

Mark Gunner
Oakhills Construction Ltd
1, Long Street,
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Gloucestershire,
GL8 8AA

GGT/Q1902-15

18th April 2019

Dear Mark,

**PRELIMINARY GEOTECHNICAL SLOPE STABILITY ASSESSMENT,
LITTLE ORCHARD, LOWER KINGSDOWN, CORSHAM, SN13 8 BD.**

Following your recent instructions, we are pleased to report as follows:

1.0 INTRODUCTION

Mr and Mrs Pim de Witte purchased Little Orchard in early 2018. They have recently had the dormer bungalow demolished and they are now proposing to have a new property constructed over a similar plan area. Oakhills Construction Ltd are their contractors for the new-build. Charles Manning is the project architect.

Intégrale Ltd are commissioned to complete a Preliminary Geotechnical Slope Stability Assessment, to be followed by a suitable scope of intrusive ground investigation. The strategy being adopted was outlined in notes prepared following a site visit on 1 March.

This initial report describes the main features of the site and the published geology, summarises other nearby ground investigations and outlines a strategy for dealing with the potential site instability aspects. It anticipates the depth to the basal slip surface of ancient Landslip and it reports on an initial parametric slope stability study, before concluding on the likely current Factor of Safety against instability (FoS). It also indicates the FoS required for long-term stability following construction of the new house, and discusses appropriate foundations and retaining works for two alternative schemes, namely either including a basement, or not including a basement.

2.0 THE SITE

The property is about 6.5 km east, north-east of Bath City Centre; it has a National Ordnance Survey grid reference of .

The site is approximately 65 m long, down from the east to west, and typically 25 m wide. The former house was demolished in February 2019, and the levelled plot where it was located the south-east end, is about 20 m by 10 m in plan.

It is bounded upslope to the south-east by the access road, the levelled plot being about 2.5 m lower. In between are low masonry stone and blockwork retaining walls. Temporary access down onto the proposed building plot, is via a ramp constructed at the southern corner. The new lower formation level as locally, been excavated, below the footing of the retaining wall. Due south of the site, is a split-level contemporary house, whilst to the north-east another new-build house is under construction. The recently demolished house on that adjacent site was known as Lawton, and its' boundary with Little Orchard includes a leylandii conifer hedge.

A new earth bank has been constructed- out and downslope from the levelled plot on which Little Orchard previously sat. The architect's working drawings currently indicate no other significant changes to the rear garden downslope.

Further details can be seen on the site photographs appended.

Mark Lovell, a structural engineer, visited the property in early February, before it was demolished. He spoke to the writer and confirmed that there had been significant cracking within both the superstructure as well as the surrounding terraces and steps; he believed the structural distress to be due mainly to the dormer bungalow having been located on unstable Fullers' Earth Landslip, on inadequate foundations. Service trenches nearby may also have been located inappropriately, which may have worsened the stability.

3.0 PUBLISHED GEOLOGY

According to the most recent BGS geology map (Sheet 265, Bath) this site is located on Ancient Landslip, apparently derived predominantly from the Fullers' Earth Formation. This is predominantly a sequence of over-consolidated clays and mudstones with subordinate limestone bands. Directly upslope on the hillside, is 'cambered' Great Oolite Limestone.

Previously landslipped Fullers' Earth strata in this district are notorious. Structures built on conventional, unreinforced shallow footings can exhibit significant structural distress and modern day re-activations of slope instability do occur. Many new houses are now being supported on deep piled foundations, taken down through the Basal Slip Surface of the ancient Landslip and designed to accommodate lateral earth pressure. It is important to accurately assess the site specific depth of landslip, and the lateral loading due to unstable strata upslope.

4.0 OUTLINE HISTORY

The Tythe map of 1840 shows the site as predominantly rough open ground, with a few small cottages off to the east, and somewhat more distant to the west. That did not change on the 1900, 1921 and 1923 map editions. It seems likely that the previous house, believed to have dated to the 1940s or 1950s, may well have been the first development on the site.

Downslope, about 100 – 125 m from Little Orchard is a bulge of land at and beyond the field boundary. This is the toe of an old mudslide and it seems likely that the site of the house was within the influence of that mudsliding; the topography of the mudslide toe appears quite fresh and therefore it may be (a reactivation of movement) of historic age rather than being 'ancient'.

