Report

Seismic Design, Liquefaction and Ground Improvement

Pauanui Waterways, Stage 3 - The Hammerhead

Prepared for Pauanui Waterways Limited

Prepared by Earthtech Consulting Limited

20 November 2023
Reference: R2717-5 Rev G

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Document Control

Geotechnical Assessment

Pauanui Waterways, Stage 3 – The Hammerhead

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Document Control			
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R2717-5	0	29/01/2021	Draft
R2717-5	A	04/06/2021	Final
R2717-5	B	20/12/2021	Finished floor levels raised
R2717-5	C	03/04/2023	Update to include Auckland Vertical Datum
R2717-5	D	16/05/2023	Update following coastal inundation assessment
R2717-5	E	19/05/2023	Update to geogrid locations on Figure 4
R2717-5	F	12/10/2023	Update following coastal inundation assessment
R2717-5	G	20/11/2023	Update for datum correction

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Report

Seismic Design, Liquefaction and Ground Improvement

Pauanui Waterways, Stage 3 – The Hammerhead

1. Introduction

Pauanui Waterways Limited are to develop the area of land of Stage 3, known as The Hammerhead, located at the "head" of Canal 4, on Waterways Parade. The area bounds Lots 172 to 183 and Lot 322. The land was filled as part of earlier earthworks during the construction of Waterways Parade and Canal 4 in 2010. The building platform area is now generally flat with ground level from RL14*m* to RL15*m* over a centreline length of some 250*m*. The canal edge slopes down to the top of the rock revetment wall. Levels in this report relate to Pauanui Waterways Datum unless stated otherwise, where the Pauanui Waterways Datum = Auckland Vertical Datum 1946 (AVD46) plus 11.34*m*.

This report provides details of geotechnical investigations undertaken on the site (from 1991 to 2020) and provides recommendations for the development of the land as "residential" up to two stories high. The report is intended to provide sufficient information to support building consent applications. This revision includes minimum floor levels as defined by the October 2023 Coastal Inundation Assessment (Tonkin and Taylor, 2023). Finished ground levels levels are now RL4.04*m* in AVD46 and RL15.38*m* in the Pauanui Waterways Datum.

The MBIE guidelines in regard to the potentially liquefiable ground are now being required by the Thames Coromandel District Council (TCDC), and this aspect is also addressed.

2. Development History

Detailed geotechnical investigations and design of the Pauanui Waterways site commenced in 1991. The work included comprehensive site investigation data, the construction of two full-scale lengths of revetment wall, dewatering trials, compaction trials and a detailed assessment of liquefaction effects by an independent third party.

Stage 1 construction commenced in 1992 and was completed in 1993. Stage 2 and 3 continued with bulk earthworks using the same methodology as for Stage 1, i.e., bulk excavation with a dragline to preload stockpiles on the residential sections followed by final spreading and compaction using a dozer and spreader bar drawn by a tractor.

Stage 3 (which includes the Canal 4 Hammerhead site) was completed in 2010 with the Stage 3 Earthworks Completion Report provided by Airey Consultants Limited (File 4094-94, May 2010). A note in that report confirms that Lots 320 and 172 to 183 were filled to a lower level than required for flood protection. Levels are reported as RL14*m* to RL12.6*m* at the back of the revetment wall. Hence, the ground levels required topping up to the minimum finished ground level of RL15.38*m* (RL4.04*m* in AVD46) for residential construction. Levels were deliberately left low at that time for a planned hotel and basement development on these lots.

The earthworks were undertaken by Hopper Construction Limited in 2009/2010. The rock revetment wall was also constructed at that time. Depth of fill isopachs are provided in Drawing FTP2, sheet 2 of 3, prepared by Airey Consultants Limited (attached). This indicates at least 0.5*m* of fill over the entire site with up to 3*m* of fill on the eastern side. Additional fill was placed on the site between 2010 and 2020.

Original ground levels (1991) are shown indicatively on the sections.

Revised rising sea level projections now require a finished ground level of RL15.38*m* (RL4.04*m* in AVD46), which is increased by over 0.5*m* from the Revision A report. Imported fill is required to shape and profile the building area to achieve this.

3. Ground and Soil Conditions

Extensive investigations have been carried out for the Pauanui Waterways Development area and, more specific to this Hammerhead area, Cone Penetrometer Tests (CPT) were carried out in September 2020 numbered HH1 to HH6A. An earlier set of CPT's were undertaken in 2007, prior to placement of the existing fill. These investigations show the Pauanui Hammerhead to be underlain generally by:

- (Unit 1) Compacted Fill
  0.0*m*-2.0*m* Well compacted engineered fill, medium dense to dense sands.
- (Unit 2) In-Situ Sands and Upper Silts
  2.0*m*-6.0*m* Loose to medium dense sands with minor silts (thin marine silt in CPT HH3 at 3*m*).
- (Unit 3) Refusal Layer was encountered at a depth of 3*m* to 6*m* in five of the six new CPT's. Excavations to the south of Waterways Parade exposed this layer as dense, rounded cobbles and small boulders.
- (Unit 4) Lower Sands and Silts.
  Loose to medium dense sands and minor silts.
- (Unit 5) Lower Silts
  Firm to stiff silts (marine mud).

Site-specific investigations for the site included the cone penetrometer tests shown in Figures 1, 2 and 3, which are included in Appendix A.

The site-specific CPT data indicates some variability in Unit 1. This is likely to be due to a combination of previous earthworks constructed more recently overlaying previously constructed engineered fill material and bulk sand filling from the drag-line operations.

4. Groundwater Conditions

Groundwater is now controlled by tidal levels in Canal 4, subsoil drains installed along Waterways Parade and an upgradient open ditch drain on the far side of Waterways Parade. The ditch drain is partially influenced by high tide. For design purposes, groundwater may be taken at RL11.47*m* (RL0.13*m* in AVD46) (increased from 11.43*m*) with occasional fluctuations to RL12.6*m* (RL1.26*m* in AVD46) (increased from 12.3*m*).

5. Engineering Properties of the Site Soils

The following soil properties have been determined on the Pauanui Waterways site:

	Effective Cohesion c'	Phi' $Ø'$	Undrained Shear Strength S_u	Bulk Density γ	Allowable Bearing Capacity
Engineered Fill, Unit 1	0*kPa*	35°	n/a	19kN/m^3	100*kPa* at 300*mm* depth on sand fills
Sands and Silts, Unit 2	0*kPa*	30°	40*kPa*	17kN/m^3	n/a
Boulder Layer, Unit 3	0*kPa*	33°	n/a	20kN/m^3	n/a
Lower Sands and Silts, Unit 4	0*kPa*	30°	40*kPa*	17kN/m^3	n/a
Lower Silts, Unit 5	0*kPa*	26°	40*kPa*	17kN/m^3	*not suitable for foundations

6. Seismic Design Parameters and Liquefaction

6.1 Seismic Classification and Design Values

The site is classified as a “deep or soft soil site”, Class D with reference to AS/NZS1170.5:2004 (Clause 3.1.3.5 and Table 3.2).

Unweighted Peak Ground Accelerations (PGA’s) and magnitude values for use in liquefaction and stability analyses are shown in the table below. These are calculated from the NZTA Bridge Manual (3rd ed. and amendments to October 2018) as recommended by the New Zealand Geotechnical Society.

The design has adopted a 1/500yr ULS event, appropriate for Importance Level 2 residential housing with a 50*yr* design life.

6.2 Seismic Risk Assessment

Unweighted PGA and Magnitude Values:

	Return Period 1/	Applies To	Design Event Description	$C_{0,1000}$**	R_u	F+	PGA (Class D Soil)	Magnitude
1	25	SLS	Serviceability Limit State	0.30	0.25	1.0	0.06*g*	5.8
2	500	ULS	Ultimate Limit State	0.30	1.0	1.0	0.23*g*	5.7

+Class D Soil (Ref 6.2.2 Bridge Manual), **Figure 6.1(b) and Table C6

We note that at the time of this report revision in May 2023, the seismic design guidelines have been further updated. *Module 1 Earthquake Geotechnical Engineering Practice* now provides a ULS event of 0.28*g* and M5.9, and a SLS event of 0.07*g* and M5.9. We recommend that these current guidelines be adopted for design purposes. The slight increase in the PGA does not affect the geotechnical recommendations in this report.

Building Code amendments came into effect in November 2021, affecting residential sites on liquefaction prone land. Essentially liquefiable sites no longer meet the NZS3604 (2011) definition of "good ground", and the MBIE Guidelines (2012) prepared for the Canterbury Earthquake Recovery apply to all New Zealand. These guidelines specify the liquefaction remedial works required depending on predicted liquefaction effects.

To achieve full compliance with the MBIE Guidelines, future canal frontage houses would require enhanced foundations in addition to ground improvement works. The MBIE Guidelines include standard details for a variety of enhanced foundations, which generally consist of additional reinforcement, bracing and so forth. This is further discussed in Section 8.

The Pauanui Waterways site has been designed from Stage 1 in 1991 to meet best practice guidelines and national standards. A full seismic assessment was undertaken by an independent party (Engineering Geology Limited) in 1992, prior to the construction of Stage 1. Treatment of the ground to reduce the effects of liquefaction was undertaken for all stages, including the Hammerhead area. As the bulk of the earthworks and the revetment walls were completed to best-practice standards in 2010, there is no need to readdress the earthworks and overall stability for the remaining 11 lots. However, the liquefaction analyses have been undertaken to 2021 guidelines and measures to improve seismic resilience have been incorporated in this report.

6.3 Liquefaction Analyses

The effects of soil liquefaction have been assessed from the CPT investigations carried out along the canal perimeter. CPT's carried out in September 2020 have been analysed using Boulanger and Idriss (2014). Of the six CPT's carried out, only HH3 penetrated through the boulder layer to probe the underlying sands and silts. The other CPT's refused between 3*m* to 6*m* depth on the boulder layer. This is a very conservative assumption and extension of the CPT data as the boulder layer provides a positive confining effect to liquefaction.

To assess liquefaction for the full soil profile, the CPT profile from HH3 has been added to the bottom of each refusing CPT to allow liquefaction to be assessed to 17.5*m* depth at each location (e.g., HH1 refused at 6*m* depth, and the profile from HH3 6*m* to 17.5*m* has been added to the base of HH1). Although a "synthetic" approach, this allows variability in Units 1 and 2 to be incorporated at each location.

Results indicate that Units 2 and 4 comprising sandy and silty soils are liquefiable under the 1/500*yr* event. Liquefaction is not predicted under the 1/25*yr* event.

6.4 Liquefaction Induced Settlements

Predicted liquefaction induced settlements for each seismic event are shown in the following table. This indicates that predicted total liquefaction induced settlements under the ULS event range between 130*mm* to 185*mm*. No liquefaction induced settlement is predicted under the SLS event as liquefaction is not triggered.

CPT	SLS	ULS (full soil profile)	ULS (upper 10*m* of soil profile)
HH1	0*mm*	145*mm*	85*mm*
HH2	0*mm*	130*mm*	65*mm*
HH3	0*mm*	185*mm*	120*mm*
HH4	0*mm*	155*mm*	90*mm*
HH5A	0*mm*	140*mm*	70*mm*
HH6	0*mm*	170*mm*	105*mm*
Mean Value	**0*mm***	**154*mm***	**89*mm***

The mean value of the upper 10*m* soil profile liquefaction induced settlement prediction is less than the maximum 100*mm* limit set by MBIE for TC2 type foundations. Therefore, the site is suitable for TC2-type foundations, which will adequately address liquefaction induced settlement effects.

7. Compliance with MBIE Guidelines

The Hammerhead residential lots have been classified as follows:

- Technical Category 2 (TC2), in regard to liquefaction induced settlements (<100*mm*).
- Technical Category 3 (TC3), as the lateral stretch exceeds 50*mm*, due to the proximity to the canal edge.

Full compliance with the MBIE guidelines will require ground improvements to reduce lateral spread effects and the construction of TC2 type building foundations.

- Ground improvement requirement excavate to 1.4*m* below finished ground level (or deeper) and place one layer of uniaxial geogrid ACE GG400 (or similar) as per detail shown in Figure 4. Cover with a 200*mm* layer of compacted sand and place one layer of biaxial grid (Duragrid X40/40 or similar). Cover with 200*mm* of compacted sand. Imported GAP100 rock can then be placed and compacted to approx. 0.5*m* below the finished ground level. A 0.4*m* thick sand layer, capped with 100*mm* of topsoil, should be placed at the ground surface to allow for foundation and buried service trench excavations.

- TC2 type building foundations as per options referred to in Appendix C.

- If buildings are extended at a later date outside of the prepared building platforms there is an option to undertake specific design and use the suite of "surface structures" listed in the MBIE guidelines, i.e.:
    - Surface structures: Construction of enhanced stiffened and re-levellable building foundations with lightweight cladding and roofing materials, and simple building footprints. Examples of surface structures include two slabs which can be jacked against each other, pre-stressed concrete foundation beams, or re-levellable double bearers for timber floors.

In all cases, lightweight cladding and roofing materials would be required, and simple building footprints are recommended. This implies that all foundation structures will require site-specific structural design.

Note that the conditions which allow NZS3604 foundations to be adopted vary between Waterways projects (Pauanui, Whitianga, Marsden) depending on the magnitudes of settlement and lateral spreading calculations which vary according to the underlying ground conditions. The MBIE (2012) Guidelines, as they currently stand, are not straightforward to interpret and are sometimes contradictory. In summary, there are combinations of ground improvement and enhanced slab options which are viable for the site. The primary focus of the MBIE guidelines is to protect life and to provide more seismically resilient structures. The combination of ground improvements using geogrids and site-specific foundation designs will provide more resilient structures.

8. Canal Edge

The canal edge is constructed to the same standard and detail as the rest of Pauanui Waterways. Geotechnical inspections were undertaken during construction, and any weak zones were undercut and backfilled prior to construction of the base slab for the wall.

The steeper beach profile (1 on 3) has been protected from erosion by placing a layer of rock rip-rap over a geofabric filter layer to reduce canal maintenance needs.

There is a minimum canal edge setback zone which must be complied with.

9. Conclusions and Recommendations

Pauanui Waterways Limited is to develop the remaining area of land of Stage 3, known as The Hammerhead, located at the head of Canal 4, on Waterways Parade. Finished ground levels will need to be raised to RL15.38*m* (RL4.04*m* in AVD46) to meet the revised rising sea level predictions and recommendations (increased by over 0.5*m* from the Revision A version of this report prepared in June 2021).

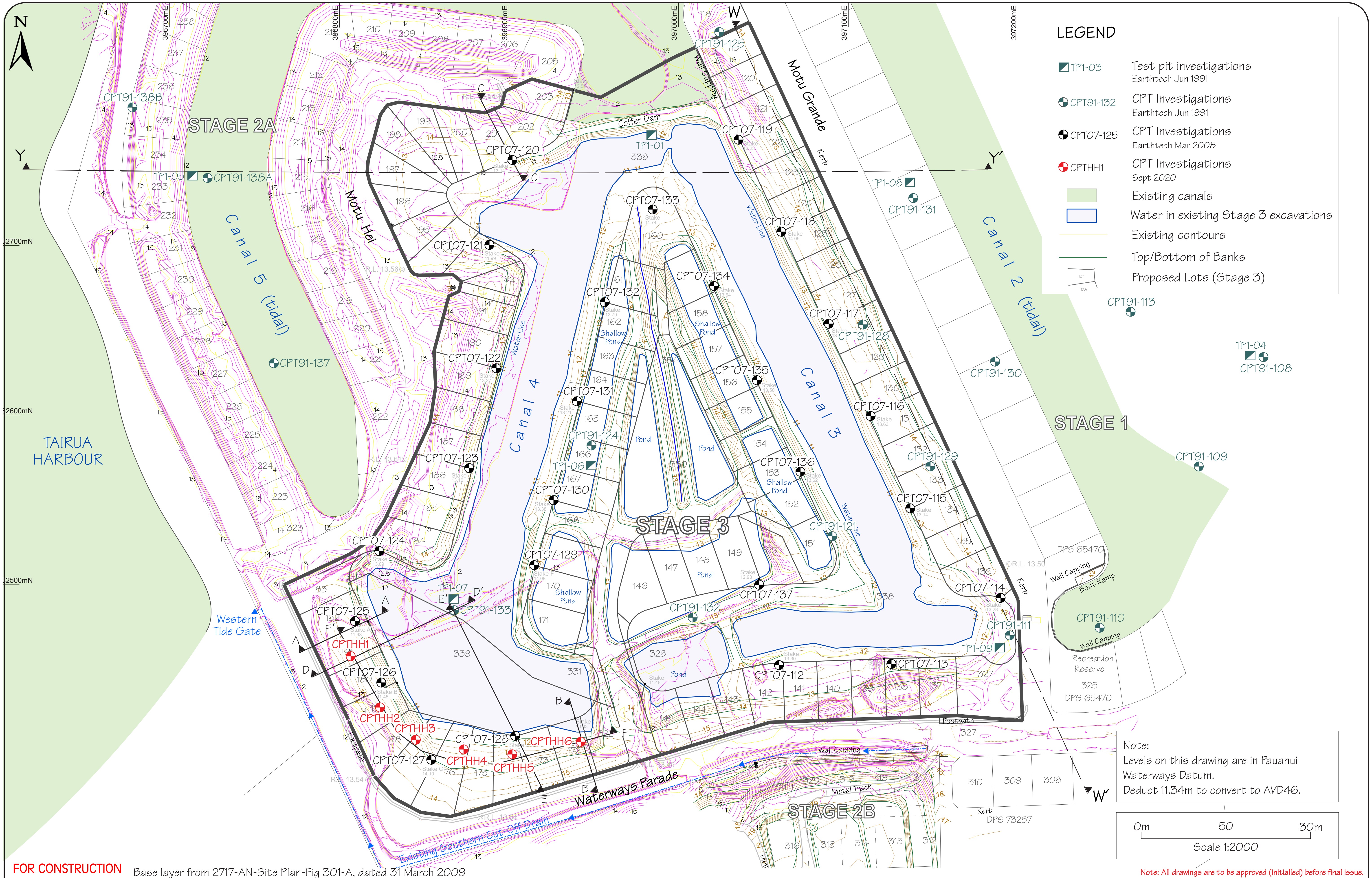
CPT tests were carried out in the Hammerhead area in September 2020, in addition to the existing tests carried out as part of the wider Pauanui development. These indicated 2*m* of compacted fill, overlying sands and silts. A layer of rounded boulders and cobbles extends across the site between 3*m* to 6*m* depth which is underlain by sands and silts.

The sands and silts are liquefiable to approximately 10*m* depth under a 1/500*yr* event. No liquefaction is predicted under the SLS (1/25*yr*) event. Liquefaction induced settlements are generally between 130*mm* to 180*mm* over the full profile and ≤100*mm* over the upper 10*m* profile. The revetment wall was constructed in accordance with best practice in 2010 and included undercutting of any weak zones.

