



SEAGC2018

20th SOUTHEAST ASIAN GEOTECHNICAL CONFERENCE & 3RD AGSSEA CONFERENCE

In conjunction with

22nd HATTI ANNUAL SCIENTIFIC MEETING

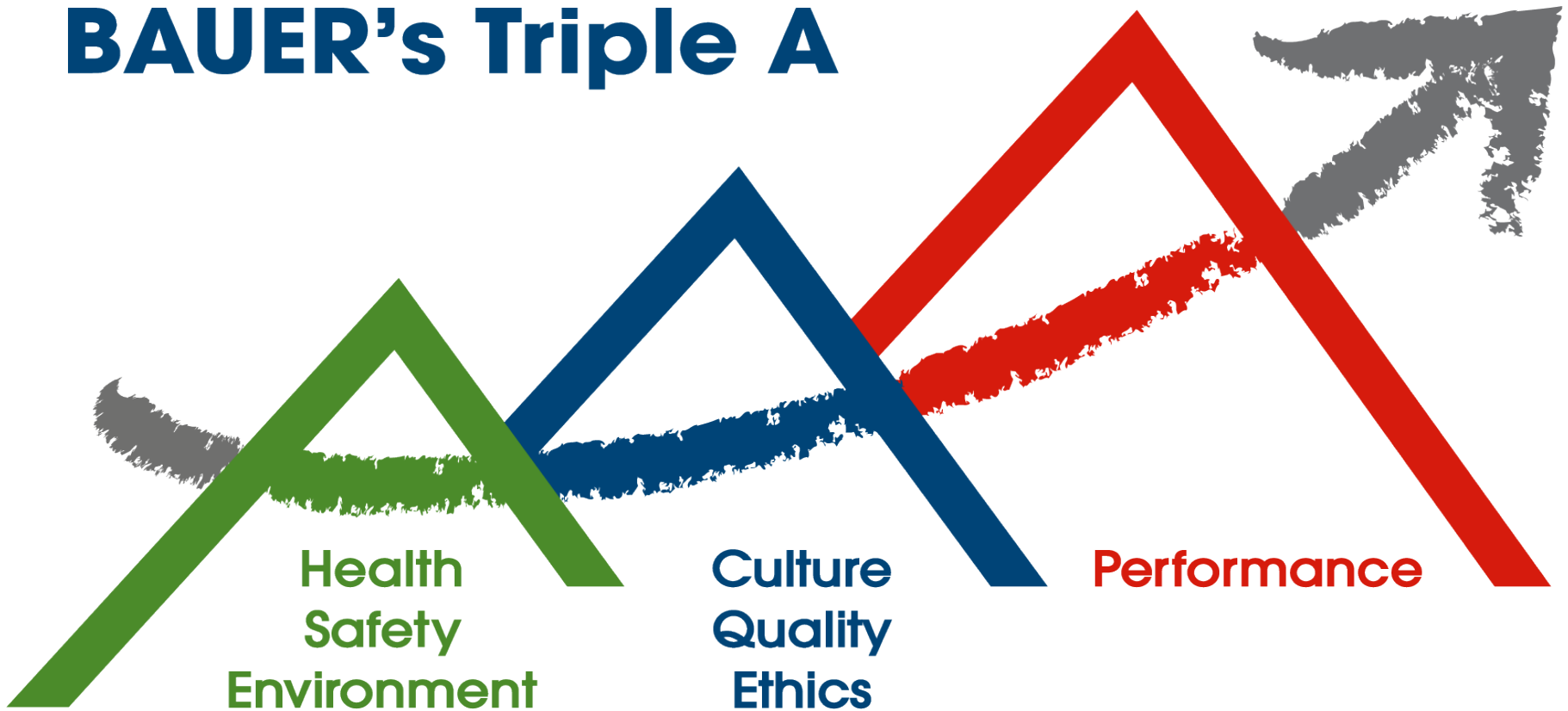
**GEOTECHNICAL CHALLENGE FOR
MEGA INFRASTRUCTURES**

Thomas Domanski

Regional Director Bauer South East Asia Pacific



BAUER's Triple A





*PASSION for
PROGRESS*



CONSTRUCTION



EQUIPMENT



RESOURCES

Bored Piling using Rotary Kelly Drilling Mega Piles





Contents of Presentation

Section 1: Introduction

- **Viaducts in Congested Urban Areas**
- **Rotary Bauer Drilling Rigs enabling the Construction of Mega Piles**

Section 2: Monopiles for Viaduct Structures

Section 3: Deep Piles

- **Bored Pile Foundation for KLCC Lot L&M, A World Record in the Making**

Section 4: Technical Challenges Deriving from Mega Piles

- **Borehole Stabilization**
- **Concrete Mixture**
- **Verticality Measurements**



Section 1

INTRODUCTION

Urban Viaduct Structures



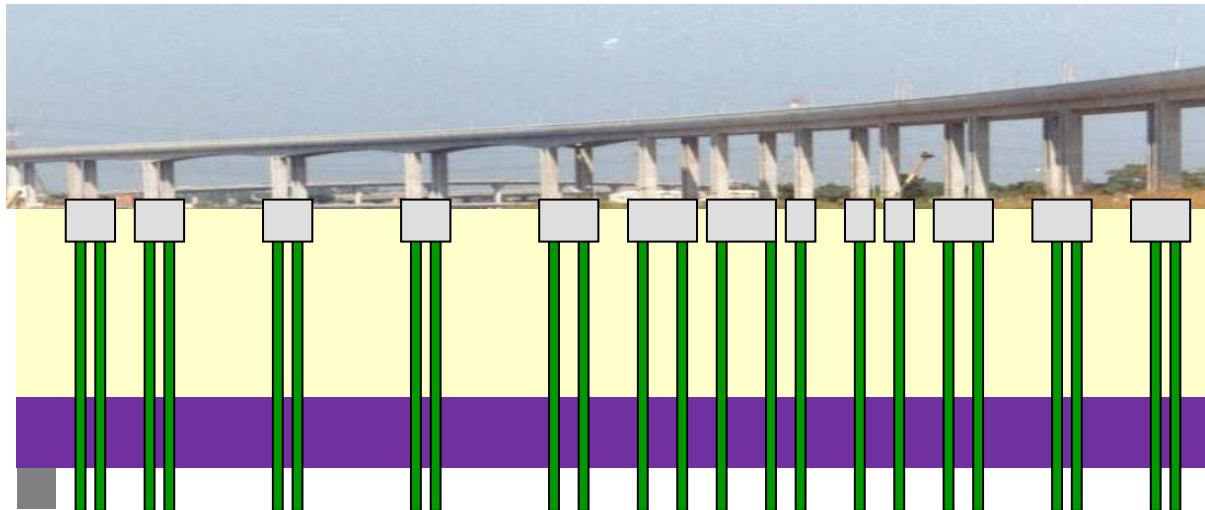
Bauer Bored Piles for Viaduct Construction



Bauer Bored Piles on Roads



Hong Kong KCRC CC201 New Territories



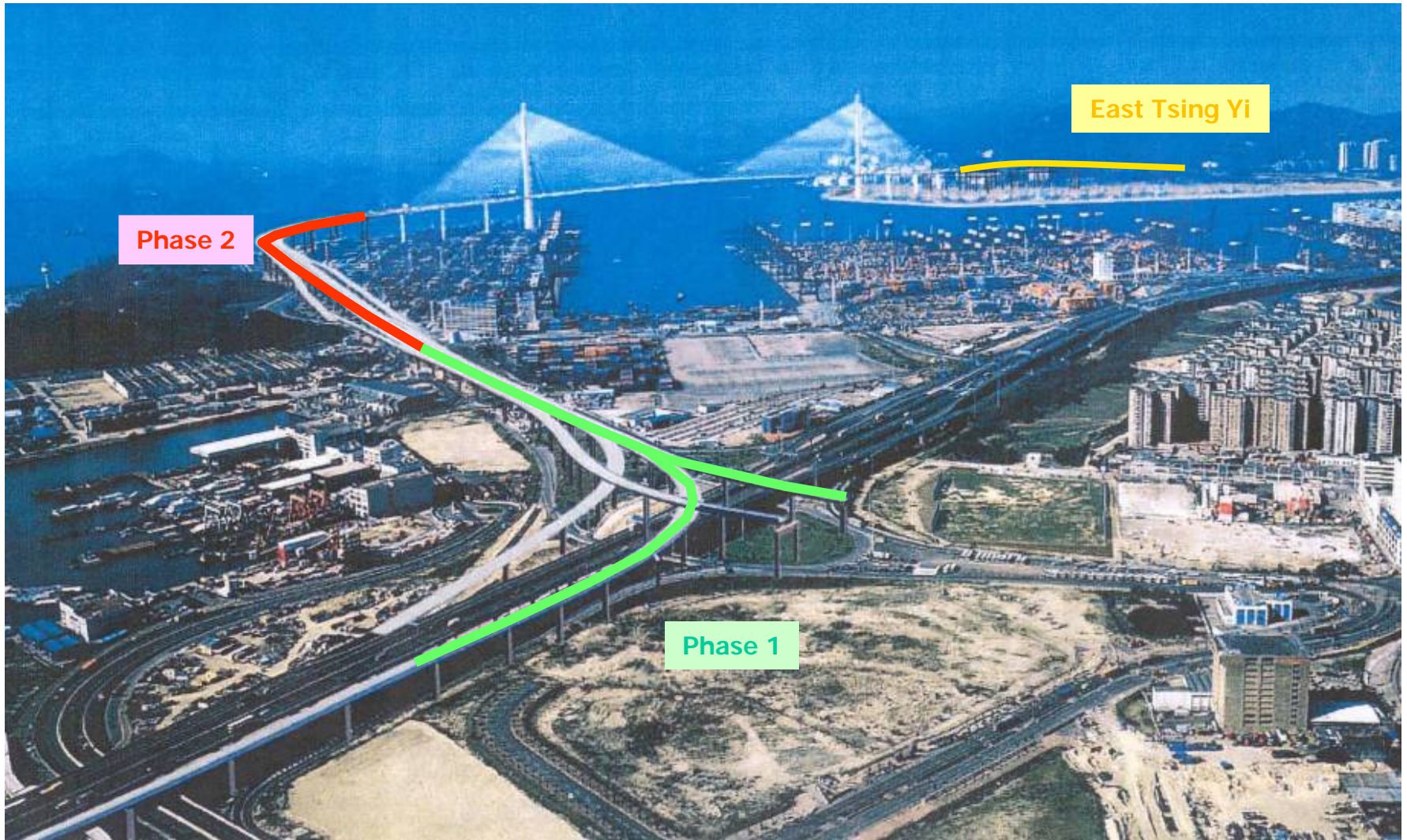
Hong Kong

Route 9 Phase 2 (Viaduct Approaches to Stonecutter Bridge)



Hong Kong

Route 8 (Viaduct Approaches to Stonecutter Bridge)



