Report

Odour impact assessment for Cambridge Water Recycling Centre

Client: Cambridge City Council
Mandela House
Cambridge

Report number: CACC17A_08_final
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Executive Summary

Cambridge City Council (CCC) commissioned Odournet UK Ltd to undertake an odour impact assessment for Anglian Water's Water Recycling Centre (WRC) in Cambridge. The overall objective of the study was to assess the level of odour impact risk posed by the WRC in the surrounding area to inform the Council's ongoing and future planning decisions and policy.

The scope of the study was as follows:

1. To clarify the current WRC configuration and operations.
2. To undertake an odour survey and define odour emission estimates for each of the key elements of the treatment process at the WRC.
3. To undertake odour dispersion modelling of the WRC under the current operational conditions and assess the extent of potential odour impact risk in the surrounding area.

The study was conducted in accordance with the relevant aspects of published UK guidance issued by the Institute of Air Quality Management (IAQM) the Environment Agency and DEFRA. The study involved an odour measurement survey which was conducted at the WRC in summer 2017 with the cooperation of Anglian Water. The results of the survey were used alongside operational information for the WRC and odour measurement data collected at other UK sewage treatment works to define odour emission estimates for each aspect of the works operations. Odour dispersion modelling was then undertaken in order to assess the long-term odour exposure levels which are likely to occur around the site under the current operational conditions.

The key findings of the study are summarised as follows:

1. The odour survey identified a range of odour sources at the WRC under the current operational conditions. These sources include the raw sewage reception and screenings/grit removal plant, the stormwater storage tanks, the primary settlement tanks, the anoxic and aerobic secondary treatment plant, and the sludge handling and storage operations.
2. The estimated time weighted summer odour emissions from the WRC are approximately 73,000 ou_E/s. Of these emissions approximately 20% are generated by the preliminary treatment stage, 1% from storm water handling, 15% by the primary treatment stage, 22% by the secondary treatment stage and 42% from the sludge handling and treatment operations.
3. The largest individual contributors to the total site emissions are the emissions from the raw sludge belt thickening plant, the secondary sludge digestion tanks, the D stream anoxic plant and the primary settlement tanks.
4. The results of dispersion modelling which was undertaken to assess the level of odour impact risk under the foreseeable long term operational conditions at the works (current operations plus both secondary digestion tanks assumed to be in use and gas collection issues addressed) indicate that odour exposure levels in the area immediately surrounding the works exceed the $C_{98,\ 1\text{-hour}}$ = 3, 5 and 6 ou_E/m^3 odour impact criteria discussed in section 2.3 of this report. On this basis any residential developments in these areas are likely to be at risk of odour impact. For any commercial or industrial developments in these areas, the degree to which odour impact is likely to occur is less clear for the reasons discussed within this report.
5. The likely increase in exposure to odours that would be experienced periodically in the vicinity of the storm overflow lagoon should be considered if the suitability of this land for development is to be reviewed.

Table of Contents

1 Introduction and scope

1.1 Introduction

Cambridge City Council (CCC) commissioned Odournet UK Ltd to undertake an odour impact assessment for Anglian Water's Water Recycling Centre (WRC) in Cambridge. The overall objective of the study was to assess the level of odour impact risk posed by the WRC in the surrounding area to inform the Council's ongoing and future planning decisions and policy.

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The study was conducted in accordance with the relevant aspects of published UK guidance issued by the Institute of Air Quality Management (IAQM) the Environment Agency and DEFRA. The study was conducted by specialist consultants drawn from Odournet's UK consultancy team who have extensive experience assessing the odour impact of sewage treatment operations.

1.2 Structure of report

The report is structured as follows:

1. Section 2 describes the methodology undertaken to conduct the assessment.
2. Section 3 provides an overview of the current site operations.
3. Section 4 identifies the odour sources associated with the operation of the WRC.
4. Section 5 presents the results of the odour survey conducted at the works.
5. Section 6 presents an estimation of odour emissions from the WRC.
6. Section 7 assesses the predicted odour exposure levels in the area surrounding the WRC under the current operational conditions.
7. Section 8 summarises the findings of the study.

Supporting information is provided in the Annex.

1.3 Quality Control and Assurance

Odournet's odour measurement, assessment and consultancy services are conducted to the highest possible quality criteria by highly trained and experienced specialist staff. All activities are conducted in accordance with quality management procedures that are certified to ISO9001 (Certificate No. A13725).

