



Centennial Park, Palmerston North

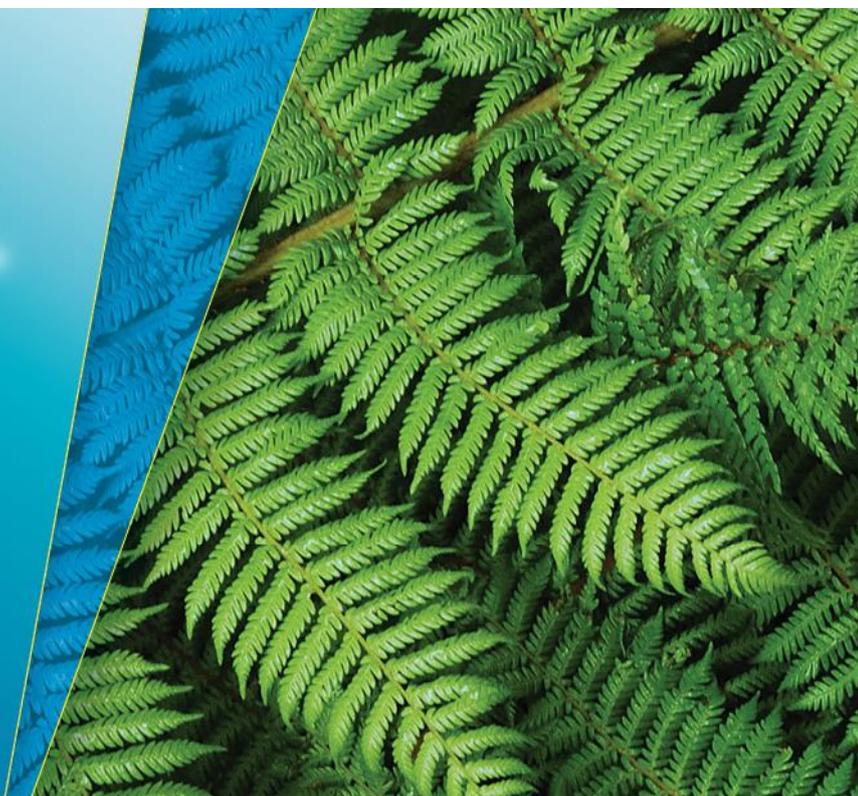
Geotechnical Investigation and Liquefaction Assessment

Prepared for
Wallace Development Company Ltd

Prepared by
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1 Introduction

Tonkin & Taylor Ltd (T+T) was engaged by Wallace Development Company Ltd to conduct a geotechnical investigation and liquefaction assessment of the Hokowhitu Campus located on Centennial Drive, Palmerston North (Refer Figure 1). The work was undertaken in accordance with our proposal dated 22 September 2017.

The site is proposed to be developed in 3 key stages. Stage 1 is the land to the north of the existing institutional buildings (and involves the removal of some smaller buildings). Stage 2 involves development of the open space located on the southern portion of the site (Refer Figure 1 in Appendix A). Stage 3 will involve the area of existing buildings onsite that are currently used by the NZ Defence Force training centre and the Te Wānanga o Aotearoa. This stage is currently not considered for development and is not assessed as part of the current report.

The purpose of the work is to provide detailed area-wide assessment for plan change and subdivision consent to enable the continued use of the site for the existing institutional activities on the site and future residential development.

This report outlines the following for Stages 1 and 2:

- Assessed likelihood and consequences of liquefaction across the site.
- Assessed liquefaction for 1/100 year and 1/500 year seismic events.
- Identified areas of low, medium and high liquefaction vulnerability category.
- Options for lateral spread mitigation methods/measures ;
- Assessed likely performance of possible lateral spread mitigation options;
- Identify appropriate foundation options for the proposed development.

Geotechnical investigations at the site were undertaken between 13 August and 18 August 2018 and included:

- Site walkover, visual assessment, and mark out of investigation locations.
- 40 Cone Penetration Tests (CPTs).
- 5 machine boreholes (BHs)

The locations of the investigations are presented on Figure 2 in Appendix A, with a typical spacing between investigation locations of approximately 30 – 50m. A detailed summary of the site investigation is provided in Appendix B. The liquefaction assessment presented in this report has been undertaken at detail Level C (detailed area wide assessment) as defined in MBIE/MfE guidance ¹, with the intended purpose of supporting resource consent for subdivision. However, the area-wide site investigation layout has been designed with the intention to provide sufficient deep ground investigation information to support Level D (site specific assessment) for individual sites in future (e.g. to support specific engineering design for Building Consent) without the need for additional site-specific deep investigations in most cases.

¹ “Planning and engineering guidance for potentially liquefaction-prone land”, Ministry of Business, Innovation & Employment and Ministry for the Environment, 2017.
<https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/planning-engineering-liquefaction-land/>

2 Site description

The site is located on Centennial Drive, 2 km southeast of Palmerston North city centre. The site is approximately 540 m long and ranges in width from 180 m to 270 m, with a total area of approximately 10 Ha.

The topography in the northern area consists of a raised platform and slopes towards the Hokowhitu oxbow lagoon in the west, and the Manawatu Golf course in the east. Campus carparks are gently sloping with undulating grassed boundaries. The northern area of the site includes the majority of the existing buildings, ranging from single to multi-levels in height.

The southern area of the site consists of a flat sports field with a concrete tennis court located in the south eastern corner. The south western area is occupied by single story school buildings. An approximate 3m high earth embankment and the Manawatu River is located along the southern property boundary.

3 Ground and groundwater conditions

3.1 Geology

The published geological map of the area² indicates the site is underlain by Holocene aged, moderately to well sorted, alluvial flood plain gravel, with some sand and/or silt, minor clay and local peat. The location and shape of the Hokowhitu Lagoon relative to the Manawatu River indicates a historic meandering river channel (now infilled) is likely to pass through the southwest of the site.

3.2 Geotechnical model

Based on our investigation, the general soil profile of the site is inferred to be as summarised in Table 3.1.

Table 3.1: Geotechnical model

Layer no.	Geological unit	Description	Depth to top of layer (m)	Layer thickness (m)	Typical SPT 'N' Value	Typical CPT Resistance, qc (MPa)
1	Top Soil	SILT with trace sand; brown. Very soft, moist, moderate plasticity.	0.0	0.5 to 1.0	N/A	N/A
2	Fill	Fine to coarse GRAVEL with trace silt; brown. well graded. sub angular to sub rounded.	0.5 to 1.0	0.5 to 1.0	N/A	N/A
3a	Holocene Alluvial Deposits	Sandy SILT; brown. Soft, low plasticity.	0.5 to 1.5	0.5 to 1.5	3 - 6	0 - 4
3b		Fine to coarse SAND, trace silt; orange-brown, moist, poorly graded.	0.5 to 1.5	0.5 to 6.0	1 - 36	4 -16
4	Alluvial Deposits	Fine to coarse GRAVEL with some sand and trace silt; light brown. Medium dense, saturated, well graded.	1.5 to 7.5	16.5+ <i>Deepest explored elevation of RL 8m</i>	12– 50+	8 – 25+

² Lee, J.M., Begg, J.G. (compilers) 2002: Geology of the Wairarapa area. Institute of Geological & Nuclear Sciences 1:250,000 geological map 11. 1 sheet + 66 p. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Limited.

3.3 Groundwater

Based on our geotechnical investigation, site history, and subsequent groundwater readings, we expect the groundwater level to vary approximately between RL 25.0 m and RL 27.5 m across the site. The typical water levels in the adjacent water bodies are approximately RL 27.5 m in the Hokowhitu Lagoon to the west of the site, and RL 22 m in the Manawatu River to the south.

For the liquefaction assessment undertaken for this report we have conservatively adopted a high groundwater level of RL 27.5m across the entire site (or the maximum level measured during site investigations, if higher) for the 100 year earthquake scenario. This provides a sensitivity check for potential areas of perched groundwater or for earthquake events occurring during periods of high groundwater levels. For the 500 year earthquake scenario we have adopted the expected long term median levels from our site-specific groundwater model, in line with standard industry practice¹, as there is a low likelihood of an extreme earthquake occurring at the same time as extreme groundwater levels.

3.4 Site topography

T+T was supplied with LiDAR³ data for the Palmerston North region by PNCC⁴. LiDAR is a surveying method that measures ground survey elevations with a laser light. The LiDAR data is based on the 1980 Geodetic Reference System (GRS80) Ellipsoid vertical datum. This data was referenced when determining the relative levels of each investigation location at the site.

The site elevation varies between RL 28.0 and 30.5m. The area adjacent to the lagoon represents the lower elevation and appears to be relatively flat with a 2m rise in elevation towards the southern and eastern boundary. The highest elevations are located along the bank adjacent to Manawatu River and the eastern boundary.

³ Light Detection and Ranging

⁴ <https://geosite.pncc.govt.nz>

4 Liquefaction assessment

4.1 Assessment methodology

The calculations and analyses used in our liquefaction assessment focused on 50 Cone Penetration Tests (CPTs) from the 2017 and 2018 investigations of the site. Areas outside the limits of the Site Extent as shown on Figure 2, Appendix A, have not been included in this assessment.

The assessment included analyses of 100-year and 500-year levels of earthquake shaking. In qualitative terms, for Palmerston North these could be described respectively as ‘moderately strong’ and ‘very strong’ earthquakes.

Technical details regarding the methodology used to undertake the liquefaction analysis, and the calculated results, are provided in Appendix D.

4.2 Liquefaction categories

Each CPT location at the site has been categorised into one of the following liquefaction vulnerability categories presented in Table 4.1, below, depending on the expected likelihood and consequences of liquefaction damage at the ground surface.

Table 4.1 Liquefaction vulnerability category summary ⁽¹⁾

Liquefaction vulnerability category	Degree of damage expected on average across the area (some locations within an area may have more or less damage)
Low	Significant liquefaction-induced ground damage is unlikely.
Medium	Liquefaction-induced ground damage is possible. A large earthquake would be required to cause significant liquefaction damage, and the degree of ground damage is generally expected to be Moderate or less.
High	Liquefaction-induced ground damage is possible. Compared to the Medium category, significant liquefaction damage could occur in smaller earthquakes and/or the ground damage could be more severe and extensive.

Notes:

1. Since the original liquefaction hazard assessment work for this site was undertaken for PNCC, MBIE/MfE have released planning and engineering guidance for potentially liquefaction-prone land ⁽¹⁾. To maintain consistency with the earlier work undertaken for PNCC we have kept the liquefaction vulnerability category descriptions and colours as used previously, rather than switch to the recommended legends from the new guidance. The meaning of Low / Medium / High as used in this report is consistent with the new MBIE/MfE guidance.

4.3 Liquefaction assessment summary

The majority of the site is assigned a liquefaction vulnerability category of **Low** or **Medium** with some portions of the site (adjacent to the lagoon and the central area at the southern end of the site) assigned a liquefaction vulnerability category of **High**. The liquefaction categories assigned across the site are presented in Appendix A, Figure 2.

4.3.1 Lateral spreading assessment

A strip of land approximately 100 m wide along the western boundary of the site, adjacent to Hokowhitu Lagoon, is potentially susceptible to lateral spreading⁵ during large earthquake events (e.g. 500-year level shaking). This area is shown in Appendix A, Figure 2. The area susceptible to lateral spreading is located within the areas assigned liquefaction categories of **Medium** and **High**.

During a large earthquake event, the ground surface in this area could displace towards the lagoon. During 500-year levels of earthquake shaking, lateral stretch is expected to be less than 100mm in the area categorised as **Medium**, and possibly greater than 100mm (but less than 200mm) in the area categorised as **High**. For the residential lots in these areas, ground improvement and/or foundation options will need to be selected which can accommodate the potential lateral spreading ground displacements.

We have also assessed the potential for lateral spreading to be caused by the approximately 8m high free face along the Manawatu River (approximately 50 m beyond the southern boundary of the site) or for toe-bulging type displacements to be caused by the adjacent 3 m high embankment (which lies immediately to the south of the site). We consider it unlikely that these features will trigger substantial liquefaction-induced ground deformations in an earthquake, because normal groundwater levels in this area are expected to lie within predominantly gravelly material (Unit 4 in Table 3.1) with low liquefaction susceptibility. However, minor ground deformations could occur due to local lenses of liquefiable soils or seismic slope movement. For a 500 year earthquake scenario we expect lateral stretch of up to 50 mm could occur within 100 m of the river edge, or within 25 m of the embankment toe. This magnitude of lateral stretch is expected to be readily accommodated by the enhanced foundation options already recommended for the land in this area (which is categorised as **Medium** or **High** liquefaction vulnerability), so we expect that additional measures to manage lateral spreading will not be required here.

5 Site development considerations

5.1 Overview

For foundations of dwellings in **medium** and **high liquefaction vulnerability category** land, a number of options are available for mitigating the effects of liquefaction and lateral spread. These options are grouped into:

- Enhanced Foundations (e.g. a waffle slab, enhanced lightweight foundation on timber piles, timber piles on a reinforced concrete slab, or deep piles.)
- Ground Improvement (e.g. gravel raft, soil-cement raft, stone columns, or columns of highly compacted aggregate)

⁵ Lateral spreading is generally defined as the horizontal displacement of surficial blocks of soil towards an open slope face as a result of liquefaction of the underlying soils. Generally for lateral spreading to occur a relatively continuous layer of liquefiable soils extending to an open slope face such as a river bank or open channel must be present.

Development of the site would be appropriate subject to the options provided. Site specific assessments required for design will provide greater clarity for foundation design and ground improvement requirements for individual lots. This assessment does not remove any requirements for site specific assessment for detailed design, such as selecting appropriate foundation systems for a particular building and undertaking shallow ground investigations to confirm soil bearing capacity at a specific lot. All requirements for design as stated in the Building Code and NZS 3604 (if used) still apply (noting that NZS 3604 is not considered suitable for design of foundations on land assigned a liquefaction vulnerability category of **Medium** or **High**).

5.2 Expected performance of development options

The descriptions of performance provided in Tables 5.1 and 5.2 are for preliminary assessment of the expected performance of the various development options. Refer to Appendix E for a description of the hazards and minimum foundations requirements for the individual lots as per Drawing No. 51-37652-C001 provided by GHD (Appendix E). Appropriate foundation details should be selected for each lot as part of the detailed design of each individual building. Depending on the particular site and building details, this may require input from a Chartered Professional Engineer and site-specific deep ground investigations⁶.

⁶ The existing area-wide site investigation layout has been designed with the intention to provide sufficient deep ground investigation information to support foundation design for Building Consent without the need for additional site-specific deep investigations in most cases. Any need for additional site-specific deep investigations would be a matter of judgement for the design engineer, and would likely only be required in special circumstances (e.g. to suit the particular requirements of the preferred ground improvement and/or foundation option).

Table 5.1: Expected performance of development options: away from lateral spreading areas

Development option	Medium Liquefaction Vulnerability Category, 500-year earthquake shaking ⁷	High Liquefaction Vulnerability Category	
		100-year earthquake shaking	500-year earthquake shaking
Standard NZS 3604 foundation with no ground improvement	Moderate settlement of dwellings, could be expensive or not possible to repair. Significant damage to roads and public and private services.	Minor to moderate settlement of dwellings, could be expensive to repair. Some damage to roads and public and private services.	Moderate to severe settlement of dwellings, may not be repairable. Widespread damage to roads and services.
Enhanced foundation with no ground improvement	Minor to moderate settlement of dwellings, likely to be readily repairable. Significant damage to road and public and private services.	Minor to moderate settlement of dwellings, likely to be readily repairable. Some damage to roads and public and private services	Moderate to major settlement of dwellings, repair probably feasible but could be expensive ⁸ . Widespread damage to roads and services.
Enhanced foundation with ground improvement beneath dwelling footprint only	Minor settlement of dwellings, likely to be readily repairable. Significant damage to roads and services apart from those adjacent to dwellings.	Minor settlement of dwellings, likely to be readily repairable. Some damage to roads and services apart from those adjacent to dwellings.	Minor to moderate settlement of dwellings, likely to be readily repairable. Widespread damage to roads and services.

Table Legend:

Yellow shading *Unlikely to meet Building Code requirements*

White shading *Likely to meet Building Code requirements⁸*

Blue shading *Provides additional resilience beyond minimum Building Code requirements*

⁷ No more than minor liquefaction damage expected at 100-year levels of earthquake shaking on medium category land.

⁸ As outlined in Section 5.3.2, enhanced foundation options cover a range of situations – to meet Building Code requirements, options towards the more robust end of the range may be required for land assigned a liquefaction vulnerability of High, or for heavier or more settlement-sensitive buildings. We also note that there are some important differences between this site and typical ground conditions in Christchurch where TC3-type enhanced foundations were initially developed. For the Centennial Park site the High categorisation is primarily due to thin-crust/high-LSN issues (rather than large thicknesses of liquefied soil with large settlement index values) for the 500 year ULS scenario (rather than the 25 year SLS scenario). This means that minimum Building Code requirements are expected to be more readily achievable for this site (with more modest foundation enhancements) than for typical TC3 sites in Christchurch.

Table 5.2: Expected performance of development options: within lateral spreading areas

Development option	Medium Liquefaction Vulnerability Category, 500-year earthquake shaking ⁹	High Liquefaction Vulnerability Category	
		100-year earthquake shaking	500-year earthquake shaking
No specific mitigation; standard NZS 3604 foundations	Lateral spreading not reduced. Dwellings distorted due to ground stretching across dwelling footprint (possible collapse risk), which would be expensive or not feasible to repair. Underground services stretched or disconnected at junctions. Cracks up to 100 mm wide may form in roads and pavements.	Lateral spreading not reduced. Dwellings distorted due to ground stretching across dwelling footprint (possible collapse risk), which would be expensive or not feasible to repair. Underground services stretched or disconnected at junctions. Cracks up to 100 mm wide may form in roads and pavements.	Lateral spreading not reduced. Dwellings distorted due to ground stretching across dwelling footprint (possible collapse risk), which would be expensive or not feasible to repair. Underground services stretched or disconnected at junctions. Cracks greater than 100 mm wide may form in roads and pavements.
Enhanced foundations with no ground improvement	Lateral spreading not reduced. Dwelling foundations resist stretching, reducing building damage and simplifying repair. Underground services stretched or disconnected at junctions. Cracks up to 100 mm wide in roads and pavements.	Lateral spreading not reduced. Dwellings distorted due to ground stretching across dwelling footprint (possible collapse risk), which would be expensive or not feasible to repair. Underground services stretched or disconnected at junctions. Cracks greater than 100mm may form in roads and pavements	Lateral spreading not reduced. Dwellings distorted due to ground stretching across dwelling footprint (possible collapse risk), which would be expensive or not feasible to repair. Underground services stretched or disconnected at junctions. Cracks greater than 100mm may form in roads and pavements
Enhanced foundations with shallow ground improvement	Lateral spreading not reduced. Dwelling foundations resist stretching, reducing building damage and simplifying repair. Underground services stretched or disconnected at junctions. Cracks up to 100 mm wide around edges of improved areas.	Lateral spreading not reduced. Dwelling foundations resist stretching, reducing building damage and simplifying repair. Underground services stretched or disconnected at junctions. Cracks up to 100 mm wide around edges of improved areas.	Lateral spreading not reduced. Dwelling foundations resist stretching, reducing building damage and simplifying repair. Underground services stretched or disconnected at junctions. Cracks greater than 100 mm wide around edges of improved areas.

Table Legend:

Yellow shading *Unlikely to meet Building Code requirements*

White shading *Likely to meet Building Code requirements*

⁹ Lateral spreading only expected during large earthquakes (i.e. 500-year levels of shaking). Lateral spreading not expected to occur during 100-year levels of shaking.

5.3 Foundation options

5.3.1 Land assigned a liquefaction vulnerability category of **Low**

For land assigned a liquefaction vulnerability category of **Low**, standard NZS 3604 foundations are likely to be sufficient to satisfy minimum Building Code performance requirements. However, we note that enhanced slab foundations (refer Table 5.3) can provide a substantial improvement in foundation performance for only a small increase in construction cost. Even with land assigned a liquefaction vulnerability category of **Low**, there still remains residual risk related to the potential for minor liquefaction-induced ground damage and other unfavourable ground conditions. Therefore, we encourage adoption of enhanced slab foundations to provide increased resilience, as an optional upgrade beyond minimum Building Code requirements.

NZS 3604 (or for enhanced slabs, the MBIE guidance for Canterbury ¹⁰) details checks which need to be undertaken to confirm that the standard details can be used, such as shallow soil testing to confirm soil bearing capacity. Subgrade preparation will be required, such as removal of unsuitable topsoil material (expected depth of approximately 0.3m) and compaction of the exposed subgrade.

Specialised geotechnical engineering input and specific engineering design are not expected to be required for land assigned a liquefaction vulnerability category of **Low** where standard NZS 3604 or enhanced slab foundations are adopted.

5.3.2 Land assigned a liquefaction vulnerability category of **Medium** (all areas), or **High** (away from lateral spreading areas)

For land assigned a liquefaction vulnerability category of **Medium** (all areas) or **High** (away from lateral spreading areas only), enhanced foundations as outlined below are likely to satisfy minimum Building Code requirements.

Table 5.3 below outlines enhanced foundation options which are likely to be suitable for single or two-storey lightweight residential structures in these areas. These foundation options cover a range of situations, and include both TC2-type and TC3-type foundations from the MBIE Canterbury guidance (refer to previous footnote 8 for details of the differences between this site and typical TC3 ground conditions in Christchurch). Options towards the more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure) may be required for land assigned a liquefaction vulnerability of **High**, or for heavier or more settlement-sensitive buildings. Engineering input will be required to select and design the appropriate foundation for the specific ground conditions and building details at each individual site.

Optionally, for increased seismic performance the enhanced foundation options below can be combined with ground improvement as outlined in Table 5.4. Other foundation options may also be possible, subject to site-specific engineering design.

Table 5.3: Enhanced foundation options

Foundation option	Description
Option 1: Enhanced slab	Enhanced reinforced concrete slab on grade foundation. Four example options are presented in Section 5.3.1 of the MBIE residential construction guidance for Canterbury ¹⁰ . Can also be combined with a shallow geogrid-reinforced gravel raft for increased performance (this is termed a hybrid TC2/TC3 foundation in the MBIE Canterbury guidance).
Option 2: Deep piles	Piles founding on dense (non-liquefiable) ground at depth. Various example options are presented in Section 15.2 of the MBIE residential construction guidance for Canterbury ¹⁰ .
Option 3: Surface structures	Lightweight and flexible releve-able platforms with shallow foundations, designed to tolerate differential ground settlement and lateral stretch with the intention of being readily-repairable following and SLS-level earthquake event. Various example options are presented in Section 15.4 of the MBIE residential construction guidance for Canterbury ¹⁰ , with the most relevant options for these areas being Type 1 or Type 2A surface structures. The guidance outlines various recommendations for the building superstructure, which will be particularly relevant for land assigned a liquefaction vulnerability category of High .

5.3.3 Land assigned a liquefaction vulnerability category of **High** (within lateral spreading areas)

Where land assigned a liquefaction vulnerability category of **High** is also within the identified areas of greater lateral spreading potential, more robust foundation systems are required to satisfy minimum Building Code requirements. One option is to combine enhanced foundation elements such as those outlined in Table 5.3 with ground improvement options such as those outlined in Table 5.4. Other robust foundation options may also be possible, subject to site-specific engineering design. Deep piles are unlikely to be a suitable foundation option in the lateral spreading area, unless specifically designed to accommodate the expected magnitude of lateral ground displacement.

There are five principle methods¹¹ generally employed to improve the ground and increase its resistance to liquefaction. The ground improvement method which is selected for a particular site depends on the extent of treatment (typically at least 1m beyond dwelling footprint), the ground conditions, cost effectiveness, performance requirements, and engineering judgement. For the soil types encountered on site the ground improvement options outlined in Table 5.4 are likely to be the most suitable.

¹⁰ "Repairing and rebuilding houses affected by the Canterbury earthquakes", Part A and C, Ministry of Business, Innovation and Employment, 3rd Edition, Published on 1 December 2012, Updated on 29 May 2018.

¹¹ MBIE and NZGS (2017) Earthquake Geotechnical Engineering Practice, Module 5: Ground Improvement of soils prone to liquefaction, dated June 2017

Table 5.4: Ground improvement options

Ground improvement option	Description
Option A: Reinforcement	Formation of a grid of individual columns with a 1.5–2.5 m grid spacing using either timber or concrete piles or stone columns. Depending on the location of the proposed dwelling, reinforcement (piles or stone columns) may be constructed within the upper 4m, bearing into the gravel layer (Layer 2).
Option B: Densified crust	Excavation of liquefiable soils and replacement with dense/stabilised soil. Depending on the location of the proposed dwelling a reinforced gravel raft may be constructed to approximately 1.2m depth, consisting of compacted crushed gravel with geo-grid reinforcement (Option G1d in the MBIE Canterbury guidance). Alternatively, in some cases it may be preferable to excavate to approximately 2.0m depth (or to the top of the gravel layer) and recompact the excavated material, with geo-grid reinforcement (Option G1a in the MBIE Canterbury guidance).

Specialised geotechnical engineering input will be required to select and design the appropriate foundation system for each site. It should be noted that ground improvement would likely reduce the effects of liquefaction and lateral spreading in a future earthquake, but not eliminate the hazard entirely.

Generally, measures to mitigate the effects of liquefaction and lateral spreading can be implemented either on an individual house-by-house basis (e.g. separate “islands” of ground improvement and/or robust foundations) or as co-ordinated area-wide ground improvement (e.g. a large area improved as a single block). Both options are likely to be able to meet minimum Building Code requirements, however there can be a difference in the level of overall community resilience that is achieved. Compared to an area-wide approach, undertaking the work on a house-by-house basis can mean the ground improvement is less effective and leaves a greater potential for disruption to the community in a large earthquake (e.g. due to damaged roads and services). The costs associated with design and construction of ground improvement can be substantial, so it is important that the purchasers of these lots are aware of the requirement for them to undertake this work. We have discussed these two approaches with Wallace Development Company, and understand that their preference for the Centennial Park development is for any ground improvement works to be undertaken by each purchaser on an individual house-by-house basis.

5.4 Foundation bearing capacity

Prior to constructing foundations, subgrade preparation will be required – such as removal of unsuitable topsoil material (expected depth of approximately 0.3m) and compaction of the exposed subgrade. Additional local undercutting of weaker soils may also be required. Following site-wide earthworks and site-by-site subgrade preparation work, we anticipate that design geotechnical ultimate capacities of 200kPa or greater could be achieved. Shallow ground testing such as hand augers boreholes and scala penetrometer testing should be undertaken across each site to confirm that the bearing capacity assumed for design is achieved.

5.5 Infrastructure

For all infrastructure servicing the proposed Centennial Park development, detailed design should take account of any liquefaction and lateral spreading expected to occur at the particular location. General considerations are summarised in Table 5.5, however these details could be revised taking into account specific infrastructure locations as part of detailed design.

Where practicable, it would be preferable to avoid locating key elements of the infrastructure network within the area identified as susceptible to lateral spreading. If this is not possible, it would be preferable to locate infrastructure as far away from the lagoon edge as practical.

In all parts of the site, consideration should be given to incorporating principles of resilience and repairability into the design. For example, where buried services are to be founded below the water table, it is recommended that the service trenches be backfilled with free draining gravel, lined with filter fabric and designed to withstand uplift pressures and differential settlements. Flexible pipes and connections should be used where practicable. Guidance and further references for these principles is provided in the MBIE/MfE guidance document *“Planning and engineering guidance for potentially liquefaction-prone land”* (refer Section 6.9).

Table 5.5: General liquefaction and lateral spreading considerations for infrastructure design

Hazards present		Liquefaction and lateral spreading considerations for infrastructure design, for a 500 year earthquake event
Outside the area identified as susceptible to lateral spreading	Low liquefaction vulnerability	No specific considerations for liquefaction and lateral spreading.
	Medium liquefaction vulnerability	Consider differential ground deformation of approximately 50mm vertical over a 50m length.
	High liquefaction vulnerability	Consider differential ground deformation of approximately 100mm vertical over a 50m length.
Within the area identified as susceptible to lateral spreading	Low liquefaction vulnerability	Consider differential ground deformation of approximately 25mm vertical and 50mm horizontal over a 50m length.
	Medium liquefaction vulnerability	Consider differential ground deformation of approximately 50mm vertical and 100mm horizontal over a 50m length.
	High liquefaction vulnerability	Consider differential ground deformation of approximately 100mm vertical and 200mm horizontal over a 50m length.

5.6 RMA Section 106

With respect to Section 106 of the 1991 Resource Management Act (RMA), we make the following comments:

- The site is not considered to be susceptible to falling debris, coastal hazards, rockfall, or landslip given its topography and geographical location. The potential for any future small-scale erosion during construction will need to be managed by the Erosion and Sediment Control Plan for the site (to be prepared by others).
- The site is not within the extent of flooding in a 200 year event modelled by Horizons Regional Council¹². We expect that management of stormwater will be addressed as part of detailed civil engineering design for the subdivision (to be prepared by others).
- Site investigations did not identify soils susceptible to substantial ongoing long-term subsidence (e.g. peat deposits).
- Liquefaction-related inundation and subsidence have the potential to affect the site. However, our assessment indicates that if the geotechnical recommendations outlined in this report are followed, then these effects will be reduced to an acceptable level, and the proposed site development works will comply with the intent of RMA Section 106.

5.7 Further work

Further geotechnical engineering work will be required as the Centennial Park development progresses through design and construction. This future work includes (but is not limited to):

- Specification, site observations, and testing required for earthworks associated with the redevelopment, to confirm suitability of the completed works.
- For areas assigned a liquefaction vulnerability category of **Medium** or **High**, site-specific geotechnical assessment should be undertaken for each individual lot. This is in order to confirm that the ground improvement and/or foundation design is appropriate for that site and the details of the proposed building. It is likely that in most cases this geotechnical assessment can be undertaken using the deep ground investigation information already available from the area-wide investigations (refer Appendix B and C) without the need for additional deep investigations on each specific site.
- As is typical for all residential construction, additional shallow investigation and testing (e.g. hand augers and scala penetrometer testing) will be required within the location of the proposed structure. This is in order to confirm that the foundation design and/or ground improvement is appropriate for the ground bearing conditions at the site.

This work should be overseen by a Chartered Professional Engineer (CPEng) with current accreditation in the geotechnical practice field as administered by Engineering NZ and/or a Professional Engineering Geologist with current registration on the Engineering NZ PEngGeol register. The reports should include all relevant factual and interpretative geotechnical information, clearly distinguishing between fact and interpretation and providing a commentary on uncertainty (and potential consequences). The reports should address the pertinent geotechnical aspects of all natural hazards relevant to the site (including, but not limited to, liquefaction).

¹² <http://www.horizons.govt.nz/flood-emergency-management/flood-plain-mapping/flood-plain-mapping-portal>

6 Applicability

This report has been prepared for the exclusive use of our client Wallace Development Company Ltd, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Recommendations and opinions in this report are based on data from boreholes and CPTs. The nature and continuity of subsoil away from the borehole and CPT locations are inferred, and it must be appreciated that actual conditions could vary from the assumed model.

Tonkin & Taylor Ltd

Report prepared by:

Authorised for Tonkin & Taylor Ltd by:



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Christopher Sandoval

Geotechnical Engineer

.....

Mike Jacka

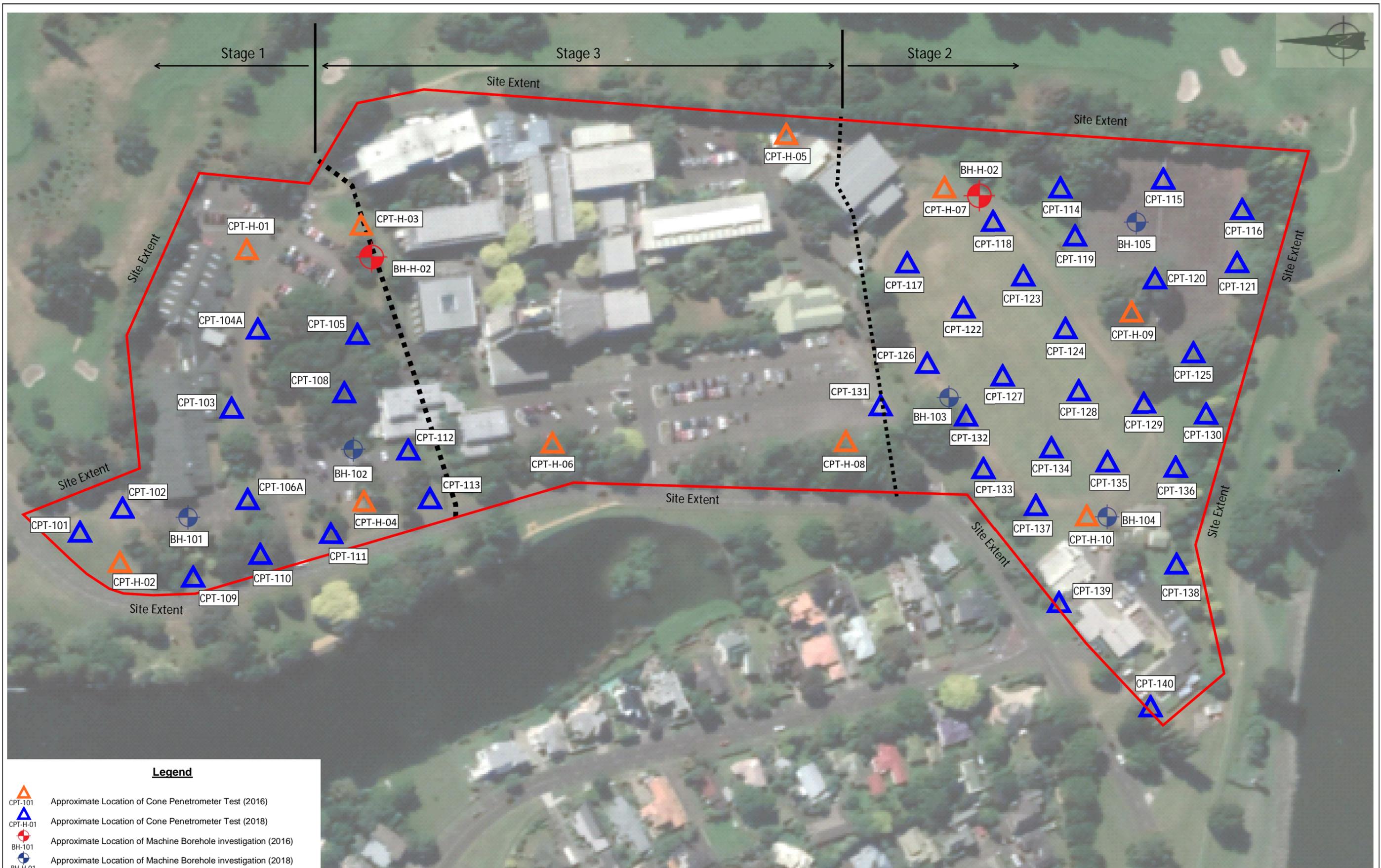
Senior Geotechnical Engineer

cvs

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Appendix A: Figures

- **Figure 1 – Site Plan**
- **Figure 2 – Liquefaction Assessment Results**



Legend

- CPT-101 Approximate Location of Cone Penetrometer Test (2016)
- CPT-H-01 Approximate Location of Cone Penetrometer Test (2018)
- BH-101 Approximate Location of Machine Borehole investigation (2016)
- BH-H-01 Approximate Location of Machine Borehole investigation (2018)



- NOTES:
1. Aerial photo and property boundary sourced from Linz Data Service <<https://data.linz.govt.nz/>>, licensed by LINZ for re-use under the Creative Commons Attributions New Zealand licence (CC BY 3.0 NZ)
 2. Coordinate Datum: NZGD2000, New Zealand Transverse Mercator (NZTM2000).
Level Datum: LINZ (MSL) Wellington Vertical Datum 1953
 3. Contours designed based on CPT data.
 4. Land outside the Site Extent has not been assessed.

Tonkin+Taylor
Level 4, 2 Hunter St, Wellington
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DRAWN	AGDS	10/18
DRAFTING CHECKED	CVS	10/18
APPROVED	MES	10/18
CADFILE : \\85442.0040-LQ-F3.dwg		
SCALES (AT A3 SIZE)		
1:2000		
PROJECT No.	1004625.001	FIG. No. Figure 1

WALLACE DEVELOPMENT GROUP
CENTENNIAL PARK
Hokowhitu Campus, Palmerston North
Geotechnical Site Investigation Plan

	REV. 0
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Legend

- CPT-101 Approximate Location of Cone Penetrometer Test (2016)
- CPT-H-01 Approximate Location of Cone Penetrometer Test (2018)
- BH-101 Approximate Location of Machine Borehole investigation (2016)
- BH-H-01 Approximate Location of Machine Borehole investigation (2018)
- Low Vulnerability: Liquefaction-induced damage is minor or not evident in a 500-year return period earthquake
- Medium Vulnerability: Moderate liquefaction - induced damage is expected in a 500-year return period earthquake; no more than minor liquefaction-induced damage is expected in a 100-year return period earthquake.
- High Vulnerability: Moderate liquefaction-induced damage is expected in a 100-year return period earthquake; and/or severe liquefaction-induced damage is expected in a 500-year return period earthquake.
- Approximate area of land susceptible to lateral spreading
- Designated lot boundaries according to DWG 51-37652-C001 provided by GHD

NOTES:
 1. Aerial photo and property boundary sourced from Linz Data Service <https://data.linz.govt.nz/>, licensed by LINZ for re-use under the Creative Commons Attributions New Zealand licence (CC BY 3.0 NZ)
 2. Coordinate Datum: NZGD2000, New Zealand Transverse Mercator (NZTM2000).
 Level Datum: LINZ (MSL) Wellington Vertical Datum 1953
 3. Contours designed based on CPT data.
 4. Land outside the Site Extent has not been assessed.



 Tonkin+Taylor Level 4, 2 Hunter St, Wellington www.tonkintaylor.co.nz	DRAWN	AGDS 10/18	WALLACE DEVELOPMENT GROUP CENTENNIAL PARK Hokowhitu Campus, Palmerston North Liquefaction Assessment - Findings	FIG. No. Figure 2	REV. 1
	DRAFTING CHECKED	CVS 10/18			
	APPROVED	MES 01/19			
	CADFILE :	\\85442.0040-LQ-F3.dwg			
SCALES (AT A3 SIZE)	1:2000				
PROJECT No.	1004625.001				

Appendix B: Site investigation summary

B.1 Investigation summary

Geotechnical investigations were carried out at the project site between the 13 August and 18 August 2018. The investigations comprised of seven (7) cone penetrometer tests (CPTs); CPT 1 to CPT 7

The locations of the investigations were surveyed by hand held GPS, and are presented on Figure 2 in Appendix A.

B.2 Cone Penetration Tests

The pushing of forty (40) Cone Penetrometer Tests (CPTs) was undertaken by Prodrill between the 13 August and 18 August 2018. In all cases, the CPTs were targeting a depth of 12 m, however 'refusal' occurred at shallower depths in all locations due to the cone terminating on or within a hard, impenetrable strata such as dense gravel.

The CPT locations are presented on Figure 1 in Appendix A. A summary of the CPT locations and termination depths is presented in Table B.1 below.

Table B.1: Cone penetration test (CPT) summary

CPT ID	Location (NZTM) ⁽¹⁾		Ground Surface Elevation (GRS80)	Termination depth (m)	Reason for termination
	Easting (m)	Northing (m)	RL (m)		
CPT101	1823242	5528044	29.39	2.94	Cone resistance refusal
CPT102	1823256	5528026	29.91	3.93	Cone resistance refusal
CPT103	1823304	5527970	29.44	4.6	Cone resistance refusal
CPT104A	1823339	5527963	29.57	5.02	Cone resistance refusal
CPT105	1823344	5527917	29.71	4.49	Cone resistance refusal
CPT106A	1823260	5527969	29.56	2.41	Cone resistance refusal
CPT107	1823286	5527946	29.07	2.62	Cone resistance refusal
CPT108	1823309	5527919	29.5	4.76	Cone resistance refusal
CPT109	1823220	5527996	28.38	2.41	Cone resistance refusal
CPT110	1823231	5527954	28.27	2.76	Cone resistance refusal
CPT111	1823241	5527928	28.68	1.34	Cone resistance refusal
CPT112	1823286	5527899	29.87	2.62	Cone resistance refusal
CPT113	1823254	5527881	28.22	2.41	Cone resistance refusal
CPT114	1823408	5527585	28.53	4.41	Cone resistance refusal
CPT115	1823410	5527537	28.69	2.43	Cone resistance refusal
CPT116	1823409	5527493	28.93	3.6	Cone resistance refusal
CPT117	1823376	5527659	28.2	2.71	Cone resistance refusal

CPT ID	Location (NZTM) ⁽¹⁾		Ground Surface Elevation (GRS80)	Termination depth (m)	Reason for termination
	Easting (m)	Northing (m)	RL (m)		
CPT118	1823388	5527617	28.33	3.85	Cone resistance refusal
CPT119	1823379	5527574	28.33	3.36	Cone resistance refusal
CPT120	1823369	5527540	28.57	4.87	Cone resistance refusal
CPT121	1823365	5527496	29.1	7.67	Cone resistance refusal
CPT122	1823347	5527625	28.26	3.82	Cone resistance refusal
CPT123	1823359	5527602	28.36	2.21	Cone resistance refusal
CPT124	1823340	5527579	28.35	3.83	Cone resistance refusal
CPT125	1823334	5527532	28.4	3.65	Cone resistance refusal
CPT126	1823327	5527649	28.18	6.35	Cone resistance refusal
CPT127	1823322	5527611	28.24	6.14	Cone resistance refusal
CPT128	1823313	5527579	28.34	5.09	Cone resistance refusal
CPT129	1823312	5527556	28.36	3.66	Cone resistance refusal
CPT130	1823308	5527515	28.41	4.42	Cone resistance refusal
CPT131	1823310	5527666	28.05	5.81	Cone resistance refusal
CPT132	1823306	5527639	28.2	6.03	Cone resistance refusal
CPT133	1823292	5527626	28.17	4.98	Cone resistance refusal
CPT134	1823292	5527596	28.24	3.88	Cone resistance refusal
CPT135	1823282	5527579	28.22	4.2	Cone resistance refusal
CPT136	1823284	5527529	28.39	4.96	Cone resistance refusal
CPT137	1823258	5527600	28.08	4.89	Cone resistance refusal
CPT138	1823234	5527530	28.13	3.42	Cone resistance refusal
CPT139	1823211	5527587	29.68	2.21	Cone resistance refusal
CPT140	1823156	5527538	30.56	5.13	Cone resistance refusal

Note 1. Elevations are based on supplied Lidar data.

B.3 Machine boreholes

The machine borehole within the site was undertaken on 13 August and 18 August 2018. The boreholes were undertaken using a tracked drilling rig, supplied and operated by Prodrill.

In situ Standard Penetration Testing (SPT) was undertaken in 1.5 m intervals.

The recovered drill core was photographed and logged to NZGS 'Field Description of Soil and Rock' guidelines.

