HR Wallingford
Working with water

Kingfisher Pond - Northstowe Hydrogeological Assessment

Phase III Report

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Executive Summary

In 2015 residents in Longstanton reported that water levels in the local Kingfisher Pond had declined. There have been ongoing concerns since then. The year 2015 coincided with initial development at adjacent Northstowe Phase 1.

HR Wallingford has been commissioned by South Cambridgeshire District Council (SCDC) on behalf of Longstanton Parish Council (the client) to complete an independent review on the hydrogeology of Northstowe, Cambridgeshire.

HR Wallingford proposed a three-phase approach which was:

I. Review the hydrology and hydrogeology of the Kingfisher Pond and surrounding area prior to concerns being raised about its condition (2015) and develop a conceptual model of the area;

II. Review the more recent hydrology and hydrogeology and determine if the Kingfisher Pond has changed since 2015 and, if there is a change then;

III. Determine the cause of the changes in the hydrology and hydrogeology of the Kingfisher Pond.

The Phase I report was completed and distributed to Longstanton Parish Council and South Cambridgeshire District Council in February 2021. That report detailed how the pond and local hydrogeology operates under natural conditions. SCDC and Longstanton Parish Council (LPC) were in agreement of the conclusions presented in the Phase I report. The report was distributed to residents and other stakeholders who agreed with the understanding of the Kingfisher Pond's hydrogeology. However, there were some comments on the report. To ensure transparency all the comments received regarding the Phase I report have been added to an appendix in a revised Phase I report.

The Phase II report was completed and distributed in April 2021. That report detailed the available data between 2015 and 2021 for hydrogeology, climate, and land use change. It was concluded that groundwater levels fell below normal conditions between autumn 2015 and winter 2020/21. By March 2021 groundwater levels had risen, but the water level in the Kingfisher Pond was below those experienced prior to 2015. It is unclear if this represents a temporary or sustained recovery. SCDC and LPC reviewed the data and conclusions presented in the Phase II report. As with the Phase I report, all comments have been added to an appendix in a revised Phase II report.

This report completes the **third phase** and presents HR Wallingford's understanding of the reasons for recent hydrogeological changes to the Kingfisher Pond and the shallow aquifer which underlies the area. The key findings are presented in Box 1.

Box 1: Summary of key findings of the changes to local hydrogeology of the Kingfisher Pond

Our key findings are:

The Kingfisher Pond is situated in, and in hydraulic continuity with, the underlying River Terrace Deposit (RTD) aquifer. The water table is shallow and therefore changes to the RTD will have a large impact on the Kingfisher Pond's water levels. The groundwater levels in the RTD fell below the normal historic range between autumn 2015 and autumn 2020.

Regional and local climate data indicates that there were several dry periods between 2015 and 2020. The RTD is responsive to weather and therefore groundwater elevation will be expected to fall following prolonged dry weather. Periods of below average rainfall throughout the previous 6 years are expected to have reduced the aquifers ability to naturally recharge. Recent heavy rainfall in winter 2020/21 coincided with a recorded rise in groundwater level. It is not clear if this increase in groundwater elevation will be sustained.

Local land use change as a result of the development of Northstowe is concluded as the most significant impact on the RTD groundwater elevation. The key impacts are as follows:

- Initial construction dewatering in 2015 and 2016 lowered groundwater levels to 5 m below ground level and the rate of abstraction was reported as being approximately 6 Ml/d. Dewatering is a standard approach for construction above a shallow aquifer. The dewatering of the RTD for the construction of Northstowe resulted in an initial drying out of the Kingfisher Pond, due to its close proximity (c. 100 m) of dewatering activities.
- The construction of Northstowe has changed the recharge of the RTD and ponds and other groundwater-fed features, in particular the Kingfisher Pond.
- It is unclear if the design principles of the greenways have been met, or if they will continue to reduce groundwater levels in the RTD and Kingfisher Pond below historic levels.

Water levels in the Kingfisher Pond were observed to have risen in early 2021. The rise in water level coincided with above average rainfall between December 2020 and February 2021. However, despite the above average rainfall, the water levels remained approximately 0.3 m below pre-2015 pond water levels. Whilst water levels in the Kingfisher Pond have risen recently, it is currently unclear if water levels in the Kingfisher Pond will be sustained, or if, as a result of the land use change and greenways, the pond will generally have lower water levels than in the past, or will be more susceptible to dry weather. Given the location of the pond, it is considered to be more susceptible to these land use and drainage changes than other ponds. The evidence suggests the other ponds and groundwater-fed features in Longstanton are unlikely to be affected in the long-term.

Whilst we conclude that the dewatering during the development of Northstowe is the primary cause of the changes to the Kingfisher Pond and this dewatering impacted on other ponds in the area as well, secondary causes are likely to have been periods of low rainfall and changes to recharge due to land urbanisation.

Longstanton Parish Council raised concerns about cracks observed in Longstanton Village Institute and All Saints Church. We suggest a specialist be asked to comment on this. We can provide names of suitably qualified experts.

We recommend that monitoring is installed and maintained to determine the impacts of the Northstowe Development on the Kingfisher and other groundwater-fed features.

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1. Introduction

1.1. Background

Longstanton is a village and civil parish located 10 km north east of Cambridge, Cambridgeshire. Throughout the village there are several water features, including the Kingfisher Pond. The Kingfisher Pond is a large pond with a surface area of 3000 m^2 (when full) and a depth up to 2 m. The Kingfisher Pond is located on the main site of Northstowe Phase 1 (52°17'6.53"N, 0° 3'0.60"E) and is underlain by a shallow aquifer called the River Terrace Deposits (RTD).

The water levels in the Kingfisher Pond were reported to decline in autumn 2015, coinciding with a reported decline in water level at several other lakes, ponds, and wells in Longstanton. HR Wallingford are reviewing these reported changes in the Kingfisher Pond since 2015. Other hydrogeological features which are located in the RTD are also being reviewed to understand the extent of changes to the local hydrogeology.

HR Wallingford completed and distributed the Phase I report to SCDC and LPC in February 2021. The report was to review the hydrology and hydrogeology of the Kingfisher Pond and surrounding area prior to concerns being raised about its condition (2015) and develop a conceptual model of the area the local hydrogeology. The emphasis of the Phase I report was on the importance of the RTD which underlay Longstanton and are the principal water supply to surface water features including the Kingfisher Pond. The RTD are classified as a Secondary A aquifer with significance to local groundwater (WSP, 2014a; Environment Agency, 2017a).

