Soft Ground Seminar-AGS Perth 14 November 2014

Ground Improvement at the Waterbank Precinct-East Perth

Alan Berry & Andrew Keep

Artist Impression Only

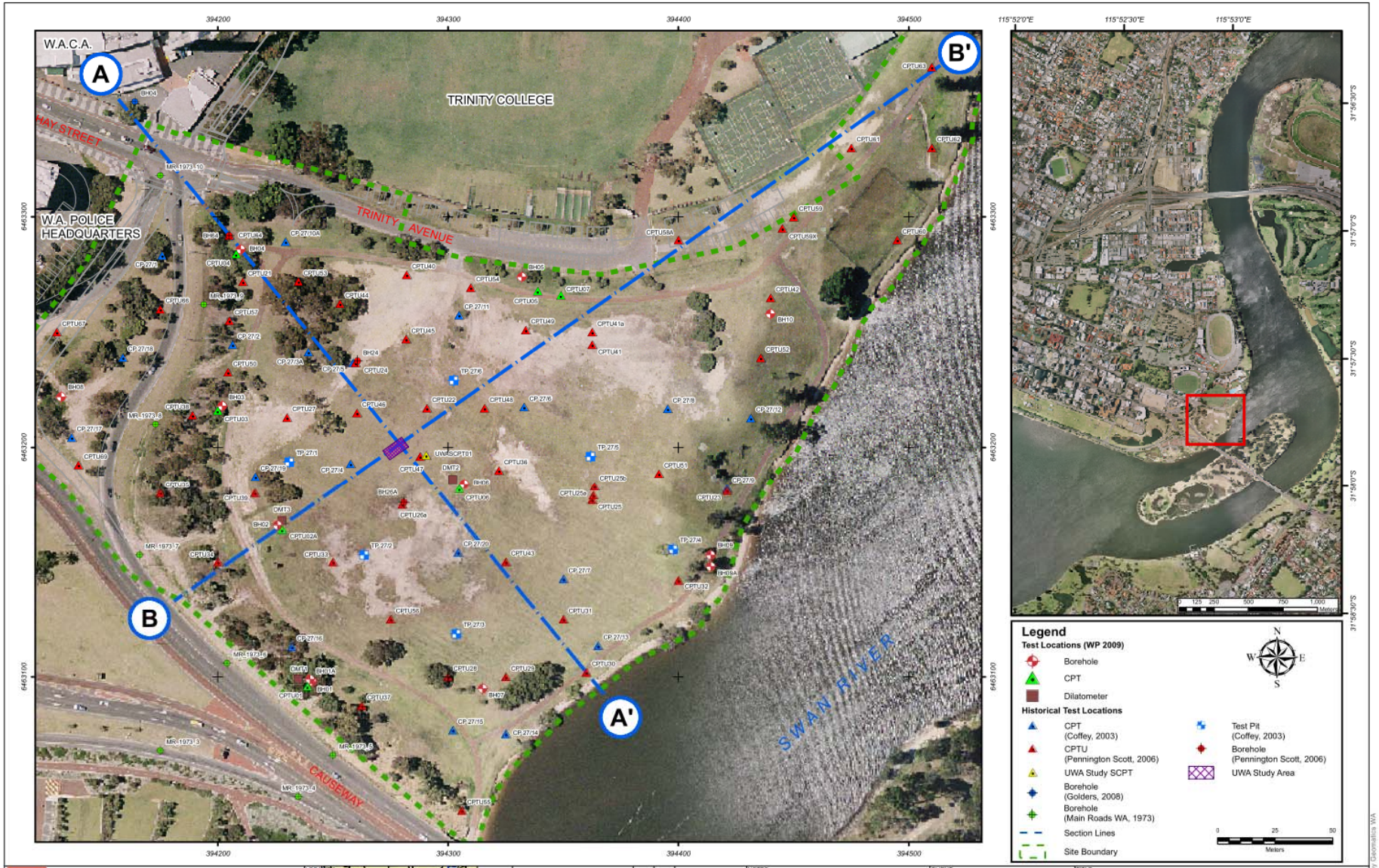
WorleyParsons
consulting practices

EcoNomics

Summary of presentation

Design summary (19 June 2012)

- Overview
- Design parameters
- Design targets –settlement & creep
- Consolidation time
- Verification
- Wick drain trial at Burswood
- Monitoring results
- Creep estimation long term
- Conclusions
    - Alan Berry: Principal Geotechnical Consultant
    - Andrew Keep: Senior Geotechnical Consultant



WorleyParsons EcoNomics
resources & energy

WORLEYPARSONS PROJECT	SCALE	
301012-I00544	1:1,500	@ A3
DATUM	GCS GDA 1994 MGA z50S	

LOCALITY

REV	REVISION DESCRIPTION	DRN	CHK	DATE
0	ISSUED TO CLIENT	PIR	NHL	18-12-2009
B	FOR INFORMATION ONLY	PIR	JAP	19-10-2009

NOTES

CLIENT: epra

TITLE: RIVERSIDE DEVELOPMENT
WATERBANK PRECINCT GEOTECHNICAL INVESTIGATION
HISTORICAL AND 2009 TEST LOCATIONS

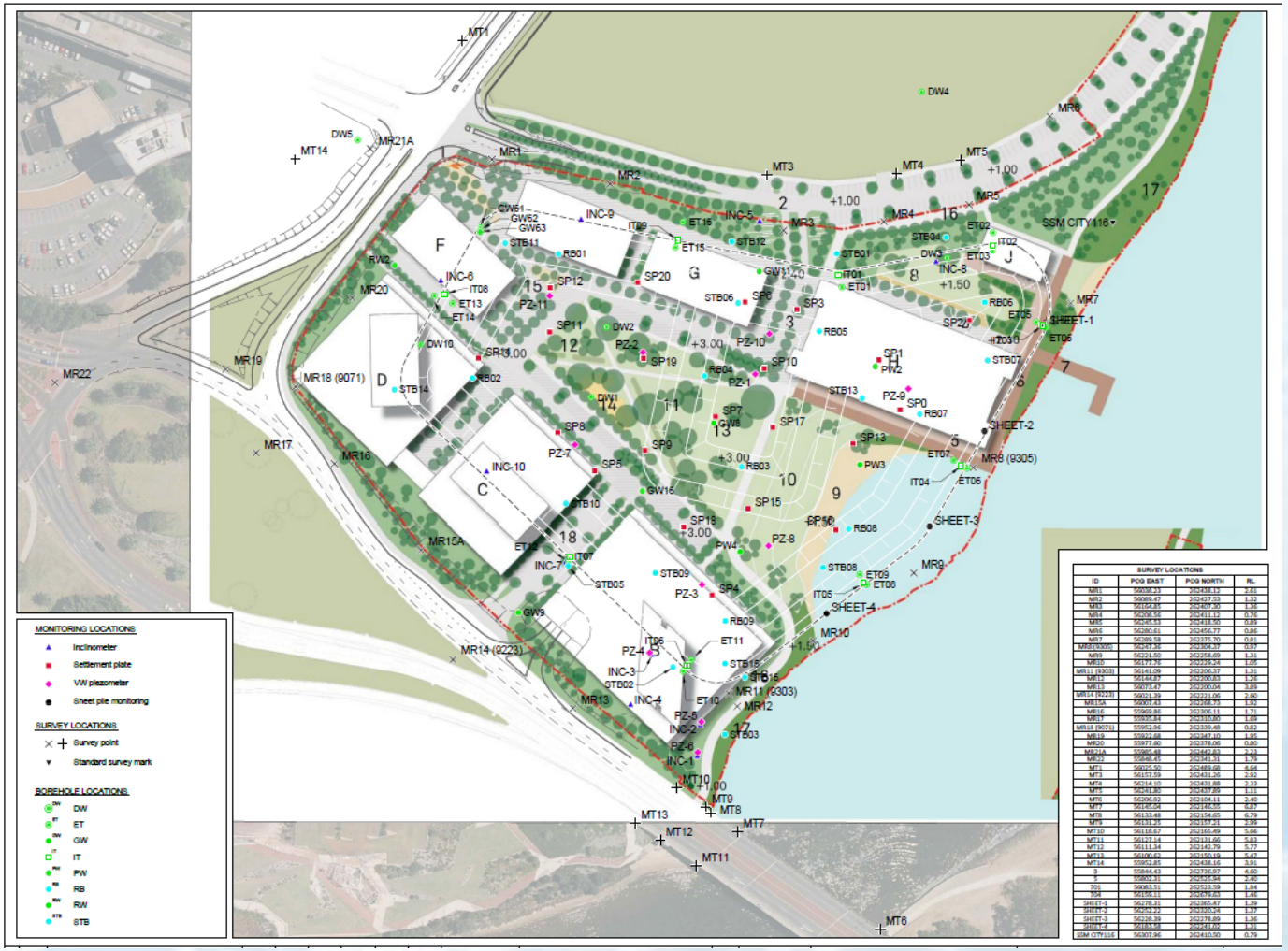
DRG NO: FIGURE 1

REV: 0

Produced by Daniel Hornby Geomatics WA

File Location:\Projects\I00544 Riverside Geotech Investigation\10.0 Engineering\GIS\03Project\Workspace_SKT\20091208 FINALS\Figure 1.mxd

Master plan



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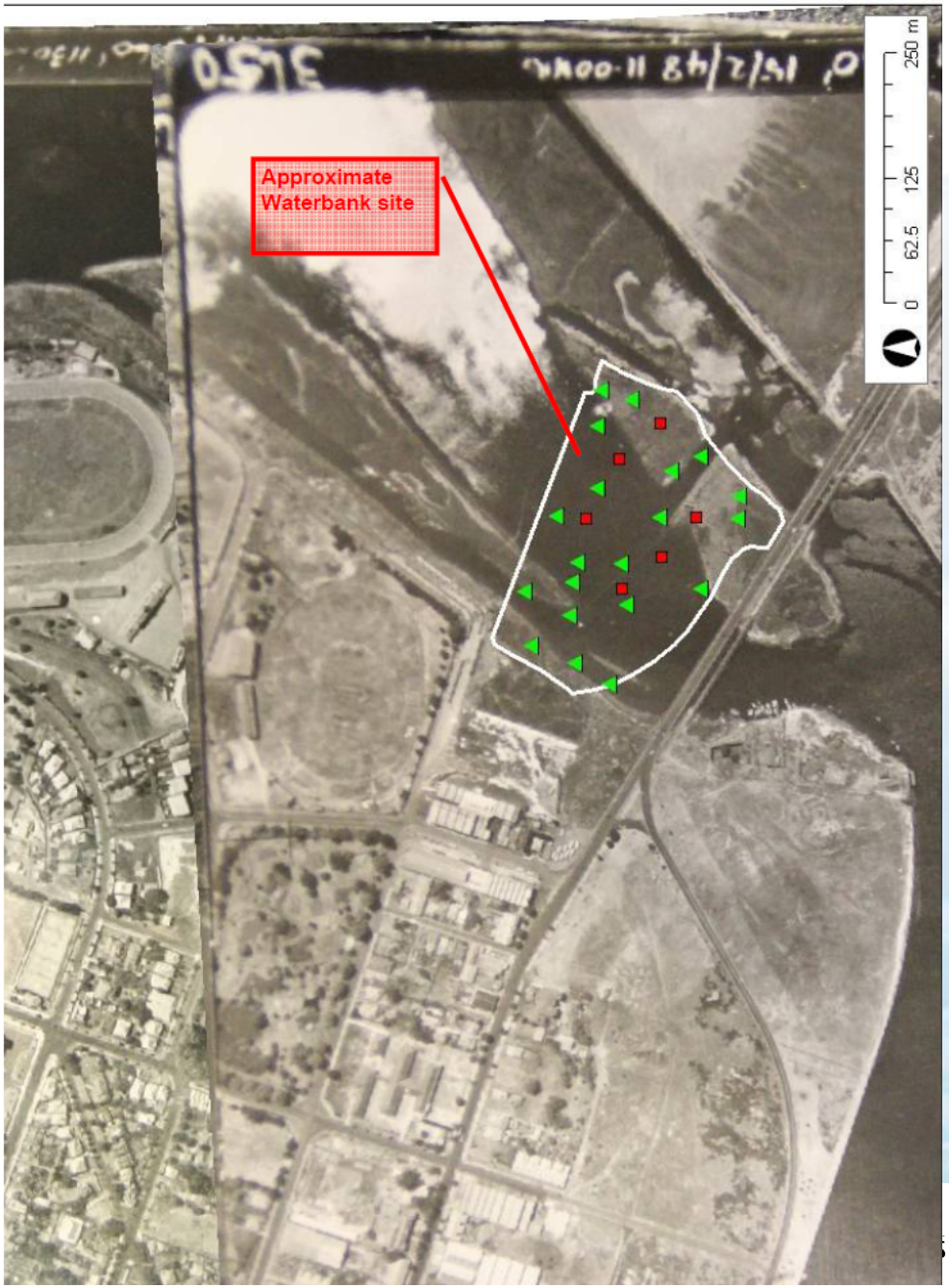
Palaeo Channels concerns…



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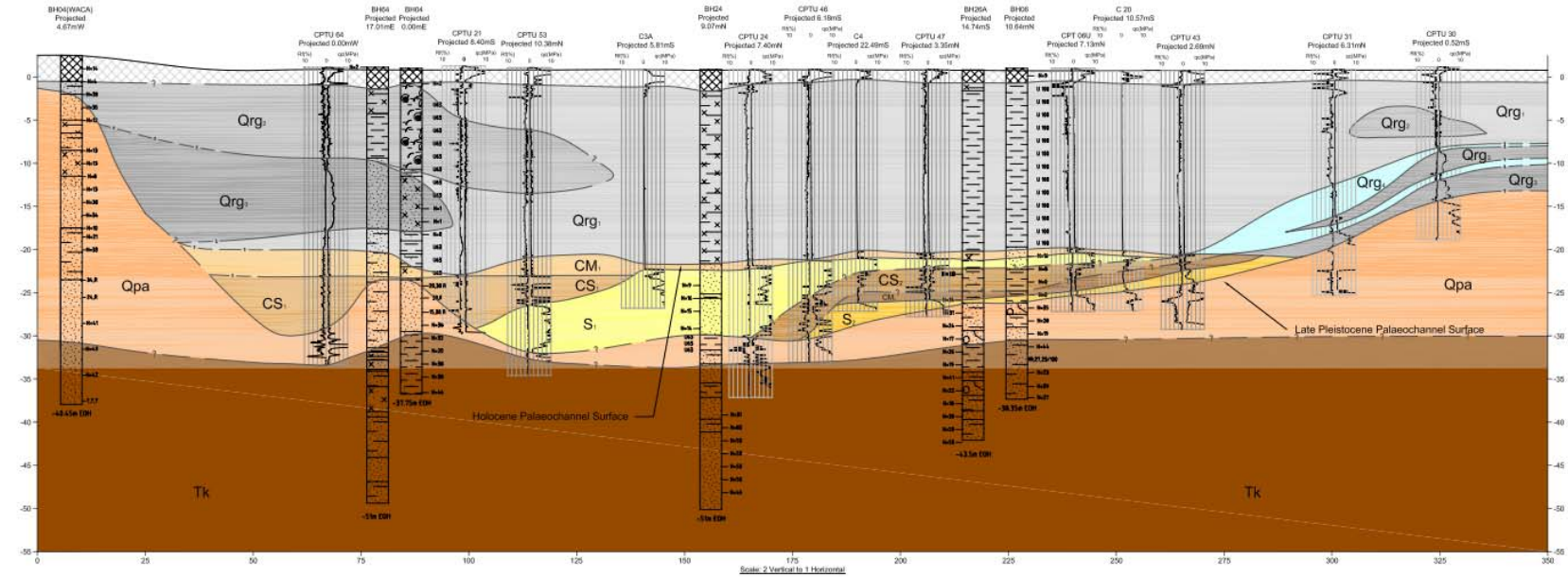

FILL: Predominantly SAND, yellow, brown, grey with variable amounts of brick, concrete rubble and fines.

NOTES: SPT N values from BH64 have not been included in this section.

Qrg Estuarine Deposits

- Qrg1: CLAY: dark grey, high plasticity with trace to some shells.
- Qrg2: CLAY and Shells / Sandy CLAY: grey/dark grey, high plasticity numerous shells including complete oysters, matrix supported.
- Qrg3: SAND: grey fine to coarse grained with low plasticity silt.
- Qrg4: CLAY and SILT: fines with shells.

Qra Recent Alluvium

- CM1: Silty SAND and Sandy SILT: grey, low plasticity fines, fine to coarse sand.
- CS1: Interbedded CLAY, Sandy CLAY, Clayey SAND and SAND: low plasticity fines, weakly laminated clay, coarse sand, trace of wood.
- S1: SAND and Silty SAND: fine to coarse grained pale grey/grey with lenses/flecks of wood.
- CM2: Interbedded CLAY, SILT and SAND: grey, low plasticity fines, fine to coarse sands.
- CS2: CLAY and Sandy CLAY: low plasticity with pockets/lenses of sand and silt.
- S2: Clayey SAND, Silty SAND and SAND: grey, fine to coarse grained, low plasticity fines.

Qpa Pleistocene Alluvium

- Qpa: Interbedded / Lenticular CLAY, SILT, SAND and GRAVEL: typical colours comprise mottled brown, pale grey, yellow, reds, sands and gravels comprise quartz and lithics.

Tk Kings Park Formation

- Tk: SAND: fine medium and fine to coarse subrounded quartz, dark brown generally becoming pale grey with depth with thin lenses of clay/sandy clay.

Interpereted Geological Boundary

Inferred Geological Boundary

REV	DATE	REVISION DESCRIPTION	DRAWN	DRAFT CHK	DESIGNED	ENG CHK	APPROVED	CUSTOMER	REF DRAWING No	REFERENCE DRAWING TITLE
0	16-12-09	ISSUED TO CLIENT	PIR		JAP					
B	26-10-09	ISSUED FOR CLIENT REVIEW	PIR		JAP					

A1 SHEET SCALE AS SHOWN

WORLEYPARSONS PROJECT No. 301012-00544

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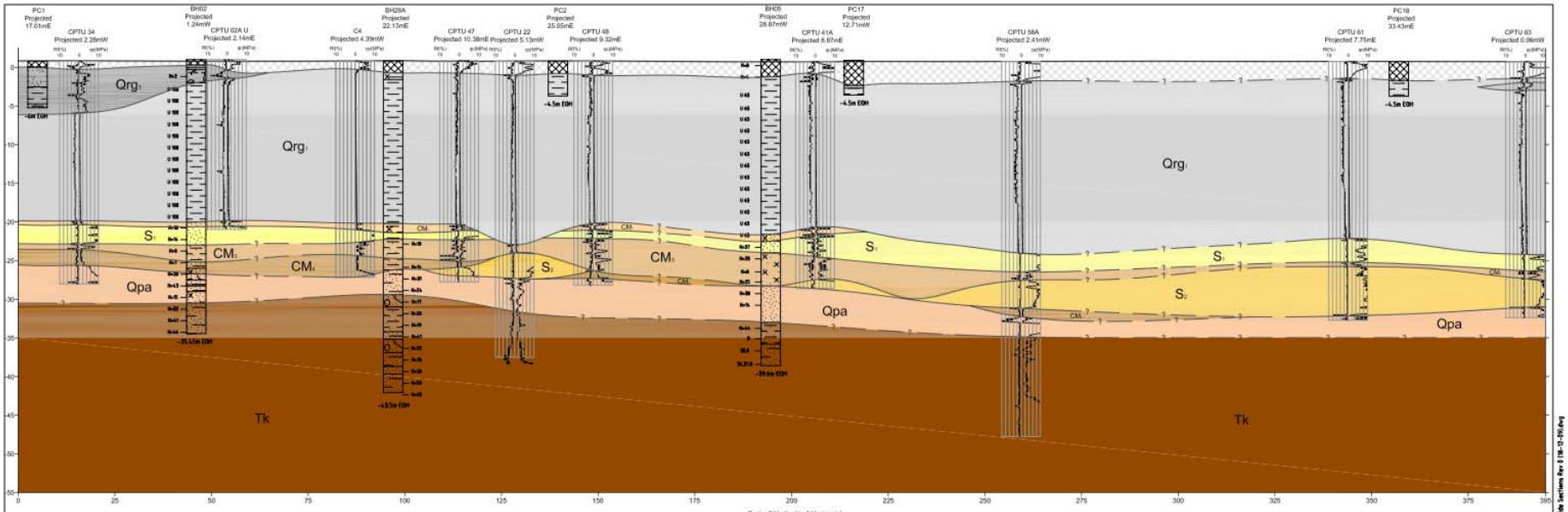
RIVERSIDE DEVELOPMENT
GEOLOGICAL REVIEW of WATERBANK PRECINCT
GEOLOGICAL SECTION A - A'

DRG No FIGURE 3 REV 0

DATE & TIME: 16/12/2009 02:45:58 PM USER NAME: paul.reiffa LOCATION: J:\Projects\60054 Riverside Geotech Investigation\11 Drawings\Geotechnical\Figures\Riverside Sections Rev 0 (16-12-09).dwg



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- Interpereted Geological Boundary
- Inferred Geological Boundary

REV	DATE	REVISION DESCRIPTION	DRAWN	DRAFT CHK	DESIGNED	ENG CHK	APPROVED	CUSTOMER	REF DRAWING No	REFERENCE DRAWING TITLE
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B	20-10-09	ISSUED FOR CLIENT REVIEW	PIR		JAP					

