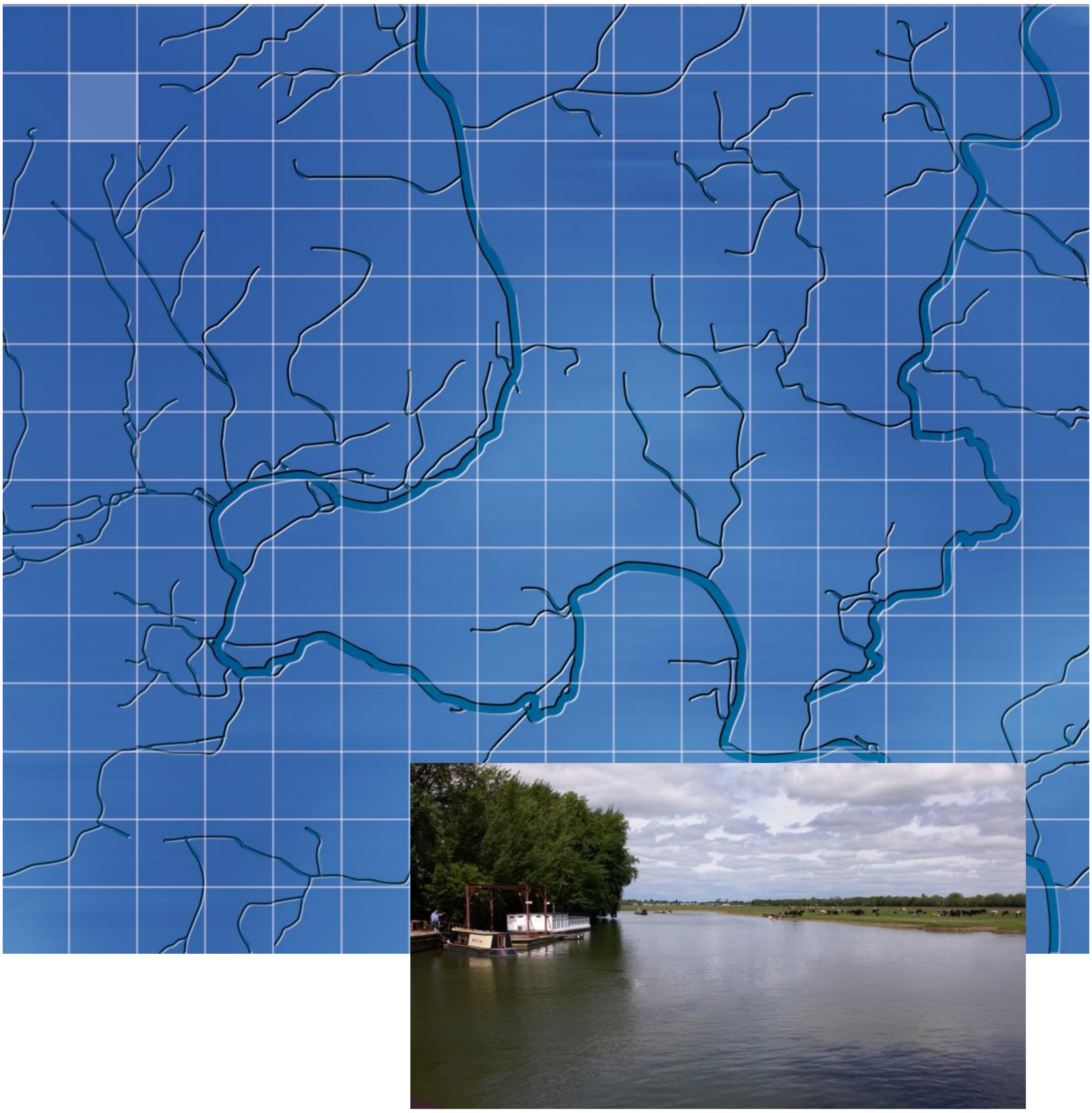
Oxford City Council

March 2019

Phase 1 Oxford City Water Cycle Scoping Study



Wallingford HydroSolutions Limited

www.hydrosolutions.co.uk

Oxford City Council

Phase 1 Oxford City Water Cycle Scoping Study

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Contents

1 Background

Wallingford Hydrosolutions Ltd (WHS) have been commissioned by Oxford City Council (OCC) to undertake a water cycle scoping study to provide the basis for any further detailed assessment that may be required subsequently.

The purpose of a Water Cycle Study, is to identify in a holistic sense and if possible to quantify, the capacity of all water related infrastructure and the wider environment within the city to support new housing and commercial developments. This encompasses a range of factors which can be designated to four key areas, namely:

- Environmentally, economically and licenced availability of water resources for abstraction and use.
- Flood risk arising from further development.
- Sewerage treatment and disposal (subdivided into environmental and infrastructural capacity).
- Other environmental considerations and constraints to development.

This scoping study seeks to identify and evaluate a number of important questions relating to the four key areas listed and provide initial feedback to the Council on the status of key assets. Areas where there are clear knowledge gaps will be identified, prior to the potential furthering of the study. This process includes the examination of all relevant data, and where this isn’t freely available, communication with relevant authorities within the region to ascertain what evidence is available, and how this might be augmented.

2 Method Statement

Phase 1 of the Oxford City water cycle study is to assess the strategic capacity to accommodate development in Oxford. The specific detail of delivering the scale of growth should be considered through further technical work to assist the delivery of the local development plan.

The water cycle study looked at two different development scenarios suggested by OCC to quantify the implications of future development in the Oxford Area:

- Scenario 1 – 8,000 homes by 2036, this is a realistic scenario based on development constraints
- Scenario 2- 12,000 homes by 2036, this is a notional higher growth scenario

These scenarios were converted into population estimates using figures quoted from Thames Water's latest draft Water Resource Plan published in 2018[1]. The water resource plan also provided information on the impacts of climate change, the current and future supply-demand position, and potential resource options moving forward. Further data was also gathered on site specific infrastructure and abstraction licenses. All this information has been collated and reviewed to determine the availability of water and whether it is sufficient to accommodate development.

Water disposal and quality issues have also been assessed against future housing growth to determine whether the environmental and infrastructural capacity exists in the Oxford area to manage the expected increase in waste water discharges. Thames Water's catchment plan for Oxford published in 2018[2] provides details on current issues related to wastewater in the city, and potential measures to address these in the short to long term. It has been reviewed, along with information on the Oxford Sewage Treatment Works (STW) and site-specific data on the foul sewer network to estimate infrastructural capacity. To assess environmental capacity, the EA's catchment data explorer[3] has been used to find the ecological and chemical status of a number of watercourses in the Oxford area. Further data on groundwater and sewerage discharges has been integrated into the assessment. The Thames river basin management plan[4] has been reviewed to identify the current measures in place to maintain water quality and protect ecosystems and the findings of two recent assessments undertaken by the Environment Agency[5] and South Oxfordshire District Council (SODC)[6 & 7] have been used to determine the future measures necessary to achieve environmental compliance.

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[1] Thames Water (2018), *Our draft Water Resources Management Plan 2019,* corporate.thameswater.co.uk/About-us/Our-strategies-and-plans/Water-resources/Our-draft-Water-Resources-Management-Plan-2019 accessed on 04/04/18

[2] Thames Water (2018), *Our catchment plan*, corporate.thameswater.co.uk/-/media/Site-Content/Thames-Water/Corporate/AboutUs/Investing-in-our-network/Sewerage-catchment-studies/2018-catchment-plans/Oxford-catchment-plan.pdf accessed on 04/04/18

[3] Environment Agency (2018) *Catchment Data Explorer*, http://environment.data.gov.uk/catchment-planning/ accessed 04/04/18

[4] DEFRA, Environment Agency (2015) Part 1: Thames river basin district River basin management plan, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/718342/Thames_RBD_Part_1_river_basin_management_plan.pdf

[5] Environment Agency (2018) *Water Industry National Environment Programme* data.gov.uk/dataset/a1b25bcb-9d42-4227-9b3a-34782763f0c0/water-industry-national-environment-programme

[6] JBA Consulting (2019) *SODC Local Plan Water Cycle Study Update Phase 1: Assessment of potential site allocation options* published November 2018

[7] JBA Consulting (2019) *SODC Local Plan Water Cycle Study Update Phase 2: Assessment of proposed strategic allocations* published January 2019

A high-level review of flood risk in Oxford, and the potential impact of development has also been undertaken. Information from the ongoing Oxford SFRA[8] has been used to summarise the existing development pressures in Oxford, and the two housing scenarios provided by OCC have been used to estimate the land uptake required for new development by 2036. Several site-specific and catchment-wide mitigation measures have also been considered.

Additionally, other environmental constraints in Oxford have been identified. These largely relate to protected land, including the Oxford Meadows, and several sites of special scientific interest (SSSI) which are monitored and subject to controls on land use. Building restrictions in Oxford are also briefly covered in this section.

[8] Wallingford Hydrosolutions (2017) Level 1 Strategic Flood Risk Assessment, *WHS1459 - Oxford City Council Level 1 SFRA_v1.1.pdf*

3 Water resources and supply

3.1 Introduction

This section assesses the current water resources serving the Oxford area, future housing growth, and the supply-demand position moving forward. The assessment looks to confirm whether there will be enough water resources available to manage the projected growth levels in Oxford sustainably. The existing abstraction licenses in Oxford are also reviewed.

3.2 Water Company Planning

Thames water is responsible for water supply across the entire Oxford City Administrative area, shown in Figure 1.

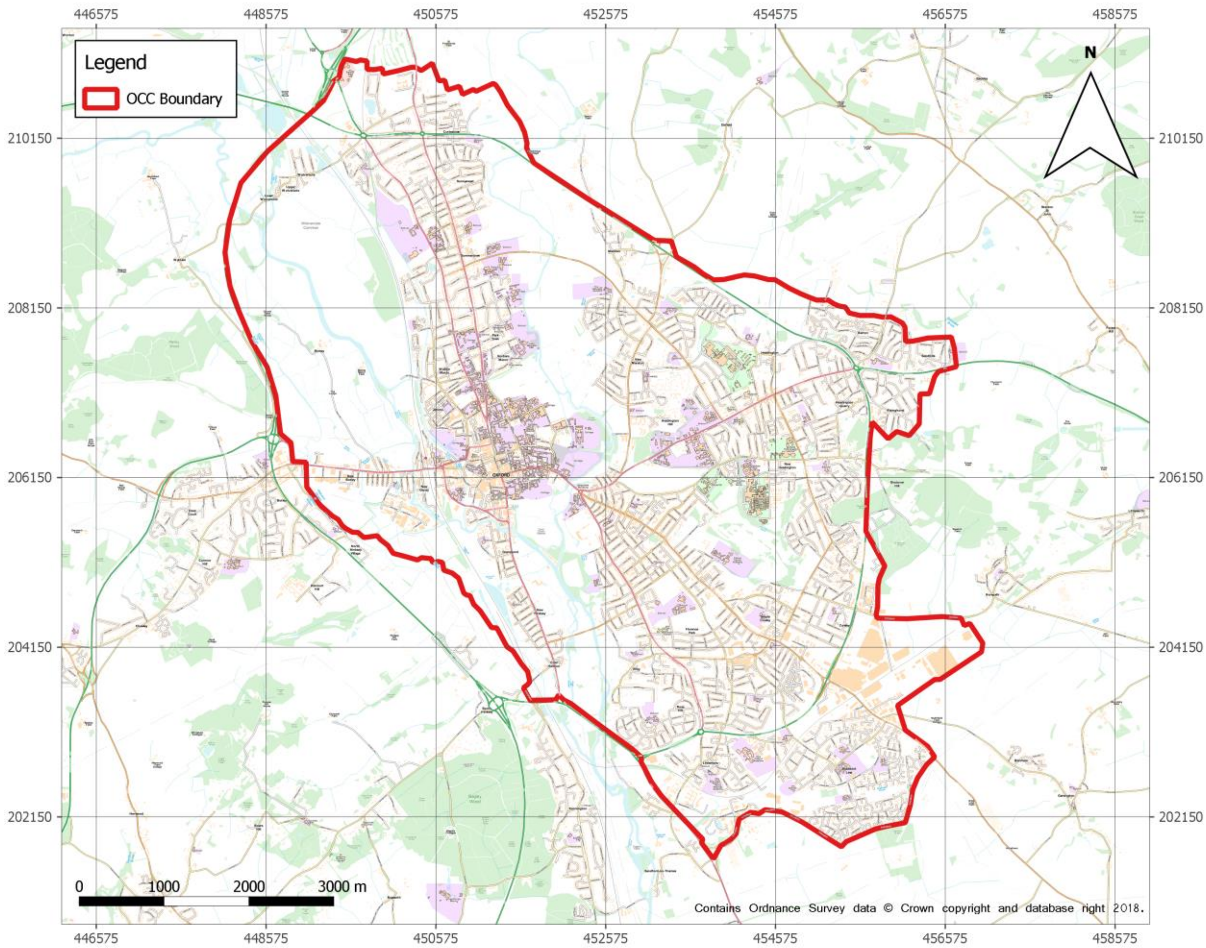

Figure 1- Oxford Administrative Area

The water companies within England responsible for providing water supply and wastewater collection and treatment, are funded in 5-year planning periods. The money they have available to spend is determined by The Water Services Regulation Authority (OFWAT) in consultation with government, the EA and consumer organisations amongst others. The consultation process is known as the Periodic Review (PR), and the next review PR19, will determine how much money they have available to spend between 2020 and 2025. Once funding has been obtained for upgrading and/or building new infrastructure, there remain significant lead times for planning and construction before infrastructure can be considered functional. In this respect the water companies require detailed information on likely housing development well in advance. Table 1 outlines the lead time estimates provided by Thames Water.

Table 1- Thames Water estimate of infrastructure lead in times

Resource	Lead in time
Wastewater treatment upgrade	3-5 Years
Sewerage network upgrades	1-3 Years
Major resource development (new reservoir, new STW etc)	8-10 + Years

3.3 Water Resource Zone

The Oxford City Administrative Area falls within the Swindon and Oxfordshire (SWOX) Water Resource Zone (WRZ) as shown in Figure 2.

