MOTT MACDONALD

Review of Monk Lakes Environmental Statement Groundwater Impact Assessment

Hydrogeological advice to MBC in relation to planning application ref. 11/1948

July 2019

Maidstone Borough Council

Mott MacDonald
Victory House
Trafalgar Place
Brighton BN1 4FY
United Kingdom

T +44 (0)1273 365000
F +44 (0)1273 365100
mottmac.com

Maidstone Borough Council
Maidstone House
King Street
Maidstone
Kent ME15 6JQ

Review of Monk Lakes Environmental Statement Groundwater Impact Assessment

Hydrogeological advice to MBC in relation to planning application ref. 11/1948

July 2019

Maidstone Borough Council

Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
A	29/03/19	A Irving	S Watson	S Watson	Draft
B	05/06/19	A Irving	J Dottridge	S Watson	Draft
C	09/07/19	A Irving	J Dottridge	Not Approved	Draft with track changes for discussion
D	11/07/19	A Irving	J Dottridge	J Dottridge	Final

Document reference: 354620 | 02 | D

Information class: Standard

Contents

1 Introduction

1.1 Terms of Reference

1.1.1 Mott MacDonald has been appointed by Maidstone Borough Council (MBC) to provide hydrogeological advice in relation to potential groundwater flooding impacts associated with a partially retrospective planning application 11/948.

1.1.2 The purpose of this report is to assist MBC in reaching a view on the groundwater impacts of the development, taking into account all of the information presented to-date by the Applicant, neighbouring landowners and others, so that a recommendation can be made to the planning committee.

1.2 Background

1.2.1 In September 2003 planning permission was granted by the Council for a change of use of land and physical works to create an area for a recreational fishing site known as 'Monk Lakes', at Staplehurst Road, Marden, Maidstone, Kent, TN12 9BU. The application involved the formation of ponds and lakes, the erection of a building, and car park.

1.2.2 After this was granted, the then owners of the site carried out significant engineering works including below ground works and land-raising through bringing large quantities of soil, construction and demolition waste on site. This was judged as not in accordance with the 2003 permission by the Council, and an Enforcement Notice was issued in 2008.

1.2.3 The site was sold in 2008 and the new owners submitted a planning application (Ref. 11/1948) in 2011, in an attempt to rectify the situation through seeking retrospective permission for some of the lakes, and permission to create three others through remodelling of the earthworks on site.

1.2.4 The Council approved the application subject to conditions on 06/09/12. It included a condition that full details of proposed groundwater controls be submitted to the Council before any more material was brought on site.

1.2.5 This decision was subject to judicial review by a neighbour (Mr Padden) to the site and quashed by the High Court on 22/01/14. In the ruling, amongst other reasons, the judge found that the Council had unlawfully failed to have proper regard to groundwater flooding matters within the application/EIA process before making a decision. The application must now be re-considered by the Council.

1.2.6 One of Mr Padden's concerns is the potential for offsite groundwater flooding at Hertsfield Farm, located adjacent to the western site boundary. He has reported waterlogging and a need for increased pumping to drain the sewage treatment works sump and, to prevent the water level of Hertsfield Farm pond rising above ground level.

1.2.7 In 2015 an Addendum Environmental Statement was submitted, based on work undertaken by Peter Brett Associates (PBA). This acknowledged groundwater flooding as a potential impact and proposed groundwater control measures to mitigate it. This was reviewed by consultants ESI on behalf of Mr Padden (ESI, 2015) and Mott MacDonald on behalf of the Council (Mott MacDonald, 2016).

1.2.8 The Council subsequently requested clarification and further assessment of certain issues, relating to groundwater and drainage. This additional information was provided in a report (Hafren Water, 2017) by the Applicant's new consultant, Hafren Water, in July 2017.

1.2.9 The key deficiency of the 2015 impact assessment and subsequent Hafren Water report is the lack of baseline data, which makes it impossible to establish conclusively what the pre-development groundwater conditions were, in 2003. To enable MBC to make a decision on the application, the Council has asked the Applicant to assess potential impacts against their interpretation of the likely baseline conditions, based on the available information and their professional judgement.

1.2.10 To ensure that adequate information is provided to support the revised assessment, MBC set out a series of further issues to be addressed in two letters, dated 18th October 2018 and 25th January 2019. These letters also highlighted unresolved issues that were previously communicated to the Applicant by the Environment Agency (EA) in a letter dated 20th September 2017 and Kent County Council, in a letter dated 18th September 2018.

1.2.11 Hafren Water, on behalf of the Applicant, has now provided a further technical report (Hafren Water, 2019), that is structured around these issues and cross-references earlier documents that were produced in support of the application. The report forms the basis for the 'Flood Risk, Hydrology, Hydrogeology and Groundwater and Drainage' chapter of the Revised ES (NextPhase Development, 2019), which was submitted to MBC in February 2019 and supersedes all previous submissions.

1.3 Preamble

1.3.1 The retrospective assessment of groundwater impacts for this Application is difficult due the lack of baseline data. Specifically, no pre-development groundwater level measurements are available for the site; and, because of the significant earthworks undertaken at the site, the pre-development geological conditions are also uncertain. So, whilst a conceptual understanding of the pre-development hydrogeological conditions can be developed, no data are available either to verify it or, to enable precise quantification of the magnitude of change that has occurred since the site was developed.

1.3.2 Because of this uncertainty, the Applicant proposed groundwater control and surface water drainage measures to mitigate potential offsite groundwater flooding. A significant amount of work has been undertaken (by the Applicant) since then, to develop a conceptual understanding of pre- and post-development hydrogeological conditions. This is presented in the Revised ES, submitted in February 2019 and, has included the drilling of additional boreholes and monitoring of groundwater levels.

1.3.3 The Revised ES is based on the text of the 2019 Hafren Water technical report (Hafren Water, 2019), which is formatted as a response to questions and comments from consultees. Whilst this format allows consultees to easily see how their queries have been addressed, it does not present a comprehensive description (conceptual site model) of the assumed baseline hydrogeology, that includes all the available data for the site.

1.3.4 The Revised ES and technical report do not address all of issues raised by stakeholders (refer to commentary presented in Appendix A). Nevertheless, this is not essential because once all of the available information is taken into account, the Council is not precluded from reaching a view on the suitability of the proposed mitigation. This is based on a reasonable worst-case assessment of the impacts.

2 Review

2.1 Scope of Review

2.1.1 The ES has been revised in several areas however, this Review is confined to the specific issue of potential groundwater flooding impacts to the west of the site boundary, focussing on the Hertsfield area.

2.1.2 The key deficiency of the 2015 impact assessment and subsequent Hafren Water report is the lack of baseline data, which makes it impossible to establish conclusively what the pre-development groundwater conditions were, in 2003. To enable MBC to make a decision on the application, it has been agreed that the Applicant should assess potential impacts against their interpretation of the likely baseline conditions, based on the available information and their professional judgement.

2.1.3 Following the submission of additional information by the Applicant in 2017 (Hafren Water, 2017) MBC set out a series of issues to be addressed in two letters, dated 18th October 2018 and 25th January 2019. The second letter also highlighted unresolved issues that were previously communicated to the Applicant by the Environment Agency (EA) in a letter dated 20th September 2017, and Kent County Council, in a letter dated 18th September 2018.

2.1.4 Hafren Water, on behalf of the Applicant, has provided a further technical report (Hafren Water, 2019) in response, that is structured around these issues and cross-references earlier documents that were produced in support of the application. That report forms the basis for the 'Flood Risk, Hydrology, Hydrogeology and Groundwater and Drainage' chapter of the Revised ES (NextPhase Development, 2019), which was submitted to MBC in February 2019 and supersedes all previous submissions.

2.1.5 The Flood Risk, Hydrology, Hydrogeology and Drainage chapter of the Revised ES refers to the following reports:

- Response 2 To Maidstone Borough Council Regarding Water Issues at Monk Lakes (Hafren Water, February 2019)
- Flood Risk Assessment, Proposed Fishing Lake Development Near Marden, Kent (N Reilly Consulting Engineer, February 2012)
- Hydrogeological Appraisal Desk Study (Peter Brett Associates, July 2014)
- Addendum to 2011 Environmental Statement (Hydrology and Flood Risk, January 2015)
- Drainage Strategy Report (Peter Brett Associates, July 2015)
- Groundwater Monitoring Report (Peter Brett Associates, July 2015)
- Monk Lakes Groundwater Assessment (Mott Macdonald, November 2016)
- Response to Maidstone Borough Council regarding water issues at Monk Lakes (Hafren Water, July 2017).

2.1.6 This Review of the Revised ES (NextPhase Development, 2019) and supporting technical report (Hafren Water, 2019) considers whether:

1. the Applicant's interpretation of baseline groundwater conditions, prior to development in 2003, is reasonable;
2. the Applicant's conclusions regarding groundwater impacts of the development, when compared to the baseline position in 2003, are logical and robust;

3. the proposed mitigation is likely to be effective in preventing off-site groundwater impacts.

2.1.7 A report prepared by Dr. Ellis of GeoSmart Information Ltd. (Geosmart Information, 2019), was submitted to Maidstone Borough Council in May 2019, on behalf of local residents, in response to the Revised Environmental Statement submitted by the Applicant in February 2019. The findings of this report have been taken into account in our Review, where appropriate.

2.2 Conceptual Site Model (CSM)

Agreed Concepts

2.2.1 All studies undertaken to-date agree that it is not possible to conclusively establish the magnitude of change at the site due to a lack of pre-development, baseline information. The impact assessment must therefore be based on an interpretation of the available information and reasonable assumptions. Concepts supported by all parties are outlined in Table 1.

