

Our ref: JEZ8883/DAPPERS LANE ANGMERING/PJ/RW/L001v1

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Dear Christian,

GEOTECHNICAL AND HYDROGEOLOGICAL REVIEW DAPPER'S LANE, ANGMERING

Independent review and CAT3 Check of Attenuation Basin Liner with respect to Hydraulic Uplift

1 INTRODUCTION

Further to your (Persimmon) instruction dated 22nd February 2022 and our earlier fee proposal of 27th January 2022, reference JEZ8883/Dapper's Lane Angmering/PJ/RW/Feev1 please find below the findings of our independent review and CAT3 Check of Attenuation Basin Liner with respect to Hydraulic Uplift associated with the attenuation basin proposals for the Persimmon's proposed development at Dapper's Lane, Angmering.

Reference has been made solely to a defined list of scoping documents which set out the background to the project and provided a data file containing pertinent information. A list of that information for clarity is provided as Enclosure A to this letter. No physical inspection or further investigatory or monitoring works have been undertaken.

2 BACKGROUND

2.1 Planning Status

We understand that Persimmon Homes Thames Valley as the developer for the site submitted detailed Civil Engineering design (including drainage proposals for the site) on 30th April 2021 to Arun District Council to satisfy and discharge Condition 18 and 19 of planning permission A/76/20/PL dated 9th February 2021.

As part of those proposals a scheme was developed to provide a geosynthetic lined attenuation basin. Queries have been raised by Arun District Council specifically on the attenuation basin constructability, with respect to the interpreted groundwater level and its effect on the associated attenuation basin liner.

2.2 Site Investigations Undertaken to Date

A number of ground investigations have been undertaken at the site including the following:

- May 2019 – LEAP - Dapper's Lane - Phase I and Phase II Site Investigation Report LP1877.
- January 2020 – LEAP - Groundwater Winter Monitoring, Land off Dapper's Lane, Angmering. Letter Report Reference MW/20/LP1877.
- September 2021 – Jomas - Dapper's Lane - Geotechnical Deep Boreholes P3876J2380.
- November 2021 – Ibex - Dapper's Lane - Pond Boreholes Factual Letter Report ICE0013

With the exception of the Jomas investigation a number of groundwater monitoring installations were included within the scope of the works, and the results of monitoring are discussed further below.

It is noted that the LEAP Investigation borehole and trial pit logs do not contain ground elevations, and as such for the purpose of this review, ground elevations have been estimated using the LEAP location plans and the topographic survey (Midland Survey Ltd H1027/R1 dated March 2017).

3 TOPOGRAPHICAL AND GEOLOGICAL CONDITIONS

3.1 Topographical Setting

The subject site is situated on the southern flank of a ridge that is located to the north of Angmering. As shown on the topographic survey drawing, the site rises from an elevation of 19.41mAOD located in the southwestern corner of the site, in a general north easterly direction, to a maximum elevation of 29.41mAOD. The fall across the site is approximately 1 (v) in 17 (h) in the northern most field, slackening to approximately 1 in 30 across the southern fields. Based on an inspection of the topographic levels and associated inferred contours, there does not appear to be evidence of any depressional features that would enable ponding of surface water runoff.

3.2 Geological Setting

The 1:50 000 scale geological map of the area (BGS, 2006) indicates the natural geology in the area of the Site comprises the London Clay Formation with the Lambeth Group and White Chalk Formations at depth. Historical borehole and water well records held in the British Geological Survey archive indicate the London Clay Formation is likely to extend to between approximately 18m below ground level (mbgl), with the Lambeth Group (Formally Woolwich and Reading Beds) extending to a depth of circa 51.5mbgl. (See Enclosure B)

Head including possible River Terrace Gravel (valley gravels) are shown overlying the London Clay Formation over the majority of the site. These typically comprise gravelly clays and gravel layers of varying thicknesses, of a total of up to 7m in thickness.

There is no record of Made Ground at the site rather it appears to be in agricultural land use, and records of land drains are recorded within the topsoil / subsoil.

3.3 Sitewide Geology

The site wide geology has been established with reference to the following reports:

- May 2019 – LEAP - Dapper's Lane - Phase I and Phase II Site Investigation Report LP1877.
- January 2020 – LEAP - Groundwater Winter Monitoring, Land off Dappers Lane, Angmering. Letter Report Reference MW/20/LP1877.
- September 2021 – Jomas - Dapper's Lane - Geotechnical Deep Boreholes P3876J2380.
- November 2021 – Ibex - Dapper's Lane - Pond Boreholes Factual Letter Report ICE0013

The various site investigations at the site have generally confirmed the anticipated sequence of geology as mapped by the BGS. The Head deposits at the site comprise a variable thickness of orange brown gravelly

clay which towards the south of the site is typically underlain by variable and increasing thicknesses of very gravelly clay/clayey gravel (Valley Gravel).

The investigations to date have then shown the Head and Valley Gravel deposits to be underlain by the basal beds of the London Clay, which typically comprise stiff grey slightly silt and slightly sandy Clay. It is noted however that on occasion the London Clay is logged as containing extremely weak claystone / mudstone gravel.

None of the site investigations reviewed penetrated the full thickness of the London Clay, and as such it is inferred to be approximately 18m in thickness based on the historical BGS boreholes referred to in section 3.2 above. See also Enclosure B.

3.4 Geological Conditions in relation to the proposed Attenuation Pond

With respect to the geological conditions at the location of the Attenuation Pond reference has been made to the following Borehole records:

- May 2019 – LEAP
Boreholes WS3, HA1 and Trial Pit TP6.
- January 2020 – LEAP
Borehole WS102.
- November 2021 – Ibex
Boreholes WS01, WS03, WS04, WS05, WS06 and WS08.

In summary, the various investigation have shown that persistent gravel layer has been encountered typically at along the southern boundary of the site, varying in thickness from 0.35 to 1.3m. Furthermore, the underlying London Clay is shown to have an undulating surface along the length of the pond such that the base of the gravel deposits varies from 16.33mAOD (WS08), to 17.49mAOD (WS01), i.e., rising west to east. The centre of the pond, at WS05 however forms a slight ridge at 17.90mAOD forming a shallow buried valley type feature either side trending northwest to southeast.

Table 3-1 below and Drawing No. 9452/0002 in Enclosure C shows the elevations at the top of the valley gravel, it's thickness and basal elevation (Top of London Clay).

Table 3-1 Granular Horizon in area of Attenuation Pond

Location	WS08	WS3*	WS06	WS05	WS04	WS102*	WS03	WS01
Ground Level (mAOD)	19.78	20.13	19.89	20.05	20.38	20.93	20.48	20.94
Total Thickness of Superficial Soils (m)	3.45	3.00	2.70	2.15	3.20	>3.45	3.10	3.45
Top of Granular horizon(s)								
Depth (mbgl)	2.20	0.40/ 2.25	1.95	1.30	1.90	0.80	2.50	3.10
Elevation (mAOD)	17.58	19.73/ 17.88	17.94	18.75	18.48	20.13/ 17.93	17.98	17.84
Thickness of granular horizon (m)	1.25	0.70/ 0.75	0.75	0.85	1.30	0.80/ >0.45	0.60	0.35
Top of London Clay (mAOD)	16.33	17.13	17.19	17.90	17.18	<17.48	17.38	17.49

*Inferred from BH logs based on observations.

4 HYDROGEOLOGICAL CONDITIONS

The hydrogeological setting of the site comprises two separate groundwater bodies. The principal Aquifer at depth is formed from the White Chalk Formation which is under sub artesian conditions created by overlying cohesive strata within the Lambeth Group and London Clay Formations. Above this, the hydrogeology

comprises a shallow aquifer within the granular clayey gravel/gravelly clay layers found within the within the Head deposits.

4.1 Hydrogeological Setting

A review of the BGS borehole records (Enclosure B) shows that the White Chalk at depth constitutes a Principal Aquifer.

- The well records held in the BGS digital archive show that during the drilling of a well (TQ00NE63) in April 1976 at Water Lane, Hammerpot New Barn in Angmering, (approximately 280m to the east of the site), that water was struck at 52.5mbgl, 70mbgl and 126mbgl, within the White Chalk Formation. The water was sub artesian in nature with a resting water level recorded at that time as being 27mbgl (circa 0.2mAOD). In August 1994 the resting water level was recorded as being at 24.94mbgl. It is noted however that the borehole was cased during drilling and remained cased in the well construction to a depth of 70mbgl.
- A well drilled in 1935 located 200m south of the site at The Nursery at 1 Dapper's Lane (TQ00SE4), reveals that a seepage was recorded at 11.2mbgl, within the London Clay/ Lambeth Group, and also at 54mbgl within the White Chalk. The sub artesian resting water level was anecdotally recorded in 1957 as being circa 12mbgl.
- A well drilled in 1938 located 200m southeast of the site at Chantryfield Nurseries (TQ00SE6), reveals that water was struck at 61.4mbgl and the sub artesian resting water level was at 13.4mbgl (4.6mAOD).