All sensory odour analysis and odour sampling services are undertaken using UKAS accredited procedures (UKAS Testing Laboratory No. 2430) which comply fully with the requirements of the international quality standard ISO 17025: 2005 and the European standard for olfactometry EN13725: 2003. Where required, Odournet are accredited to conduct odour sampling from stacks and ducts in accordance to ISO 17025: 2005 and EN13725: 2003 under the MCERTS scheme. Odournet is the only company in the UK to have secured UKAS accreditation for all elements of the odour measurement and analysis procedure.

The Odournet laboratory is recognised as one of the foremost laboratories in Europe, consistently out performing the requirements of the British Standard for Olfactometry in terms of accuracy and repeatability of analysis results.

2 Description of approach

2.1 Identification of odour sources and estimation of odour emissions

The odour sources associated with the WRC operations under the current conditions were defined on the basis of a review of the site operations (site audit) which was undertaken on 18th January 2017 by Mr Paul Ottley (senior consultant at Odournet) in the company of an experienced Anglian Water Treatment Manager (Mr Ceri Williams) and Senior Growth Planning Engineer (Mr Richard Lyon).

Emission estimates (expressed in terms of European odour units) for each source were defined primarily on the basis of data collected at the works during an odour survey which was conducted by Odournet in August 2017. The odour survey was undertaken in summer conditions after a period of dry weather. In defining appropriate emission rates library data collected by Odournet from other operational sewage treatment facilities in the UK and contained in Odournet's odour emission database were reviewed where necessary.

All of the Odournet measurement data utilised was collected using sampling and analysis techniques compliant with the British Standard for Olfactometry BS EN 13725: 2003[1]. Further details regarding the sampling and analysis techniques applied during the studies are presented in Annex A.

Consideration was given to the influence of the following factors to derive representative and comparable emission values:

- Turbulence of aspects of the process handling odorous liquid and solid material.
- The effect of seasonal changes in the influent quality and rate of biological generation of odours within the process.
- The frequency and duration of release of intermittent activities.

2.2 Odour dispersion modelling

On the basis that odour annoyance or 'nuisance' is a symptom that develops through intermittent exposure to odours over extended time periods (see Section 2.3 below), the study focused on assessing the long-term odour exposure levels which may occur around the site under the current operational conditions[2].

The assessment was performed using mathematical atmospheric dispersion modelling techniques which provided statistical analyses of the odour exposure levels that are likely to occur in the area around the site for each individual meteorological year of a 5 No. year dataset.

Data describing the topography of the local area was obtained from Ordnance Survey. The locations of the odour sources at the facility were defined using detailed aerial imagery of the site along with observations made during the site audit.

The dispersion modelling was conducted using the US EPA AERMOD dispersion model (version 7.12.1). The model was run in accordance with guidance issued by the US EPA and guidance relevant to odour assessment published by the Environment Agency. Details of the assumptions applied within the model are presented within the main body of this report.

[1]BS EN 13725:2003, *Air quality - Determination of odour concentration by dynamic olfactometry*

[2] For the current operations model it was assumed that the recent issue of odorous biogas leakage has been resolved (Anglian Water have indicated that the flare stack is now fully operational, and that by the end of October 2017 a replacement gasholder bag will be operational).

2.3 Criteria for assessment of impact risk

In general terms, odour annoyance is recognised as a symptom that develops as a result of intermittent but regular exposure to odours that are recognisable and have an offensive character. The key factors that contribute to the development of odour annoyance can be usefully summarised by the acronym FIDOL:

- **F**requency of exposure.
- **I**ntensity or strength of exposure.
- **D**uration of exposure.
- **O**ffensiveness.
- **L**ocation sensitivity.

In acknowledgement of these factors, a number of odour impact criteria have been developed that enable the odour impact risk of facilities to be predicted using dispersion modelling techniques. These criteria are generally defined in terms of a minimum concentration of odour (reflecting the intensity/strength element of FIDOL) that occurs for a defined minimum period of time (reflecting duration and frequency element of FIDOL) over a typical meteorological year. The concentration element of these criteria can be increased or lowered to reflect variations in the offensiveness of the odours released from a specific type of facility, and the sensitivity of nearby sensitive locations.

There are currently a range of odour criteria applied in the UK to attempt to gain an insight into the probability of odour annoyance developing at a given location. However, there is no firm consensus on which odour impact criteria should be applied for sewage treatment works and the issue is currently a matter of debate.

In the UK, odour impact criteria are generally expressed in terms of a European odour unit concentration that occurs for more than 2% of the hours of a typical meteorological year, and have been designed for application to permanent residential properties which are considered to be the most sensitive from an impact risk perspective.

The most commonly applied criterion from this perspective is the 'Newbiggin criterion'. This criterion was originally introduced into a public inquiry for a new sewage works at Newbiggin-by-the-sea in 1993, and equates to an odour exposure level of 5 European odour units per cubic meter ($C_{98,\ 1\text{-hour}} > 5\ ou_E/m^3$). This 5 European odour units criterion has been successfully applied during numerous planning and odour nuisance assessment studies since 1993 for sewage, waste, food and a range of other industrial and agricultural activities.

