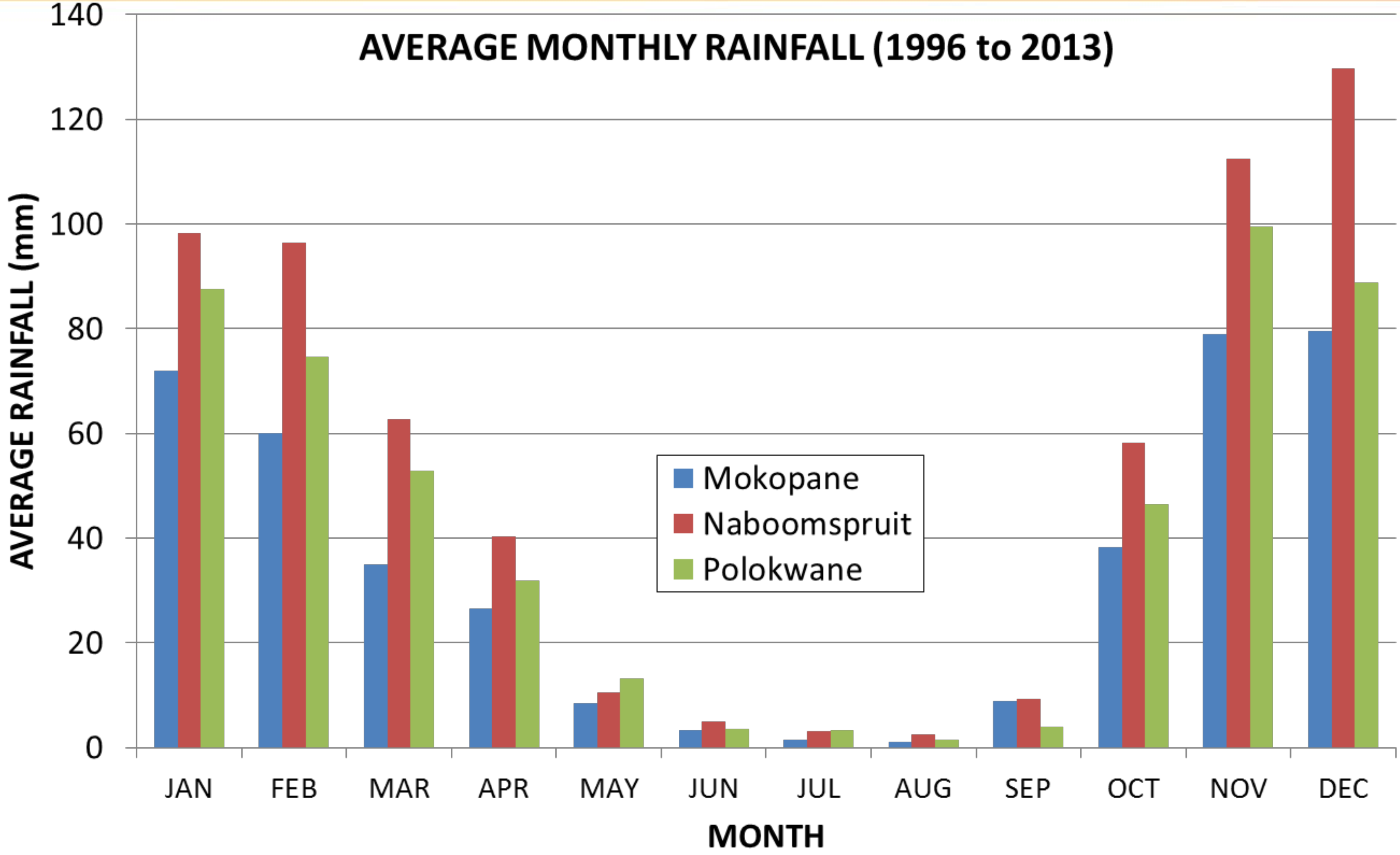


ROAD PAVEMENT

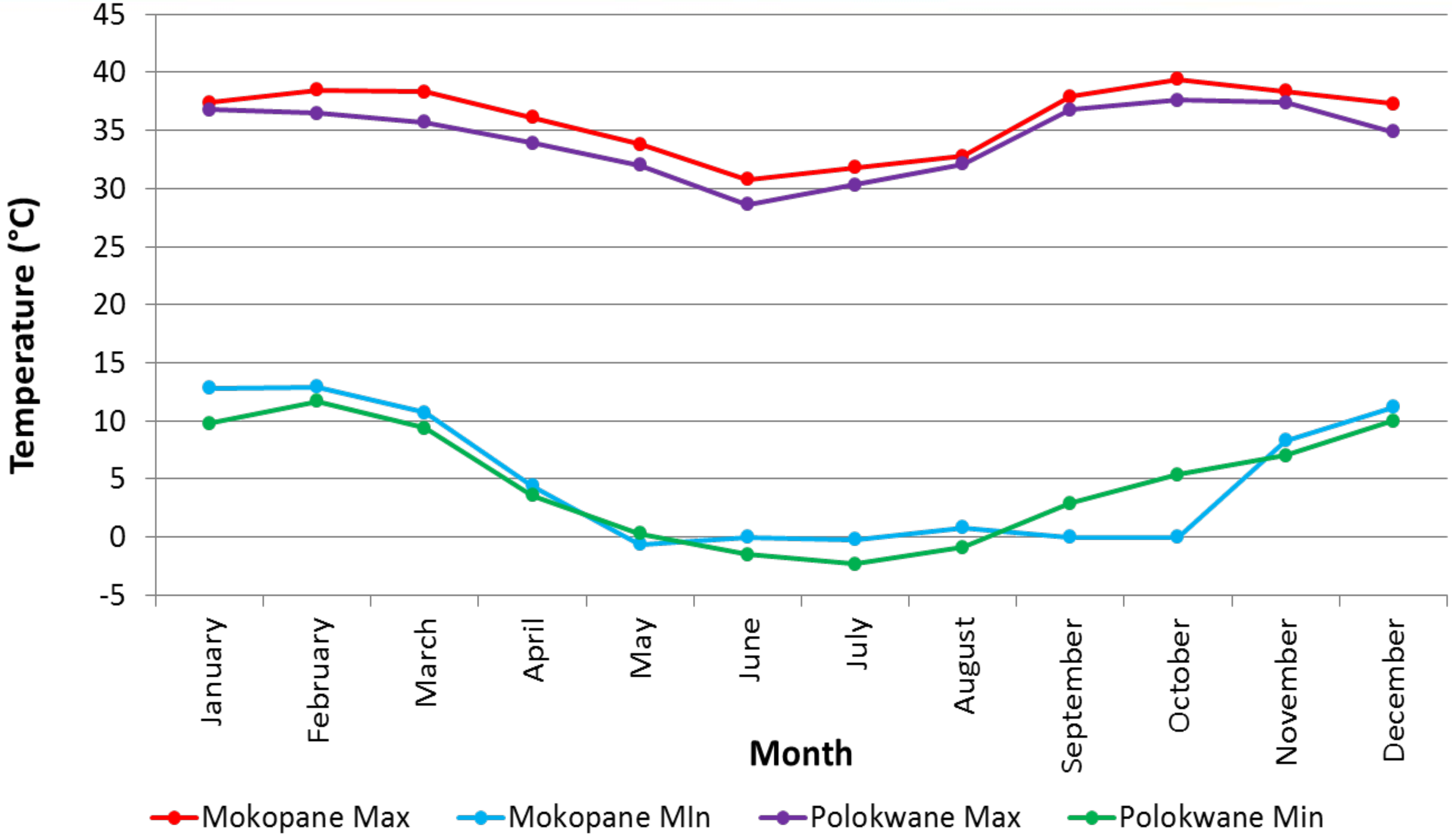

Section 1 (Old)
Section 2 (New)
33.27 km
N1/23 (km 42.41)
N1/24 (km 20.65)
123.16 km
N1/26 (km 29.31)
MAINTENANCE INTERVENTIONS
3 > 6.7 / 13.2 mm inverted reseal (full width and shoulders)
2 > 2.5 % surface repairs and 15 % 6.7 mm reseal with SBS binder in the slow lane
1 > Repair and 13.2 mm reseal with SBR modified binder
3 2008
2 2003
1 1997
4 > 13.2 mm reseal (full width and shoulders)
4 2008
INITIAL CONSTRUCTION (1988)
40 AG (1988)
> 40 mm asphalt
150 G1 (1988)
> 150 mm crushed stone base (G1)
150 C3 (1988)
> 150 mm cement stabilised upper subbase (C3)
150 C4 (1988)
> 150 mm cement stabilised lower subbase (C4)
INITIAL CONSTRUCTION (1997)
35 AC (1997)
> 35 mm asphalt
125 G1 (1997)
> 125 mm crushed stone base (G1)
125 C3 (1997)
