Australian Research Council

Centre of Excellence for Geotechnical Science and Engineering

www.cgse.edu.au

Ballina National Geotechnical Field Testing Facility

Dr Richard Kelly

Visiting Industry Fellow: University of Newcastle

Senior Principal: Coffey

The University of Newcastle Australia

The University of Western Australia — Achieving International Excellence

University of Wollongong

coffey geotechnics — SPECIALISTS MANAGING THE EARTH

Douglas Partners — Geotechnics / Environment / Groundwater

Advanced Geomechanics

Contents

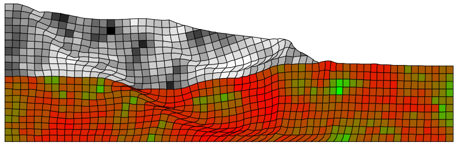
- The Ballina Field Testing Facility
  - In-situ testing
  - Sampling and laboratory testing
  - Embankments
  - Footings
- Future plans

RESEARCH TEAM

CoE for Geotechnical Science and Engineering

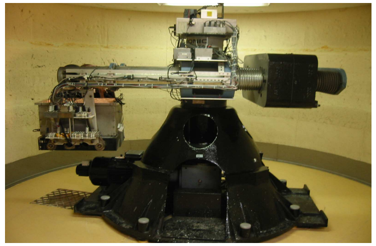
Centre for Geotechnical & Materials Modelling (CGMM, Newcastle)
- Computational modelling
- In-situ testing NEWSYD

Centre for Offshore Foundation Systems (COFS, UWA)
- Physical modelling (centrifuges, O-Tube)
- Offshore geotechnics



Energy & Transport Infrastructure

Geotechnics & Railway Engineering Centre (GRE, Wollongong)
- Railway geotechnics
- Soft soils



RESEARCH PROGRAM

COMPUTATIONAL TECHNIQUES

GEOTECHNICAL SCIENCE

Geomaterial Science
- Soft soils
- Creep
- Anisotropy
- Rate effects
- Rail ballast

Multiphysics Modelling
- Solid-fluid transitions
- Liquefaction
- Thermal effects
- Gassy soils

Moving Bdry Problems
- Pipelines
- Piles
- Penetrometers
- Anchors
- Risers

GeoRisk
- Stochastic analysis
- Geohazards
- Reliability
- Slopes

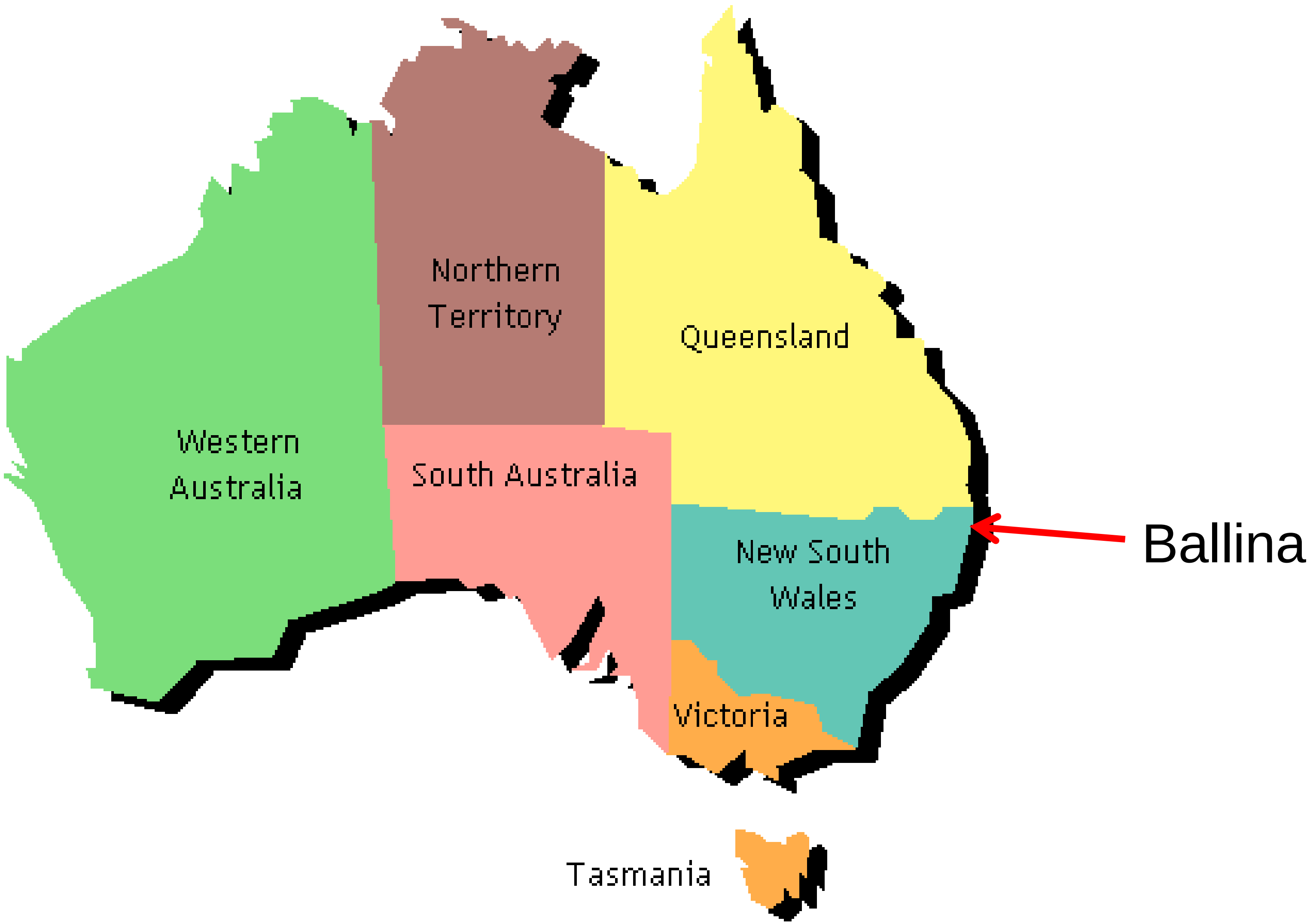
PHYSICAL MODELLING

NEW TOOLS

ENGINEERING APPLICATIONS

NEW TOOLS

Ballina Field Testing Facility



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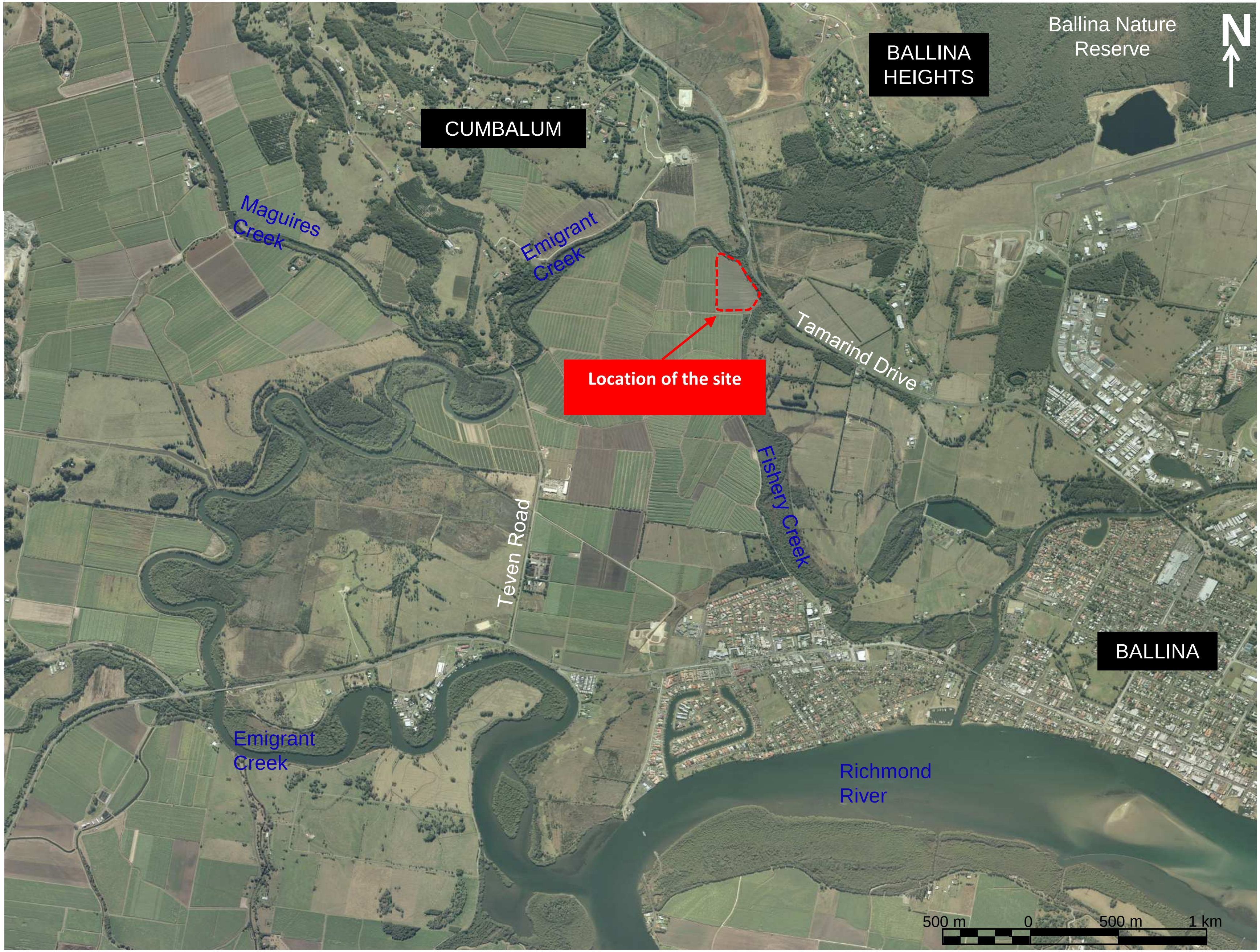
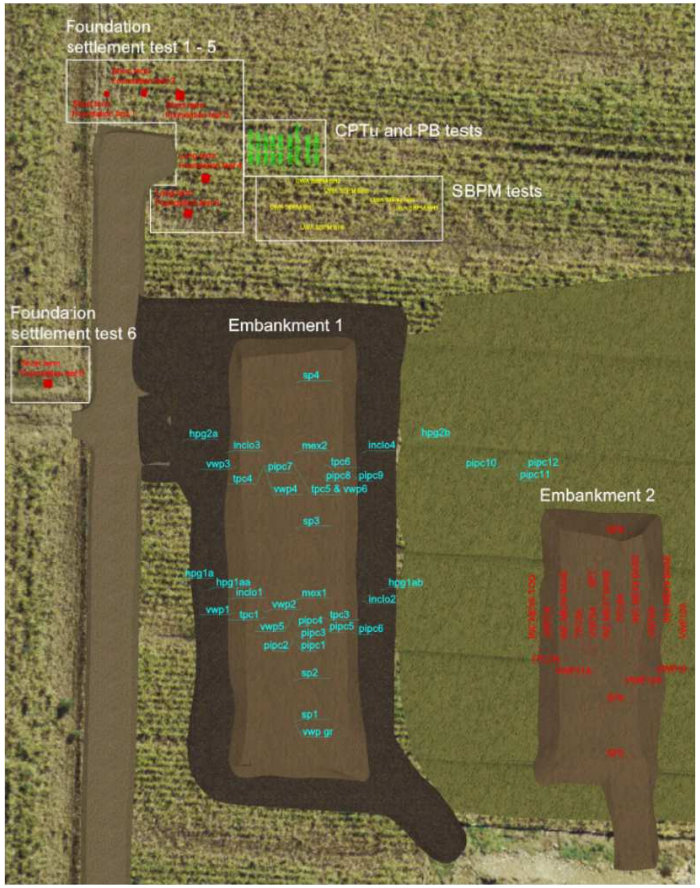


Source: Ballina Bypass Alliance 2005

Site plan


Foundation settlement test 1 - 5
CPTu and PB tests
SBPM tests
Foundation settlement test 6
Embankment 1
Embankment 2
sp4
hpg2a
inclo3
mex2
inclo4
hpg2b
vwp3
pipc7
tpc6
tpc4
pipc8
pipc9
vwp4
tpc5 & vwp6
pipc10
pipc12
pipc11
sp3
hpg1a
hpg1aa
hpg1ab
inclo1
mex1
inclo2
vwp2
vwp1
tpc1
tpc3
vwp5
pipc4
pipc3
pipc5
pipc6
pipc2
pipc1
sp2
sp1
vwp gr

AIMS

- **Demonstrating performance of technology (eg)**
  - IGS Piston Sampler
  - Jute drains
  - Horizontal drains in lieu of drainage blanket
  - Penetrometers
  - Variable rate in-situ tests
- **Improved methods of site characterisation and geotechnical modelling**
  - Enhanced geophysics
  - Technology transfer offshore to onshore
- **Methods to assess variability**
- **Advanced numerical modelling for embankment deformations**

ACTIVITIES (1)

- **In-situ Testing (UoN, UWA)**
  - Sampling methodologies (Sherbrooke, piston, tube)
  - Detailed site characterisation (Geophysics, various CPT, SDMT, SV, SBPM, HPT)
  - Development of new penetrometer technology (Tbar, Piezoball)
  - Develop geophysics as basis for a geotechnical model
- **Laboratory Testing (UoN, UWA, UoW)**
  - Sample disturbance
  - Effects of soil and water chemistry
  - Geological model
  - Conventional characterisation for comparison with in-situ tests
  - Constitutive modelling

ACTIVITIES (2)

- **Embankments (UoN, UoW)**
  - Jute and plastic PVDs with and without aggregate drainage blanket
  - Smear during installation of PVDs
  - Control embankment without ground improvement

Monitoring will continue for a minimum of 10 years => invaluable source of high quality field data

Data to be (eventually) accessible to geotechnical public through CGSE website

Field testing complemented by advanced numerical modelling and centrifuge testing

International prediction symposium to assess state-of-the-art numerical methods (September 2016)

ACTIVITIES (3)

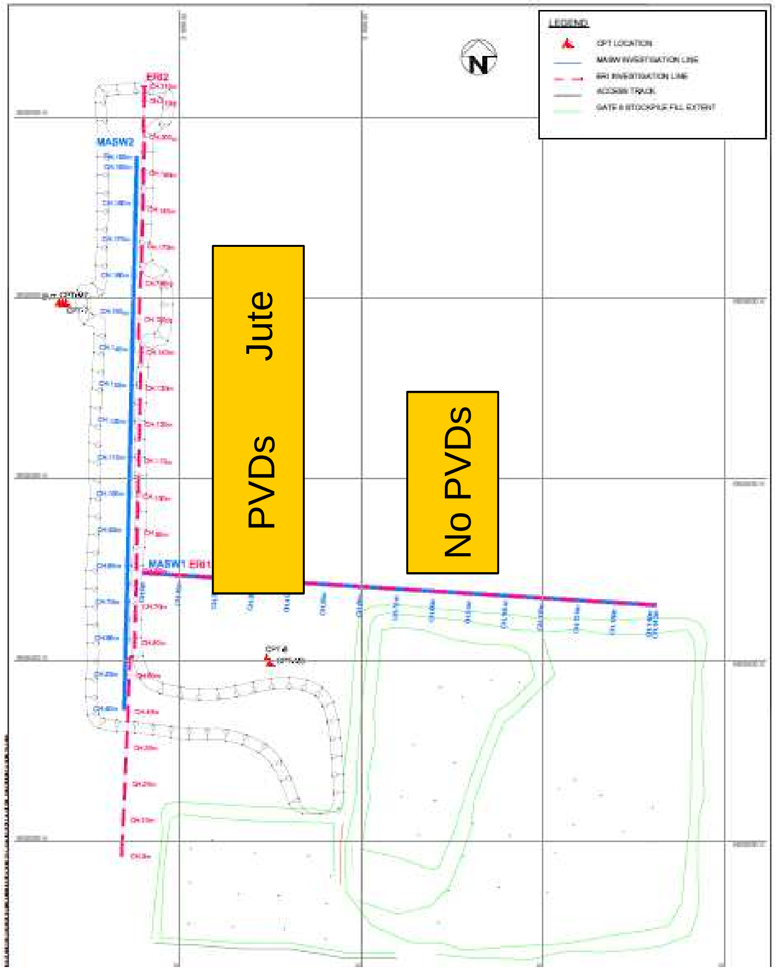
- **Footings (UWA)**
  - Footings tested to failure: central and eccentric loading
  - Consolidation of footings
  - Prediction symposium being considered
- **Model Piles (UWA)**

