SPECIFYING SITE INVESTIGATION

Ir. Liew Shaw Shong

G&P GEOTECHNICS

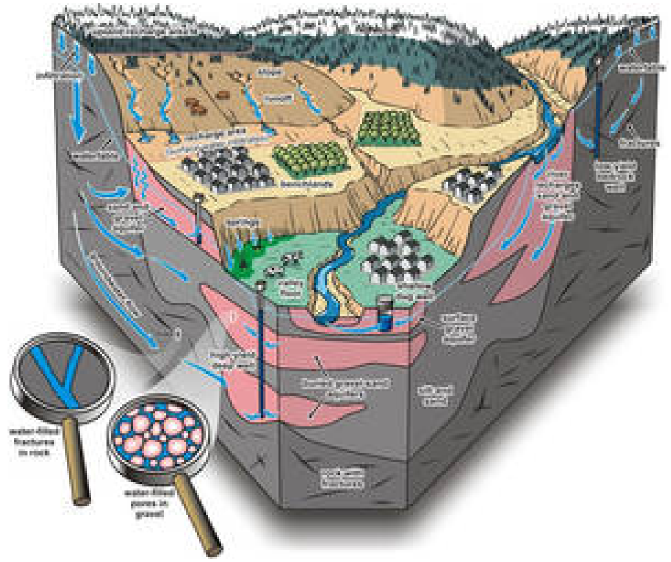
Introduction

Scope

- **Site Investigation**
  - Information on Hydrology, Meteorology, Environment, Natural Resources, Activities & Topography
- **Ground Investigation**
  - Information on Ground & Groundwater conditions
- **Monitoring**
  - Time dependent changes in ground movements, groundwater fluctuation & movements

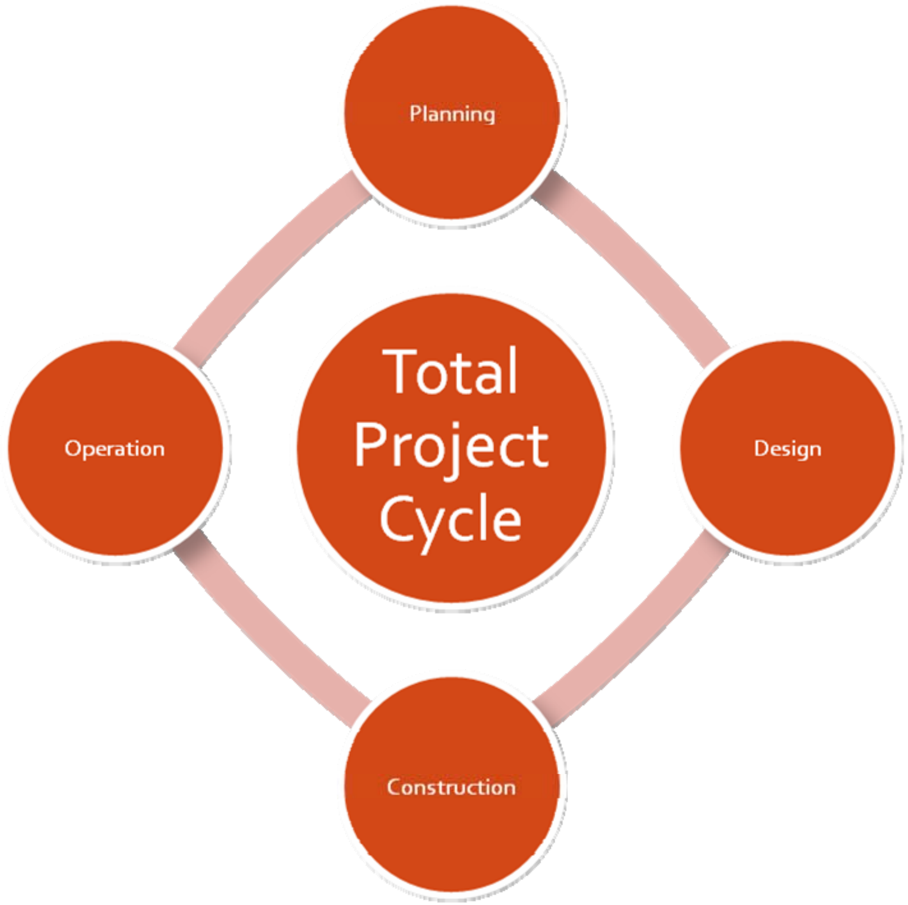
Introduction

Purpose



Introduction

- Project Cycle
- Ground Investigation
- Common Problems & Trend
- Conclusion



Why doing GI? Why Geotechnical Engineer? What Risk & Consequence

Why doing GI?

It is regard as necessary, but not a rewarding expense. (Uncertainty, sufficiently accurate design options for Cost & Benefit study)

Why Geotechnical Engineer?

Geotechnical engineer as an underwriter for risk assessment.

What Risk in Ground & its Consequence ?

Ground Variability & Geo-hazards.

Financial Viability & Cost Overrun (Construction & Operation).

'My design saves the cost of a site investigation ...'

WITHOUT SI, GROUND IS AN HAZARD

Sink hole triggers dramatic Florida viaduct collapse

SITE INVESTIGATIONS failed to pick up a sink hole which caused a motorway viaduct to collapse in Tampa, Florida, last month.

Ground investigations involved borehole probes to 3.5m below the base of the 19.5m foundations for each of the viaduct's 212 piers.

Project client Tampa-Hillborough Expressway Authority said this was double normal requirements.

A 6m high pier for the 10km long highway sank suddenly into the ground on 13 April during construction of a glued segmental deck span.

The reinforced concrete pier almost completely disappeared.

The collapse was slow enough for workers to get clear, although two were taken to hospital. The busy Lee Roy Selman Crosstown Expressway which runs beneath the viaduct was closed until traffic could be redirected.

Cause of the collapse is thought to be a limestone sink hole, more than 30m below the site. A spokeswoman for the Authority said Florida was largely underlain by limestone and sink holes were prevalent. It was impossible to determine the location of every one.

Ground investigation was by Dames & Moore, subcontractor to the Authority's general engineering consultant URS. Additional input was made by Williams Earth Science.

Ground radar and seismic probing may now be used to check the remaining pier locations for the highway. The existing 160 piers should be okay said the Authority spokeswoman.

"The pier sank when the launching truss for assembling the 16 segment precast span was fully loaded which means it had half a 700,000lb (320t) load on it," she said. Existing piers have already received this de facto load test.

The $310M project, due for completion next year, will create an additional three lanes, 6m above a busy existing commuter route. Traffic flow will reverse between morning and night.

Designer for the elevated structure is the Figg Engineering Group and contractor PCL Civil Constructors from Canada.

Source :http://www.sptimes.com/2004/04/16/Tampabay/At_site_of_collapse__.shtml

WITHOUT SI, GROUND IS AN HAZARD

Light saves man in sinkhole scare

IPOH: When Lee Pek Sang, 84, got up to answer nature's call at 5am yesterday, he realised something was amiss.

The toilet at his home in Bukit Mertah New Village, was missing — lost to a sinkhole.

The sinkhole, measuring 2.44m by 4.57m, was the 21st that had occurred in the area since last October, according to Geological Survey Department officers.

Lee said he would have fallen into the sinkhole if not for the light outside the toilet which was always switched on.

He also said he cannot leave his home because he had nowhere else to go.

The last sinkhole which appeared at the new village next to a cobbler's house on May 16 measured 2m by 8m.

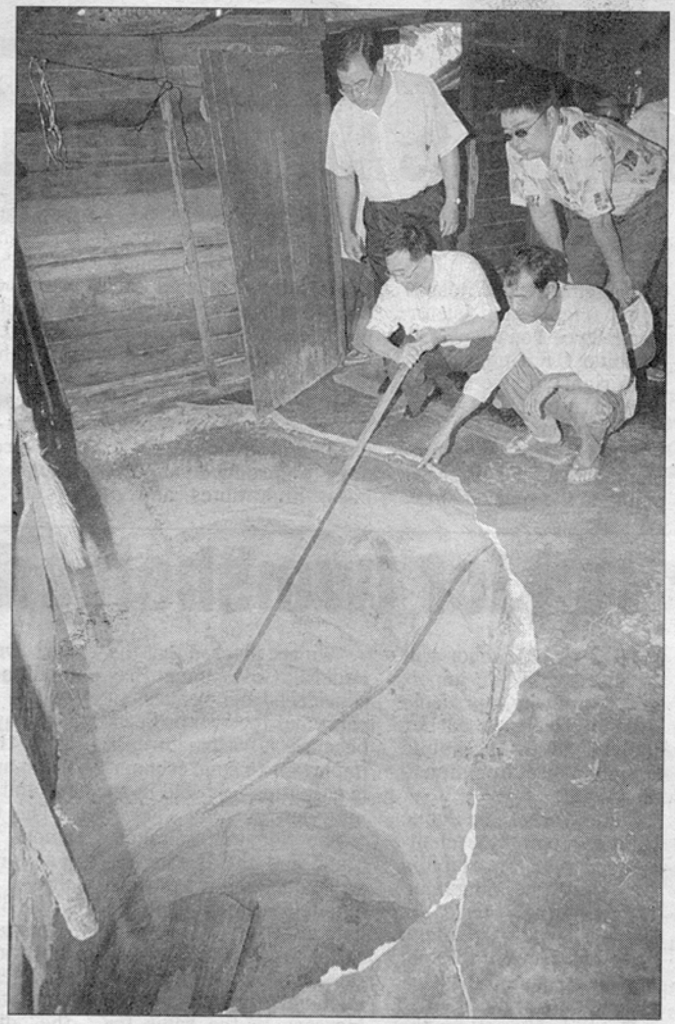
MP for Batu Gajah Yeong Chee Wah will ask to make public the findings on the frequent appearance of sinkholes at the Bukit Merah new village during the Dewan Rakyat sitting in July.

Yeong said the affected villagers have been living in fear since October, adding that some form of remedial action should be taken.

At present, the sinkholes are a threat to 50 houses located side-by-side in three rows in the village.

The village elders when questioned about the occurrence of sinkholes there, said water from a nearby mining pool was drained away underground below the affected houses and could be the main reason for the sinkholes.

The Lahat mines about 500m away from the Bukit Merah New Village is a large and very deep dry mine which has existed for years and has been dubbed the "Grand Canyon of Malaysia" since it could be seen when travelling on the new Ipoh-Lumut outer ring road.



DEEP TROUBLE … Yeong (standing, left) peering into the sinkhole at what used to be Lee's toilet yesterday. The MP pledges to follow up on the matter at the Dewan Rakyat in July.

WITH SI, GROUND CAN BE A HAZARD

Source :National Geographic (Jan 2008)

WITH SI, GROUND CAN BE A HAZARD

By Andrew Marshall
Photographs by John St

By dawn, the tr
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had become a scalding
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manages a store in the
Java. As it smothered fu
Sumitro and Indayani,
and fled. "I knew the m
he says. "My house wa
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source of his woes: a n
source of some contro
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was the trigger.
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sia's geologic turmoil
spewed millions of b
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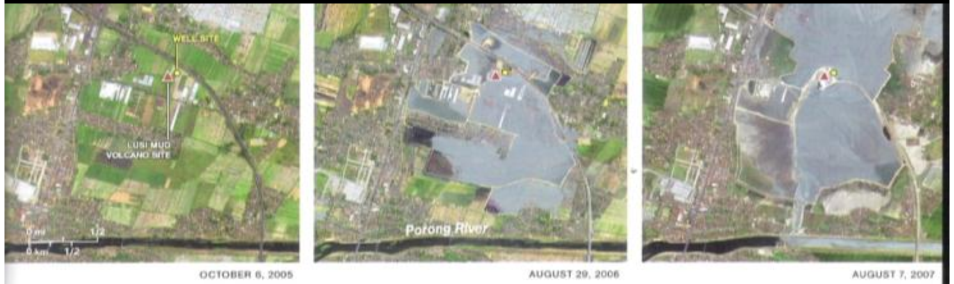
York City's Central P
peared under the mu
and 10,000 families
their homes. So far, a
mate, the catastroph
billion dollars—nearly
and triggered spasms
being Indonesia, it ha
to the supernatural.
Lusi—a nickname
Indonesian word for
arjo, the name of the n
erupting for decades
backhoes work relentl
age, fortifying dikes a
of mud that continu
Pipes disgorge the
River; theoretically, r
it doesn't choke the
Surabaya, a city of 2.5
With the mud cam
witch doctors, Balin
celebrity soothsayer,
they could stop the de
geese, and monkeys

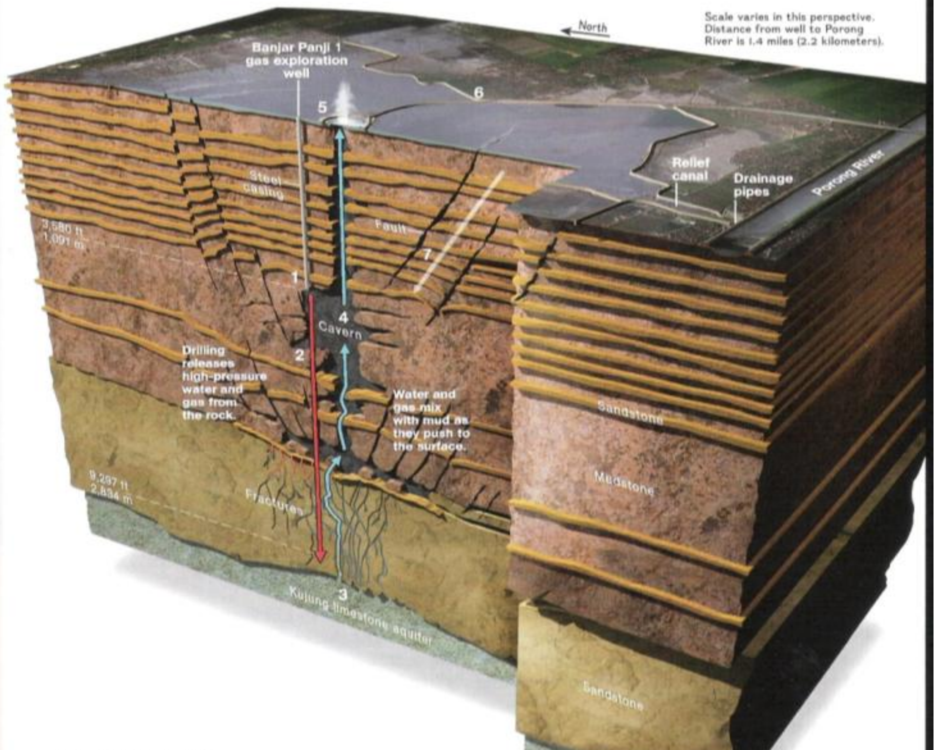
60

UNDER THE MUD VOLCANO

It began with a burst of steam and a splurt of mud. But the gloopy surge that locals call Lusi soon became a sprawling nightmare. Satellite images (top) show Lusi swallowing more than two square miles in the Porong District. A cross section (right) illustrates what geologist Richard Davies believes caused the disaster.

1. Drillers exploring for gas bored 3,580 feet down, then inserted a steel casing to strengthen the hole.
2. Drilling went deeper without the steel casing. Water and gas filled the hole, and the resulting pressure fractured unprotected rock strata.
3. Hot, high-pressure water was released, probably from the Kujung aquifer.
4. The water raced upward and liquefied masses of mudstone.
5. Mud surged through layers of mudstone and sandstone and broke through the surface.
6. Engineers built dikes in an attempt to contain the mud.
7. Underground, caverns formed and collapsed, causing faults.





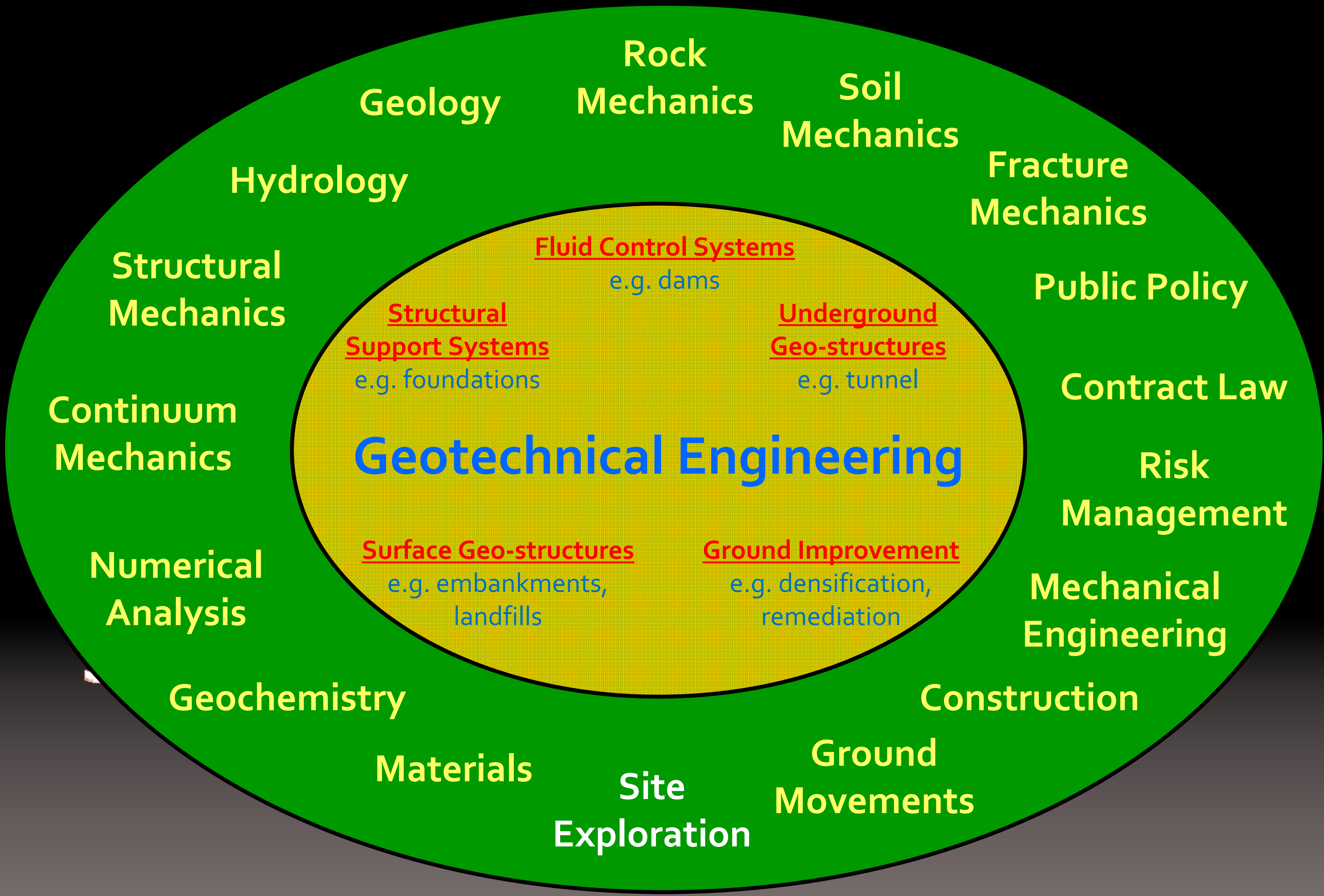
SOURCES: IKONOS SATELLITE IMAGES BY CRISP, NATIONAL UNIVERSITY OF SINGAPORE; MUD VOLCANO PROFILE FROM RICHARD DAVIES, DURHAM UNIVERSITY
ART BY DON FOLEY
LISA R. RITTER, NGM MAPS

Source :National Geographic (Jan 2008)