The overlying Head Deposits are recorded as being a Secondary (undifferentiated) Aquifer. Whilst the BGS records do not report monitoring of groundwater within this deposit, and that wells historically have utilised the sub artesian water from the deeper White Chalk Aquifer, water within the gravel layers above the London Clay are likely to be present. In addition, whilst the London Clay is typically a non-aquifer (classified by the Environment Agency as Unproductive Strata), the nature of the basal beds of the London Clay can become less cohesive in nature and can themselves contain shallow groundwater on occasion.

The shallow groundwater within the gravel beds, can become confined by overlying more cohesive less permeable strata, and so can also exist under sub artesian conditions where the geomorphology of the area allows accumulation of water to occur.

4.2 Sitewide Hydrogeology and Groundwater Monitoring

As part of the site investigations undertaken at the site and number of groundwater monitoring installations and monitoring rounds have been undertaken at the wider development site. These are summarised below:

May 2019 – LEAP - Dapper's Lane - Phase I and Phase II Site Investigation.

The site investigation included the installation of groundwater monitoring standpipes in 4No. holes, (WS1, WS2, WS3 and WS5). Each of the installations comprises a standpipe with a monitoring zone extending typically below 1m to full depth of the borehole. A bentonite seal and flush monitoring cover were provided. We are not aware if the monitoring well pipe was fitted with a bung or gas tap as no details are provided. The wells were unfortunately constructed across geological boundaries and as such determination of the precise level of water ingress is difficult to determine. The logs typically contain a note that the 4.0m to 5.0m window sampler was recovered as being wet. It is not apparent as to whether this therefore results from water ingress within the gravelly clay or clayey gravel layers in the Head and Valley Gravels, or from mudstone gravel layers within the London Clay.

The groundwater monitoring was undertaken over a period of six visits between 1st March 2019 to 13th May 2021. Whilst the initial readings taken one week after installation recorded a shallow groundwater table close to surface, this then slowly dropped by to levels of between 1.6mbgl and 2.4mbgl.

Corresponding maximum groundwater levels at the second visit were between 26.11mAOD (WS01) at the north of the site, 23.16mAOD (WS05) in the east of the Site and an elevation of 19.57mAOD (WS03) in the southwestern corner of the site, in the area of the Attenuation Pond.

It has been suggested that the boreholes had become inundated with water following rainfall, albeit it would not be expected that all the wells would have been affected to the same extent given general topographic falls across the site and absence of any significant depressional features. During this investigation no mention is made of any attempt to bail out the boreholes at any time during this initial period of monitoring to confirm or otherwise if the groundwater levels were in fact representative of a temporary rise due to inundation.

January 2020 – LEAP - Groundwater Winter Monitoring, Land off Dapper's Lane, Angmering.

The site investigation included the installation of two new groundwater monitoring standpipes (WS101, and WS102). Both of the installations comprised a standpipe with a monitoring zone extending typically below 1m to full depth of the borehole. A bentonite seal and upstand monitoring cover were provided. We are not aware if the monitoring well pipe was fitted with a bung or gas tap as no details are provided. The wells were again unfortunately constructed across geological boundaries and as such determination of the precise level of water ingress is difficult to determine. The borehole log for WS102 located at the eastern end of the proposed Attenuation Pond records a shallow seepage occurring at 1.0mbgl, corresponding to a 0.8m thickness gravelly clay horizon.

In addition to the installation of these two new monitoring locations the original wells (except for WS05) were remediated by removal of the cover and upper 0.5m of the bentonite seal and replacement with a new flush cover. These boreholes were then included in the subsequent groundwater monitoring.

The groundwater monitoring was undertaken over a period of three visits between 29th November 2019 to 6th January 2020. It is noted that borehole WS3 (located at the eastern end of the Attenuation Pond) was bailed dry on the 22nd November 2019 and had recovered to a level of 2.25mbgl by the 29th November 2019 before continuing to rise to a depth of 0.35mbgl (19.78mAOD) on the final visit on the 6th January 2020. Boreholes WS101 and WS102 both recorded shallow groundwater levels at circa 0.15mbgl (20.78mAOD in WS03). The original wells also recorded shallow groundwater levels consistent with the maximum levels recorded in March 2019.

Given that WS03 had been bailed and recovered to the shallow groundwater levels originally recorded and the remediation of the original headworks, it is considered that the shallow groundwater levels are reflective of sub artesian groundwater levels within the gravelly clay/ clayey gravel (valley gravel) horizon that is present to the southern area of the site.

4.3 Hydrogeology in area of Attenuation Pond and Groundwater Monitoring

To assist in determination of geological and hydrogeological conditions in the area of the proposed Attenuation Pond, a further investigation and ground water monitoring was commissioned as follows:

November 2021 – Ibex - Dapper's Lane - Pond Boreholes Factual Letter Report

The Ibex investigation was targeted in the area of the proposed Attenuation Pond and comprised 6No. window sampler holes, each with corresponding monitoring installations.

The installations typically comprised a standpipe with a monitoring zone extending typically below 1m to full depth of the borehole, circa 10mbgl. A bentonite seal and upstand monitoring cover were provided. We are not aware if the monitoring well pipe was fitted with a bung or gas tap as no details are provided. The wells were again unfortunately constructed across geological boundaries and as such determination of the precise level of water ingress is difficult to determine. Table 4-1 below records the strikes and observations, which were encountered in all investigations within the persistent clayey gravel horizon, or claystone layers / laminated London Clay .

Table 4-1: Groundwater Strikes

Exploratory Hole	Strike Depth (mbgl)	Strike Elevation (mAOD)	Depth after 20 mins (mbgl)	Rise Elevation (mAOD)	Strata
WS01	7.00	13.93	8.00	12.93	London Clay (Initial rise to 6.7mbgl after 10 mins)
WS03	2.50	17.97	0.51	19.96	Head Deposits (Valley Gravel)
WS04	3.00	17.37	1.00	19.37	Head Deposits (Valley Gravel)
WS05	N/R	N/R	N/R	N/R	N/R
WS06	9.73	10.16	9.68	10.21	London Clay
WS08	N/R	N/R	N/R	N/R	N/R
WS102	1.0	19.93	Seepage only	N/R	Head Deposits (granular horizons)
TP10	2.2	22.21	Seepage only	N/R	Possible London Clay.

Note: N/R: Not Recorded.

The groundwater monitoring was undertaken on a single visit on the 2nd November 2021, with groundwater monitoring undertaken only in WS01, WS04, WS06 and WS08, (the remaining boreholes yet to be completed). The monitoring recorded groundwater levels between 0.24mbgl (WS04) and 2.51mbgl (WS08) corresponding to elevations of between 17.26mAOD at the western end of the Attenuation Pond (WS08) and 20.4mAOD at the eastern end of the Attenuation Pond (WS01).

It is considered that these levels do not necessarily represent worst case conditions given that only one monitoring round has been completed, and they are lower than those levels recorded in the earlier site wide investigation. They do however confirm that sub artesian conditions persist at the site with groundwater typically encountered within the gravel layers encountered at the southern area of the site.

The following Table 4-2 presents a summary of the groundwater data encountered during the ground investigations. Graphs presenting monitored Groundwater Depth (mbgl) and Groundwater Elevations (mAOD) vs time are presented in Enclosure D. The maximum groundwater elevation is also presented in Drawing 9452/0001 in Enclosure C.

Table 4-2 Groundwater Level Monitoring

Date	Groundwater mAOD									
	WS1	WS2	WS3	WS5	WS101	WS102	WS01	WS04	WS06	WS08
04/03/2019	21.17	19.70	15.15	18.30	-	-	-	-	-	-
18/03/2019	26.11	24.37	19.57	23.16	-	-	-	-	-	-
01/04/2019	25.85	23.99	19.31	22.70	-	-	-	-	-	-
15/04/2019	25.71	23.94	19.21	22.40	-	-	-	-	-	-
29/04/2019	25.48	23.82	19.09	22.28	-	-	-	-	-	-
13/05/2019	24.77	22.95	18.52	21.16	-	-	-	-	-	-
29/11/2019	26.14	24.24	17.89*	-	22.66	20.78	-	-	-	-
27/12/2019	26.25	24.52	19.53	-	22.61	20.73	-	-	-	-
06/01/2020	-	24.32	19.78	-	22.66	20.78	-	-	-	-
02/11/2021	-	-	-	-	-	-	20.40	20.13	17.59	17.26
Maximum	26.25	24.52	19.78		22.66	20.78	20.40**	20.13**	17.59**	17.26**

*Bailed dry on 22/11/19.

