

# **Ground Improvement Trials**

## **Problem Statement**

Existing ground improvement methods used to engineer a thicker non-liquefying soil crust to support TC3 foundation designs and/or used for Category 8 land damage repairs are proving to be expensive and in many cases not cost effective. The reasons are not fully understood, but the following bullet points outline possible explanations:

- Practicalities of apply the methods on individual residential sites
- Practicalities of working below the ground water table
- Consenting requirements
- Limited supply of contractors and construction plant set up in Christchurch to do this type of work
- Limited supply of residential ground improvement projects

## Project Objectives

- Expand the number of ground improvement options available by finding alternative ground improvement methods which can be applied which are:
  - Cost effective
  - Practical to construct on residential properties
- Understanding the constraints of each method (e.g. vibration characteristics, heave effects, etc)
- Certainty of the effectiveness of the ground improvement work to allow engineers to be less conservative in their ground improvement design
- Development of appropriate ground improvement verification test methods
- Involve consent authorities so they can better understand what they are consenting and enable them to develop more appropriate consent conditions
- Education for non-engineering community of what ground improvement work involves, how it works, how it will be practically constructed on properties, effects, and expected future performance

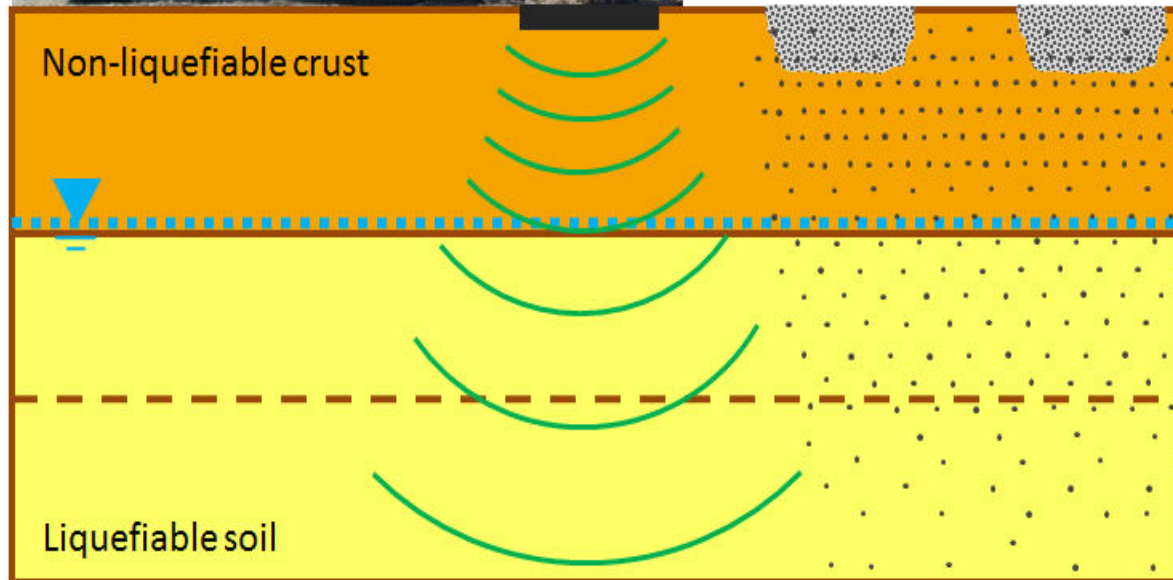
## **Ground Improvement Methods**

- RIC              Rapid Impact Compaction
- RAP             Rammed Aggregate Piers
- LMG            Low Mobility Grout
- Horizontal Permeation Grouting which has now morphed into Horizontal Mechanical Mixing

# Rapid Impact Compaction (RIC)



H<sub>1</sub> (Post-Improvement)



Large improvement  
in soil strength

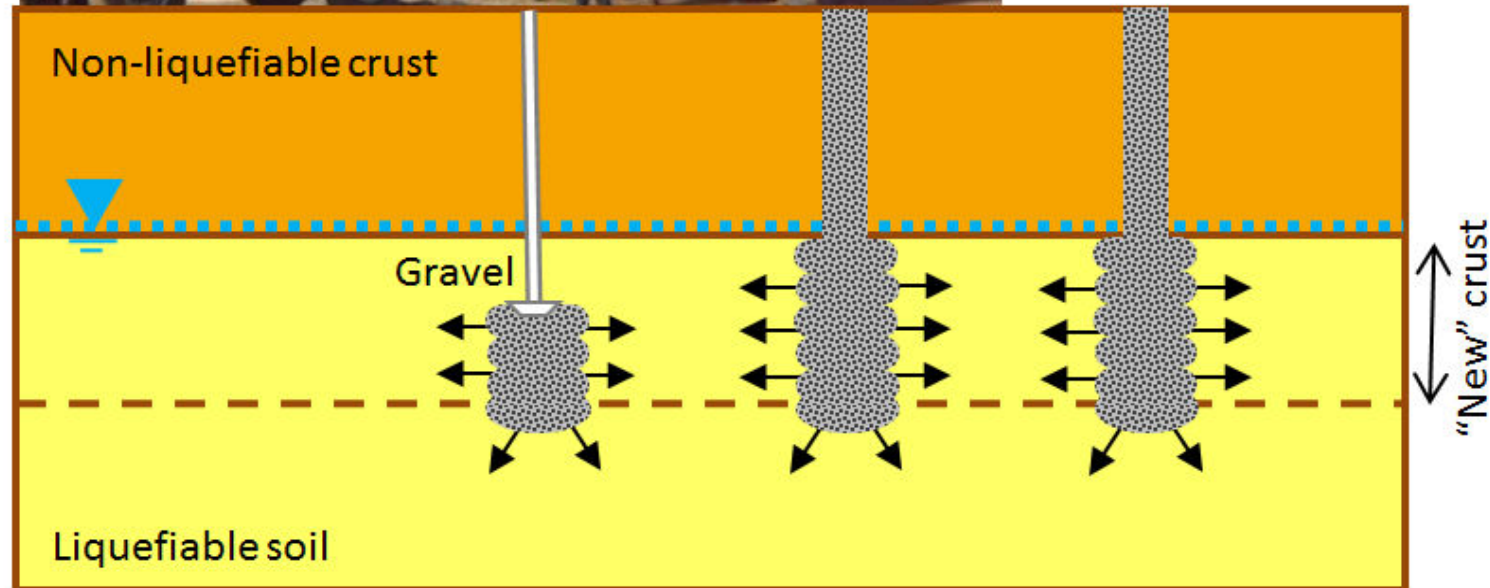
Target improvement  
in soil strength

Moderate improvement  
in soil strength down to  
several metres depth

# Rammed Aggregate Piers (RAP)



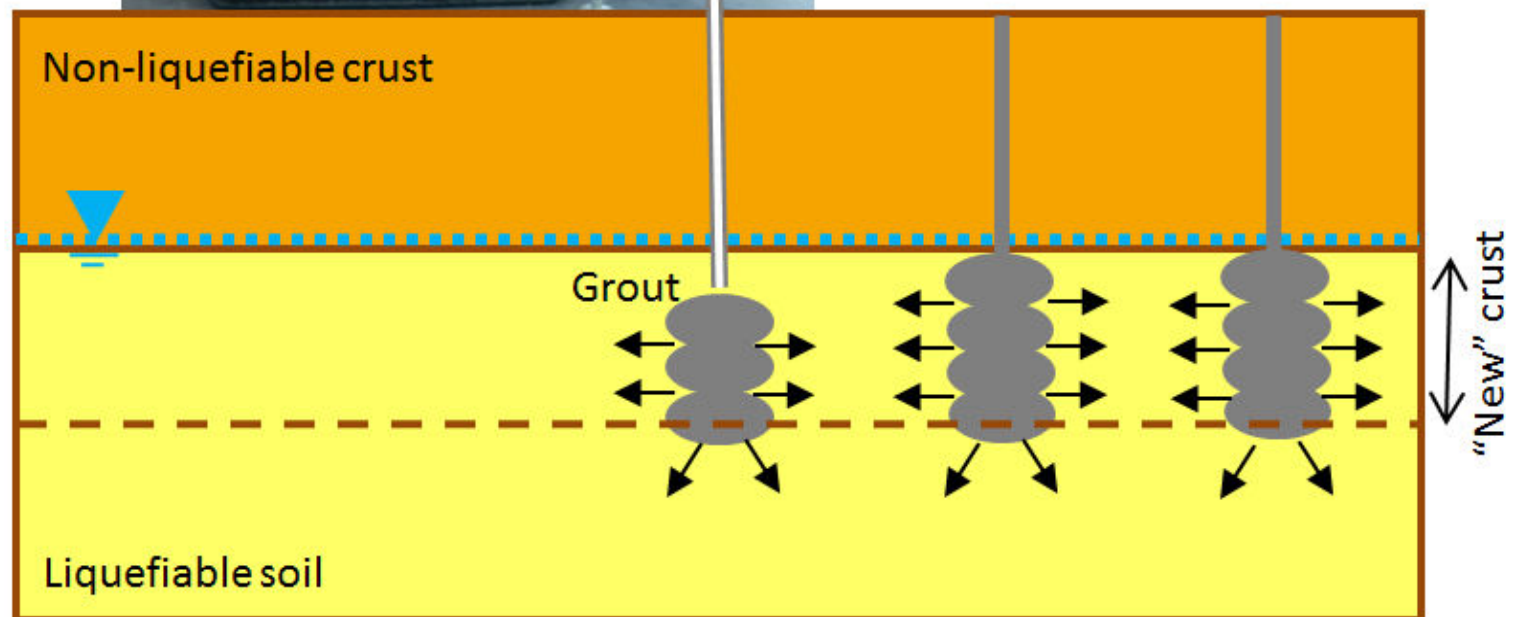
H1 (Post-Improvement)



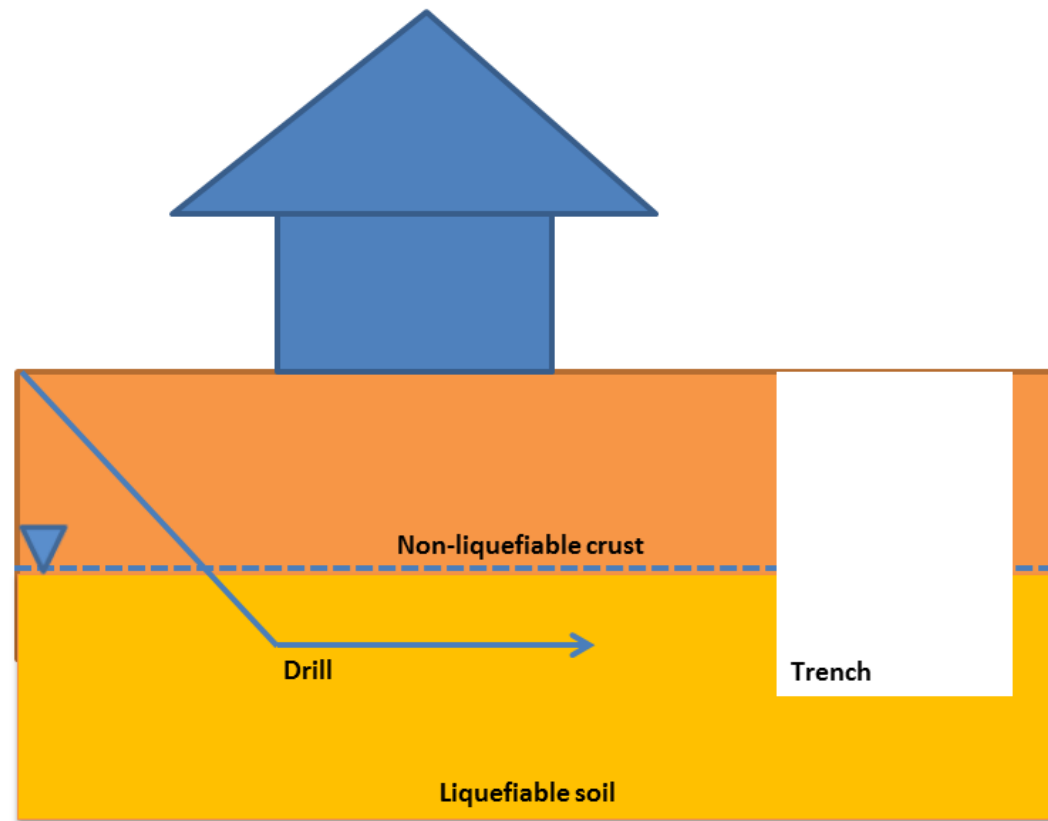
## Low Mobility Grout (LMG)