AT SHEET SCALE AS SHOWN

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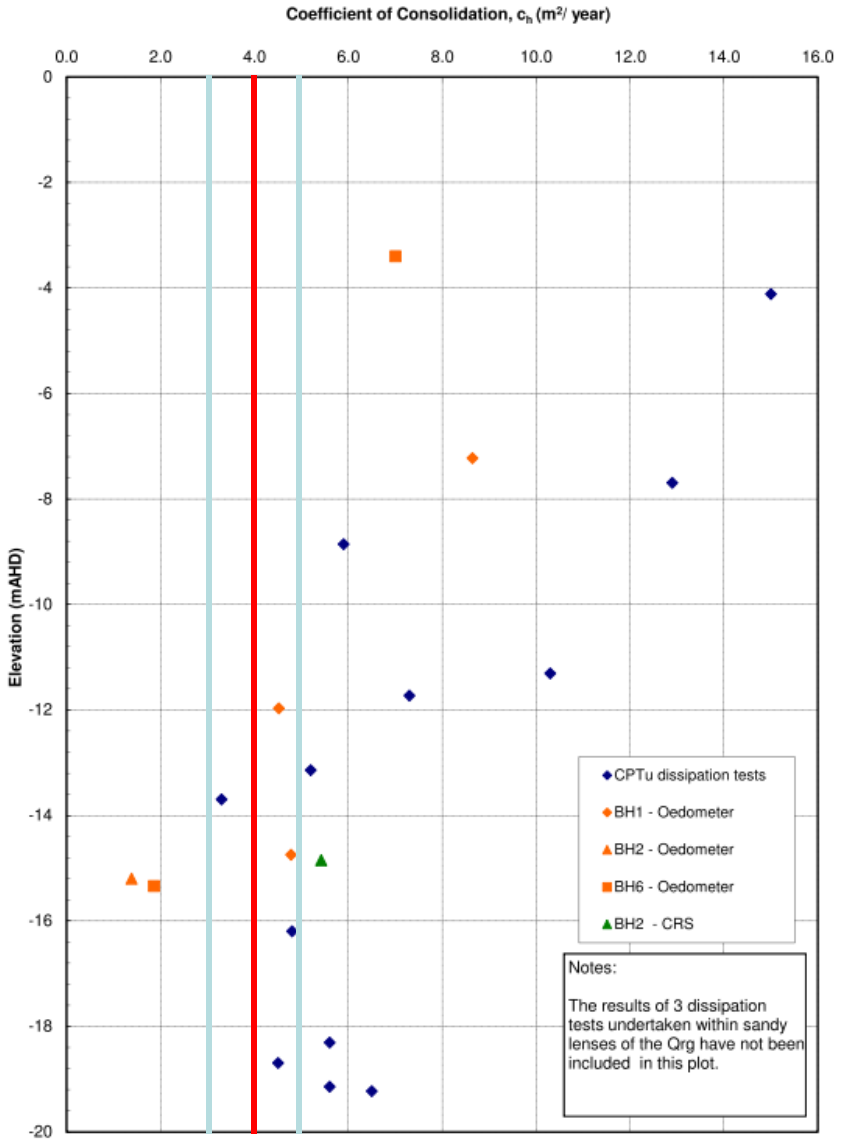
RIVERSIDE DEVELOPMENT
GEOLOGICAL REVIEW of WATERBANK PRECINCT
GEOLOGICAL SECTION B - B'

DRG No FIGURE 4 REV 0

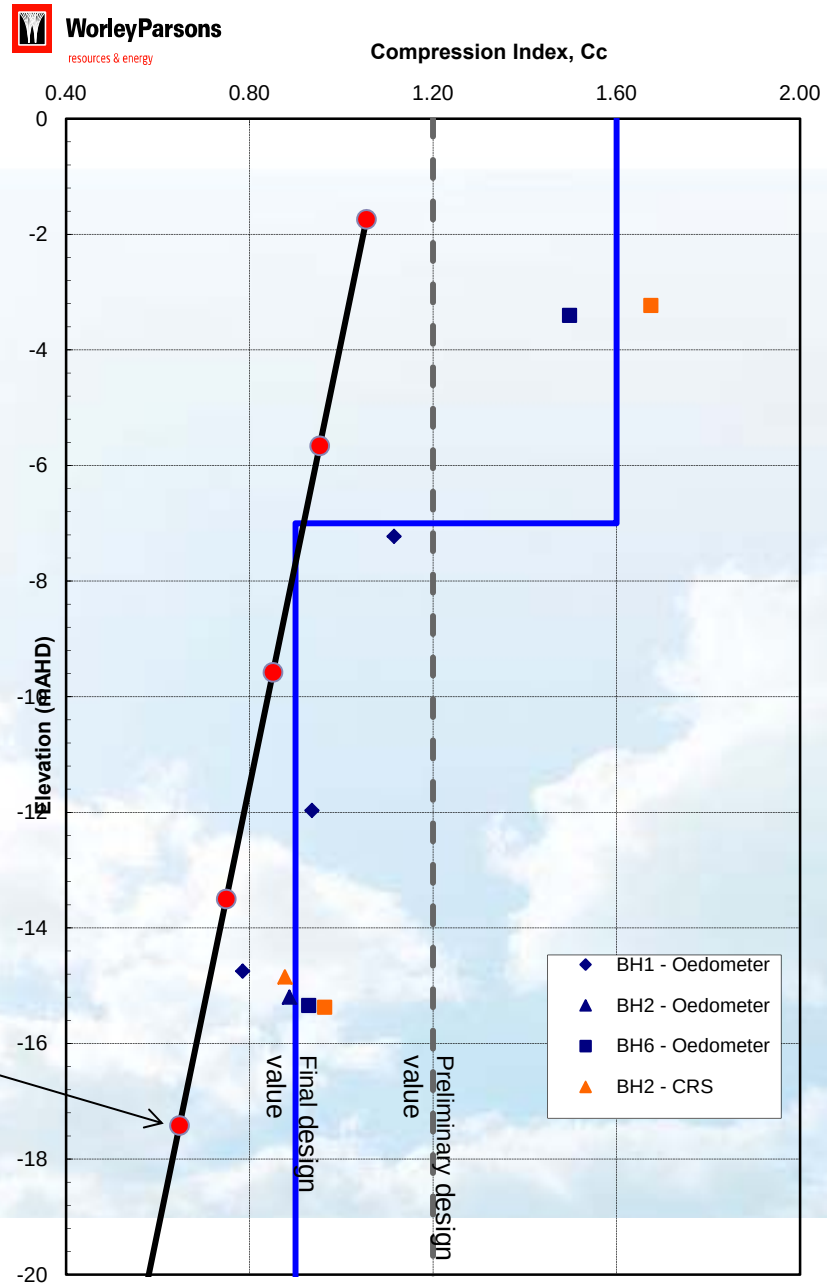
DATE & TIME: 16/12/2009 03:49:02 PM USER NAME: paul.rafte LOCATION: I:\Projects\301044 Riverside Geotech Investigation\10 Drawings\Geotechnical\Figures\Riverside Sections Rev 0 (16-12-09).dwg

Estimation of Cv & Ch for hand c

Interpreted ch (m2/yr)…

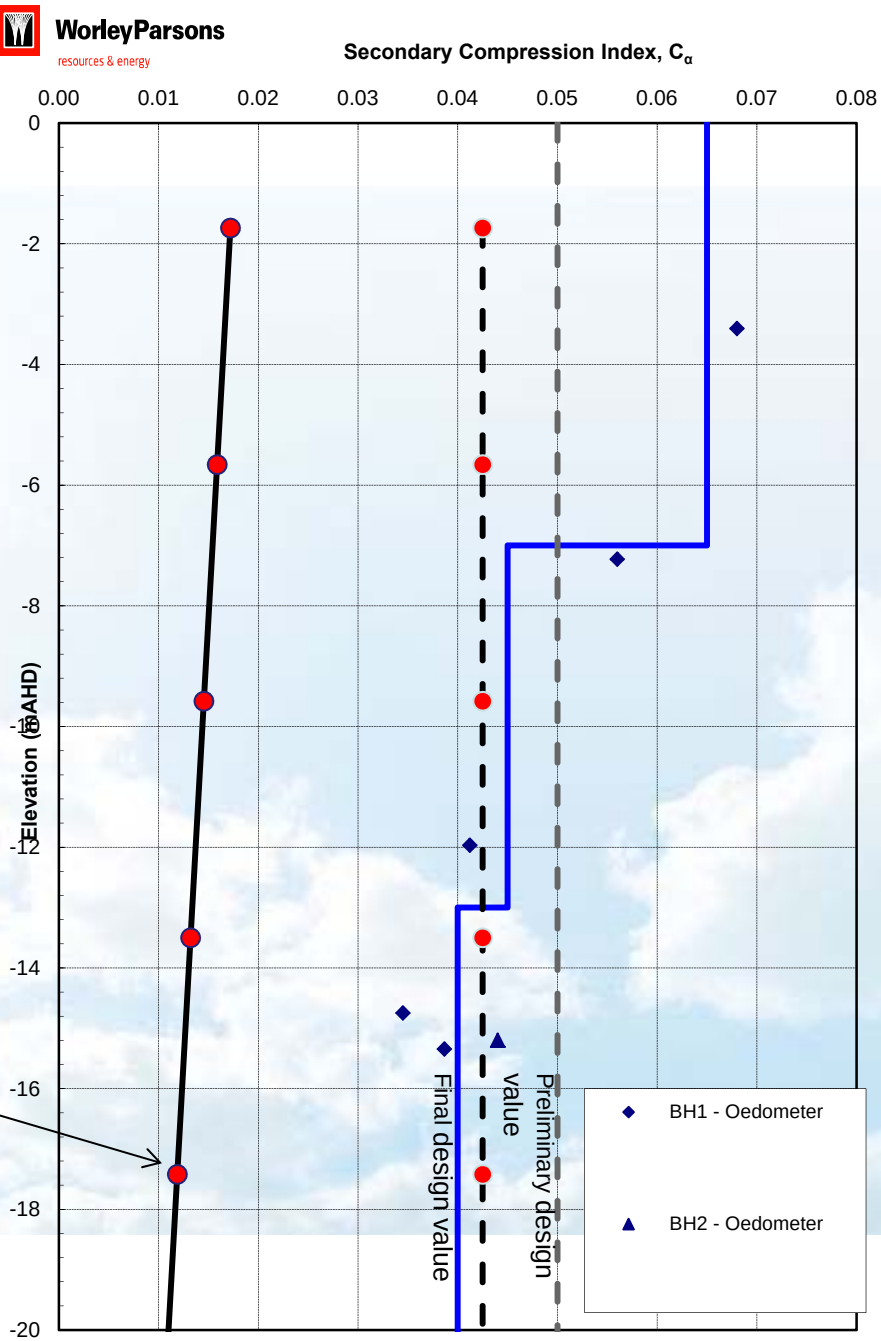


Design soil parameters



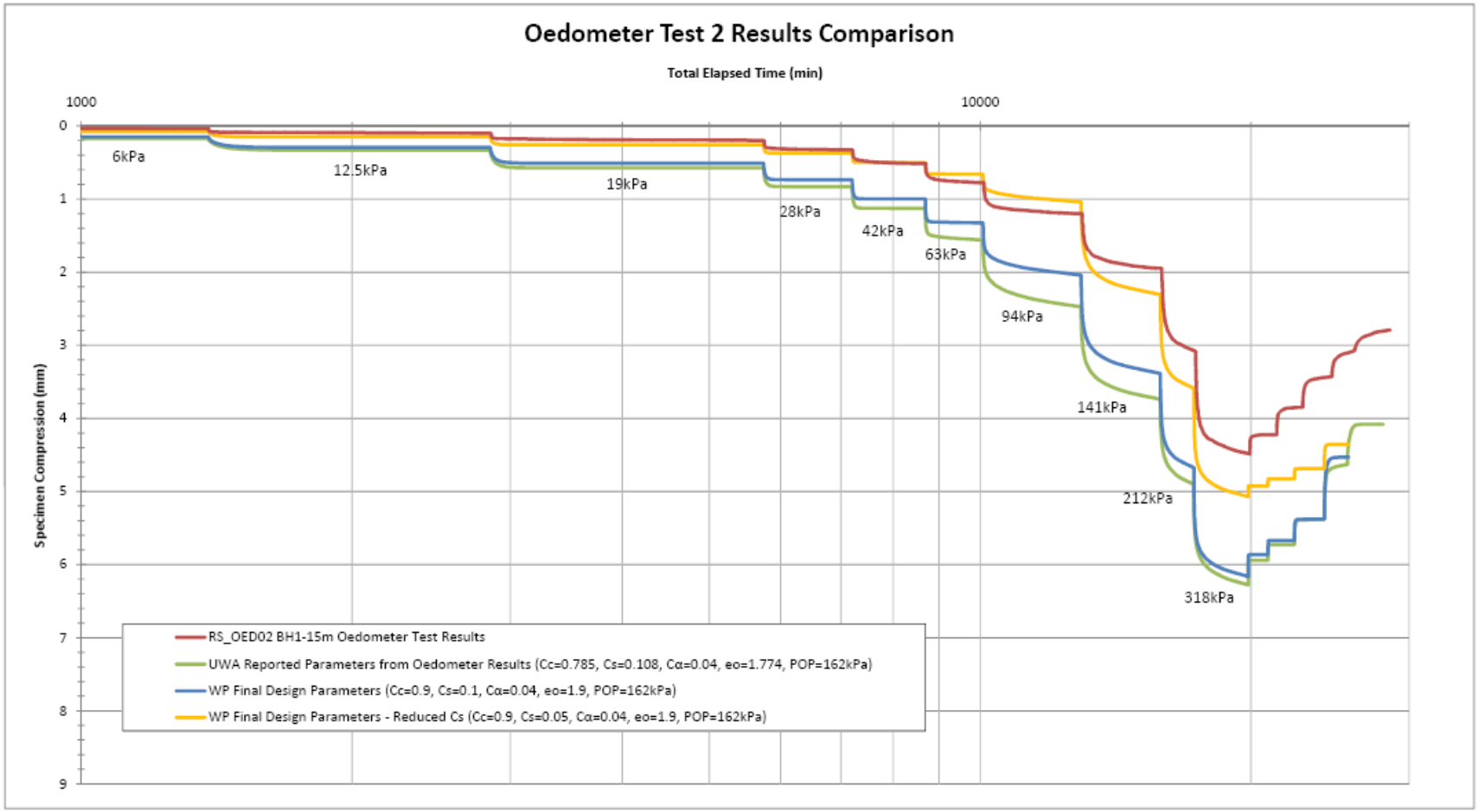
Burswood trial embankment

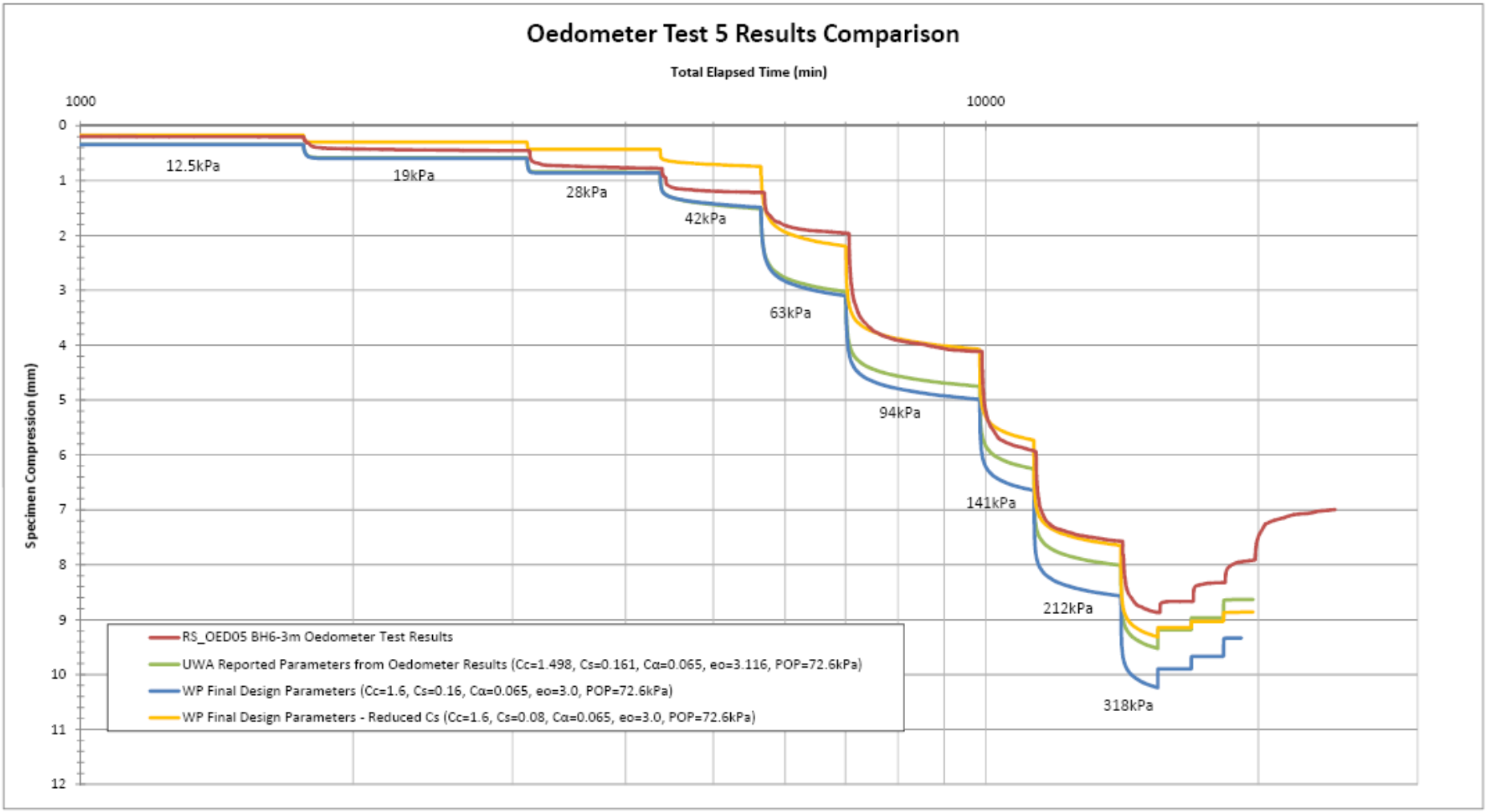
Calpha (creep)



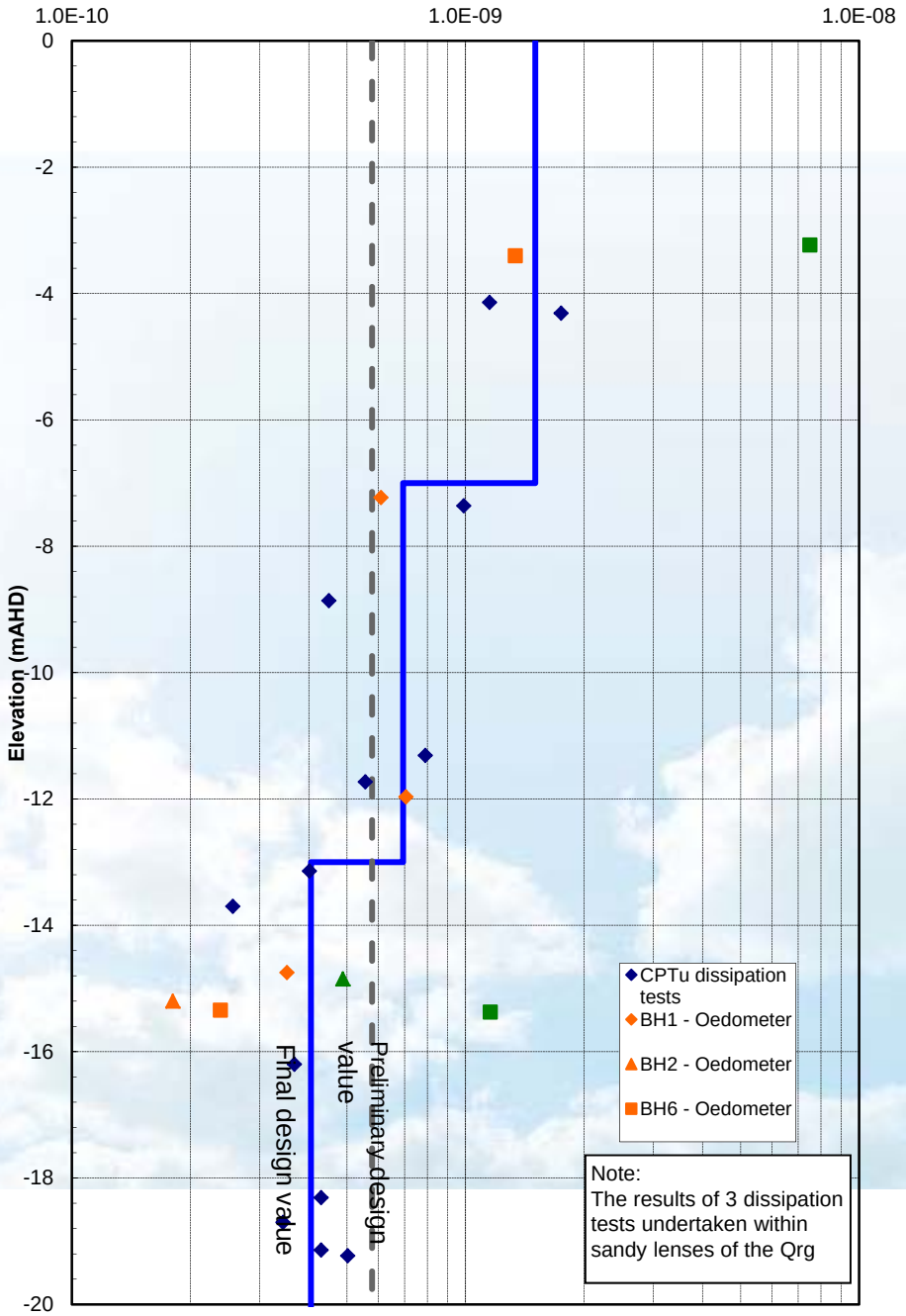
Burswood trial embankment

Very good simulation using Single element modelling of creep tests




Oedometer Test 5 Results Comparison
Total Elapsed Time (min)
1000
10000
Specimen Compression (mm)
0
1
2
3
4
5
6
7
8
9
10
11
12
12.5kPa
19kPa
28kPa
42kPa
63kPa
94kPa
141kPa
212kPa
318kPa
RS_OED05 BH6-3m Oedometer Test Results
UWA Reported Parameters from Oedometer Results (Cc=1.498, Cs=0.161, Cα=0.065, eo=3.116, POP=72.6kPa)
WP Final Design Parameters (Cc=1.6, Cs=0.16, Cα=0.065, eo=3.0, POP=72.6kPa)
WP Final Design Parameters - Reduced Cs (Cc=1.6, Cs=0.08, Cα=0.065, eo=3.0, POP=72.6kPa)

Permeability



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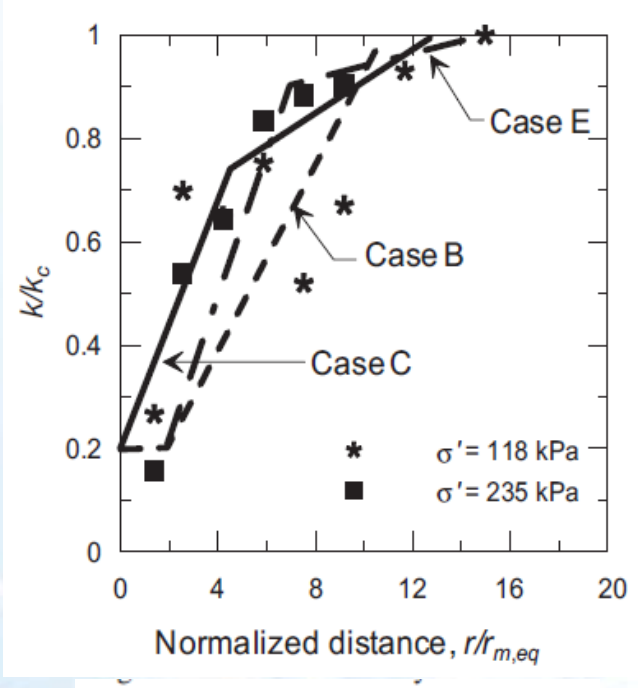
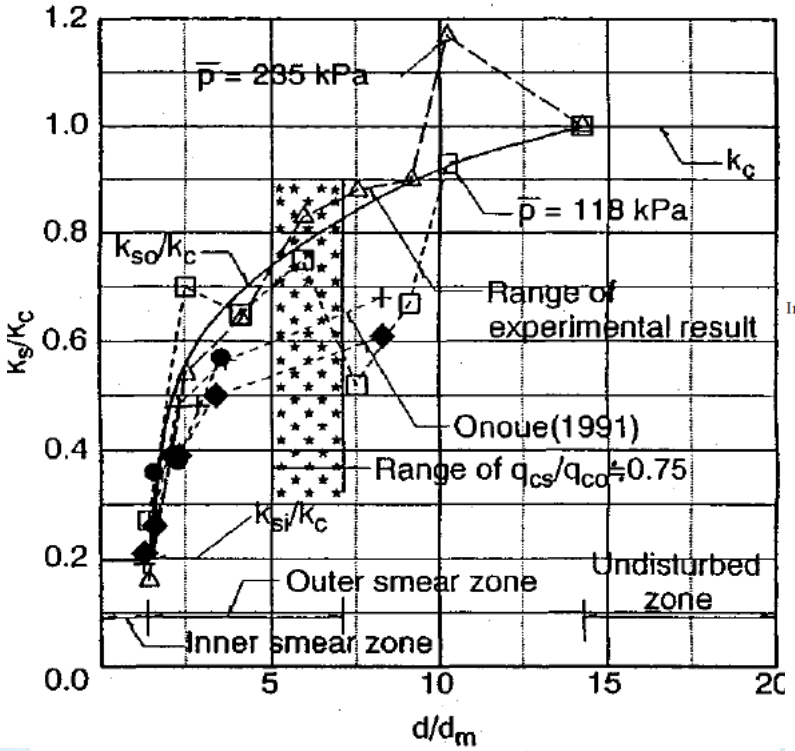
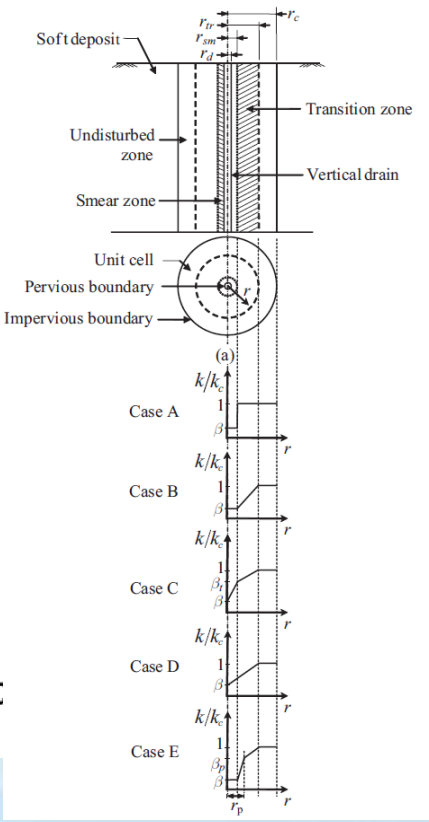
Modelling wick drains in Plaxis



(Reproduced from Madhav *et al.* 1993.)