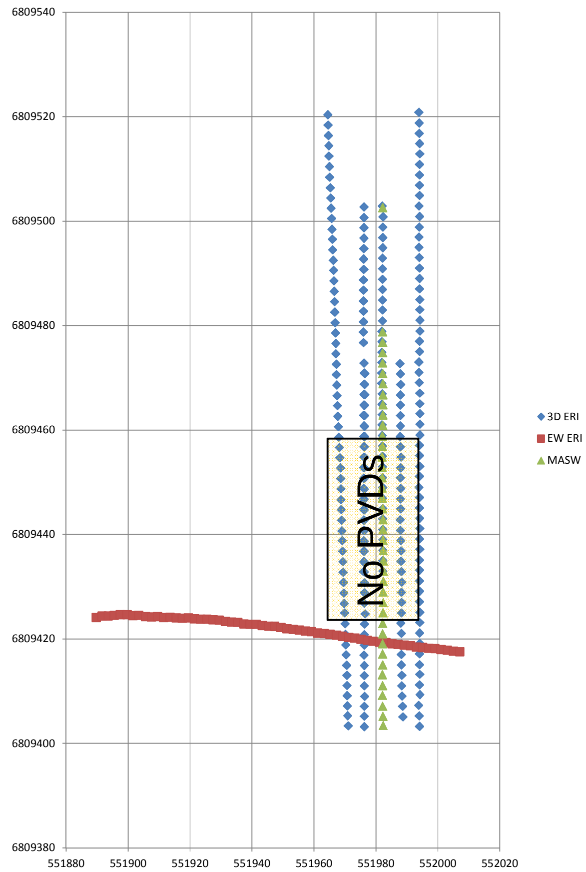
Geophysics

Geophysics

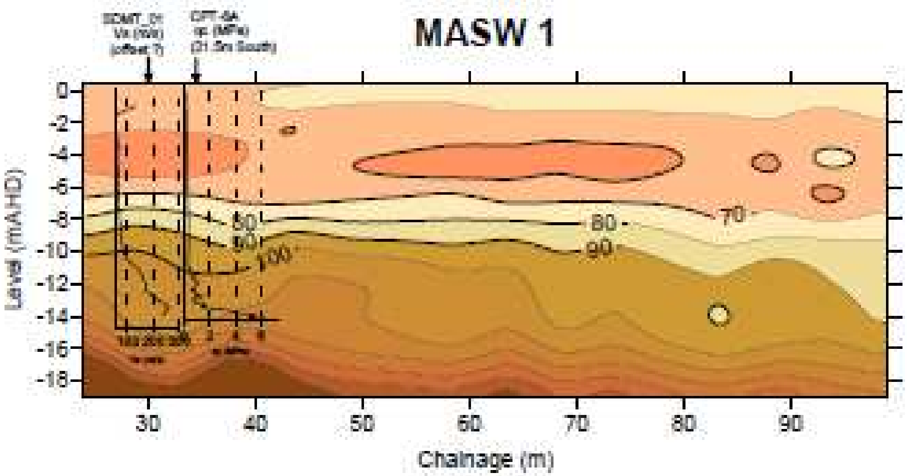
- Required for international credibility
- Base line 2D site characterisation prior to disturbing ground using MASW and ERI (and MRI)
- Conventionally used to assess stratigraphy and any variations, palaeochannels etc in 2D
- Correlate with in-situ and laboratory tests to allow estimation of engineering parameters
- Key input for future geotechnical modelling
- Assess progress of consolidation below an embankment

Locations of traverses





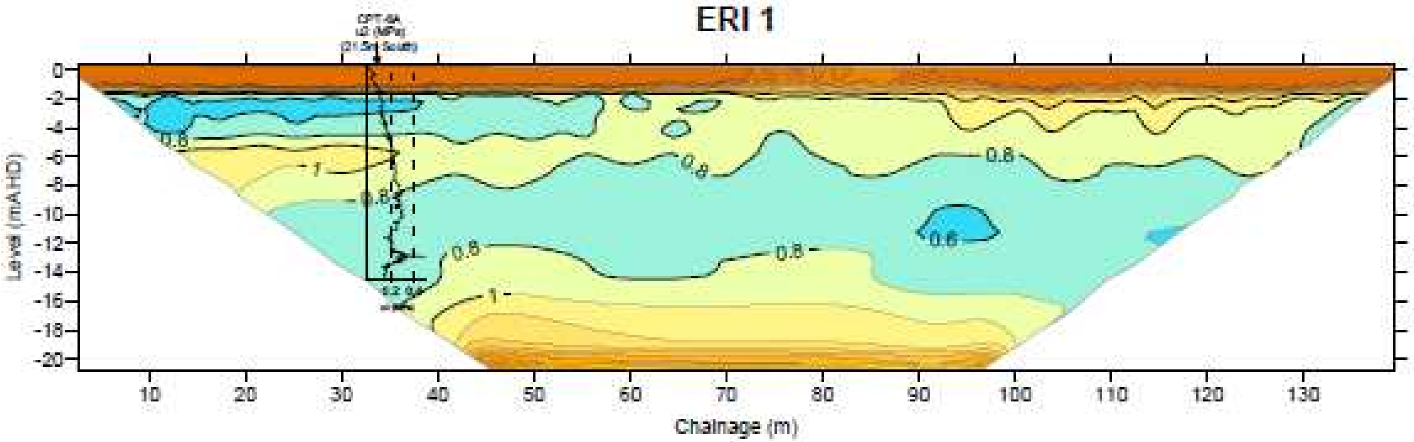
Multichannel Analysis of Surface Waves (MASW)



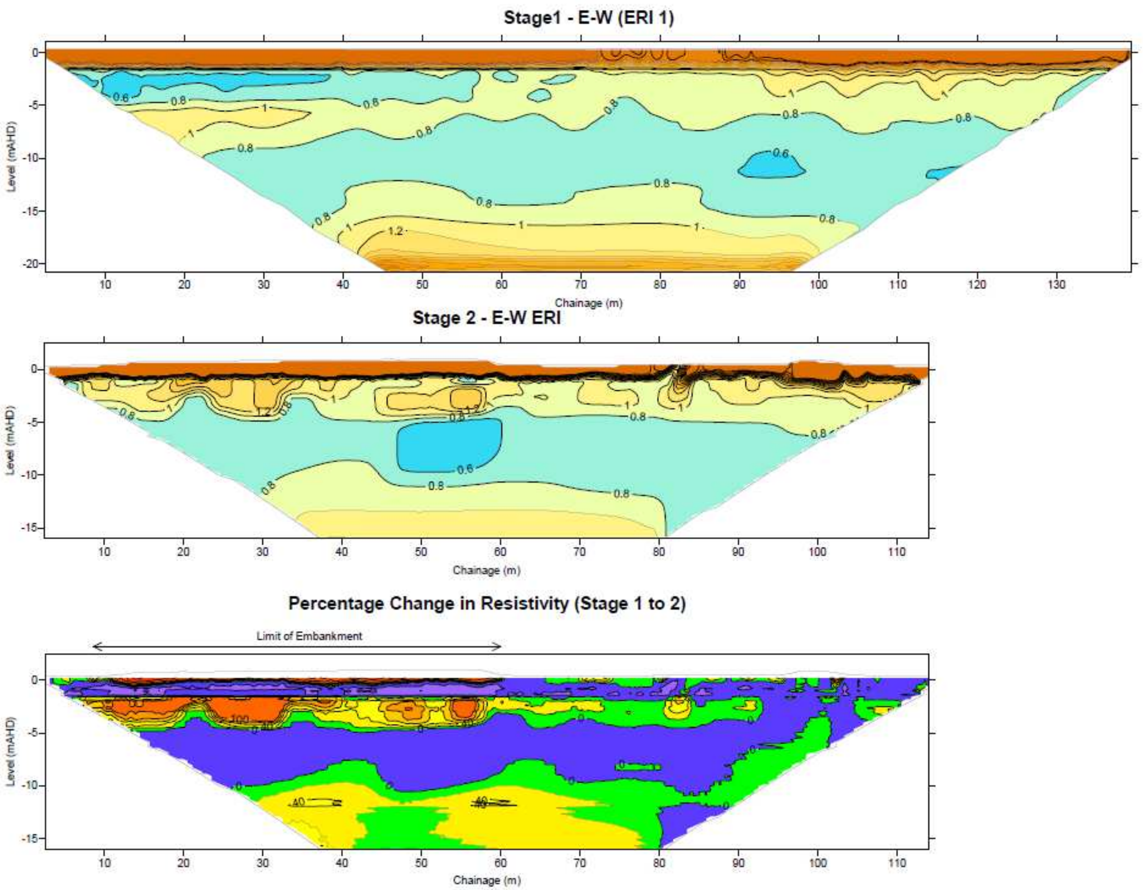
Courtesy Aidan Fitzallen (Coffey)

Surface ERI and Surface to Borehole ERI

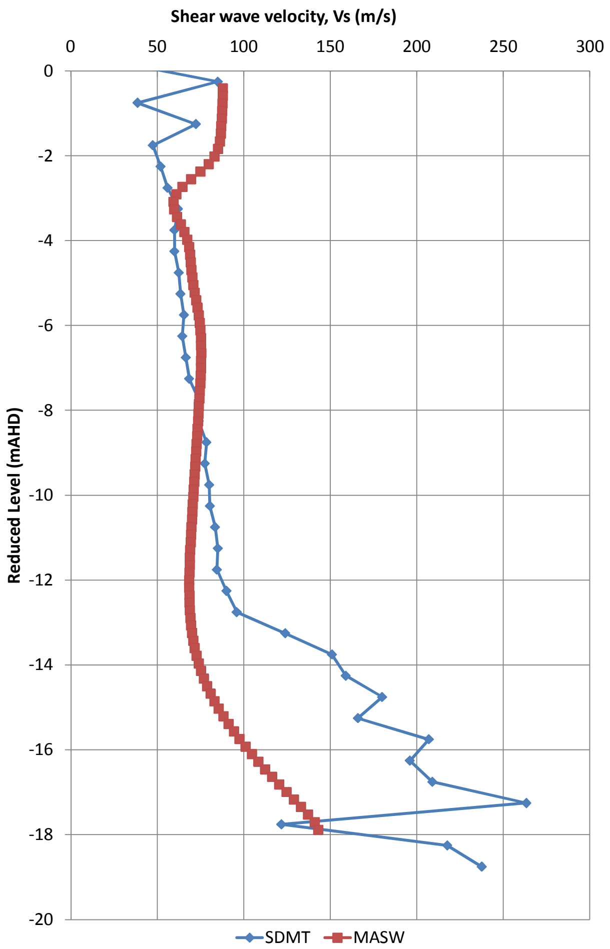
Results from Surface ERI

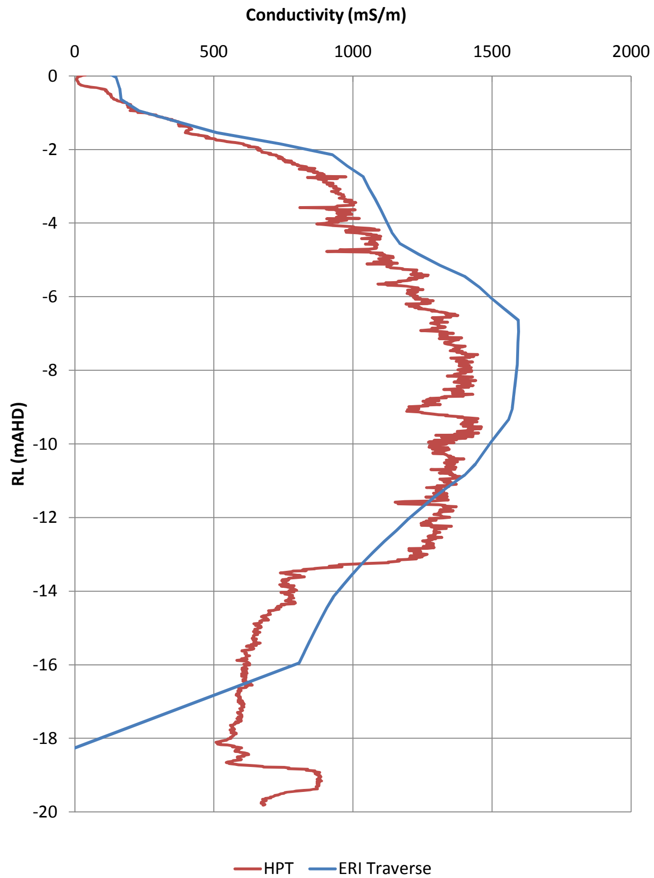


Proof of concept: Consolidation and ERI



Comparison of preliminary surface and in-situ geophysics





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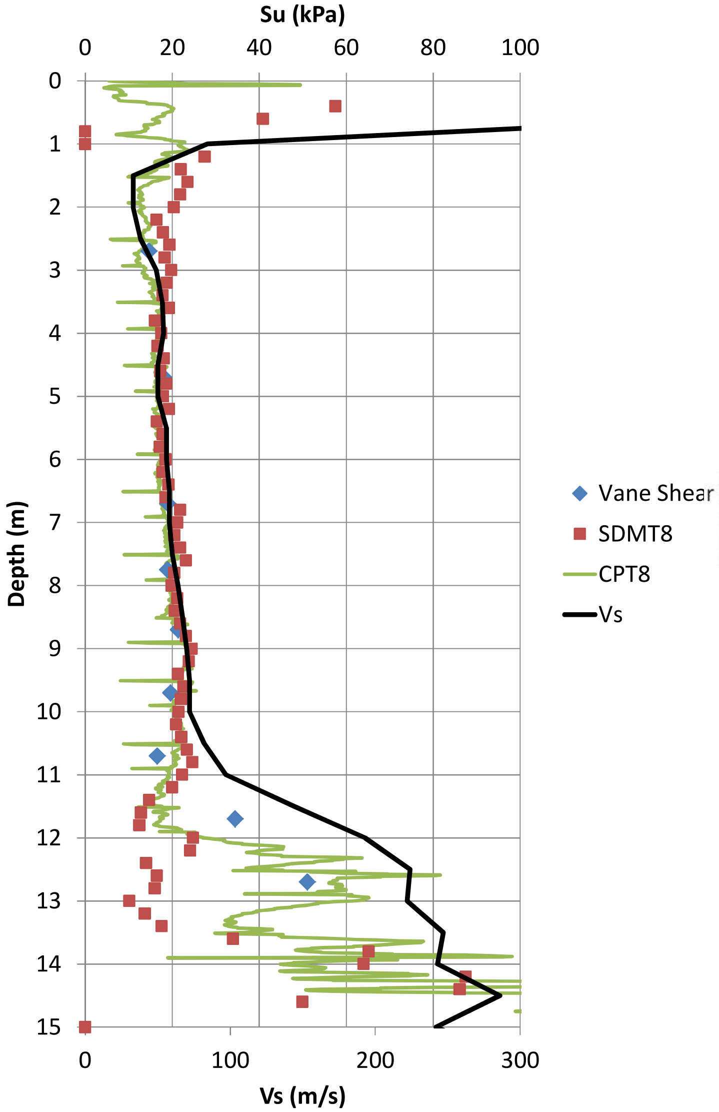
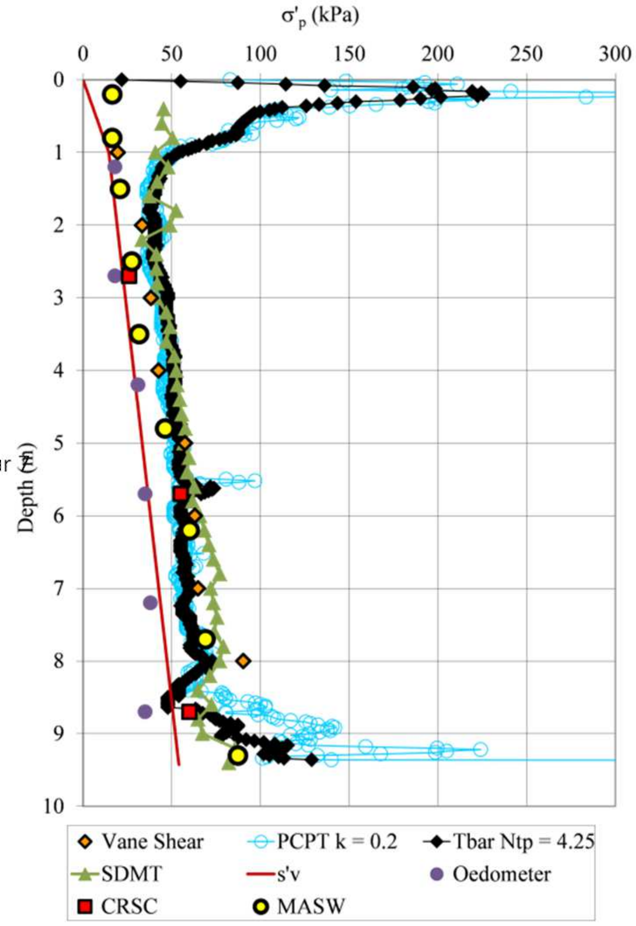
Shear wave velocity and s_u and σ'_p