The key findings of the Phase I report were:

- The pond is sited in RTD which consists of sands and gravels which overlay low permeability clay.
- Water in the Kingfisher Pond and RTD are in hydraulic continuity, meaning that the water levels in the pond will reflect water levels in the RTD. This means that if water levels in the RTD rise then the water levels in the Kingfisher Pond will also rise, up to the level of an overflow pipe. Likewise, if groundwater levels in the RTD fall, then water levels in the Kingfisher Pond will fall.
- There are several other ponds and lakes also situated on the drift deposits. These will be affected by a change in groundwater level under the assumption they are also in hydraulic continuity with the drift deposits.
- There is limited measured data on water levels in the Kingfisher Pond prior to 2015.
- There is no evidence in the data of a long-term trend of reducing rainfall in the area (1961-2015).
- There are several useful boreholes in the area, which show:
  - That there is no long-term evidence of groundwater levels declining before 2015.
  - The water level in the pond is at the same level as groundwater level in the drift deposits.

Following the Phase I report, HR Wallingford completed the Phase II report in April 2021 which described the change in RTD groundwater level and other relevant hydrogeological data since 2015. The Phase II report presented analytical data and observational evidence compiled in the local area from 2015 onwards, the approximate time at which there were reports that the water levels in the Kingfisher Pond had declined. The key findings of the Phase II report were:

- The groundwater elevation in the RTD underlaying Longstanton and the Kingfisher Pond have dropped to below normal conditions in the period between autumn 2015 to autumn 2020.

- The water level in the Kingfisher Pond and other water features on the RTD rose to near pre-2015 levels in winter 2020/21, however water levels in the Kingfisher Pond were about 0.3 m below pre-2015 levels. The winter 2020/21 increase in groundwater elevation coincided with above average rainfall across large parts of the UK, with extensive flooding in some parts of East Anglia.

The conclusions drawn in the Phase II report were supported by the following evidence:

- Observational evidence and photographs confirm that the water levels in the Kingfisher Pond and other local ponds initially declined in autumn 2015. The minimum level observed at the Kingfisher Pond occurred in 2017 when the Kingfisher Pond completely dried out. The pond's water levels have remained below normal between autumn 2015 and 2020.
- Groundwater levels on the site of Northstowe initially declined in autumn 2015. This followed below average spring rainfall and the dewatering of Northstowe Phase 1A.
- Boreholes monitored on the site of Northstowe show that groundwater levels were below typical levels throughout March 2017 to December 2020. This did not coincide with prolonged dry weather.

Local land use change includes both the construction of the A14 and the construction of Northstowe. Analysis of planning reports show that:

- Construction dewatering of the RTD aquifer to a depth of 5 m below ground level occurred in two phases: Phase 1A in May to September 2015 and Phase 1B in May to November 2016.
- The Northstowe surface drainage strategy comprises of swales and two greenways feeding the clay lined attenuation ponds.
- The urbanisation of the site has changed the surface area of permeable land available for direct infiltration and recharge of the RTD.

1.2. Report Scope

This report is intended to conclude on the reasons for the recent hydrological changes and decline in groundwater elevation. The focus of this report is the Kingfisher Pond, however other local ponds within the same RTD hydrogeological system are considered where appropriate.

The conclusions within this report are based upon analytical assessment of available data, resident survey results and a site visit.

The report includes the following sections:

- Summary of available data and limitations (Section 2);
- Summary of conceptual hydrogeology model (Section 3);
- Discussion of recent changes in local hydrogeology (Section 4);
- Conclude the reasons for the decline in groundwater levels (Section 5);
- Recommendations for further work (Section 6).

The aim of this report is to:

- Summarise the Phase I and Phase II report;
- Conclude the reasons for the change in local groundwater levels since 2015;
- Highlight limitations of the report;
- Provide recommendations for the Kingfisher Pond;

- Outline next steps, including consulting on this document to ensure that all relevant parties have accessed it and agree with it.

2. Summary of available data

2.1. Overview

Data from a range of sources was considered to ensure that the review provided a comprehensive summary of all changes occurring in the local area. This section intends to summarise the limitations and uncertainties in the data and how they may impact the conclusions presented in this report.

The key points of this section are:

- There is comprehensive data and literature on the bedrock and superficial geology;
- There is comprehensive rainfall data available which is considered suitable for the purpose of the report;
- There is available groundwater elevation data for the RTD from several sources, however there are limitations of the temporal and spatial coverage of the data;
- There are limited surface water level data at the Kingfisher Pond. Therefore, conclusions of changes to the Kingfisher Pond's surface water elevation are primarily based upon observational evidence, including photographs.

2.2. Data limitations and uncertainty

Within the Phase I and Phase II report, limitations to the available data have been highlighted alongside the data presented where appropriate.

In this section, the data has been highlighted as Low, Medium, or High confidence depending on the comprehensiveness, quality, and resolution of the data. Classifications are given as a confidence index in Table 2.1. The classifications are assigned to the data and are summarised in full in Table 2.2.

Table 2.1: Confidence index

Score	Data
High	Comprehensive data availability.
Medium	Data available but resolution is either temporally or spatially relatively coarse for purpose.
Low	Limited data availability or the data cannot be verified

Notes: Note that this provides indicative guidance only.

Table 2.2: Summary of data and limitations

Data type	Data subcategory	Source	Confidence classification and justification *
Geological	Bedrock geology	BGS (1975; 1981; 1976; 2020a; 2020d; 2020e) Wardell Armstrong (2017) WSP (2014a)	Bedrock geology confirmed as the Ampthill Clay (AmC) from multiple sources including BGS maps and Northstowe on-site ground investigation. There is high confidence in the bedrock geology classification.
	Superficial geology	BGS (1975; 1981; 1976; 2020b; 2020c; 2020f) Wardell Armstrong (2017) WSP (2014a)	Superficial geology confirmed as the RTD by multiple sources including BGS maps and Northstowe on-site ground investigation. There is high confidence in the superficial geology classification.
Climate	Rainfall	Cambridge National Institute of Agricultural Botany (NIAB) (Met Office, 2021) Had-UK 1 km gridded daily rainfall (Met Office, 2019)	The Cambridge NIAB rain gauge is located 5 km away from the Kingfisher Pond. While local variations in regional rainfall do occur, the use of the Cambridge NIAB rainfall station is not a significant limitation in this assessment. The Phase I report confirmed that this data was consistent with Met Office Had-UK 1km gridded data.
	PET	Robinsons et al. (2020)	The rate of open water evaporation was estimated using CHESS-PE (Robinsons et al., 2018) data converted to open water evaporation with the use of empirical factors (Environment Agency, 2001). This method is documented in detail in the Phase I report appendix. The open water evaporation is an