** Values do not necessarily represent maximum value as only recorded on a single occasion

5 ATTENUATION POND DESIGN

5.1 Existing Design Components

Our review is restricted to providing a check and commentary with respect to the proposals as set out on Drawing "20079 - 211 F - Attenuation Basin Cross Section Plan 1 of 2". A copy of this plan is provided as Enclosure D for ease of reference

The Attenuation Pond is located in the south of the proposed development area, covering an area of circa 0.1ha. The Attenuation Pond is proposed to have an invert level of between 18.40mAOD, in permanently wetted areas, increasing to 18.70mAOD in a central area. The Attenuation Pond is to be constructed with h side slopes of 1 (V) in 5 (H) in the area of potential wetting, increasing to 1(V) in 3 (H) in areas of dry slope.

In summary the engineering design comprises emplacement of a 1mm thickness fully welded Polypropylene (PP) geomembrane (Geosynthetic Technology Limited 1.00mm Exceliner PP) which is anchored into a perimeter anchor trench at the crest. It has been assumed that this in turn is overlain GT limited non-woven geotextile to provide puncture resistance to the covering soils. A data sheet has been provided for such but drawing 20079 - 211 F does not specifically state that this would be employed.

The covering soils are shown to be 300mm thickness of soils, locally thickened to 600mm in areas where seasonally drier areas are proposed in the centre of the pond.

It is understood that the pond capacity has been modelled to provide sufficient volume to accommodate the 1 in 100-year storm (plus climate change) rainfall which would result in a pond level of 19.798mAOD. The minimum crest level is located at the western end of the Attenuation Pond at a level of 20.52mAOD, and hence there is an additional freeboard of circa 720mm.

The sizing of the pond and the associated surface water discharge modelling has not been verified and is beyond the scope of this report.

5.2 Hydraulic Uplift Calculations

The current assessment presented on Drawing 20079 - 211 F - Attenuation Basin Cross Section Plan 1 of 2, do not account for worse case sub artesian groundwater levels, rather they only consider groundwater levels as being controlled to the top of the gravel layer in discrete locations.

It is recognised that in part the current design allows for partial excavation of the granular deposits , but not their full excavation and as such groundwater will flow into the excavation until such times as an equilibrium head of water is established. This has not been accounted for in the calculations. Where the current pond design shows excavation only in the overlying head deposits, no recognition has been made on the potential uplift pressures that exist on that layer, which in effect would fail as a result of hydraulic pressures resulting in uplift to the liner.

RPS calculations on the worst-case design scenario at the western end of the pond are presented in Enclosure E. These show that failure due to uplift may result.

In summary therefore the present assessment of potential uplift pressures, based on the current design, is incorrect and failure of the liner could occur.

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The ground investigations undertaken at the site have shown that in the area of the proposed Attenuation Pond, a persistent band of valley gravel is present below a more cohesive layer of Head Deposits. During

subsequent monitoring rounds, groundwater was recorded within all ten window sample wells across the site with either near complete, or partial saturation (residing within the basal granular horizon), of the valley gravel. Groundwater within that gravel layer is partially confined by such overlying soils, creating a sub artesian shallow groundwater body. As such this shallow groundwater body presents a risk of hydraulic uplift to any excavations in the southern area.

The gravels are underlain by the basal beds of the London Clay Formation in part contain mudstone / claystone gravel. Groundwater strikes encountered within the London Clay during the investigations within two window sample boreholes either dropped after 20 minutes or remained relatively static indicating localised water bearing strata (potentially due to granular inclusions or fissuring) rather than a discrete water body. At this stage in absence of discrete groundwater monitoring from the London Clay strata this is not considered to represent a significant risk of Hydraulic uplift to the overlying strata but would need to be confirmed.

The deeper groundwater body contained within the White Chalk Formation whilst itself is sub artesian in nature is sufficiently confined by a considerable thickness of London Clay and Lambeth Group Formations.

The uplift calculations undertaken and presented on Drawing 20079 - 211 F - Attenuation Basin Cross Section Plan 1 of 2, do not account for worse case sub artesian groundwater levels, rather they only consider groundwater levels reaching equilibrium at the top of the gravel layer. This is an incorrect assessment of potential uplift pressures, and as such based on the current design, failure of the liner could occur.

Should an alternative design be put forward, consideration of the impact of groundwater flow and its control would need to be undertaken for both construction and operational phases of the development. If control measures are put in place, a quantitative assessment of the rate of groundwater flow discharge as a contributing base flow to the Attenuation Pond at the proposed lowered permanent water level, would need to be considered as part of the overall surface water management strategy and a reappraisal of the required total storage volume to meet the agreed development surface water discharge rate in flood conditions.

6.2 Recommendations

Since the monitoring installations have been constructed across geological strata, the current historical boreholes do not allow for an assessment of groundwater conditions that may specifically exist within the Valley Gravel deposits separately from the mudstone/claystone within the London Clay Formation. As such at this stage the design should consider the worse-case groundwater levels as obtained by LEAP in WS3 and WS102 as being the minimum design levels for further consideration of the effects of groundwater on the Attenuation Pond, on the assumption that they are derived from the Valley Gravel deposits.

In the absence of confirmation data specifically on the effects of any hydraulic uplift from the London Clay, sufficient partial factors of safety should be applied to make allowance in the design of the potential variability. We would therefore recommend that loads should be factored in the Ultimate Limit State (ULS) design conditions using a partial factor of 1.1 for destabilising actions (e.g. porewater pressure), and 0.9 for stabilising permanent actions (e.g. water and soil weight), in accordance with an EC7 design approach.

To mitigate the groundwater pressures at site, consideration could be given to the following, critically subject to detailed design and further hydrogeological assessment and modelling of the base flow groundwater. The following elements are critically not presented as a final design solution, rather as being an option to consider further. Each competent needs to be reviewed as part of the final design solution:

- Installation of a cut off wall / drain to the northern and eastern perimeter of pond extending into the top of the London Clay to allow control of groundwater pressures on the side slopes and allow transfer of groundwater to the attenuation pond outfall pipe network and hence prevent groundwater mounding up slope of the pond. The cut off wall/ drain could be used to assist in control of groundwater during construction to facilitate subsequent excavation and placement of clay and geomembrane liners in dry conditions.
- Over excavation of the granular layer, from beneath the Attenuation Pond to the top of the London Clay Formation to remove the principal water bearing strata from within the footprint of the pond. The

resultant excavation could then be backfilled to pond invert level with a suitable engineered low permeability clay overlain by a geomembrane. The clay liner and geomembrane should extend up the slopes to the proposed crest level.

- Reassessment of the surface water drainage strategy and calculations to confirm that the current pond has sufficient storage to account not only for attenuation of flows above the site surface water control discharge rate limits, but also to allow a contribution of calculated groundwater baseflow if the final solution needs to accommodate further contributions of inflow made from collection of groundwater from any associated control measures outside of the pond.

Alternative solutions to an open pond, could also be considered to provide attenuation of surface water flow such as a reinforced or precast concrete storage system that could be designed to accommodate uplift pressures. Consideration may need to be required to allow for anchor piles, to resist residual uplift pressures should the weight of the structure not be sufficient to resist the uplift forces from groundwater.

In addition, the volume of attenuation flow storage could be reduced by installation of on line storage within oversized pipes within the development network (with associated control devices as required), such that storage is provided within the entire network and not solely within the final pond/structure. A reduction in volume may reduce the depth of excavation and hence resultant uplift pressures for the storage structure.

6.3 Closure

If you have any questions or require clarification of our findings or recommendations, please do not hesitate to contact us.

