Revision of the South African Pavement Design Method

SAPDM: Environmental Monitoring

RPF, Pretoria
6-7 November 2012
Project SAPDM/E-1

P Paige-Green
Presented by R Leyland

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Objectives

- Monitor seasonal road/air temperature & moisture changes
- Current status
  - Matrix developed
  - Sites selected, inspected and 43 (39) installed
  - Test pitting done at 27 sites (32 by next week)

Site 28

Current matrix (Granular)

Climate		Good		Poor	
		Deep	Shallow	Deep	Shallow
Arid			N1-8 (24) Beaufort North	N00106N (25) Leeu-Gamka	N01402 (8) Kakamas
Semi-arid		N00808E (27) Kimberly	N00125N (19) (Pietersburg) (actually dry sub humid outlier but Semi-arid region)	N00112S (23) Colesberg	N00113S (22) Gariepdam
Dry sub Humid		N4 01E (1) Pretoria N1-18N (12) Kroonvaal	N00412E (2) Pelindaba	N01217N (11) Potch SS91 (42) Bethlehem	N01217N (10) Potchefstroom
Moist sub humid		N00229N	N00222N N01103N		N01103N,
Humid		N00228N	N00125N (18) (Potgietersrus)		P10/2 (43) Bergville

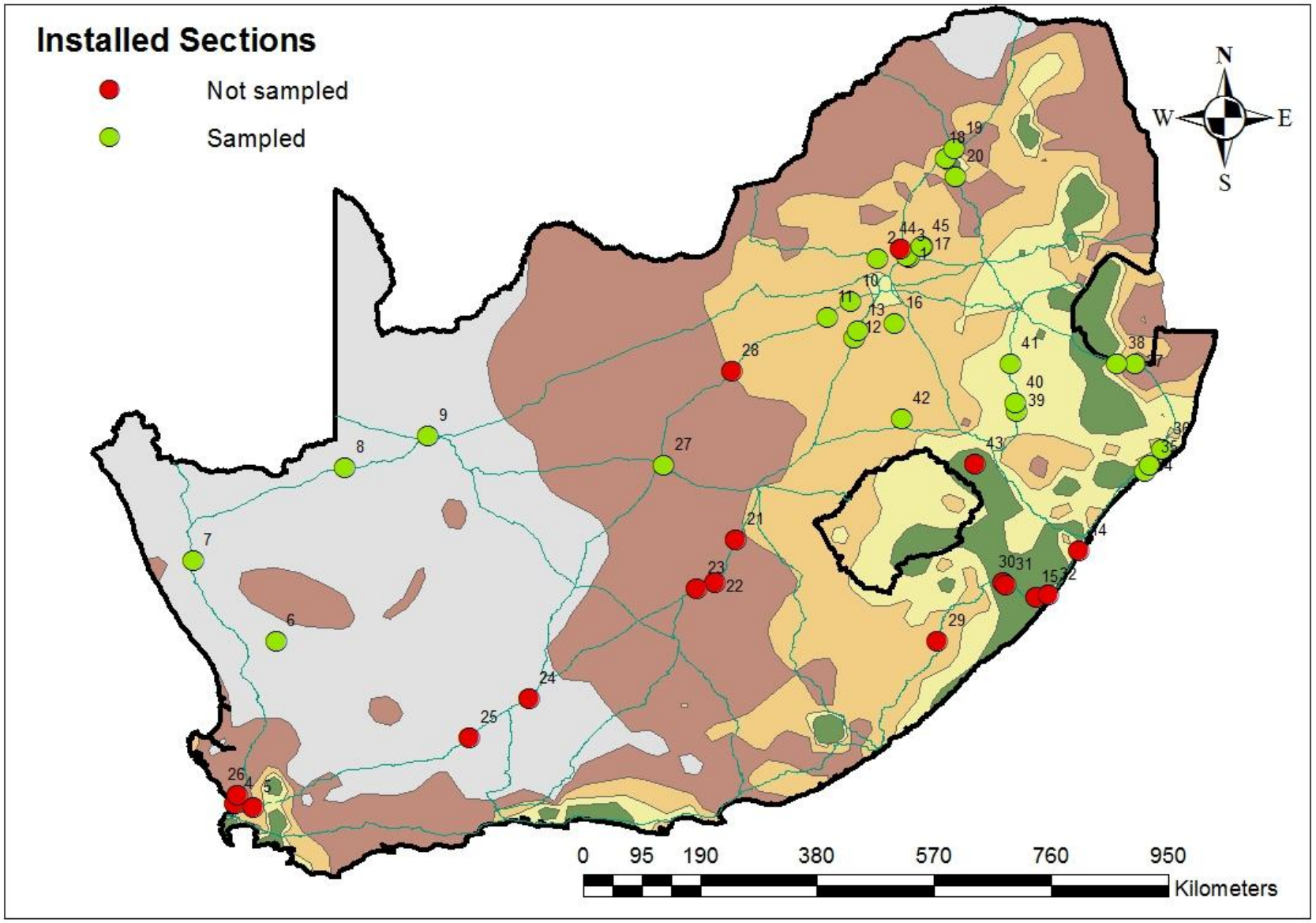
Current matrix (Treated)

Climate	Young		Old	
	Good	Poor	Good	Poor
Arid	R27-8 (6) Niewoudtville		N7-7 (7) Kamieskroon	N01405E (9) (Upington)
Semi-arid	N00114S (Trompsburg FS) EBT/cem?		N7-1 (4) Malmesbury	N011-12N (20) (Roedtan) Actually Dry sub humid but close)
Dry sub humid			N00401 on ramp (3) (Pretoria) P243/1 (16) Vereeniging LTPP R2388 (17) Cullinan LTPP	N00101 (5) Paarl
Moist sub humid			N00224N (14) (Amanzimtoti)	
Humid	N00222N (15) (Paddock KZN)			

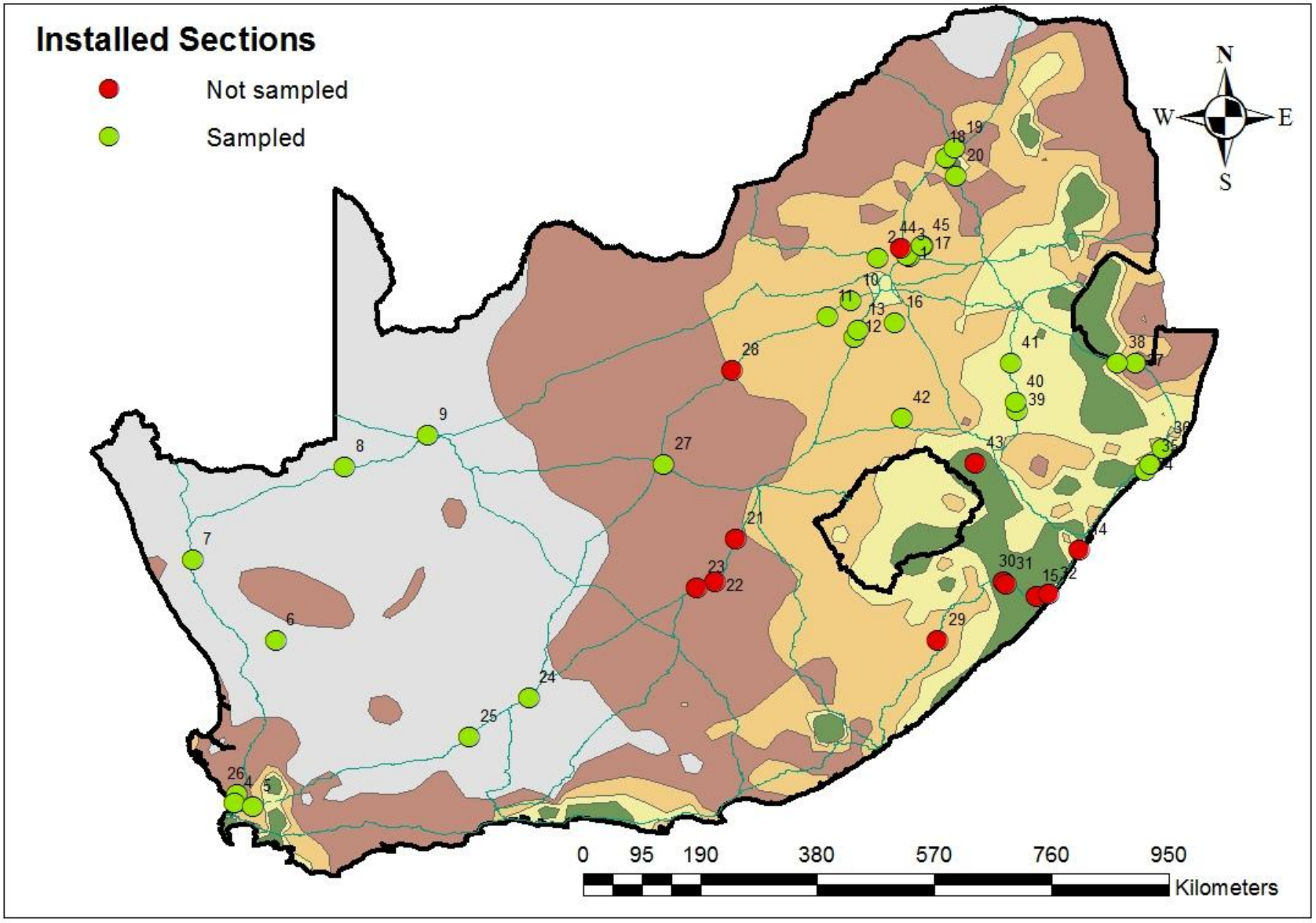
Current matrix (Asphalt)

Climate		Good		Poor	
		Deep	Shallow	Deep	Shallow
Arid					
Semi-arid			N00701N (26) Malmesbury		N01214N (28) Bloemhof (very close to dry sub humid)
Dry sub Humid			N00118N (13) Vaal plaza		N00219E
Moist sub humid			N00229N		
Humid			N00221N		N00221N