Data type	Data subcategory	Source	Confidence classification and justification *
			approximation and not derived from local physical data, however the limitations of this method are considered minimal within the context of the conclusions drawn from the data.
Groundwater level	Environment Agency (East Anglia) groundwater levels at Redlands Hall and Therfield Rectory	Environment Agency (2018; 2021)	The groundwater elevation is recorded at regular intervals using industry standard techniques. These boreholes are not significantly affected by abstractions, making them suitable for analysis of climatic variation. There is high confidence in the quality of the data available. Within this project, the data is used as a reference for regional changes and is not used directly to infer conclusions on the Kingfisher Pond or RTD.
	Northstowe Phase 1 groundwater levels	WSP (2014a) Wardell Armstrong (2017)	There is limited data available during the period of dewatering throughout 2015 and 2016. The extent to which groundwater drawdown occurred during the initial dewatering is therefore uncertain. The process of groundwater level recovery following initial dewatering is unclear due to lack of regular data recordings.
	Groundwater levels recorded by borehole loggers at BH144 Northstowe Phase 1	L&Q (2021)	Regular data available throughout period 2017 to 2020 have been supplied by L&Q. There is high confidence of this data due to the frequency of data and the consistency with observational evidence.

Data type	Data subcategory	Source	Confidence classification and justification *
	RTD Environment Agency monitoring boreholes at Unwin's Farm and New Farm	Environment Agency (2020)	There are limited measurements available, and data has not been collected at regular intervals. The data is therefore only used as an indicator of long-term trends but interpolation of groundwater elevation between data points is unreliable.
	Groundwater level obtained by HR Wallingford in March 2021	HR Wallingford (2021b)	HR Wallingford took a measurement at Unwin's Farm borehole during the site visit. This measurement was added to the Environment Agency data.
Kingfisher Pond water level	Recordings of surface water level of the Kingfisher Pond	Wardell Armstrong (2017)	There are minimal recordings taken during the Northstowe Phase 1 development. Therefore, conclusions of changes to the Kingfisher Pond's surface water elevation are primarily based upon observational evidence and absolute water depth is an approximation.
Surface water flow	Longstanton river and stream flow data	A data request was submitted to the Environment Agency however no information was held for the Cottenham Lode, Longstanton Brook and Reynolds Drain or for relevant gauging or flow records in the area	No data avallabile.
Site Observations	Photographs	HR Wallingford, 2021b	Dated photographs of the local area provide a useful understanding of the conditions at the specific location and point in time. The data is used as supporting evidence and conclusions are not drawn solely from photographs. The

Data type	Data subcategory	Source	Confidence classification and justification *
			confidence associated with this data has therefore been classified as high.
Resident Surveys	Photographs	NA	Resident surveys are intended to gain an understanding of local changes and the history of the local area. Dated photographs of the local area provide a useful understanding of the conditions at the specific location and point in time. The data is used as supporting evidence and conclusions are not drawn solely from photographs. The confidence associated with this data has therefore been classified as high.
	Anecdotal Evidence	NA	Anecdotal evidence has been used as supporting evidence but not relied on as stand-alone data. Survey data may include personal bias in recollection where not supported by physical data. There are therefore limitations associated with this data and it has been classified as medium confidence.

*Notes: * Uncertainty classifications provided in Table 2.1.*

3. Conceptual model

3.1. Overview

The Phase I report (HR Wallingford, 2021a) presented a conceptual understanding of the hydrogeology of the Kingfisher Pond. This detailed the bedrock geology, superficial geology and how the pond recharges under natural conditions.

The key points of the conceptual model are:

- The Kingfisher Pond has been a continual feature in Longstanton for many decades since it was dug out in the late 1960/early1970's;
- The pond is situated in the centre of the RTD and confined below by the Ampthill Clay (AmC) (BGS 2020a, BGS 2020b) (Figure 3.1; Figure 3.2);
- The depth of the pond (when full) is less than 2 m. Because it is a shallow pond, a small drop in groundwater levels can significantly affect the pond;
- Rainfall falls directly on the pond and onto the RTD, topping up the pond and increasing groundwater levels;
- There will be evaporation from the pond, particularly during summer;
- The pond and RTD are in hydraulic continuity, so there is exchange of water between the pond and the RTD, which means that the water level in the pond will change as groundwater levels in the RTD change;
- The RTD is isolated from other aquifers given its linear nature and the underlying AmC (BGS 2020a, BGS 2020b);
- An overflow pipe was implemented in the pond to prevent the water overtopping the banks of the pond during periods of high winter rainfall. The pipe therefore partially controls levels in the pond in the event groundwater levels are high.

3.2. Model diagram

Figure 3.1 presents a conceptual diagram of the pond and the underlying geology. This diagram displays a conceptualisation of the exchange between groundwater and surface water. Figure 3.2 present the BGS 1:50 000 drift deposit map (BGS, 2020c) highlighting the location of the Kingfisher Pond within the RTD.