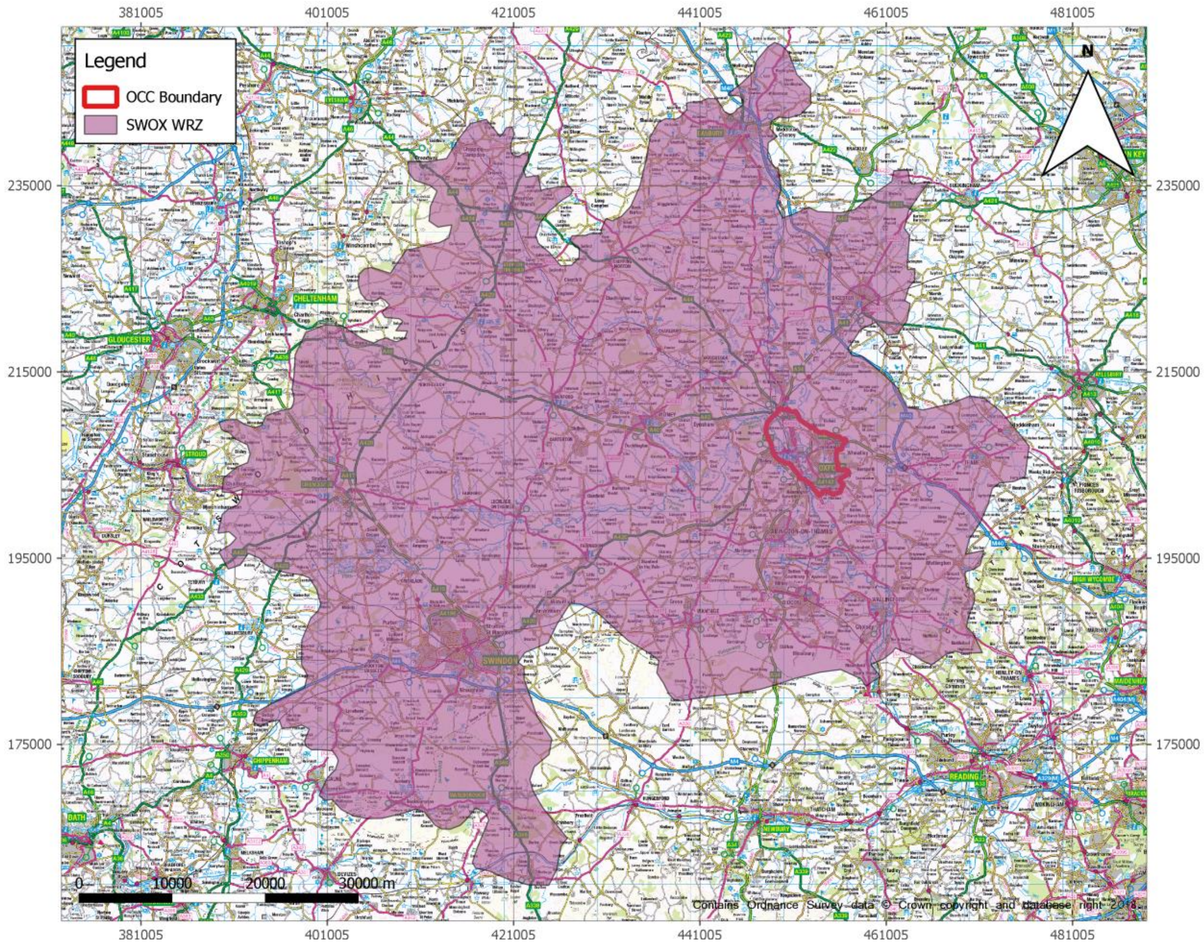

Figure 2- SWOX WRZ boundary

3.4 Population Forecast

Thames water have assessed the impact of forecast population and housing growth on water resources as part of their draft Water Resources Management Plan (WRMP) 2019. It sets out how they plan to provide a secure and sustainable supply of water for customers over the next 80 years (2020-2100). This scoping study has used the information from this latest WRMP to delineate the potential impact of housing growth in Oxford, considering the two scenarios proposed by OCC.

As part of their WRMP, Thames Water working with demographic analytics calculated a range of population and property growth forecasts across its supply area. The core forecasts relate to the 2016-2045 planning horizon based on local authority plans, and guidance provided by Department for Environment, Food and Rural Affairs (DEFRA). Population and property forecasts have been developed for each WRZ based on an aggregate of the findings for each local authority area.

According to the WRMP the base population (2016/17) in the SWOX area is 1,021,824. Oxford has a population of 154,600 based on the office of national statistics (ONS) 2017 mid-year estimate[9], which translates to approximately 15% of the total SWOX base population.

The population forecasts for the SWOX area show a increase in population from the base year of 250,000 by 2036. In the absence of a breakdown for each local authority area, population growth is assumed to be uniform across the SWOX area. The population growth in Oxford is therefore expected to be 15% of 250,000 at 37,500. Figure 3 shows a plot of population growth for the SWOX WRZ based on figures extracted from Thames Water's WRMP.

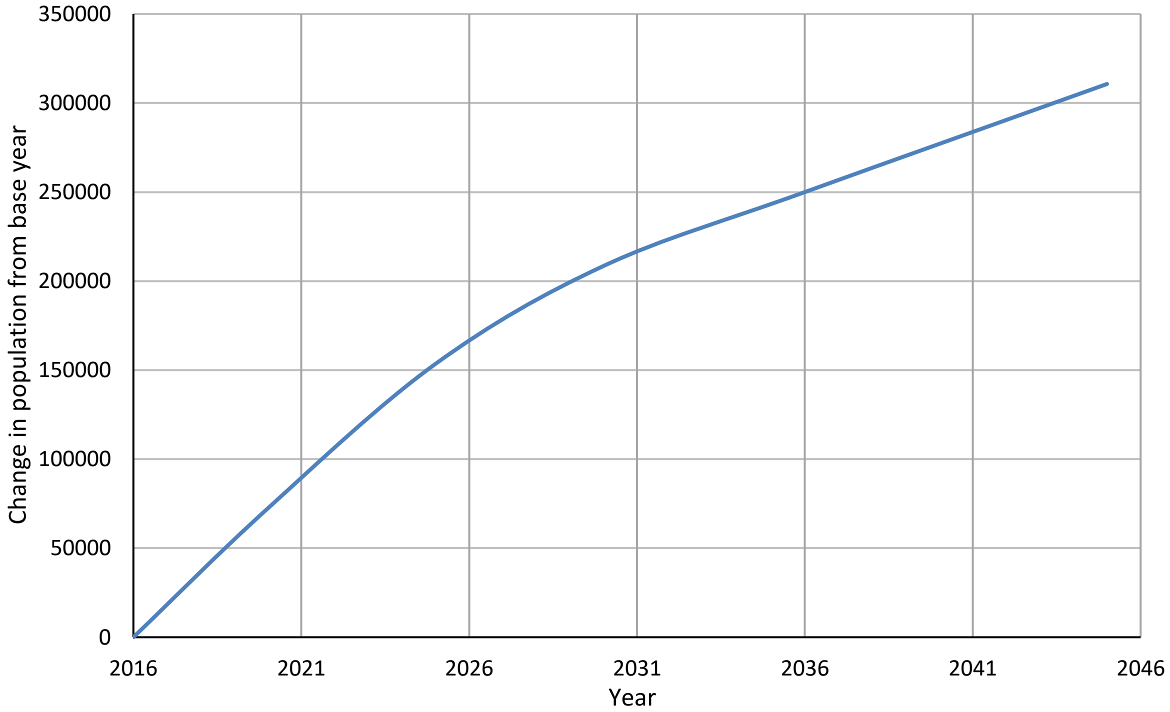

Figure 3- Projected change in population from base year (2016-2045) based on data extracted from Thames Water WRMP

[9] Oxford City Council (2017), *Oxford's Population*, https://bit.ly/2uQGueK, accessed on 20/06/18

Both scenarios refer to property numbers rather than population growth. The WRMP has also calculated the projected number of dwellings up to 2045 using local authority plans. For the base year (2016/2017) the SWOX area has a total of 425,681 properties, by 2036 an additional 105,485 properties are expected to have been built. Based on this information the WRMP predicts an occupancy of 2.37 per property in 2036, slightly lower than the present day (see Table 2).

Table 2- Average Occupancy forecast for SWOX WRZ

	2016/17	2019/20	2024/25	2029/30	2036	2044/45
Occupancy (Persons)	2.40	2.43	2.41	2.39	2.37	2.3

Taking the occupancy rate and forecasted population growth for the SWOX area and translating it to the Oxford area specifically, suggests that 15,800 properties will be needed to accommodate the additional 37,500 people expected to live in the city by 2036.

Aforementioned, an assumption has been made in terms of uniform population growth across the SWOX WRZ, however population growth is more likely to be concentrated in urban areas such as Oxford so 37,500 is not thought to be an overestimation. The property growth forecast is higher than both scenarios put forward in this study, therefore the conclusions reached by the WRMP are considered to be more conservative.

3.5 Demand

Demand includes household use, non-household use, operational use, water taken unbilled and leakage. The main driver on demand is population, however several other factors also play a role, including the effects of climate change, improvements in efficiency, and changes in household / non-household consumption.

In terms of per capita demand this is expected to fall moving forward with changes in behaviour and increases in water efficiency. Climate change is expected to offset this slightly with increasing demand due to hot and dry weather, in which customers are likely to use more water for activities such as garden watering. On the other hand, climate change is likely to lead to milder winters, which will reduce leakages caused by contraction in cold weather.

Current consumption in the SWOX area is 137.8 l/person/day, by 2035/36 due to the factors discussed above, this is expected to fall to 133.2 l/person/day based on the Dry Year Annual Average (DYAA) baseline forecast. The WRMP also undertook an analysis using the Dry Year Critical Period (DYCP) forecast, which describes the average daily demand during the peak week for water demand, rather than an annual average across the year. The impacts of climate change in the DYCP are greater, with an increase in household water demand of 3.0% relative to 0.5% in the DYAA scenario. Per capita consumption for the DYCP scenario was not provided in the WRMP, however projections for total consumption are detailed below.

For the DYAA forecast despite the per capita reduction in consumption, total household consumption in the SWOX region is expected to increase from 141 Ml/d in 2016/17 to 165 Ml/d by 2035/36 due to population growth. This is largely offset by Non-Household Consumption which is predicted to fall from 59 Ml/d to 46 Ml/d by 2035/36; leakage remains broadly the same. Based on the DYAA forecast overall demand shows only a slight increase from 265 Ml/d to 270 Ml/d by 2035/36.

The DYCP forecast shows a more pronounced increase in demand. This is largely thought to be due to the greater weight given to climate change in the DYCP scenario. In 2016/17 total demand is estimated at 330 Ml/d, for 2035/36 total demand is forecast to be 345 Ml/d.

Figure 4 and Figure 5 show the forecasts for the DYAA and DYCP respectively.

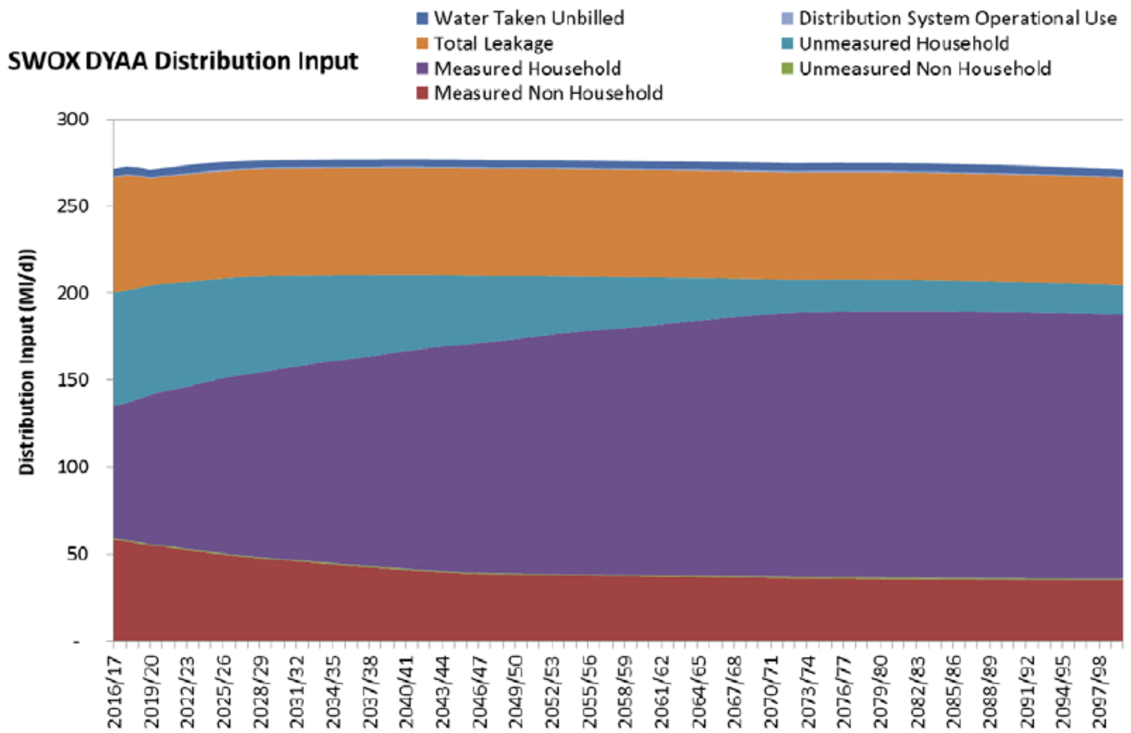

Figure 4- SWOX DYAA Total Demand (extracted from Thames Water WRMP[10])

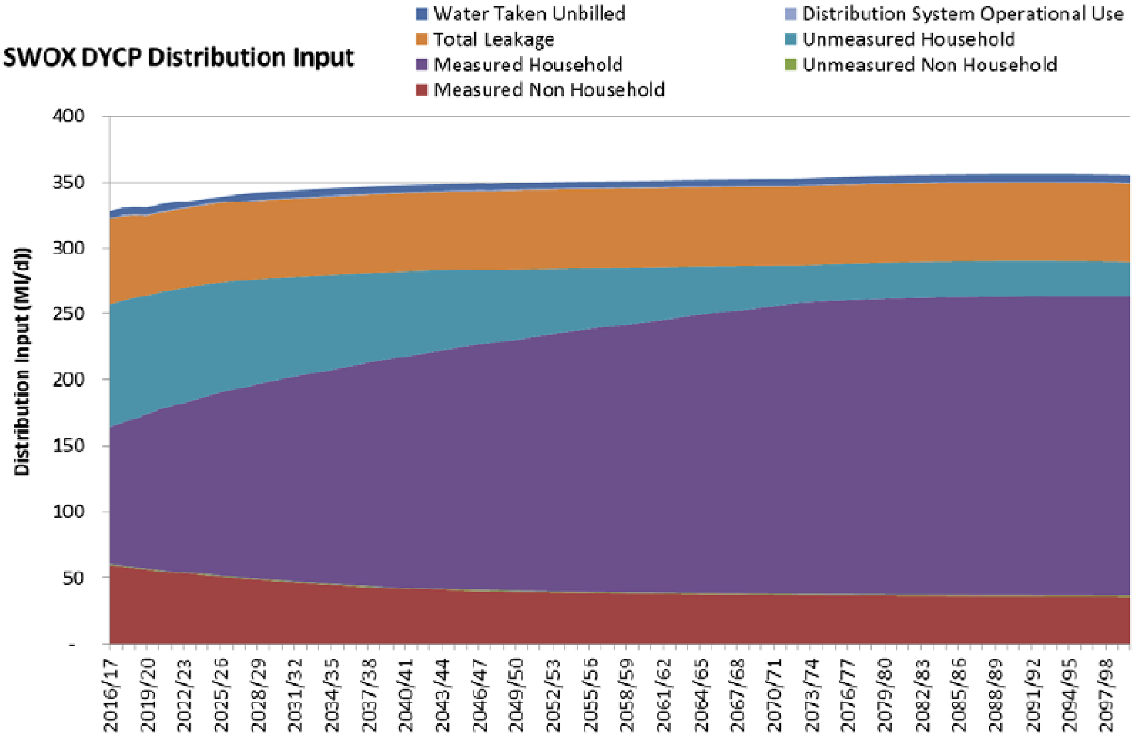

Figure 5- SWOX DYCP Total Demand (extracted from Thames Water WRMP)

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[10] Thames Water (2018) Draft water resources management plan 2019 Section 3: Current and Future Demand for Water

3.6 Supply

The Thames basin supplies Oxford. It is one of the most intensively used water resource systems in the world. Around 55% of effective rainfall is licensed for abstraction and 82% of that is for public water supply. Upstream of London, approximately 30% of abstractions are from surface water, with 70% from groundwater. Figure 6 shows the existing water resources in the Thames catchment.