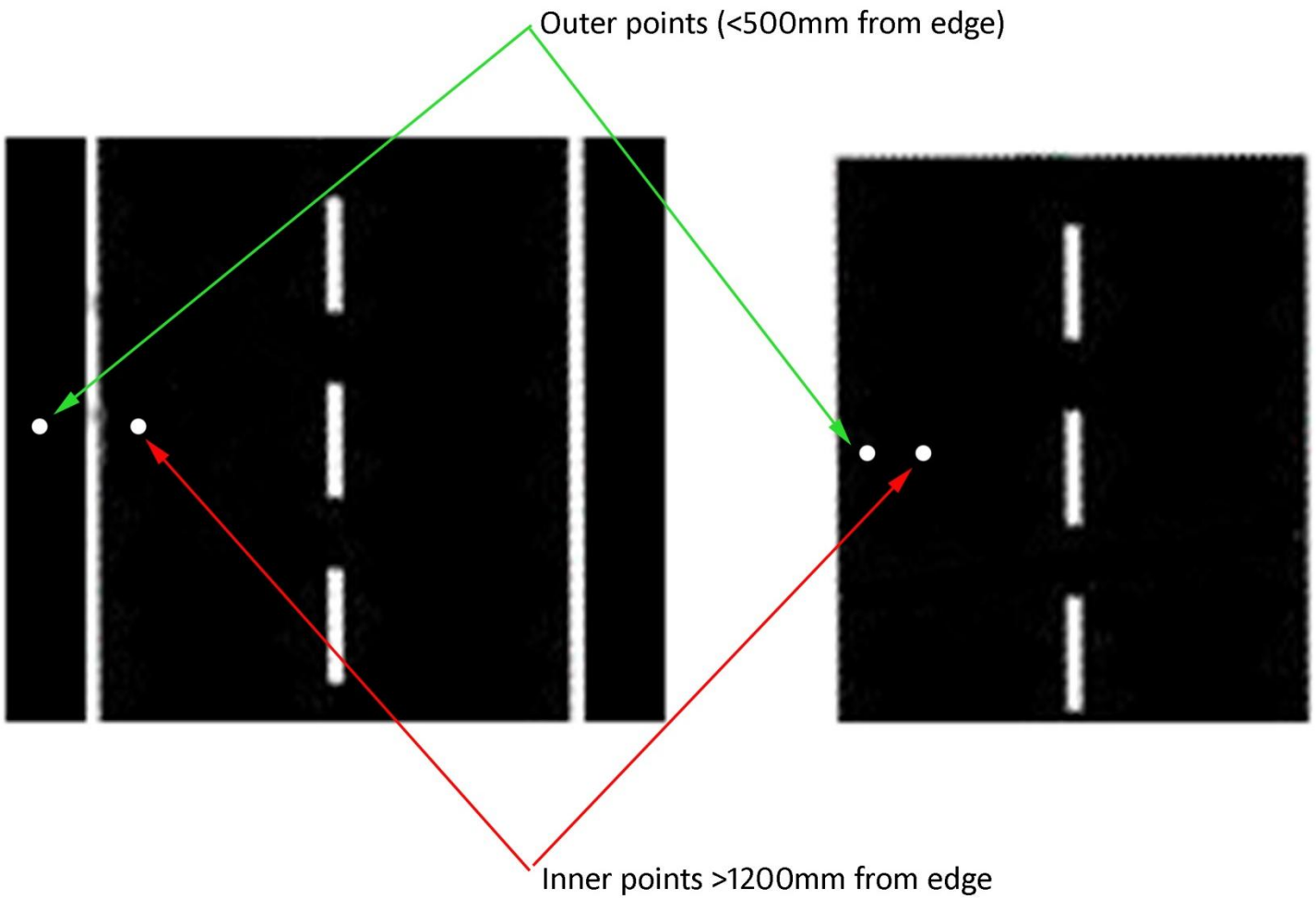
Current sites



Current sites



MC & Temperature monitoring

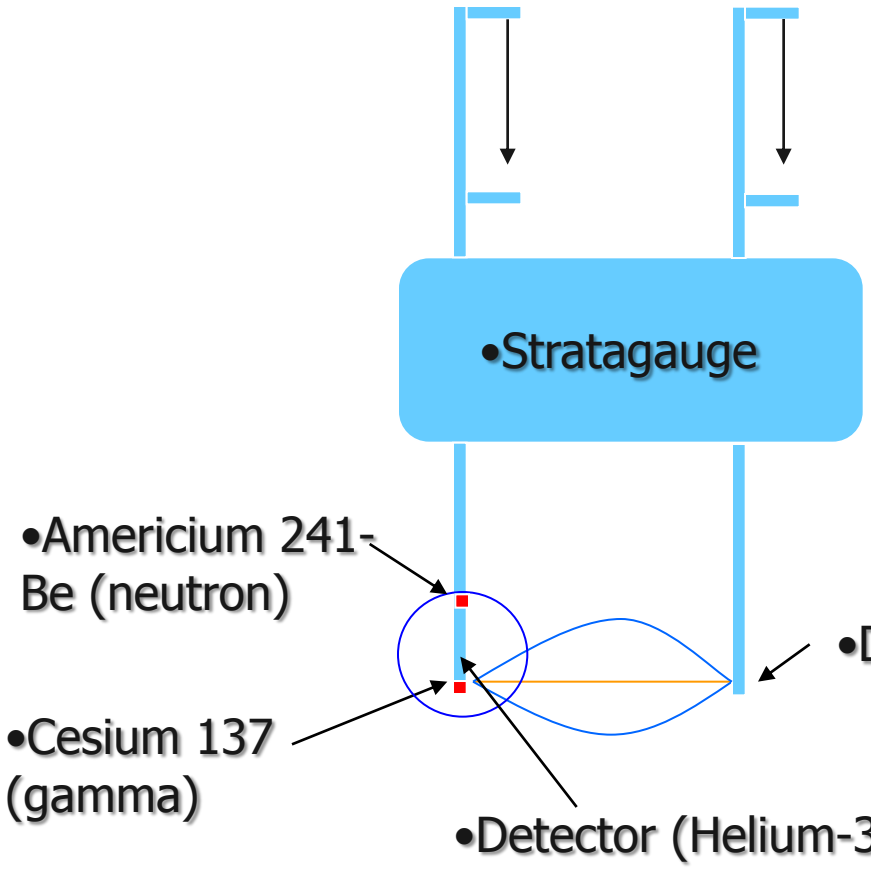


Temperature at 20 and 200 mm (between two points) and ambient air (shade)

Monitoring

- ± Once every 5 weeks (between 4 & 19 times)
- Moisture content & wet density using Stratagauge
- Temperature buttons

Stratagauge



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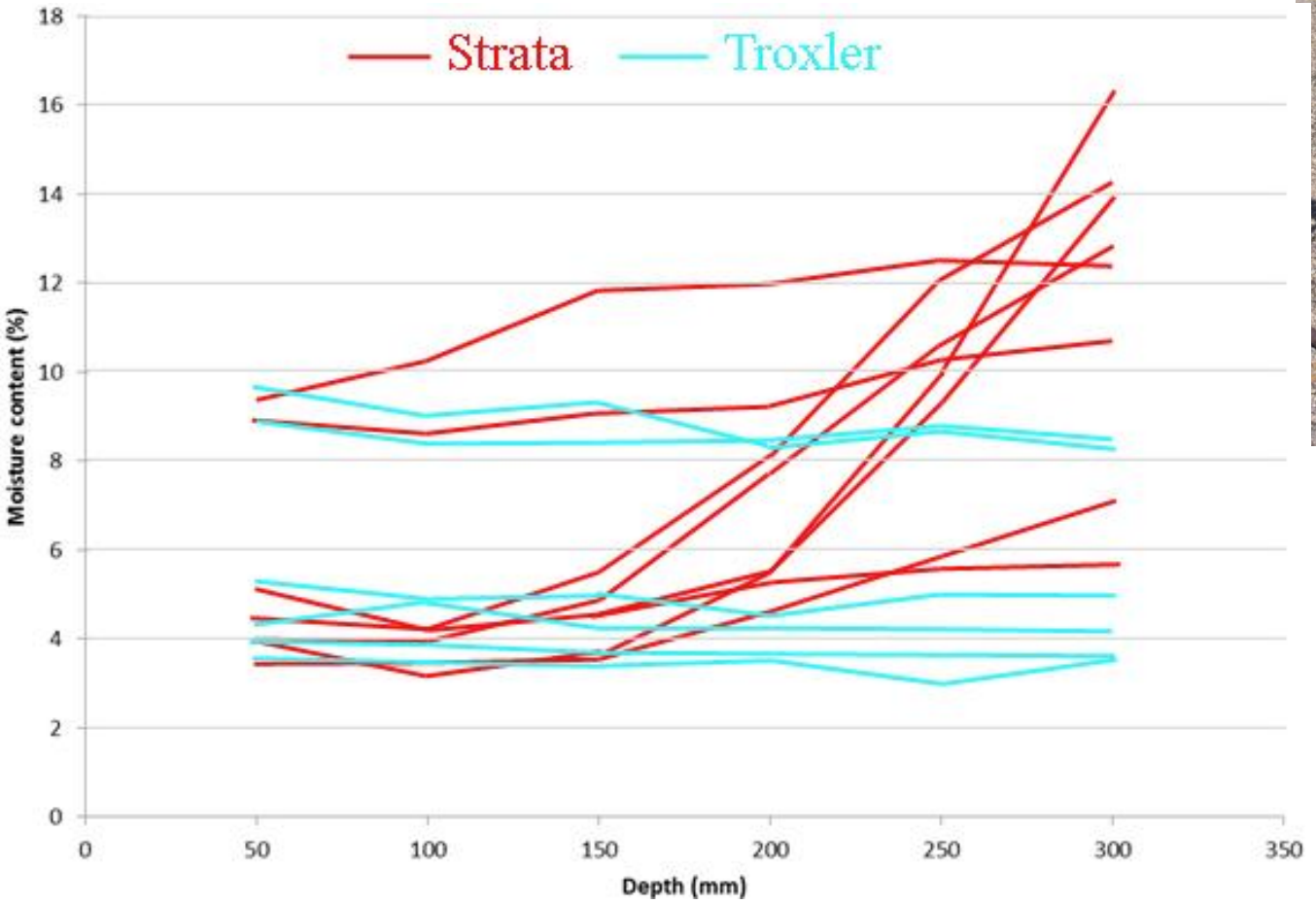
Moisture content measurement

- Poor correlation between Troxler & StrataGauge
- Also at R35
- Compared results



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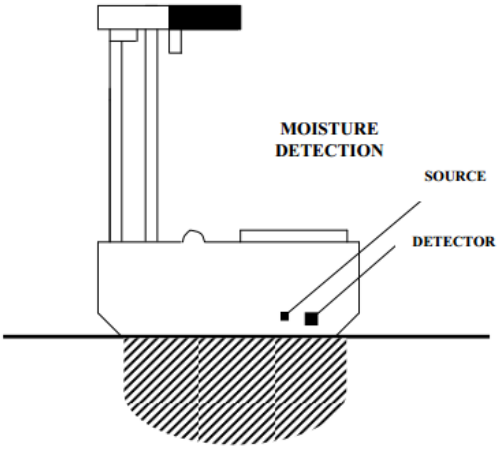
Moisture reading mechanisms