Bauer Bored Piles for Viaducts



Hong Kong Zhuhai Macau Bridge

Completed Bridge



Rotary Kelly Drilling for the Deep Water Section



BG 40 Drilling Hard Granite Rock for the HKZMB

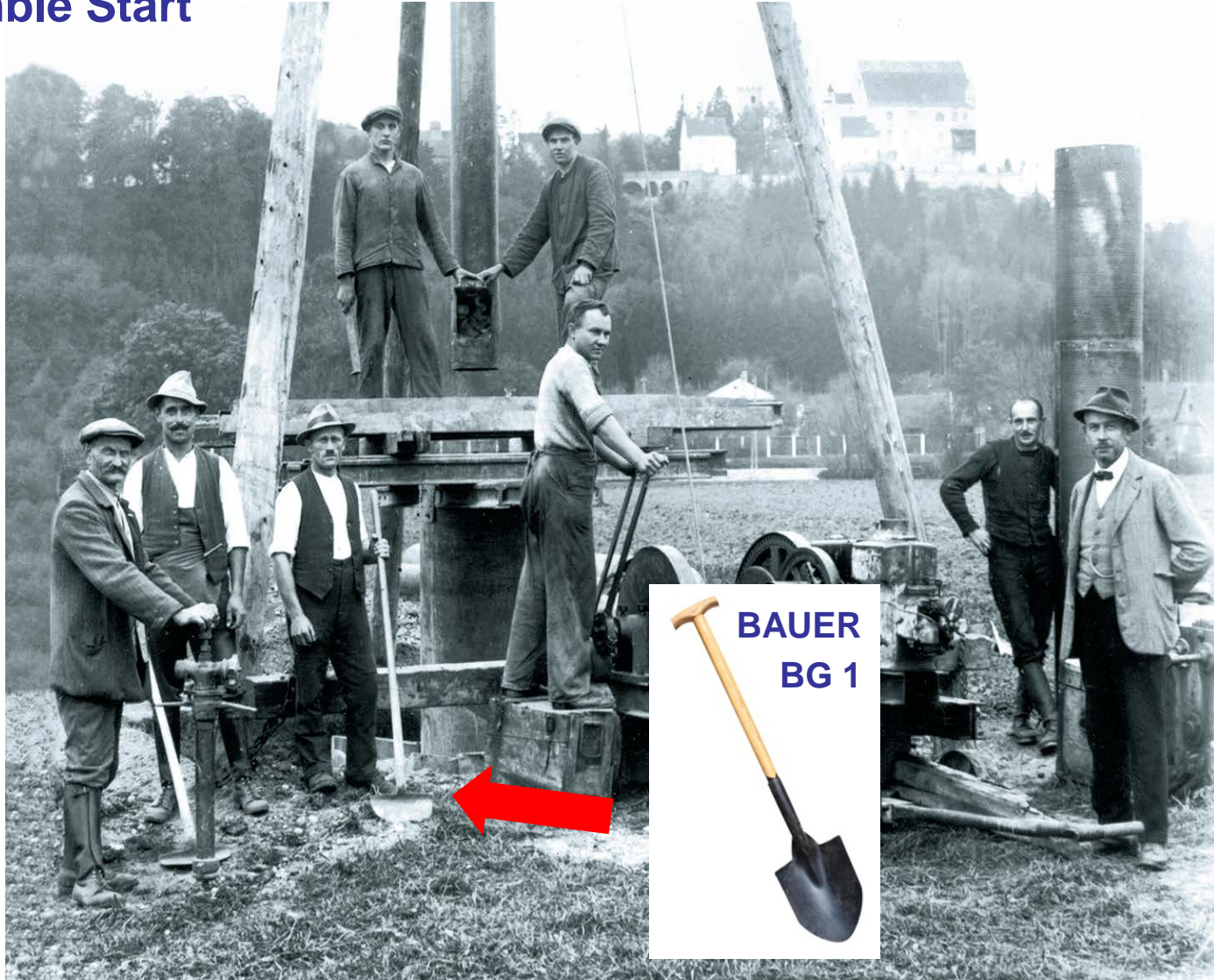


Bauer Equipment for Mega Piles



Bauer is > 225 years old!

The Humble Start

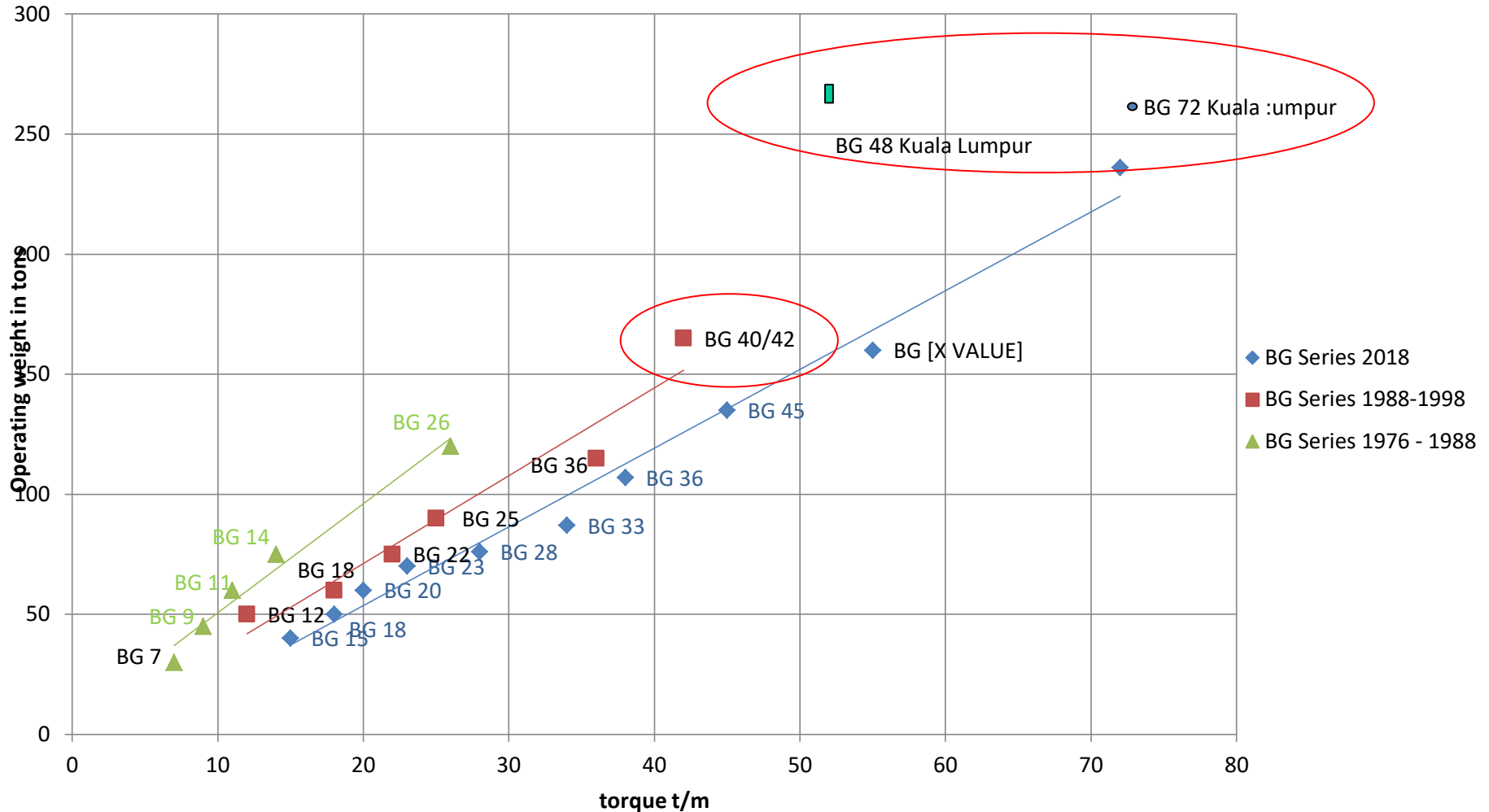




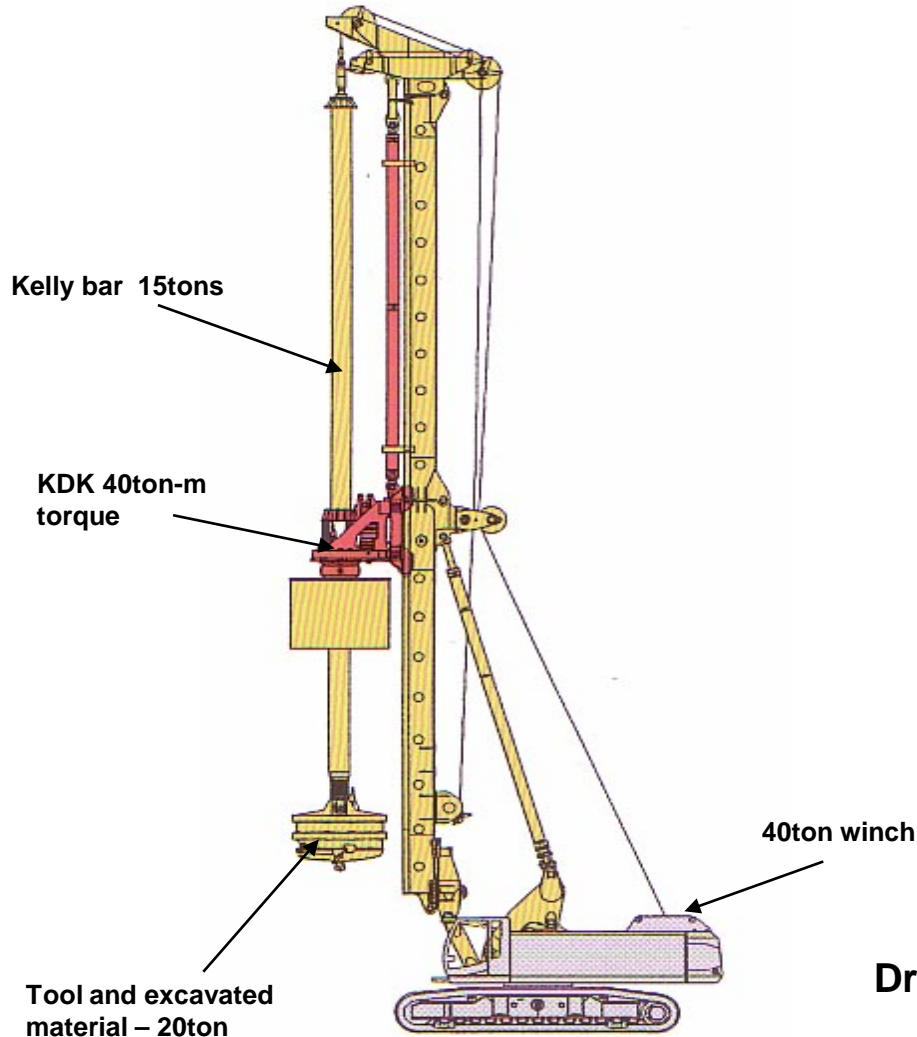
Bauer BG Drill Rigs

Drill Rig History, Mega Rigs for Mega Piles

Development of the BG rigs



Drilling Rig



BG 40 BS 110

Overall height	29 - 32meter
Torque	367kNm
Engine power	563 HP
Main winch	400kN
Auxiliary winch	150 kN
Max. diameter	3000 mm
Max. Drilling depth	90 m
Undercarriage	BS 110
Crawler length	6000 mm
Crawler width	4900mm
Width of track shoes	1000mm
Operating weight	160 tons

Drilling Diameter can be increased to 3,500mm by installing a sledge adaptor



Year 2018, Kuala Lumpur

The 2 biggest BG Rigs in the World

BG 48, Drilling Depth 125m w/o Kelly Extension

BG 72, Drilling Depth 150m w/o Kelly Extension

Max Drilling Diameter 4.6m (with slide adaptor)



Section 2

MONOPILES FOR VIADUCT STRUCTURES



Section 2

Monopiles for Viaduct Structures

- **The concept of Monopiles**
- **Examples of diameter 3.0m and 3.5m Monopiles on Road Viaducts in Kuala Lumpur**
- **DUKE Highway**
- **SUKE Highway**



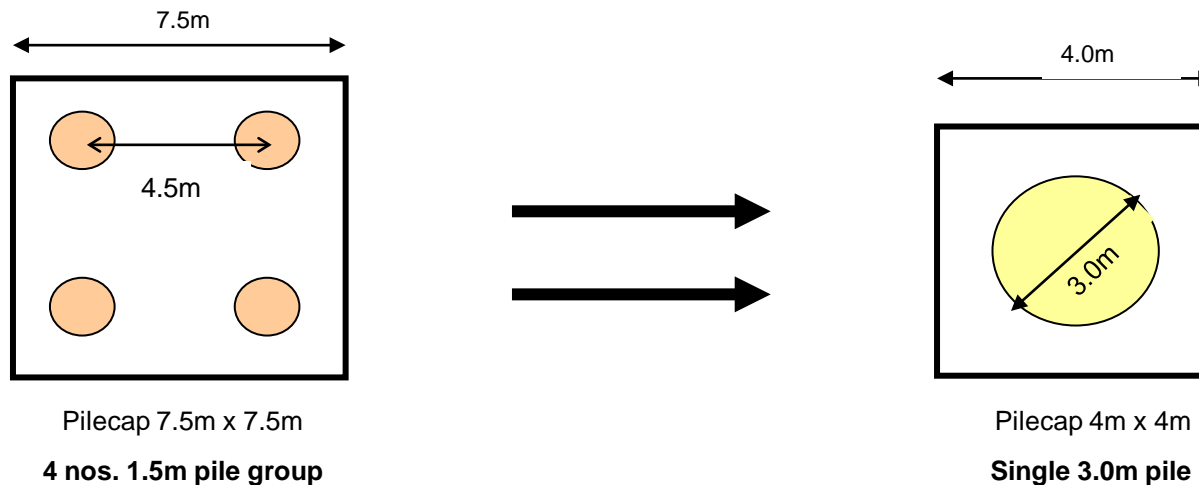
A Monopile is defined as

A foundation consisting of a single, generally large diameter, structural element that supports the entire load of a large above-surface structure

Why Monopiles ?