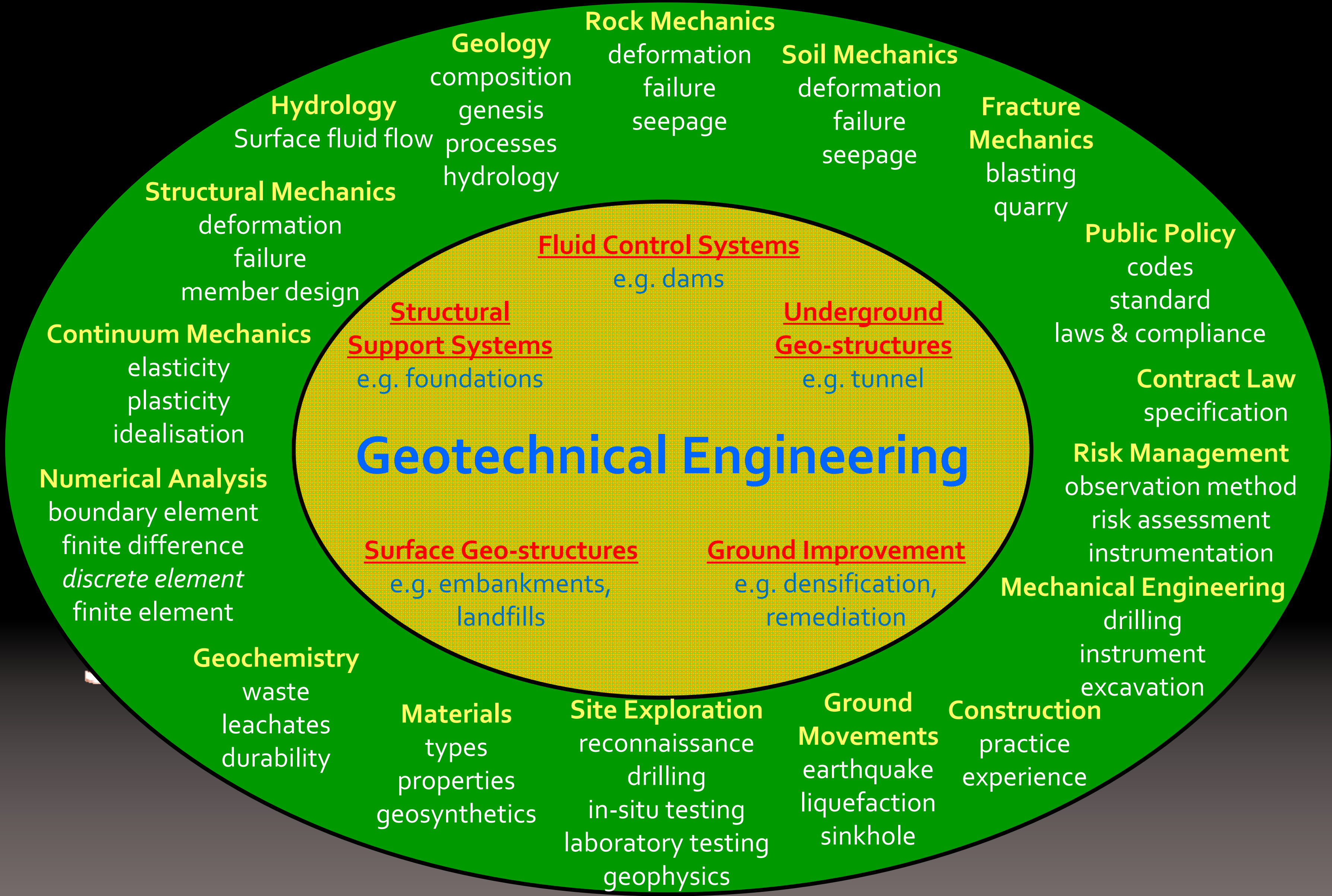
GOD CREATION & HUMAN CREATION

Elements to deal with Uncertainties

- Pertinent Knowledge
- Observation & Experience
- Information
- Careful Interpretation & Assessment



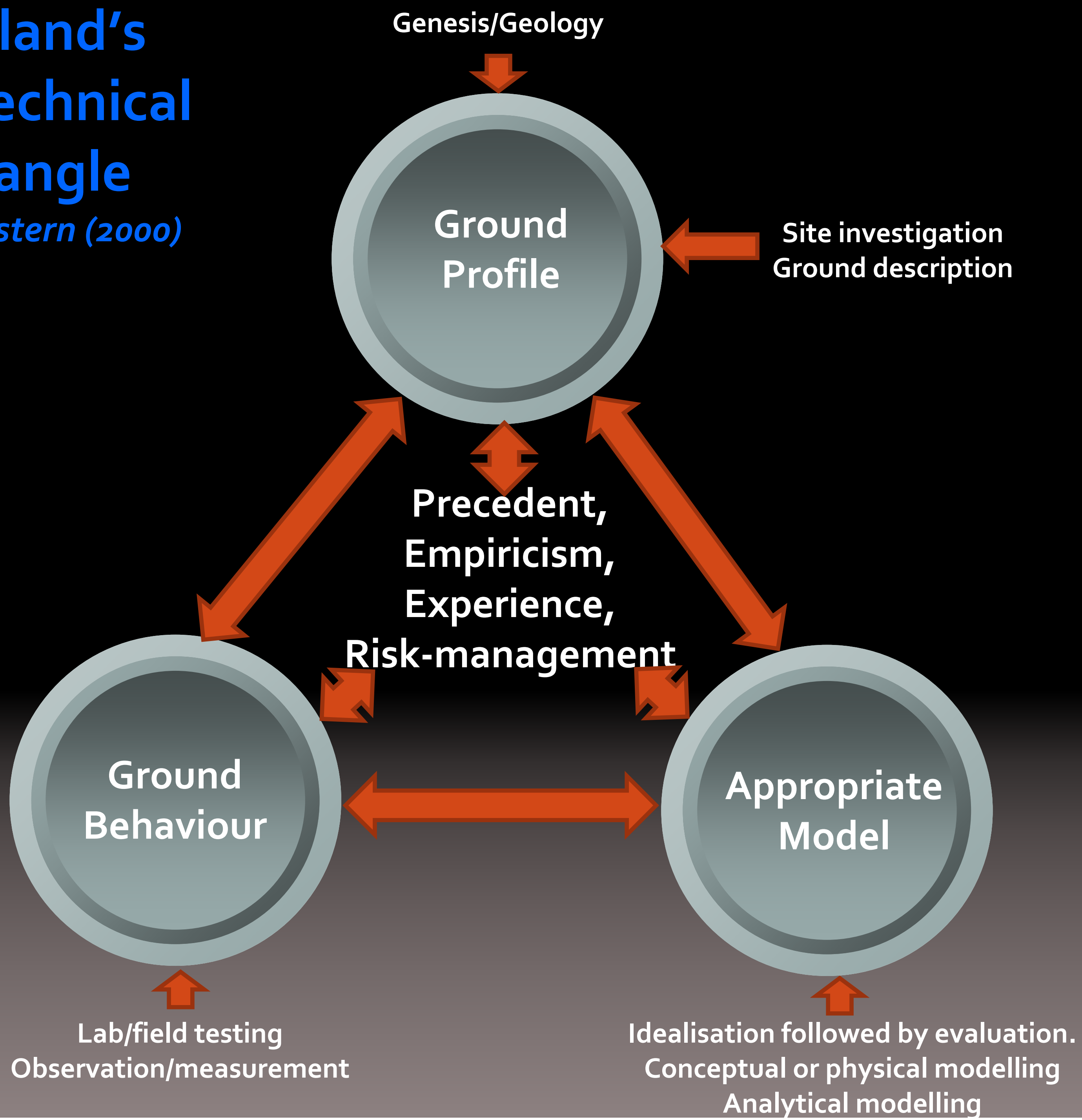
Modified from Morgenstern (2000)



Modified from Morgenstern (2000)

Burland's Geotechnical Triangle

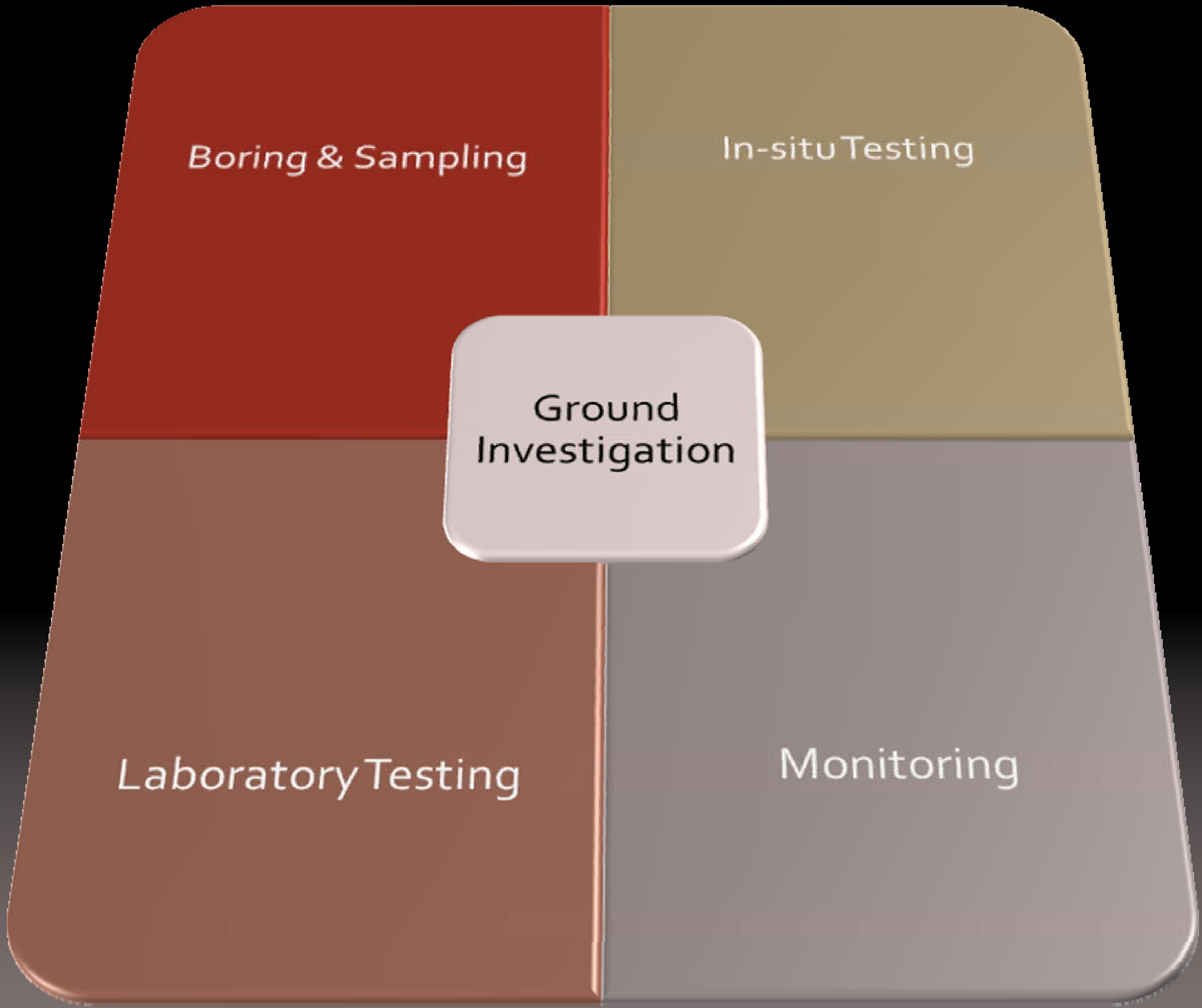
Morgenstern (2000)



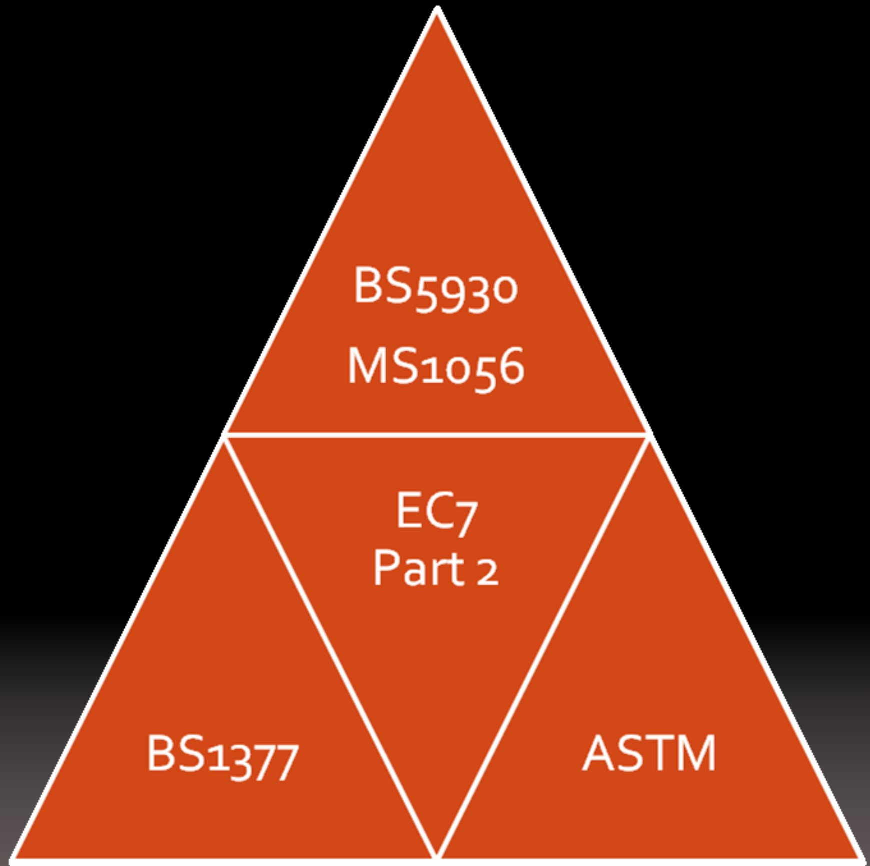
- How GI cost

Consequence

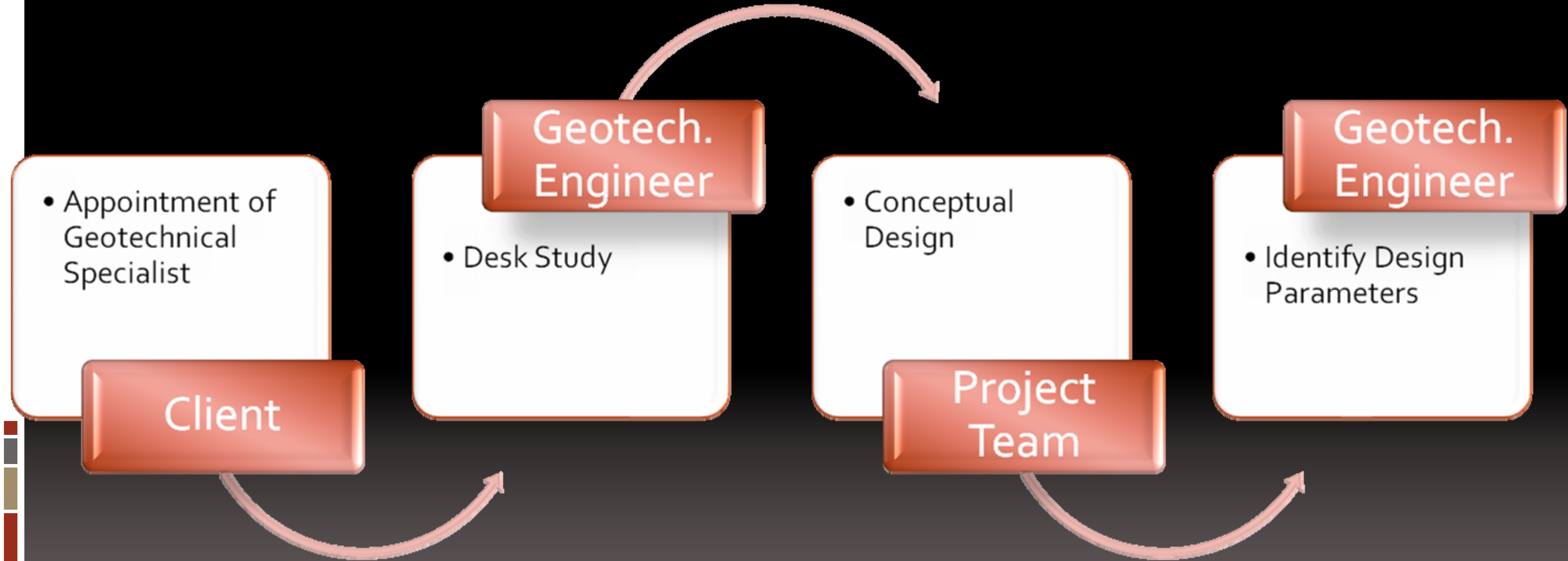
How GI shall be done ?


Boring & Sampling
In-situ Testing
Ground Investigation
Laboratory Testing
Monitoring

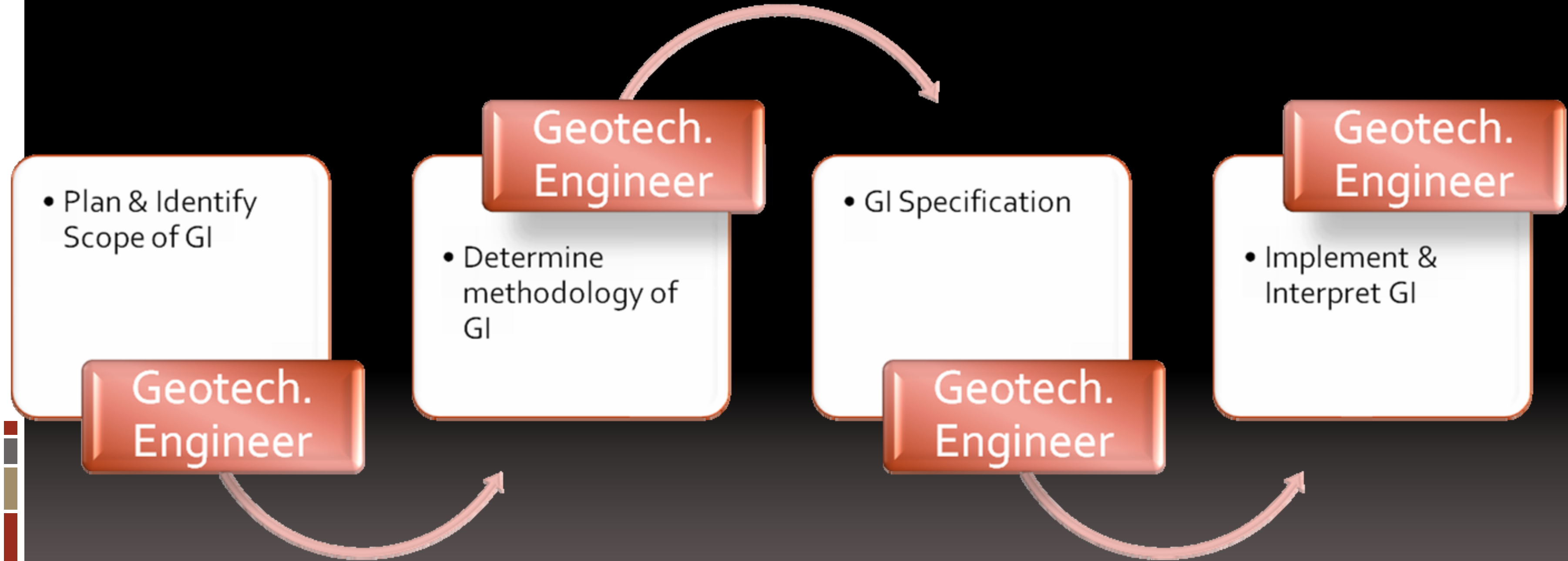
Codes & Standards



Process Diagram of Ground Investigation



Process Diagram of Ground Investigation



Stage 1 of GI

Planning

- Desk Study
- Site Walk-over Survey
- Identify Project Need
- Scope of GI
- Bid Document & Tender

Stage 2 of GI

Implementation

- Field Supervision
- Sampling, In-situ Testing, Geophysical Survey
- Monitoring
- Laboratory Testing
- Work Certification

Stage 3 of GI

Interpretation & Reporting

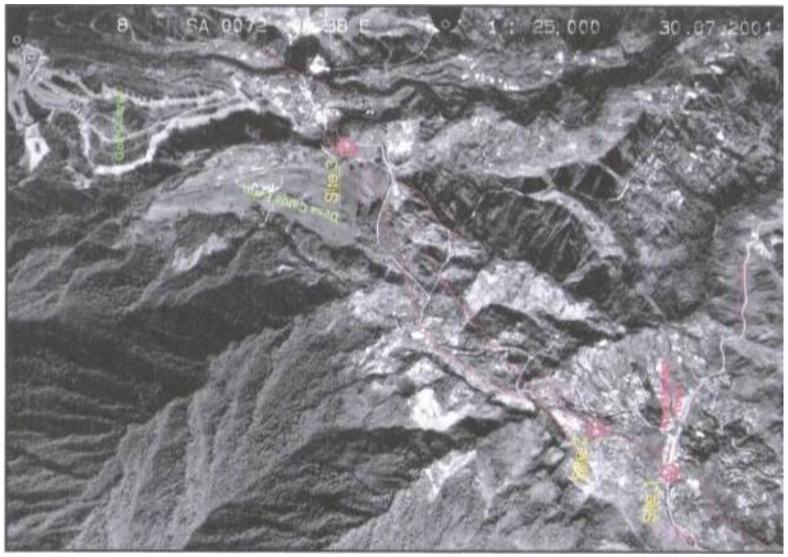
- Factual Data Compilation
- Interpretation
- Report Preparation