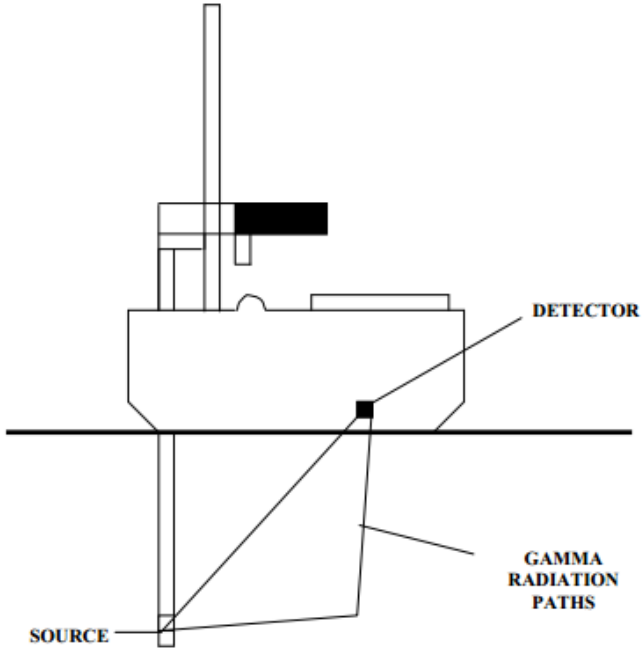
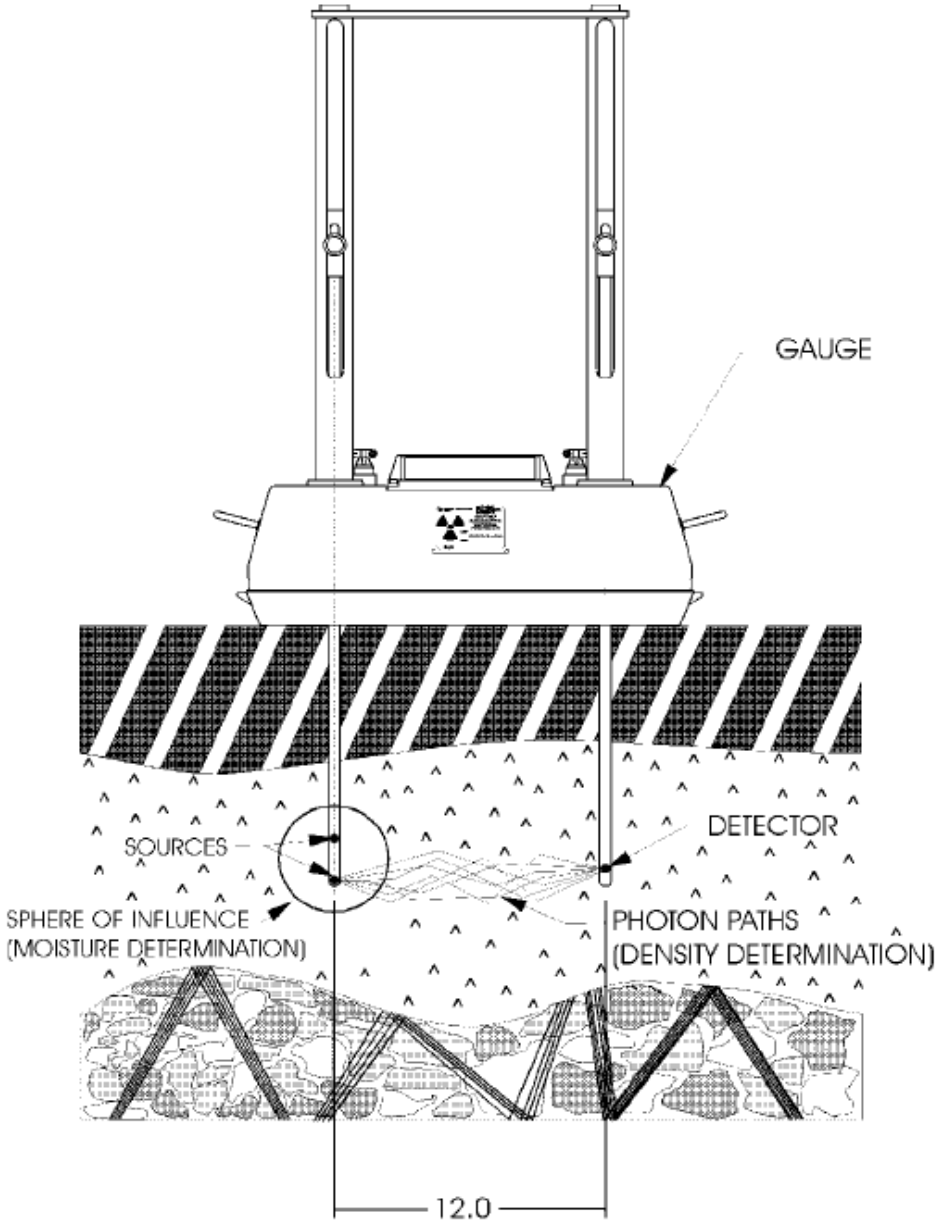
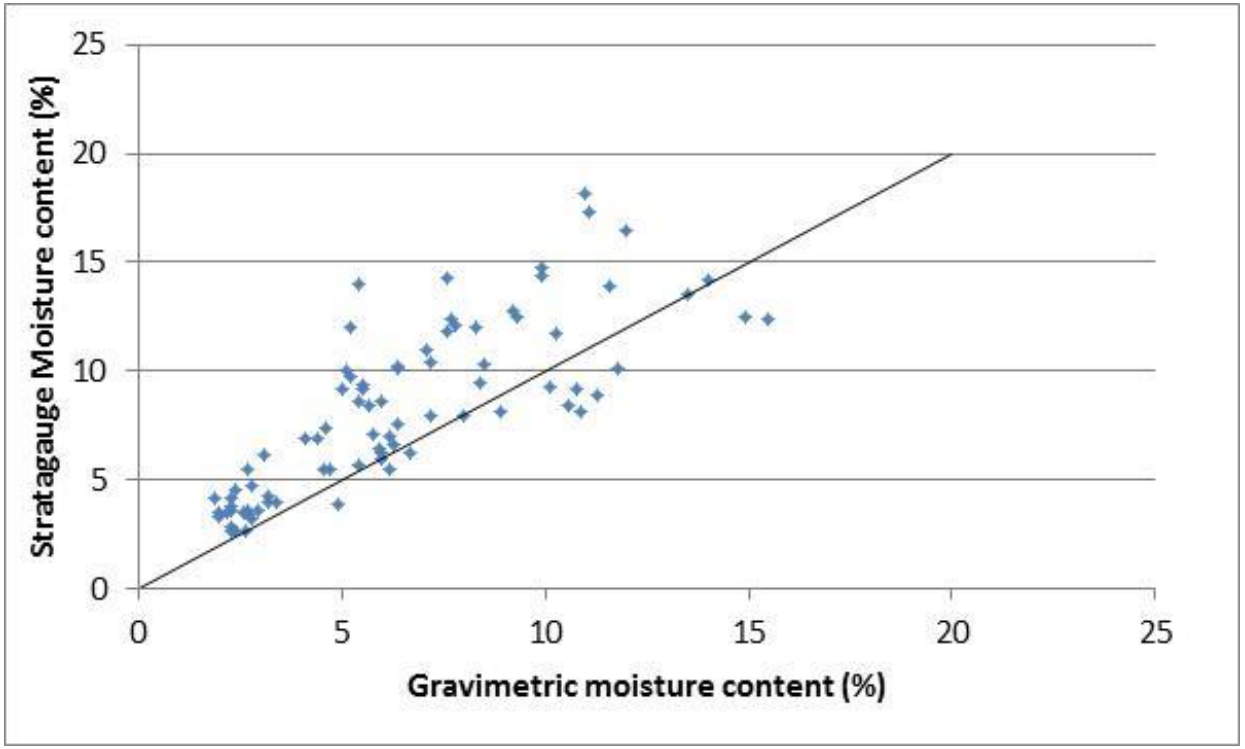


Figure 1: Direct Transmission Mode



Typical analysis



- Depth of measurement (mm) = 280 – (0.27m)

where m = moisture in kg/m^3

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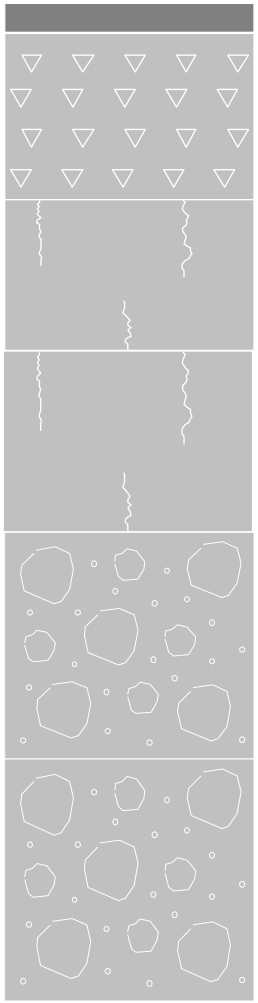
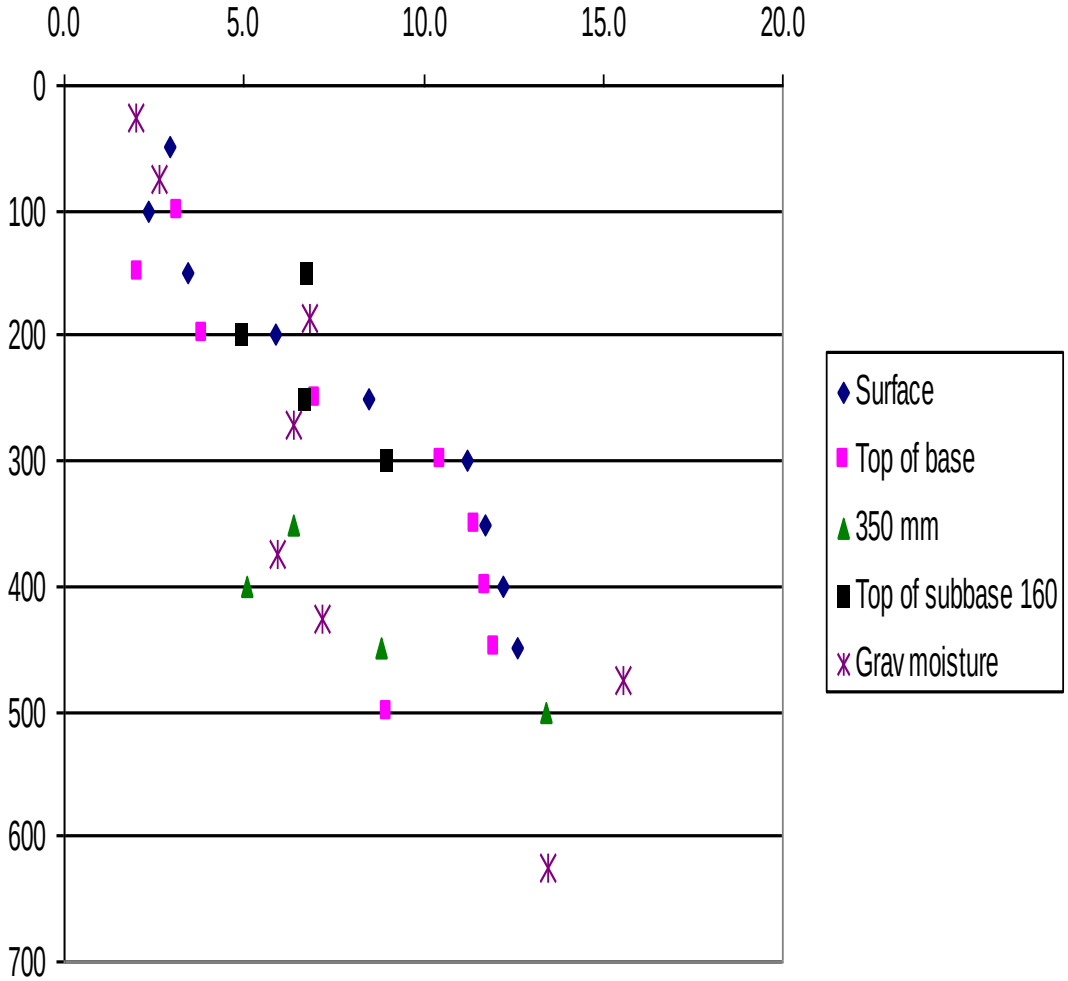
Stratagauge & gravimetric MC