> 125 mm cement stabilised upper subbase (C3)
150 C3 (1997)
> 150 mm cement stabilised lower subbase (C4)
150 G7 (1997)
> 150 mm selected upper subgrade (G7)
150 G7 (1997)
> 150 mm selected lower subgrade (G7)
* Schematic only
JW/0001M/2014 (J11925)

DATA COLLECTION AND MONITORING

Climate


AVERAGE MONTHLY RAINFALL (1996 to 2013)
AVERAGE RAINFALL (mm)
140
120
100
80
60
40
20
0
Mokopane
Naboomspruit
Polokwane
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH

Climate



45
40
35
30
25
20
15
10
5
0
-5
Temperature (°C)
January
February
March
April
May
June
July
August
September
October
November
December
Month
Mokopane Max
Mokopane MIn
Polokwane Max
Polokwane Min

Traffic

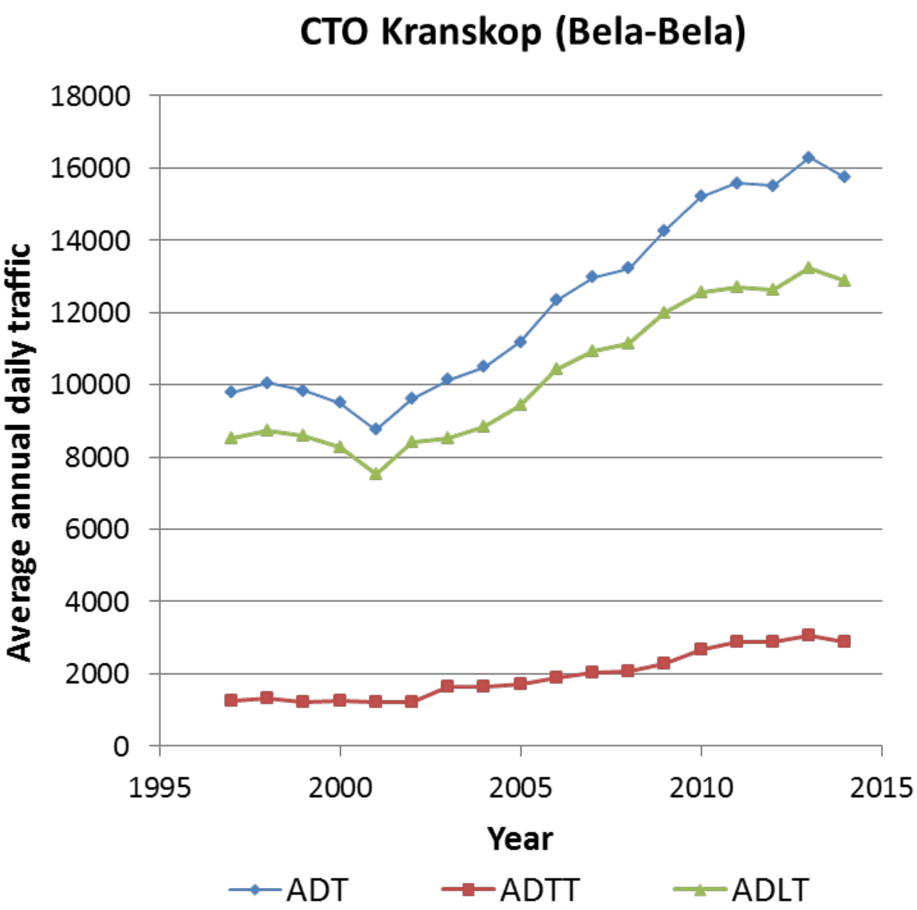
- **Data collection**
  - Two High-Speed Weigh-In-Motion (HSWIM)stations along route: Kranskop (Section 1) and Pietersburg (Section 2)
  - Period 1997 to date