Table 1: Conceptual site model accepted by all parties

Ref.	Pre-development	Post-development
1	Whilst groundwater may be present within permeable horizons of the Weald Clay, it is unlikely that this has any significant interaction with groundwater in the overlying superficial deposits or surface water drainage system.	No change
2	Hertsfield Farm pond is situated on the River Terrace Deposits aquifer and is not connected to any surface watercourse, so is likely to be groundwater fed.	No change
3	Groundwater would be expected to flow north or north-west, towards the River Beult. However, no data are available to verify this.	Groundwater level data indicate that groundwater flow within the superficial deposits is generally northward, as expected. Locally to the western site boundary, there is a westerly component of groundwater flow, inferred from on-site groundwater levels that are higher than the water level in Hertsfield Farm Pond (14.7m AOD).
4	The western boundary ditch was 200m long and only present at the northern end of the site. It probably received discharge from the adjacent field drainage systems and may have interacted with groundwater in the river terrace deposits to the north of Hertsfield Farm.	The western boundary ditch has been extended southwards, along the whole of the western site boundary. Bed levels appear to be slightly deeper than pre-development ground levels, indicating that it may have been cut into the River Terrace Deposits. It is unlined, so there is likely to be some interaction between the ditch and groundwater within the River Terrace Deposits aquifer. Between Lakes 2 and 3 (and adjacent to Hertsfield Barn) there is a high point in the ditch bed profile (15.9m AOD), which causes the accumulation of standing water for approximately 120m upstream (as far as BH1A). This water level approximates to maximum groundwater levels (recorded at the closest on-site boreholes (BH2A: 15.88m, BH3A: 16.09m and BH4: 16.10m), suggesting hydraulic continuity between the ditch and on-site superficial deposits. Ground levels at off-site receptors to the west (c.15m AOD) and the water level of Hertsfield Farm Pond (14.7m AOD) are lower than both the impounded water level and the base of the ditch in this area (15.23 to 15.84m AOD).
5	Groundwater recharge to the River Terrace Deposits aquifer was derived from the infiltration of direct rainfall and field drainage from soils overlying the Weald Clay, on the southern part of the site.	Notwithstanding the potential for leakage from the lakes (see 2.2.2, item 3), the removal of the field drainage system and placement of low permeability clay may have reduced groundwater recharge to the River Terrace Deposits. Direct rainfall now either flows through the lake system to the river or enters the site drainage system.

Ref.	Pre-development	Post-development
		Runoff from the northern, eastern and southern side-slopes enters the lower lakes or river, via the eastern drainage system. Runoff from the western side-slopes of Lakes 2 and 3 now flows into the western boundary ditch. Given the potential hydraulic connection between the ditch and the aquifer and, the fact that it cannot drain freely (see point 4 above), the ditch may be acting as a preferential pathway for the infiltration of this surface runoff, at the site boundary. Overall groundwater recharge at the site may have reduced as a result of the development. However, the post-development concentration of groundwater recharge at the site boundary may have increased groundwater levels locally, compared to the predevelopment condition.

Source: Mott MacDonald

Key Disputed Concepts

2.2.2 There are numerous concepts upon which the investigations to-date disagree, mainly because the evidence is open to interpretation. Whilst this is to be expected, there are some key points in the most recent submission (Hafren Water, 2019) that may have a bearing on the effectiveness of the proposed mitigation. These are discussed below.

1. Hafren Water have disregarded the off-site groundwater level monitoring data presented by ESI, claiming that these installations do not follow best practice.
   a. Whilst this is true, it is the only off-site data available, and should be considered in the assessment with an appropriate degree of caution. The observations made during the ESI ground investigation (regarding groundwater strikes and seepages) are also relevant and should be considered in the CSM.
   b. Off-site data is available for drive point piezometer DP03, located between the site and Hertsfield Barn, and DP02, located adjacent to the south-eastern bank of Hertsfield Farm pond. Both locations were dry during the February 2015 monitoring visit. At DP02, no groundwater was observed during drilling or the February 2015 monitoring visit. At DP03, no groundwater was observed during drilling (other than some wetting up of a sandy pocket) or the February 2015 monitoring visit. The groundwater elevation recorded in March 2015 was 16.27mAOD, which is above the 15.9mAOD level that water in the ditch rises to (as a result of its uneven gradient). It is also above the maximum groundwater levels recorded at the closest on-site boreholes to the Hertsfield Barn (BH04, BH1A, BH2A, BH3A, which would suggest that groundwater ought to be flowing into the ditch from the west. This does not fit well with any of the conceptual models presented to-date and may be one reason why Hafren Water disregarded the data.
   c. Whilst all are agreed that the western boundary ditch may provide a route for runoff to enter the aquifer, if this were actually occurring, groundwater levels either side of the ditch would be lower than the surface water level. However, the available data indicate that groundwater levels are slightly higher on both sides, suggesting the ditch is actually draining the aquifer. This discrepancy could be due to measurement error or the conceptual model may be incorrect. An alternative explanation that has not been explored by the Applicant is that excavation and replacement of the River Terrace Deposits with low permeability clay may be obstructing northward groundwater flow, fed by recharge from the Weald Clay outcrop. Pre-development, runoff from the Weald Clay outcrop south of Staplehurst Road would have flowed down the lane towards Hertsfield Farm. This water may have been able to infiltrate and fan out into the River Terrace Deposits in the low-lying area around Hertsfield Barn. Post-development, the aquifer to the east has been significantly thinned, reducing the aquifer's capacity to accommodate

this recharge, particularly after heavy rainfall. Unfortunately, there are insufficient measurements of off-site groundwater levels, and none of ditch water levels, so it is not possible to draw any conclusive inferences on this matter.

2. The Applicant states (Hafren Water, 2019, p. 7) that pre-development, an element of westward groundwater flow is "*considered highly likely"*.
   a. However, despite presenting groundwater levels that indicate a north-westerly hydraulic gradient, which necessarily has a westward flow component, and a cross section that supports this, the Applicant suggests (Hafren Water, 2019, pp. 4,12) that post-development, these data may be misleading and there may not in fact be westward groundwater flow, towards Hertsfield Barn. This is a peculiar contradiction and, if there is some doubt that westward flow has ceased, no explanation is given for the post-development change in groundwater flow direction.
3. The Applicant concludes (Hafren Water, 2019, p. 9) that leakage from the constructed lakes is unlikely, as they were lined with compacted, low permeability clay.
   a. However, it is noted by PBA (Peter Brett Associates, 2015a) that the Made Ground comprises a variety of materials and exhibits variable permeability; and, whilst the site owner reports minimal top-up of the lakes is required, this does not prove that they do not leak. This is the reason that the drainage strategy (Peter Brett Associates, 2015b) incorporated a groundwater infiltration drain. The need to establish the permeability of the lake embankments and consider leakage in the CSM was identified in MBC's review of the work undertaken by PBA (Mott MacDonald, 2016).
   b. Dr Ellis (Geosmart Information, 2019) further notes that no records have been presented to verify that the lakes were properly constructed and, that the site operators have been observed to pump water from the river, presumably to top-up the system.
   c. The Applicant has not presented (as requested by MBC) a water balance that demonstrates whether or not recharge from lake leakage could be contributing to increased groundwater water levels. It is therefore unclear whether or not overall groundwater recharge has decreased or increased as a result of the development.
4. In comparison to pre-development ground levels (based on Lidar data with an accuracy of ±0.25m), maximum observed groundwater levels are relatively shallow (<0.5m BGL approx.). At boreholes 01, 02, 04 and 08 the maximum groundwater level is potentially higher than the pre-development ground levels. The Applicant considers this apparent increase in groundwater level to be insignificant.
   a. Dr Ellis (Geosmart Information, 2019) considers this to be evidence of a significant change in groundwater conditions and suggests that the increase is caused by recharge from leakage through the lake embankments.
   b. Whilst we agree that the evidence suggests an increase in groundwater level post-development, this could be related to removal of the field drainage system and the establishment of confined conditions beneath the clay fill material (rather than lake leakage).
5. The Applicant suggests that the River Terrace Deposits has a limited extent and contains little water.
   a. We presume that they wish to imply that replenishment of the source of groundwater flooding is very limited. However, this is not supported by published mapping, which indicates that the River Terrace Deposits are present all along the River Beult valley. Site data indicate that the overlying Alluvium is variably permeable; therefore, it is likely that there is some hydraulic continuity between the two units and, surface water within the river. Furthermore, the classification of the River Terrace Deposits as a Secondary A

Aquifer recognises their importance locally for supply and as a source of baseflow for the River Beult.

6. The Applicant seeks to explain observed groundwater level trends through various mechanisms, as a direct result of the earthworks undertaken at the site.
   a. The Applicant does not give sufficient weight to seasonal variability of groundwater level in their interpretation. We consider that the groundwater level hydrograph trends are not conclusive because they are relatively short with significant gaps (18 and 20 months). The observed variability between different locations could be due to differences in connectivity with the River Beult, which defines the base water level of the system, or other surface water features.
   b. Dr Ellis (Geosmart Information, 2019) notes that changes due to the site works are likely to have stabilised prior to the monitoring period and suggests that other factors, including leakage from the Ponds 2 and 3, are at least as likely to have influenced groundwater level, particularly given that some permeable fill material appears to have been used in their construction. As stated above, we agree that leakage has not been discounted but, it is our opinion that no clear long-term rising trend is visible in any of the groundwater level datasets, that would support the idea that leakage is occurring.

Summary

2.2.3 In summary, there is general agreement that on-site groundwater levels could have increased as a result of the development. Whilst there is some disagreement over the exact mechanism by which this could have occurred, there is agreement that the existing western boundary ditch has the potential to act as a preferential pathway for the infiltration of surface runoff, which may have led to locally elevated groundwater levels and off-site waterlogging.