5.0 NEARBY GROUND INVESTIGATIONS

5.1 By Integrale

An investigation and slope stability assessment were completed at Tanglewood, c. 25 m south, in 2001. Investigations included mechanically dug trial pits and window sample boreholes. That site straddles the boundary between the foundered Great Oolite Limestone and landslipped Fullers' Earth. The BGS geology map shows that site being at the south-west end of the Corsham Fault, and this may have enhanced groundwater flow worsening stability. These investigations were also used in a later assessment at Hornbeams, a neighbouring bungalow (c. 50 m SW of Little Orchard) in 2018.

An interpretive geological section suggests 5-6m of yellowish brown, soft to firm/firm, silty sandy Clay with some limestone gravel and cobbles, forming the ancient Fullers' Earth Landslip. The underlying Insitu Fullers' Earth was firm to stiff/stiff/very stiff, dark grey, silty Clay. Groundwater seepage was encountered at c.2-3m depth. Laboratory classification tests revealed the clay soils to be of High Plasticity. Sulphate concentrations were not raised and special measures were not required to protect buried concrete.

An investigation and slope stability assessment was completed at Glen Echo, c. 75 m north-east in 1991. Investigations again included mechanically dug trial pits and 'Marlow Mole' auger and rotary boreholes, in a similar geological location to the site described above. Directly downslope of landslipped blocks of limestone, the brown-grey, Fullers' Earth Landslip was proven to be 6-7m deep, with the Insitu strata beneath being stiff/very stiff grey Clay with thin beds of limestone. The deepest borehole was taken to c.16m depth.

Investigations and slope stability analyses were undertaken at The Firs and Kingsdown Livery Stables between 2000 – 2002, typically 100 – 150 m north-east of Little Orchard. Investigations at 6, The Firs, utilised window sample boreholes. The boreholes in the upslope area were terminated between 2 – 3.5 m on limestone bedrock. A greater thickness of c.5m of Landslipped Fullers' Earth was anticipated in the lower area.

In 2001, Integrale completed slope analyses for the Livery Stables, following examination of the trial pits, because there was a long history of ground movements (worsened in the winter of 2000/2001) and part of the stables were demolished following severe structural distress. We oversaw a program of slope stability drainage installation to reduce the risk of future damaging slippage.

5.2 By Others

A ground investigation and geotechnical assessment were completed for the neighbouring property Lawton, in mid 2017. Integrale were provided with a copy of that report by Oakhills Construction. 4 dynamic sample boreholes were advanced to c. 5.5 m depth, and 2 mechanically dug trial pits to c. 4m.

The investigation proved between 0.5 – 3 m of Made Ground (typically brown sandy clay overlying sandy, clayey gravel), overlying soft becoming firm/stiff, yellow-grey-brown sandy silty Clay of the Fullers' Earth. The investigation does not appear to demarcate the depth to the basal slip surface, due to the ancient instability.

The geotechnical advisers concluded that the site is unstable and that special stability works are required. However, they said that conventional foundations may be suitable, founding into the FE Clay beneath the Made Ground.

Since that investigation does not draw a distinction between previously landslipped strata, and underlying insitu ground, it is necessary to make a judgement of whether it has proven undisturbed strata at or above 5.5 m depth. Based on the strata descriptions provided, and the results of SPT testing, Integrale tentatively suggest that the basal slip surface could be at typically 4-5m depth.

5.3 Likely Depth to Basal Slip Surface at Little Orchard

In line with the above, it seems quite likely that the basal slip surface could be at a depth of 5m to 7m, beneath the proposed building plot. That is based on the inferred geological sections established at Tanglewood, and at Glen Echo. That is an adequate judgement on which to initiate preliminary slope stability analysis.

6.0 PRELIMINARY SLOPE STABILITY ASSESSMENT

6.1 General

It is appropriate to consider both 'Global' and 'Local' Stability. From the previous Integrale investigations we have boreholes and trial pit information nearby from both the Glen Echo and Tanglewood/Hornbeams sites. Here the anticipated superficial geology and ground conditions are likely to be very similar to Little Orchard.