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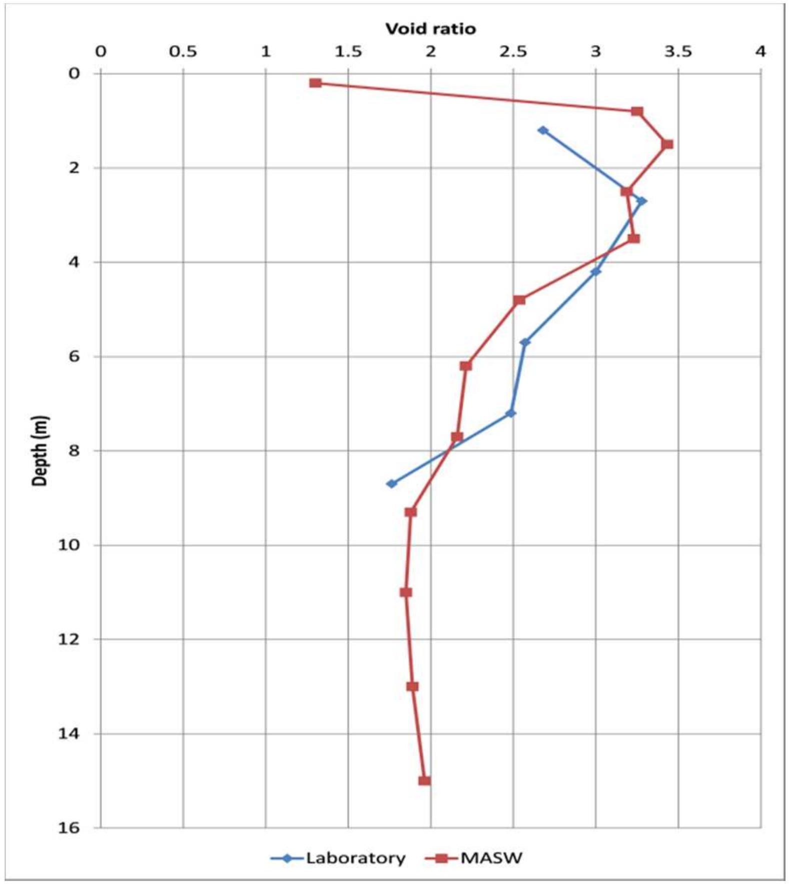
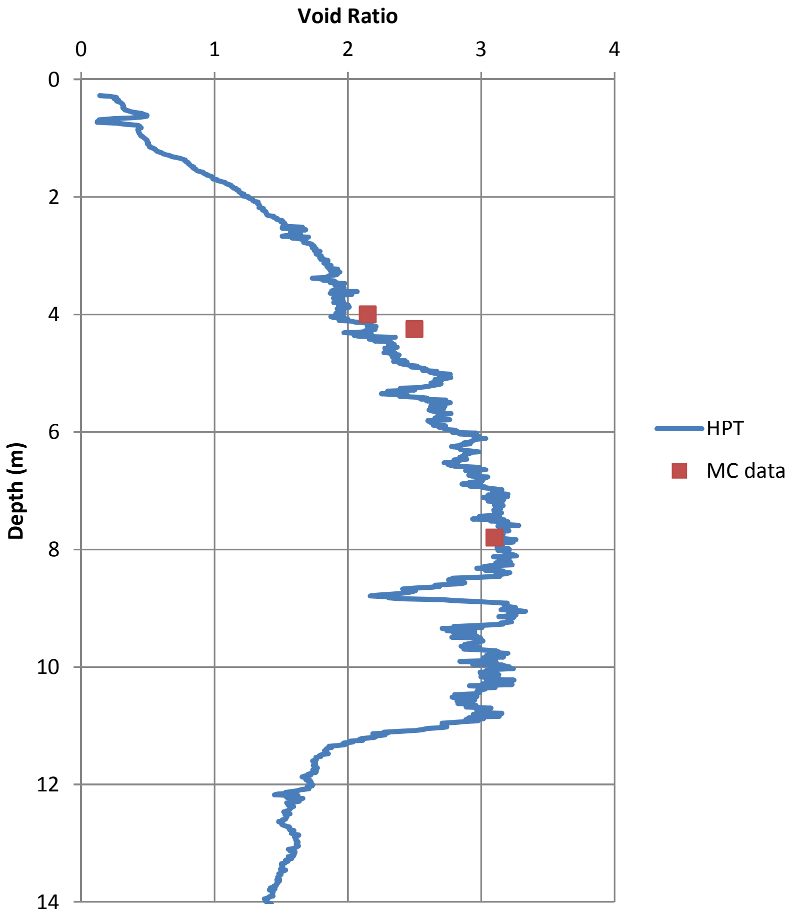
Correlating with void ratio





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Penetrometry and other in-situ tests

Aims of Penetrometry

- Compare high capacity versus low capacity cones
- Characterise stratigraphy and estimate engineering parameters
- Further develop full flow penetrometers
- Act as basis for comparison with other tests
- Dissipation / rate tests to estimate c_h
- Stochastic site investigation

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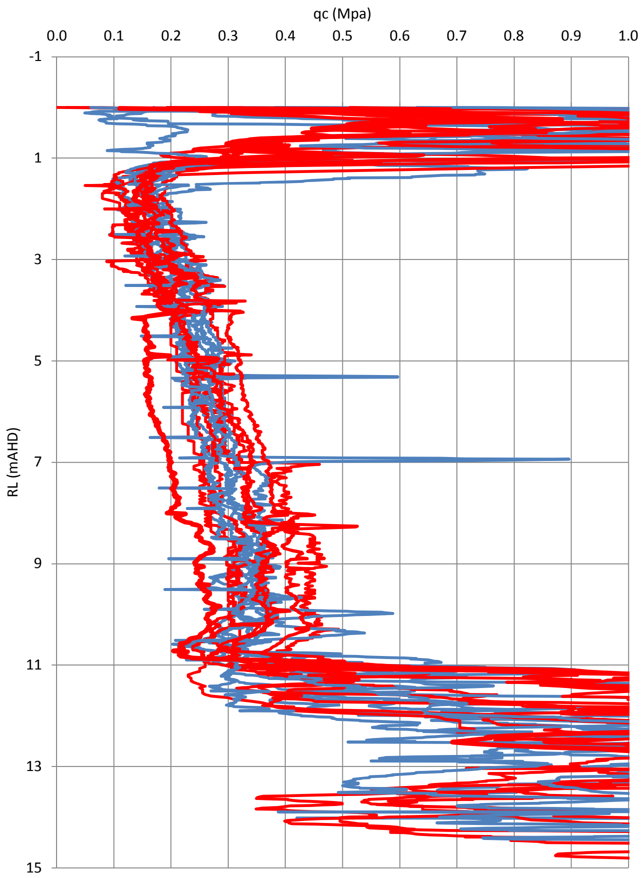
Insitu Test Equipment

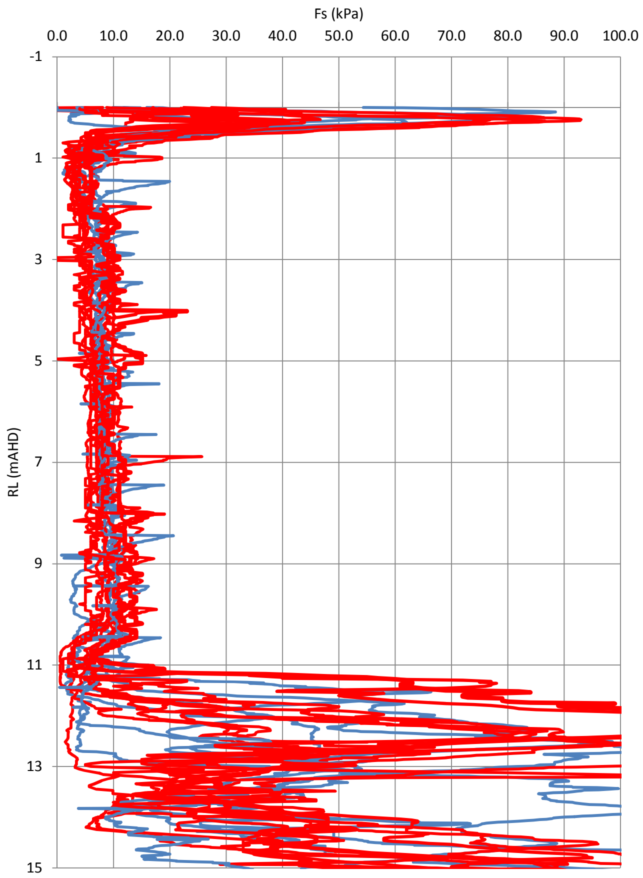
Full flow penetrometers

- Have more tightly bounded theoretical solution than CPT
- Are only slightly affected by overburden pressure
- Have large area for accurate testing of soft sediments
- Need calibration to a measure of shear strength as per CPT

Insitu Test Equipment

Comparison of different capacity CPT





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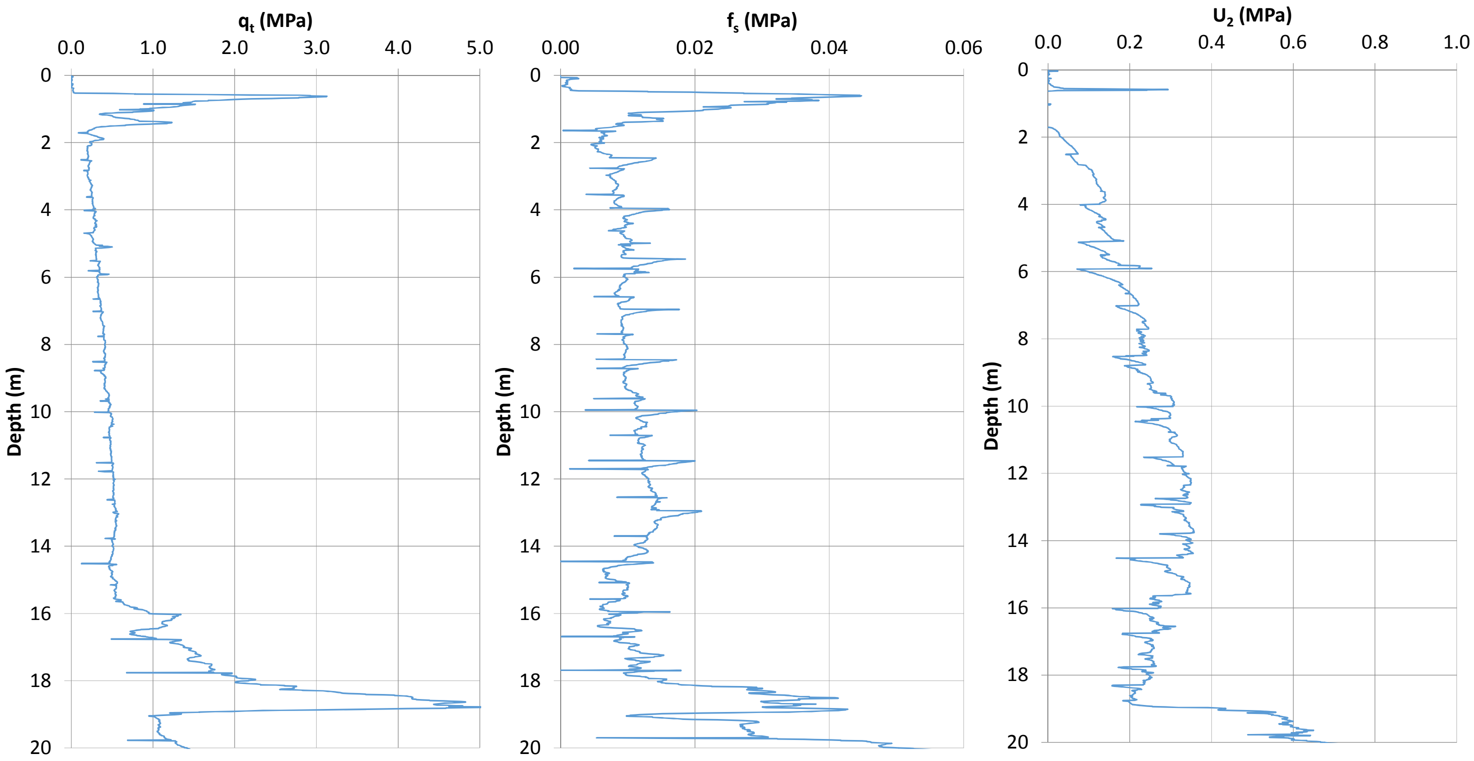
Typical CPTu data



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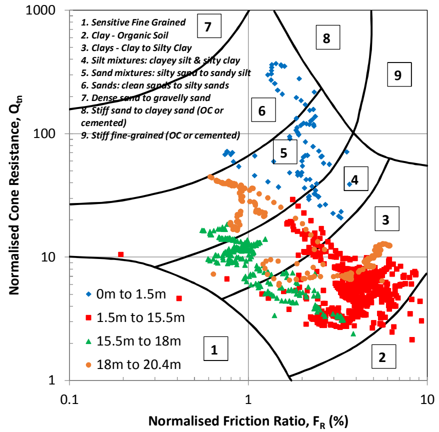
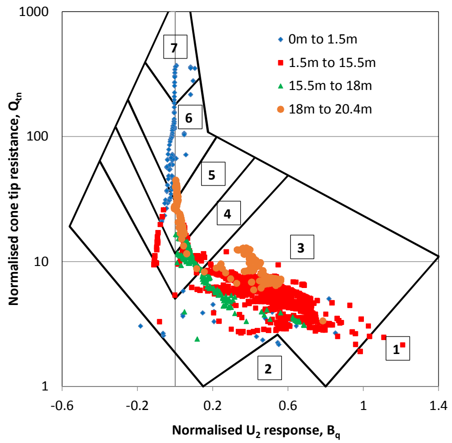
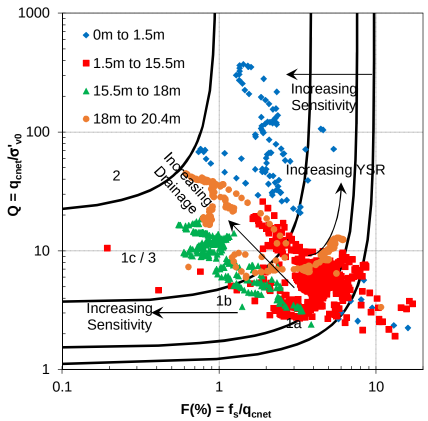
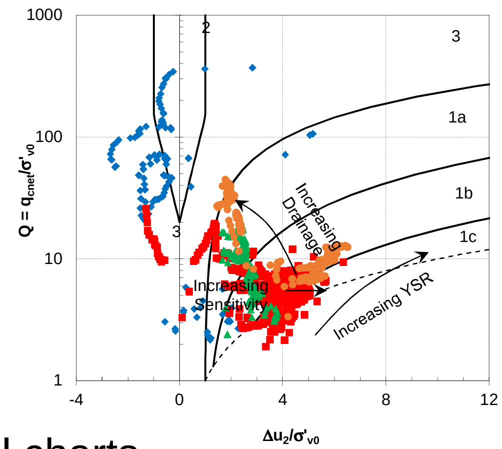
Classification





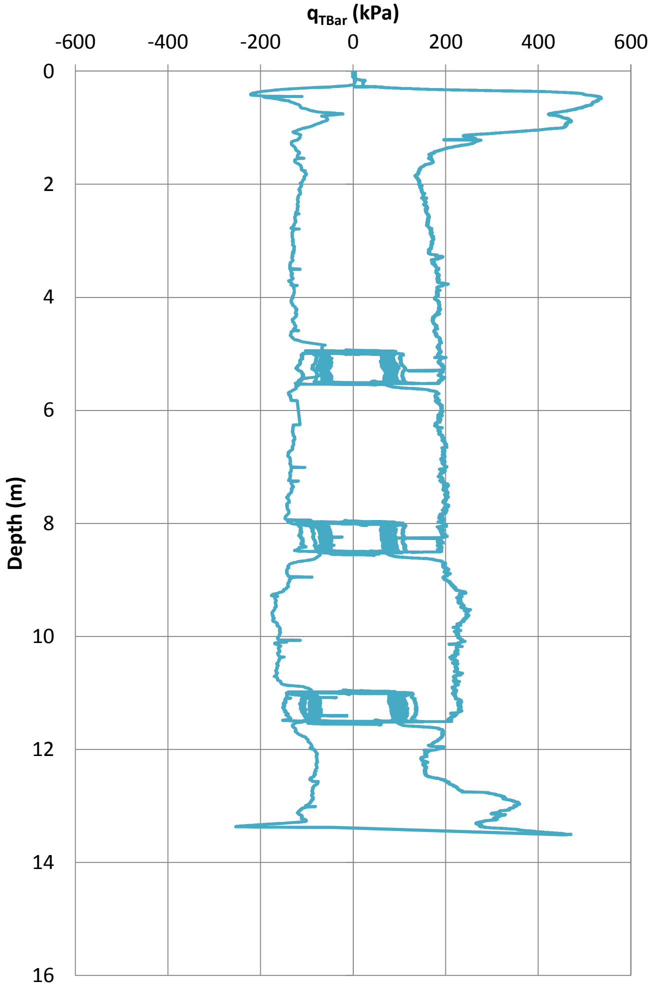
Robertson et al charts



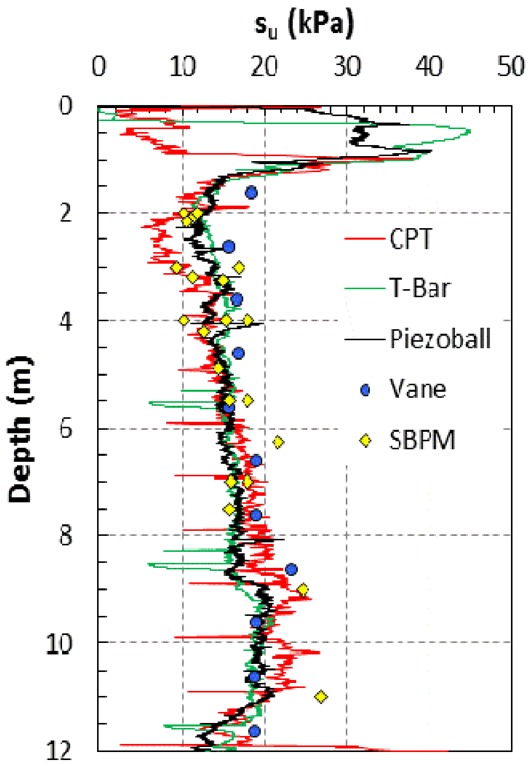


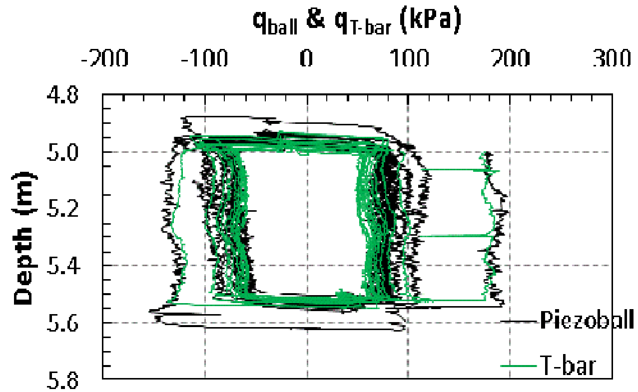
Schnieder et al charts

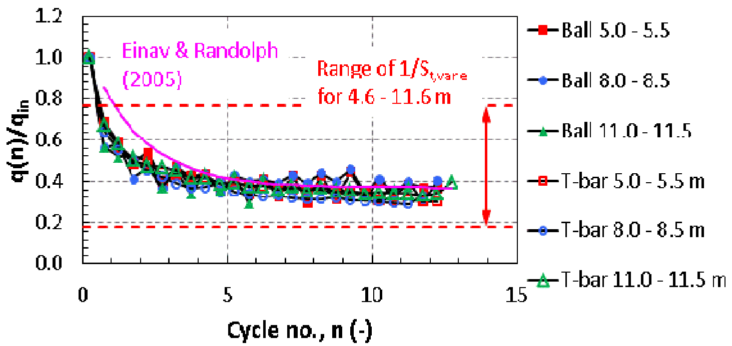
Full flow penetrometry



Undrained shear strength







Cathal Colreavy
(UWA)