Yours sincerely,
for RPS Consulting Services Ltd

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ENCLOSURES

Enclosure A List of Project Reference Documents
Enclosure B BGS Well Records
Enclosure C Drawing No. 9452/0001/01 Drawing No. 9452/0002/02
Enclosure D Groundwater Monitoring Graphs
Enclosure E Uplift Calculations

Enclosure A
List of Project Reference Documents

Reference Documents

Folder 1	Decision Notice
	DECISION NOTICE: Arun District Council Application Ref: A/76/20/PL
Folder 2	Civil Engineering Design
	20079 - 100S104 G - Section 104 Agreement Plan.pdf 20079 - 100S38 J - Section 38 Agreement Plan.pdf 20079 - 100S98 J - Section 98 - Sewer Requisition Agreement Plan.pdf 20079 - 101 G - External Levels & Features Layout - Sheet 1 of 3.pdf 20079 - 102 G - External Levels & Features Layout - Sheet 2 of 3.pdf 20079 - 103 F - External Levels & Features Layout - Sheet 3 of 3.pdf 20079 - 105 A - Section 38 Street Name Plates.pdf 20079 - 111 G - Private Drainage Layout - Sheet 1 of 3.pdf 20079 - 112 G - Private Drainage Layout - Sheet 2 of 3.pdf 20079 - 113 G - Private Drainage Layout - Sheet 3 of 3.pdf 20079 - 116 C - Master Drainage Layout Plan - Sheet 1 of 3.pdf 20079 - 117 D - Master Drainage Layout Plan - Sheet 2 of 3.pdf 20079 - 118 C - Master Drainage Layout Plan - Sheet 3 of 3.pdf 20079 - 131 C - Contours and Chainages Plan.pdf 20079 - 141 F - Adoptable Kerbing and Finishes Plan.pdf 20079 - 142 A - Private Kerbing & Surface Finishes Plan.pdf 20079 - 161 D - Flood Routing Exceedance Layout Plan.pdf 20079 - 171 B - Surface Water Catchment Areas Plan.pdf 20079 - 172 A - Permavoid Collector Catchment Areas Plan.pdf 20079 - 181 A Combined Services Plan - Sheet 1 of 3.pdf 20079 - 182 A Combined Services Plan - Sheet 2 of 3.pdf 20079 - 183 A Combined Services Plan - Sheet 3 of 3.pdf 20079 - 191 A - House Setting Out Plan.pdf 20079 - 192 A - HV Easement Setting Out Plan.pdf 20079 - 195 Road Setting Out Plan.pdf 20079 - 197 A Piling Setting Out.pdf 20079 - 198 Borders & Visibility Splay Setting Out Plan.pdf 20079 - 201 B - Highway and Drainage Longitudinal Sections - Sheet 1 of 3.pdf 20079 - 202 B - Highway and Drainage Longitudinal Sections - Sheet 2 of 3.pdf 20079 - 203 B - Highway and Drainage Longitudinal Sections - Sheet 3 of 3.pdf 20079 - 206 D - S98 Longitudinal Sections & MH Schedule Plan.pdf

	20079 - 211 F - Attenuation Basin Cross Section Plan - Sheet 1 of 2.pdf
	20079 - 212 A - Attenuation Basin Cross Section Plan - Sheet 2 of 2.pdf
	20079 - 220 B - Watercourse Diversion and Cross Section Plan - Sheet 1 of 2.pdf
	20079 - 221 - Watercourse Diversion and Cross Section Plan - Sheet 2 of 2.pdf
	20079 - 222 Watercourse Diversion Construction Details Plan.pdf
	20079 - 251 D - Storm & Foul Manhole Schedules.pdf
	20079 - 311 A - Construction Details Drainage.pdf
	20079 - 315 C - Construction Details - Cellular Storage CS01.pdf
	20079 - 316 C - Construction Details - Cellular Storage CS02.pdf
	20079 - 320 D - Construction Details - Control Structure CC38.pdf
	20079 - 321 C - Construction Details - Control Structure CC12.pdf
	20079 - 322 B - Construction Details - Control Structure CC28.pdf
	20079 - 326 E - Construction Details - Private Driveway.pdf
	20079 - 327 A - Footpath Construction Detail.pdf
	20079 - 330 B - Construction Details - Pond Inlet and Outlet Headwalls HW01 & HW02.pdf
	20079 - 331 C - Construction Details - Attenuation Basin.pdf
	20079 - 900 - Volumetrics Assessments.pdf
	20079 - 950 A - Vegetation Clearance Coordinates.pdf
	20079 - 951 - Tree Protection Fencing Setting Out.pdf
	20079 - Basin Floatation Calculations Rev A - 2021.10.04.pdf
	20079 - Cellular Storage Floatation Calculations Rev A - 2021.10.04.pdf
	20079 - SK21.10.2021 - Extents of Developable Area Plan.pdf
	20079 101 G External Levels & Features Layout - Sheet 1 of 3.pdf
	20079 102 G External Levels & Features Layout - Sheet 2 of 3.pdf
	20079 103 F External Levels & Features Layout - Sheet 3 of 3.pdf
	20079_Dappers Lane_discon_TN01.pdf
	20079_Drainage Operation and Maintenance_Rev 01.pdf
	2021-10-20-Addendum for Attenuation Pond 656 Sketch.pdf
	2021-10-20-Addendum for Attenuation Pond-656.pdf
	Dappers Lane Planning Consultation.pdf
	SHE-0084-4200-1950-4200_Design_Drawing.pdf
	SHE-0084-4200-1950-4200_Hydraulic_Characteristics.pdf
	SHE-0112-7200-1920-7200_Design_Drawing.pdf
	SHE-0112-7200-1920-7200_Hydraulic_Characteristics.pdf
	SHE-0138-9200-1150-9200_Design_Drawing.pdf
	SHE-0138-9200-1150-9200_Hydraulic_Characteristics.pdf

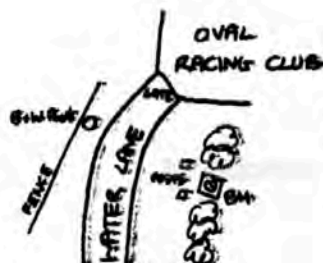
Folder 2.1	Calculations
	20079 - Storm Super Network 1 - 2yr, 30yr & 100yr + 40 - 2021.10.04
Folder 2.2	Pond Liner
	Exceliner PP - 1.00mm (SMX).pdf GT Prestige Lake Portfolio.pdf GT Reservoirs Lagoons & Storm Ponds.pdf SNW 80 Geotextile.pdf
Folder 3	Site Data
Folder 3.1	2017 03 Topo Survey
	H1027-R1.pdf H1027-R2.dwg
Folder 3.2	2020 09 Approved FRA
	D1260 FRA 1.4.pdf D1260-PL200C Impermeable Area Comparison 2020-09-03.pdf D1260-PL300C Proposed Drainage Strategy.pdf D1260-PL301C Proposed Drainage Strategy (Alt. Solution) 2020-09-03.pdf D1260-PL400A Catchment Area Plan 2020-09-04.pdfD1260-PL500A Indicative Pond Sections 2020-09-04.pdf
Folder 3.3	Designer Instructed Ground Model
	21 08 Arena Geo - Dapper's Lane - Ground Model Letter Report.pdf
Folder 3.4	Various Site Investigations
	19 05 LEAP - Dapper's Lane - Phase I and Phase II Site Investigation Report LP1877.pdf 21 09 Jomas - Dapper's Lane - Geotechnical Deep Boreholes P3876J2380.pdf 21 11 Ibex - Dapper's Lane - Pond Boreholes Factual Letter Report ICE0013.pdf
Folder 4	Correspondence
	20079_Dappers Lane_discon_TN01_Rev A
Folder 5	Design Development
	20079 - 211 C - Attenuation Basin Cross Section Plan 1 of 2
	20079 - 211 F - Attenuation Basin Cross Section Plan - Sheet 1 of 2