In November 2021, the MBIE (2012) Guidelines for rebuilding on liquefaction prone land were made compulsory nationwide. In terms of MBIE (2012), the Pauanui site has a TC3 classification, which allows residential development using ground improvement/reinforcement in conjunction with enhanced TC2 type foundations. In order to achieve compliance two layers of geogrid should be installed and all houses must be constructed with TC2 type foundations (with additional reinforcement compared to standard foundations). Installation of the two layers of geogrid and the additional fill is shown as a typical detail in Figure 4. This detail provides a "best practical option" approach to meeting the intent of the MBIE guidelines, i.e., protecting life and providing increased resilience to seismic effects. Additional fill to make up any shortfall may consist of any type of granular fill (sand or hardfill). Clay fill is not recommended.

10. References

Boulanger, R. W., & Idriss, I. M. (2014)	*CPT and SPT based liquefaction triggering procedures.* Center for Geotechnical Modelling (Report No. UCD/CGM-14/01). University of California, Davis, California: Boulanger/Idriss.
MBIE (2012)	*Repairing and rebuilding houses affected by the Canterbury earthquakes*. Ministry of Business, Innovation and Employment. December 2012 (updated May 2018). https://www.building.govt.nz/building-code-compliance/canterbury-rebuild/repairing-and-rebuilding-houses-affected-by-the-canterbury-earthquakes/
NZTA (2018)	Bridge Manual SP/M/022, third edition, Amendment 3.
Tonkin and Taylor (2023)	*Hammerhead, Pauanui: Coastal Inundation Assessment*. Report prepared by Tonkin and Taylor Limited for Pauanui Waterways Limited, dated 12 October 2023, ref. 1018453 (updated for datum correction in November 2023).



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PAUANUI HAMMERHEAD
Pauanui Waterways Limited

Site Plan (Existing Contours September 2007)

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
A	29-01-21	DRAFT FOR COMMENT	A.N	A.N	C.M/S.H	
B	26-05-21	FINAL	A.N	A.N	C.M/S.H	
C	03-04-23	UPDATE TO INCLUDE AVD46	A.N	A.N	C.M/S.SW	

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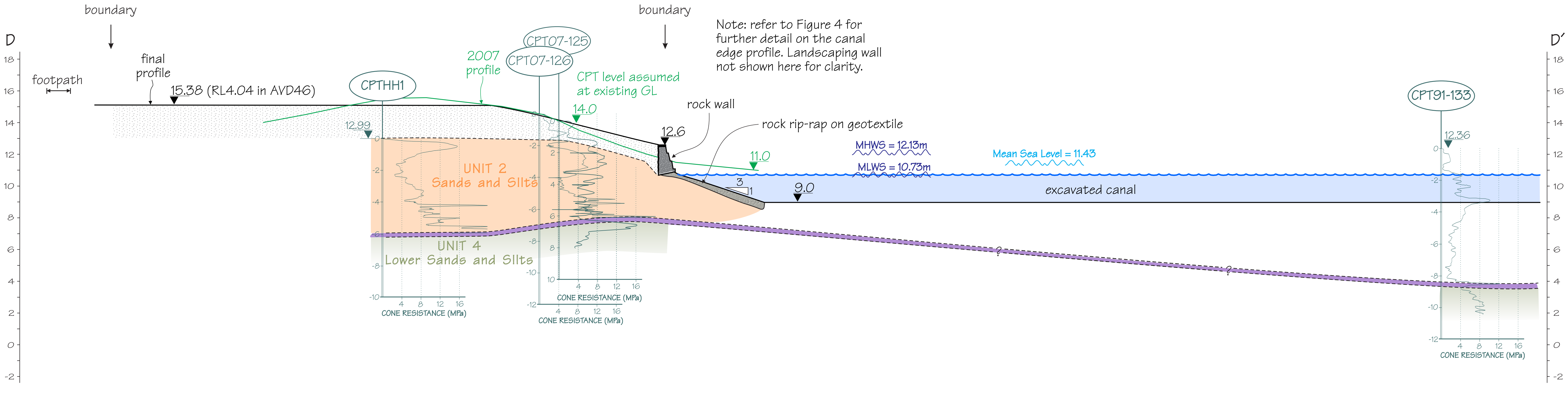

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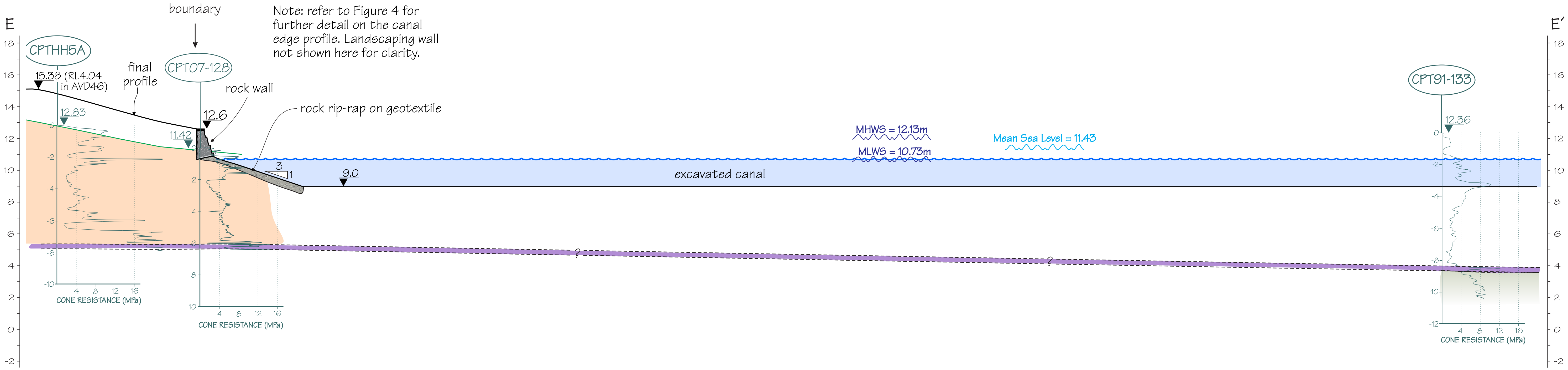
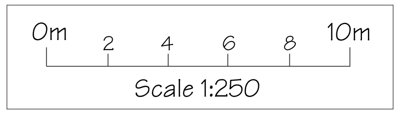


Section E-E



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Note: All drawings are to be approved (initialled) before final issue.

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Cross-Sections D-D and E-E

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
B	26-05-21	FINAL	A.N	A.N	S.H	AM
C	03-04-23	UPDATE TO INCLUDE AVD46	A.N	A.N	S.SW	AM
D	16-05-23	UPDATE FOLLOWING COASTAL INUNDATION ASSESSMENT	A.N	A.N	C.M	MLW
E	12-10-23	UPDATE FOLLOWING REVISED COASTAL INUNDATION ASSESSMENT	A.N	A.N	C.M	MLW
F	20-11-23	UPDATE FOLLOWING DATUM CORRETION	A.N	A.N	C.M	MLW

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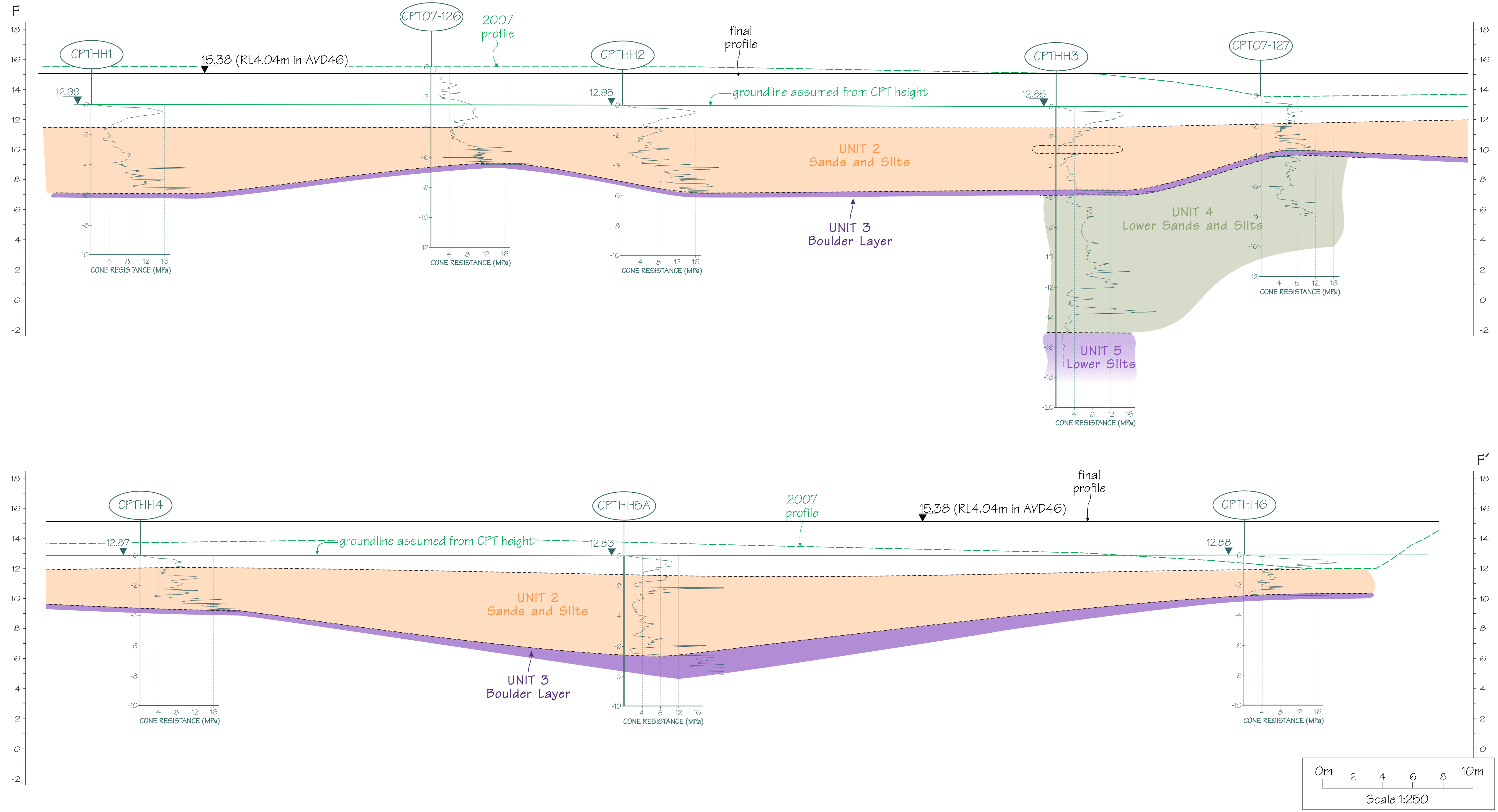

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Pauanui Waterways Limited

Long-Section F - F

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
B	26-05-21	FINAL	A.N	A.N	S.H	[illegible]
C	03-04-23	UPDATE TO INCLUDE AVD46	A.N	A.N	S.SW	[illegible]
D	16-05-23	UPDATE FOLLOWING COASTAL INUNDATION ASSESSMENT	A.N	A.N	C.M	MLW
E	12-10-23	UPDATE FOLLOWING REVISED COASTAL INUNDATION ASSESSMENT	A.N	A.N	C.M	MLW
F	20-11-23	UPDATE FOLLOWING DATUM CORRECTION	A.N	A.N	C.M	MLW

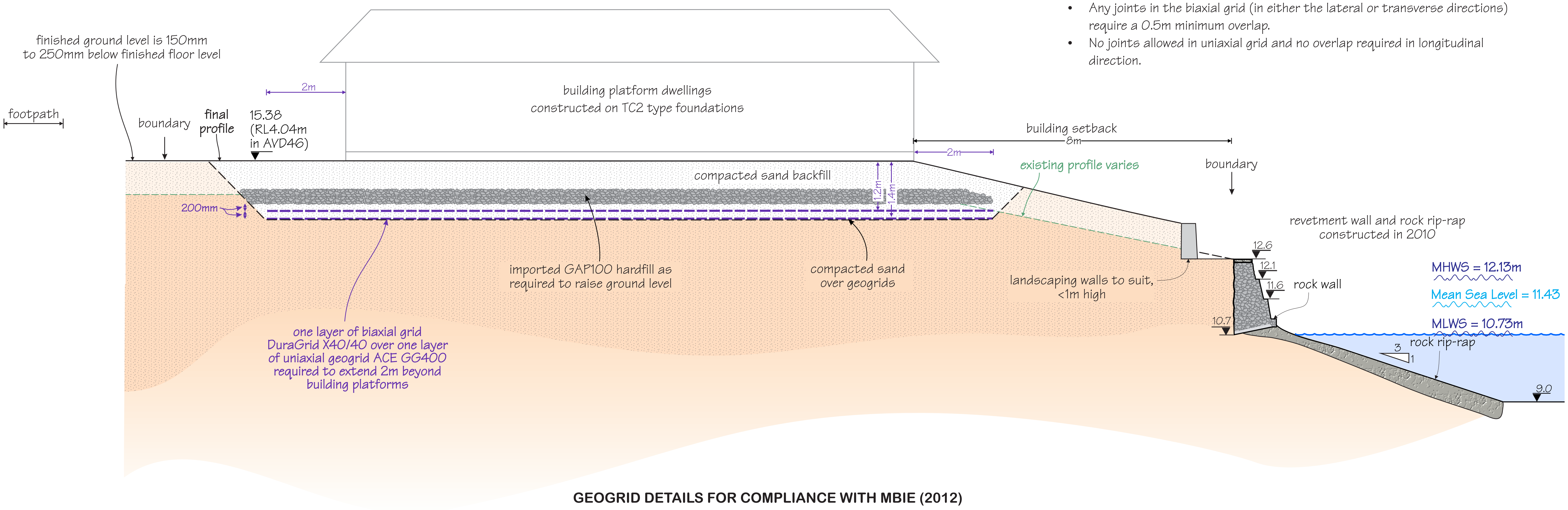
DRAWING NO.: FIG. 3

REF: 2717

SCALE: as shown

Notes:

- Grids to be installed at depths shown, extending 2m beyond the building footprints. A minimum of 1.5m may be adopted only if constrained by the boundary, for example if the house is constructed with a 1.5m yard setback distance.
- Sand or hardfill backfill above grids.
- Any joints in the biaxial grid (in either the lateral or transverse directions) require a 0.5m minimum overlap.
- No joints allowed in uniaxial grid and no overlap required in longitudinal direction.



GEOGRID DETAILS FOR COMPLIANCE WITH MBIE (2012)

0m 1 2 3 4 5m
Scale 1:100

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Note: All drawings are to be approved (initialled) before final issue.

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Typical Geogrid Details

REV	DATE	AMENDMENT/ISSUE	DRAWN BY	CHECKED	TRACED BY	APPROVED BY
C	21-12-21	FINAL	M.W	A.N	S.H/C.M	[illegible]
D	03-04-23	UPDATE TO INCLUDE AVD46	M.W	A.N	S.SW/C.M	MLW
E	16-05-23	UPDATE FOLLOWING COASTAL INUNDATION ASSESSMENT	A.N	A.N	C.M	MLW
F	19-05-23	UPDATED GEOGRID LOCATION	M.W	A.N	C.M	MLW
G	12-10-23	UPDATE FOLLOWING REVISED COASTAL INUNDATION ASSESSMENT	M.W	A.N	C.M	MLW
H	20-11-23	UPDATE FOLLOWING DATUM CORRECTION	M.W	A.N	C.M	MLW

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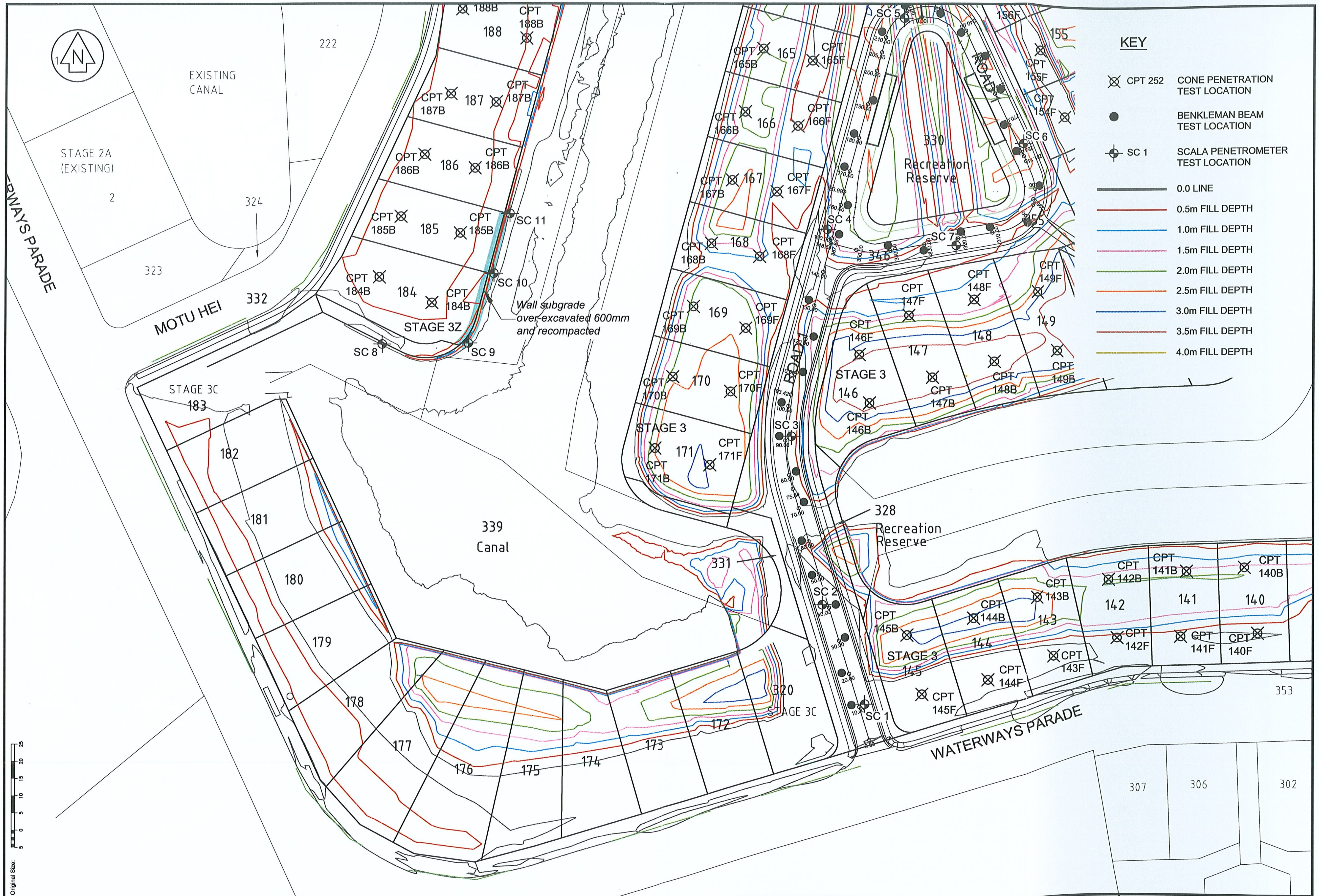


No.	Revision Details	Date	No.	Revision Details	Date	Design JG Survey HCL Drawn CJM Checked CJM Date APRIL 2010 Scale 1:500 (A1) 1:1000 (A3) CAD Filename 4094-049-AB-Fill Tests.dwg

Job Title.