Summary borehole details are presented in Table C.2 below.

Table B.2: Borehole summary

BH ID	Location (NZTM) ⁽¹⁾		Ground Surface Elevation (GRS80)	Termination depth (m)	Reason for termination
	Easting (m)	Northing (m)	RL (m)		
BH101	1823251	5527999	29.38	11.05	Maximum explored
BH102	1823287	5527911	29.07	11.05	Maximum explored
BH103	1823316	5527638	28.13	11.05	Maximum explored
BH104	1823258	5527561	28.17	11.05	Maximum explored
BH105	1823392	5527551	28.58	11.05	Maximum explored

Note 1. Co-ordinates are from hand-held GPS and elevations are based on supplied Lidar data.

B.4 Groundwater

During the investigation all investigation locations encountered groundwater (CPTs and BHs). All water levels were measured by dipping the hole. Summary details of the groundwater measurements are presented in Table B.2 below.

Table B.2: Groundwater summary

CPT ID	Location (NZTM)		Ground Surface Elevation (GRS80), RL (m)	Depth to water, below ground level (m)
	Easting (m)	Northing (m)		
BH101	1823251	5527999	26.48	2.9
BH102	1823287	5527911	27.27	1.8
BH103	1823316	5527638	27.08	2.3
BH104	1823258	5527561	24.97	3.2
BH105	1823392	5527551	25.38	4.0

BOREHOLE LOG

BOREHOLE No.: **BH-101**

Hole Location: East end of Campus, in carpark.

SHEET: 1 OF 2

PROJECT: Centennial Park, Hokowhitu	LOCATION: Centennial Drive, Palmerston North	JOB No.: 1004625.0010
CO-ORDINATES: 5527999.00 mN (NZTM2000) 1823251.00 mE	DRILL TYPE: Fraste XL	HOLE STARTED: 16/08/2018
R.L.: 29.38m	DRILL METHOD: SNC	HOLE FINISHED: 16/08/2018
DATUM: NZVD2016	DRILL FLUID: WATER	DRILLED BY: ProDrill
		LOGGED BY: EJWL
		CHECKED: PAWR

GEOLOGICAL		ENGINEERING DESCRIPTION																
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION	FLUID LOSS (%)	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)		COMPRESSIVE STRENGTH (MPa)		DEFECT SPACING (cm)	Description and Additional Observations
													20	100	1	5		
Fill			100	PQTT				29			M	L						ASPHALT
			46	PQTT				1										Fine to coarse SAND some gravel, brownish grey. Loosely packed, moist, well graded, subangular; Gravel, fine to coarse, subangular to subrounded.
Holocene Alluvial Sand Deposits			100	SPT		1/1 1/0 2/3 N=6 No liner		28				S						No recovery
			100	SPT		5/4 4/2 4/4 N=14 No liner		26			D	MD						Fine to coarse SAND some gravel trace silt, brownish grey. Medium dense, dry, well graded, subangular; Gravel, fine to coarse, subangular to sub rounded.
			100	SPT				27										
			100	SPT				25				W						Fine to coarse GRAVEL some sand trace silt, brownish grey. Medium dense, wet, well graded, subangular; Sand fine to coarse, subangular.
Holocene Alluvial Gravel Deposits			100	SPT		3/5 5/4 4/3 N=16 No liner		24										3.90 - 4.00m: wood log
								25										5.30m: gravel subangular to subrounded.

COMMENTS: Fraste XL SPT Hammer; 110% Energy Transfer Ratio (Pro-Drill Calibration Certification 6/9/2017); All SPT inferred densities are un-corrected for ETR | Borehole backfilled with Bentonite Pellets 16/8/2018

Hole Depth
11.05m

Scale 1:30

Rev.: A

BOREHOLE LOG

BOREHOLE No.: **BH-101**

Hole Location: East end of Campus, in carpark.

SHEET: 2 OF 2

PROJECT: Centennial Park, Hokowhitu	LOCATION: Centennial Drive, Palmerston North	JOB No.: 1004625.0010
CO-ORDINATES: 5527999.00 mN (NZTM2000) 1823251.00 mE	DRILL TYPE: Fraste XL	HOLE STARTED: 16/08/2018
R.L.: 29.38m	DRILL METHOD: SNC	HOLE FINISHED: 16/08/2018
DATUM: NZVD2016	DRILL FLUID: WATER	DRILLED BY: ProDrill
		LOGGED BY: EJWL
		CHECKED: PAWR

GEOLOGICAL		ENGINEERING DESCRIPTION																
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION		WATER	100 CORE RECOVERY (%)	100 METHOD	100 CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	20 SHEAR STRENGTH (kPa)	100 COMPRESSION STRENGTH (MPa)	200 DEFECT SPACING (cm)	Description and Additional Observations		
Holocene Alluvial Gravel Deposits			100	SPT		7/10 6/8 8/9 N=31 No liner	█	23			D					[CONT] Fine to coarse GRAVEL some sand trace silt, brownish grey. Medium dense, wet, well graded, subangular; Sand fine to coarse, subangular.		
			100	PQTT					7							6.10m: dense		
			100	SPT		22/15 35/15 for 70mm N>=50 No liner	█		8			VD					6.90m: trace cobbles, up to 8cm length.	
			100	PQTT					21								7.60m: very dense	
			100	SPT		7/12 20/10 10/10 N>=50 No liner	█		20									
			100	PQTT					10									
			100	SPT		9/9 10/10 15/8 N=43 No liner	█		11			W	D				Fine to coarse SAND some gravel trace silt, grey. Dense, wet, well graded, subangular; Gravel, fine to coarse, subangular to subrounded.	
			100	PQTT	130mm				19									
										18								11.05m: Target depth

COMMENTS: Fraste XL SPT Hammer; 110% Energy Transfer Ratio (Pro-Drill Calibration Certification 6/9/2017); All SPT inferred densities are un-corrected for ETR | Borehole backfilled with Bentonite Pellets 16/8/2018

Hole Depth
11.05m
Scale 1:30

BoreLog - 12/09/2018 1:01:36 PM - Produced with Core-GS by GeRoc

BOREHOLE LOG

BOREHOLE No.: BH-102
Hole Location: East of lagoon, North end of Campus
SHEET: 1 OF 2

PROJECT: Centennial Park, Hokowhitu **LOCATION:** Centennial Drive, Palmerston North **JOB No.:** 1004625.0010
CO-ORDINATES: 5527911.00 mN (NZTM2000) 1823287.00 mE **DRILL TYPE:** Fraste XL **HOLE STARTED:** 16/08/2018
R.L.: 29.07m **DRILL METHOD:** SNC **HOLE FINISHED:** 16/08/2018
DATUM: NZVD2016 **DRILL FLUID:** WATER **LOGGED BY:** EJWL **CHECKED:** PAWR

GEOLOGICAL		ENGINEERING DESCRIPTION															
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION		FLUID LOSS (%)	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (cm)	Description and Additional Observations
Fill				100	PQTT				29			D	ϕ				Sandy SILT, greyish brown. Soft, dry, non-plastic; Sand, fine to medium. 0.10 - 0.30m: minor medium to coarse gravel, rounded.
	Holocene Alluvial Sand Deposits		16/08/2018 cave in	100	PQTT		4/7 4/3 3/2 N=12 No liner		28	1		M	L				Fine to coarse SAND minor gravel, brownish grey. Loosely packed, moist, well graded, subangular; Gravel, fine to coarse, subangular to subrounded.
			100	SPT				27	2		W	MD				Sandy fine to coarse GRAVEL, brownish grey. Medium dense, wet, well graded, subangular to subrounded; Sand, fine to coarse, subangular.	
			100	PQTT				26	3			VD					Fine to coarse GRAVEL some sand, grey. Very dense, wet, well graded, sub angular to rounded; Sand, fine to coarse, subangular (Fine sands washed out during coring) 3.20 - 3.40m: Wood log.
			100	PQTT			3/4 8/11 17/14 for 65mm N>=50 No liner		25	4							4.00 - 4.30m: Wood log 4.30 - 4.50m: some silt
Holocene Alluvial Gravel Deposits				100	SPT		1/2 4/5 4/4 N=17 No liner		24	5		MD					4.50m: medium dense
																	No Recovery

COMMENTS: Fraste XL SPT Hammer; 110% Energy Transfer Ratio (Pro-Drill Calibration Certification 6/9/2017); All SPT inferred densities are un-corrected for ETR | Borehole backfilled with Bentonite Pellets 16/8/2018

Hole Depth
11.05m
Scale 1:30

BOREHOLE LOG

BOREHOLE No.: **BH-102**

Hole Location: East of lagoon, North end of Campus

SHEET: 2 OF 2

PROJECT: Centennial Park, Hokowhitu	LOCATION: Centennial Drive, Palmerston North	JOB No.: 1004625.0010
CO-ORDINATES: 5527911.00 mN (NZTM2000) 1823287.00 mE	DRILL TYPE: Fraste XL	HOLE STARTED: 16/08/2018
R.L.: 29.07m	DRILL METHOD: SNC	HOLE FINISHED: 16/08/2018
DATUM: NZVD2016	DRILL FLUID: WATER	LOGGED BY: EJWL CHECKED: PAWR

GEOLOGICAL										ENGINEERING DESCRIPTION									
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION										Description and Additional Observations									
WATER										GRAVEL LOG									
CORE RECOVERY (%)										MOISTURE CONDITION / WEATHERING									
METHOD										STRENGTH/DENSITY CLASSIFICATION									
CASING										SHEAR STRENGTH (kPa)									
TESTS										COMPRESSION STRENGTH (MPa)									
SAMPLES										DEFECT SPACING (cm)									
RL (m)																			
DEPTH (m)																			
Holocene Alluvial Gravel Deposits										[CONT] No Recovery									
										Fine to coarse GRAVEL some sand (as described above). Medium dense.									
										6.85 - 6.95m: some cobbles, up to 7cm length									
										Gravely fine to coarse SAND trace silt, brownish grey. Very dense, wet, well graded, subangular; Gravel, fine to coarse, subangular to subrounded.									
										8.40 - 8.50m: cobble, up to 7cm length									
										8.80m: minor silt									
										Sandy fine to coarse GRAVEL trace silt, brownish grey. Dense, wet, well graded, subangular to rounded; Sand, fine to coarse, subangular.									
										11.05m: Target depth									
										11.05m: Target depth									
										11.05m: Target depth									

COMMENTS: Fraste XL SPT Hammer; 110% Energy Transfer Ratio (Pro-Drill Calibration Certification 6/9/2017); All SPT inferred densities are un-corrected for ETR | Borehole backfilled with Bentonite Pellets 16/8/2018

Hole Depth 11.05m
Scale 1:30

BoreLog - 12/09/2018 1:01:39 PM - Produced with Core-GS by GeRoc

BOREHOLE LOG

BOREHOLE No.: **BH-103**

Hole Location: North side of Rugby Field

SHEET: 1 OF 2

PROJECT: Centennial Park, Hokowhitu	LOCATION: Centennial Drive, Palmerston North	JOB No.: 1004625.0010
CO-ORDINATES: 5527638.00 mN (NZTM2000) 1823316.00 mE	DRILL TYPE: Fraste XL	HOLE STARTED: 15/08/2018
R.L.: 28.13m	DRILL METHOD: SNC	HOLE FINISHED: 15/08/2018
DATUM: NZVD2016	DRILL FLUID: WATER	DRILLED BY: ProDrill
		LOGGED BY: EJWL
		CHECKED: PAWR

GEOLOGICAL		ENGINEERING DESCRIPTION																
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION		FLUID LOSS (%)	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (cm)	Description and Additional Observations	
Holocene Alluvial Sand Deposits		15/08/2018 10.00		100	PQTT				28	1	[Yellow with small black dots]	M	FI				Sandy Silt, orange grey. Firm, moist, non-plastic; Sand, fine.	
				100	SPT		1/0 1/0 1/1 N=3 No liner		27	1	[Yellow with small black dots]		S				Silt some clay, orange grey. Soft, moist, moderate plasticity.	
				100	PQTT				26	2	2	[Yellow with small black dots]	W	VL				Fine SAND some silt trace rootlets and wood fragments, grey mottled orange. Very loose, wet, poorly graded.
				100	SPT		2/2 2/3 3/3 N=11 No liner		25	3	3	[Yellow with small black dots]	M	MD				Fine to medium SAND, orange grey. Medium dense, moist, poorly graded, subangular to subrounded.
				100	PQTT				24	4	4	[Yellow with small black dots]						Fine to coarse SAND interbedded with fine to medium SAND, orange grey and grey. Medium dense, moist, well to poorly graded, subangular to sub rounded; Interbedding cm scale. 3.90 - 4.10m: trace fine gravel, rounded. 4.10 - 4.20m: orange brown 4.30 - 4.40m: trace interbedded silt.
		100	SPT		1/1 0/0 1/1 N=2 No liner		23	5	5	[Yellow with small black dots]	W	VL					Fine to medium SAND, interbedded with sandy SILT and trace wood fragments, grey. Very loose, wet, poorly graded, subangular to subrounded. 5.20 - 5.35m: Wood fragments.	

COMMENTS: Fraste XL SPT Hammer; 110% Energy Transfer Ratio (Pro-Drill Calibration Certification 6/9/2017); All SPT inferred density using un-corrected N value| Borehole backfilled with Bentonite Pellets 15/8/2018

Hole Depth 11.05m
Scale 1:30

PROJECT: Centennial Park, Hokowhitu	LOCATION: Centennial Drive, Palmerston North	JOB No.: 1004625.0010
CO-ORDINATES: 5527638.00 mN (NZTM2000) 1823316.00 mE	DRILL TYPE: Fraste XL	HOLE STARTED: 15/08/2018
R.L.: 28.13m	DRILL METHOD: SNC	HOLE FINISHED: 15/08/2018
DATUM: NZVD2016	DRILL FLUID: WATER	DRILLED BY: ProDrill
		LOGGED BY: EJWL CHECKED: PAWR

GEOLOGICAL		ENGINEERING DESCRIPTION																		
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION		FLUID LOSS (%)	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION	WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (cm)	Description and Additional Observations		
Holocene Alluvial Gravel Deposits		0		100	SPT		9/8 8/9 13/12 N=42 No liner		22									Fine to coarse GRAVEL, some sand, grey. Dense, wet, well graded, subrounded to rounded, sandstone; Sand, fine to coarse, subangular to subrounded.		
				100	PQTT				7									6.70 - 6.90m: Cobbles, up to 8cm length, subrounded to rounded.		
				100	PQTT					21									7.30 - 7.40m: some cobbles, up to 8cm length.	
				100	SPT			8/11 12/12 10/10 N=44 No liner		8									7.50 - 7.60m: some angular gravel	
				100	PQTT					20										
				100	SPT			9/10 14/12 14/10 N>=50 No liner		19				VD						9.10m: very dense.
				100	PQTT					18										9.30m: trace silt
				100	SPT			1/2 3/4 5/16 N=28 No liner		11				S	MD					Fine SAND some silt, grey. Medium dense, saturated, poorly graded.
				77	SPT		130mm													No recovery
											17									11.05m: Target depth

COMMENTS: Fraste XL SPT Hammer; 110% Energy Transfer Ratio (Pro-Drill Calibration Certification 6/9/2017); All SPT inferred density using un-corrected N value| Borehole backfilled with Bentonite Pellets 15/8/2018

BoreLog - 12/09/2018 1:01:42 PM - Produced with Core-GS by GeRoc

Hole Depth
11.05m
Scale 1:30

BOREHOLE LOG

BOREHOLE No.: **BH-104**

Hole Location: West side of rugby field

SHEET: 1 OF 2

PROJECT: Centennial Park, Hokowhitu	LOCATION: Centennial Drive, Palmerston North	JOB No.: 1004625.0010
CO-ORDINATES: 5527561.00 mN (NZTM2000) 1823258.00 mE	DRILL TYPE: Fraste XL	HOLE STARTED: 15/08/2018
R.L.: 28.17m	DRILL METHOD: SNC	HOLE FINISHED: 15/08/2018
DATUM: NZVD2016	DRILL FLUID: WATER	DRILLED BY: ProDrill
		LOGGED BY: EJWL
		CHECKED: PAWR

GEOLOGICAL		ENGINEERING DESCRIPTION																
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION	FLUID LOSS (%)	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)		COMPRESSIVE STRENGTH (MPa)		DEFECT SPACING (cm)	Description and Additional Observations
													20	100	1	50		
Holocene Alluvial Sand Deposits			100	PQTT				28			M	F						Sandy SILT, orange grey. Firm, moist, non-plastic; Sand, fine. 0.30 - 0.40m: trace medium to coarse gravel, subrounded.
			100	SPT		1/1 0/0 0/1 N=1 No liner		27	1		W	L						SILT, some clay, orange grey mottled orange. Firm, moist, moderate plasticity, Silty fine to medium SAND, orange grey. Loosely packed, wet, poorly graded, 1.50m: very loose
			100	PQTT				26	2			M	L					2.25m: interbedded with silt some clay, moderate plasticity., orange banding .
			100	SPT		3/5 4/3 6/6 N=19 No liner		25	3				MD					Fine to medium SAND, orange grey. Loosely packed, moist, poorly graded, subangular to subrounded. Gravelly fine to coarse SAND, orange brown. Medium dense, moist, well graded, subangular; Gravel, fine to coarse, subrounded to rounded.
			100	PQTT				24	4			W	D					Fine to coarse GRAVEL some sand, orange grey. Medium dense, wet, well graded, subangular to subrounded; Sand, fine to coarse, subangular.
Holocene Alluvial Gravel Deposits			100	SPT		3/3 3/3 3/3 N=12 No liner		23	5									4.95 - 5.50m: gravel angular to subrounded. 5.60 - 6.10m: reddish brown.

COMMENTS: Fraste XL SPT Hammer; 110% Energy Transfer Ratio (Pro-Drill Calibration Certification 6/9/2017); All SPT inferred densities are un-corrected for ETR| Borehole backfilled with Bentonite Pellets 15/8/2018

Hole Depth 11.05m

Scale 1:30

BoreLog - 12/09/2018 1:01:44 PM - Produced with Core-GS by GeRoc

Rev.: A

BOREHOLE LOG

BOREHOLE No.: **BH-104**

Hole Location: West side of rugby field

SHEET: 2 OF 2

PROJECT: Centennial Park, Hokowhitu	LOCATION: Centennial Drive, Palmerston North	JOB No.: 1004625.0010
CO-ORDINATES: 5527561.00 mN (NZTM2000) 1823258.00 mE	DRILL TYPE: Fraste XL	HOLE STARTED: 15/08/2018
R.L.: 28.17m	DRILL METHOD: SNC	HOLE FINISHED: 15/08/2018
DATUM: NZVD2016	DRILL FLUID: WATER	DRILLED BY: ProDrill
		LOGGED BY: EJWL
		CHECKED: PAWR

GEOLOGICAL		ENGINEERING DESCRIPTION																	
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION		FLUID LOSS (%)	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION	WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (cm)	Description and Additional Observations	
Holocene Alluvial Gravel Deposits			100	100	SPT		2/4 2/3 4/5 N=14 No liner	22										[CONT] Fine to coarse GRAVEL some sand, orange grey. Medium dense, wet, well graded, subangular to subrounded; Sand, fine to coarse, subangular.	
				100	PQTT				7	21		W	MD					6.60m: trace cobbles, upto 7cm length	
				100	SPT		10/20 50 for 75mm N>=50 No liner		8	20			VD					7.60m: very dense	
				0	PQTT				9									8.05 - 8.10m: Cobble up to 8cm length.	
				100	SPT		10/12 12/12 12/13 N=49 No liner		19				D					No recovery due to cobble	
				100	PQTT				10	18									9.50 - 9.60m: cobble , up to 8cm
				73	SPT	130mm	20/15 20/20 10 for 30mm N>=50 No liner		11					VD					10.60m: very dense.
									17										11.05m: Target depth

COMMENTS: Fraste XL SPT Hammer; 110% Energy Transfer Ratio (Pro-Drill Calibration Certification 6/9/2017); All SPT inferred densities are un-corrected for ETR| Borehole backfilled with Bentonite Pellets 15/8/2018

Hole Depth
11.05m
Scale 1:30

PROJECT: Centennial Park, Hokowhitu	LOCATION: Centennial Drive, Palmerston North	JOB No.: 1004625.0010
CO-ORDINATES: 5527551.00 mN (NZTM2000) 1823392.00 mE	DRILL TYPE: Fraste XL	HOLE STARTED: 15/08/2018
R.L.: 28.58m	DRILL METHOD: SNC	HOLE FINISHED: 15/08/2018
DATUM: NZVD2016	DRILL FLUID: WATER	DRILLED BY: ProDrill
		LOGGED BY: EJWL
		CHECKED: PAWR

GEOLOGICAL		ENGINEERING DESCRIPTION																		
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION		FLUID LOSS (%)	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION	WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (cm)	Description and Additional Observations		
Fill				100	PQTT				28	1		M	MD					ASPHALT		
														D	F					Sandy fine to coarse GRAVEL, grey. Tightly packed, moist, well graded, sub angular to subrounded; Sand, fine to coarse, angular to subangular. (Sand washed away during drilling)
Holocene Alluvial Sand Deposits				100	PQTT				27	2									SILT, orange brown. Firm, dry, non-plastic	
														D	F					Fine to coarse GRAVEL, orange brown. Loose, wet, well graded, subangular to subrounded.
Holocene Alluvial Sand Deposits				100	SPT		4/7 8/6 7/9 N=30 No liner		26	3									Sandy SILT, orange brown. Firm, dry, non-plastic; Sand, fine.	
																				Gravelly fine to coarse SAND trace silt, orange grey. Medium dense, dry, well graded, subangular to subrounded; Sand, fine to coarse, subangular.
Holocene Alluvial Sand Deposits				100	SPT		4/4 9/9 9/9 N=36 No liner		25	4										
Holocene Alluvial Sand Deposits				100	SPT		4/7 6/5 6/4 N=21 No liner		24	5										
														M						
Holocene Alluvial Sand Deposits									23											
														S						

COMMENTS: Fraste XL SPT Hammer; 110% Energy Transfer Ratio (Pro-Drill Calibration Certification 6/9/2017); All SPT inferred densities are un-corrected for ETR | Borehole backfilled with Bentonite Pellets 15/8/2018

Hole Depth 11.05m
Scale 1:30

PROJECT: Centennial Park, Hokowhitu	LOCATION: Centennial Drive, Palmerston North	JOB No.: 1004625.0010
CO-ORDINATES: 5527551.00 mN (NZTM2000) 1823392.00 mE	DRILL TYPE: Fraste XL	HOLE STARTED: 15/08/2018
R.L.: 28.58m	DRILL METHOD: SNC	HOLE FINISHED: 15/08/2018
DATUM: NZVD2016	DRILL FLUID: WATER	LOGGED BY: EJWL CHECKED: PAWR

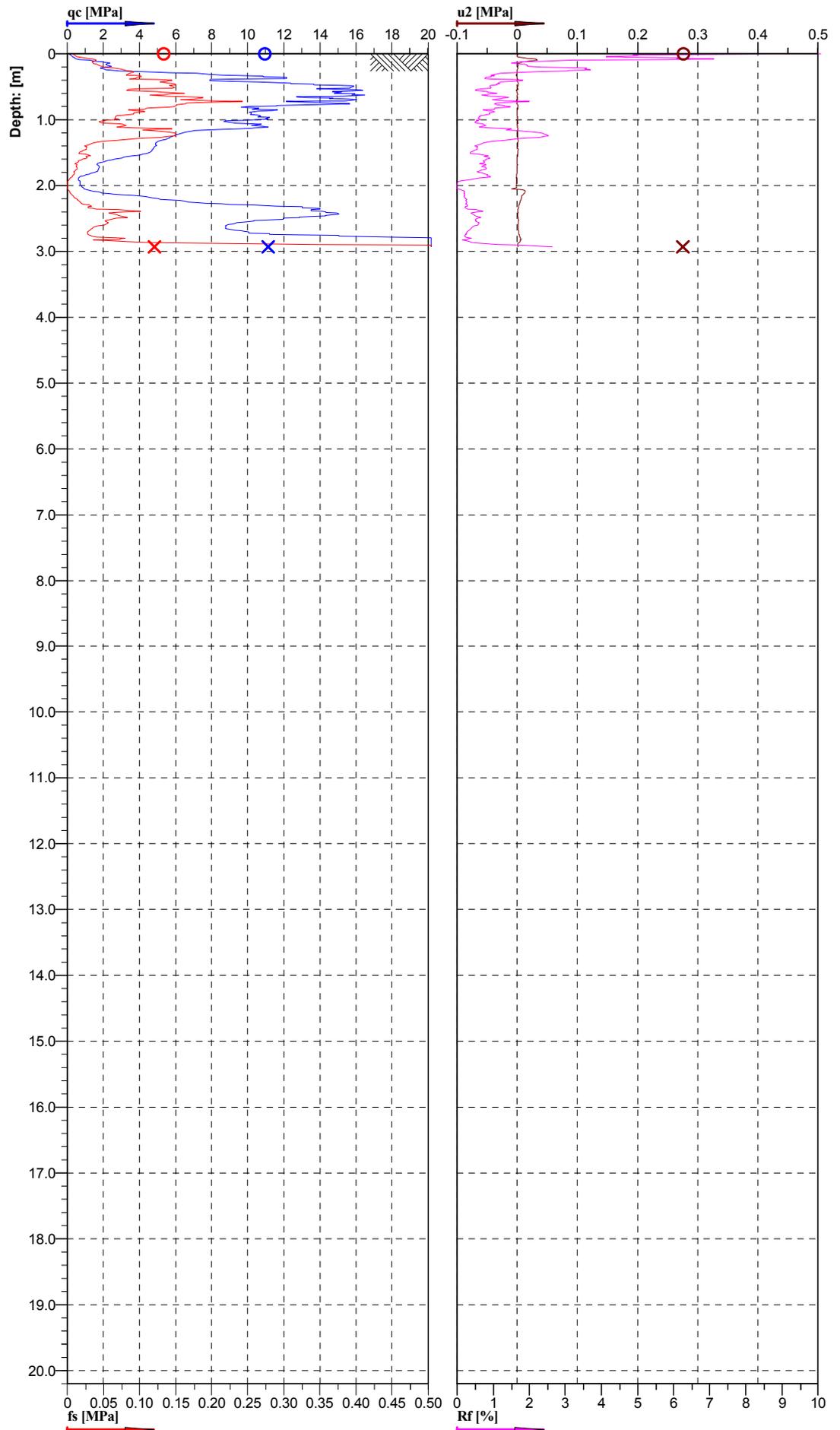
GEOLOGICAL		ENGINEERING DESCRIPTION																
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION		FLUID LOSS (%)	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION	WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (cm)	Description and Additional Observations
Holocene Alluvial Sand Deposits	100	100	SPT	2/3 4/3 2/5 N=14 No liner					22									[CONT] Fine silty SAND, grey. Medium dense, saturated, poorly graded.
	100	100	PQTT						7			S	D					6.60 - 6.75m: trace medium gravel, subrounded.
Holocene Alluvial Gravel Deposits	100	100	SPT	6/9 7/9 9/8 N=33 No liner					21									Fine to coarse GRAVEL some sand trace silt and cobbles, grey. Dense, saturated, well graded, subangular to subrounded; Sand, fine to coarse, subangular; Cobble up to 7cm length.
	100	100	PQTT						20									
	100	100	SPT	4/7 8/9 11/13 N=41 No liner					19									
	100	100	PQTT						10									10.10 - 10.20m: Sandy gravel
	100	100	SPT	8/9 7/5 3/11 N=26 No liner		130mm			18				MD					10.60m: medium dense.
									11									11.05m: Target depth
									17									

COMMENTS: Fraste XL SPT Hammer; 110% Energy Transfer Ratio (Pro-Drill Calibration Certification 6/9/2017); All SPT inferred densities are un-corrected for ETR | Borehole backfilled with Bentonite Pellets 15/8/2018

Hole Depth 11.05m
Scale 1:30

**Classification by
Robertson 1986**

- Clay (3)
- Sand to silty sand (8)
- Sandy silt to clayey silt (6)
- Sensitive fine grained (1)
- Sand (9)

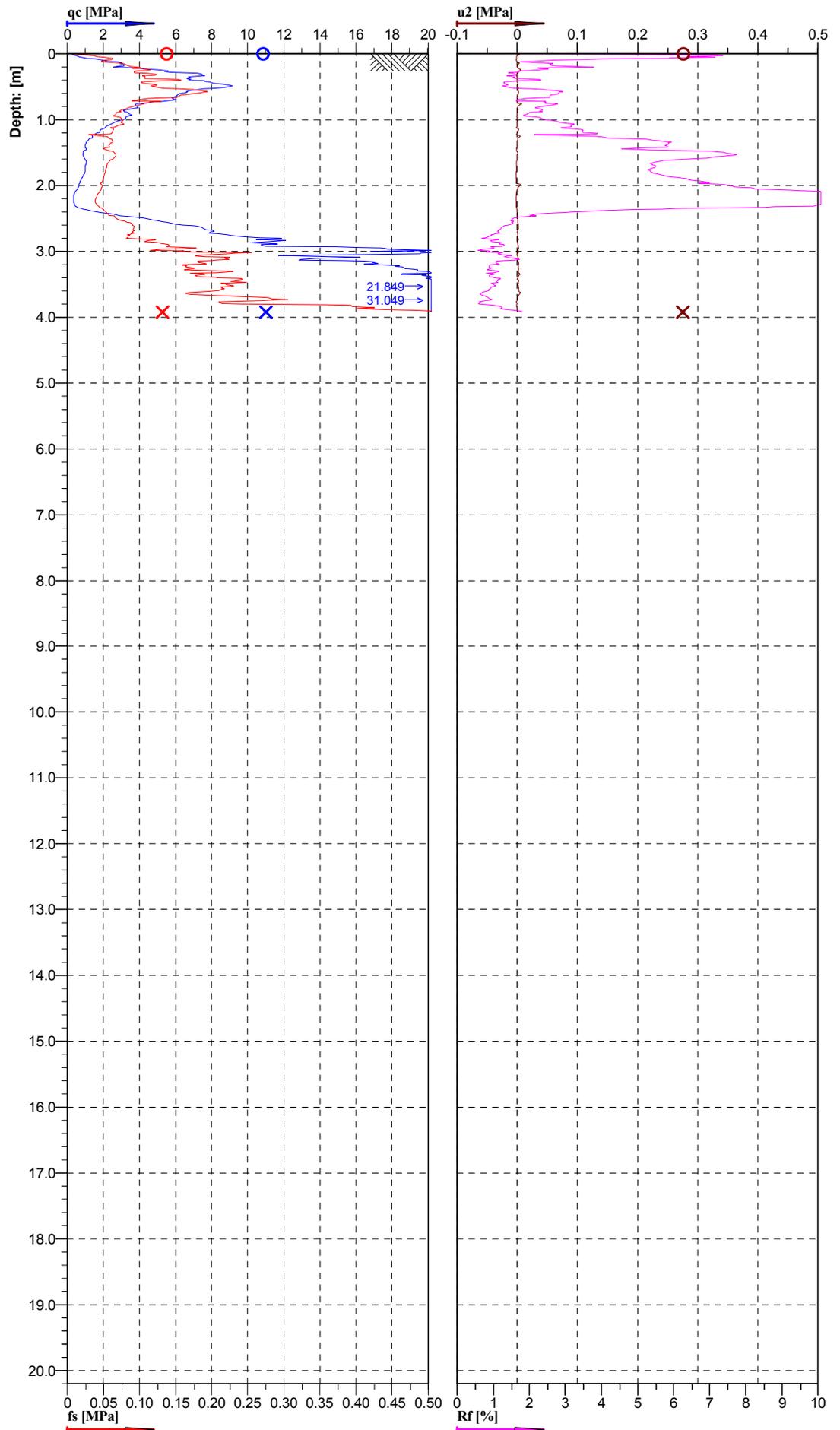


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT 101
Project ID:	Client: T&T	Date: 16/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT101.cpt	

Classification by Robertson 1986

- Organic material (2)
- Sandy silt to clayey silt (6)
- Clay (3)
- Organic material (2)
- Sand to silty sand (8)
- Sand (9)

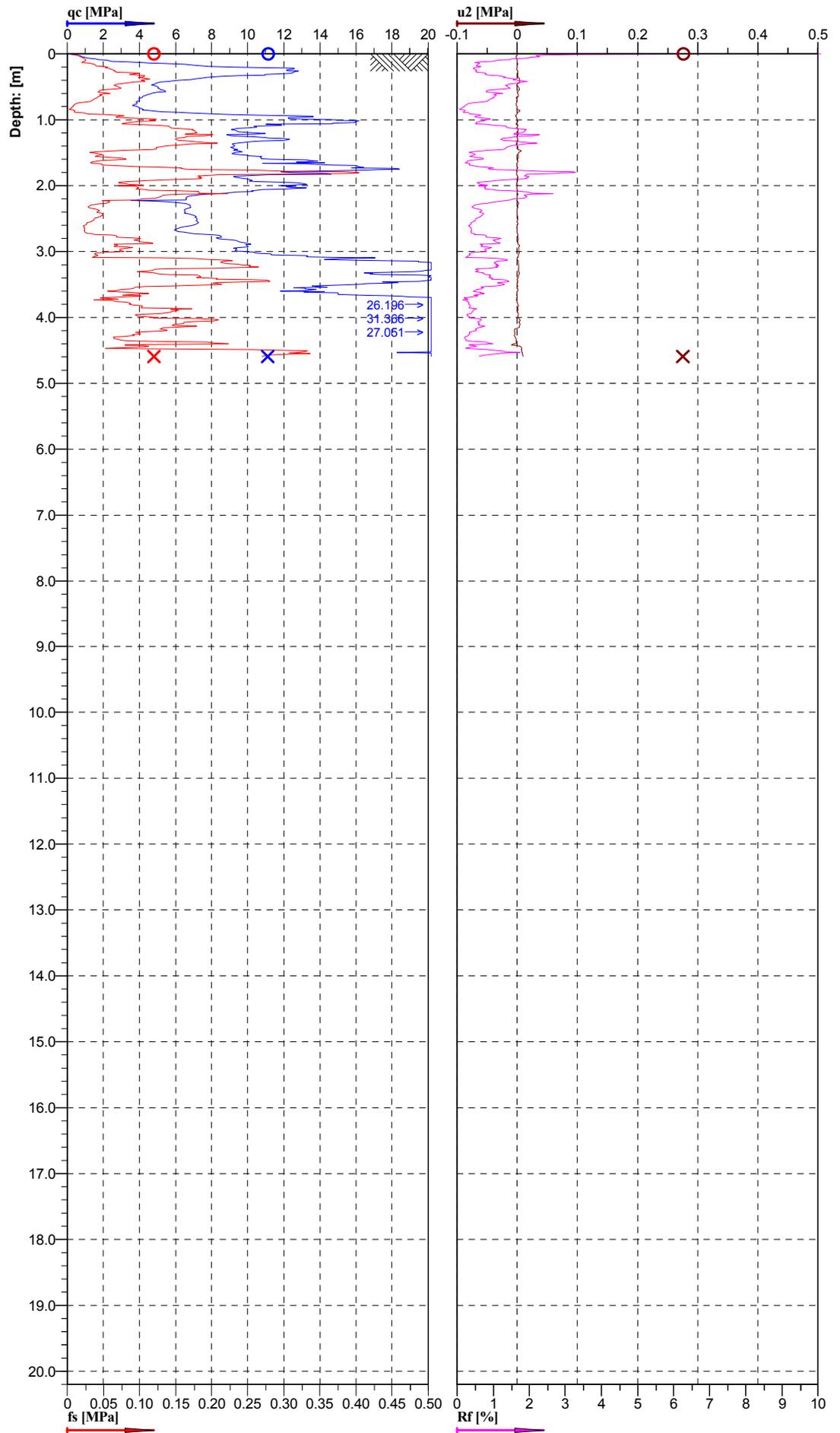


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT102
Project ID:	Client: T&T	Date: 16/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT102.cpt	

**Classification by
Robertson 1986**

- Silty clay to clay (4)
- Silty sand to sandy silt (7)
- Sand (9)
- Sand to silty sand (8)
- Sand (9)
- Gravely sand to sand (10)

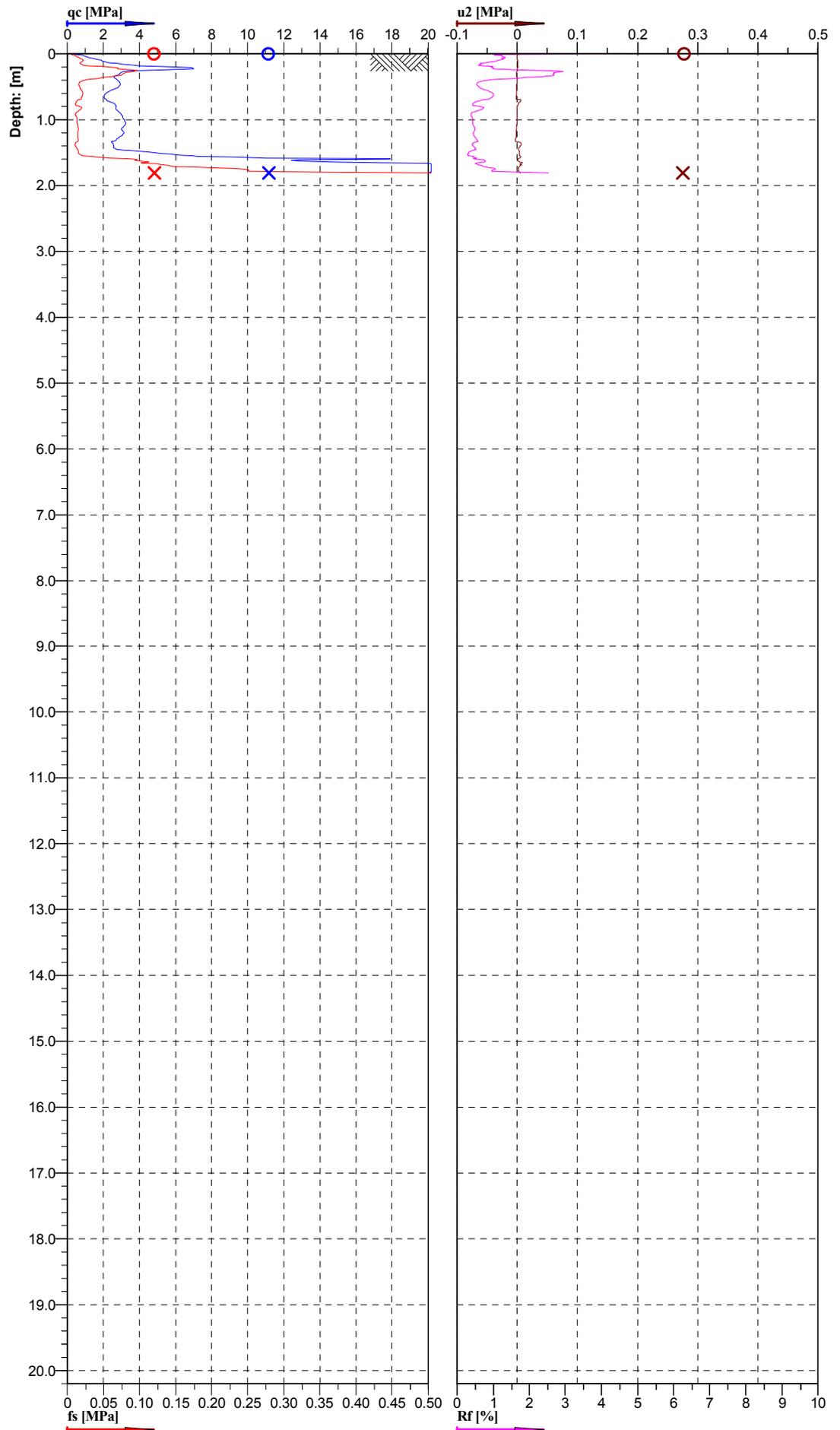


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT103
Project ID:	Client: T&T	Date: 16/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT103.cpt	

Classification by
Robertson 1986

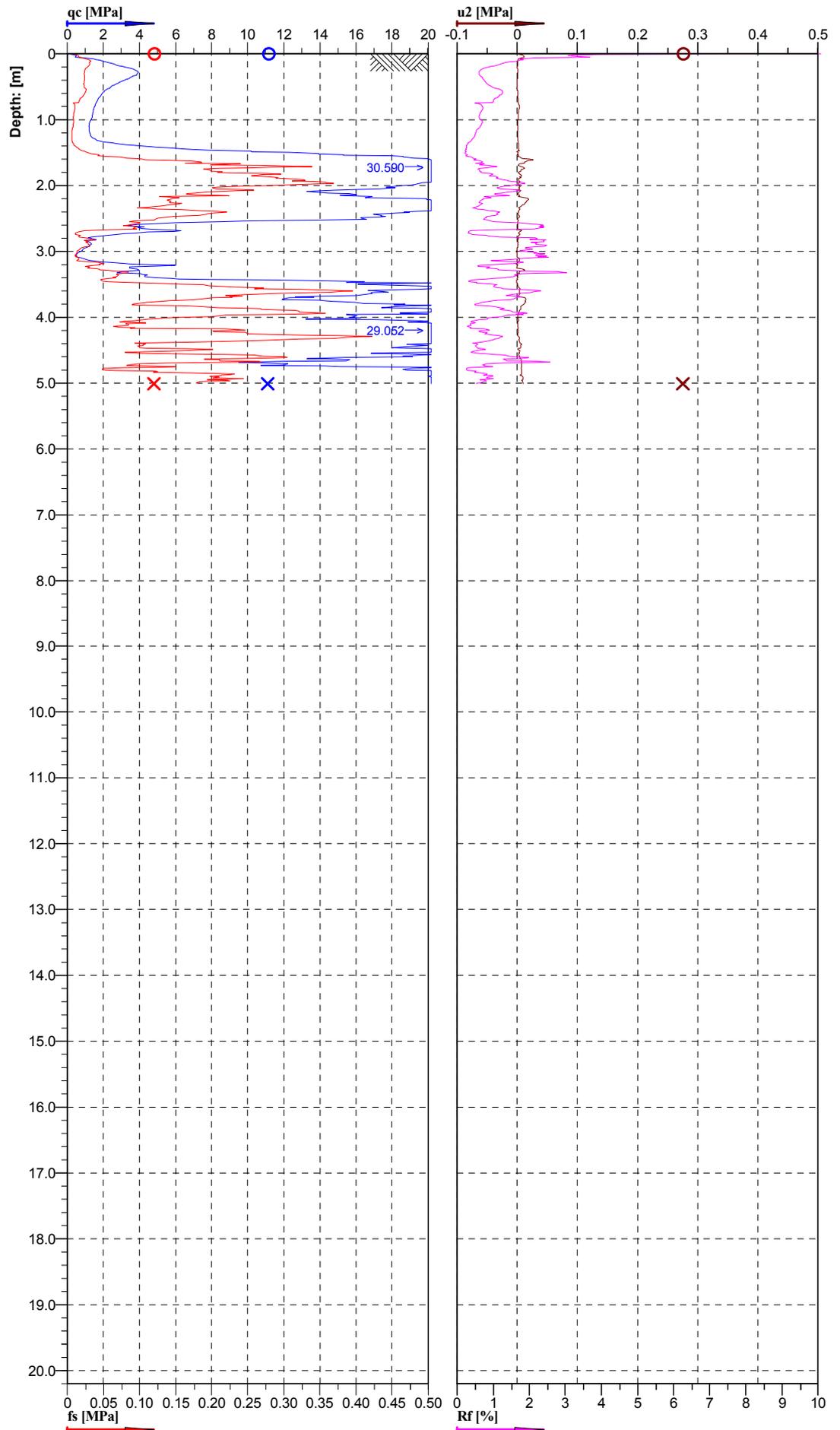
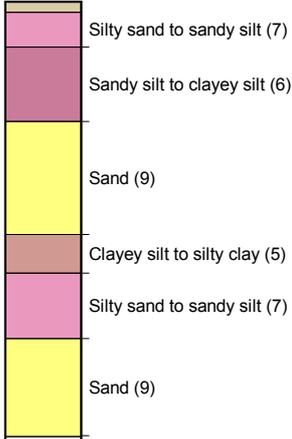
- Sand to silty sand (8)
- Silty sand to sandy silt (7)
- Sand (9)



Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT 104
Project ID:	Client: T&T	Date: 16/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
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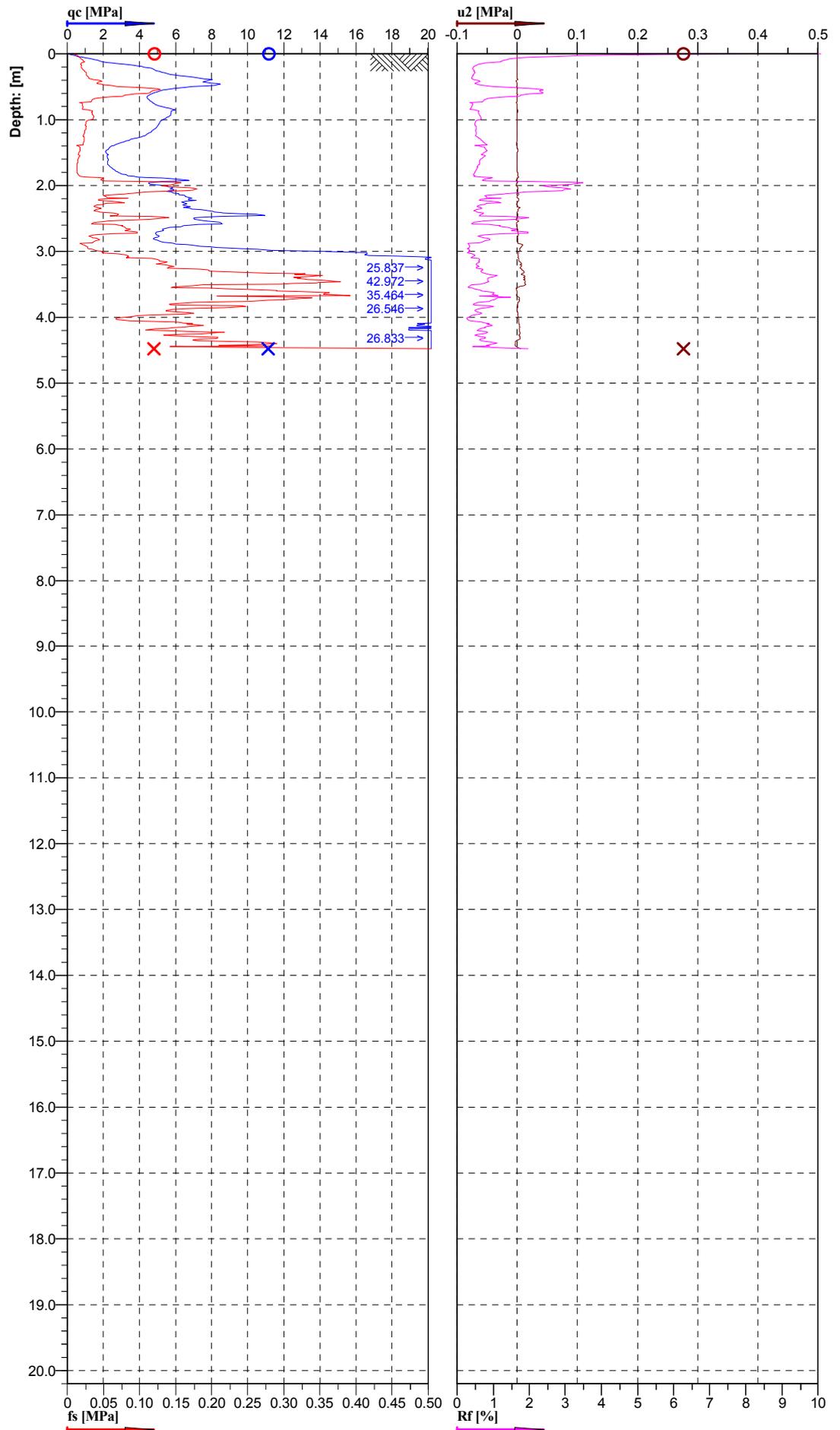
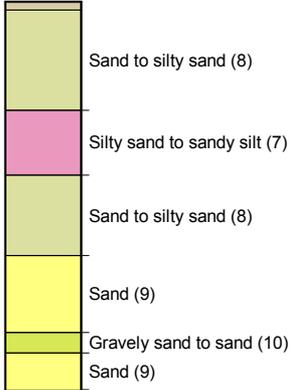
Classification by
Robertson 1986



Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT104A
Project ID:	Client: T&T	Date: 16/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT104A.cpt	

Classification by Robertson 1986



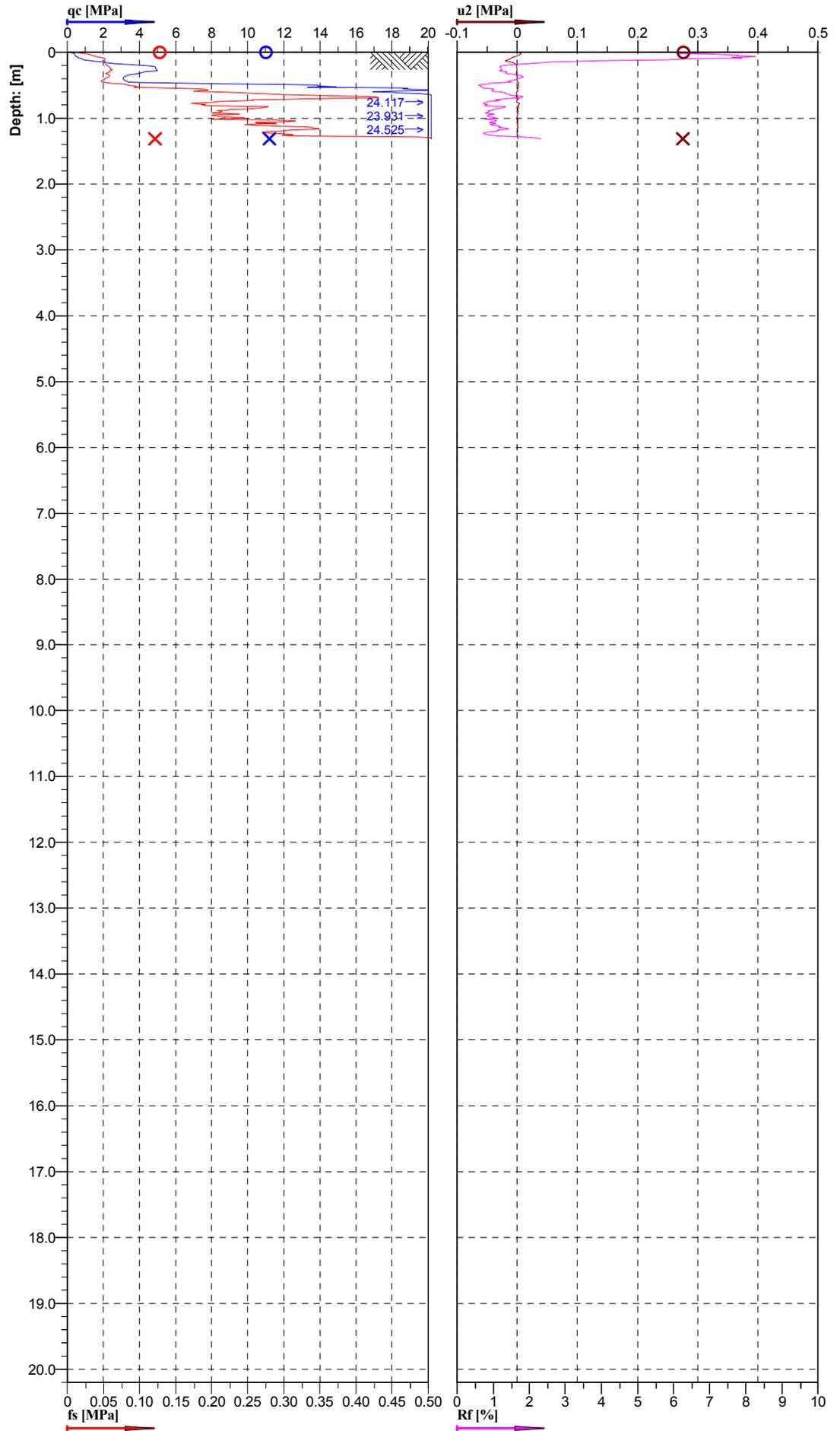
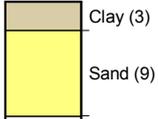
PRO-DRILL
SPECIALITY DRILLING ENGINEERS



Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT105
Project ID:	Client: T&T	Date: 16/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT105.cpt	

Classification by
Robertson 1986



PRO-DRILL
SPECIALITY DRILLING SERVICES

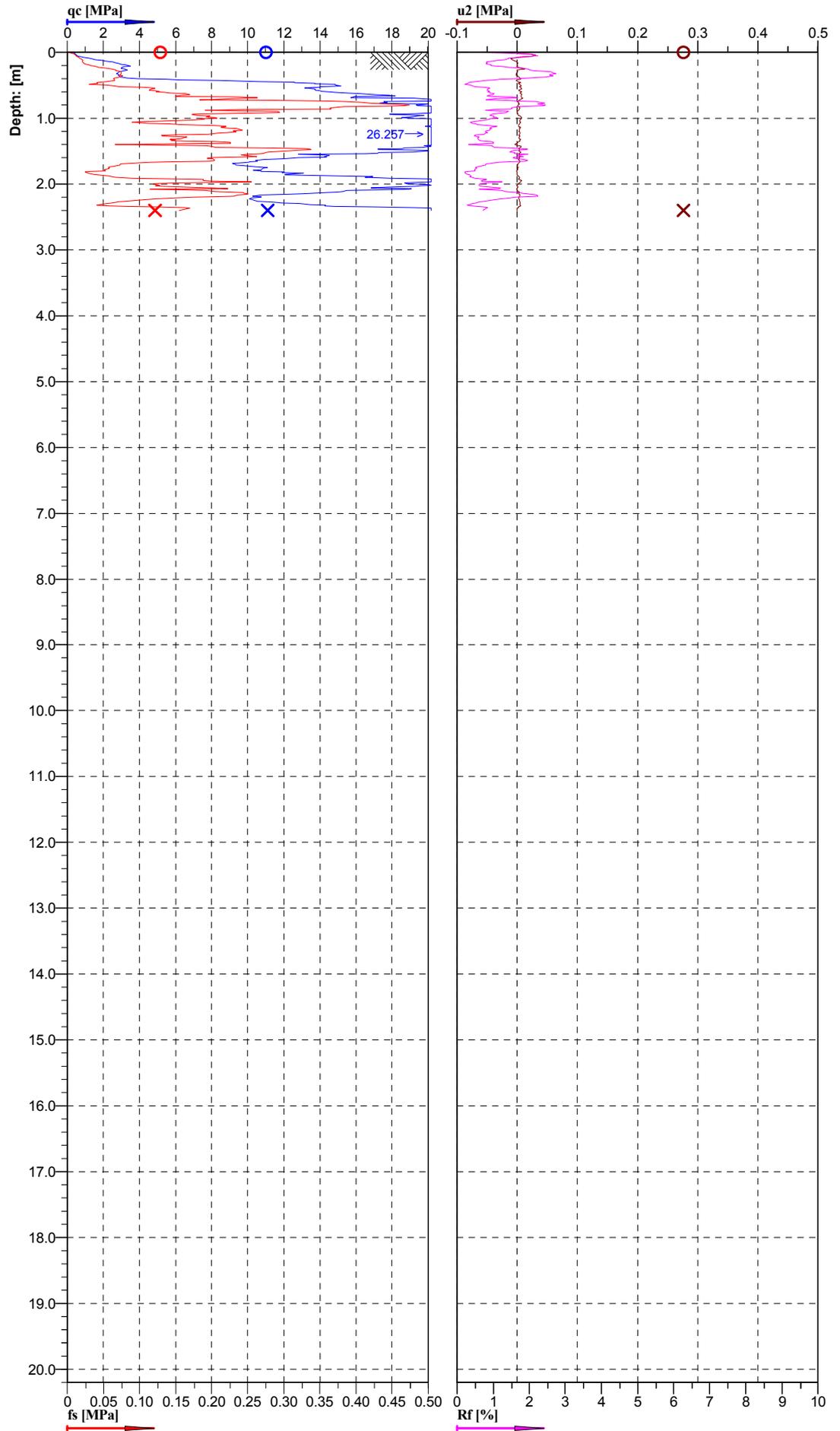


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT106
Project ID:	Client: T&T	Date: 16/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT106.cpt	

Classification by Robertson 1986

- Clay (3)
- Sandy silt to clayey silt (6)
- Sand (9)
- Sand to silty sand (8)
- Sand (9)

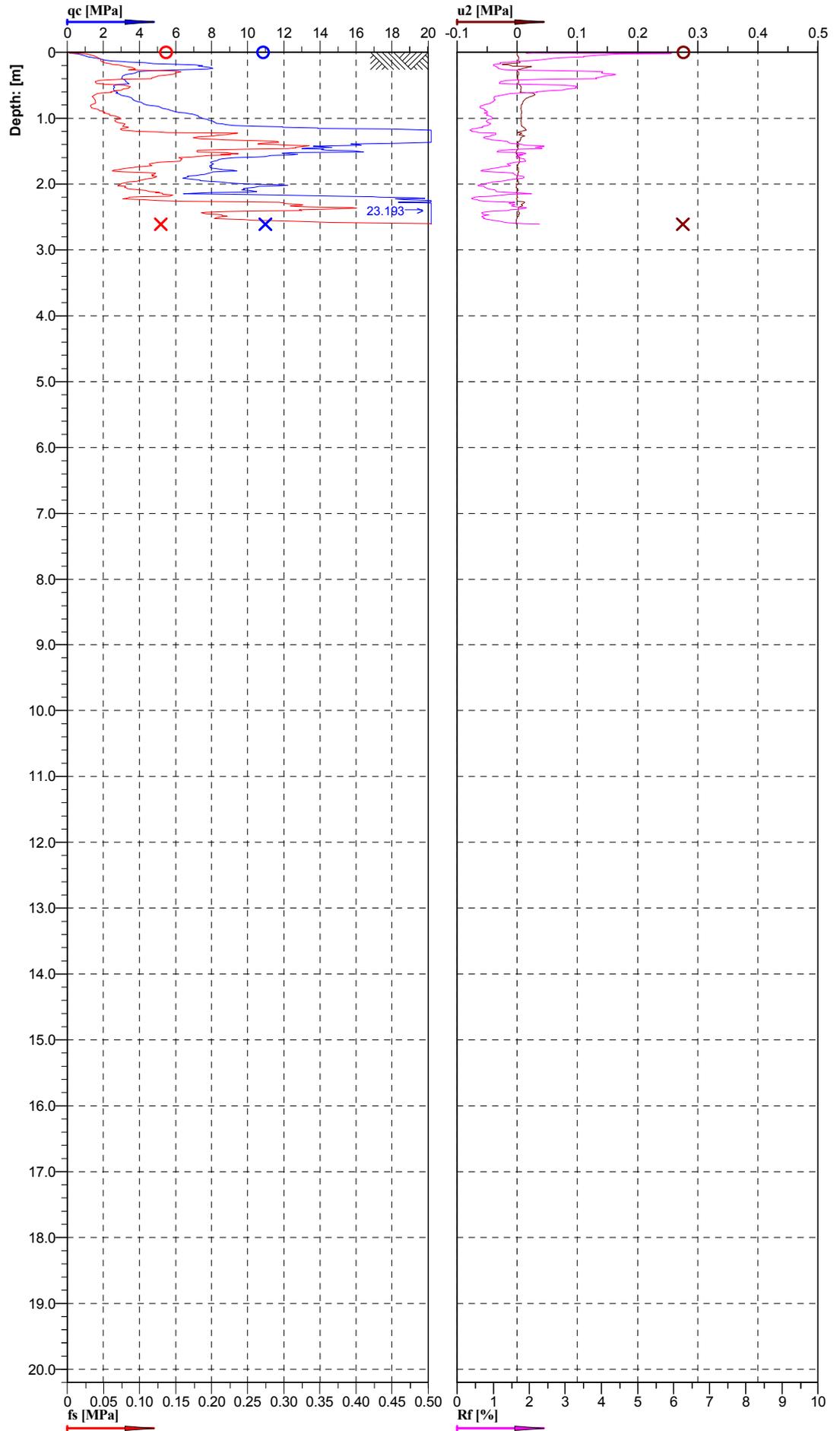


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT106A
Project ID:	Client: T&T	Date: 16/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT106A.cpt	

Classification by Robertson 1986

- Clay (3)
- Silty sand to sandy silt (7)
- Sand to silty sand (8)
- Sand (9)
- Silty sand to sandy silt (7)
- Sand (9)

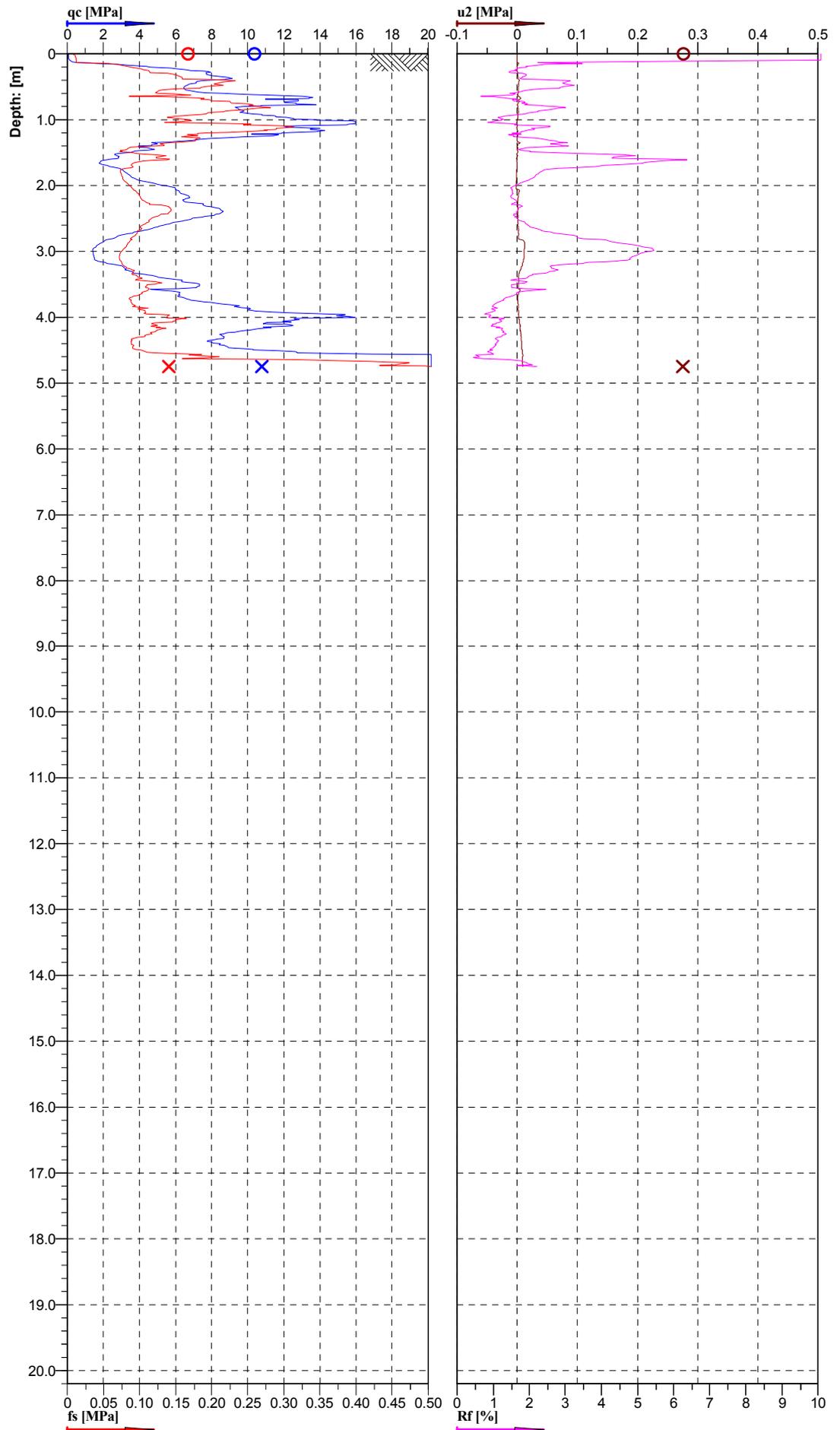


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT107
Project ID:	Client: T&T	Date: 15/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT107.cpt	

Classification by Robertson 1986

- Organic material (2)
- Silty sand to sandy silt (7)
- Sand to silty sand (8)
- Clay (3)
- Sandy silt to clayey silt (6)
- Silty sand to sandy silt (7)
- Clay (3)
- Silty sand to sandy silt (7)
- Sand to silty sand (8)

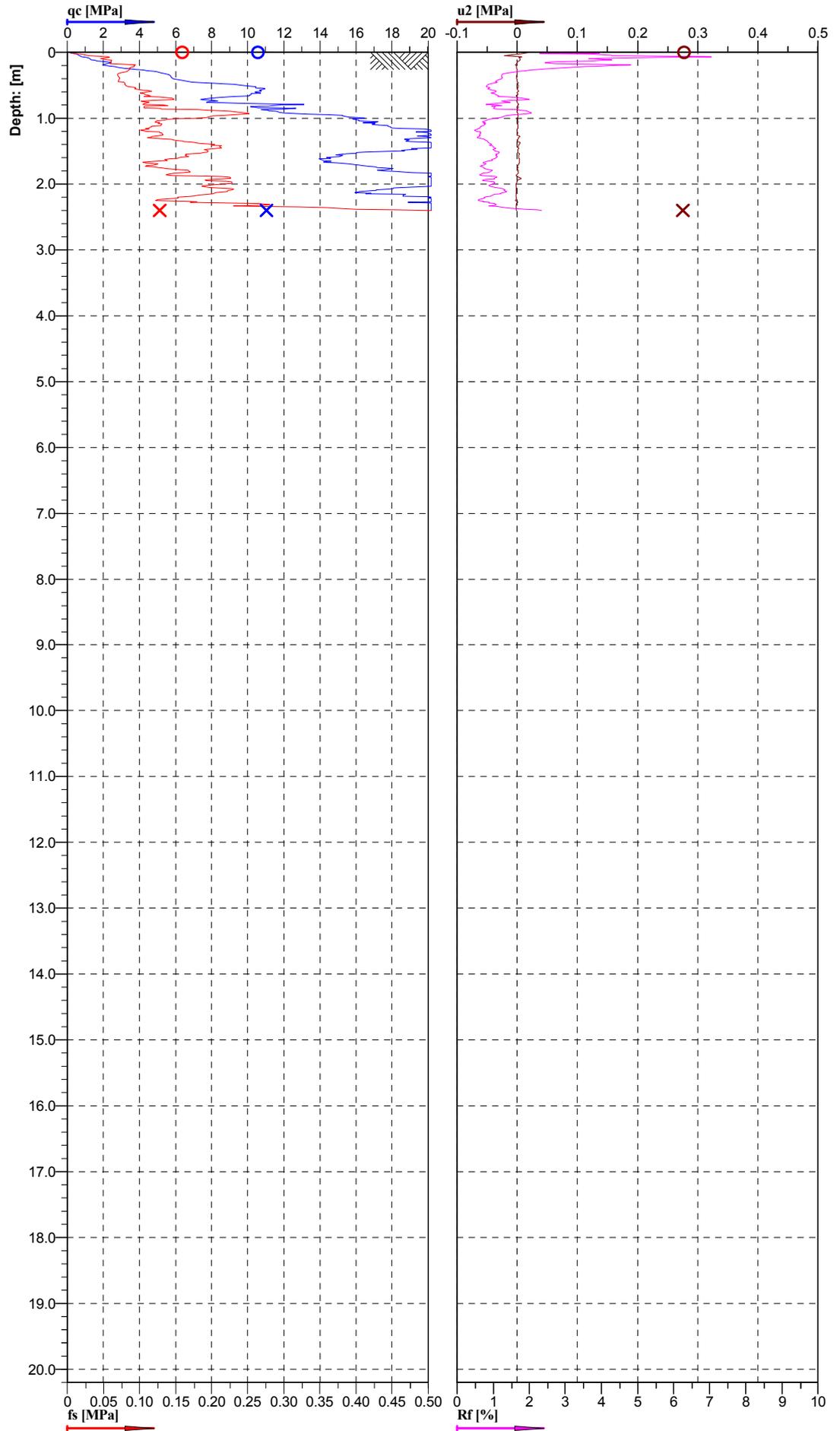


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT108
Project ID:	Client: T&T	Date: 15/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT108.cpt	

Classification by Robertson 1986

- Sensitive fine grained (1)
- Sand to silty sand (8)
- Silty sand to sandy silt (7)
- Sand (9)



PRO-DRILL
SPECIALITY DRILLING SERVICES

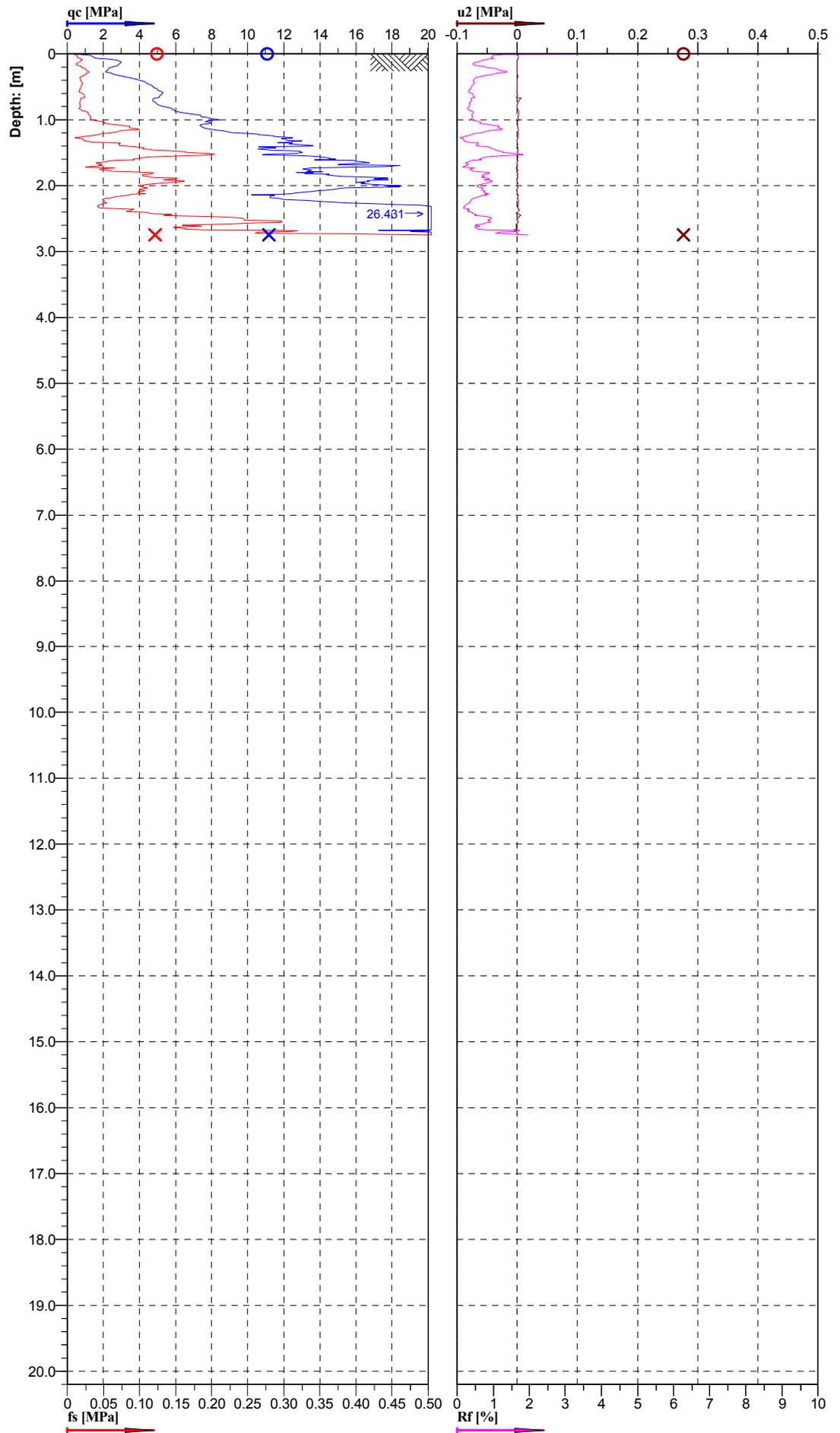


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT109
Project ID:	Client: T&T	Date: 16/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
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Classification by
Robertson 1986

- Silty sand to sandy silt (7)
- Sand to silty sand (8)
- Sand (9)

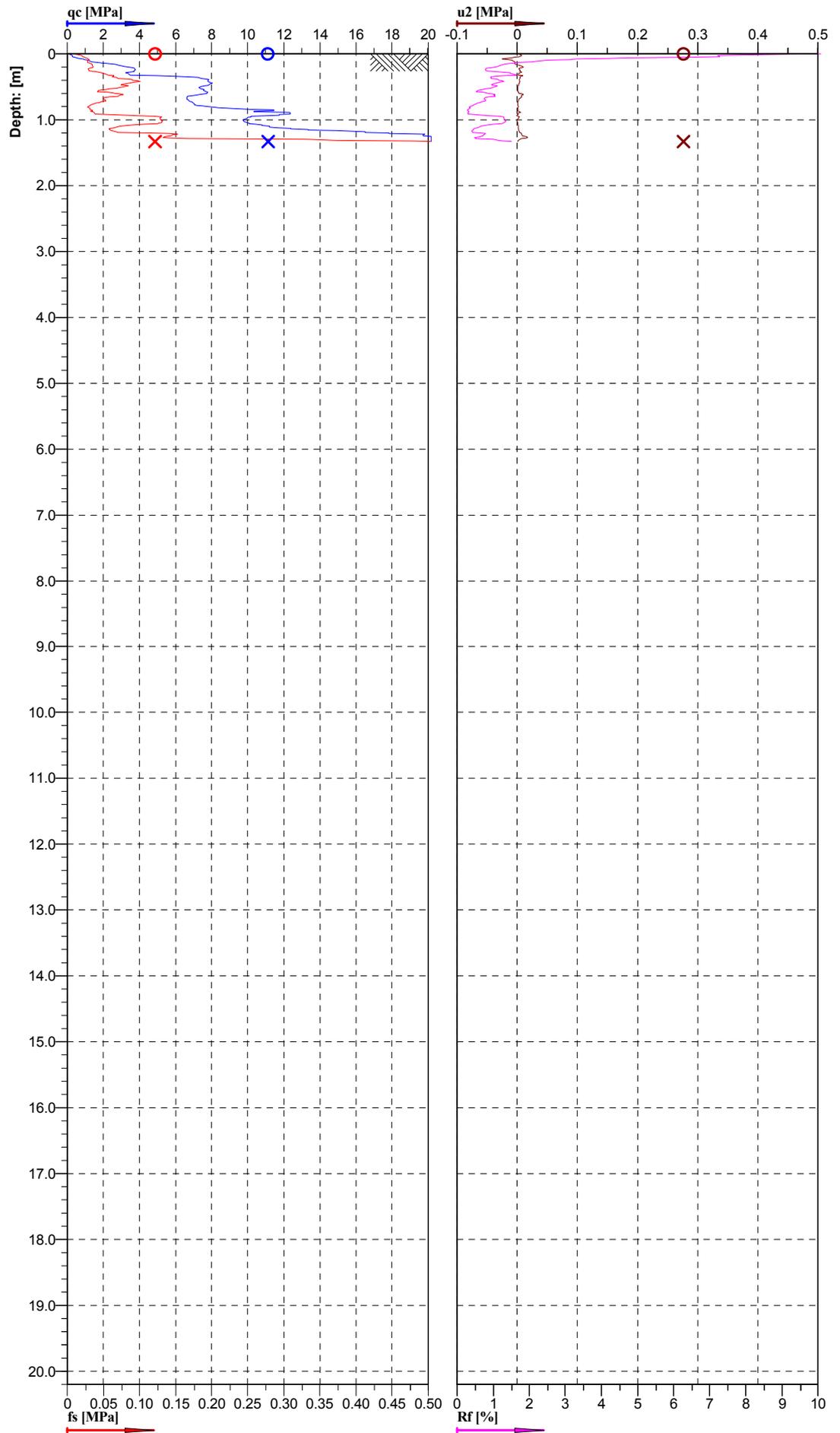


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT110
Project ID:	Client: T&T	Date: 16/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
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Classification by
Robertson 1986

- Organic material (2)
- Sand to silty sand (8)
- Sand (9)

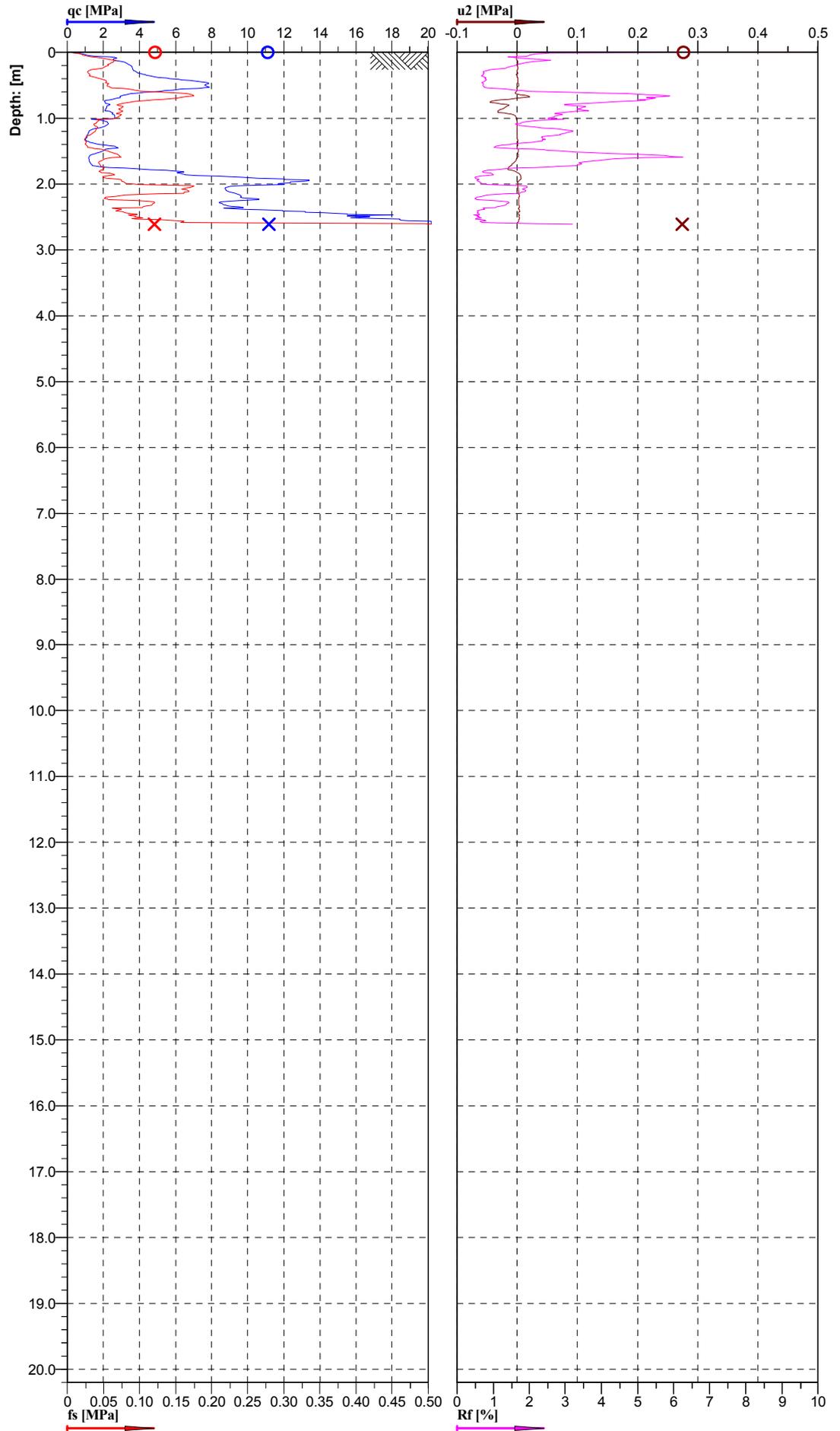


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT111
Project ID:	Client: T&T	Date: 15/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT111.cpt	

Classification by Robertson 1986

- Clayey silt to silty clay (5)
- Sand to silty sand (8)
- Clayey silt to silty clay (5)
- Sand (9)

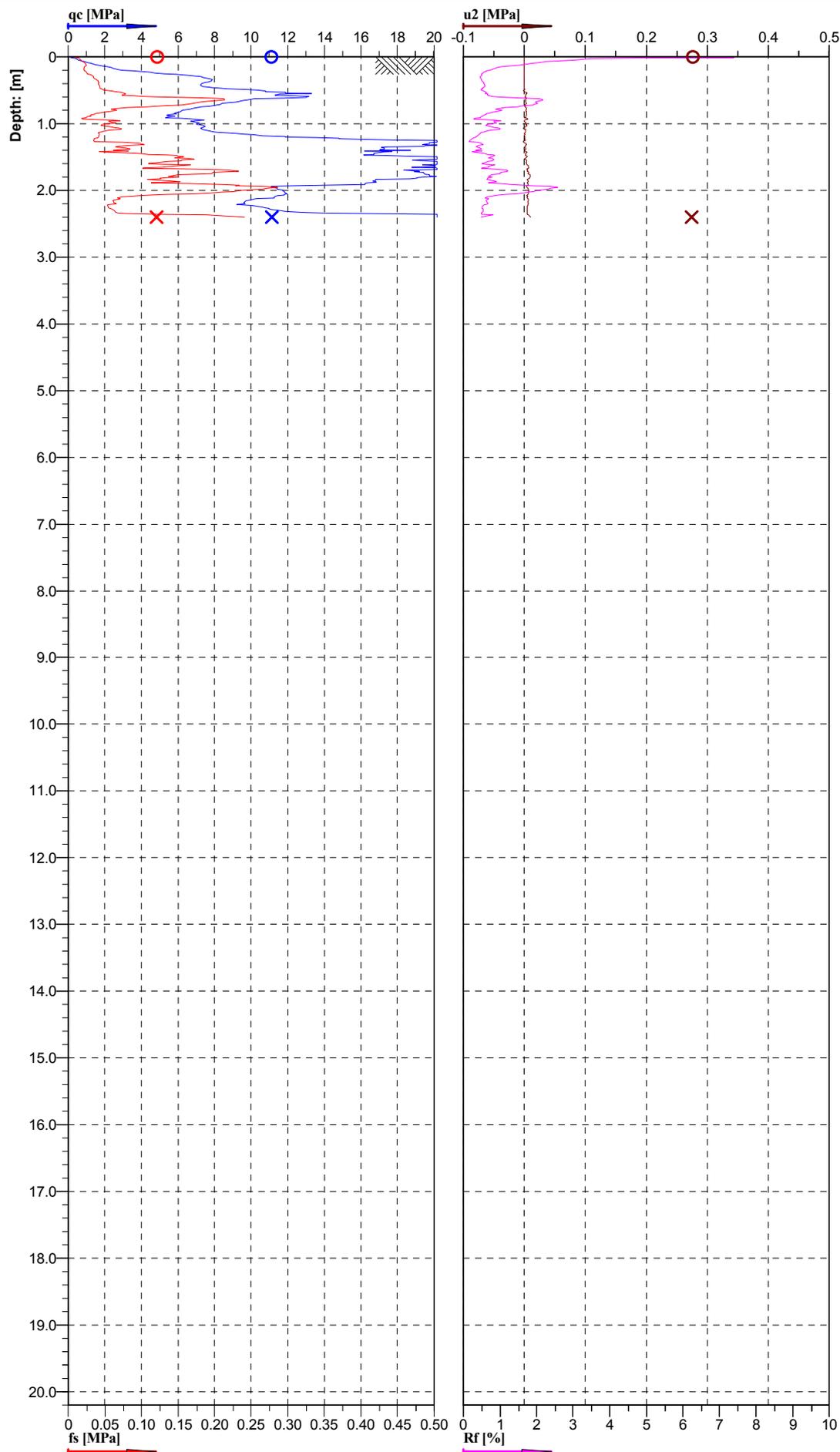


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT112
Project ID:	Client: T&T	Date: 16/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
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Classification by Robertson 1986

- Clay (3)
- Sand to silty sand (8)
- Sand (9)