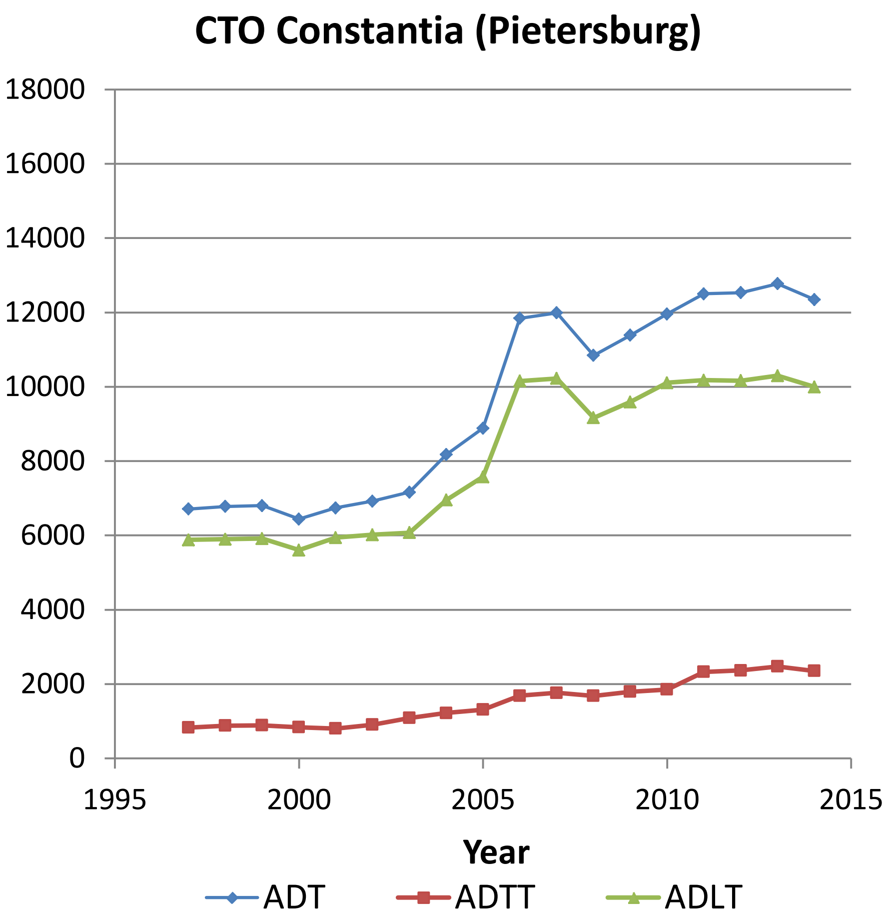
- **Parameters determined/obtained**
  - Vehicles classified in toll classes 1,2,3 and 4
  - Average daily traffic (ADT) determined for four classes
  - E80/HV determined for trucks (classes 2,3,4)

Traffic

- **Toll Classes**
  - Class 1(Light vehicles): motor vehicles, with or without a trailer, including motorcycles
  - Class 2 (Medium heavy vehicles): heavy vehicles with two axles.
  - Class 3 (Large heavy vehicles): heavy vehicles with three or four axles.
  - Class 4 (Extra large heavy vehicles): heavy vehicles with five or more axles

Traffic


CTO Kranskop (Bela-Bela)
Average annual daily traffic
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1995
2000
2005
2010
2015
Year
ADT
ADTT
ADLT


CTO Constantia (Pietersburg)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1995
2000
2005
2010
2015
Year
ADT
ADTT
ADLT

Pavement performance monitoring

- **Data collection**
  - Annual visual assessments (THM9) degree and extent 200m long segments
  - Regular instrument measurements in slow lane WTs: Profilometer (IRI, Rutting,); FWD defections

Pavement performance monitoring

Applicable Specification	Parameter	Acceptance Criteria
Functional condition (during operation)	Road roughness (International Roughness Index – IRI in m/km)	< 2.9 over 90 % of 5km sections < 3.6 over 95 % of 5km sections 4.6 maximum
	Skid resistance (Sideway-force coefficient)	> 0.4 over 90 % of 1km sections 0.35 minimum
	Rut Depths (mm)	< 15 over 90 % of 1km sections 25 maximum
	Structural failures (length of patches, potholes etc)	< 50m per 1km sections
Structural condition (at end of contract)	Deflection at end of contract	Do < 370 µm (90th percentile per uniform section) BLI < 180 µm (90th percentile per uniform section) ROC > 120 µm (90th percentile per uniform section)
	Visual condition per uniform section at end of contract	VCI > 50 per 1 km segment Maximum annual change in VCI is 25% Degree / Extent* Crocodile cracking ≤ 3 / ≤ 5 Longitudinal cracking ≤ 3 / ≤ 10 Pumping All / ≤ 5 Patching ≤ 3 / ≤ 5 * % of length

Pavement performance monitoring

- **Optimization of maintenance actions**
  - Continuous condition monitoring data was used to predict future pavement condition and to time maintenance actions to ensure conformance to the contractual condition criteria

PAVEMENT PERFORMANCE MODELLING

Pavement performance modelling

- **Modelling the road**
  - Software used : HDM-4 Version 2
  - Two uniform sections : Sections 1 and 2 based on difference in pavement, traffic, maintenance actions
  - Period : 1997 to 2014
  - Road modelled as four lane carriageway; 17.8 m wide

- **Primary variables in HDM-4 deterioration models**
  - Pavement structure, type and age
  - Traffic loading
  - Climate
  - Maintenance actions and timing
  - Initial pavement condition and condition after each maintenance action
  - Calibration factors

Pavement performance modelling

Climate Parameter		unit	Weather Station			Project road section
			Naboomspruit (Mookgapong)	Mokopane	Polokwane	
Temperature	Minimum Temperature	°C	-	-0.6	-2.3	-1.2
	Maximum Temperature	°C	-	39.4	37.6	38.8
	Average Temperature Range	°C	-	14.2	13.7	13.9
	Mean Temperature	°C	-	20.7	18.6	19.6
	Days T >32°C	No	-	59.3	23.0	41.1
	Temperature Classification	-	-	Subtropical-Hot	Subtropical-Hot	Subtropical-Hot
Moisture	Mean Monthly Precipitation (MMP)	mm	52.4	32.2	42.4	42.3
	Duration of dry season	months	5	5	5	5
	Thornthwaite's Moisture Index (Im)	-	-20 to 0	-20 to 0	-40 to 0	-20 to 0
	Moisture Classification	-	Sub-Humid Dry	Sub-Humid Dry	Sub-Humid Dry/Semi-Arid	Sub-Humid Dry