The common Approach

Typical Pile Cap for Viaduct Pier using 4 or more Piles
which now will be replaced by 1 Mega Pile diameter 3.0m to 3.5m





Monopiles are

FASTER AND COST EFFECTIVE Compared to Multi-Pile Group Caps



Reason 1:

Logistic and Time during Pile Construction



Piling Program (subject to Specific Changes)

- **4 Pile Group (the uninterrupted construction of 4 Pile Group Caps require the availability of minimum 3 cap location at a time)**

- Mobilization - 1.0 day
- Install Pile 1 - 1.0 day
- Install Pile 3 - 1.0 day
- Install Pile 2 - 1.0 day
- Install Pile 4 - 1.0 day
- Shifting 11 times between 3 Pile Caps

**4.0 days
Construction plus
shifting**

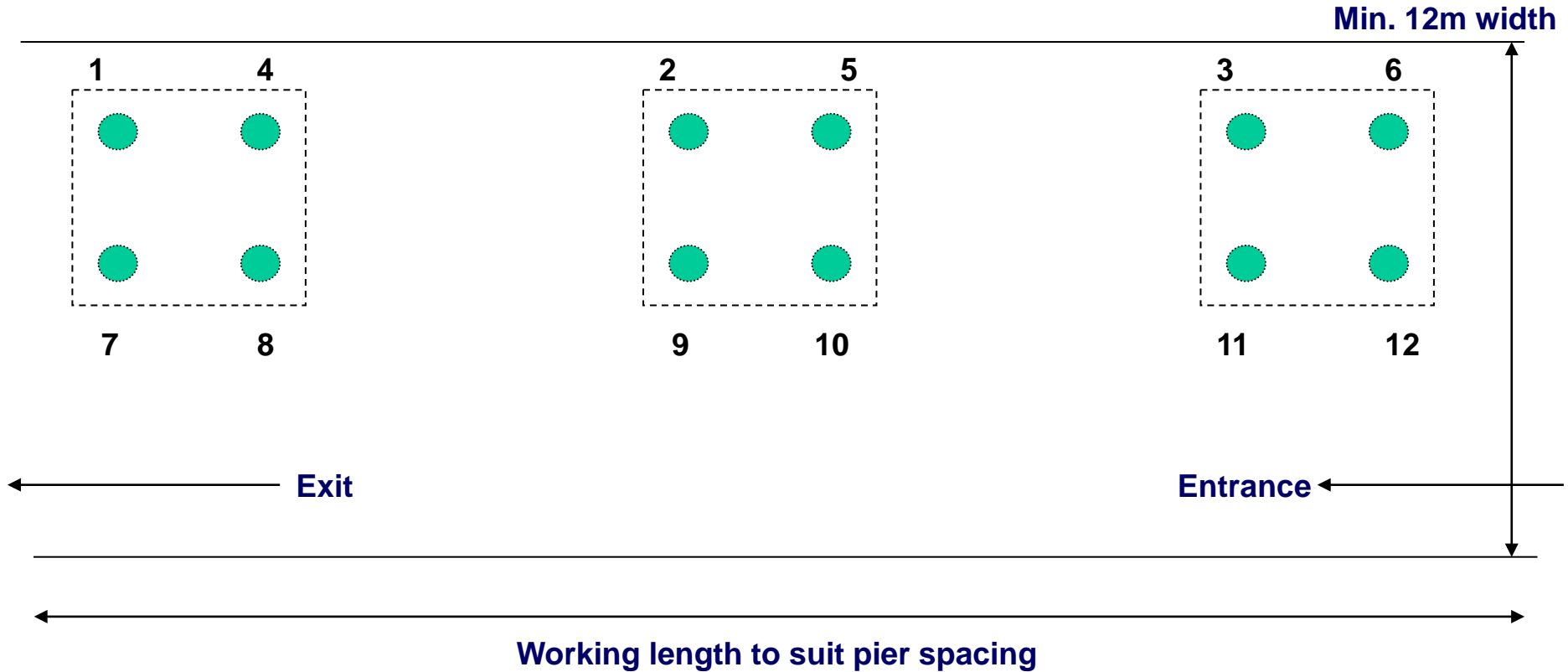
- **Single Pile Group**

- Mobilization - 1.0 day
- Install Pile 1 - 1.0 day
- Shifting 2 times between 3 Pile Caps

**1.0 day Construction
plus shifting**

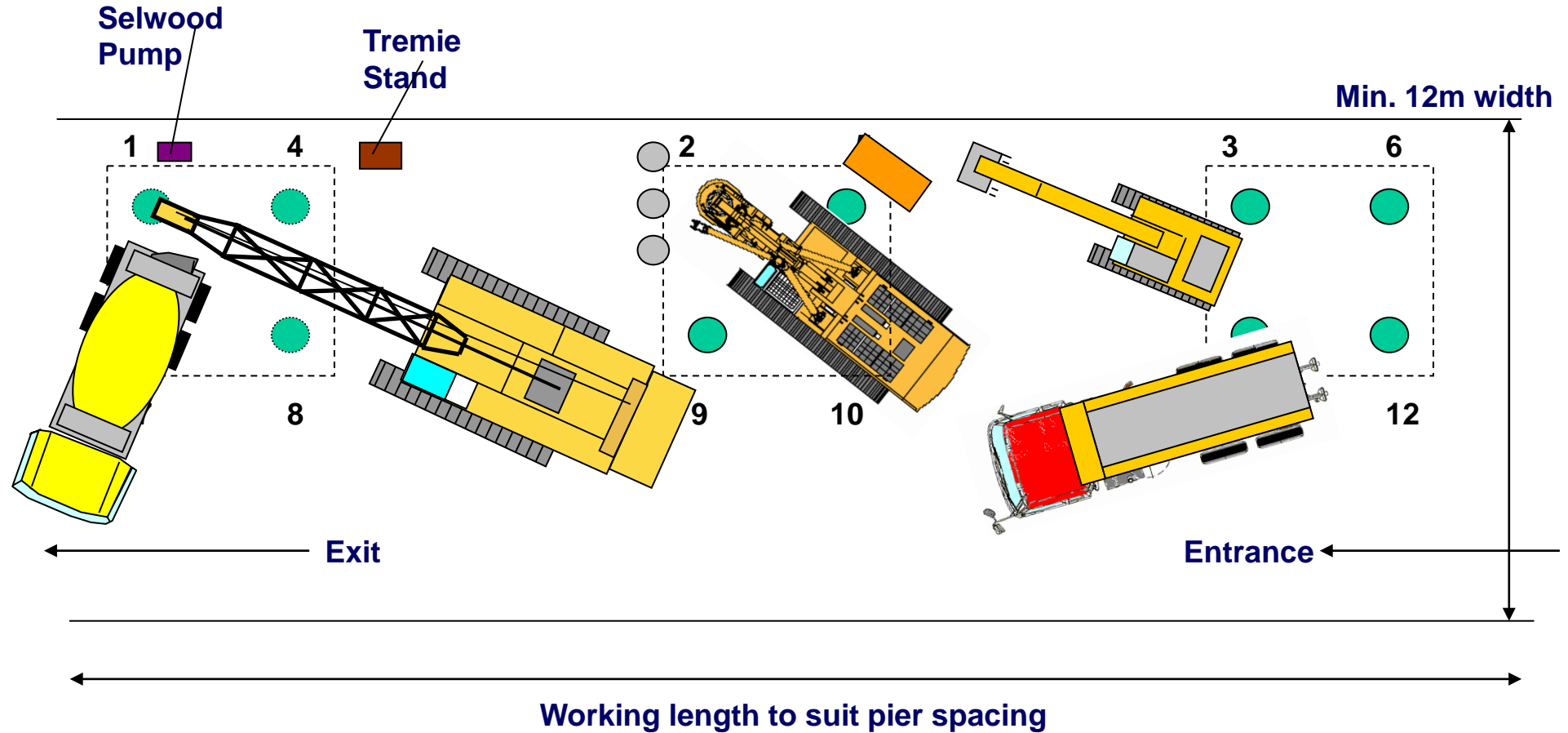


Typical Working Sequence for conventional 4-Pile Group Cap 3 piers with link up platform