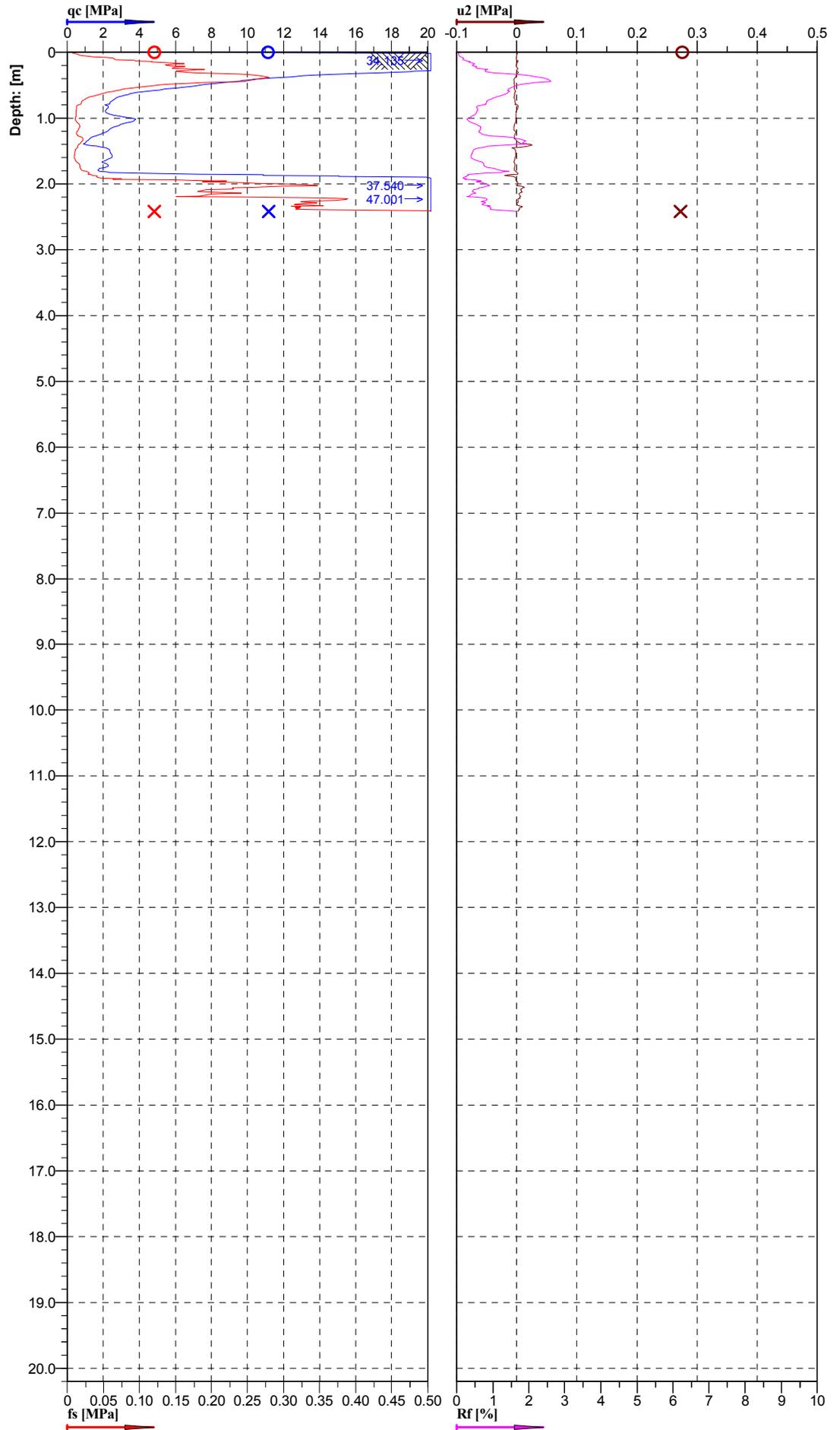


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT113
Project ID:	Client: T&T	Date: 15/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT113.cpt	

Classification by
Robertson 1986

- Gravelly sand to sand (10)
- Silty sand to sandy silt (7)
- Gravelly sand to sand (10)



PRO-DRILL
SPECIALITY DRILLING SERVICES

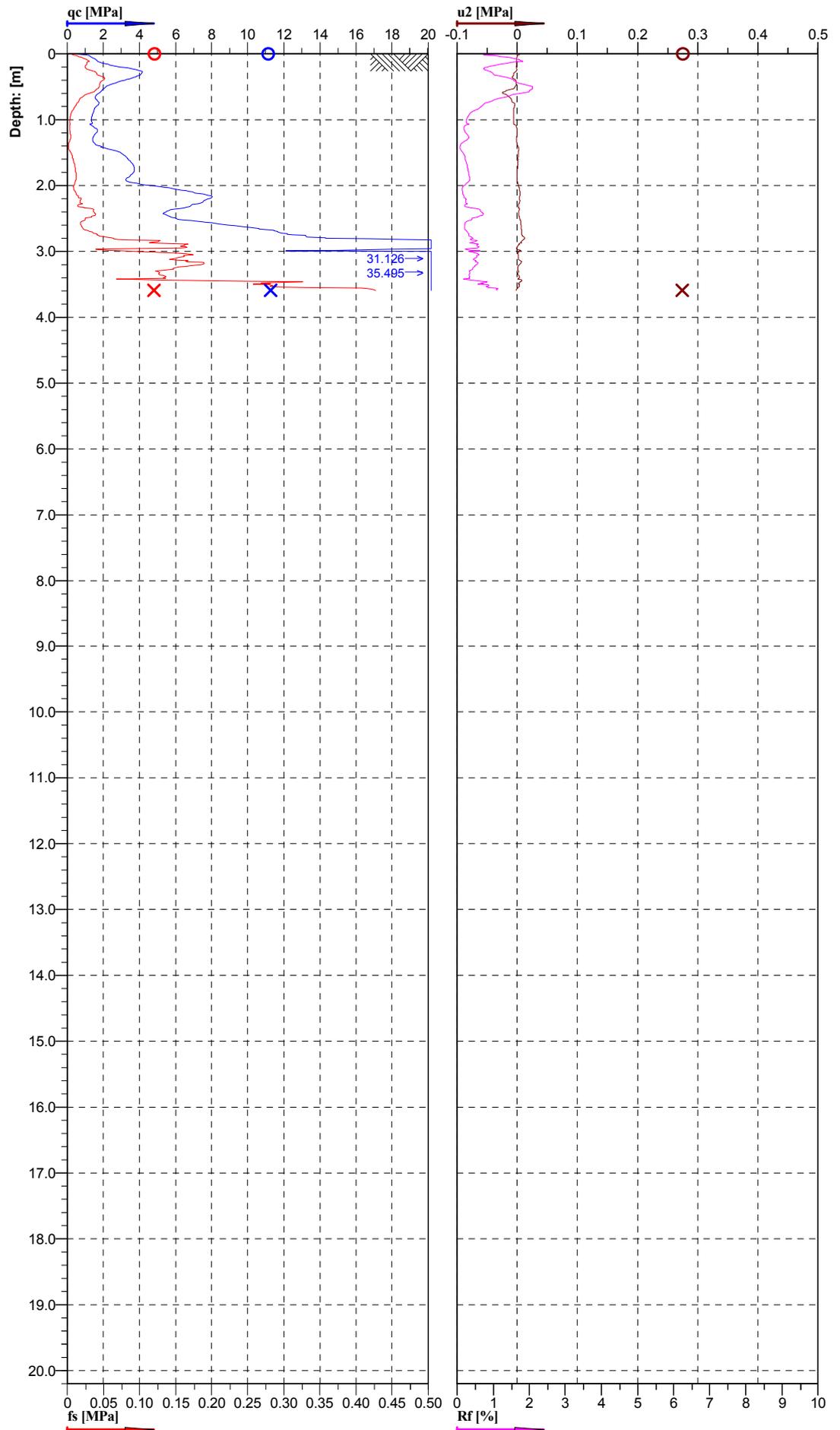


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT115
Project ID:	Client: T&T	Date: 15/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhитуCPT115.cpt	

**Classification by
Robertson 1986**

- Silty sand to sandy silt (7)
- Silty sand to sandy silt (7)
- Silty sand to sandy silt (7)
- Sand to silty sand (8)
- Sand (9)
- Gravelly sand to sand (10)

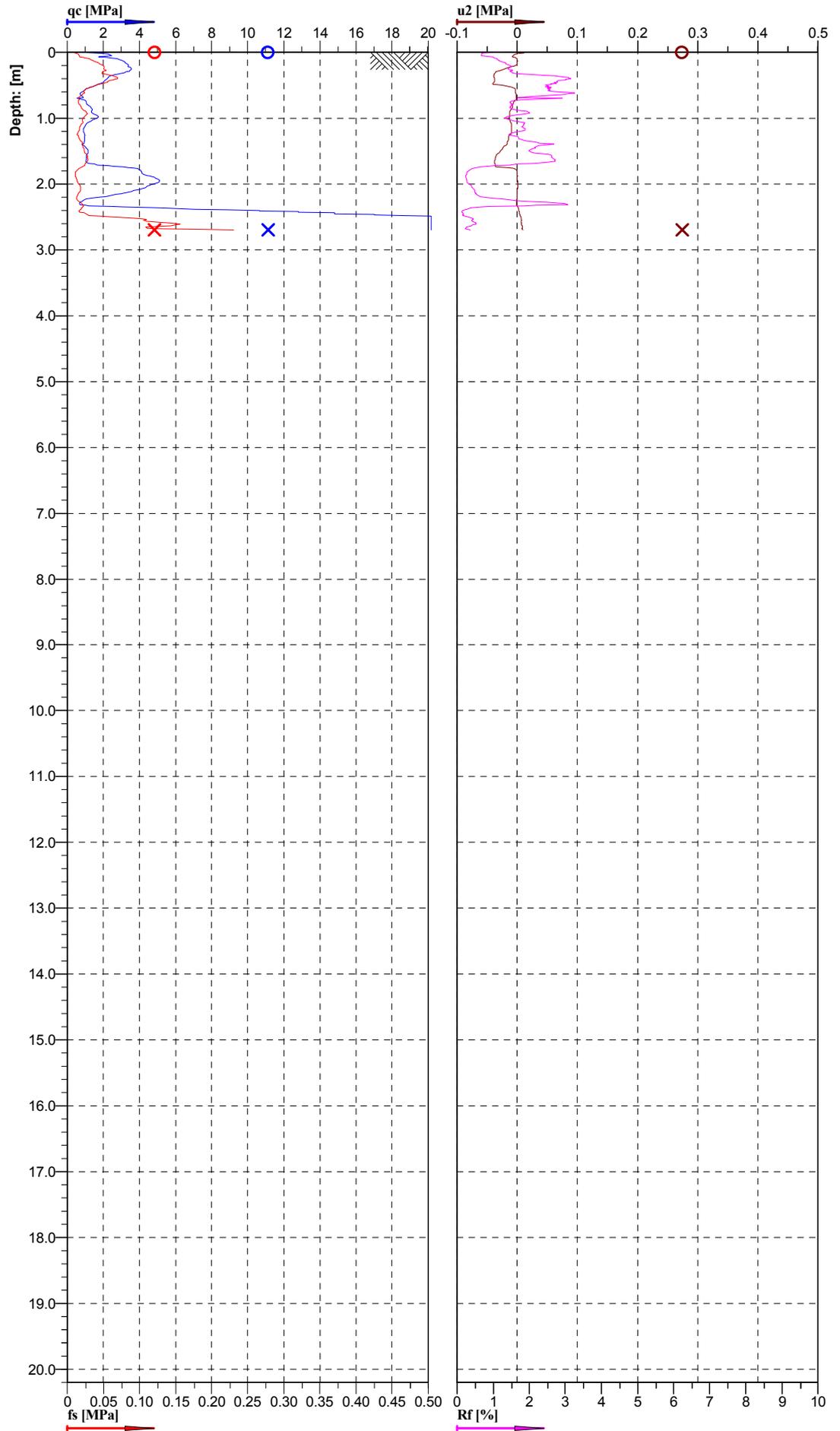


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT116
Project ID:	Client: T&T	Date: 15/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT116.cpt	

Classification by Robertson 1986

- Silty sand to sandy silt (7)
- Clayey silt to silty clay (5)
- Sand to silty sand (8)
- Silty sand to sandy silt (7)
- Sand (9)

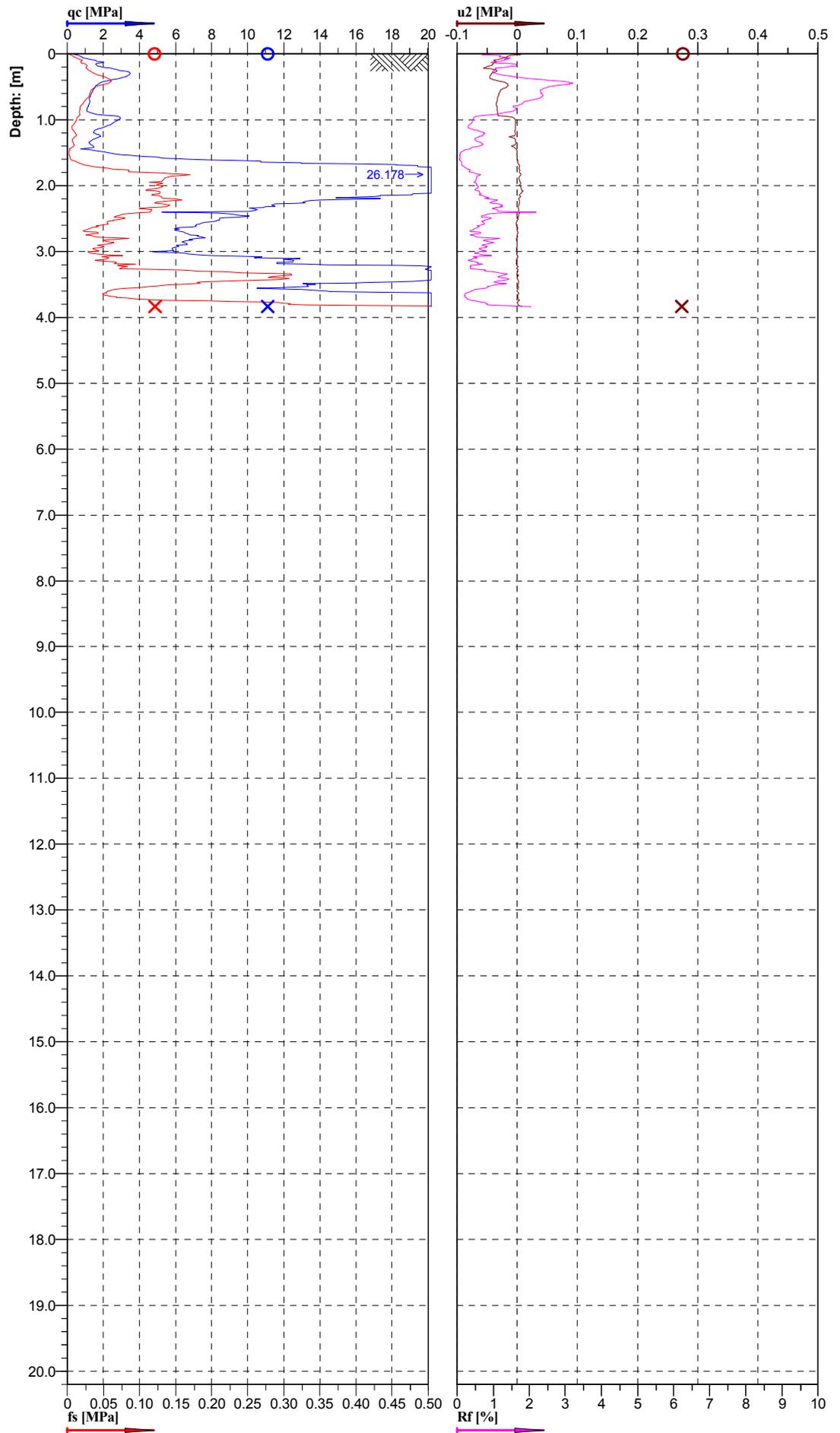


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT117
Project ID:	Client: T&T	Date: 14/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT117.cpt	

**Classification by
Robertson 1986**

- Clayey silt to silty clay (5)
- Silty sand to sandy silt (7)
- Sandy silt to clayey silt (6)
- Sand (9)
- Sand to silty sand (8)
- Sand (9)
- Gravely sand to sand (10)



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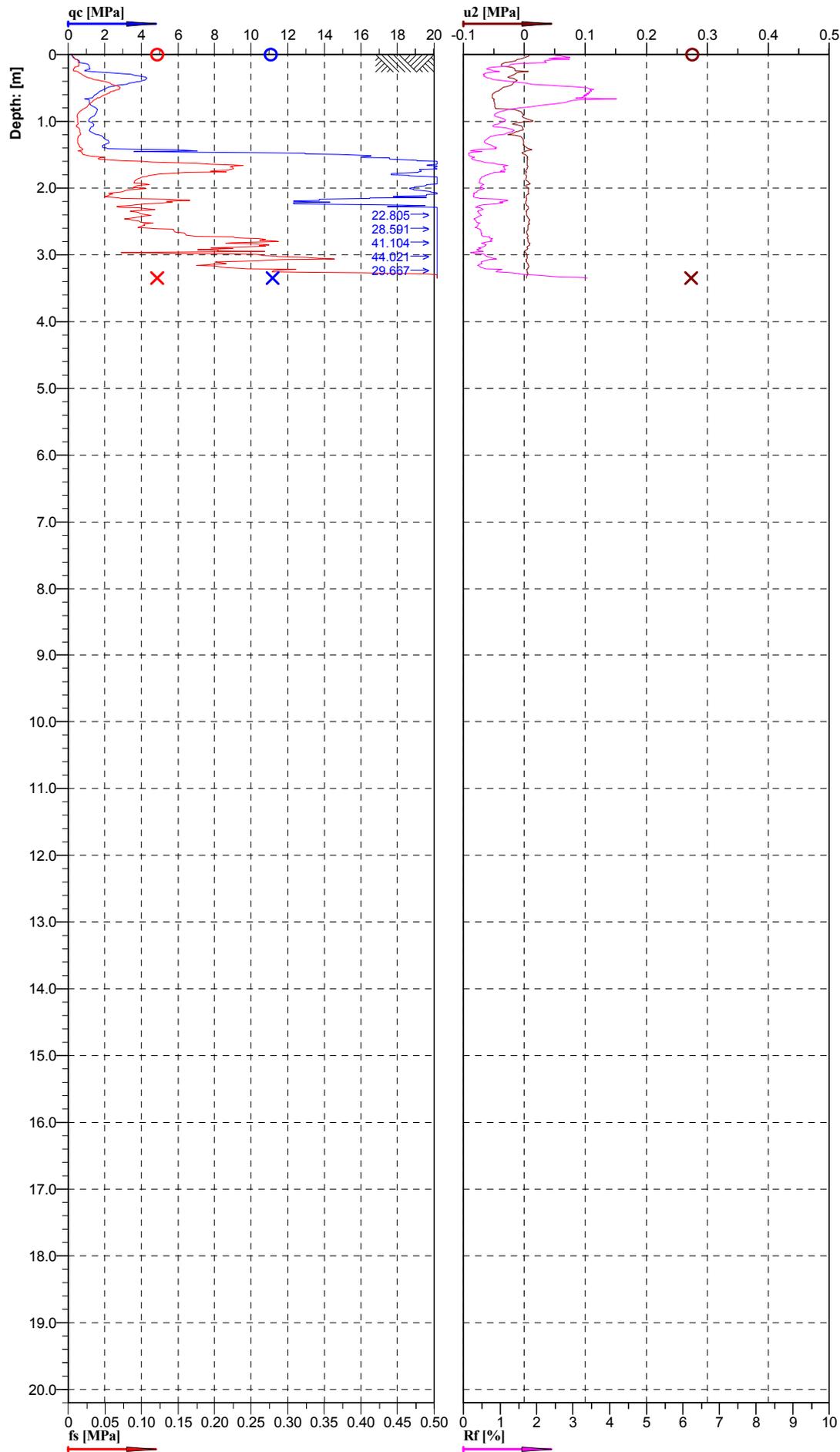


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT118
Project ID:	Client: T&T	Date: 15/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT118.cpt	

Classification by Robertson 1986

- Clay (3)
- Silty clay to clay (4)
- Sandy silt to clayey silt (6)
- Sand (9)
- Gravely sand to sand (10)

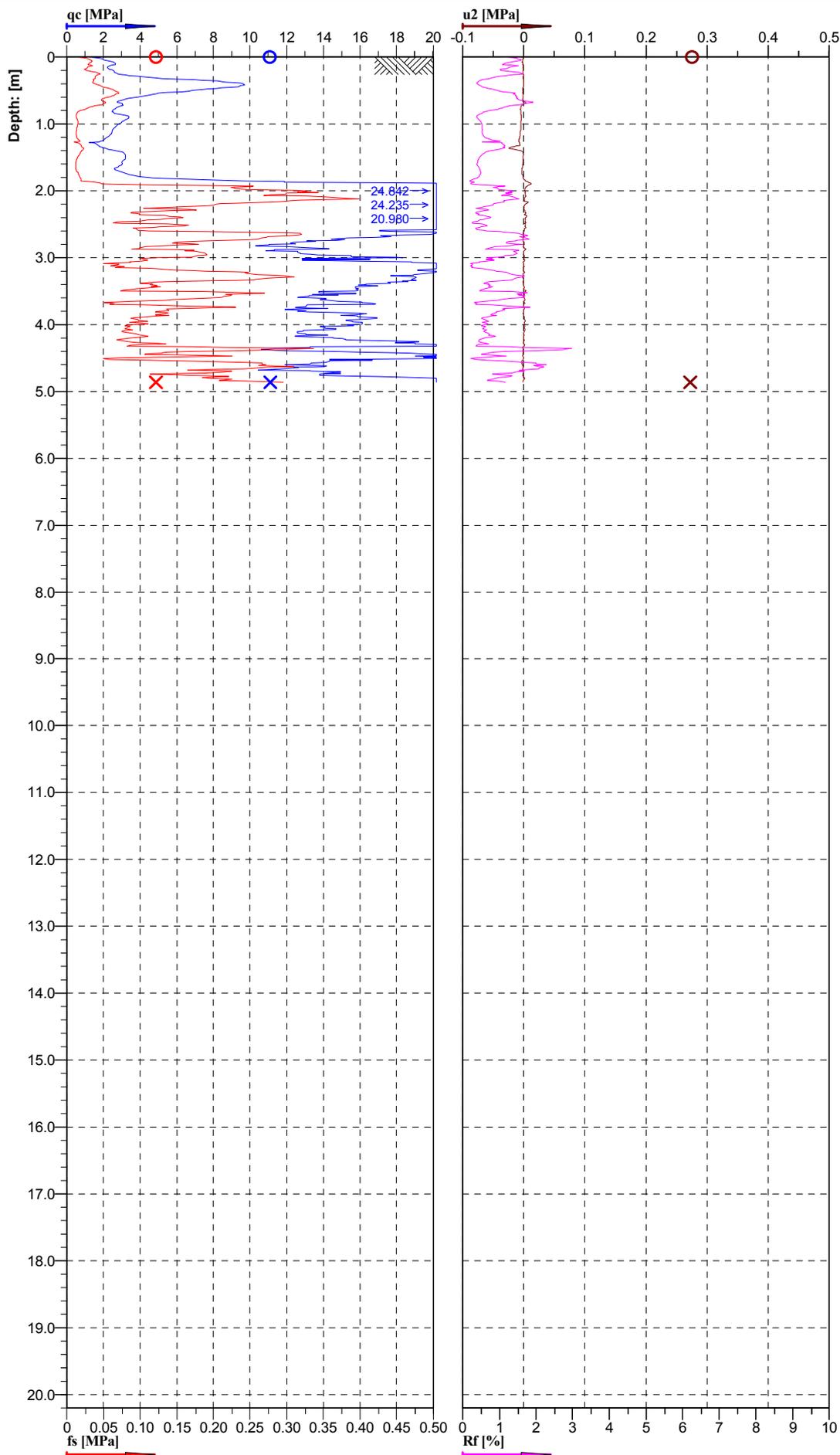
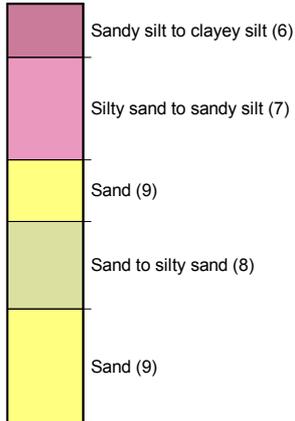


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150



Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT119
Project ID:	Client: T&T	Date: 14/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT119.cpt	

Classification by Robertson 1986

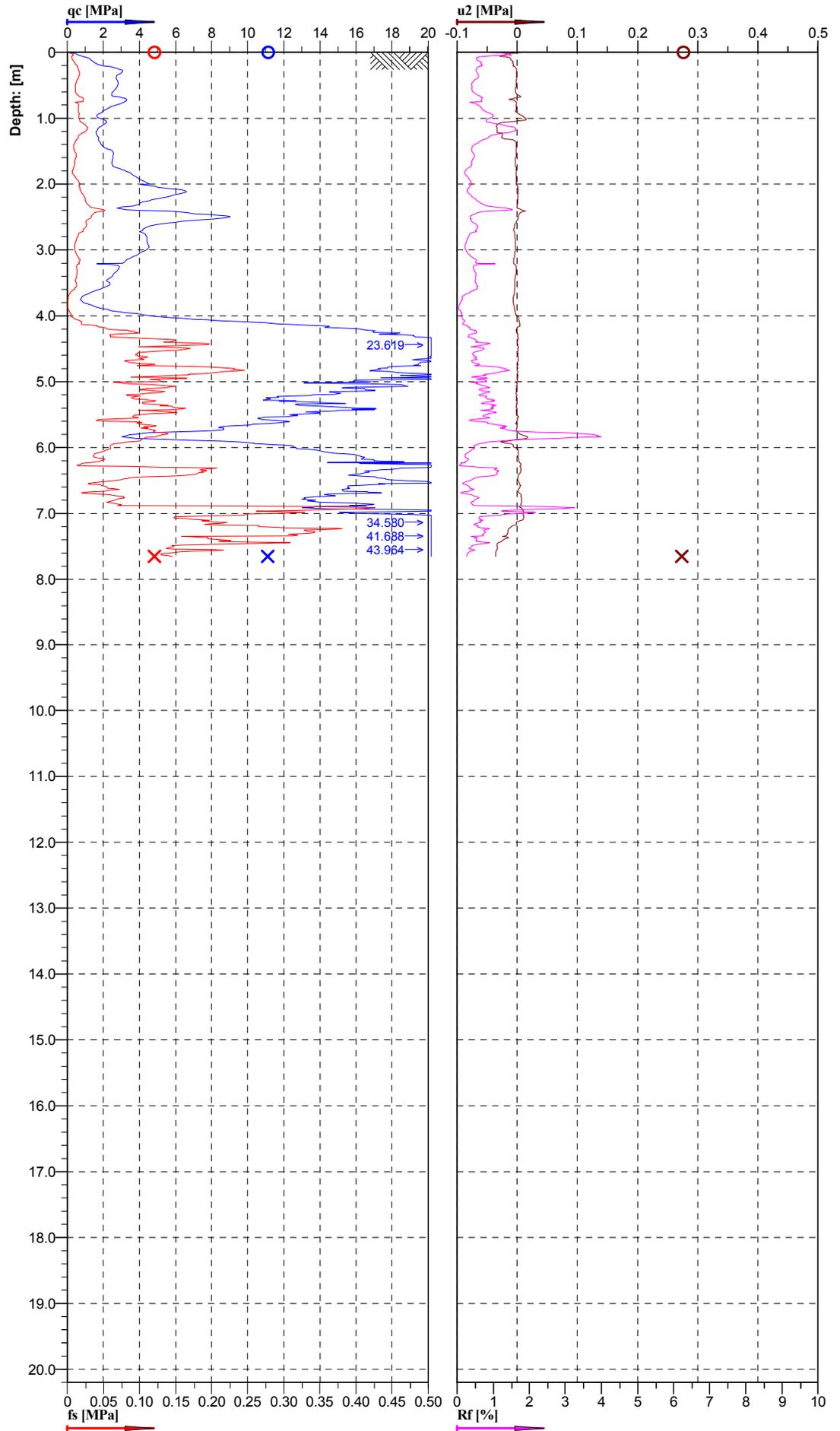


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT120
Project ID:	Client: T&T	Date: 14/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT120.cpt	

Classification by Robertson 1986

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- Silty sand to sandy silt (7)
 - Sandy silt to clayey silt (6)
 - Silty sand to sandy silt (7)
 - Sand to silty sand (8)
 - Silty sand to sandy silt (7)
 - Sensitive fine grained (1)
 - Sand (9)
 - Gravely sand to sand (10)

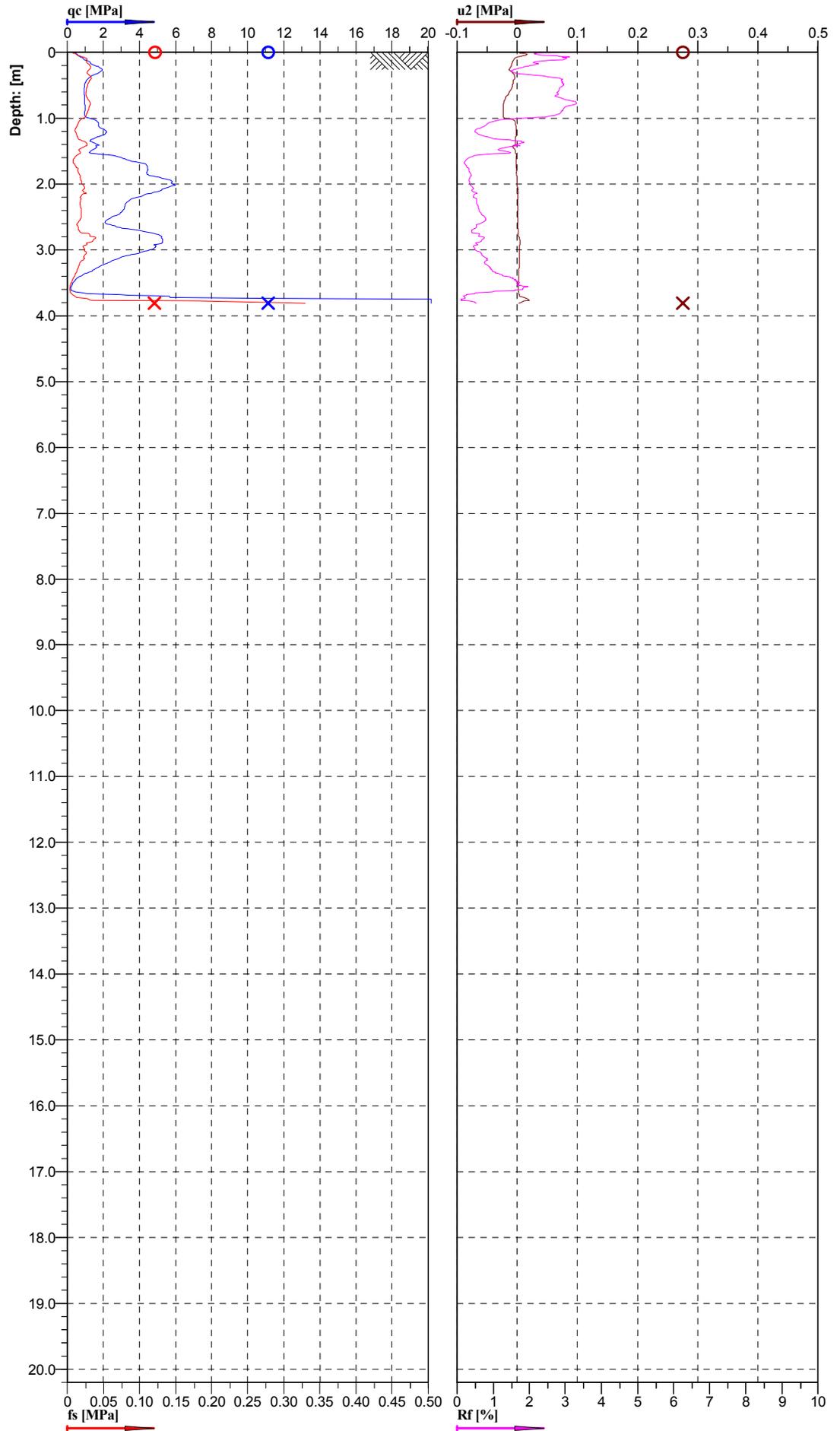


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT121
Project ID:	Client: T&T	Date: 15/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT121.cpt	

Classification by Robertson 1986

- Silty clay to clay (4)
- Silty clay to clay (4)
- Sandy silt to clayey silt (6)
- Sand to silty sand (8)
- Silty sand to sandy silt (7)
- Sand to silty sand (8)
- Silty sand to sandy silt (7)
- Sensitive fine grained (1)

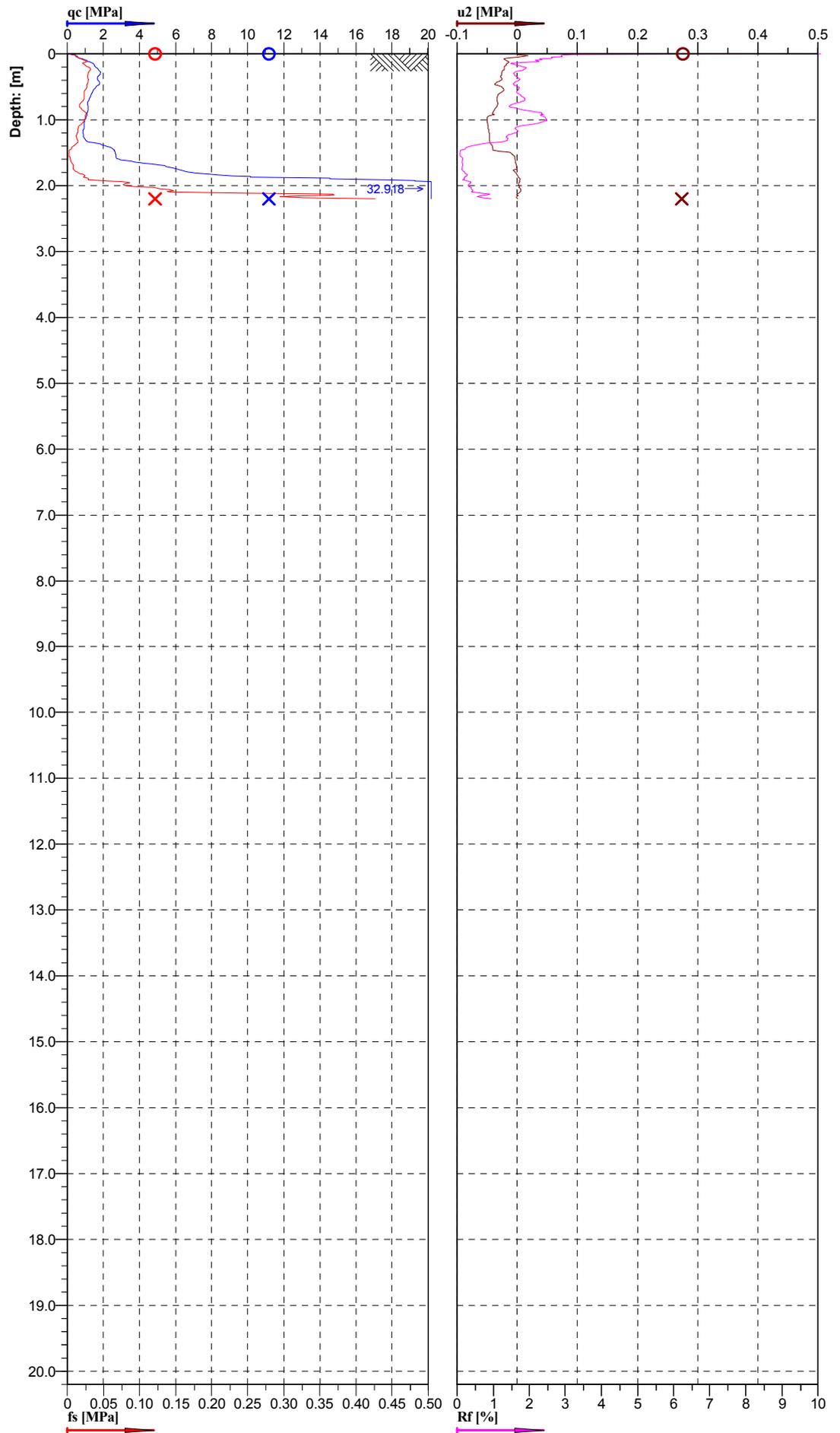


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT122
Project ID:	Client: T&T	Date: 14/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT122.cpt	

Classification by
Robertson 1986

- Sandy silt to clayey silt (6)
- Clayey silt to silty clay (5)
- Silty sand to sandy silt (7)
- Sand to silty sand (8)
- Gravely sand to sand (10)

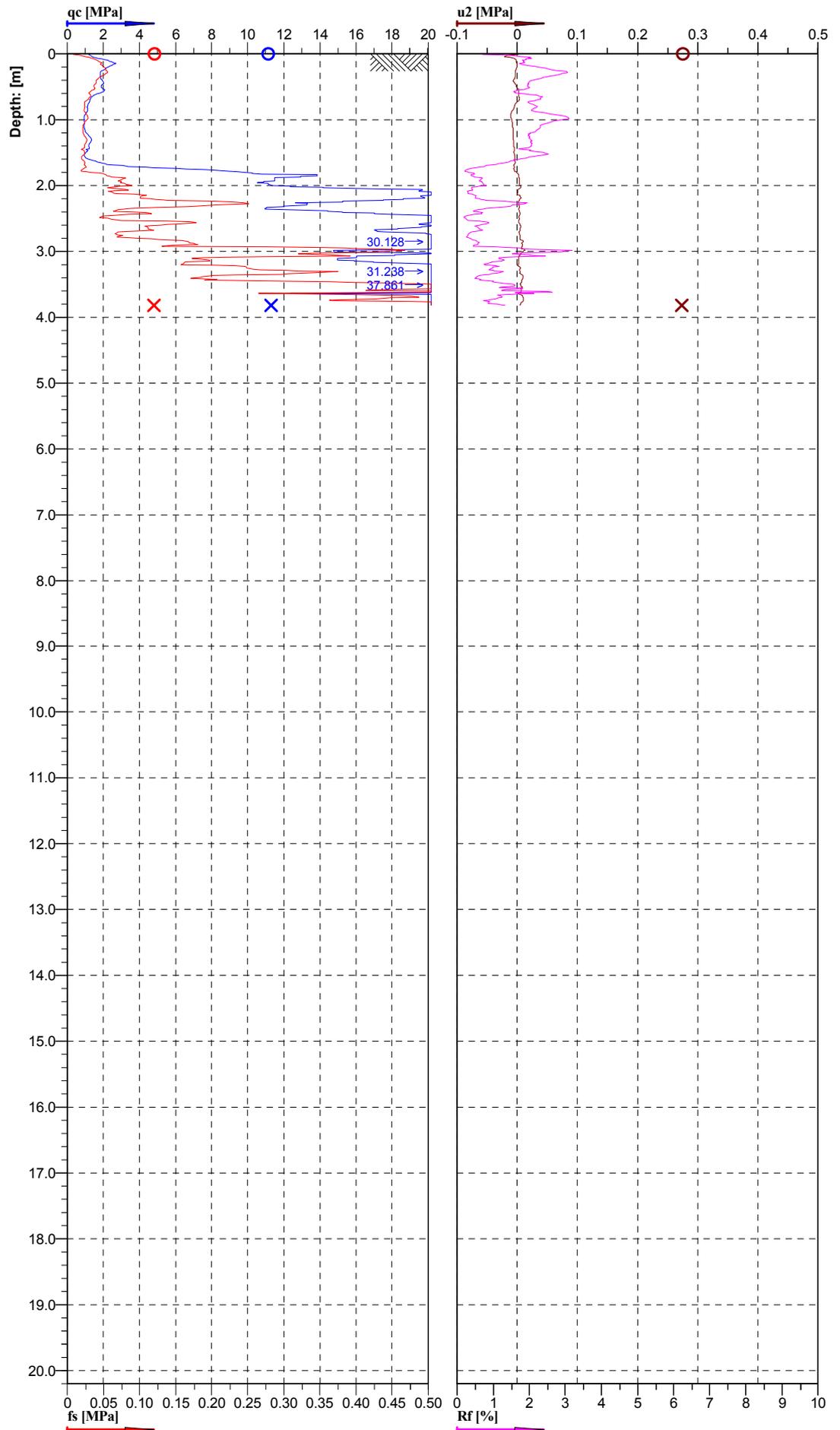


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT123
Project ID:	Client: T&T	Date: 15/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT123.cpt	

Classification by Robertson 1986

- Clayey silt to silty clay (5)
- Sandy silt to clayey silt (6)
- Clayey silt to silty clay (5)
- Sand (9)
- Gravely sand to sand (10)
- Sand (9)

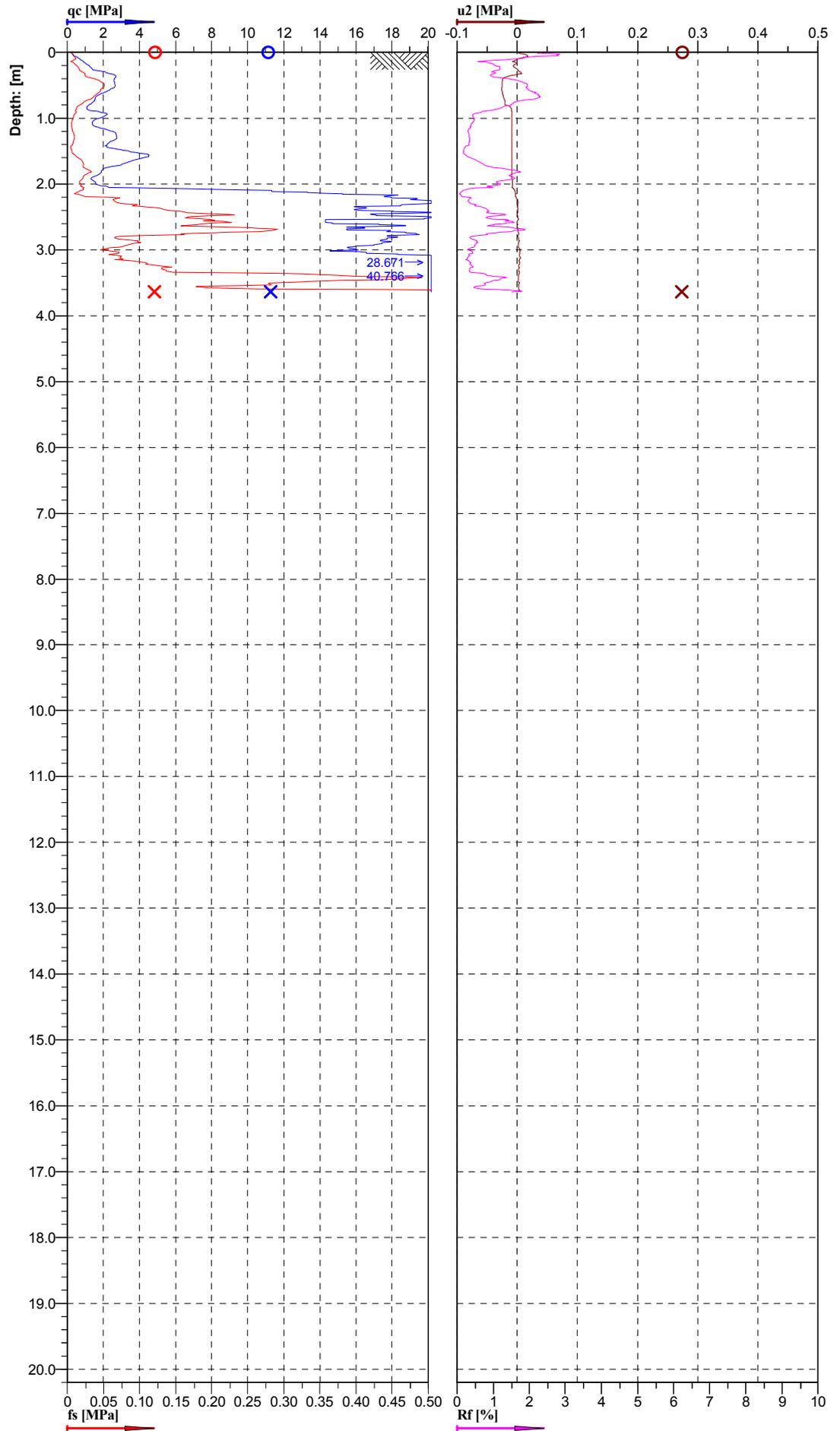


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT124
Project ID:	Client: T&T	Date: 14/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT124.cpt	