土木学会論文集 No. 499／Ⅲ-28, pp. 51~58, 1994. 9



Analytical solutions for consolidation aided by vertical drains

D. BASU, P. BASU and M. PREZZI*

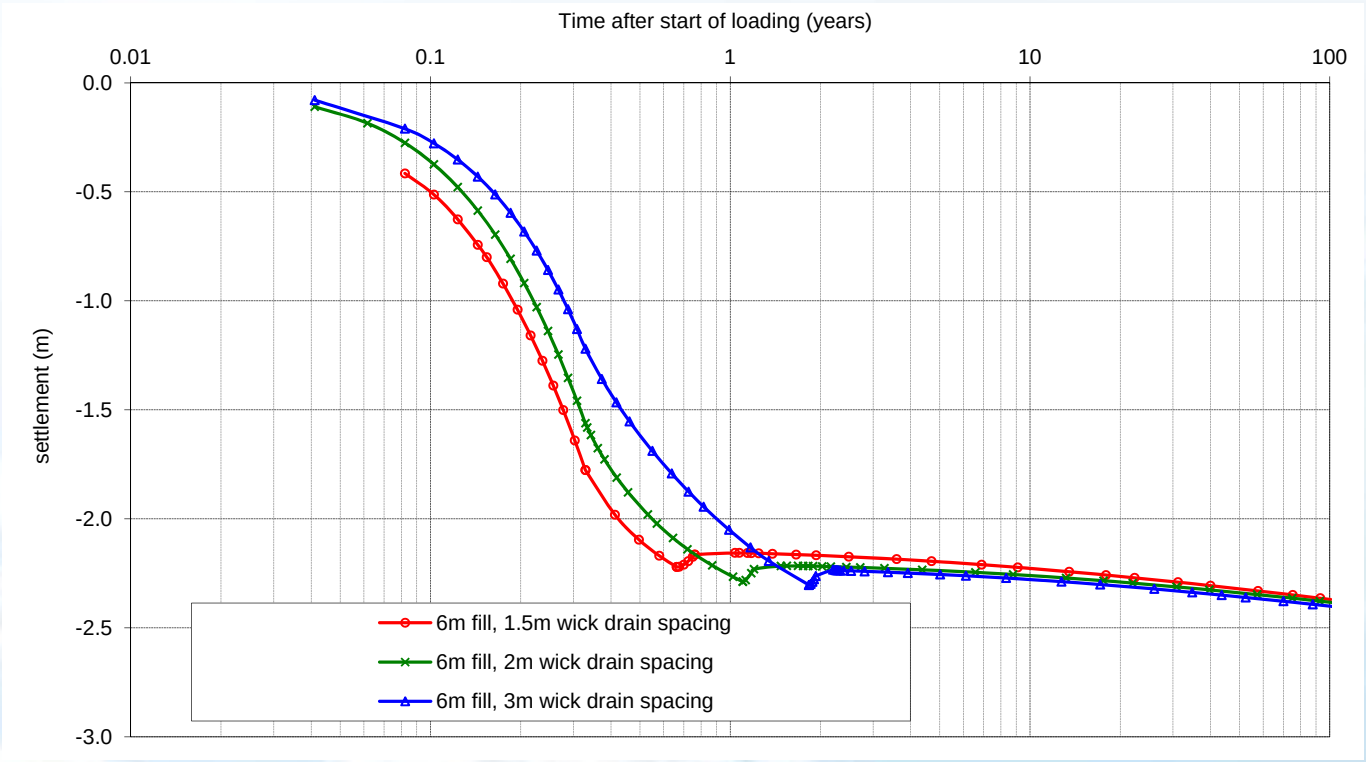
School of Civil Engineering, Purdue University, West Lafayette, IN 47907, USA

Geomechanics and Geoengineering: An International Journal
Vol. 1, No. 1, March 2006, 63–71

Design targets/objectives

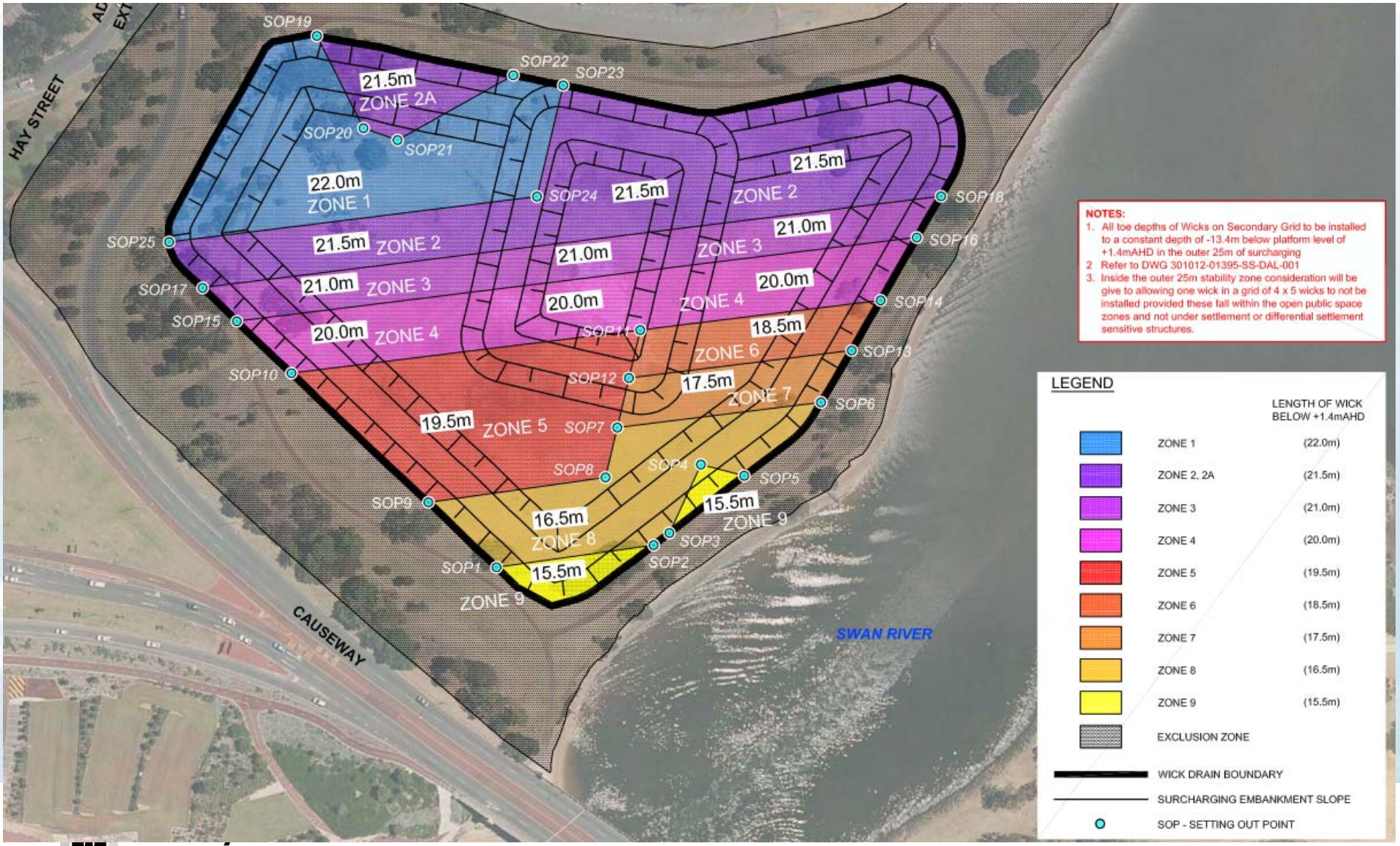
- Push down PASS Material >1.5m
- Reduce creep to acceptable levels, 200mm target value suggested by WP
- Minimise damage to services and surrounding area. Bridge, HP sewer, rods etc
- >80% consolidation targeted – aiming for 90%
- 90%MMDD in fill

Analysis results-final surcharging report



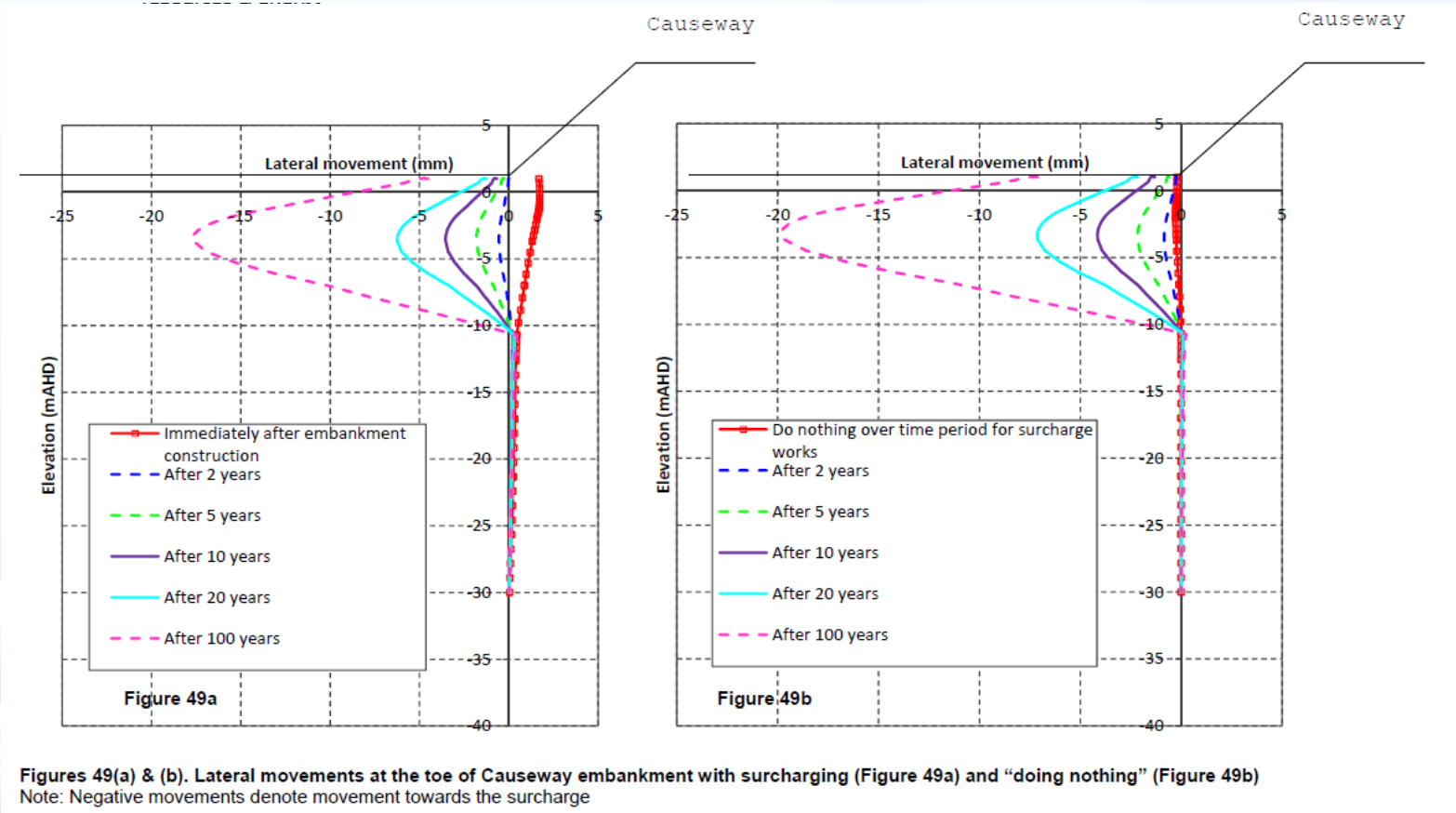
Revised proposed layout

Wick drain lengths adjusted to suit Palaeo-channel



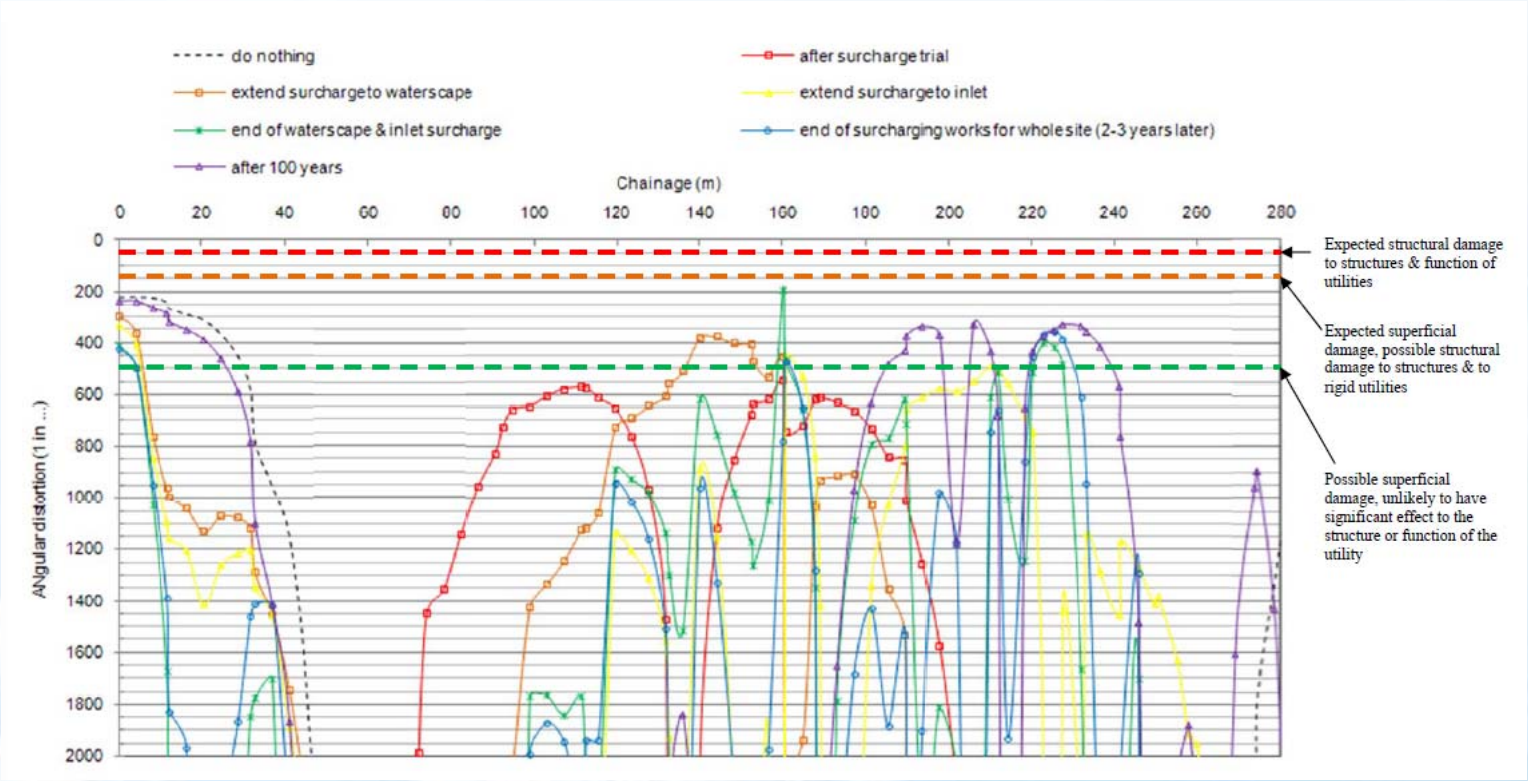
consulting practices

Checks on Causeway bridge movements

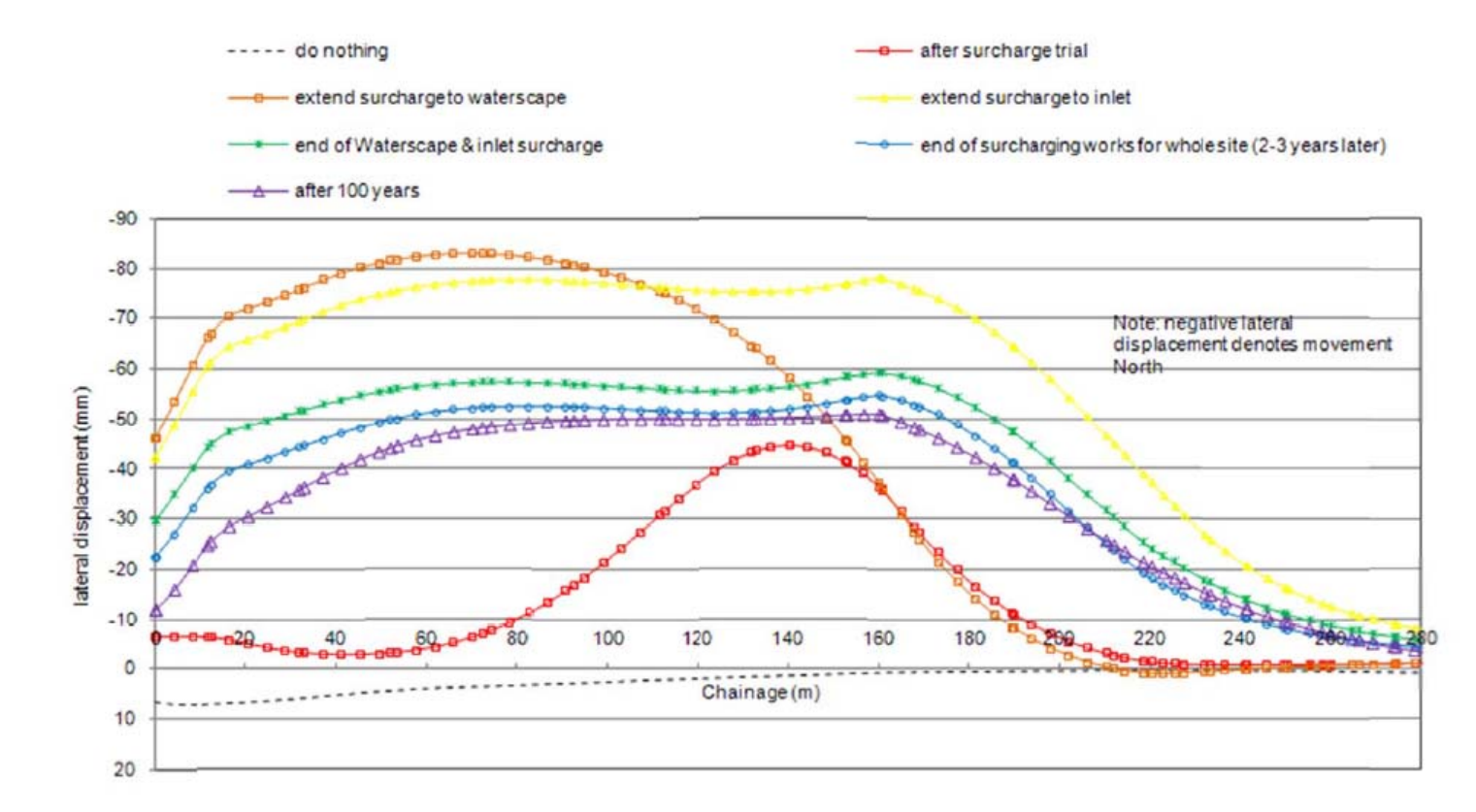


Figures 49(a) & (b). Lateral movements at the toe of Causeway embankment with surcharging (Figure 49a) and "doing nothing" (Figure 49b)
Note: Negative movements denote movement towards the surcharge