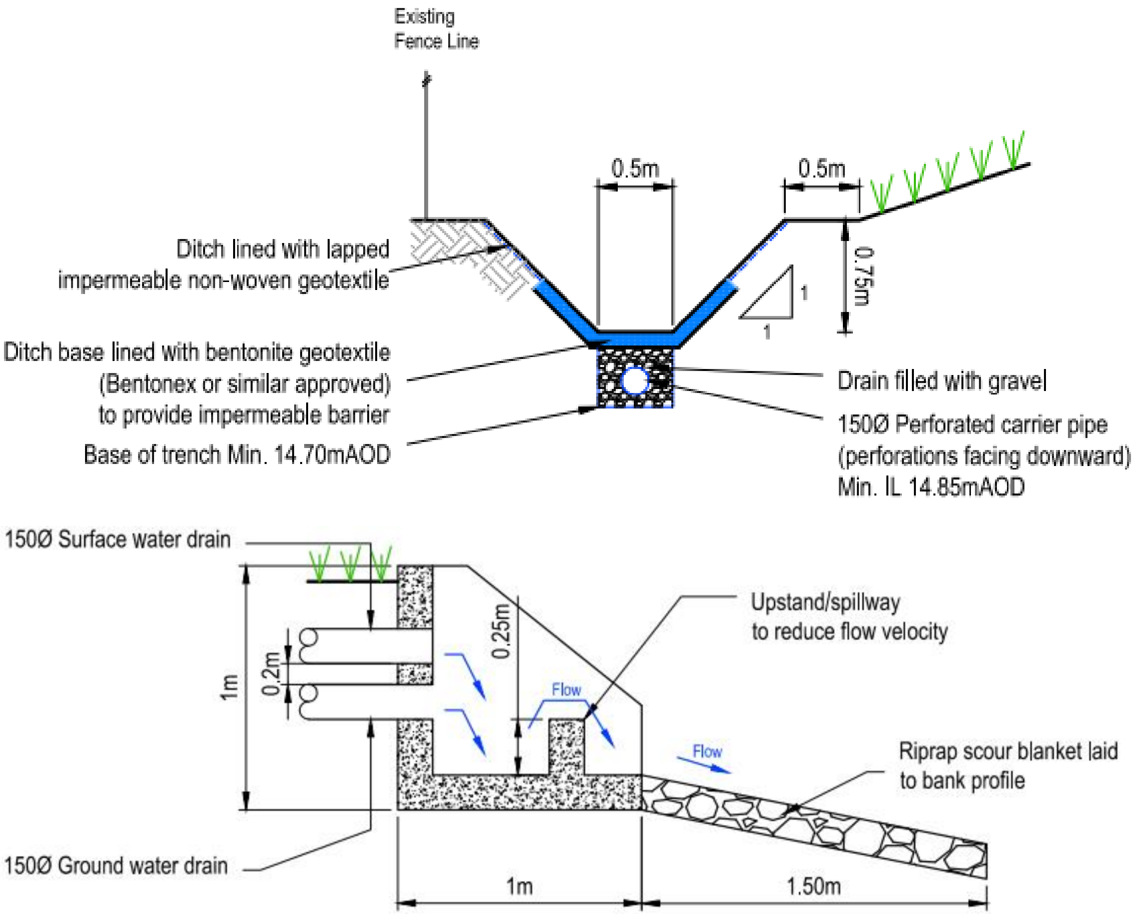
2.2.4 Alternative explanations are that leakage from the lakes has increased recharge, which has neither been proven nor discounted; or, that replacement of the permeable superficial deposits with low permeability clay has obstructed groundwater flow, leading to localised increases in groundwater level.

2.3 Proposed Mitigation

Proposed Drainage system

2.3.1 The mitigation proposed by the Applicant involves re-working the existing western boundary ditch to prevent infiltration of surface water through the ditch base and, the installation of a groundwater infiltration pipe below the ditch, to limit the potential for elevated groundwater levels. A cross sectional drawing of the proposed design is shown below.

Figure 1: Typical sections of proposed surface water ditch and groundwater interceptor drain



Source: (Peter Brett Associates, 2015b)

2.3.2 The base of the proposed trench (in which the perforated section of pipe would be set) slopes downward from 14.95 to 14.7mAOD, at which point solid pipe would be used to convey flow through the River Terrace deposits to the outfall (to avoid re-infiltration of the water).

2.3.3 The Applicant states (Hafren Water, 2019, pp. 11,38) that the ditch modifications would be undertaken exactly as specified in the drainage strategy report. However, in Section 4.1 (Hafren Water, 2019, pp. 30-31) it is stated that additional weirs and non-return valves would be installed to attenuate discharge flow and prevent inflow from the River Beult, when in flood.

2.3.4 The drainage strategy (Peter Brett Associates, 2015b) makes it clear (in section 9.1.5) that additional work would be required to finalise the design of the drainage scheme: *"The ditch upgrade works should be designed by a suitably qualified engineer and any planting on the embankment should be confirmed by a person suitably qualified in assessing any negative effects it may have on the reservoirs. Design of any works is outside the scope of this report."*

2.3.5 It is therefore assumed that the Applicant proposes further work to adapt and refine the design of the drainage system; however, this is not stated.

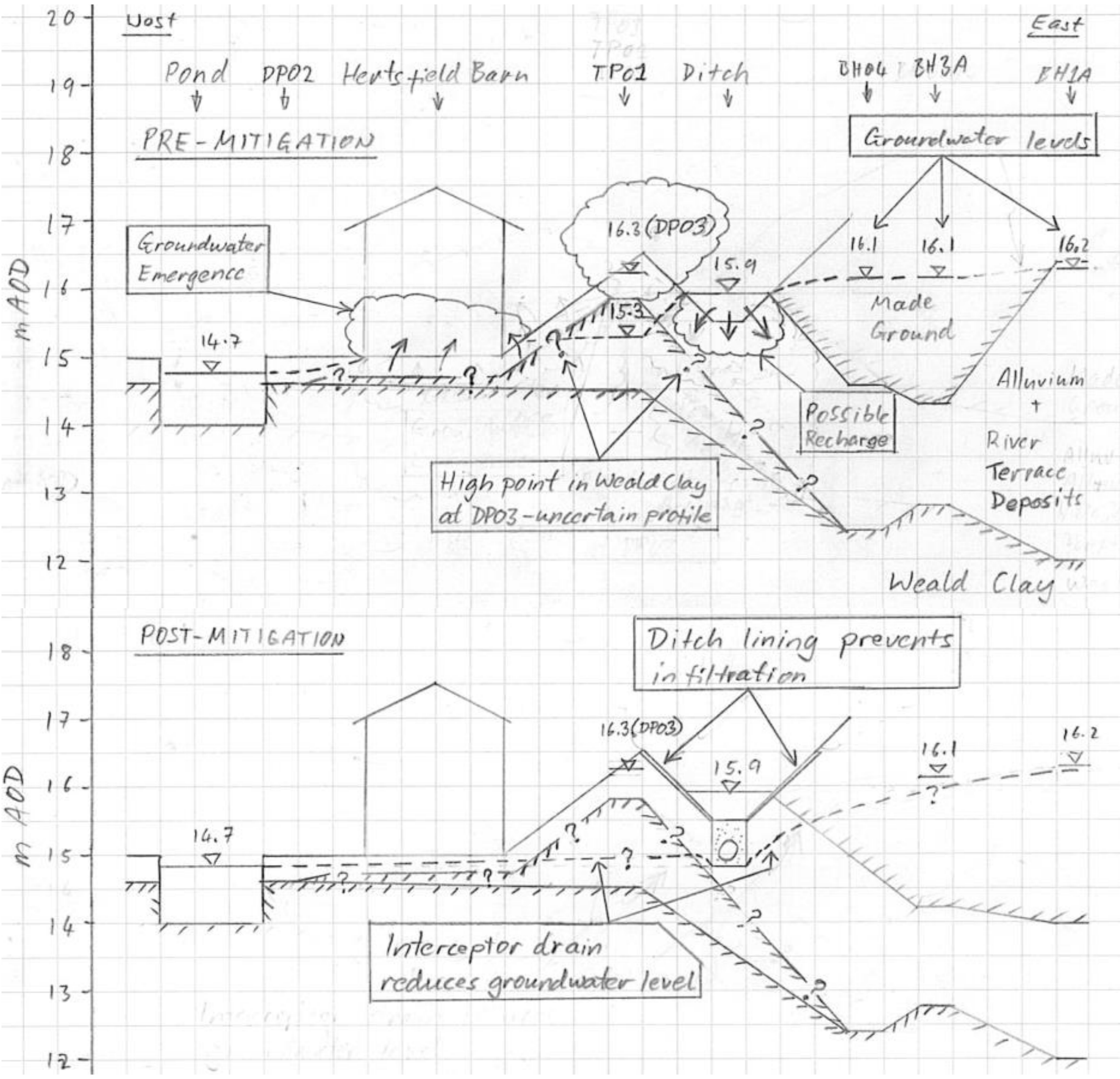
Review of Proposed Design

2.3.6 The mechanism by which the groundwater interceptor would prevent offsite waterlogging is shown in the schematic below, which this illustrates the key concepts described in Table 1. In our opinion the design is conceptually sound and should intercept groundwater before it emerges at the surface.

2.3.7 Its effectiveness would depend on a number of parameters that should be subjected to sensitivity testing during development of the detailed design. In particular, off-site groundwater levels appear to be naturally shallow. The outline design recognises the need to place the interceptor drain as low as possible in the ground, to maximise drawdown below the off-site receptors without impacting on the water level of Hertsfield Farm pond. Given this likely sensitivity in the design, it would be advisable to confirm the elevation of the pond water level.

2.3.8 Sensitivity (of the design) to aquifer permeability and thickness; and, the potential for future increases in groundwater level should also be considered.

Figure 2: Schematic showing effect of proposed mitigation on groundwater level



Source: Mott Macdonald (not to scale)

2.3.9 We have conservatively estimated a maximum groundwater inflow of 15l/s, using data presented by the Applicant (see Appendix B). These estimates do not allow for uncertainties such as increased groundwater level due to climate change, inaccurate permeability estimates, or variations in aquifer thickness, which could all increase the rate of inflow.

2.3.10 Based on a ditch bed gradient of 1 in 455 (determined from the Interceptor Drain Long Section shown on drainage strategy drawing 29431/001/SK03), the carrying capacity of the proposed 150mm carrier pipe would be 8.2l/s. The proposed design therefore appears to have insufficient capacity to ensure its long-term effectiveness.