Tentative up and down slope Geological Cross Sections have been prepared for each of those two sites. On each of them we have indicated the most likely comparable, offset location of the proposed Little Orchard Building Plot. It can be seen that the anticipated ground conditions are very similar. We have also returned to the Little Orchard site and with simple surveying techniques (taped lengths and slope inclinations using an inclinometer) we have established a site specific section for more detailed analysis. As well as interrogating likely

FoS, for a variety of slip geometries, we have computed the likely required Horizontal Restoring Forces (HRF) for 'no basement' and basement depths of 2 m, 3 m, 4 m and 5 m.

Appended to this report are the sections we have analysed, the typical sliding modes we have considered (these having been based on similar slope failures we have seen on other nearby Bath hillslopes and other previous projects), and also included are the tabulated results of FoS computed for the analyses completed.

6.2 Effective Shear Strength Parameters

From previous Integrale projects, the published technical literature (e.g. Cripps and Taylor, 1981, Engineering Properties of British Mudrocks, QJEG) and other documented case histories, we would expect the 'local residual effective shear strength' along existing slip surfaces to generally be in the range 12.5 – 17.5°. We have initially considered 12.5°, 15° and 17.5°, before fine tuning the value in our back analysis. We have assumed residual cohesion as zero (as is normal practice).

By inspection, it has been tentatively concluded that the 'local residual effective shear strength' for the Little Orchard building plot, is likely to be about 16°.

6.3 Modes of Failure

For the Glen Echo section, three circular failures are considered, encompassing the site (c. 15 m in extent), and extending downslope between 25 – 40 m, referenced Slips A, B and C, respectively. A more extensive 75 m long noncircular slip, referenced Slip D, extending both upslope and downslope, has also been analysed.

For the Hornbeams/Tanglewood site, two other similar, shallow circular failures have been considered and referenced Slip BB and Slip DD.

6.4 Global Stability

Stability computer runs, utilising the software developed and offered under licence by OASYS Ltd, and known as SLOPE, have been interrogated for the three values of residual internal friction described above, without groundwater ('Dry') and with groundwater at 2 m depth, and for each of the slip modes, described. The tabulated Factors of Safety Against Instability are appended to this report.

For both the Glen Echo and Hornbeams sections, it was tentatively concluded that local residual effective shear strength of between 15° and 17.5°, is likely to apply. A value of c. 16° has been adopted for the Little Orchard building plot, for this preliminary slope stability assessment.

Four supplementary slip geometries have been investigated, extending upslope from the building plot. Slip E extends 30 m upslope, and 20 m downslope of the building plot, with the basal slip at (between 4-8m, averaging) 6 m depth. A similar, but less extensive Slip F, is 30 m remote upslope, but daylights at the foot of the retaining wall supporting the upslope plot boundary, (between 2-4m, averaging) typically to 3 m depth. Slips G and H are shallow circular failures, about 2-4m deep, also daylighting at the foot of that retaining wall, and extending 30 m and 15 m upslope of it, respectively. By inspection, Slip H is the most critical, with computed FoS of about unity, particularly when water pressures are introduced. It was noted that there is evidence of a tension crack in the hard surface of the track, directly upslope of the site. That tends to support the hypothesis that Slip H is the most critical potential failure.

6.5 Horizontal Restoring Force

We extended the above analyses to judge what HRF would be required to predict a Factor of Safety Against Instability of 1.3. This is a 'generic' value indicative of stability to be achieved for design purposes, in cohesive materials. A higher value of 1.5 is usually adopted for granular materials.

The minimum HRF required would be about 40 kN/m², if the existing plot surface were to be the development level.

However, it is possible that the client may decide to pursue a scheme involving a basement. Consequently, we have considered a range of reduced elevations between 1 m and 5 m below current site level. For a 1 m, 2m,

3m, 4m and 5m reduced level, we have computed HRF's of c. 75 kN/m², 125 kN/m², 200 kN/m², 275 kN/m² and 375 kN/m², respectively.

Based on past experience, Intégrale infer that a basement deeper than about c. 3 m, may well not be cost-effective.

7.0 GENERAL DISCUSSION.

It seems likely that the depth to the Basal Slip Surface, below the Little Orchard building plot could be 5-7m. The Fullers' Earth Landslip materials are likely to include soft to firm, yellow and brown highly plastic Clay, with varying proportions of limestone gravel and cobbles (with occasional limestone boulders). It may be that Window Sampling boreholes could 'hang-up' on limestone obstructions within the Landslip, and that drilling technique has no facility for boring deeper into harder materials. Consequently, Intégrale believe that conventional Percussion Boring, with a Shell and Auger rig, is to be the preferred drilling technique. (We have spoken to an experienced driller who says he can manoeuvre is rig up and down the steep temporary ramp, to gain access onto the levelled site). This method of boring has the facility of heavy duty chiselling to breakthrough some obstructions, and to assist deeper boring into weathered, more rocky strata. It will also be significantly less expensive than conventional rotary core drilling.