Checks on Sewer pipeline distortions



Checks of stormwater pipeline displacements



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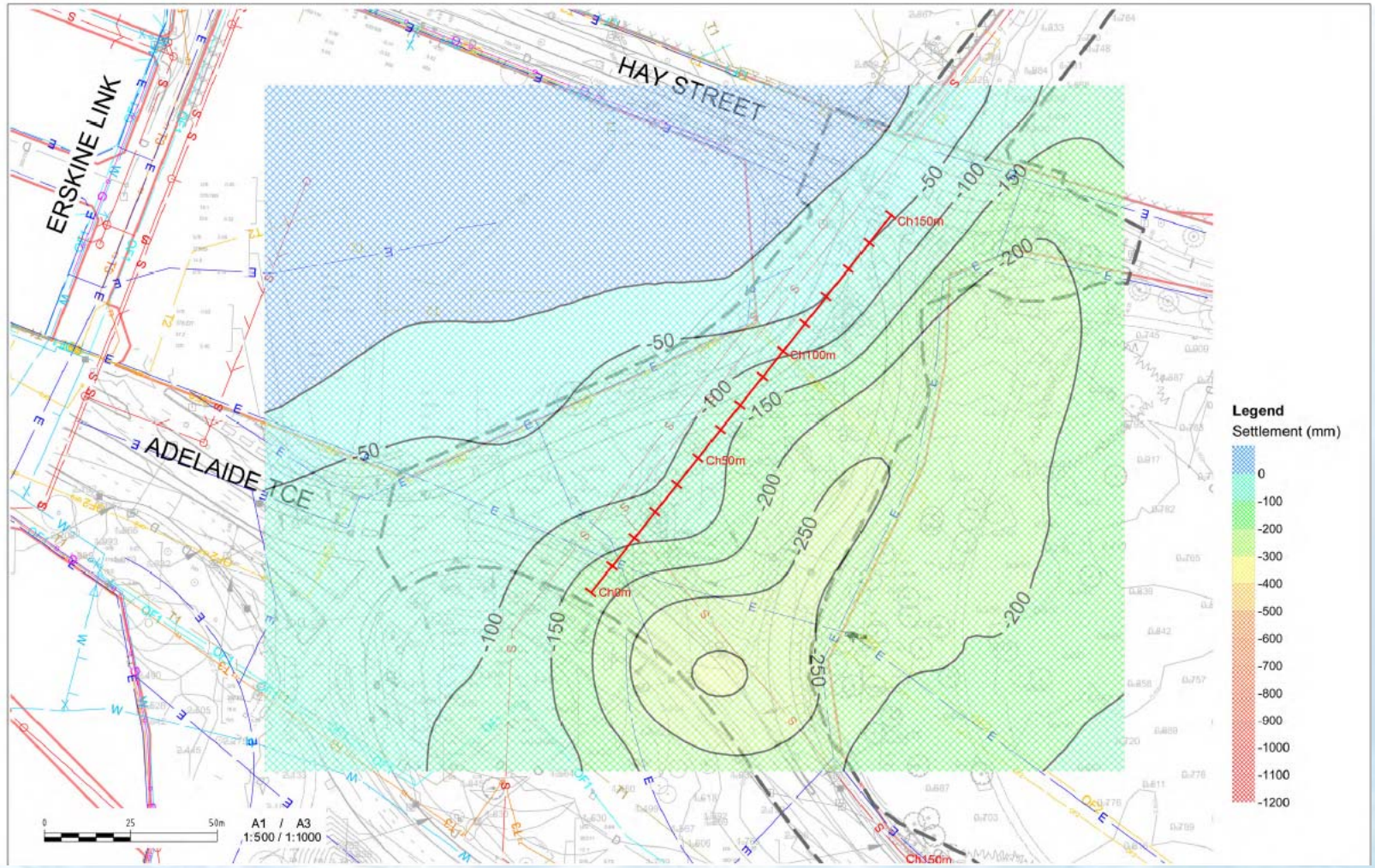
Intersection settlements of roadways



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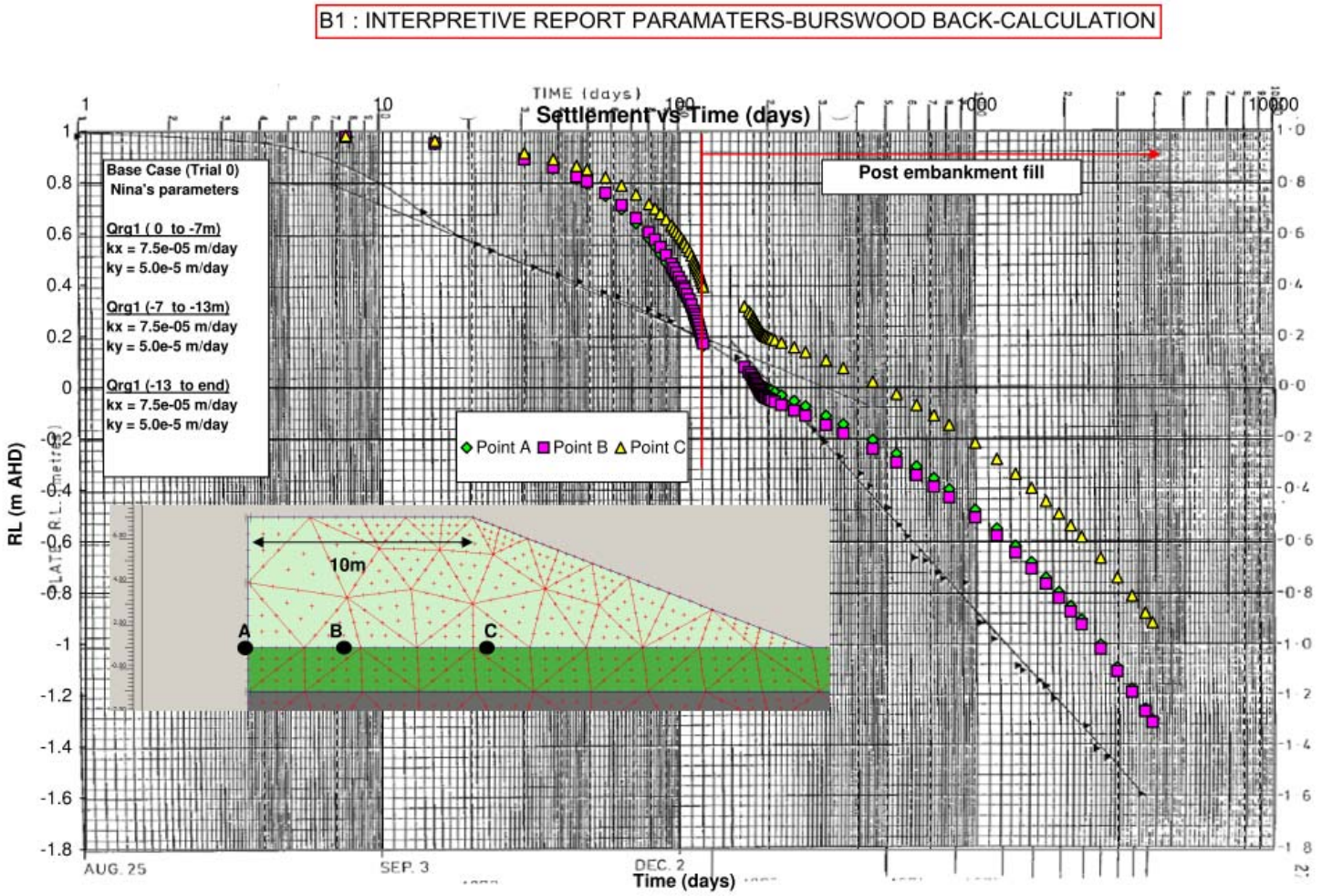
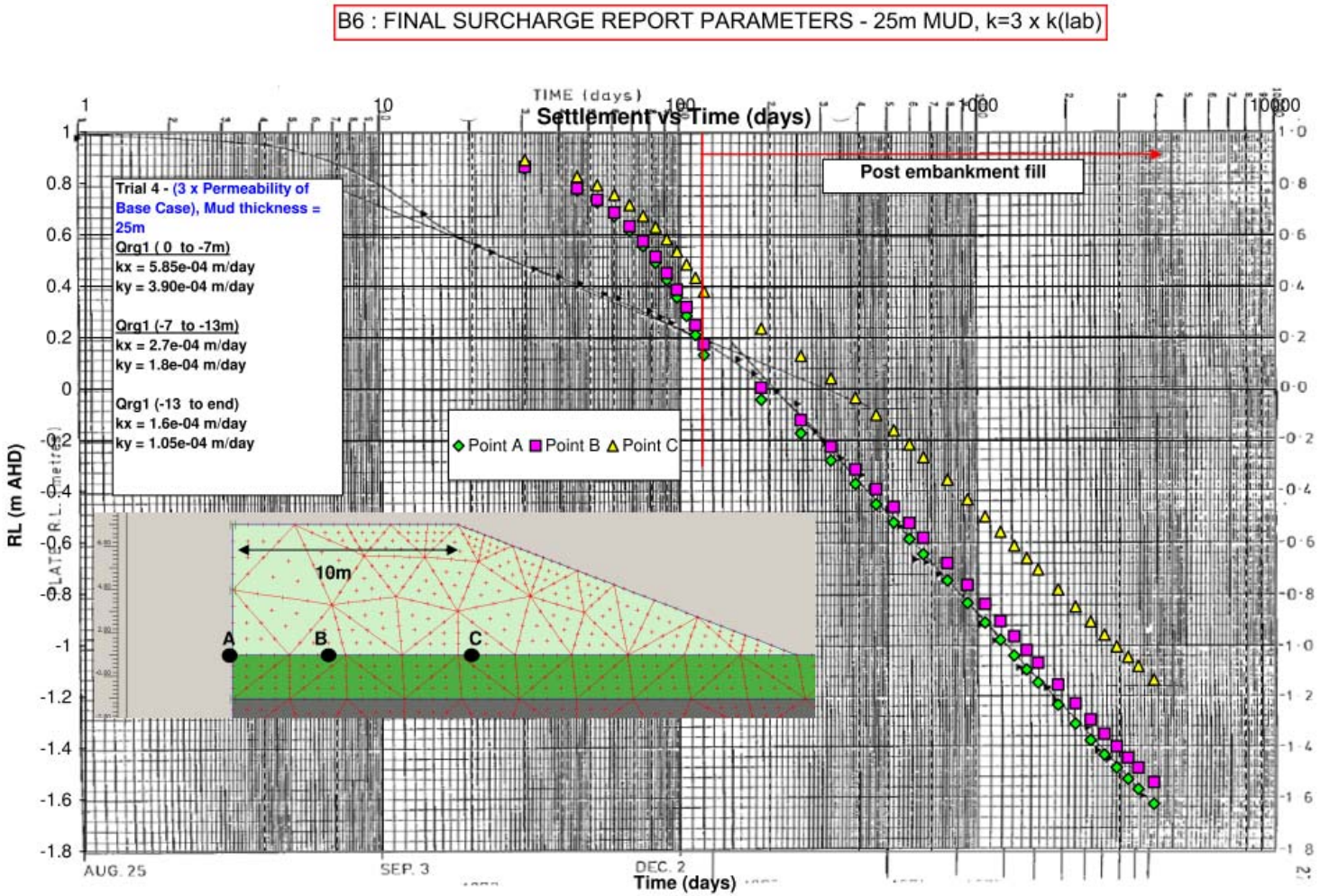
Verification done at the time – back-analysis of Burswood trial without wick drains…



Data from report Main Rds No 83/12

Revised parameters…(no drains)



Updated analysis

Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Unload

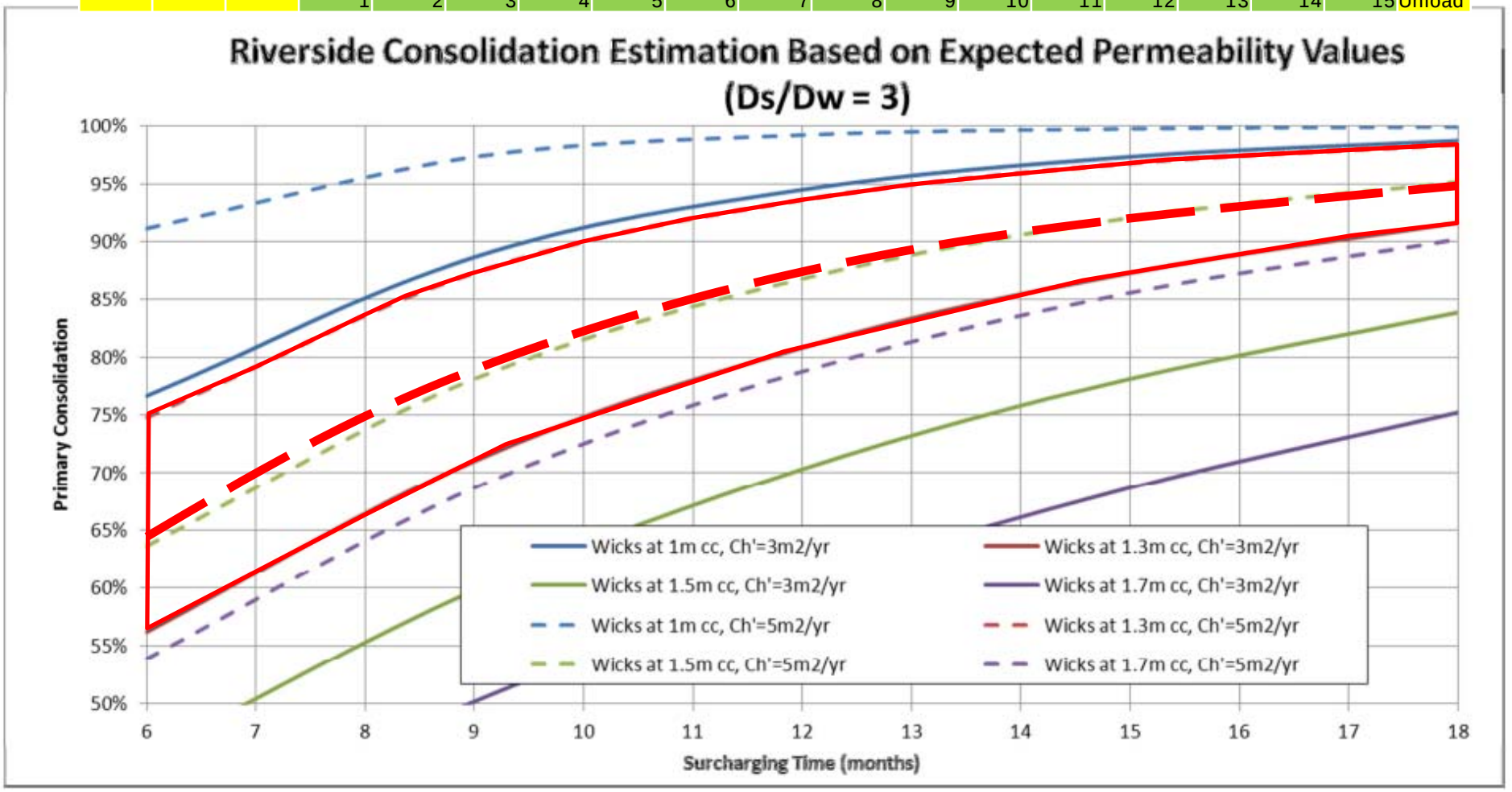
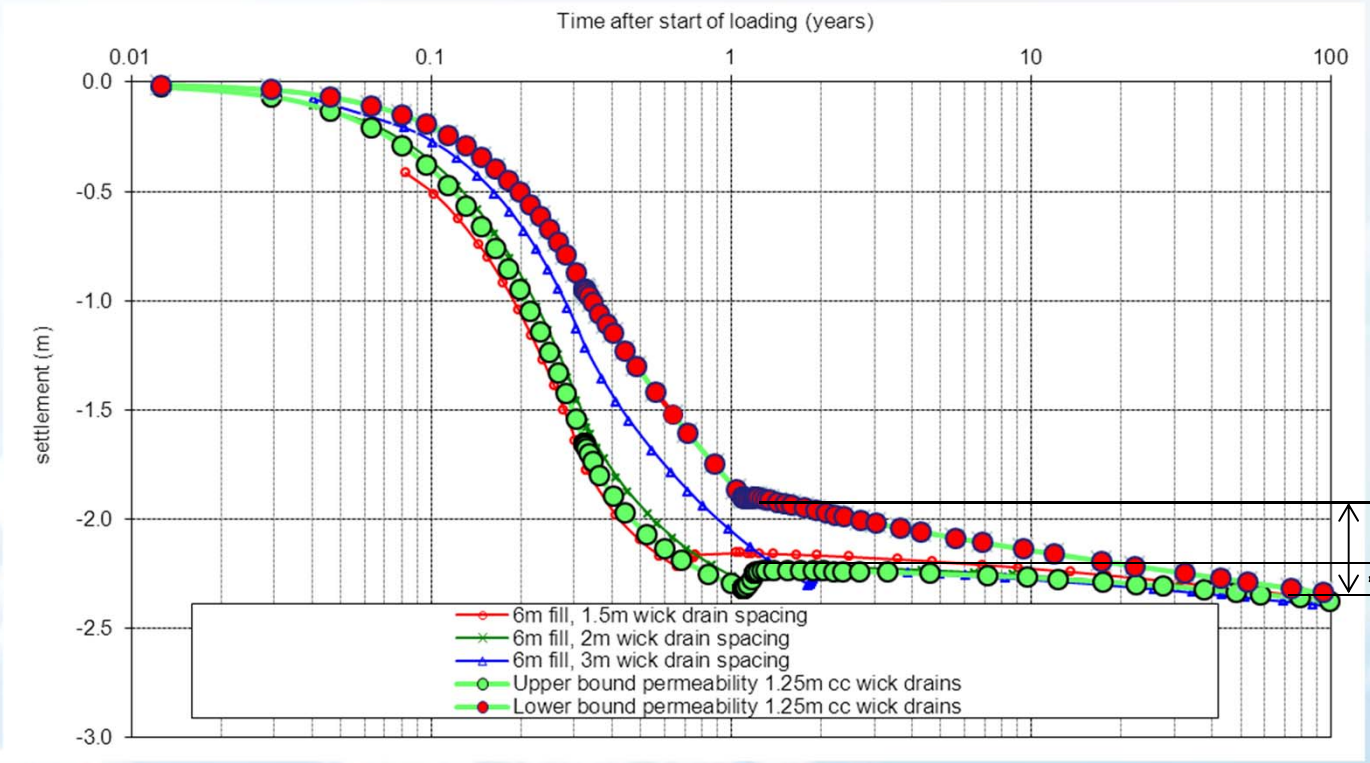


Figure 2: Wick drain spacing vs consolidation time results for Ds/Dw = 3.

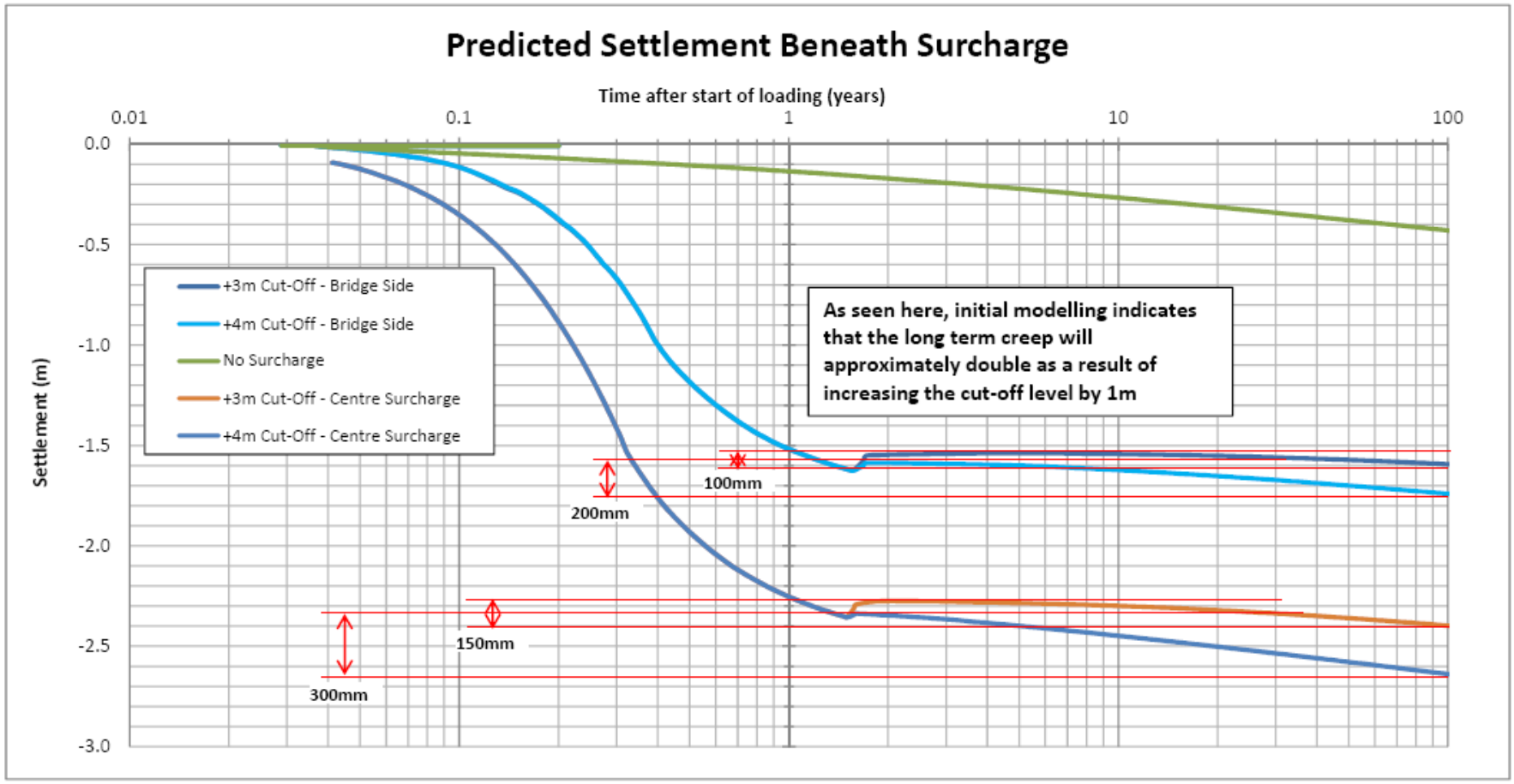
1.25m cc wick drains 18m long-range of performance expected (20m mud thickness)



200 to 500mm of creep possible depending on effective permeability, with RL+3m
(RL +4m finish could double these values using current methodology!)