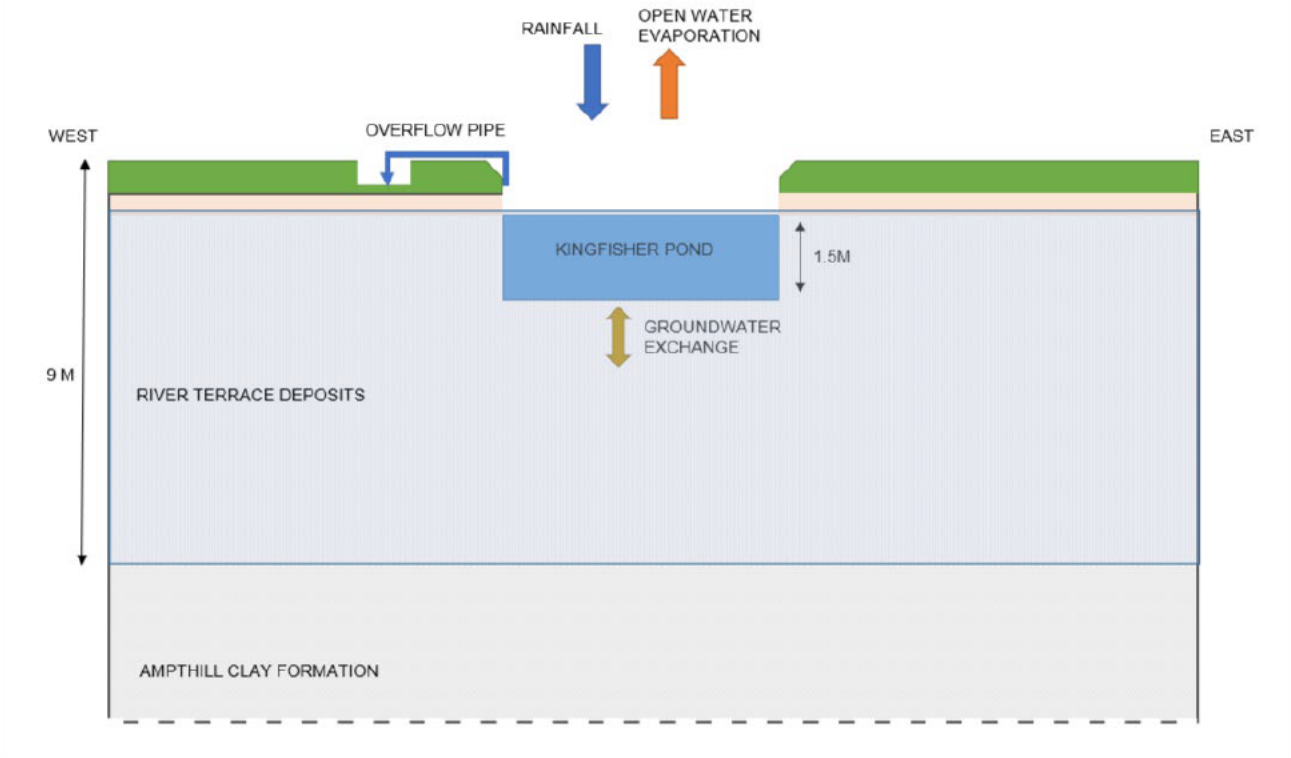

Figure 3.1: Schematic diagram describing the hydrogeological interaction of the Kingfisher Pond with the RTD aquifer

Source: HR Wallingford (2021a)
Notes: All measurements are approximate.

Figure 3.2: Geological map showing location of the Kingfisher Pond on the RTD

Source: British Geological Survey 1:50 000 drift and bedrock geology, reproduced in QGIS. All rights reserved. OpenStreetMap reproduced in QGIS.

4. Discussion of recent changes

4.1. Changes to local climate

The Phase I (HR Wallingford, 2021a) and Phase II (HR Wallingford, 2021b) report presented local climate data from Cambridge NIAB meteorological station (Met Office, 2021).

The results indicate that there were no long-term trends in rainfall and open water evaporation between 1961 and 2015. The results also show that while the cumulative rainfall between 2015 and February 2021 has been similar to the long-term average (LTA) (1961 – 2020), there have been several periods when recorded rainfall was below the LTA.

It is documented that the RTD is highly responsive to local rainfall (WSP, 2014a). Therefore, the dry periods will have had an impact on groundwater levels. Conversely, heavy rainfall would be expected to be followed by a quick increase in RTD groundwater. The response occurs in two way: firstly, direct rainfall onto the surface area of the pond and second by infiltration through permeable topsoil to recharge the RTD.

The main periods of below average rainfall between 2015 and 2021 occurred in spring 2015, summer 2016, summer 2018, winter to spring 2019 and spring 2020. During these periods, it is likely that below average rainfall contributed to the drop in RTD groundwater elevation.

However, anecdotal evidence from residents highlights that previous dry summers prior to 2015 have not resulted in the Kingfisher Pond, Nethergrove Lake and Larkfield Well drying out. This included notable dry years including 1976, 2003 and 2011. Additionally, periods of heavy rain in 2016 and 2017 did not restore groundwater levels, as evidenced by the photographic evidence and the that the overflow pipe has not been needed to be used.

It is therefore concluded that the while dry periods between 2015 and 2021 may have exacerbated the drop in groundwater levels, they were not the principal cause for the decline.

4.2. Changes to groundwater level

The Phase I (HR Wallingford, 2021a) and Phase II (HR Wallingford, 2021b) report presented groundwater level for both local (RTD) and regional (chalk) aquifers.

4.2.1. Regional boreholes

The regional chalk monitoring boreholes showed that there were several periods where groundwater levels were classified as below normal for prolonged periods in 2017 and 2018. The Environment Agency monthly water reports attribute the flux in groundwater level to climatic conditions.

Notably, these chalk groundwater levels remained within the normal range during 2015. Therefore, this does not imply that the initial drop in Northstowe groundwater levels was reflective of a regional dry climate. Nevertheless, the dry climate in 2017 to 2019 implies that that there was regionally low rainfall. This would have impacted the low Northstowe groundwater elevation and impeded recovery.

4.2.2. Local boreholes

Data was presented for the Environment Agency monitoring boreholes situated along the RTD within 10 km of Longstanton. The RTD Environment Agency boreholes do not exhibit a long-term trend throughout the period of data available between 1977 and 2021.

Data was also presented for the site of Northstowe. There is limited data available on the boreholes between 2015 and 2017 when initial observations of a decline in water level at the Kingfisher Pond were reported.

The data points collated at monitoring boreholes on site show that following dewatering in 2015 there was a decline in groundwater elevation. The available data for Northstowe Phase 1 boreholes recorded in January 2015 and January 2016 shows that groundwater elevations recorded in January 2016 (post Phase 1A dewatering) were comparable to those recorded in January 2015 (pre-Phase 1A dewatering). However, groundwater levels in March 2017 were lower than the winter of 2016. This indicates that the groundwater levels did partially recover following the initial dewatering, however more recent data (observational and physical) shows that this was not sustained. There is a lack of regular data points recorded in this period and therefore conclusions drawn on the groundwater elevation during this time are limited.

More regular data from borehole loggers on the site of Northstowe show that groundwater elevation on the RTD was below typical levels (as defined by Wardell Armstrong) throughout March 2017 to December 2020.

Seasonal fluctuations are on the order of 1 m. Maximum winter groundwater elevation exceeded the boreholes' lowest pre works level, however groundwater elevation dropped up to 0.8 m below the lowest pre works elevation in summer. Groundwater elevation rose to above typical levels in December 2020 and remained at or above typical groundwater level between December 2020 and March 2021.

The groundwater level data shows that the drop in groundwater level was partially reflected in trends exhibited in the chalk aquifer. This highlights the importance of regional climate to local groundwater. However more detailed data shows depressed groundwater elevations occurring following initial dewatering and throughout 2017 to 2020. The groundwater elevation remained depressed despite several periods of above average rainfall. It is therefore concluded that the low rainfall periods between 2015 and 2021 exacerbated the drop in groundwater levels but were not the primary cause for the decline in 2015 or the reason that Northstowe groundwater levels were consistently below typical elevation for the proceeding years.