H<sub>1</sub> (Post-Improvement)

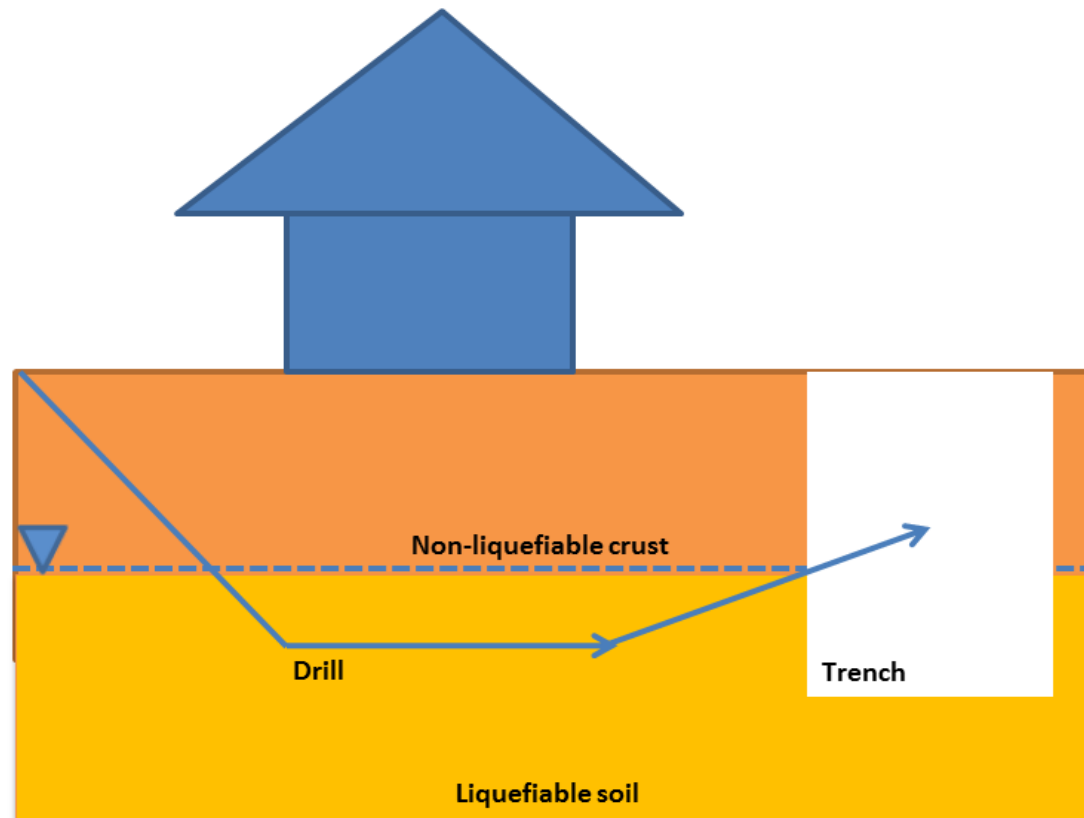


# Horizontal Mechanical Mixing

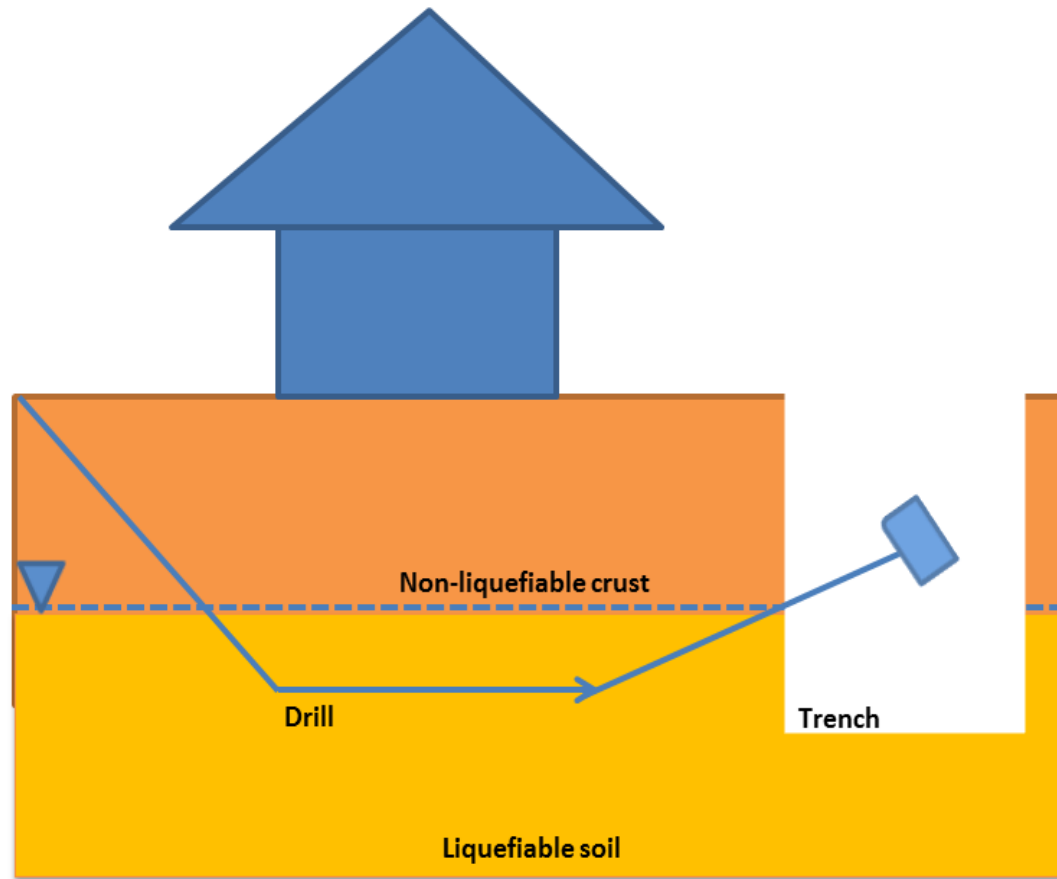




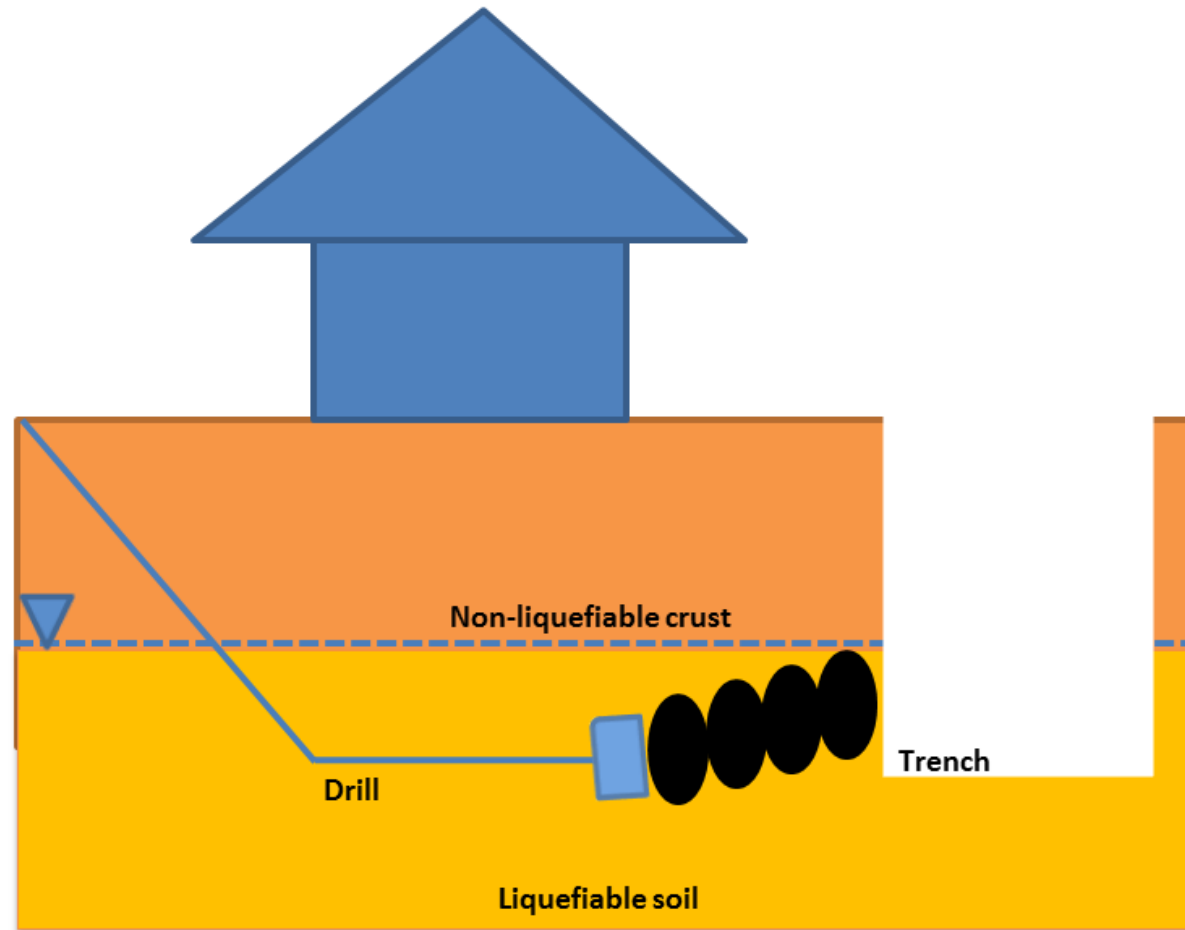
# Horizontal Mechanical Mixing



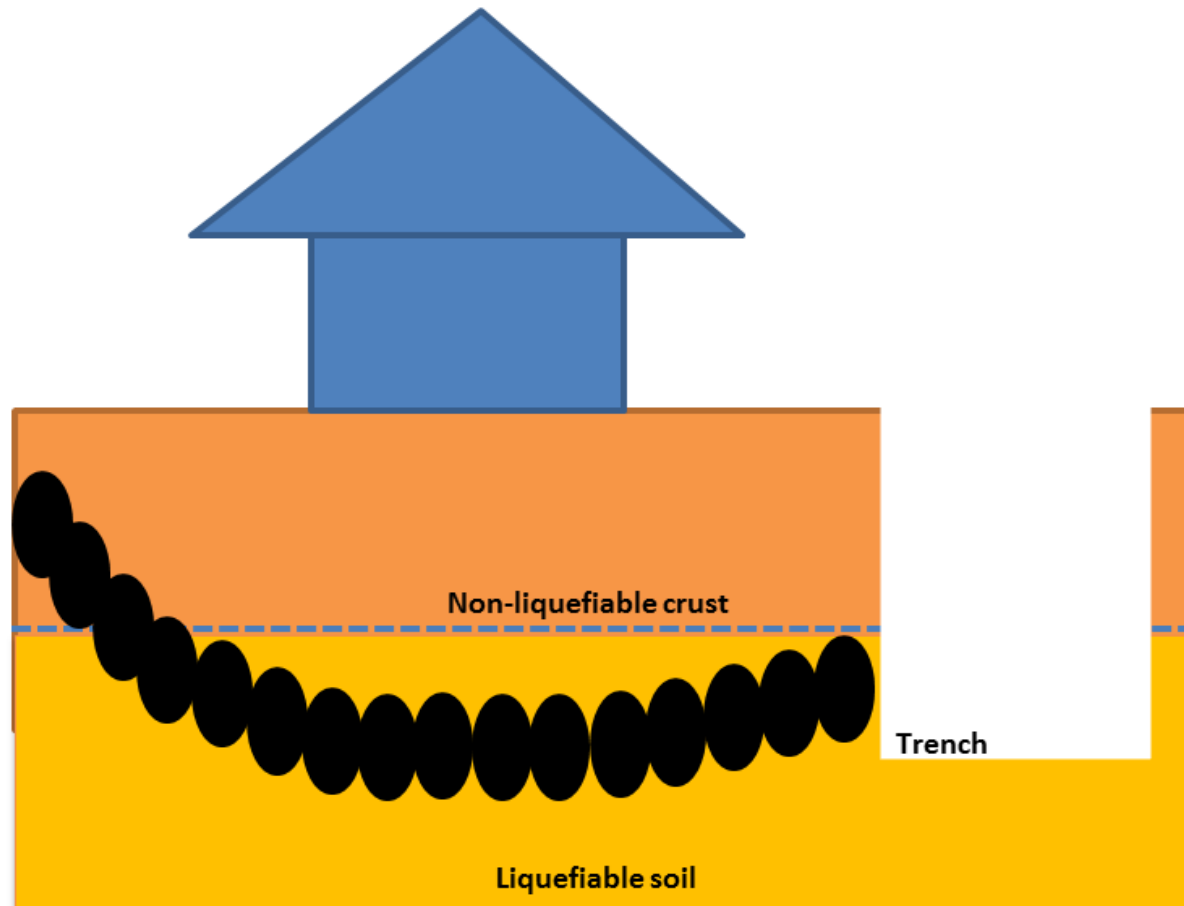
# Horizontal Mechanical Mixing



# Horizontal Mechanical Mixing



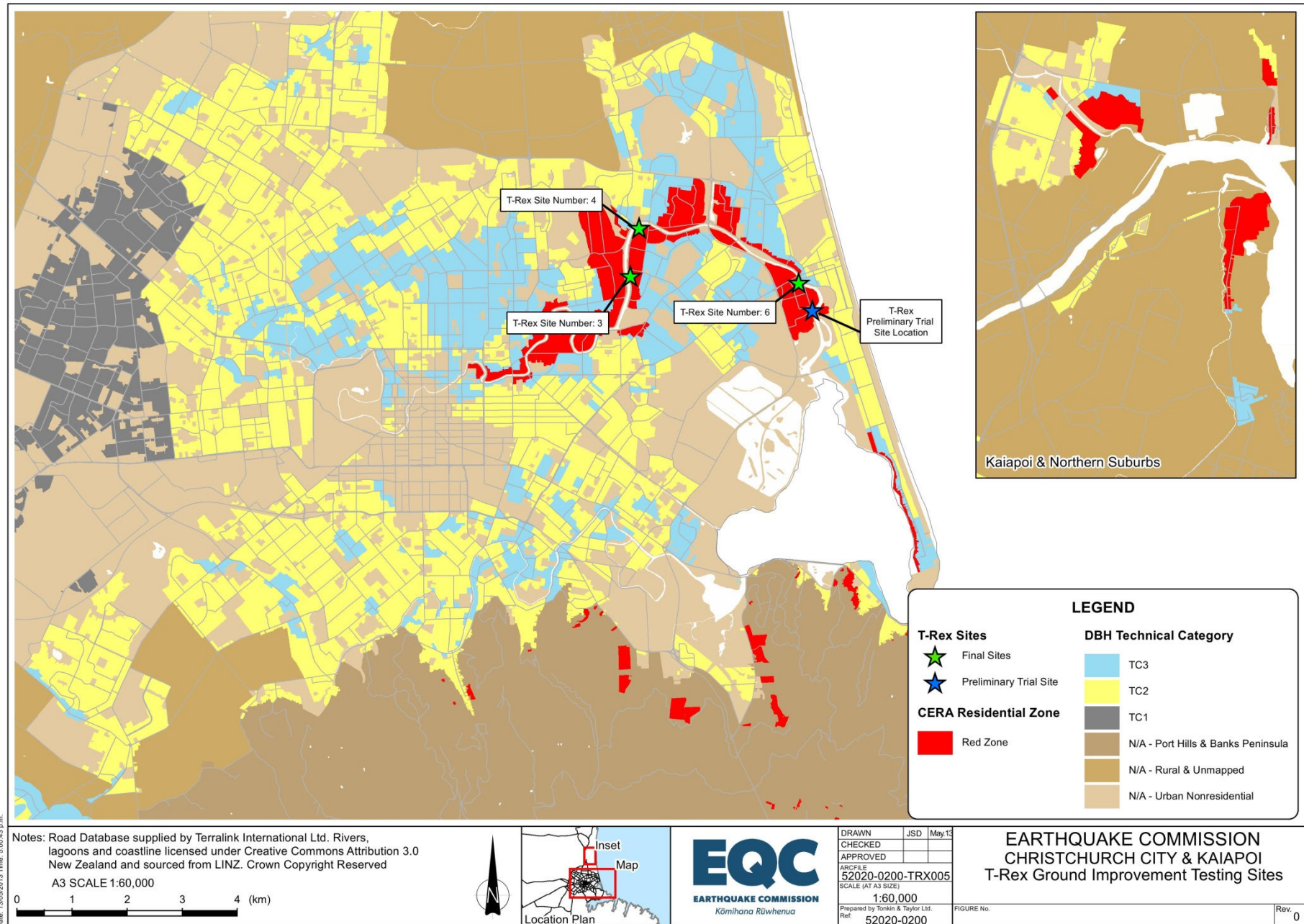
# Horizontal Mechanical Mixing



## Project Outline

1. Identification of potential sites for ground improvement trials
2. Geotechnical characterisation for site selection – so that the trials are undertaken in areas with soil characteristic which are representative for 90% of the TC3 residential properties
3. Consenting and land owner approval
4. Site selection and detailed site characterisation
5. Construct the ground improvement methods in practice areas while varying the spacing, depth, energy levels, cement mixtures etc with pre and post CPT testing
6. Evaluation of selected methodologies (i.e. selected spacing, depth, etc) for each improvement method