PAUANUI WATERWAYS SUBDIVISION - STAGE 3

PAUANUI WATERWAYS

AIREY CONSULTANTS LTD.

CONSULTING CIVIL & STRUCTURAL ENGINEERS
Takapuna, Pukekohe, Howick, Waiuku, Orewa

Drawing Title.

FILL TEST LOCATION AND ISOPAC PLAN SHEET 2 OF 3

File No. 4094/049

Rev. -

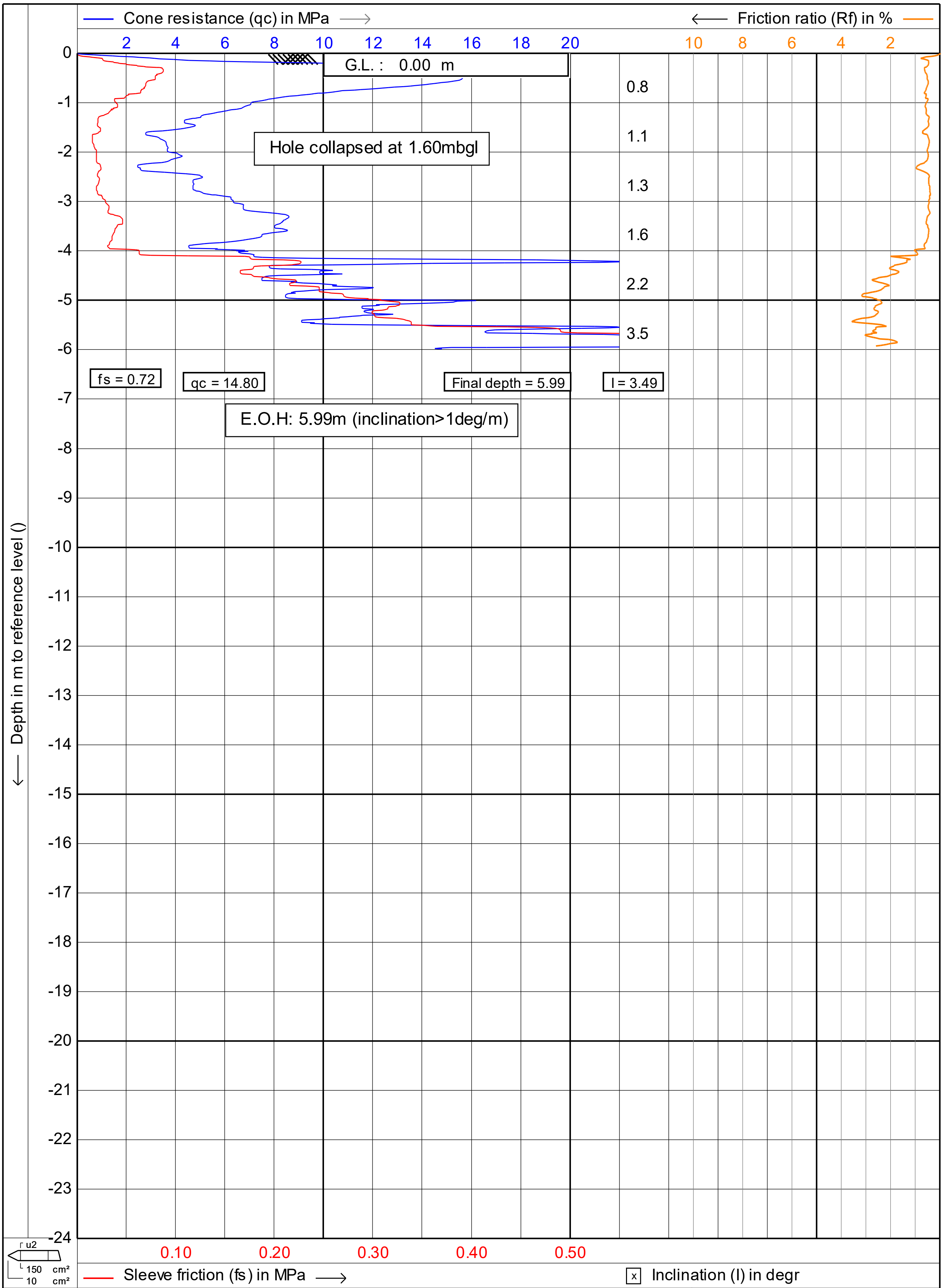
Drawing No. FTP 2

Seismic Design, Liquefaction and Ground Improvement

Pauanui Waterways, Stage 3 - The Hammerhead

Appendix A

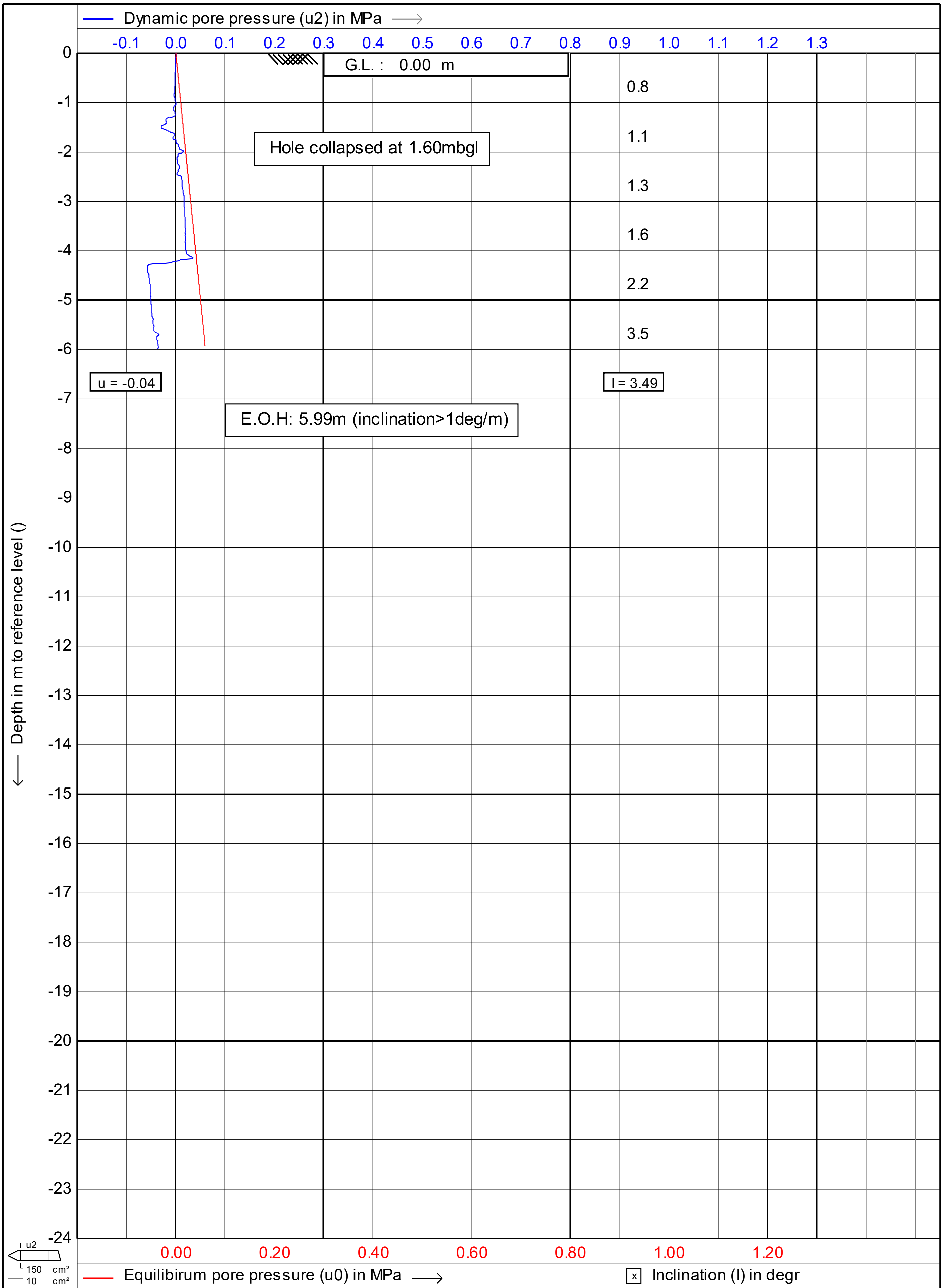
Site Investigations



DRILLFORCE
THE DRILLING SPECIALISTS

Test according NEN 5140 class 1	
Project : **Waterways Parade**	Date : **24/09/2020**
Location: **Waterways Parade, Pauaunui**	Cone no. : **S10CFIIP.S15298**
Position: **175.85263, -37.03116 WGS 84**	Project no. : **DF19GE167**
	CPT no. : **CPT_HH1** **1/15**

1.47



DRILLFORCE THE DRILLING SPECIALISTS

Test according NEN 5140 class 1	Date	: **24/09/2020**
Project : **Waterways Parade**	Cone no.	: **S10CFIIP.S15298**
Location: **Waterways Parade, Pauaunui**	Project no. :	**DF19GE167**
Position: **175.85263, -37.03116 WGS 84**	CPT no.	: **CPT_HH1** **2/15**

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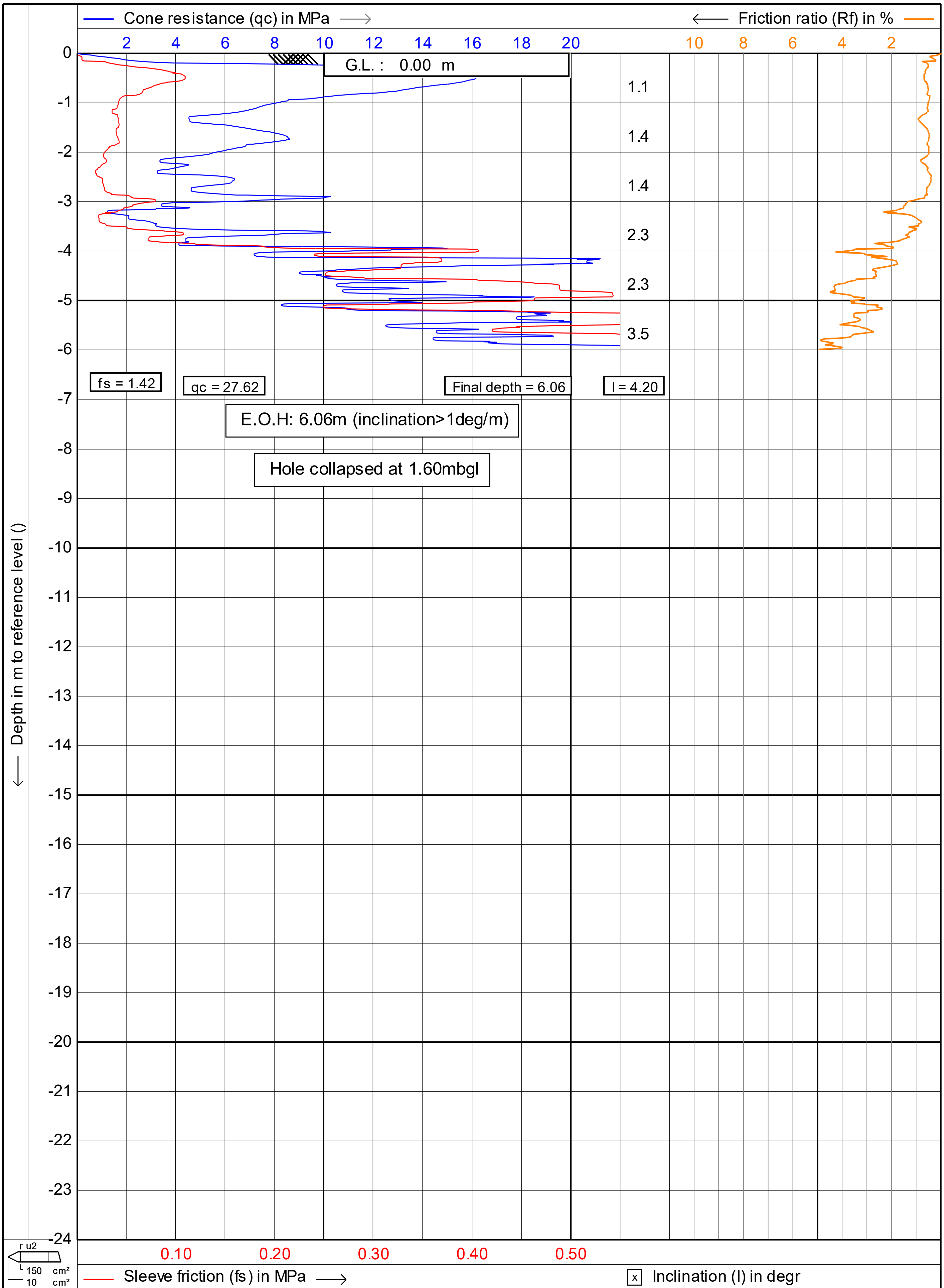
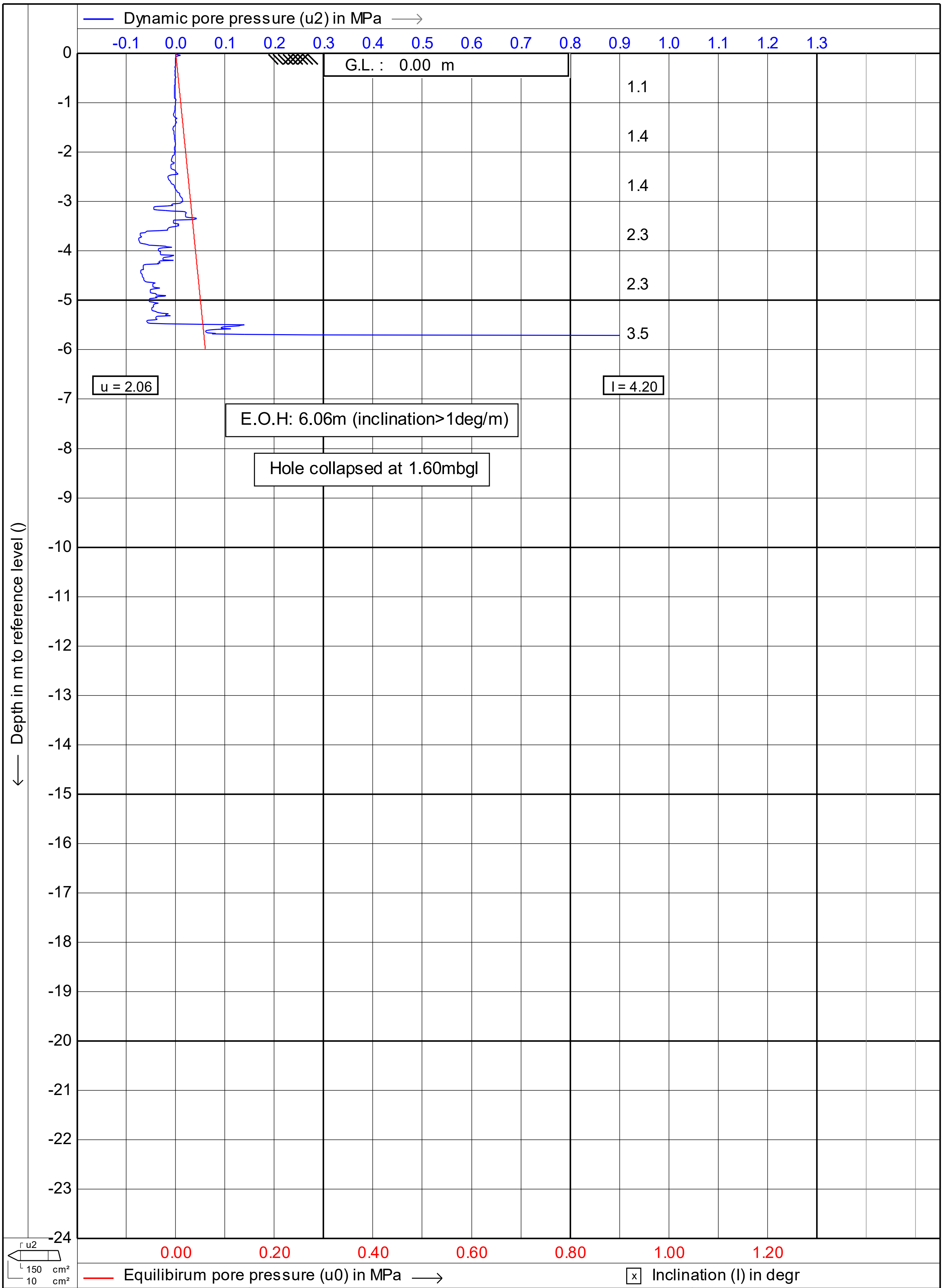


DRILLFORCE THE DRILLING SPECIALISTS

Test according NEN 5140 class 1		Date	: **24/09/2020**
Project	: **Waterways Parade**	Cone no.	: **S10CFIIP.S15298**
Location:	**Waterways Parade, Pauaunui**	Project no. :	**DF19GE167**
Position:	**175.85283, -37.03143 WGS 84**	CPT no.	: **CPT_HH2** **1/15**