Dr Conleth
O'Loughlin
(UWA)

Nathan Burns
(UoN)

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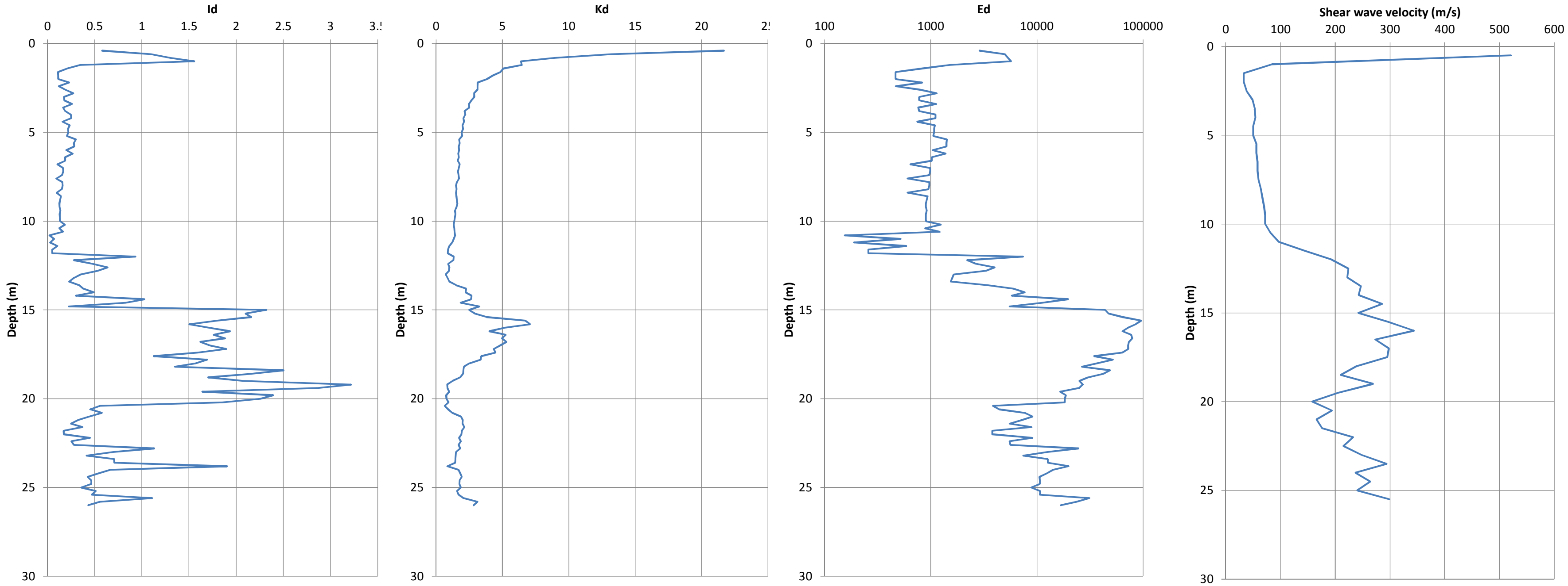
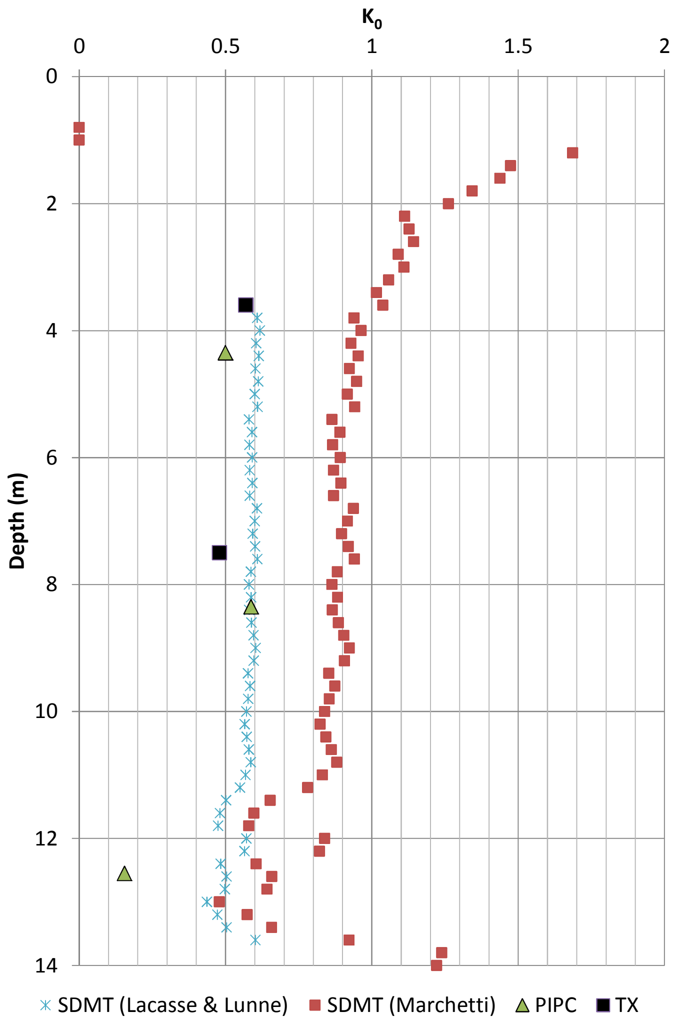
SDMT

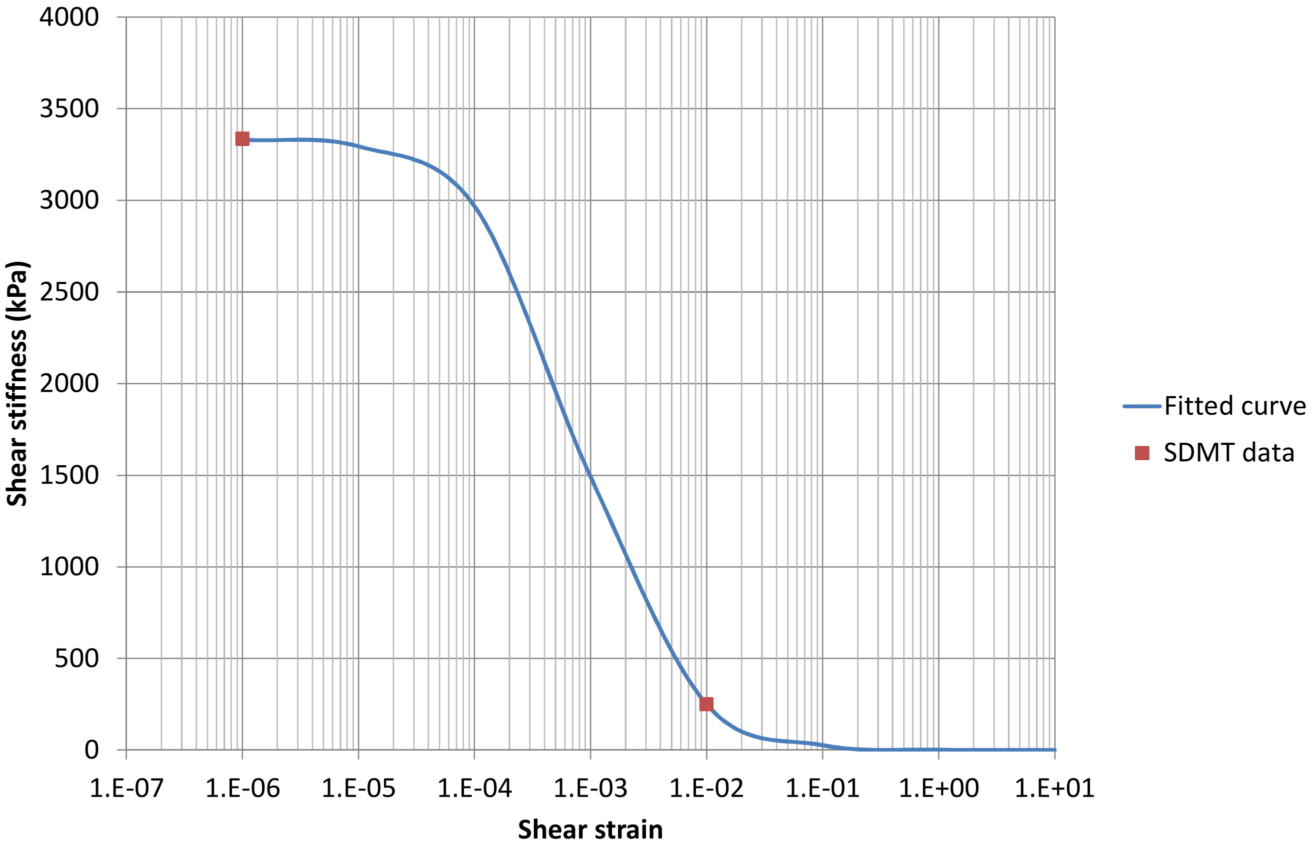

Id
Kd
Ed
Shear wave velocity (m/s)
Depth (m)
0
0.5
1
1.5
2
2.5
3
5
10
15
20
25
30
100
1000
10000
100000
200
300
400
500
600

K_0 and SDMT



K_0
0
0.5
1
1.5
2
0
2
4
6
8
10
12
14
Depth (m)
SDMT (Lacasse & Lunne)
SDMT (Marchetti)
PIPC
TX

SDMT and Stiffness



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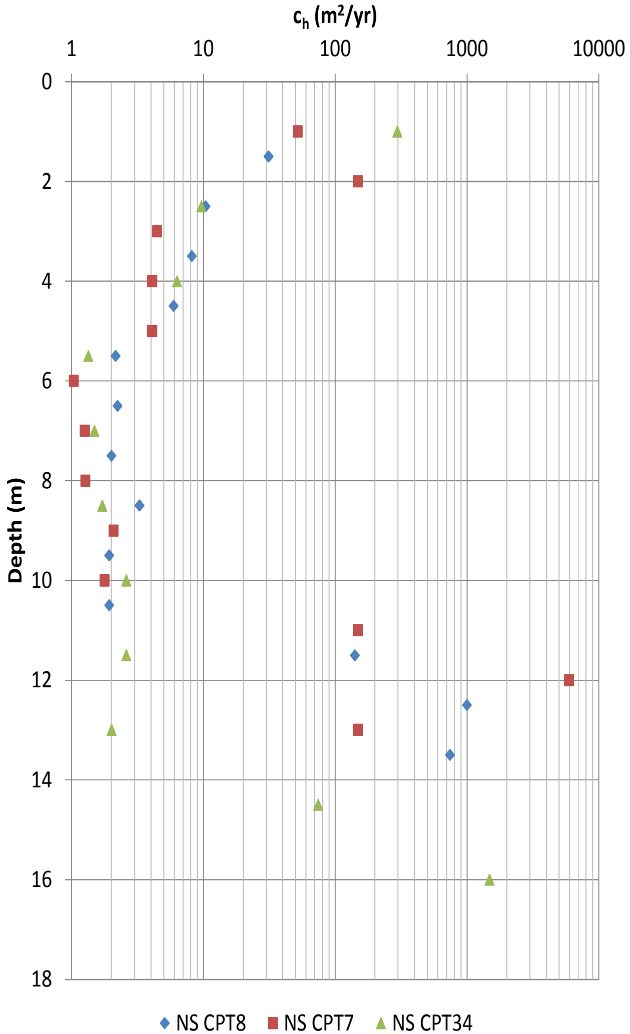
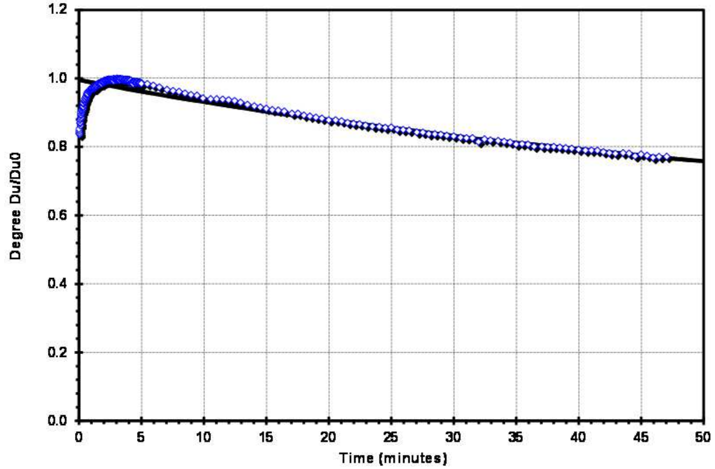
Dissipation testing





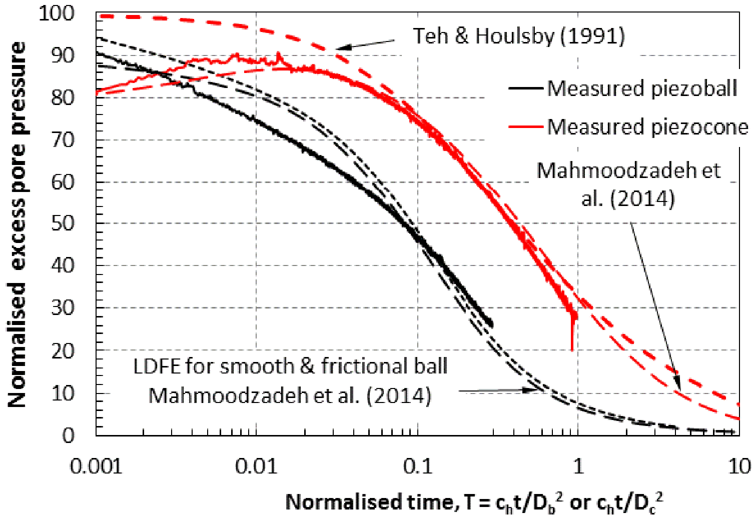
Disadvantages

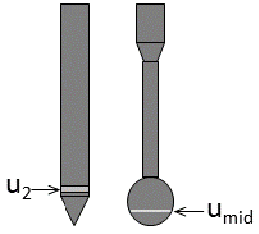
- "dilatory" response
- Rigidity index used in interpretation

Other methods

- Piezoball (no analytical solution)
- SBPM (with FEM analysis)
- Variable rate tests
- Packer testing in standpipe
- Constant/Falling Head tests

Piezoball dissipation

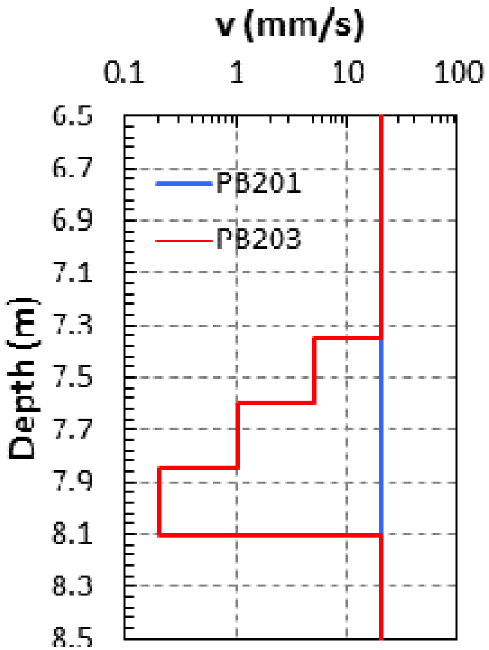


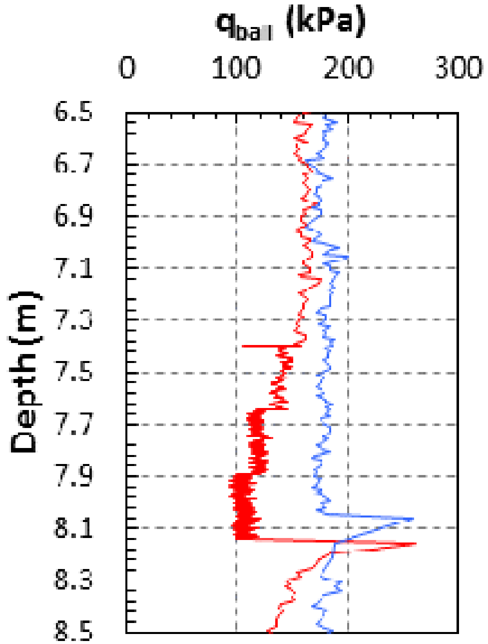


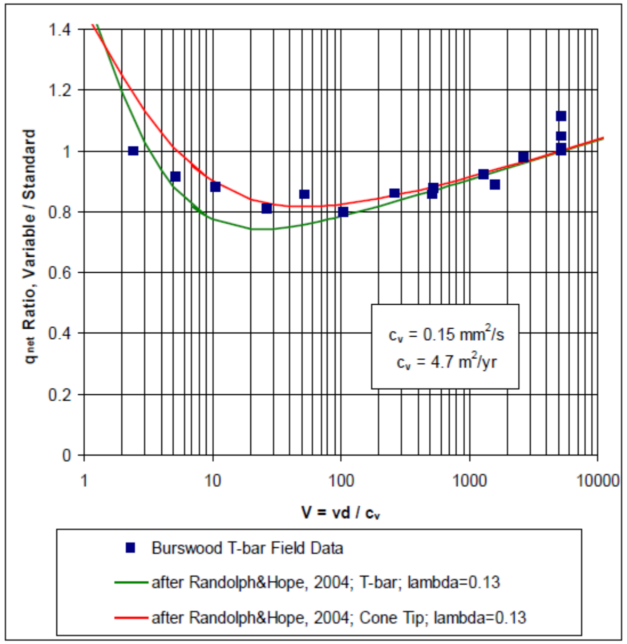
Courtesy Dr Conleth O'Loughlin (UWA)