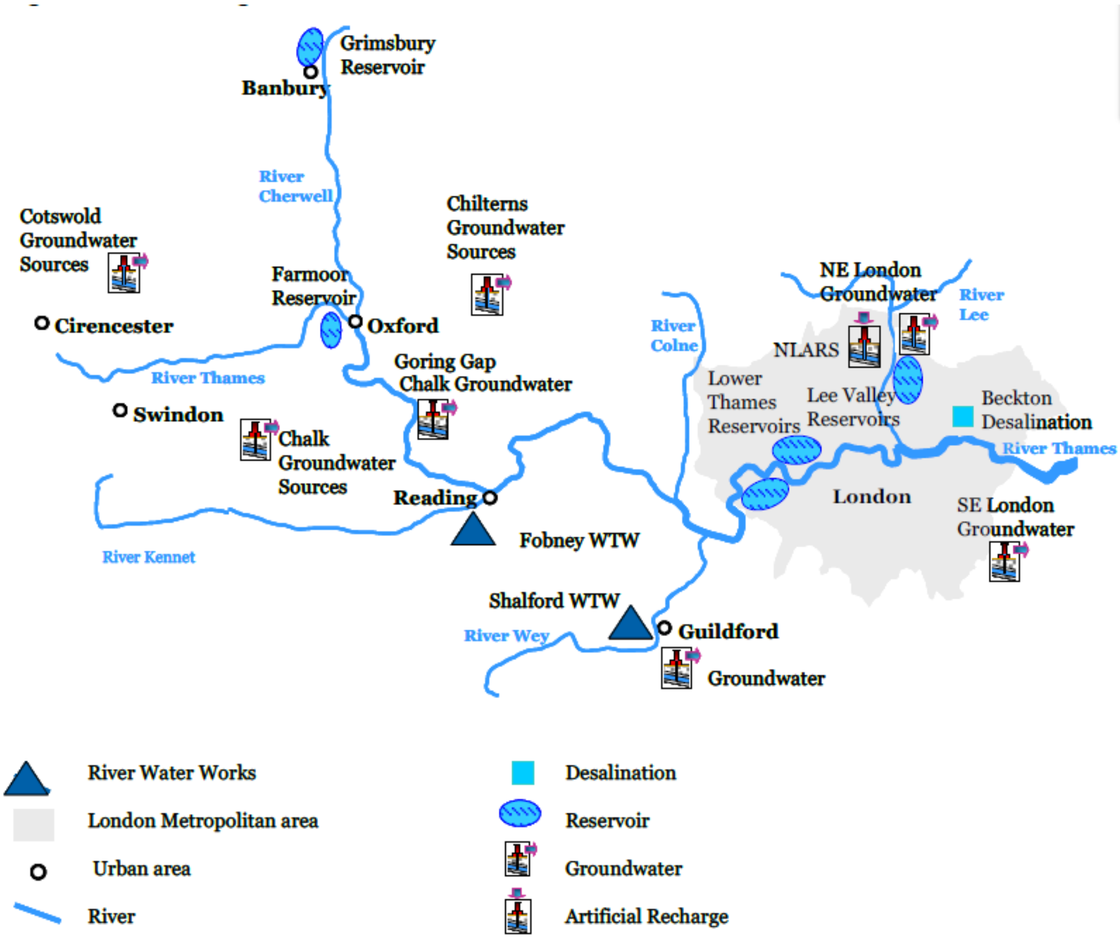

Figure 6- Existing water resources in the Thames catchment (extracted from Thames Water WRMP[11])

Looking to the future, baseline water supplies are forecast to fall, the main cause being climate change. In the SWOX WRZ the water available for use (WAFU) in the base year 2016/17 is 369.2 Ml/d under DYCP conditions. This is modelled to fall to 351.5 Ml/d in 2035/36. Under DYAA conditions supply is estimated to be 311.5 Ml/d and 294.0 Ml/d for 2016/17 and 2035/36 respectively.

A marginal forecast is modelled throughout the planning period under DYAA conditions. However, the SWOX WRZ has a supply-demand deficit under DYCP conditions from 2022 onwards, with the deficit in 2036 estimated to be 19.0 Ml/d. The growth in demand due to population growth outstrips

[11] Thames Water (2018) Draft water resources management plan 2019 Section 3: Current and Future Water Supply

any water demand management activity. Also, climate change affects the amount of water available to supply. Figure 7 shows a plot of supply against demand for the SWOX region from 2016-2099.

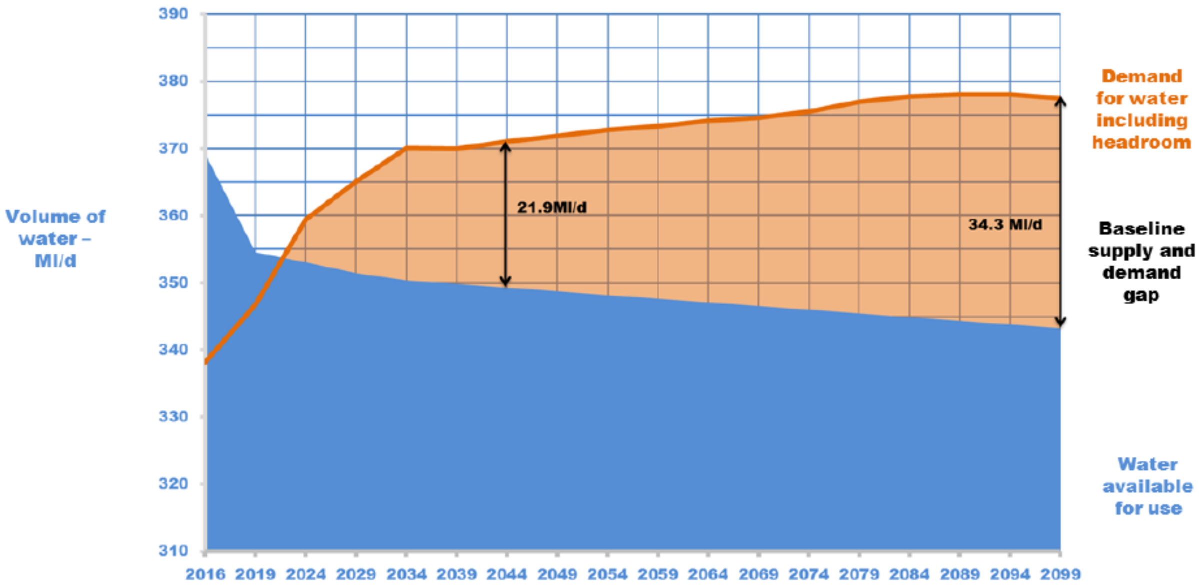

Figure 7- Baseline SWOX supply demand summary (Ml/d) – peak week (extracted from Thames Water WRMP[12])

Translating what was found for the SWOX WRZ to Oxford specifically, the deficit in Oxford under DYCP conditions will be approximately 2.85 Ml/d in 2035/36. This scenario assumes that 15,800 properties will be developed in this period accommodating 37,500 people, significantly more than the scenarios proposed by OCC.

If we take the 8,000 and 12,000 dwelling scenarios, and assume the same occupancy rate, this translates to 19,000 and 28,500 people respectively. The per capita use in 2036 under DYCP conditions is not directly referenced in the WRMP, however has been estimated as 172.5 l/person/day. This is based on dividing the projected total household consumption (219 Ml) by the projected population in the SWOX area (1.27 Million) for 2036.

Multiplying the estimated per capita use in 2036 by each of the population figures derived for the development scenarios gives the additional household demand in Oxford for 2036. This has been used to determine the resultant change in the estimated DYCP deficit. Table 3 shows the findings for each scenario.

[12] Thames Water (2018) Draft water resources management plan 2019 Section 3: Current and Future Water Supply

Table 3- Estimated Household Consumption and DYCP Deficit for Development scenarios in Oxford

Scenario	Additional Household Consumption (Ml/d)	DYCP Estimated Deficit (Ml/d)
Thames Water (15,800 Dwellings)	2.73	2.85
12,000 Dwellings	2.07	2.19
8,000 Dwellings	1.38	1.50

It should be noted that the values stated are based on several assumptions and are subject to uncertainty. Namely uniform population growth across the SWOX area was assumed in calculating the initial deficit of 2.85 Ml/d, and non-household demand remains the same across each of the scenarios with employment growth rate assumed to remain constant. The latter potentially causes an overestimation of the deficit for the 8,000 and 12,000 development scenarios given that employment growth rate is likely to be correlated to some degree with housing development, which would result in lower non-household use.

In any case the results show that without corrective action, the supply for Oxford could be less secure for all the scenarios tested. This means that there could be a greater probability that demand restrictions will be required in dry years.

3.7 Demand Management and Resource Options

Demand management options can be categorised into either leakage reduction or usage reduction. In terms of leakage reduction measures include mains replacement and pressure management. The WRMP have identified demand management as the best means to negate a water deficit in the SWOX area in the short to medium term (2020-2045). The key features of the preferred demand plan are:

- Continue to focus on reducing leakage, achieving around 9 Ml/d of water saved by 2030.
- Implement the smart metering programme to households, involving the installation of around 125,000 and achieving 98% metering penetration by 2030.
- Continue to promote water efficiency including use of reward-based incentive scheme. This will look to provide around 23 Ml/d benefits by 2030.

In terms of resource options, the latest WRMP has identified a number of potential resource options following a screening process which was primarily based on stakeholder engagement, and scenario testing. Table 4 summarises the feasible list of resource options for the SWOX WRZ.

The main options proposed include new proposals for a reservoir in Abingdon, which is planned to be built by 2043 in response to projected population growth in both the SWOX and London WRZs. Proposals were made for the reservoir in 2006 however these were rejected in 2011. Thames Water estimate that the reservoir could supply an additional yield of up to 20 Ml/d to the SWOX region.

Raw water transfers could also supply a significant amount of additional yield. A raw water transfer from Deerhurst in Gloucestershire to Culham which lies approximately 7 miles south of Oxford, could potentially supply up to 20 Ml/d of additional yield, and a transfer from the Oxford Canal up to 15Ml/d.

A further yield of 19.4 Ml/d could be found from groundwater abstractions, internal inter-zonal transfers, and inter-company transfers. Whilst these supply options offer large increases in yield they are subject to significant lead times, with the majority forming part of Thames Water's long-term plan (2045-2099).

Table 4-Feasible list of resource options for SWOX WRZ

Option Type	Name	Yield (Ml/d)
Raw Water Transfer	Deerhurst-Culham Severn Thames Transfer	20
	Oxford Canal	15
New Reservoir	Abingdon Reservoir	20
Groundwater	Moulsford	3.5
Removal of Constraits to DO	Ashton Keynes borehole pumps	1.6
Internal Inter-Zonal Transfer	Henley to SWOX	2.4
	Kennet Valley to SWOX	6.7
	Kennet Valley to SWOX	2.3
Inter-Company Transfers	Wessex Water to SWOX	2.9

Unlike the supply options, the demand options are able to deliver from the first year of implementation due to shorter lead times. Whilst the yield from such measures are typically less than those found for the supply options, they still offer significant savings. By 2030 reductions in leakage and continued water efficiency saving could yield up to 31 Ml/d in the SWOX area, which based on population approximately translates to 4.6 Ml/d in Oxford. This should be sufficient to offset the deficits measured in all of the development scenarios. Moving beyond 2036, supply measures will further reinforce the availability of water resources in the SWOX area.

3.8 Site Specific Assessments (RAG reports)

The analysis undertaken to this point has focused on current and future water availability in the SWOX WRZ and scaled this down to Oxford City. However, whilst sufficient water may be available in the short to medium term, the infrastructural capacity needs to be in place to ensure that water can be transferred to new developments.

To help assess existing capacity Thames Water were provided with a list of 37 sites allocated for development. They assessed these against the existing capacity of the surface water and waste water networks, and generated a series of RAG (red, amber, green) reports which scored each site based on the available capacity and the requirement for local upgrades.

For the majority of sites, no infrastructure concerns are envisaged for surface water, and the existing network has sufficient capacity to support the new developments. However, for 5 of the sites, Blackbird Leys central area (009), Cowley Centre (014), Kassam Stadium (028), Summertown Safeguarded Land (003) and the Warneford Hospital Site (063), the water network capacity in the surrounding area may be unable to support the demand anticipated from the development.

In these locations local upgrades to the existing water network infrastructure may be required to ensure sufficient capacity is brought forward ahead of the development. The developer is encouraged to work Thames Water early on in the planning process to understand what infrastructure is required, in addition to where, when and how it will be delivered. Any development needs to consider the lead times detailed in Table 1.

Figure 8 shows the location of each of the sites, and their water supply score (RAG) following Thames Water’s assessment. Thames Water’s original RAG reports for both water supply and waste water are provided in Appendix 1.

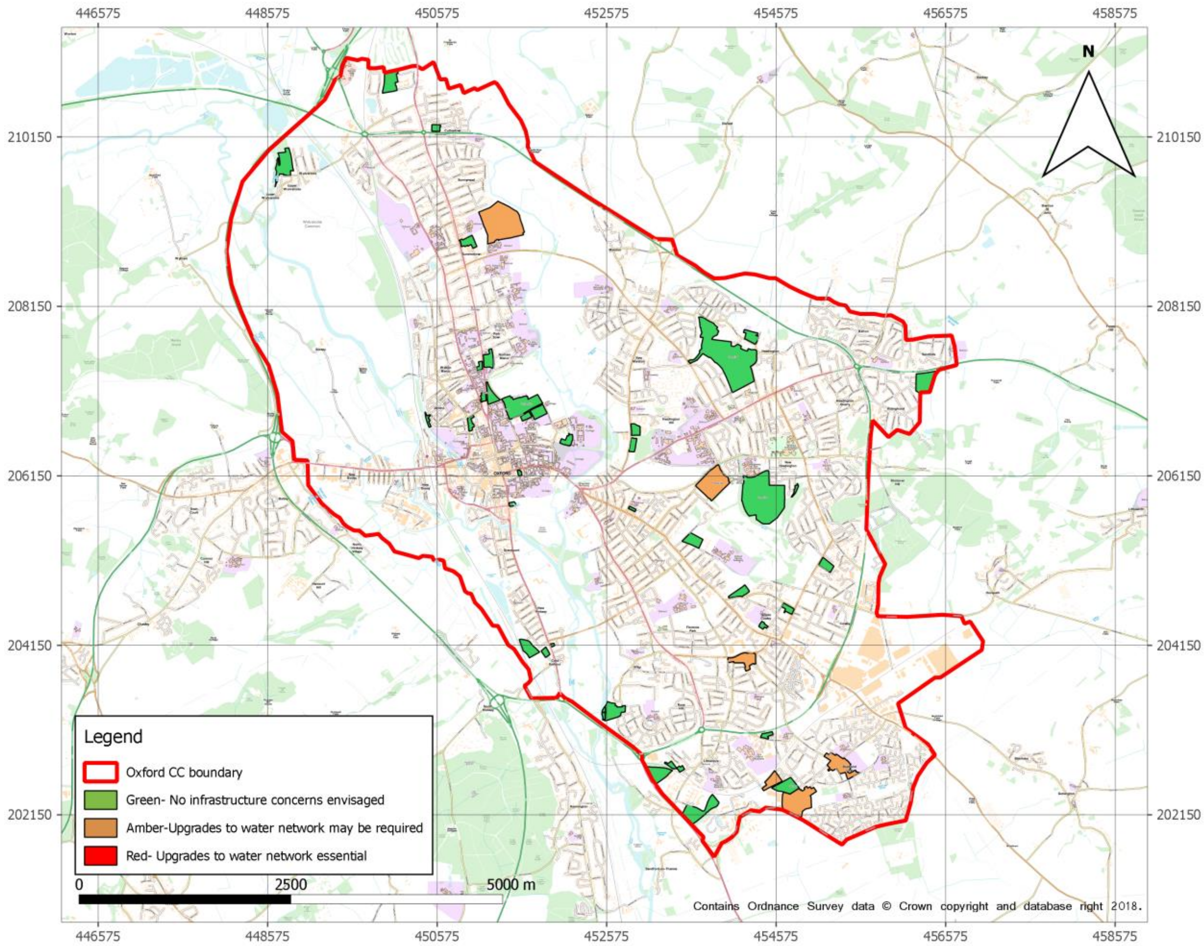

Figure 8- Map showing sites allocated for development and their associated water supply RAG score

3.9 Abstraction Licenses

A data request was sent to the EA to establish the existing water abstraction licenses currently in use in Oxford City. Table 5 lists the four abstraction licenses the EA have on record.