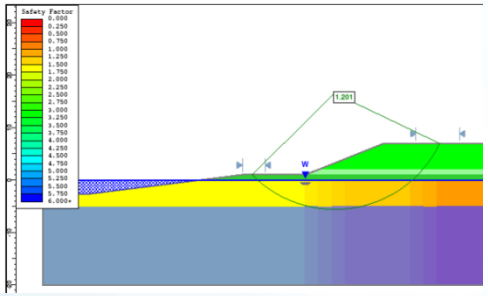
Note: based on finished max RL of +3mAHD, after 6m surcharge filling: Note that creep affected by effective permeability, mud thickness, wick drain length, final RL , surcharge duration and magnitude of unloading and timing thereof

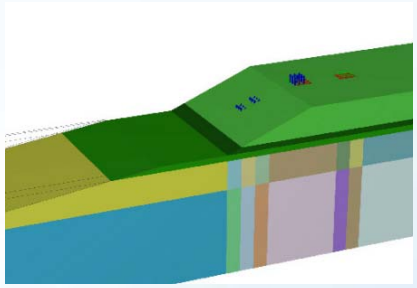
Effect of +4mRL instead of +3mRL



Post meeting Note: this calc was done using the optimistic permeability-the previous slide shows the creep goes from 200-500mm with the lower permeability- hence effect may be doubled again (hence this slide understates the likely effect of +4mRL: its intent is to highlight that ***creep in the previous slide*** is doubled by RL+4m

Stability checks

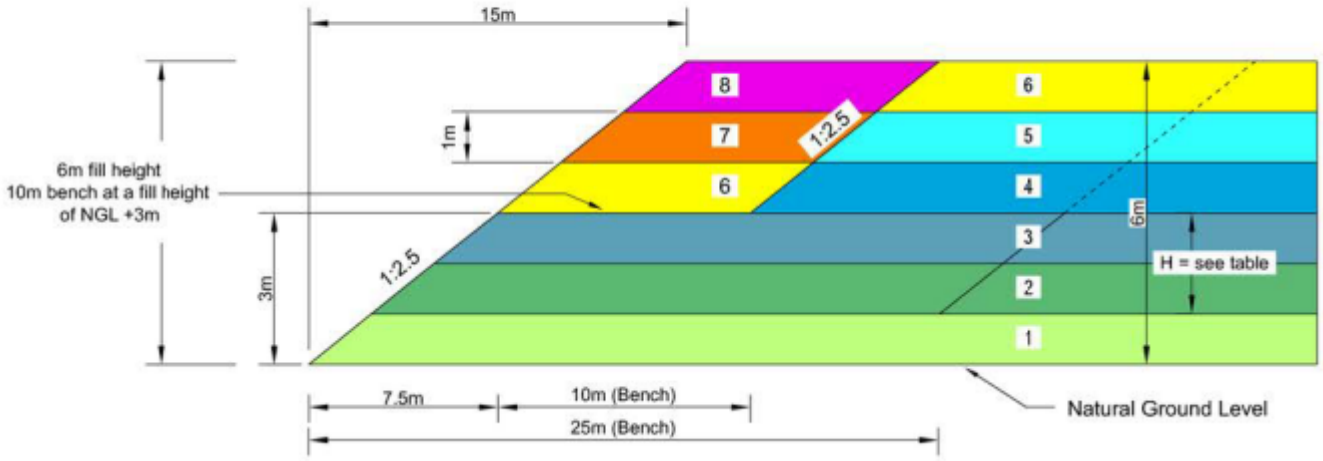




CONSTRUCTION SEQUENCE AND SURCHARGE DURATION

STAGE	LIFT HEIGHT	MAX LAYER THICKNESS (within lift)	WAITING TIME (days)	MAX ADDITIONAL MATERIAL HEIGHT FOR INTERNAL AREAS THICKNESS, H (25m from toe)
8	1.0m	1.0m	tbc	approx 14mnths (tbc)
7	1.0m	1.0m	35	na
6	1.0m	1.0m	10	na
5	1.0m	1.0m	25	0m
4	1.0m	1.0m	25	1m
3	1.0m	1.0m	10	2m
2	1.0m	1.0m	10	2m
1	1.0m	1.0m	10	2m
		Total	125	

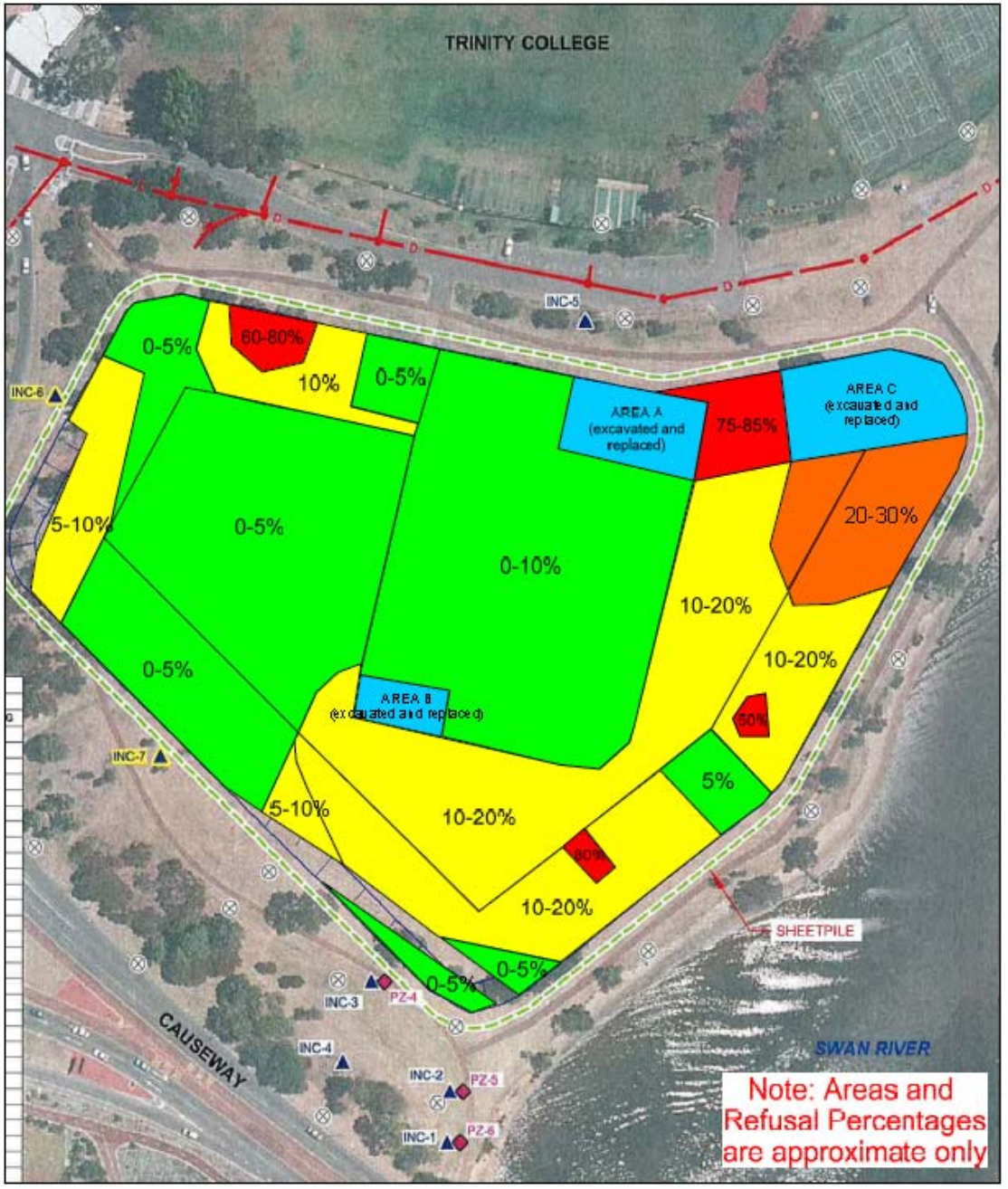
TYPICAL SECTION SHOWING CONSTRUCTION SEQUENCE



Wick drain installation

Plate 3: Obstructions found within old fill during Area C excavation (1)

Plate 1: Wick drains along eastern edge of site (pink flag indicates auger refusal)



Approximate Percentages of Auger Refusal

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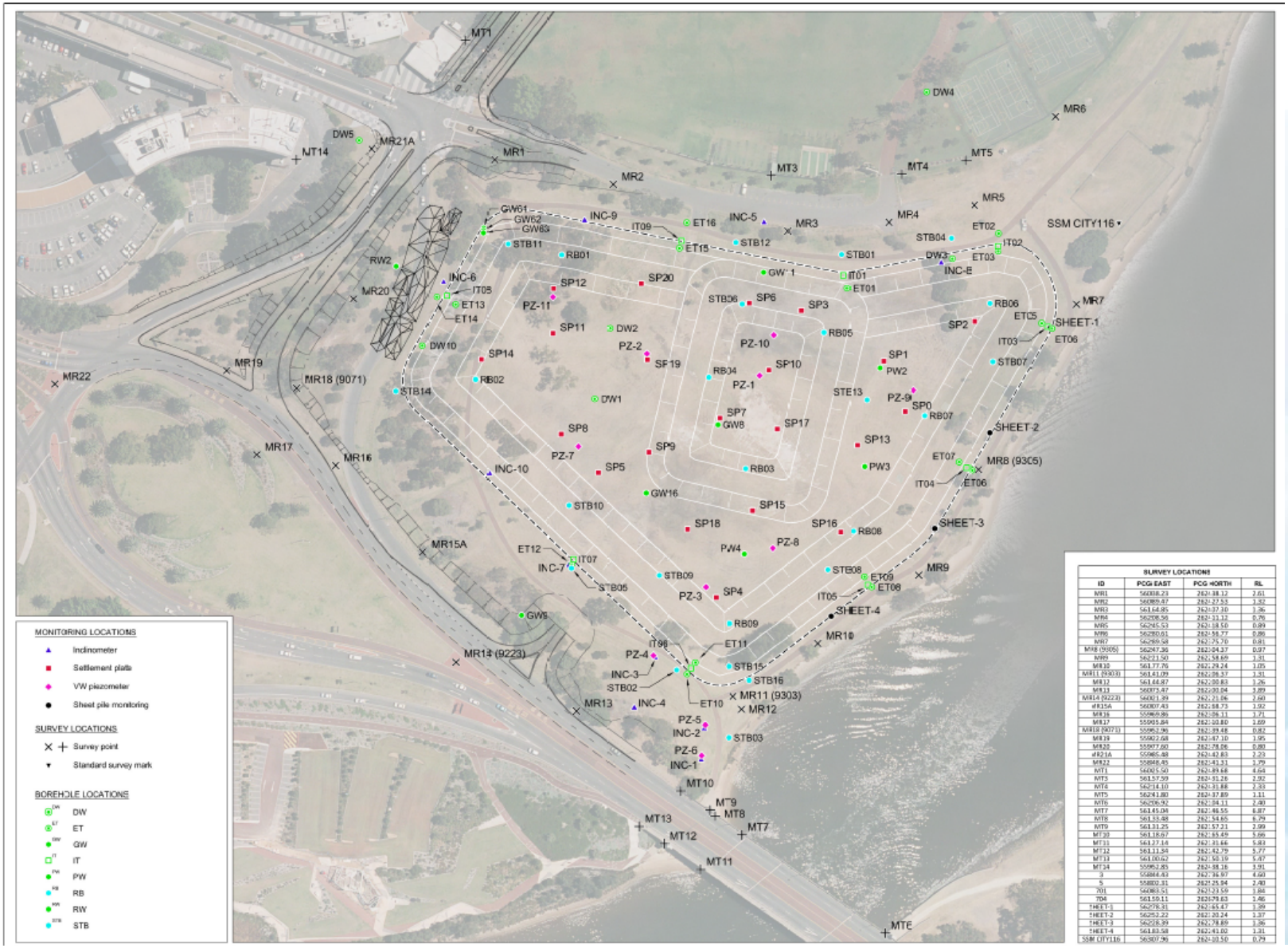
Monitoring



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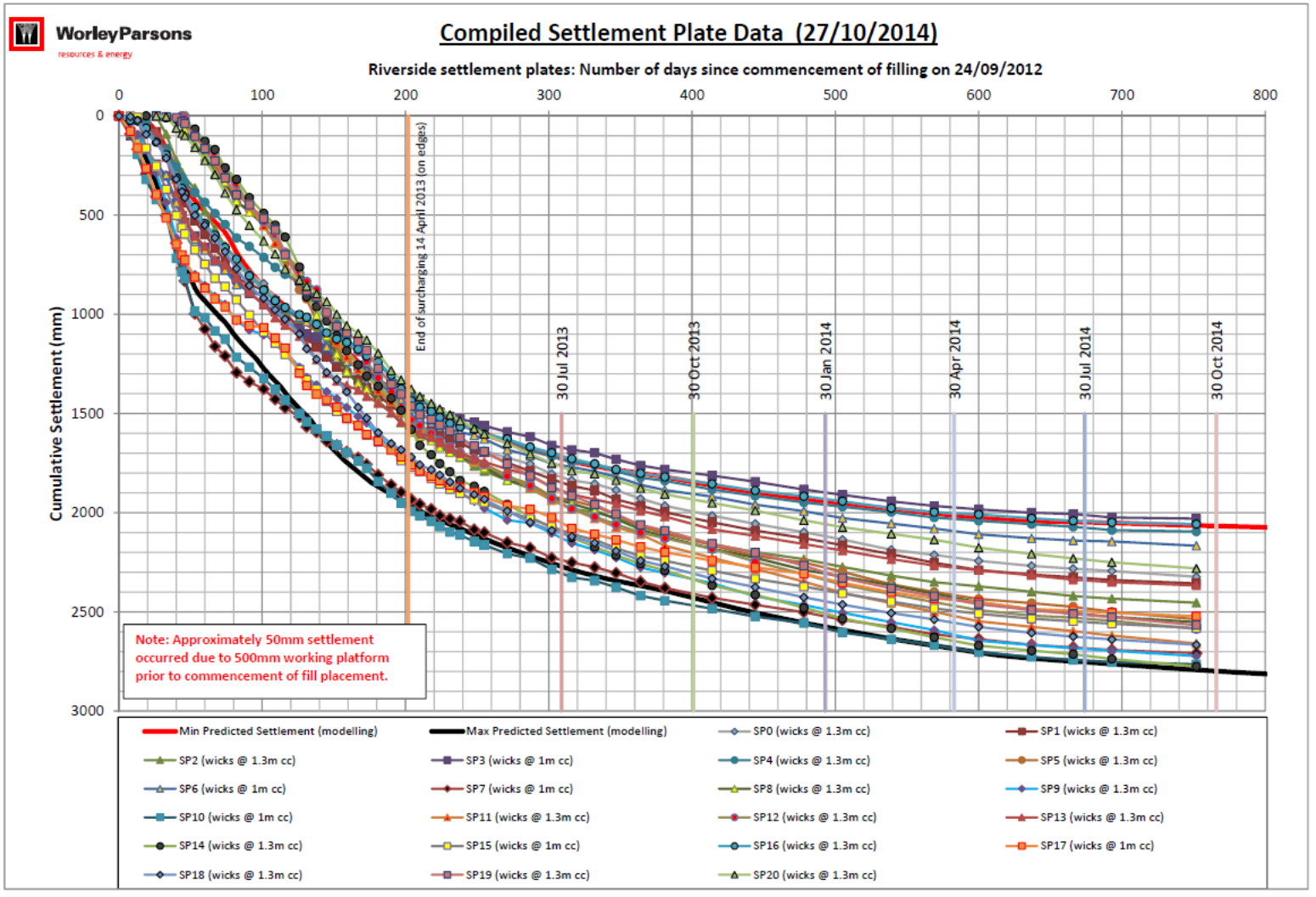
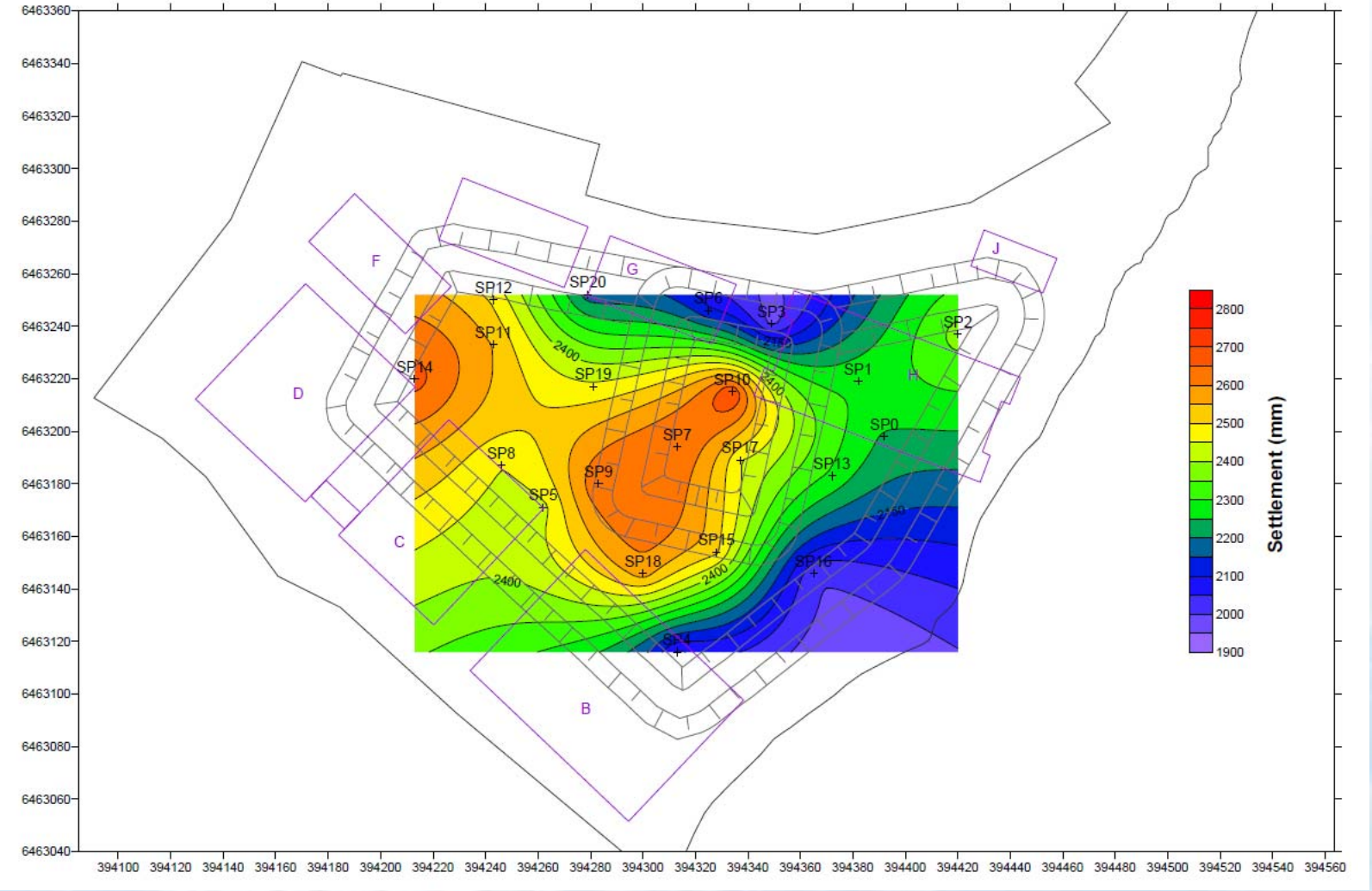
Settlement plates