- 30 mm AC
- 125 mm G1
- 125 mm C2
- 125 mm C2
- 150 mm G5
- 150 mm G5





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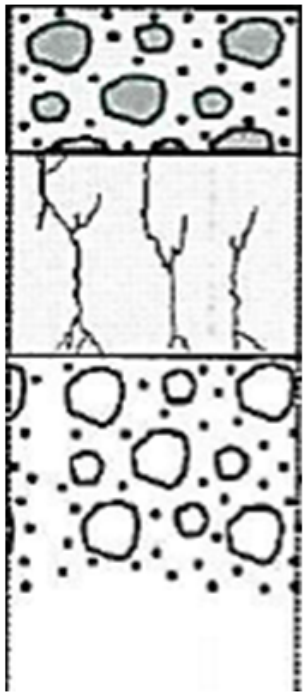
SANRAL MONITORING SITES — PTA area — Day trip — Cape trip — KZN trip

Site No.	Nearest Town	Road No.	Kilo Post	Elevation Metres	Date Installed	Follow up Dates																				
1	Silver lakes	N4-1	24.0E	1300	15/01/2010	09/03/2010	14/04/2010	08/06/2010	12/08/2010	29/09/2010	18/11/2010	14/01/2011	04/03/2011	19/04/2011	28/06/2011	09/09/2011	14/10/2011	05/12/2011	15/01/2012	17/02/2012	26/05/2012	02/07/2012	13/08/2012			
2	Pelindaba	N4-12	11.9E	1200	09/03/2010	15/04/2010	08/06/2010	11/08/2010	30/09/2010	05/11/2010	13/01/2011	25/02/2011	20/04/2011	03/06/2011	13/09/2011	14/10/2011	06/12/2011	15/01/2012	17/02/2012	26/05/2012	29/06/2012	12/08/2012				
3	Hans Strydom	N4-1 (onramp)	20.6E	1300	14/04/2010	08/06/2010	12/08/2010	29/09/2010	18/11/2010	14/01/2011	04/03/2011	19/04/2011	28/06/2011	09/09/2011	14/10/2011	05/12/2011	15/01/2012	17/02/2012	26/05/2012	02/07/2012	13/08/2012					
4	Cape Town (WB)	N7	South	62.8	25/05/2010	20/07/2010	31/08/2010	15/11/2010	23/01/2011	06/03/2011	13/04/2011	13/06/2011	06/09/2011	28/11/2011	25/01/2012	22/02/2012	30/03/2012	30/05/2012	16/07/2012	16/08/2012						
5	Paarl	N1-1	35.0S	162.1	25/05/2010	20/07/2010	31/08/2010	15/11/2010	23/01/2011	06/03/2011	13/04/2011	13/06/2011	06/09/2011	18/10/2011	28/11/2011	25/01/2012	22/02/2012	18/03/2012	30/05/2012	16/07/2012	16/08/2012					
6	Nieuwoutsville	R27-8	3.2E	732.9	26/05/2010	21/07/2010	31/08/2010	11/11/2010	23/01/2011	09/03/2011	13/04/2011	11/06/2011	06/09/2011	25/11/2011	24/01/2012	21/02/2012	21/03/2012	29/05/2012	13/07/2012	16/08/2012						
7	Kammieskroon	N7-7	47.1N	757.6	27/05/2010	21/07/2010	01/09/2010	11/11/2010	23/01/2011	09/03/2011	12/04/2011	10/06/2011	05/09/2011	24/11/2011	24/01/2012	21/02/2012	21/03/2012	29/05/2012	11/07/2012	15/08/2012						
8	Kakamas	N14-2	83.0E	853.3	27/05/2010	22/07/2010	01/09/2010	10/11/2010	22/01/2011	10/03/2011	12/04/2011	10/06/2011	05/09/2011	24/11/2011	23/01/2012	20/02/2012	21/03/2012	28/05/2012	11/07/2012	15/08/2012						
9	Upington	N14-5	16.4E	851.8	28/05/2010	22/07/2010	02/09/2010	10/11/2010	22/01/2011	10/03/2011	12/04/2011	10/06/2011	05/09/2011	24/11/2011	23/01/2012	20/02/2012	22/03/2012	28/05/2012	09/07/2012	14/08/212						
10	Potchefstroom (1)	N12-17	59.758W	1600	01/06/2010	23/07/2010	03/09/2010	09/11/2010	21/01/2011	11/03/2011	11/04/2011	09/06/2011	04/05/2011	23/11/2011	22/01/2012	19/02/2012	14/03/2012	27/05/2012	08/07/2012	13/08/2012						
11	Potchefstroom (2)	N12-17	14.2W	1400	01/06/2010	23/07/2010	03/09/2010	09/11/2010	21/01/2011	11/03/2011	11/04/2011	09/06/2011	04/05/2011	23/11/2011	22/01/2012	19/02/2012	15/03/2012	27/05/2012	08/07/2012	13/08/2012						
12	Kroonvaal Plaza	N1-18	56.6N	1500	01/06/2010	18/07/2010	29/08/2010	17/11/2010	25/01/2011	04/03/2011	15/04/2011	15/06/2011	09/09/2011	16/10/2011	30/11/2011	27/01/2012	24/02/2012	18/03/2012	01/06/2012	04/07/2012	18/08/2012					
13	Vaal Plaza	N1-18	71.1N	1500	01/06/2010	18/07/2010	29/08/2010	17/11/2010	25/01/2011	04/03/2011	15/04/2011	15/06/2011	09/09/2011	16/10/2011	30/11/2011	27/01/2012	24/02/2012	18/03/2012	01/06/2012	04/07/2012	18/08/2012					
14	Amanzimtoti	N2-24	19.2N	35.4	23/06/2010	03/08/2010	14/09/2010	03/11/2010	11/01/2011	23/02/2011	07/04/2011	01/06/2011	30/08/2011	11/10/2011	14/12/2011	12/01/2012	14/02/2012	28/03/2012	23/05/2012	26/06/2012	10/08/2012					
15	Paddock	N2-22	10.5N	481.6	23/06/2010	02/08/2010	13/09/2010	03/11/2010	10/01/2011	22/02/2011	06/04/2011	31/05/2011	29/08/2011	10/10/2011	14/12/2011	12/01/2012	13/02/2012	27/03/2012	23/05/2012	26/06/2012	10/08/2012					
16	Vereeniging	P243	14.5W	1500	24/06/2010	01/08/2010	12/09/2010	17/11/2010	09/01/2011	21/02/2011	03/04/2011	30/05/2011	09/09/2011	09/10/2011	13/11/2011	10/01/2012	12/02/2012	26/03/2012	21/05/2012	24/06/2012	06/08/2012					
17	Brandbach	R2388	3.2W	1300	24/06/2010	12/08/2010	29/09/2010	18/11/2010	14/01/2011	04/03/2011	19/04/2011	28/06/2011	09/09/2011	14/10/2011	05/12/2011	15/01/2012	17/02/2012	05/04/2012	26/05/2012	02/07/2012	13/08/2012					
18	Potgietersrus	N1-25	52.4N	1100	25/06/2010	11/08/2010	30/09/2010	05/11/2010	13/01/2011	25/02/2011	20/04/2011	03/06/2011	01/09/2011	13/10/2011	07/12/2011	14/01/2012	16/02/2012	13/03/2012	25/05/2012	29/06/2012	12/08/2012					
19	Pietersburg	N1-25	72.4N	1300	25/06/2010	11/08/2010	30/09/2010	05/11/2010	13/01/2011	25/02/2011	20/04/2011	03/06/2011	01/09/2011	13/10/2011	07/12/2011	14/01/2012	16/02/2012	12/03/2012	25/05/2012	29/06/2012	12/08/2012					
20	Roedan	N11-12	53.0S	958.5	25/06/2010	11/08/2010	30/09/2010	05/11/2010	13/01/2011	25/02/2011	20/04/2011	03/06/2011	01/09/2011	13/10/2011	07/12/2011	14/01/2012	16/02/2012	13/03/2012	25/05/2012	28/06/2012	12/08/2012					
21	Trompsburg North	N1-14	37.2S	1400	19/07/2010	30/08/2010	16/11/2010	24/01/2011	05/03/2011	14/04/2011	14/06/2011	08/09/2011	17/10/2011	30/11/2011	26/01/2012	23/02/2012	18/03/2012	31/05/2012	18/06/2012	18/08/2012						
22	Gariep Dam	N1-13	16.2S	1300	19/07/2010	30/08/2010	16/11/2010	24/01/2011	05/03/2011	14/04/2011	14/06/2011	08/09/2011	17/10/2011	30/11/2011	26/01/2012	23/02/2012	18/03/2012	31/05/2012	18/06/2012	18/08/2012						
23	Colesburg	N1-12	24.98S	1200	19/07/2010	30/08/2010	16/11/2010	24/01/2011	05/03/2011	14/04/2011	14/06/2011	08/09/2011	17/10/2011	30/11/2011	26/01/2012	23/02/2012	18/03/2012	31/05/2012	18/06/2012	18/08/2012						
24	Beaufort North	N1-8	30.2N	972.8	20/07/2010	30/08/2010	16/11/2010	24/01/2011	05/03/2011	14/04/2011	14/06/2011	07/09/2011	17/10/2011	29/11/2011	26/01/2012	23/02/2012	19/03/2012	31/05/2012	18/06/2012	17/08/2012						
25	Leeu-Gamka	N1-6	38.03N	547.8	20/07/2010	30/08/2010	16/11/2010	24/01/2011	05/03/2011	14/04/2011	14/06/2011	07/09/2011	18/10/2011	29/11/2011	25/01/2012	22/02/2012	19/03/2012	30/05/2012	17/07/2012	17/08/2012						
26	Malmesbury	N7-1	30.4N	89.7	21/07/2010	31/08/2010	15/11/2010	23/01/2011	06/03/2011	13/04/2011	12/06/2011	06/09/2011	28/11/2011	25/01/2012	21/02/2012	20/03/2012	30/05/2012	16/07/2012	16/08/2012							
27	Kimberley (to Bloem)	N8-8	5.6E	1200	23/07/2010	02/09/2010	09/11/2010	22/01/2011	10/03/2011	11/04/2011	09/06/2011	04/09/2011	23/11/2011	23/01/2012	19/02/2012	22/03/2012	27/05/2012	08/07/2012	14/08/2012							
28	Bloemhof	N12-14	34.0S	1300	23/07/2010	03/09/2010	09/11/2010	21/01/2011	11/03/2011	Site Gone																
29	Umtata (Mthatha)	N2-19	26.0N	1100	02/08/2010	13/09/2010	02/11/2010	10/01/2011	22/02/2011	06/04/2011	31/05/2011	29/08/2011	10/10/2011	14/11/2011	11/01/2012	13/02/2012	27/03/2012	22/05/2012	25/06/2012	09/08/2012						
30	Staffords Post 1	N2-21	45.8N	1100	02/08/2010	13/09/2010	02/11/2010	10/01/2011	22/02/2011	06/04/2011	31/05/2011	29/08/2011	10/10/2011	14/11/2011	11/01/2012	13/02/2012	27/03/2012	22/05/2012	25/06/2012	10/08/2012						
31	Staffords Post 2	N2-21	50.8N	997.4	0208/2010	13/09/2010	02/11/2010	10/01/2011	22/02/2011	06/04/2011	31/05/2011	29/08/2011	10/10/2011	14/11/2011	11/01/2012	13/02/2012	27/03/2012	23/05/2012	26/06/2012	10/08/2012						
32	Marburg	N2-22	35.0N	44.6	03/08/2010	14/09/2010	03/11/2010	10/01/2011	22/02/2011	06/04/2011	31/05/2011	29/08/2011	10/10/2011	14/12/2011	11/01/2012	13/02/2012	27/03/2012	23/05/2012								
33	Mtunzini 1	N2-28	43.2N	33.3	03/08/2010	14/09/2010	03/11/2010	No more a Site																		
34	Mtunzini 2	N2-28	56.04N	41.7	03/08/2010	14/09/2010	03/11/2010	11/01/2011	23/02/2011	07/04/2011	01/06/2011	30/08/2011	11/10/2011	14/12/2011	12/01/2012	14/02/2012	28/03/2012	23/05/2012	26/06/2012	10/08/2012						
35	Mhlatuzi	N2-29	4.087	34.1	03/08/2010	14/09/2010	03/11/2010	11/01/2011	23/02/2011	07/04/2011	01/06/2011	30/08/2011	11/10/2011	14/12/2011	12/01/2012	14/02/2012	28/03/2012	23/05/2012	27/06/2012	10/08/2012						
36	Mapelane	N2-29	39.8N	77.6	04/08/2010	15/09/2010	03/11/2010	11/01/2011	23/02/2011	07/04/2011	01/06/2011	30/08/2011	11/10/2011	14/12/2011	12/01/2012	14/02/2012	28/03/2012	23/05/2012	27/06/2012	10/08/2012						
37	Pongola 1	N2-32	16.35N	257.7	04/08/2010	15/09/2010	04/11/2010	11/01/2011	23/02/2011	07/04/2011	01/06/2011	30/08/2011	11/10/2011	14/12/2011	12/01/2012	14/02/2012	28/03/2012	24/05/2012	27/06/2012	11/08/2012						
38	Pongola 2	N2-32	49.51N	577.3	04/08/2010	15/09/2010	04/11/2010	11/01/2011	23/02/2011	07/04/2011	02/06/2011	31/08/2011	12/10/2011	13/12/2011	13/01/2012	15/02/2012	29/03/2012	24/05/2012	27/06/2012	11/08/2012						
39	Kalabas River	N11-3	25.4N	1300	05/08/2010	16/09/2010	01/11/2010	12/01/2011	24/02/2011	08/04/2011	02/06/2011	31/08/2011	12/10/2011	13/12/2011	13/01/2012	15/02/2012	29/03/2012	24/05/2012	28/06/2012	11/08/2012						
40	Newcastle	N11-3	40.2N	1200	05/08/2010	16/09/2010	01/11/2010	12/01/2011	24/02/2011	08/04/2011	02/06/2011	31/08/2011	12/10/2011	13/12/2011	13/01/2012	15/02/2012	29/03/2012	24/05/2012	28/06/2012	11/08/2012						
41	Volksrust	N11-5	5.2N	1800	05/08/2010	16/09/2010	01/11/2010	12/01/2011	24/02/2011	08/04/2011	02/06/2011	31/08/2011	12/10/2011	13/12/2011	13/01/2012	15/02/2012	29/03/2012	24/05/2012	28/06/2012	11/08/2012						
42	Bethlehem	S191	8.2S	1600	09/01/2011	21/02/2011	04/04/2011	30/05/2011	28/08/2011	09/10/2011	13/11/2011	10/01/2012	12/02/2012	26/02/2012	21/05/2012	24/06/2012	06/08/2012									
43	Bergville	P10/2	10.55E	1200	09/01/2011	21/02/2011	05/04/2011	30/05/2011	28/08/2011	09/10/2011	13/11/2011	10/01/2012	12/02/2012	26/02/2012	21/05/2012	24/06/2012	06/08/2012									
44	Pumulani Plaza	N1-22	2.4N	1200	06/12/2011	17/01/2011	17/02/2012	20/08/2012																		
45	Brandbach	R2388	W	1400	19/01/2012	17/02/2012	05/04/2012	26/05/2012	02/07/2012	13/08/2012																