Pavement performance modelling

HDM-4 Climate Zones (SA Coverage)												
CZ_NAME	MOISTCLASS	TEMPTYPE	DAYS GT32	ANN TEMPRGE	FREEZE IDX	MOSIT IDX	MM P	MEAN TEMP	DRY SEASON	PC TDS	PC TDW
SA - Arid (Im <-40)	Arid	Subtropical-Hot	60	17	60	-50	12	21	10.8	0	2
SA - Semi Arid (-40<Im<-20)	Semi-Arid	Subtropical-Hot	60	17	50	-30	38	18	8	0	5
SA - Sub Humid Dry (-20<Im<0)	Sub-Humid Dry	Subtropical-Cool	40	13	30	-10	48	16	6	0	8
SA - Sub Humid Moist (0<Im<20)	Sub-Humid Moist	Subtropical-Hot	30	12	10	10	66	18	6	0	10
SA - Humid (Im > 20)	Humid	Temperate-Cool	15	10	5	50	92	18	6	0	15

HDM-4 Calibration Values (Typical)							
CZ_NAME	MOISTCLASS	kcia	kcpa	kciw	kcpw	kvp	kgm
SA - Arid (Im <-40)	Arid	1.5	0.2	1.5	0.3	0.3	0.39
SA - Semi Arid (-40<Im<-20)	Semi-Arid	1.3	0.3	1.3	0.3	0.5	0.5
SA - Sub Humid Dry (-20<Im<0)	Sub-Humid Dry	1.2	0.4	1.2	0.4	0.6	0.61
SA - Sub Humid Moist(0<Im<20)	Sub-Humid Moist	1.1	0.6	1.1	0.6	0.9	0.61
SA - Humid (Im > 20)	Humid	1.1	0.6	1.1	0.6	0.9	0.88

COMPARISON OF PREDICTED WITH ACTUAL PERFORMANCE

Comparison of predicted with actual performance

- **Processing of visual assessment data**
  - Visual assessment data in terms of degree and extent for 200 m segments
  - HDM-4 predictions for defects generally in terms of % of total road area
  - Used cracking index to compare measured with predicted

$$CI = \sum_{i=1}^{5} W_i . C_i$$

Where:

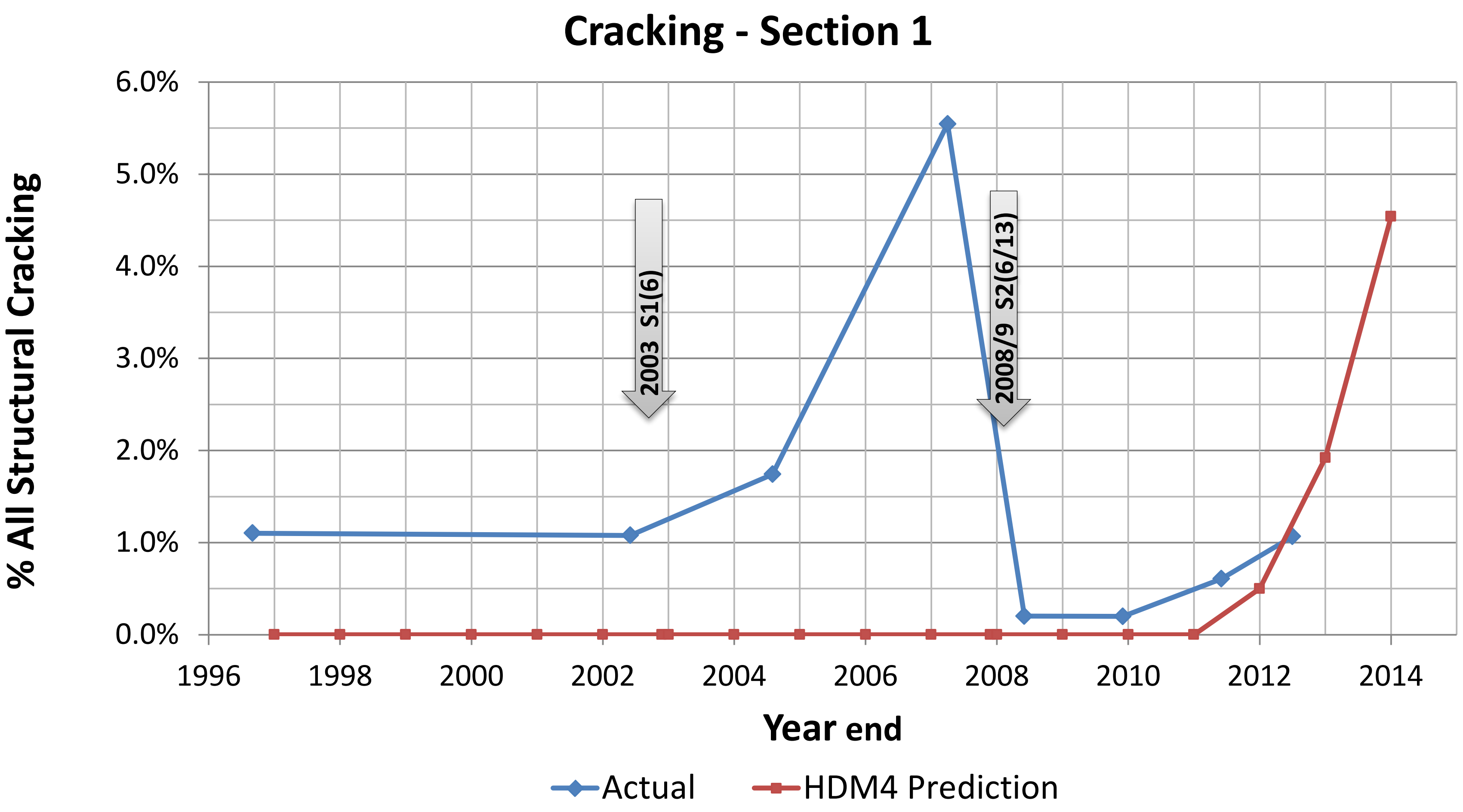
- Wi = Weighing factor for crack type i,
- and Ci = Percentage (%) cracked area for crack type i
- All cracks: degree 1 to 5
- Wide cracks: degree 3 to 5