Settlement Plate measurements as of 17 May 2014



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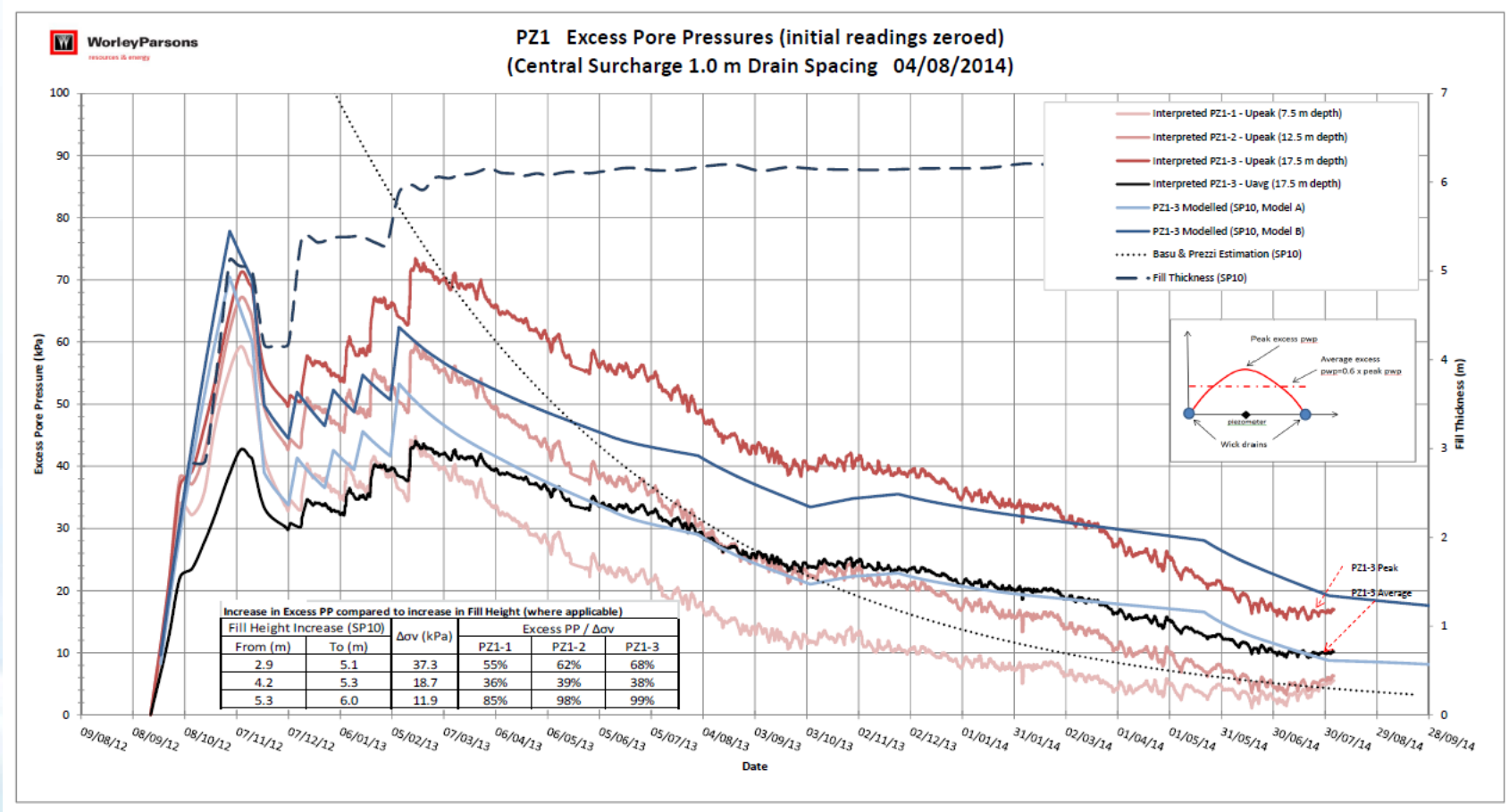
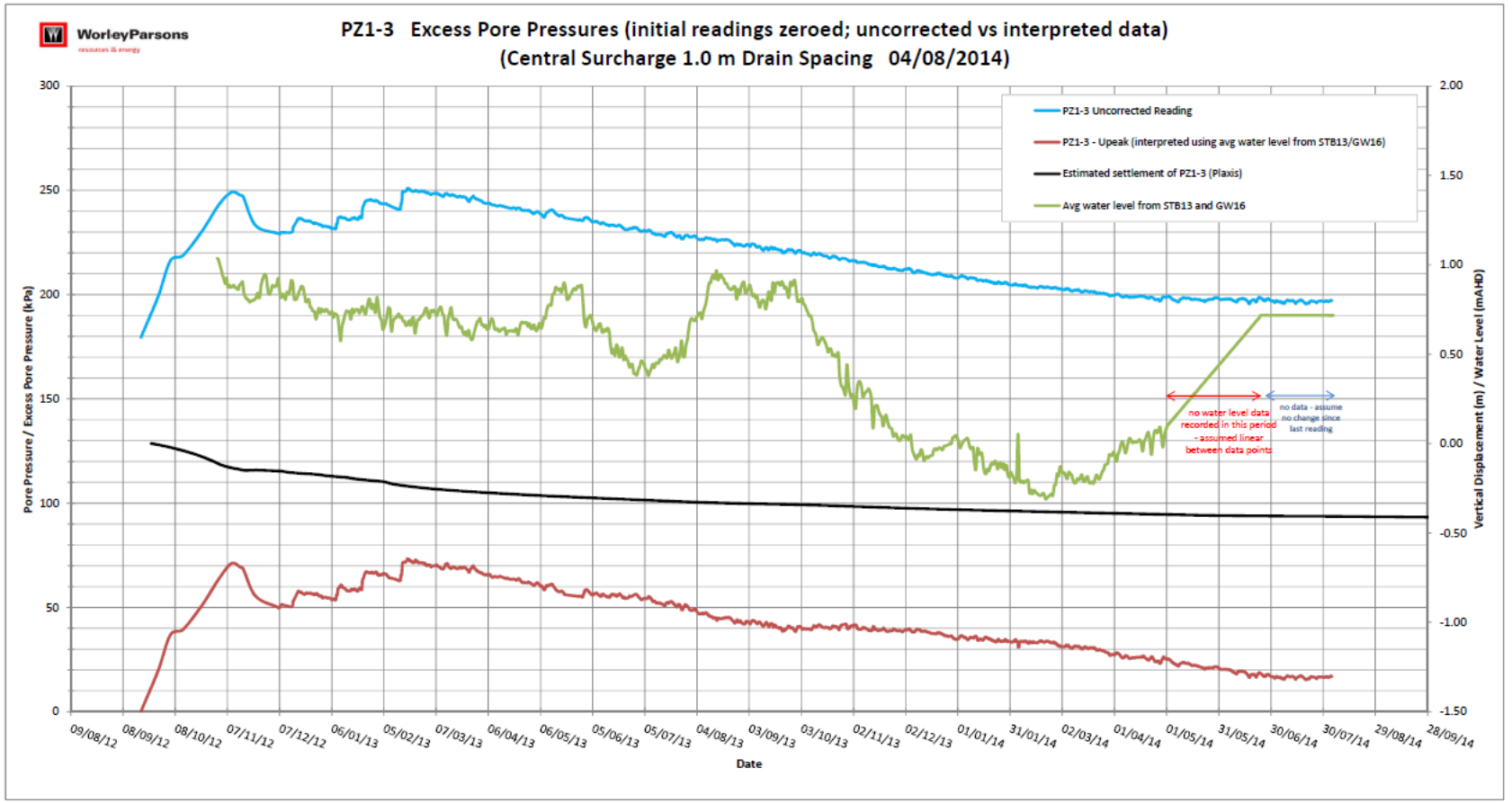
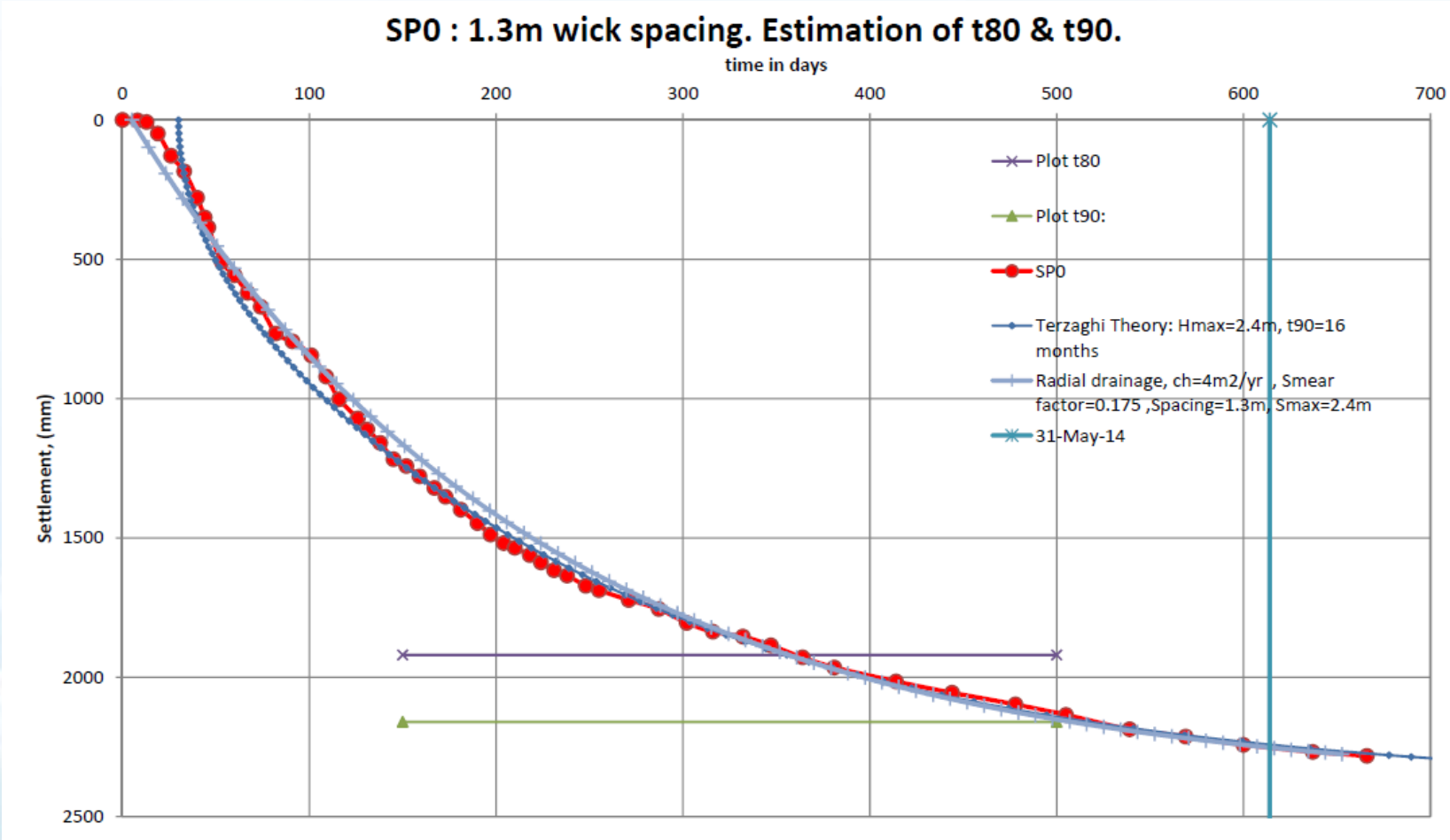
Piezometers No 1



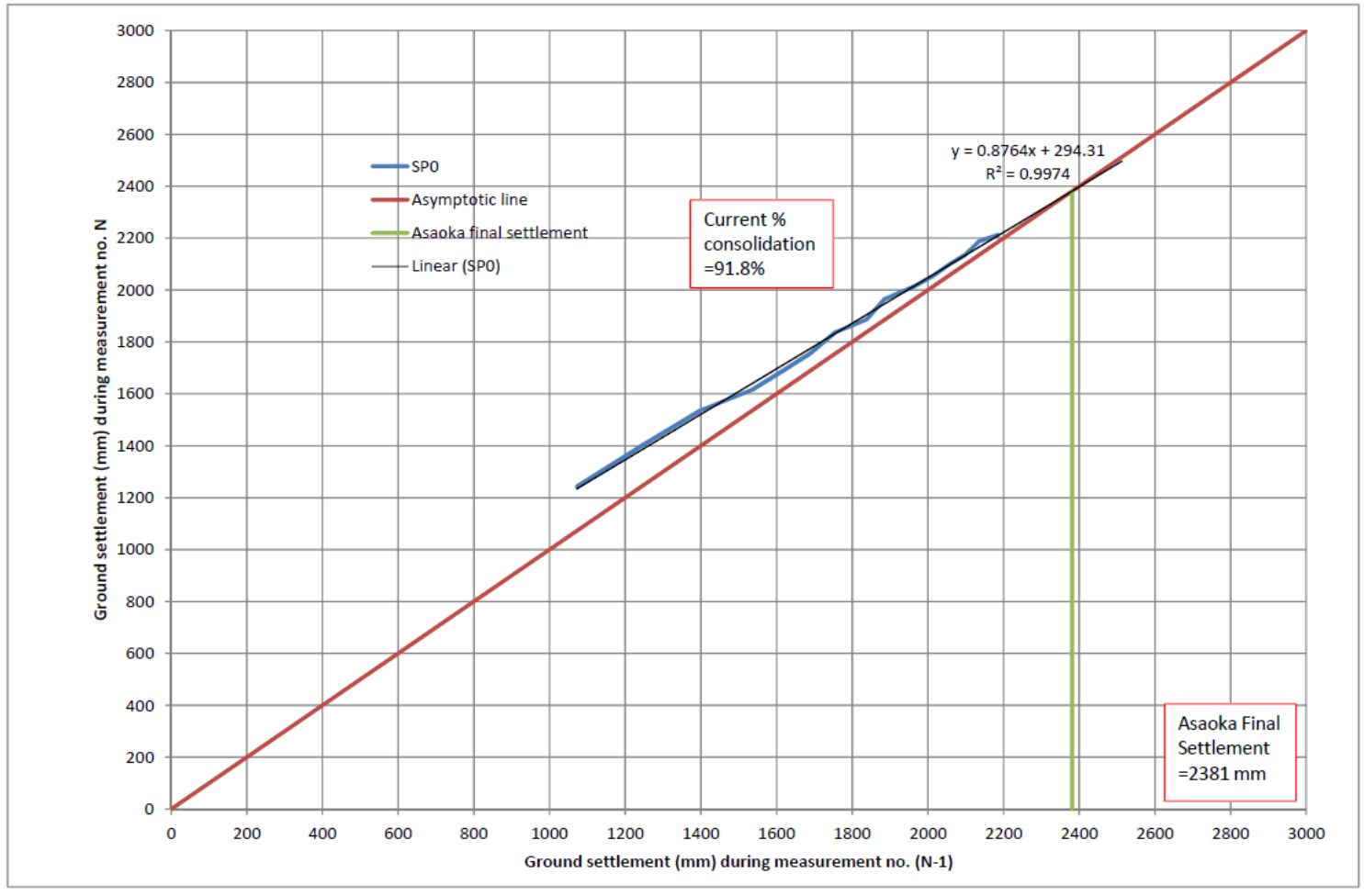
Breakdwon of piezometer calculations



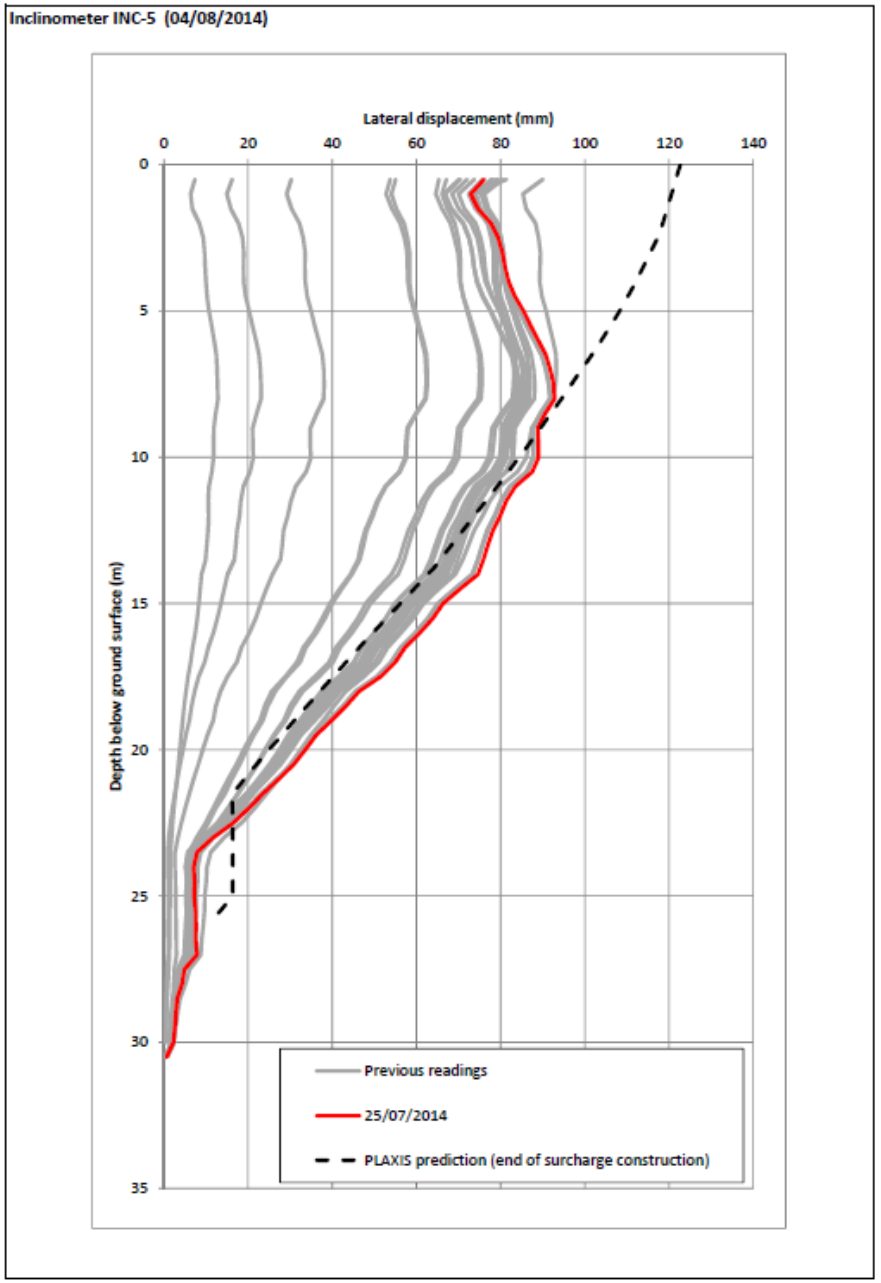
Estimation of t90…



Asaoka plots…



Inclinometers—North



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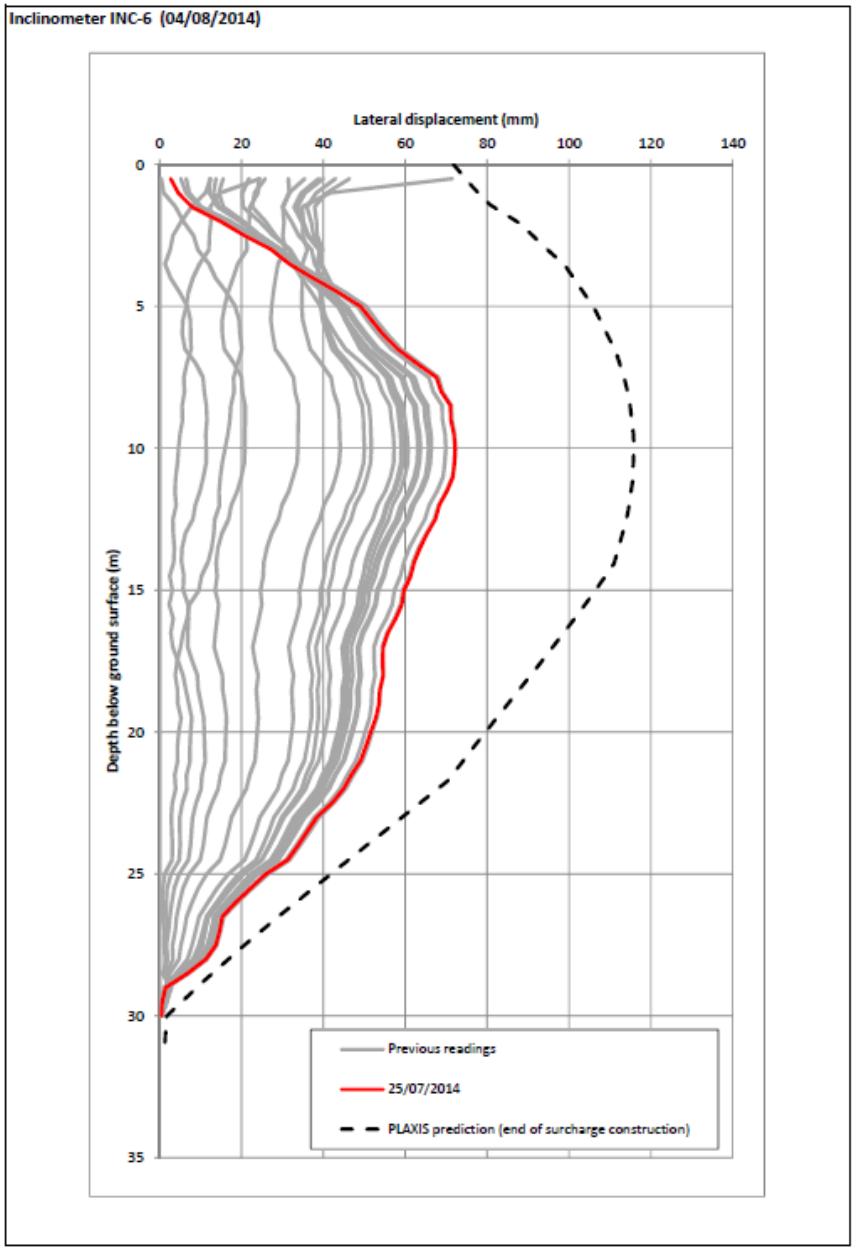
Inclinometers - West



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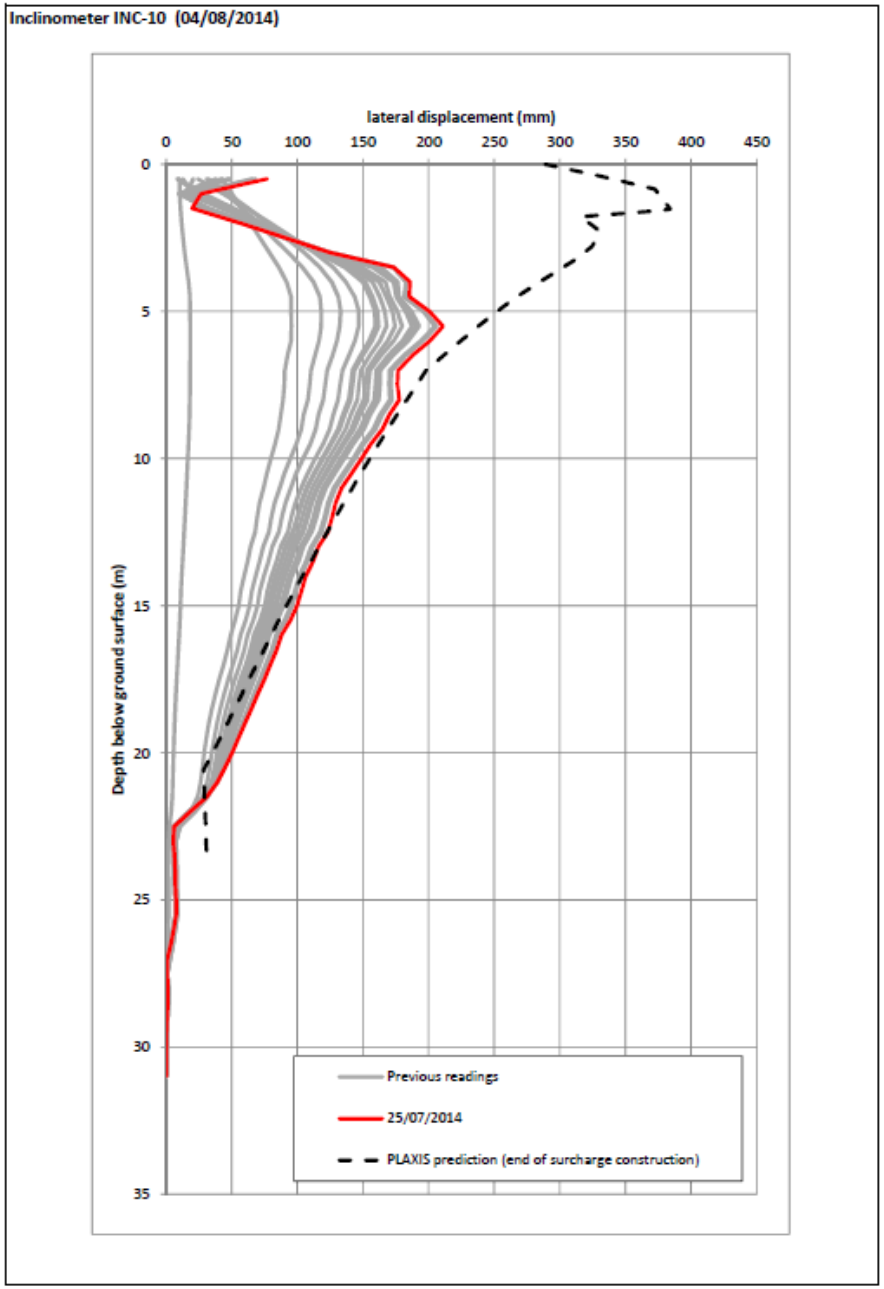
Inclinometer - south