Cathal Colreavy (UWA)
Dr Conleth O'Loughlin (UWA)

Permeability interpretation using variable rate







Cathal Colreavy (UWA)
Dr Conleth O'Loughlin (UWA)

New rig under construction at UoN/UWA

A/Prof Andrew Abbo (UoN)
Lachlan Bates (UoN)
Prof David White (UWA)

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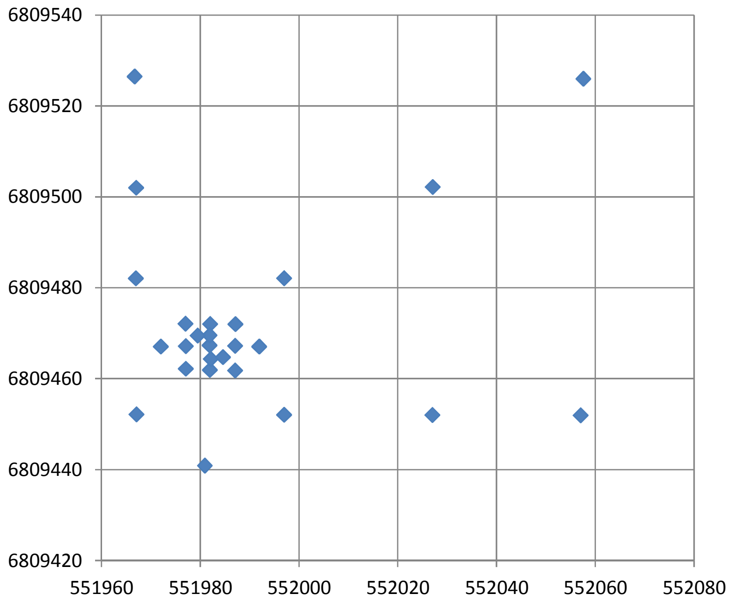
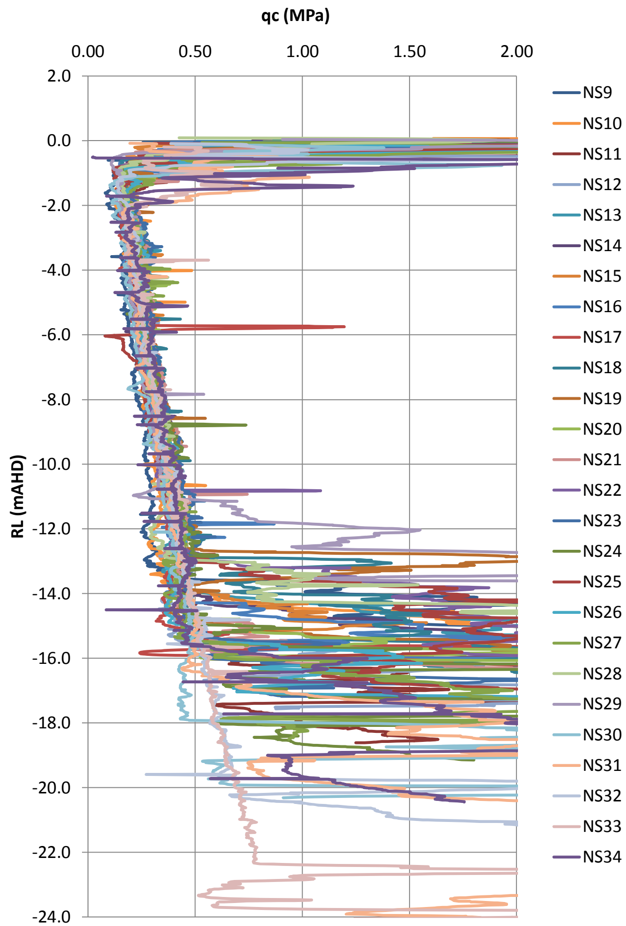
Spatial Variation

Stochastic Site Investigation

Dr Lisa Li (UWA), Dr Jinsong Huang (UoN)

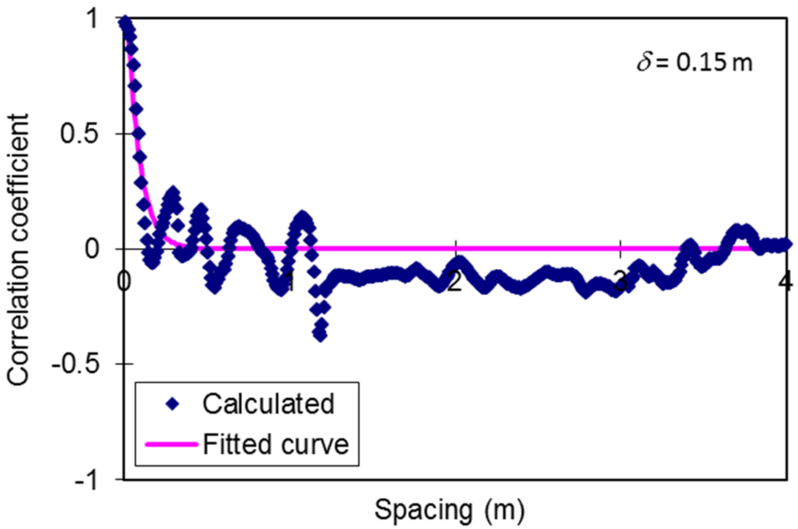




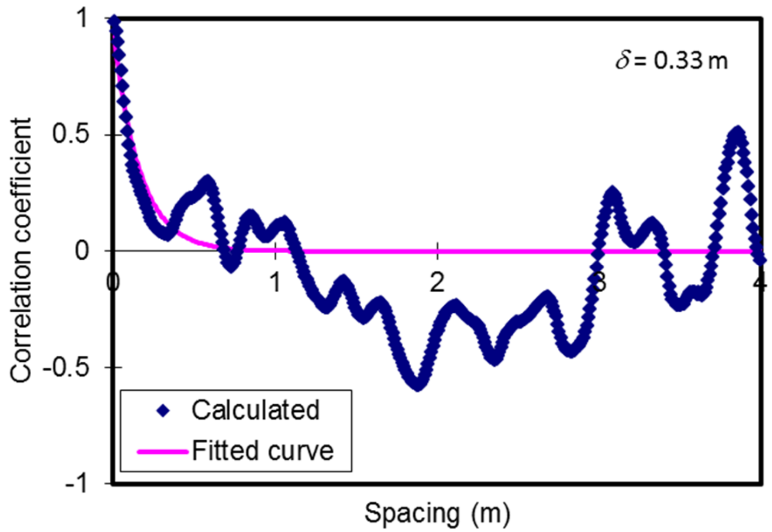
Preliminary results from Stochastic SI

Dr Lisa Li (UWA), Dr Jinsong Huang (UoN)

Vertical correlation



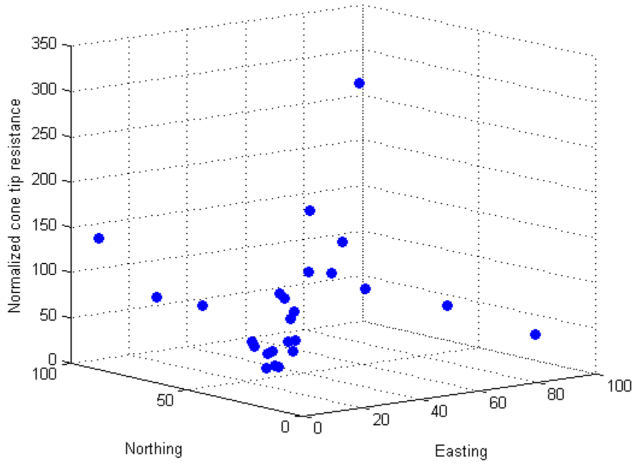
(a) Normalized cone tip resistance



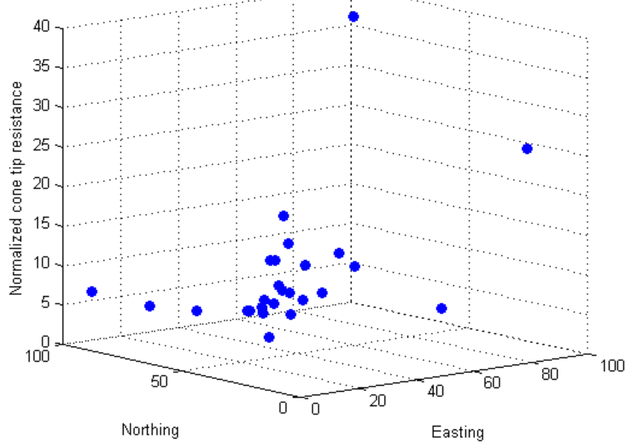
(b) Friction ratio

Horizontal Correlation

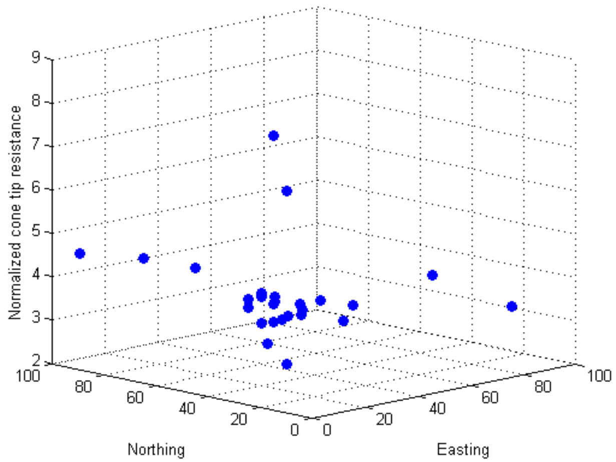
Dr Lisa Li (UWA), Dr Jinsong Huang (UoN)



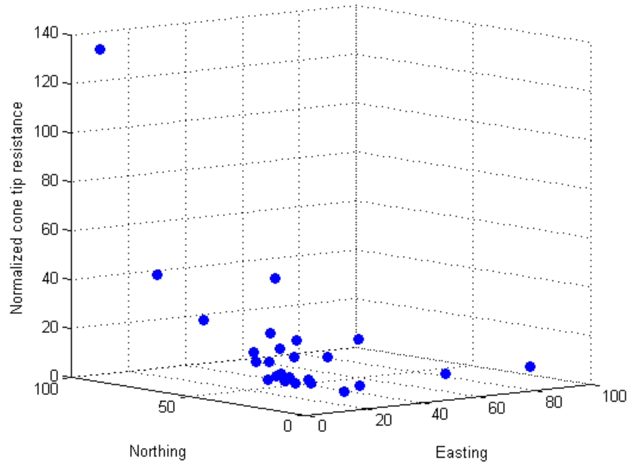
(a) At depth of 0.80 m



(b) At depth of 1.65 m



(c) At depth of 10.20 m



(d) At depth of 15.70 m

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Self boring pressuremeter

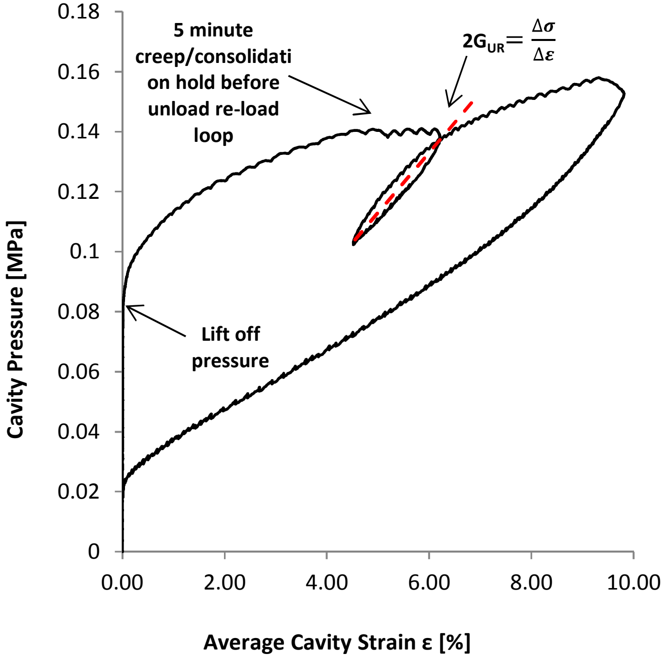
Aims of SBPM

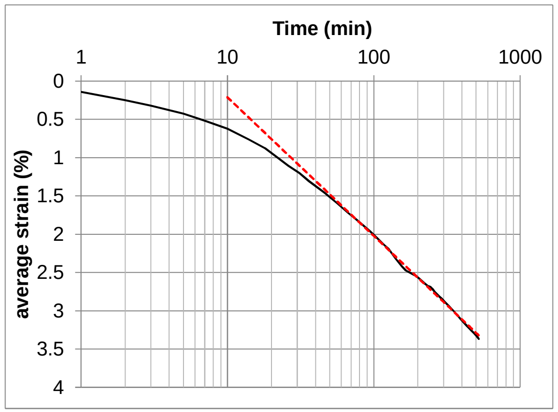
- Test using different stress path to other insitu tests
- Direct assessment of σ_H, s_u, G and ~c_h.
- Test at various rates of inflation
- Basis for back analysis of future pad footing tests
- Potentially use to calibrate rate dependent anisotropic constitutive model

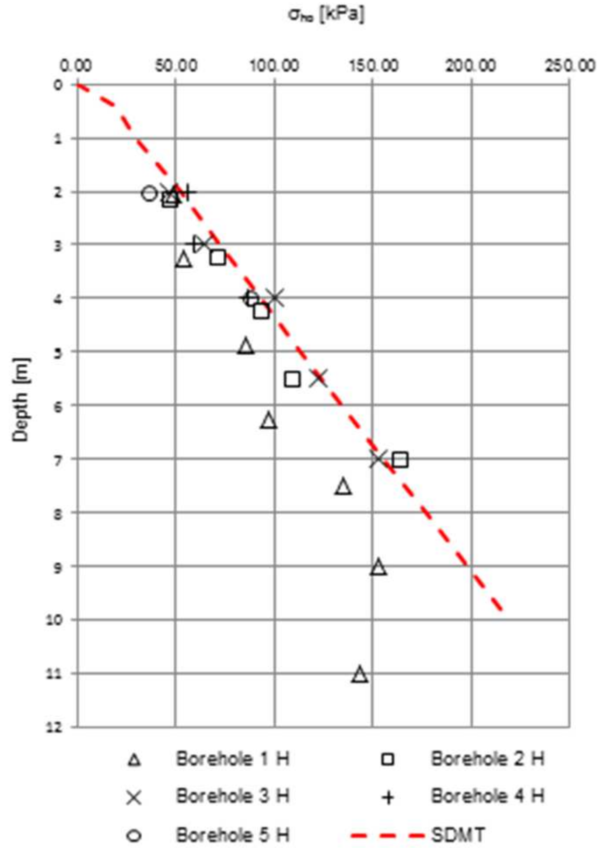
Self Boring Pressuremeter

Fillippo Gaone (UWA)
A/Prof James Doherty (UWA)
Prof Suzie Gourvenec (UWA)

Interpretation of SBPM







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Sampling and laboratory testing

Sampling and laboratory testing

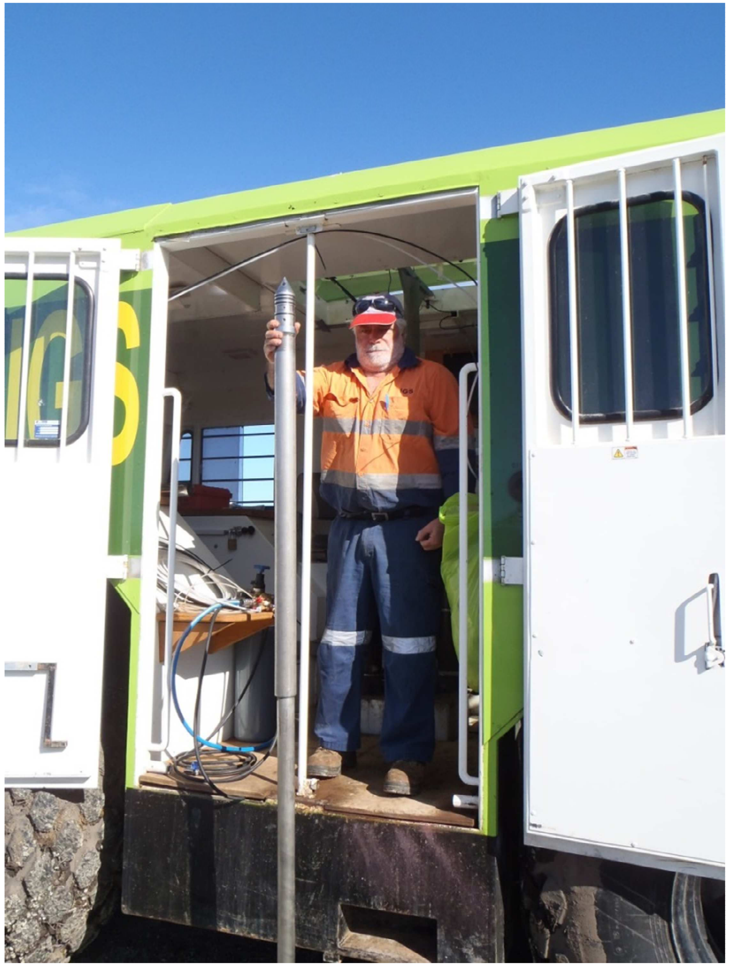
Dr Jubert Pineda (UoN), Dr Laxmi Suwal (UoN), Dr Daniel Bishop (UoN), Prof Antonio Cararro (UWA), Prof Nathalie Boukpeti (UWA), Guan Lim (UWA), A/Prof Cholachat Rujiatkamjorn (UoW), Dr Ana Heitor (UoW), Darshana Perera (UoW), Prof David Airey (Usyd)