Comparison of predicted with actual performance

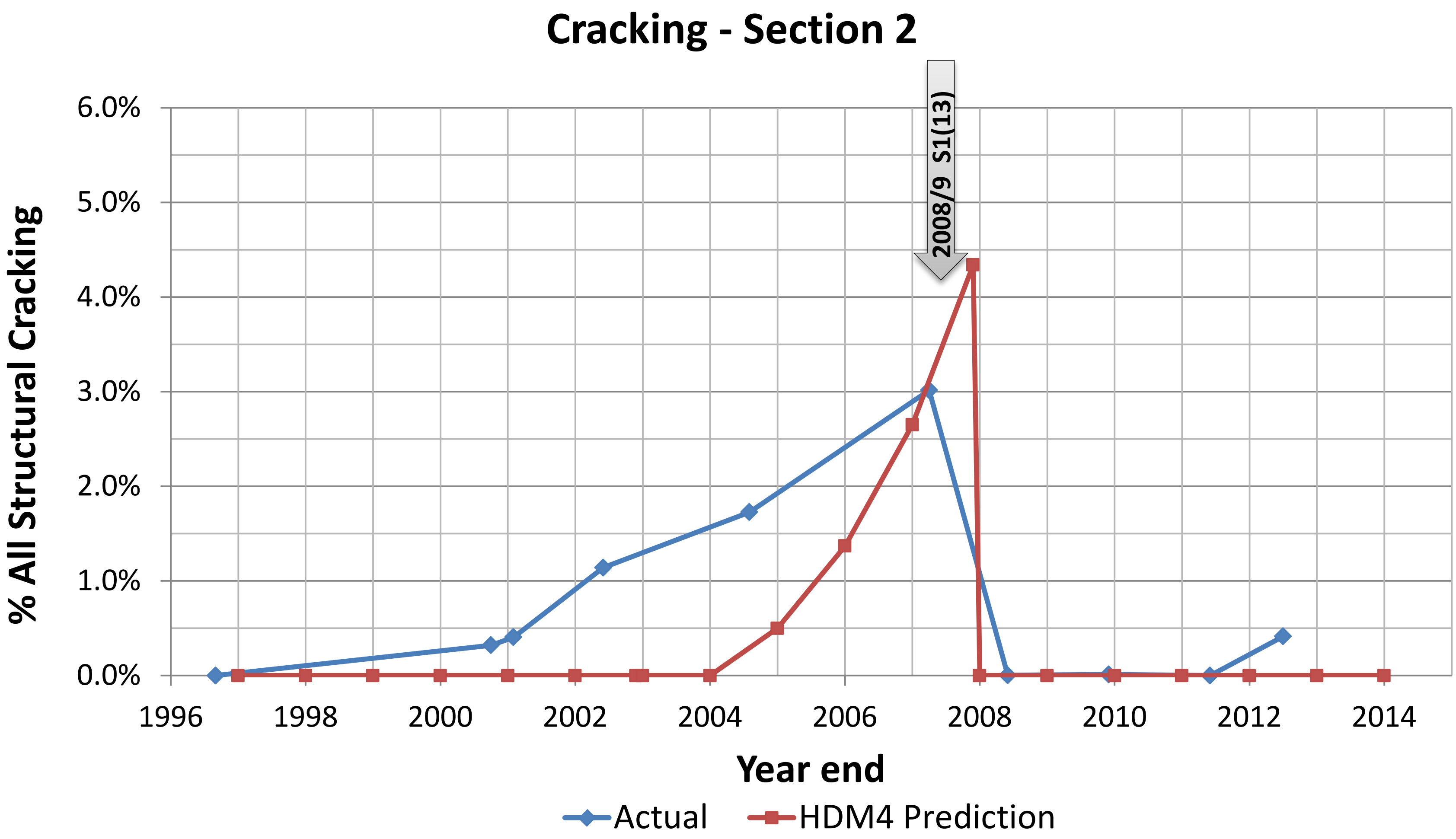
Crack Types And Weighing Factors Used For Cracking Index		
Crack Type	**Weighting Factor**	**Comment**
Crocodile Cracks	1.67	Includes Wheelpath And General Crocodile Cracking
Map Cracks	0.80	None
Longitudinal Cracks	0.72	Includes Only Longitudinal Cracking In The Wheelpath
Transverse Cracks	0.77	None
Block Cracks	1.04	Includes Block Cracks With Spacing Of 0.5 m And Greater

Conversion between Extent Rating for Cracking and the % Cracked Area					
Extent Rating	% Area Cracked				
	Crocodile cracks	Surface or Map Cracks	Longitudinal Cracks	Transverse Cracks	Block Cracks
1	1.5	1.5	0.7	0.5	3.5
2	3.5	3.5	1.7	1.6	7.0
3	6.25	6.25	3.2	2.5	10.5
4	10	10	5.7	5.3	14.5
5	20	20	7.3	6.1	20