The main findings from our Preliminary Slope Stability Assessment are as follows:

1. The Local Residual Effective Shear Strength, for the Little Orchard building plot, is likely to be about 16°.
2. The most critical failure modes are relatively restricted circular or noncircular 'slumps' daylighting either at the foot of the current retaining wall, or at the base of whichever reduced elevation basement slab level is chosen. Those slumps are unlikely to extend upslope more than about 15 m, and 5 m may be more realistic.
3. If no basement is to be included in the scheme, the new foundations will need to extend through the Landslip, and into the undisturbed strata beneath. Consequently, some form of piled foundation will be appropriate. From past experience, bored piling will be preferred to driven. Bored piles should be taken an adequate depth below the basal landslip surface. Depending on the overall scheme of piling adopted, the piles could extend almost twice the depth of the Landslip thickness. 10-15m piles could be appropriate, unless supplementary raking piles are included in the scheme.

It will be appropriate to sink investigation borings at a minimum of two locations, to a depth of 10 – 15 m.

For a scheme without a basement, and HRF of about 40 kN/m² a new retaining structure, may well be appropriate.

4. If a basement is to be included within the scheme, then a contiguous bored pile wall may be the most technically and cost-effective method to adopt. That wall can accommodate a 2-3m deep basement, and may need to be designed for an HRF in the range 150 – 200 kN/m².

The intrusive ground investigation is due to commence in a few weeks time. At this stage it would be appropriate to issue a copy of this report to an experienced bored piling contractor to estimate the size of bored piles required, together with the appropriate reinforcement. That will enable realistic costings to be prepared for both the 'no basement' and 'basement' options so that appropriate decisions can be reached.

END OF LETTER REPORT

We hope that the above and the attached are suitable for your present purposes. I will be writing to you separately to provide a detailed breakdown of the drilling, testing and technical supervision/reporting costs for the intrusive investigation. Please do not hesitate to give me a call if you have any queries.

Yours sincerely

Gareth Thomas
Managing Director.

Enclosures: Sections for Slope Analysis
Tabulated Results of Slope Analyses.

Geotechnical • Engineering • Geoenvironmental • Consultancy
Understanding Ground Conditions

9287 Little Orchard, Lower Kingsdown Road

Re: Summary of Preliminary Slope Stability Analyses

18th April 2019

GLOBAL STABILITY

Little Orchard & Glen Echo Section

	12.5°		15°		17.5°	
	Dry	GW at 2m	Dry	GW at 2m	Dry	GW at 2m
Slip A	0.90	0.60	1.09	0.75	1.30	0.90
Slip B	1.05	0.75	1.25	0.95	1.50	1.10
Slip C	1.25	1.05	1.50	1.25	1.75	1.50
Slip D	0.90	0.55	1.10	0.65	1.30	0.75

Little Orchard & Hornbeam Section

	12.5°		15°		17.5°	
	Dry	GW at 2m	Dry	GW at 2m	Dry	GW at 2m
Slip BB	0.95	0.80	1.15	0.95	1.35	1.10
Slip DD	0.90	0.65	1.10	0.80	1.30	0.95

LOCAL STABILITY

Case A – As Present

	12.5°		15°		17.5°	
	Dry	GW at 2m	Dry	GW at 2m	Dry	GW at 2m
Slip E	0.9	0.65	1.15	0.75	1.35	0.9
Slip F	0.8	0.65	0.95	0.8	1.15	0.95
Slip G	0.8	0.7	0.95	0.85	1.2	0.98
Slip H	0.9	0.85	1.05	1.0	1.2	1.15

	16°	
	Dry	GW at 2m
5m Upslope	0.55	0.55
10m Upslope	0.9	0.9
15m Upslope	1.2	1.15
HRF $\geq$ 1.3 kN/m ²	35-40	35-40

Results shown in tables above are Factors of Safety Against Instability (FoS)