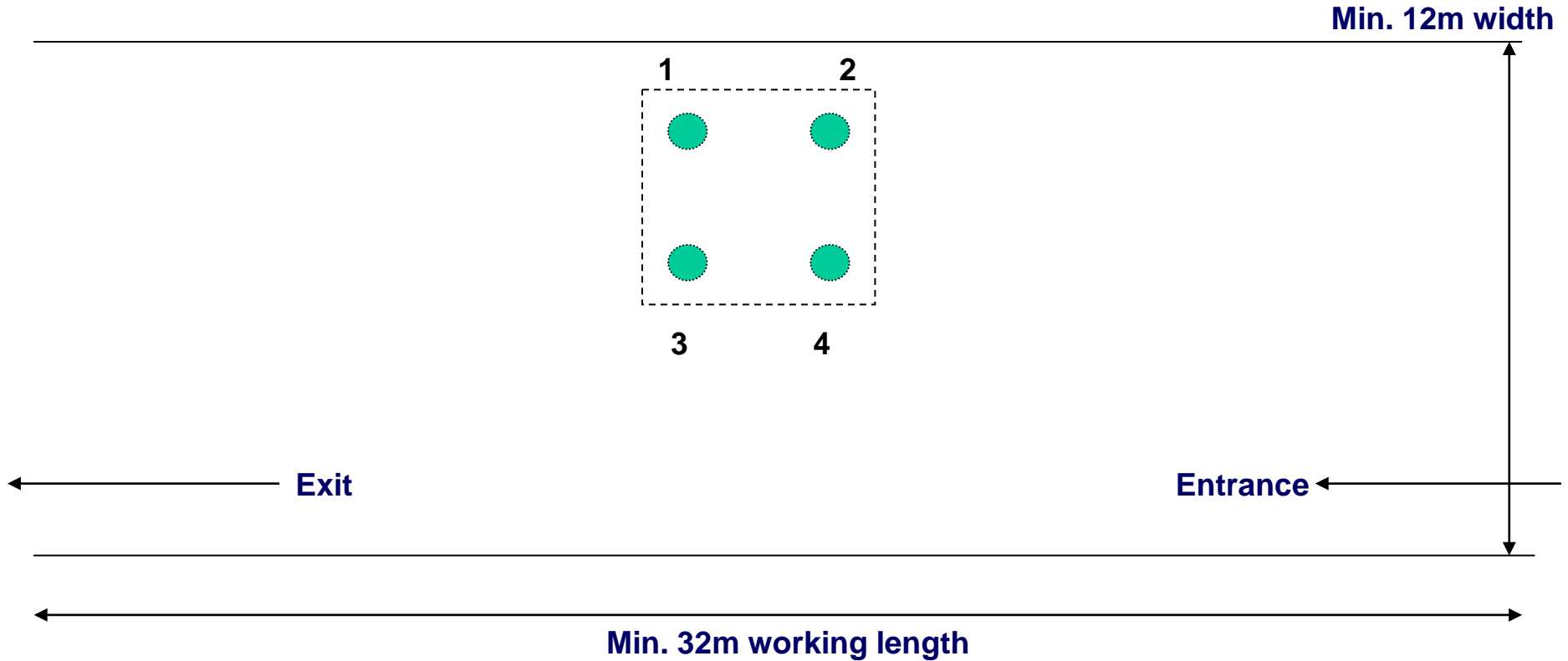


Pier Groups – Stage 2, Drilling Pile 2, Ancillary works at Pier 1



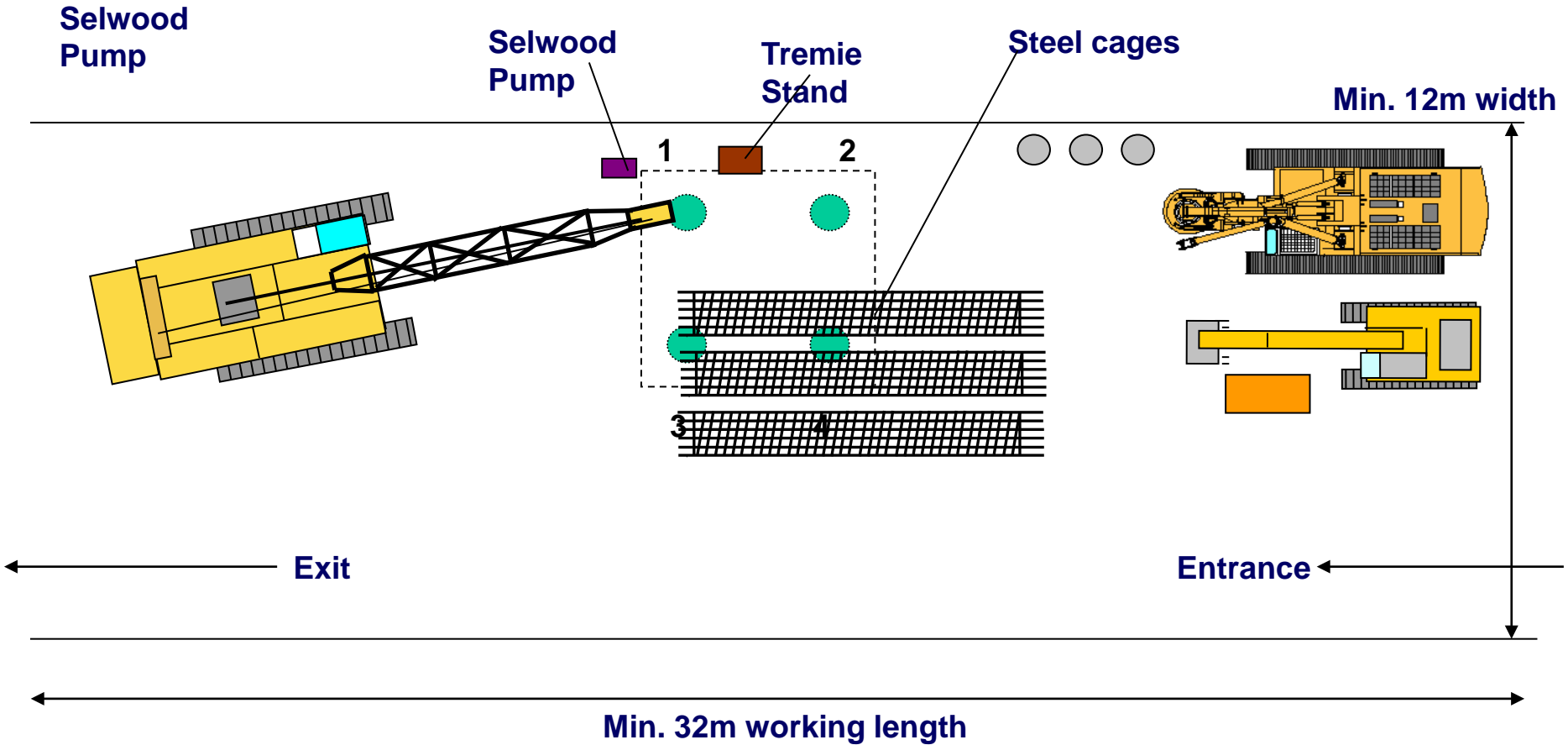


Typical Working Sequence – Isolated Pile Cap





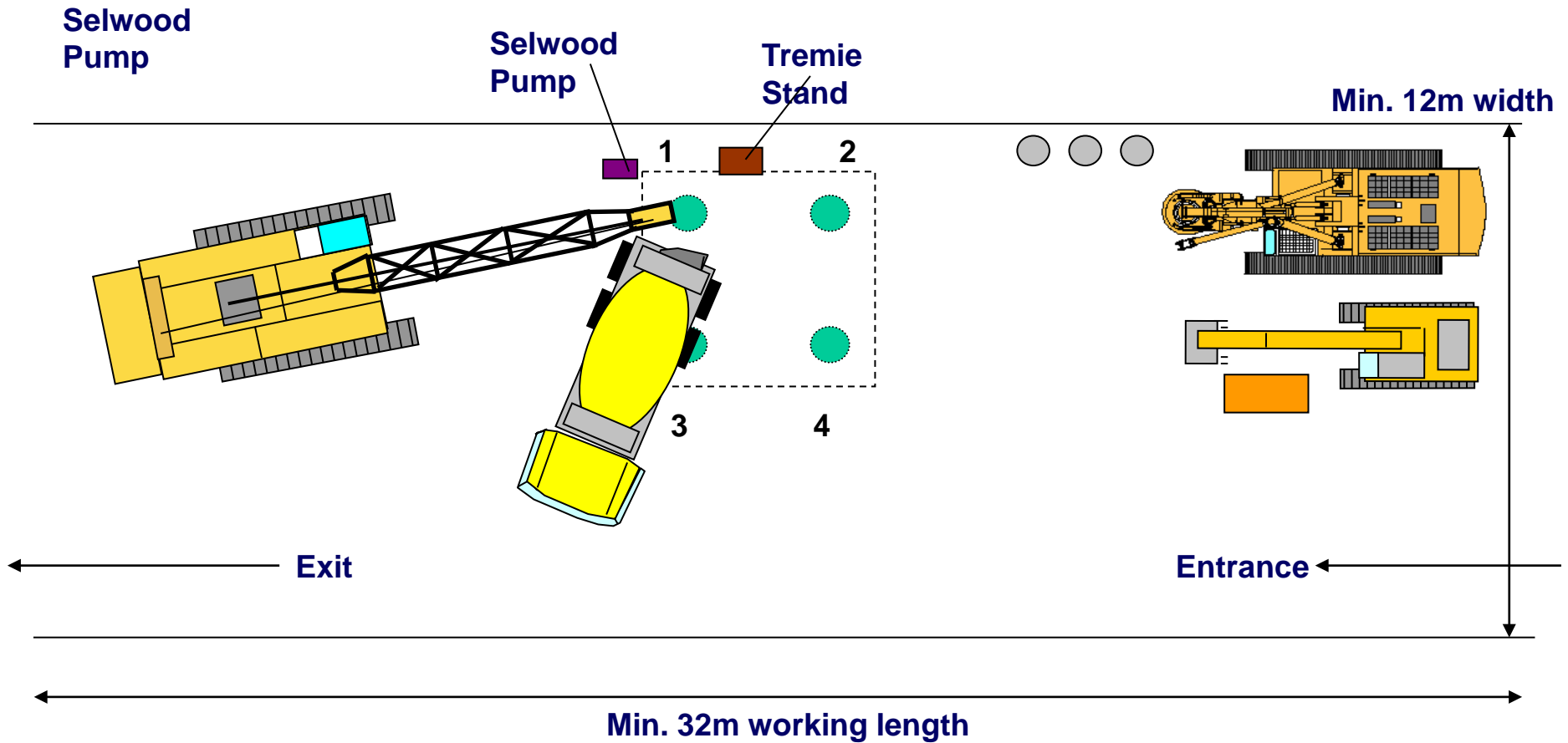
Isolated Pile Cap: Stage 2 – Reinforcement at Pile 1