- Investigation of sampling and testing processes
  - Sample disturbance
    - Sherbrooke block samples
    - 100mm dia free piston sampler
    - O90 fixed piston sampler
    - IGS 63mm dia fixed piston sampler
    - U75, U63, U50
    - Cutting toe angles from 5 degrees to 90 degrees
    - CT Scans
  - Effects of chemistry

- Laboratory tests
  - Geological profile
  - Geotechnical profile with depth
  - Constitutive modelling

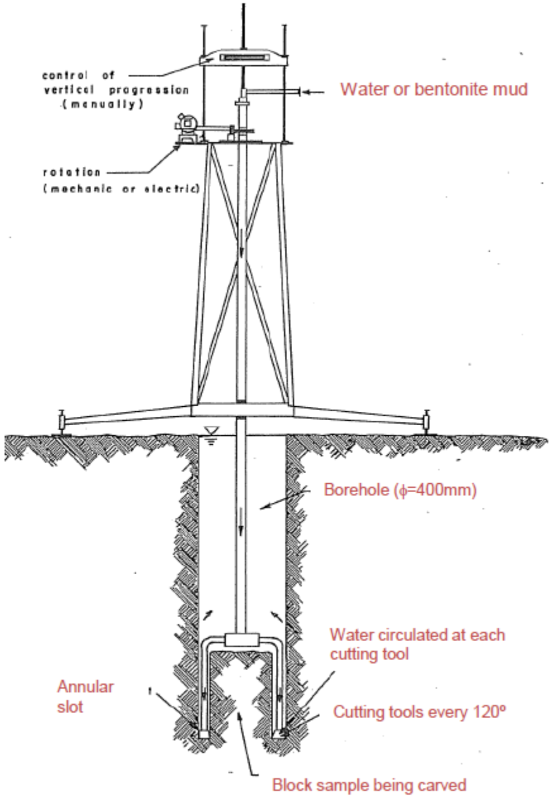
Piston Samplers

IGS PISTON SAMPLER



Sherbrooke sampling

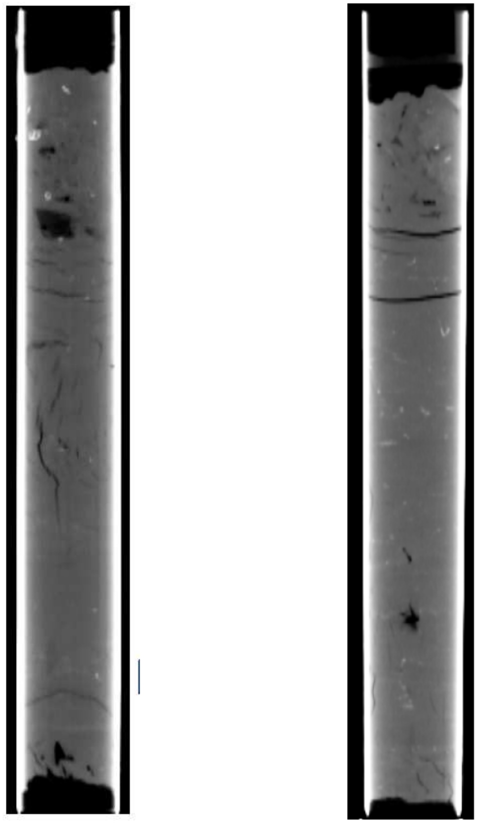
❑ The Sherbrooke sampler



IGS_BH1 IGS_BH2

Fixed Piston sampler (ϕ=**63** mm)

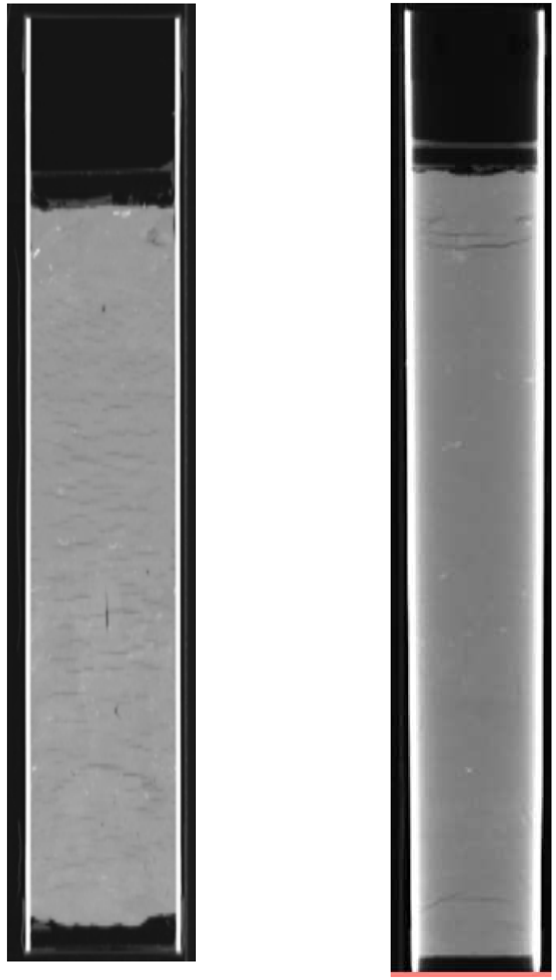
U75 VPW_GR U75 VPW_4



Open (Shelby) sampler (ϕ=**75** mm)

Depth: -7.5 / -8.1m

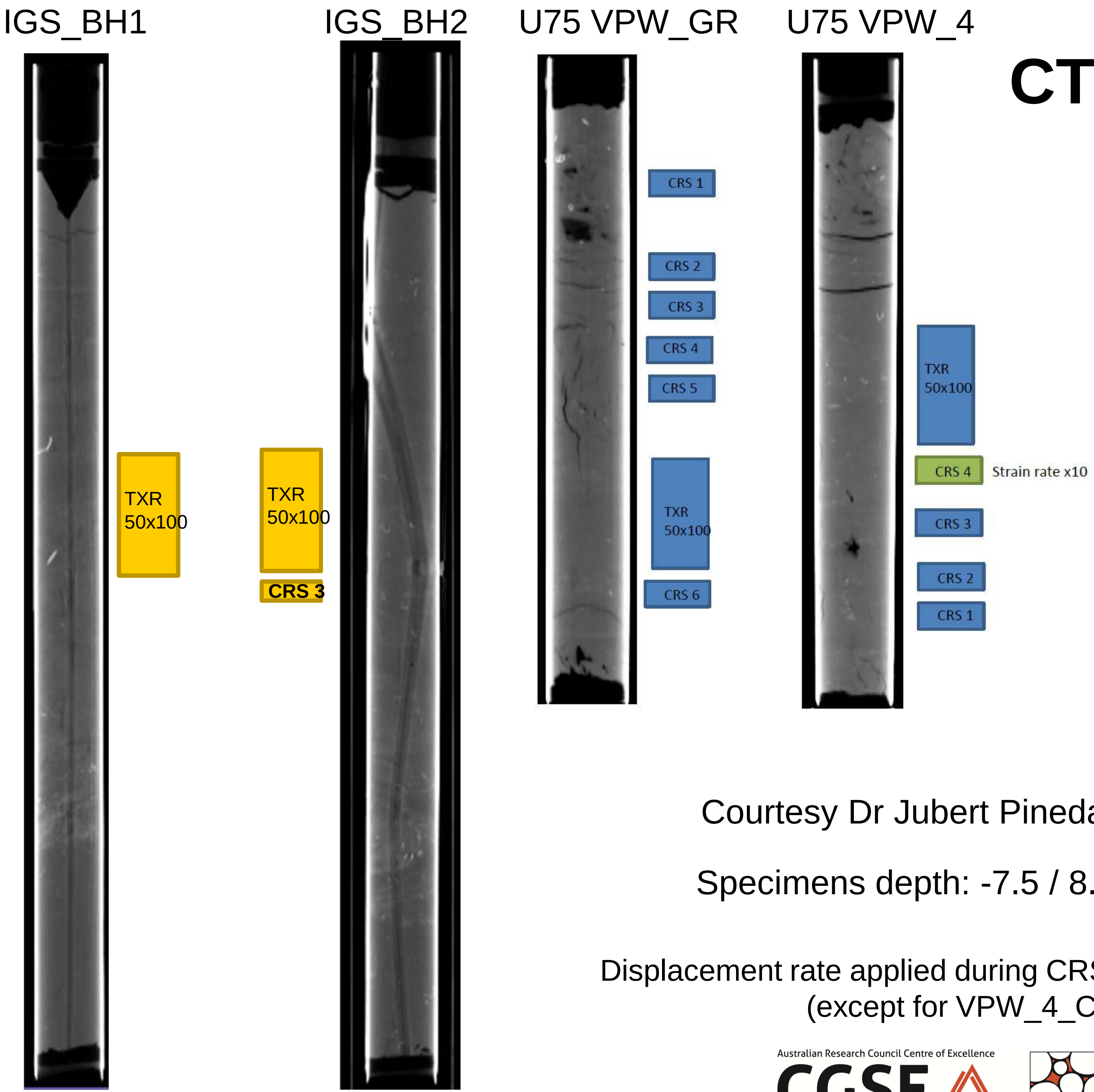
INCLO 1 INCLO 2



Free Piston sampler (ϕ=**100** mm)

Fixed Piston sampler (ϕ=**90** mm)

CT SCANS



Courtesy Dr Jubert Pineda (UoN)

Specimens depth: -7.5 / 8.1m

Displacement rate applied during CRS tests: 0.004mm/min (except for VPW_4_CRS 4)

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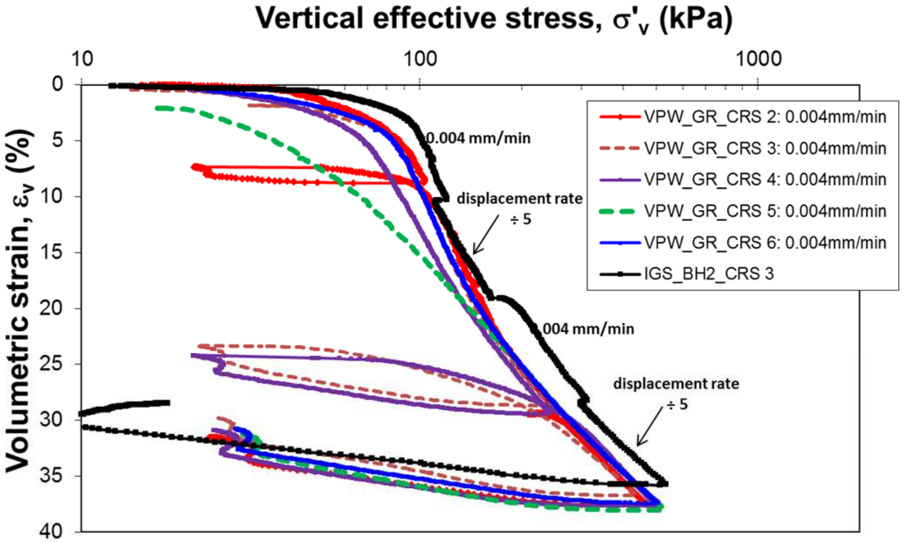
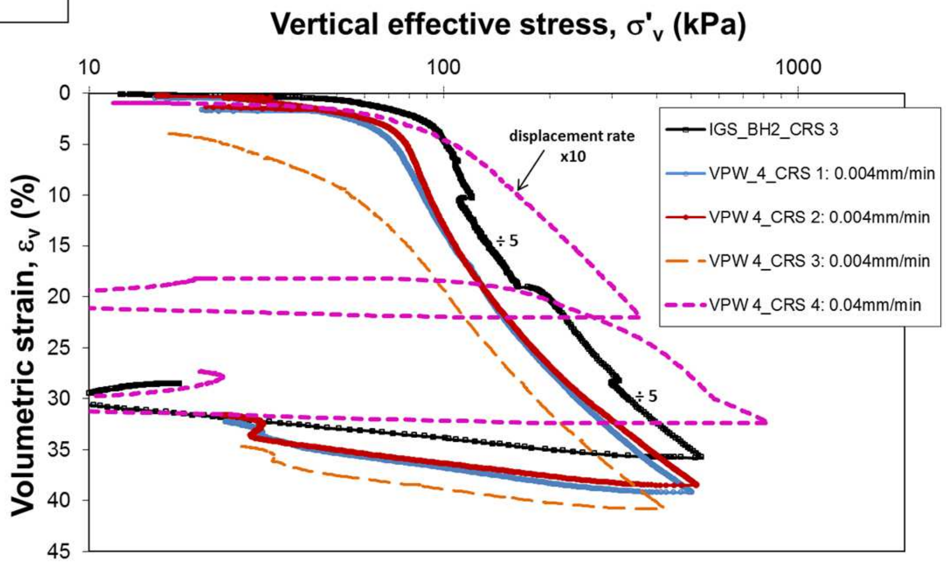
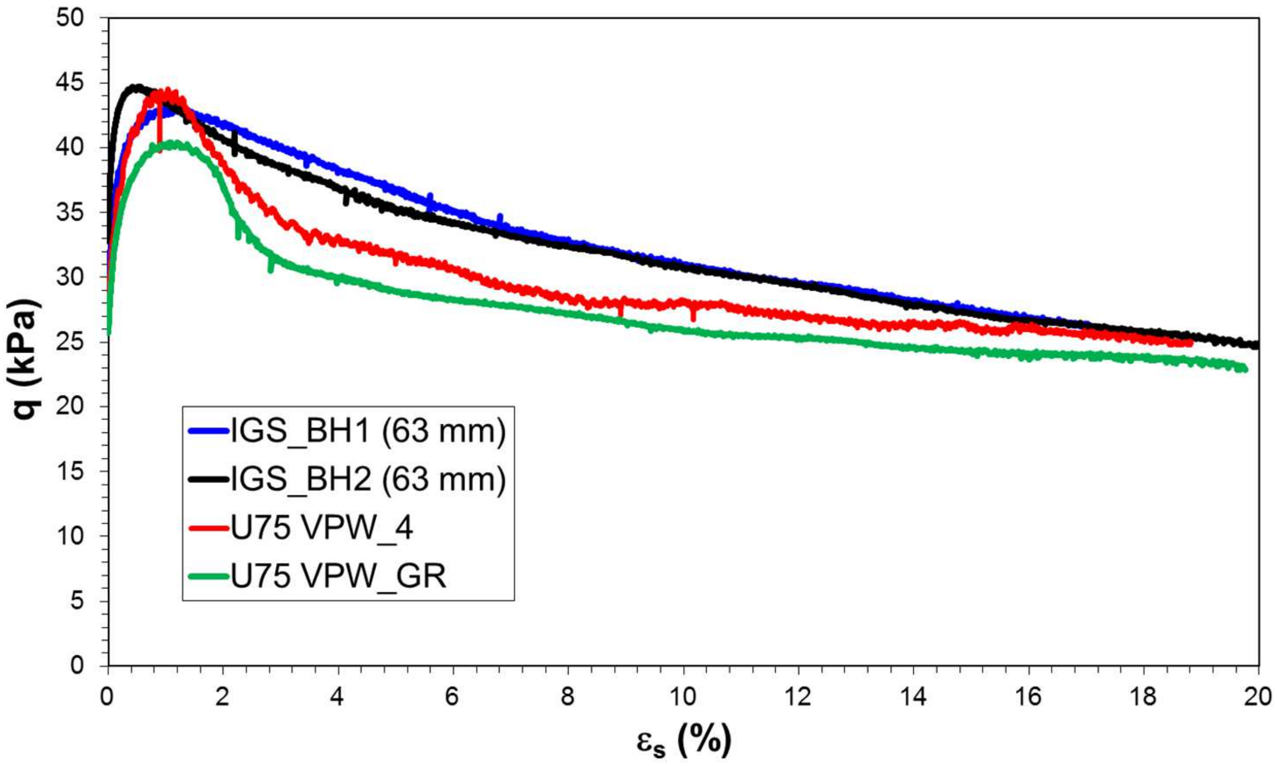
Preliminary CRSC tests



Courtesy Dr Jubert Pineda (UoN)