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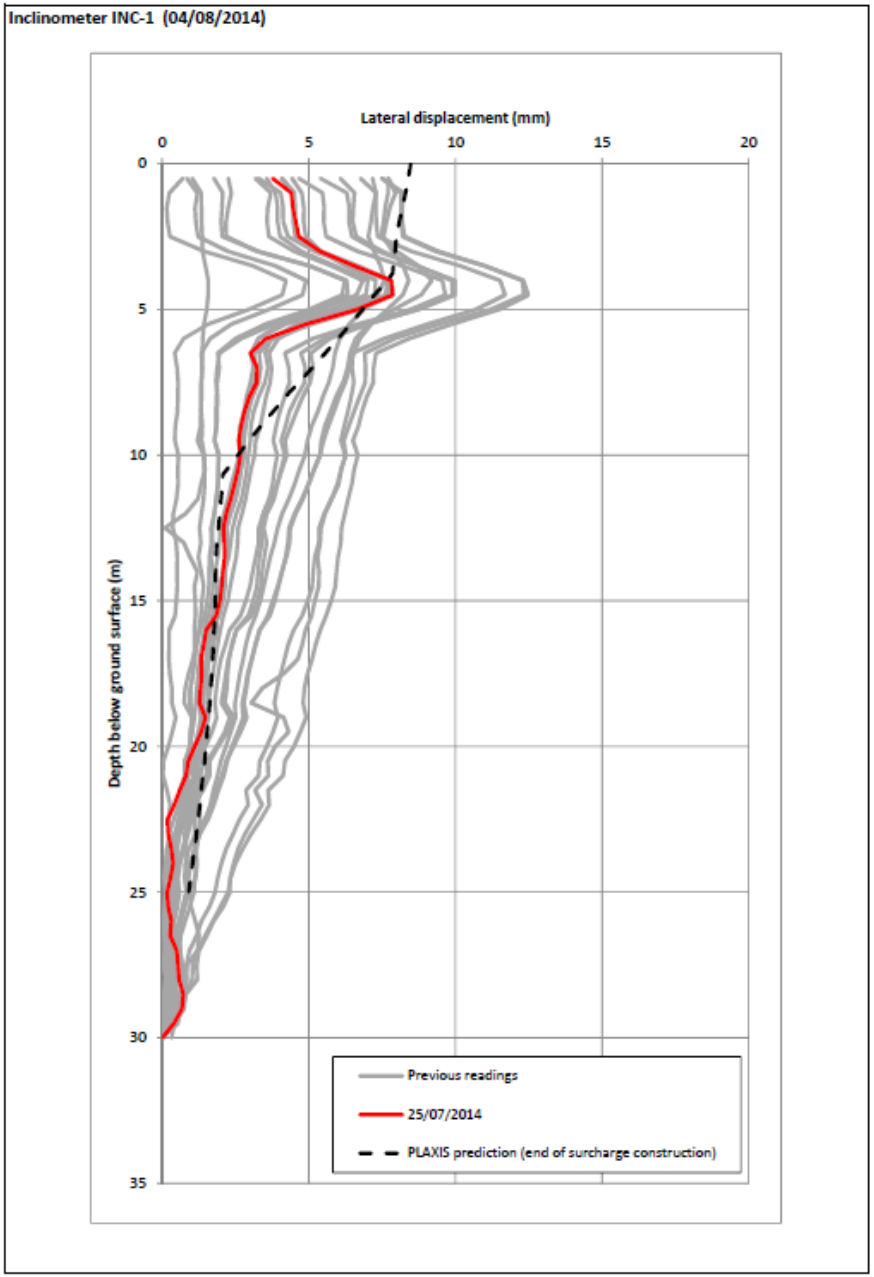
Inclinometers-near bridge



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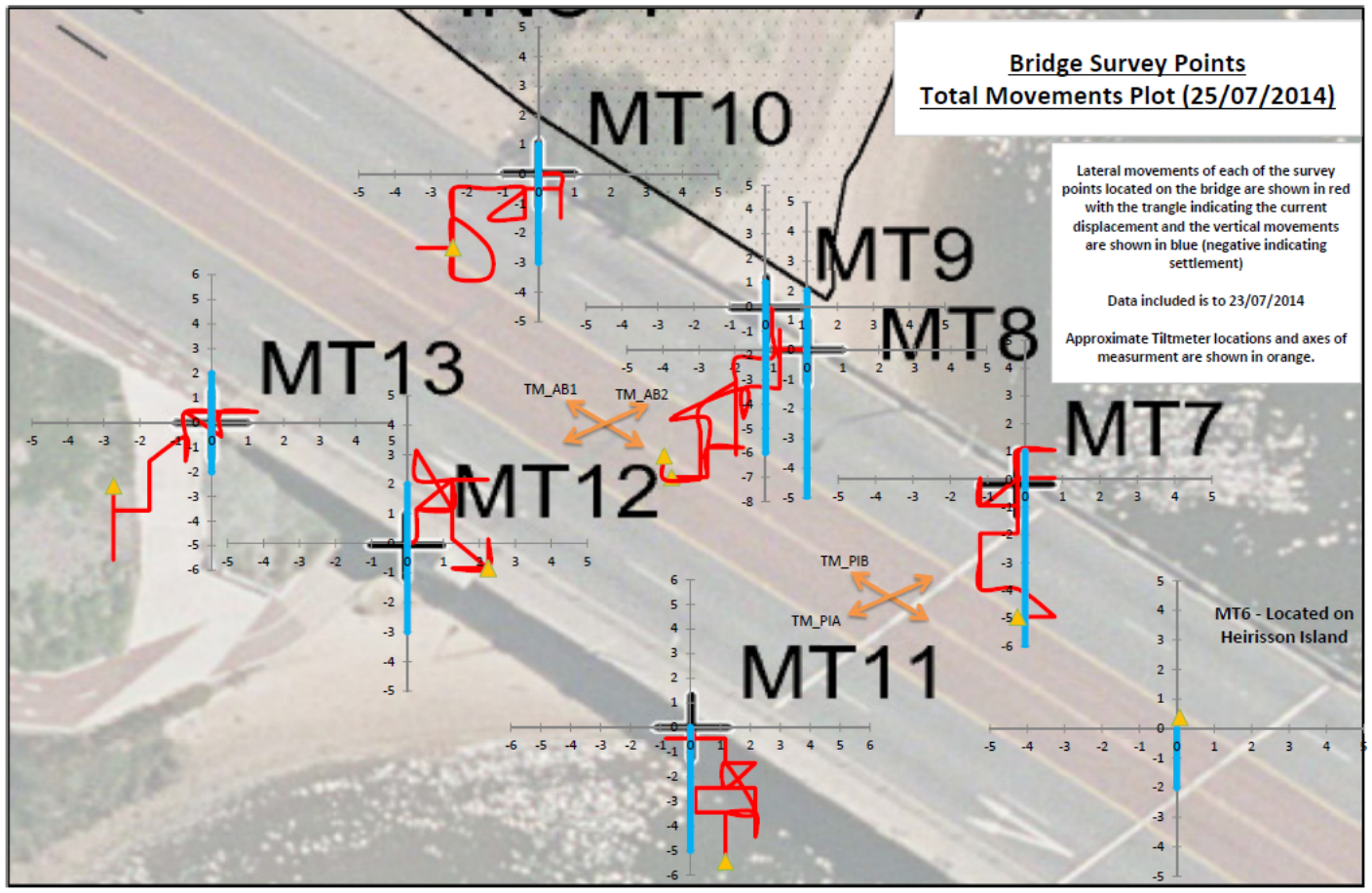
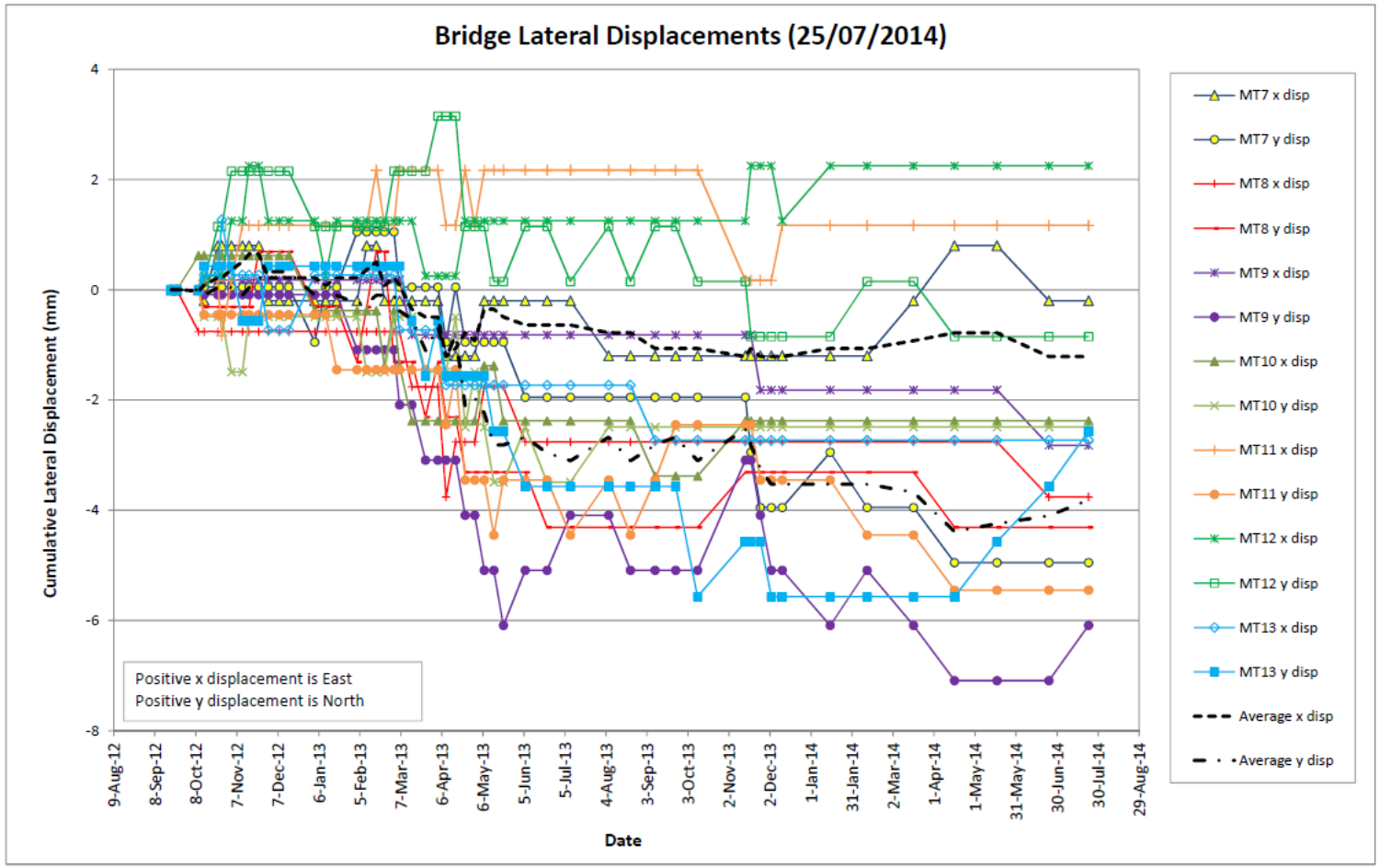
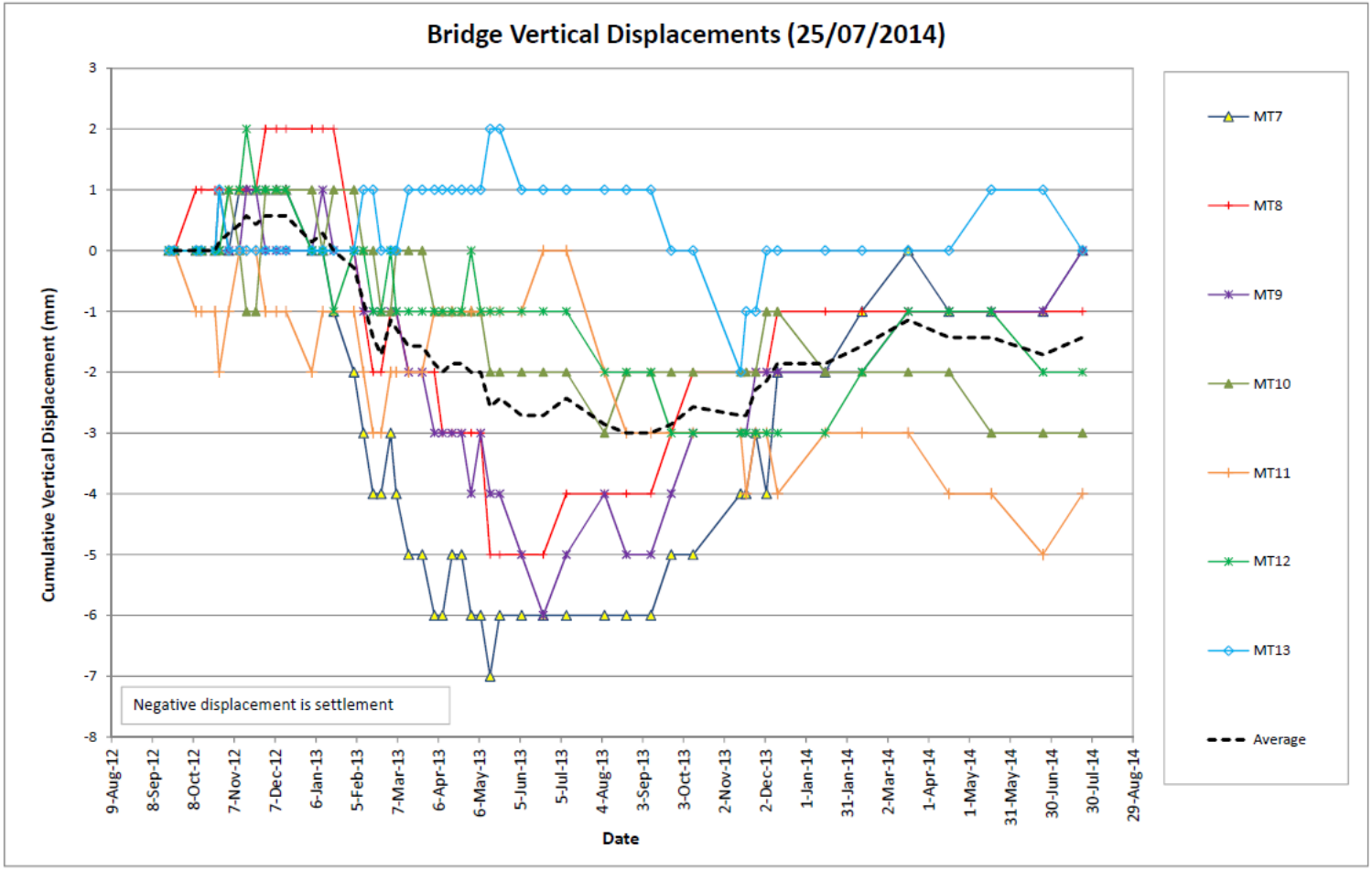
Survey points xyz

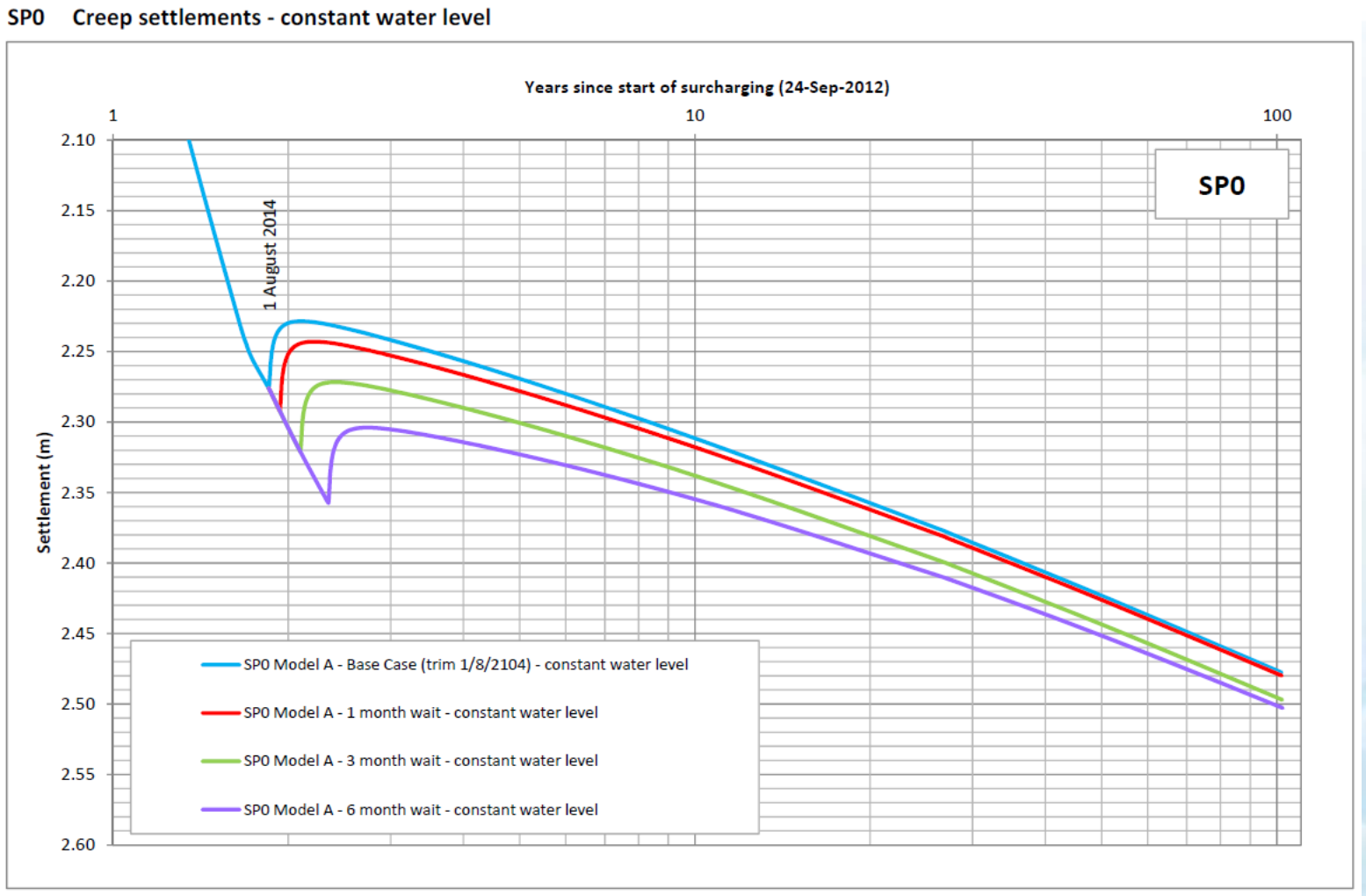


Bridge movements



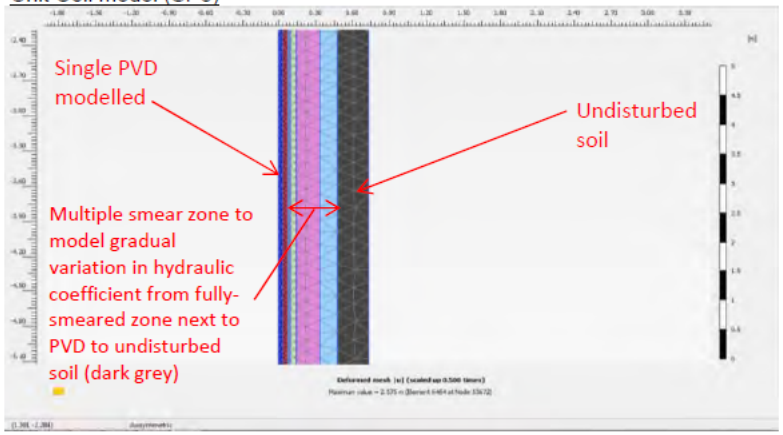

Bridge Vertical Displacements (25/07/2014)
Cumulative Vertical Displacement (mm)
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
Negative displacement is settlement
9-Aug-12
8-Sep-12
8-Oct-12
7-Nov-12
7-Dec-12
6-Jan-13
5-Feb-13
7-Mar-13
6-Apr-13
6-May-13
5-Jun-13
5-Jul-13
4-Aug-13
3-Sep-13
3-Oct-13
2-Nov-13
2-Dec-13
1-Jan-14
31-Jan-14
2-Mar-14
1-Apr-14
1-May-14
31-May-14
30-Jun-14
30-Jul-14
29-Aug-14
Date
MT7
MT8
MT9
MT10
MT11
MT12
MT13
Average

Delayed removal to minimise creep…

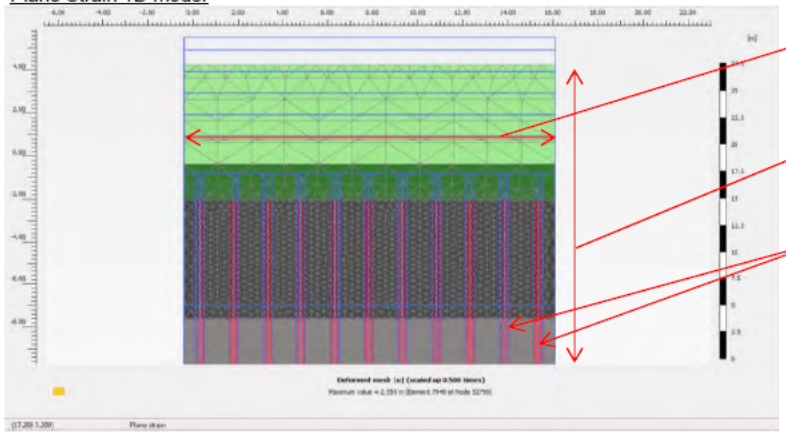


Lateral deflection estimates for long term – effect on piles…

Unit Cell model (SP8)



Plane Strain 1D model

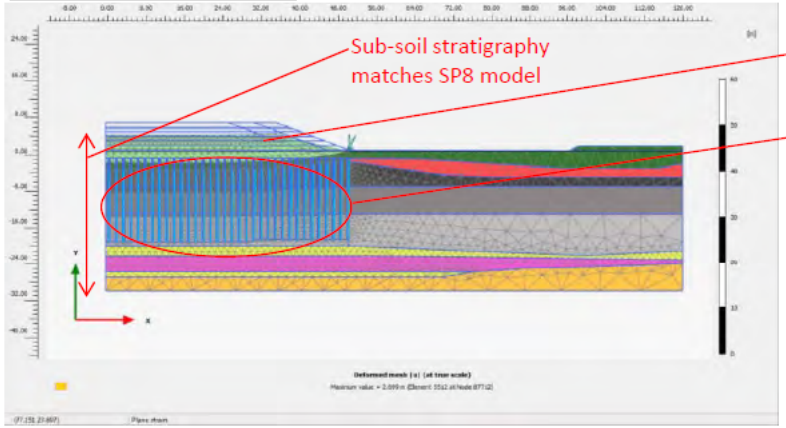


Infinite fill surcharge to model 1D consolidation behaviour

Sub-soil stratigraphy matches SP8 model

Multiple PVDs modelled, each with a single layer of smeared zone on each side of the PVD instead of multiple numbers in the unit cell model. Fine mesh of 4 elements in the undisturbed soils column , and 1 element on each side of smeared zone.

Plane Strain 2D Section 7 model



Fill embankment modelled

Even more PVDs drawn with the same dimensions as the 1D model. Due to model size, coarse mesh is adopted: 2 elements per undisturbed soil column, and 1 element on each side of smeared zone.