7. Construction of specified ground improvements in the panel areas
8. Post improvement testing – CPT, S-Wave and P-Wave and SWS
9. T-Rex testing
10. Test pitting through the T-Rexed ground improvements to visually inspect what was tested
11. Reporting

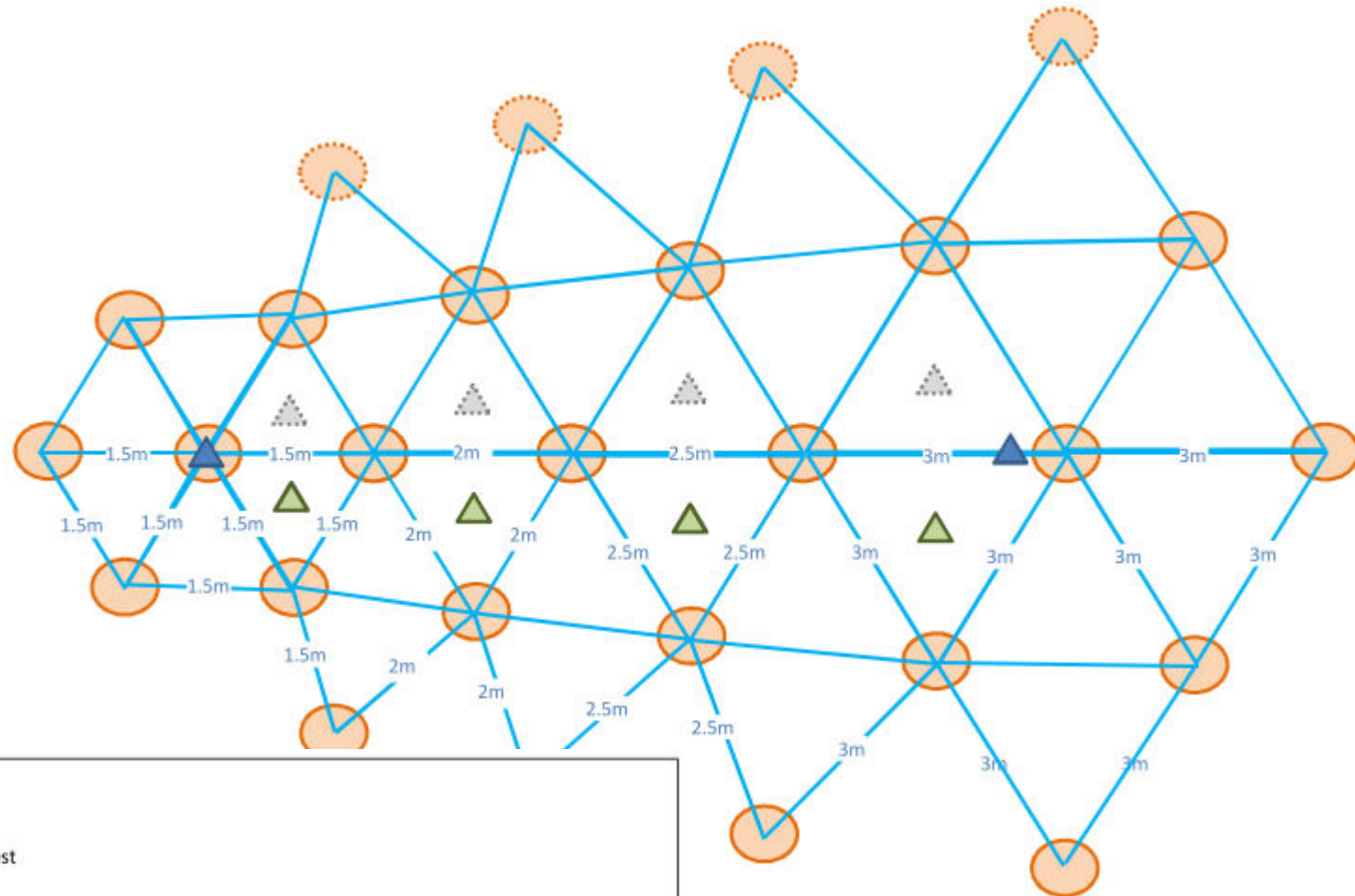
# Ground Improvement Trials – Final Site Selection







# Ground Improvement Spacing Trials

3 methods x 3 areas x 4 spacings.

Pre improvement and post improvement (14 day and 28 day) CPT



## LEGEND

-  Pre-improvement CPT test
-  Post-improvement CPT test (14 days after construction)
-  Rammed Aggregate Pier location
-  Potential for additional CPT or aggregate pier test to improve statistical reliability

# 5m x 5m T-Rex Test Layout Plan for the Ground Improvements

## 3 Areas

- Pre Improvement CPT, SWS and S&P-wave cross hole testing
- Ground water monitoring
- Instrumentation and T-Rex testing
- Post Improvement CPT, SWS and S&P-wave cross hole testing
- Trenching and logging of as-built ground improvements