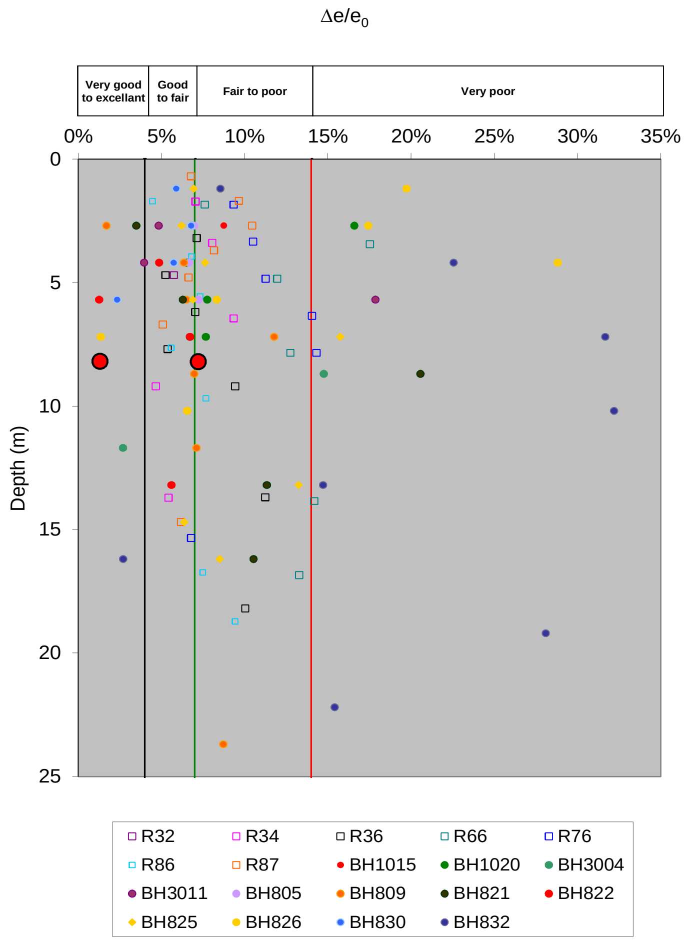


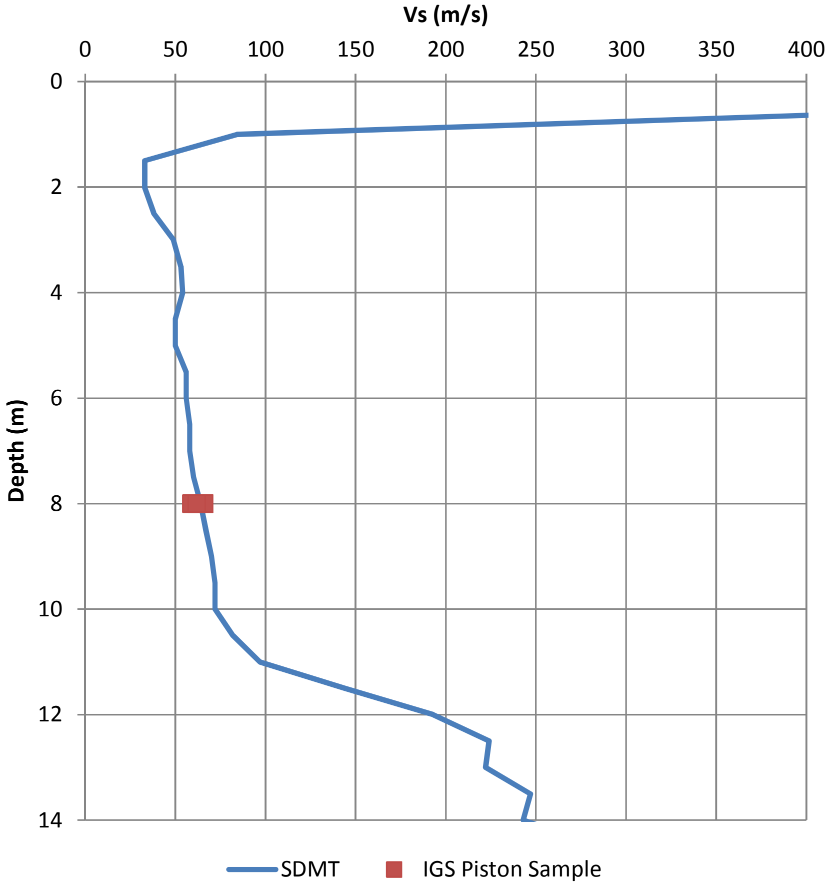
Preliminary CK_0UC Triaxial Tests



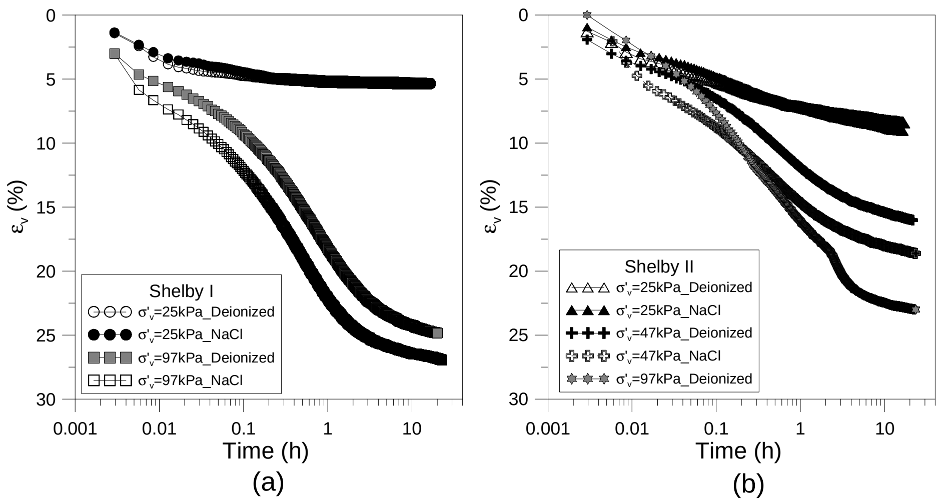
Courtesy Dr Jubert Pineda (UoN)

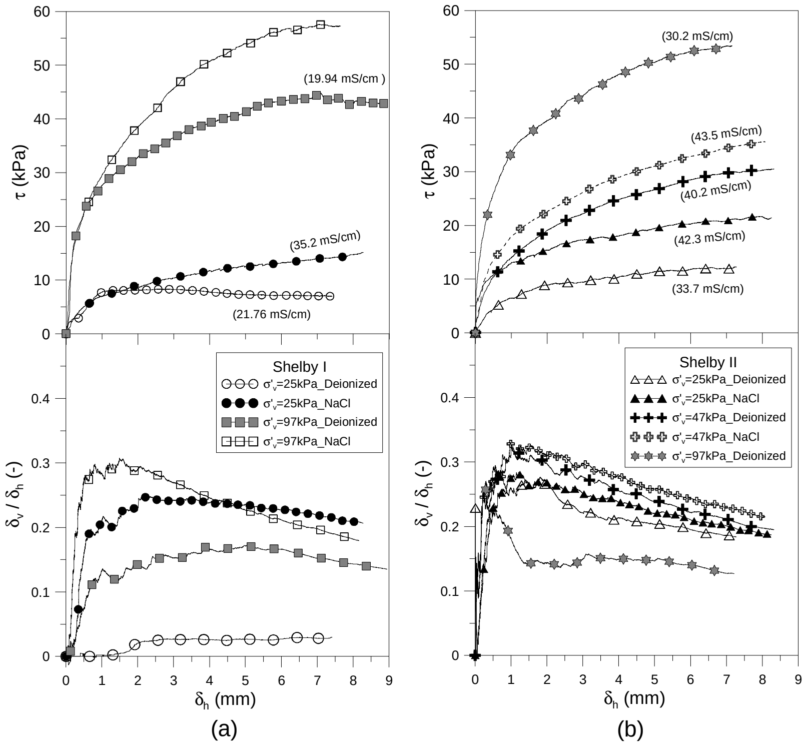
Assessment of sample quality

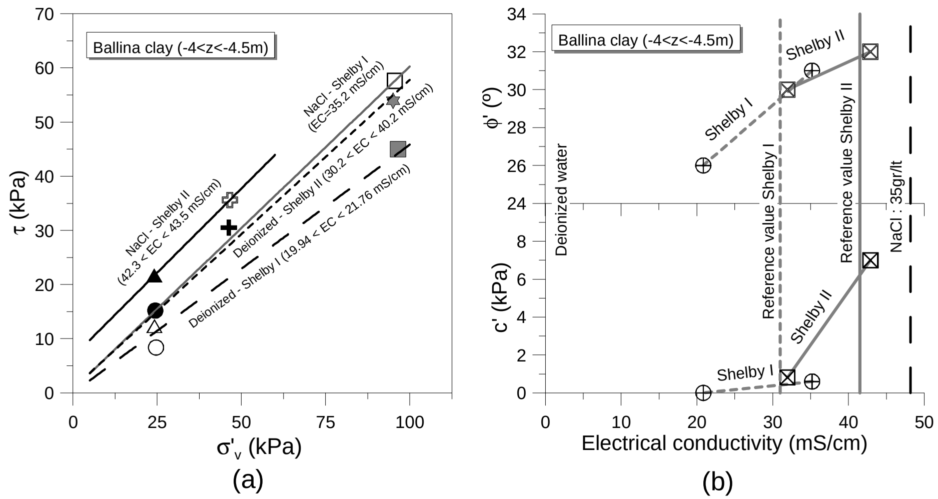




Laboratory tests: Pore water salinity







Courtesy Dr Jubert Pineda (UoN)

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Plastic Limits

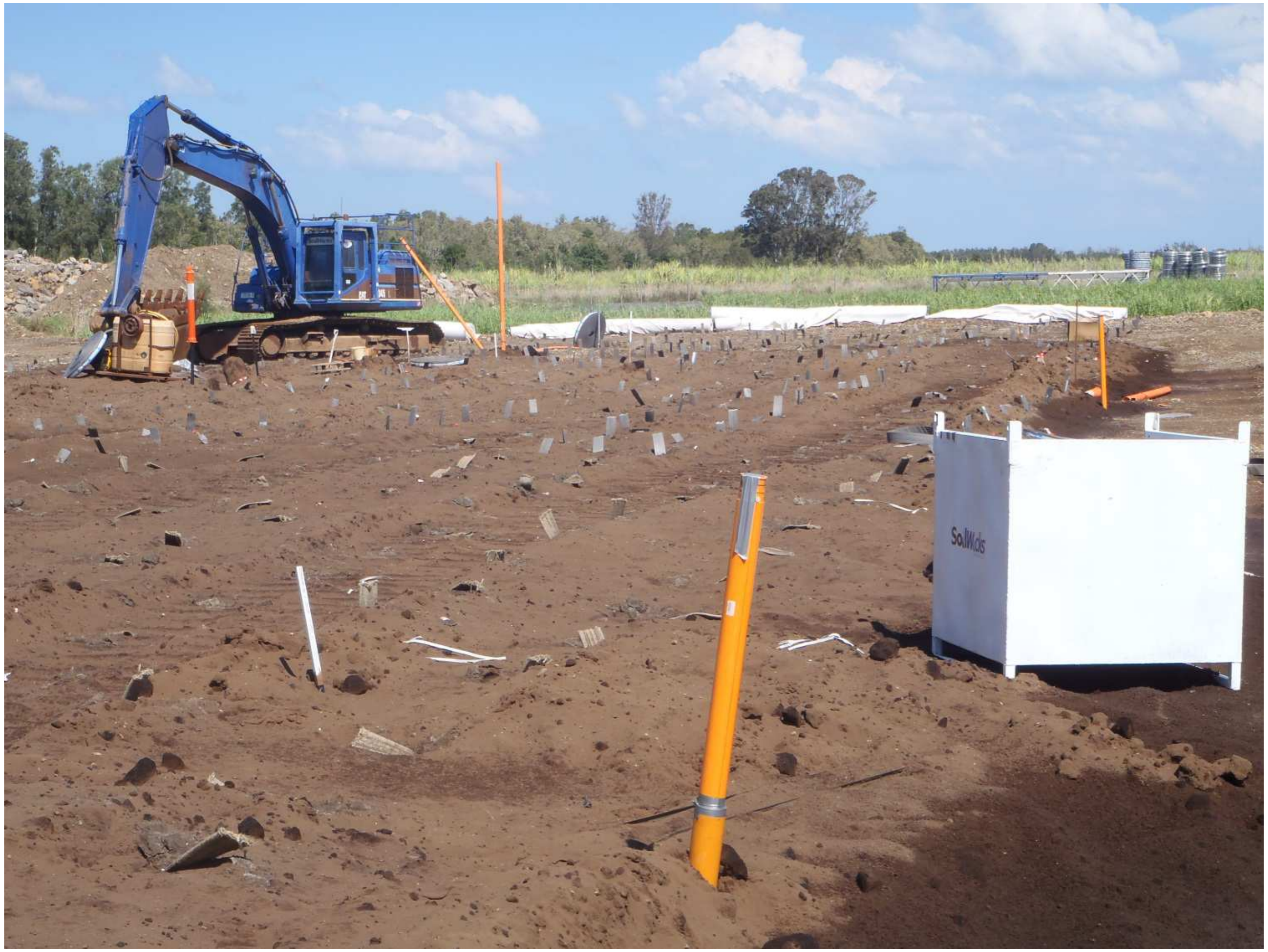
Depth (m)	MC (%)	LL (%)	PL (%)	I_P (%)	I_L (%)	MC oven temp	LL oven temp
4-4.5	91	104	26	78	0.83	110 deg.	Air
4-4.5	87	73	23	50	1.28	50 deg.	50 deg.
5.5-6.0	112	131	36	95	0.80	110 deg.	50 deg.
5.5-6.0	112	93	36	57	1.33	110 deg.	110 deg.
8.5-9.0	114	118	40	78	0.95	110 deg.	50 deg.
8.5-9.0	114	69	37	32	2.41	110 deg.	110 deg.

Trial Embankments

Embankments

- Jute and conventional PVDs
- Granular drainage layer versus horizontal wick drains
- Smear during installation
- Control embankment

JUTE and conventional PVDs



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Characterization of smear zone due to installation of vertical drains

Cholachat Rujikiatkamjorn
Buddhima Indraratna
Darshana Perera

Centre for Geomechanics and Railway Engineering

University of Wollongong

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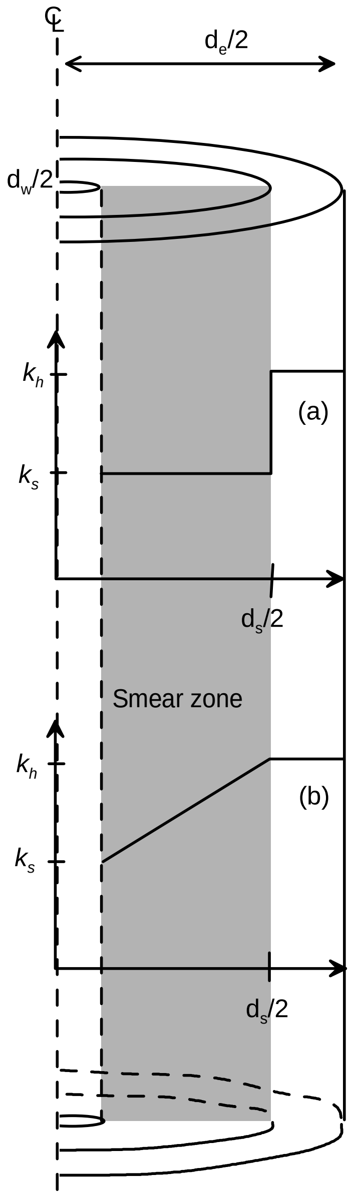
coffey geotechnics SPECIALISTS MANAGING THE EARTH