Table 5- Abstraction License Details

License Number	License Holder Name	License Expires	NGR	Source	Purpose	Total Amount/Yr (m^3)
TH/039/0016/001	Osney Lock Hydro Ltd	31/03/2028	SP503059	Surface Water	Energy Production	126,489,600
28/39/16/0083/TR	WH Munsey Ltd	31/03/2028	SP503059	Surface Water	Energy Production	101,191,680
28/39/16/0070	C Gee & Partners	N/A	SP496073	Ground Water	Irrigation	3,410
28/39/14/0198	Worcester College	N/A	SP508064	Surface Water	Commercial & Public	6,819

Abstraction licenses are limited in Oxford mainly due to the Oxford Meadows, which is a special area of conservation (SAC). This is to reduce the risk of drought, in turn protecting several plant and animal species which live in the meadows.

Based on the yearly total provided in Table 5, the total volume abstracted daily has been calculated at 623 Ml/d, over 99% of which is used to produce energy around Osney Lock (TH/039/0016/001, 28/39/16/0083/TR). The means of abstraction for both these licenses is via gravity flow with water transferred over a sluice and through an Archimedean Screw Turbine for energy production. The water abstracted is therefore returned to the Thames system after use. Furthermore, abstraction can only take place when the level of water in the River Thames as measured by the gauge post immediately upstream of Osney Mill (SP5037 0589) is greater than a specified level.

The other abstraction licenses do not return any water to the river system, which total a volume of 0.03 Ml/d. Therefore, only have a minor impact on water resources in Oxford.

In terms of expiration, both hydroelectric licenses are valid until 2028. The two other licenses have no expiration date, this is thought to be due to the small volumes of water abstracted.

3.10 Summary

Based on the DYAA forecasts in Thames Water's latest WRMP there should be enough water to supply Oxford for the majority of the year up to 2036 and beyond. However, the DYCP forecasts show that during periods of peak demand a deficit will begin in 2022, growing to potentially 2.85 Ml/d by 2036. Without corrective action, the supply for Oxford could be less secure which will mean a greater probability that demand restrictions will be required in dry years.

The WRMP have identified demand management through a combination of leakage reduction, smart metering and the promotion of water efficiency as the best means to negate a water deficit in the SWOX area in the short to medium term (2020-2045). This has been estimated to provide a 4.6 Ml/d saving by 2030 which should be sufficient to offset the deficits estimated. Confidence in this estimate is generally high, however the estimate is based on several assumptions, and further technical work by Thames Water would be required in order to refine population estimates and derive the specific deficit for Oxford.

Demand options are a sustainable means to address the water resource concerns for Oxford. However, beyond 2036 several supply options are also planned such as the Abingdon Reservoir. These are likely to come under more scrutiny in terms of sustainability given their potential impacts on local residents, roads and the environment.

In terms of infrastructural capacity, 32 of the 37 sites earmarked for development have no envisaged capacity issues. For the 5 remaining sites, local upgrades to the existing water network infrastructure may be required to ensure sufficient capacity is brought forward ahead of the development. These upgrades typically have a lead time of 1-3 years. Given that they are limited to a small number of sites, this should mean that any upgrades can be funded and delivered in time for development.

Abstraction licenses are limited in Oxford mainly due to the Oxford Meadows, which is a special area of conservation (SAC). In total there are four licenses, the majority of these are not for public use, and their impact on water resources in Oxford is thought to be minimal.

4 Water disposal and quality issues

4.1 Introduction

This section assesses the infrastructural capacity of the wastewater system and environmental capacity of receiving water environment. The infrastructural capacity is defined as the ability of the wastewater system to collect, transfer and treat wastewater from homes and business. The environmental capacity is defined as the water quality needed to protect aquatic and wildlife environment. The latter is associated with the water quality targets required to protect wildlife and associated STW and storm discharge environmental permits[13].

Both are assessed against the proposed housing growth in Oxford to determine whether there will be a detrimental impact on water quality, and whether new wastewater infrastructure can be delivered accordingly.

4.2 Infrastructural Capacity

4.2.1 Overview

Thames Water have released a high-level catchment plan for Oxford[14], outlining how the existing sewer network can cope with current and future demands.

The Oxford sewer network manages demand from over 250,000 customers sited in Oxford and surrounding areas. The catchment is served by the Oxford STW, located to the south of the city, and Littlemore Sewage Pumping Station (SPS).

Problems do currently exist, where some areas have experienced sewer flooding with associated pollution. Property misconnections are a major cause of the flooding, as they allow surface water to drain into the foul sewer network. Furthermore, the deterioration of some sewers has allowed groundwater ingress into foul sewers, for example in the Grandpont area, and vegetation growth has restricted some outfalls along the Abingdon Rd. In some areas, sewers have also been laid at relatively shallow gradients, such as along the Ferry Road. This has increased the likelihood of debris and blockages forming.

At the Oxford STW, a project to upgrade the sludge stream at the treatment works to include a Thermo Hydrolysis plant was completed in March 2014. The upgrade of Oxford STW was to provide the required additional sludge treatment capacity required for the growing local population. It increased treatment capacity from 17.4 tds/d (total dissolved solids per day) to 67.0 tds/d[15]. This has significantly increased the capacity for treatment, and even before this upgrade Thames Water confirmed in the 2011 Oxford core strategy[16] that the STW had sufficient treatment capacity to cater for the wastewater flows anticipated up to 2026 (8,000 new dwelling between 2011-2026).

Despite the treatment capacity of the Oxford STW being sufficient, the STW operate a fully-compliant permanent storm overflow, which stores additional flow in tanks during heavy rainfall. This component is close to capacity, and Thames Water have assessed the growth requirements for the works and identified that the volume of debris which needs to be screened out at the start of the

[13] EA Water Cycle Study Guidance – Thames Area, Sept 16
[14] Thames Water- Oxford catchment plan 2018 https://corporate.thameswater.co.uk/-/media/Site-Content/Thames-Water/Corporate/AboutUs/Investing-in-our-network/Sewerage-catchment-studies/2018-catchment-plans/Oxford-catchment-plan.pdf
[15] Back A, Tankard D (2014) Oxford STW Sludge Stream Upgrade, https://bit.ly/2L7nqmM
[16] Oxford City Council (2011), *Oxford Core Strategy Habitats Regulations Assessment*

process is causing blockages. In the short-term, Thames Water are working on a solution to reduce the impact caused by this debris and to increase capacity.

If not properly managed, the problems with sewer flooding and at the STW could get worse due to the increased likelihood of more intense rainfall events, development, population growth and loss of green spaces which previously provided natural drainage. For development specifically, there are two main ways in which new development can affect river quality:

- Altered surface runoff flow and quality impacting on the ecology of the watercourses running through Oxford.
- Increase in treated foul effluent form Oxford STW affecting the hydrology and quality of the River Thames.

The first problem can be mitigated by the use of SuDS to ensure development does not affect or has minimal impact on water quality or flow regimes. The second depends on the available headroom for development, this relates to both the environmental and infrastructural capacity.

In the catchment management plan for Oxford, Thames Water have put forward several short-term, medium-term and long-term solutions to increase headroom and manage current and future water demand. These are summarised in Table 6.

Table 6- Thames Water's Proposed Actions in Catchment management plan for Oxford

Short-term Activities	Medium-term Activities	Long-term Activities
● Regular maintenance of tanks and blockage hot spots including tanks in Marston, Ferry Road and Botley Road. ● Develop interventions that address problems occurring at the inlet to STW. ● Funding the Oxford Flood Alleviation Scheme.	● Work with customers to reduce property-level runoff ● Continue to identify and rectify property misconnections. ● Implement interventions that address problems occurring at inlet to STWs. ● Undertake sewer rehabilitation where infiltration occurs. ● Work with stakeholders to implement street-level SuDS.	● Surface water management to offset flows from new development. ● Continue to monitor the effects of growth and climate change, and their impacts on STW. ● Targeted implementation of SuDS. ● Ongoing monitoring and customer consultation, leading to refinement and enhancement of our activities. ● Live monitoring of weather conditions and sewer flows to maximise storage.

The Oxford catchment management plan is currently at the options appraisal stage, with the recommendations are largely qualitative at this stage. It is therefore difficult to assess in detail the current and future stresses on the wastewater system. However, the management plan does provide some insight into the likely strategies to be implemented.

There is a focus on the implementation of SuDS, which will indirectly reduce stresses on the foul water system caused by misconnections, with less surface water inappropriately draining to the network. There are also several commitments with regards to maintenance and refurbishment which look to reduce issues in at risk areas.

The management plan makes no direct promise to significantly increase the capacity of the Oxford STW. However, in the short to medium term there is a commitment to implement interventions that address any problems occurring at the inlet to the STW. In the longer term, there is a commitment to continue to monitor the effects of growth and climate change on the STW to ensure that it can cope with any future increases in catchment population.

4.2.2 Site Specific Assessments (RAG reports)

To help further assess existing infrastructural capacity, Thames Water were provided with a list of 37 sites allocated for development. They assessed these against the existing capacity of the surface water (see section 3.8) and waste water networks, and generated a series of RAG (red, amber, green) reports which scored each site based on the available capacity and the requirement for local upgrades.

In terms of waste water for the majority of sites, no infrastructure concerns are envisaged, and the existing network has sufficient capacity to support the new developments. However, for 8 of the sites, Blackbird Leys central area (009), Land North of Littlemore Healthcare Trust (029), Lincoln College Sports Ground (032), Littlemore Park (034) the Oxford University Press Sports Ground (049), Railway Lane, Littlemore (052), Temple Cowley Pools (058) and Warneford Hospital (063) the scale of development is likely to require upgrades to the wastewater network.

It is recommended that the Developer and the Local Planning Authority liaise with Thames Water at the earliest opportunity to agree a housing and infrastructure phasing plan. The plan should determine the magnitude of spare capacity currently available within the network and what phasing may be required to ensure development does not outpace delivery of essential network upgrades to accommodate future development. The lead times detailed in Table 1 should also be considered.

Figure 9 shows the location of each of the sites, and their wastewater score (RAG) following Thames Water’s assessment. Thames Water’s original RAG reports for both water supply and waste water are provided in Appendix 1.

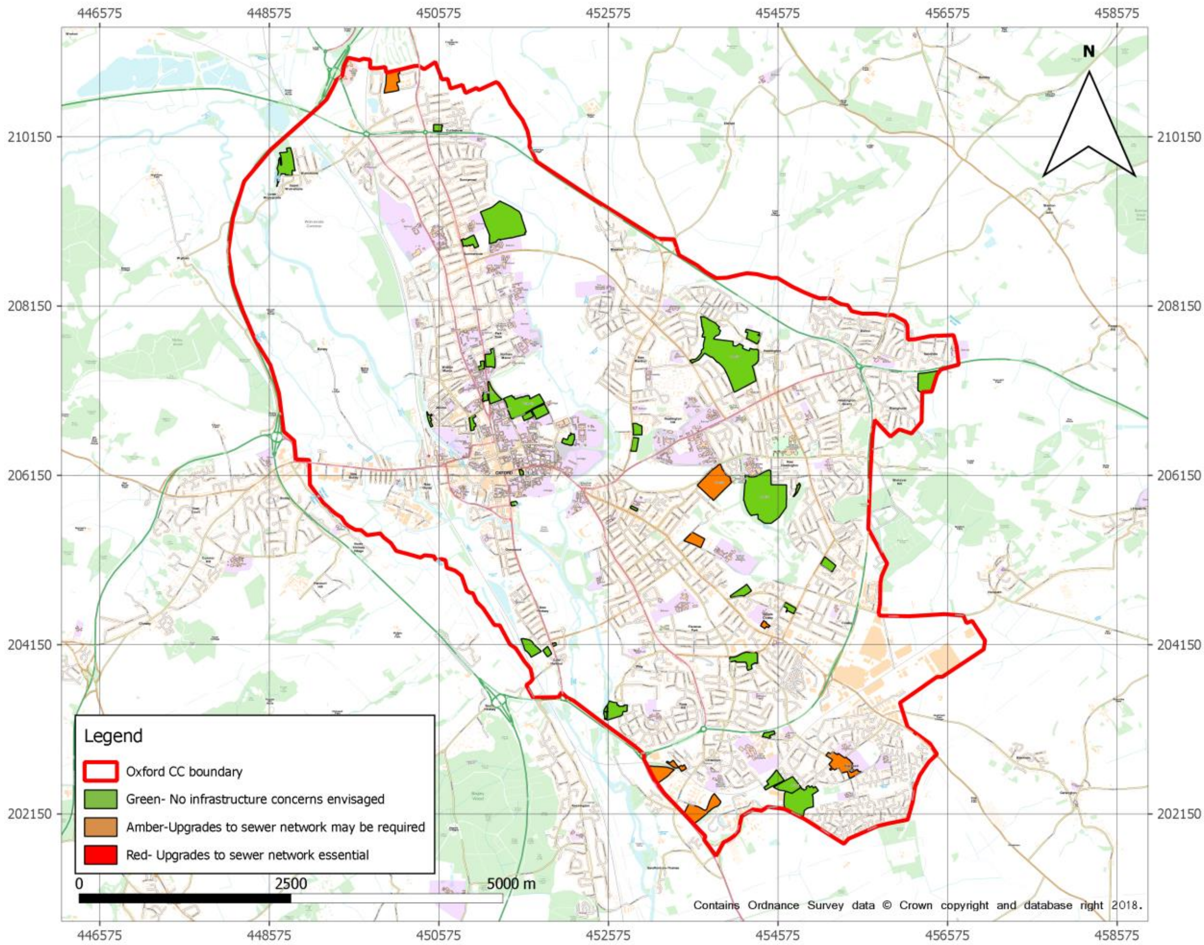

Figure 9- Map showing sites allocated for development and their associated wastewater RAG score

4.3 Environmental Capacity

4.3.1 Thames river basin management plan

The Thames river basin management plan (RBMP) was published by DEFRA and the EA in 2015[17]. The purpose of the management plan is to provide a framework for protecting and enhancing the benefits of the water environment. To achieve this, and because water and land resources are closely linked, it also informs decisions on land use planning.

The plan contains four sets of information that groups who manage land and water should pay attention to:

- Baseline classification of water bodies
- Statutory objectives for protected areas
- Statutory objectives for water bodies
- Summary programme of measures to achieve statutory objectives

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[17] DEFRA, Environment Agency (2015) Part 1: Thames river basin district River basin management plan, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/718342/Thames_RBD_Part_1_river_basin_management_plan.pdf

The Water Framework Directive (WFD)[18] provides most of the legislative basis for the RBWP. Water bodies are assessed based on the WFD indicator, which measures the health of the water environment assigning them a status. The assessment is based on a range of quality elements relating to the biology and chemical quality of surface waters. Table 7 gives a description of each of the status classes.

Table 7-Definition of status in Water Framework Directive (extracted from the Thames RBMP)

Status	Definition
High	Near natural conditions. No restriction on the beneficial uses of the water body. No impacts on amenity, wildlife or fisheries.
Good	Slight change from natural conditions as a result of human activity. No restriction on the beneficial uses of the water body. No impact on amenity or fisheries. Protects all but the most sensitive wildlife.
Moderate	Moderate change from natural conditions as a result of human activity. Some restriction on the beneficial uses of the water body. No impact on amenity. Some impact on wildlife and fisheries.
Poor	Major change from natural conditions as a result of human activity. Some restrictions on the beneficial uses of the water body. Some impact on amenity. Moderate impact on wildlife and fisheries.
Bad	Severe change from natural conditions as a result of human activity. Significant restriction on the beneficial uses of the water body. Major impact on amenity. Major impact on wildlife and fisheries with many species not present.