RIP



RAP



Control Panel



Horizontal Mixing

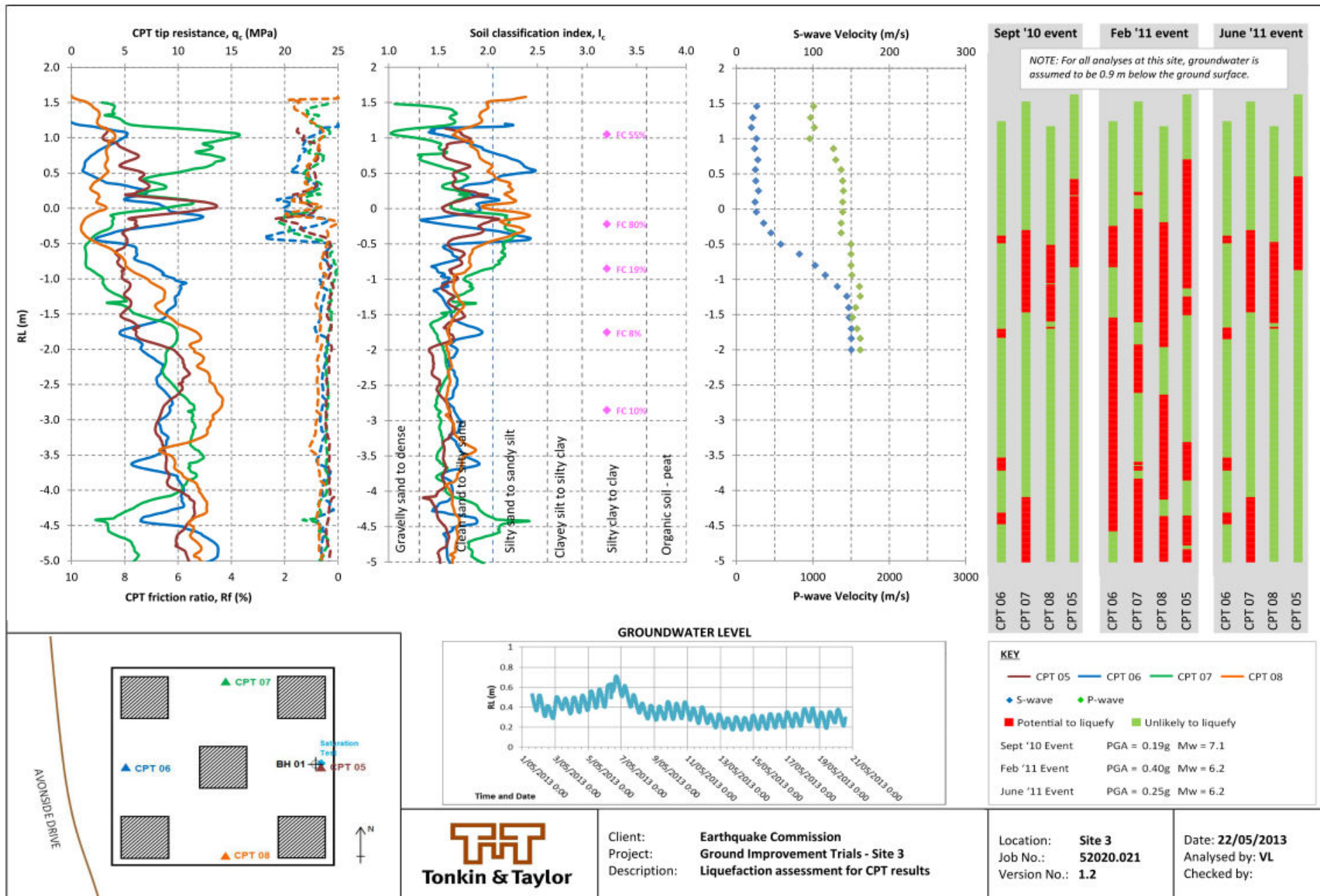


LMG

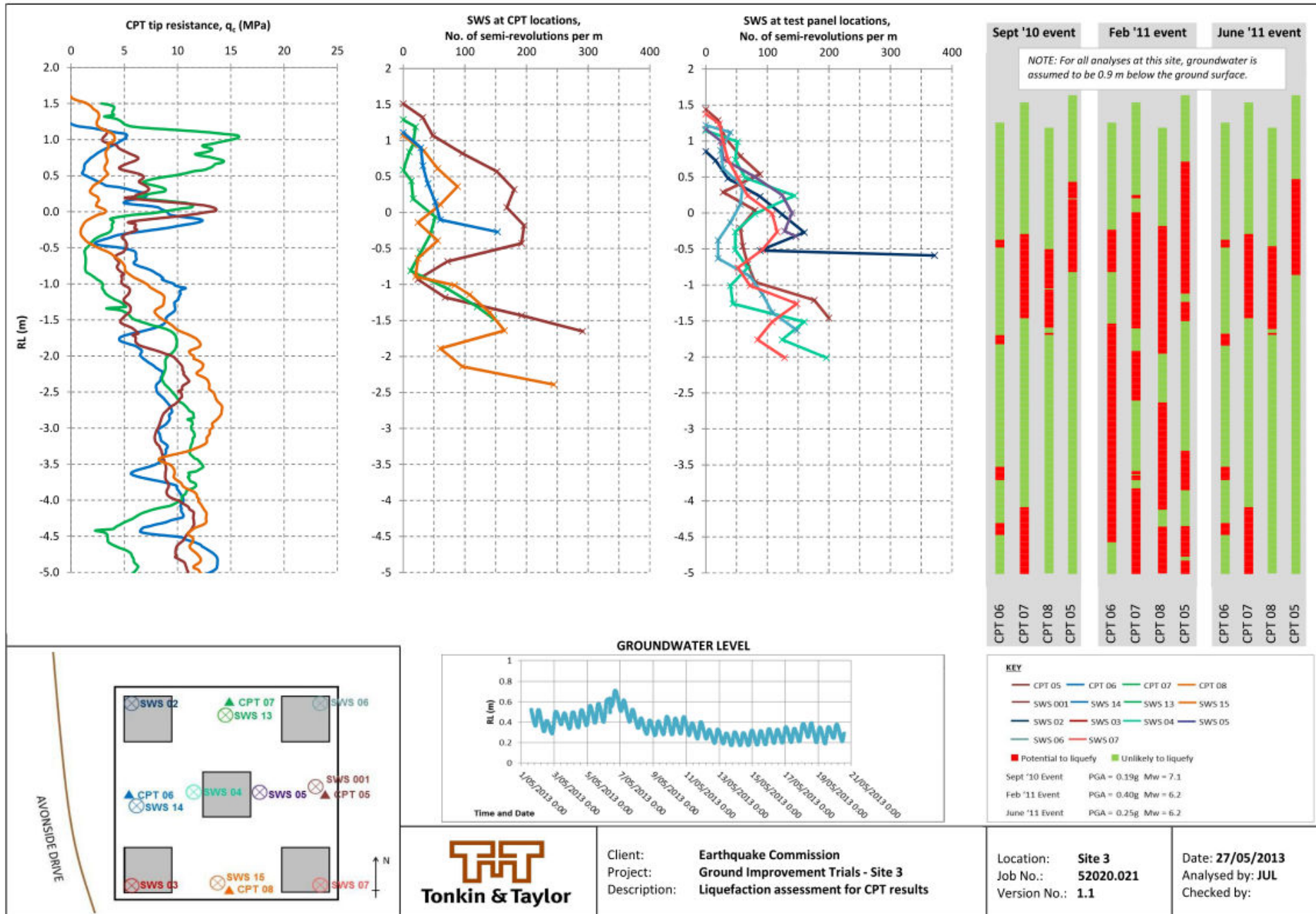




# Detailed Site Characterization – Site 3 (Wainoni) – CPT Data

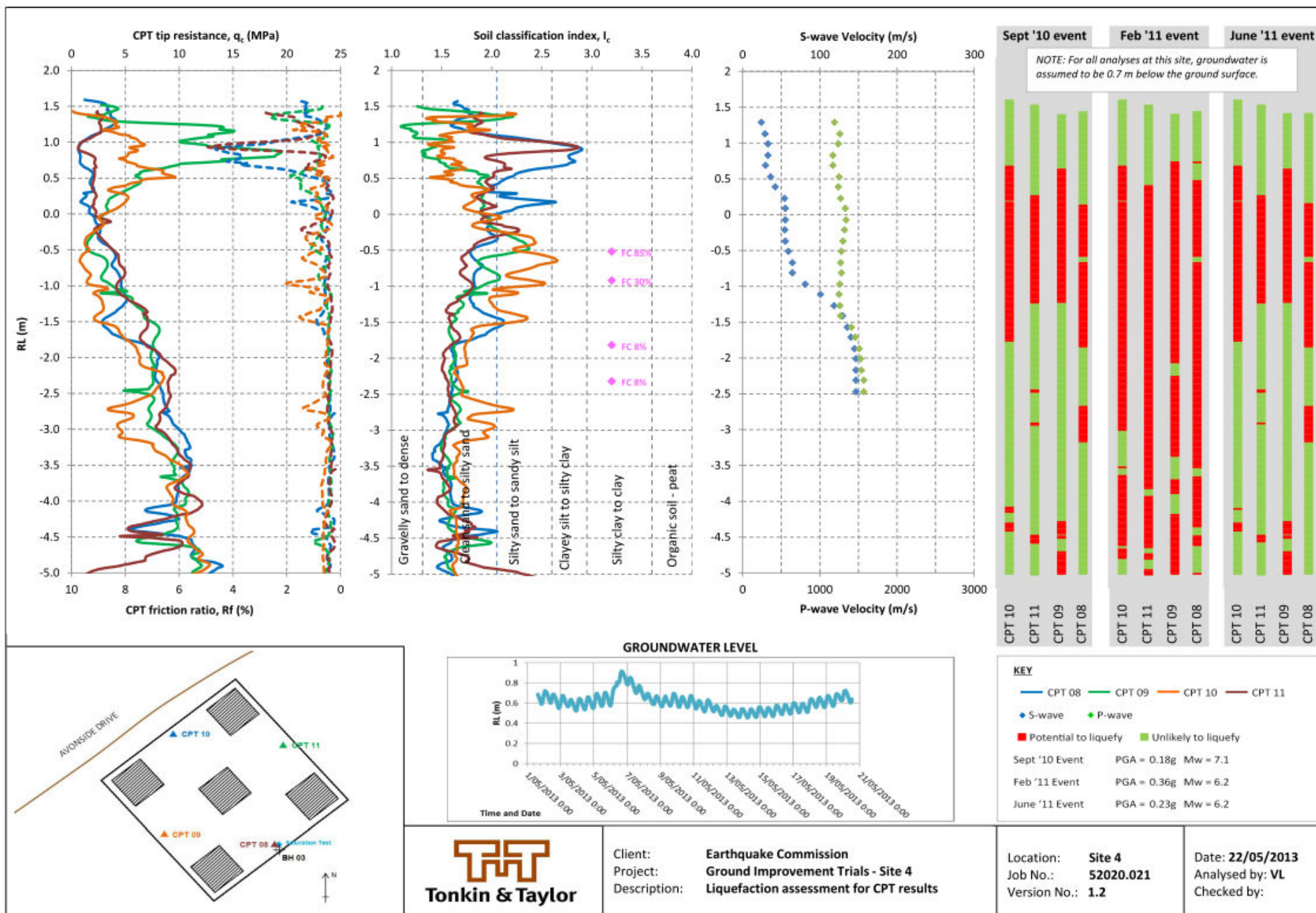


# Detailed Site Characterization – Site 3 (Wainoni) – SWS Data

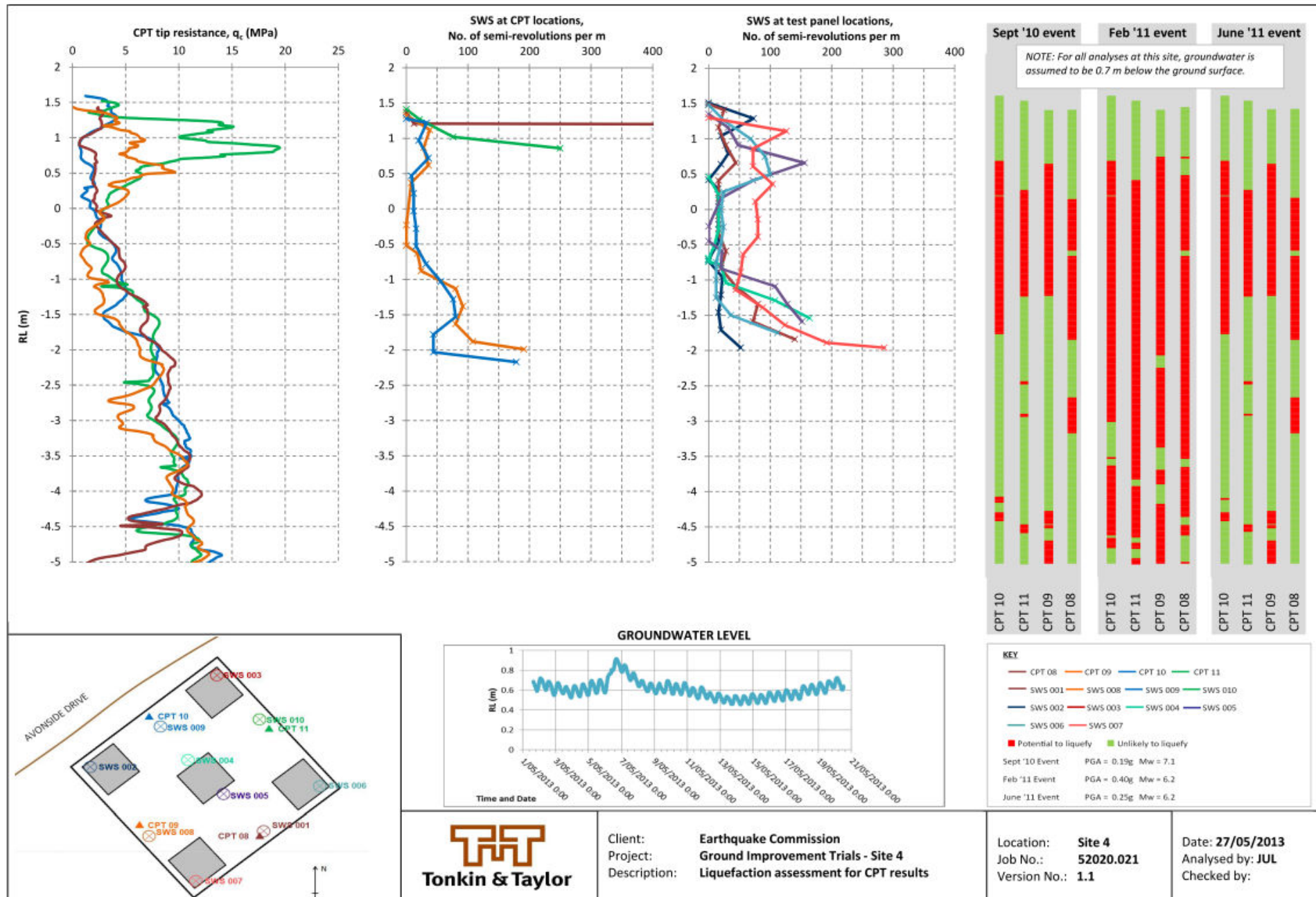




# Detailed Site Characterization – Site 4 (Avondale) – CPT Data

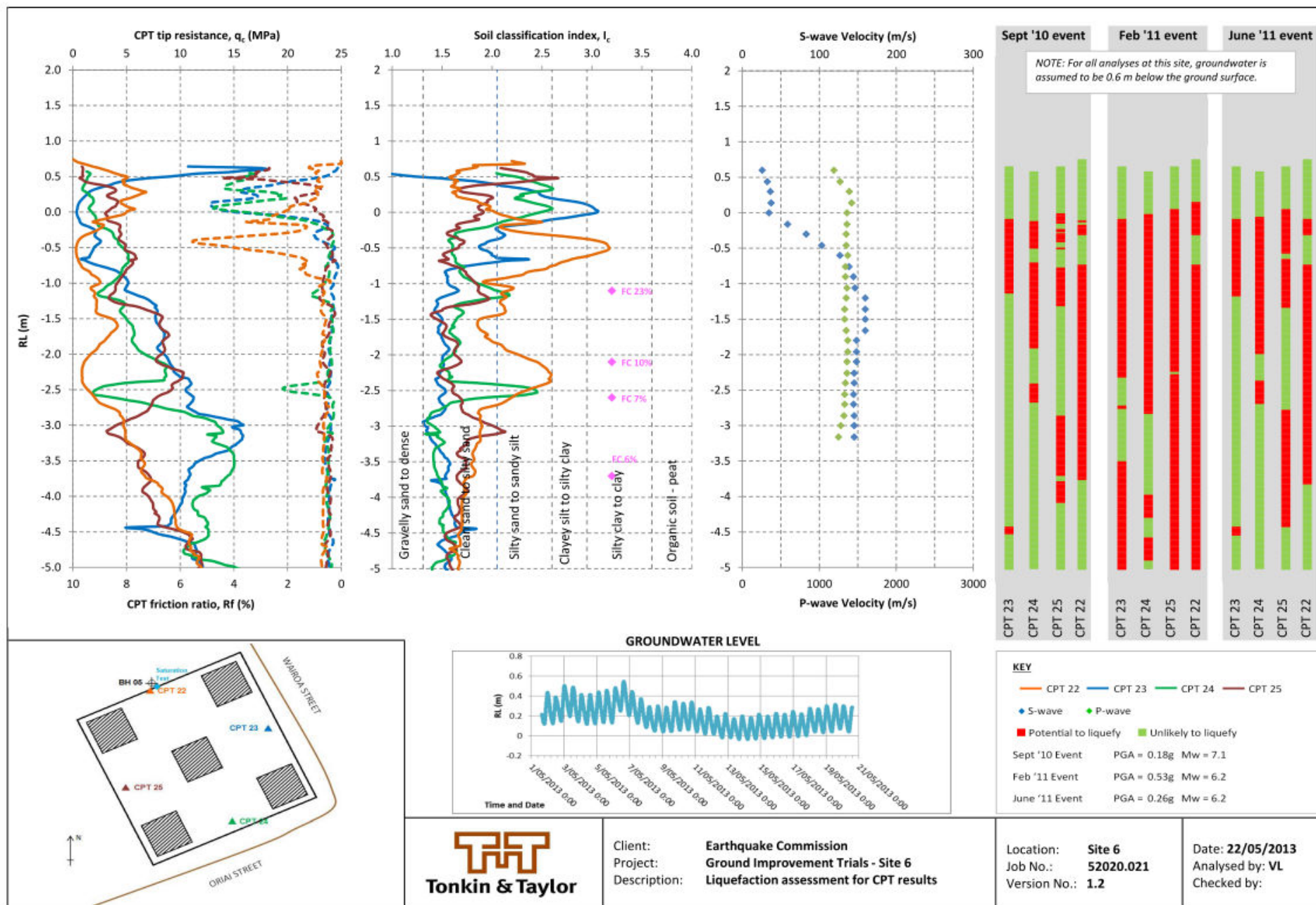


# Detailed Site Characterization – Site 4 (Avondale) – SWS Data

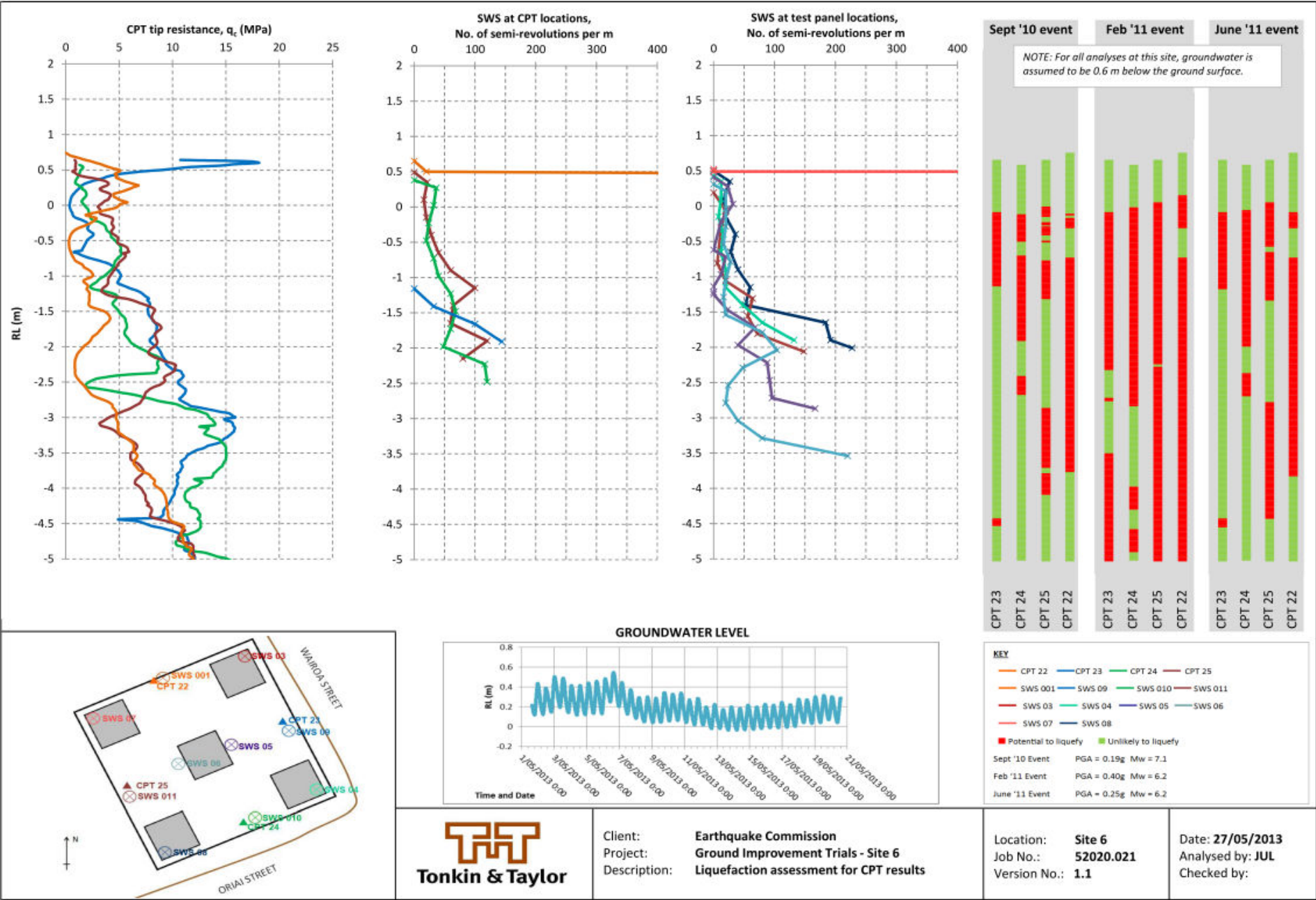