4.3. Changes to land use

Within the Phase II report (HR Wallingford, 2021b), significant changes to local land use were reviewed. These were the construction of the A14 and the development at Northstowe.

The A14 is not considered to be an important factor influencing the RTD. This is concluded because the construction began in autumn 2016, notably after the initial drop in groundwater elevation in autumn 2015. Significantly, the A14 does not intersect with the RTD near Longstanton and is therefore unlikely that the construction would impact recharge of the RTD.

The development of Northstowe is the **primary cause** for the drop in groundwater elevation observed from 2015 to 2020. The data evidenced in the Phase II report (HR Wallingford, 2021b) is used to conclude the following:

4.3.1. Dewatering

- The reason for dewatering was to remove groundwater from the site during the construction work. Although the amount of water abstracted during the dewatering was not measured, there is some information provided, including in the Wardell Armstrong Interim Report (Wardell Armstrong, 2017). This report describes 1.5 km of trenches and typical flow rates of 5 l/s per 100 m of trench. This equates to around 6.5 Ml/d. In the first period of dewatering (May and September 2015) the amount of dewatering is therefore calculated to be between 580 Ml and 970 Ml. In the second period (May and November 2016) the amount of dewatering is calculated to be between 970 Ml and 1360 Ml. By comparison the volume in the Kingfisher Pond (when full) is approximately 6 Ml. Initial construction dewatering in May to September 2015 lowered RTD groundwater level by 5 m (Wardell Armstrong, 2017). Following the cessation of initial Phase 1A dewatering, the groundwater levels partially recovered.
- Construction dewatering in May to November 2016 for Phase 1B caused a further drop in RTD groundwater elevation and the Kingfisher Pond, Lady Walk Pond and Hatton's Farm Ponds surface water elevation.
- During Phase 1B water was recycled back to the Kingfisher Pond, however it was unable to sustain a recovery of water levels as the water drained through the bottom of the pond to the underlying RTD.

Given the agreed conceptual model, it is infeasible that the dewatering that occurred adjacent to the Kingfisher Pond did not result in a reduction of levels in the Kingfisher Pond (and any other ponds or features affected by the lowering of groundwater levels in the RTD).

4.3.2. Change in recharge

Following the dewatering, urbanisation and the reduction of permeable land cover has changed the recharge to the RTD and the Kingfisher Pond. Immediately surrounding the pond are various houses, tennis courts and sports pitches. Each of these will have changed the recharge to the RTD immediately around the Kingfisher Pond. Further afield the construction of roads, other buildings and other changes in land use will also have affected recharge.

It is noted that Wardell Armstrong (Wardell Armstrong, 2017) state that "Land Drainage from the sports pitches in the east of the site is directed towards the Kingfisher Pond" however it is not clear if or how this has been implemented. WSP (2014b) state in the Surface Drainage Strategy that infiltration to the RTD would occur from the sports pitches, allotments and orchards. While recharge to the RTD would support the water levels in the Kingfisher Pond, it has not been shown to be effective in allowing the RTD to recharge to previous levels.

4.3.3. Changes to drainage

The design of Northstowe includes the installation of ditches (referred to as greenways) to prevent flooding. These greenways provide a preferential flow pathway allowing water to travel attenuation ponds. The attenuation ponds are an artificial feature and are not in hydraulic continuity with the RTD. Therefore, water is able to be sustained in the attenuation ponds during periods where the groundwater elevation in the RTD is below average. A key design principle was to maintain the greenways above the water table otherwise the greenways would convey groundwater from the aquifer towards the attenuation ponds (Wardell Armstrong, 2017). Given the shallow groundwater table, careful construction of the greenways would be required to prevent permanent lowering of the water levels in the RTD.

WSP (2014) state that the typical water level in the RTD is 0.5 to 2 m below ground level. Photograph 4.1 (HR Wallingford, 2021) shows a typical section of one of the greenways. In this photo it is apparent that there are long sections of the greenways which are greater than 0.5 m deep. It is unclear if the design principle of maintain the greenways above the water table has been met. There is a possibility that these greenways are located below the natural water table in the RTD in some sections.

Photograph 4.1: Greenways on the site of Northstowe

Source: HR Wallingford, March 2021

5. Conclusion

This report combines the evidence collected in the Phase I and II reports, a subsequent visit to the site and our expertise. This report concludes that there are several key factors which have resulted in the decline in groundwater levels and therefore impacts on the Kingfisher Pond and other ponds in the area:

5.1. De-watering

Dewatering during the early development at Northstowe initially reduced groundwater level to 5 m below surface level. Large quantities of water were abstracted during the two dewatering phases. This caused an almost immediate and significant drying out of the Kingfisher Pond and the RTD. There is very strong evidence to support this, including the fact that work during the Phase 1B dewatering to recycle water into Kingfisher Pond was not able to sustain water levels in the pond.

5.2. Post dewatering (2016 to 2020)

The groundwater levels have not recovered for a number of reasons, including:

- Recharge has been affected by urbanisation;
- The greenways on the site of Northstowe may provide a preferential flow pathway for water from the RTD to the greenways and to the attenuation ponds, and it is not clear if the design principle has been met. These greenways provide a mechanism for maintaining groundwater levels at below their pre-2015 levels.

5.3. Post 2020

As evidenced in the Phase II report (HR Wallingford, 2021b) the groundwater levels at Northstowe and the Kingfisher Pond had **mostly** recovered in winter 2020/21, although the water levels in the Kingfisher Pond were approximately 0.3 m below those shown in historic photographs. This period coincided with regional high groundwater levels and above average rainfall recorded between December 2020 and February 2021. Rainfall in March 2021 was similar to the long term average.

Of all the groundwater-fed features in the area, the Kingfisher Pond is the closest to the development at Northstowe. It is most likely to be affected by the changes in recharge and drainage.

At the time of writing (April 2021) it is unclear if the levels in the Kingfisher Pond will return to their pre-2015 levels. It is also unclear if the pond will be more susceptible to periods of low rainfall in the future.

5.4. Other factors

Regional rainfall has remained at or below average for most of the time since 2015, which has compounded the difficulty in understanding the various impacts on water levels in the RTD. The RTD is shallow, and responds quickly to rainfall, so during periods of dry weather water levels will decline. However, the evidence shows that in spite of these fluctuations in rainfall, the initial dewatering is the main cause of the drying out of Kingfisher Pond and the RTD.

We can find no evidence of other impacts (e.g. the construction of the A14). The A14 is not situated on the RTD and both the temporary construction and post operation of the road are unlikely to have had any significant impacts on the groundwater levels in the RTD or Kingfisher Pond.