1.47



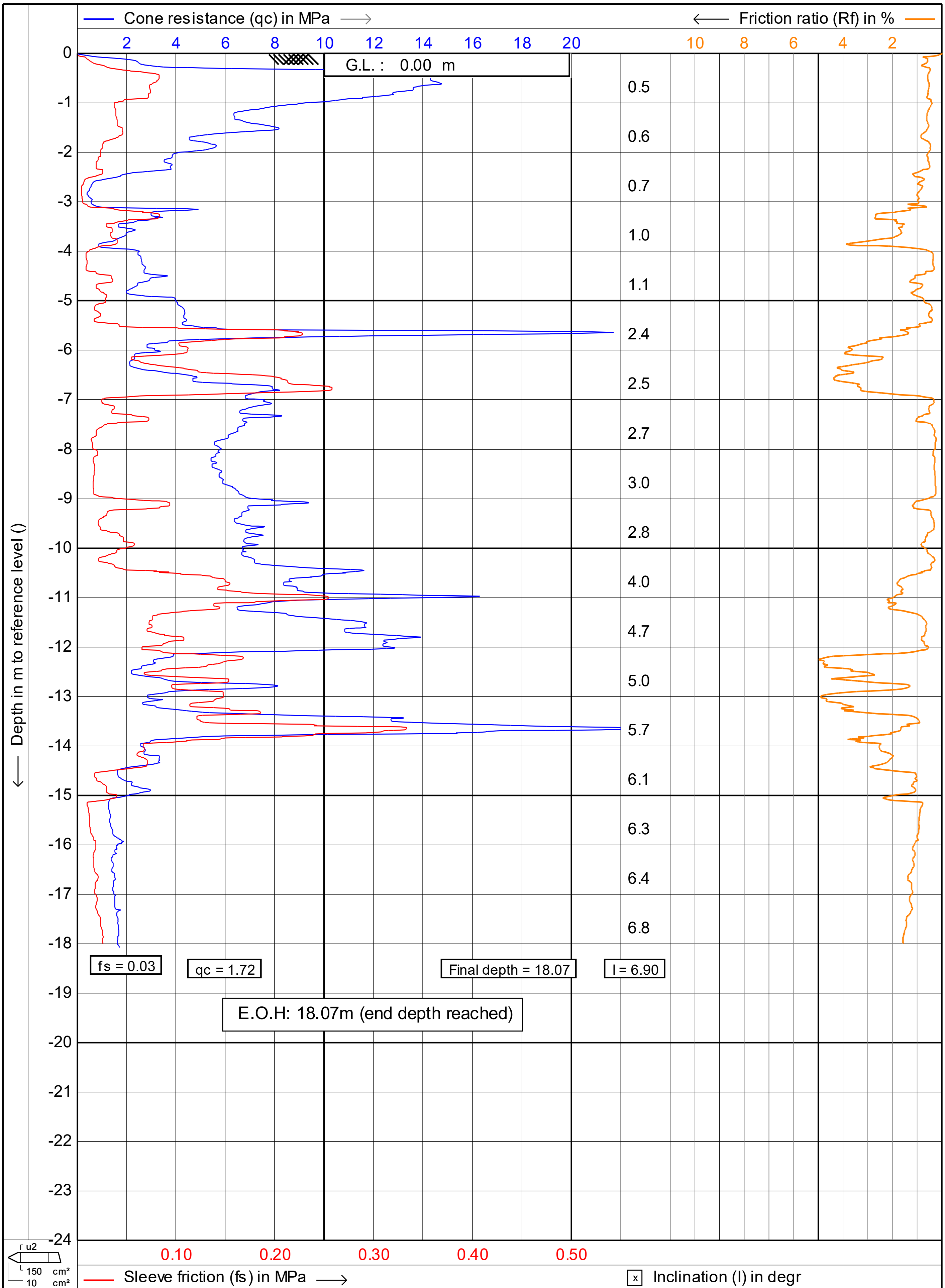
DRILLFORCE THE DRILLING SPECIALISTS

Test according NEN 5140 class 1

Project : **Waterways Parade**
Location: **Waterways Parade, Pauaunui**
Position: **175.85283, -37.03143 WGS 84**

Date : **24/09/2020**
Cone no. : **S10CFIIP.S15298**
Project no. : **DF19GE167**
CPT no. : **CPT_HH2** **2/15**

1.47



DRILLFORCE
THE DRILLING SPECIALISTS

Test according NEN 5140 class 1

Project : **Waterways Parade**

Location: **Waterways Parade, Pauaunui**

Position: **175.85307, -37.0316 WGS 84**

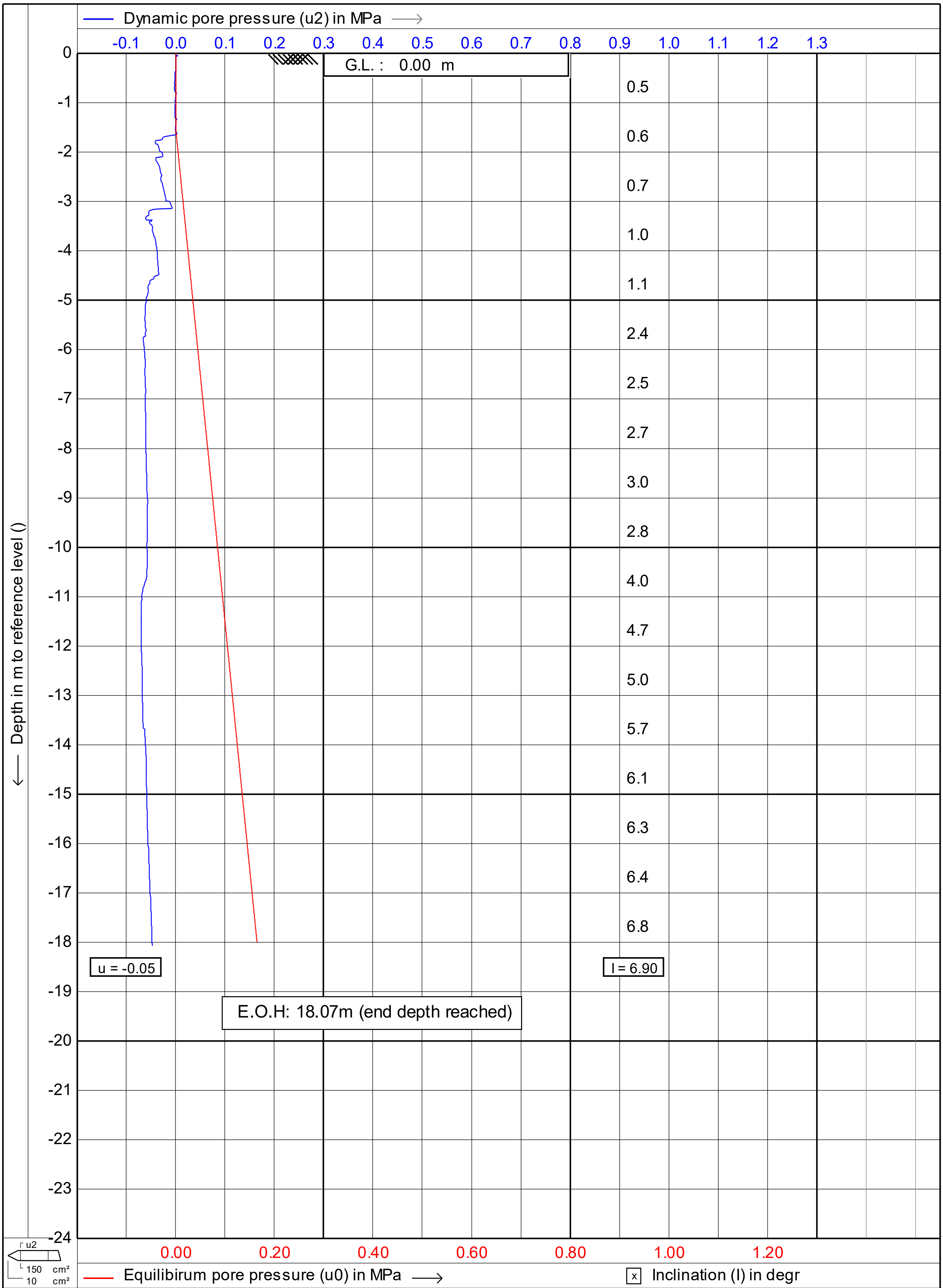
Date : **24/09/2020**

Cone no. : **S10CFIIP.S15298**

Project no. : **DF19GE167**

CPT no. : **CPT_HH3** **1/15**

1.47



DRILLFORCE THE DRILLING SPECIALISTS

Test according NEN 5140 class 1

Project : **Waterways Parade**

Location: **Waterways Parade, Pauaunui**

Position: **175.85307, -37.0316 WGS 84**

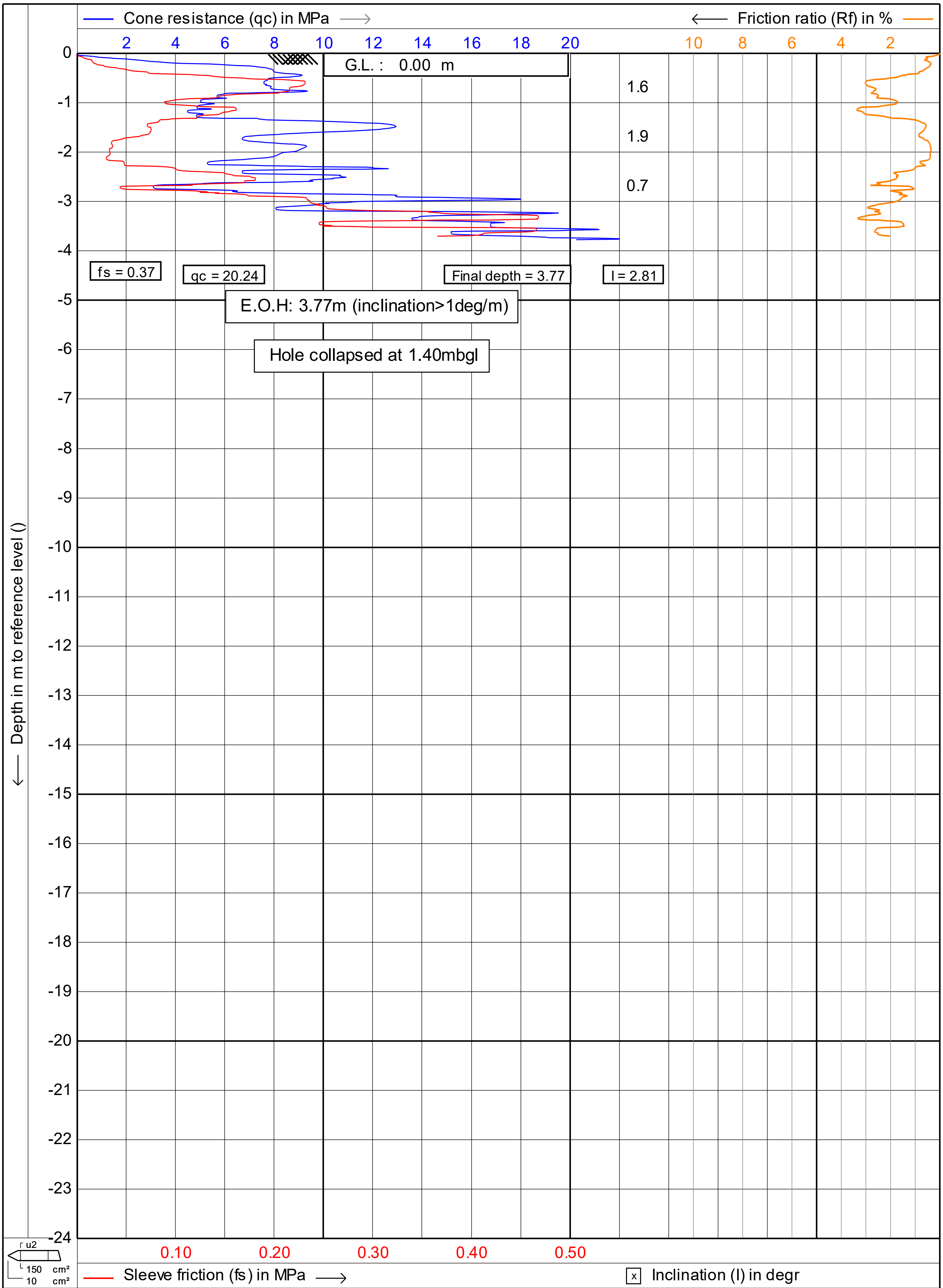
Date : **24/09/2020**

Cone no. : **S10CFIIP.S15298**

Project no. : **DF19GE167**

CPT no. : **CPT_HH3** **2/15**

1.47



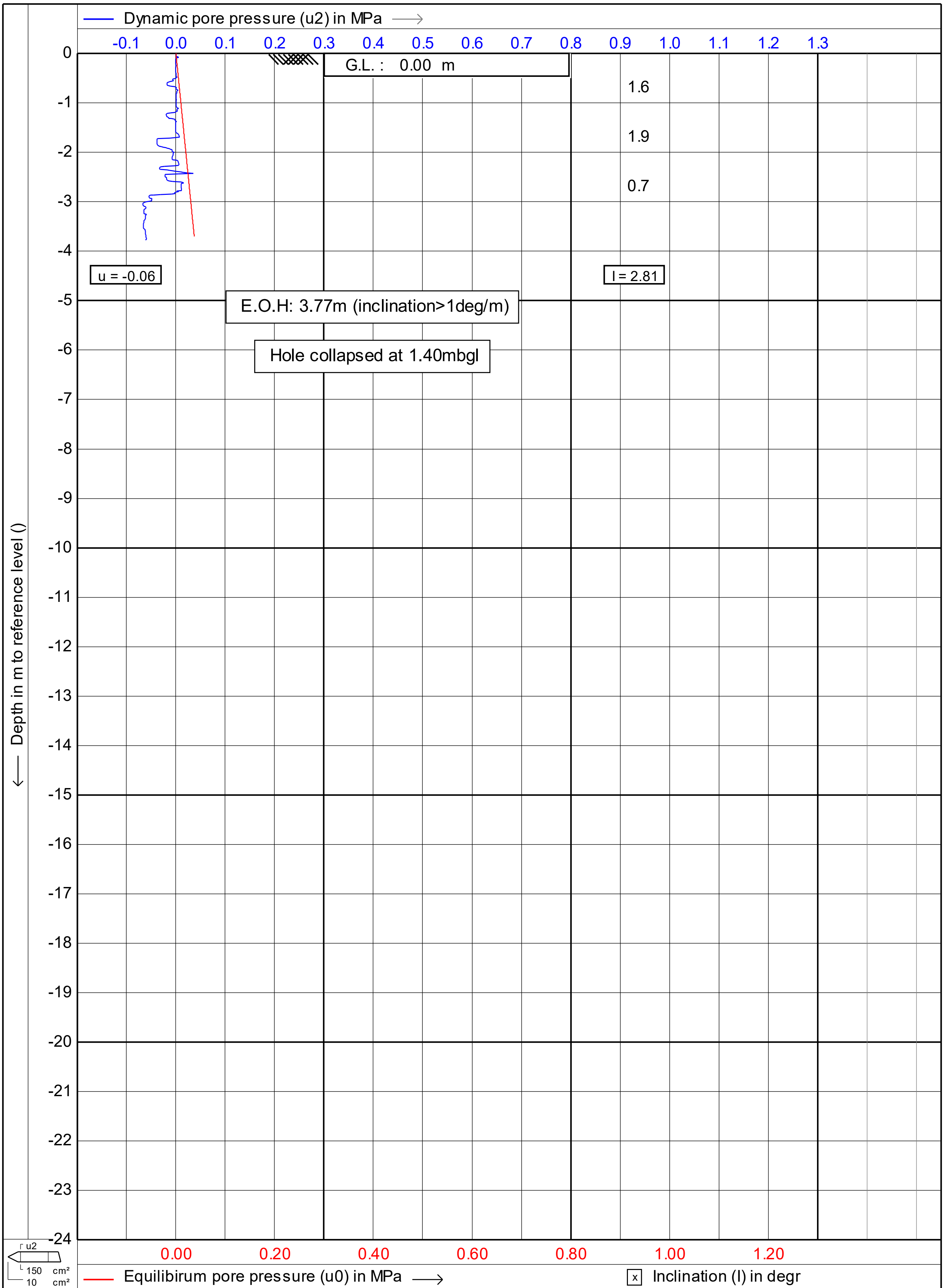
DRILLFORCE THE DRILLING SPECIALISTS

Test according NEN 5140 class 1

Project : **Waterways Parade**
Location: **Waterways Parade, Pauaunui**
Position: **175.85432, -37.03166 WGS 84**

Date : **24/09/2020**
Cone no. : **S10CFIIP.S15298**
Project no. : **DF19GE167**
CPT no. : **CPT_HH4** **1/15**

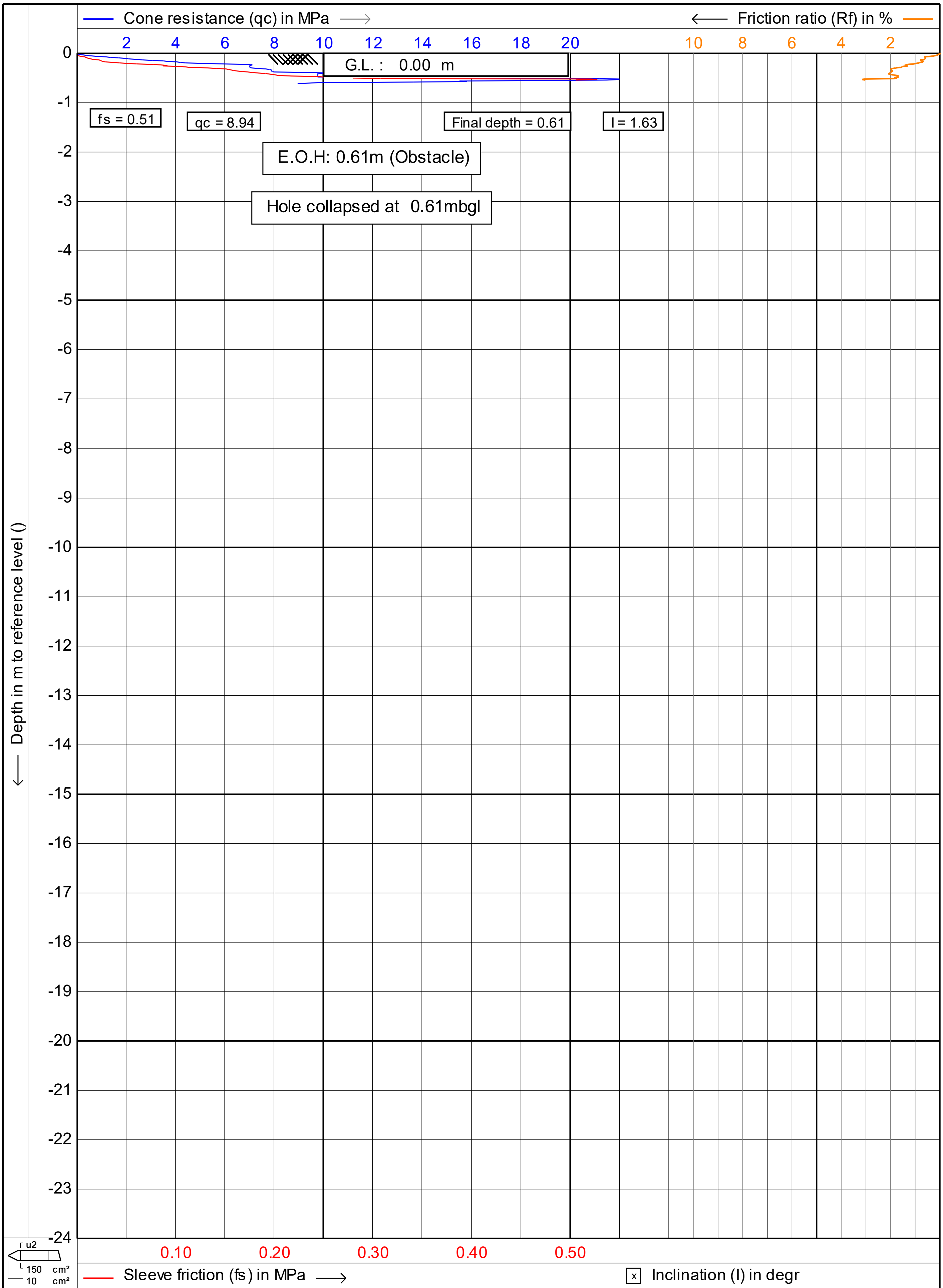
1.47



DRILLFORCE
THE DRILLING SPECIALISTS

1.47

Test according NEN 5140 class 1	Date : **24/09/2020**
Project : **Waterways Parade**	Cone no. : **S10CFIIP.S15298**
Location: **Waterways Parade, Pauaunui**	Project no. : **DF19GE167**
Position: **175.85432, -37.03166 WGS 84**	CPT no. : **CPT_HH4** **2/15**