Case B – With a 5m Basement

	12.5°		15°		17.5°	
	Dry	GW at 2m	Dry	GW at 2m	Dry	GW at 2m
Slip E	0.75	0.45	0.9	0.55	1.05	0.65
Slip F	0.8	0.65	0.95	0.8	1.15	0.95
Slip G	0.8	0.7	0.95	0.85	1.1	0.95
Slip H	0.9	0.85	1.05	1.0	1.2	1.15
Horizontal Restoring Force Required for FoS ≥ 1.3 kN/m ²	1,050	1,400	700	1,000	350	700

	16°	
	Dry	GW at 2m
5m Upslope	0.4	0.25
10m Upslope	0.45	0.3
15m Upslope	0.75	0.5
HRF ≥ 1.3 kN/m ²	350	400

	16°		17.5°	
	Dry	GW at 2m	Dry	GW at 2m
5m Upslope	1.5	1.7	1.5	1.65
10m Upslope	1.15	1.15	1.15	1.15
15m Upslope	1.45	1.2	1.5	1.25
HRF ≥ 1.15 kN/m ²	320	375	300	360

Results shown in tables above are Factors of Safety Against Instability (FoS)

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Case B – With a 4-4.5m Basement

	16.5°		17.5°	
	Dry	GW at 2m	Dry	GW at 2m
5m Upslope	0.45	0.35	0.5	0.4
10m Upslope	0.65	0.5	0.7	0.5
15m Upslope	0.85	0.6	0.9	0.65
HRF ≥ 1.15 kN/m ²	215	285	200	265

Case B – With a 3-3.5m Basement

	16°		17.5°	
	Dry	GW at 2m	Dry	GW at 2m
5m Upslope	0.6	0.5	0.65	0.55
10m Upslope	0.75	0.6	0.8	0.65
15m Upslope	1.02	0.7	1.1	0.8
HRF ≥ 1.15 kN/m ²	145	200	125	175