5.5. Damage to buildings

During this study we received reports of cracks in various buildings, including All Saints Church and Longstanton Village Institute. The reasons for such cracks are a specialist subject, and HR Wallingford is not able to comment on the cause of such cracks. We suggest that further advice is obtained from a specialist.

6. Recommendations

Our recommendations depend on stakeholders' expectations for the Kingfisher Pond and how the pond and groundwater levels in the RTD respond in the long-term.

6.1. If the Kingfisher Pond recovers

It is possible that after further extensive rainfall groundwater levels in the RTD may fully recover to their pre-2015 levels. To understand this than HR Wallingford recommend the following:

- Regular monitoring of the Kingfisher Pond surface water levels and other ponds in the area (namely Nethergrove Lake and Lady Walk Pond);
- Regular monitoring of the groundwater elevation in the RTD underlying Northstowe and Longstanton;
- Regular monitoring of groundwater levels adjacent to and flows in the greenways to ensure that they have been constructed in accordance with the Design Principles and that they are not dewatering the RTD. The flooding impacts need to be considered.

6.2. If the Kingfisher Pond does not fully recover

It remains possible that the Kingfisher Pond and other features may be affected in the long-term by the changes in recharge and construction of the greenways. This may include being more susceptibility to dry periods or a more permanent lowering of groundwater levels. If this occurs then it may be necessary to make some engineering changes, which could include:

1. Supporting water levels in the Kingfisher Pond;
2. Deepening the pond;
3. Improving the greenways to ensure that they are in accordance with the design principles.

Given concerns about cracks in the brickwork of the Longstanton Village Institute and All Saints Church specialist advice should be sought.

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Appendices

A. Review of Phase III Report

This report was distributed to LPC, SCDC, L&Q and residents of Longstanton in May 2021. All of the comments received within a four week review period are presented below. Actions taken based on feedback has been updated in this revised and report and summarised in Appendix B.

Longstanton Parish Council (3rd June 2021)

Following the extra ordinary meeting of Longstanton Parish Council on Monday 24th May 2021, members have asked me [redacted] to share with you their thoughts following receipt of the above report.

Longstanton Parish Councillors thank you for all the work you have put in to create these reports. Though they are disappointed that the report does not provide specific details about the lack of water in the aquifer due to the lack of data over the last 6 years. Members are pleased to see that HR Wallingford believes that Northstowe has caused the changes in the water levels.

Longstanton Parish Council will be approaching South Cambridgeshire District Council to find out what their thoughts are on the report and what their next steps will be.

Having received your final report, Longstanton Parish Council would like to look at perhaps working with HR Wallingford about long-term monitoring of the water levels and would appreciate a discussion with someone about this.

South Cambridge District Council (16th June 2021)

[redacted] from SCDC confirmed by email on 16th June 2021 that SCDC had no further comment to make on the Phase III report document.

[redacted] (Longstanton resident) (25th May 2021)

The purpose of this final report is to determine the cause of the changes in the hydrology and hydrogeology of the Kingfisher Pond. The Key Findings of this report state that the Kingfisher Pond is situated on and in hydraulic connectivity with the underlying River Terrace Deposit (RTD) aquifer. It makes clear that the water table is shallow and therefore changes to the RTD will have a large impact on the Kingfisher Pond.

The report states that groundwater levels in the RTD fell below normal historical range between autumn 2015 and autumn 2020. However, local residents notified SCDC planners that the pond water levels were collapsing late in 2015 and through 2016. Residents' concerns coincided with the two phases of construction de-watering that this report and Report 2 has identified. This final report makes clear that large quantities of water were removed by de-watering on Phase 1 and the report states that there is strong evidence to support the fact that this de-watering caused the almost immediate and significant drying out of the Kingfisher Pond. However, the hydraulic connectivity of this pond with all the other ponds and ground-water features across Longstanton means that if the Kingfisher Pond dried out because of de-watering, the other ponds and well would too. This report is absolutely clear in its key finding that it was the initial construction de-watering that led to the drying out of the Kingfisher pond, not the below average rainfall that the reports states occurred between 2015 and 2020. Rainfall data for this period is simply immaterial – lack of rainfall cannot have been the problem in 2015 - 2016. If that were the case the developer would not have spent the time and trouble de-watering Phase 1 down to a depth of 5 metres. Lack of rainfall from 2017 onwards,

undoubtedly made the situation worse but it is clear that the damage was already done by the de-watering process.

However, one question does arise from these key findings. If rainfall was below average from 2015, why did the developer feel the need to de-water the Phase 1 site down to a depth of 5 metres? Surely, if it was clear that below average rainfall was an issue this de-watering should not have been necessary? Perhaps the decision to de-water in these circumstances could be considered negligent? Maybe this applies also to the failure of the planning authority to put in place adequate monitoring of the RTD aquifer, to ensure that the Kingfisher Pond and the other ponds and ground-water features were not negatively impacted by the development; particularly as some of these ponds and features lie within the Longstanton Conservation Area? The report also makes clear that de-watering took place in two phases in 2015 and 2016. I raised the alarm with SCDC planners regarding the collapsing water levels in the pond in December 2015 – if action had been taken when concerns were first raised, the second phase of de-watering could have been stopped.

It cannot be made any clearer – this report states that the construction of Northstowe has changed the recharge of the RTD and the ponds and other ground-fed features. This should not have happened. This is simply unacceptable and both the developer and the planning authority should be held responsible; not just for what happened but also for the failure to take action when the problem was reported to them by local residents and the Environment Agency. Furthermore, the report makes clear that the damage caused might not be repairable and the water levels in the Kingfisher Pond and Longstanton's ponds and ground-water features may not recover to pre-Northstowe levels. The report also suggests that any recovery due to above average rainfall earlier in the year may not be sustainable, exposing all the ponds to drying out in hot weather.

However, what is of really serious concern is the question-mark the report raises as to whether the design principles of the greenways have been met, or if they will continue to reduce groundwater levels in the RTD and the Kingfisher Pond. This is indeed a shocking statement and yet again, if SCDC planners had taken action after they were contacted regarding collapsing groundwater levels in December 2015 – the greenways would not have been completed and it would have been possible to have identified any design or construction errors. Failure to act on residents' concerns allowed those greenways to be completed with any potential errors or changes to the design principles buried below ground. It can come as no surprise and it was indeed the only possible conclusion that Northstowe Phase 1 works were the primary cause of the changes to the Kingfisher Pond, and the other ponds and groundwater features across Longstanton.

However, this is where the remit limitations of H R Wallingford's brief are exposed.