# Detailed Site Characterization – Site 6 (Bexley) – CPT Data

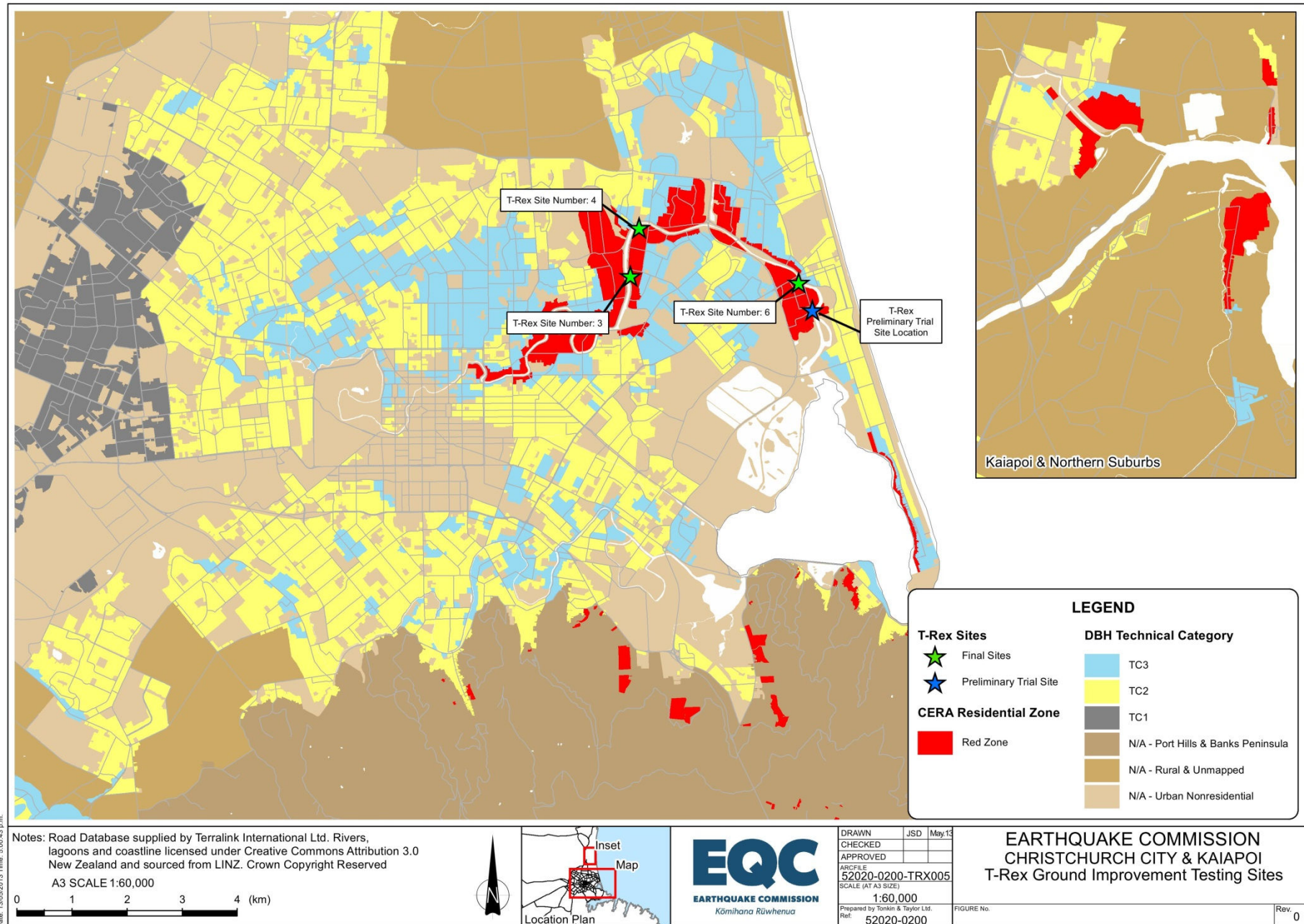


# Detailed Site Characterization – Site 6 (Bexley) – SWS Data





# Ground Improvement Trials – Final Site Selection



# 5m x 5m T-Rex Test Layout Plan for the Ground Improvements

## 3 Areas

- Pre Improvement CPT, SWS and S&P-wave cross hole testing
- Ground water monitoring
- Instrumentation and T-Rex testing
- Post Improvement CPT, SWS and S&P-wave cross hole testing
- Trenching and logging of as-built ground improvements