Enclosure B
BGS Well Records

British Geological Survey
Hydrogeology Group
Logging Record

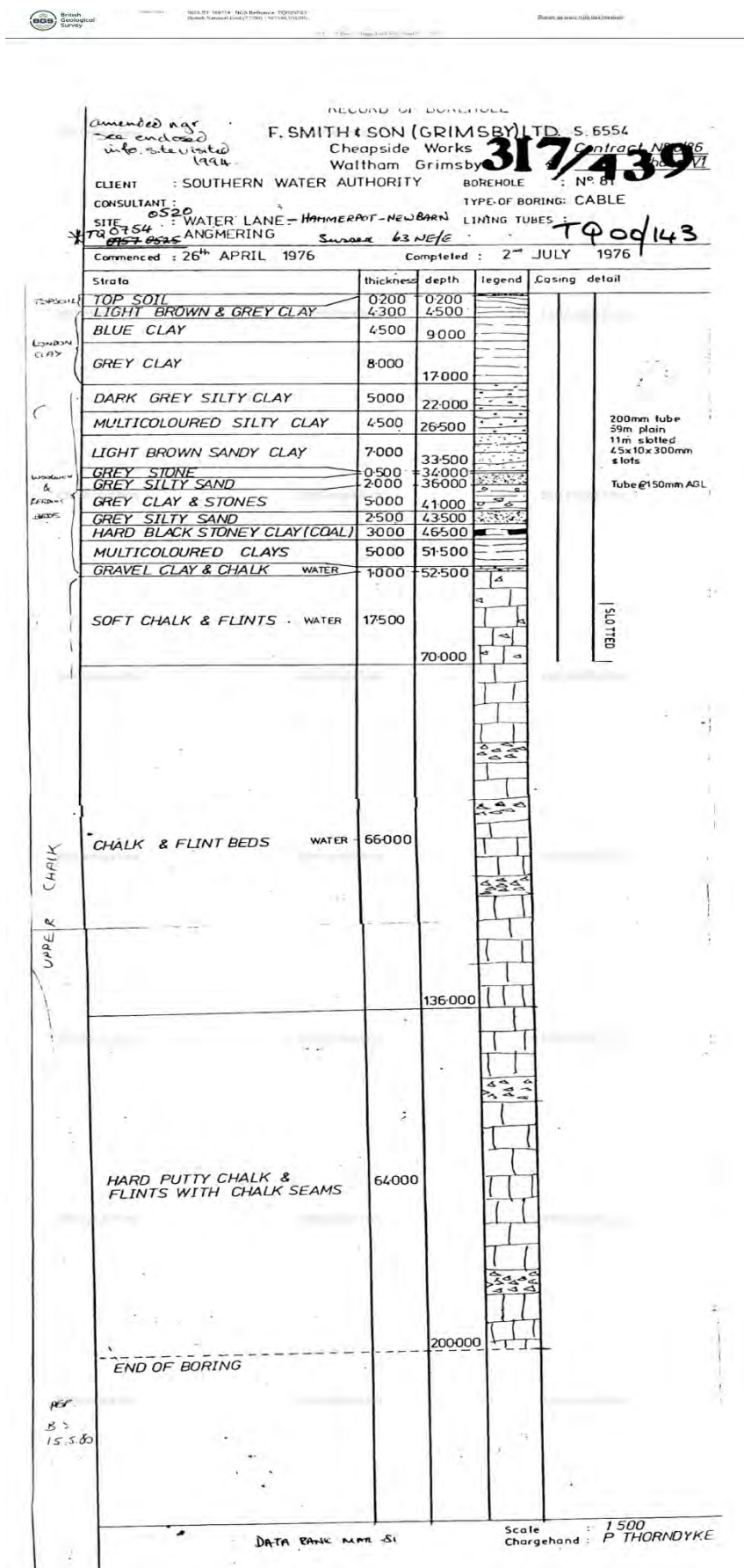
BGS Registration Number : TQ00NE - 63
Archive Record Number : TQ 00/I43
Borehole Name : Water Lane - Hammerpot New Barn, Angmering
National Grid Reference : TQ 0754 0520
Date Drilled : 26/04/76 - 02/07/76
Date Visited : 04/08/94 and 15/08/94
Datum Used : GL
OD Elevation (GL) : 27.20m
Drilled Diameter : 200mm (8")
Total Depth (bGL) : 198.13m
Water Level (bGL) : 24.94m @ 1045 and @ 1617
Total Casing Depth (bGL) : 70.2m
Logs Run : Conductivity
Temperature
Spontaneous Potential
Point Resistance
Caliper
Natural Gamma
Focussed Resistance
Magnetic Susceptibility
Inductance
Operator : J C Talbot
Notes : BH has 8" casing 0.29m above GL on concrete plinth

Site Plan :



Signature and Date :

J C Talbot 9/9/94





Form 2886

BGS ID: 569719 · BGS Reference: TQ00NE63
British National Grid (27700) : 507540,105200

Report on site with this borehole

Print Page 1 of 1

317/439
TQ00/143

The rest water level was 27.0 metres below ground level. The hole is cased with 200mm diameter solid steel casing to 58m below surface, and with 200mm diameter slotted steel casing from 58m to 69m below surface.

Water was struck at 52.5m, 70m and 136m below surface.

Levelled surface datum = 27.20 metres above Ordnance Datum.

Depth Bank



Form 2886

BGS ID: 369934 - BGS Reference: TQ00553
British National Grid (27700) : 507160, 104980

Replaces an older version of this form.

TO 00 SE/4
8716 0498

Survey No. 508
1" N.S. 317
1" O.S. _____

RECORD of WELL or BORING

at (house or farm) Nursery 1 Dappers Lane, 1/2 m NNE of Pch.

Town, Village, &c. Angmering County _____

Exact site (unless a tracing from a map is supplied, give distance and direction from parish church, cross-roads, or other object shown on maps). _____

Surface level of ground _____ ft. above Ordnance Datum. Well or Bore commenced at _____ ft. below surface level of ground.

Sunk _____ ft., diameter _____ ft. Bored _____ ft.; diameter of boring: at top _____ in., at bottom _____ in.

Details of lining tubes (internal diameters preferred) _____

Water struck at depths of (feet) 37' (small supply), + 179'

Rest-level of water below top of well or bore _____ ft. Pumping level _____ ft. Time of recovery _____ hours.

Suction at _____ ft. depth. Yield: (i) on test 1000 galls. per hour (ii) normal _____ galls. per _____

Quality (attach copy of analysis if available). _____

Made by _____ for Mr. Boxall. Date of boring 1935

Information from Major Pogson.

(For Survey use only). GEOLOGICAL CLASSIFICATION.	NATURE OF STRATA. (and any additional remarks)	THICKNESS.		DEPTH.	
		Feet.	Inches.	Feet.	Inches.
<u>by S.H.E.</u> <u>1.11.35</u>			M		m
<u>Drift.</u>	<u>Loam (Head)</u>	<u>5</u>		<u>5</u>	<u>1.5</u>
<u>London Reading Clay.</u>	<u>Gravel + flints (Brighton Road East)</u>	<u>14</u>	<u>4.3</u>	<u>19</u>	<u>5.8</u>
<u>U. Chalk.</u>	<u>Blue clay</u>	<u>155</u>	<u>47.2</u>	<u>174</u>	<u>53.0</u>
	<u>Chalk</u>	<u>29</u>	<u>8.9</u>	<u>203</u>	<u>61.9</u>
	<u>Green clay</u>	<u>2</u>	<u>0.6</u>	<u>205</u>	<u>62.5</u>
	<u>* probably an infilling of a fissure. S.H.E.</u>				
<u>Drift (Hilling)</u>	<u>Loam</u>	<u>5</u>	<u>0</u>	<u>5</u>	<u>0</u>
<u>gravel</u> 19'	<u>Gravel and flints</u>	<u>14</u>	<u>0</u>	<u>19</u>	<u>0</u>
<u>London clay</u> 155'	<u>Blue clay</u>	<u>155</u>	<u>0</u>	<u>174</u>	<u>0</u>
<u>Reading Beds</u>	<u>Chalk</u>	<u>29</u>	<u>0</u>	<u>203</u>	<u>0</u>
<u>Upper Chalk</u> 38'	<u>Green clay</u>	<u>29</u>	<u>0</u>	<u>203</u>	<u>0</u>
<u>M.H. 1/2/73.</u>		<u>2</u>	<u>0</u>	<u>205</u>	<u>0</u>
		<u>7</u>		<u>212</u>	<u>0</u>
<u>Lansdowne Nursery</u> Sited on 6" furrow 63 NE-W OD 60 Bored by Paine Thompson & Lephart, Worthing Disused because pump brought up large quantities of clay. May be re-bored & deepened. Visited S. H. E. 27.2.41. Re-bored by Dando about 1938 to a depth of 212 feet. In use continually for nurseries & according to Mr Boxall the water level is generally at about 140 feet b.g. Pumping equipment prevents measurement of R.W.L. Visited M.H. 21.10.57					



Form 1244

BGS ID: 569956 BGS Reference: TQ00SE6
British National Grid (27700) : 506840, 104980

Report an issue with this borehole

<< Prev Page 1 of 3 Next >>

RECORD of WELL or BORING

317

TQ 00 SE 16

Survey No.

N.S. 317

1° OS

at (house or farm) Chantryfield Nurseries Arundel Rd

Town, Village, &c. Angmering County Sussex

Exact site (unless a tracing from a map is supplied, give distance and direction from parish church, cross-roads, or other object shown on map) 220 yds. North of Church

Six-inch map. Sheet

one-inch map. Square

Surface level of ground 4.5 ft. above Ordnance Datum. Well or Bore commenced at 0 ft. below surface level of ground.

Sunk 226 ft., diameter 6 in. Bored 226 ft.; diameter of boring: at top 6 in., at bottom 4 1/2 in.

Details of lining tubes (internal diameters preferred) 6" I.D. Tubes surface to 137'0"

4 1/2" " from 133' to 163'0"

Water struck at depths of (feet) 202'0"

Rest-level of water below top of well or bore 44 ft. Pumping level ft. Time of recovery hours.