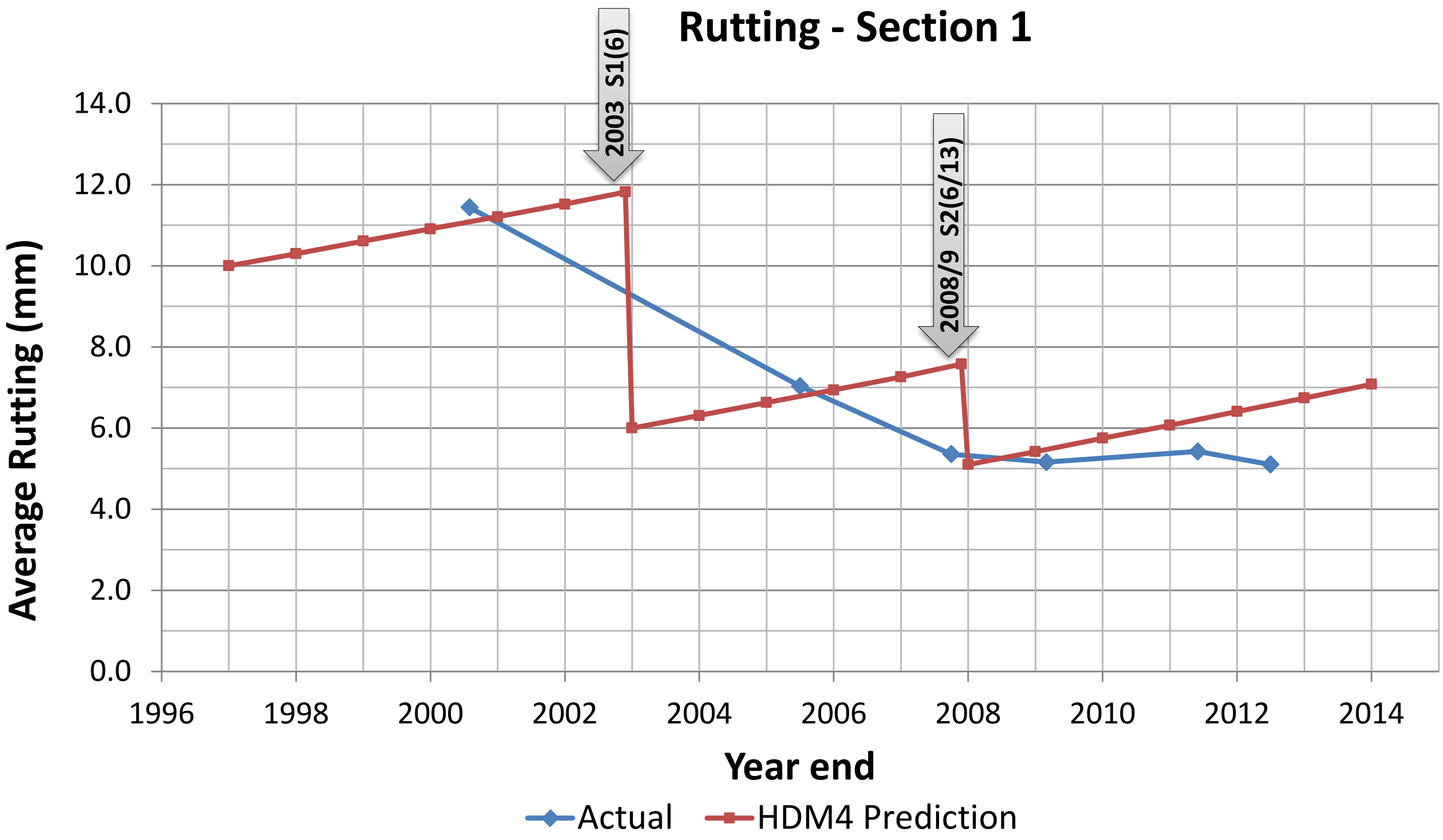
Comparison of predicted with actual performance



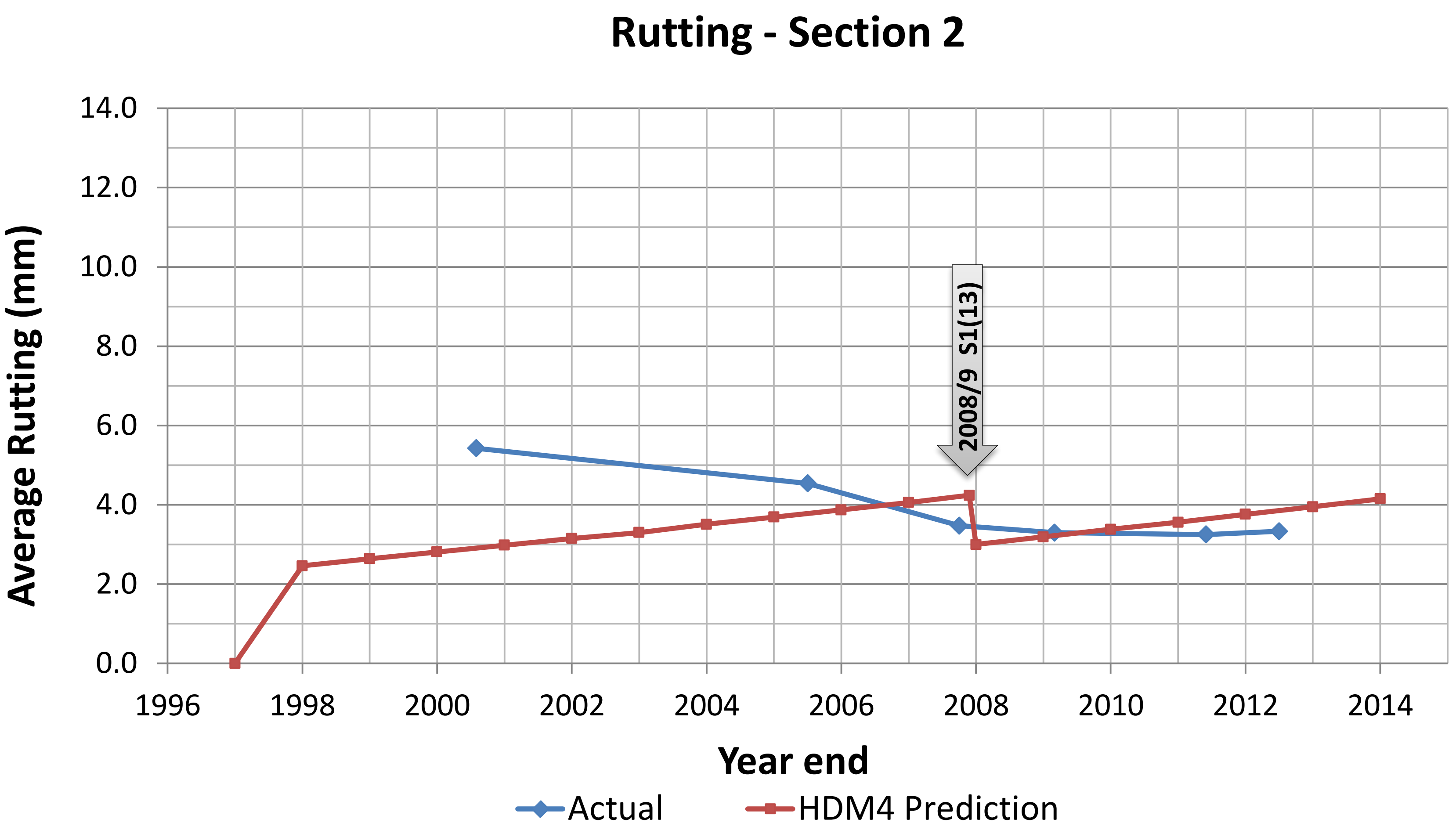
Comparison of predicted with actual performance