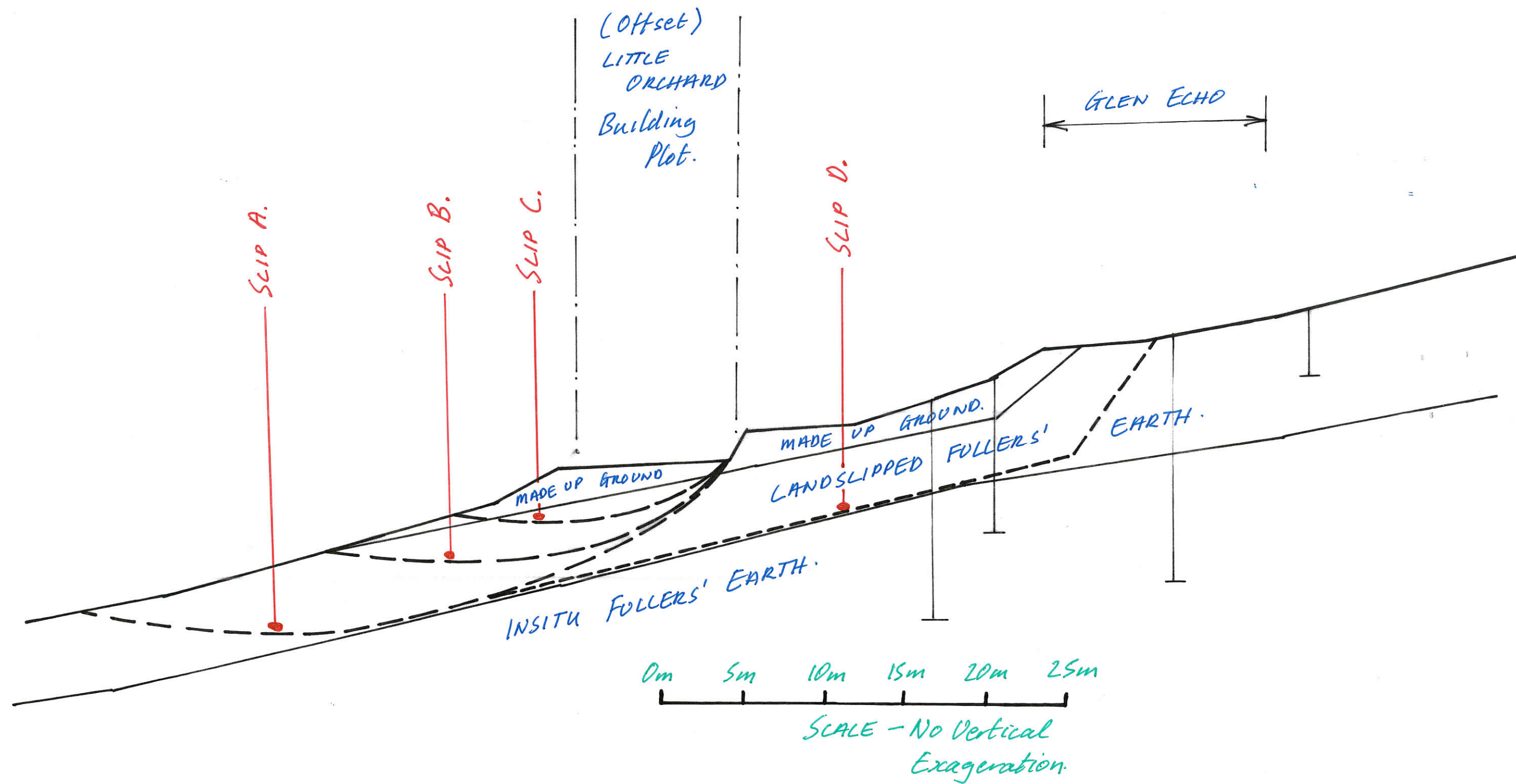
Case B – With a 2-2.5m Basement

	16°		17.5°	
	Dry	GW at 2m	Dry	GW at 2m
5m Upslope	0.75	0.6	0.8	0.7
10m Upslope	0.85	0.65	0.9	0.75
15m Upslope	1.15	0.85	1.25	0.95
HRF ≥ 1.15 kN/m ²	90	125	75	110