Typical analysis

- Site 17 Brandbach – R2388
- Old HVS site
  - Labour based with emulsion treated ash



100 mm Emulsion treated Sasol ash

125 mm cemented treated (C4) residual sandstone

Imported granular selected layer (G7) ferrugenised soil

SOIL PROFILE:

Dry, dark grey mottled white, loose, intact, sandy gravel. SASOL ASH.

Slightly moist, brown mottled white and red-brown, loose, intact, sandy coarse gravel with cobbles and boulders. Residual SANDSTONE

Moist, dark brown mottled red brown and orange, stiff, intact, sandy clay with ferricrete nodules. FERRUGENISED SOIL

Figure 1: Pavement structure at Brandbach (site 17)

Brandbach

- Testing
  - 3 points at each site tested in field
    - Stratagauge (Density & MC), Troxler, LWD, FWD, DCP
    - On each layer where appropriate
    - Moisture content and bulk samples of each layer
    - Undisturbed where possible for in situ bulk density
    - Profile
  - Laboratory testing
    - MDD and OMC
    - Grading and Atterbergs
    - BRD and ARD

DCP

- Results
  - Some quite consistent, others quite variable
    - Deep pavement
    - Base strength increases inwards (end of wet season)
    - Subgrade strengths surprisingly variable (opposite of base)

Property	Test 1	Test 2	Test 3
Location (from edge of seal) (mm)	250	750	1250
DSN_{800}	183	167	189
DN base (mm/blow)	3.34	2.66	2.41
CBR base (%)	89	118	134
DN subbase (mm/blow)	2.24	2.53	1.76
CBR subbase (%)	147	126	189
DN selected subgrade (mm/blow)	4.17	5.89	7.27
CBR selected subgrade (%)	67	43	33
Balance number (A)	2820	2390	3560
Balance number (B)	22	25	31

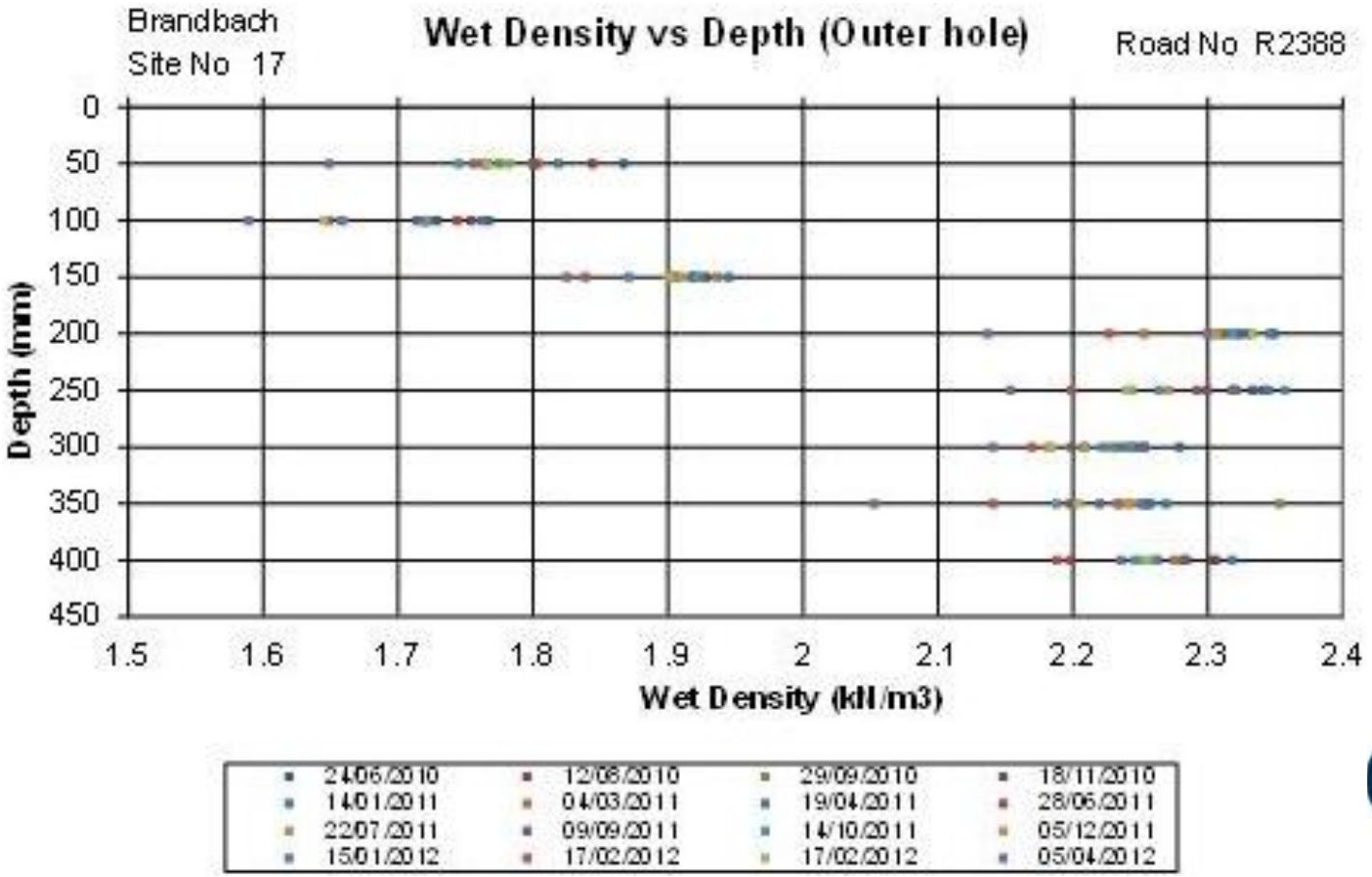
LWD

- Results
  - Some interesting aspects – not explained yet
    - Decrease in deflection at top of subbase
    - Relatively consistent at different positions on surface

Property	Position 1 (A)	Position 2 (B)	Position 3 (C)
Deflection (on asphalt) (µm)	425	439	429
Deflection at top of base (µm)	493	-	-
Deflection at top of subbase (µm)	270	-	-
Deflection at top of selected layer (µm)	538	-	-
Stiffness (on asphalt) (MPa)	209	205	210
Stiffness at top of base (MPa)	182	-	-
Stiffness at top of subbase (MPa)	342	-	-
Stiffness at top of selected layer (MPa)	167	-	-