Sequence repeated for piles 2, 3 and 4



Isolated Pile Cap: Stage 3 – Concreting at Pile 1

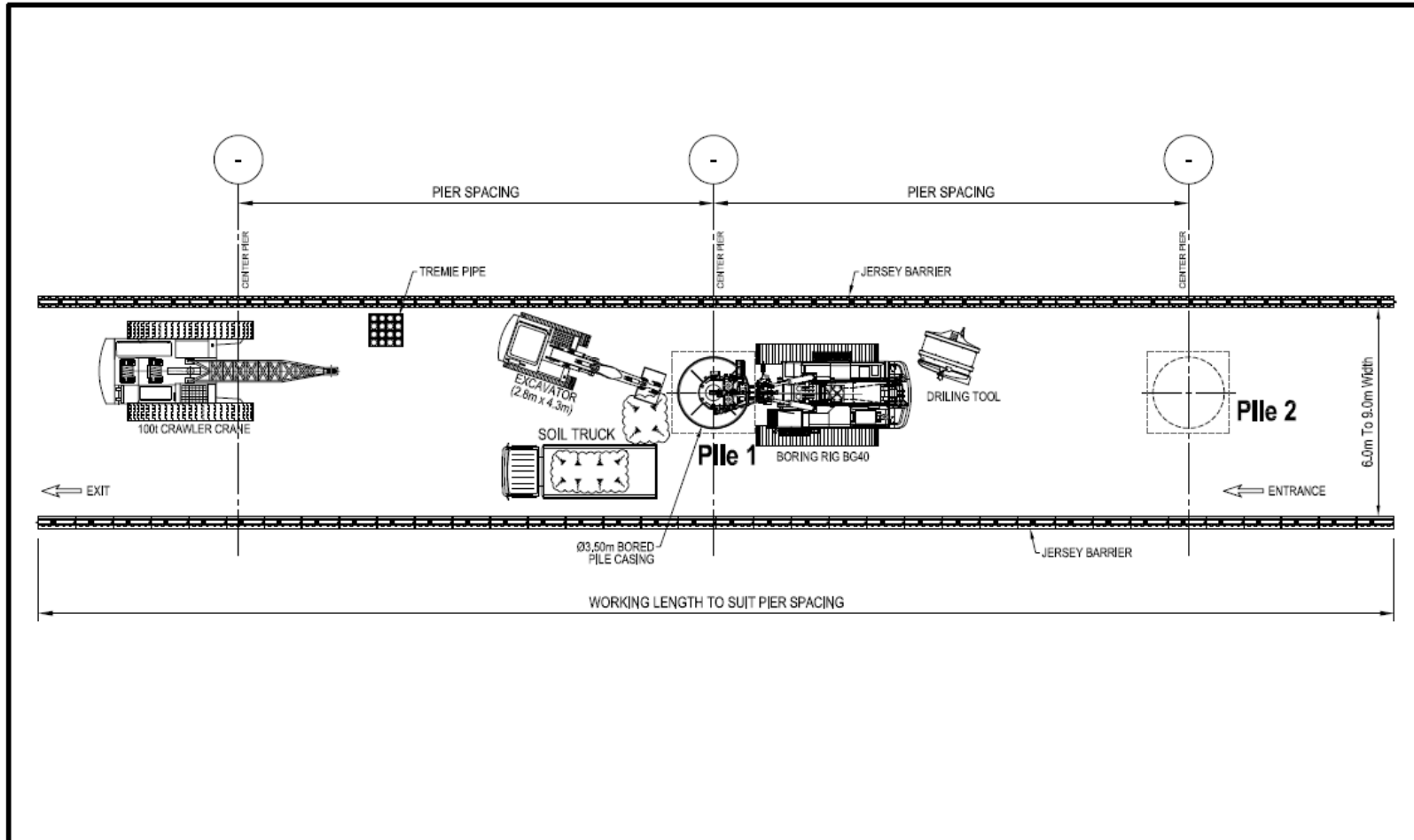


Sequence repeated for piles 2, 3 and 4

Between every Pile drilling 24 hrs idling after concreting

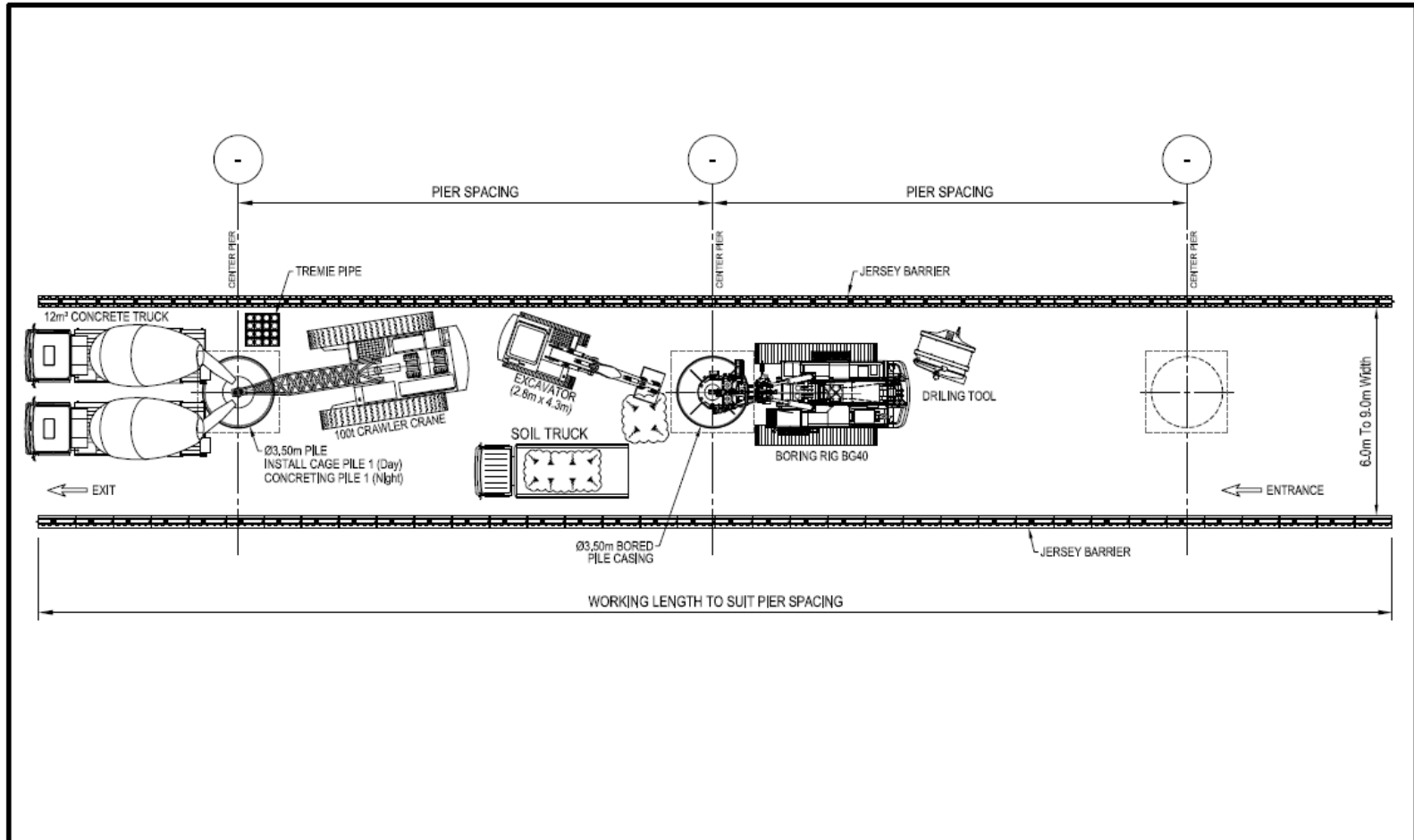
Piling Sequence for Monopiles

Pier Groups – Stage 1: Drilling Pile 1



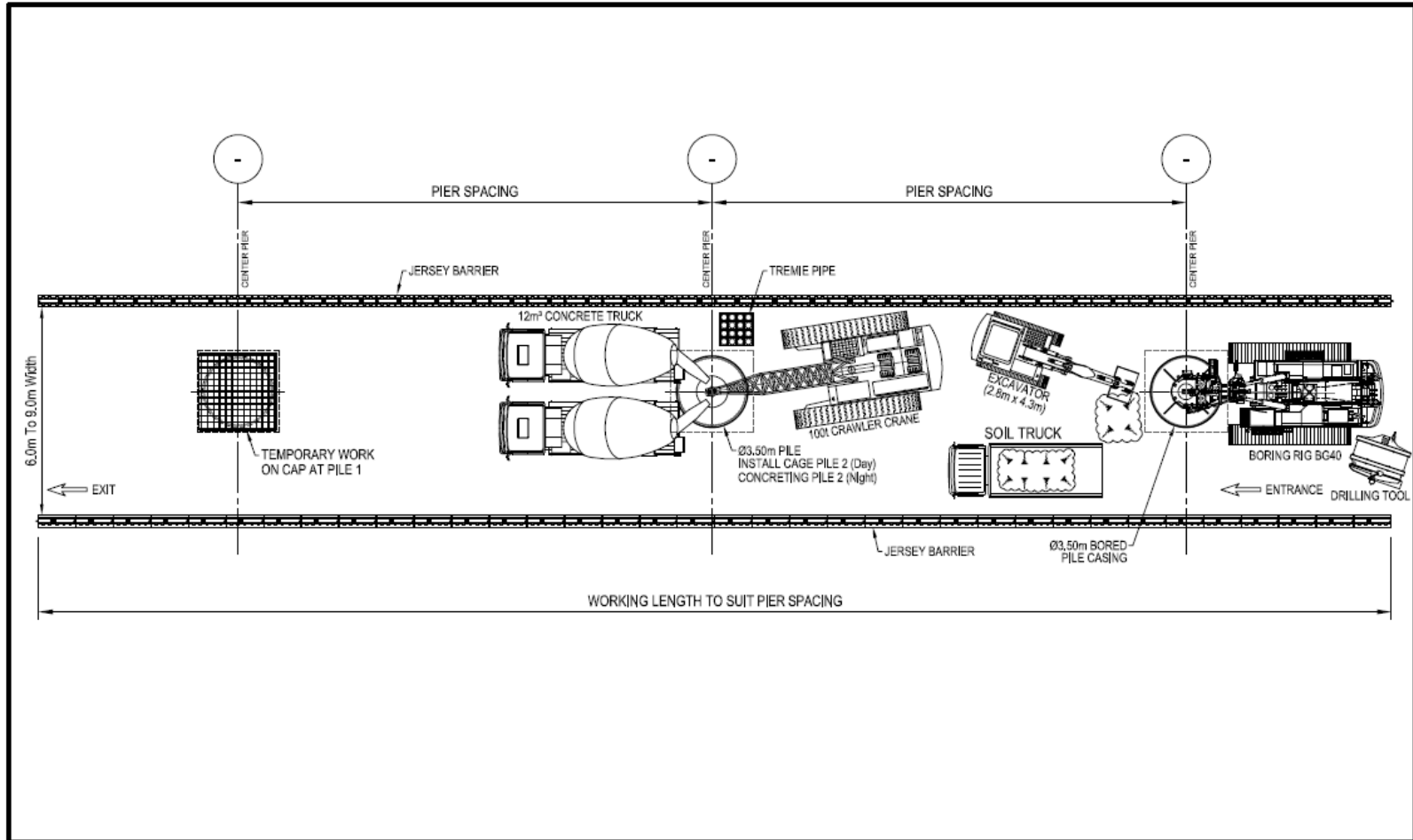
Piling Sequence for Monopiles

Pier Groups – Stage 2: Drilling Pile 2 Ancillary Works at Pile 1



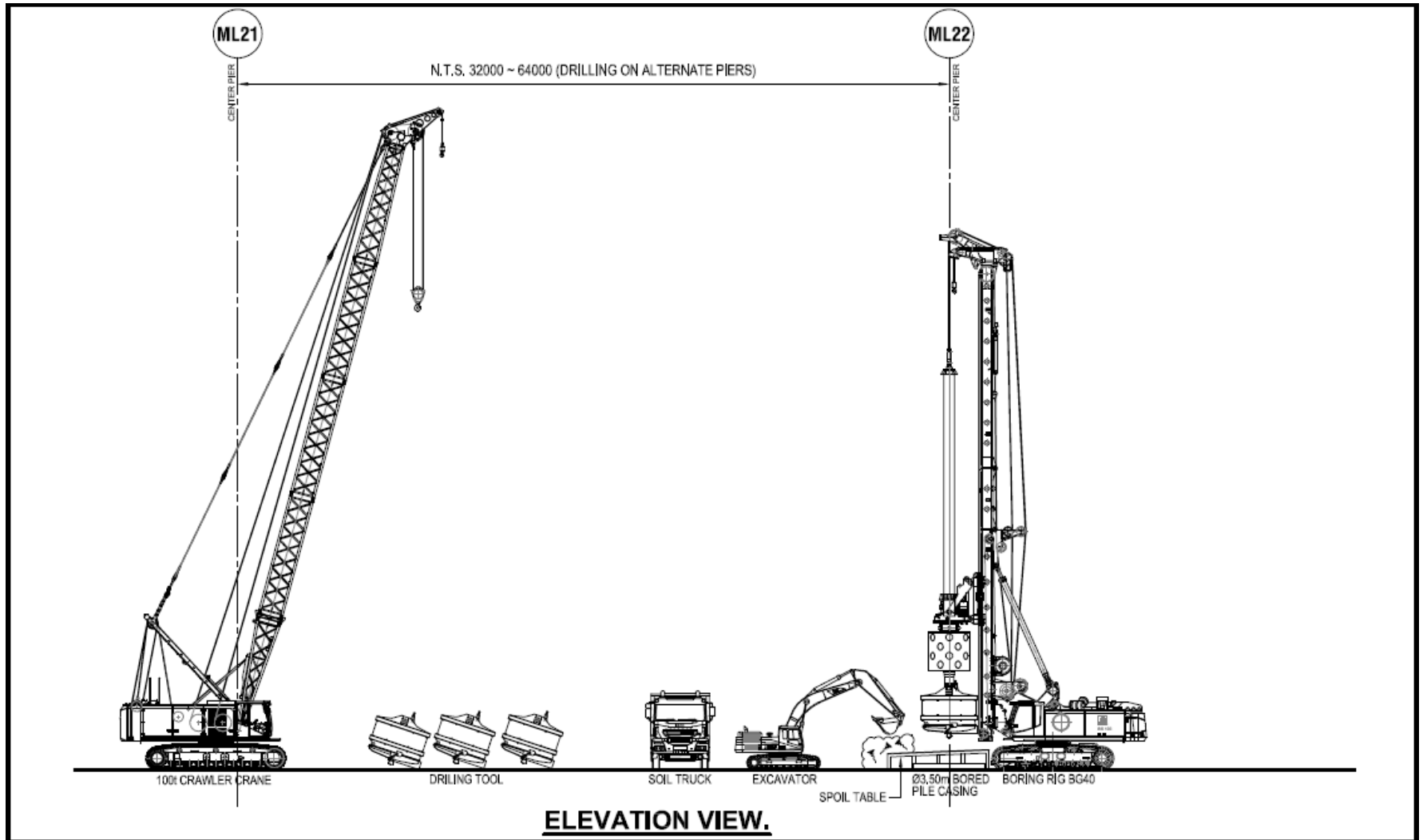
Piling Sequence for Monopiles

Pier Groups – Stage 3: Drilling Pile 3 Ancillary Works at Pile 1 & 2

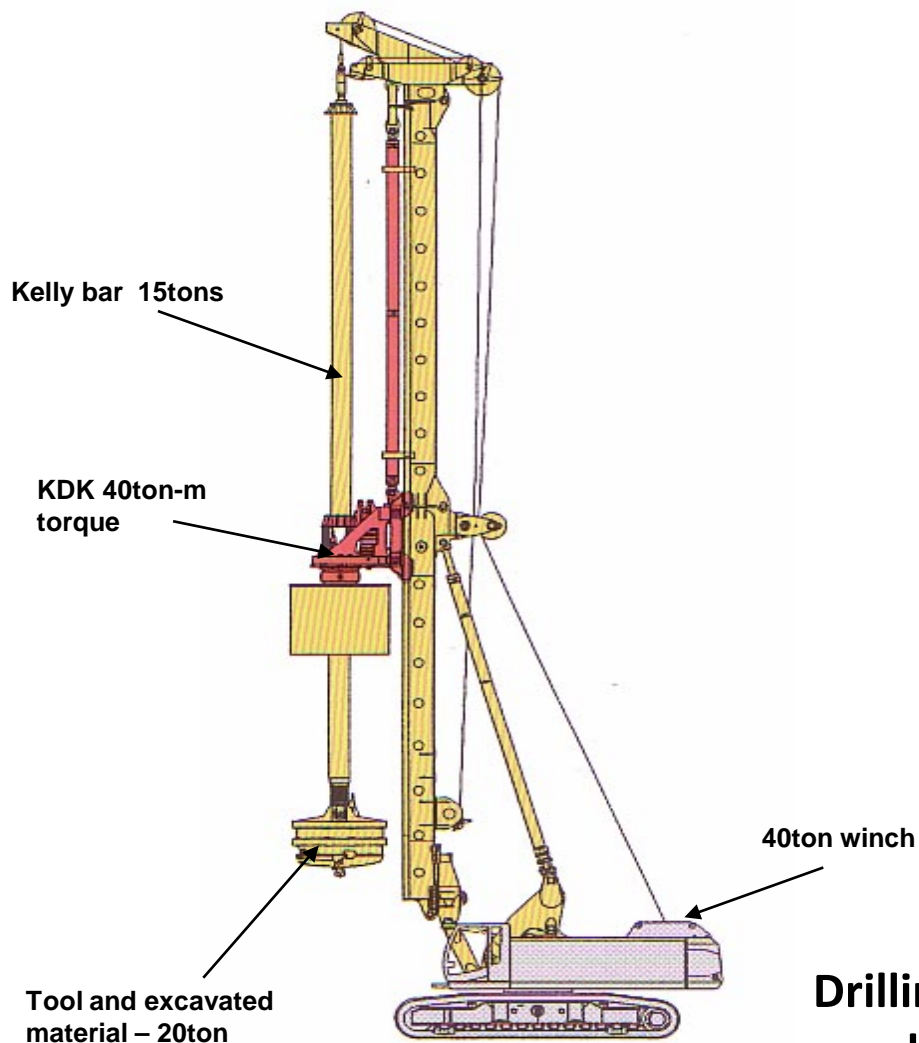


SPE - DUKE Phase 3

Rig Arrangement 2



Drilling Rig



BG 40 BS 110

Overall height	29 - 32meter
Torque	367kNm
Engine power	563 HP
Main winch	400kN
Auxiliary winch	150 kN
Max. diameter	3000 mm
Max. Drilling depth	90 m
Undercarriage	BS 110
Crawler length	6000 mm
Crawler width	4900mm
Width of track shoes	1000mm
Operating weight	160 tons

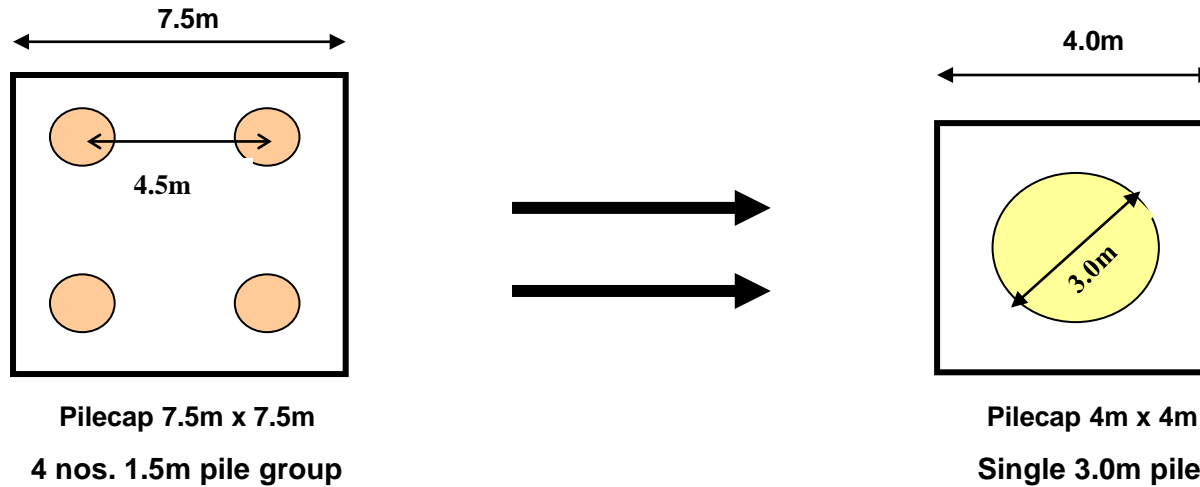
Drilling Diameter can be increased to 3500 mm by installing a sledge adaptor