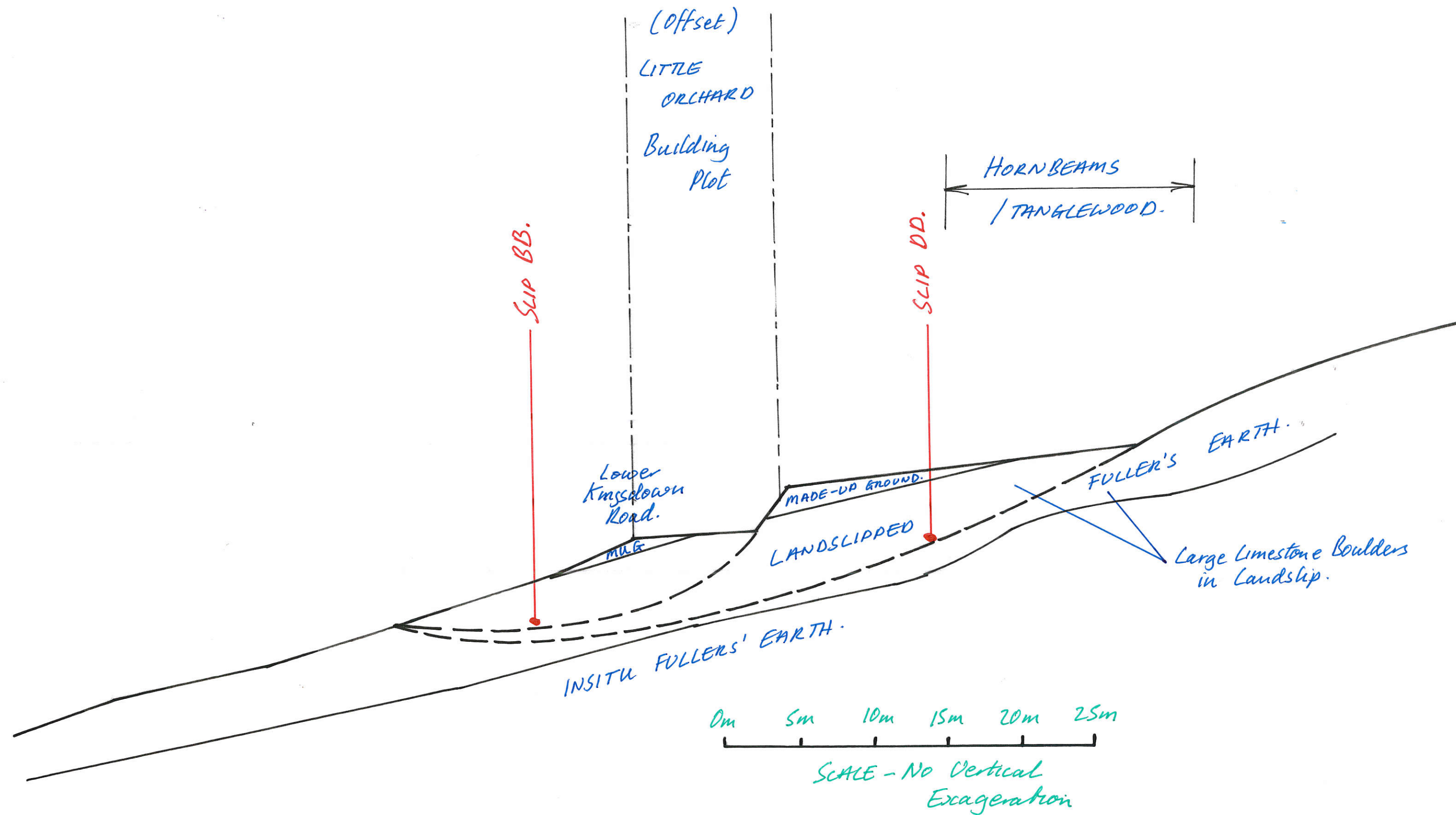
Case B – With a 1-1.5m Basement

	16°		17.5°	
	Dry	GW at 2m	Dry	GW at 2m
5m Upslope	0.85	0.75	0.9	0.8
10m Upslope	1.01	0.9	1.1	1.01
15m Upslope	1.15	0.95	1.25	1.05
HRF ≥ 1.15 kN/m ²	50	75	40	50

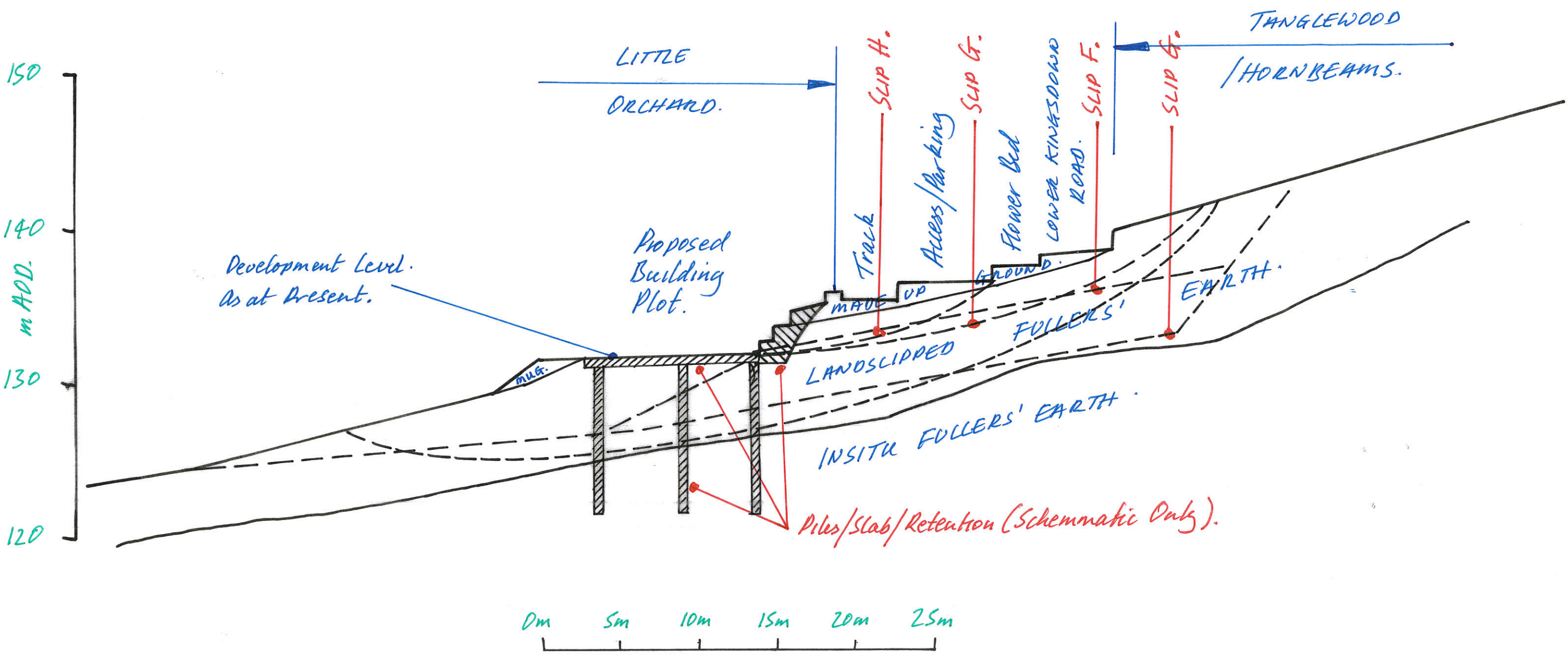
Results shown in tables above are Factors of Safety Against Instability (FoS)