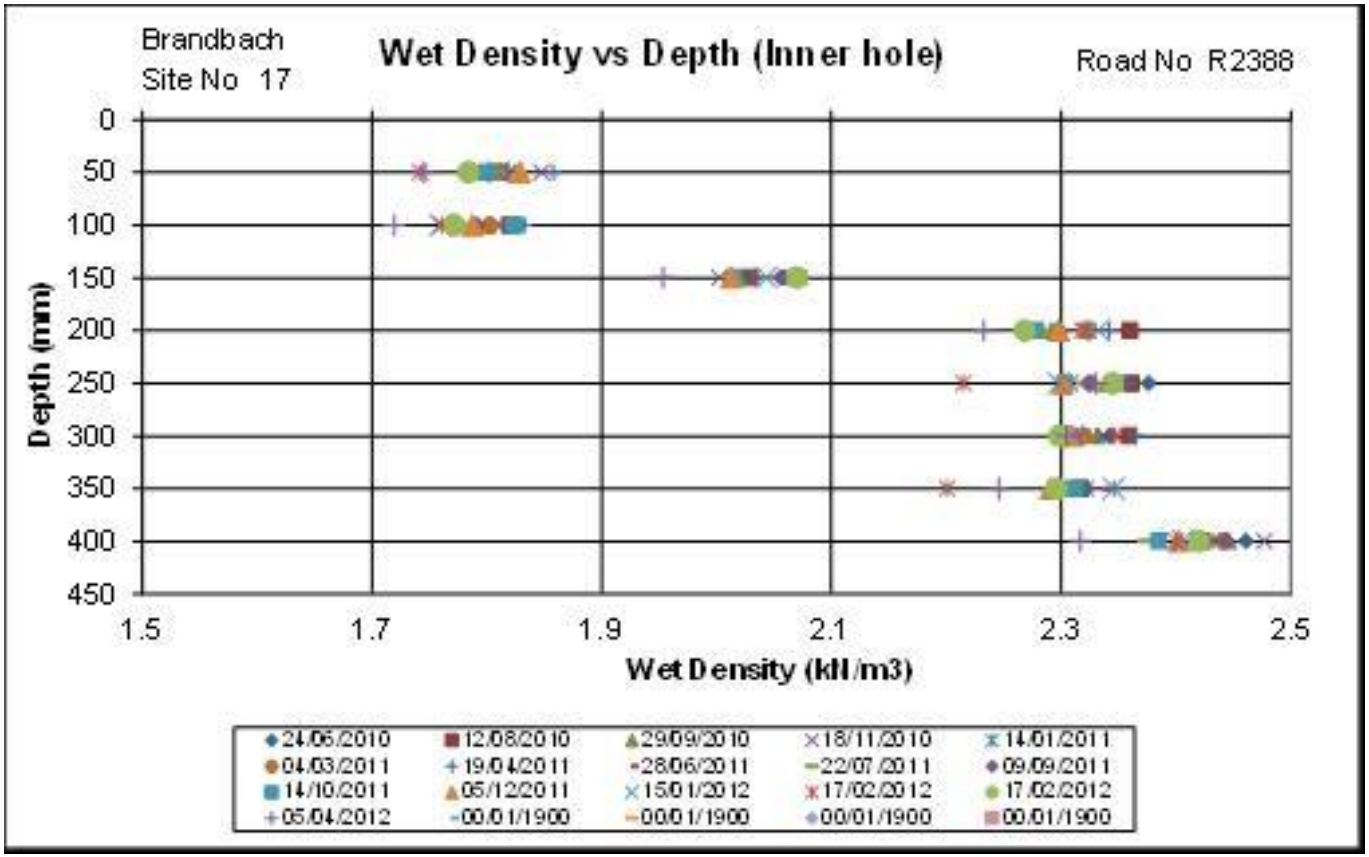
Wet density

- Results (outer holes)
  - Strong trends
    - Expected variation
    - Related to seasonal moisture variation

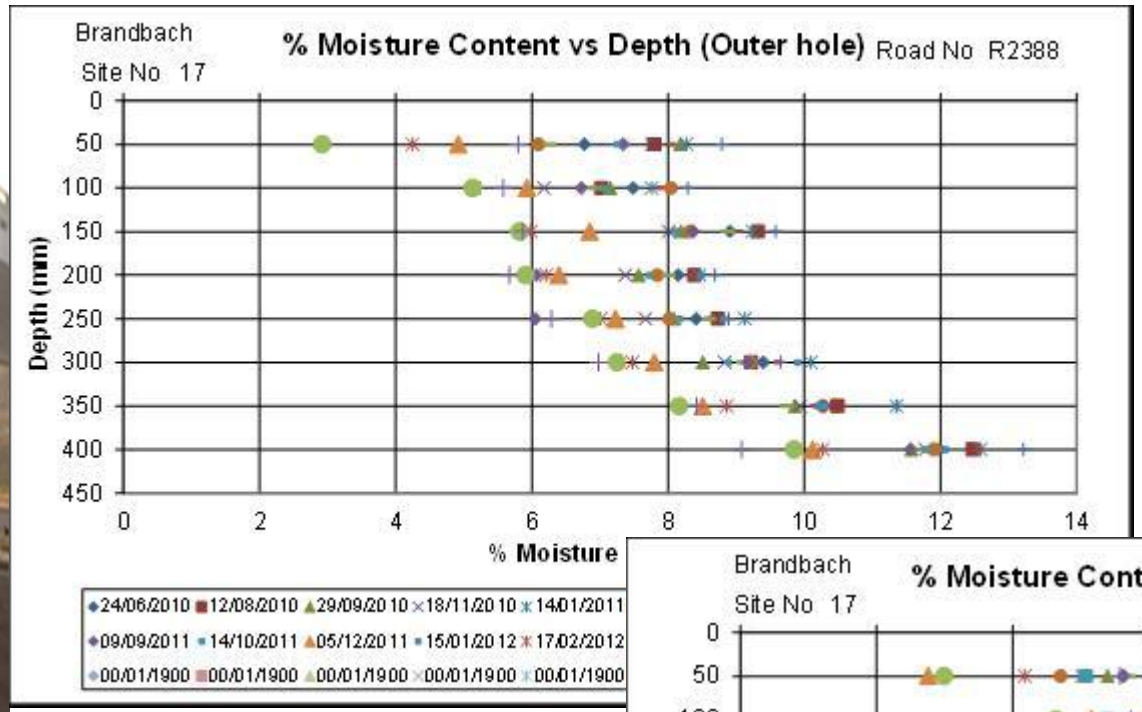


Wet density

- Results (inner hole)
  - Strong trends
    - Variation is less
    - Even so, more than expected 1500 mm from edge of seal



Moisture


Brandbach
Site No 17
% Moisture Content vs Depth (Outer hole) Road No R2388
Depth (mm)
0
50
100
150
200
250
300
350
400
450
0
2
4
6
8
10
12
14
% Moisture
24/06/2010
12/08/2010
29/09/2010
18/11/2010
14/01/2011
09/09/2011
14/10/2011
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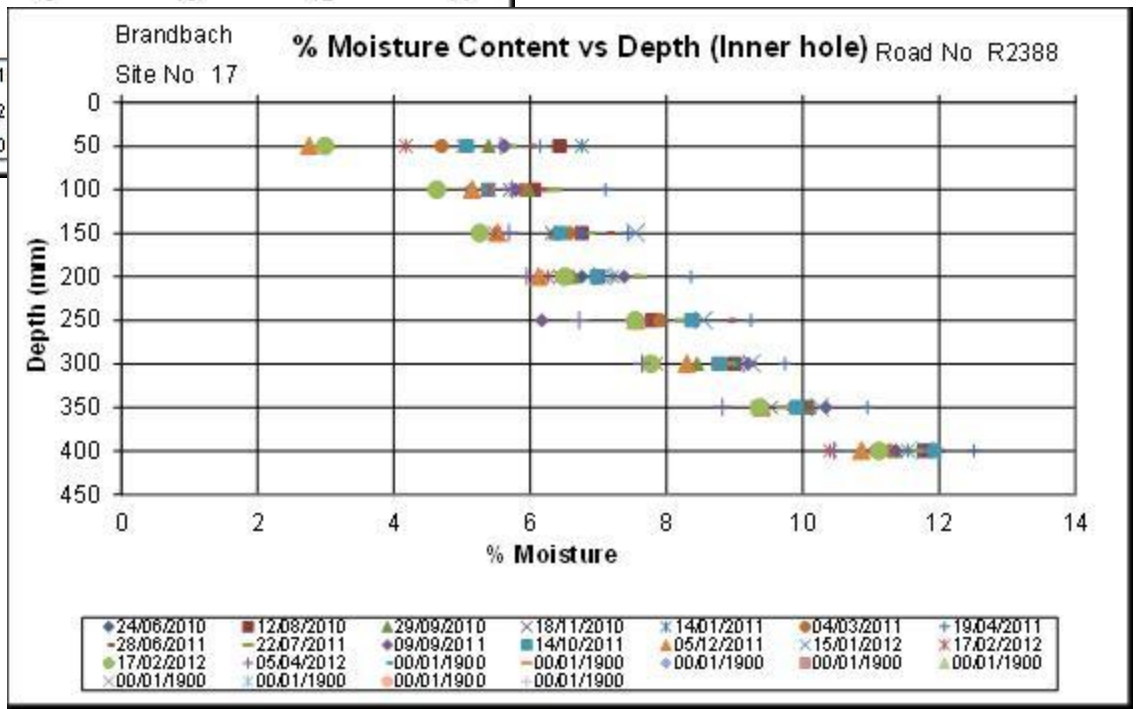
00/01/1900
00/01/1900