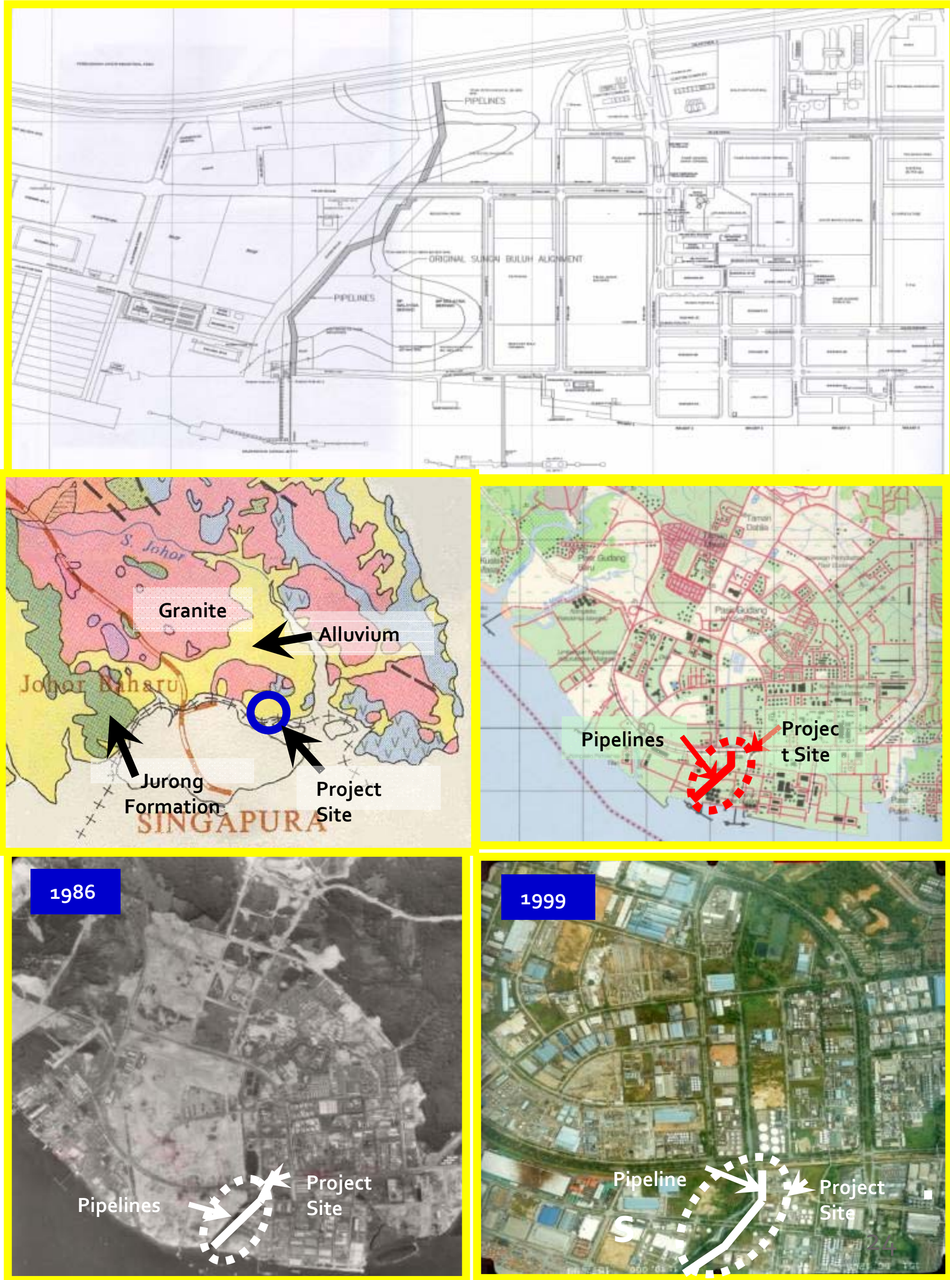
"Without Site Investigation, Ground is a Hazard"

Desk Study

Information for Desk Study :

- Topographic Maps
- Geological Maps & Memoirs
- Site Histories & Land Use
- Aerial Photographs
- Details of Adjacent Structures & Foundation
- Adjacent & Nearby Ground Investigation





Site Walkover Survey

- Confirm the findings from Desk Study
- Identify additional features & information not captured by Desk Study

GI Planning

Layout

- Direct influence beneath the proposed structure/works
- Distant Impact from the proposed structure/works

Frequency

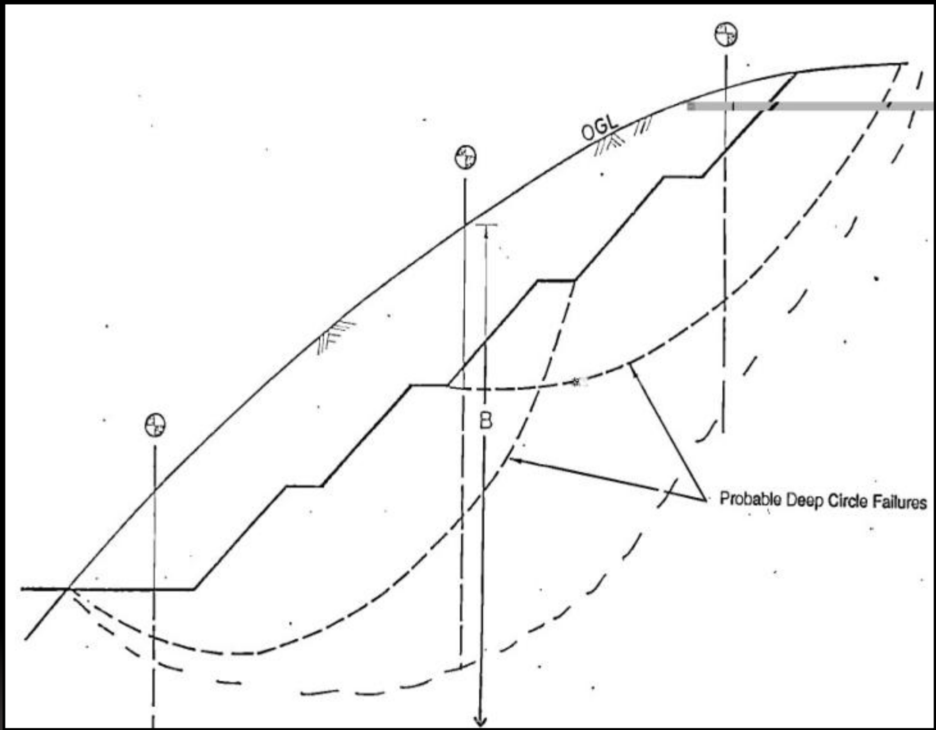
- Light structure
- Compact structure (3 ~ 5 points)
- Linear infrastructure (Representation of each geological unit)
- Slope : 3 probing per critical section

Vertical Extent

- Foundation : 10% stress bulb or to competent founding strata
- Slope : Hard strata or bedrock, not less than overall slope height

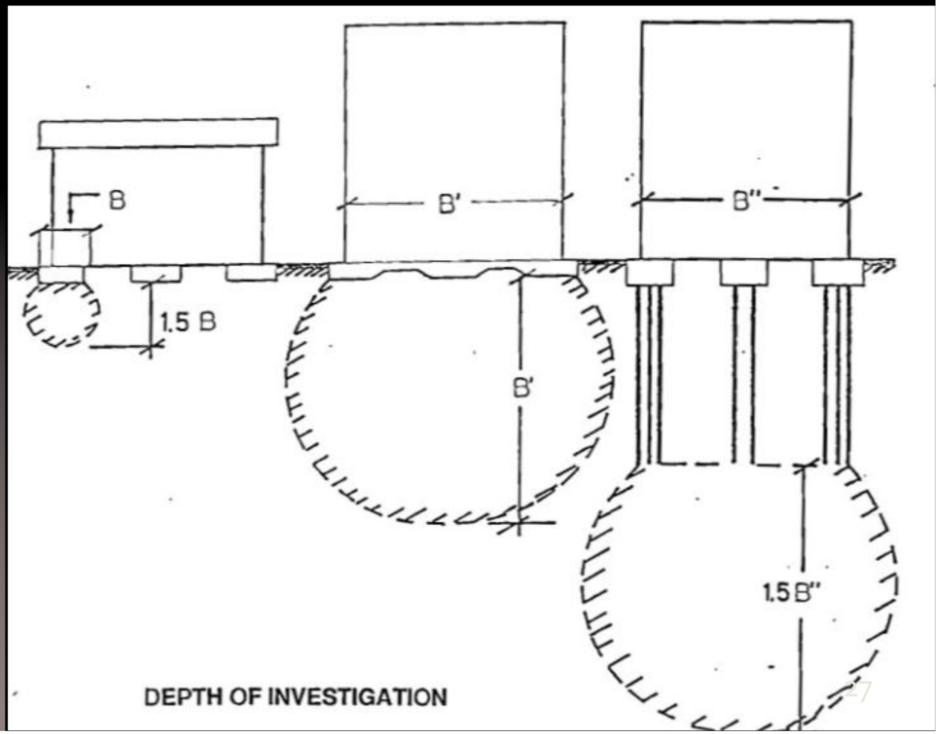
Watch-out for boulder, cavity, hard pan, necessary depth for weathering profile

Depth of Investigation



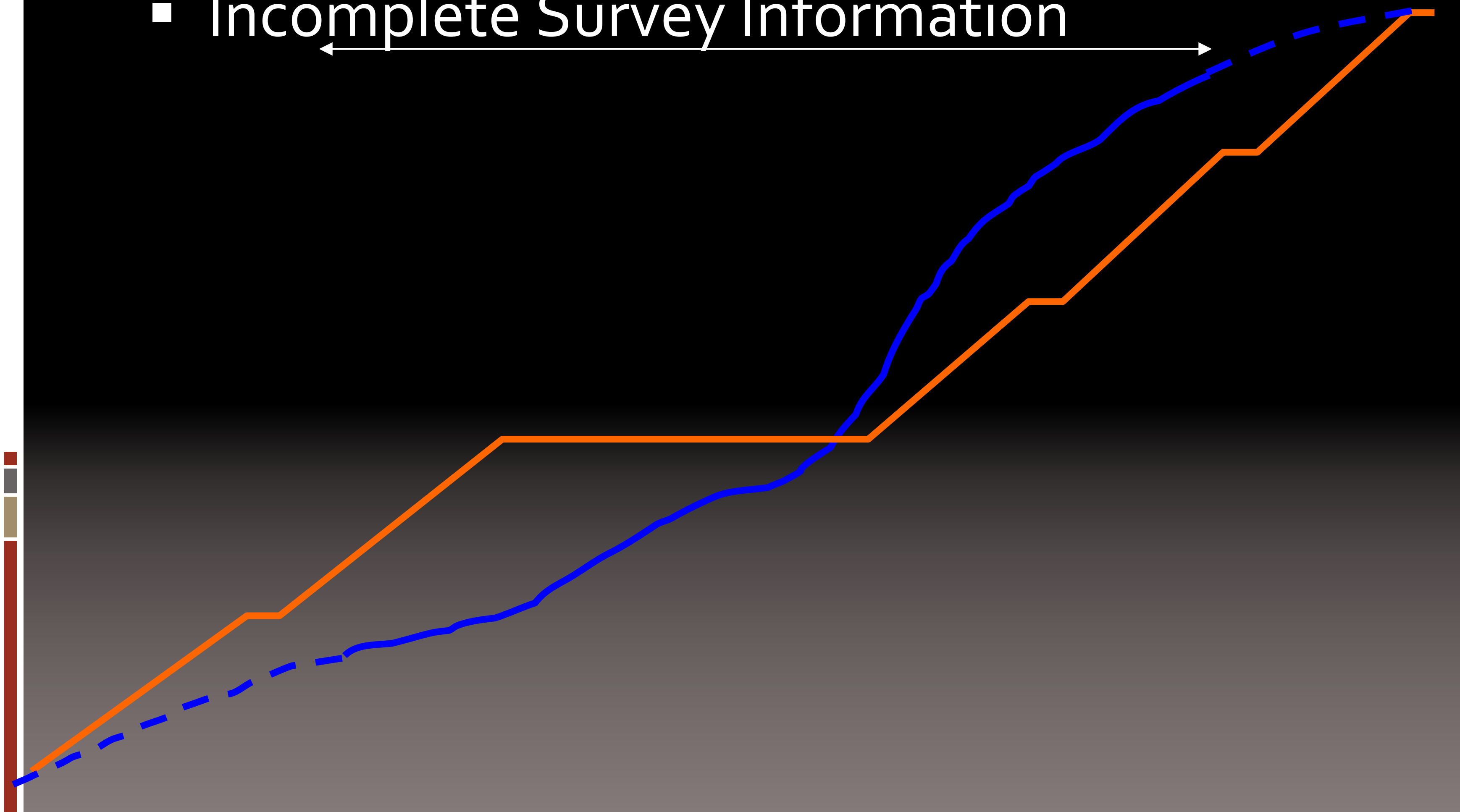
Stability Analysis

Foundation Design



Common Problems

- Incomplete Survey Information



GI Planning

Sampling

- Reasonable samples in each soil strata and bedrock
- Groundwater samples

In-situ Test

- Advance indication on strength, stiffness, permeability
- Direct testing
- Less sample size effect
- In-situ stress

Laboratory Test

- Sample quality & disturbance
- Late availability of result
- Stress path controlled & effective strength are possible under controlled environment

GI Planning

Monitoring

- Ground movement (sliding surface, settlement/compression)
- Groundwater Fluctuation
- Appropriate timing & monitoring duration
- Identify potential failure mechanism

Stage of Investigation

- Preferably in three stages (strategically)
  - Preliminary GI with contingency provision – Broad overview of ground conditions
  - Detailed GI – At critical areas for more information
  - GI in Construction Verification - Areas not covered in previous GI/design modification

Flexibility

- Allow for flexibility of information coverage catering for option exploration

Specification

- Objectives (study, design, forensic, construction)
- Type of investigation, mapping & field survey
- Vertical & lateral extent (termination depth)
- Sampling requirements (types, sampling locations & techniques)
- In-situ and laboratory testing requirements (standards)
- Measurement/monitoring requirements (instrument types & frequency)
- Skill level requirements in specialist works & interpretation
- Report format & data presentation

Specification

- Work schedule & GI resources planning
- Payments for services, liability, indemnity, insurance cover

Boring/Drilling

Recover Sample

- Subsurface stratification/profile
- Material classification & variability
- Laboratory tests

In-situ Testing

- Allow in-situ tests down hole (profiling)
- Direct measurement of ground behaviours

Monitoring

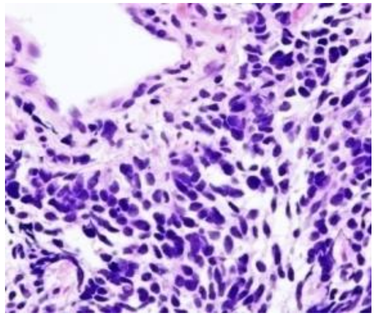
- Allow monitoring instruments installed down hole

Direct Method – Boring, Sampling, In-situ & Laboratory Testing

Medical Applications

- Biopsy sampling



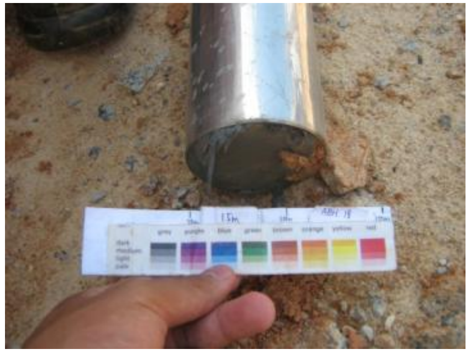


Geotechnical Applications

- Boring, Trial Pitting & Sampling
  - Thin-walled, Piston Sampler
  - Mazier Sampler
  - Block Sample

-In-situ Testing
  - SPT, MP, CPTu, VST, PMT, DMT, PLT,
  - Permeability Test
  - Field Density Test

-Laboratory Testing
  - Classification Test
  - Compressibility Test (Oedometer/Swell)
  - Strength Test (UU/UCT/CIU/DS)
  - Permeability Test
  - Compaction Test
  - Chemical Test (pH, Cl, SO_4, Organic Content, Redox, etc)
  - Petrography & XRD


Indirect Method – Geophysical Survey

Medical Applications

- X-ray, Computer Tomography & MRI

- Ultra-sound

Geotechnical Applications

<u>Geophysical Survey</u>

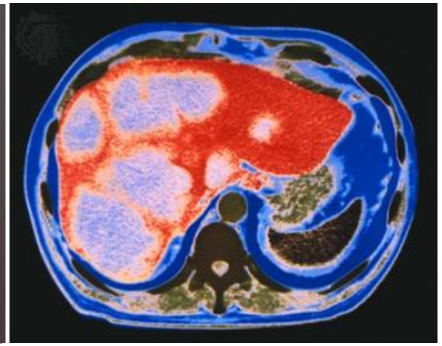
- Electromagnetic Waves

(***Permeability, Conductivity & Permittivity***)

- Mechanical Wave

(Attenuation, S-waves & P-waves)

- Resistivity Method
- Microgravity Method
- Transient Electro-Magnetic Method
- Ground Penetration Radar
- Seismic Method



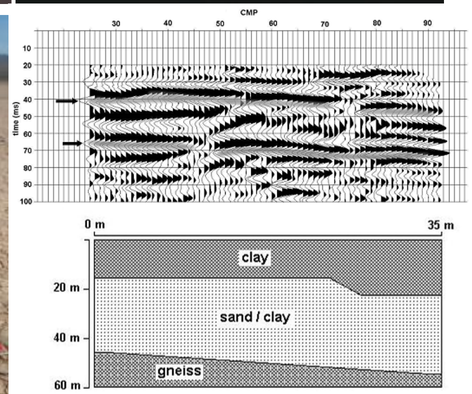
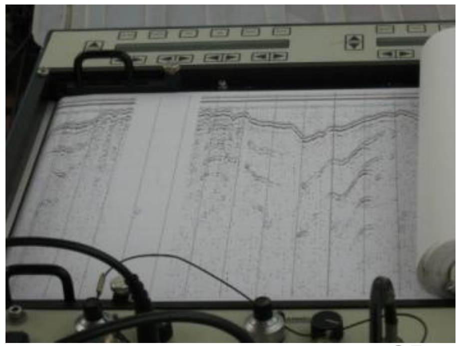


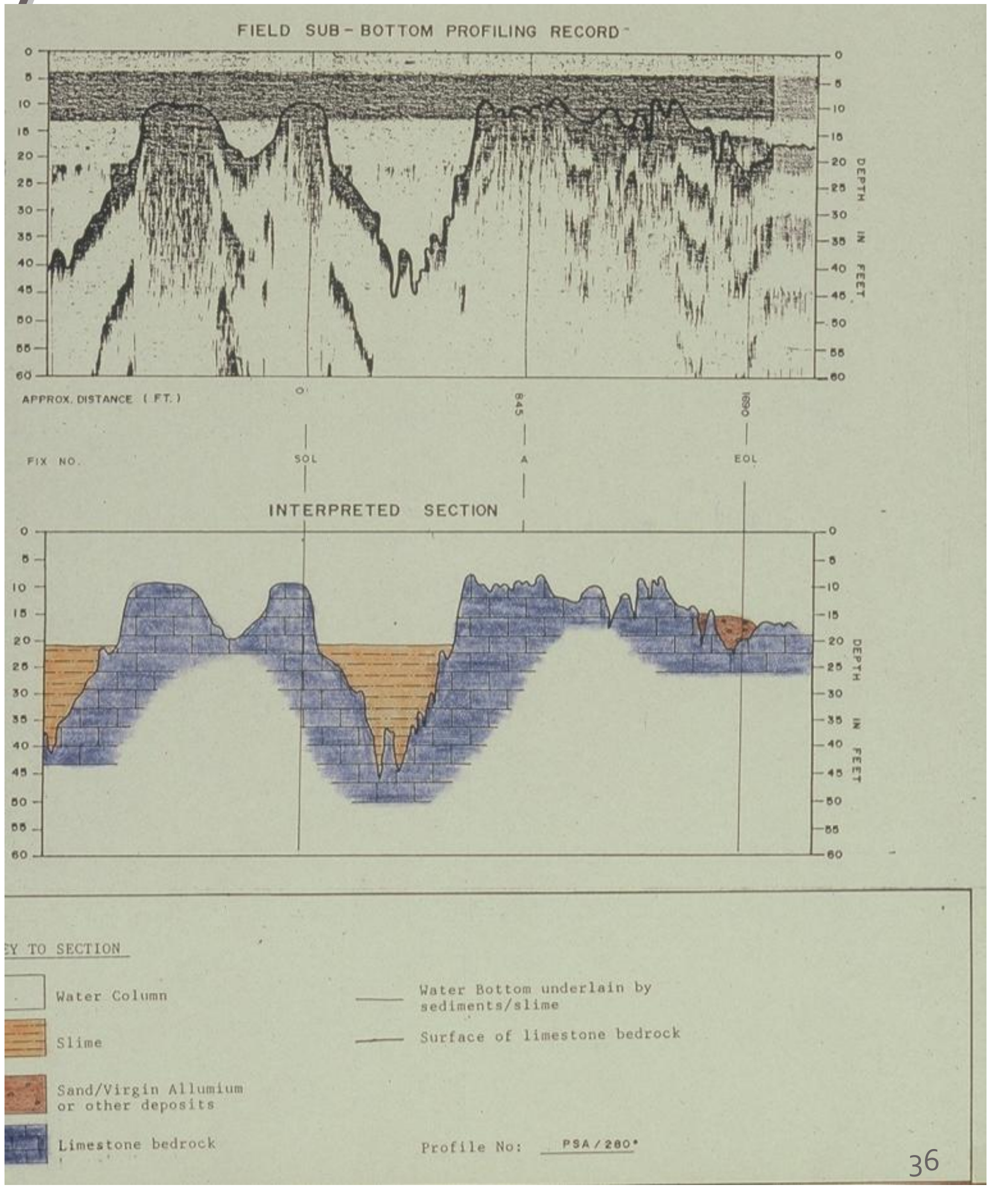
Figure 9 – Final stacked section of the Area 2.
Figura 9 – Seção sísmica empilhada final e seção interpretada da Área 2.