RIC



RAP



Control Panel



Horizontal Mixing

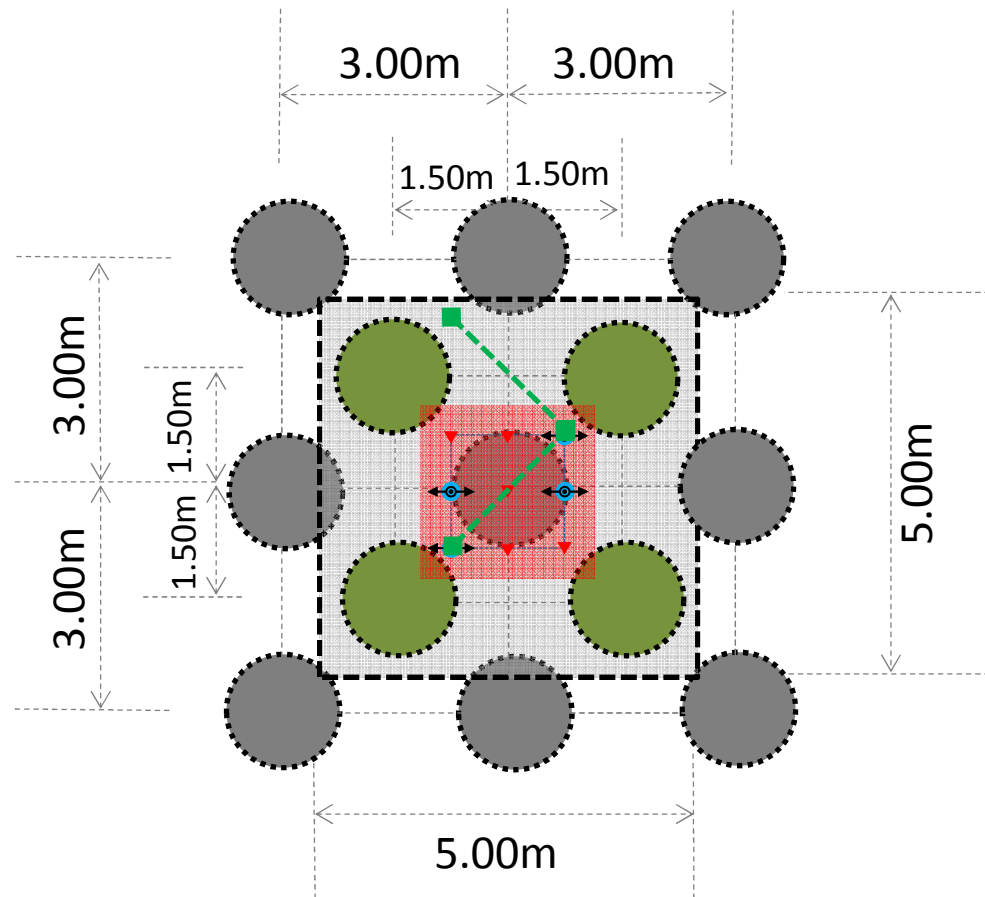


LMG



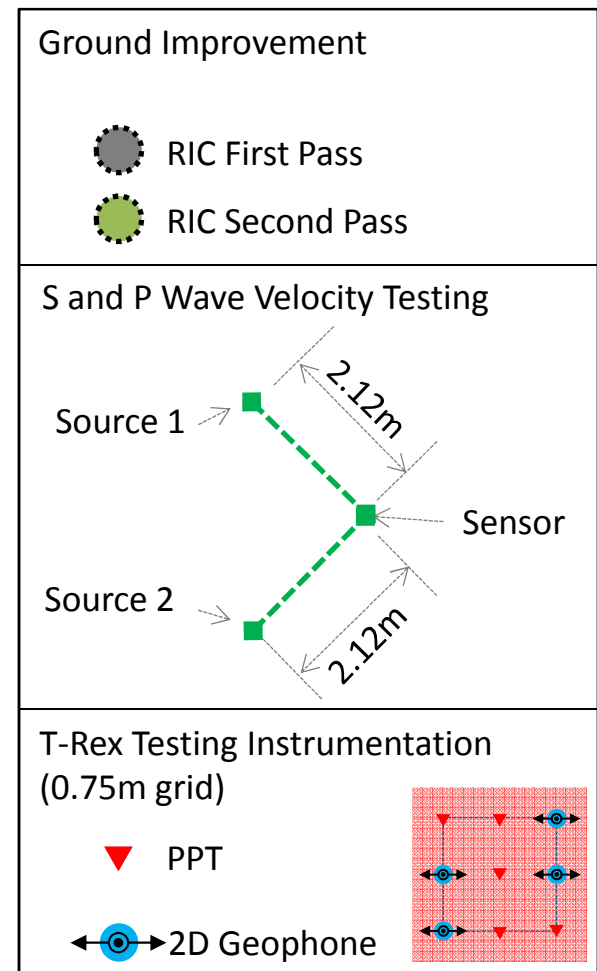


# RIC Test Panel Layout at Sites 3 and 4 with the Indicative Instrumentation Layout for a In-line Shaking Orientation

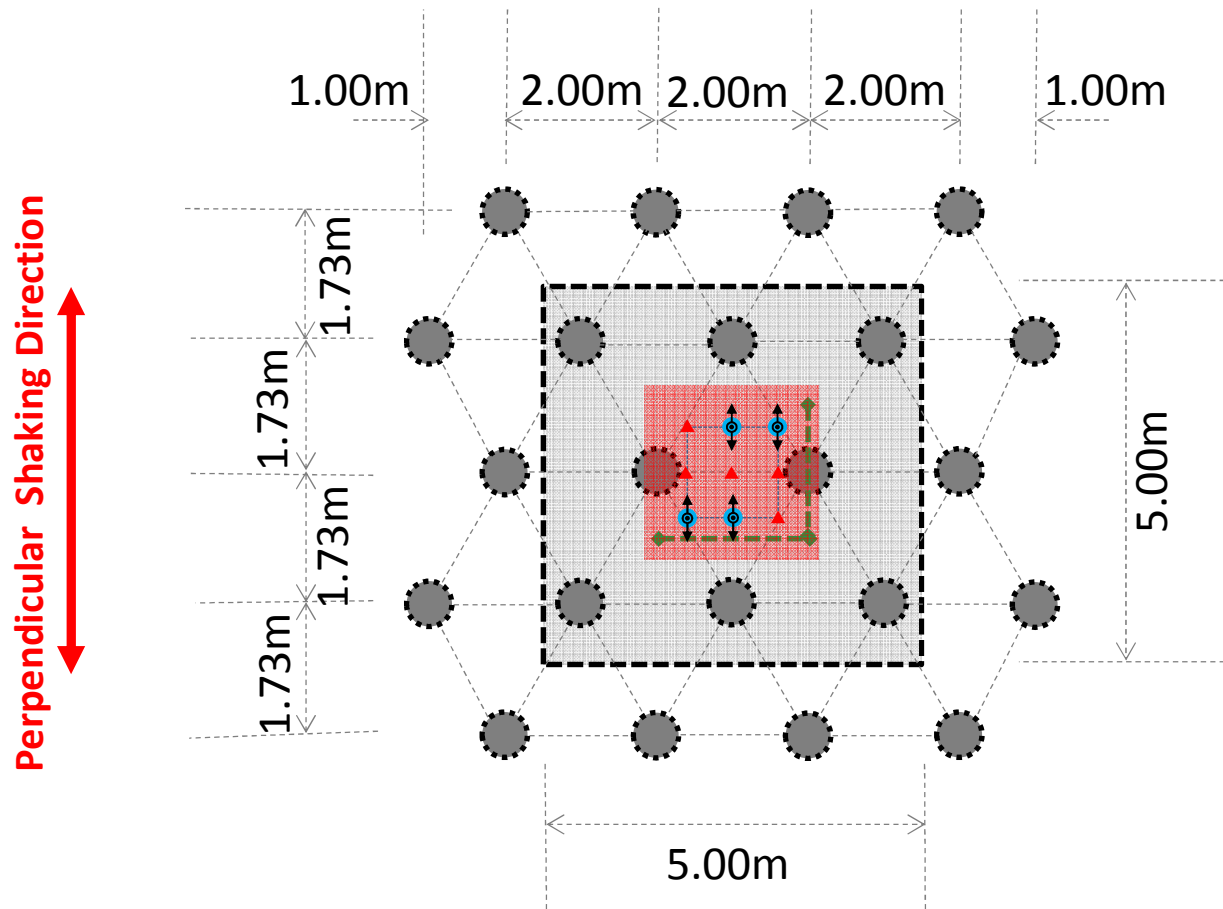


**In-line Shaking Direction**

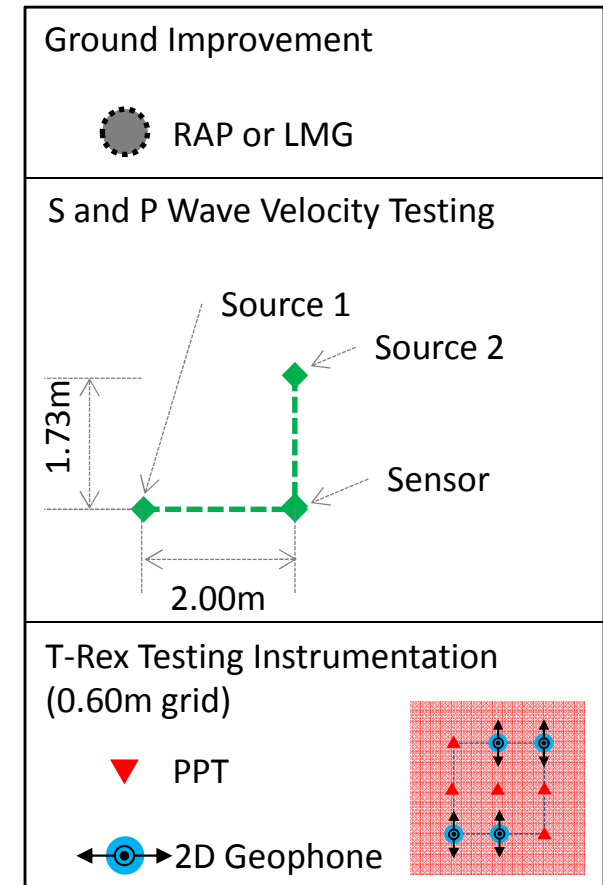
Construct RIC at 75% hammer drop height with 1.5m Dia. plate  
 Hammer until refusal or a maximum penetration of 0.5m  
 Complete the first pass, wait 60mins and then complete the second pass