Suction at 100 ft. depth. Yield: (i) on test 2,000 galls. per hr., (ii) normal galls. per

Quality (attach copy of analysis if available)

Made by Duke & Cockenden Ltd for Mr. J.B. Knaggs Date of boring Dec. 1938

Information from Duke & Cockenden Ltd., Artesian Well Engineers, London & Littlehampton.

(For Survey use only).
GEOLOGICAL
CLASSIFICATION.

NATURE OF STRATA.
(and any additional remarks)

THICKNESS.

DEPTH.

Feet. Inches.

Feet. Inches.

Drift 13' Gravel
Brown clay
London clay 36' Gravel
Blue Clay
Reading Beds 97' Sandy Clay
Stiff Clay
Mottled Clay
Upper Chalk 70' Clay and Gravel
Chalk and flints

18 0
3 0
2 0
36 0
47 0
28 0
13 0
9 0
70 0

18 0
21 0
23 0
59 0
106 0
134 0
147 0
156 0
226 0

(Id.) F.H.E.
6.1.39

TQ 00 SE/6
0684 0498

Recd. 6/1/39
Letter on
6,000 Gen.

Sited on 6" Sussex 63NE.W

OD 52

Visited S. Graham
27.2.41

Pumping equipment prevents measurement R.W.L.
In use for nursery. Visited HP 21.10.54.

GEOLOGICAL SURVEY AND MUSEUM,
SOUTH KENSINGTON,
LONDON, S.W.7.

For Survey use only.

Date received.	G.S.M.	M. of H. notified.	Site marked on 1" map.
6/1/39	647		

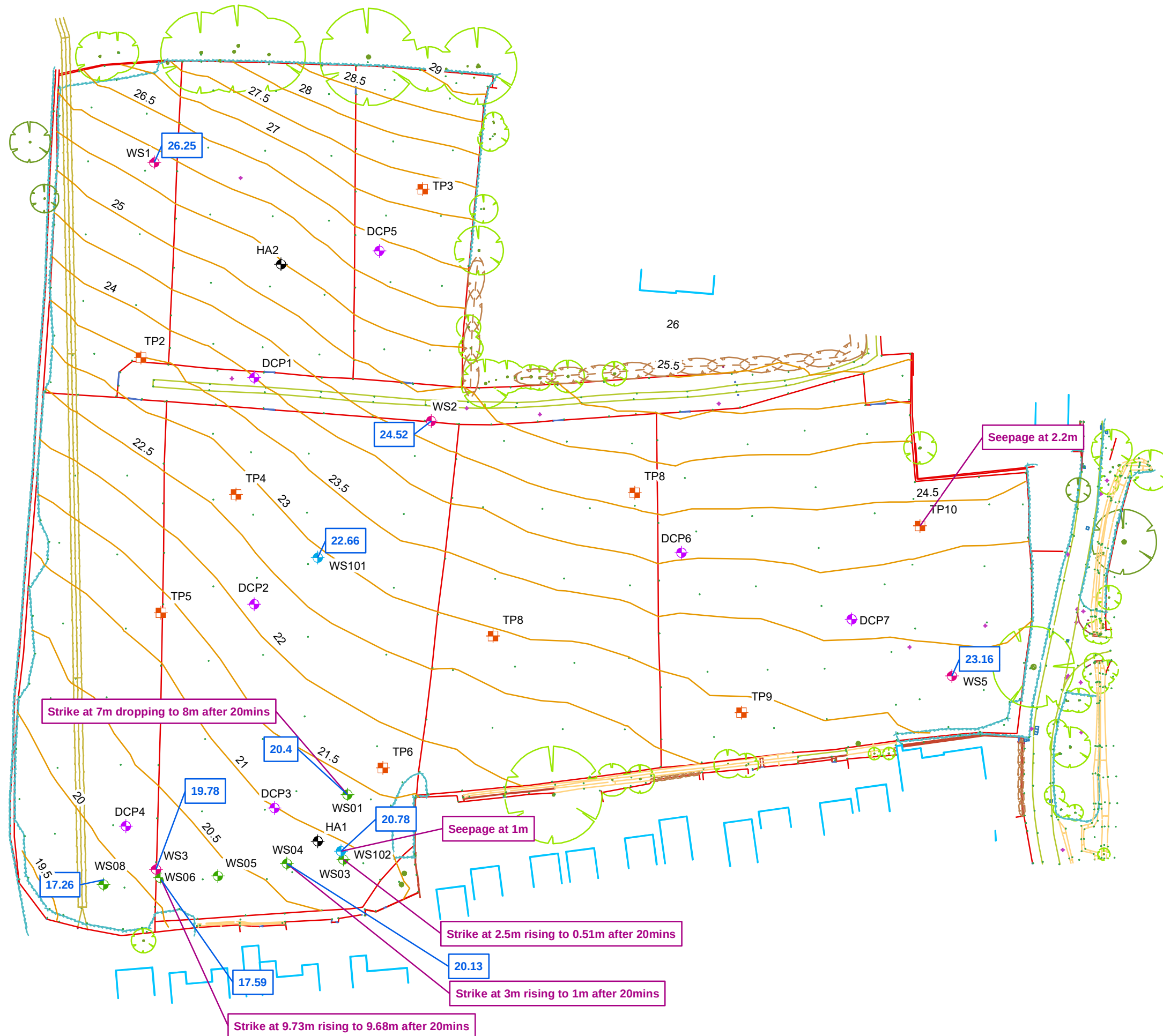
(24738C) W1 20000/225 8,000 11/26
H. J. R. & L. Ltd Op 615

Chalk - 95

Enclosure C

Drawing No. 9452/0001

Drawing No. 9452/0002



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Notes

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2. If received electronically it is the recipients responsibility to print to correct scale. Only written dimensions should be used.

Legend

- DCP (Feb 2019)
- Hand Auger (March)
- Window Sample Borehole (November 2019)
- Trial pit (March 2019)
- Window Sample Borehole (Feb 2019)
- Window Sample Borehole (October 2021)

Labels in blue = maximum groundwater level recorded (mAOD)

Rev	Description	By	CB	Date



Willow Mere House, Compass Point Business Park, Stocks Bridge Way,
St Ives, Cambridgeshire, PE27 5JL
T: +44(0)1480 466 335 E: rpscm@rpsgroup.com

Client -

Project -

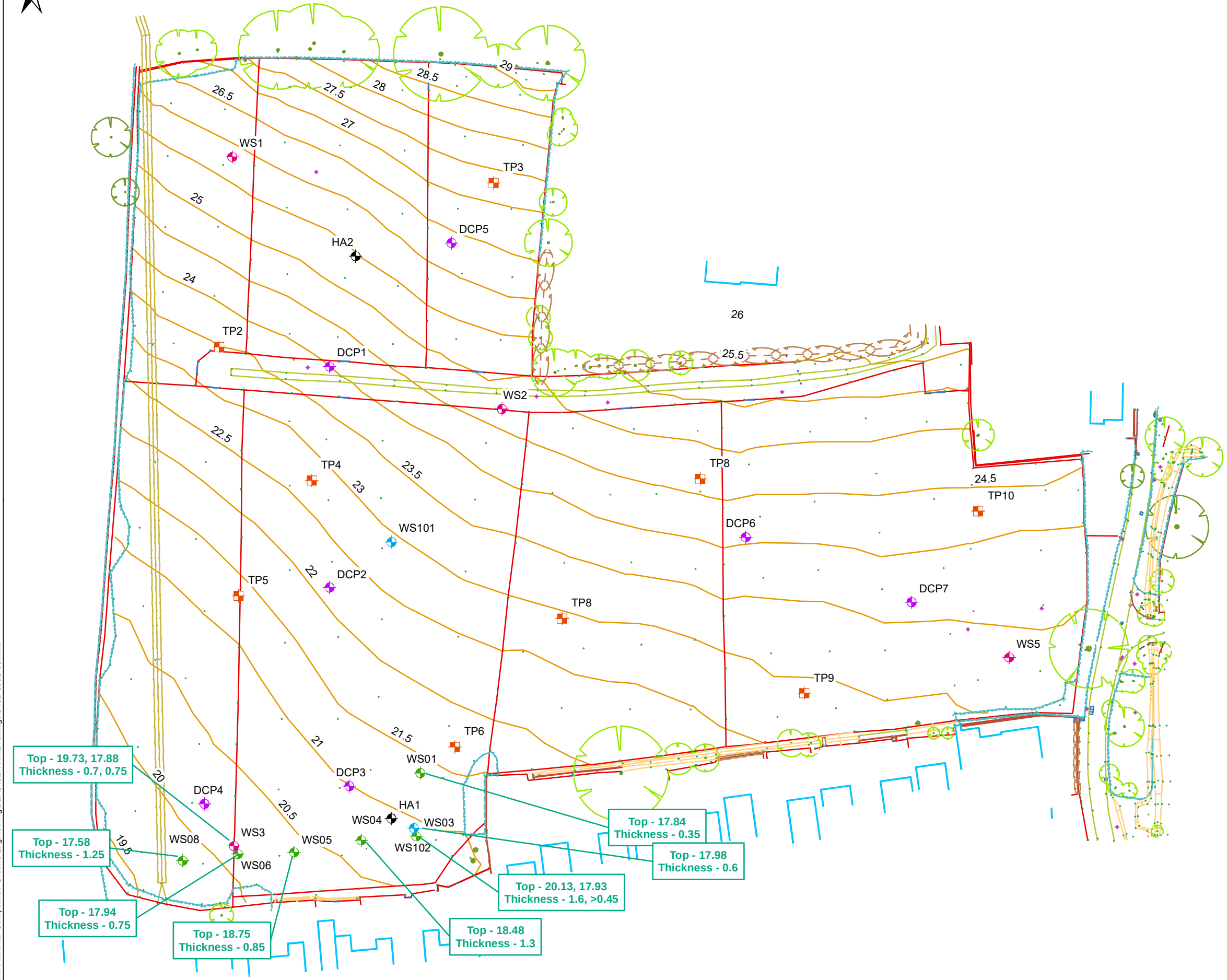
Title Water Strikes and Maximum
Monitored Groundwater Levels