Santamarina, J. C. (2008) - http://www.elitepco.com.tw/ISC3/images/Keynote-03-Santamarina.pdf

Geophysical Survey

- Merits
  - Lateral variability (probing location)
  - Profiling (sampling & testing)
  - Sectioning (void detection)
  - Material classification
  - Engineering parameters (G_o & $G_{dynamic}$)
- Problems
  - Over sale/expectation
  - Misunderstanding between engineers, engineering geologists & geophysicists
  - Lack of communication
  - Wrong geophysical technique used
  - Interference/noise



Sampler

Split Spoon

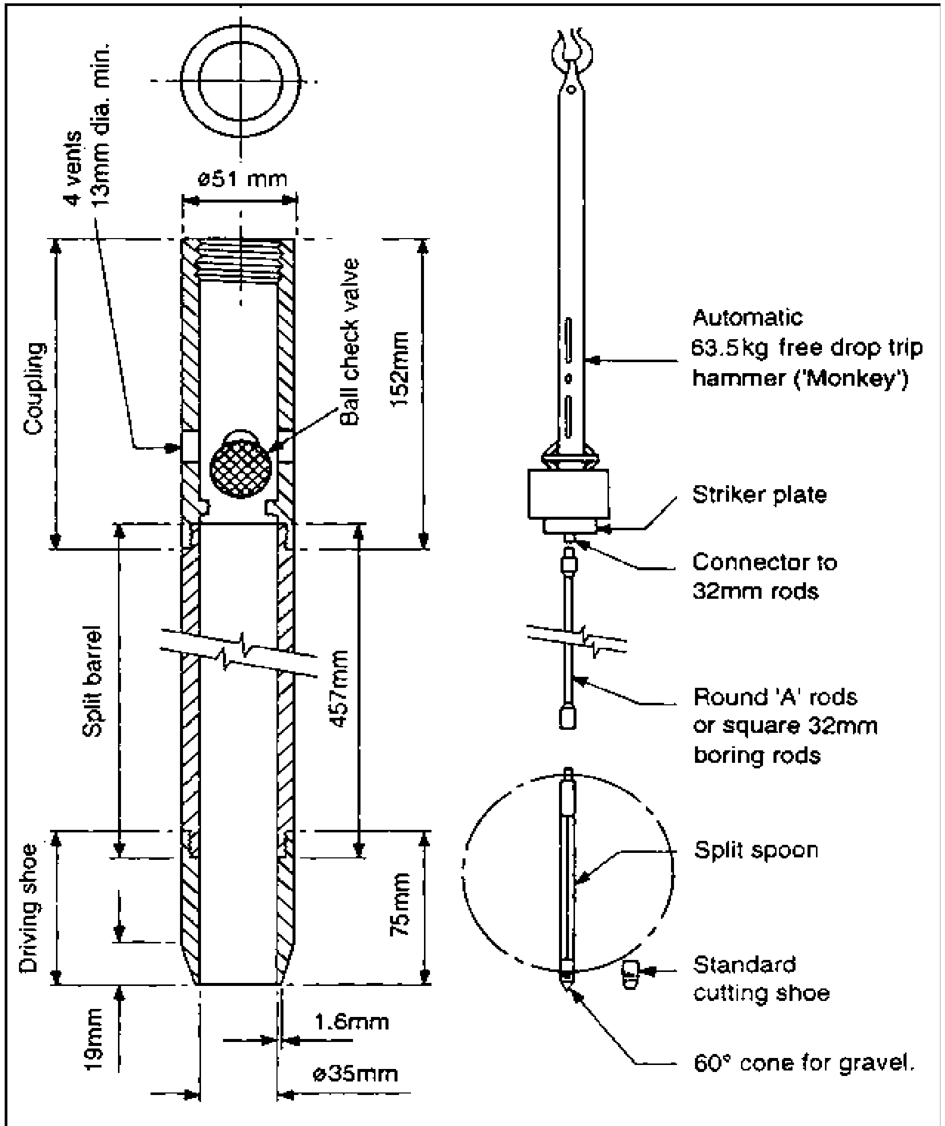
Thin-Walled

Piston Sampler

Mazier Sampler

Core Barrel

Wire-line



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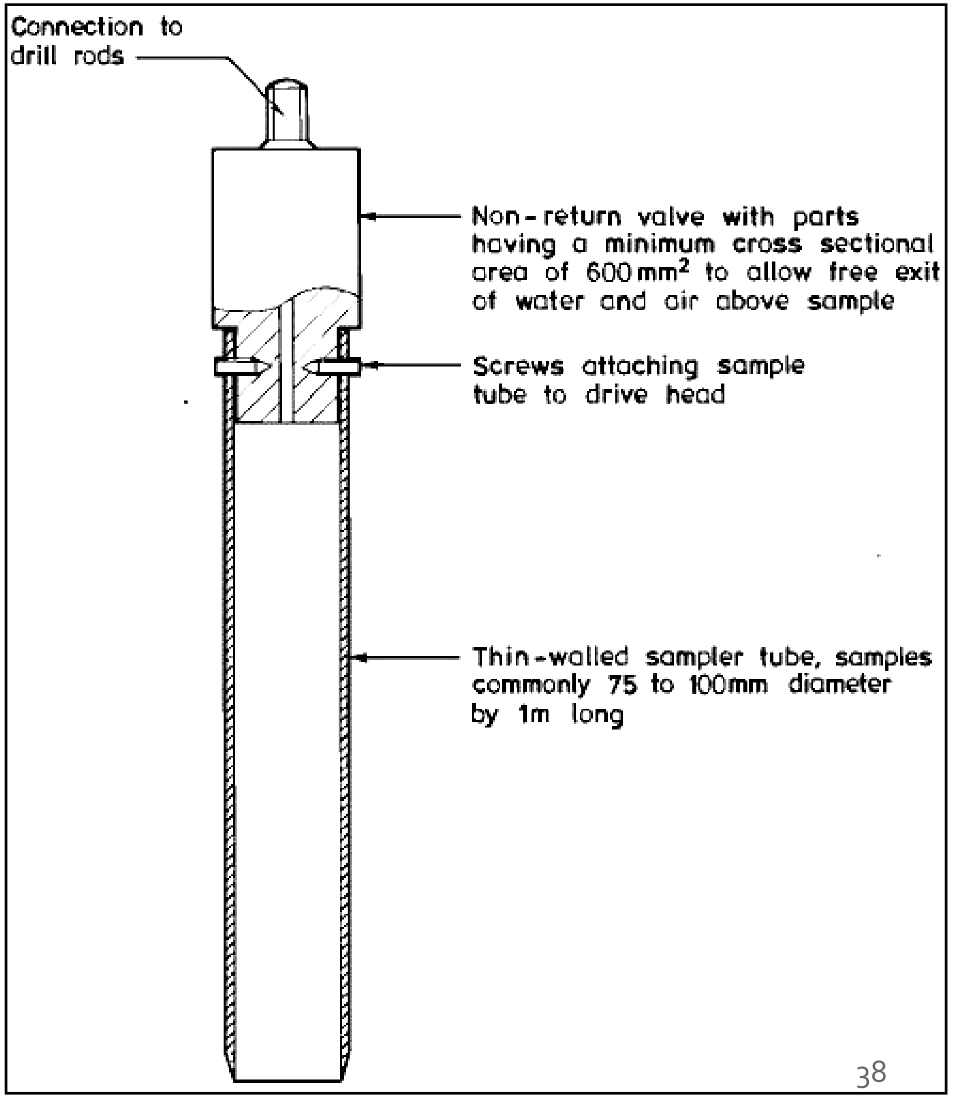

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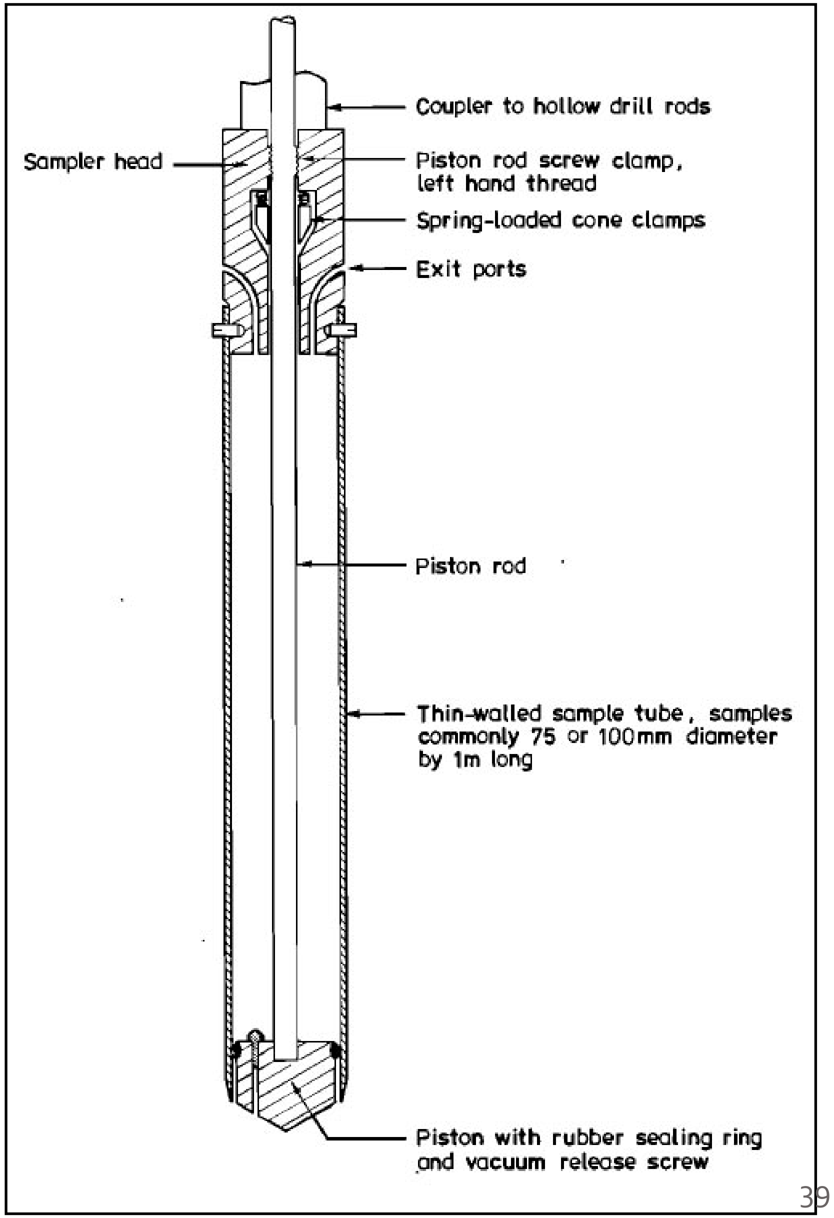

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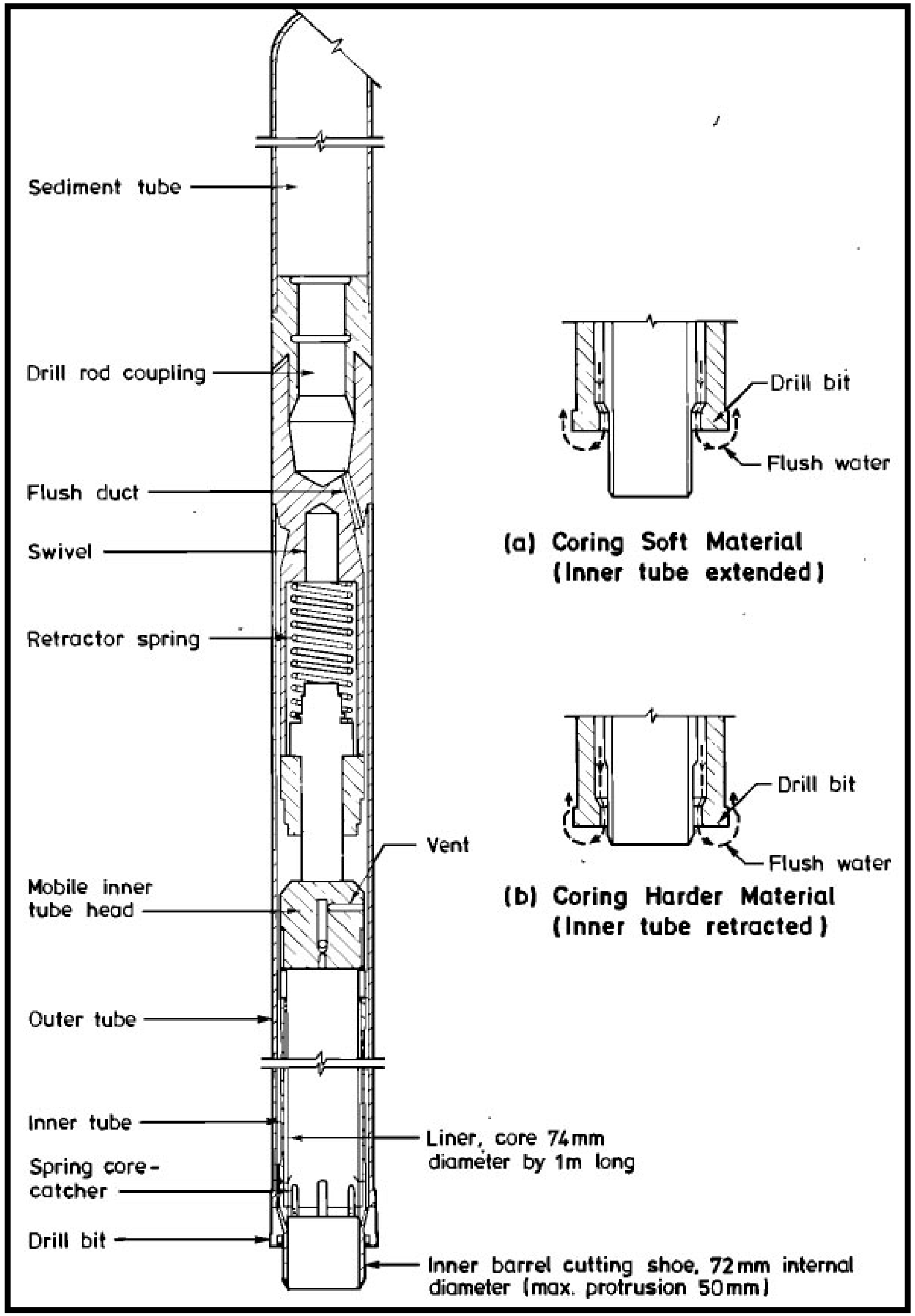

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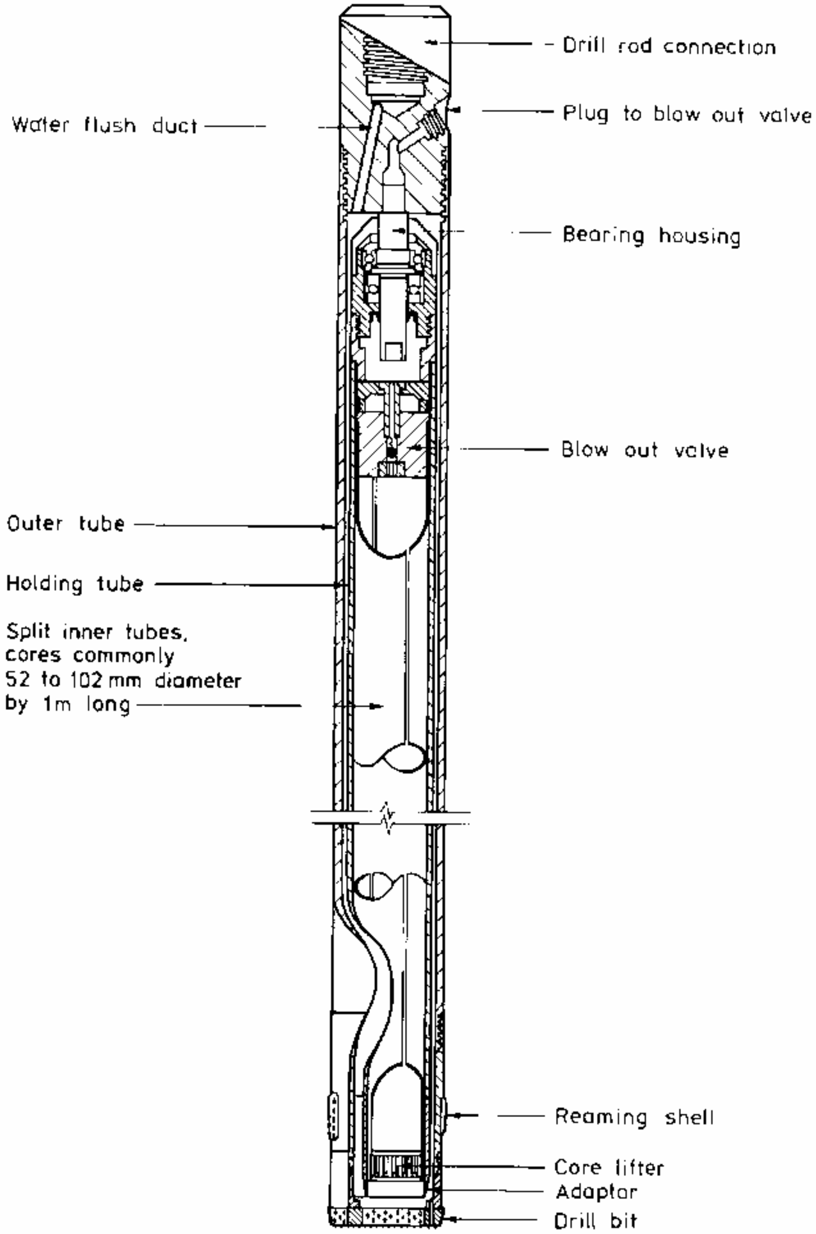
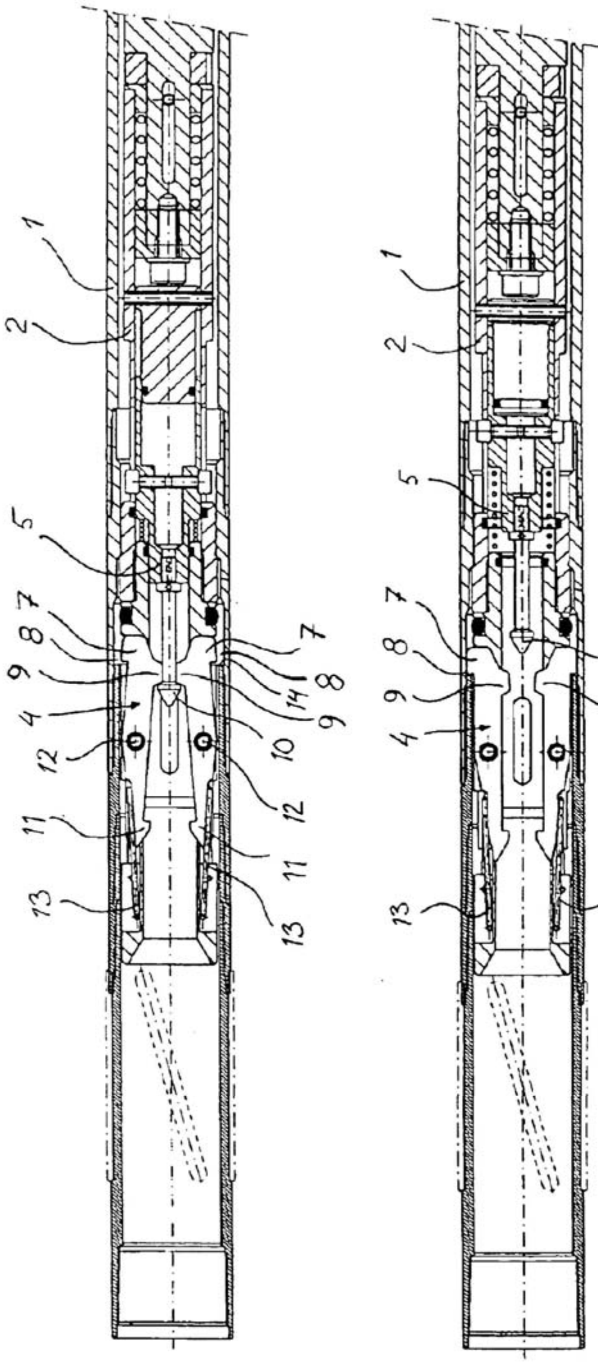