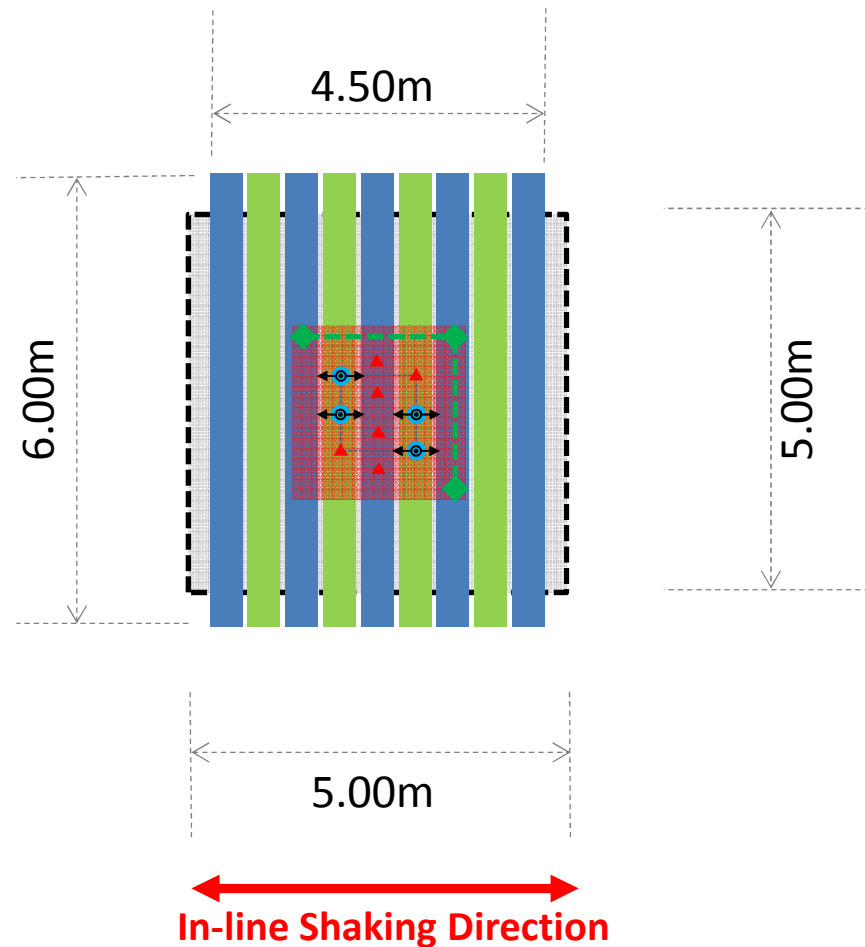
# RAP and LMG Test Panel Layout at Sites 3 and 4 with the Indicative Instrumentation Layout for a Perpendicular Shaking Orientation



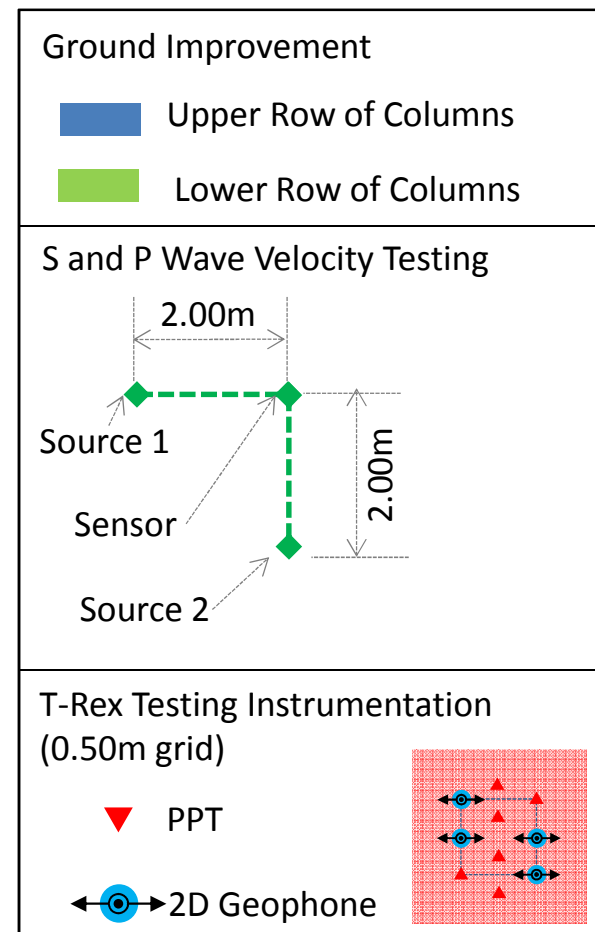
- Construct RAP and LMG columns to 4m depth from the ground surface
- Construct RAP with 100% vibration energy
- Construct LMG with the initial top grout bulb at 1.5m below the ground surface



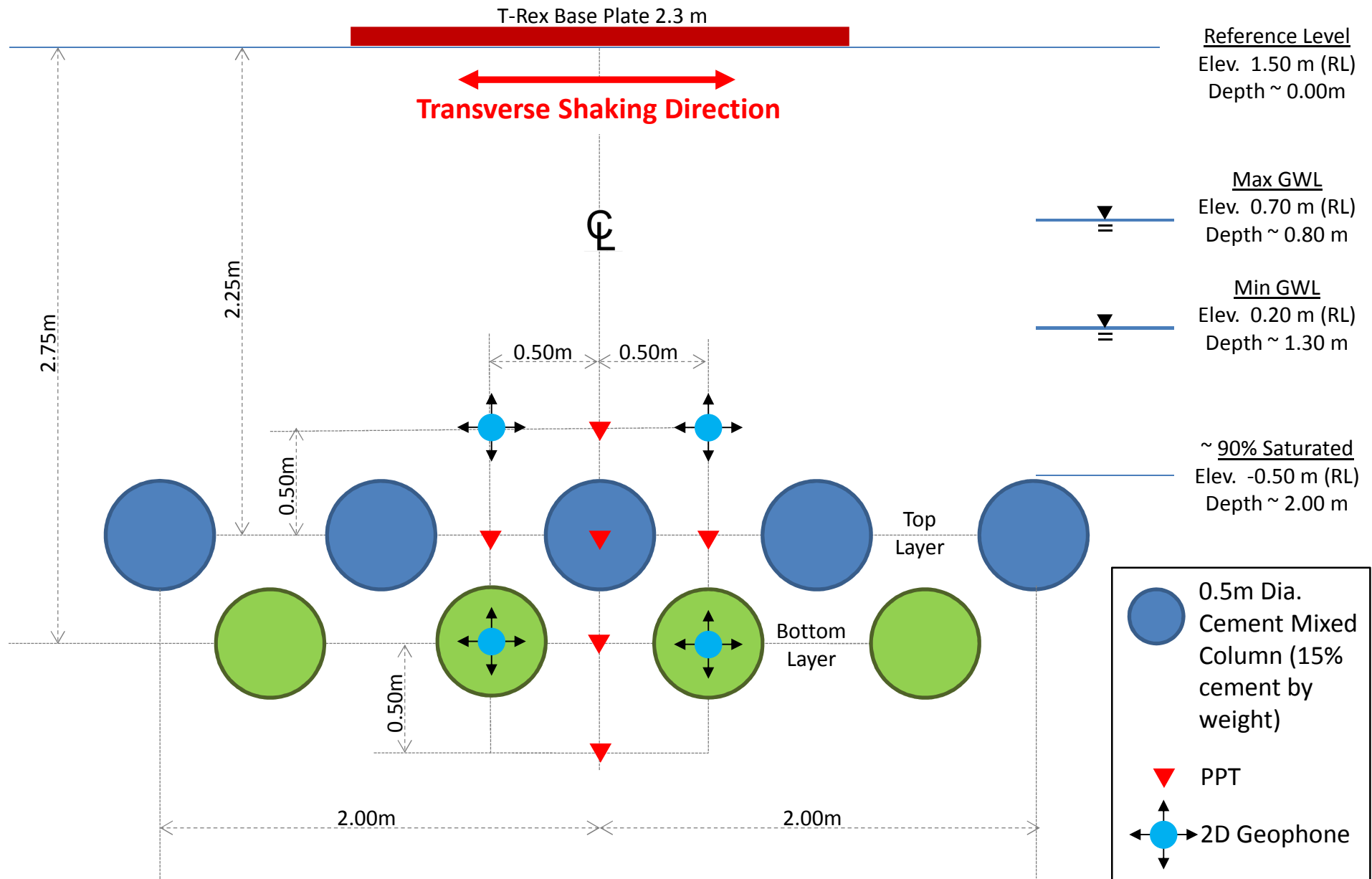
# Horizontal Mixing Test Panel Layout at Site 3 with the Indicative Instrumentation Layout for a Transverse Shaking Orientation



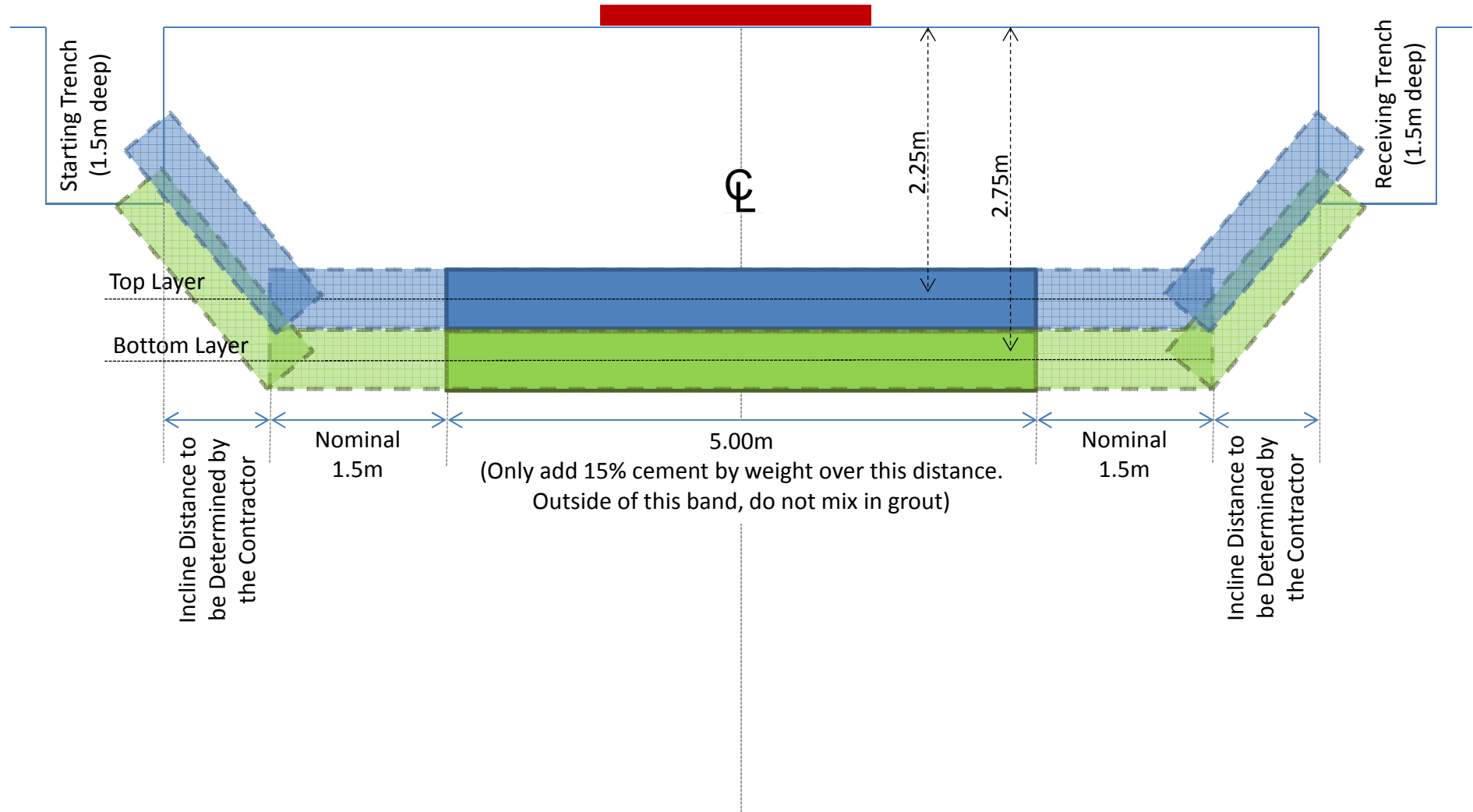
Construct 0.5m dia. horizontal cement mixed columns with 15% cement by weight  
 Top row at 1.00m spacing and bottom row at 1.00m spacing in a staggered pattern  
 Column row centrelines of 2.25m to 2.75m below the ground surface