2.3.11 The calculated flows are indicative of potential maximum flow rates, that could be experienced during an extreme event or as a result of sustained recharge. Under normal circumstances flow to the interceptor drain would probably be much lower. However, given the uncertainties in the conceptual site model, the drain should be sized to accommodate flows that take these risks into account.

2.3.12 The elevation of the interceptor drain relative to off-site receptors is critical to the effectiveness of the system and to prevent any adverse impact on the water level of Hertsfield Farm pond. The design is reliant on a single water level measurement taken by ESI in 2015. It is recommended that this water level measurement is confirmed as accurate and that any other relevant off-site receptor elevations are sought prior to detailed design.

2.3.13 It is noted that the side slopes of the drainage ditch are relatively steep, which may result in some settlement that could (in addition to reducing its capacity to carry surface water) adversely impact on the integrity of the impermeable liner.

2.3.14 The Applicant provides a maintenance schedule (Hafren Water, 2019, p. 35) for swales and filter / French drains but does not appear to have considered the potential for blockage or clogging of the filter material associated with the groundwater interceptor drain. It is recommended that a geotextile wrap be used to prevent sediment and fines entering the pipe, and that the maintenance programme be expanded to include the groundwater drain.

Risks

2.3.15 The conceptual site model is highly uncertain, due to a lack of baseline data and limited off-site, post-development data. However, this is not unusual for proposed developments, which are often progressed based on conservative assumptions to manage the associated risks. In our view, and notwithstanding that the data were collected post-development, the level of investigation undertaken at the site is appropriate for this type of development.

2.3.16 The proposed mitigation should be effective if the conceptual model is representative of site hydrogeological conditions. However, there are several uncertainties, notably the distribution of higher permeability horizons (comprising sand and gravel) within the River Terrace Deposits; and, the degree to which waterlogging is caused by high groundwater conditions or storm runoff (if at all).

2.3.17 The source of water causing waterlogging off-site to the west could be any or all of the following:

- On-site: Concentrated recharge of runoff from the lake side-slopes, via the western boundary ditch
- On-site: Leakage through potentially permeable fill materials used in the lake embankments

- Off-site: Naturally high groundwater conditions, unrelated to the development
- Off-site: Storm runoff from the Weald Clay outcrop to the south (unchanged by the development)

2.3.18 To be effective, the interceptor drain would need to be in hydraulic connection with the River Terrace Deposits off-site to the west. The available off-site data indicate that in comparison to the southern end of the site boundary (at TP01 and TP04), in the vicinity of Hertsfield Barn (at DP03), the top surface of the Weald Clay is elevated and that the River Terrace Deposits comprise low permeability materials. On-site data suggest the River Terrace Deposits adjacent to this location (BH1A, 2A and 3A) comprise sand and gravel. It is clear then, that the geology of the site is highly variable. If the interceptor is isolated from the offsite permeable deposits by undulations in the surface of the Weald Clay or low permeability pockets within the River Terrace deposits, it may not be able to receive groundwater originating off-site.

Recommended Planning Conditions

2.3.19 The Applicant has presented an outline design for the interceptor drain, which needs to be refined prior to implementation. It is recommended that if the application is approved, the following requirements are added as conditions, to allow for uncertainties in the conceptual site model.

1. The detailed design should be submitted to and approved by the Council, prior to construction.
2. The detailed design should be supported by calculations and justified assumptions, that fit with the established hydrogeological conceptual site model and provide confidence that the design is appropriate. As a minimum, the Applicant should:
   a. Calculate the anticipated volume of groundwater to be intercepted by the system.
   b. Undertake sensitivity testing of the design to allow for uncertainties, including aquifer thickness and permeability, hydraulic gradient and future increases in groundwater level (e.g. due to climate change).
   c. Confirm (if possible) the elevations of relevant off-site receptors.
   d. Provide a maintenance plan for the groundwater interceptor drain and surface drainage ditch, to ensure its long-term integrity and functionality. This should identify who is responsible for maintenance and a means of demonstrating that the plan is being adhered to.
   e. Demonstrate that the design will resist long-term threats to its integrity and effectiveness, such as climate change, settlement, further developments at the site, etc.
3. There should be adequate supervision during construction to verify that ground / groundwater conditions are consistent with the conceptual site model. The construction work should be photographed and documented to demonstrate that this is the case, and this evidence must be provided to the Council in a Verification Report.
4. The Applicant should have in place a protocol to deal with unforeseen ground / groundwater conditions during construction. If ground / groundwater conditions are found to be inconsistent with the conceptual site model, the Applicant should report this to the Council and obtain their written agreement before implementing any necessary alterations to the approved design.

3 Conclusions

3.1.1 The Applicant has undertaken additional ground investigation, monitoring and data interpretation since the 2015 planning application was submitted. In our view, the total work undertaken to investigate the potential for off-site groundwater flooding impacts is proportional to the level of risk and, commensurate with our expectations for a proposed development of this nature.

3.1.2 In all geological investigations it is good practice to develop a credible conceptual site model (CSM) that explains the observed data. In this case, where baseline data are unavailable and a decision must be based on professional judgement, it is essential to recognise the assumptions and uncertainties inherent in the CSM and, the associated risks.

3.1.3 The Revised ES addresses most of the specific issues highlighted by consultees adequately but does not present a comprehensive hydrogeological conceptual site model contrasting the pre- and post-development situations.

3.1.4 The Hafren Water (2019) report does acknowledge the potential for an off-site impact on groundwater level but the overall tone of the document attempts to diminish the significance of the unmitigated effect. In doing so, the conclusions drawn are sometimes tenuous.

3.1.5 Whilst the Applicant suggests that groundwater impacts due to the development have been minimal, this has not been conclusively demonstrated. Neither has the potential for increased groundwater levels been discounted. We must therefore take the position that groundwater levels at the site may have been increased by the proposed development and thus, mitigation is required.

3.1.6 The impact assessment presented in the Revised ES (NextPhase Development, 2019) concludes that there would be an adverse impact of high significance, but it is not clear exactly which effect would be responsible for this, as flood risk, hydrology, hydrogeology and drainage are lumped together.

3.1.7 The Applicant states that the proposed mitigation would prevent any potential increase in groundwater level west of the site boundary, above the recorded water level of Hertsfield Farm pond (14.7m AOD); and, once implemented, the offsite impacts would be negligible. We agree that the proposed drainage system is a suitable solution but, the outline design needs to be refined.

3.1.8 The Applicant states that the drainage system would be installed as per the description given in the site drainage strategy (Peter Brett Associates, 2015b), as follows:

- *"A lower drain, comprising perforated pipe surrounded by granular material, would intercept high groundwater levels and convey intercepted water northwards.*
- *An upper section of the ditch, hydraulically isolated from the lower, would collect surface water and convey it northwards to the River Beult*.
- *The design of the ditch is such that surrounding groundwater levels could not rise to a level where they would cause off-site waterlogging whilst also ensuring the continuation of water supply to groundwater-supported features to the west of the site. The lining of the surface water ditch would prevent infiltration to ground."*

3.1.9 However, the Applicant states elsewhere that additional features would be included to attenuate discharge flows and prevent flooding from the River Beult and the drainage strategy clearly states that further design work would be required. It is therefore assumed that the Applicant intends to complete detailed design of the system upon approval of the application.

3.1.10 Our review of the design presented for the groundwater interceptor system indicates that the proposed 150mm carrier pipe may have insufficient capacity for the anticipated volume of groundwater inflow. Pipe capacity should be reviewed and revised by the Applicant during development of the detailed design.

3.1.11 In summary, it is our opinion that:

- the amount work undertaken to investigate the potential for offsite groundwater flooding is appropriate for a proposed development of this nature;
- the Applicant's interpretation of pre-development (baseline) hydrogeological conditions has some flaws and is not as comprehensive as it could be;
- the Applicant's interpretation of post-development hydrogeological conditions seeks to diminish the potential impacts without providing sufficient evidence to do so conclusively;
- the Applicant has not demonstrated their claim that the development has reduced recharge to the Superficial Deposits, nor have they discounted the potential for increased groundwater levels to the west of the site boundary;
- the development may not have increased groundwater levels in the vicinity of the western site boundary but, since this has not been discounted, we must conservatively assume that the reported off-site waterlogging may be caused by the development and, that mitigation is therefore required;
- whilst there is still some uncertainty regarding the ground and groundwater conditions (both on- and off-site), this is the usual situation for any proposed development;
- the Applicant has recognised uncertainties within the CSM and presented an outline design for drainage measures to mitigate the associated risks;
- whilst the proposed mitigation is a suitable solution, the design must be developed further to allow for uncertainties in the conceptual site model and, to ensure its long-term effectiveness;
- we have made several recommendations to manage risks associated with uncertainties in the conceptual site model, which should be incorporated as planning conditions if planning permission is granted.

4 References

CIRIA. (2016). *Groundwater control: design and practice, second edition (C750).* CIRIA.

ESI. (2015). *The potential for groundwater flooding resulting from the unauthorised development at the neighbouring property known as Monk Lakes.*

ESI. (2017). *Re: Hertsfield Barn - Review of new technical data.*

Geosmart Information. (2019). *Re: Hertsfield Barn: response to EIA statement for Monk Lakes.*

Hafren Water. (2017). *Response to Maidstone Borough Council regarding water issues at Monk Lakes .*

Hafren Water. (2019). *Response 2 To Maidstone Borough Council Regarding Water Issues at Monk Lakes.*

Mott MacDonald. (2016). *Monk Lakes Groundwater Assessment.*

NextPhase Development. (2019). *Environmental Statement For the part retrospective retention of completed lakes Bridges and Puma, the retention and completion of part completed raised reservoirs Lakes 1, 2 and 3... along with club house and detailed landscaping scheme at Monk Lakes.*

Peter Brett Associates. (2015a). *Monk Lakes, Marden, Kent - Groundwater Monitoring Report.*

Peter Brett Associates. (2015b). *Monk Lakes, Marden, Kent - Drainage Strategy Report.*

Appendices

A. Commentary on Applicant Response

A.1 Commentary

A.1.1 The Applicant has addressed each point raised by consultees in their technical report (Hafren Water, February 2019). In the following sections we set out whether, in our professional opinion, the Applicant has adequately addressed those issues relating to groundwater.