Classification by Robertson 1986

- Clay (3)
- Sandy silt to clayey silt (6)
- Clayey silt to silty clay (5)
- Silty sand to sandy silt (7)
- Sandy silt to clayey silt (6)
- Sand (9)
- Sand to silty sand (8)
- Sand (9)
- Gravely sand to sand (10)

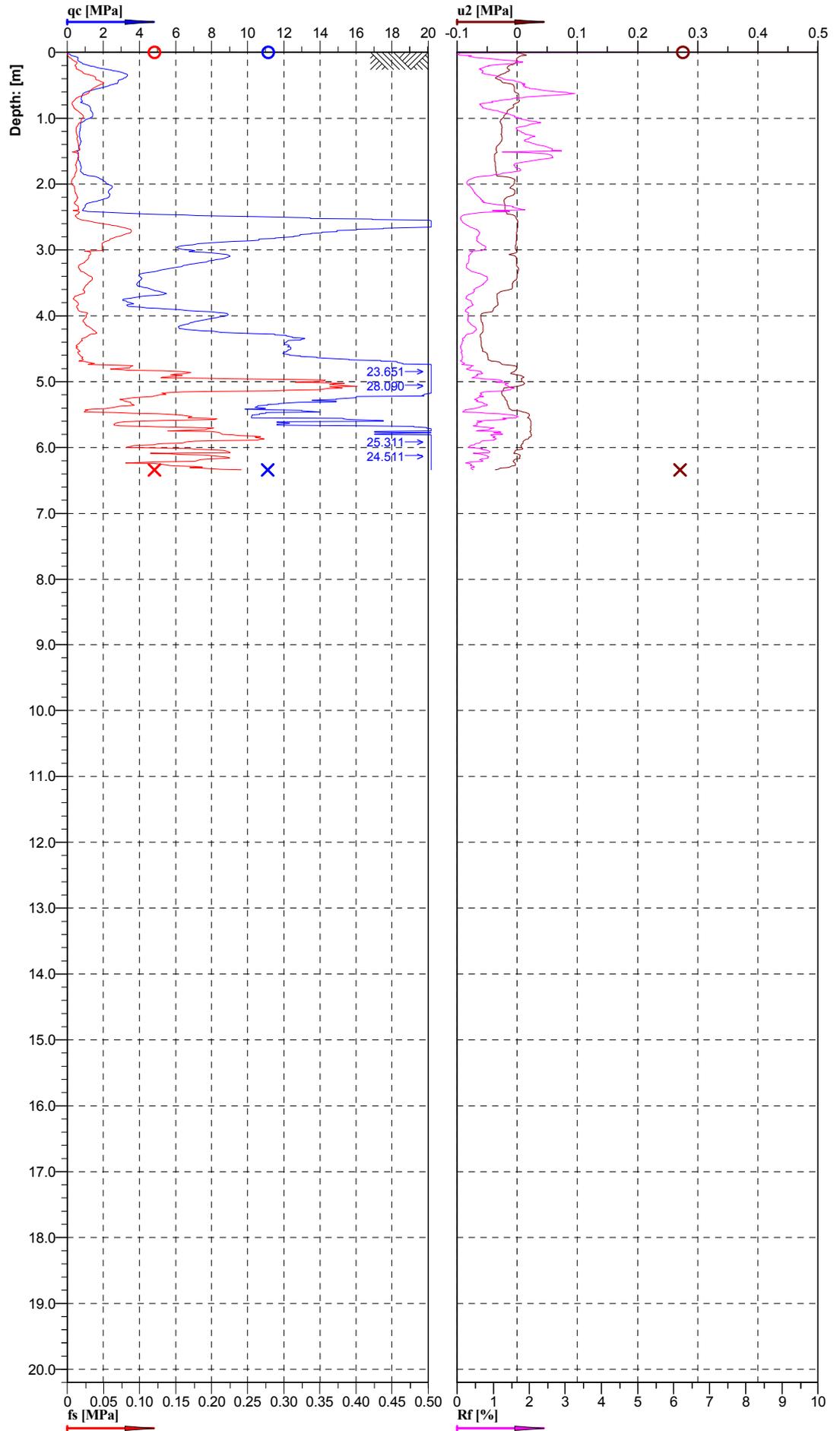


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT125
Project ID:	Client: T&T	Date: 14/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT125.cpt	

Classification by Robertson 1986

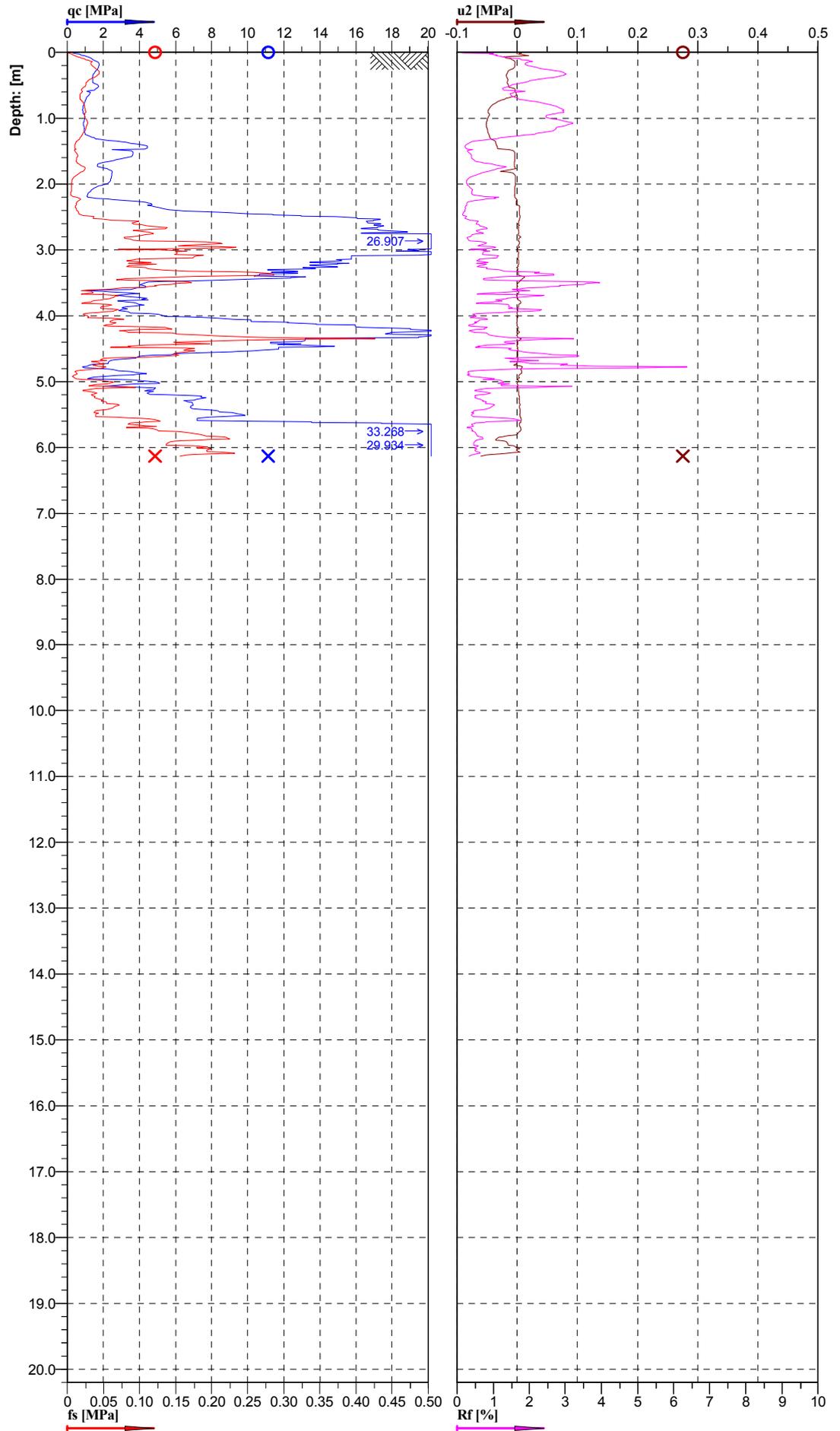
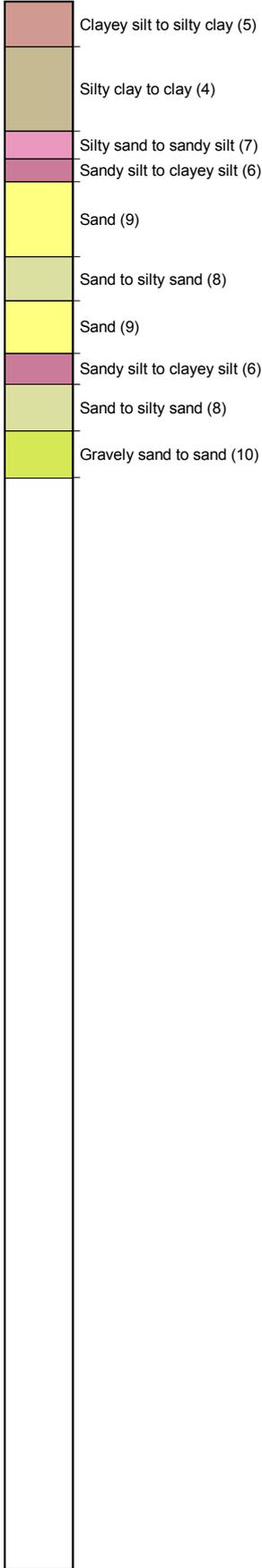
- Sensitive fine grained (1)
- Silty sand to sandy silt (7)
- Sandy silt to clayey silt (6)
- Clayey silt to silty clay (5)
- Silty clay to clay (4)
- Clayey silt to silty clay (5)
- Silty sand to sandy silt (7)
- Clayey silt to silty clay (5)
- Sand (9)
- Sand to silty sand (8)
- Silty sand to sandy silt (7)
- Sand to silty sand (8)
- Sand (9)



Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT126
Project ID:	Client: T&T	Date: 14/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT126.cpt	

Classification by Robertson 1986

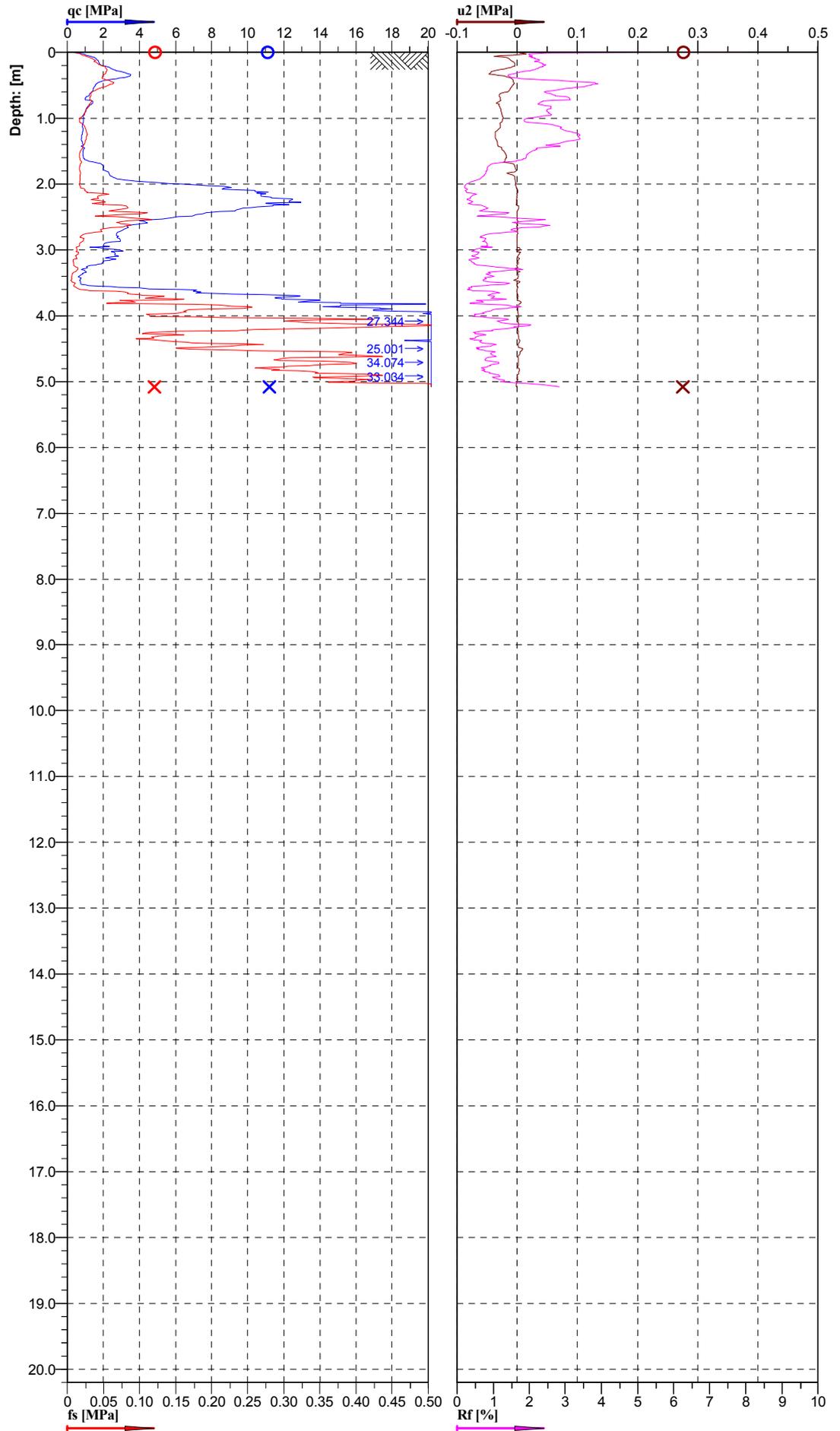


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT127
Project ID:	Client: T&T	Date: 14/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT127.cpt	

Classification by Robertson 1986

- Clayey silt to silty clay (5)
- Silty clay to clay (4)
- Clayey silt to silty clay (5)
- Silty sand to sandy silt (7)
- Sand (9)
- Sandy silt to clayey silt (6)
- Silty sand to sandy silt (7)
- Sensitive fine grained (1)
- Sand to silty sand (8)
- Sand (9)

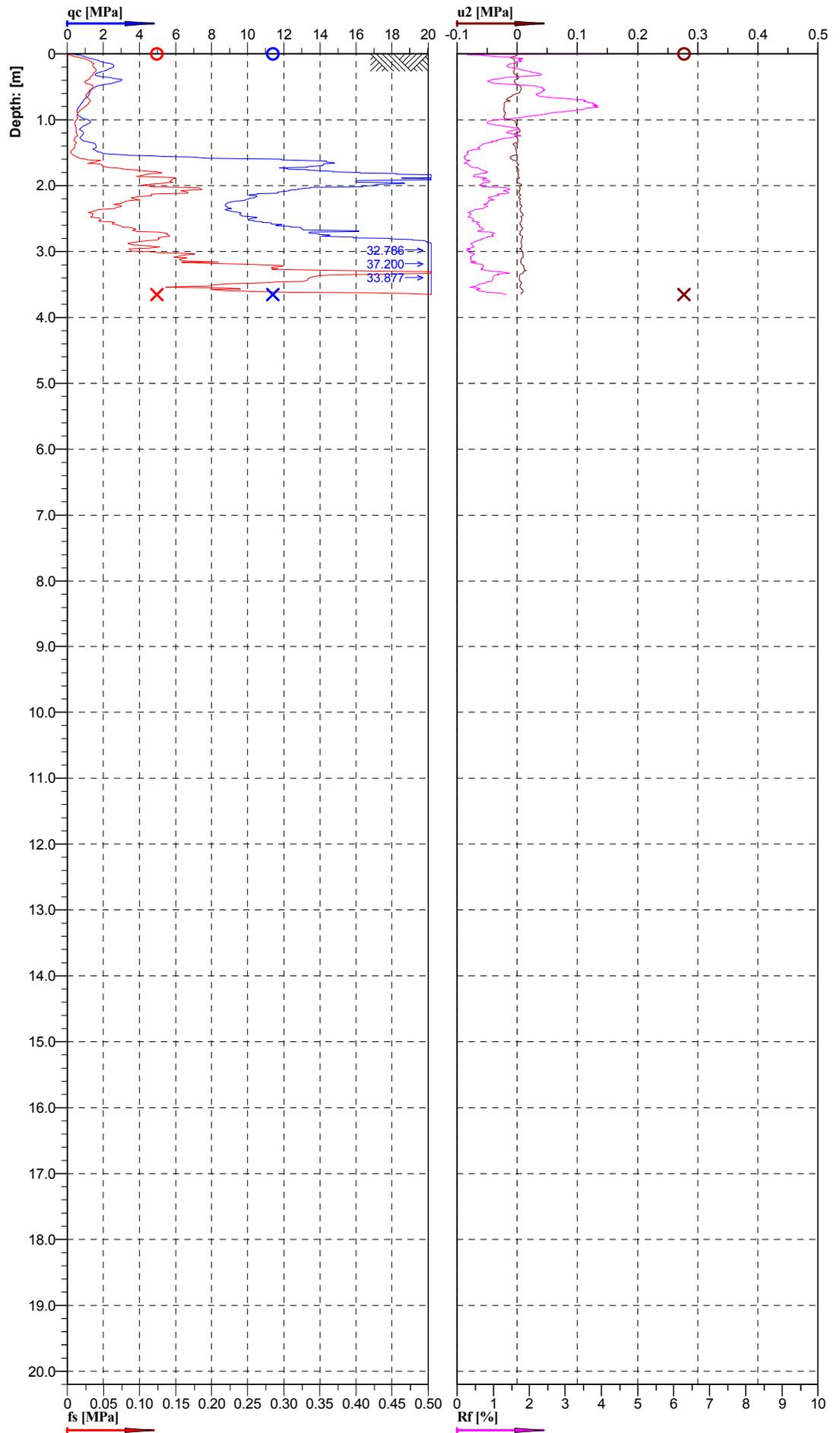


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT128
Project ID:	Client: T&T	Date: 14/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT128.cpt	

Classification by Robertson 1986

- Sandy silt to clayey silt (6)
- Clayey silt to silty clay (5)
- Clay (3)
- Clayey silt to silty clay (5)
- Sand (9)
- Sand to silty sand (8)
- Sand (9)
- Gravely sand to sand (10)

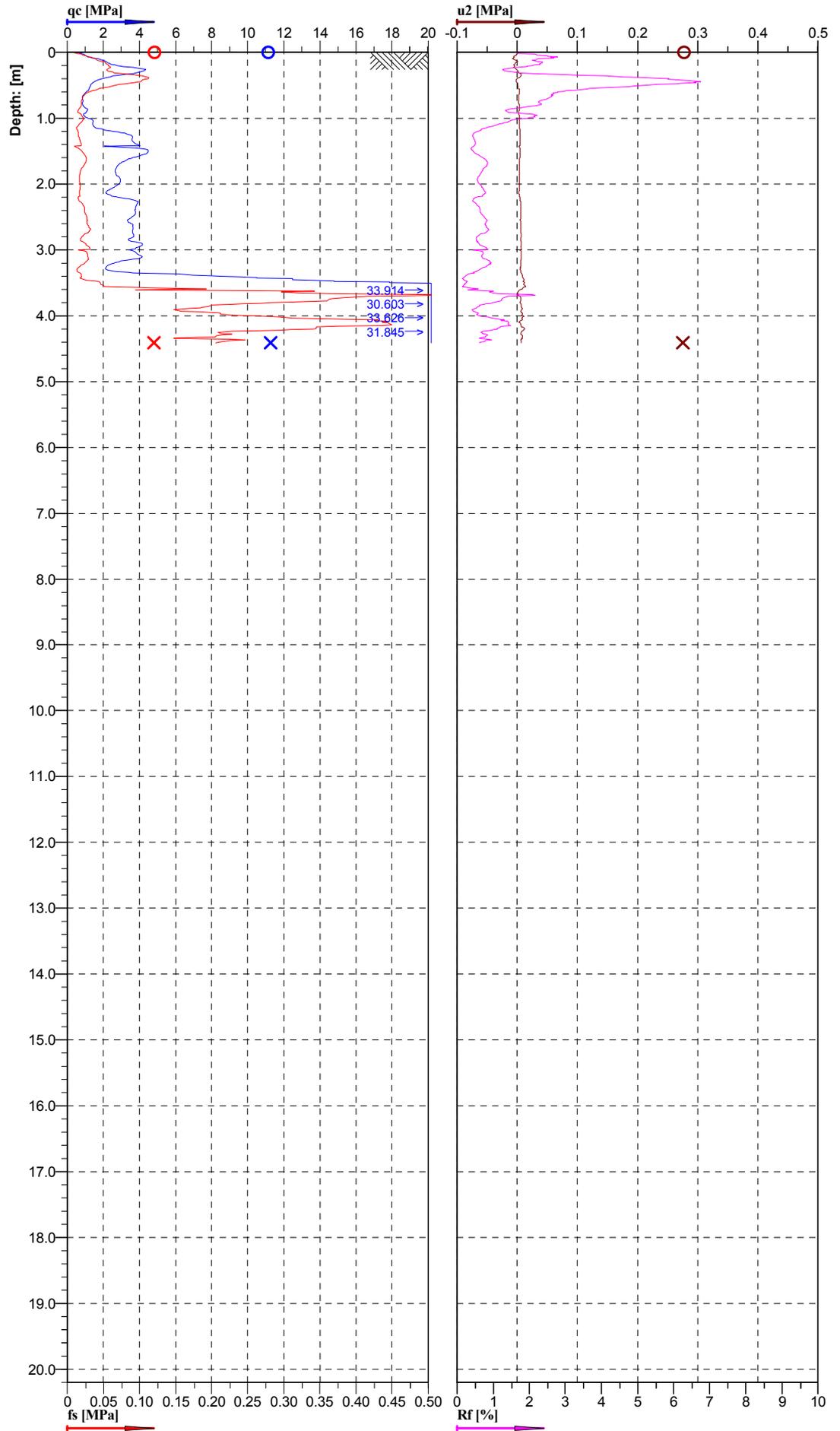


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT129
Project ID:	Client: T&T	Date: 13/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT129.cpt	

Classification by Robertson 1986

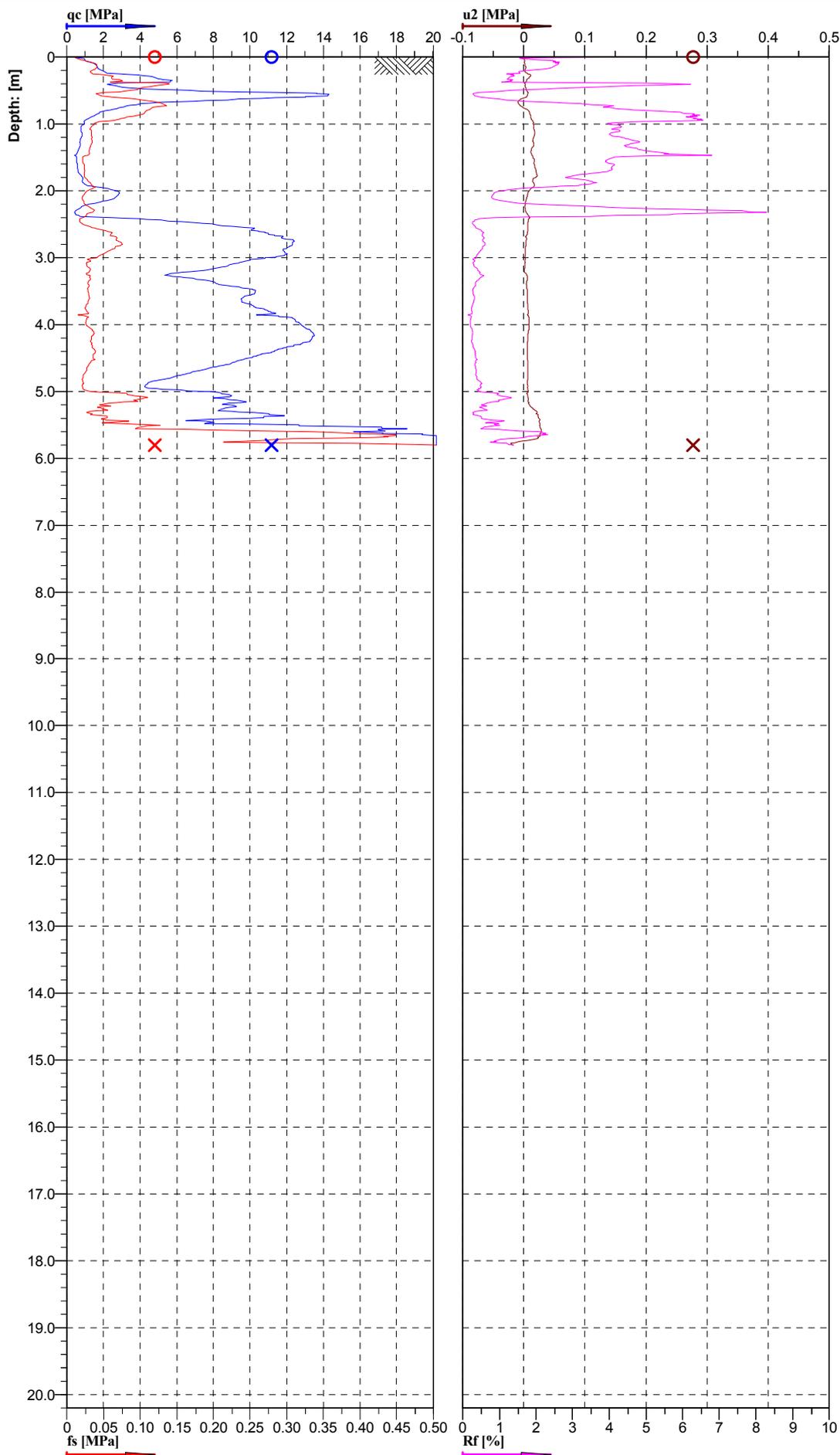
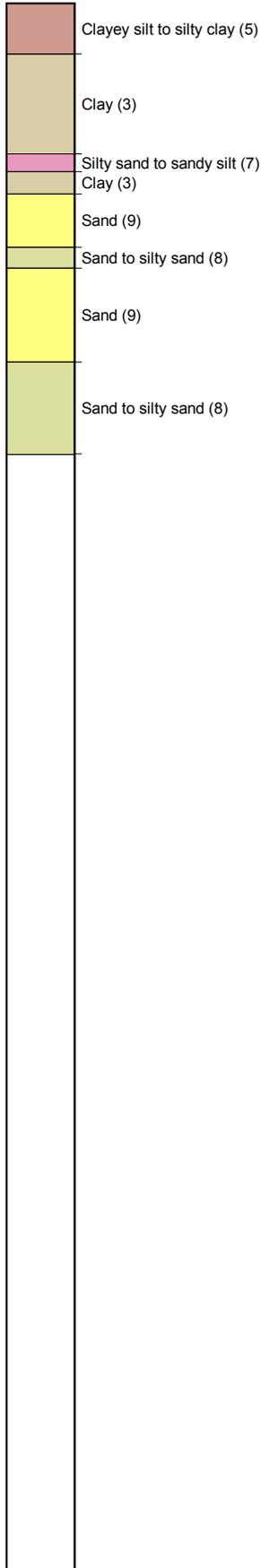
- Clayey silt to silty clay (5)
- Clay (3)
- Clayey silt to silty clay (5)
- Silty sand to sandy silt (7)
- Sand (9)



Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT130
Project ID:	Client: T&T	Date: 13/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhитуCPT130.cpt	

Classification by Robertson 1986



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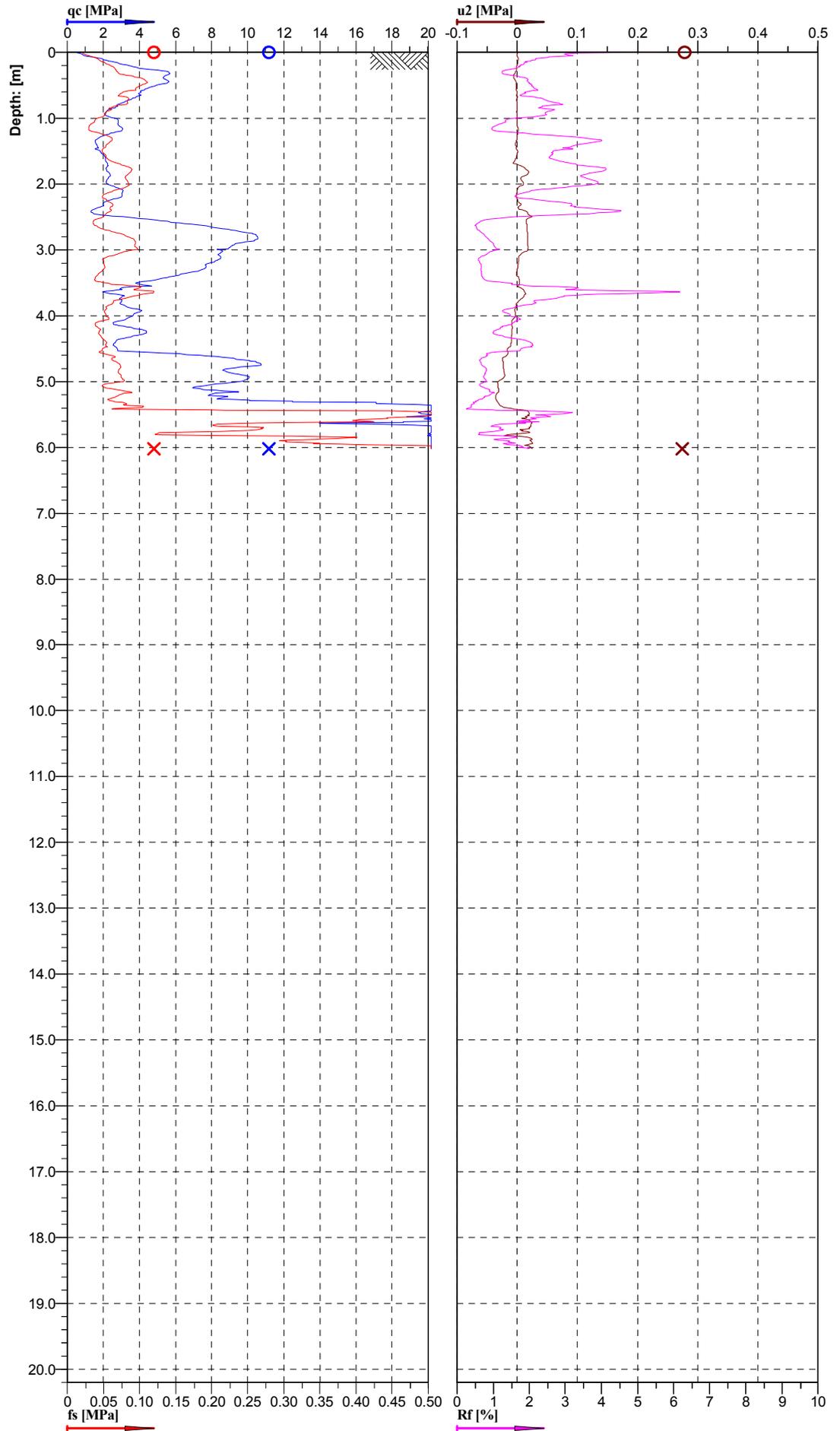


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT131
Project ID:	Client: T&T	Date: 13/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT131.cpt	

Classification by Robertson 1986

- Silty clay to clay (4)
- Silty sand to sandy silt (7)
- Sandy silt to clayey silt (6)
- Clayey silt to silty clay (5)
- Silty clay to clay (4)
- Sandy silt to clayey silt (6)
- Sand to silty sand (8)
- Sandy silt to clayey silt (6)
- Sand to silty sand (8)
- Silty sand to sandy silt (7)
- Sand (9)

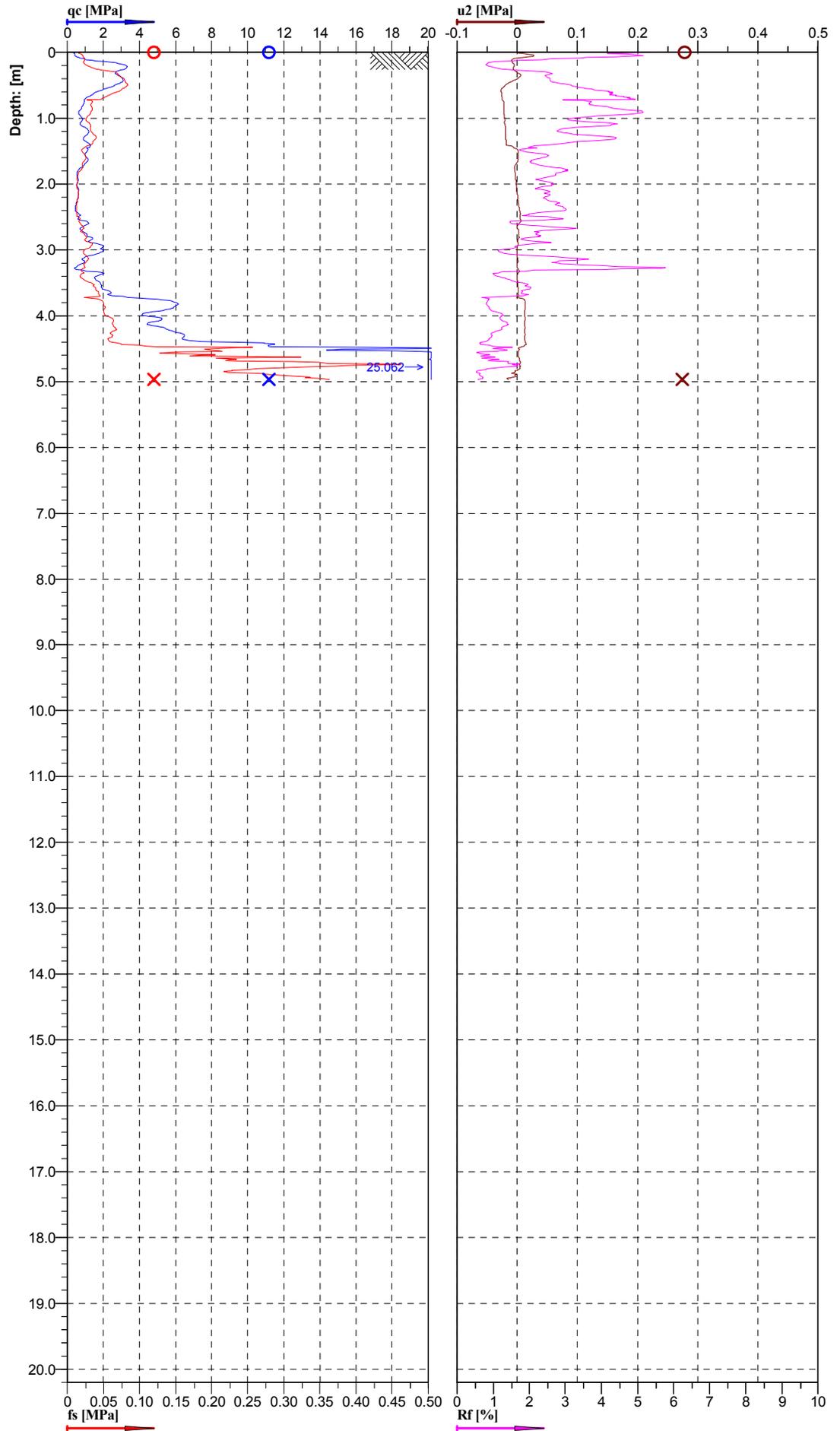


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT132
Project ID:	Client: T&T	Date: 13/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT132.cpt	

Classification by Robertson 1986

- Clay (3)
- Sandy silt to clayey silt (6)
- Clay (3)
- Clayey silt to silty clay (5)
- Silty clay to clay (4)
- Clayey silt to silty clay (5)
- Clay (3)
- Sandy silt to clayey silt (6)
- Silty sand to sandy silt (7)
- Sand (9)

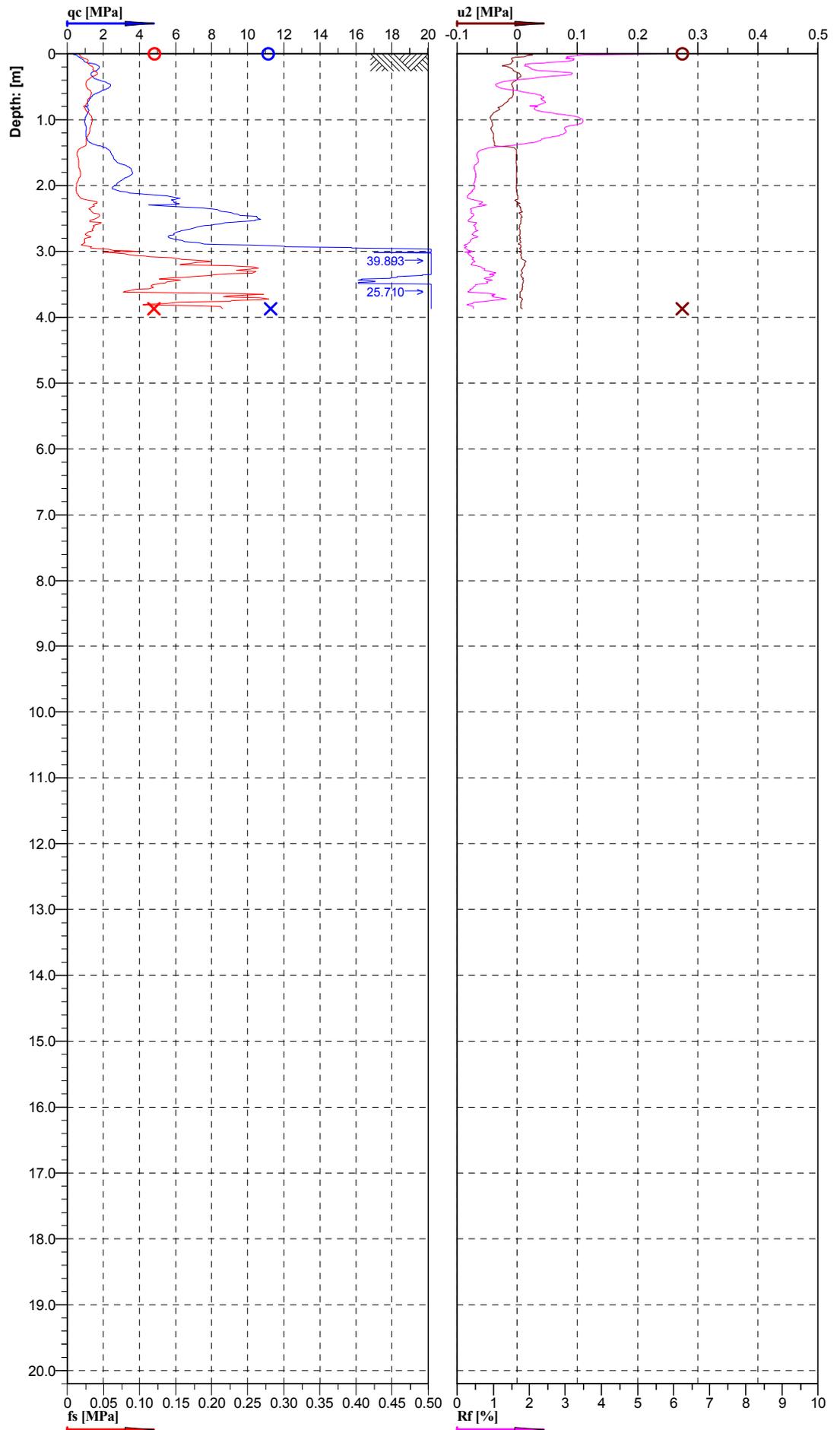


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT133
Project ID:	Client: T&T	Date: 13/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT133.cpt	

Classification by Robertson 1986

- Clay (3)
- Sandy silt to clayey silt (6)
- Clayey silt to silty clay (5)
- Silty clay to clay (4)
- Silty sand to sandy silt (7)
- Sand to silty sand (8)
- Sand (9)
- Sand to silty sand (8)
- Gravely sand to sand (10)
- Sand (9)

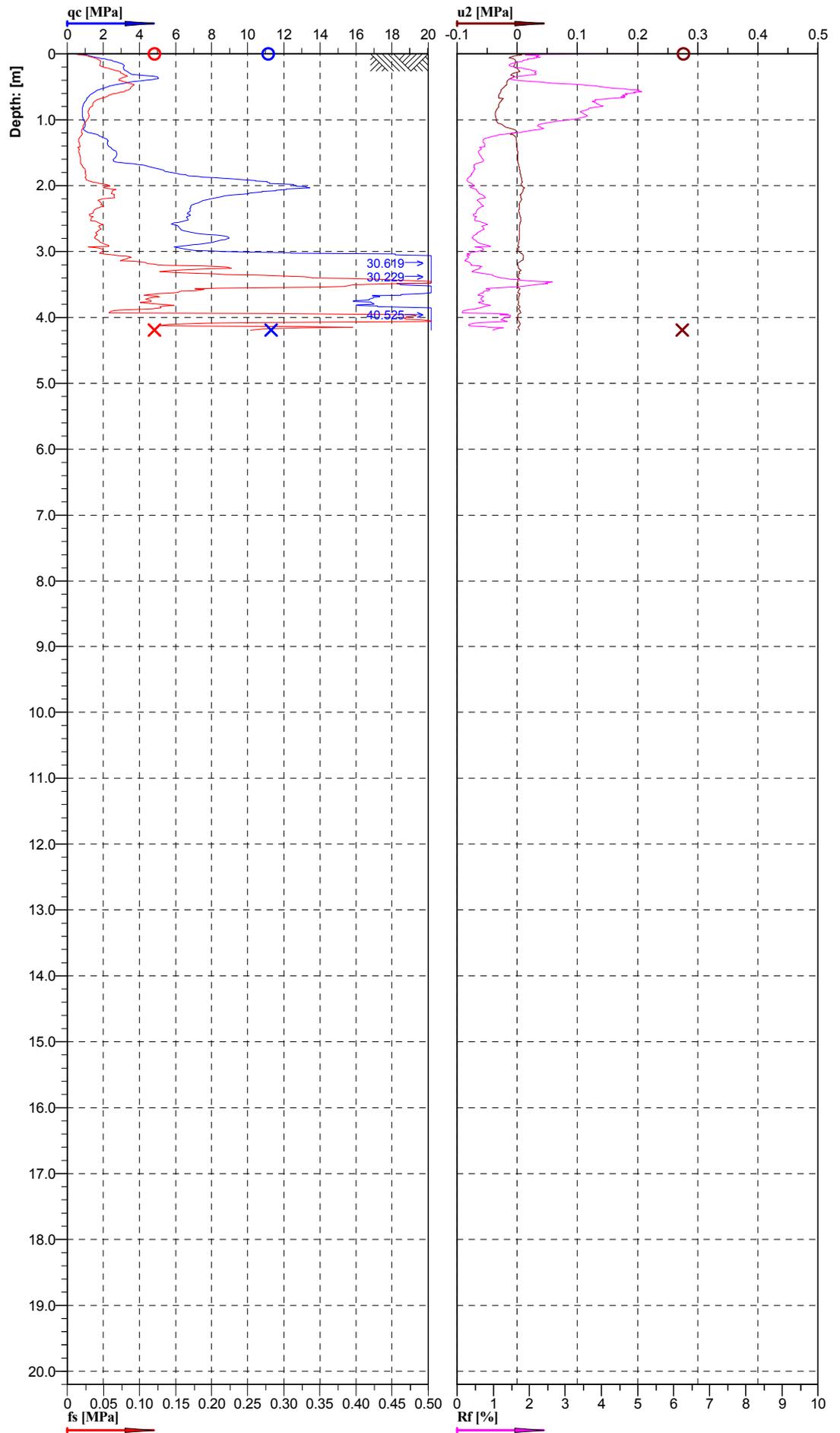


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT134
Project ID:	Client: T&T	Date: 14/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT134.cpt	