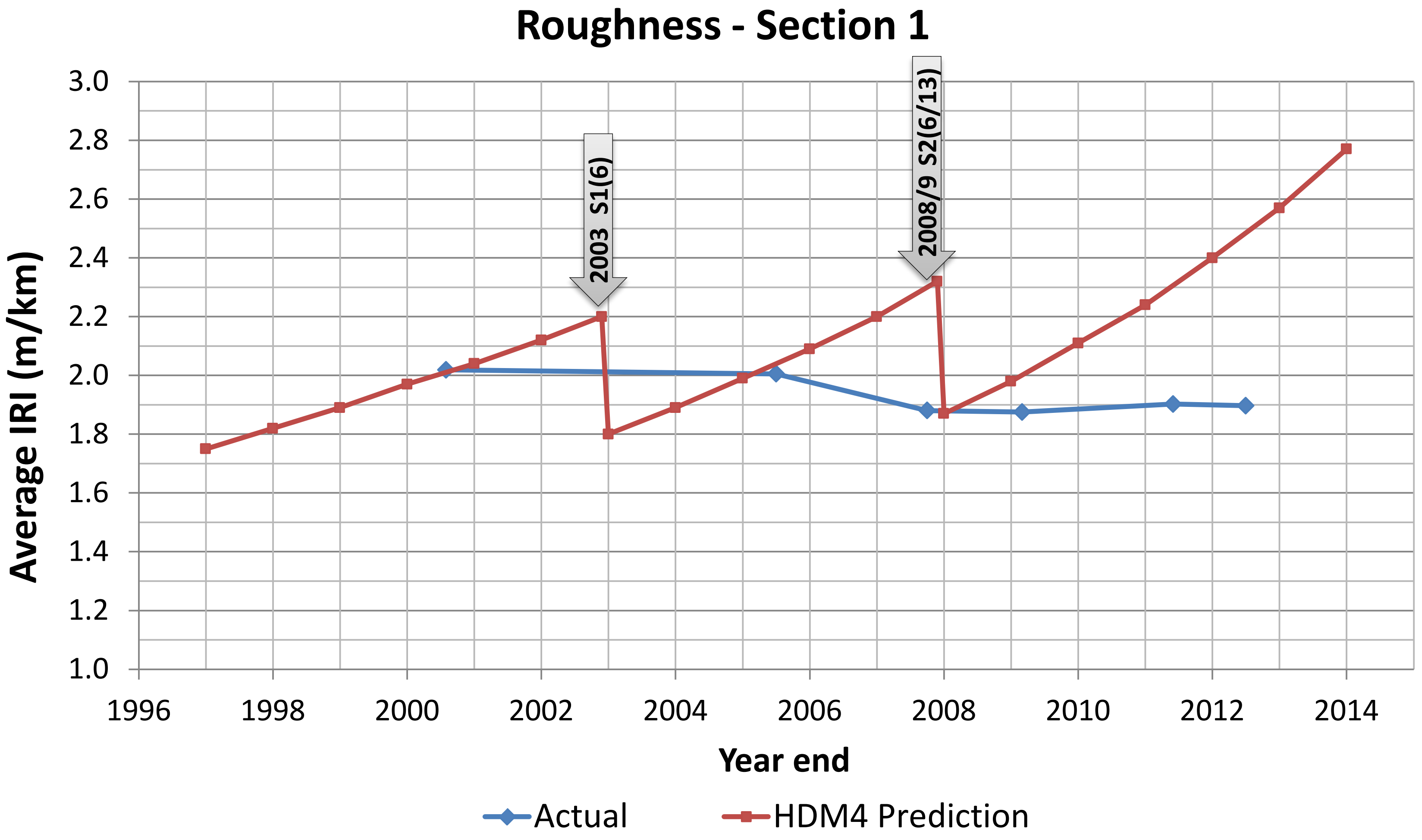
Comparison of predicted with actual performance



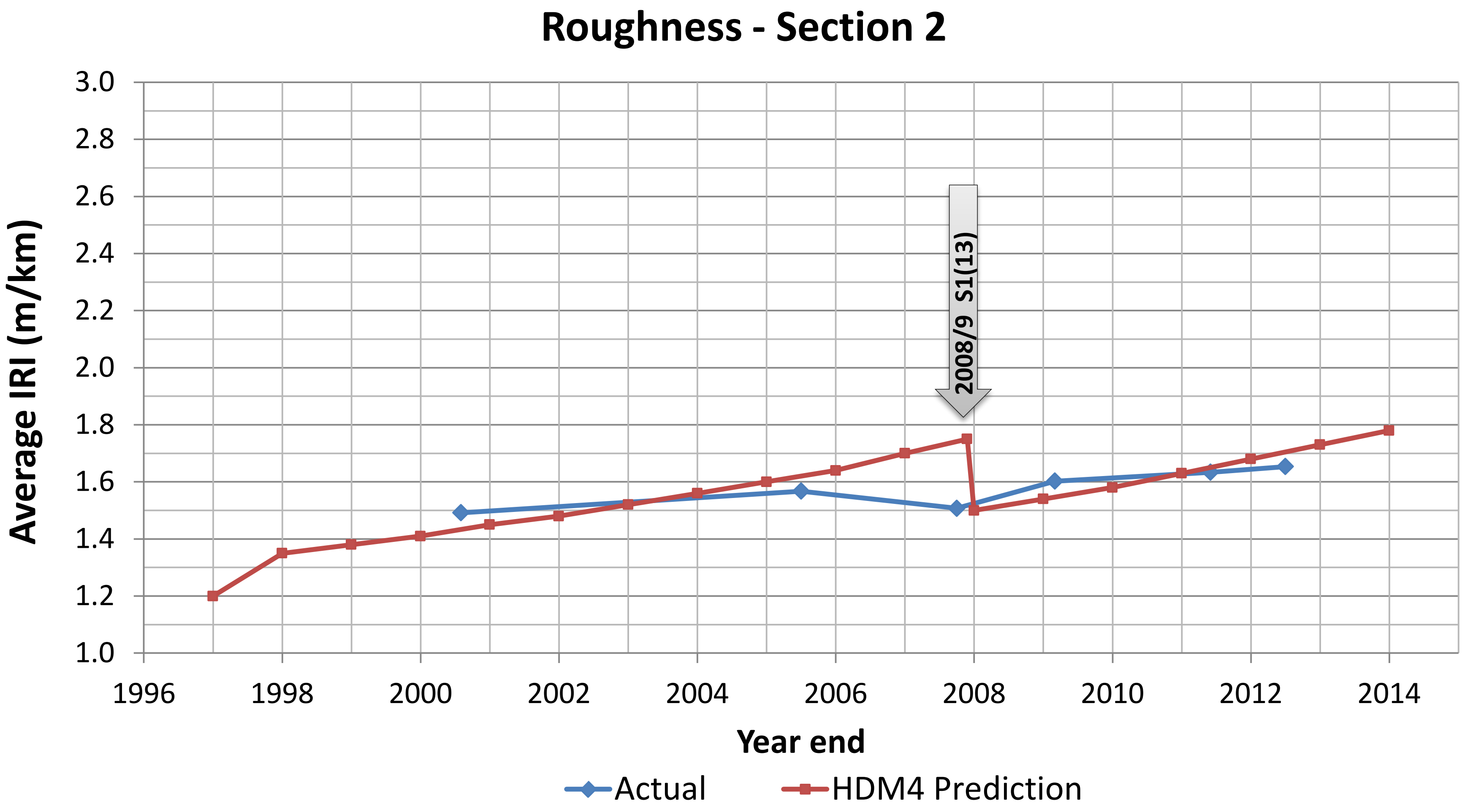
Comparison of predicted with actual performance