A.2 MBC LETTER OF 18th OCTOBER 2018 AND E-MAIL OF 25th JANUARY 2019

1. *All the groundwater level data presented in 2375/WIA/05 shows even spacing for the data points but the readings were not collected with an even spacing (see Appendix 2375/WIA/A3). The rainfall data in 2375/WIA/05 is not aligned with the groundwater level data and February 2017 has two monthly totals shown. This needs to be clarified.*

A.2.1 The hydrograph has been re-plotted correctly (2675/MBCR2/01) but does not now show rainfall, therefore it is now impossible to discern any relationship between groundwater level and rainfall.

2. *Figures 2375/WIA/11 and 2375/WIA/12 need to be checked as, for the same date in April 2017, the boreholes are shown with the same groundwater level but different strata elevations eg BH1A shows the water table at the Made Ground/Alluvium boundary in 2375/WIA/11 but at the Alluvium / River terrace deposit boundary in 2375/WIA/12.*

A.2.2 The cross sections have been corrected (2675/MBCR2/02 and 03).

3. *In 2375/WIA/12 the pond level is noted as inferred at 16m AOD, but the level is given as 14.70m AOD by ESI (2015). By setting the pond water level approximately 1.3m higher than a measured value the hydraulic gradient from the Made Ground west towards the pond is not revealed. Figure 2375/WIA/12 is inadequate to show the relationship between the pond, ditch and groundwater level relationship. This needs to be clarified.*

A.2.3 The cross-section has been amended (2675/MBCR2/03), with the elevation of the Hertsfield Barn pond water level shown as 14.7m AOD, but in some cases (e.g. BH1A) the stratum levels detailed in the report do not correspond well to the vertical scale on the plot.

A.2.4 It is noted in the text that the apparent westward hydraulic gradient towards the pond (indicated by the cross section) may not be representative of the groundwater flow direction. The implied suggestion is that the overall direction of groundwater flow is not parallel to the line of section. However, this caveat is not necessary; whatever the overall direction of flow, on-site groundwater levels are higher than the water level in the pond, so there will be some component of flow towards it.

A.2.5 A more representative depiction of the hydraulic gradient between the selected boreholes (BH04, BH1A and BH3A), Hertsfield Barn and the Pond, could have been presented by drawing a NNW-SSE trending section line through all of them.

A.2.6 It is also noted that an attempt to confirm the pond level was made in December 2018 but surveyors were denied access.

4. *The applicant should clarify if groundwater flow remains as prior to development, considering whether there has been a change in direction due to emplacement of Made Ground and reservoir construction and, if it has, what is the potential impact on the adjacent site to the west. Alternatively if the PBA designed interceptor drainage channel would mitigate any*

effect then this should be clearly set out. The Hafren Water report only refers to the western ditch and the interceptor drainage channel proposed by PBA is not explicitly mentioned (it is contained in Appendix App 2375/WIA/A12). It is not clear if the interceptor drain remains part of the application. Clarification of whether this still forms mitigation and the mitigation that it offers should be provided.

A.2.7 The pre-development drainage ditch located to the south of the site (2675/MBCR2/05) is incorrectly reported as flowing north-eastwards. Based on the topography presented, the ditch would flow north-west and south-east from a central high point.

A.2.8 No pre-development groundwater level data are available for the superficial deposits at the site. The Applicant postulates that pre-development:

- *"water could recharge these deposits via infiltration of overland flow off the lower permeability Weald Clay outcrop to the south and/or intraflow from soil and sub-soil from the southern sections of the site. It is anticipated that recharge volumes would be relatively small. The northern ditches within the River Terrace deposits may have intercepted groundwater."*

A.2.9 In the absence of pre-development groundwater level data, the Applicant presents a description of pre-development groundwater conditions, with reference to landform (topography) and surface drainage regime, which have been determined from EA Lidar data (2002) and historical OS mapping.

A.2.10 It is clear from the isopachyte elevation difference plan (2675/MBCR2/06) that ground levels have increased (since 2002) in all areas of the site except at the toes of the northern and eastern embankments to Lake 3. The greatest increase is approximately 7m around the crest of the Lake 2 embankment, which grades down to zero along the line of the western boundary ditch.

Pre-development water environment

A.2.11 With respect to the pre-development water environment, the Applicant concludes that:

- *Groundwater within the low permeability Weald Clay is considered likely to have had no interaction with the surface water regime.*
- *total volumes of groundwater within the River Terrace deposits would be relatively small, due to the limited areal extent of this shallow aquifer and small rainfall catchment area to its south.*
- *the expected groundwater flow direction would be broadly northwards, towards the River Beult. However, ground contours also exhibit a decline north westwards, particularly at the western site boundary; An element of groundwater flow in this direction is also therefore considered highly likely.*
- *"Small-scale undulations in the form of the River Terrace deposits sub-surface elevations would lead to localised variations in groundwater flow direction."*
- *"field drains, field-boundary ditches and ponds…. would produce efficient drainage of areas overlying Weald Clay, in the south of the site, as well as reducing the volume of water available to recharge the River Terrace deposits. Conveyance of water to the River Beult would have been efficient."*

A.2.12 The second bullet point above suggests that the River Terrace Deposits is not a significant aquifer because it has a small catchment. This implies that the aquifer is isolated from lateral groundwater flows within the superficial deposits and the River Beult. However, the Superficial

Deposits are designated as a 'Secondary A Aquifer'[1] by the EA the areal extent of their surface outcrop is significantly larger than the site. There are numerous outcrops along the Beult valley and the aquifer may extend some distance beneath the Alluvium to the north. The Alluvium (a 'Secondary Undifferentiated Aquifer') is likely to be variably permeable and is potentially hydraulically connected to the River Terrace Deposits and / or the river. The base of the River Terrace Deposits at BH6 (11.85 m AOD) lies below the water level of the River Beult (12.2m AOD on plans given in PBA, 2015), so it is likely that there is some interaction between surface water and groundwater.

A.2.13 Whilst the fourth bullet point above may be a reasonable assumption, the Applicant does not present the evidence to support this, nor do they explain the relevance of the statement. It is assumed that the Applicant wishes to suggest that although some data indicate a westward groundwater head gradient at a local scale, the overall direction of groundwater flow is north-north-westwards, towards the river.

A.2.14 Regarding the fifth bullet point, limited evidence of pre-development field drainage is visible in the EA Lidar data (2002) and historical OS mapping. However, the efficiency of the drainage is unknown. We consider it likely that some field drains would have discharged to the River Terrace deposits contributing to groundwater recharge, rather than flowing directly to the river via the ditch network.

Post-development water environment

A.2.15 The Applicant concludes that groundwater within the Weald Clay Formation would be unaffected. We agree with this conclusion.

A.2.16 Within the River Terrace Deposits, a decreasing trend is reported in four boreholes (BH1, BH4, BH2A and possibly BH3A) and an increasing trend is seen in BH6 and BH8. The Applicant suggests several possible explanations for this:

- Increased groundwater level due to:
  - groundwater rebound caused by removal of a confining layer, possibly the Alluvium; or,
  - compaction of the aquifer, resulting in reduced storage and transmissivity (although this is considered unlikely as sand and gravel is not readily compressible)
- reduced groundwater level, as a result of:
  - reduced direct recharge to the superficial deposits in the areas of Lakes 2 and 3, which are now covered by low permeability made ground (compacted Weald Clay).
  - reduced recharge to the superficial deposits due to the removal of field drains (which would have carried runoff and interflow northwards from the Weald Clay outcrop) during the construction of Lake 2

A.2.17 Whilst reduced recharge is a possible effect of the development, the data presented are not continuous and could merely be reflective of seasonal variability. Furthermore, the Applicant does not acknowledge the presence of higher permeability waste material within the lake banks (Peter Brett Associates, 2015a) and, discounts the possibility for recharge from lake leakage based on their client's description of the construction works and required top-up volumes, without presenting any supporting evidence (such as pumping records or construction photographs). We consider that the groundwater level hydrograph trends are not conclusive

[1] Secondary Aquifers A: permeable strata capable of supporting water supplies at a local rather than strategic scale and in some cases forming an important source of base flow to rivers; - Secondary Aquifer B: predominantly lower permeability strata which may in part have the ability to store and yield limited amounts of groundwater by virtue of localised features such as fissures, thin permeable horizons and weathering. - Secondary Undifferentiated: In cases where it has not been possible to attribute either category A or B to a rock type (https://data.gov.uk/dataset/ef2399f1-acf4-45a7-abf3-c7369c0c8640/aquifer-designation-map-superficial-deposits).

because they are relatively short with significant gaps (18 and 20 months). The observed variability between different locations could be due to differences in connectivity with the River Beult, which defines the base water level of the system, or other surface water features.

A.2.18 No explanation is offered by the Applicant for the final groundwater level measurement recorded in February 2019, when all boreholes show a significant increase. Furthermore, where rainfall data previously accompanied the hydrographs (Hafren Water, 2017), this has not been presented in the revised report therefore it is not possible to speculate on the cause of this rise in groundwater level. Such a wide-ranging response could be related to a change in the base level of the River Beult, which appears to have been in flood on the day groundwater levels were measured[2].

A.2.19 The Applicant goes on to draw the following conclusions regarding the impacts of the development works on the groundwater regime:

- *"The total volume of groundwater within the site is considered likely to have been reduced due to the reduction in recharge"*
- *"groundwater levels in at least four of the monitoring boreholes are declining, which could be due to the decrease in recharge leading to a steady depletion of the aquifer."*

A.2.20 These conclusions rely on the assumption that recharge has reduced due to the placement of clay across the site. Whilst this is a reasonable assumption, it has not been demonstrated by the water balance calculation (see A.3.2). This is important because no real evidence has been presented to discount the possibility that recharge is occurring due to lake leakage (see A.2.17).