Douglas Partners Geotechnics / Environment / Groundwater

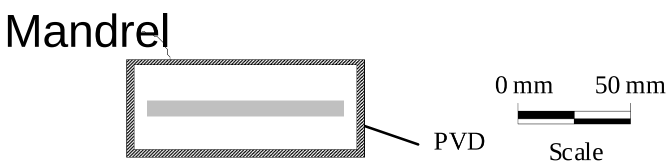
Advanced Geomechanics

Smear zone characterization created due to PVD

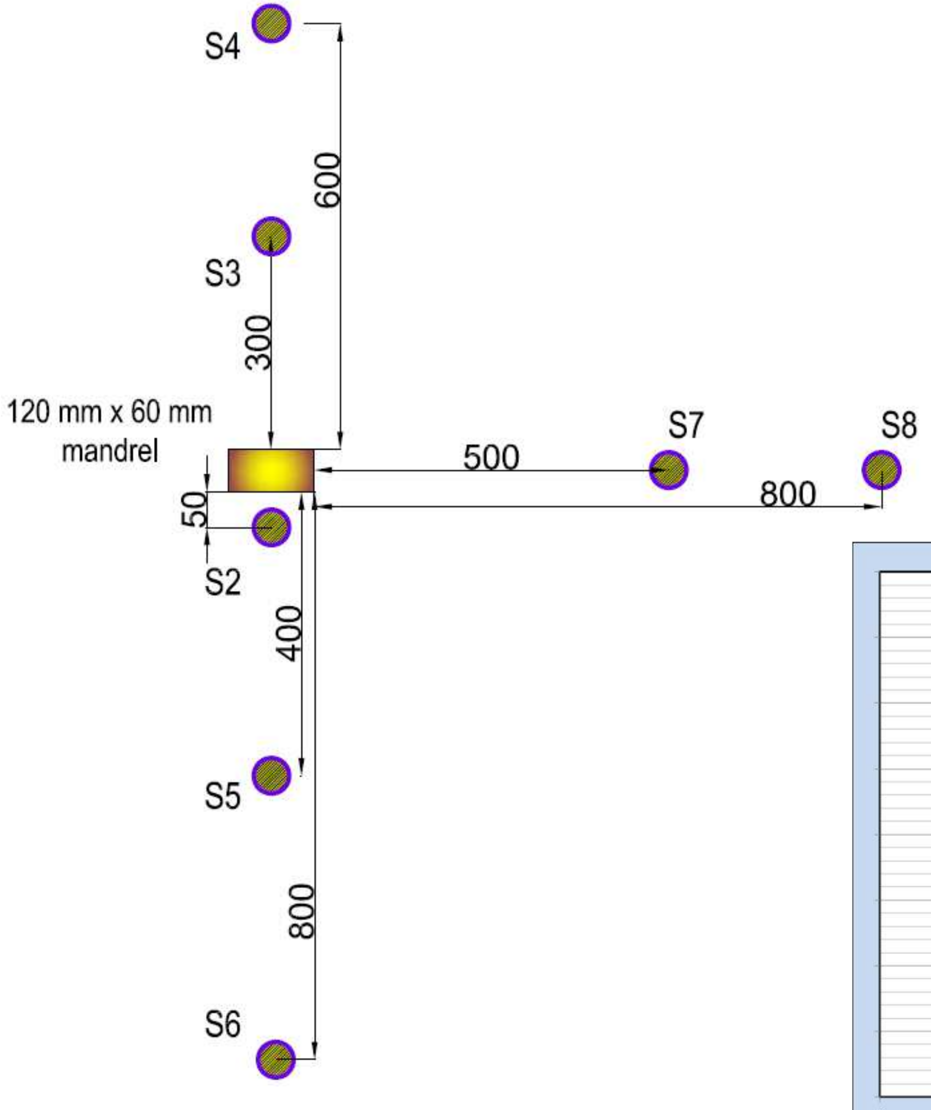


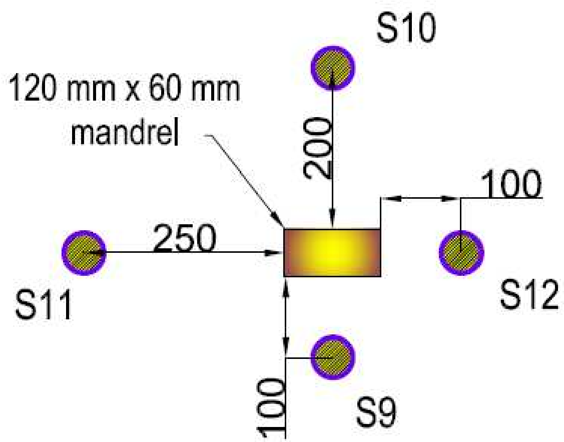
Indraratna and Redana 2000

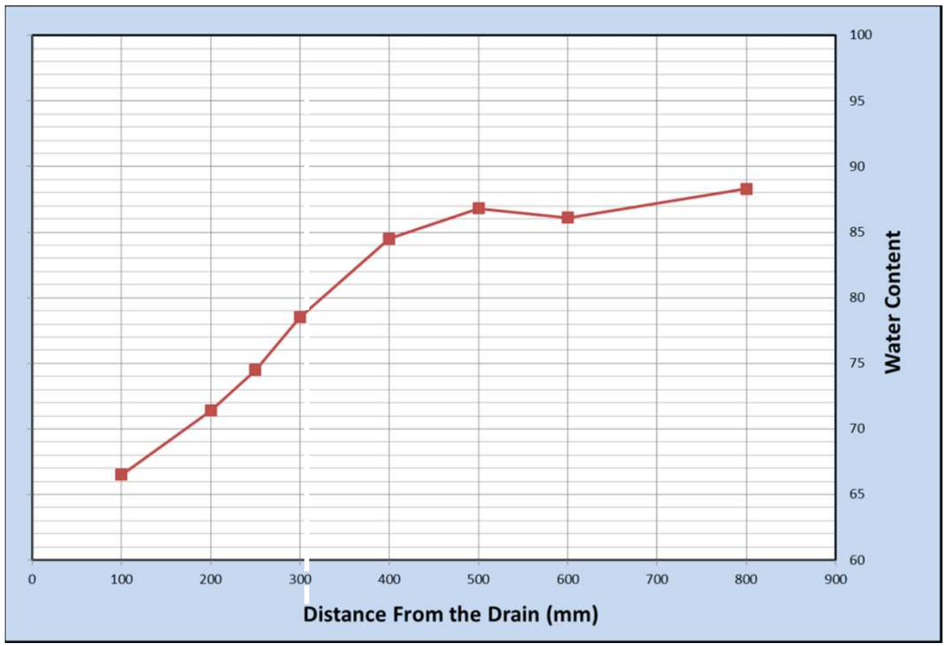
Walker and Indraratna 2007



Sample locations







Water Content Approach

Sathananthan and Indraratna 2006

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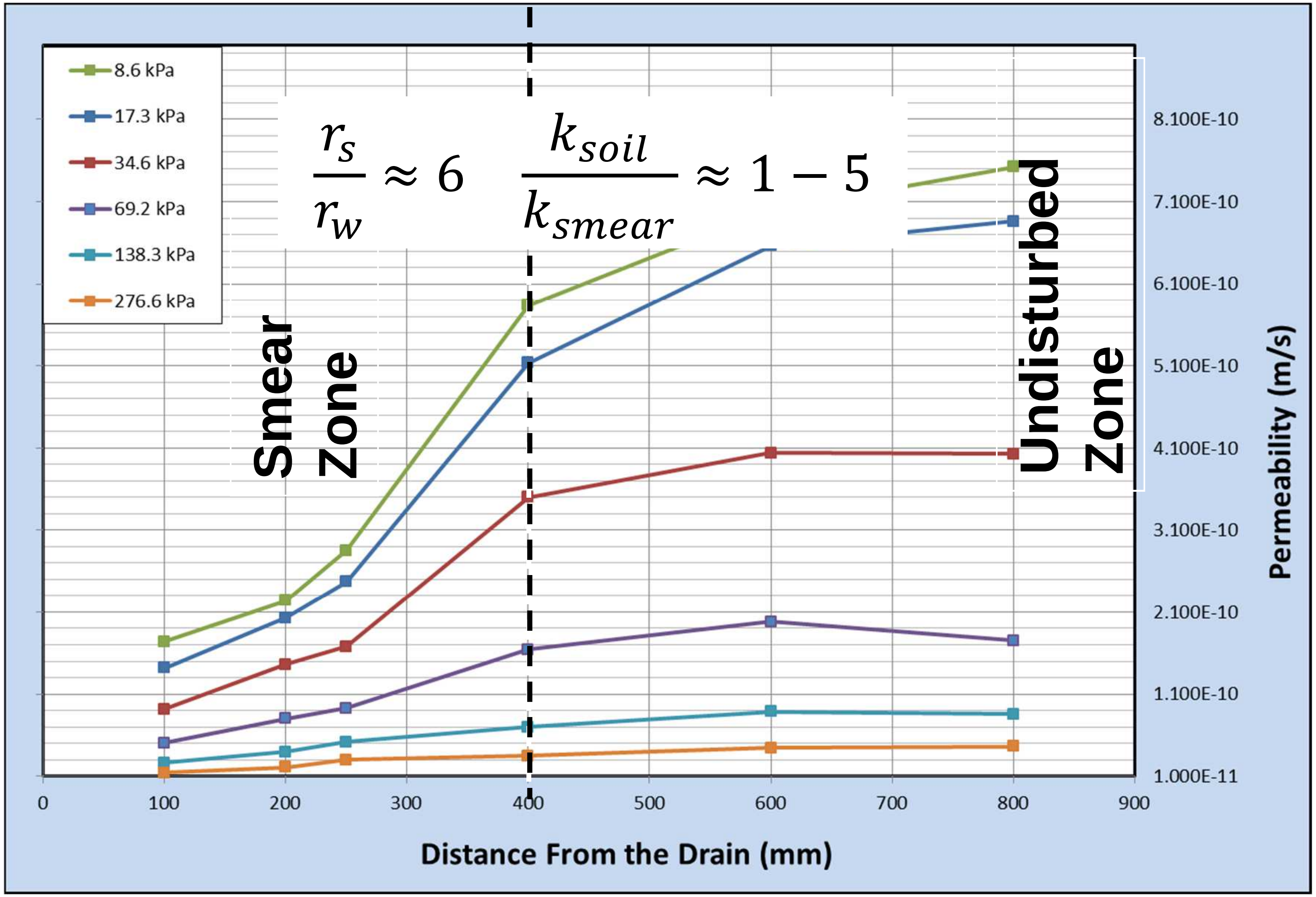
Radial Distribution of Horizontal Permeability



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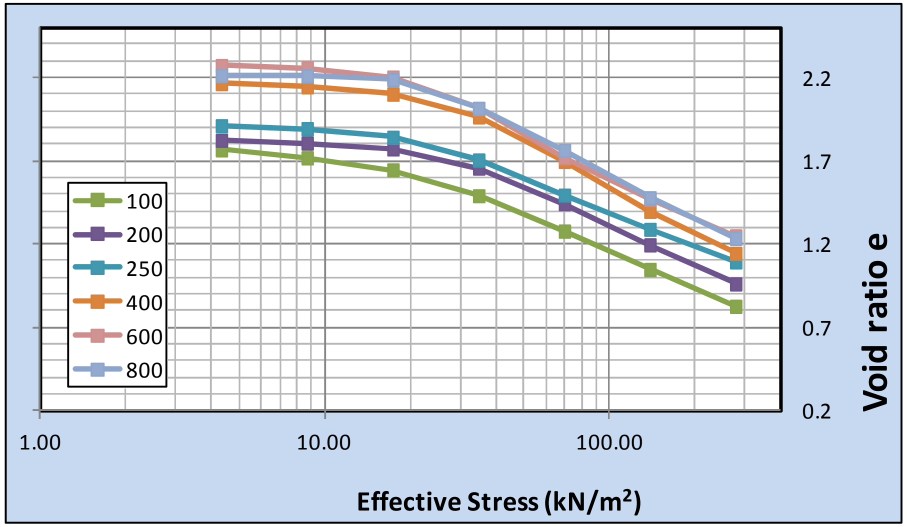
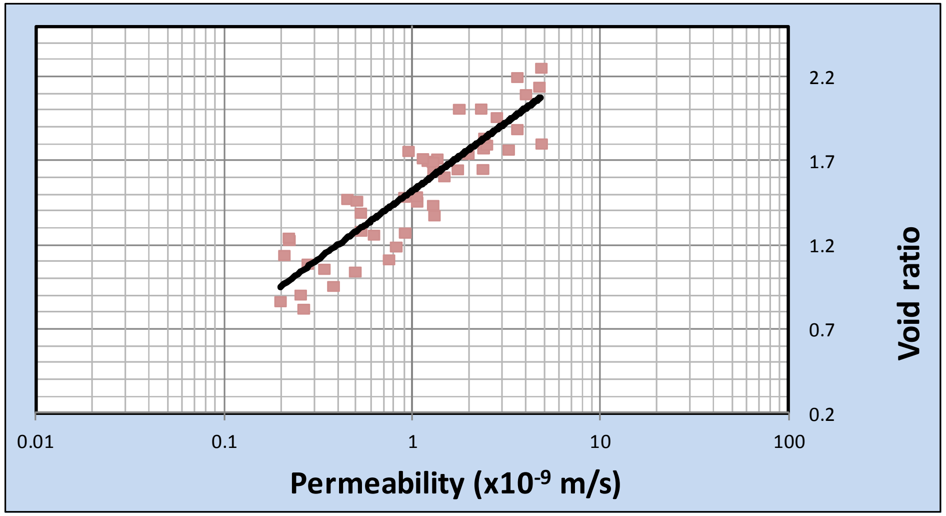
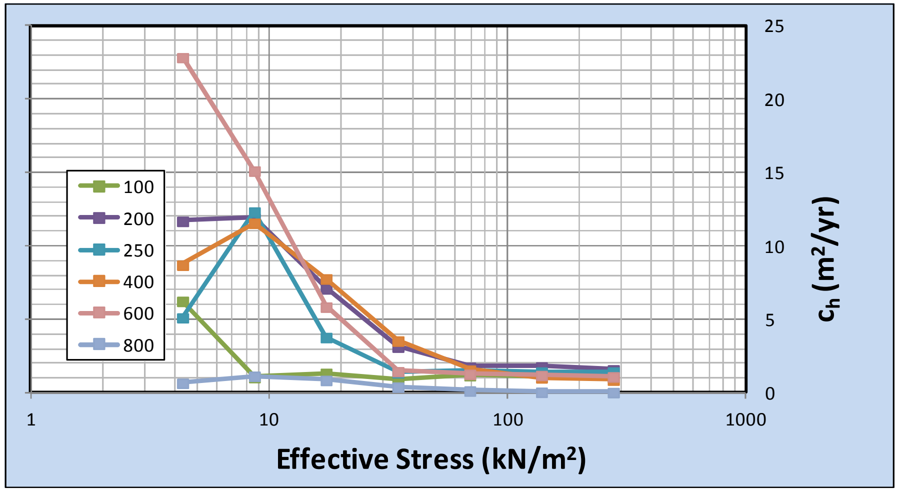
Effect of soil disturbance on soil consolidation parameters

$$c_h = \frac{k_h}{m_v \gamma_w}$$







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Footing tests

Footing tests to failure

Courtesy
Fillippo Gaone
(UWA)

Future Activities

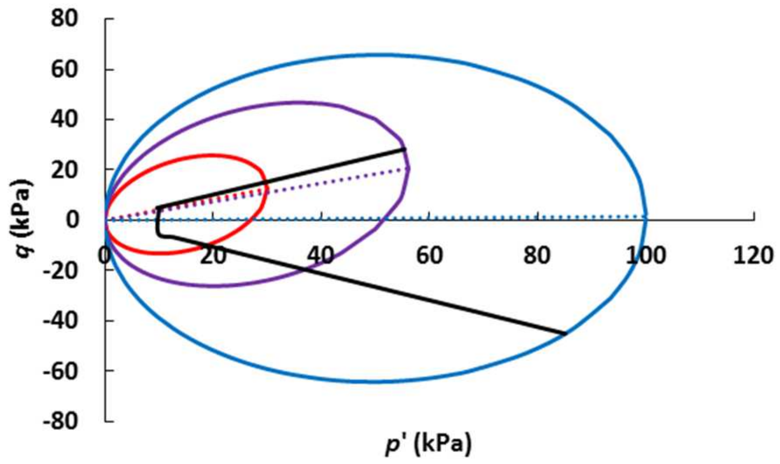
Future Activities

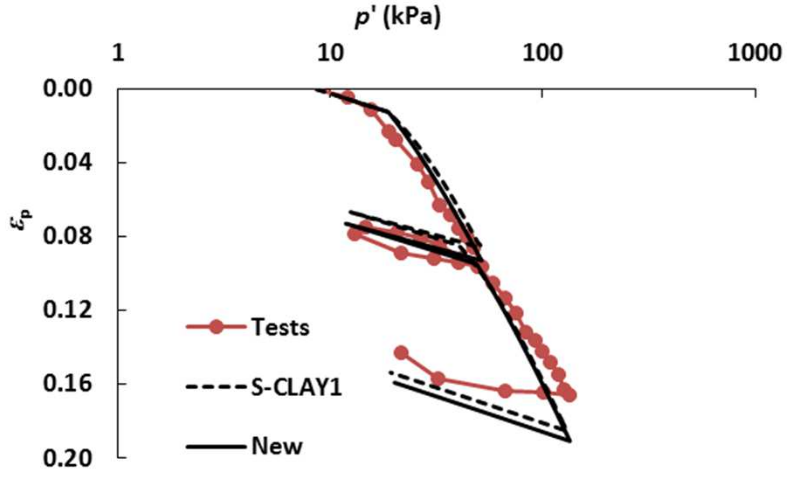
- 2014-2015 Detailed laboratory testing programme

- Geological parameters
  - XRF/XRD
  - SEM
  - Organics
  - Water and soil chemistry
  - Age
- Geotechnical profile with depth
  - w, I_L, I_P
  - s_u
    σ_p
    ϕ
  - k, c_v, c_h
  - C_c, C_s, C_α
  - G_0
  - Conductivity

Constitutive modelling

- Critical state, rate dependent, anisotropic, structured soil, bounding surface model
  - Stress path controlled triaxial tests
  - Hollow cylinder tests for deviatoric plane
  - CRSC at different strain rates
  - Creep tests
  - Test Sherbrooke block samples





Courtesy Dr Chao Yang (UoN)

Future Activities

- Commissioning SI rig with variable electric drive 2014 (UoN, UWA, UoW)
- Instrumenting and loading stone columns (UoW)
- Installation of model piles (UWA)
- International Numerical Prediction Symposium, University of Newcastle 2016!
- International Conference on Site Characterisation ISC5 Gold Coast September 2016

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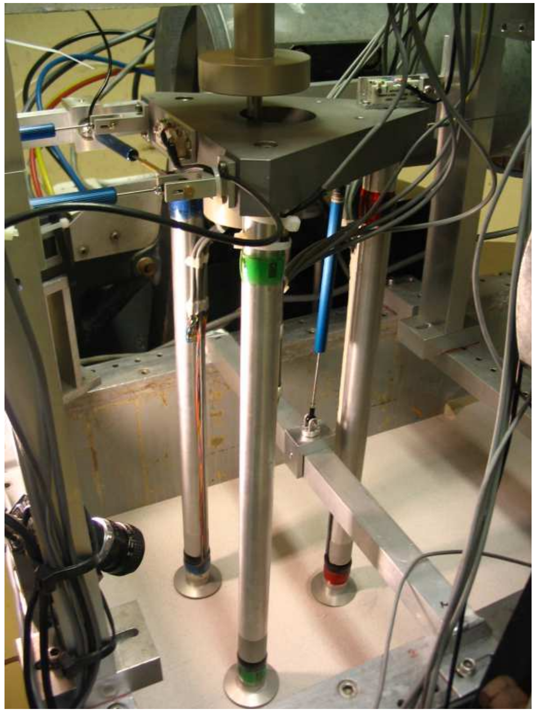
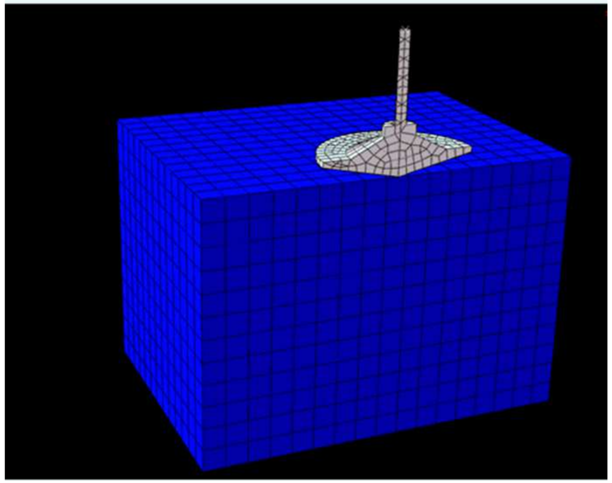
QUESTIONS?

Keppel jack-up rig
160m high



Centrifuge model
0.45m high



Advanced numerical
model