Workspace & Traffic Diversion



- 4 pile group needs 10m to 12m width
- Monopile cap – 6.0m to 9.0m
- Easier for approval from Authorities
- Road Diversion is minimized
- Traffic Flow much better
- Saving in Traffic Diversion
- Implementation of Traffic Management Scheme faster

Design Effect on Materials



- **Pile Length** – Varies depending on soil parameter but a single 3.0m pile would normally be 15%-20% longer than a 1.5m pile
- **Concrete Volume** – There would be no quantity saving in volume. It is even fair to say the volume is slightly higher
- **Steel Tonnage** – Saving would be negligible
- **In summary** the installation cost of 1 no. 3.0m pile is about the same or slightly higher than that of 4 nos. 1.5m pile



Reason 2:

**Faster and More Economic Construction of
Pile Cap**

Pile Cap and Temporary Works, Group of 4 Piles



4 Pile Group

- Sheet pile
- Excavation
- Strutting
- Dewatering
- Pile cap
- Construction time @ 3 weeks

Single Pile Group

- Temporary work can be minimized or even omitted
- Construction period can also be minimized

Monopile Cap

COL Close to Ground Level



Monopile Cap

Temporary work is minimal or can be even omitted
Construction period is very short

Cap Work for Pile with Deeper COL

Pile Cap Temporary Works using a Thin Temporary Casing





Conclusion

Monopile Solution versus Multi Pile Group

- **Design** - **Well established**
- **Pile Construction** - **Logistically easier and faster**
- **Work Area** - **Smaller**
- **Traffic Management** - **Faster and Cheaper**
- **Construction Period** - **Faster**
- **Temporary Works** - **Minimized and Cheaper**
- **Pile Cap** - **Can be omitted or cheaper**
- **Traffic Flow** - **Minimum Disruption**



IN SUMMARY:

**MONOPILE SOLUTIONS ARE
FASTER AND MORE COST
EFFECTIVE THAN CONVENTIONAL
MULTIPILE GROUP CAPS**

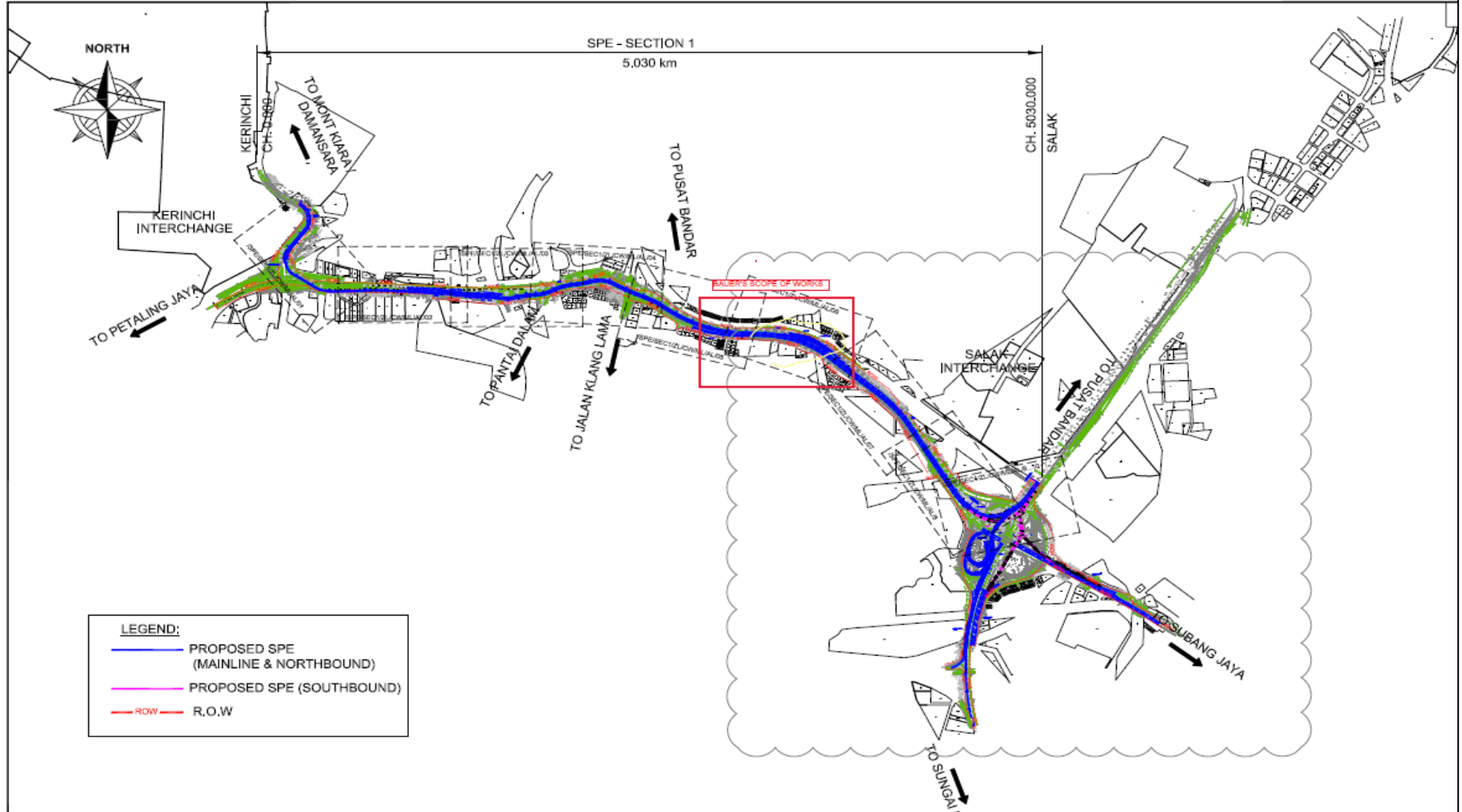


Project - Examples

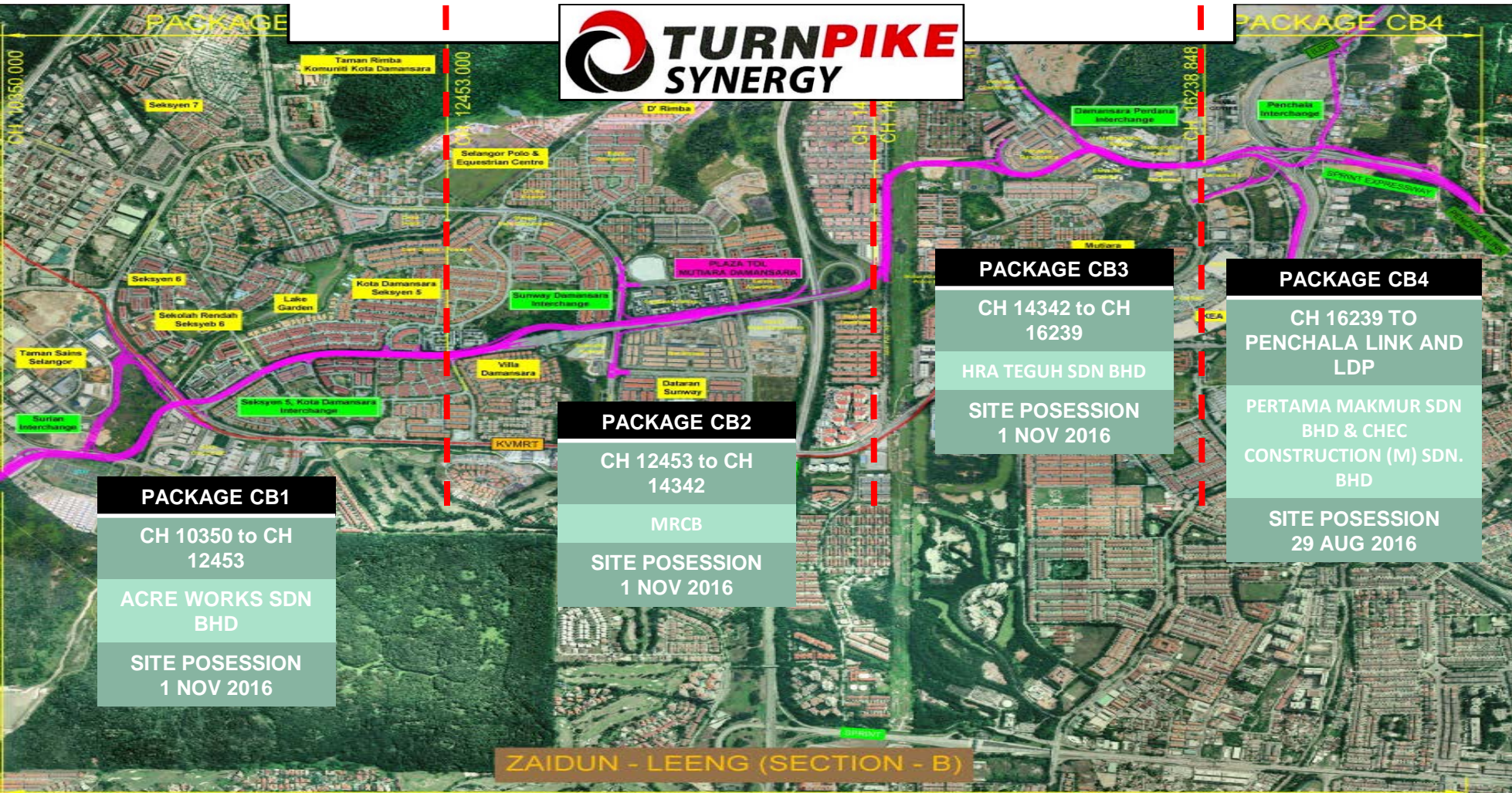
3 Highways in Kuala Lumpur



DUKE Highway Phase 3, Kuala Lumpur

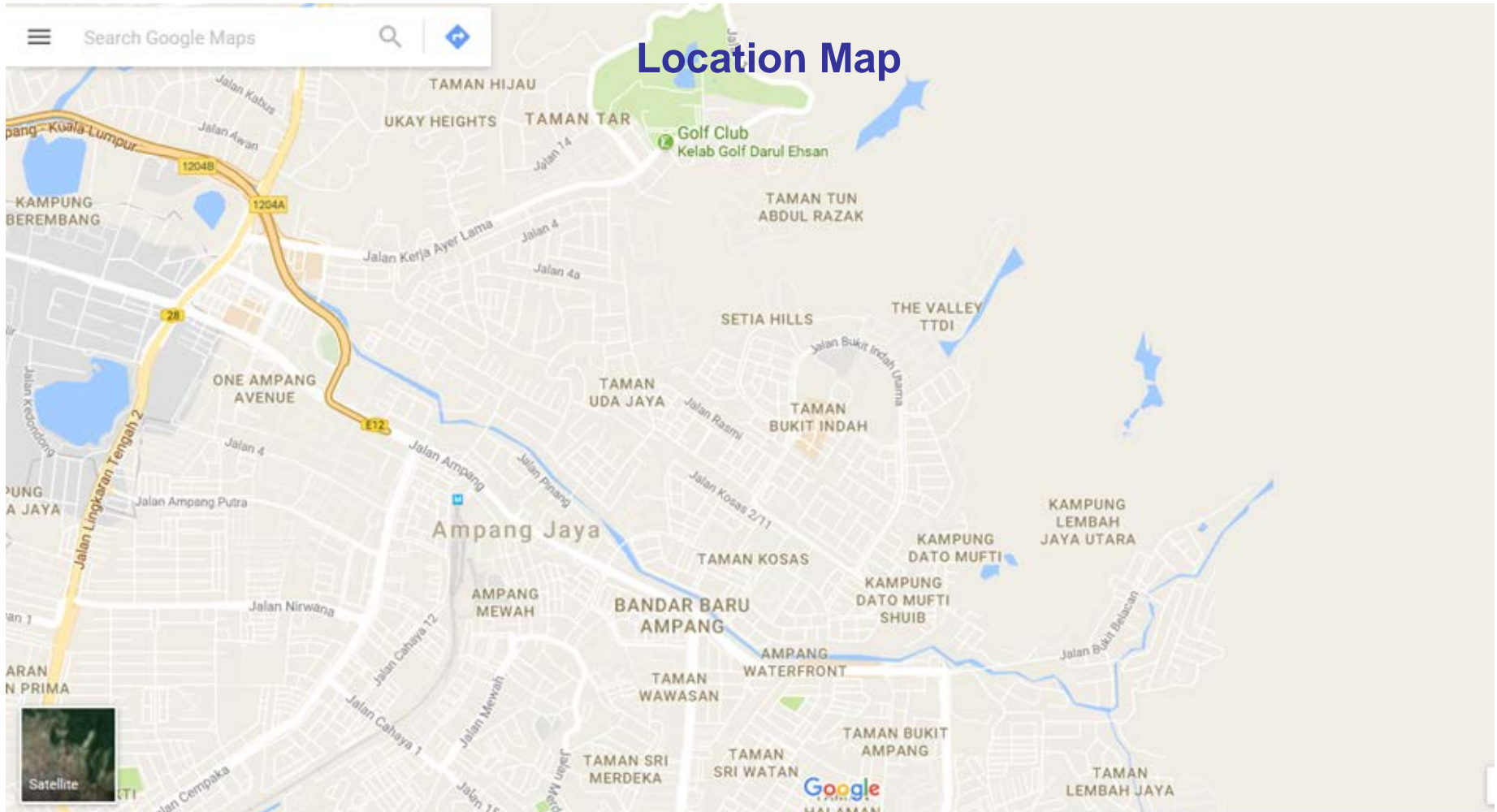


DASH, Monopiles on ACRE Works Section





Monopiles for Multi Highway Bridge (SUKE CB3 & CB4) Sg. Besi – Ulu Klang, Kuala Lumpur, MALAYSIA