These classes feed into the overall environmental objectives of the WFD and the associated RBWP. The environmental objectives are:

- To prevent deterioration of the status of surface waters and groundwater
- To achieve objectives and standards for protected areas
- To aim to achieve good status for all water bodies or, for heavily modified and artificial water bodies, good ecological potential and good surface water chemical status
- To reverse any significant and sustained upward trends in pollutant concentrations in groundwater
- The cessation of discharges, emissions and loses of priority hazardous substances into surface waters
- Progressively reduce the pollution of groundwater and prevent or limit the entry of pollutants

The RBMP outlines the measures needed to achieve these statutory objectives and the regulators/operators responsible. These measures are/will be essential in maintaining environmental capacity in response to increased housing and population growth. Table 8 summarises the relevant measures applicable in Oxford City. Some of the legislation has been updated since the RBWP was published, and the updated legislation has been listed in the table.

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[18] European Commission, *Water Framework Directive (2000)*, http://ec.europa.eu/environment/water/water-framework/index_en.html

Table 8- Measures to achieve the environmental objectives

Category	Description	Stakeholders	Measures
Measures to prevent deterioration- Physical modifications	Includes physical changes such as widening, deepening and straightening rivers.	Local government & Internal Drainage board (IBD)	• Grant land drainage consents under Land Drainage Act 1991. • Grant flood risk activity permits under Water Resources Development Act 2016. • Local government & IBD assess applications for schemes or activities for their potential effect on local flood risk and the environment.
		EA	• Make sure new abstraction and impoundment licenses and environmental permits include protection for freshwater fish where relevant.
Managing pollution from waste water	Pollutants in waste water can affect the dissolved oxygen levels and can in some cases be directly toxic.	EA	• Grant and review environmental permits under the Environmental Permitting Regulations 2018 to the water industry, manufacturing business and other sectors to protect the environment from pollutants. • Work with water industry to develop long term strategy for sewerage to prevent deterioration of permitted discharges resulting from growth, climate change etc. In addition to minimising risks to the water environment from misconnected sewerage.
		Local government	• Consider the impact on water quality in their preparation of spatial plans, decisions on spatial planning, development management, new buildings and infrastructure.
	Rainwater draining from roads and	Local government	• Uses planning conditions, legal agreements and enforcement power under the Town and Country Planning Act 1990 to prevent or stop pollution from developments, roads and other infrastructure.

Managing Pollution from towns, cities and transport	pavements carries many pollutants.		• Makes sure new development use SuDS to manage and treat surface water from new developments.
		EA	• Uses anti-pollution works powers under Water Resources Act, 1991 to prevent or clean up small scale pollution.
Changes to natural flow and levels of water	Taking too much water from freshwater or tidal rivers, canals, lakes and groundwater damages the environment.	EA	• Grant licenses under the Water Resources Act, 1991 to regulate how much water is taken from surface water bodies and groundwater. • Change or revoke permanent licenses to protect the environment from actual or potential damage.
		Water Industry	• Complete statutory Water Resource Management Plans, setting out how supplies and demand for water will be managed over a 25-year period. • Encourage water efficiency measures, including water industry work on metering, leakage, audits, providing water efficient products • Produce Drought Plans.

The RBWP also outlines some of the specific measures and aims in the Cherwell and Cotswold catchments, which include the Thames through Oxford. The measures relevant to Oxford, include creating more backwaters between Banbury and Oxford helping re-naturalise the river corridor in the Cherwell catchment. For the Cotswold catchment there may be potential for a major project to restore degraded ecosystems along the river source of the Thames to Oxford, targeting the connectivity of riparian and aquatic habitats with the aim to improve flood management, water quality and soil quality. Schemes such as these may help increase the environmental capacity for the water environment in Oxford. The next sections assess the existing environmental capacity in Oxford against the projected housing growth.

4.3.2 Surface Water

Surface Waterbodies in Oxford Area

The EA's catchment data explorer was used to extract information about the water environment for several catchments in the Oxford area. The dataset provides information on the ecological and chemical status of catchments throughout the UK.

Aforementioned, the ecological status of catchments can be classified as *Bad, Poor, Moderate, Good* and *High*. For the chemical status, catchments are classed as either as a *Fail* or *Good*. For this study the classifications are used to assess the existing pressures on specific catchments in the Oxford area and get an idea of their environmental capacity. Figure 10 shows the location of the waterbodies which have been identified.

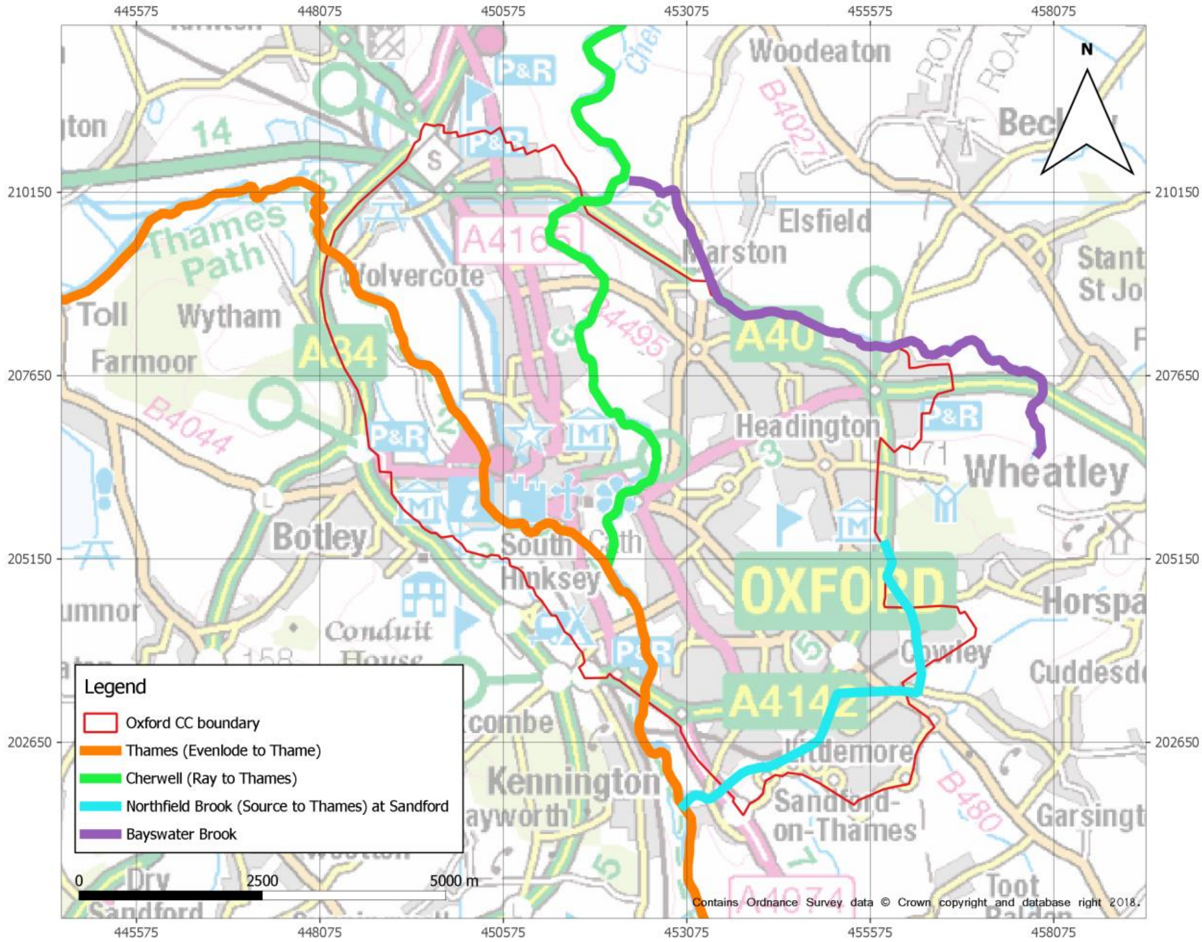

Figure 10- Waterbodies identified in Oxford area[19]

WFD Status

Table 9 shows the overall, ecological and chemical status for the four water bodies. The classifications shown are the latest 2016 cycle 2 classifications. Cycle 2 refers to the second cycle of river basin planning under the WFD, running from the last publication of river basin management plans in 2015 until 2021.

The overall water body and ecological status for three out of the four water bodies is poor, which indicates a major change from natural conditions as a result of human activity, with a moderate impact on wildlife and fisheries. This is with the exception of the Thames (Evenlode to Thame) which shows a moderate overall water body and ecological status. Moderate in this case indicates some impact on wildlife with no impact to amenity.

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[19] EA (2019) Catchment Data Explorer, https://environment.data.gov.uk/catchment-planning/ accessed 11/03/19

In terms of chemical classification three out of the four water bodies have good status. However, the Thames (Evenlode to Thame) is categorised as a fail.

Table 9- Ecological and Chemical Status of Waterbodies in Oxford Area

Water body	Eastings	Northings	Overall Water Body	Ecological Status	Chemical Status
Thames (Evenlode to Thame)	445741	211361	Moderate	Moderate	Fail
Bayswater Brook	452925	210152	Poor	Poor	Good
Cherwell (Ray to Thames) and Woodeaton Brook	451209	209547	Poor	Poor	Good
Northfield Brook (Source to Thames) at Sandford	453717	202133	Poor	Poor	Good

The reasons for not achieving good status are outlined in Table 10. Many of the causes such as agricultural land practices are unlikely to be linked to population growth and development. However, sewage discharge is a major factor contributing to the failure to reach good status in a number of the waterbodies and this will be affected by population growth if not properly managed.

Table 10- Reasons for not achieving good status

Water body	Reasons for not achieving good Ecological status	Reasons for not achieving good Chemical status
Thames (Evenlode to Thame)	**Reason:** Phosphate **Causes:** Poor nutrient management due to agriculture & sewage discharge **Reason:** Invertebrates **Causes:** Suspect data & invasive species (N.American crayfish)	**Reason:** Tributyltin Compounds above threshold **Cause:** Sewage discharge
Bayswater Brook	**Reasons:** Invertebrates & Macrophytes and Phytobenthos **Causes:** Agricultural land drainage	N/A
Cherwell (Ray to Thames) and Woodeaton Brook	**Reason:** Phosphate **Causes:** Poor nutrient management due to agriculture, sewage discharge & urbanisation **Reason:** Invertebrates **Cause:** Invasive species (N.American crayfish) **Reasons:** Macrophytes and Phytobenthos **Cause:** Sewage discharge	N/A
Northfield Brook (Source to Thames) at Sandford	**Reason:** Invertebrates **Cause:** Sewage discharge, agricultural land drainage & invasive species (N.American crayfish) **Reasons:** Phosphate, Ammonia, Dissolved Oxygen, Macrophytes and Phytobenthos **Cause:** Sewage discharge	N/A

For the Cherwell (Ray to Thames) and Woodeaton Brook, the reasons for not achieving good status are partly associated with poor nutrient management as a result of agriculture. Aforementioned this is considered to be relatively unaffected by future development proposals. However, two of the other causes; sewer discharges and urbanisation may be affected by future development.

The source of sewer discharges into the Cherwell and Woodeaton Brook catchment are likely to come from STWs serving areas upstream of Oxford, including the Banbury STW, Bicester STW and several smaller STWs serving isolated settlements. Significantly discharges from these sites are unlikely to be influenced by development in Oxford City, which drains to the Oxford STW outside of the Cherwell catchment. Proposed development in Oxford should therefore not have an adverse effect on sewer discharges into the Cherwell, however it will increase urbanisation in the lower end of the catchment. To limit the impacts of urbanisation, the regulation of SuDS to limit surface water discharges and control water quality from developments will be important.

The reasons for the Bayswater Brook not achieving good status are considered to be solely due to agricultural land drainage which is again thought to be largely independent from the development plans in Oxford City. The development sites currently proposed also lie outside of the catchment area of the Brook so are unlikely to have a significant impact on its current status. If development is sited within the catchment the same SuDS principles outlined above will be important to limit the effects of urbanisation.

The Northfield Brook and Thames (Evenlode to Thame) are potentially more vulnerable to future development plans in Oxford City. The source of sewer discharge into the Northfield Brook, which has been identified as a major cause for a number of the reasons for the watercourse not achieving good status, is the Oxford STW which manages a large amount of the wastewater from Oxford City. As the Northfield Brook is a tributary of the Thames the discharges also affect the Thames (Evenlode to Thame) water body.

The sections below detail the current permit in place at the Oxford STW, the existing pressures in the two waterbodies and the measures required to address these whilst supporting future development in Oxford City.

Oxford STW Permit

Discharges from the Oxford STW are controlled by discharge consents set by the EA, which detail flow rate and effluent quality that the STW has to meet to achieve water quality targets. The current discharge permit for the STW[20] which took effect from 17/01/2019 has been obtained from the EA. A full copy of the permit document is provided in Appendix 2. In terms of the main parameters it states the following:

- Dry weather flow shall not exceed 50,985 m^3/day, equivalent to 0.59 m^3s^{-1}.
- The maximum daily discharge volume shall not exceed 150,000 m^3 per day, equivalent to 1.74 m^3s^{-1}.
- Discharge shall not contain more than 3 mg/l of Ammoniacal nitrogen or 10 mg/l of Biochemical Oxygen Demand (BOD) as O_2.
- Note that depending on the number of samples collected over a 12-month period a certain number of samples are permitted to exceed the above limits. For example, where 8-16 samples are taken, a maximum of 2 are permitted to exceed the limit for a given parameter, this is applied to account for unusual weather which may adversely affect the operation of the STW.
- Ammoniacal nitrogen shall never exceed 14 mg/l (1 May-31 October) or 20 mg/l (1 November to 30 April) even on occasions where unusual weather conditions adversely affect the operation of the STW.
- BOD shall never exceed 50 mg/l even on occasions where unusual weather conditions adversely affect the operation of the STW.
- The annual mean concentration of Total Phosphorus shall not exceed 1 mg/l or needs to demonstrate a minimum of 80% removal compared to the influent.

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[20] Environment Agency (2019) *Oxford Wastewater Treatment Works Permit number 709*

Existing Pressures

The latest permit limits seek to help address some of the short to medium term issues in both waterbodies, especially in the Northfield Brook where effluent is discharged. The Brook has shown a general deterioration in status since 2009, despite a slight upturn in 2016 (see Table 11) and is failing on a number of the different elements used to assess ecological status (see Table 12). The Thames (Evenlode to Thame) on the other hand is relatively stable with no clear signs of ecological deterioration. The chemical status of the water body is failing due to the presence of Tribuyltin Compounds which are suspected to be from sewer discharge. The EA have confirmed that the failure is in fact occurring in the Clifton Hampden ditch downstream of Culham STW, it is therefore not relevant to the scope of this study.

Table 11- Ecological Status 2009-2016

Water body	2009	2010	2011	2012	2013	2014	2015	2016
Thames (Evenlode to Thame)	Poor	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Northfield Brook	Moderate	Moderate	Moderate	Moderate	Moderate	Bad	Bad	Poor

Table 12- Current failing elements in Northfield Brook

WFD Element	Thames (Evenlode to Thame) Status in 2016	Northfield Brook Status in 2016
Fish	Good	Not Assessed
Invertebrates	Moderate	Poor
Macrophytes	Not Assessed	Moderate
Ammonia	High	Bad
Dissolved Oxygen	High	Poor
Phosphate	Moderate	Poor

Environment Agency Modelling Screening Exercise (January 2018)

The EA undertook a modelling screening exercise[21] for the water company price review (PR19) in early 2018. The work undertaken by the EA considered all Thames Water STWs and sought to set out what investments Thames Water would need to make to ensure environmental compliance, in particular compliance with the WFD objectives. Part of this work included an assessment of risk to water quality based on predicted growth figures up to 2027, based on figures provided by Thames Water.