Brandbach
Site No 17
% Moisture Content vs Depth (Inner hole) Road No R2388
Depth (mm)
0
50
100
150
200
250
300
350
400
450
0
2
4
6
8
10
12
14
% Moisture
24/06/2010
12/08/2010
29/09/2010
18/11/2010
14/01/2011
04/03/2011
19/04/2011
28/06/2011
22/07/2011
09/09/2011
14/10/2011
05/12/2011
15/01/2012
17/02/2012
17/02/2012
05/04/2012
00/01/1900
00/01/1900
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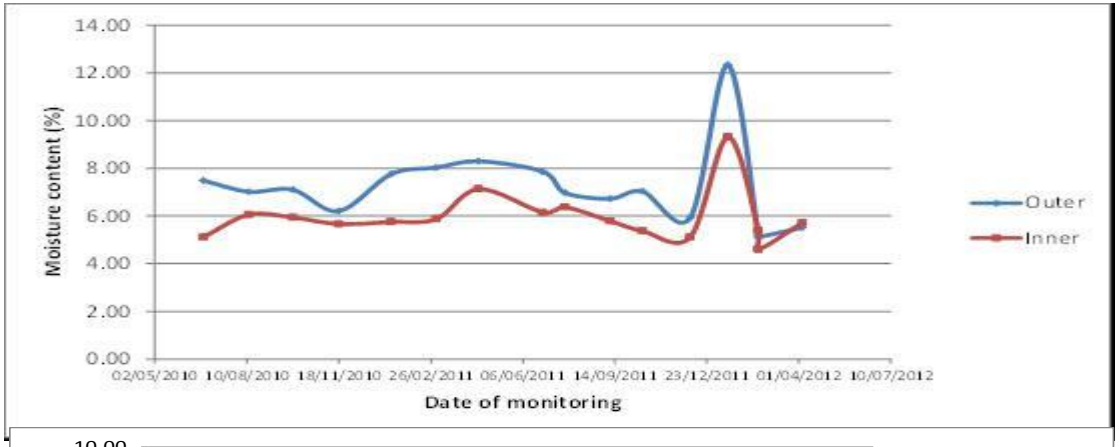
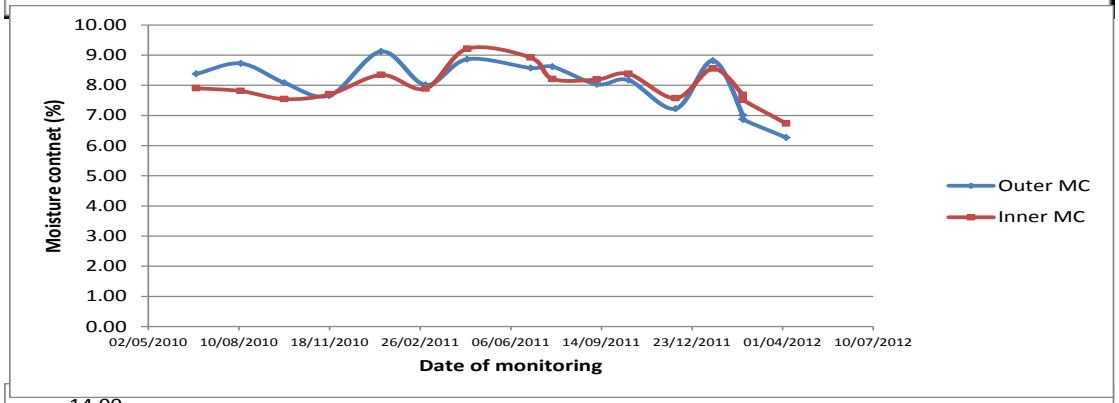
00/01/1900
00/01/1900

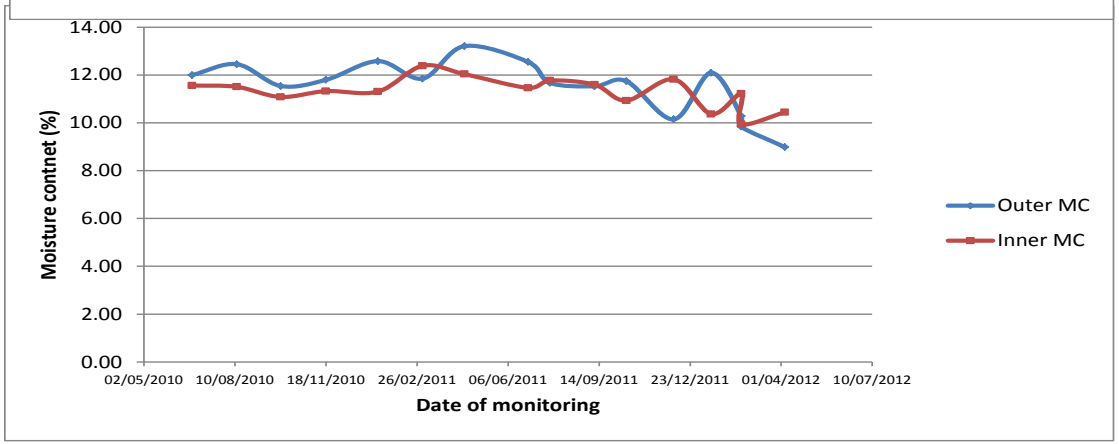
Moisture



BASE



SUBBASE



SUBGRADE

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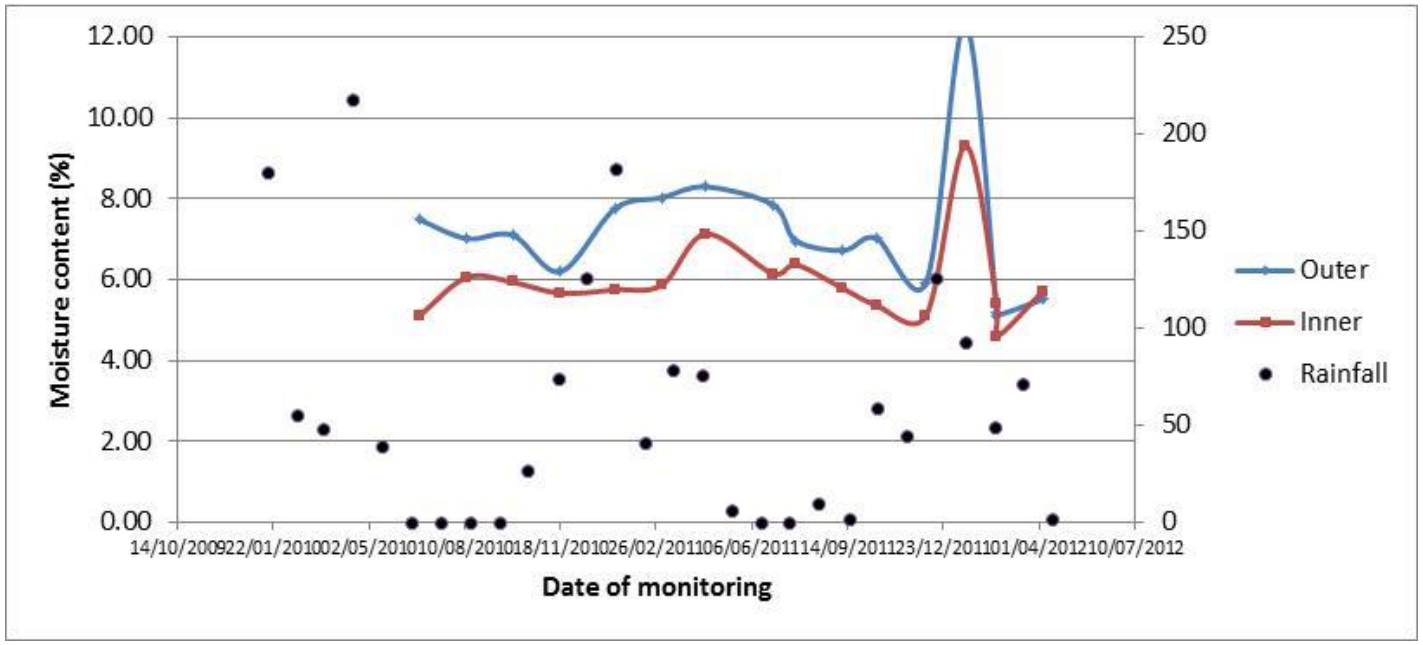
Moisture