A.2.21 It is also noted that:

- *"Surface water distribution and flow has been modified due to the changes in topography and the loss of the pre-existing drainage system – including both field drains and field boundary ditches."*

A.2.22 With regard to mitigation, the Applicant confirms that the Western Drainage Ditch would be constructed according to the submitted PBA design (2675/MBCR2/08), comprising:

- a groundwater interceptor drain to prevent increases in groundwater level west of the site boundary; and,
- a lined open surface water drain to collect surface runoff and prevent this from recharging the aquifer at the western site boundary.

5. *As has been made clear on a number of occasions, the baseline for this development is the pre-2003 condition prior to any development taking place. It is appreciated that evidence is limited, however, an attempt needs to be made to compare the baseline condition with the proposed development in respect of groundwater impacts and, if there are implications, how this would be mitigated. The Hafren Water report only refers to groundwater levels back to 2014.*

A.2.23 For a comparison of pre- and post-development conditions the Applicant refers to their response to item 4. The Applicant considers that *"if any [groundwater effects] do exist, they are small"*, and that the proposed modifications to the Western Ditch would *"mitigate any potential effects, particularly to the west of the development"*.

---

[2] The Environment Agency flow gauge located at Staplehurst Road recorded the annual maximum river flow on 02/02/19, which appears to be the date on which groundwater levels were measured (https://nrfa.ceh.ac.uk/data/station/info/40005).

A.2.24 The applicant reproduces the description of the Western ditch proposals presented in the PBA Drainage Strategy Report and makes the following judgement regarding its effectiveness:

- *"It is important that the proposed groundwater drainage is located above the water level of nearby ponds as they may be recharged by groundwater; the groundwater drainage system could, if incorrectly installed, create drawdown of the water level in these features. The proposed invert levels of the re-engineered ditch take this criteria into account. We are satisfied that the specification of the Western boundary ditch will fulfil the drainage requirements."*

A.2.25 The perforated pipe would be installed no higher than 14.7m AOD, which is *"slightly above the recorded water level of nearby water features and ponds"*.

A.2.26 This response indicates that the design of the surface water ditch is unchanged from 2015 however, on page 30 the report states that weirs would be added to in the ditch to attenuate discharge flows.

6. *Although new groundwater levels are presented by Hafren Water in report ref 2375/WIA in tabular and graphical form, no updated groundwater contour plot was presented and discussed. The 15.5m AOD contour originally drawn by PBA (Figures 8 and 9), and previously commented on by Mott MacDonald (2016), suggests that groundwater is moving towards land to the west.*

A.2.27 The Applicant presents a single groundwater contour plot (2675/MBRC2/07) of water levels in the western area of the site only, recorded on 26/01/19. No off-site data are presented. The Applicant concedes that this *"appears to indicate an element of westwards groundwater flow in the vicinity of boreholes BH2A and BH3A"* but makes the following observations concerning the reliability of the data:

- *"BH2 is installed within the Weald Clay*
- *BH2A is installed on the southern extremity of the River Terrace deposits*
- *The response zones of boreholes BH2 and BH4 are throughout the majority of the drilled sequence whereas those of BH2A and BH3A are solely within the River Terrace deposits"*

A.2.28 The response indicates that the applicant has low confidence that the plotted data are representative of site conditions and is reluctant to concede that there is a component of westerly groundwater flow. Whatever the case, we would expect the Applicant to have presented a minimum of two groundwater level contour plots, representative of seasonal high and low groundwater conditions across the whole site.

7. *Figure 2375/WIA/12 shows groundwater levels within the Made Ground adjacent to the western boundary in BH4 and BH3A, which indicates groundwater levels are higher than when the River Terrace Deposits formed the ground surface prior to development. This needs commentary in the report as it indicates a changed groundwater gradient and may have implications for the direction and rate of groundwater movement. It is acknowledged that the groundwater levels for BH2A and 3A show a declining trend (see Figure 2375/WIA/05) nonetheless the level is still within the Made Ground so is likely to be higher than prior to emplacement of the Made Ground.*

A.2.29 The Applicant provides four possible explanations for the above observation but does not draw a conclusion as to which is / are responsible:

a. Removal of topsoil and subsoil, and possibly some of the river Terrace deposits, prior to emplacement of the imported material
b. Compaction of the River Terrace Deposits (considered unlikely)

c. Removal of field drains and ditches, which would previously have drained the area
d. Confined groundwater resulting from emplacement of impermeable material over the River Terrace Deposits (evidenced by water levels in boreholes 2A and 3A).

A.2.30 Explanation a) implies that groundwater levels may not have changed whereas b), c), and d) imply that groundwater levels may have increased compared with the baseline.

8. *In Figures 2375/WIA/11 and 2375/WIA/12, an April 2017 date was used for groundwater level but a December 2014 date was used for surface water level in the Lakes. Since April has the lowest groundwater levels recorded, whereas December has high groundwater levels (see Figure 2375/WIA/05), this decision should either be justified or more comparable dates be used for both.*

A.2.31 The Applicant states this has been corrected in drawings 2675/MBCR2/02 and 03. However, the plotted groundwater levels date from April 2017 whereas the Lake levels are for December 2018. As shown on 2675/MBCR2/01, there are significant differences in groundwater levels at certain locations on these dates. The reason why the seasonal difference between the groundwater and lake levels has not been addressed is not given; it may be that the lakes are maintained at constant levels but if this is the case, it is not stated, nor is the means by which it is achieved.

9. *There is both a rising and falling trend for groundwater elevation to the west of Lake 2 near the site boundary. BH1A indicates a rising trend and BH2A and BH3A a decline over the same period. The lower permeability of the imported Made Ground compared to the River Terrace Deposits, combined with the impermeable areas created by the reservoirs is expected to increase run-off and capture rainfall in the reservoirs compared to the baseline conditions. This is expected to result in a reduction in overall recharge to groundwater at the site and produce lower groundwater levels under the Monks Lake site. However, the rising groundwater level in BH1A indicates this may not be the case. It is possible that the landscaping is increasing run-off, particularly from the western flanks of Lake 2, and concentrating infiltration along the western margin of the site compared to pre-construction. There is no recent information presented about groundwater levels on the downgradient (west) side of the western ditch i.e. beyond the site boundary, which might indicate whether or not a focused infiltration effect is occurring; however this does not mean it can be discounted. The Hafren Water report should clarify the rising trend indicated by BH1A and its potential to influence groundwater beyond the western site boundary.*

A.2.32 The Applicant points out that the rising trend is minimal (in the order of 0.3-0.4 m) and, makes the observation that this has now ceased and that the water level in borehole 1A is in decline. It is also noted that the head difference between borehole 1A and both 2A and 3A has decreased, indicating that any westward groundwater flow has reduced. The Applicant states that without more data collected to the west of the site boundary it is not possible to undertake a more detailed assessment of changes in groundwater flow.

A.2.33 With reference to the hydrograph plotted on 2675/MBCR2/01, we agree that the rising trend at BH1A during 2017 is slight and levels during 2019 are indeed lower. The most recent data indicate a trend that is broadly in line with other boreholes, including 2A and 3A. As stated in A.2.17, in our view there are insufficient data and too many gaps in the dataset to conclude that the observed trends in groundwater level represent anything other than seasonal variation.

10. *One would expect the 1m deep surface water diversion channel (interceptor drainage channel) proposed by PBA to intercept the run-off from the sides of Lake 2 and divert it to the river, so long as the drain is lined as designed to minimise groundwater recharge.*

Hafren Water should comment on this as mitigation for this effect if it still forms part of the proposed plan.

A.2.34 The Applicant states that the proposed channel is an essential component of the development, which is expected to fully mitigate surface and groundwater impacts to the west of the site.

11. *Please clarify whether the western ditch continues to function as prior to 2003 in relation to drainage of groundwater – i.e. there has been no significant change in base elevation of the ditch and the relationship of the ditch base, pond level on land to west of the site and groundwater levels at the Monks Lake site.*

A.2.35 The Applicant re-iterates that the ditch has been significantly extended (southwards) since 2003. Pre-development, it is thought to have carried field drainage and runoff from the north of the site towards the river and played no role in the control of groundwater level. The 2018 survey indicates that the bed of the ditch is generally above local groundwater level and the reported elevation of the Hertsfield Farm pond (14.7m AOD). The applicant does not comment on whether the bed elevation of the northern (original) section of the ditch has changed.

12. *Rainfall data and flooding from 2014 has been presented, as it was in ESI, 2015. No new information has been presented so it is unclear if this means that there has been no new flooding at Hertsfield Barn Pond since 2015. Hafren Water's report implies that there has been, but no specific dates seem to have been given. It would therefore be helpful to know if there have been any flood events since 2014 against which rainfall and groundwater levels could be compared.*

A.2.36 The Applicant clarifies that they are unaware of any flooding events at Hertsfield Farm since 2014, and neither have any been identified by ESI.

A.3 MBC e-mail of 25th January 2019

Water Balance

13. *Water Balance*: *We would expect to see a calculation showing a pre-construction water balance for the green field site compared to the water balance for the completed reservoirs construction. It needs to consider the effect across the summer/winter seasons and also how it has changed in different areas across the site eg for the impermeable reservoirs and the additional runoff produced from the reservoir side slopes on the west. Calculating an average for the whole site is not detailed enough given the potential local effects. From the predicted changes to recharge it should be possible to comment on likely impacts on groundwater flow direction across the site due to the development.*

A.3.1 The Applicant has attempted water balance calculations of the following form.

- Pre-development:
  - IN (effective rainfall + interflow + runoff from adjacent areas) = OUT (ditch outflow + groundwater outflow + runoff to adjacent areas)
- Post-development
  - IN (direct rainfall + off-site runoff) = OUT (ditch outflow (incl. runoff) + groundwater outflow + pumped water from Lakes 1-3 + lake evaporation)

A.3.2 The pre-development calculation assumes that the hydraulic gradient is equal to that of the topography. It would be more appropriate to estimate a range, based on assumed water levels from a pre-development conceptual site model, had one been presented. Similarly, rainfall is based on a single annual estimate for the region, rather than data from a nearby measuring station. The Applicant acknowledges that this provides only an *"indicative result"*.