The Oxford STW and Northfield Brook were assessed in the screening exercise. The PR19 work suggested that there is a low risk of further deterioration in WFD status for Phosphate even when considering a deterioration in the future performance of the STW. Phosphate levels currently sit far

[21] Environment Agency (2018) *Water Industry National Environment Programme* data.gov.uk/dataset/a1b25bcb-9d42-4227-9b3a-34782763f0c0/water-industry-national-environment-programme

below the *Bad* WFD threshold. However, there is more concern for Ammonia and Dissolved Oxygen which have both deteriorated significantly since 2009.

Ammonia has deteriorated from *Good* status in 2009 to *Bad* status in 2016. The PR19 modelling found that an Ammonia permit of 1mg/l should restore the *Good* status in Northfield Brook assuming the works was performing at its full permitted flow of 50,985 m^3/day dry weather flow. This is significantly lower than the current Ammonia permit and is considered the industry's lowest technically achievable limit (TAL). The dry weather flow is also likely to increase with further development.

Dissolved Oxygen (DO) is also a concern, which has also deteriorated from *High* Status in 2009 to *Poor* status in 2016. The EA suggested that the Biochemical Oxygen Demand (BOD) permit could be tightened to the industry recognised TAL limit of 5mg/l under dry weather flow conditions which may safeguard against further deterioration.

South Oxfordshire District Council Water Cycle Study Update Phase 2 (January 2019)

The findings of the PR19 assessment outlined above are based on growth figures estimated by Thames Water. As shown in section 3.4, these are likely to be higher than the growth scenarios provided by OCC. Therefore, based on the PR19 assessment alone, there was uncertainty over whether the proposed growth in Oxford City will cause further deterioration in the Northfield Brook and Thames (Evenlode to Thame).

To further assess the environmental capacity in relation to the OCC growth scenarios, the SODC Water Cycle Study update[22 & 23] has been reviewed. Phase 2 of this update conducted a future growth scenario which incorporated the growth from SODC draining to the Oxford STW, in addition to neighbouring authorities including OCC and Cherwell District Council. The EA's SIMCAT model for the Thames river basin district was used for the assessment.

Considering OCC, the growth scenario adopted by SODC to assess the impact of increased effluent discharges from the Oxford STW was a notional higher growth scenario of 12,000 homes. Therefore, the work undertaken by SODC provides the most robust assessment available on the impact of proposed growth within Oxford City's Local Plan on the WFD status of the Northfield Brook and Thames (Evenlode to Thame).

The main findings of this assessment were as follows:

- In terms of flow capacity, the Oxford STW are currently well within its consented discharge, however as there is significant growth planned in OCC and the neighbouring authorities it is estimated that the permit would be reached in Asset Management Plan 9 (2030-2035) if no improvement were made to capacity.
- Thames Water STW upgrades can take between 18 months to 3 years to design and build, in this regard there is time available to make the strategic upgrades required provided Thames Water work closely with the local planning authorities and vice versa.
- In terms of water quality assessment results, the percentage deterioration as a result of growth is predicted to be between 1% and 2% for all determinands at points downstream of the STW. Consequently, no significant deterioration is predicted as a result of the proposed growth.

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[22] JBA Consulting (2019) *SODC Local Plan Water Cycle Study Update Phase 1: Assessment of potential site allocation options* published November 2018
[23] JBA Consulting (2019) *SODC Local Plan Water Cycle Study Update Phase 2: Assessment of proposed strategic allocations* published January 2019

- In terms of achieving *Good* status for Ammonia specifically, the required discharge quality factoring in the increase in dry weather flow was modelled to be 0.95mg/l, which is slightly below the TAL of 1mg/l. This is still considered within a range that should make it possible to improve the current status and reach *Good* status with time. Especially when considering potential reductions in the TAL in the future.
- For BOD to achieve *Good* status, the required discharge quality was modelled to be 6.20 mg/l, which is slightly above the TAL of 5mg/l. DO was not assessed as part of the SODC study, however as the EA stated in their PR19 study a tightening of the BOD permit should safeguard against further deterioration.
- *Good* status is not achievable for phosphate, as this would require treatment (0.13 mg/l) significantly beyond the limits of current treatment technology (0.25 mg/l), however as mentioned previously the risk of further deterioration is unlikely.
- In general, the planned growth should not compromise the ability to achieve *Good* status in the Northfield Brook for the majority of determinands provided the STW are upgraded and the permit is revised accordingly in the future. This should also safeguard against deterioration in the Thames (Evenlode to Thame) Water body from an ecological standpoint.

4.3.3 Groundwater

The EA catchment data explorer was also used to assess the status of groundwater bodies. The Headington Corallian is the only groundwater body which underlies Oxford. Groundwater bodies are measured against a Quantitative Status, where a good quantitative status consists of five criteria, as follows:

- The total abstraction from the groundwater body should not exceed the recharge to the groundwater body.
- Groundwater abstraction should not cause a reversal in groundwater flow direction which results in the significant intrusion of poor-quality water into the groundwater body.
- Groundwater flows to dependent surface water bodies should not be diminished by groundwater body related pressures to the extent that they do not achieve good status.
- Groundwater body related pressures should not diminish groundwater flows or levels which could cause "significant damage" to groundwater dependent terrestrial ecosystems (GWDTEs) in relation to conservation objectives.
- A review of available groundwater level monitoring data is conducted, may be helpful in investigating potential abstraction impacts on GWDTE receptors.

The Headington Corallian has a *good* quantitative status. The aquifer also achieved a *good* chemical status.

4.4 Summary

The sewer network in Oxford currently manages the demand of over 250,000 customers. This is set to increase significantly as a result of population growth, and it is essential that there is sufficient infrastructural and environmental capacity to safeguard against issues such as sewer flooding and ecological damage.

The Oxford STW are the most important infrastructural asset with respect to future development in Oxford. They have recently benefited from a large increase in capacity following a project to upgrade the sludge stream and introduce a Thermo Hydrolysis plant. The upgrade is said to provide the required additional sludge treatment capacity required for the growing local population, however further technical work by Thames Water may be required to measure the capacity of all components of the STW directly against planned housing growth.

Thames Water's latest management plan for the Oxford area makes no direct promise to increase the capacity of the Oxford STW further. However, in the short to medium term there is a commitment to implement interventions that address any problems occurring at the inlet to the STW. In the longer term there is a commitment to continue to monitor the effects of growth and climate change on the STW to ensure that it can cope with any future increases in catchment population.

On a site-specific basis, the infrastructural capacity in most locations is sufficient to permit development, however there are several sites particularly in the south of the city where upgrades to the sewer network may be required. At this stage these are not expected to be significant large-scale upgrades, however careful planning will be required to ensure the infrastructural capacity is in place before development proceeds.

In terms of environmental capacity, the EA's catchment data explorer suggests that most of the watercourses in the Oxford area have *Poor* ecological status, and *Good* chemical status. The reasons for not achieving *Good* ecological status are primarily associated with agricultural practices and sewer discharges. The former is not believed to be sensitive to future development proposals however sewer discharges will be.

The Cherwell catchment is considered to be relatively insensitive to future development in Oxford City, as sewer discharges are likely to originate from outside of the city boundaries. However, the implementation of SuDS will be important in the lower part of the Cherwell catchment to limit the effects of urbanisation.

The two waterbodies most vulnerable to future development are the Northfield Brook and Thames (Evenlode to Thame), with the Oxford STW discharging into the Brook and lying within the wider Thames catchment. The Northfield Brook has also shown significant deterioration since 2009. Work undertaken on behalf of SODC for their recent water cycle study update has shown that firstly planned growth in Oxford City (12,000 homes) should not cause significant deterioration at points downstream of the STW, and secondly that the planned growth should not compromise the ability to achieve *Good* Status for the majority of determinands provided the existing permit is modified accordingly (within current TALs) and the capacity of the STW is increased post-2030.

In summary there should be sufficient environmental capacity to manage the proposed growth in Oxford City. However the correct measures will need to be followed by several stakeholders including Thames Water, OCC, neighbouring authorities, developers and the EA to ensure that the current statuses of the watercourses either stay the same or improve. This is particularly important for the Thames given the sensitivity of the Oxford Meadows.

5 Flood Risk

5.1 Introduction

This section includes a high-level review of flood risk in Oxford, and its relationship with development proposals. How flood risk might be managed moving forward is also addressed.

5.2 Overview of River Catchments & Fluvial Flood Risk

The Thames is the largest river running through Oxford. It flows from the north, passing through Wolvercote before entering the City Centre from the west near New Botley. To the north of the city the main flood risk is to Wolvercote. South of Wolvercote the river flows through a wide and flat floodplain corridor in the form of Port Meadow. In this area the flood plain consists mostly of farmland with few properties at risk.

As the river flows south east towards the River Cherwell, the urban areas of New Botley and Osney are at risk from flooding. Both areas have in the past been subject to regular flooding. In this area there are a number of smaller watercourses including the Botley Stream, Fiddler's Island Stream, Wytham Stream, Bulstake Stream, Osney Ditch, Castle Mill/Wareham Stream, Mill Stream and Hinksey Stream. The majority of flooding from the main River Thames is constrained to the west of the raised railway embankment which carries the mainline railway service between London Paddington and Hereford. Castle Mill Stream which joins the Thames in the centre of Oxford between New Osney and Jericho, poses a risk to properties in both these areas, although damage to properties is rare.

The River Cherwell originates from the north east and passes between Marston and Summertown, entering the city centre to the east before it flows into the River Thames near Christ Church Meadow. The floodplain of the River Cherwell is mostly characterised by farm and recreational land as it flows between Marston and Summertown. The overall risk to properties and infrastructure is low, with only small areas of Summertown and New Marston shown to be at risk in the EA's flood map.

The River Cherwell adds a significant discharge to the River Thames in the city centre, and as the River Thames flows southwards out of the city boundary, it poses a significant flood risk to the suburbs of Grandpont and New Hinksey. In these areas, the floodplain contains a number of housing estates which are at significant flood risk and are known to have flooded in the past. The majority of these areas are located in Flood Zone 3.

The Boundary Brook flows from west to east from Headington through Cowley and Iffley before joining the River Thames south of New Hinksey. The main flood risk is in Cowley and Iffley, associated with a culverted section of channel. Significant flooding is predicted within the surrounding residential areas for both the 100 year and 1000-year events.

Littlemore Brook poses a flood risk to areas in Blackbird Leys and Littlemore in the south east of the city with these areas flooded in the past. The Bayswater Brook flows along the north eastern boundary of the OCC administrative boundary, and the floodplain on the left bank is shown to affect some parts of Barton.

Figure 11 shows the main watercourses in the Oxford area and the associated flood map.

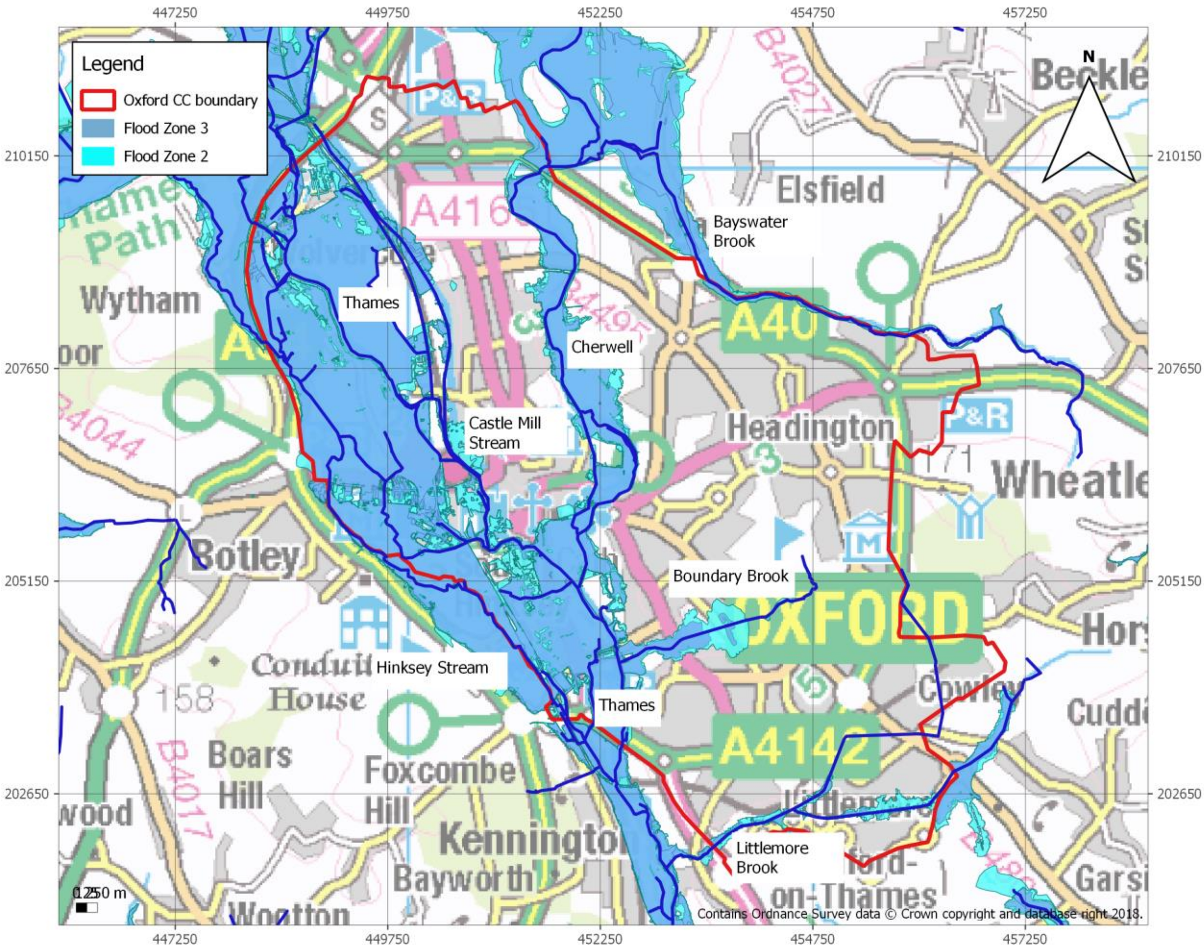

Figure 11- Main watercourses and Flood Extent in Oxford Area[24]

5.3 Other Sources of Flood Risk

Ordinary watercourses with catchments less than 3km^2 are not represented in the fluvial flood maps provided by the EA. The key ordinary watercourses have been identified as follows:

- Marston Brook: A small stream which runs towards Old Marston from the Northern Bypass road. This appears to be a potential flood risk for a number of properties in Old Marston.
- Peasmoor Brook: A small stream to the south east of Marston Brook which poses a potential flood risk, to properties to the east of Marsh Lane in New Marston.
- Unnamed watercourse at Cutteslowe: A small unnamed watercourse and drainage ditch, both running through Cutteslowe Park towards Cutteslowe. They put many parts of Cutteslowe at medium to high risk of flooding based on the EA's surface water flood maps.
- Northfield Brook West: A small stream which flows east to west through Blackbird Leys before it joins the Littlemore Brook; flooding is predicted along the majority of its length, posing a significant risk to properties in Blackbird Leys.

Another source of flooding is surface water flooding. It is often the result of high peak rainfall intensities, and insufficient capacity in the sewer network. Surface water flooding is a significant

[24] EA (2018) Flood Map for Planning

flood risk in an urban area like Oxford, due to the high proportion of impermeable surfaces, which cause a significant increase in runoff rates and consequently the volume of water that flows into the sewer network.