Despite all the evidence and the confident conclusion that dewatering of Northstowe caused the damage to the Kingfisher Pond and by implication the other ponds and groundwater features, the report appears to have only recommended that monitoring is installed and maintained to determine the impacts of the Northstowe development on the Kingfisher Pond and other ground-fed water features. Whilst monitoring of the RTD across Longstanton and Northstowe is welcome and should have been in place from the start of work out on Phase 1, there is no mention of what action must be taken to repair the damage to the aquifer and to ensure that the groundwater levels in the RTD do recover to pre Northstowe levels. Allowing what was originally meant to be an 'eco and exemplar' new town to cause an environmental disaster on this scale is not acceptable and restoration and mitigation measures need to be enforced. I refer to the Environment Agency letter to the SCDC planner in December 2016, in which they recommended that SCDC take enforcement action to mitigate for the damage caused – this was not done then but it could be actioned now.

In addition, other more recent and on-going issues exist which do not appear to have been dealt with by this report. I am concerned that the H R Wallingford final report fails to acknowledge or explain how and why the

Phase 1 lake could fill with water whilst the Kingfisher Pond emptied at the same time. This juxta-position is illustrated by the photograph of the Kingfisher Pond on 26 December 2017, which shows a dry and empty pond whilst an on-line video, *Drones Over Northstowe* dated December 2017, shows the Phase 1 lake with plenty of water. Also not explained by this report is the reason for water being pumped off Northstowe Phase 1 in significant quantities over extended periods of time which I reported to local councillors, H R Wallingford and others, late in 2020. I also asked the question early in 2021, 'who had turned the tap off' when in January 2021 onwards, no water was being discharged off Phase 1 into the Rampton drain; even though local trackways and fields were flooded and Northstowe Phase 2 was actively pumping water into the Rampton drain to prevent flooding on their site.

If there is a connection between the cessation of water being pumped off the Phase 1 site from January 2021 onwards, and the H R Wallingford reports and site visit in March 2021, then this needs to be properly investigated. If Phase 1 has buried beneath the ground a means of deliberately pumping or discharging RTD aquifer water off site, this is serious and needs to be investigated also as this could be a breach of the terms of the original planning permission. If this is proves to be the case then de-watering on Northstowe has not been limited to two phases in 2015 and 2016 as suggested and H R Wallingford's concerns about the design of the greenways could be significant.

I note that H R Wallingford have stated that they would be available to carry out further work under a new contract and I hope this will be carried out with the remit being what restoration work and mitigation can repair the damage caused by the Phase 1 de-watering of the RTD aquifer. In addition, any further investigations need to address the above concerns as to why water was being pumped off site in significant quantities up to December 2020, only to stop for the period that H R Wallingford was carrying out their investigations. Any further investigation also needs to determine how the Phase 1 lake can fill with water at the expense of the Kingfisher Pond. Any direct connection between the two needs to be fully understood, as does how filling the lake impacts on the RTD aquifer as a whole.

What is clear is that whilst the H R Wallingford investigations and reports 1-3 are welcome, serious questions remain to be answered. It is important that they are for confidence to be restored in the drainage works associated with the Northstowe development.

Please note: these are personal comments and are not submitted on behalf of any organisation that I am associated with.

L&Q (Developers of Northstowe) (11th June 2021)

L&Q requested a four week extension to the review period. However, the decision was made by LPC to not extend the review period until mid-July 2021.

The following are [L&Q's] Consultant WSP's high level comments:

- HR Wallingford report acknowledges that the average rainfall between 2015 and 2021 has been lower than average and will impact on the RTD and therefore water level within the Kingfisher Pond.
- HR Wallingford report acknowledges that the levels within the Kingfisher Pond have risen as a result of above average rainfall between December 2020 and February 2021 but state that they are unsure whether this increase in level will be sustained.
- Acknowledges that the main periods of below average rainfall in spring 2015, summer 2016, summer 2018, winter to spring 2019 and spring 2020 would have impacted in the RTD groundwater level. However, they rely on the anecdotal evidence from residents to conclude/suggest that previous dry summers of 1976, 2003 and 2011 didn't cause the Kingfisher Pond to dry out. We would question the credibility of placing such 'weight/confidence' on anecdotal evidence of this nature.

- The different conclusions between the appraisal of the Wardell Armstrong report and the HR Wallingford report in relation to the impact of the two phases of dewatering should be explored further.
- When referencing the impact of the surface water drainage strategy/greenways on the groundwater levels within the RTD, HR Wallingford do not appear to have taken into account the different approaches to greenway depth taken in different parts of the site and the interplay/interface between the RTD and the Ampthill Clay Formation. The understanding of this aspect of the design should be discussed/explored in more detail.
- We remain unconvinced that the evidence presented in the HR Wallingford report is sufficiently strong or conclusive to warrant the definitive conclusions they have reached.

B. Meeting minutes: HR Wallingford and L&Q

Date: 15 June 2021

Time: 14:30

Venue: Microsoft Teams Meeting

Attendees

[redacted] L&Q) [redacted] (L&Q) [redacted] (L&Q)
[redacted] (HR Wallingford) [redacted] (HR Wallingford)

B.1. Introductions

Action

1.1. Everyone on the call introduced themselves and described their role.

B.2. Process

2.1. [redacted] explained the process for the three reports. [redacted] explained that L&Q accepted that this was an independent report. L&Q had asked Jeremy Ben Associates (JBA) to review the report. This would take four weeks.

B.3. Questions from HR Wallingford

3.1. [redacted] set out some of the key findings, which were that the dewatering had impacted on the Kingfisher Pond. [redacted] considered that this aligned with the Wardell Armstrong report commissioned by L&Q. The recharge around the Kingfisher Pond had changed and that there was uncertainty if the design principles of the Greenways had been met.

3.2. [redacted] pointed out that the WSP report (Northstowe Phase 1, Planning Condition Discharge, 31/3/14) had a section (G-G) in drawing 0481-EWK-001 which indicated that the River Terrace Deposits may have been incised by the North Greenway. This was inconsistent with the design strategy.

3.3. [redacted] suggested that the dewatering information used in the HR Wallingford's report was incorrect. [redacted] confirmed that this information was taken from the Wardell Armstrong report commissioned by L&Q. In particular the Wardell Armstrong Report (Appendix 7) shows the dewatering to be c. 100m from the Kingfisher Pond and pp13 describes the depth of dewatering as 5m.