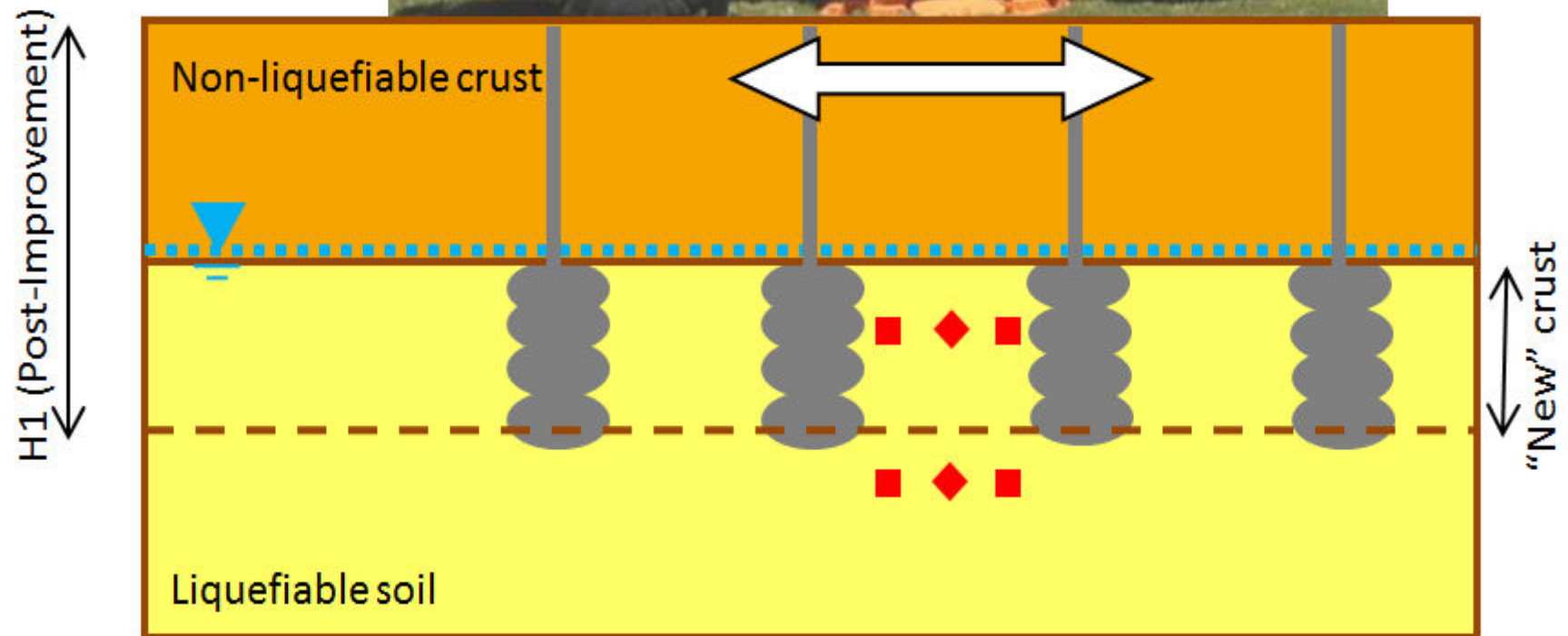


# Horizontal Mixing Test Panel Layout at Site 3 with the Indicative Instrumentation Layout for a Transverse Shaking Orientation



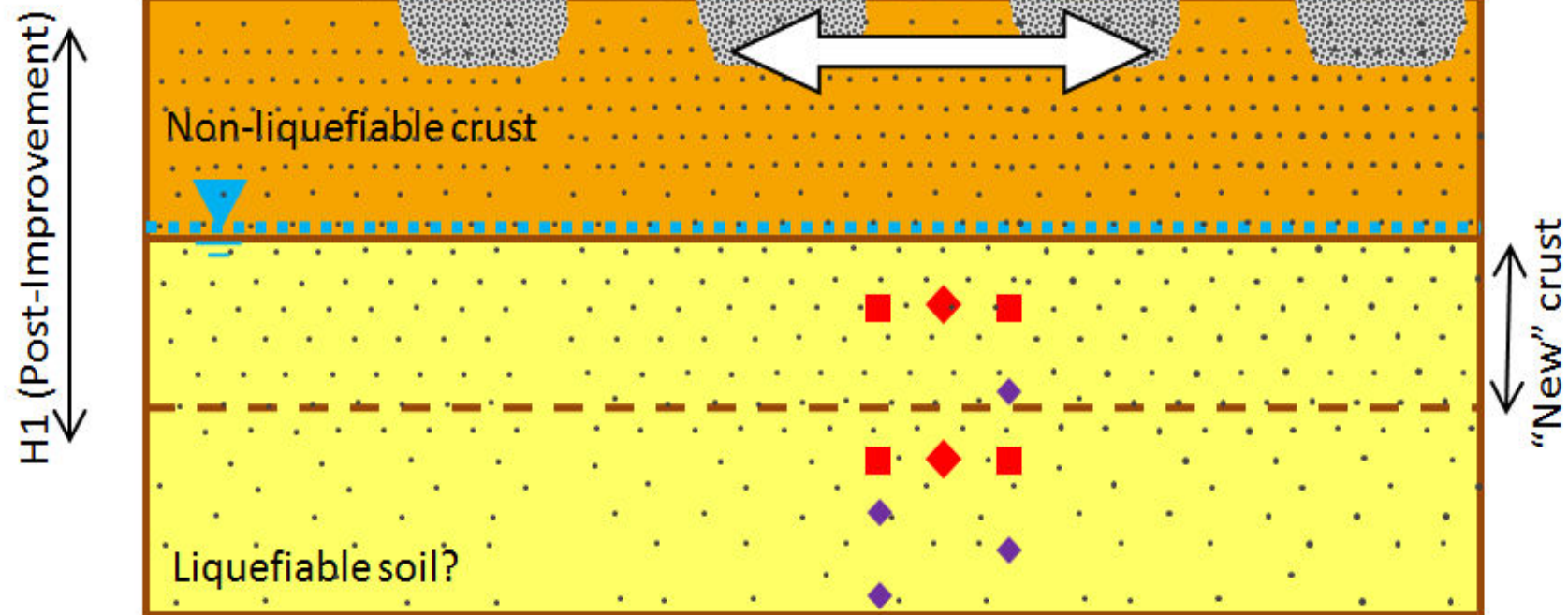
# Horizontal Mixing Test Panel Layout at Site 3 - Long Section



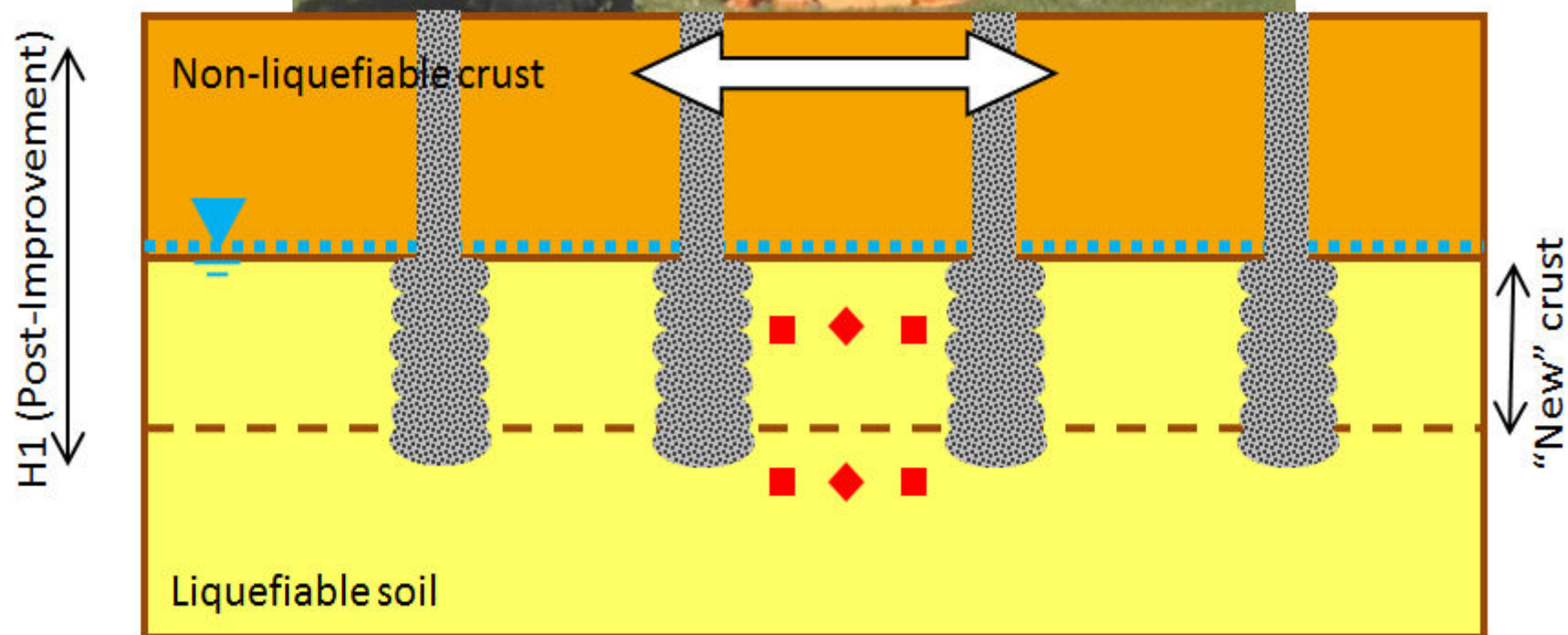


- T-Rex velocity transducer
- ◆ T-Rex pore pressure transducer



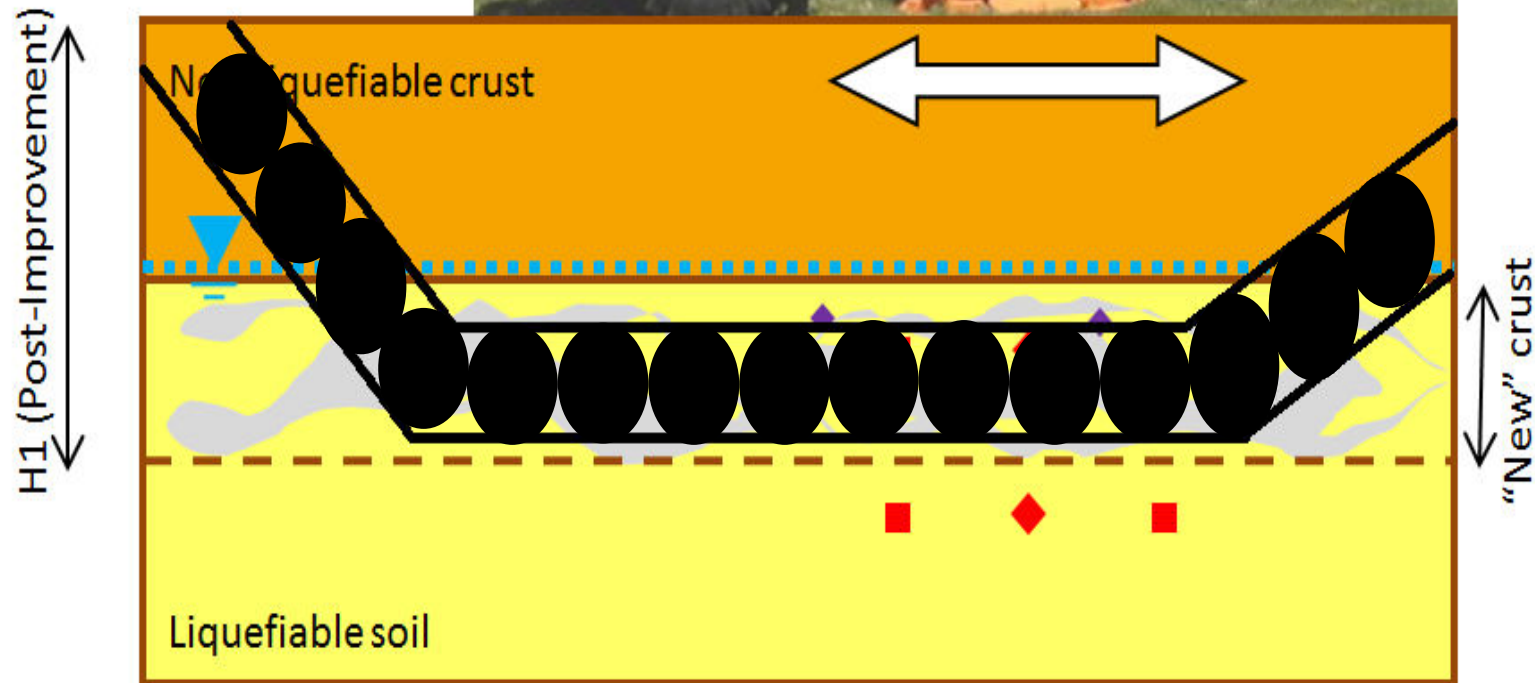


- T-Rex velocity transducer
- ◆ T-Rex pore pressure transducer
- ◆ Additional piezometers (electronic divers)



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