Sampler

- Split Spoon
- Thin-Walled
- Piston Sampler
- Mazier Sampler
- Core Barrel
- **Wire-line**



Sample Storage, Handling, Transportation

Sample Preparation







Sampling

- Sample Sizes
  - Representative mass (particle sizes, fabric, fissures, joints)
  - Adequate quantity for testing
- Sample Disturbance
  - Stress conditions
  - Deformation behaviours
  - Moisture content & void
  - Chemical characteristics

At Different Stages of SI		
Before	**During**	**After**
Stress relief	Stress relief	Stress relief
Swelling	Remoulding	Moisture migration
Compaction	Displacement	Extrusion
Displacement	Shattering	Moisture loss
Base heave	Stone at cutting shoe	Heating
Piping	Mixing or segregation	Vibration
Caving	Poor recovery	Contamination

Clayton et al (1982)

Sample Disturbance

- Poor recovery
  - Longer rest period for sample swelling
  - Slight over-sampling
  - Use of sample retainer
- Sample contamination

Sample Quality Classification

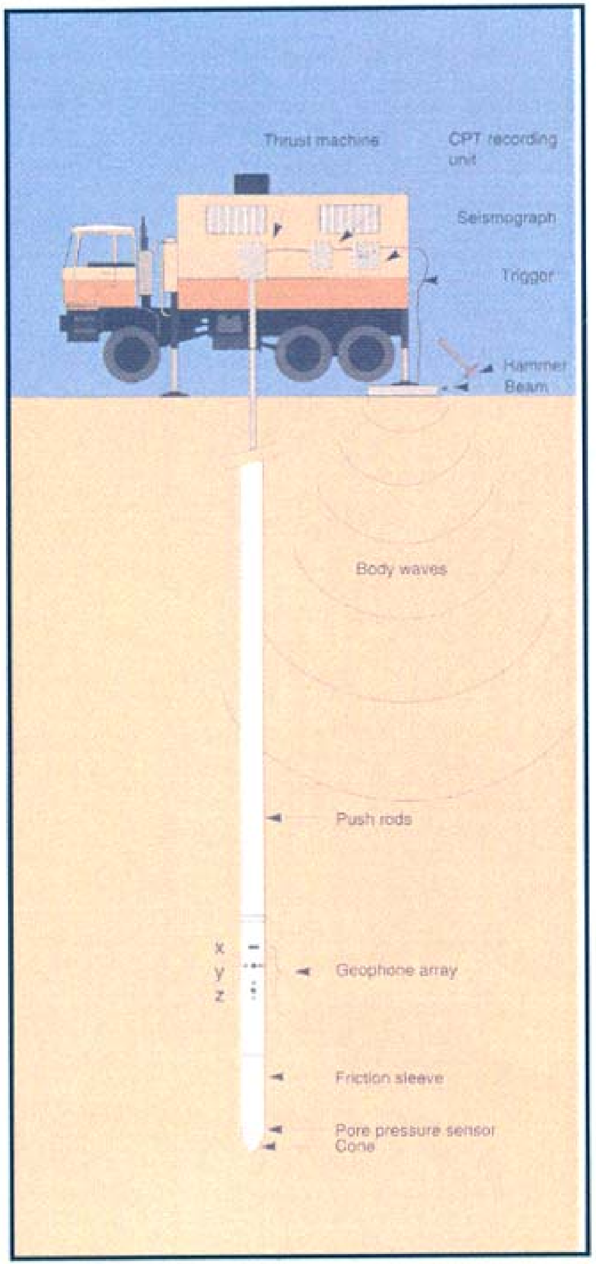
Sample Quality	Soil Properties					
	Classification	Moisture Content	Density	Strength	Deformation	Consolidation
Class 1	✓	✓	✓	✓	✓	✓
Class 2	✓	✓	✓	✗	✗	✗
Class 3	✓	✓	✗	✗	✗	✗
Class 4	✓	✗	✗	✗	✗	✗
Class 5	✗	✗	✗	✗	✗	✗

BS 5930 (1981)

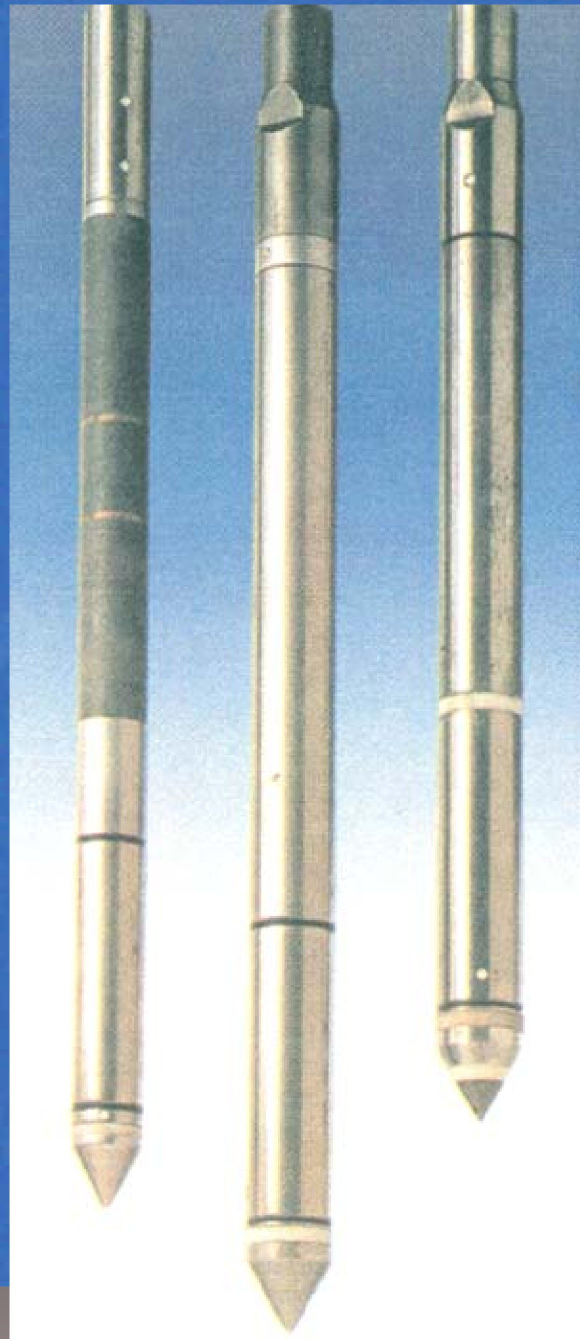
In-situ Tests

Piezocone (CPTu)

CPT Equipment



- The Seismic Cone Penetration Test (SCPT) is a reliable, cost effective technique to determine the insitu seismic wave velocity.
- Seismic wave velocities give an indication of ground characteristics such as low strain shear modulus and Poisson's ratio.
- Data from the cone penetrometer is used in delineating the strata changes identified by the seismic results.



In-Situ Tests

- BS1377 : Part 9
- Suitable for materials with difficulty in sampling
  - Very soft & sensitive clay
  - Sandy & Gravelly soils
  - Weak & Fissured soils
  - Fractured rocks
- Interpretation
  - Empirical
  - Semi-empirical
  - Analytical

Applicability of In-situ Tests

Test	Stress	Strength			Stiffness			Permeability
	K_o	ϕ'	C_u	σ_c	E'/G	E_u	G_{max}	k
SPT		G	C	R	G	C	G	
CPT/CPTu		G	C		G			
DMT	G, C				G			
Borehole PMT			C		G, R	C		
PLT			C		G, R	C		
VST			C					
Seismic							G, C, R	
SBPMT	G, C	G	C		G, C			
Falling/ Rising Head Test								G
Constant Head								C
Packer Test								R

Clayton , et al (1995)

G = granular, C = cohesive, R = Rock

Applicability of In-situ Tests

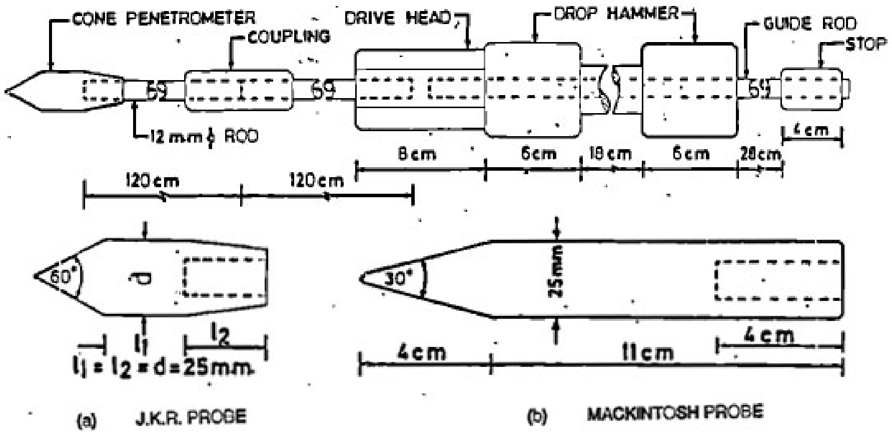
SUMMARY ON THE COMMON TYPES OF GROUND INVESTIGATION, FIELD TESTS, SAMPLING & LABORATORY TESTS

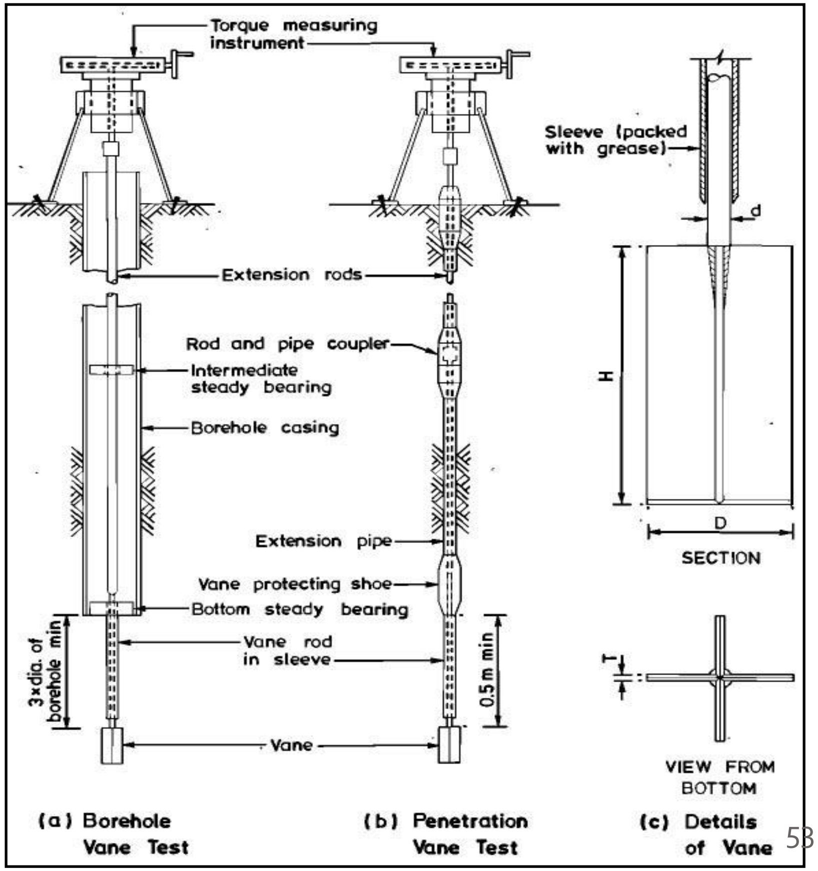
Description	Types of Ground Investigation						Field Test					Laboratory Test							
	JP	HA	TP	BH	PZ	GS	SPT	PM	PLT	VS	PW	C	M/C	γ	Con	UU	UCT	CIU	Chem
1) Soft ground treatment	m	m	m	y	y	m	-	-	-	y	m	y	y	y	y	y	y	m	m
2) Shallow foundation																			
cohesive soil	y	m	m	y	-	-	y	m	y	m	-	y	y	y	y	y	y	m	m
non cohesive soil	y	m	m	y	m	-	y	-	y	-	-	y	y	y	-	-	-	-	m
3) Pile Foundation																			
Fill ground	m	m	m	y	m	m	y	m	-	m	-	y	y	y	y	y	y	-	m
Cut ground	-	-	m	y	-	m	y	-	-	-	-	y	y	y	-	-	-	-	m
4) Slope																			
Cut	-	-	m	y	-	y	y	-	-	-	y	y	y	y	-	y	y	y	-
Fill	m	m	m	y	m	m	y	-	-	y	m	y	y	y	y	y	y	y	m

Legend:

JP	:	JKR Probe
HA	:	Hand Auger
TP	:	Trial Pit
BH	:	Borehole
PZ	:	Piezocone
GS	:	Geophysical Survey
SPT	:	Standard Penetration Test
PM	:	Pressuremeter
PLT	:	Plated Bearing Test
VS	:	Vane Shear Test
K	:	Permeability Test
Y	:	Yes should be done
M	:	May be added
-	:	Not relevant/necessary
C	:	Classification
M/C	:	Moisture Content
γ	:	Unit Weight
Con	:	Consolidation
UU	:	Unconsolidated Undrained
UCT	:	Unconfined Compression
CIU	:	Triaxial with Pore Water Pressure
Chem	:	Chemical Test

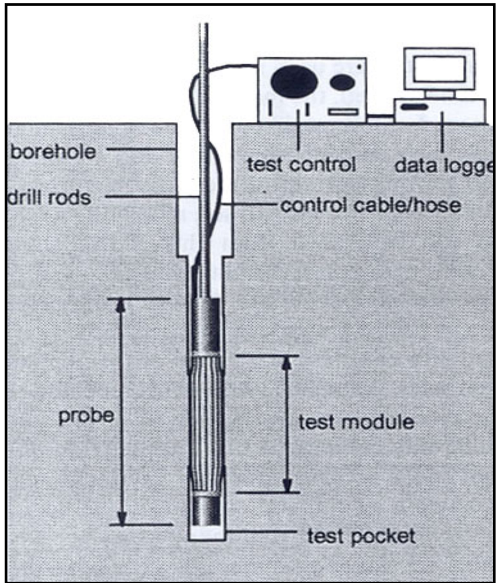
In-situ Tests





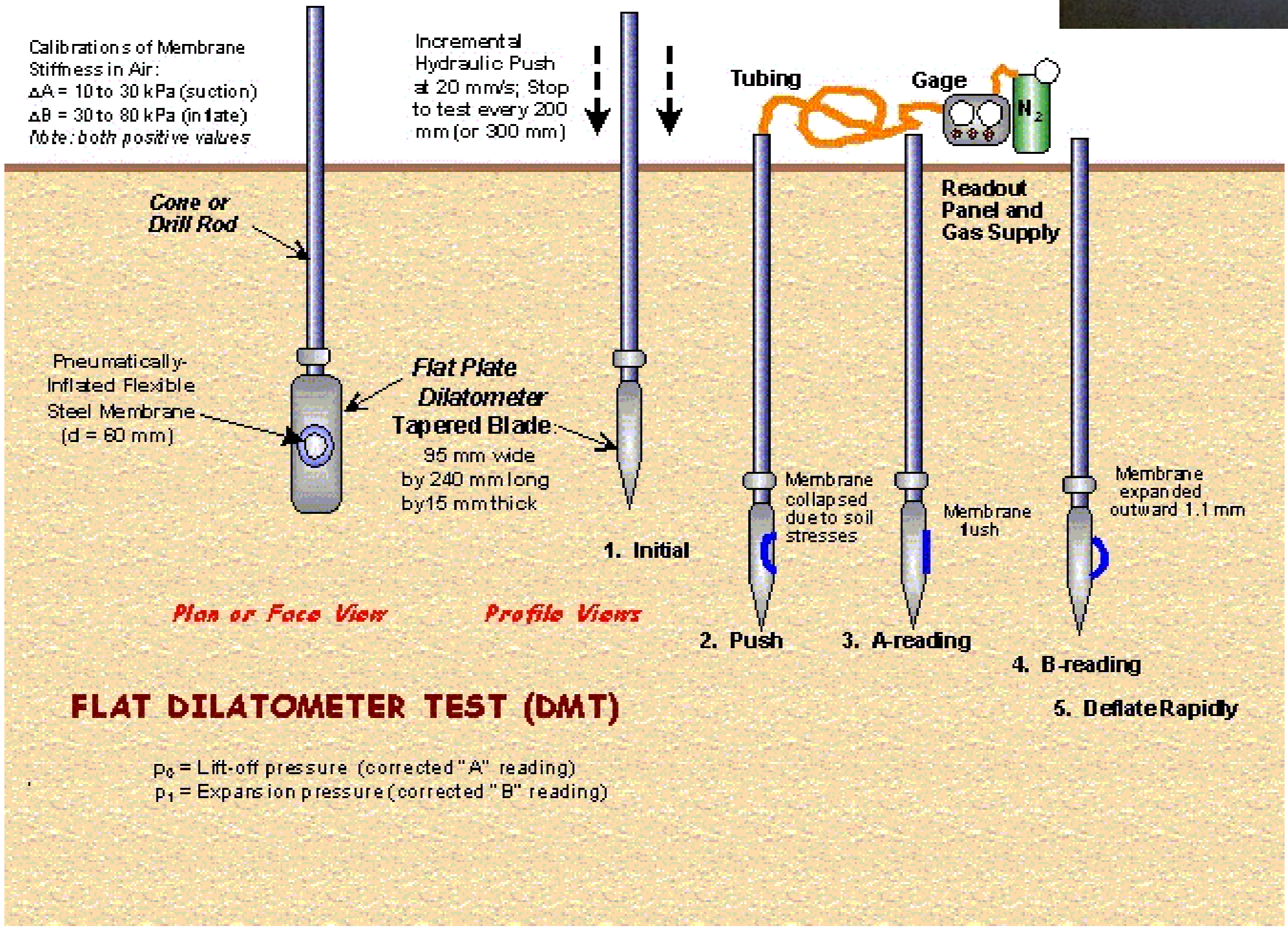
In-situ Tests

Pressuremeter (PMT)



In-situ Tests

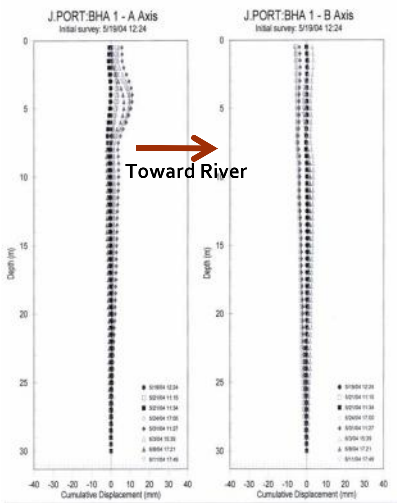
Dilatometer (DMT)