**Classification by
Robertson 1986**

- Sandy silt to clayey silt (6)
- Clay (3)
- Clayey silt to silty clay (5)
- Silty sand to sandy silt (7)
- Sand to silty sand (8)
- Sand (9)
- Sand to silty sand (8)
- Gravely sand to sand (10)
- Sand (9)
- Gravely sand to sand (10)

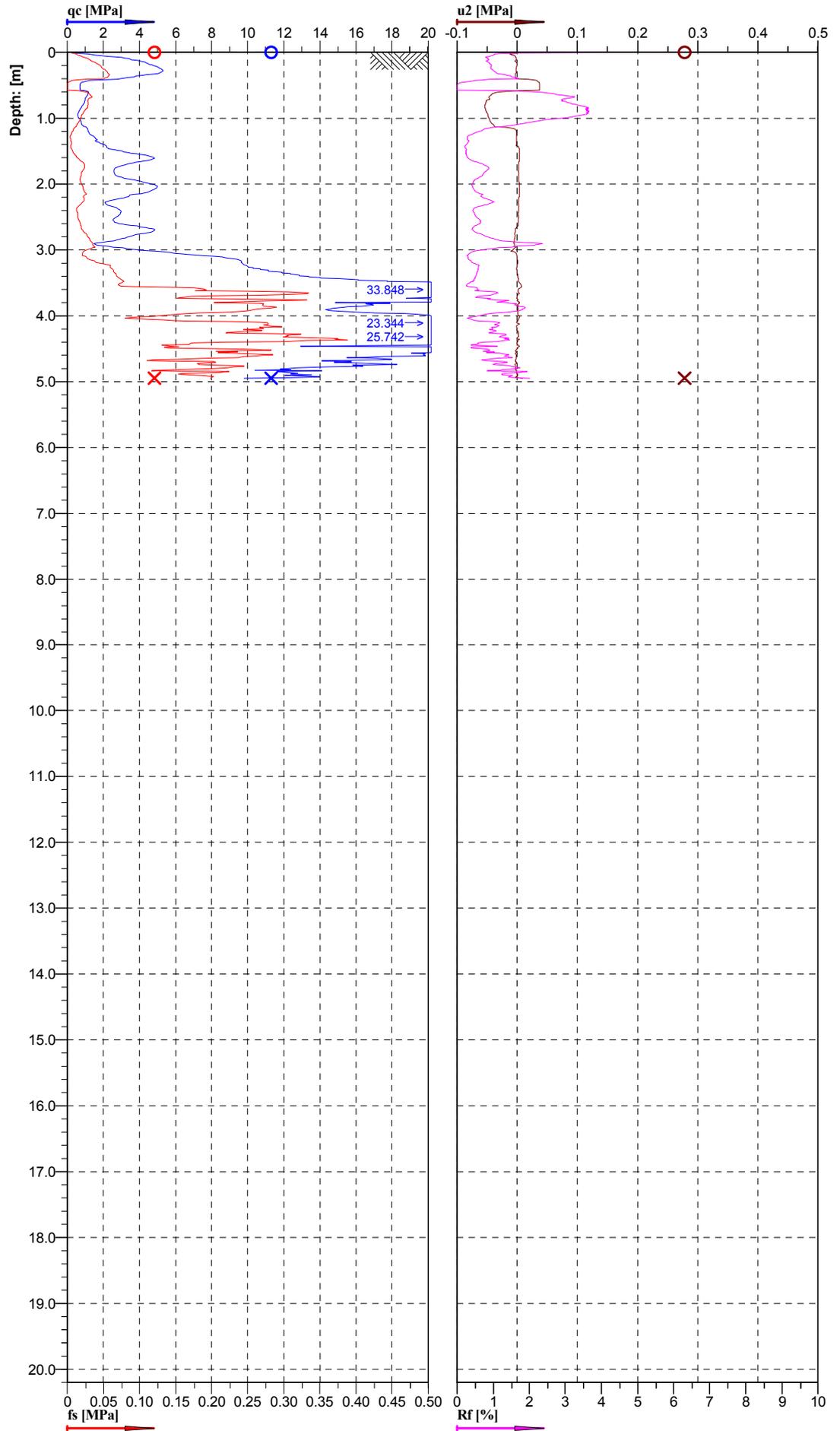


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT135
Project ID:	Client: T&T	Date: 14/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT135.cpt	

Classification by Robertson 1986

- Silty sand to sandy silt (7)
- Sensitive fine grained (1)
- Clay (3)
- Sandy silt to clayey silt (6)
- Silty sand to sandy silt (7)
- Sand (9)
- Sand to silty sand (8)

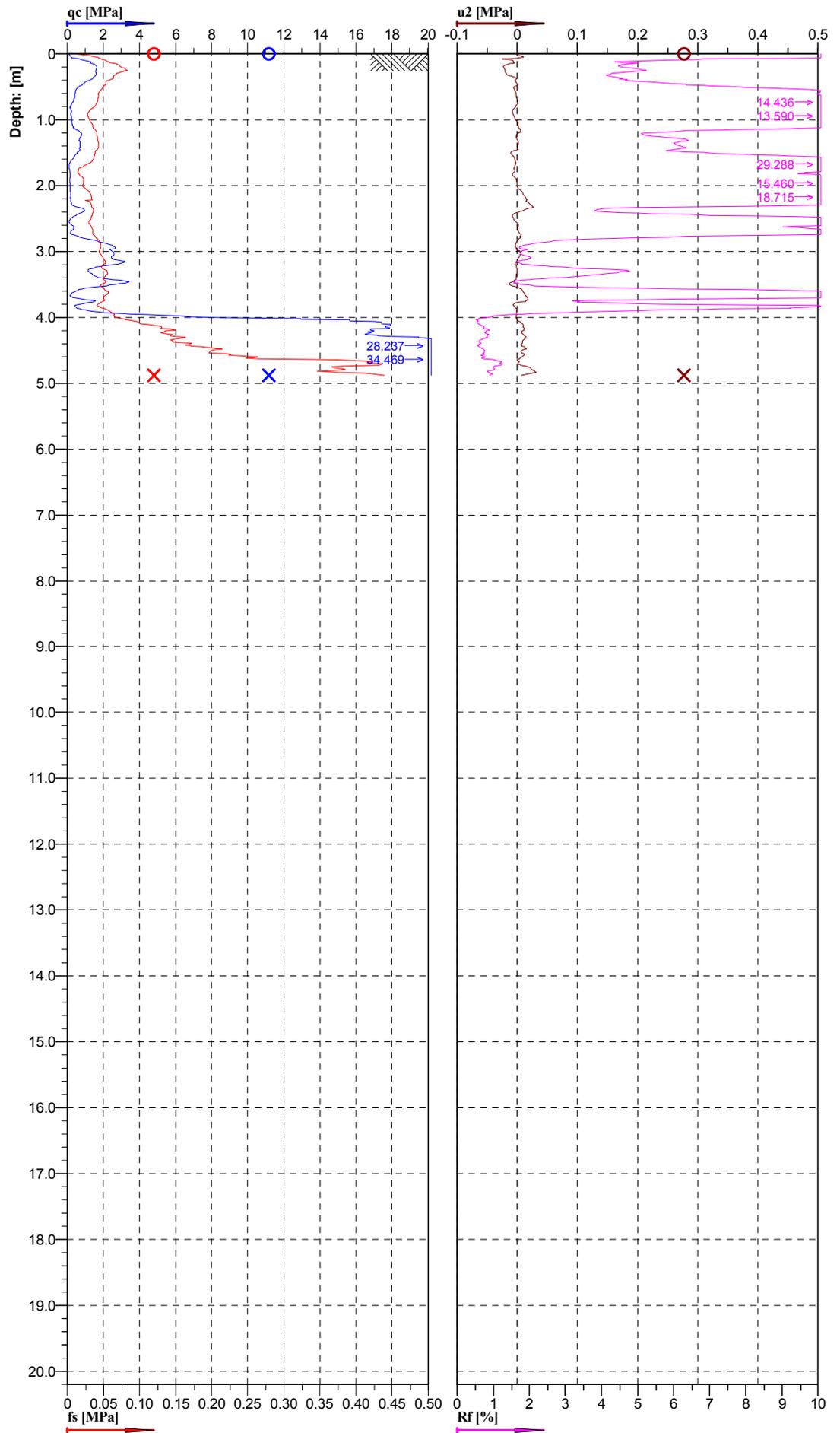


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT136
Project ID:	Client: T&T	Date: 13/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT136.cpt	

Classification by Robertson 1986

- Clay (3)
- Organic material (2)
- Clay (3)
- Organic material (2)
- Sandy silt to clayey silt (6)
- Clay (3)
- Sand (9)

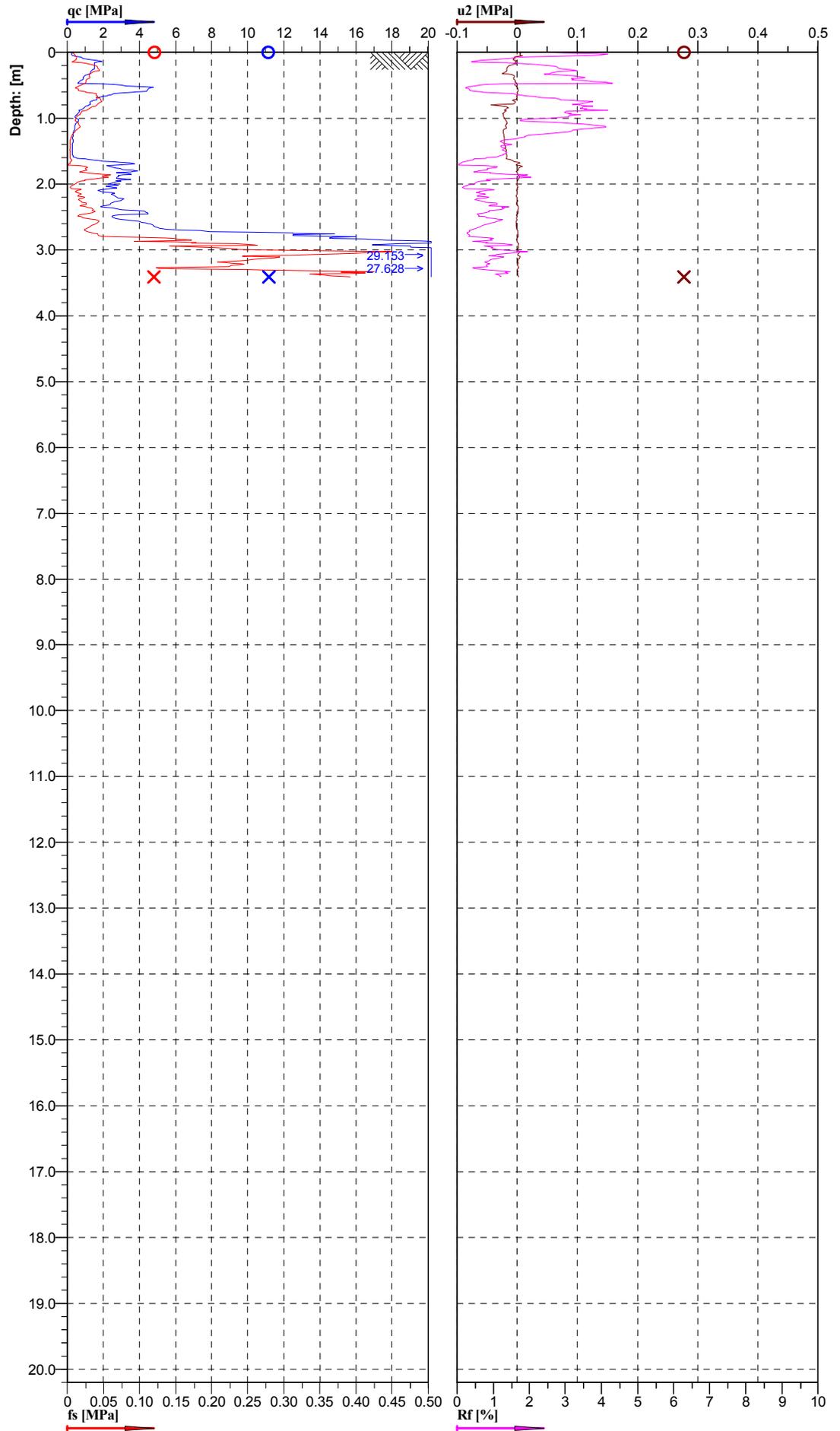


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT137
Project ID:	Client: T&T	Date: 13/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhитуCPT137.cpt	

Classification by Robertson 1986

- Clayey silt to silty clay (5)
- Sand to silty sand (8)
- Clay (3)
- Sensitive fine grained (1)
- Silty sand to sandy silt (7)
- Sand (9)

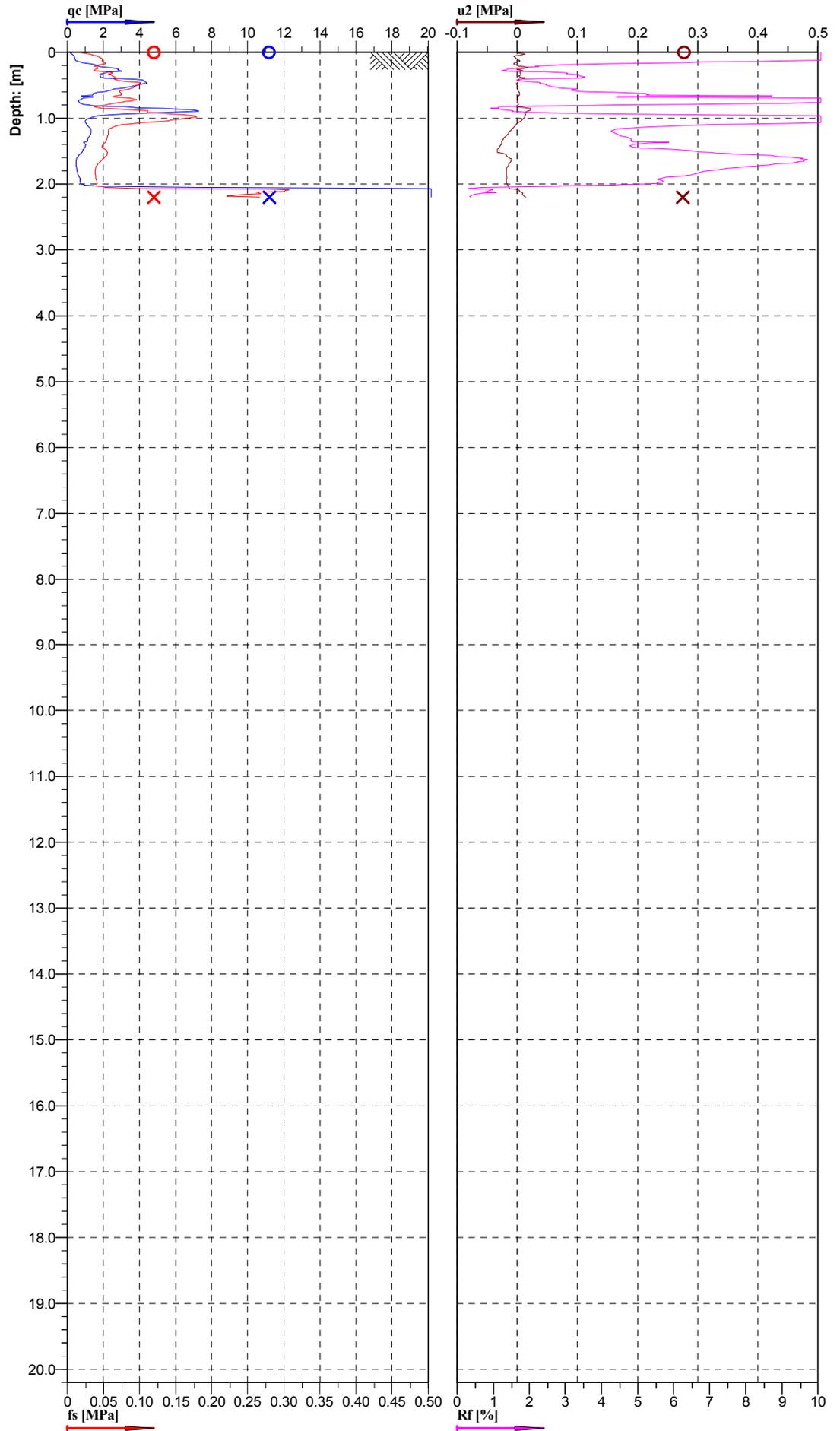


Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT138
Project ID:	Client: T&T	Date: 13/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT138.cpt	

**Classification by
Robertson 1986**

- Organic material (2)
- Clayey silt to silty clay (5)
- Clay (3)

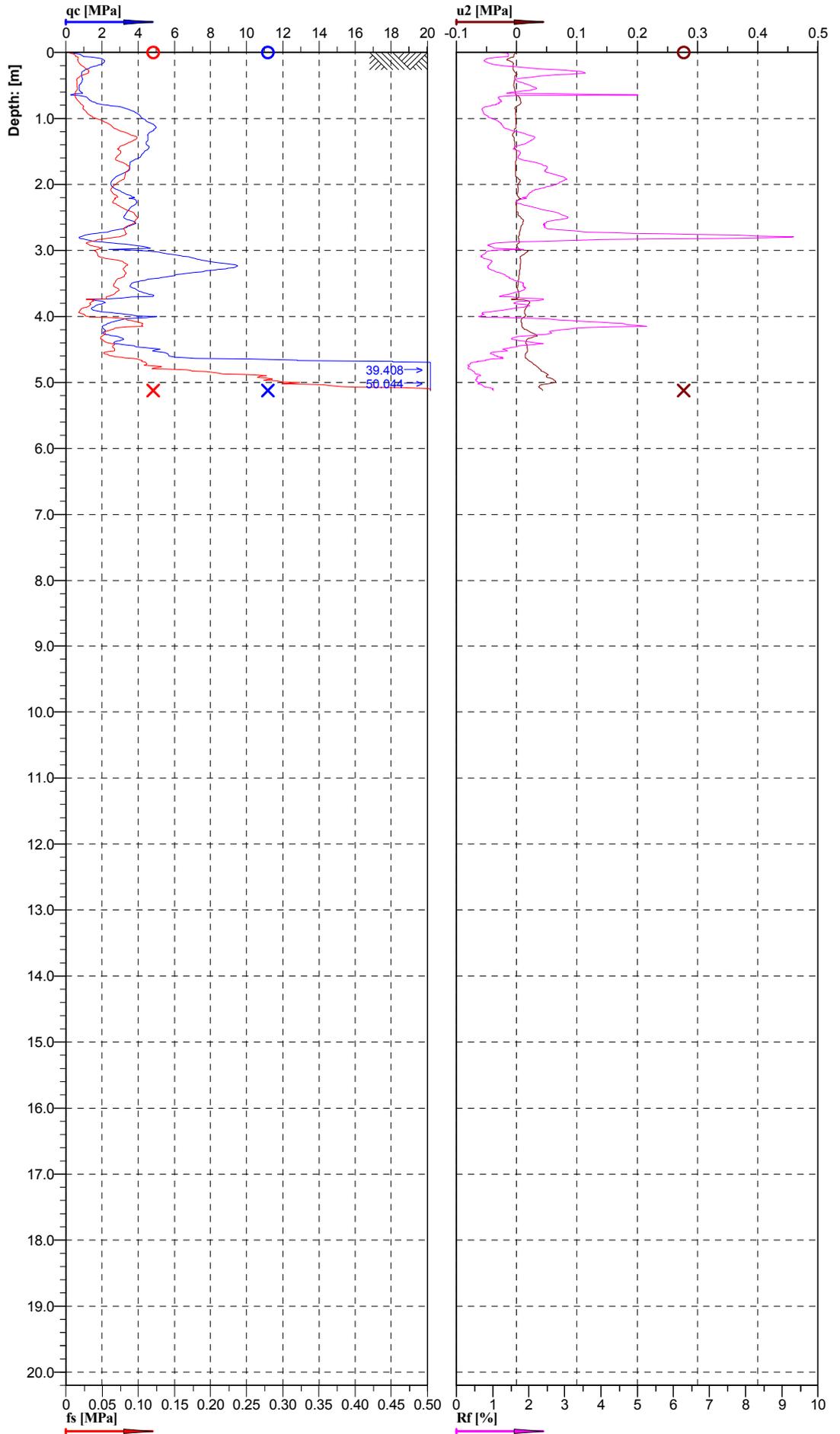


Cone No: 4494
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT139
Project ID:	Client: T&T	Date: 13/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT139.cpt	

Classification by Robertson 1986

- Silty clay to clay (4)
- Clayey silt to silty clay (5)
- Silty sand to sandy silt (7)
- Sandy silt to clayey silt (6)
- Sand to silty sand (8)
- Silty sand to sandy silt (7)
- Gravely sand to sand (10)



Cone No: 4494
 Tip area [cm²]: 10
 Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test No.: CPT140
Project ID:	Client: T&T	Date: 13/08/2018	Scale: 1 : 87
Project: HOKOWHITU		Page: 1/1	Fig.:
		File: hokowhituCPT140.cpt	

Appendix C: Previous investigation summary

C.1 Previous investigations

Geotechnical investigations were carried out at the project site on 27 and 28 July 2016. The investigations comprised of ten (10) cone penetrometer tests (CPTs) and two (2) machine borehole. These investigations were part of a larger scope of investigations and assessment of the Hokowhitu Campus areas¹³. The locations of the investigations were surveyed by hand held GPS, and are presented on Figure 2 in Appendix A.

C.2 Cone Penetration Tests

The pushing of ten (10) Cone Penetrometer Tests (CPTs) within the site were undertaken by Geotech Drilling Ltd on 27 and 28 July 2016. In all cases, the CPTs were targeting a depth of 12 m, however 'refusal' occurred at shallower depths in all locations due to the cone terminating on or within a hard, impenetrable strata such as dense gravel.

The CPT locations are presented on Figure 2 in Appendix A. A summary of the CPT locations and termination depths is presented in Table C.1 below.

Table C.1: Cone penetration test (CPT) summary

CPT ID	Location (NZTM)		Ground Surface Elevation (GRS80)	Termination depth (m) ⁽¹⁾	Reason for termination
	Easting (m)	Northing (m)	RL (m)		
CPT-H-01	1823379	5527967	29.1	2.15	Cone resistance refusal
CPT-H-02	1823230	5528024	28.6	3.04	Cone resistance refusal
CPT-H-03	1823390	5527913	30.2	6.34	Cone resistance refusal
CPT-H-04	1823258	5527913	28.9	3.62	Cone resistance refusal
CPT-H-05	1823433	5527712	30.7	3.6	Cone resistance refusal
CPT-H-06	1823287	5527823	29.1	5.94	Cone resistance refusal
CPT-H-07	1823409	5527639	28.2	2.32	Cone resistance refusal
CPT-H-08	1823287	5527675	27.64	4.34	Cone resistance refusal
CPT-H-09	1823349	5527547	28.3	3.26	Cone resistance refusal
CPT-H-10	1823253	5527571	28.15	3.54	Cone resistance refusal

Note 1. Elevations are based on supplied Lidar data.

¹³ Tonkin & Taylor Ltd (2011), Palmerston North City Council, City West and Whakarongo Growth Areas, Liquefaction Assessment Factual Geotechnical Investigation Report, dated August 2012

C.3 Machine boreholes

The machine borehole within the site was undertaken on 27 and 28 July 2016. The boreholes were undertaken using a tracked drilling rig, supplied and operated by Geotech Drilling Ltd.

In situ Standard Penetration Testing (SPT) was undertaken at 1.5 m intervals.

The recovered drill core was photographed and logged to NZGS 'Field Description of Soil and Rock' guidelines.

Summary borehole details are presented in Table C.2 below.

Table C.2: Borehole summary

BH ID	Location (NZTM) ⁽¹⁾		Ground Surface Elevation (GRS80)	Termination depth (m)	Reason for termination
	Easting (m)	Northing (m)	RL (m)		
BH-H-01	1823394	5527928	30.2	15	Maximum explored
BH-H-02	1823407	5527638	28.2	9.45	Maximum explored

Note 1. Co-ordinates are from hand-held GPS and elevations are based on supplied Lidar data.

C.4 Laboratory Testing

Laboratory testing was undertaken by Geotechnics Ltd on selected samples recovered from BH 4. Testing included Atterberg limits, fines content, and water content tests.

Summary details of the samples and laboratory test results are presented in Table B.4 below.

Table C.3: Laboratory testing summary

Borehole No.	Sample Depth (m)	Atterberg Limits			Fines Content (passing 63µm)	Water Content (%)
		Liquid Limit	Plastic Limit	Plasticity Index		
BH 4	3.0	83	36	47	97.3%	66.2

BOREHOLE LOG

BOREHOLE No.: **BH-H-01**

Hole Location: Hokowhitu Campus. Beside CPT-H-03

SHEET: 2 OF 3

PROJECT: HOKOWHITU-NAP-PNCC	LOCATION: Hokowhitu + Napier Road	JOB No.: 85442.004
CO-ORDINATES: 5527928.30 mN (NZTM 2000) 1823394.48 mE	DRILL TYPE: SONIC SAMP DRILL	HOLE STARTED: 27/07/2016
R.L.: 30.2m	DRILL METHOD: HFS	HOLE FINISHED: 27/07/2016
DATUM: GRS80 Ellipsoid	DRILL FLUID: NA	DRILLED BY: Geotech Drilling Ltd
		LOGGED BY: SSXC CHECKED: NCP

GEOLOGICAL		ENGINEERING DESCRIPTION														
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION	FLUID LOSS (%)	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION / WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (cm)	Description and Additional Observations
Alluvial Deposits			57	HFS				25								4.95 - 6.00m: CORE LOSS
								6								Recovered as fine to coarse GRAVEL with some sand and trace silt; light brown. Medium dense, saturated, well graded. Greywacke gravels are well graded, unweathered, sub angular to sub rounded. Interpreted as gravelly SAND. 5.4m: Bed of 80mm cobbles 5.8m: Trace red gravel (chert)
			40	HFS				24								6.0 - 6.9m: CORE LOSS
								7								Recovered as fine to coarse GRAVEL with minor sand and trace silt; light brown. Medium dense, saturated, well graded. Greywacke gravels are unweathered, sub angular to sub rounded. Interpreted as gravelly SAND. 7.45m: Bed of fine to medium Gravel
			56	SPT			11/8 9/10 9/11 N=39					D				Fine to coarse GRAVEL with some sand and trace silt; brownish grey. Dense, saturated, well graded, non dilatant. Greywacke gravels are unweathered, sub angular to sub rounded. Sands are fine to coarse.
			100	HFS				22								8.0m: Bed of 100mm cobbles. 8.1 - 8.2m: Bed of GRAVEL with minor sand and silt.
								21								9.6m: Bed of 90mm cobbles. 9.65 - 9.9m: Bed of GRAVEL with minor sand and silt.

COMMENTS: Recovered as: based on factual information logged on site. Interpreted as: gives an indication of insitu characteristics of the material based on engineering geological knowledge of the area

Hole Depth
15m

Scale 1:25

BOREHOLE LOG

BOREHOLE No.: **BH-H-02**

Hole Location: Hokowhitu Campus. Beside CPT-H-07

SHEET: 1 OF 2

PROJECT: HOKOWHITU-NAP-PNCC	LOCATION: Hokowhitu + Napier Road	JOB No.: 85442.004
CO-ORDINATES: 5527638.15 mN (NZTM 2000) 1823406.76 mE	DRILL TYPE: SONIC SAMP DRILL	HOLE STARTED: 28/07/2016
R.L.: 28.2m	DRILL METHOD: HFS	HOLE FINISHED: 28/07/2016
DATUM: GRS80 Ellipsoid	DRILL FLUID: NA	DRILLED BY: Geotech Drilling Ltd
		LOGGED BY: SSXC CHECKED: NCP

GEOLOGICAL										ENGINEERING DESCRIPTION									
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION										Description and Additional Observations									
FLUID LOSS (%)										DEFECT SPACING (cm)									
WATER										20 60 100 200									
CORE RECOVERY (%)										1 20 50 100 200									
METHOD										10 50 100									
CASING										1 20 50 100 200									
TESTS										10 50 100									
SAMPLES										1 20 50 100 200									
RL (m)										10 50 100									
DEPTH (m)										1 20 50 100 200									
GRAPHIC LOG										10 50 100									
MOISTURE CONDITION										1 20 50 100 200									
WEATHERING										10 50 100									
STRENGTH/DENSITY CLASSIFICATION										1 20 50 100 200									
10 50 100										1 20 50 100 200									
1 20 50 100 200										1 20 50 100 200									
Top Soil										SILT with trace sand; brown. Very soft, moist, moderate plasticity, non dilatant.									
Fill										Fine to coarse GRAVEL with trace silt; brown. Loosely packed, wet, well graded. Greywacke gravels are unweathered, sub angular to sub rounded. 0.2m: Changes to silty Gravel.									
Holocene Alluvial Deposits										Sandy SILT; brown with minor mottled specs. Soft, moist, low plasticity, slow dilatancy.									
										1.0m: Changes to SILT with minor sand. Moderate plasticity. 1mm orange mottled lenses present.									
										1.1m: Grades to SILT with trace sand, moderate to high plasticity, trace orange mottling.									
										1.2 - 1.5m: CORE LOSS									
Alluvial Deposits										Fine to medium SAND with trace silt; brown. Loosely packed, moist to wet, poorly graded, non dilatant.									
										SILT with trace sand; orange brown. Very soft, wet, moderate to high plasticity, slow dilatancy.									
										2.0 - 2.3m: CORE LOSS									
										Gravelly medium to coarse SAND; brown. Medium dense, wet, well graded, non dilatant. Greywacke gravels are fine, unweathered, sub angular to sub rounded.									
Alluvial Deposits										2.45m: 60mm bed of coarse gravel.									
										2.8 - 3.0m: 200 mm bed of silty gravel. (Very hard to drill through).									
										3.0m: Changes to saturated.									
										3.45 - 4.05m: CORE LOSS									
Alluvial Deposits										Fine to coarse GRAVEL with some sand, minor silt and trace cobbles; grey. Dense, saturated, well graded, non dilatant. Greywacke gravels are unweathered to slightly weathered, sub angular to sub rounded. Sands are angular, medium to coarse.									

COMMENTS:

Hole Depth 9.34m

Scale 1:25

BOREHOLE LOG

BOREHOLE No.: **BH-H-02**

Hole Location: Hokowhitu Campus. Beside CPT-H-07

SHEET: 2 OF 2

PROJECT: HOKOWHITU-NAP-PNCC	LOCATION: Hokowhitu + Napier Road	JOB No.: 85442.004
CO-ORDINATES: 5527638.15 mN (NZTM 2000) 1823406.76 mE	DRILL TYPE: SONIC SAMP DRILL	HOLE STARTED: 28/07/2016
R.L.: 28.2m	DRILL METHOD: HFS	HOLE FINISHED: 28/07/2016
DATUM: GRS80 Ellipsoid	DRILL FLUID: NA	DRILLED BY: Geotech Drilling Ltd
		LOGGED BY: SSXC CHECKED: NCP

GEOLOGICAL		ENGINEERING DESCRIPTION																	
GEOLOGICAL UNIT, GENERIC NAME, ORIGIN, MATERIAL COMPOSITION		FLUID LOSS (%)	WATER	CORE RECOVERY (%)	METHOD	CASING	TESTS	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	MOISTURE CONDITION	WEATHERING	STRENGTH/DENSITY CLASSIFICATION	SHEAR STRENGTH (kPa)	COMPRESSIVE STRENGTH (MPa)	DEFECT SPACING (cm)	Description and Additional Observations	
Alluvial Deposits			100	HFS			3/6 6/10 12/13 N=41		23									[CONT] Fine to coarse GRAVEL with some sand, minor silt and trace cobbles; grey. Dense, saturated, well graded, non dilatant. Greywacke gravels are unweathered to slightly weathered, sub angular to sub rounded. Sands are angular, medium to coarse. 5.2m: Changes to brown 5.3 - 5.5m: 200mm bed of gravel with some silt.	
			78	SPT					22	6				VD				Fine to coarse GRAVEL with some sand; grey. Very dense, saturated, well graded, non dilatant. Greywacke gravels are unweathered, sub angular to sub rounded. Sands are fine to coarse.	
			100	HFS					21	7									
			100	HFS					20	8									8.4 - 8.5m: Bed of medium coarse sand with wood. Recovered as 10-30mm diameter shredded wood with sand.
			88	SPT			11/20 20/20 10 for 35mm N>=50		19	9									
																		9.33m: END OF BORE HOLE Target depth was not reached due to competent ground (very dense gravel) >3m in thickness. No stand pipe installment. NB1: Refer to CPT-H-07, located 1.5m towards the west, for strength/density classifications from 0.0m to 2.3m.	

COMMENTS:

Hole Depth 9.34m

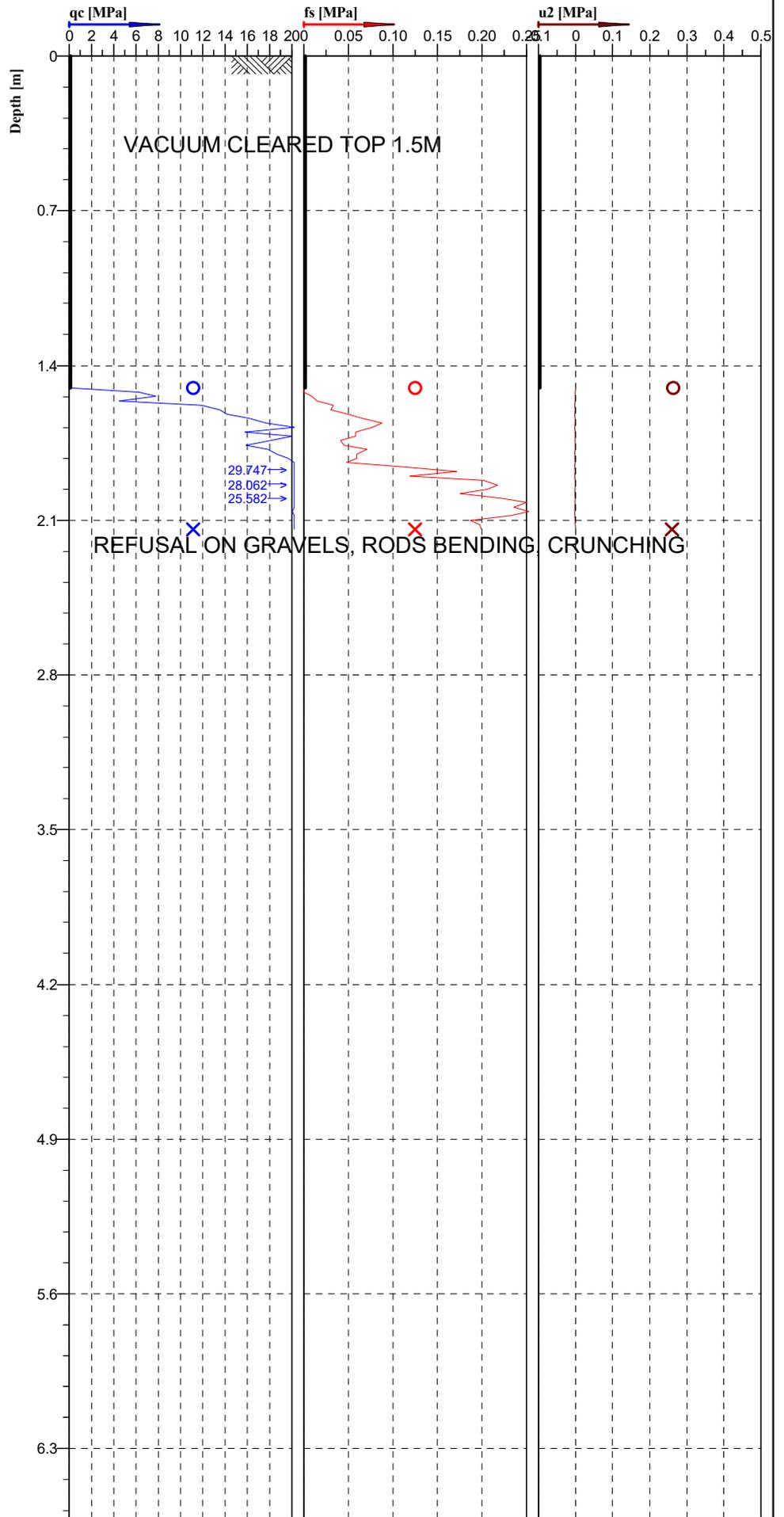
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Classification by
Robertson 1986



Sand to silty sand (8)

Sand (9)

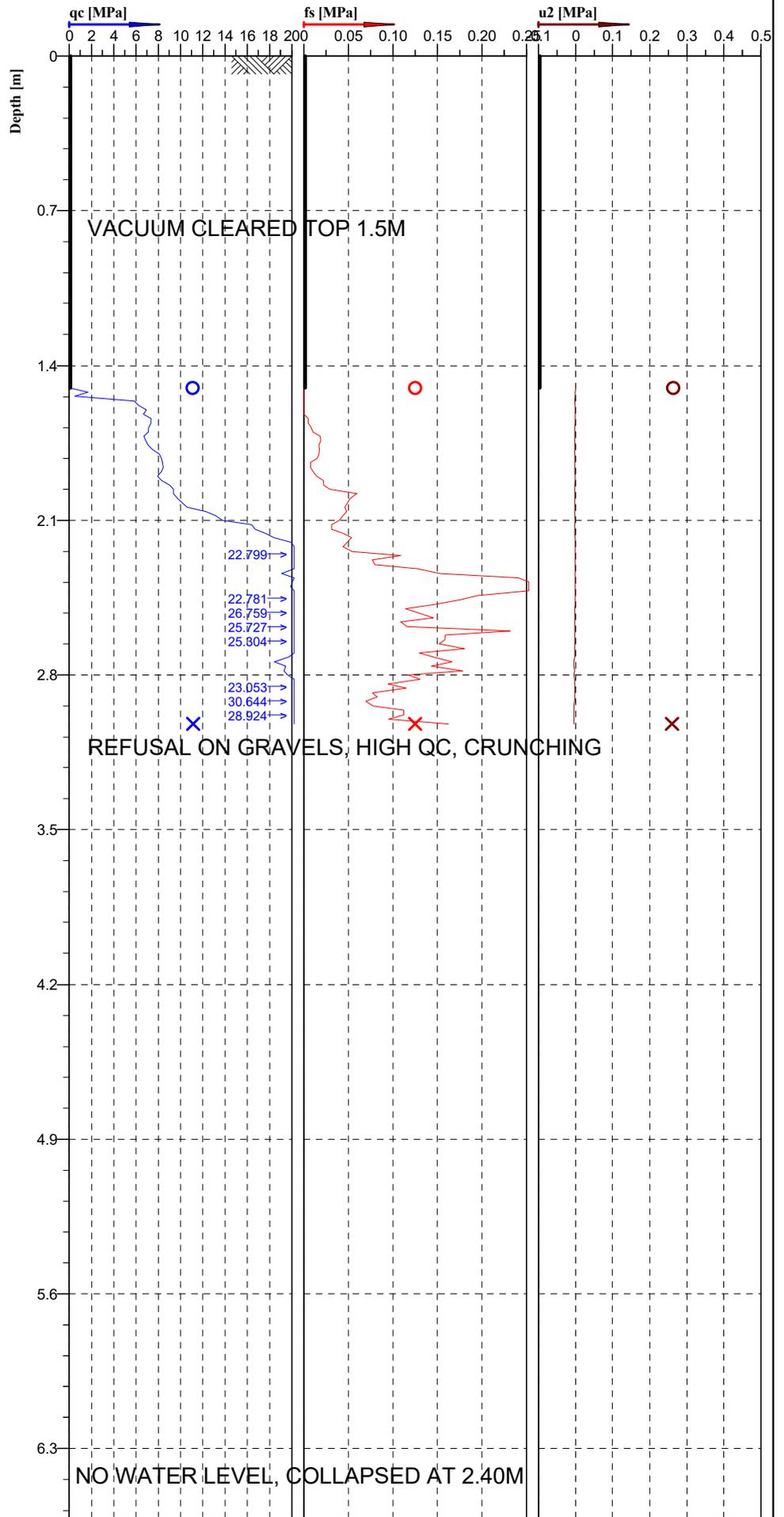
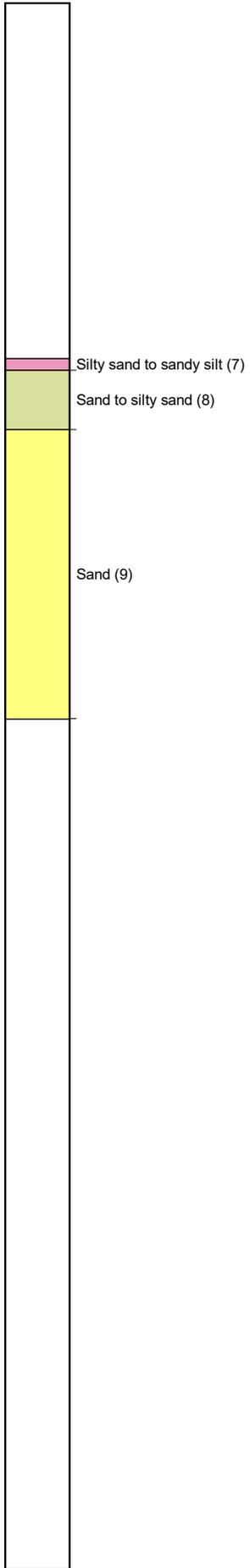


Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 01
Project ID: 85442.004	Client: TONKIN & TAYLOR LTD	Date: 20/07/2016	Scale: 1 : 27
Project: HOROWHITU CAMPUS		Page: 1/1	Fig:
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Cone No: 4696
Tip area [cm²]: 10
Sleeve area [cm²]: 150

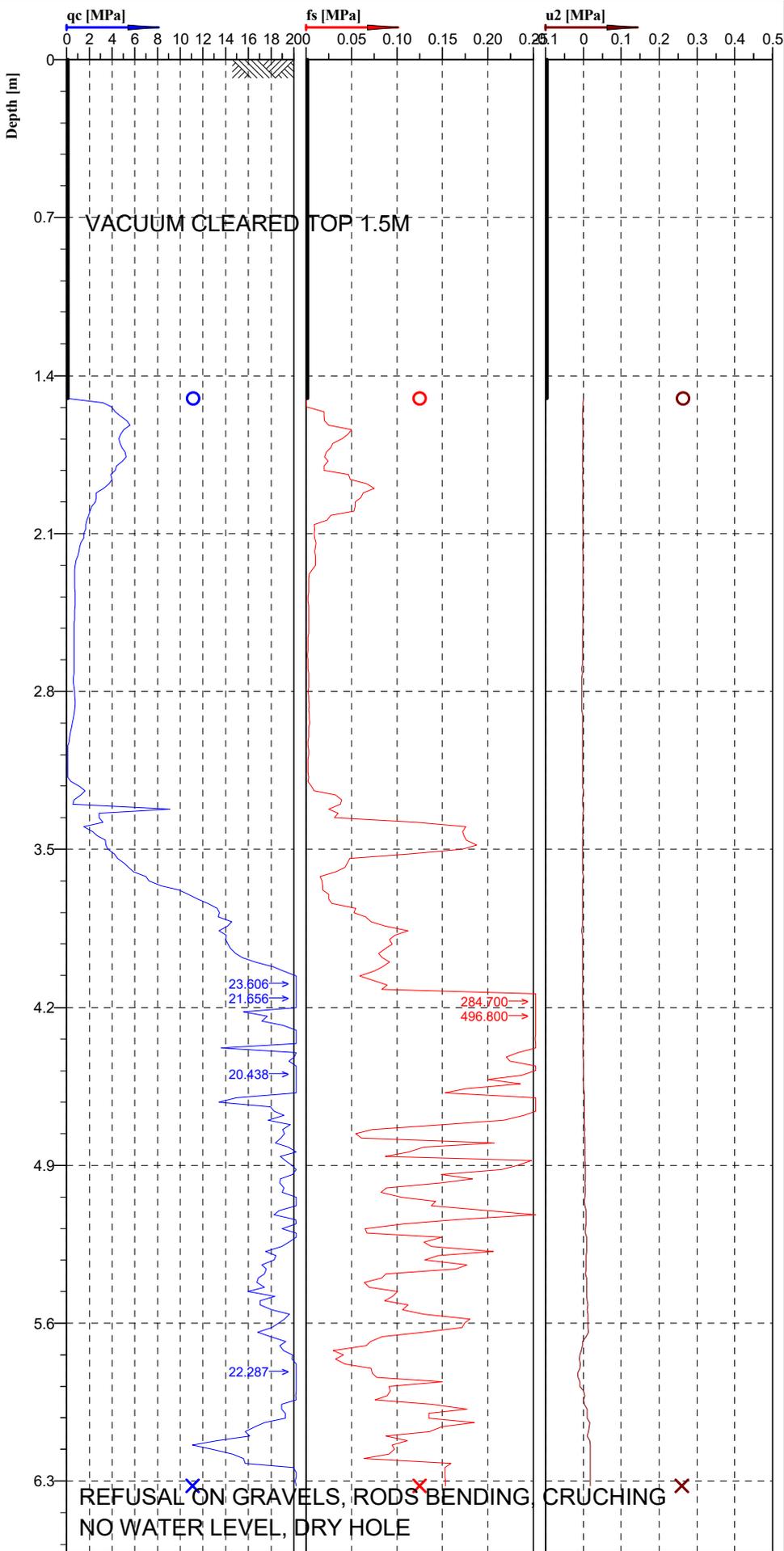
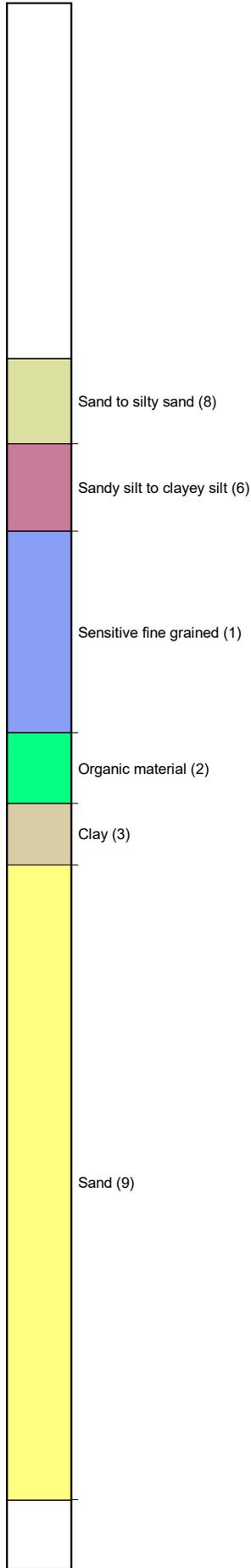
Classification by
Robertson 1986



Cone No: 4696
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 02
Project ID: 85442.004	Client: TONKIN & TAYLOR LTD	Date: 20/07/2016	Scale: 1 : 27
Project: HOROWHITU CAMPUS		Page: 1/1	Fig:
S 40°22.110 E 175°37.754		File: CPT-H-02.CPT	

Classification by Robertson 1986

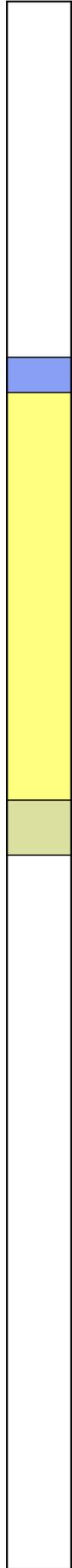


Cone No: 4696
Tip area [cm²]: 10
Sleeve area [cm²]: 150



Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 03
Project ID: 85442.004	Client: TONKIN & TAYLOR LTD	Date: 20/07/2016	Scale: 1 : 27
Project: HOROWHITU CAMPUS		Page: 1/1	Fig:
S 40°22.165 E 175°37.871		File: CPT-H-03.CPT	

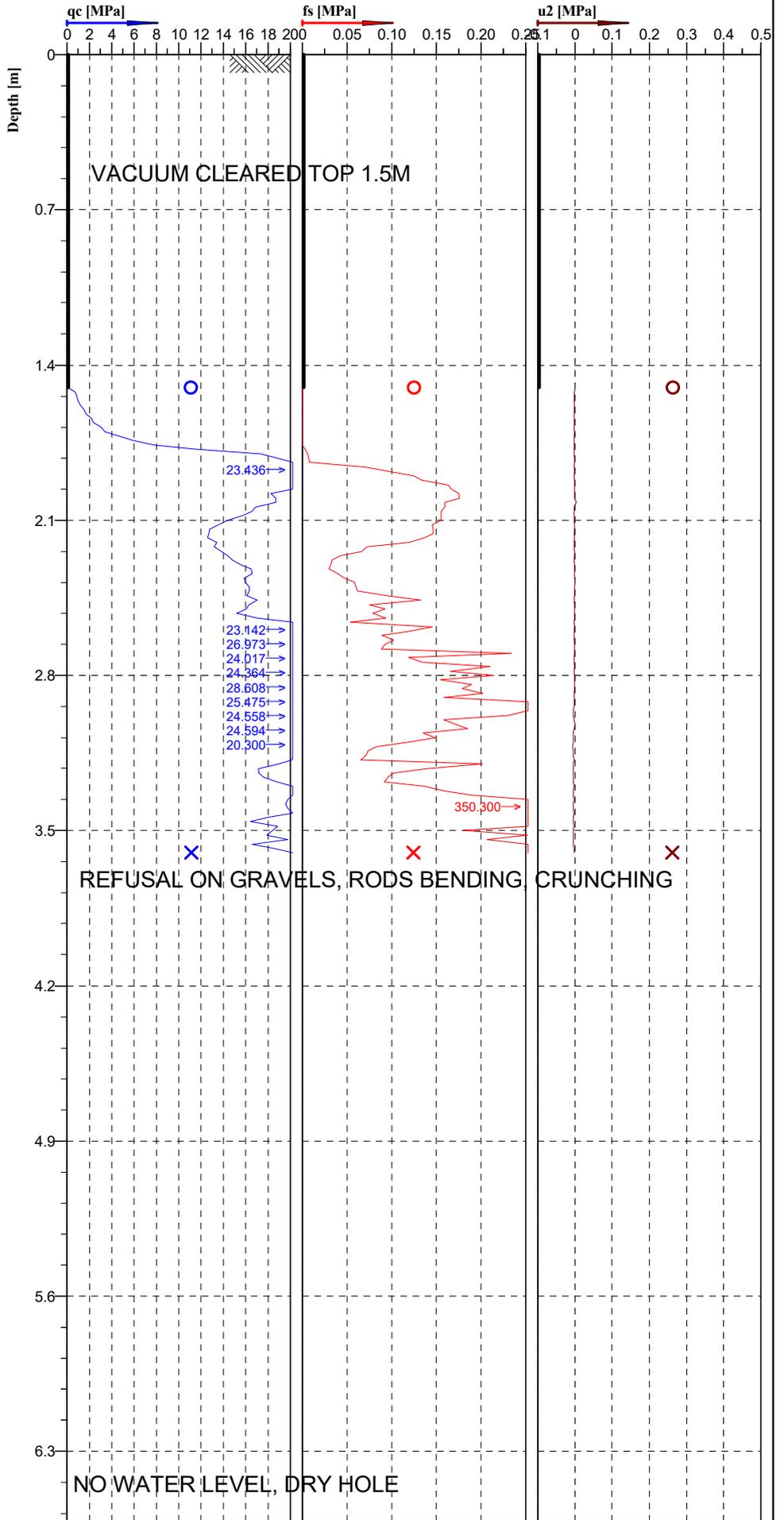
Classification by
Robertson 1986



Sensitive fine grained (1)

Sand (9)

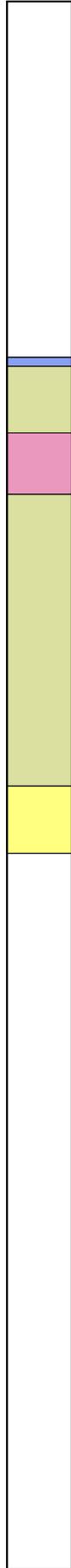
Sand to silty sand (8)



Cone No: 4696
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 04
Project ID: 85442.004	Client: TONKIN & TAYLOR LTD	Date: 20/07/2016	Scale: 1 : 27
Project: HOROWHITU CAMPUS		Page: 1/1	Fig: 1 : 27
S 40°22.168 E 175°37.774		File: CPT-H-04.CPT	

Classification by
Robertson 1986

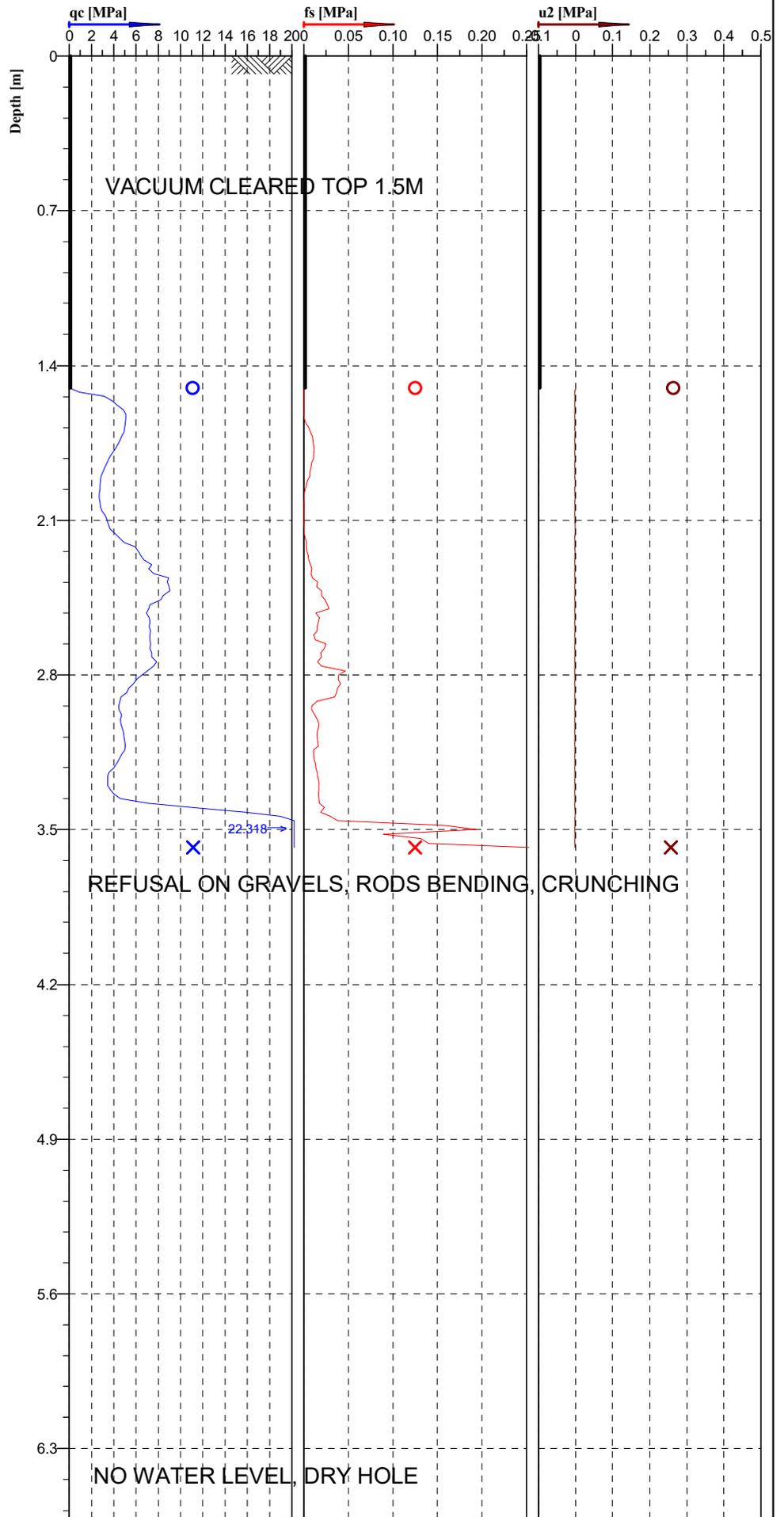


Sand to silty sand (8)

Silty sand to sandy silt (7)

Sand to silty sand (8)

Sand (9)



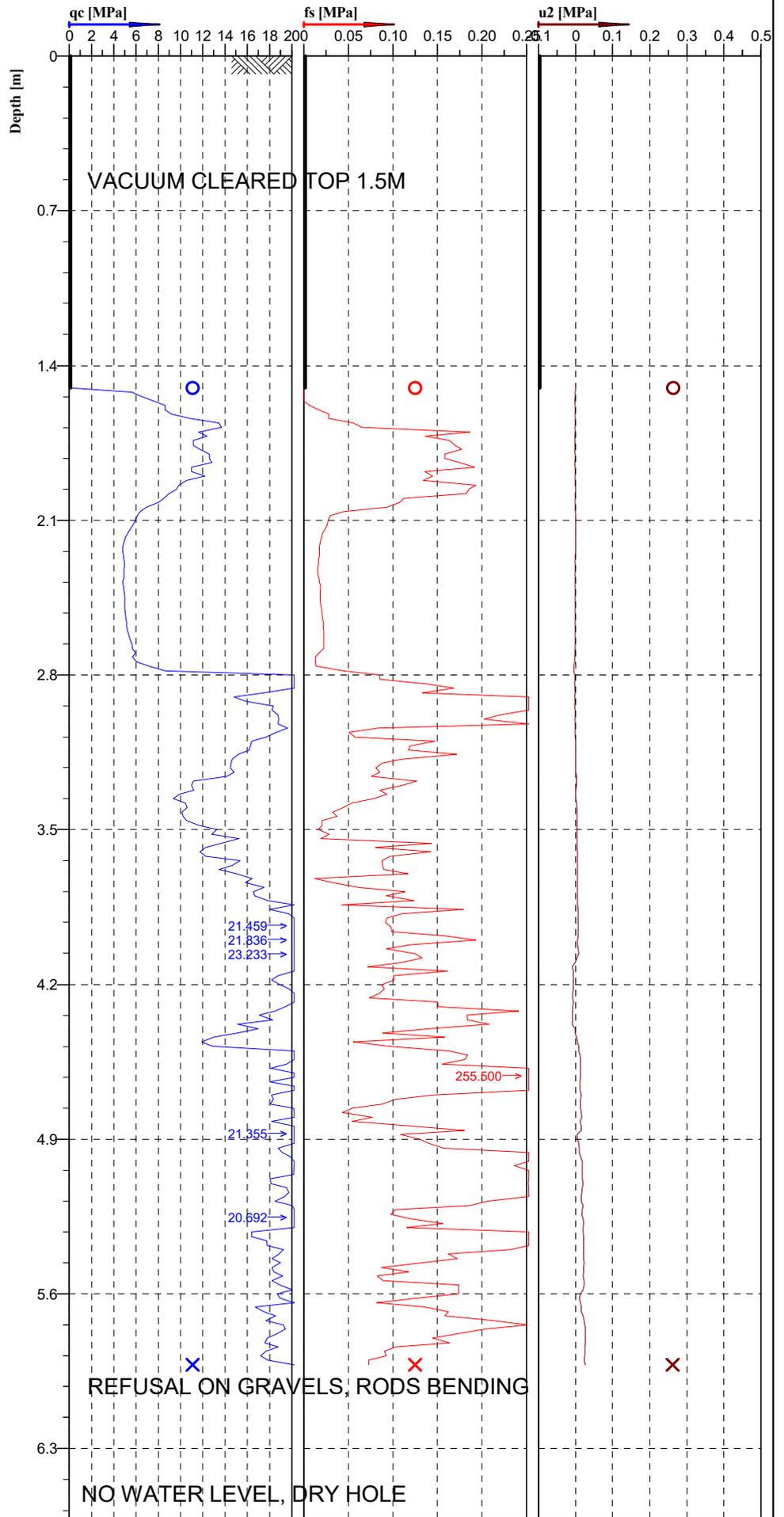
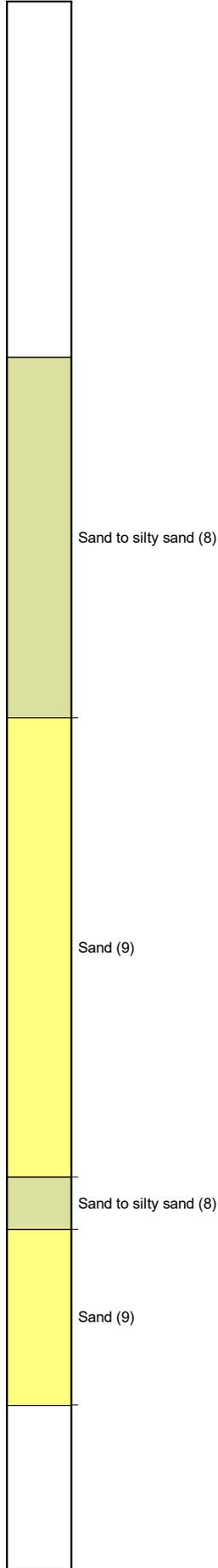
Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 05
Project ID: 85442.004	Client: TONKIN & TAYLOR LTD	Date: 20/07/2016	Scale: 1 : 27
Project: HOROWHITU CAMPUS		Page: 1/1	Fig:
S 40°22.267 E 175°37.903		File: CPT-H-05.CPT	



Cone No: 4696
Tip area [cm²]: 10
Sleeve area [cm²]: 150



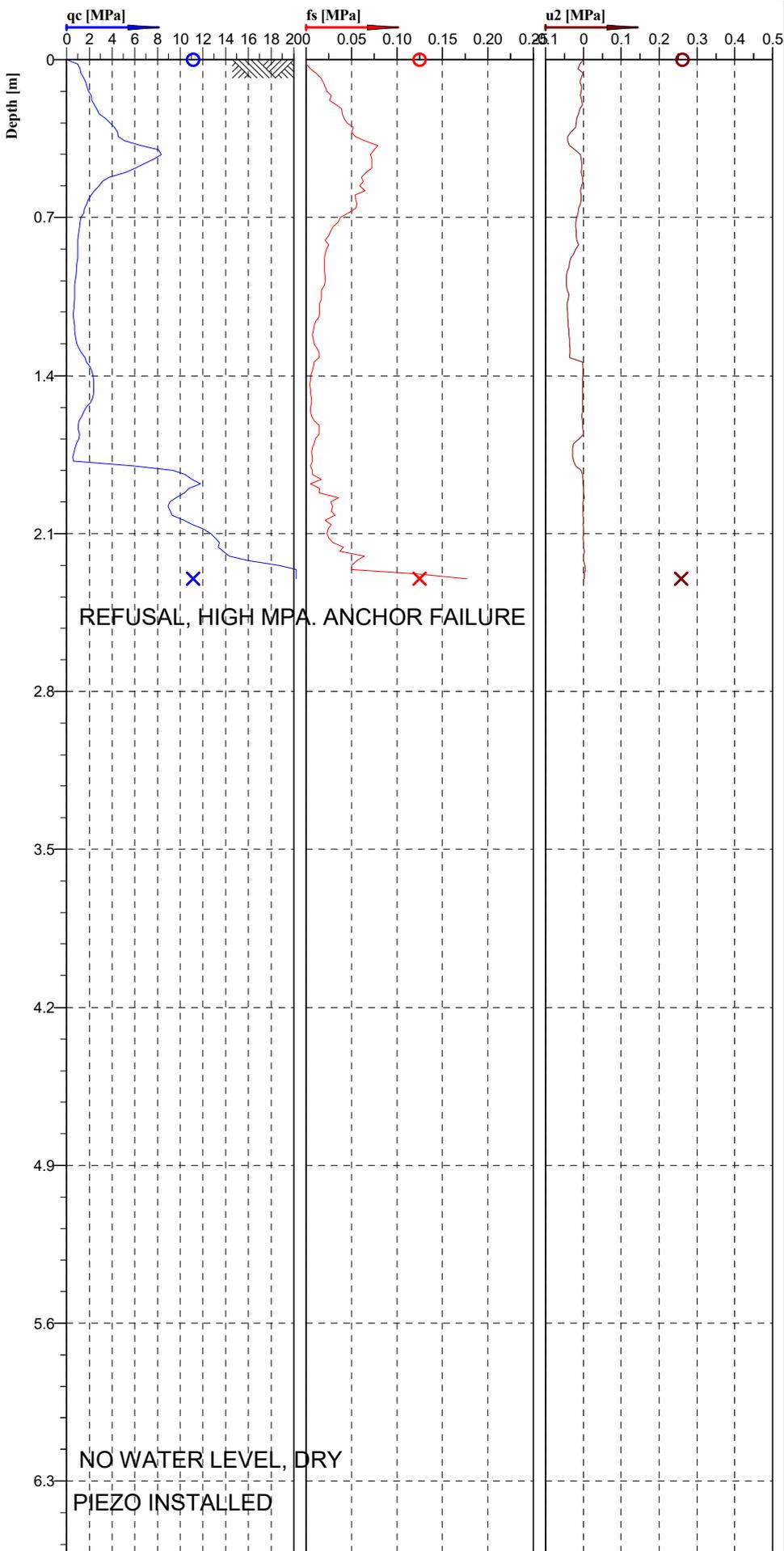
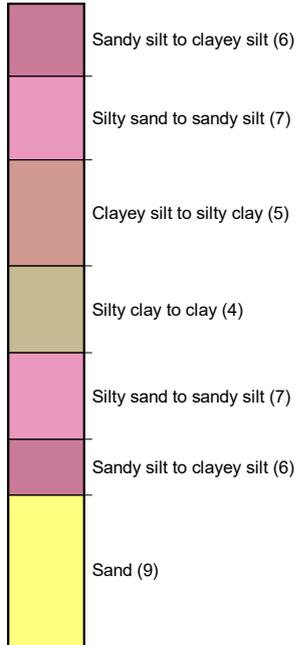
Classification by
Robertson 1986



Cone No: 4696
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 06
Project ID: 85442.004	Client: TONKIN & TAYLOR LTD	Date: 20/07/2016	Scale: 1 : 27
Project: HOROWHITU CAMPUS		Page: 1/1	Fig: 1
S 40°22.220 E 175°37.797		File: CPT-H-06.CPT	

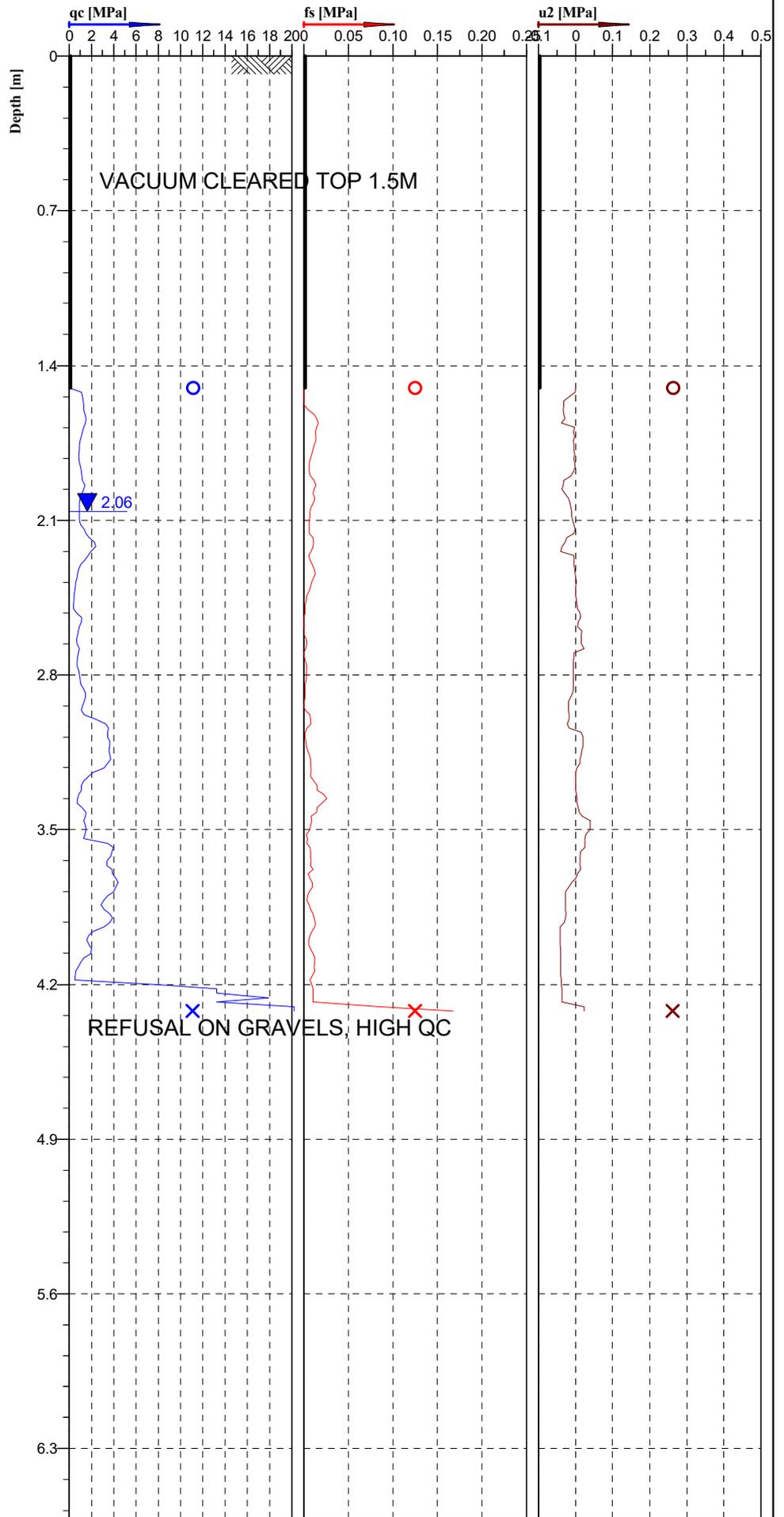
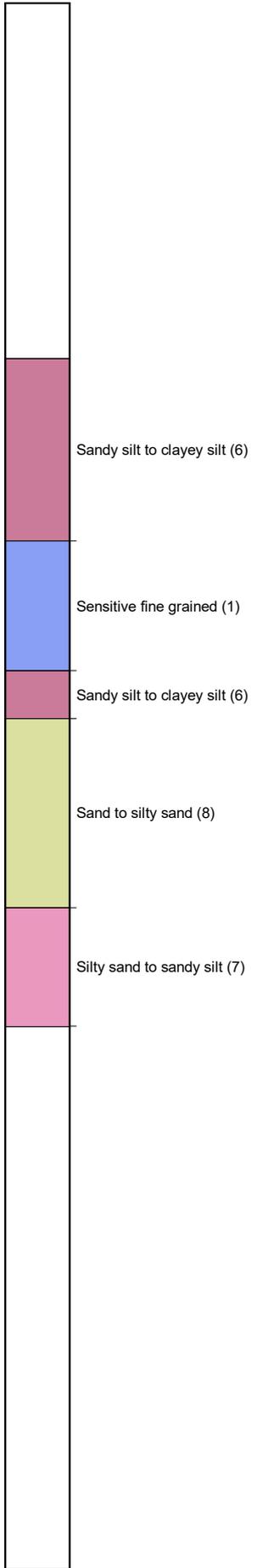
Classification by
Robertson 1986



Cone No: 4696
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 07
Project ID: 85442.004	Client: TONKIN & TAYLOR LTD	Date: 19/07/2016	Scale: 1 : 27
Project: HOROWHITU CAMPUS		Page: 1/1	Fig:
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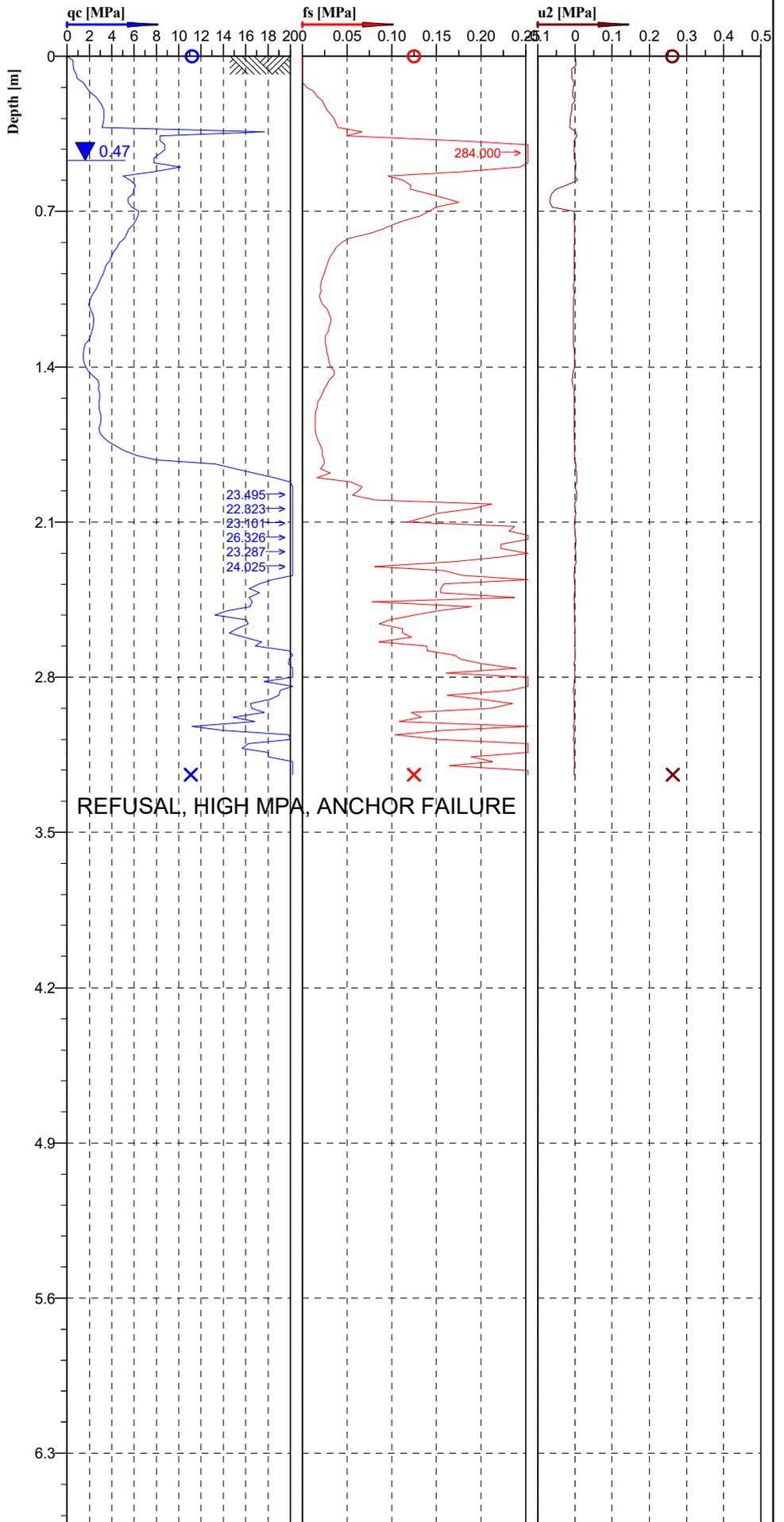
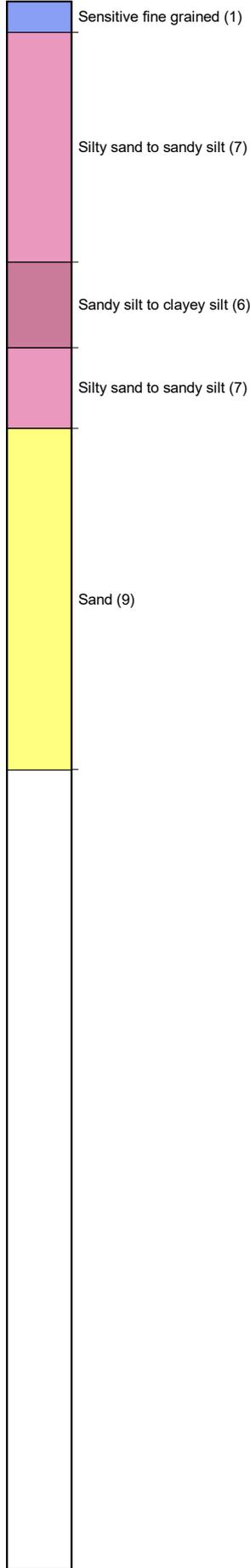
Classification by
Robertson 1986



Cone No: 4696
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 08
Project ID: 85442.004	Client: TONKIN & TAYLOR LTD	Date: 20/07/2016	Scale: 1 : 27
Project: HOROWHITU CAMPUS		Page: 1/1	Fig:
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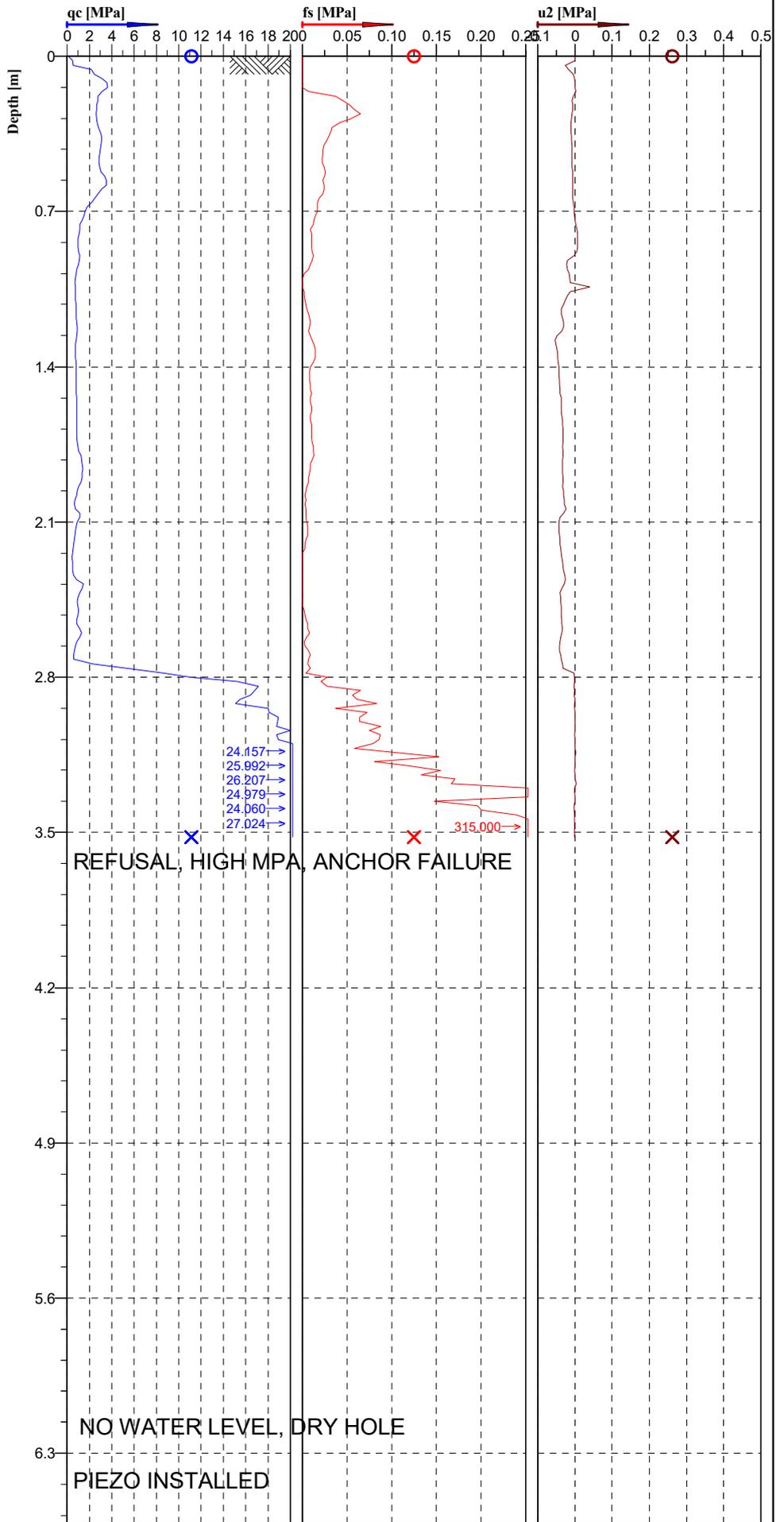
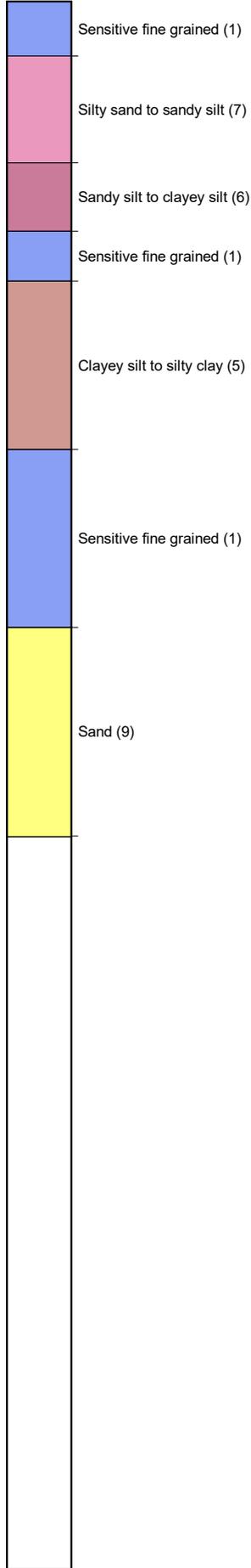
Classification by
Robertson 1986



Cone No: 4696
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 09
Project ID: 85442.004	Client: TONKIN & TAYLOR LTD	Date: 19/07/2016	Scale: 1 : 27
Project: HOROWHITU CAMPUS		Page: 1/1	Fig:
S 40°22.364 E 175°37.848		File: CPT-H-09.cpd	

Classification by
Robertson 1986



Cone No: 4696
Tip area [cm²]: 10
Sleeve area [cm²]: 150

Location: PALMERSTON NORTH	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 10
Project ID: 85442.004	Client: TONKIN & TAYLOR LTD	Date: 19/07/2016	Scale: 1 : 27
Project: HOROWHITU CAMPUS		Page: 1/1	Fig:
S 40°22.351 E 175°37.776		File: CPT-H-10.cpd	



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Geotechnics Project ID 85442.005

Customer Project ID 85442.004

Customer Project Name

DETERMINATION OF WATER CONTENT - NZS 4402:1986 Test 2.1

TEST DETAILS

LOCATION	ID	H2		
	Description	Hokowhitu Campus		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201608012	Date Received	29/07/2016
	Reference	1	Depth	1.00m
	Description	SILT with minor sand, grey. Moist, low-plasticity. Sand is fine.		
SPECIMEN	Reference	1	Depth	N/A
	Description	N/A		

TEST RESULT

Natural Water Content 25.2%

TEST REMARKS

- The material used for testing was natural.

Approved By

PB

Date

11/08/2016



2 Hunter Street,
Wellington 6011
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Geotechnics Project ID 85442.005

Customer Project ID 85442.004

Customer Project Name

DETERMINATION OF WATER CONTENT - NZS 4402:1986 Test 2.1

TEST DETAILS

LOCATION	ID	H2		
	Description	Hokowhitu Campus		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201608013	Date Received	29/07/2016
	Reference	1.9	Depth	1.90m
	Description	SILT with minor sand, grey. Moist, low-plasticity. Sand is fine.		
SPECIMEN	Reference	1	Depth	N/A
	Description	N/A		

TEST RESULT

Natural Water Content **30.7%**

TEST REMARKS

- The material used for testing was natural.

Approved By

PB

Date

11/08/2016



2 Hunter Street,
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Geotechnics Project ID 85442.005
Customer Project ID 85442.004
Customer Project Name

DETERMINATION OF WATER CONTENT - NZS 4402:1986 Test 2.1

TEST DETAILS

LOCATION	ID	H2		
	Description	Hokowhitu Campus		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201608014	Date Received	29/07/2016
	Reference	2.3	Depth	2.30m
	Description	Sandy fine to medium GRAVEL with minor silt, grey. Moist, subrounded to rounded. Sand is fine to coarse.		
SPECIMEN	Reference	1	Depth	N/A
	Description	N/A		

TEST RESULT

Natural Water Content 5.2%

TEST REMARKS

- The material used for testing was natural.