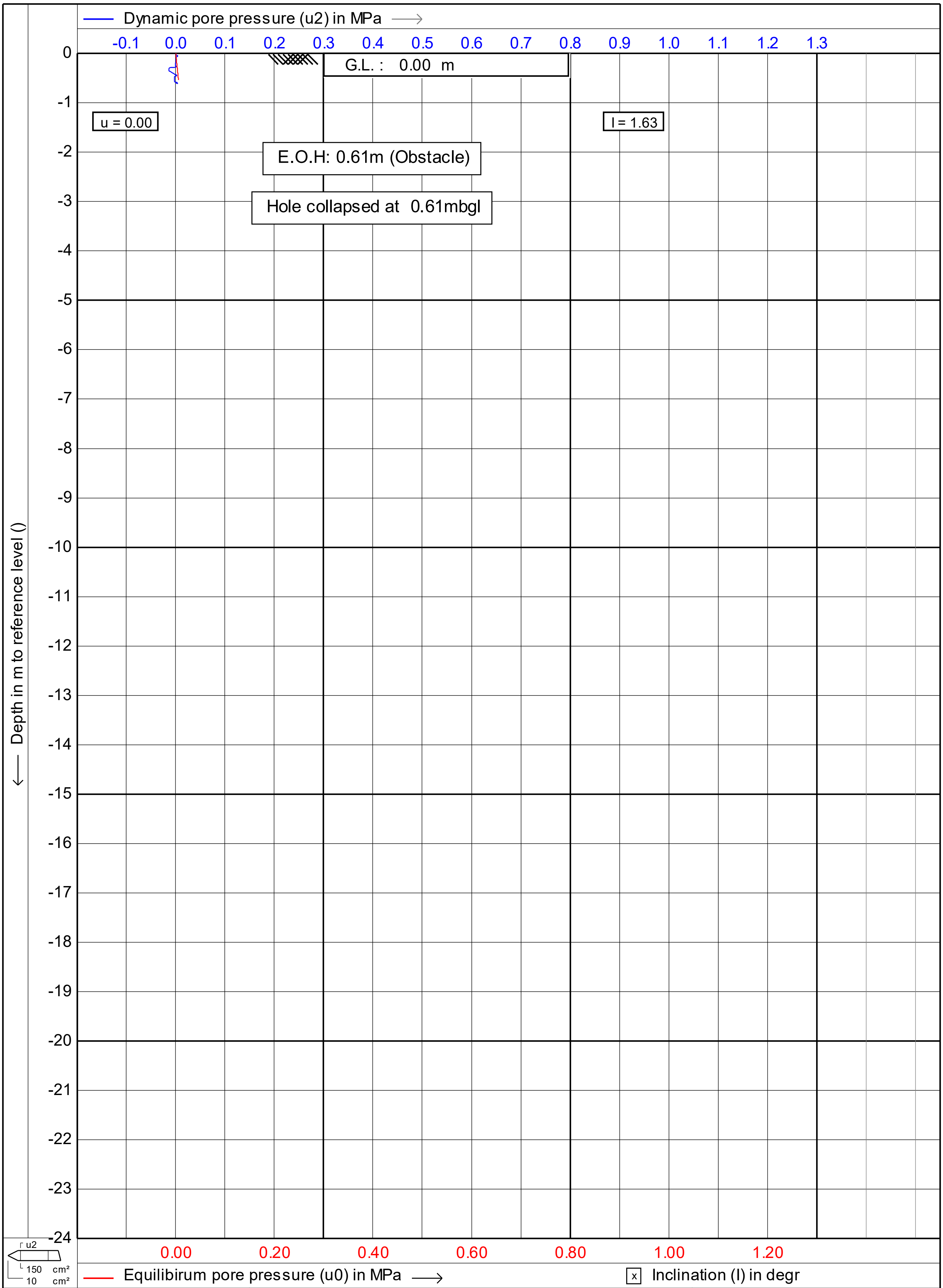


DRILLFORCE
THE DRILLING SPECIALISTS

Test according NEN 5140 class 1

Project :	**Waterways Parade**
Location:	**Waterways Parade, Pauaunui**
Position:	**175.85371, -37.03167 WGS 84**
Date :	**24/09/2020**
Cone no. :	**S10CFIIP.S15298**
Project no. :	**DF19GE167**
CPT no. :	**CPT_HH5** **1/15**

1.47



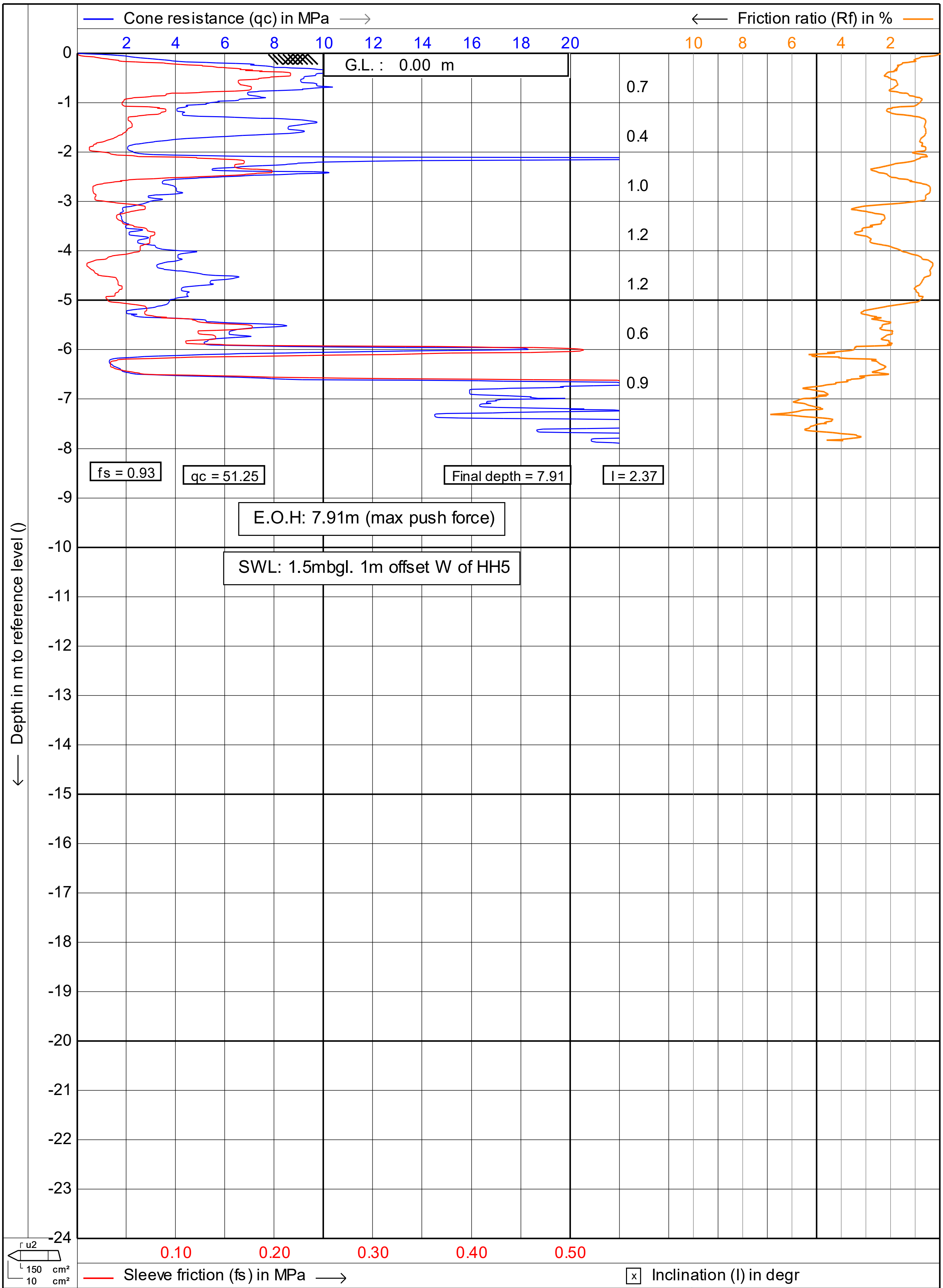
DRILLFORCE
THE DRILLING SPECIALISTS

Test according NEN 5140 class 1

Project : **Waterways Parade**
Location: **Waterways Parade, Pauaunui**
Position: **175.85371, -37.03167 WGS 84**

Date : **24/09/2020**
Cone no. : **S10CFIIP.S15298**
Project no. : **DF19GE167**
CPT no. : **CPT_HH5** **2/15**

1.47

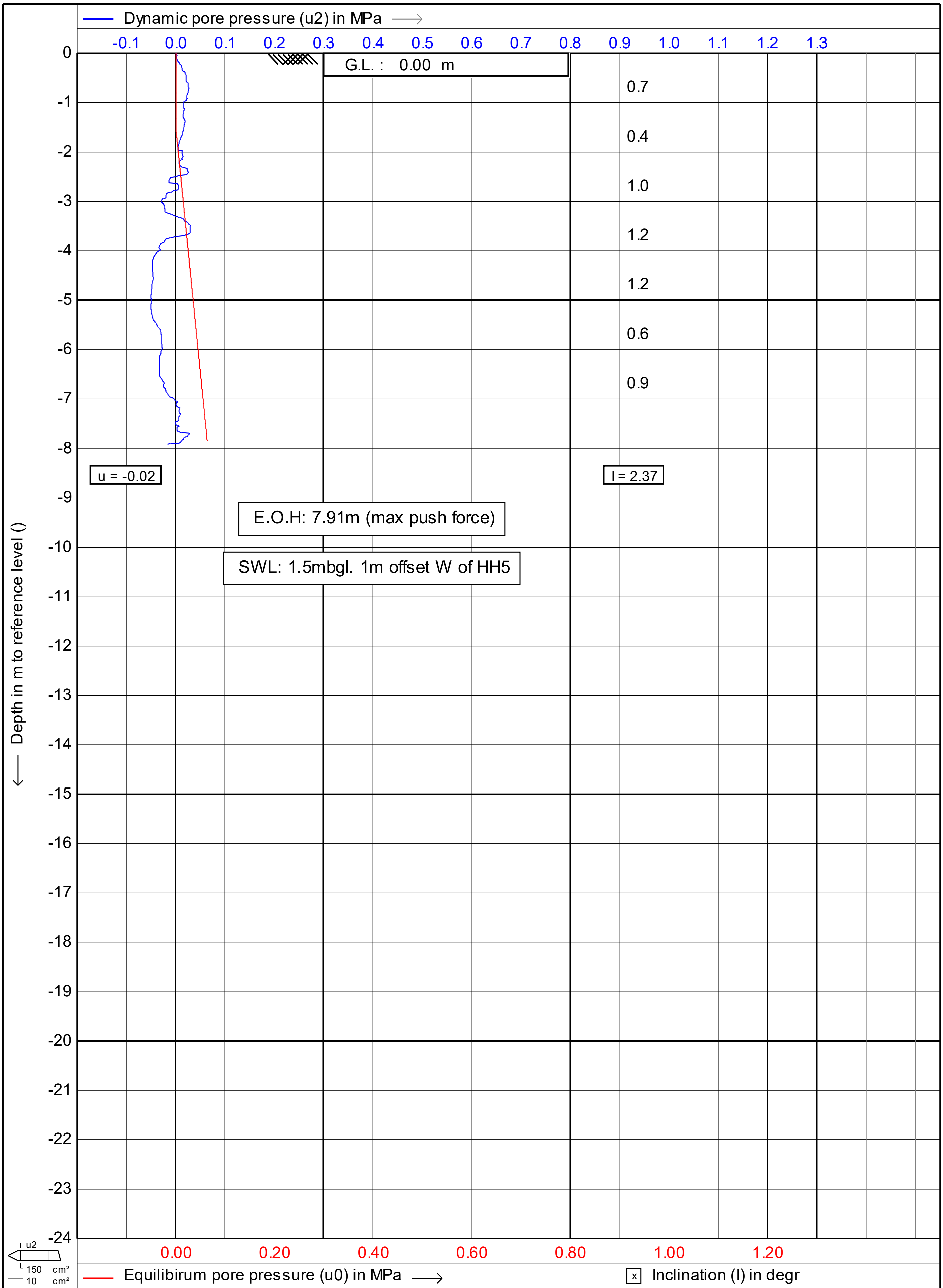


DRILLFORCE
THE DRILLING SPECIALISTS

Test according NEN 5140 class 1

Project :	**Waterways Parade**
Location:	**Waterways Parade, Pauaunui**
Position:	**175.85371, -37.03167 WGS 84**
Date :	**24/09/2020**
Cone no. :	**S10CFIIP.S15298**
Project no. :	**DF19GE167**
CPT no. :	**CPT_HH5A**

1.47



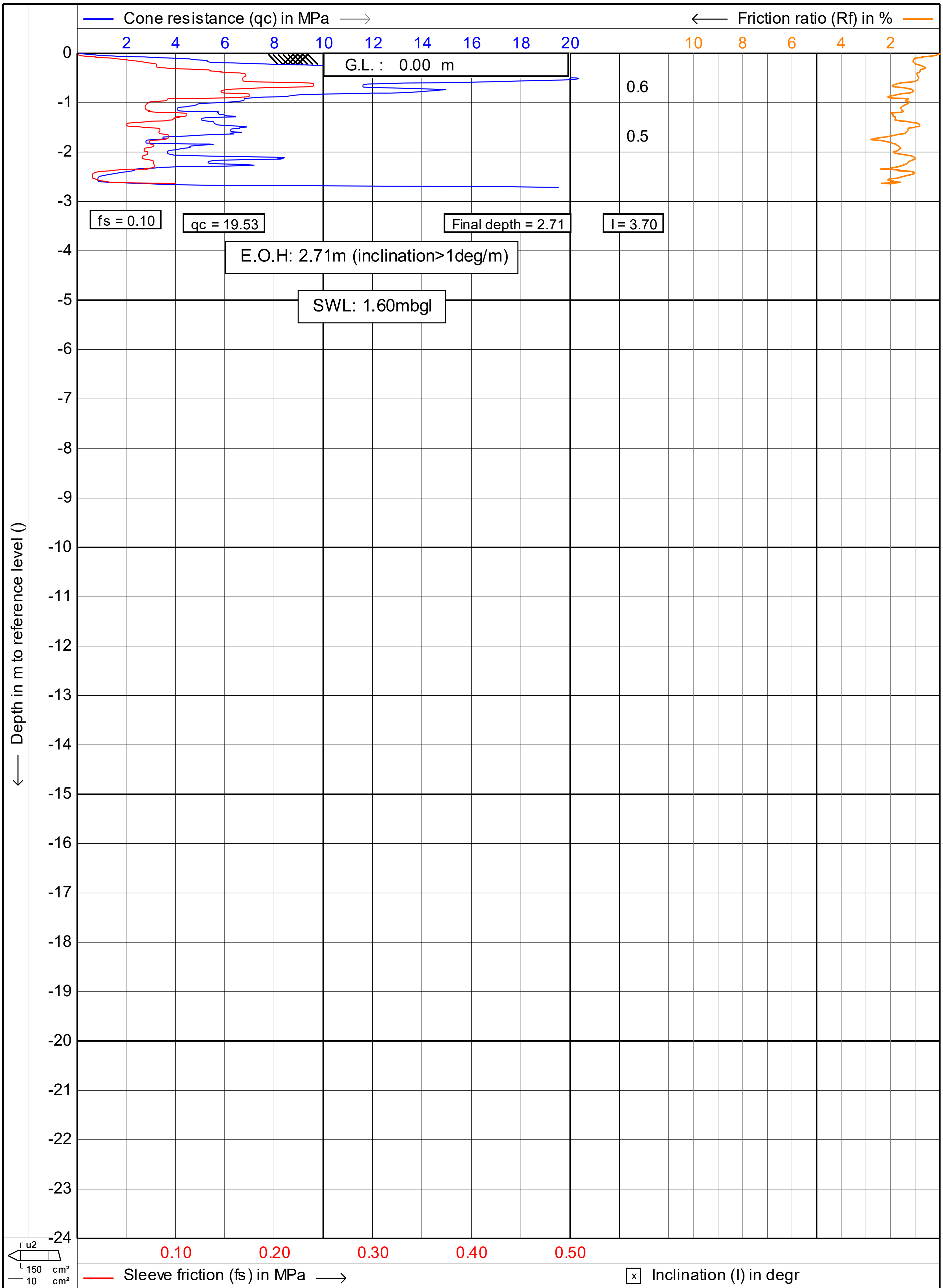
THE DRILLING SPECIALISTS

Test according NEN 5140 class 1

Project : **Waterways Parade**
Location: **Waterways Parade, Pauaunui**
Position: **175.85371, -37.03167 WGS 84**

Date	: **24/09/2020**
Cone no.	: **S10CFIIP.S15298**
Project no. :	**DF19GE167**
CPT no.	: **CPT_HH5A** **2/15**