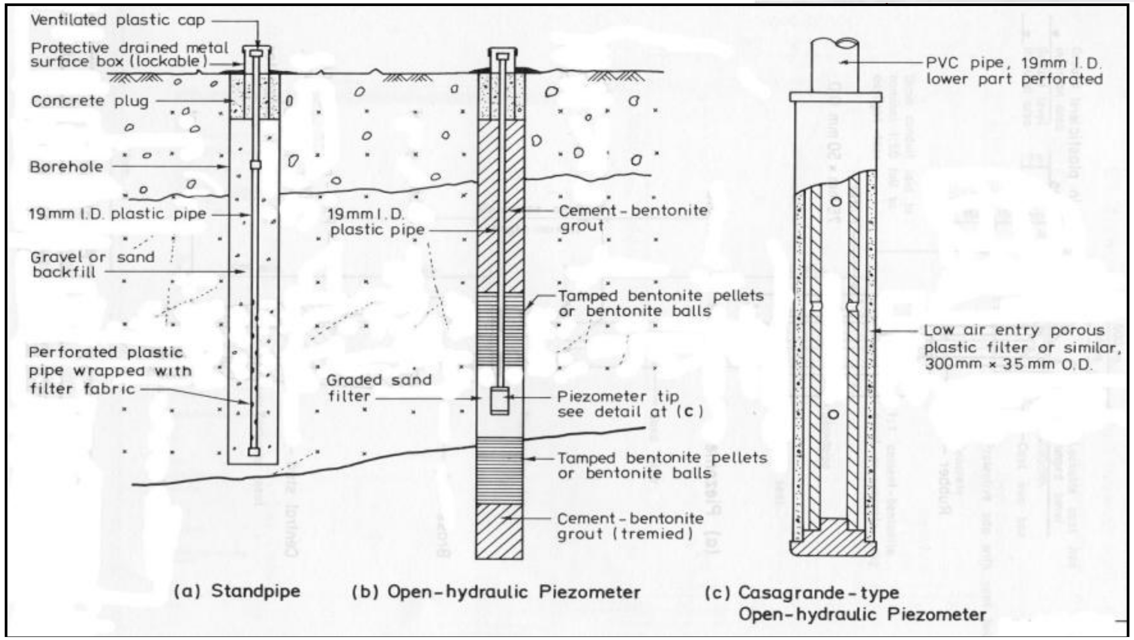


Geophysics Methods

Instrumentation Monitoring

- Inclinometer
- Extensometer
- Rod Settlement Gauge/Marker
- Piezometer
- Observation Well

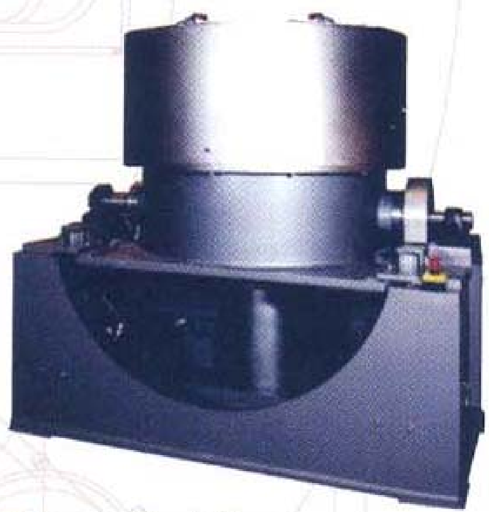




Laboratory Tests

Table Top Geotechnical Centrifuge

4000 kg Compact Geotechnical Centrifuge



Vertical orientation for high speed running

A World First - The G-max Modular CgC

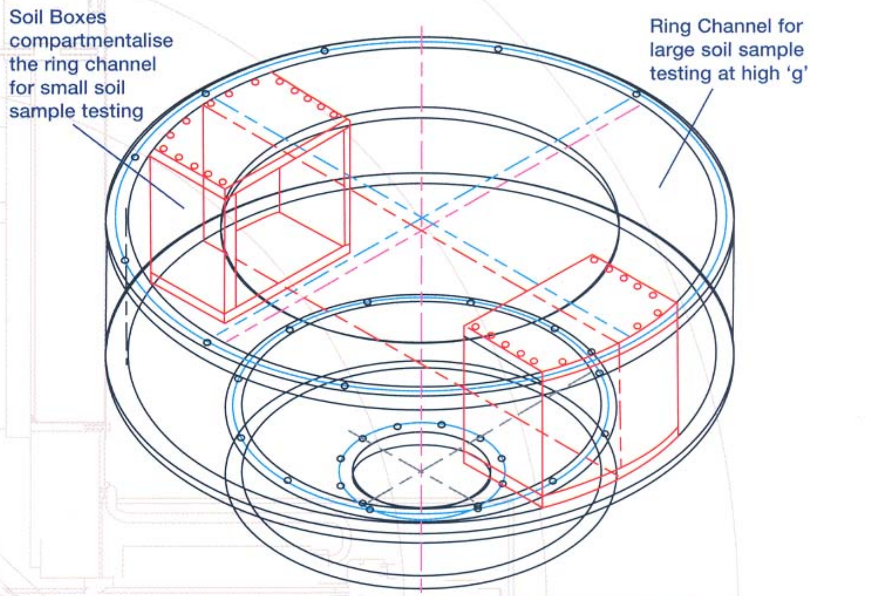


Fig 1: Drum Ring Channel with 2 Soil Compartment Boxes

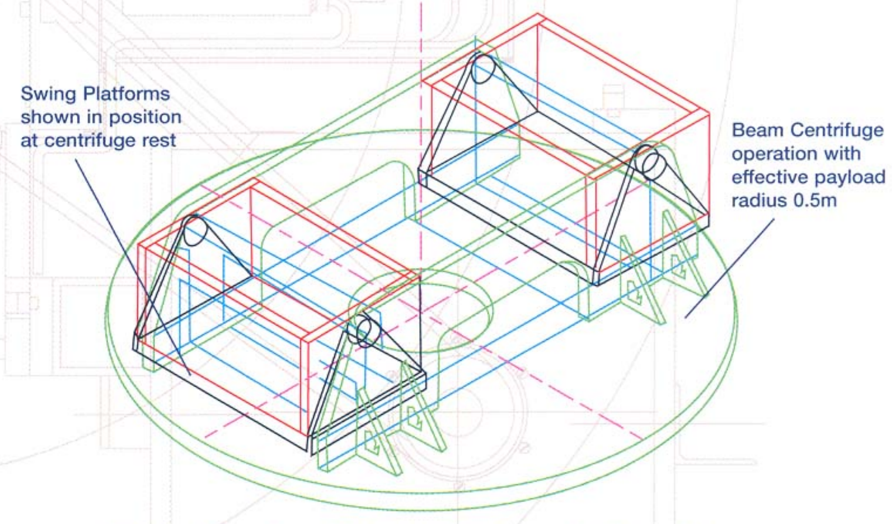
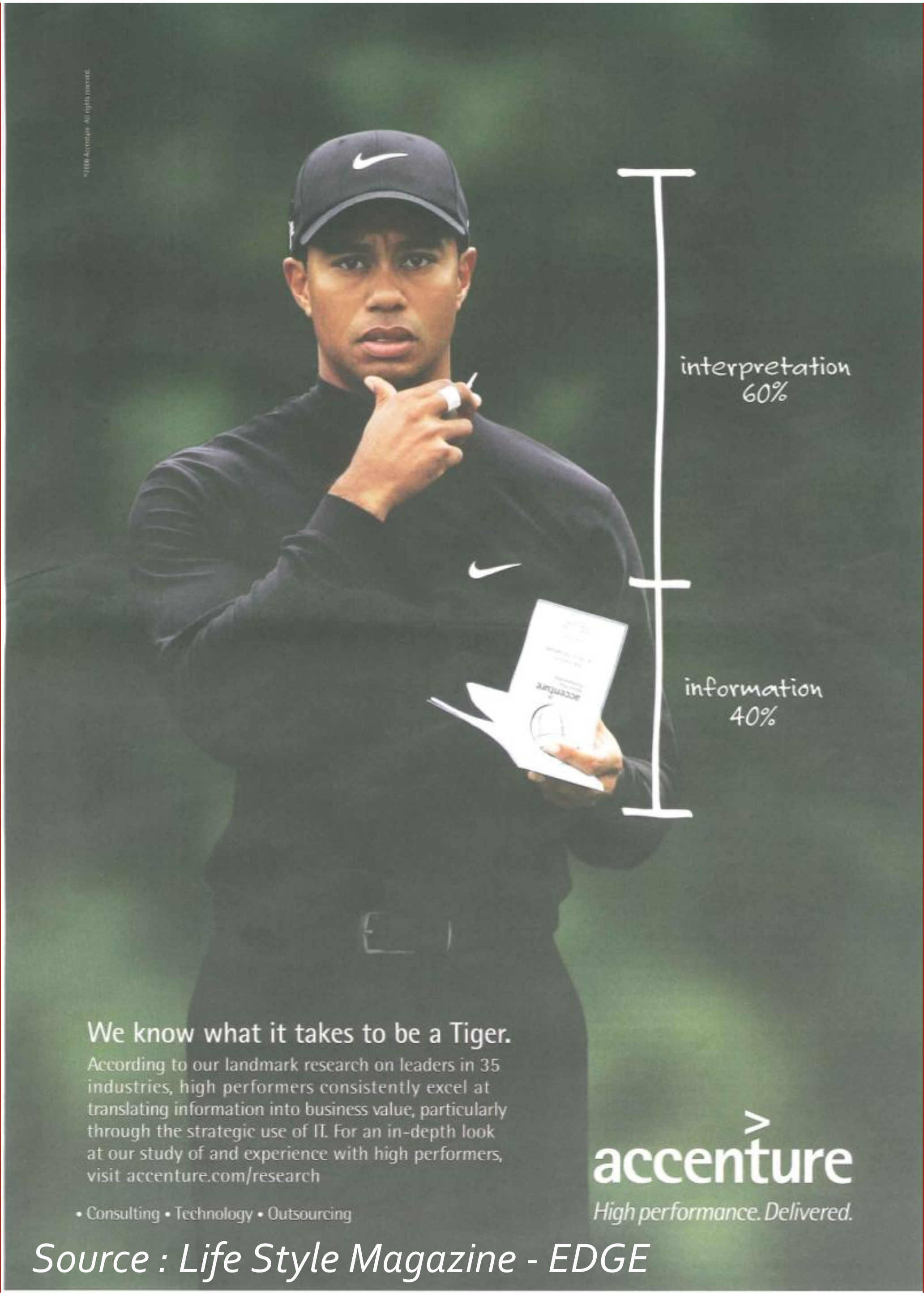
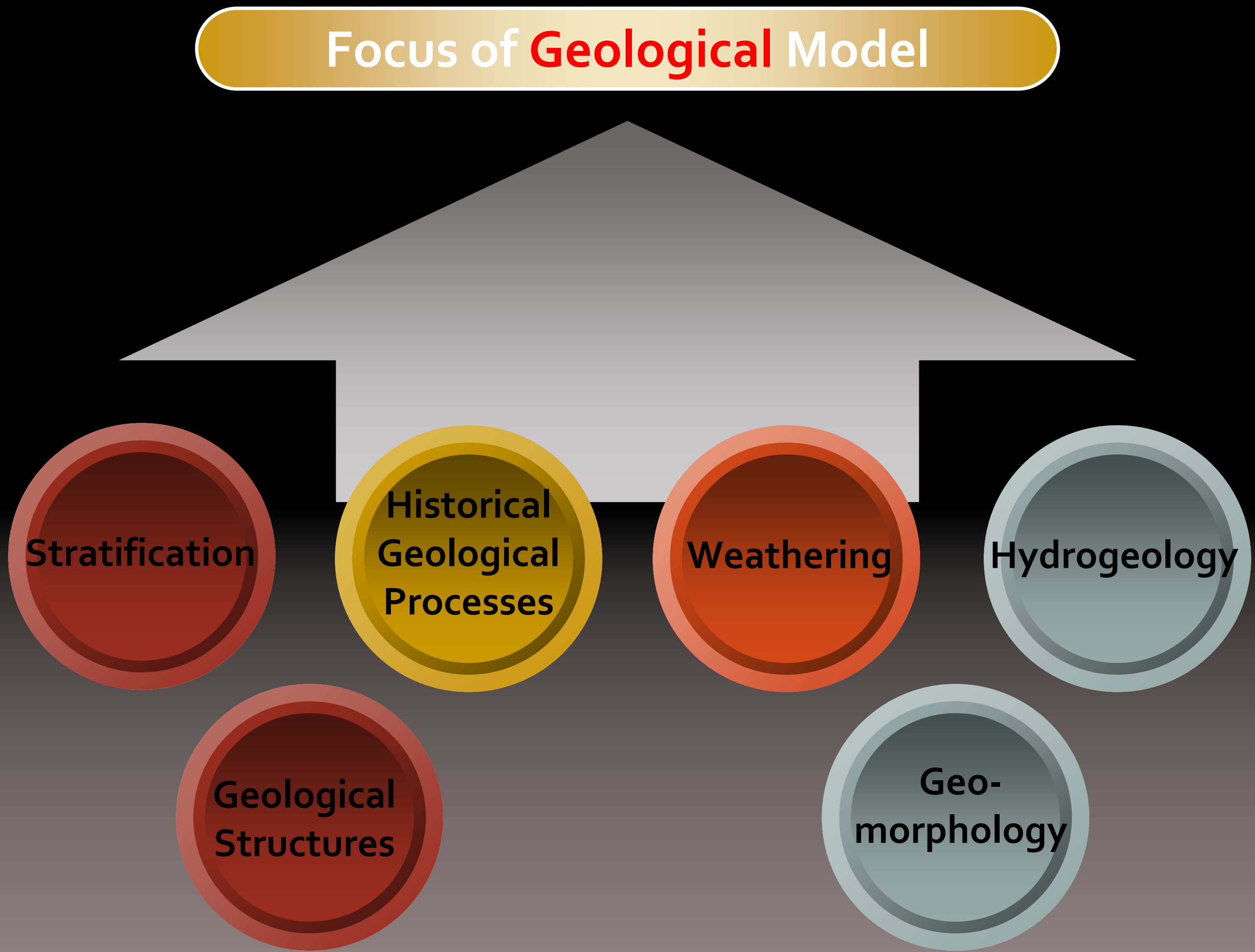


Fig 2: Beam Rotor Table with 2 Swinging Soil Strong Boxes



Source : Life Style Magazine - EDGE

Ground Characterisation



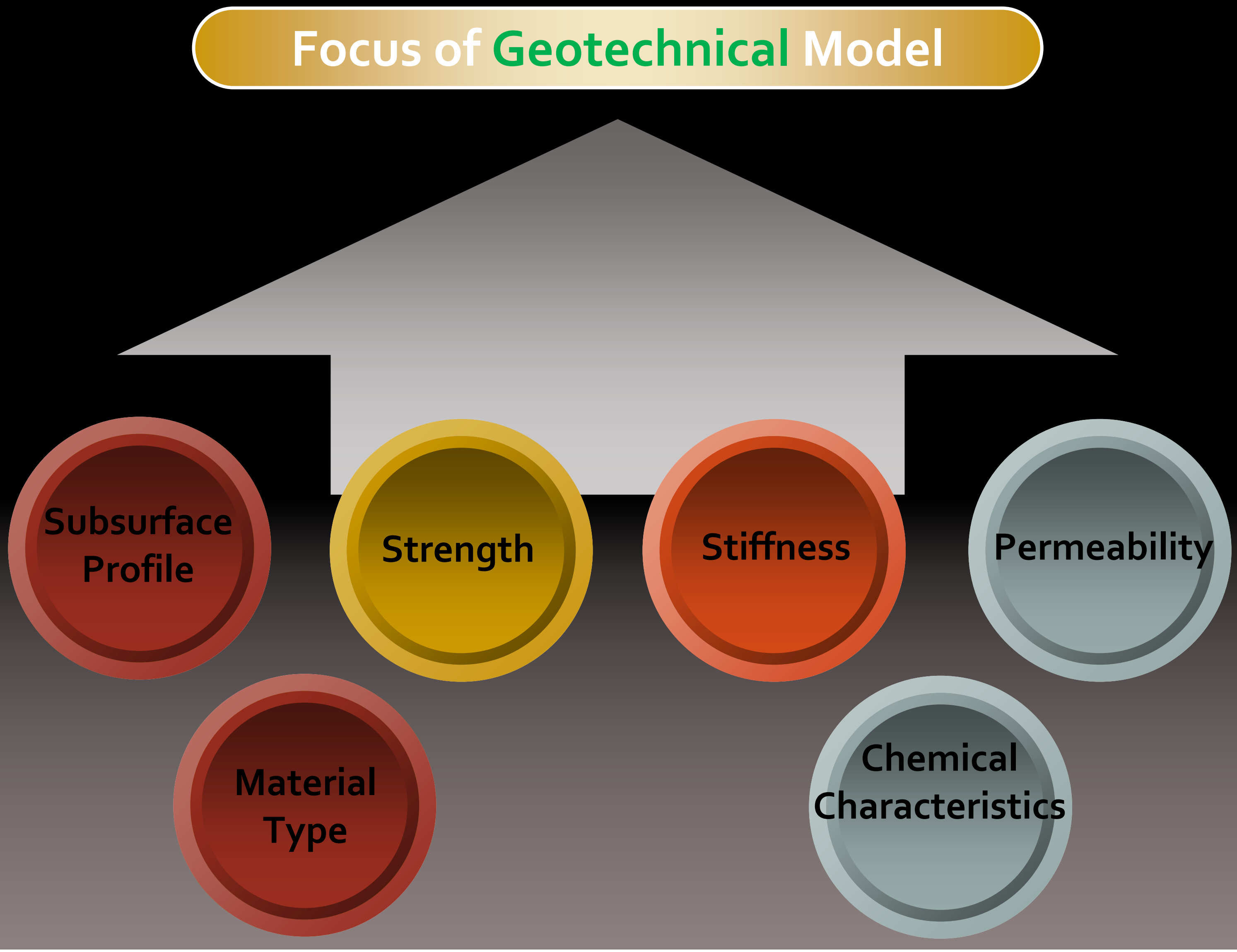
Geological Mapping

Mapping of :

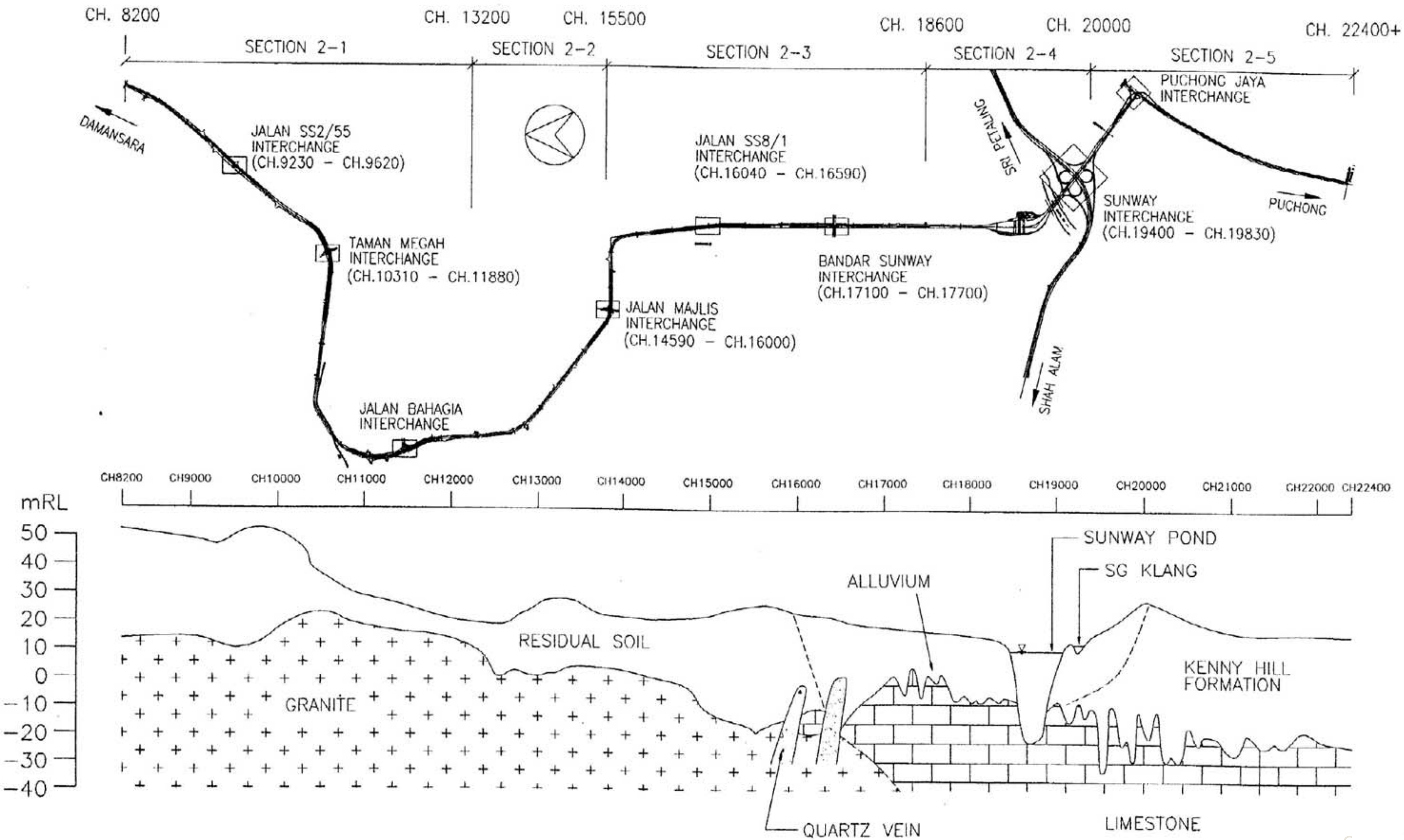
- Geological features (Structural settings)
- Weathering profile
- Outcrop exposure
- Seepage conditions

- Geomorphology
- Lithology
- Stratification
- Sequence of geological actions & history

Ground Characterisation



GEOTECHNICAL MODEL



COMMON PROBLEMS & TREND

General Dilemma of GI Industry

- Lack of pride & appreciation from consultant/client in GI industry.
- Actions done is considered work done!
  Poor professionalism.