Status ISSUE Drawn By JM PM/Checked By LW

Project Number JER9452 Scale @ A3 1:1,000 Date Created FEB 2022

Figure Number - Rev -

rpsgroup.com



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2. If received electronically it is the recipients responsibility to print to correct scale. Only written dimensions should be used.

Legend

- DCP (Feb 2019)
- Hand Auger (March 2019)
- Window Sample Borehole (November 2019)
- Trial pit (March 2019)
- Window Sample Borehole (Feb 2019)
- Window Sample Borehole (October 2021)

Blue labels = Top of granular horizon (mAOD) and Thickness of granular horizon (m)

Rev	Description	By	CB	Date



MAKING
COMPLEX
EASY

Willow Mere House, Compass Point Business Park, Stocks Bridge Way,
St Ives, Cambridgeshire, PE27 5JL
T: +44(0)1480 466 335 E: rpscm@rpsgroup.com

Client -

Project -

Title Granular Head Deposits

Status
ISSUE

Drawn By
JM

PM/Checked By
LW

Project Number
JER9452

Scale @ A3
1:1,000

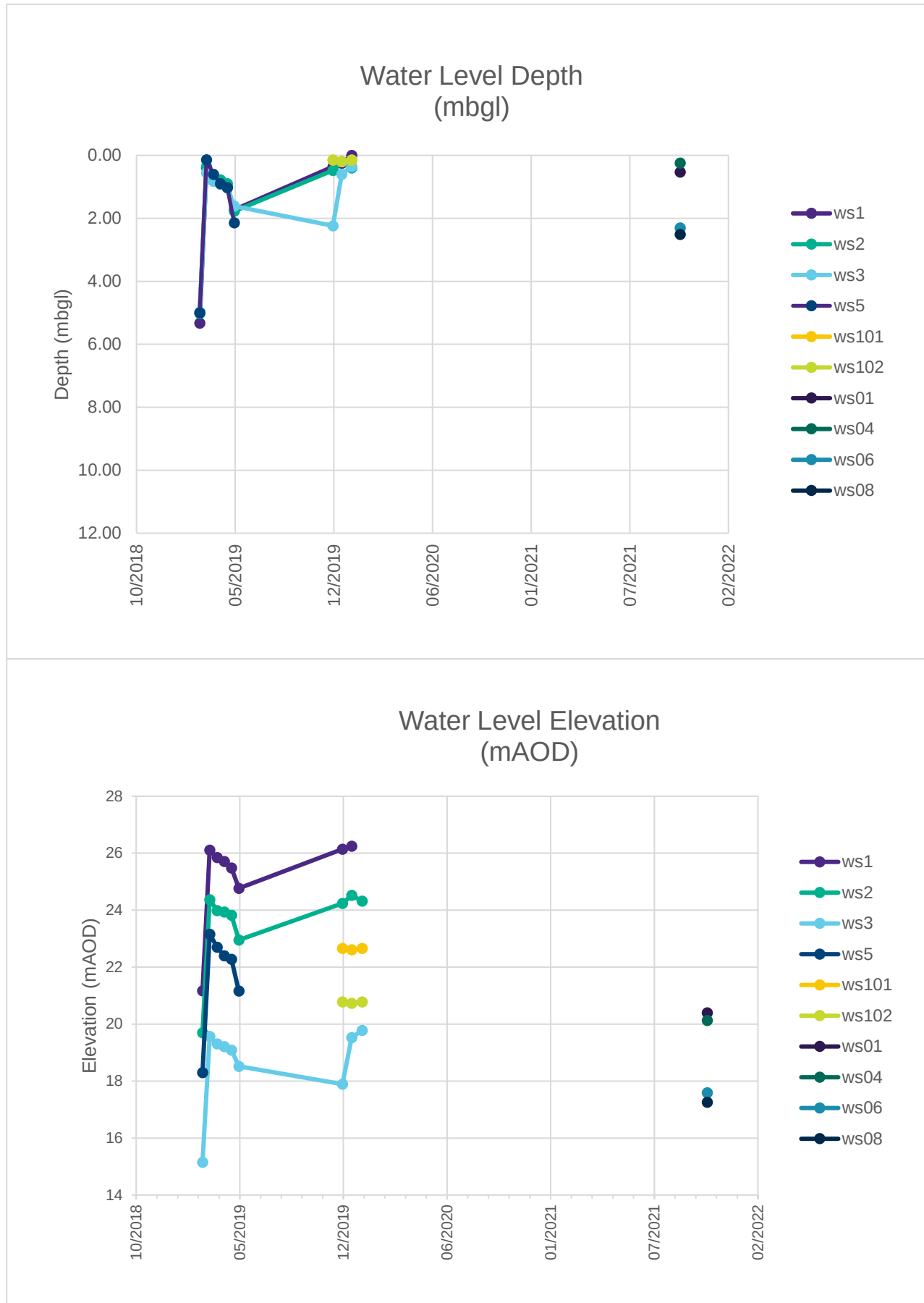
Date Created
FEB 2022

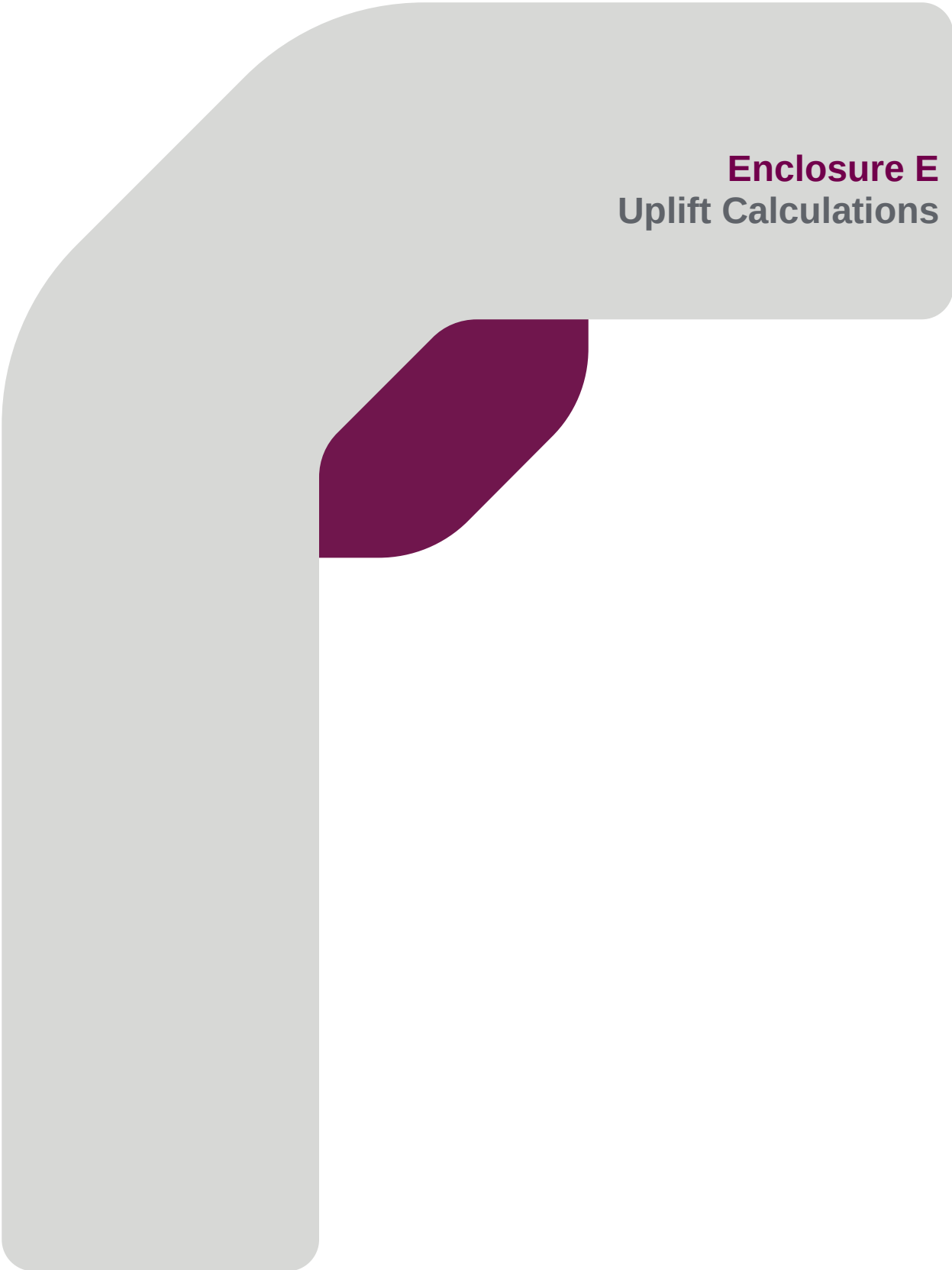
Figure Number
-

Rev
-

rpsgroup.com

Enclosure D
**Groundwater Monitoring
Graphs**





Enclosure E

Uplift Calculations

Project : Dappers Lane Angmering
Job No: JER9452/0001

Calculation of Hydraulic Uplift to Attenuation Pond

Reference Documents:

19 05 LEAP - Dapper's Lane - Phase I and Phase II Site Investigation Report LP1877.pdf
D1260 Flood Risk Assessment 1.4.pdf
21 11 Ibex - Dapper's Lane - Pond Boreholes Factual Letter Report ICE0013.pdf
20079 - 211 F - Attenuation Basin Cross Section Plan - Sheet 1 of 2

Western Pond Area

Pond Water level	18.70 mAOD		
Pond Invert Level	18.40 mAOD		
Soil Cover	300.00 mm	Soil Unit Weight	16.00 kN/m ³
Liner Level	18.10 mAOD		
Water depth	300 mm	Water Unit Weight	9.81 kN/m ³
Groundwater Elevation			
Min depth	0.35 mbgl	Based on monitoring WS 3	
Elevation	19.78 mAOD	Maximum GW level 06/01/2020	
Top of Gravel layer	17.88 mAOD	Based on WS 3	
Partial Factors	1.1 Destablising Permamnt Actions (EC7)		
Partial Factors	0.9 Stablising Permamnt Actions (EC7)		

Potential Hydraulic Uplift

$$P = \gamma_w \times h$$

$$h = 19.78 - 18.10 = 1.68 \text{ m}$$

$$\gamma_w = 9.81 \text{ kN/m}^3$$

$$P = 16.48 \text{ kN/m}^2$$

$$P' = 18.13 \text{ kN/m}^2 \quad \text{allows for EC7 Partial Factors}$$

Restraining Pressure

Permament water Pressure (R1)		
depth	0.30 m	
R1 =	2.94 kN/m ²	
Covering soil Pressure (R2)		
thickness	0.30	
R2 =	4.80 kN/m ²	
Remaining soils above gravel layer (R3)		Assume $\gamma = 20 \text{ kN/m}^3$
Thickness	0.22 m	
R3 =	4.4 kN/m ²	
Total Restraining Pressure = R1 + R2 + R3		
R =	12.14 kN/m ²	
R' =	10.93 kN/m ²	allows for EC7 Partial Factors

Resultant Uplift Pressure (P' - R')

$$U = 7.20 \text{ kN/m}^2 \quad \text{+ ve therefore Failure}$$

Project : Dappers Lane Angmering
Job No: JER9452/0001

Calculation of Hydraulic Uplift to Attenuation Pond

Reference Documents:

19 05 LEAP - Dapper's Lane - Phase I and Phase II Site Investigation Report LP1877.pdf