1.47



DRILLFORCE THE DRILLING SPECIALISTS

Test according NEN 5140 class 1

Project : **Waterways Parade**

Location: **Waterways Parade, Pauaunui**

Position: **175.85416, -37.0316 WGS 84**

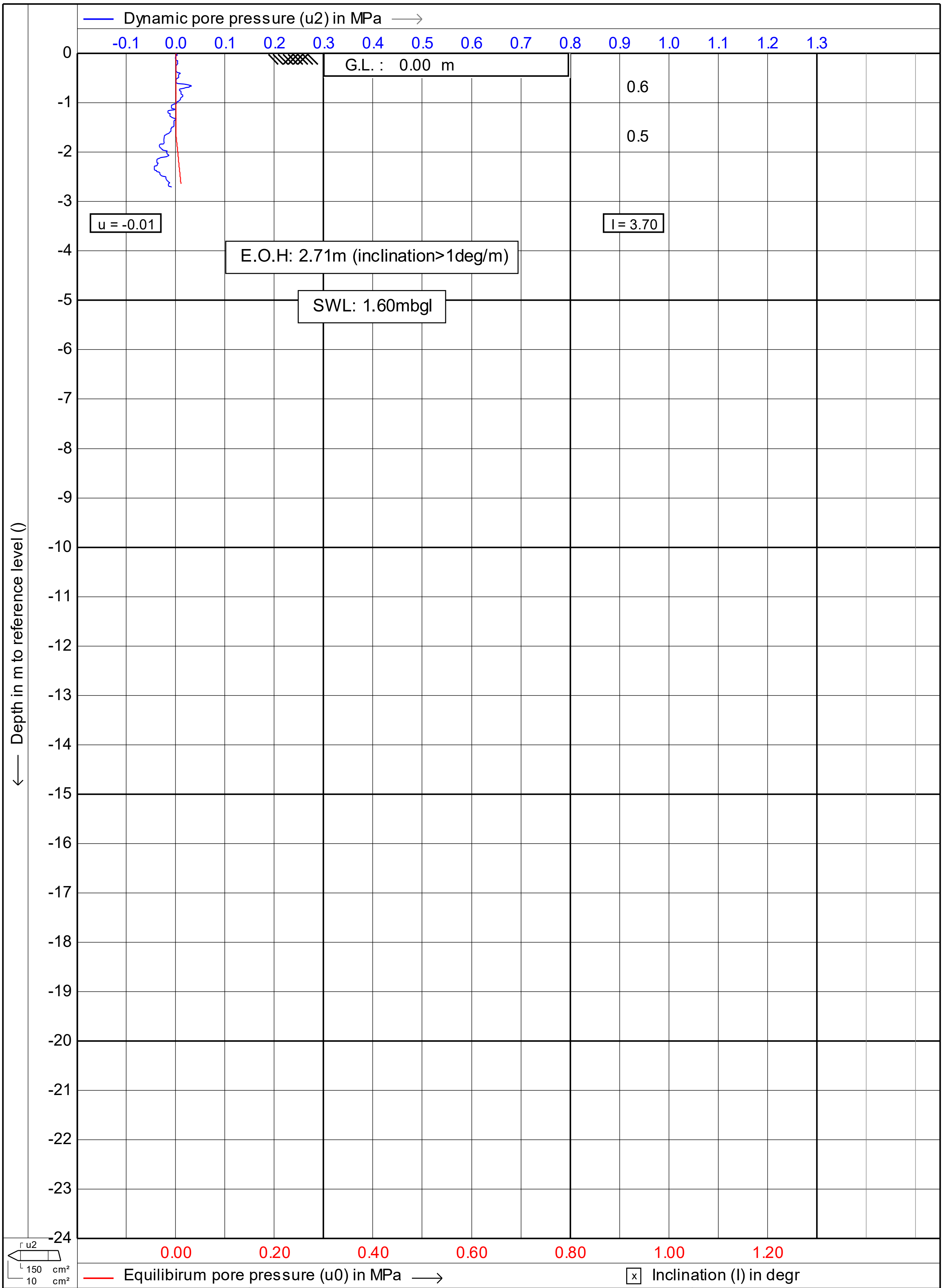
Date : **24/09/2020**

Cone no. : **S10CFIIP.S15298**

Project no. : **DF19GE167**

CPT no. : **CPT_HH6** **1/15**

1.47



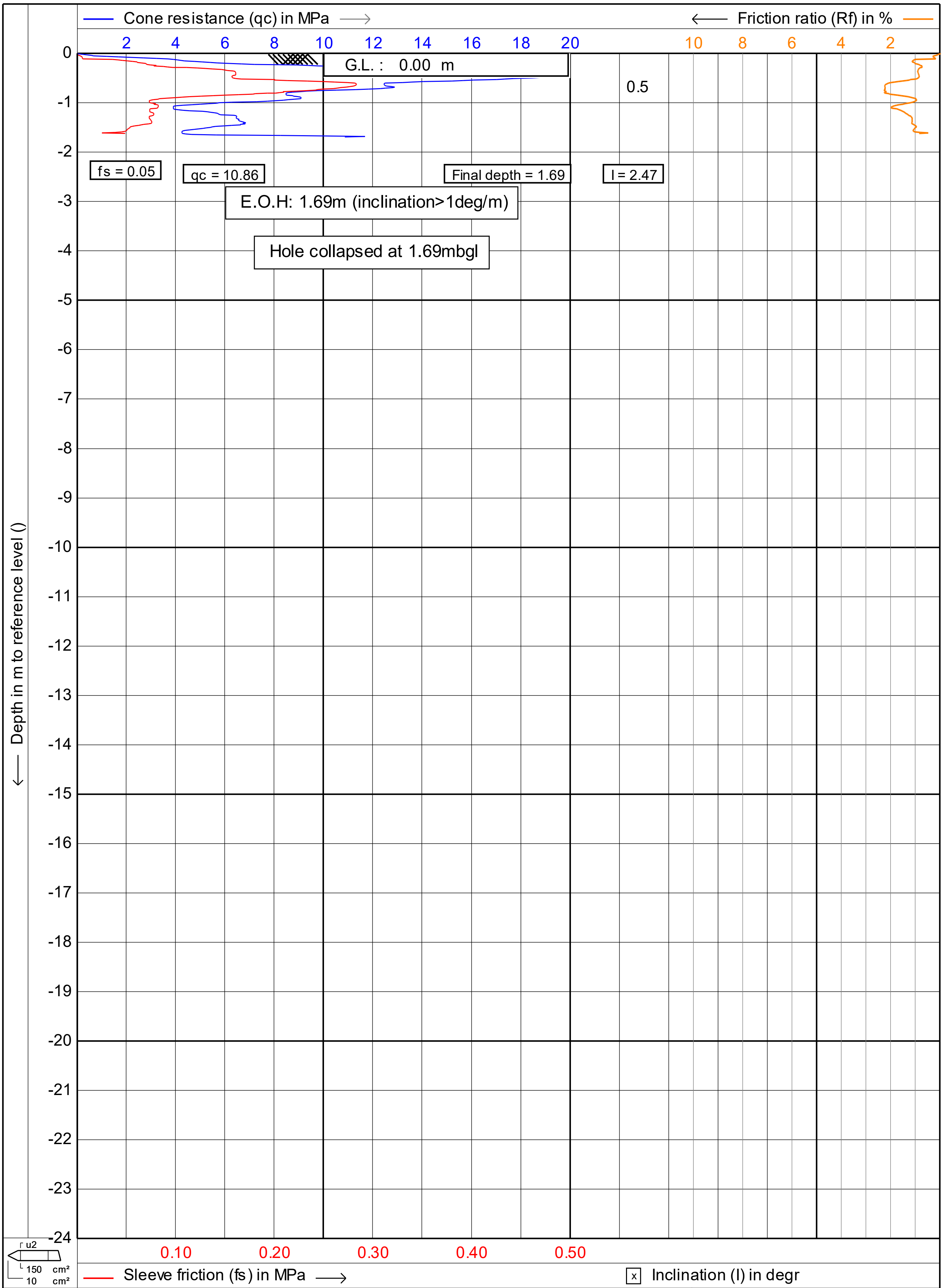
THE DRILLING SPECIALISTS

Test according NEN 5140 class 1

Project : **Waterways Parade**
Location: **Waterways Parade, Pauaunui**
Position: **175.85416, -37.0316 WGS 84**

Date	: **24/09/2020**
Cone no.	: **S10CFIIP.S15298**
Project no.	: **DF19GE167**
CPT no.	: **CPT_HH6** **2/15**

1.47



Test according NEN 5140 class 1

Project : **Waterways Parade**

Location: **Waterways Parade, Pauaunui**

Position: **175.85416, -37.0316 WGS 84**

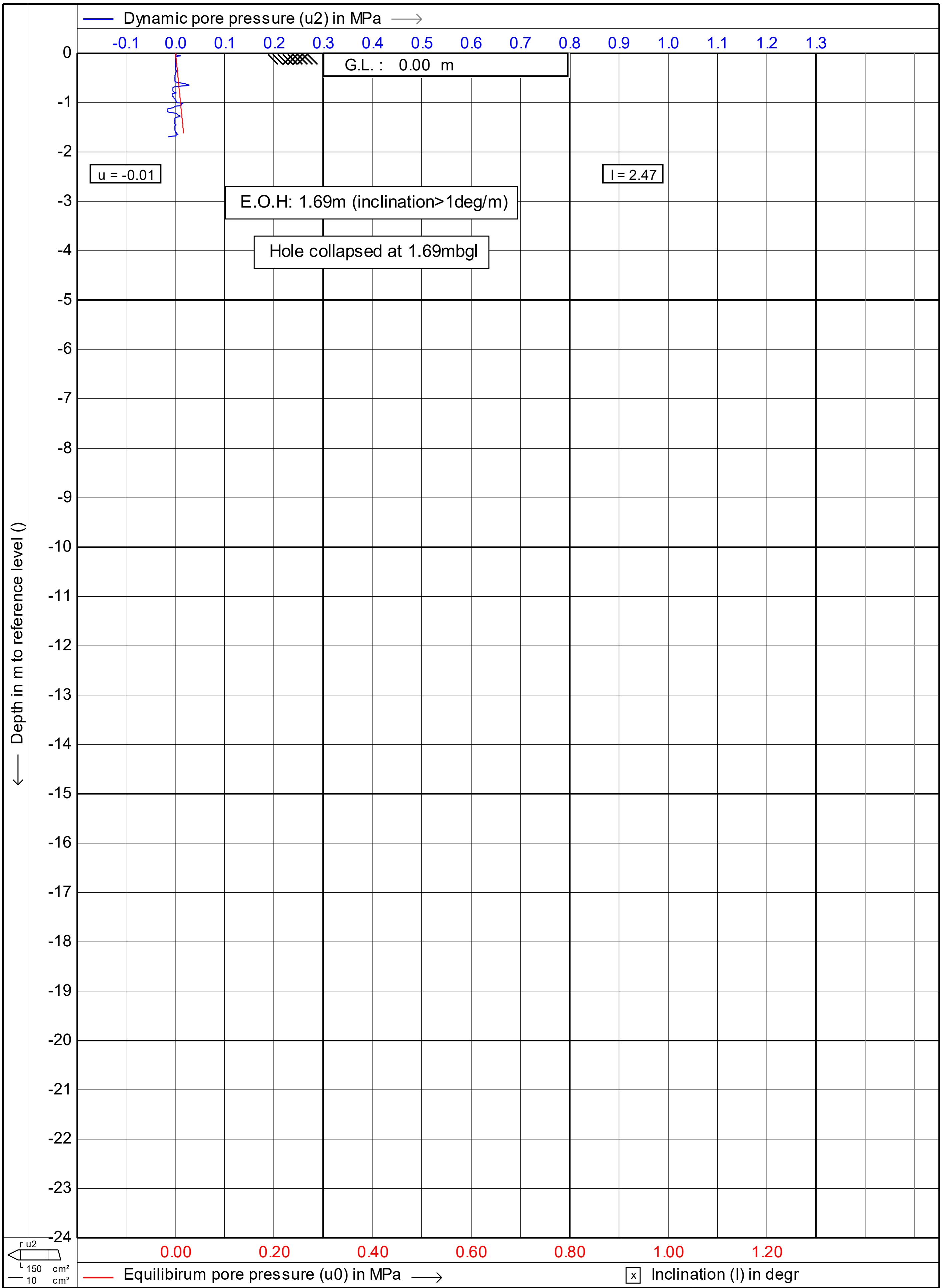
Date : **24/09/2020**

Cone no. : **S10CFIIP.S15298**

Project no. : **DF19GE167**

CPT no. : **CPT_HH6A** **1/15**

1.47



DRILLFORCE THE DRILLING SPECIALISTS

Test according NEN 5140 class 1	Date	: 24/09/2020
Project : **Waterways Parade**	Cone no.	: S10CFIIP.S15298
Location: **Waterways Parade, Pauaunui**	Project no. :	DF19GE167
Position: **175.85416, -37.0316 WGS 84**	CPT no.	: CPT_HH6A 2/15

1.47

Seismic Design, Liquefaction and Ground Improvement

Pauanui Waterways, Stage 3 - The Hammerhead

Appendix B

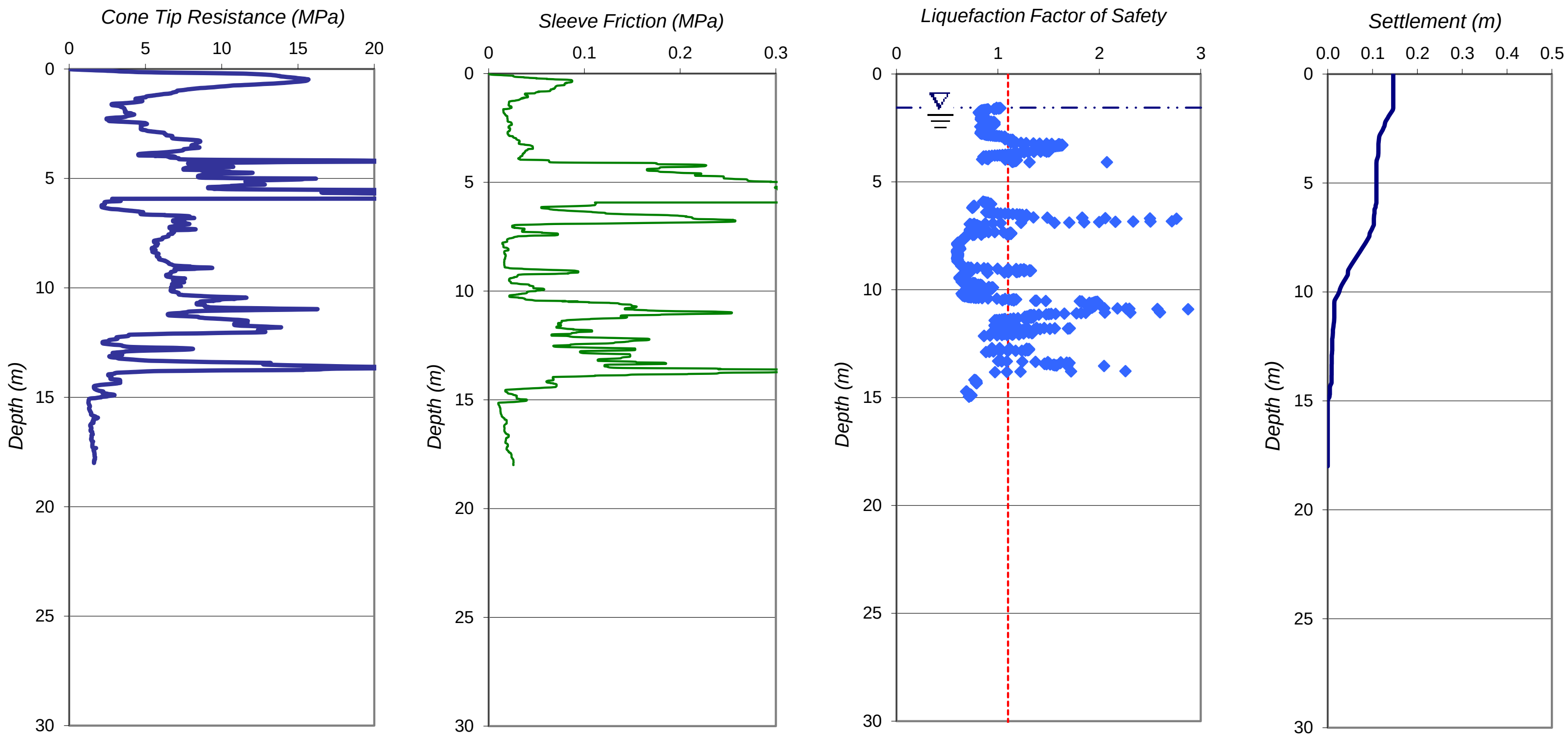
Liquefaction Analysis

Liquefaction Factor of Safety From CPT Data ver. Oct. 2019

FOS filtered to show only points with I_c smaller than 2.60

Liquefaction considered to be triggered when FoS < 1.1 (Bridge Manual cl.6.3.5)

Project	Pauanui HH	*PGA(g)*	0.23	*Unit Weight (kN/m^3)*	17	*Minimum FOS*	0.60
CPT Number	HH1	*Magnitude*	5.7	*Water Table Depth (m)*	1.56	*Ground Surface Settlement*	0.146 *m*
				Embankment height (m)	1.51	*LPI*	7.81



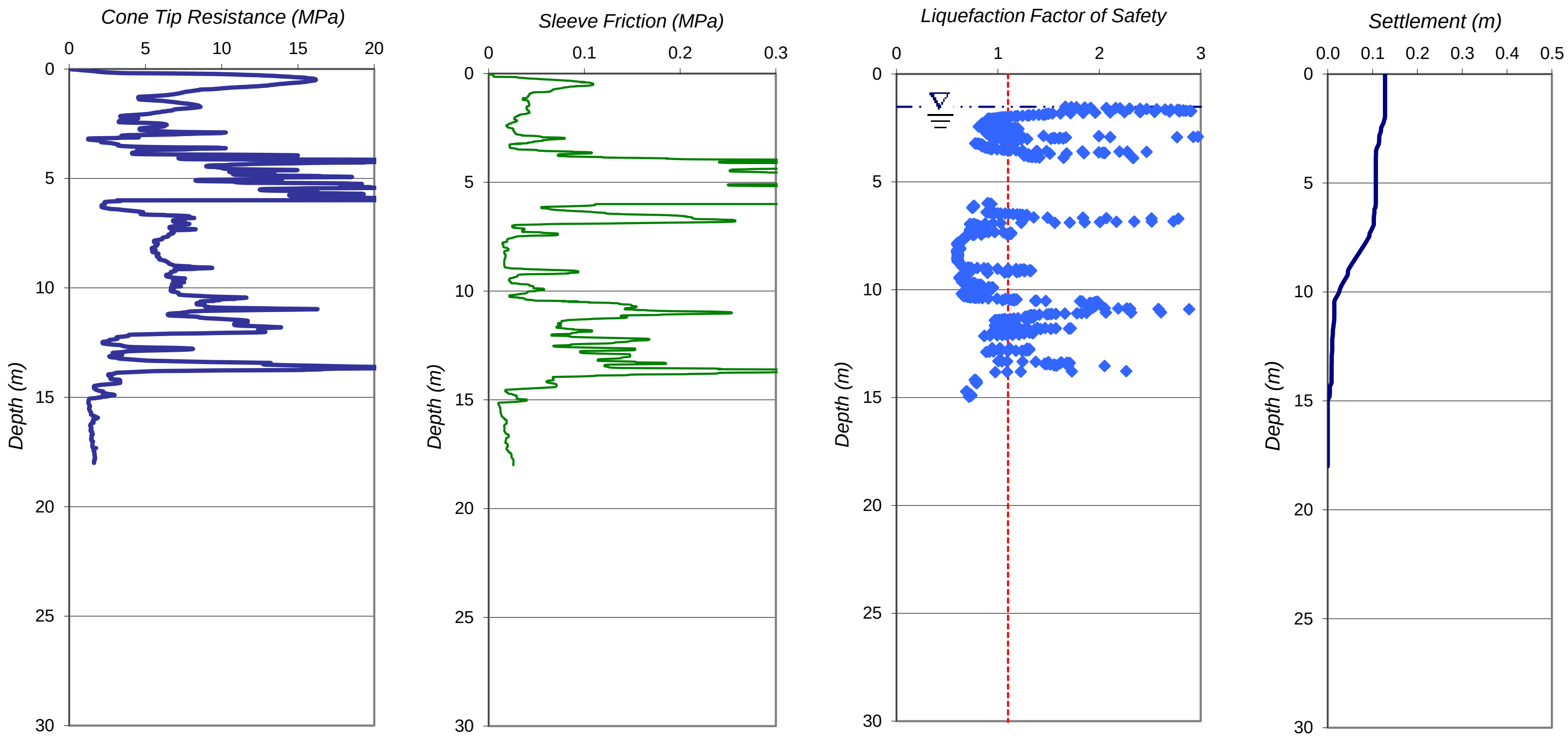
Ref. Boulanger and Idriss (2014)