Areas at significant risk of surface water flooding include parts of Cowley, Jericho, Headington, Summertown and the Woodstock Road. Surface water flooding is mainly isolated to the individual road network, rather than large areas. These areas are above the floodplains of the River Thames and River Cherwell, meaning that the main source of flooding in these areas is likely to be pluvial.

Groundwater flooding is another issue within the Thames Valley through parts of Oxfordshire. The floodplain is often characterised by buried gravels which act as underground storage reservoirs. When their capacity is exceeded, they can overspill into the floodplain.

For Oxford the groundwater register identifies 15 records of suspected groundwater flooding. These occurred between 2000 and 2003 inclusive and 2007 and 2009 inclusive. Based on the register there is a tendency for groundwater flooding to occur in low lying areas with clusters of incidents in New Hinksey, Grandpont and New Botley. However there have also been isolated incidents in higher areas such as in Sunnymead and Headington.

Typically, the incidents reported are associated with cellar and sub floorboard flooding of property and the emergence of groundwater in gardens and garages. Many of the locations have underlying gravels associated with the Thames floodplain.

5.4 Impact of Flood Risk on Development

Flood risk is a key factor in spatial planning. Government policy seeks to ensure that all developments are safe with respect to flooding, and that floodplains are used for their natural purposes. Development on a floodplain is both at risk from flooding and has the potential to reduce the ability of the river corridor to convey and store flood waters without suitable mitigation measures. This means that if development is not adequately controlled there will be a detrimental effect on third party flood risk with the floodplain’s capacity reduced and water displaced elsewhere.

Through application of the National Planning Policy Framework (NPPF)[25] and the non-statutory technical standards for sustainable drainage systems[26], any adverse impact on flood risk from development should be negated.

In Oxford, the greatest potential for adverse impact from development is in the vicinity of the River Thames and the River Cherwell. These are the two primary sources of flooding in Oxford, and any further loss of floodplain and/or increased runoff due to hard surfaces in these locations could exacerbate flooding problems.

Oxford City Council’s latest Housing and Economic Land Availability Assessment (HELAA)[27] published in 2016 outlines the current development issues facing Oxford. About 27% of Oxford’s land area is greenfield, the majority of which forms the river corridors of the Thames and Cherwell acting as floodplain and/or is designated for its nature conservation value. Except for a limited number of sites, the HELAA considered most of this greenfield land as unsuitable for development.

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[25] Department for Communities and Local Government (2012) *National Planning Policy Framework* assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/6077/2116950.pdf accessed on 10/07/18

[26] Defra (2015) Sustainable Drainage Systems: Non-statutory technical standard for sustainable drainage systems https://bit.ly/2LzDBWU accessed on 10/07/18

[27] AECOM (2016) *Oxford City Council Housing and Economic Land Availability Assessment (HELAA)*

The current total area of the sites allocated for development is 1.65 km^2, with a significant amount (1.10 km^2) of the housing requirements met from within existing urban areas through the use of brownfield land.

To accommodate between 8,000 to 12,000 properties, the total land area required for built development would be the order of 2 to 3 km^2 (assuming 40 dwellings per hectare). This would be a further 1.35 km^2 in the upper scenario. To accommodate such an expansion, it is likely that mitigation options will need to be implemented at a number of sites in order to facilitate development, ensuring development is both safe and does not increase third party flood risk elsewhere.

5.5 Mitigation Options

Development will have a significant impact on flood risk in Oxford if it is not properly managed. In line with the NPPF and the sequential test, efforts should be made to steer new development to areas with the lowest probability of flooding. Development should not be allocated or permitted if there are reasonably available sites appropriate for the proposed development in areas with a lower probability of flooding.

The issue faced in Oxford is that there are a limited number of available sites in areas with low probability of flooding. This means that it is likely that following application of the sequential test it may not be possible for a development to be located in zones with lower risk of flooding.

The exception test provides a method of managing flood risk while still allowing development to occur. There are two elements to the exception test:

- It must be demonstrated that the development provides wider sustainability/amenity benefits to the community that outweigh flood risk.
- A site-specific flood risk assessment must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and where possible reduce flood risk overall.

To achieve the second part of the test, mitigation options may need to be considered to ensure that the development is safe from flooding, and that it does not have a negative impact on flooding elsewhere. Options to be considered include:

- Increase floodplain storage/provide compensatory storage should the development require any ground raising above measured/modelled flood levels.
- SuDS guidelines to achieve no net increase in runoff as a result of the development proposals (obligatory for most development sites).
- Possibility of developer contributions to fund local improvement schemes elsewhere.
- Flood resilient and resistant building design.
- Flood incident management (flood warning) and emergency planning.
- Opportunities for integrated urban drainage schemes at locations where there is mutual benefit in relation to reducing overall flood risk to new and existing developments.

Thus, to facilitate development in Oxford, a range of potential mitigation options will need to be investigated further. Mitigation will likely be required at both the site-specific scale and at the catchment wide scale, the latter encompassing river engineering, rural land management, urban design and defence infrastructure.

Some of these larger scale mitigation measures have already been approved. The EA is working with partners on a major new flood alleviation scheme to reduce flood risk to many homes and businesses in Oxford, which is due for completion in 2022.

The scheme looks to enhance the existing floodplain west of Oxford, most of which is farmland and flood meadow. Material will be removed to lower the natural floodplain in this area, so it can carry more floodwater. This will create a narrow, deeper channel, which will always carry water, and a wider shallower area to the side of this, which will be planted with vegetation and will only carry water during a flood. This 'two-stage channel' design imitates the natural floodplain whilst making more space for water to flow during flooding.

The scheme area will be approximately 5km long, running from just north of Botley Road, down to south of the A423 near Kennington, where it joins the River Thames. It will divert water across the floodplain and away from properties. The same amount of water that enters the scheme in the north will return to the Thames at Kennington, so flood risk to properties downstream will not increase as a result. Figure 12 illustrates how the scheme will work.

Flooding is expected to become more frequent and more severe with the effects of climate change. The scheme is designed to manage flood risk to Oxford over the next 100 years. It will reduce flood risk to a number of areas including Botley, Osney, New Hinksey and Grandpont. In reducing flood risk the scheme may 'free up' some land for development.

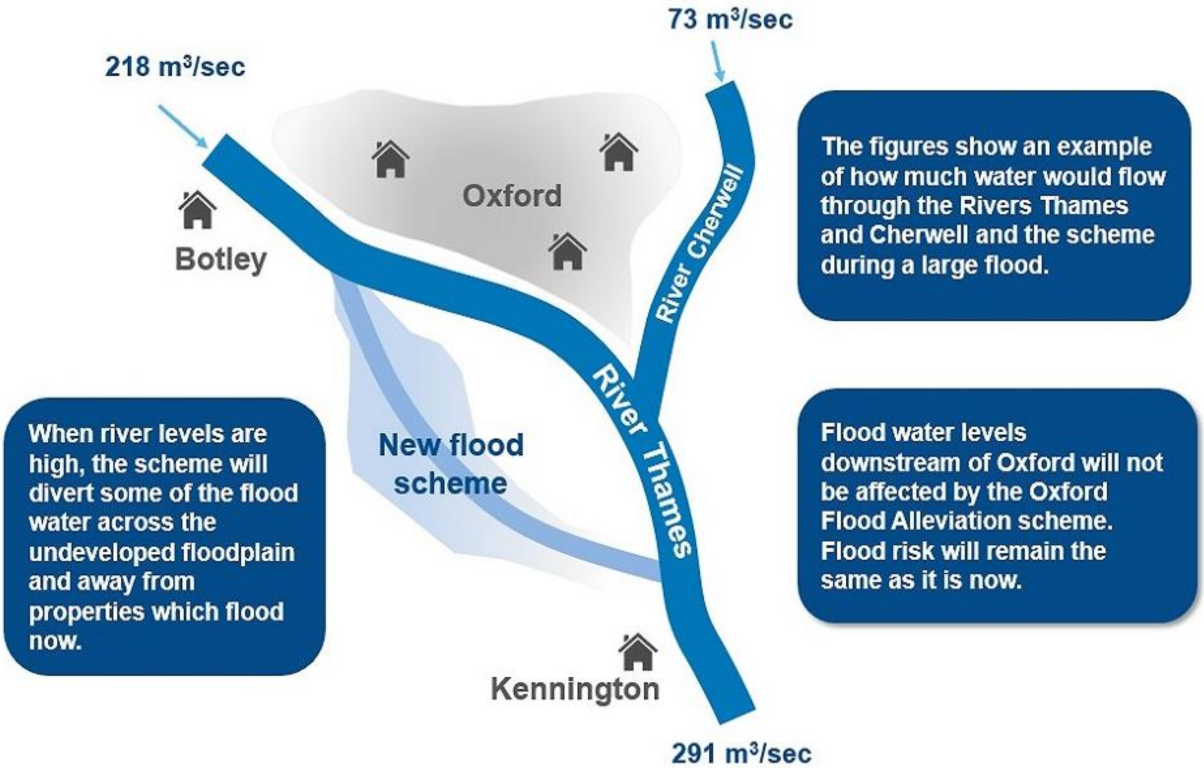

Figure 12- Schematic of Oxford Flood Alleviation Scheme[28]

[28] Environment Agency (2018), Policy Paper: Oxford flood scheme, www.gov.uk/government/publications/oxford-flood-scheme/oxford-flood-scheme, accessed on 17/07/18

5.6 Summary

Both the impact of development on flood risk, and the impact of flood risk on development can be reduced by following the sequential and exception tests outlined in the NPPF and ensuring that development in the study area follows SuDS guidelines.

The estimated area required for development is 2-3 km^2, this is not a particularly large area however a significant proportion of the green spaces in Oxford are subject to flood risk and are within areas protected for conservation. This means that land at low probability of flooding is limited, and it is likely that mitigation measures will be required to facilitate development moving forward.

At the site-specific level, mitigation measures such as SuDS, ground raising, and compensatory storage will likely need to be used at a number of sites. Alongside this catchment scale measures such as the Oxford Flood Alleviation Scheme may help reduce flood risk in a number of areas throughout Oxford, which could in turn lead to more development opportunities.

6 Other environmental constraints

Further environmental constraints in Oxford come mainly from the protected status of several sites across the city.

Firstly, the Oxford Meadows are a Special Area of Conservation (SAC). SACs are strictly protected sites designated under the European Union's Habitats Directive. Any developments that are close to or within the boundary of a SAC may require a habitat regulations assessment if they are likely to have an adverse effect on the site. An initial screening stage would be required, followed by an appropriate assessment. The aim is to ensure that land use is sustainable, and wildlife can flourish.

Where it is considered that an adverse effect on the integrity of the SAC is likely, and no alternatives are available, the project can only go ahead if there are imperative reasons of over-riding public interest and if the appropriate compensatory measures can be secured. Planning authorities can also insist that developments carried out without necessary planning permission are removed. Figure 13 shows the location of the Oxford Meadows SAC.

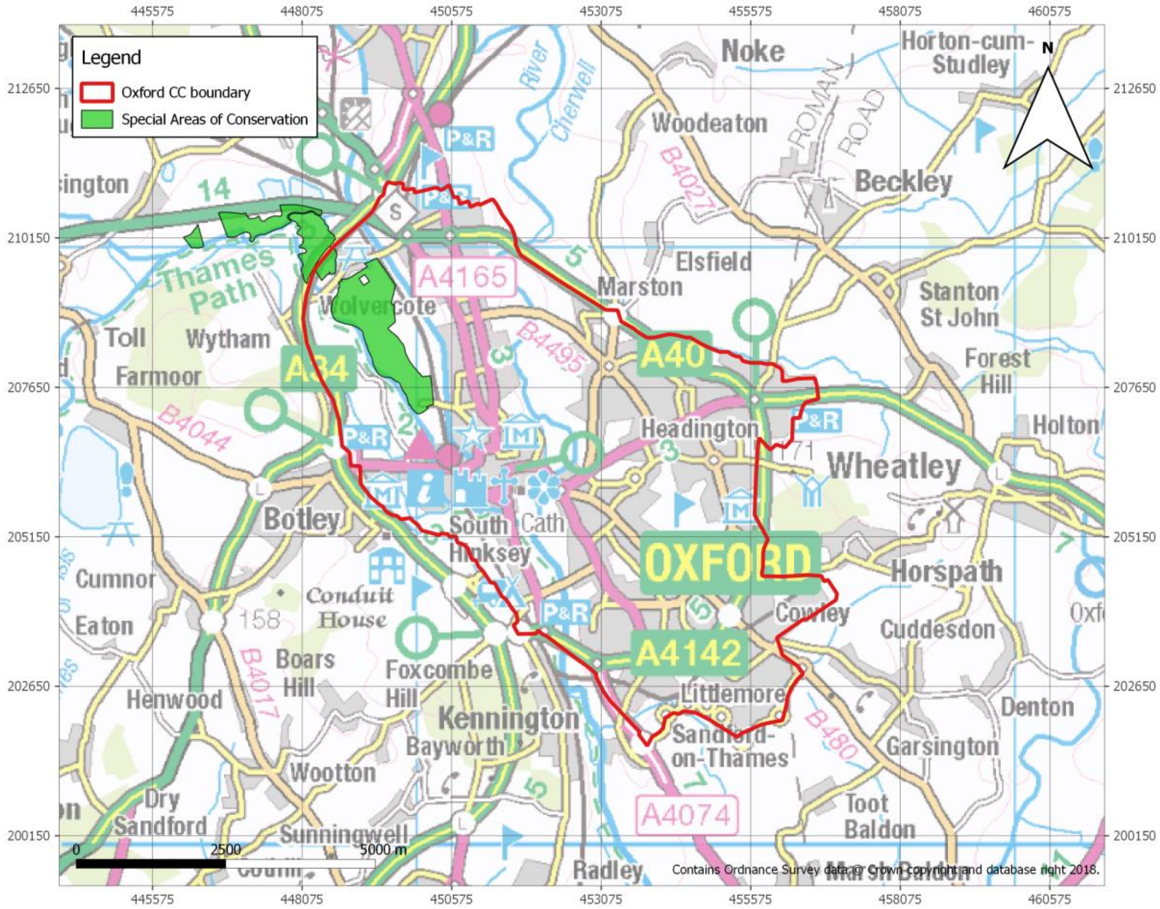

Figure 13- SAC in Oxford and the surrounding area[29]

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[29] DEFRA, Magic Map, http://magic.defra.gov.uk/MagicMap.aspx accessed 19/07/18

In addition to being designated a SAC the majority of the Oxford Meadows are part of the functional floodplain, therefore any form of development is highly unlikely. The meadows also put constraints on development outside of the SAC boundary in that they limit what can be abstracted from the Thames as water levels need to be maintained. Groundwater contamination in North Oxford is also a potential issue for the meadows therefore developments here will need account for this risk.

There are 12 Sites of Special Scientific Interest (SSSI) within the Oxford administrative boundary, with many also located in the surrounding area. Four of the sites are geological SSSIs, with the remaining 8 biological SSSI. All SSSIs are protected by law to conserve their wildlife or geology.

Local planning authorities are required to have policies in their development plans which protect SSSIs. They are also required to consult the appropriate conservation body over planning applications which might affect the interest of an SSSI. The owners or occupiers of SSSIs are also required to obtain consent from the relevant nature conservation body if they want to permit potentially damaging activities. These activities are unique for each site, but examples include grazing, the storage of materials, tree management, draining, the use of vehicles and burning. Figure 14 shows the location of SSSIs in and around the Oxford area.