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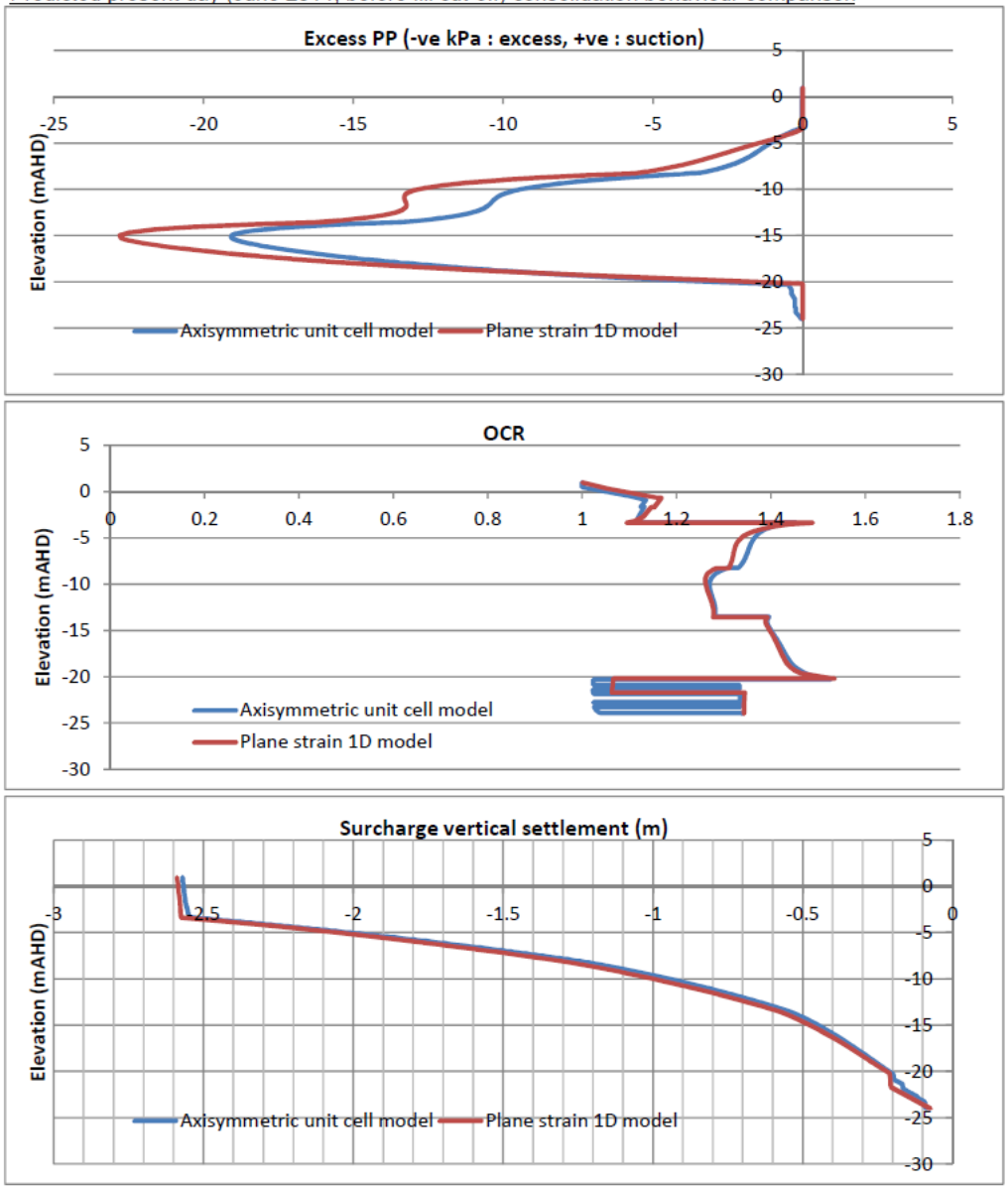
Lateral model calibration..

Predicted present day (June 2014, before fill cut-off) consolidation behaviour comparison



100-year long term additional vertical movement predicted after fill cut-off

Unit Cell model: 243 mm

Plane strain 1D model: 249 mm

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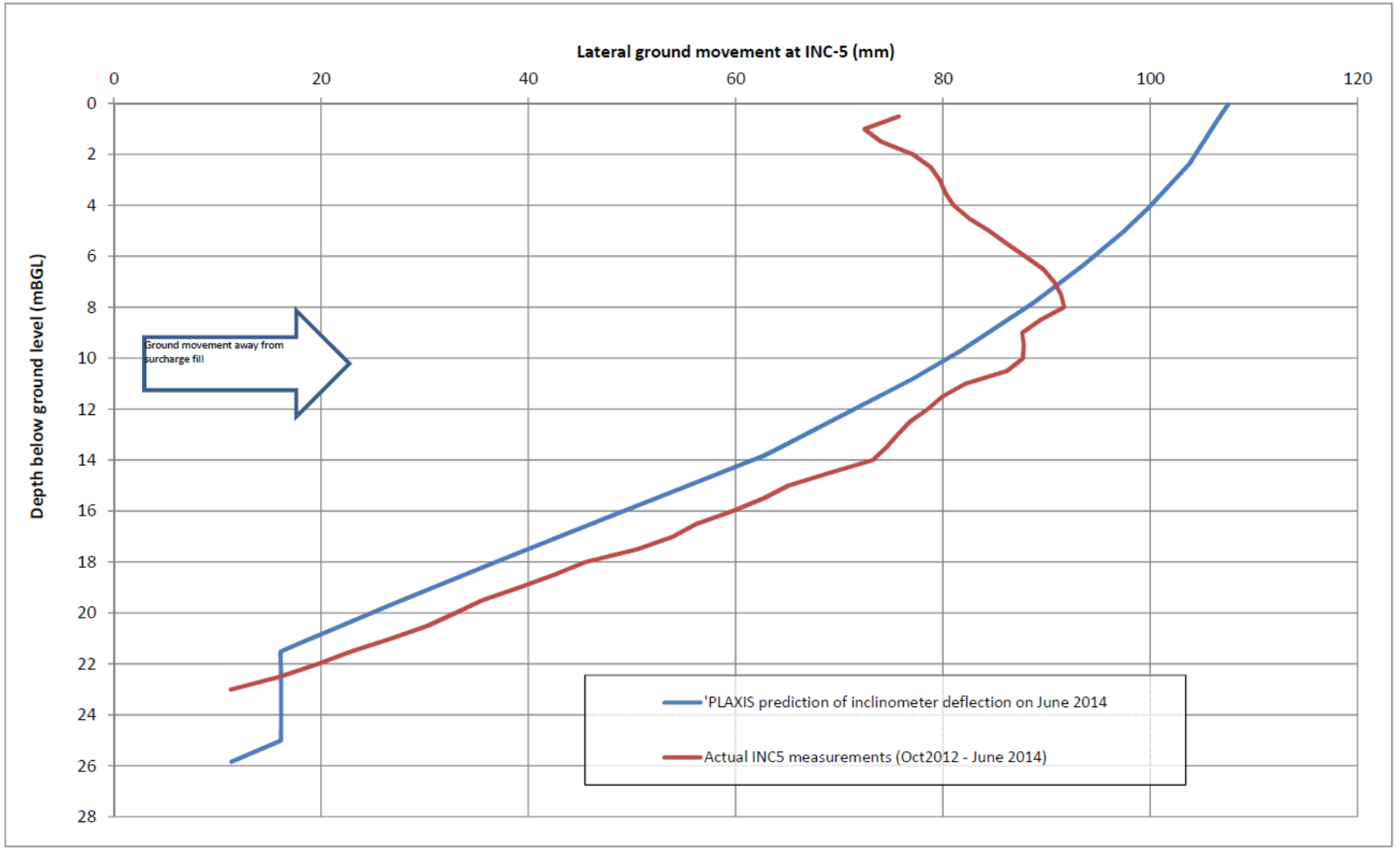
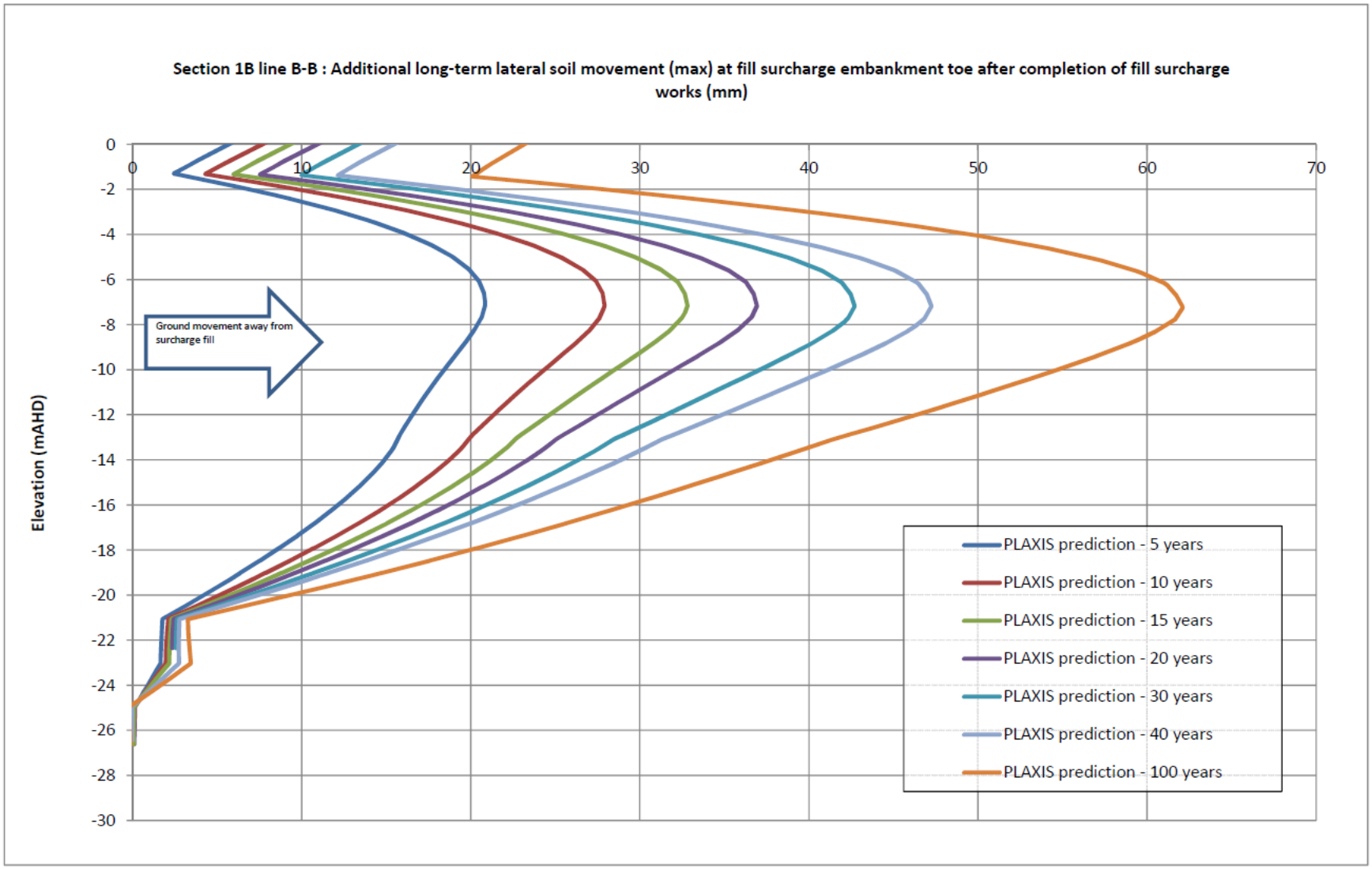
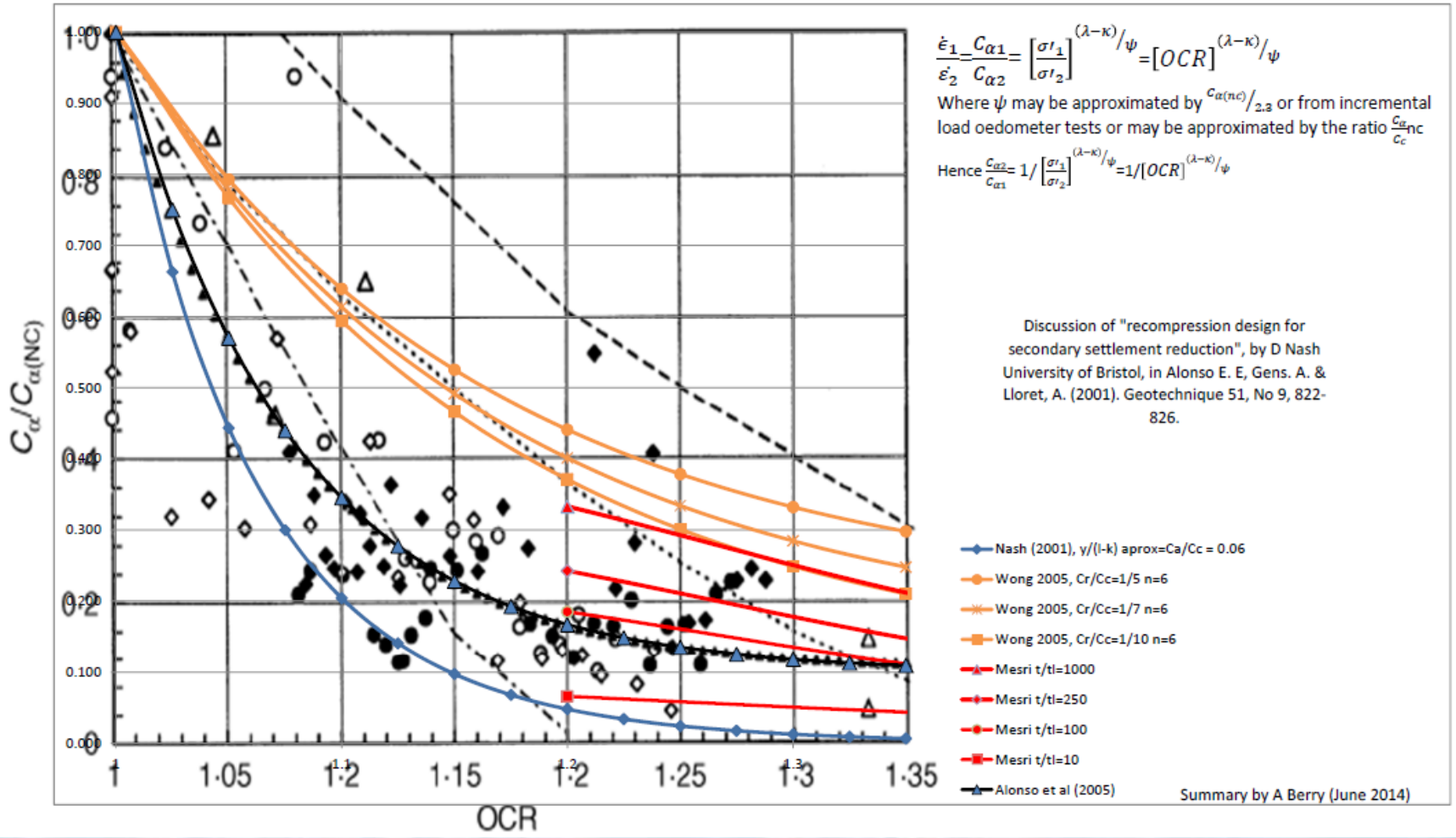
Comparison of results…



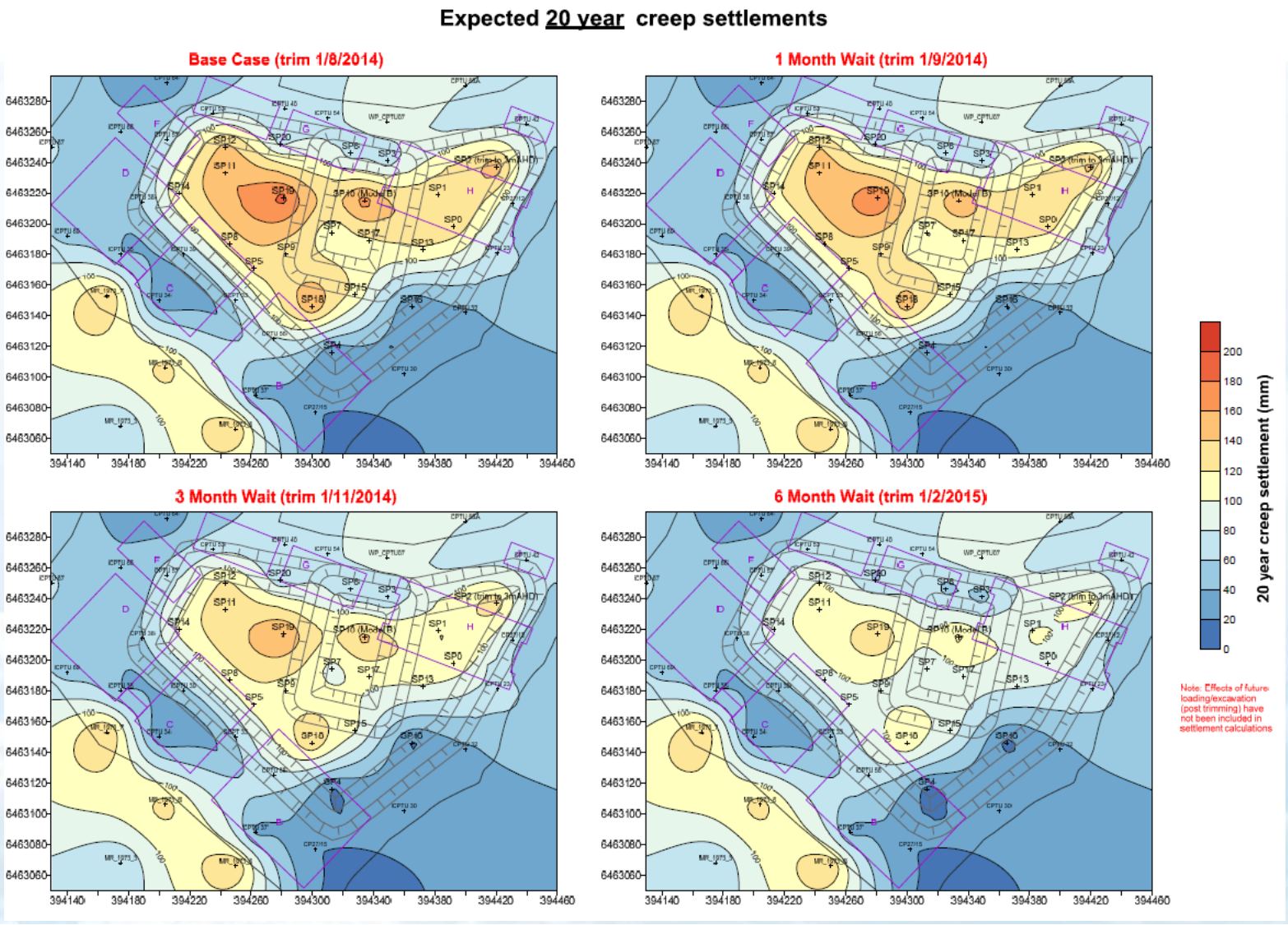
Lateral creep over time



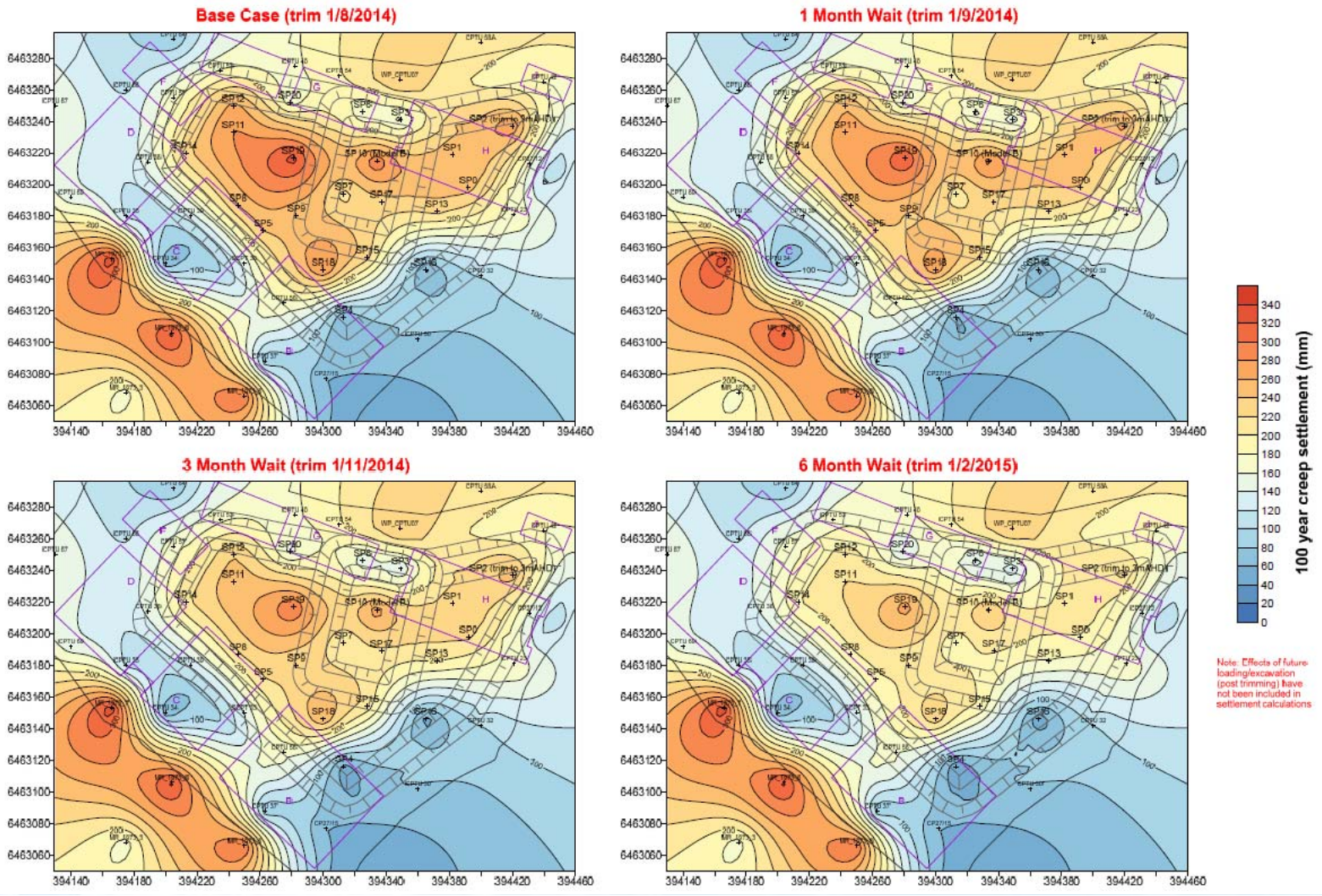
Comparison of creep methodologies…



Resulting creep estimates…



Expected 100 year creep settlements (constant water level)



THANK YOU FOR YOUR TIME

- Alan Berry & Andrew Keep
- Team effort by David Yong, Manh Tran, Ryan Colcott, Joyis Thomas, Fiona Chow, Nina Levy, Michael Page, James Petersen, Paul Rolfe, Eddie Yong's contributions all appreciated and acknowledged