Liquefaction Factor of Safety From CPT Data ver. Oct. 2019

FOS filtered to show only points with I_c smaller than 2.60

Liquefaction considered to be triggered when FoS < 1.1 (Bridge Manual cl.6.3.5)

Project	Pauanui HH	*PGA(g)*	0.23	*Unit Weight (kN/m³)*	17	*Minimum FOS*	0.60
CPT Number	HH2	*Magnitude*	5.7	*Water Table Depth (m)*	1.52	*Ground Surface Settlement*	0.128 *m*
				Embankment height (m)	1.55	*LPI*	6.92



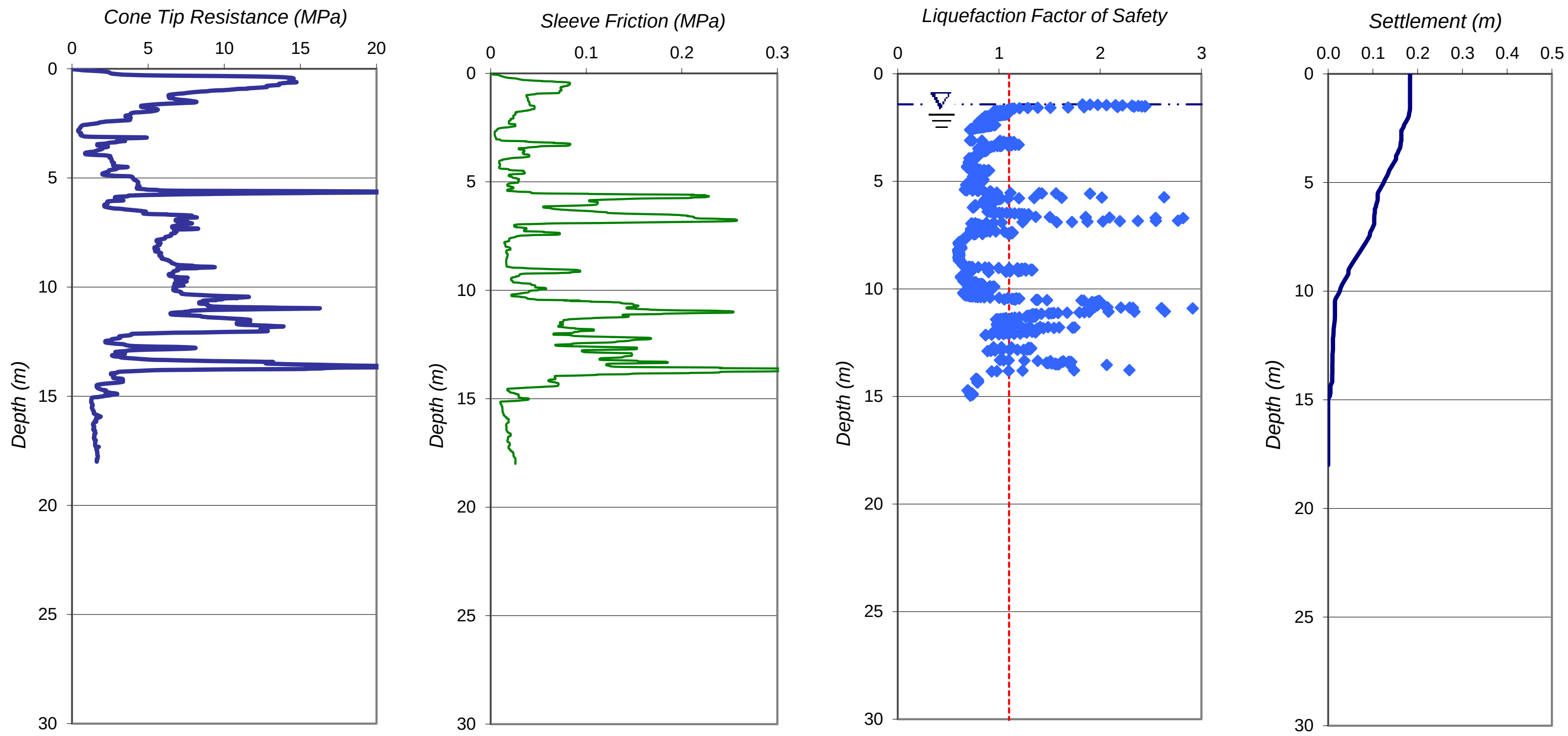
Ref. Boulanger and Idriss (2014)

Liquefaction Factor of Safety From CPT Data ver. Oct. 2019

FOS filtered to show only points with I_c smaller than 2.60

Liquefaction considered to be triggered when FoS < 1.1 (Bridge Manual cl.6.3.5)

Project	Pauanui HH	*PGA(g)*	0.23	*Unit Weight (kN/m^3)*	17	*Minimum FOS*	0.60
CPT Number	HH3	*Magnitude*	5.7	*Water Table Depth (m)*	1.42	*Ground Surface Settlement*	0.183 *m*
				Embankment height (m)	1.65	*LPI*	10.75



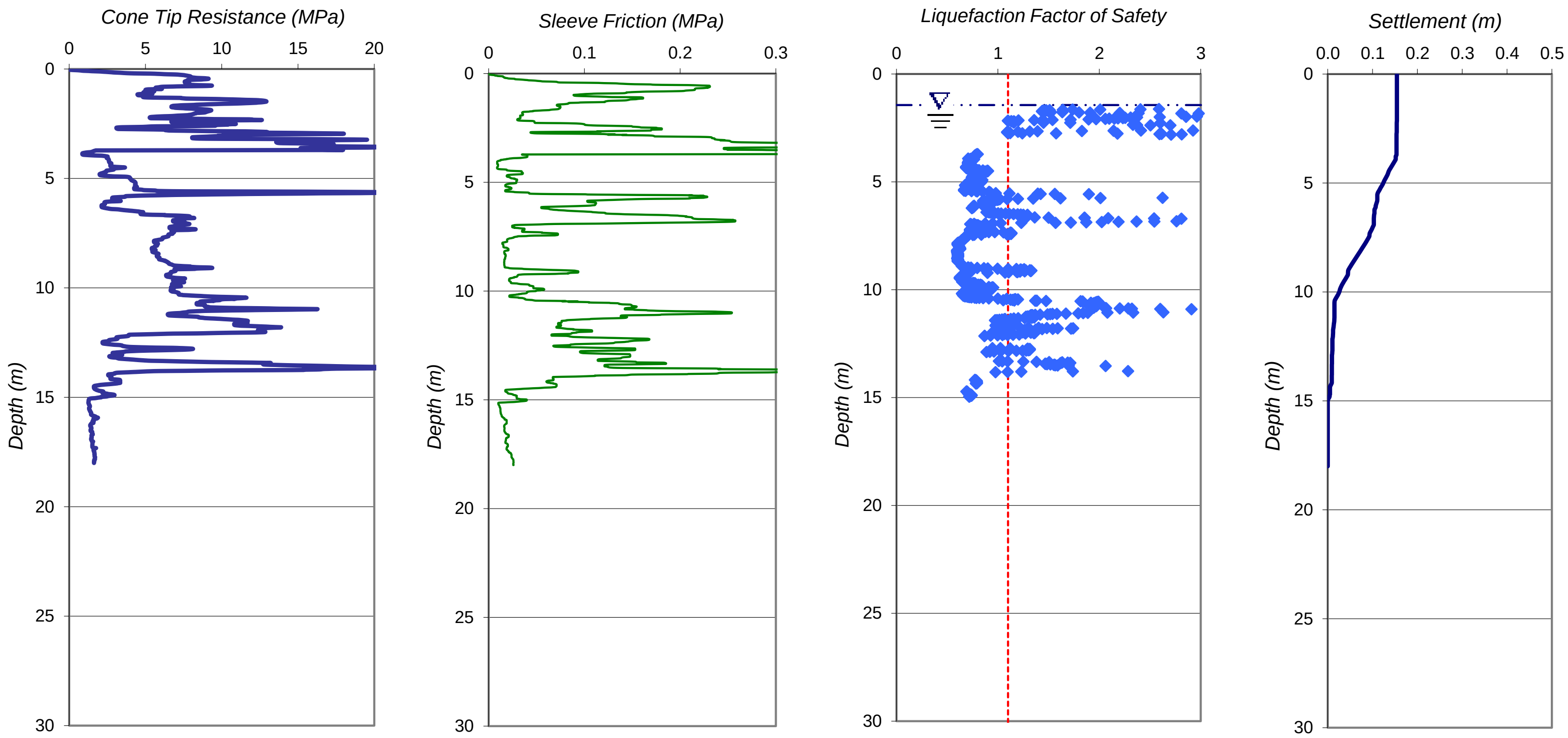
Ref. Boulanger and Idriss (2014)

Liquefaction Factor of Safety From CPT Data ver. Oct. 2019

FOS filtered to show only points with I_c smaller than 2.60

Liquefaction considered to be triggered when FoS < 1.1 (Bridge Manual cl.6.3.5)

Project	Pauanui HH	*PGA(g)*	0.23	*Unit Weight (kN/m^3)*	17	*Minimum FOS*	0.60
CPT Number	HH4	*Magnitude*	5.7	*Water Table Depth (m)*	1.44	*Ground Surface Settlement*	0.154 *m*
				Embankment height (m)	1.63	*LPI*	9.34



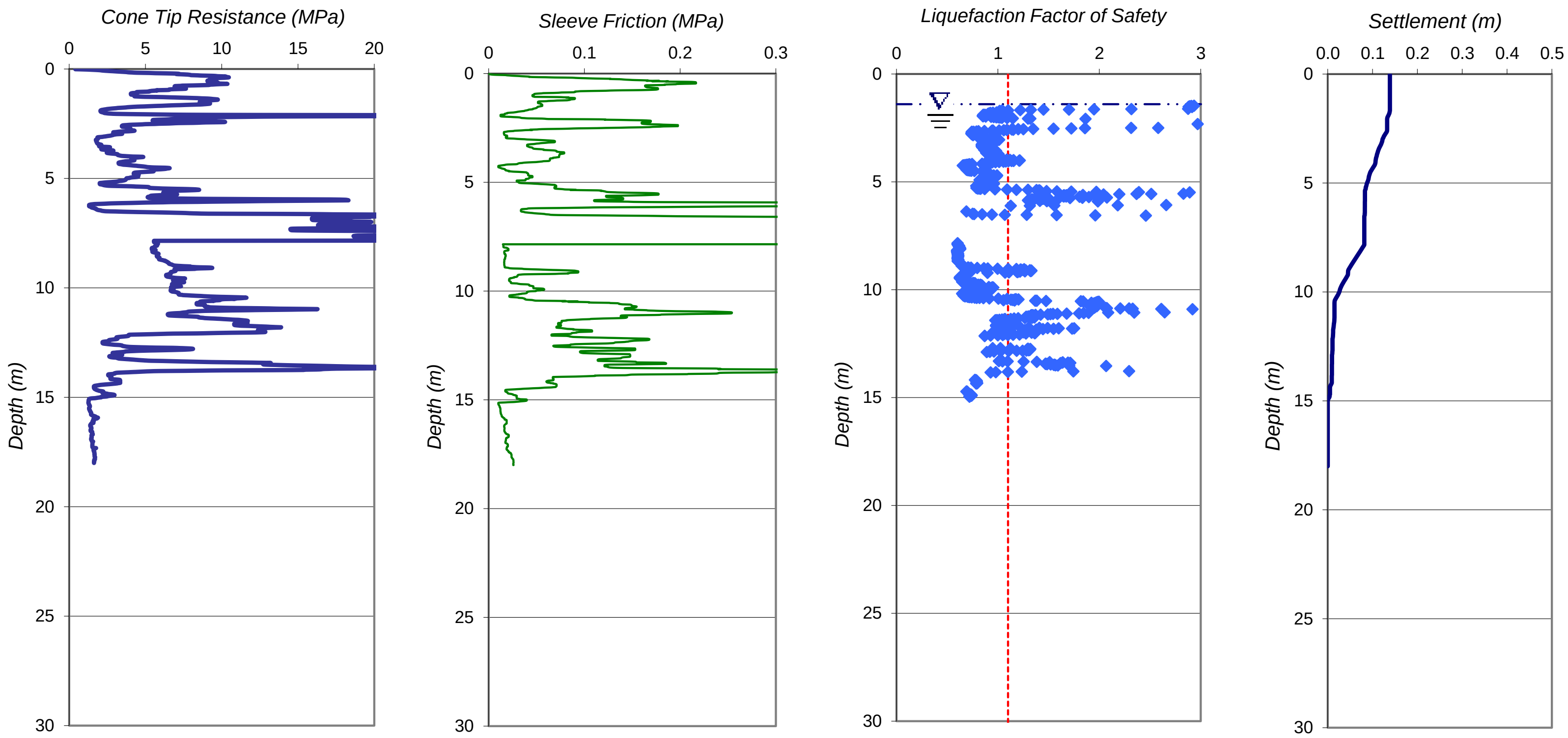
Ref. Boulanger and Idriss (2014)

Liquefaction Factor of Safety From CPT Data ver. Oct. 2019

FOS filtered to show only points with I_c smaller than 2.60

Liquefaction considered to be triggered when FoS < 1.1 (Bridge Manual cl.6.3.5)

Project	Pauanui HH	*PGA(g)*	0.23	*Unit Weight (kN/m^3)*	17	*Minimum FOS*	0.60
CPT Number	HH5A	*Magnitude*	5.7	*Water Table Depth (m)*	1.4	*Ground Surface Settlement*	0.139 *m*
				Embankment height (m)	1.67	*LPI*	7.51



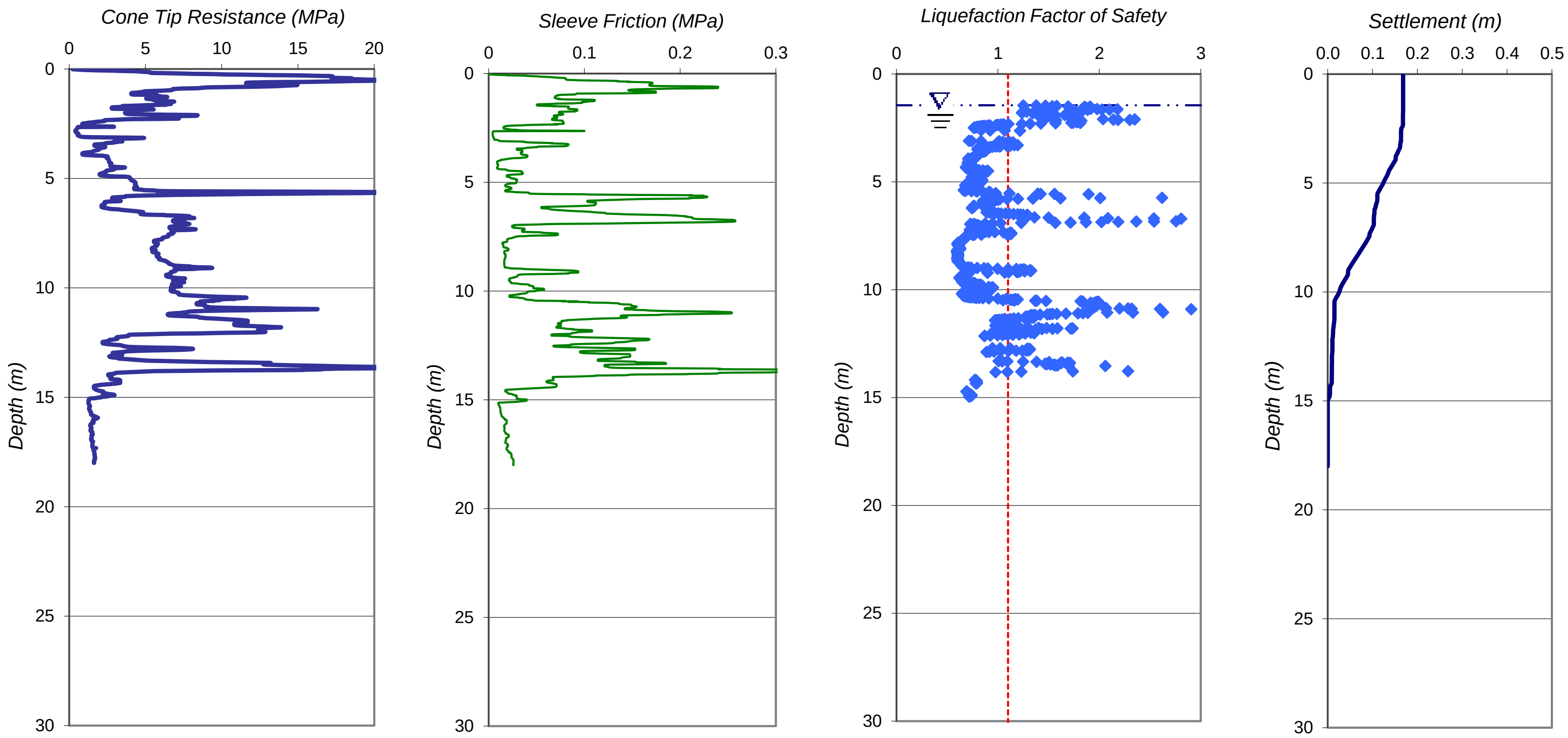
Ref. Boulanger and Idriss (2014)

Liquefaction Factor of Safety From CPT Data ver. Oct. 2019

FOS filtered to show only points with I_c smaller than 2.60

Liquefaction considered to be triggered when FoS < 1.1 (Bridge Manual cl.6.3.5)

Project	Pauanui HH	*PGA(g)*	0.23	*Unit Weight (kN/m^3)*	17	*Minimum FOS*	0.60
CPT Number	HH6	*Magnitude*	5.7	*Water Table Depth (m)*	1.45	*Ground Surface Settlement*	0.168 *m*
				Embankment height (m)	1.62	*LPI*	10.03



Ref. Boulanger and Idriss (2014)

Seismic Design, Liquefaction and Ground Improvement

Pauanui Waterways, Stage 3 - The Hammerhead

Appendix C

MBIE (2012) Sections 5.3.1 and 5.3.2

5.3.1 Reinforced concrete floor construction in TC2

Several options may be used, but each has limitations that must be recognised. In all options the NZS 3604 ground clearances adjacent to the house foundation must be complied with. Note that for clarity the damp proof membrane (DPM) has not been shown in these representative details.