Site Photo of DUKE Highway



Drilling on DUKE Highway with Spoil Removal Table



Site Arrangement DUKE Highway Sequential Drilling and Material Installation







Casing Installation of 3.5m Pile in SUKE



Drilling of 3.5m Pile in SUKE

Cage for 3.5m Bored Pile





Rebar Installation for 3.5m Pile in SUKE

Concreting of 3.5m Bored Pile in SUKE





Preparation for Pile Cap on Monopiles, SUKE



Preparation of 3.5m Bored Pile for PDA Test





Section 3

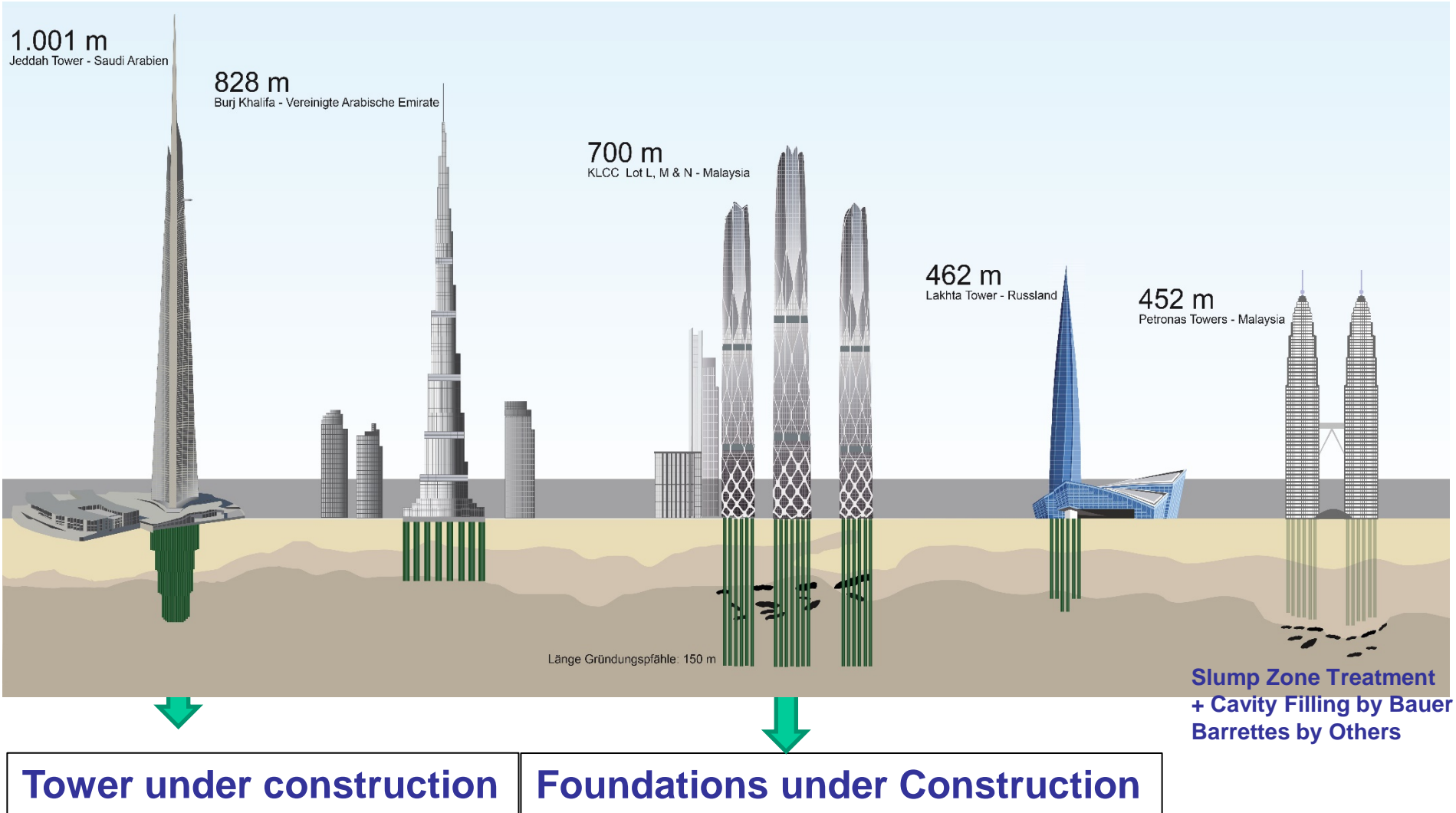
DEEP PILES

Bored Pile Foundation for KLCC Lot L&M
A World Record in the Making



The highest Buildings in the World on Bauer Foundations

Deep + Large Diameter Bored Piles by Bauer



The KLCC Developments with Twin Towers and Park



KLCC (Holdings) Sdn Bhd (KLCCH) is not embarking on the construction of a mega project, dubbed "Tower M" which a news report stated would be 145 storeys high. Read more at <https://www.thestar.com.my/business/business-news/2018/07/18/klcc-holdings-says-no-plans-for-mega-skyscraper-tower-m/#m7d2VCYplxPxtxyh.99>

The Bored Pile Foundation for the KLCC Lot L&M Towers

A World Record in the Making

**Bored Piles diameter 2.5m
up to a depth of 150m**



Site Location





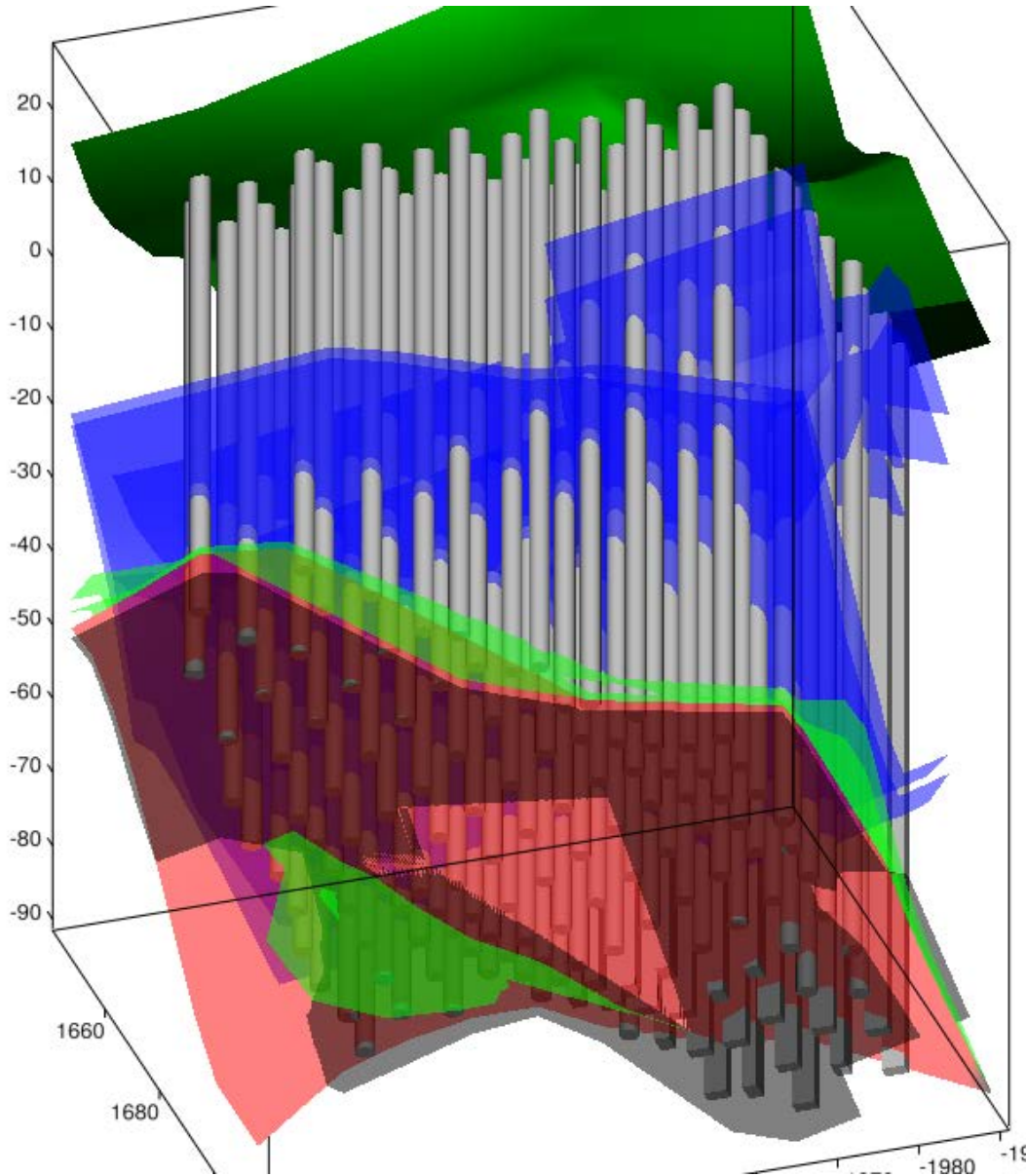


KLCC Lot L&M

Bauer's Principle Scope of Work

- Main Contractor/Client** : **Arah Moden Sdn Bhd (Company of KLCC Holding)**
- Consultant Engineer** : **Arup & LERA Sdn Bhd**
- Scope of Works** :
- **Construction of 225 nos. of Bored Pile, 2.0m and 2.5m diameter drilling depth up to 150m**
 - **Temporary utility diversion involved TNB cables storm water drain, sewerage pipe, Telecom cables, Water and Gas pipes**
 - **To carry out existing structure monitoring and geotechnical instrumentation monitoring works**
 - **Dilapidation survey and Site monitoring works**
 - **Diaphragm Wall 7,524 m² (209m) , thickness 1m, depth 33m to 39m**
- Construction Period** : **30 March 2018 – 30 August 2019**





Ground Conditions

Green: Top of the first hard Kenny Hill layer

Blue: medium dense Kenny Hill in-between two blue planes

Yellow: Slump-Zones over the rock layer

Red: Limestone-Surface (regardless if competent or not, just the top surface as per SI)

Grey / Black: Competent Rock level as per SI



Bauer BG 48 + BG 72 The Biggest Rotary Kelly Drilling Rigs in the World

BG 48:

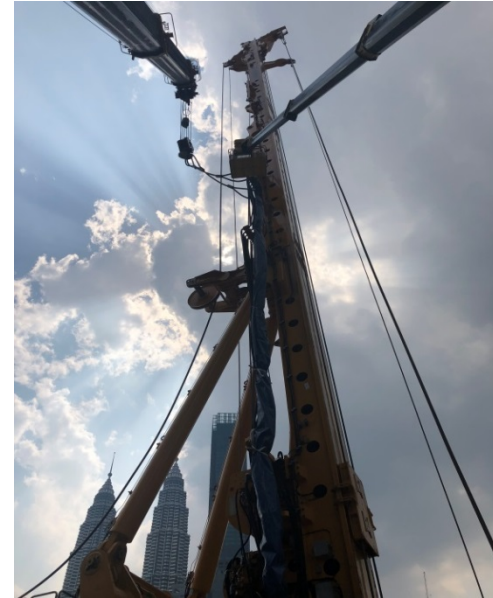
Mast Height	36 m
Main Winch	60 to
Kelly 5-fold Lockable	
Drilling Depth	125 m
Max diameter	3.5 m
Operating Weight	270 to

BG 72:

Mast Height	43 m
Main Winch	60 to
Kelly 5-fold Lockable	
Drilling Depth	150 m
Max diameter	4.6 m (with sledge adaptor)
Operating Weight	280 to



Transport and Erection



Transport:

10 nos. of Heavy Transports for the dismantled BG

Erection:

10 days erection and assembling of the BG 72

1 no. of 140 to Mobile Crane

1 no. of 360 to Mobile Crane

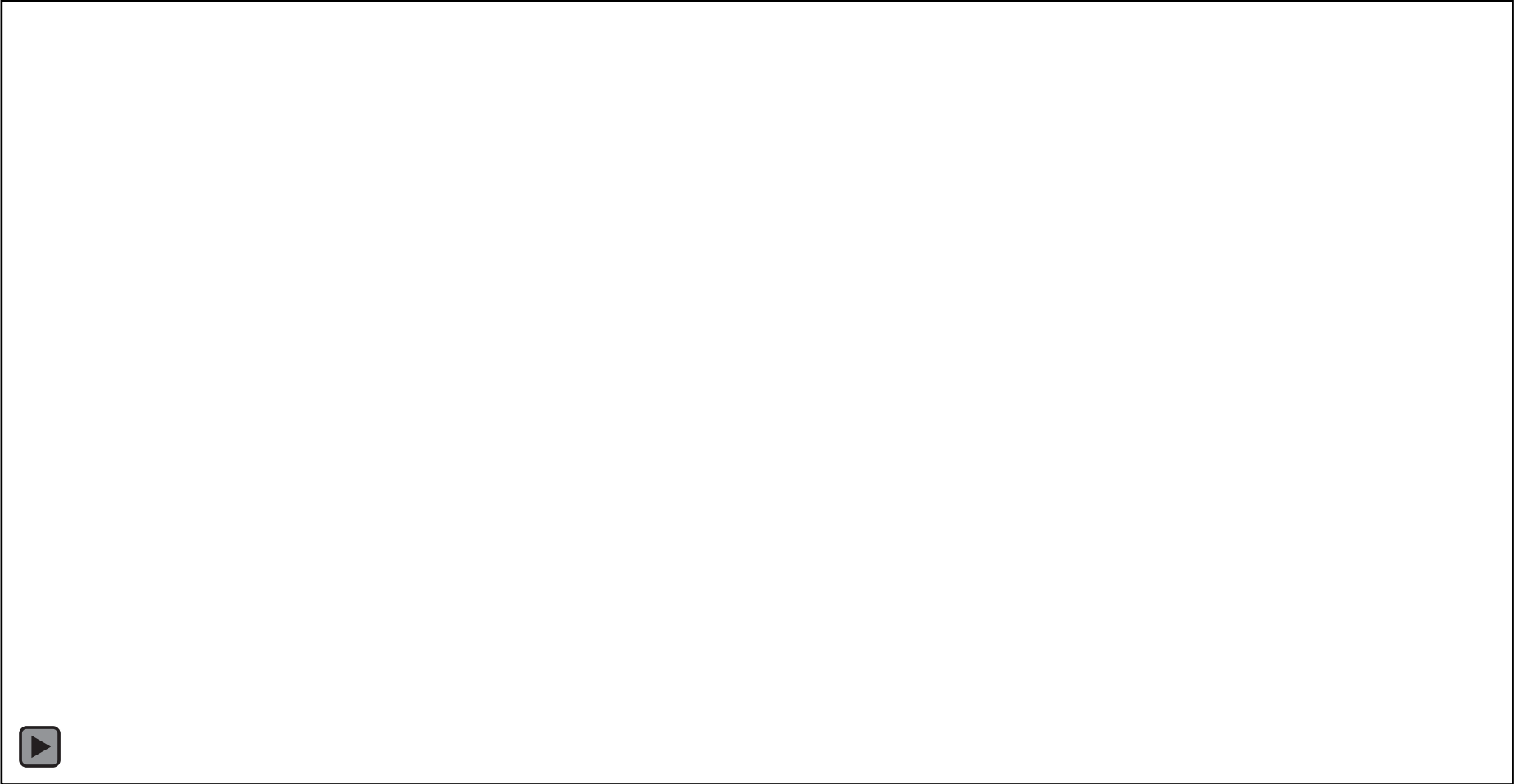
5 special Mechanics + 1 German Mechanical Engineer

Lifting Box for Mechanic to reach 35m Height





Transport and Erection



Podium Piles Completed

Test Pile 115m Deep Completed



Details of test pile:

1. Drilling Time: 46 hrs for 115 m
2. Total Concrete Volume: 480m³
3. Cage Details:
Total 77 ton (Dummy Cage - 1.5ton; Top Cage - 28.8 ton; Middle Cage1 - 19.2 ton; Middle Cage 2 - 18.3 ton; Bottom Cage - 9.3 ton)
4. Upper O-Cell – 4 ton; Lower O-Cell - 2.1 ton
5. 8.3 hours (casting time; 0130 hrs-0947 hrs 20th September 2018)
6. 3 hrs Slump Retention; 8-10hrs Setting Time

Test is completed. Deep Working Piles commence.

Lifting of Test Pile Cage With 2 Osterberg Cells



Lifting of Cage for Test Pile



Concreting of Test Pile





Section 4

TECHNICAL CHALLENGES DERIVING FROM MEGA PILES

- Borehole Stabilization
- Concrete Mixture
- Verticality Measurements



Borehole Stabilization

Polymer instead of Bentonite

Advantages:

- **Smaller Plant**
- **Lower Density**
- **Better Frictional Behavior**
- **Faster Sedimentation**
- **Faster Recycling**

Caution: Selection of Suitable Recipe
Need Experienced Supervision



Concrete Mix and Supervision

In Urban Environments the casting time can be up to 10 hours.

- **Stable Mix (beware of seggregation)**
- **Workability over Time**
- **Flowability over Time**
- **Setting Time**

Caution: Slump Test of arriving Trucks alone may not be Sufficient

Guide to Tremie Concrete (2018) Guide to Support Fluids (2019)c for Deep Foundations

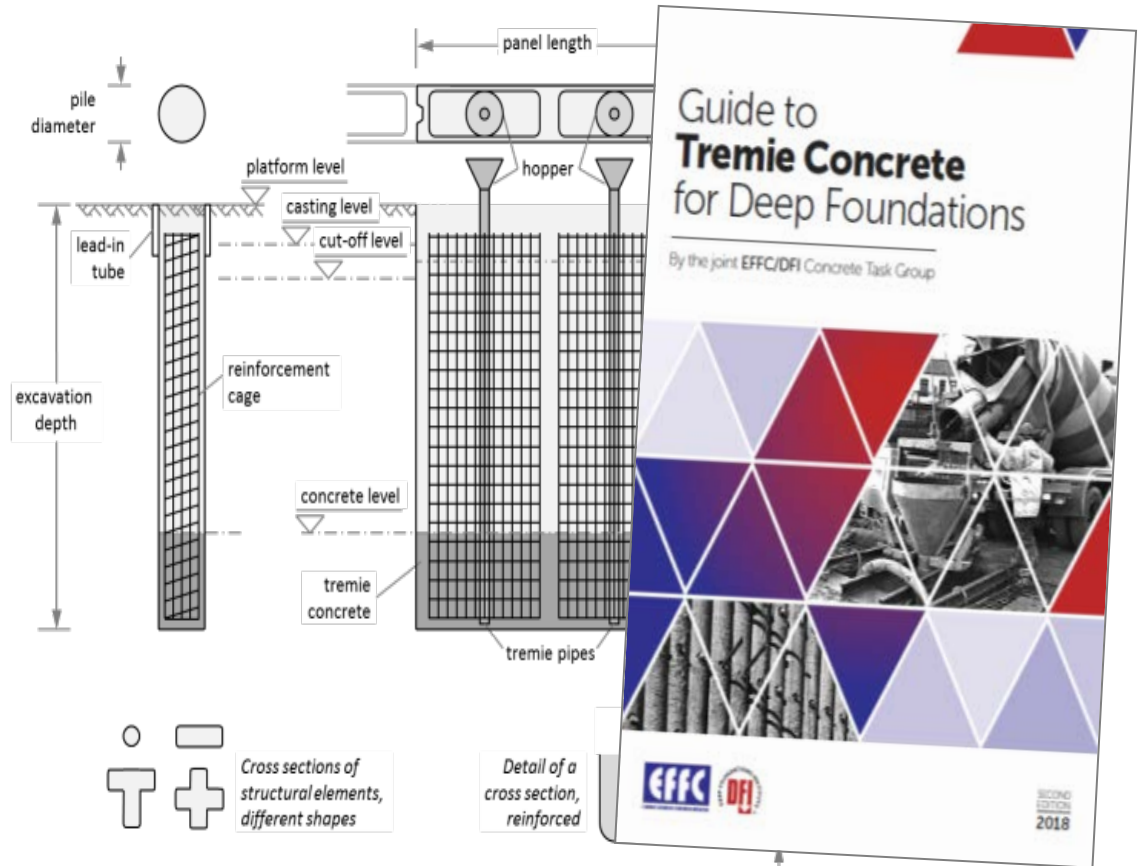


FIGURE 01 EXAMPLES OF DEEP FOUNDATIONS



Verticality Measurements

- For the Lot L&M deep piles, the Engineer specified Sonic Caliper Tests (or suitable)
- Patented System by Fugro
- No experience of measurements for such deep piles
- Wave Systems which rely on Velocity Measurements are being influenced among other issues:
 - Density of Stabilization Fluid
 - Sand Content



Verticality Measurements

Sonic Caliper

- Influence on Accuracy may not be fully understood for Piles with depth in > 110m
- Few piles have been tested around 100m

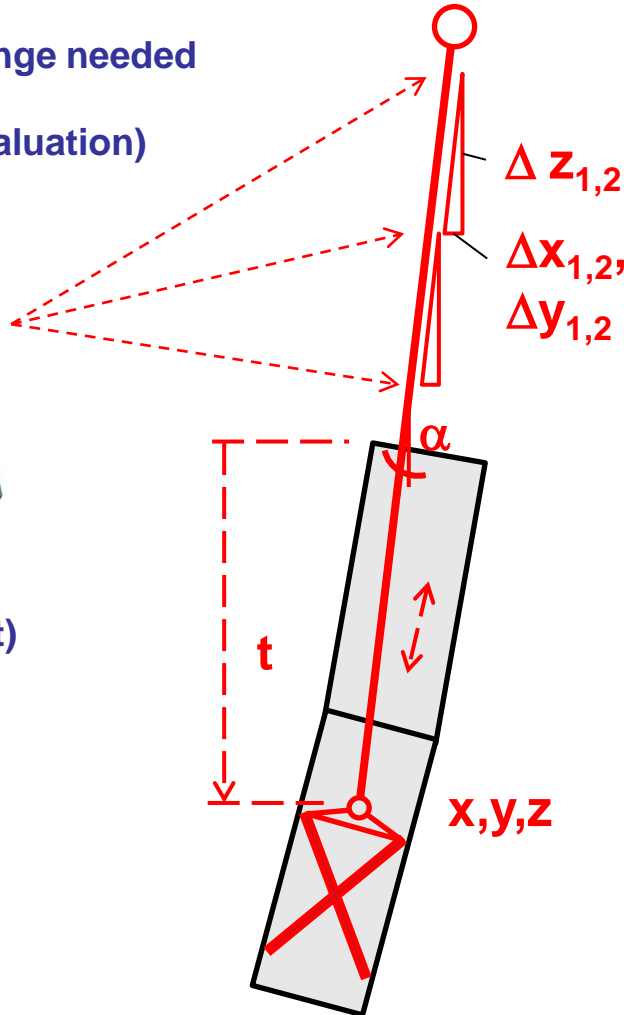
Recommendations

Use a Mechanical and Optical System as in Alternative such as:
DIS – Drilling Inclination System for Deep Shafts

DIS – Drilling Inclination System for Deep Shafts

Advantages

- Fast Survey, no slurry exchange needed
- Quick result (automatized evaluation)
- Direct, transparent recording
- Accuracy:
 $\pm 20 \text{ mm} +$
 $0.03\% \times \text{depth} + 20 \text{ mm}$
 (tolerance of cylinder in shaft)



Set-up

- Tachymetric System
- Trained Surveyor





Thank You!

We wish to thank the Organization Committee for giving us the opportunity to present this presentation. Special thanks are extended to Prof. Dr. Masyhur Irsyam and Dr. Didiek Djarwadi, for inviting us to prepare this presentation.

Bauer thanks also their Clients in Indonesia, Singapore, Hong Kong, Malaysia and throughout the world that we were given the trust to execute their difficult foundations. Particular thanks are being expressed to KLCC, Cantilever, Acre Works and Ekovest as our valued Clients who gave us the trust to carry out the foundation work for the projects mentioned in this presentation.



**Thank you very much for your
attention**

PT Bauer Pratama Indonesia
A member of the

**Bauer SE Asia Pacific
Network**

**Your reliable Partner as
Foundation Specialist**