Comparison of predicted with actual performance



Comparison of predicted with actual performance

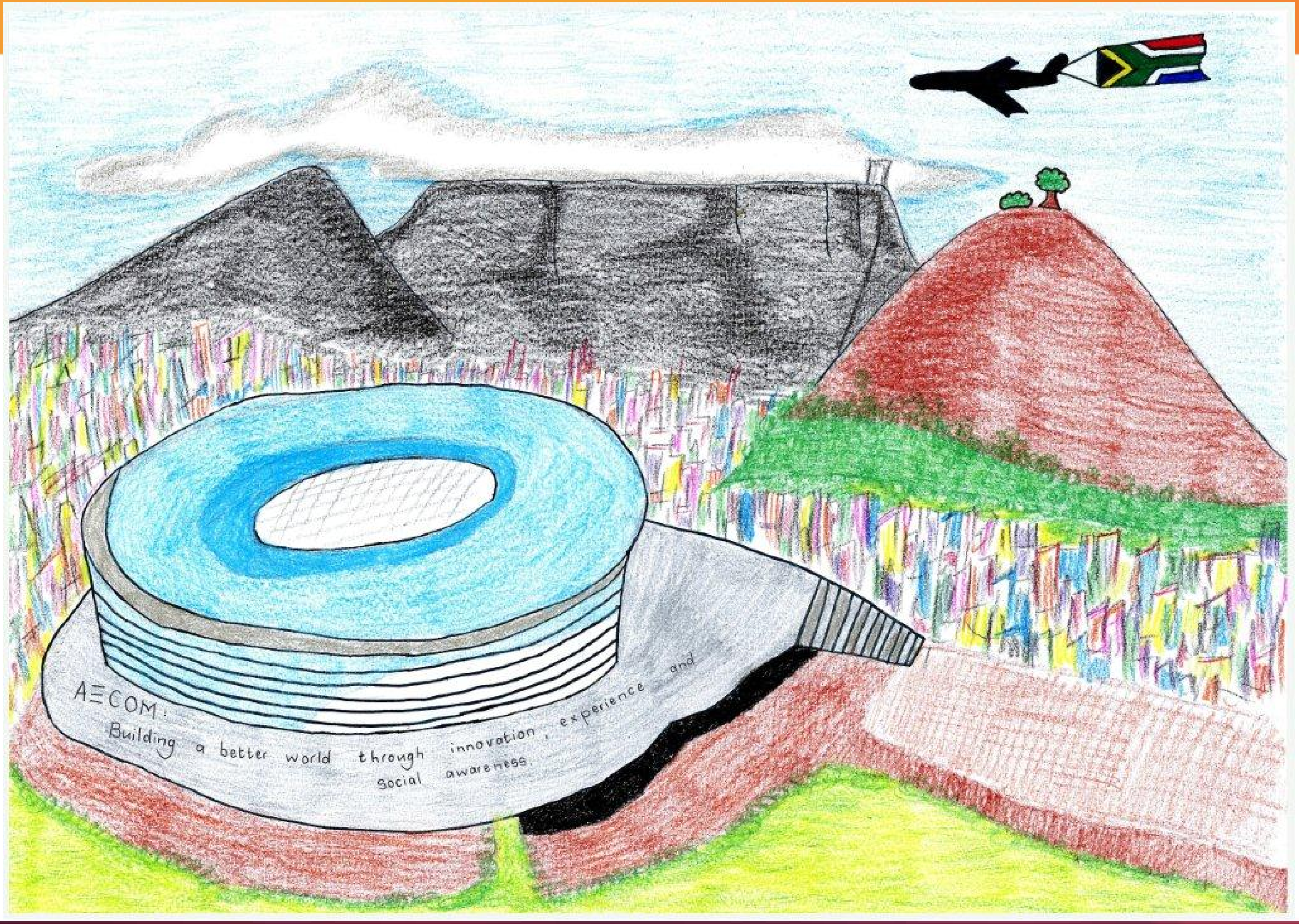


Comparison of predicted with actual performance

- **Concluding remarks**
  - The predictions are of the same order of magnitude than the actual measurements, but the rate of distress development differs
  - Some measurement data (instrument and visual data) are inconsistent; this influence comparability

- **Suggestions to improve comparability**
  - Deterioration modelling calibration factors are to be adjusted and/or calibrated with actual performance
  - Heavy vehicles; structural distresses pre-dominantly in slow lane - recommend modelling of slow lanes only
  - Accuracy of field measurements can be improved by ensuring calibration of equipment, diligent quality control, independent verification of visual assessments and use of laser technology to detect cracked areas

Thank You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