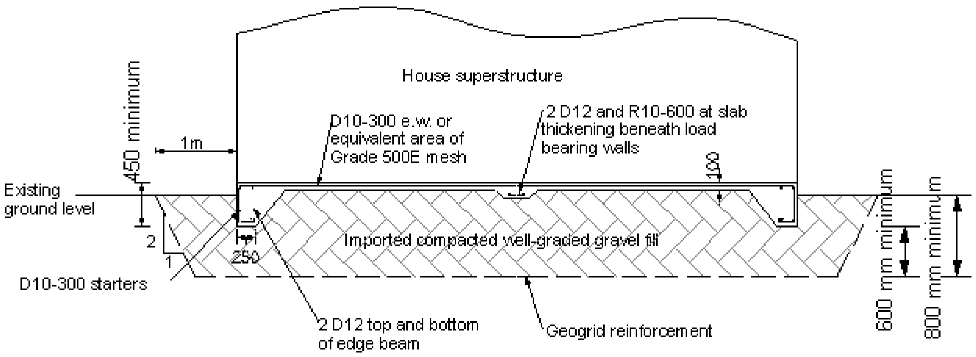
New flood freeboard requirements will also need to be considered if there has been uniform settlement over several properties (see section 8).

Option 1 – Excavation and replacement of the upper layers of soil with compacted, well-graded gravels and construction of a reinforced NZS 3604 slab foundation.

The ground immediately beneath the compacted gravel fill must have a minimum geotechnical ultimate bearing capacity of 200 kPa, or the slab should be subject to specific engineering design (see section 3.4.1).

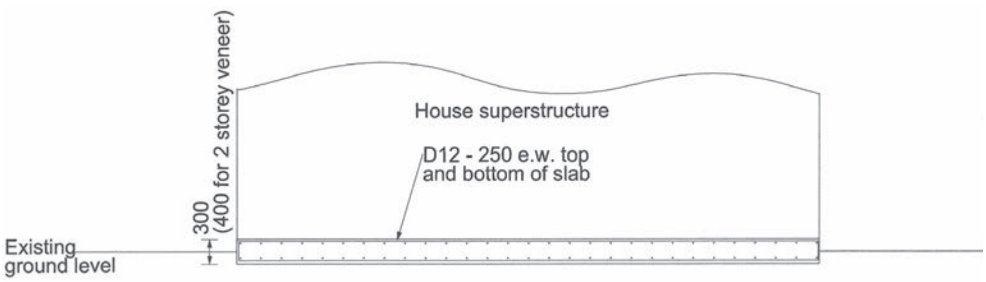
External service lines will need to be beyond the outer extent of the gravel raft and/or have flexible connections (refer to section 5.6).

Figure 5.5: Enhanced foundation slab – Option 1



Option 2 – Construct a thick slab foundation over the existing soil.

Figure 5.6: Enhanced foundation slab – Option 2



Note: NZS ground clearances adjacent to house foundation must be complied with. DPC omitted for clarity.

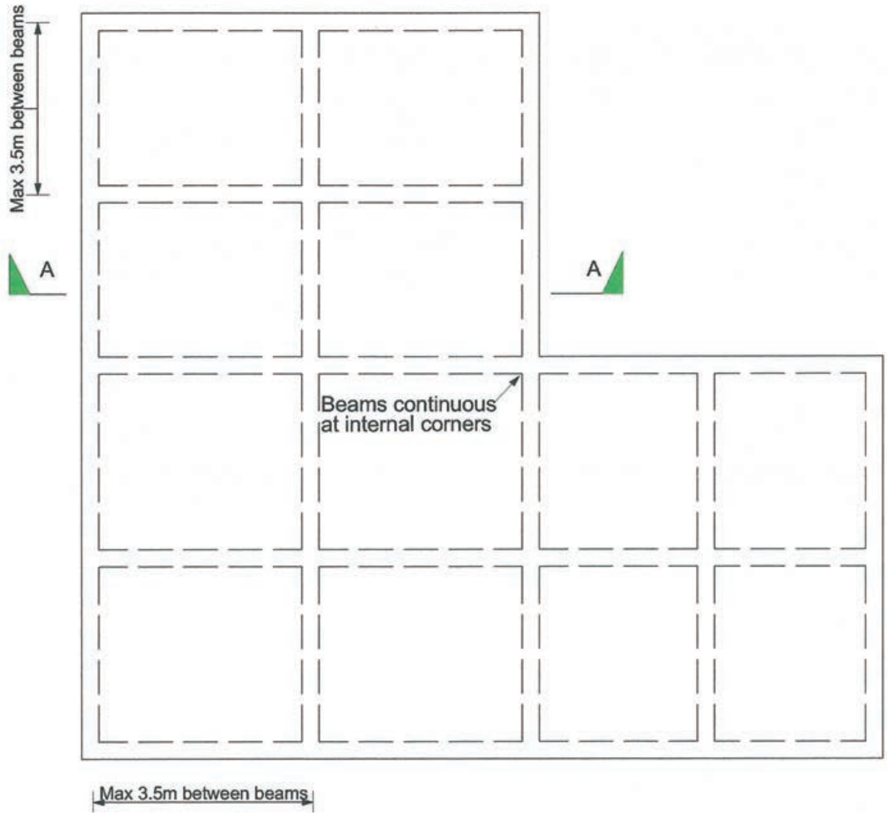
The ground immediately beneath the slab must have a minimum geotechnical ultimate bearing capacity of 200 kPa, or the slab should be subject to specific engineering design (see section 3.4.1). **Note: The thickness needs to increase to 400 mm for two-storey heavy-weight (brick veneer) construction with either a heavy or light roof cladding.**

UPDATE: December 2012

The treatment of service lines as they enter and travel within the slab requires careful consideration (refer to section 5.6).

Option 3 – Construct a generic beam grid and slab foundation.

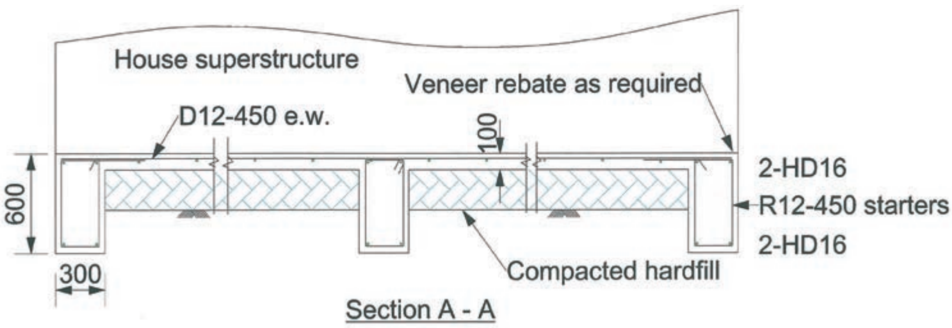
Figure 5.7: Enhanced foundation slab – Option 3 plan



Note: Reinforcing details are not sufficient for two-storey heavy-weight cladding (brick veneer) with a heavy roof but can be used for a two-storey heavy-weight cladding with a light-weight roof.

UPDATE: December 2012

Figure 5.8: Enhanced foundation slab – Option 3 cross-section



The ground immediately beneath the slab must have a minimum geotechnical ultimate bearing strength of 200 kPa, or the slab should be subject to specific engineering design (see section 3.4.1).

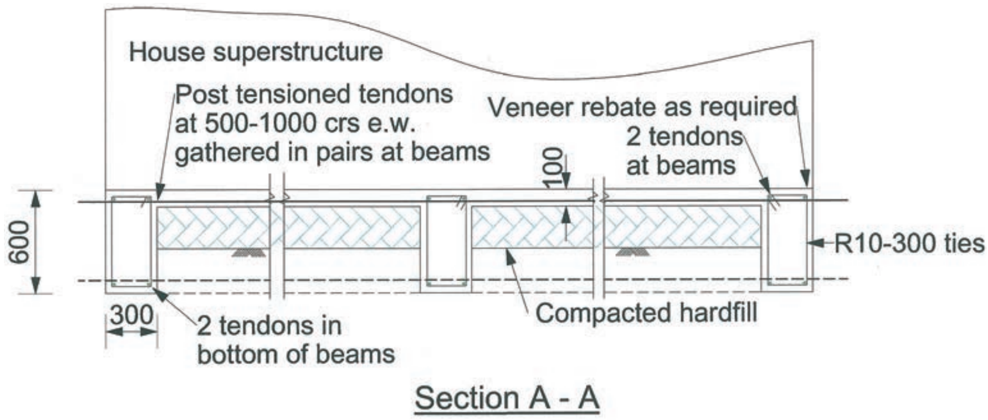
A variation to this option involves post-tensioning the slab using single 12.9 mm or 15.2 mm strand tendons in an unbonded format. The factory-applied greased and sheathed strands are supported in the slab on bar chairs and tensioned through mono-strand anchorages fixed at both ends through the perimeter formwork. Tensioning is carried out using calibrated centre-hole hydraulic jacks.

Post-tensioned slabs are tensioned to between 0.5 and 1 MPa (in time) to overcome drying shrinkage and give some bridging capacity. Spacing of the tendons is nominally 1 m centres each way.

This option requires specific engineering design.[3]

UPDATE:
December 2012

Figure 5.9: Enhanced foundation slab – Option 3 variation with post tensioning



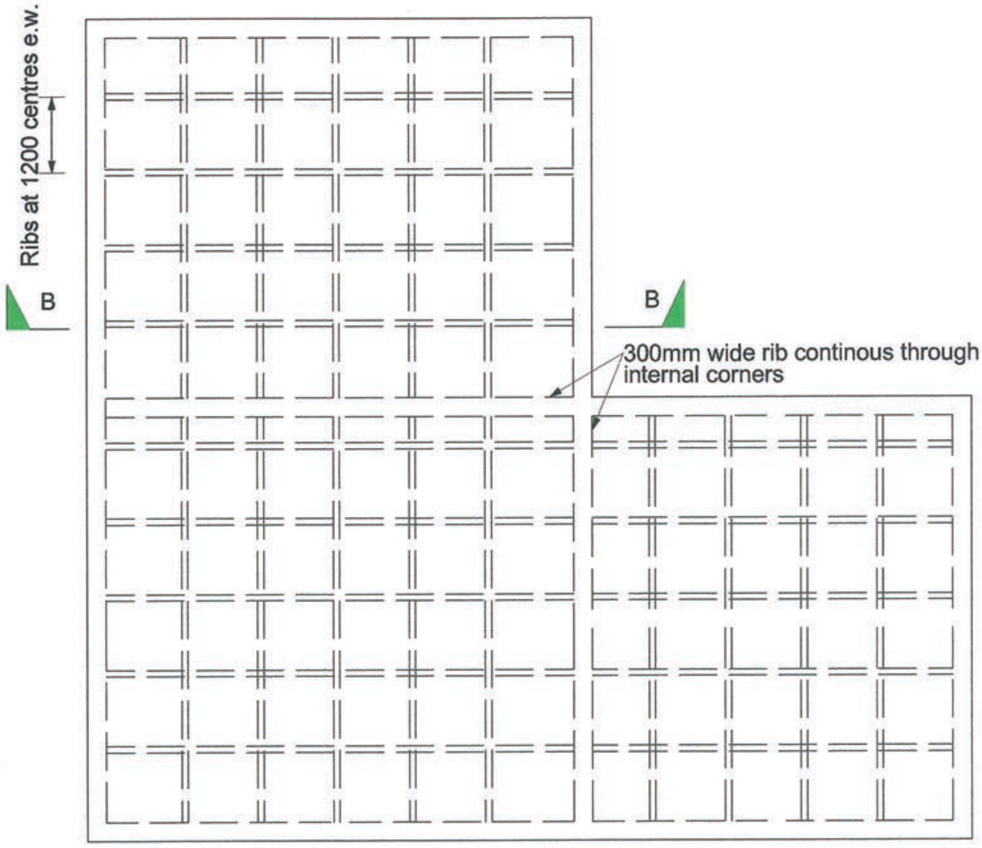
Note: Post tensioning strands are either 12.9 mm or 15.2 mm diameter and factory coated with grease inside an HDPE sheath, giving an overall outside diameter of 17 to 20 mm respectively. Strands are tensioned to provide 0.5-1.0 MPa compressive stress in the concrete.

For both Option 3 variations, it may be easier and more economical to construct the concrete foundation by replacing the compacted hardfill and soil beneath the slab down to the underside of the beams with polystyrene pods.

(3) Refer also to U.S. Post Tensioning Institute publications: Design and Construction of Post-Tensioned Slabs-On-Ground and Construction and Maintenance Procedures Manual for Post-Tensioned Slabs-On-Ground

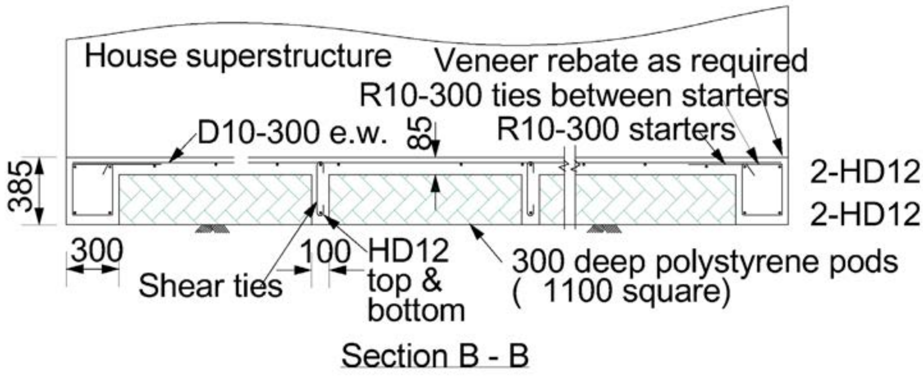
Option 4 – Construct a waffle slab over the existing soil

Figure 5.10: Enhanced foundation slab – Option 4 plan



Note: Reinforcing details are not sufficient for two-storey heavy-weight cladding (brick veneer) with either a heavy or light roof.

Figure 5.11: Enhanced foundation slab – Option 4 cross-section



The ground immediately beneath the polystyrene and ribs must have a minimum geotechnical ultimate bearing strength of 200 kPa, or the system should be subject to specific engineering design (refer to section 3.4.1). Shear ties in accordance with NZS 3101 are required in the ribs.

UPDATE:
December 2012

DELETION:
December 2012
Guidance on the use of deep piles is contained in Part C. Figure 5.11 has been deleted and is superseded by new guidance in Part C.

Option 5 – Deep piles

Install piles to a dense non-liquefiable bearing layer and construct a floor slab (refer to section 15.2)

5.3.2 Timber floor construction in TC2

Timber floors in combination with light-weight claddings and roofing provide several advantages with regard to ease of repair and relevelling.

A rebuilt timber ground floor should generally be constructed in accordance with NZS 3604. The advantage of this type of floor is that it is easy to relevel or repair because of the easy access, and its elemental nature allows straightforward replacement of damaged elements. Bracing demand will be low and standard details can be used.

The soil conditions at each site should be confirmed as suitable in accordance with the modified NZS 3604 procedure, as detailed in Table 5.2 and section 3.4.1.

Driven timber piles to NZS 3604 are suitable under suspended floors.

The level of timber floors should be set to provide a minimum crawl space under the joists of at least 450 mm (NZS 3604 requirement).

Type A dwellings

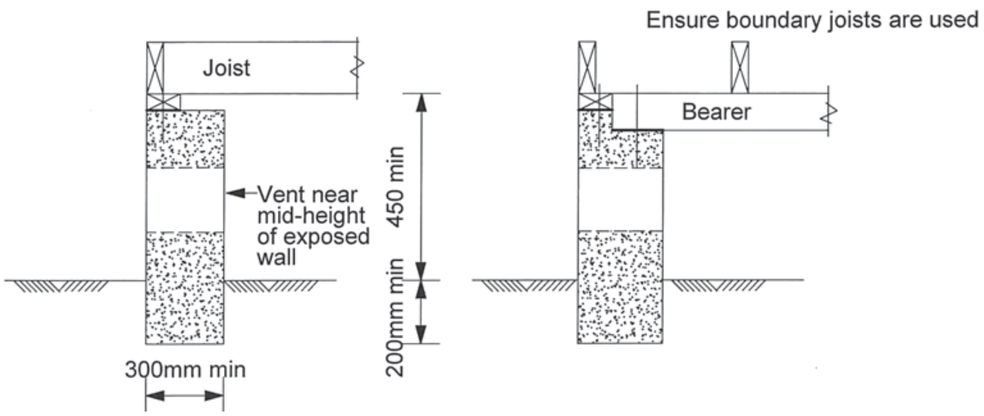
A one or two storey house with a light roof and light- or medium-weight wall cladding supported fully on an NZS 3604 shallow timber or concrete pile foundation is considered to be a valid option in TC2.

Type B dwellings

New foundation walls for one or two storey dwellings with light- or medium-weight cladding and roofing in TC2 should follow the details in Figure 5.12 below. Reinforcing details should be as shown in Figure 4.2a.

Deep piles installed under foundation walls are not within the scope of NZS 3604.
A suitable driving set and founding depth will be required to achieve the required bearing capacity, and the foundation wall will also need to be designed to span between the piles.

Figure 5.12: Timber floor with perimeter walls



Note: Reinforcement details as per Figure 4.2a

The vents in the foundation wall must be positioned near the middle of the wall below the top reinforcing bar, and not notched out of the top of the wall as is common in older houses in Christchurch.

Floor construction details in NZS 3604 are generally adequate, but in practice the jointing between members often falls short of what is required. This is particularly important where resistance to lateral spreading is required. The following should be noted:

- Pile to bearer connection: Ordinary pile connections in Figure 6.3 of NZS 3604. Braced pile connections in Figures 6.6 to 6.8. Anchor pile connection in Figure 6.9.
- Bearer to foundation wall connection: See Figure 6.17 of NZS 3604.
- Bearer butt end joints: See Figure 6.19 of NZS 3604.
- Joist butt end joints: See Figure 7.1 of NZS 3604.

5.4 Guidance for specific engineering design

UPDATE: December 2012

In many cases the '300 kPa' requirement for 'good ground' or the '200 kPa' requirement for Options 1 – 4 may not be met. Often, simple calculations of actual bearing stresses will allow redimensioning of foundations (refer section 3.4.1 for details). In other cases, specifically designed solutions other than those provided above may be devised. In these cases, the following criteria should be satisfied:

- Geotechnical investigations of the site in accordance with Table 5.2 are to be carried out before designing the foundation system.
- Design for the potential for lateral ground spreading to the extent indicated from the geotechnical investigation.

For Type C house foundations in TC2

- Design Type C house foundations for the potential for differential settlement of the supporting ground that will allow a maximum unsupported length for the ground floor of 4 m beneath sections of the floor and 2 m at the extremes of the floor (ie, ends and outer corners).
- Design to ensure that the floor does not hog or sag more than:
  – 1 in 400 (ie, 5 mm hog or sag at the centre of a 4 m length) for the case of no support over 4 m (see Figure 5.13), and
  – no more than 1 in 200 for the case of no support of a 2 m cantilever at the extremes of the floor (see Figure 5.13).
- Appropriate provision should be made for 'flexible' services entry to the dwelling to accommodate the potential differential settlement of the foundation as indicated in the geotechnical report.
- Designs should accommodate settlements as indicated in Table 5.3.