- Financial survival problem due to competitive rates in uncontrolled environment (cutting corner)
- No appropriate time frame for proper work procedures (shoddy works)
- Shifting of skilled expert to Oil & Gas or other attractive industries

Poor Planning & Interpretation

- Inadequate investigation coverage vertically & horizontally
- Wrong investigating tools
- No/wrong interpretation
- Poor investigating sequence

Poor Site Implementation

- Lack of level & coordinates of probing location
- Sample storage, handling, transportation
- Inappropriate equilibrium state in Observation Well & Piezometer

Poor In-situ & Laboratory Results

- Lack of equipment calibration
- Wear & Tear Errors
- Equipment systematic error (rod friction, electronic signal drift, unsaturated porous tip)
- Defective sensor
- Inappropriate testing procedures

- Equipment calibration (Variation of pH Values)
- Improper sample preparation
- Inadequate saturation
- Inappropriate testing rate
- Inadequate QA/QC in testing processes
- Inherent sample disturbance before testing

Poorly Maintained Tools

Over-confidence in Geophysics

- We detect everything in geophysical data, but indentify almost nothing (**Rich** but **Complex**).

-Not a unique solution in tomographic reconstruction (Indirect method)

- Poor remuneration to land geophysicist as compared to O&G

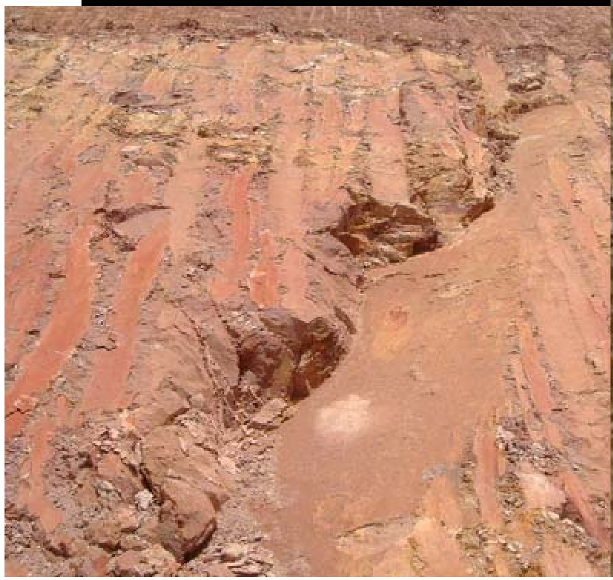
- Poor investigation specification

- Lack of good interpretative skill (human capital)

- High capital costs in equipment & software investment

Communication Problem

Difficulties in Identification of Complex Geological Settings



Difficulties in Identification of Complex Geological Settings

Weathering Profile

- Deviation of material classification between borehole and excavation

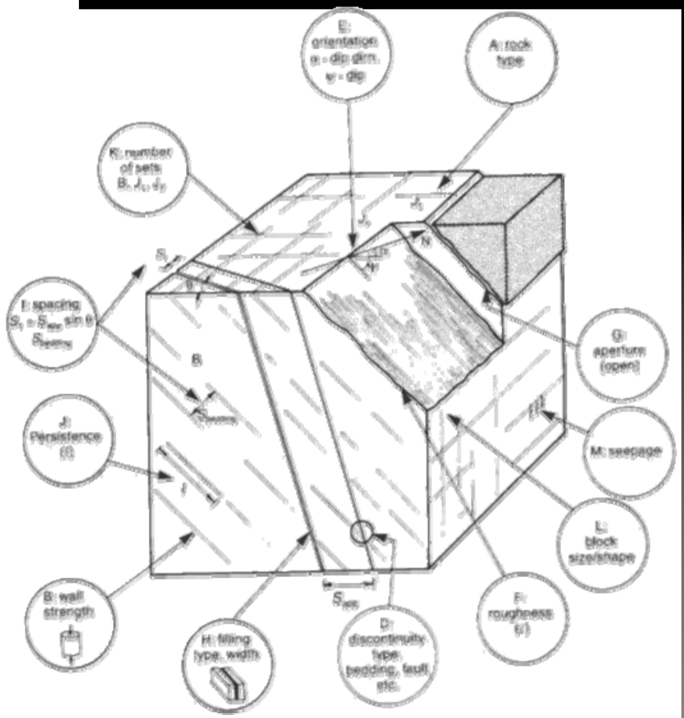
(Claim issue –

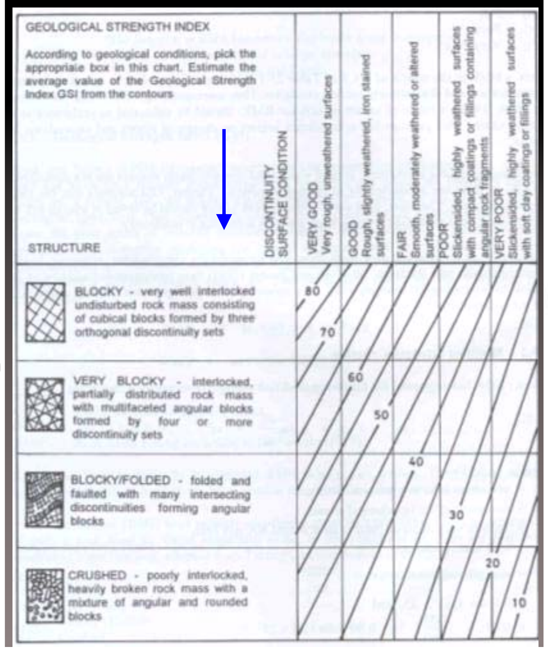
Soil or Rock ?)

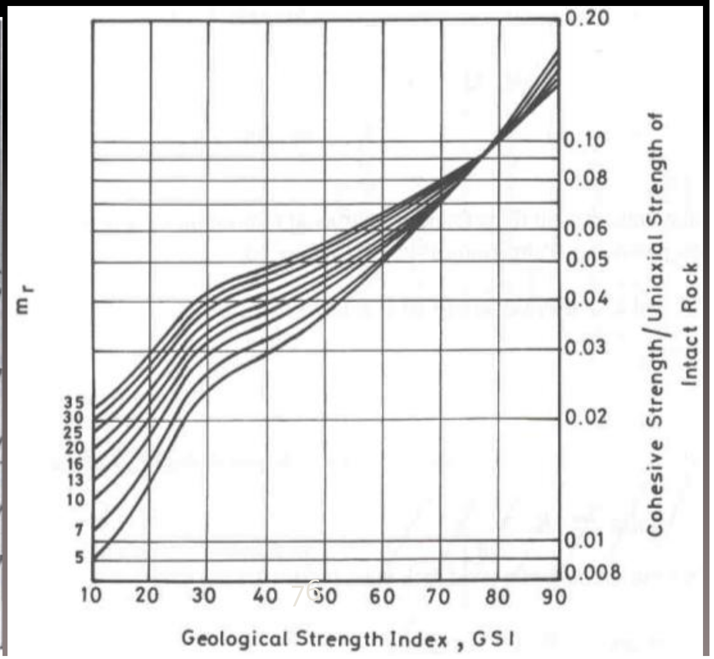
Complexity of Rock Mass Properties

- Complicated rock mass strength (slope & excavation design)
- Empiricism requiring judgement (involving subjectivity)
- Information normally only available during construction, not design stage

$$\sigma_1' = \sigma_3' + \sigma_u \left[m_b \left(\frac{\sigma_3'}{\sigma_u} \right) + s \right]^a$$







Unexpected Blowout of Underground Gas

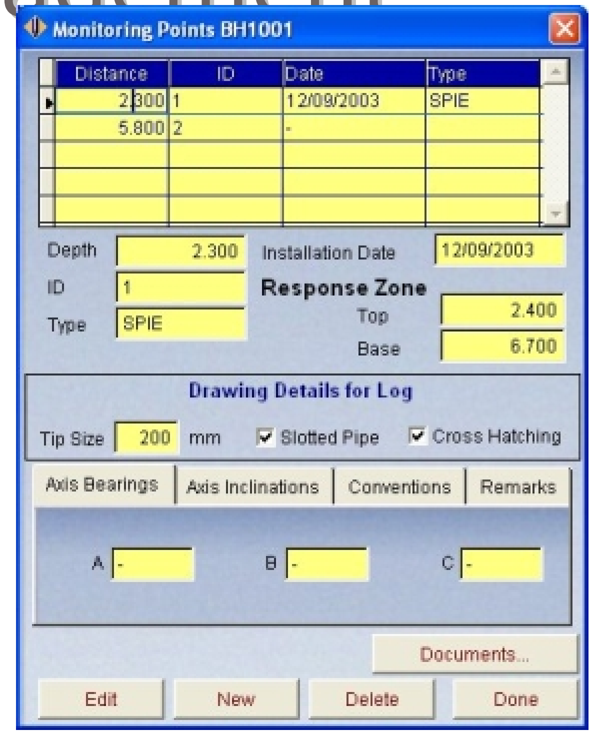
- Gas pockets at 32m bgl
- Flushing out of sand

Supervision

- Work compliance & certification
- Document critical information
- Timely on-course instruction (sampling, in-situ testing & termination)
- Checking between field records and reported information

Future Trend - Electronic Data Collection, Transfer & Management

- AGS data transfer format & AGS-M format (monitoring data)
  - First Edition in 1992, AGS(1992)
  - Second Edition in 1994, AGS(1994)
  - Third Edition in 1999
- Advantages :
  - Efficient & Simplicity
  - Minimised human error
  - GI & Monitoring Data Management System
  - Record keeping
  - Spatial data analysis



http://www.ags.org.uk/site/datatransfer/intro.cfm

Conclusions

- Nature of GI works & Geotechnical design (Uncertainties)
- Role of Geotechnical Engineer, Engineering Geologist & Geophysicist
- Stages of GI works (Planning, Implementation, Interpretation & Report)
- Specifications
- Methodology of GI (Merits & Demerits)
  - Fieldworks (Direct/Indirect) + Geological Mapping
  - Laboratory tests
- Common Problems & Future Trend

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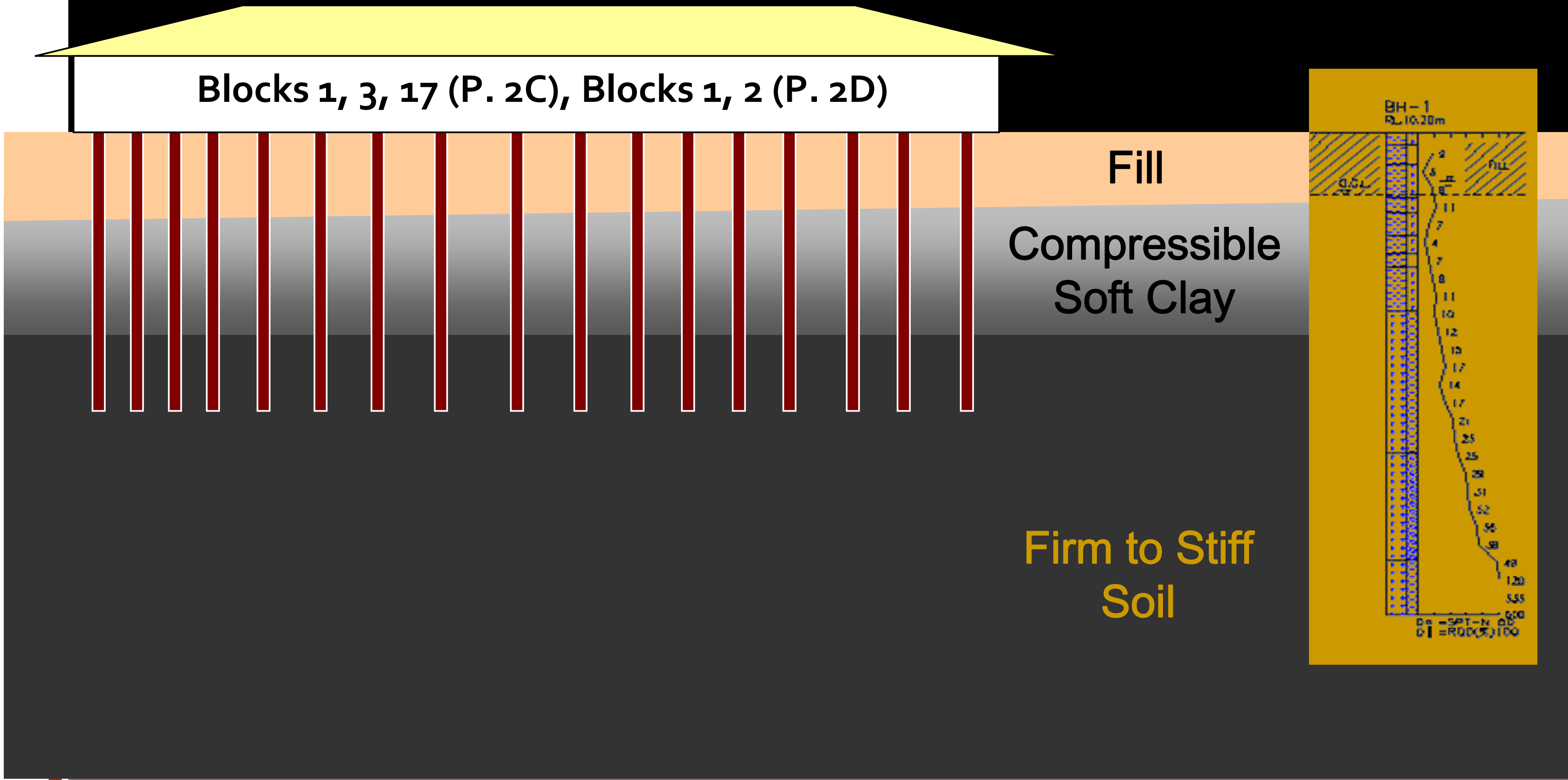
THANKYOU

SITE RECONNAISSANCE

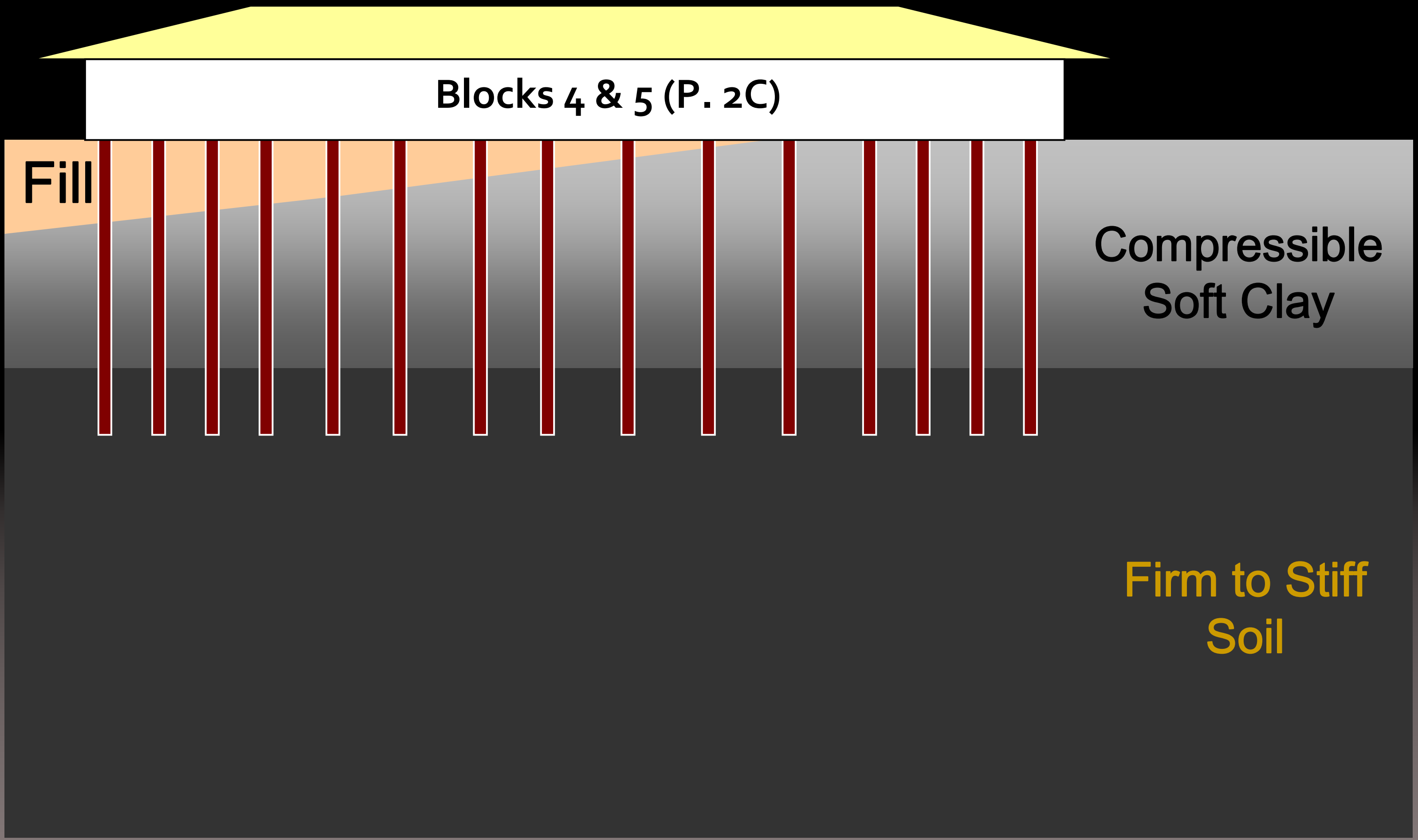
Case Study 1 - Geotechnical Review

- The underlying soils are mainly soft & compressible soils
- Characteristics:
  - Compressible
  - Settling under loading (eg. fill) with time

General Subsoil Profile



General Subsoil Profile



Site Observations

- Cracks on wall – mostly diagonal – due to differential settlement

Site Observations

- Distress due to differential settlement

Probable Causes

1. Collapse settlement of unsaturated fill
   - Occurs when saturation of loose fill (eg. during raining)
   - S.I. results confirmed existence of fill at most areas