Approved By

PB

Date

11/08/2016



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Wellington 6011
New Zealand

p. +64 4 381 8584

Geotechnics Project ID 85442.005
Customer Project ID 85442.004
Customer Project Name

DETERMINATION OF WATER CONTENT - NZS 4402:1986 Test 2.1

TEST DETAILS

LOCATION	ID	H1		
	Description	Hokowhitu Campus		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201608010	Date Received	29/07/2016
	Reference	2.7	Depth	2.70m
	Description	Fine to medium SAND with some silt, grey. Moist.		
SPECIMEN	Reference	1	Depth	N/A
	Description	N/A		

TEST RESULT

Natural Water Content 15.8%

TEST REMARKS

- The material used for testing was natural.

Approved By

PB

Date

11/08/2016



2 Hunter Street,
Wellington 6011
New Zealand

p. +64 4 381 8584

Geotechnics Project ID 85442.005

Customer Project ID 85442.004

Customer Project Name

DETERMINATION OF WATER CONTENT - NZS 4402:1986 Test 2.1

TEST DETAILS

LOCATION	ID	H1		
	Description	Hokowhitu Campus		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201608011	Date Received	29/07/2016
	Reference	3.3	Depth	3.30m
	Description	Fine to coarse SAND with some gravel and minor silt, grey. Moist. Gravel is fine to medium, subrounded to rounded.		
SPECIMEN	Reference	1	Depth	N/A
	Description	N/A		

TEST RESULT

Natural Water Content 9.9%

TEST REMARKS

- The material used for testing was natural.

Approved By

PB

Date

11/08/2016



2 Hunter Street,
Wellington 6011
New Zealand

p. +64 4 381 8584

Geotechnics Project ID 85442.005

Customer Project ID 85442.004

Customer Project Name

DETERMINATION OF LIQUID & PLASTIC LIMIT, PLASTICITY INDEX - ASTM Test D4318-10 (Method A)

TEST DETAILS

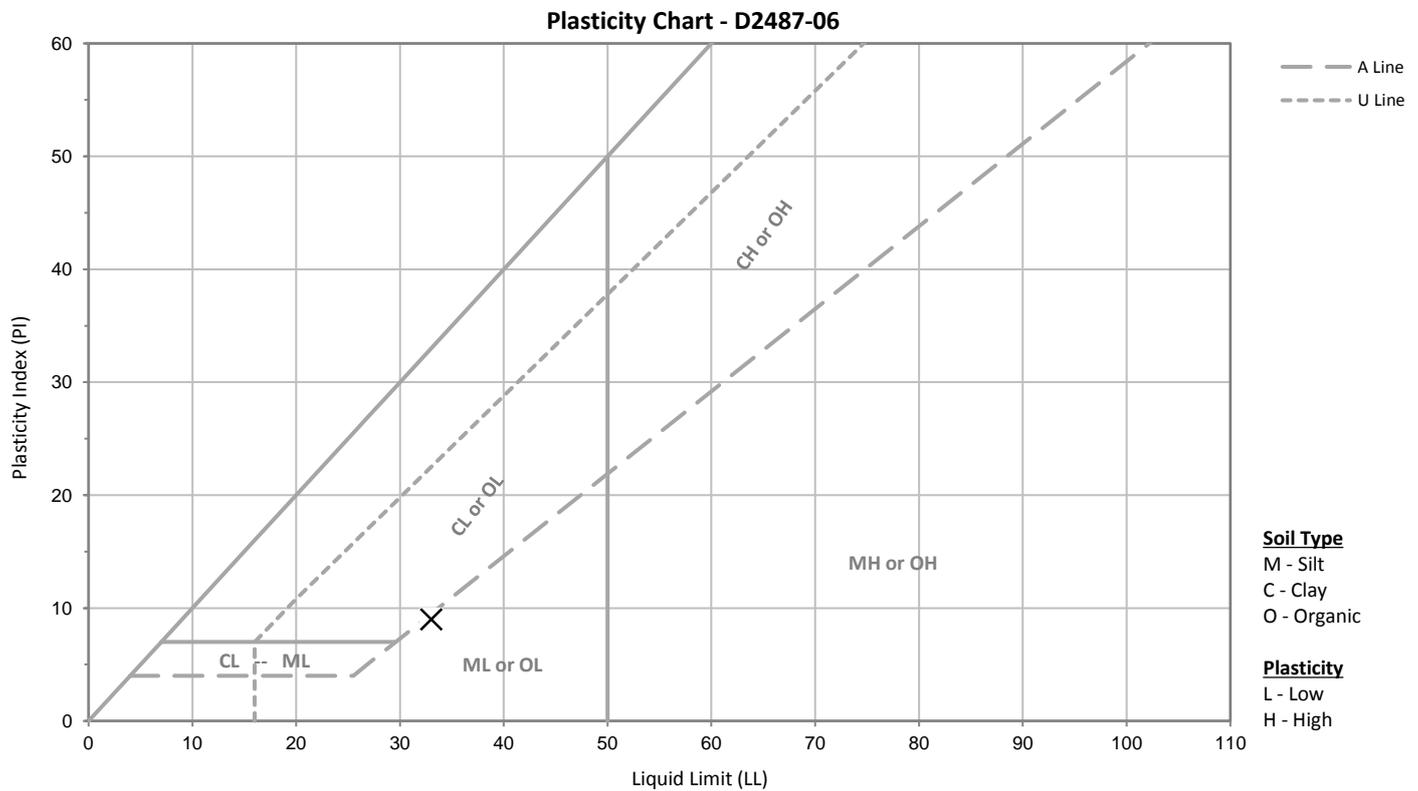
LOCATION	ID	H2		
	Description	Hokowhitu Campus		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201608012	Date Received	29/07/2016
	Reference	1	Depth	1.00m
	Description	SILT with minor sand, grey. Moist, low-plasticity. Sand is fine.		
SPECIMEN	Reference	2	Depth	N/A
	Description	N/A		

TEST RESULTS

Liquid Limit **33**

Plastic Limit **24**

Plasticity Index **9**



TEST REMARKS

- The material used for testing was natural, whole soil.
- The liquid limit was done with a manual device. The plastic limit sample was hand rolled. A metal grooving tool was used.
- The maximum grain size was approximately <2mm.

Approved By

PB

Date

11/08/2016



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Geotechnics Project ID 85442.005

Customer Project ID 85442.004

Customer Project Name

DETERMINATION OF LIQUID & PLASTIC LIMIT, PLASTICITY INDEX - ASTM Test D4318-10 (Method A)

TEST DETAILS

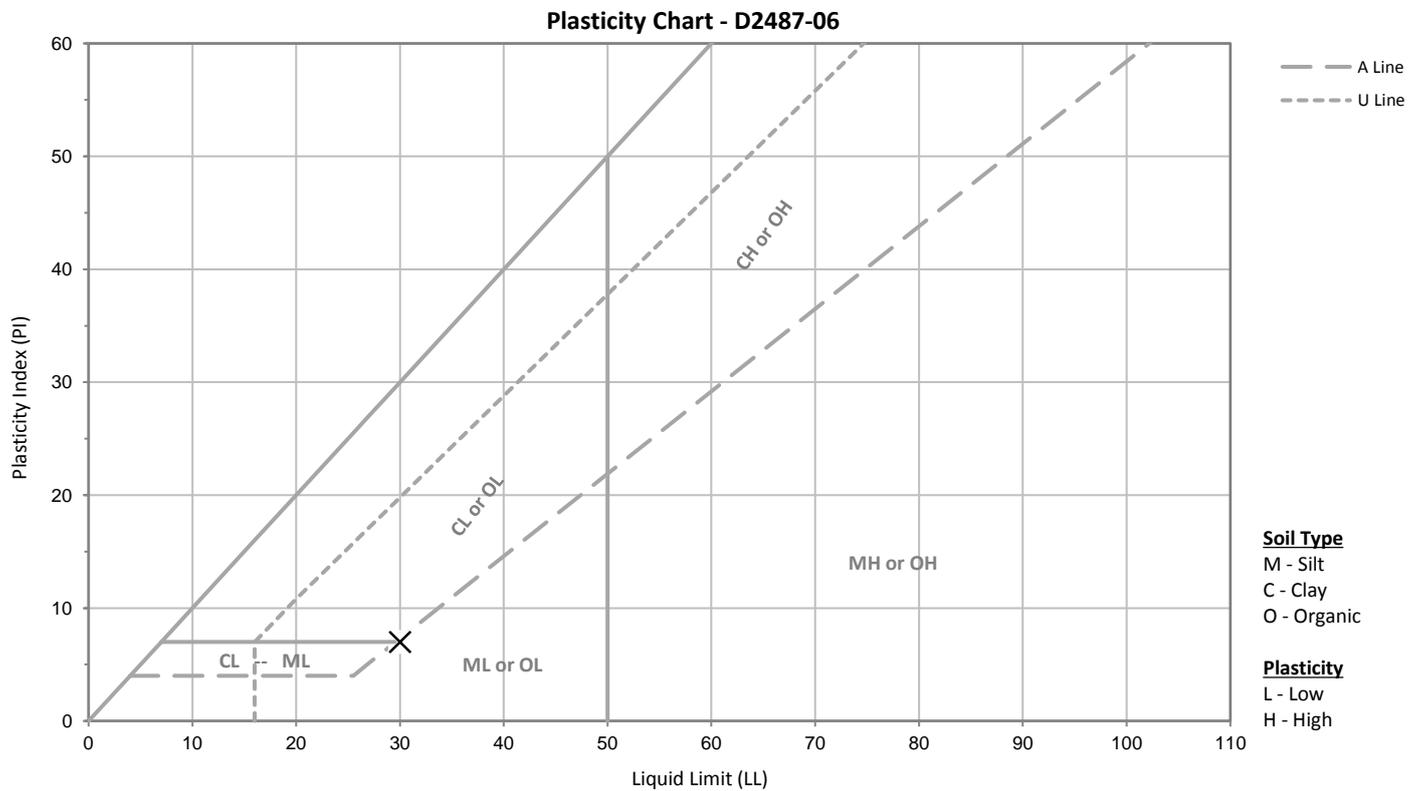
LOCATION	ID	H2		
	Description	Hokowhitu Campus		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201608013	Date Received	29/07/2016
	Reference	1.9	Depth	1.90m
	Description	SILT with minor sand, grey. Moist, low-plasticity. Sand is fine.		
SPECIMEN	Reference	2	Depth	N/A
	Description	N/A		

TEST RESULTS

Liquid Limit **30**

Plastic Limit **23**

Plasticity Index **7**



TEST REMARKS

- The material used for testing was natural, whole soil.
- The liquid limit was done with a manual device. The plastic limit sample was hand rolled. A metal grooving tool was used.
- The maximum grain size was approximately <2mm.

Approved By

PB

Date

11/08/2016



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Geotechnics Project ID 85442.005
Customer Project ID 85442.004
Customer Project Name

DETERMINATION OF THE WATER CONTENT & FINES CONTENT - GEO190-13

TEST DETAILS

LOCATION	ID	H1		
	Description	Hokowhitu Campus		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201608010	Date Received	29/07/2016
	Reference	2.7	Depth	2.70m
	Description	Fine to medium SAND with some silt, grey. Moist.		
SPECIMEN	Reference	2	Depth	N/A
	Description	N/A		

TEST RESULT

Natural Water Content	15.8%
Fines Content Passing 75µm Sieve	17.8%
Fines Content Passing 63µm Sieve	15.9%

TEST REMARKS

- The material used for testing was natural, whole soil.

Approved By PB **Date** 11/08/2016



GEOTECHNICS

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Geotechnics Project ID 85442.005

Customer Project ID 85442.004

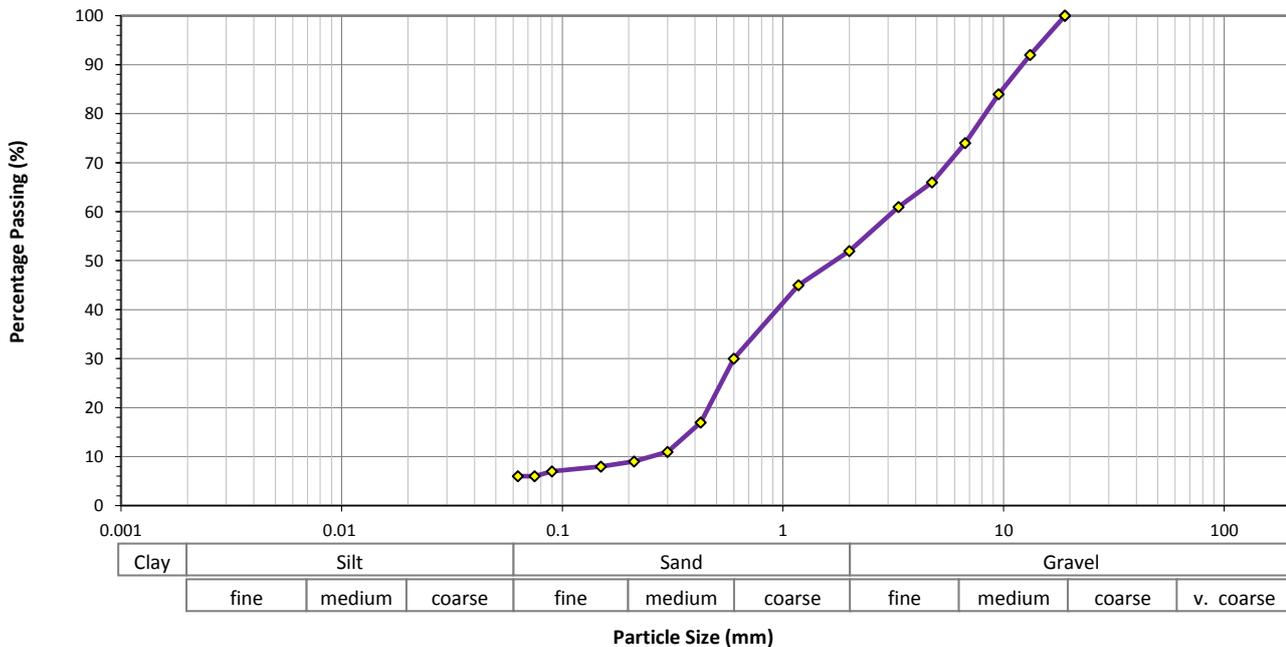
Customer Project Name

DETERMINATION OF THE PARTICLE SIZE DISTRIBUTION - NZS 4402:1986 - Test 2.8.1 (Wet Sieve)

TEST DETAILS

LOCATION	ID	H2		
	Description	Hokowhitu Campus		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201608014	Date Received	29/07/2016
	Reference	2.3	Depth	2.30m
	Description	Sandy fine to medium GRAVEL with minor silt, grey. Moist, subrounded to rounded. Sand is fine to coarse.		
SPECIMEN	Reference	2	Depth	N/A
	Description	N/A		

TEST RESULTS



Clay	Silt			Sand			Gravel			
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	v. coarse

Sieve Size (mm)	Percentage Passing (%)						
150	-	26.5	-	4.75	66	0.300	11
100	-	19.0	100	3.35	61	0.212	9
75.0	-	16.0	-	2.00	52	0.150	8
63.0	-	13.2	92	1.18	45	0.090	7
53.0	-	9.50	84	0.600	30	0.075	6
37.5	-	6.70	74	0.425	17	0.063	6

TEST REMARKS

- The material used for testing was natural, whole soil.
- The percentage passing the <0.063mm was obtained by difference.

Approved By PB Date 11/08/2016



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Geotechnics Project ID 85442.005

Customer Project ID 85442.004

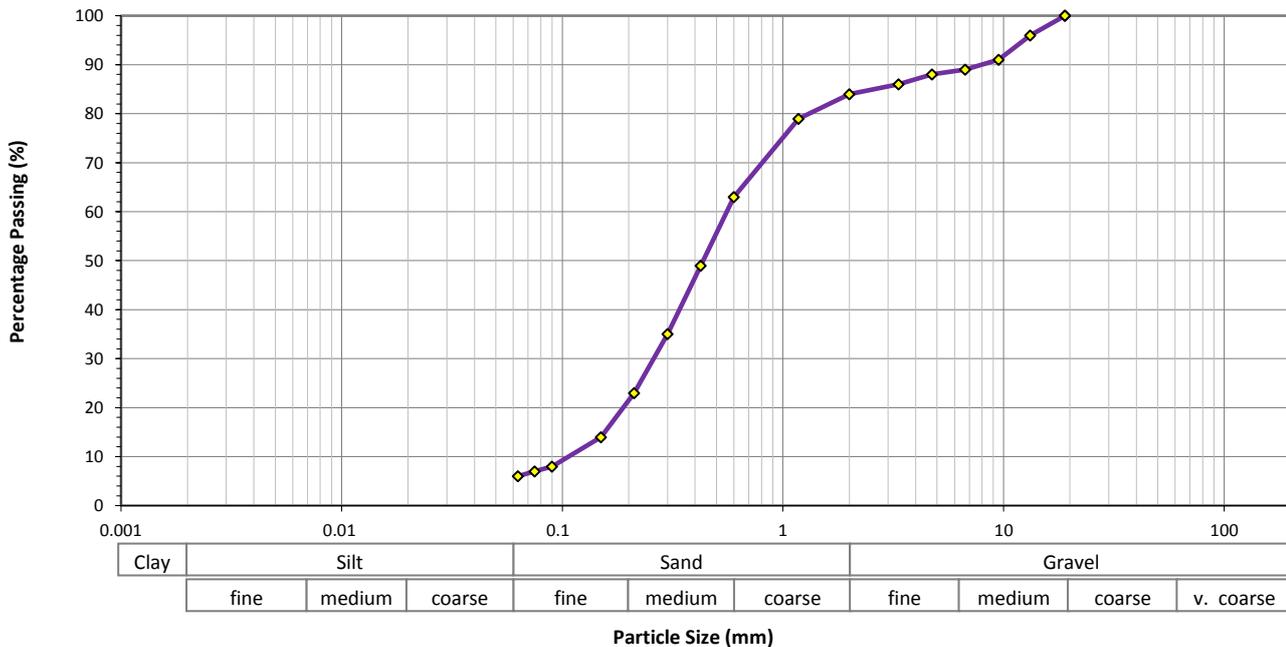
Customer Project Name

DETERMINATION OF THE PARTICLE SIZE DISTRIBUTION - NZS 4402:1986 - Test 2.8.1 (Wet Sieve)

TEST DETAILS

LOCATION	ID	H1		
	Description	Hokowhitu Campus		
	Data	N/A		
SAMPLE	Geotechnics ID	GEOT201608011	Date Received	29/07/2016
	Reference	3.3	Depth	3.30m
	Description	Fine to coarse SAND with some gravel and minor silt, grey. Moist. Gravel is fine to medium, subrounded to rounded.		
	SPECIMEN	Reference	2	Depth
	Description	N/A		

TEST RESULTS



Sieve Size (mm)	Percentage Passing (%)						
150	-	26.5	-	4.75	88	0.300	35
100	-	19.0	100	3.35	86	0.212	23
75.0	-	16.0	-	2.00	84	0.150	14
63.0	-	13.2	96	1.18	79	0.090	8
53.0	-	9.50	91	0.600	63	0.075	7
37.5	-	6.70	89	0.425	49	0.063	6

TEST REMARKS

• The material used for testing was natural, whole soil. • The percentage passing the <0.063mm was obtained by difference.

Approved By PB **Date** 11/08/2016

Appendix D: Liquefaction assessment methodology and results

Ground shaking hazard

The shaking hazard in terms of magnitude (M) and peak ground acceleration (PGA) for the site has been assessed based on the NZTA Bridge Manual (SP/M/022) Third edition, Amendment 2 (May 2016 (NZTABM)). Table D1 presents the return periods for earthquakes with various 'unweighted' peak ground accelerations (PGA) with a corresponding earthquake magnitude.

Table D1: Seismic shaking scenarios

Return Period	25 years	100 years	500 years
Earthquake Magnitude, M	6.1	6.1	6.9
Peak Ground Acceleration (PGA)	0.09	0.17 g	0.34 g

Liquefaction susceptibility

Liquefaction only occurs in some soils. Liquefaction susceptible soils are typically saturated, non-cohesive, and low to moderate permeability. Sands and low plasticity and non-plastic silts are most susceptible to liquefaction¹⁴. At the Napier road site, most of the shallow sands and silts encountered at the investigation locations fit this description, and the saturated portions of these soils are assumed to be non-susceptible to liquefaction.

Liquefaction trigger

Soils which are susceptible to liquefaction require a certain level of earthquake shaking ('trigger') to cause them to liquefy. Denser soils require more intense and/or longer duration of shaking (higher trigger) than less dense soil.

For each CPT, the trigger for each soil layer identified as being susceptible to liquefaction has been assessed by the method proposed by Boulanger and Idriss (2014)¹⁵. This method is based on an empirical relationship with the CPT tip resistance "qc" and fines content.

The trigger magnitude and PGA was then compared with the site's assessed ground shaking hazard for each of the earthquake scenarios included in Table D1.

¹⁴ Bray, K et al, 2014, "Liquefaction effects on buildings in Central Business District of Christchurch", Earthquake Spectra, 30 (1), 85-109.

¹⁵ Boulanger, R.W and Idriss, I.M., 2014. CPT and SPT based liquefaction triggering procedures." Report No. UCD/CGM-14/01, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California, Davis, CA, 134 pp.

Liquefaction vulnerability

The vulnerability of the site to liquefaction has been assessed by applying the techniques in Table D2 below to the results of the susceptibility and trigger analyses.

Table D2: Liquefaction vulnerability assessment techniques

Method	Interpretation
Crust Thickness (m) (1)	Crust thickness is the depth below the ground surface to liquefied soils. Observations from Christchurch and other earthquakes generally indicate that the greater the crust thickness, the less damage is reflected at the ground surface. Sand boils and damaging differential settlement are common for sites with a crust thickness less than 2.0 m, and rare for sites with a crust thickness greater than 3.5m.
Calculated post liquefaction reconsolidation settlement index value (S_{v1D}) (mm) (2)	Free-field settlement is simple to analyse and interpret, and can be used as an indicator of liquefaction vulnerability. However, it does not always capture all of the important aspects of land performance. In Christchurch, land for residential subdivision is delineated into technical categories (TC1 to TC3) depending on calculated free field settlement.
Liquefaction Severity Number (LSN) (3)	LSN is a parameter calculated on the basis of investigation data, and considers the potential for liquefaction and the depth at which liquefaction occurs. I.e. a site with a shallow liquefiable layer is more vulnerable than a site with a deep liquefiable layer. This parameter has been correlated with evidence of surface ground damage in Christchurch. The calculated LSN values generally indicate the following:
	LSN Range Predominant performance
	0-10 Little to no expression of liquefaction, minor effects.
	10-20 Minor expression of liquefaction, some sand boils.
	20-30 Moderate expression of liquefaction, sand boils and minor damage to ground surface; minor differential settlement of structures
	30-40 Moderate to major expression of liquefaction, with undulations of the ground surface; moderate differential settlement of structures
	40+ Extensive expression of liquefaction, major damage to ground surface, severe total and differential settlement of structures.
<p>(1) Bowen, H.G. and Jacka, M.E (2013) Liquefaction induced ground damage in the Canterbury Earthquake: Predictions versus reality. Proceedings of the 19th NZGS Geotechnical Symposium. Editor CY Chin. Queenstown, New Zealand.</p> <p>(2) Ministry of Business, Innovation & Employment Guidance - Repairing and rebuilding houses affected by the Canterbury earthquakes, Version 3 (December 2012)</p> <p>(3) van Ballegooy, S., Lacrosse, V., Jacka, M. and Malan, P. (2013) LSN – a new methodology for characterising the effects of liquefaction in terms of relative land damage severity. Proceedings of the 19th NZGS Geotechnical Symposium. Editor CY Chin. Queenstown, New Zealand.</p>	

Results Summary

Table D3: Summary of liquefaction assessment results

ID	PL	25-year				100-year				500-year			
		GW Depth (m)	LSN ⁽¹⁾	CT (m) ⁽²⁾	S _{V1D} (mm) ⁽³⁾	GW Depth (m)	LSN ⁽¹⁾	CT (m) ⁽²⁾	S _{V1D} (mm) ⁽³⁾	GW Depth (m)	LSN ⁽¹⁾	CT (m) ⁽²⁾	S _{V1D} (mm) ⁽³⁾
CPT101	15%	1.9	0	2.9	0	1.9	0	2.9	0	2.9	0	2.9	0
	50%		0	2.9	0		0	2.9	0		0	2.9	0
CPT102	15%	2.4	0	3.9	0	2.4	0	3.9	0	3.4	0	3.9	0
	50%		0	3.9	0		0	3.9	0		0	3.9	0
CPT103	15%	1.9	0	4.6	0	1.9	0	4.6	0	1.9	5	2.3	13
	50%		0	4.6	0		0	4.6	0		4	2.3	9
CPT104A	15%	2.1	0	5.0	0	2.1	0	5.0	0	2.4	4	2.7	12
	50%		0	5.0	0		0	5.0	0		3	2.8	10
CPT105	15%	2.2	0	4.5	0	2.2	0	4.5	0	2.2	4	2.3	11
	50%		0	4.5	0		0	4.5	0		3	2.4	7
CPT106A	15%	2.1	0	2.4	0	2.1	0	2.4	0	3.1	0	2.4	0
	50%		0	2.4	0		0	2.4	0		0	2.4	0
CPT107	15%	1.6	0	2.6	0	1.6	0	2.6	0	1.6	0	2.6	0
	50%		0	2.6	0		0	2.6	0		0	2.6	0
CPT108	15%	0.5	0	4.8	0	0.5	1	4.8	3	0.5	11	1.5	29
	50%		0	4.8	0		1	4.8	1		9	1.5	22
CPT109	15%	0.5	0	2.4	0	0.5	0	2.4	0	0.5	0	2.4	0
	50%		0	2.4	0		0	2.4	0		0	2.4	0
CPT110	15%	0.5	0	2.8	0	0.5	3	2.8	2	0.5	19	0.6	14
	50%		0	2.8	0		1	2.8	1		17	0.6	12
CPT111	15%	0.5	0	1.3	0	0.5	0	1.3	0	0.5	6	0.7	4
	50%		0	1.3	0		0	1.3	0		3	0.7	2
CPT112	15%	2.4	0	2.6	0	2.4	0	2.6	0	3.2	0	2.6	0
	50%		0	2.6	0		0	2.6	0		0	2.6	0
CPT113	15%	0.5	0	2.4	0	0.5	1	2.4	1	0.5	7	0.9	7
	50%		0	2.4	0		0	2.4	0		6	0.9	5
CPT114	15%	1.0	0	4.4	0	1.0	7	1.4	10	3.1	0	4.4	1
	50%		0	4.4	0		2	4.4	3		0	4.4	0
CPT115	15%	1.2	0	2.4	0	1.2	2	2.4	3	3.3	0	2.4	0
	50%		0	2.4	0		1	2.4	1		0	2.4	0
CPT116	15%	1.4	0	3.6	0	1.4	5	2.0	9	3.5	0	3.6	0
	50%		0	3.6	0		2	3.6	4		0	3.6	0
CPT117	15%	0.5	0	2.7	0	0.5	11	0.9	19	2.3	7	1.9	14
	50%		0	2.7	0		6	1.9	11		7	1.9	14
CPT118	15%	0.5	0	3.8	0	0.5	16	1.0	22	2.5	4	2.6	11
	50%		0	3.8	0		8	1.4	11		3	2.7	8

ID	PL	25-year				100-year				500-year			
		GW Depth (m)	LSN ⁽¹⁾	CT (m) ⁽²⁾	S _{V1D} (mm) ⁽³⁾	GW Depth (m)	LSN ⁽¹⁾	CT (m) ⁽²⁾	S _{V1D} (mm) ⁽³⁾	GW Depth (m)	LSN ⁽¹⁾	CT (m) ⁽²⁾	S _{V1D} (mm) ⁽³⁾
CPT119	15%	0.9	0	3.4	0	0.9	12	0.9	14	2.5	0	3.4	0
	50%		0	3.4	0		4	3.4	5		0	3.4	0
CPT120	15%	0.9	0	4.9	0	0.9	5	1.6	7	2.8	0	4.9	0
	50%		0	4.9	0		2	4.9	3		0	4.9	0
CPT121	15%	1.6	0	7.7	0	1.6	11	2.8	34	3.3	8	3.4	33
	50%		0	7.7	0		5	3.8	16		7	3.4	30
CPT122	15%	0.5	0	3.8	1	0.5	29	1.1	57	1.3	26	1.4	57
	50%		0	3.8	0		15	1.6	32		26	1.4	57
CPT123	15%	0.9	0	2.2	0	0.9	7	1.5	11	0.9	11	1.4	16
	50%		0	2.2	0		4	1.6	7		10	1.4	16
CPT124	15%	0.9	0	3.8	0	0.9	0	3.0	1	0.9	2	1.7	4
	50%		0	3.8	0		0	3.8	0		2	1.7	4
CPT125	15%	0.9	0	3.6	0	0.9	10	1.5	15	2.7	0	3.6	0
	50%		0	3.6	0		4	3.6	5		0	3.6	0
CPT126	15%	0.7	1	6.3	3	0.7	13	2.0	32	0.7	24	0.9	56
	50%		0	6.3	1		6	2.0	17		24	0.9	53
CPT127	15%	0.7	0	6.1	1	0.7	19	1.4	44	1.2	26	1.4	67
	50%		0	6.1	0		9	2.0	22		26	1.4	66
CPT128	15%	0.8	0	5.1	0	0.8	8	1.8	20	2.4	8	2.6	23
	50%		0	5.1	0		4	3.2	10		7	2.7	21
CPT129	15%	0.9	0	3.6	0	0.9	3	3.6	4	2.8	0	3.6	0
	50%		0	3.6	0		1	3.6	2		0	3.6	0
CPT130	15%	0.9	0	4.4	0	0.9	11	2.1	24	2.5	8	2.6	23
	50%		0	4.4	0		5	4.4	10		7	2.6	21
CPT131	15%	0.6	0	5.8	1	0.6	5	2.0	17	0.6	13	2.0	41
	50%		0	5.8	0		3	4.8	9		11	2.0	36
CPT132	15%	0.7	0	6.0	1	0.7	7	3.4	20	0.7	33	0.8	77
	50%		0	6.0	0		3	6.0	8		31	0.9	72
CPT133	15%	0.7	0	5.0	1	0.7	5	3.0	16	1.2	8	3.0	30
	50%		0	5.0	0		2	3.3	8		8	3.0	29
CPT134	15%	0.7	0	3.9	0	0.7	9	1.5	18	1.8	10	1.9	22
	50%		0	3.9	0		3	3.9	7		9	1.9	20
CPT135	15%	0.7	0	4.2	0	0.7	6	1.5	10	2.8	1	2.9	4
	50%		0	4.2	0		0	4.2	4		1	3.0	2
CPT136	15%	0.9	0	5.0	0	0.9	21	1.2	39	2.9	2	3.0	7
	50%		0	5.0	0		8	2.7	15		2	3.0	5
CPT137	15%	0.6	0	4.9	0	0.6	2	3.0	7	1.0	4	3.0	14
	50%		0	4.9	0		1	4.9	3		4	3.0	14
CPT138	15%	0.6	0	3.4	0	0.6	10	1.7	20	2.7	0	3.4	1
	50%		0	3.4	0		5	1.7	10		0	3.4	0

ID	PL	25-year				100-year				500-year			
		GW Depth (m)	LSN ⁽¹⁾	CT (m) ⁽²⁾	S _{V1D} (mm) ⁽³⁾	GW Depth (m)	LSN ⁽¹⁾	CT (m) ⁽²⁾	S _{V1D} (mm) ⁽³⁾	GW Depth (m)	LSN ⁽¹⁾	CT (m) ⁽²⁾	S _{V1D} (mm) ⁽³⁾
CPT139	15%	2.2	0	2.2	0	2.2	0	2.2	0	4.4	0	2.2	0
	50%		0	2.2	0		0	2.2	0		0	2.2	0
CPT140	15%	3.1	0	2.2	0	3.1	0	2.2	0	5.3	0	2.2	0
	50%		0	2.2	0		0	2.2	0		0	2.2	0

Notes:

1. Liquefaction Severity Number (T&T, 2013), refer to Table D2 for details of the seismic land performance.
2. Crust Thickness (T&T, 2013), Refer to Table D2 for details of the seismic land performance.
3. Calculated post liquefaction reconsolidation settlement index value, S_{V1D} (Zhang 2001¹⁶ and Ishihara, 1992¹⁷)

¹⁶ Zhang, G. 2001. "Estimation of liquefaction-induced ground deformations by CPT & SPT-based approaches." PhD thesis, Univ. of Alberta, Edmonton, Alta., Canada.

¹⁷ Ishihara, K., and Yoshimine, M. (1992). "Evaluation of settlements in sand deposits following liquefaction during earthquakes." Soils Found., 32 (1), 173–188

Appendix E: Minimum lot requirements

This Appendix is part of the report “Centennial Park, Palmerston North - Geotechnical Investigation and Liquefaction Assessment”, prepared by Tonkin & Taylor Ltd for Wallace Development Company Ltd, January 2019, T+T Ref: 1004625.001.v2. The full report should be referred to for full details of the geotechnical recommendations for the Centennial Park site.

The process required for design of residential dwellings in the Centennial Park development will depend on the liquefaction vulnerability and lateral spread hazard present on each lot, as summarised in Table E1 below.

For residential lots assessed as having **Medium** or **High** liquefaction vulnerability or as **susceptible to lateral spreading**, enhanced foundations and/or ground improvement are likely to be required to meet minimum Building Code requirements. Examples of potentially suitable foundation options are summarised in Table E2 and E3 below. Further detail regarding these foundation options is provided in Section 5 of this report ¹⁸ and the MBIE residential construction guidance for Canterbury ¹⁹.

The assessed liquefaction vulnerability and lateral spreading susceptibility for each of the proposed lots in the Centennial Park development is summarised in Table E4, along with the minimum foundation option likely to meet Building Code requirements.

The minimum foundation requirements outlined in Table E4 for the individual lots should be discussed with a Licensed Building Practitioner (including engineering input as outlined in Table E1) to determine foundation design and/or ground improvement appropriate for that site. Specialised geotechnical engineering input is likely to be required for land assigned a liquefaction vulnerability category of **High** or identified as **susceptible to lateral spreading**.

The assessment in Table E4 does not remove any requirement of a site specific assessment necessary for the detailed design of individual lots (refer Table E1). Additional shallow ground investigation and testing (e.g. hand augers and scala penetrometer testing) will be required within the location of the proposed dwelling to confirm the foundation design and/or ground improvement appropriate for that site.

The existing area-wide site investigation layout has been designed with the intention to provide sufficient deep ground investigation information to support foundation design for Building Consent without the need for additional site-specific deep investigations in most cases. Any need for additional site-specific deep investigations would be a matter of judgement for the design engineer, and would likely only be required in special circumstances (e.g. to suit the particular requirements of the preferred ground improvement and/or foundation option).

¹⁸ “Centennial Park, Palmerston North - Geotechnical Investigation and Liquefaction Assessment”, report prepared by Tonkin & Taylor Ltd for Wallace Development Company Ltd, January 2019, T+T Ref: 1004625.001.v2

¹⁹ “Repairing and rebuilding houses affected by the Canterbury earthquakes”, Part A and C, Ministry of Business, Innovation and Employment, 3rd Edition, Published on 1 December 2012, Updated on 29 May 2018.

Table E1: Process required for design of residential dwellings

Hazards present on the residential lot		Process required for design of residential dwellings
Outside the area identified as susceptible to lateral spreading	Low liquefaction vulnerability	Design to be undertaken by a Licensed Building Practitioner (LBP). No requirement for specific engineering design. Standard NZS 3604 foundations are expected to meet minimum Building Code requirements, but we encourage enhanced slab foundations for increased resilience as they can provide a substantial improvement in foundation performance for only a small increase in construction cost.
	Medium liquefaction vulnerability	Design to be undertaken by a Licensed Building Practitioner (LBP), with input from a Chartered Professional Engineer (CPEng.) Specific engineering design required, however the engineer may judge it appropriate to adopt one of the standard “off the shelf” foundation details presented in the MBIE residential construction guidance for Canterbury.
	High liquefaction vulnerability	Design to be undertaken by a Licensed Building Practitioner (LBP), with input from a Chartered Professional Engineer (CPEng.) <i>with competence in geotechnical engineering.</i> Specific engineering design required, however the engineer may judge it appropriate to adopt one of the standard “off the shelf” foundation details presented in the MBIE residential construction guidance for Canterbury.
Within the area identified as susceptible to lateral spreading	Low liquefaction vulnerability	Design to be undertaken by a Licensed Building Practitioner (LBP), with input from a Chartered Professional Engineer (CPEng.) with competence in geotechnical engineering.
	Medium liquefaction vulnerability	Specific engineering design required, however the engineer may judge it appropriate to adopt one of the standard “off the shelf” foundation details presented in the MBIE residential construction guidance for Canterbury.
	High liquefaction vulnerability	Specific engineering design required, however the engineer may judge it appropriate to adopt one of the standard “off the shelf” foundation details presented in the MBIE residential construction guidance for Canterbury.

Table E2: Enhanced foundation options

Foundation option	Description
Option 1: Enhanced slab	Enhanced reinforced concrete slab on grade foundation. Four example options are presented in Section 5.3.1 of the MBIE residential construction guidance for Canterbury. Can also be combined with a shallow geogrid-reinforced gravel raft for increased performance (this is termed a hybrid TC2/TC3 foundation in the MBIE Canterbury guidance).
Option 2: Deep piles	Piles founding on dense (non-liquefiable) ground at depth. Various example options are presented in Section 15.2 of the MBIE residential construction guidance for Canterbury.
Option 3: Surface structures	Lightweight and flexible relevel-able platforms with shallow foundations, designed to tolerate differential ground settlement and lateral stretch with the intention of being readily-repairable following and SLS-level earthquake event. Various example options are presented in Section 15.4 of the MBIE residential construction guidance for Canterbury, with the most relevant options for these areas being Type 1 or Type 2A surface structures. The guidance outlines various recommendations for the building superstructure, which will be particularly relevant for land assigned a liquefaction vulnerability category of High .

Table E3: Ground improvement options

Ground improvement option	Description
Option A: Reinforcement	Formation of a grid of individual columns with a 1.5–2.5 m grid spacing using either timber or concrete piles or stone columns. Depending on the location of the proposed dwelling, reinforcement (piles or stone columns) may be constructed within the upper 4m, bearing into the gravel layer (Layer 2).
Option B: Densified crust	Excavation of liquefiable soils and replacement with dense/stabilised soil. Depending on the location of the proposed dwelling a reinforced gravel raft may be constructed to approximately 1.2m depth, consisting of compacted crushed gravel with geo-grid reinforcement (Option G1d in the MBIE Canterbury guidance). Alternatively, in some cases it may be preferable to excavate to approximately 2.0m depth (or to the top of the gravel layer) and recompact the excavated material, with geo-grid reinforcement (Option G1a in the MBIE Canterbury guidance).

Table E4: Minimum foundation requirements for each lot

Lot numbers are as shown on Drawing No. 51-37652-C001 provided by GHD attached.

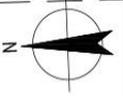
Lot #	Hazards				Minimum foundation option likely to meet Building Code requirements
	Liquefaction Vulnerability			Lateral Spread	
	Low	Medium	High		
1	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
2	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
3	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
4	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
5	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
6	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
7	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
8	X	X		X	Enhanced foundation
9	X	X		X	Enhanced foundation
10		X	X	X	Enhanced foundation plus Shallow ground improvement beneath dwelling footprint
11		X	X	X	Enhanced foundation plus Shallow ground improvement beneath dwelling footprint
12		X	X	X	Enhanced foundation plus Shallow ground improvement beneath dwelling footprint
13		X	X	X	Enhanced foundation plus Shallow ground improvement beneath dwelling footprint
14		X	X	X	Enhanced foundation plus Shallow ground improvement beneath dwelling footprint
15		X	X	X	Enhanced foundation plus Shallow ground improvement beneath dwelling footprint
16		X	X	X	Enhanced foundation plus Shallow ground improvement beneath dwelling footprint
17		X	X	X	Enhanced foundation plus Shallow ground improvement beneath dwelling footprint
18		X		X	Enhanced foundation
19		X		X	Enhanced foundation
20		X		X	Enhanced foundation
21		X		X	Enhanced foundation
22	X	X		X	Enhanced foundation
23	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
24	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
25	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
26	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
27	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.
28	X	X		X	Enhanced foundation
29	X				Standard NZS 3604 foundation as a minimum, but we encourage enhanced slab foundations for increased resilience.

Table E4 (continued): Minimum foundation requirements for each lot

Lot #	Hazards			Lateral Spread	Minimum foundation option likely to meet Building Code requirements
	Liquefaction Vulnerability				
	Low	Medium	High		
30	X	X			Enhanced foundation
31		X			Enhanced foundation
32		X			Enhanced foundation
33		X			Enhanced foundation
34		X			Enhanced foundation
35		X			Enhanced foundation
36		X			Enhanced foundation
37		X			Enhanced foundation
38		X			Enhanced foundation
39		X			Enhanced foundation
40		X			Enhanced foundation
41		X			Enhanced foundation
42		X			Enhanced foundation
43		X			Enhanced foundation
44		X			Enhanced foundation
45		X			Enhanced foundation
46		X	X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
47			X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
48		X			Enhanced foundation
49		X			Enhanced foundation
50		X			Enhanced foundation
51		X	X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
52			X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
53		X	X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
54		X			Enhanced foundation
55		X			Enhanced foundation
56		X	X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
57		X	X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
58			X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)

Table E4 (continued): Minimum foundation requirements for each lot

Lot #	Hazards				Minimum foundation option likely to meet Building Code requirements
	Liquefaction Vulnerability			Lateral Spread	
	Low	Medium	High		
59			X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
60			X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
61			X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
62			X	X	Enhanced foundation plus Shallow ground improvement beneath dwelling footprint
63			X	X	Enhanced foundation plus Shallow ground improvement beneath dwelling footprint
64		X			Enhanced foundation
65		X			Enhanced foundation
66		X			Enhanced foundation
67			X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
68			X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
69			X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
70			X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
71			X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
72		X	X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
73		X	X		Enhanced foundation - more robust end of the range (e.g. Hybrid TC2/TC3 enhanced slab, deep piles, or Type 2 surface structure)
74		X			Enhanced foundation
75		X			Enhanced foundation
76		X			Enhanced foundation



STAGE 3

STAGE 2

STAGE 1



PRELIMINARY

A	PRELIMINARY	PK	SD	25/09/18		
No	Revision	Note: * indicates signatures on original issue of drawing or last revision of drawing	Drawn	Job Manager	Project Director	Date



DO NOT SCALE	Drawn P KENDALL	Designer S DOIDGE
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Approved (Project Director)	Date 25/09/18	Scale AS SHOWN

Client	WALLACE DEVELOPMENT COMPANY LIMITED
Project	CENTENNIAL PARK DEVELOPMENT
Title	OVERALL SITE PLAN
Original Size	A1
Drawing No:	51-37652-C001
Rev:	A