A.3.3 The Applicant concludes that there are too many unknowns to calculate a meaningful post-development water balance. As above, our view is that this could have been done using assumptions and parameter ranges consistent with those used for the pre-development conceptual site model.

A.3.4 The calculations presented do not address the key requirements of point 13 (seasonality and changes in recharge / runoff within different areas of the site), so the Applicant is unable to demonstrate whether recharge to the superficial deposits could have been reduced by the placement of low permeability fill or, to discount the possibly of lake leakage. Neither can they draw any conclusions regarding potential impacts on groundwater flow direction.

Water Level Comparison

14. Water level comparison: You should consider the original land surface elevation and estimate baseline groundwater levels. This could be based on elevation of ditches, and pond and river levels with assumed gradients. And then comment on how the observed groundwater level has changed relative to those, particularly on the west of the site where it appears there is a perched water table developing in the made ground relative to that original land surface. These new groundwater elevations and associated flow paths should be related to the adjacent property and levels and show how the mitigation measures (i.e. the western engineered drainage ditch (if it is still part of the proposal) will maintain groundwater levels at an elevation that protects the adjacent land and property.

A.3.5 The Applicant refers to their response to item 4 and comments from Kent County Council (see item 15 below). The Applicant concludes that groundwater is not present within the Made Ground but is confined beneath it, in the superficial deposits. However, they do not present a clear conceptual site model contrasting the pre- and post-development situations; nor have they adopted the suggestion to use assumed gradients based on the known levels of ditches and the River Beult, which could have been used in the water balance assessment.

A.3.6 The Applicant states in their response to item 5 that the installation of the groundwater infiltration drain at or above 14.7m AOD would maintain groundwater at this level, mitigating impacts to offsite receptors including Hertsfield Farm pond. Relative levels are illustrated in cross-section 2675/MBCR2/03 but there is no schematic to show how the mitigation system would work. Neither are any calculations presented (in either the Hafren Water or PBA reports) to estimate the potential volume of groundwater discharge the system would carry.

A.4 KENT COUNTY COUNCIL LETTER OF 21ST SEPTEMBER 2017 (MBC/2017/062654)

Groundwater Levels

15. We would appreciate further clarification on the baseline topography of the site in relation to the most recently observed groundwater levels (i.e. the topography of the site prior to the construction of any of the lakes now present). If these recently determined groundwater levels appear to be close to or higher than the pre-development ground levels, it would be reasonable to conclude that the development has altered the hydrogeological regime.

A.4.1 The Applicant refers to their response to item 4 and compares maximum and minimum groundwater levels with 2002 Lidar data (accuracy ±0.25m). Only boreholes BH1 and BH8 exhibit maximum water levels (decimetres) above the pre-development ground level, therefore the applicant concludes that the groundwater regime has been altered *"insignificantly"*.

A.4.2 The Applicant presents the data in metres above ordnance datum (mAOD) however, it would be more useful to present this as depth below pre-existing ground level (mBGL) as follows. This shows that in addition to BH01 and BH08, the water depth at BH2 and BH4 is within the 0.25m Lidar accuracy, so could be also above the pre-development ground level. The remaining boreholes exhibit relatively shallow depths to groundwater, particularly if 0.25m is subtracted from the ground levels.

Table 2: Groundwater levels compared to pre-development ground levels

	Borehole:	01	02	04	05	06	07	08	1A	2A	3A
Pre-development ground level (±0.25m)	mAOD	16.75	17.25	16.25	16.25	15.5	16.25	16.25	16.75	16.75	16.5
Max. groundwater level	mAOD	17.58	17.17	16.1	15.5	14.64	15.85	16.41	16.23	15.88	16.09
Min. groundwater level	mAOD	15.69	16.37	15.54	15.07	13.94	15.6	15.75	15.9	15.5	15.65
Max. groundwater level	mBGL	**-0.83**	**0.08**	**0.15**	0.75	0.86	0.4	**-0.16**	0.52	0.87	0.41
Min. groundwater level	mBGL	1.06	0.88	0.71	1.18	1.56	0.65	0.5	0.85	1.25	0.85

Adapted from (Hafren Water, 2019). Bold text indicates groundwater level potentially above pre-development ground level.

A.4.3 The Applicant notes that "BH1 is located in predominantly clayey material of the Weald Clay and may always have exhibited confined groundwater conditions", which is possible.

16. *We would appreciate clarification on the likely reason for the water level in Lake One to be lower than the observed groundwater levels in the boreholes located approximately to the south and north of the feature. Given that the lake and groundwater levels were deemed to be relatively stable, we would have expected to see a continuity in ground/lake water levels. If pumping from Lake One to the rest of the system is more significant than stated, there may be additional losses throughout the system that have not yet been accounted for.*

A.4.4 The Applicant considers Lake 1, which is excavated into the low permeability Weald Clay and has a water level consistently below the top of the Weald Clay, to be hydraulically isolated from the local water environment. We agree that this is likely.

17. *It is unclear as to why the groundwater levels observed in borehole one have not manifested themselves a seepage/springs emerging from the embankment to the south and west. Whilst we appreciate that the borehole was not located immediately adjacent to the southernmost boundary, the extrapolated of borehole data would suggest that this should be the case.*

A.4.5 The Applicant states that because borehole BH01 is installed in the Weald Clay and made ground (comprising compacted Weald Clay), which are both low permeability materials, *"the distance over which raised groundwater levels would occur would be expected to be extremely limited… It is not expected that the water levels recorded in BH1 would be exhibited in the embankment as a groundwater table"*. This is consistent with the idea that the Weald Clay Formation is isolated from the overlying permeable units (see A.2.15).

A.5 Environmental Statement Conclusions

A.5.1 The technical report (Hafren water, 2019) draws the following conclusions.

- Pre-development, the River Terrace Deposits aquifer may have been locally confined, where overlain by Alluvium, which would have allowed borehole water levels to rise until they reached equilibrium;
  - This seems to be provided as an explanation for observed groundwater levels being close to or above pre-development ground levels; however, this is not stated. In our view, this conclusion is not well supported by the report.
- The apparent decline in groundwater levels in the west of the site may be due to reduced groundwater recharge as a result of the development;

  - In our view, insufficient evidence has been presented to conclusively demonstrate a decline in offsite groundwater levels and the observed fluctuations are more likely explained by seasonal variability.
- The proposed mitigation, installed as per the PBA specification (Peter Brett Associates, 2015b), would mitigate any offsite waterlogging whilst maintaining groundwater flow to offsite receptors (i.e. Hertsfield Farm pond);
  - This is contrary to the statement in Section 4.1 (Hafren Water, 2019, pp. 30-31) that additional weirs and non-return valves would be installed to attenuate flow and prevent inflow from the River Beult, when in flood.

A.5.2 The Revised ES concludes (in Table 10.1) that combined impacts on flood risk, hydrology, hydrogeology and drainage would be:

- Adverse – high significance, without mitigation; and
- Negligible – neutral significance, with the proposed mitigation in place.

A.5.3 The Applicant considers that the effects would be Long-term, Direct and Irreversible. Identified receptors are Local Watercourse and Local Community, which are assessed to be of High Sensitivity.

A.5.4 The amalgamation of several different receptor groups has resulted in none of the discrete impacts being assessed individually. However, we agree that if the proposed mitigation is effective, impacts on the neighbouring properties to the west, due to increased groundwater levels, would be negligible.

B. Drainage Calculations

B.1 Groundwater Interceptor Drain Capacity

B.1.1 Pipe capacity was calculated using the Colebrook-White Equation, based on a pipe gradient of 1 in 455 determined from the Interceptor Drain Long Section shown on drainage strategy drawing 29431/001/SK03 (Peter Brett Associates, 2015b). The calculation parameters and result are shown below.

Table 3: Groundwater interceptor drain – pipe capacity

Parameter	Units	Value
Flow	l/s	8.187
Velocity	m/s	0.463
Diameter	mm	150
Depth	mm	150
Slope	m/km	2.198
Roughness	mm	0.6
Temperature	°C	15
Energy coeff		1.060

Source: Mott MacDonald

B.2 Groundwater Inflow Rate

B.2.1 The required capacity of the groundwater interceptor drain has been estimated using data presented by the Applicant. Calculations were undertaken using the equation for groundwater flow to a fully penetrating trench, presented in CIRIA Report C750, Groundwater control: design and practice (CIRIA, 2016, p. 124).

B.2.2 Flow rates have been calculated for boreholes installed within the River Terrace Deposits aquifer, close to the western site boundary, assuming confined groundwater conditions on-site and unconfined conditions off-site, to the west (as suggested by the available data). The trench containing the groundwater interceptor drain is conservatively assumed to fully penetrate the aquifer, which is reasonable given apparent thinning of the aquifer at this location. Partial penetration would result in slightly reduced flows.

B.2.3 The permeability of the River Terrace deposits is assumed to be 10m/d, which is the maximum value reported by the Applicant and used in their calculations. The permeability of the River Terrace Deposits typically ranges from 5 to 50m/d; 10m/d is typical of well sorted sand and gravel, so is considered to be conservative, given the clay content reported in the exploratory hole records. Aquifer parameters for each borehole are given in Table 4.