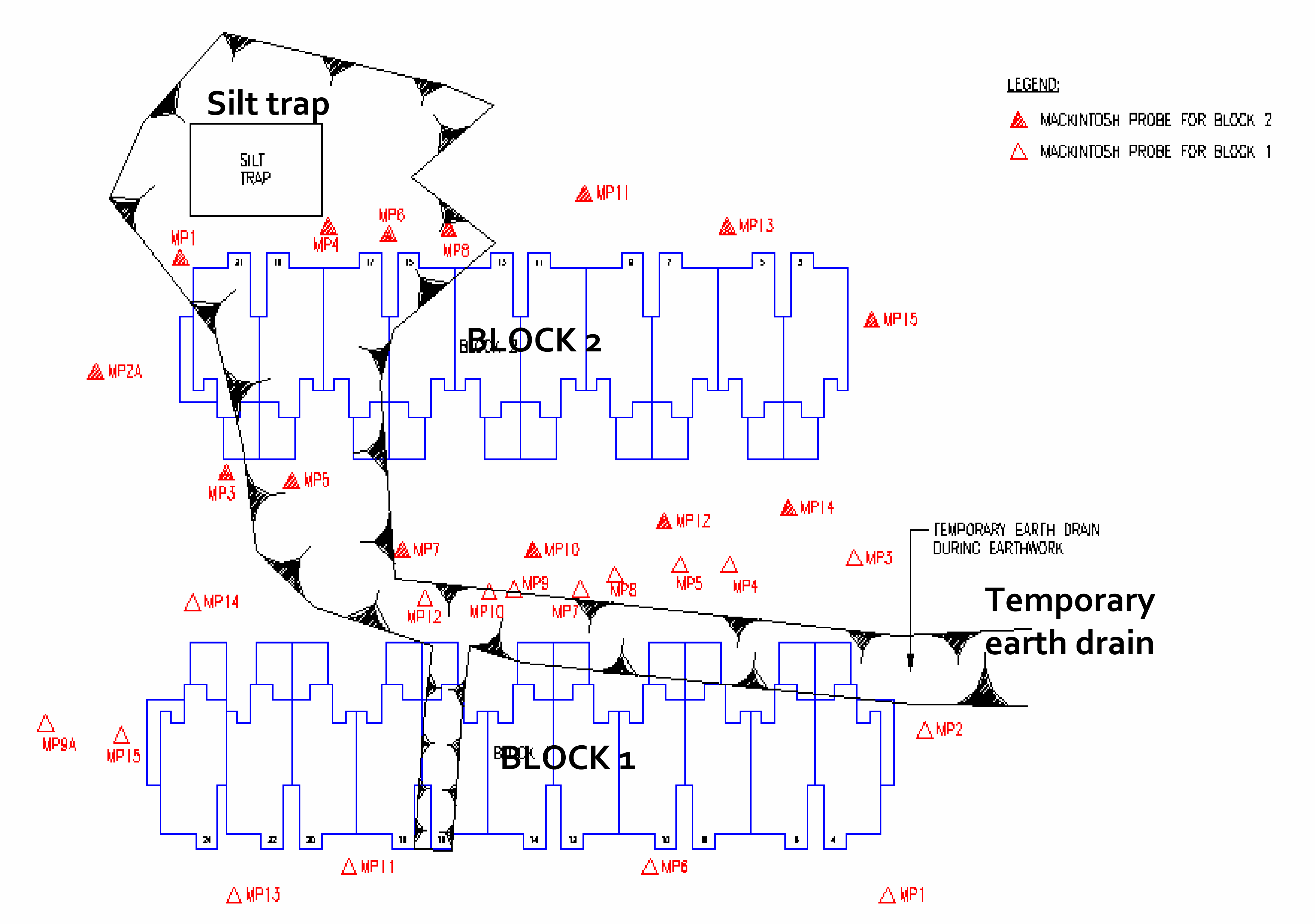
Probable Causes

2. Long term settlement of compressible soft soil
   - Occurs when filling over soft soil
   - S.I. results confirmed existence of soft soil

Probable Causes

3. Left-over soft deposits within silt trap & temporary drains
   - Results in localised soft spots – more compressible
   - Additional S.I. results confirmed existence of soft soil

Phase 2D1



Silt trap
SILT TRAP
LEGEND:
MACKINTOSH PROBE FOR BLOCK 2
MACKINTOSH PROBE FOR BLOCK 1
BLOCK 2
BLOCK 1
TEMPORARY EARTH DRAIN DURING EARTHWORK
Temporary earth drain
MP1
MP2A
MP3
MP4
MP5
MP6
MP7
MP8
MP9
MP9A
MP10
MP11
MP12
MP13
MP14
MP15

Probable Causes

Subsoil settlement

↓

Additional drag load on pile

↓

Pile settlement

↓

Differential settlement due to different load, support, fill & soft soil thickness

↓

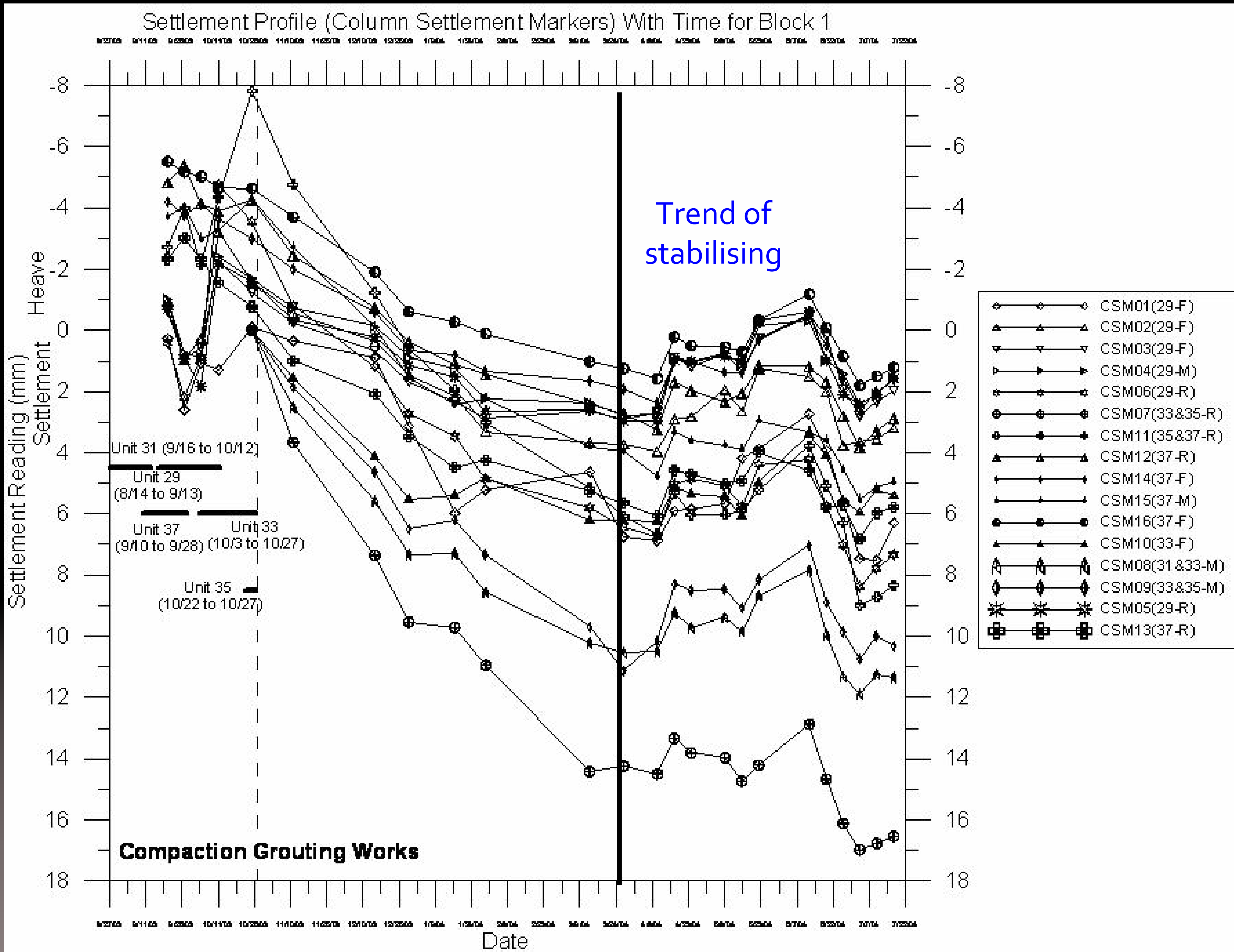
Distress on Structures

Remedial Works by Specialist Contractor

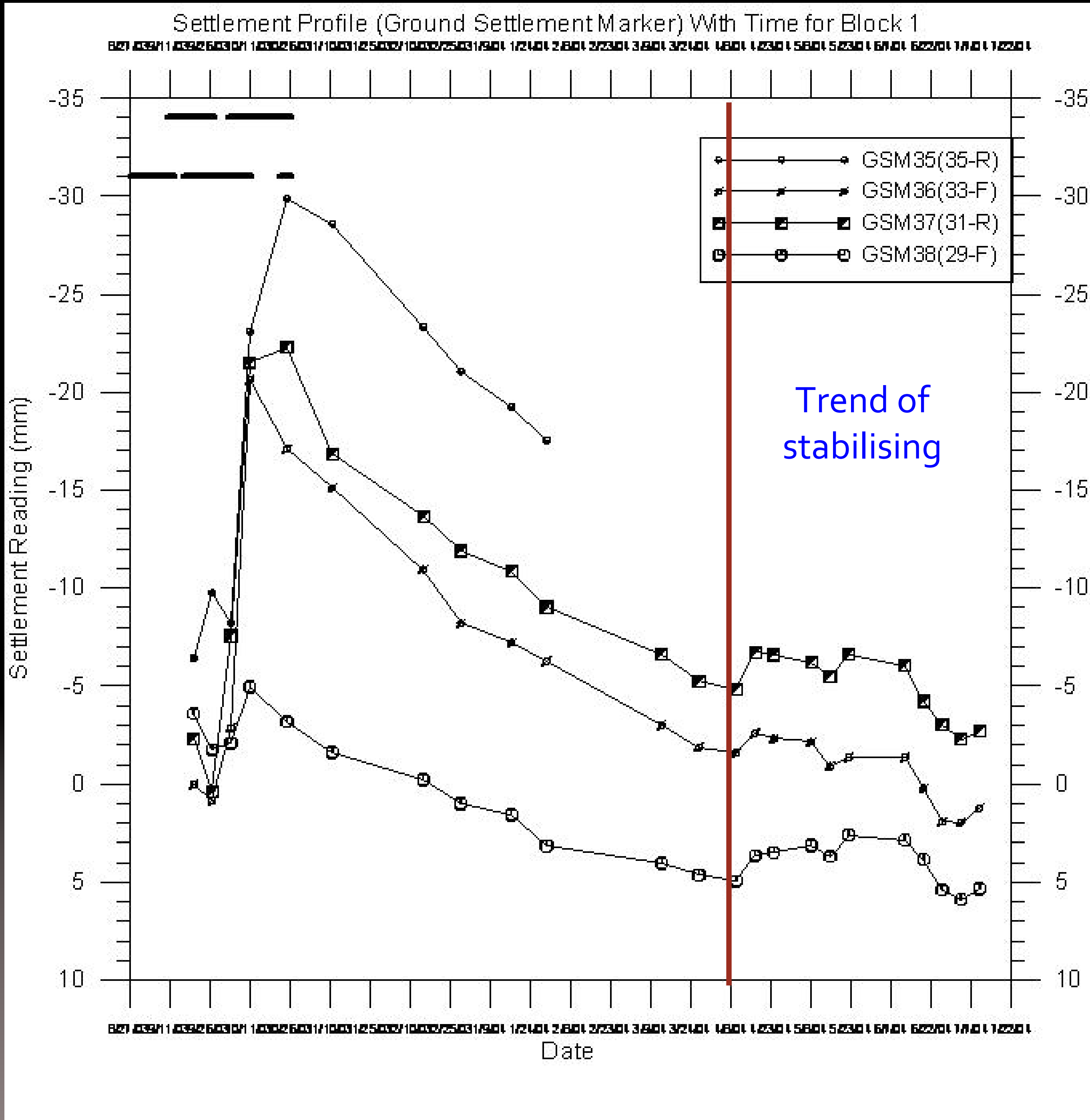
- Grouting has been carried out by specialist contractor at Block 1 of Phase 2C2
- Purpose: Fill in voids and densify compressive soft soil to eliminate ground settlement

Remedial Works by Specialist Contractor

- Settlement is stabilising after grouting treatment



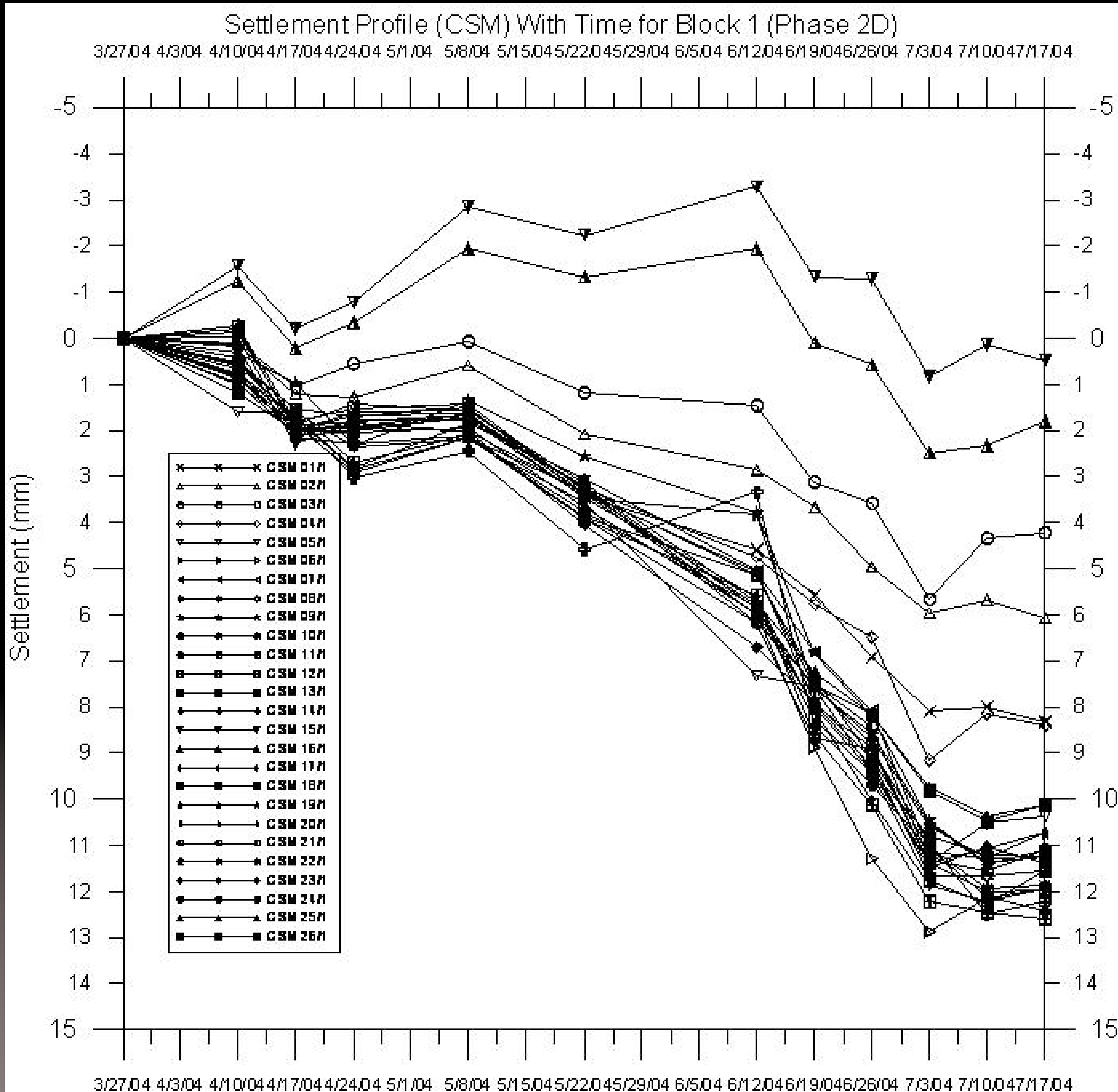
Settlement Profile (Column Settlement Markers) With Time for Block 1
Settlement Reading (mm)
Heave
Settlement
Date
Trend of stabilising
Unit 31 (9/16 to 10/12)
Unit 29 (8/14 to 9/13)
Unit 37 (9/10 to 9/28)
Unit 33 (10/3 to 10/27)
Unit 35 (10/22 to 10/27)
Compaction Grouting Works
CSM01(29-F)
CSM02(29-F)
CSM03(29-F)
CSM04(29-M)
CSM06(29-R)
CSM07(33&35-R)
CSM11(35&37-R)
CSM12(37-R)
CSM14(37-F)
CSM15(37-M)
CSM16(37-F)
CSM10(33-F)
CSM08(31&33-M)
CSM09(33&35-M)
CSM05(29-R)
CSM13(37-R)



Settlement Profile (Ground Settlement Marker) With Time for Block 1
Settlement Reading (mm)
Date
GSM35(35-R)
GSM36(33-F)
GSM37(31-R)
GSM38(29-F)
Trend of stabilising

Monitoring Results

- Crack monitoring (3 months)
- Settlement monitoring (10 months)
  - Ground settlement
  - Column settlement


Settlement Profile (CSM) With Time for Block 1 (Phase 2D)
3/27/04 4/3/04 4/10/04 4/17/04 4/24/04 5/1/04 5/8/04 5/15/04 5/22/04 5/29/04 6/5/04 6/12/04 6/19/04 6/26/04 7/3/04 7/10/04 7/17/04
Settlement (mm)
-5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
CSM 01/I
CSM 02/I
CSM 03/I
CSM 04/I
CSM 05/I
CSM 06/I
CSM 07/I
CSM 08/I
CSM 09/I
CSM 10/I
CSM 11/I
CSM 12/I
CSM 13/I
CSM 14/I
CSM 15/I
CSM 16/I
CSM 17/I
CSM 18/I
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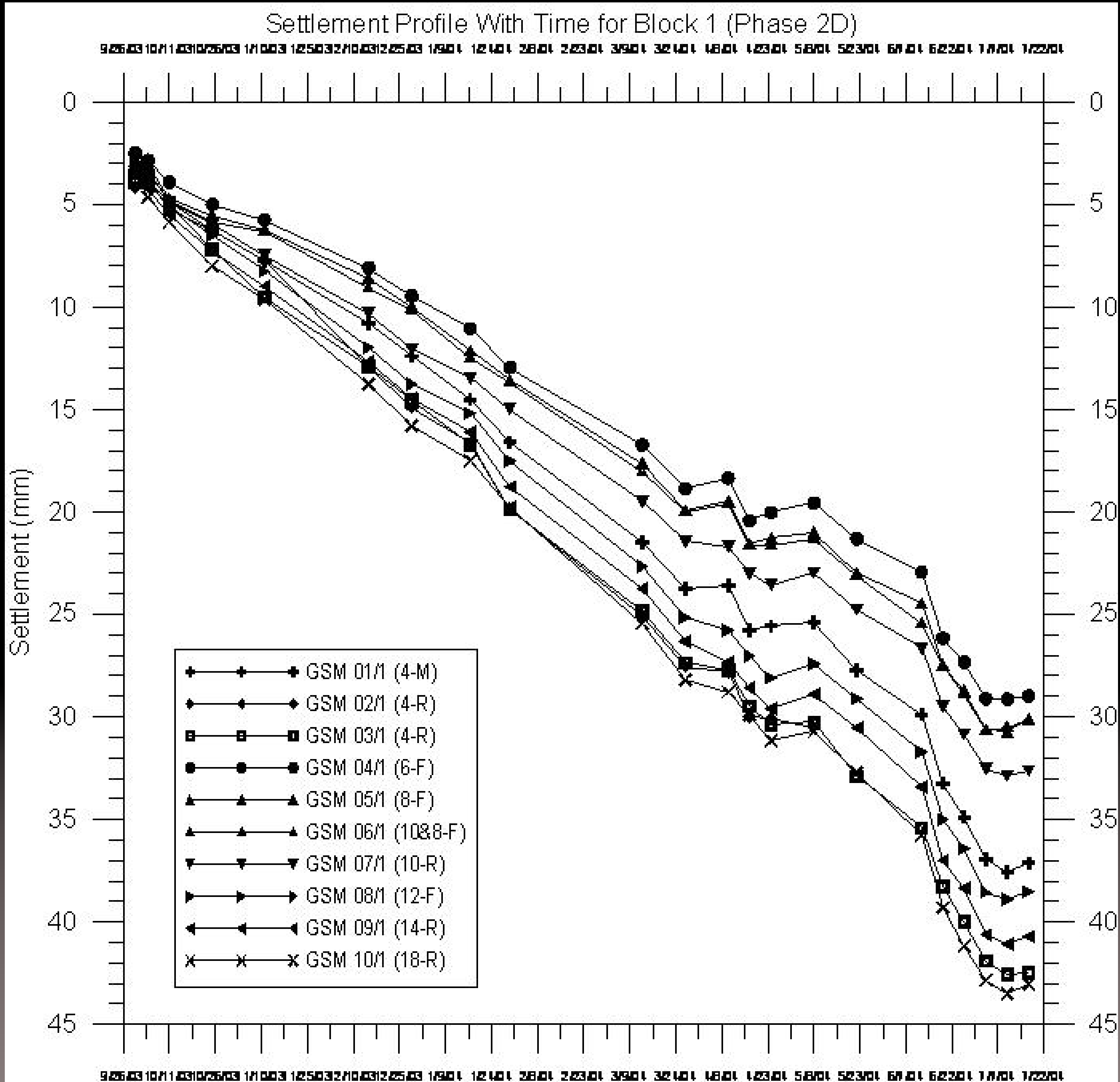
CSM 24/I
CSM 25/I
CSM 26/I



Settlement Profile With Time for Block 1 (Phase 2D)
Settlement (mm)
0
5
10
15
20
25
30
35
40
45
GSM 01/1 (4-M)
GSM 02/1 (4-R)
GSM 03/1 (4-R)
GSM 04/1 (6-F)
GSM 05/1 (8-F)
GSM 06/1 (10&8-F)
GSM 07/1 (10-R)
GSM 08/1 (12-F)
GSM 09/1 (14-R)
GSM 10/1 (18-R)