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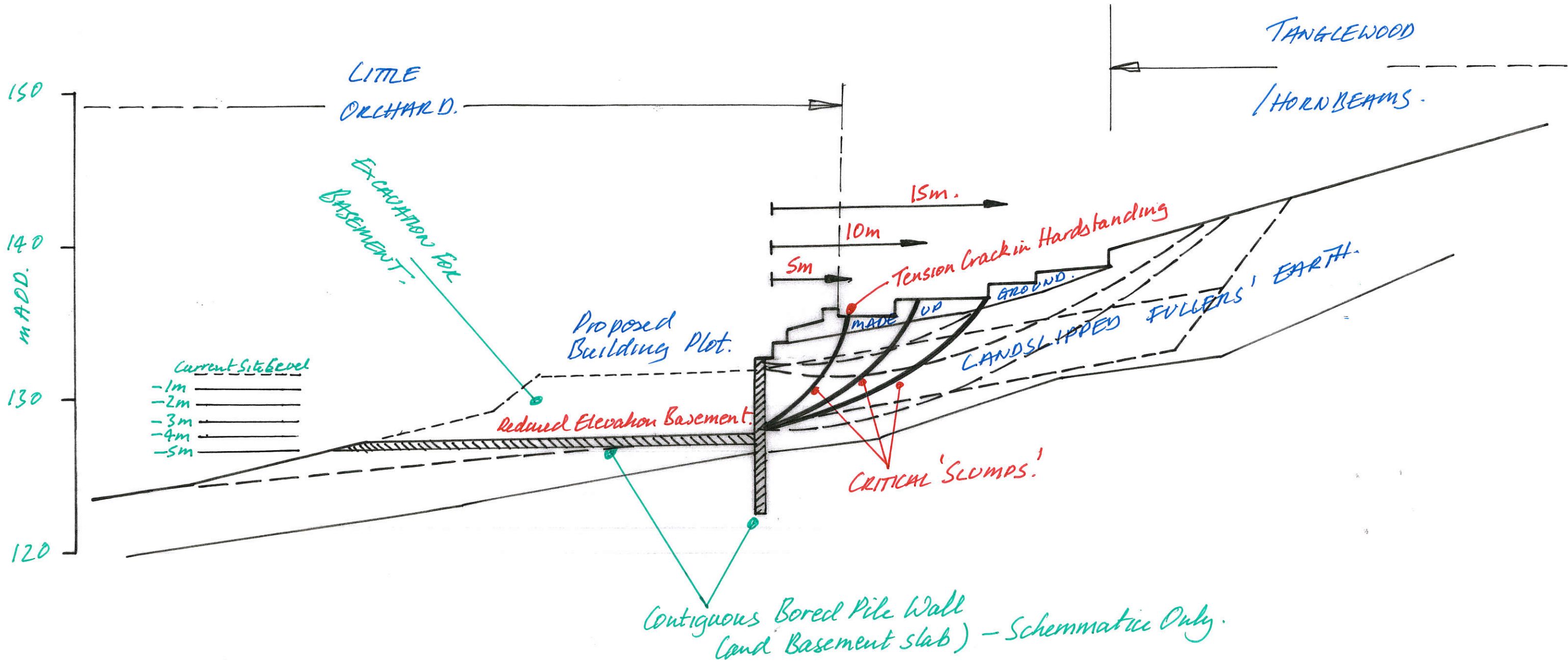


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SCALE - NO Vertical Exaggeration.

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