Table 4: Aquifer parameters influence

Parameter	Symbol	Borehole					Source
	(Units)	BH1A	BH2A	BH3A	BH04	BH05	
Ground level	(mAOD)	22.19	18.01	19.17	17.76	16.57	Hafren Water, 2017
Depth to Alluvium	(m)	5.9				3	Hafren Water, 2017
Depth to River Terrace Deposits	(m)	8.2	4	4.9	3.2	4.2	Hafren Water, 2017
Depth to Weald Clay	(m)	9.8	4.8	6	5.3	6	Hafren Water, 2017

Parameter	Symbol	Borehole					Source
Maximum groundwater elevation	(mAOD)	16.23	15.88	16.09	16.1	15.5	Hafren Water, 2019
Aquifer thickness	B (m)	3.9	0.8	1.1	2.1	3	Calculated
Permeability	K (m/d)	10	10	10	10	10	Maximum assumed value from Hafren Water, 2019
Permeability	K (m/s)	1.16E-04	1.16E-04	1.16E-04	1.16E-04	1.16E-04	Calculated

Source: Mott Macdonald

B.2.4 The total groundwater discharge has been calculated from the sum of unconfined flow from the west and confined flow from the east. The calculations require the radius of influence (R_0) of the drain (distance to the point where drawdown of groundwater level due to the ditch is negligible). This has been estimated using the Sichardt equation[3], assuming that the maximum groundwater level for each borehole equals the height of piezometric surface above base of aquifer (H). In most cases the ratio of R_0/H is slightly greater than the ideal maximum of 5, so calculated flows may be slightly underestimated.

To allow for potential lake leakage, inflow from the east has also been calculated assuming a recharge boundary at Lakes 2 and 3[4] (i.e. R_0 = distance from trench to lake, and H = lake level above aquifer base). The results are presented in the following tables.

Table 5: Confined groundwater discharge from east – assume Sichardt radius of influence

Parameter	Symbol					Borehole	Source
Distance to drain from borehole	L (m)	46.1	6.8	16.3	6.4	8.7	Hafren Water, 2019
Height of drain above aquifer base	h (m)	2.31	1.49	1.53	2.24	4.13	Calculated
Height of groundwater above aquifer base at borehole	H (m)	3.84	2.67	2.92	3.64	4.93	Calculated
Sichardt Radius of influence	Ro (m)	32.9	25.4	29.9	30.1	17.2	Calculated
Ro/H (ideally <5)		8.6	9.5	10.2	8.3	3.5	Calculated
Flow per unit length	Q/x (m3/s)	2.10E-05	4.30E-06	5.92E-06	1.13E-05	1.61E-05	Calculated
Interceptor drain length	x (m)	273	273	273	273	273	Calculated
Total groundwater flow	Q (m3/s)	0.006	0.001	0.002	0.003	0.004	Calculated
	Q (l/s)	5.727	1.175	1.615	3.084	4.406	Calculated

Source: Mott Macdonald

Table 6: Confined groundwater discharge from east – assume recharge boundary at Lake 2 / 3

Parameter	Symbol	Borehole					Source
	Units	BH1A	BH2A	BH3A	BH04	BH05	
Distance to drain from lake	L (m)	77.5	77.5	77.5	77.5	45.5	Hafren Water, 2019
Height of drain above aquifer base	h (m)	2.31	1.49	1.53	2.24	4.13	Calculated
Height of lake water level above aquifer base at borehole	H (m)	8.31	7.49	7.53	8.24	7.93	Calculated
Sichardt Radius of influence	Ro (m)	129.1	129.1	129.1	129.1	81.8	Calculated
Ro/H (ideally <5)		15.5	17.2	17.1	15.7	10.3	Calculated

[3] Calibration factor (C) = 2000 as per C750 guidance.
[4] BH05 only

Parameter	Symbol	Borehole					Source
Flow per unit length	Q/x (m3/s)	3.49E-05	7.17E-06	9.86E-06	1.88E-05	2.90E-05	Calculated
Infiltration drain length	x (m)	273	273	273	273	273	Calculated
Total groundwater flow	Q (m3/s)	0.010	0.002	0.003	0.005	0.008	Calculated
	Q (l/s)	**9.540**	**1.957**	**2.691**	**5.137**	**7.917**	Calculated

Source: Mott Macdonald

Table 7: Unconfined groundwater discharge from west – assume Sichardt radius of influence

Parameter	Symbol	Borehole					Source
	Units	BH1A	BH2A	BH3A	BH04	BH05	
Distance to drain from borehole	L (m)	46.1	6.8	16.3	6.4	8.7	Hafren Water, 2019
Height of drain above aquifer base	h (m)	2.31	1.49	1.53	2.24	4.13	Calculated
Height of lake water level above aquifer base at borehole	H (m)	3.84	2.67	2.92	3.64	4.93	Calculated
Sichardt Radius of influence	Ro (m)	32.9	25.4	29.9	30.1	17.2	Calculated
Ro/H (ideally <5)		8.6	9.5	10.2	8.3	3.5	Calculated
Flow per unit length	Q/x (m3/s)	1.65E-05	1.12E-05	1.20E-05	1.58E-05	2.44E-05	Calculated
Infiltration drain length	x (m)	273	273	273	273	273	Calculated
Total groundwater flow	Q (m3/s)	0.005	0.003	0.003	0.004	0.007	Calculated
	Q (l/s)	**4.516**	**3.054**	**3.267**	**4.317**	**6.652**	Calculated

Source: Mott Macdonald

B.2.5 A wide range of flows has been determined from different boreholes, due to variations in aquifer thickness and hydraulic gradient. The total maximum flow (from east and west) is shown in Table 8 for both conditions. Data from BH05 results in the highest (and therefore most conservative) flow estimates, of 15l/s, assuming there is leakage from Lake 2, or 11l/s without leakage.

Table 8: Total maximum groundwater flow to interceptor drain

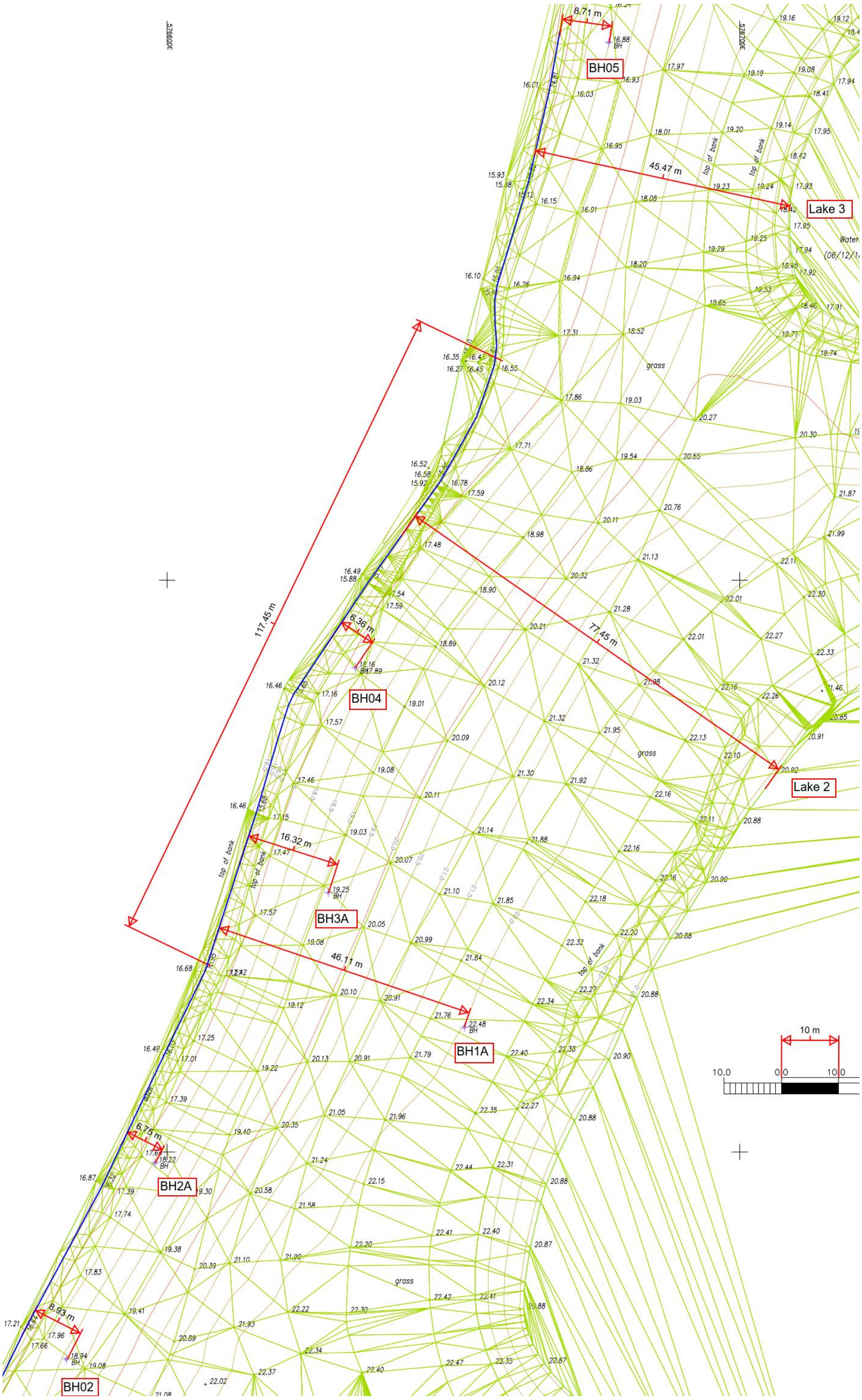
Total Flow Condition	Units	BH1A	BH2A	BH3A	BH04	BH05
Assume lake recharge boundary	Q (l/s)	14.056	5.011	5.958	9.455	**14.569**
Assume Sichardt radius of influence	Q (l/s)	10.243	4.229	4.883	7.401	**11.058**

Source: Mott Macdonald

B.2.6 The calculated flows are indicative of potential maximum flow rates, that could be experienced during an extreme event or as a result of sustained recharge. Under normal circumstances flow to the interceptor drain would probably be much lower. However, given the uncertainties in the conceptual site model, the drain should be sized to accommodate flows that take these risks into account.

B.2.7 All distances have been measured from Sheet 3 of the 2018 survey drawing presented in Appendix 4 of the Applicant's technical report (Hafren Water, 2019), as shown on the annotated image below.

Figure 3: Borehole distances from western boundary ditch



Source: (Hafren Water, 2019)

mottmac.com