3.4. [redacted] would check with Wardell Armstrong that this information was correct L&Q

3.5. [redacted] described inconsistencies in the information on the Greenways. The Wardell Armstrong report says that the design principles of maintaining the Greenways above "above the water table was not possible in the centre of the site close to the

geological boundary between the RTD and ACF. However, where the Greenway A drain is located below the water table is within the ACF". [redacted] said that "as built drawings" of the ditch would help HR Wallingford understand if the design principles had been met. If that data were made available HR Wallingford could amend the report.

B.4. Questions from L&Q

4.1. [redacted] read an extract from the Executive Summary. It was felt that the executive summary was not a reflection of the full report. [redacted] said that some people would only read the Executive Summary. [redacted] said that HR Wallingford would be happy to review and consider rewording the executive summary. AB

4.2. [redacted] explained that it would take 2 weeks to provide any survey data for the Greenways. L&Q asked for a four week extension to the report. [redacted] explained that the Council Leader and SCDC procurement had been chasing delivery of the various reports. As HR Wallingford's client it was up to SCDC and Longstanton PC to agree to any extension. [redacted] will ask both SCDC and Longstanton if they are happy to delay the report. [redacted] queries why it would take two weeks to provide existing survey data. [redacted] said it would need to be reviewed, and may take less than two weeks.

B.5. Summary

5.1. There was a summary of the discussion. [redacted] asked about HR Wallingford's findings. [redacted] reiterated that HR Wallingford were confident that the dewatering was the initial cause of the Kingfisher Pond drying out. Without further dewatering there was little risk that the pond would dry out in the future. However, land use changes may make the pond less resilient if there was less recharge, and if the Greenways were constructed so they intercepted the RTD then the pond may remain with a lower water level then in the past.

5.2. [redacted] asked about the other ponds in the report. [redacted] replied that these ponds were generally within about 1km of the dewatering.

5.3. [redacted] questioned whether data from external ground water monitoring boreholes had been assessed, outside the footprint of the site. [redacted] confirmed that EA borehole monitoring data had been obtained via a data request. [redacted] confirmed that that borehole data indicated no evidence of receding ground water levels outside the footprint of the site.

5.4. [redacted] to review statements related to other ponds and provide further substantiation given item 5.3 above.

5.5. [redacted] asked if HR Wallingford needed to mention the cracks reported in the village hall and church. [redacted] said that Longstanton PC had specifically pointed these issues out.

5.6. [redacted] asked if HR Wallingford would meet JBA to discuss any questions it had. [redacted] replied that HR Wallingford that this was not within scope and depended on the client agreeing to delay the report. However, if the client agreed to an extension

for L&Q to respond, then HR Wallingford would be happy to have a meeting with JBA.

B.6. Agreed Actions

6.1. [redacted] to contact SCDC and Longstanton PC about a four week extension to allow JBA to undertake its review and for L&Q to provide survey data on the Greenways. [redacted]

6.2. [redacted] to contact Wardell Armstrong to check if the dewatering information, provided in the Wardell Armstrong report was correct. [redacted]

6.3. [redacted] to provide information on surveys of the Greenways.

6.4. [redacted] to meet with JBA (if JBA request a meeting and SCDC/Longstanton PC agree to the extension). [redacted]

B.7. Additional Questions

7.1. When discussing the agenda for the meeting HR Wallingford asked for various clarifications. These were not discussed during the meeting but we would be keen to understand:

7.1.1. Were the recommendations the Wardell Armstrong report caried out, and if not why not?

7.1.2. pp 17 of the Wardell Armstrong report says "the water level in the Kingfisher Pond recovered after Phase 1B supported by intense rainfall in November". We can see no evidence of this in Figure 6.3 and wondered how Wardell Armstrong drew this conclusion.

C. Actions following Phase III review

Table C.1: Summary of amendments to the Phase III report

Received from	Comment	HR Wallingford Response	Amendments
LPC	Members are disappointed that the report does not provide specific details about the lack of water in the aquifer due to the lack of data over the last 6 years.	The three reports from HR Wallingford compiled all available data relating to local hydrogeology. This report highlights limitations relating to temporal and spatial coverage of the data, however no amendments to the report can be made in the absence of additional data.	No.
LPC	Longstanton Parish Council would like to look at perhaps working with HR Wallingford about long-term monitoring of the water levels.	HR Wallingford are open to discussing on going work and advice, subject to new contracts.	No.
[redacted]	This report is absolutely clear in its key finding that it was the initial construction de-watering that led to the drying out of the Kingfisher pond, not the below average rainfall that the reports states occurred between 2015 and 2020.	Our conclusions state that the initial construction de-watering caused the initial drying out of the Kingfisher Pond. Below average rainfall throughout this period is expected to have reduced the aquifers ability to naturally recharge.	Clarification in executive summary.
[redacted]	Rainfall data for this period is simply immaterial – lack of rainfall cannot have been the problem in 2015 - 2016. If that were the case the developer would not have spent the time and trouble de-watering Phase 1 down to a depth of 5 metres.	Construction dewatering is a standard approach when constructing in close proximity to a shallow aquifer. The dewatering was required to reduce the local groundwater for foundations to be constructed for Northstowe. However, as a result, this had a negative impact on ponds and wells in the local area.	No.
[redacted]	I am concerned that the H R Wallingford final report fails to acknowledge or explain how and why the Phase 1 lake could fill with water whilst the Kingfisher	The attenuation ponds on Northstowe are not in hydraulic continuity with the RTD. The attenuation ponds fill from surface run-off directed to the attenuation ponds via the Greenways. Following	Clarification in Section 4.3.3.

Received from	Comment	HR Wallingford Response	Amendments
	Pond emptied at the same time.	the initial dewatering, it would take many months for the aquifer to recharge naturally. It is therefore feasible that the attenuation ponds would be full when the Kingfisher Pond is emptied given their different hydrogeology.	
L&Q	Concerns were raised in the meeting on 15/06/2021 (Appendix B) that the executive summary was not reflective of the report's conclusions.	HR Wallingford agreed to include more detail in the executive summary.	Clarifications made to executive summary.
L&Q	L&Q raised questions regarding the volumes given for dewatering in Section 4.3.1.	Dewatering depths provided within this report are taken from Wardell Armstrong (2017). The volume estimates are an indicative guide based upon the dewatering rate given in Wardell Armstrong (2017). Should further data become available on this, this should be reviewed. At the time of writing, we remain of the opinion that dewatering to a depth of 5 m in the vicinity of the Kingfisher Pond would have resulted in the drying out of the pond during construction dewatering.	No.
L&Q	L&Q requested a 4-week extension (until approximately mid-July 2021) to the review period to allow consultants JBA to comment on the report.	The decision was taken by LPC to not extend the review period.	No.

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