D1260 Flood Risk Assessment 1.4.pdf
21 11 Ibex - Dapper's Lane - Pond Boreholes Factual Letter Report ICE0013.pdf
20079 - 211 F - Attenuation Basin Cross Section Plan - Sheet 1 of 2

Central Pond Area

Pond Water level	18.70 mAOD		
Pond Invert Level	18.70 mAOD		
Soil Cover	600.00 mm	Soil Unit Weight	16.00 kN/m ³
Liner Level	18.10 mAOD		
Water depth	0 mm	Water Unit Weight	9.81 kN/m ³
Groundwater Elevation			
Min depth	0.20 mbgl	Based on monitoring between WS102 and WS3	
Elevation	20.30 mAOD		
Top of Gravel layer	17.90 mAOD	Based on WS 102 /WS3	
Partial Factors	1.1 Destablising Permamnt Actions (EC7)		
Partial Factors	0.9 Stablising Permamnt Actions (EC7)		

Potential Hydraulic Uplift

$$P = \gamma_w \times h$$

$$h = 20.30 - 18.10 = 2.20 \text{ m}$$

$$\gamma_w = 9.81 \text{ kN/m}^3$$

$$P = 21.58 \text{ kN/m}^2$$

$$P' = 23.74 \text{ kN/m}^2 \quad \text{allows for EC7 Partial Factors}$$

Restraining Pressure

Permanent water Pressure (R1)			
depth	0.00 m		
R1 =	0.00 kN/m ²		
Covering soil Pressure (R2)			
thickness	0.60		
R2 =	9.60 kN/m ²		
Remaining soils above gravel layer (R3)		Assume $\gamma =$	20 kN/m ³
Thickness	0.20 m		
R3 =	4 kN/m ²		
Total Restraining Pressure = R1 + R2 + R3			
R =	13.60 kN/m ²		
R' =	12.24 kN/m ²	allows for EC7 Partial Factors	

Resultant Uplift Pressure (P' - R')

$$U = 11.50 \text{ kN/m}^2 \quad \text{+ ve therefore Failure}$$

Project : Dappers Lane Angmering
Job No: JER9452/0001

Calculation of Hydraulic Uplift to Attenuation Pond

Reference Documents:

19 05 LEAP - Dapper's Lane - Phase I and Phase II Site Investigation Report LP1877.pdf
D1260 Flood Risk Assessment 1.4.pdf
21 11 Ibex - Dapper's Lane - Pond Boreholes Factual Letter Report ICE0013.pdf
20079 - 211 F - Attenuation Basin Cross Section Plan - Sheet 1 of 2

Eastern Pond Area

Pond Water level	18.70 mAOD		
Pond Invert Level	18.40 mAOD		
Soil Cover	600.00 mm	Soil Unit Weight	16.00 kN/m ³
Liner Level	17.80 mAOD		
Water depth	300 mm	Water Unit Weight	9.81 kN/m ³
Groundwater Elevation			
Min depth	0.15 mbgl	Based on monitoring at WS102	
Elevation	20.78 mAOD	Maximum GW level 06/01/2020	
Top of Gravel layer	17.90 mAOD	Based on WS 03 / WS01	
Partial Factors	1.1 Destablising Permamnt Actions (EC7)		
Partial Factors	0.9 Stablising Permamnt Actions (EC7)		

Potential Hydraulic Uplift

$$P = \gamma_w \times h$$

$$h = 20.78 - 17.80 = 2.98 \text{ m}$$

$$\gamma_w = 9.81 \text{ kN/m}^3$$

$$P = 29.23 \text{ kN/m}^2$$

$$P' = 32.16 \text{ kN/m}^2 \quad \text{allows for EC7 Partial Factors}$$

Restraining Pressure

Permament water Pressure (R1)			
depth	0.30 m		
R1 =	2.94 kN/m ²		
Covering soil Pressure (R2)			
thickness	0.60		
R2 =	9.60 kN/m ²		
Remaining soils above gravel layer (R3)		Assume $\gamma =$	20 kN/m ³
Thickness	NIL m		
R3 =	0 kN/m ²		
Total Restraining Presure	= R1 + R2 + R3		
R =	12.54 kN/m ²		
R' =	11.29 kN/m ²	allows for EC7 Partial Factors	

Resultant Uplift Pressure (P - R)

$$U = 20.87 \text{ kN/m}^2 \quad \text{+ ve therefore Failure}$$