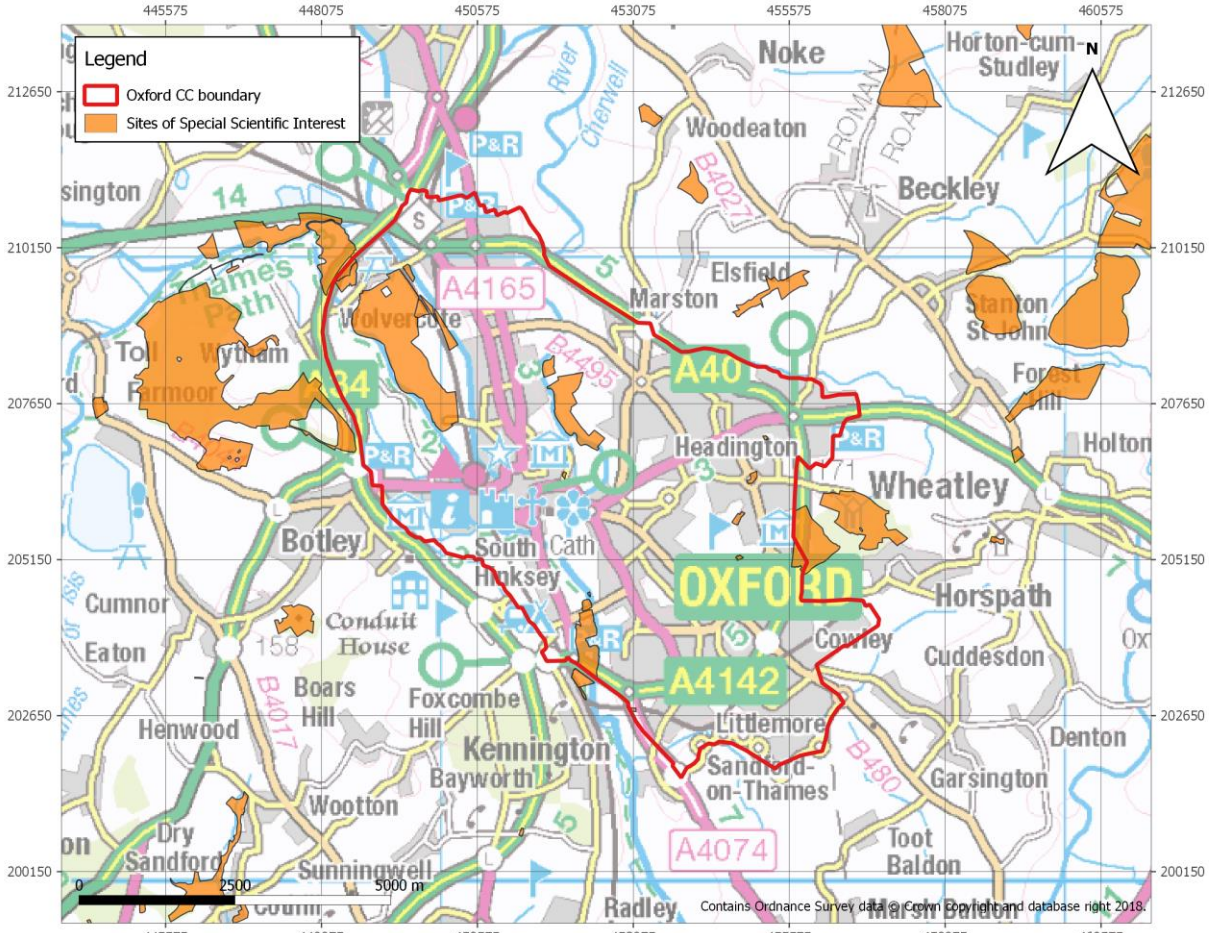

Figure 14- SSSIs in Oxford and the surrounding area[30]

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[30] DEFRA, Magic Map, http://magic.defra.gov.uk/MagicMap.aspx accessed 19/07/18

Many of the SSSIs shown in Figure 14 are sited in the meadows alongside the Thames and Cherwell. These are biological SSSIs and if development is not properly managed it could lead to a deterioration in water quality or changes in the flow regime at the SSSIs. Care needs to be taken both during and after construction to ensure that runoff from development sites is adequately treated before entering the local drainage network.

There are also three Local Nature Reserves (LNR) situated in Headington. They include the Magdalen Quarry LNR, the Rock Edge LNR and the Lye Valley LNR. LNR may be given protection against damaging operations. In most cases they also have a certain level of protection against development on and around them. However, there is no national legal protection specifically for LNRs. Figure 15 shows the location of the LNRs within Oxford.

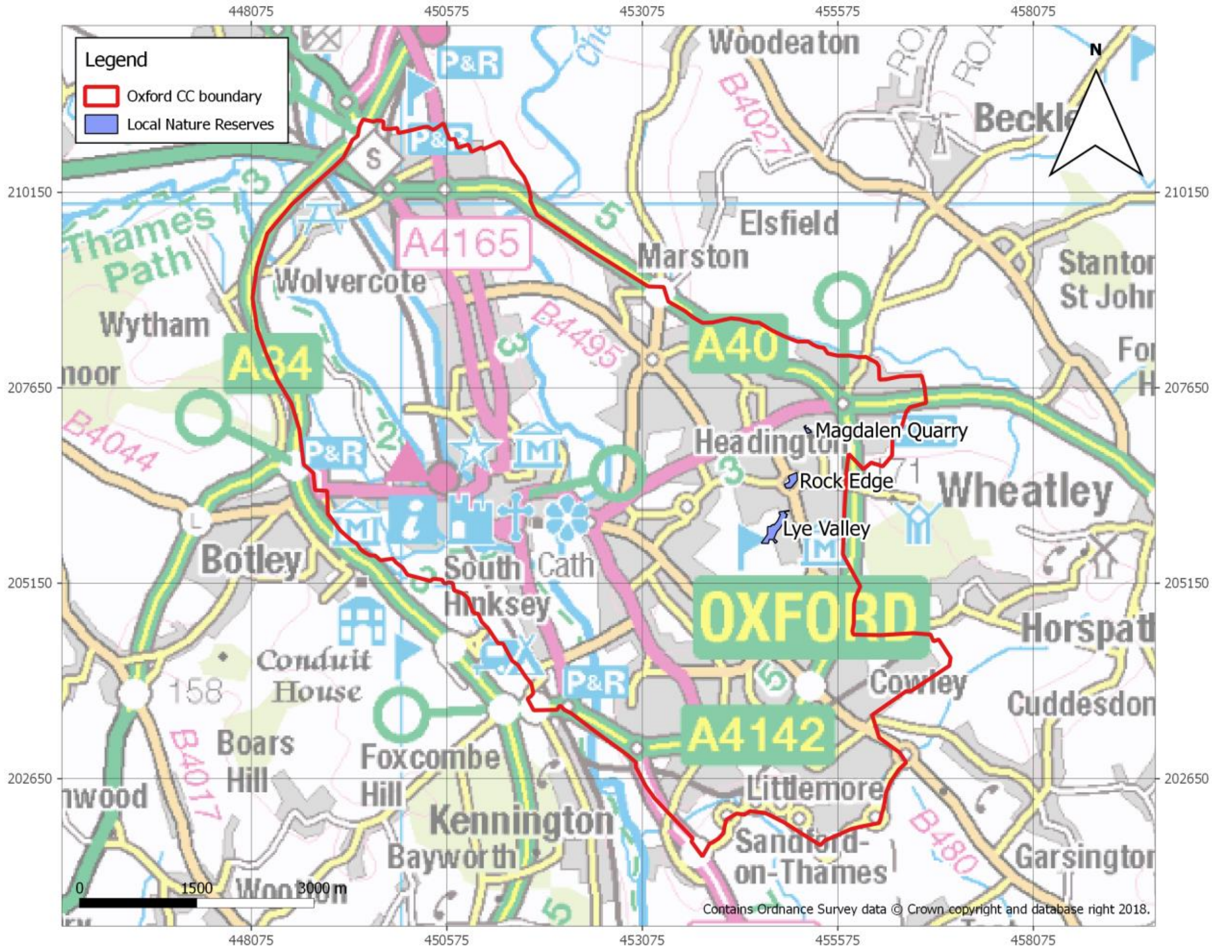

Figure 15- LNRs in Oxford and the surrounding area[31]

In addition to the designated status of any number of sites in Oxford there are a number of restrictions on planning to preserve the built environment of Oxford. These are related to the water environment as they have an impact on building footprints leading to potential issues with land availability.

[31] DEFRA, Magic Map, http://magic.defra.gov.uk/MagicMap.aspx accessed 19/07/18

Firstly, there are numerous listed buildings in Oxford. Planning permission near such buildings will only be granted for development which is appropriate in terms of its scale and location, and which use material and colours that respect the character of the surroundings.

Building height is also limited, particularly in the city centre where planning permission will not be granted for any development within a 1200 metre radius of Carfax tower which exceeds 18.2m in height or 79.3 m above sea level. Developments outside of this zone, but within the view cones must also be considered with extreme caution and similar rules are applied as within the central core (see Figure 16). This makes it difficult to build high density multiple storey developments in Oxford. These tend to take up less space, which is problematic given the limited amount of land availability caused by extensive floodplains in the city.

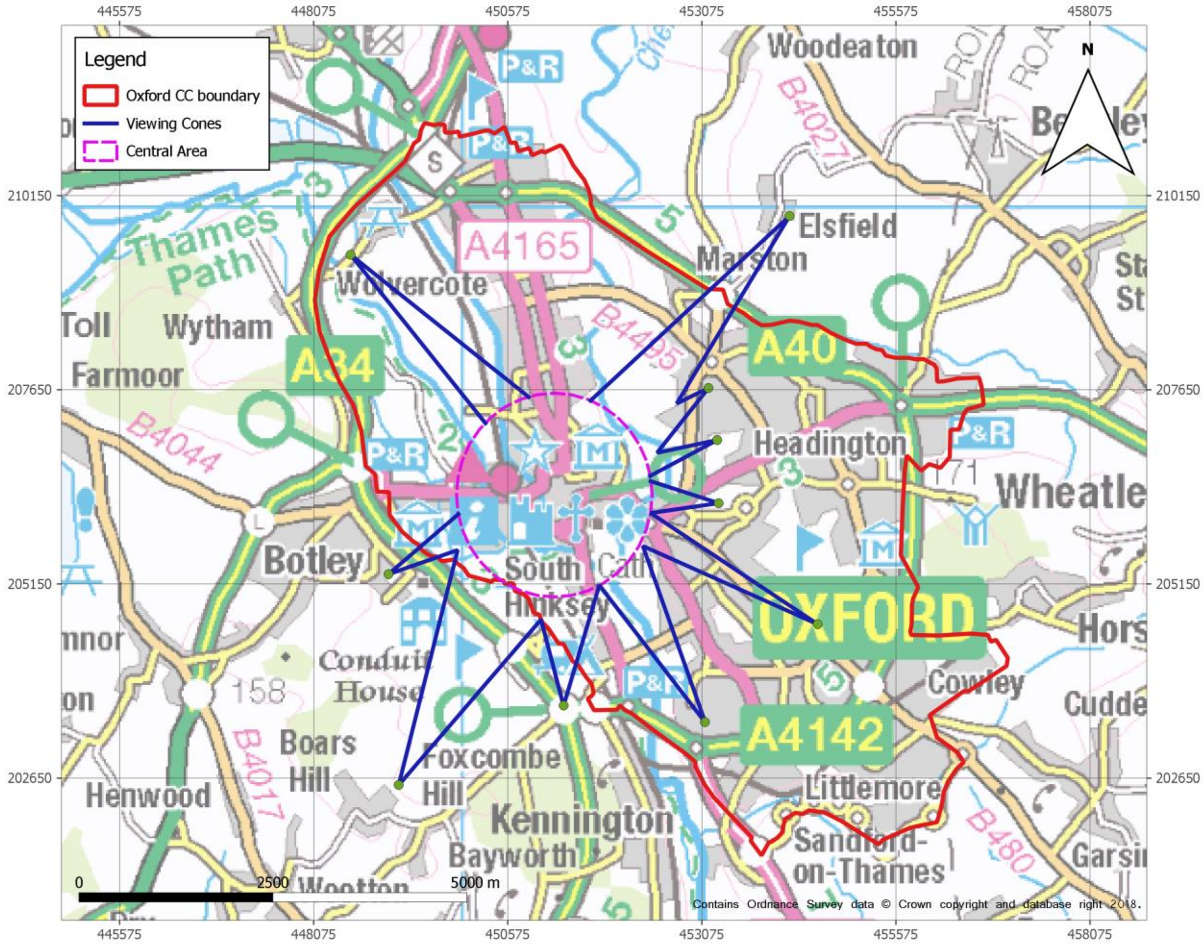

Figure 16- Viewing Cones shown in Oxford Local Plan 2001-2016[32]

[32] Oxford City Council (2001), The Oxford Local Plan 2001-2016

7 Conclusions & Recommendations

The conclusions are recommendations from this study are as follows:

Water Resources and Supply

- The development scenarios assessed will require extra water resource development.
- The water resource developments proposed by Thames Water in their latest WRMP should meet the expected increases in demand for all of the scenarios assessed.
- Of the 37 sites allocated for development currently, 5 are likely to require upgrades to the local surface water sewer network. At these sites, Thames Water should be contacted taking account of lead times to ensure that infrastructure can be delivered on time.
- Abstractions are limited in Oxford currently due to the Oxford Meadows and are not thought to have a major impact on water resources in the area.

Water Disposal and Quality Issues

- The Oxford STW recently underwent a significant upgrade to increase treatment capacity four-fold, which should mean that there is sufficient treatment beyond 2036.
- Population growth will likely lead to an increase in discharges from the STW, therefore liaison will likely be required with the EA to amend existing permits whilst ensuring that water quality and flood risk are not compromised.
- The storm overflow components of the STW will need to be monitored and upgraded where necessary to ensure that current pressures are resolved and the conditions for the applicable permit are met.
- Thames Water have proposed a range of measures including the implementation of SuDS and the identification of misconnections with the aim of improving the waste water network in Oxford.
- Of the 37 sites allocated for development currently, 8 are likely to require upgrades to the local foul sewer network. At these sites Thames Water should be contacted taking account of lead times to ensure that infrastructure can be delivered on time.
- Most watercourses running through Oxford have been classified as having *Poor* ecological status and *Good* chemical status.
- The Northfield Brook and Thames (Evenlode to Thame) are most vulnerable to future development given sewer discharges from the Oxford STW.
- A water cycle study update was carried out on behalf of SODC in January 2019 which modelled the impacts of proposed growth on the Oxford STW and assessment points downstream. The growth scenario modelled included the notional higher growth scenario for Oxford City (12,000 homes).
- The results showed that the planned growth should not cause significant deterioration at points downstream of the STW, and that it should not compromise the ability to achieve *Good* Status for the majority of determinands provided the existing discharge permit is modified accordingly and the capacity of the STW is increased post-2030.
- Based on these findings it is concluded that provided the correct measures are followed by the key stakeholders and the STW are upgraded where necessary, environmental capacity in Oxford should be sufficient to ensure that the water environment remains healthy.

Flood Risk

- Many parts of Oxford are subject to flood risk, meaning that land with low flood risk is limited.
- The impact of flood risk on new development and vice versa should be managed through application of the NPPF and SuDS guidelines.
- Mitigation measures including ground raising, compensatory storage and SuDS may be required at a number of sites to facilitate development.

- The Oxford Flood Alleviation Scheme may help reduce flood risk in a number of areas throughout Oxford, which could in turn lead to more development opportunities.

Other Environmental Constraints

- There are several protected sites in Oxford, including the Oxford Meadows SAC, 12 SSSI located around the city, and 3 LNRs in Headington. These need to be considered in the planning process.
- Building regulations in Oxford currently limit the height of buildings in many areas, which likely increases the footprint of many developments, leading to further issues with land availability.

Appendix 1 – Thames Water Site Specific RAG Reports

Appendix 2 – Oxford STW Discharge Permit (January 2019)