BASE



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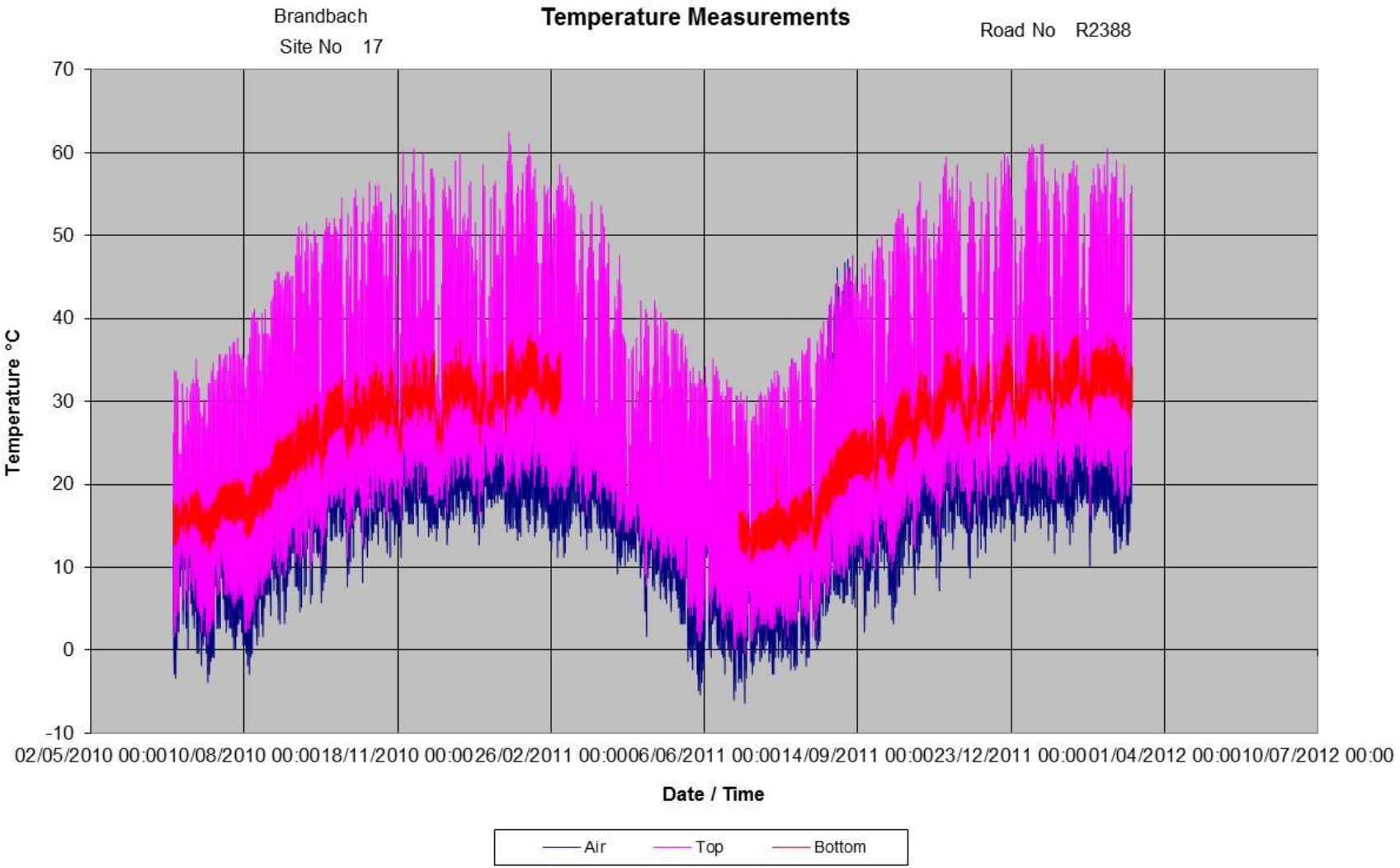
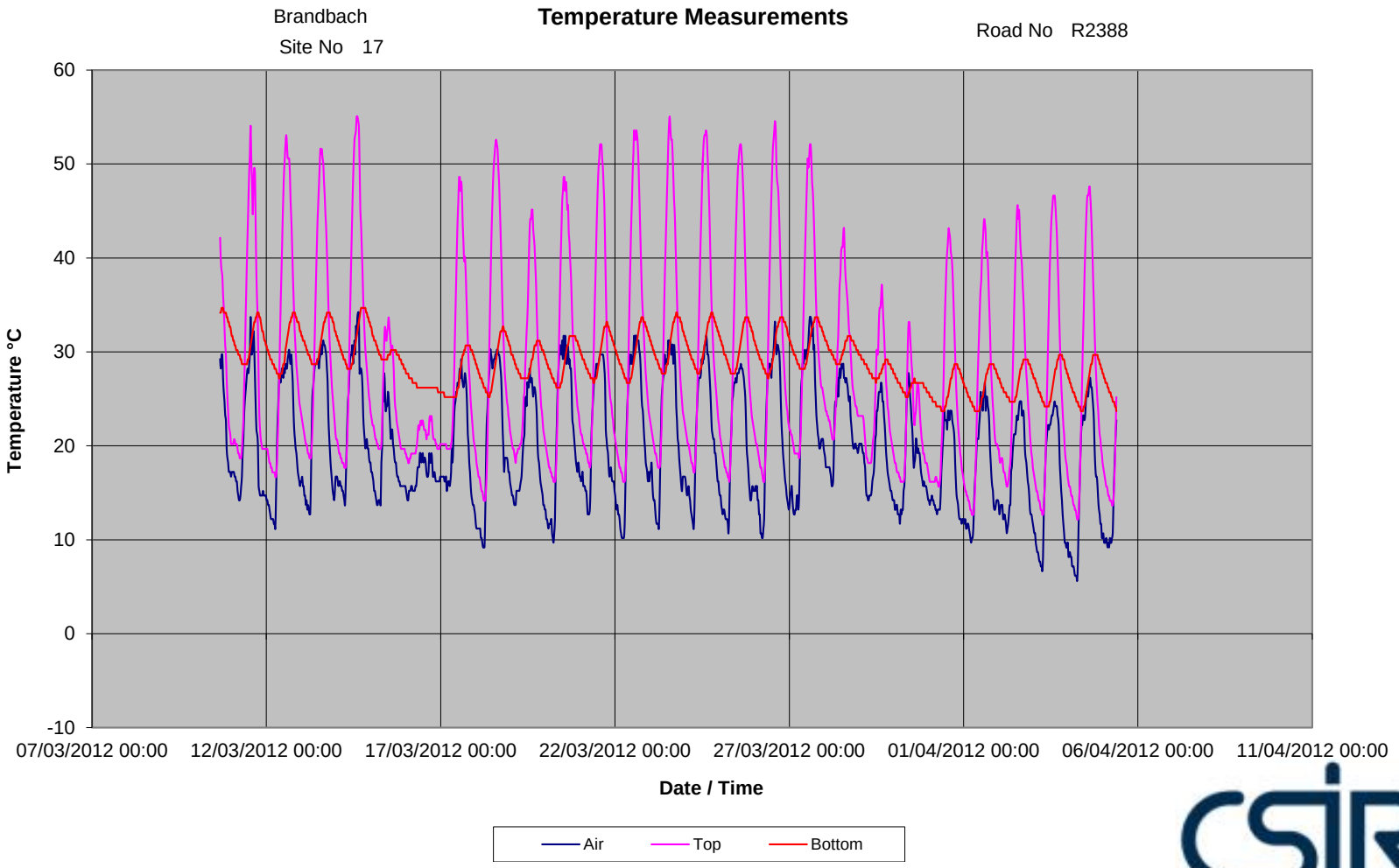
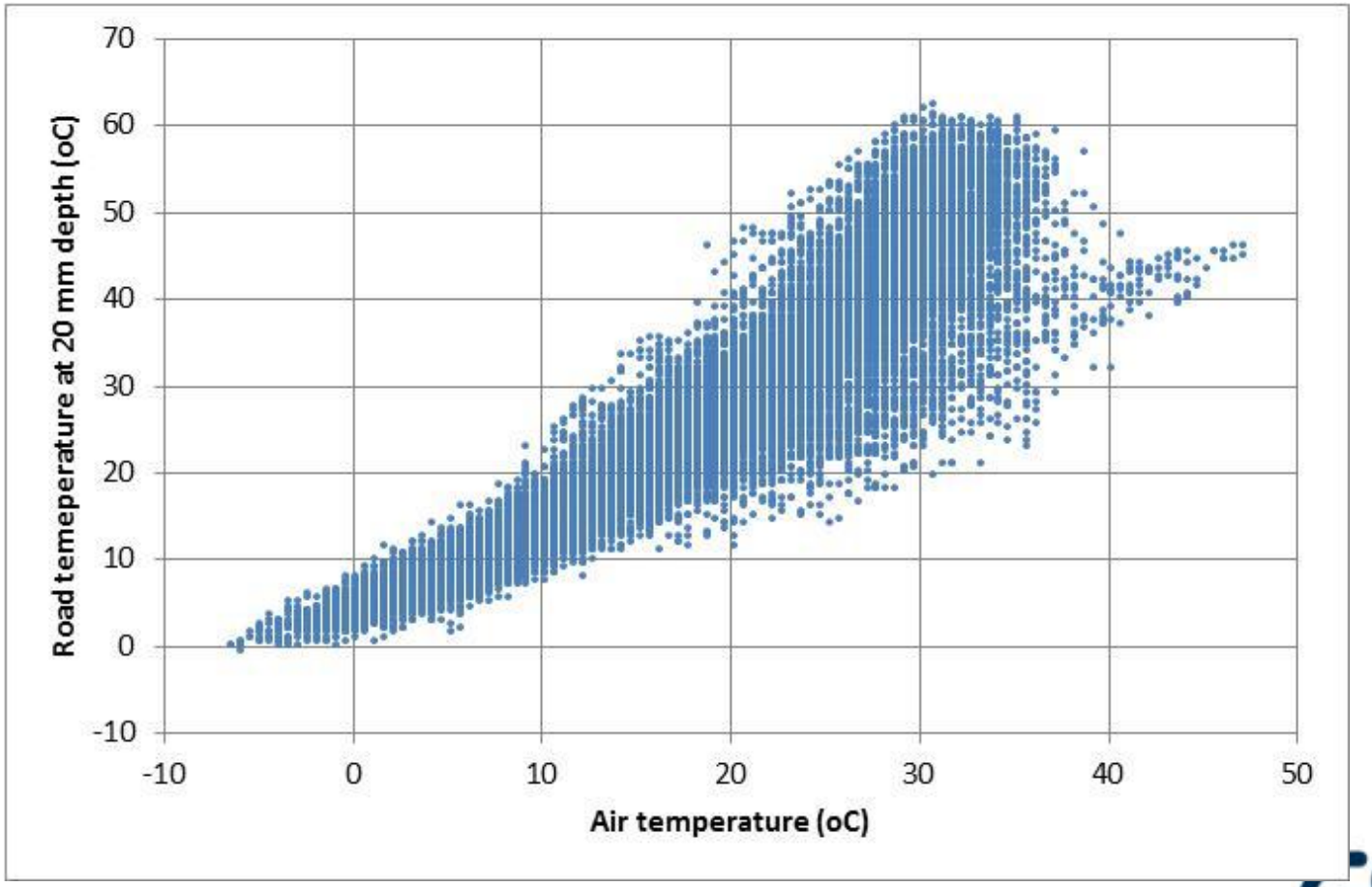
Temperature (31 000 readings)



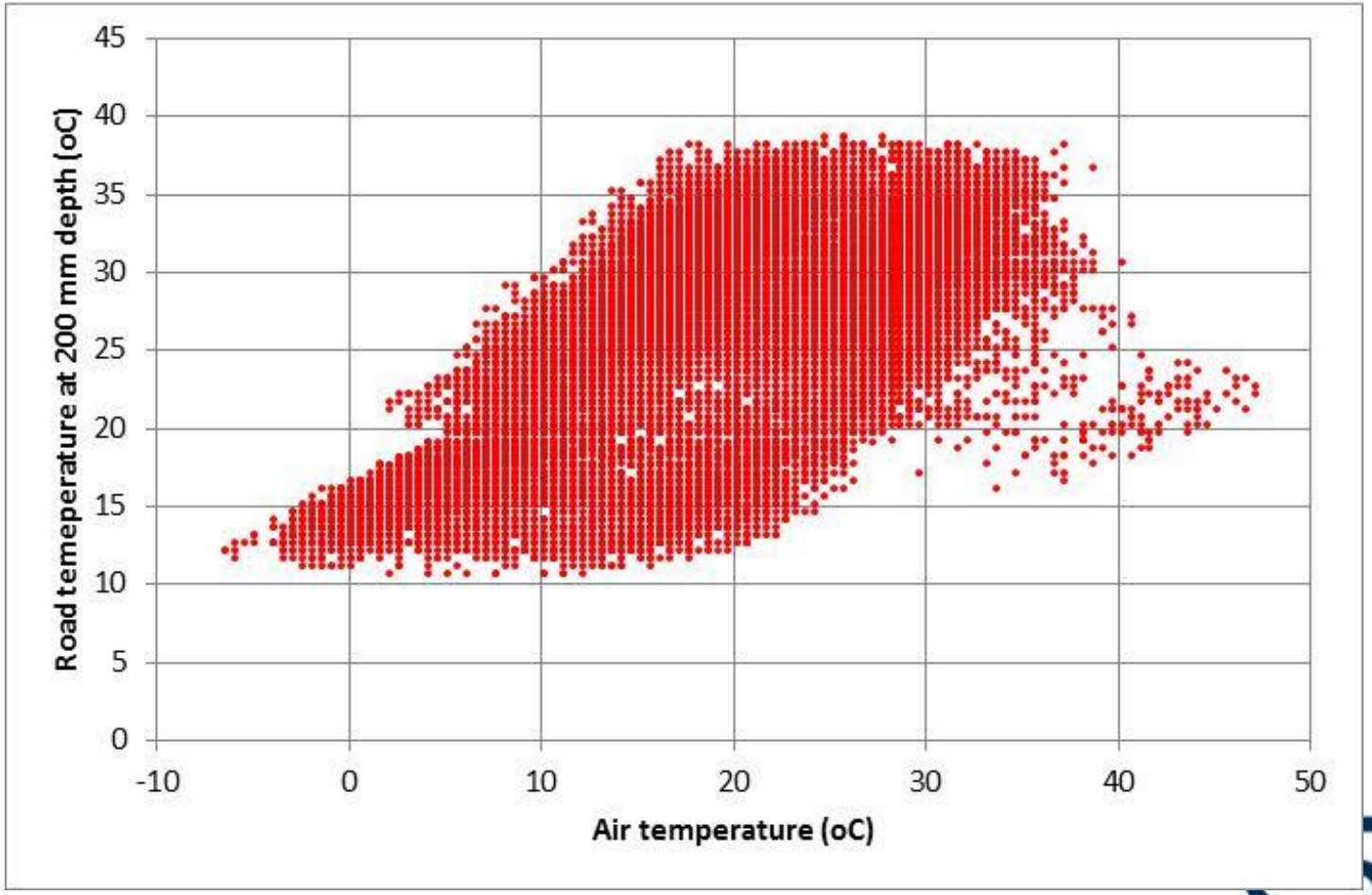
Temperature (detail)



Temperature (air and road "surface")



Temperature (air and road at 200 mm)



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Conclusions

- Preliminary analysis of 1 section
- New information emerging
- Moisture prediction models may not be as good as we think
- Moisture variation
  - material related
  - Seasonal variation more extensive than expected
  - Lateral variation more significant than expected
- New temperature relationships are emerging
- FWD analysis pending