Since 2002, a range of indicative odour annoyance criteria have also been applied to assess odour impact risk from residential properties, which have supplemented the use of the Newbiggin criterion. These criteria were introduced in the Horizontal Guidance Note for Odour Management H4 issued by the Environment Agency[3] and define three different levels of exposure at which odour impact or annoyance could potentially be expected to occur, for odours with high, moderate and low offensiveness. The indicative criteria are presented in the table below:

[3] IPPC H4 Technical Guidance Note "H4 Odour Management", published by the Environment Agency, March 2011.

Table 1: Odour impact criteria

Relative offensiveness	Indicative criterion	Typical processes
Most offensive	1.5 ou_E/m^3 98th percentile (hourly average)	Processes involving decaying animals or fish remains; septic effluent or sludge; biological landfill odours
Moderately offensive	3 ou_E/m^3 98th percentile (hourly average)	Intensive livestock rearing; sugar beet processing; fat frying (food processing); well aerated green waste composting
Less offensive	6 ou_E/m^3 98th percentile (hourly average)	Brewery; coffee roasting; confectionary; bakery

Odour guidance published by DEFRA in March 2010[4] also refers to these criteria but in less specific terms. The guidance does not state which criterion should be applied for assessing impact but does suggest that typical criteria fall within the range of $C_{98,\ 1\text{-hour}}$ = 1.5 ou_E/m^3 to $C_{98,\ 1\text{-hour}}$ = 5 ou_E/m^3.

Similarly, guidance published by the Institute of Air Quality Management (IAQM)[5] in May 2014 also refers to these criteria. This guidance does however state that odour impact may occur between $C_{98,\ 1\text{-hour}}$ = 1 ou_E/m^3 and $C_{98,\ 1\text{-hour}}$ = 10 ou_E/m^3 and that professional judgement should be applied to determine criteria on a case by case basis by considering the underlying science, sensitivity of local receptors and developing case law.

There is currently some debate as to which odour criteria currently are the most appropriate for assessing the risk of impact of odorous industries such as sewage treatment, and to what extent the criteria are able to predict occurrence of odour annoyance for different odour types. Whilst there appears to be a substantial body of evidence to support the Newbiggin-by-the-Sea impact criterion for assessing the development of odour annoyance from the sewage treatment sector, the availability of such evidence for the EA criteria is currently somewhat lacking. There is therefore a developing view within the UK odour community that the most stringent EA criteria (i.e. $C_{98,\ 1\text{-hour}}$ = 1.5 ou_E/m^3) may represent an overly precautionary standard in many cases even for highly offensive odours.

Odournet's general experience based on assessment of odours which could generally be classified as moderate to highly offensive (e.g. odours from waste water and sludge handling operations) generally supports this view, and indicates that for high sensitivity receptors such as residential premises odour annoyance is a symptom that is most likely[6] to develop at exposure levels between $C_{98,\ 1\text{-hour}}$ = 3 ou_E/m^3 and $C_{98,\ 1\text{-hour}}$ = 5 ou_E/m^3. However the occurrence of adverse impact and complaints from areas of predicted odour exposure levels below $C_{98,\ 1\text{-hour}}$ = 3 ou_E/m^3 cannot be completely ruled out.

This observation is supported to some extent by the findings of recent legal cases relating to odours from sewage treatment works (and a policy statement issued by the Chartered Institute of Water and Environmental Management) as indicated below.

- **Appeal by Sherborne School, CRUK, CLIC Sargent, Mencap and British Heart Foundation against North Dorset District Council (January 2016).** The District Council originally refused outline planning permission for the erection of homes on land in proximity to Gillingham sewage treatment works on the basis that the proposed development would have an adverse impact on the general amenity of the future occupants due to odours from the sewage treatment works.

[4] Odour Guidance for Local Authorities, published by DEFRA, March 2010.

[5] Guidance on the assessment of odour for planning, published by IAQM: April 2014.

[6] On the basis of odour exposure levels predicted by the AERMOD dispersion model using emission rates defined on the basis of site specific measurement data and taking into account local factors that will influence emissions (such as sewage turbulence in open channels/tanks, seasonal variation in emissions etc).

Odour dispersion modelling was undertaken on behalf of the appellant, and the inspector concluded that “the appropriate parameter to apply in this case is the 3 ou_E/m^3 contour line”.

- **Appeal by Abbey Homes against St Edmundsbury Borough Council (March 2012).** The Borough Council originally refused planning permission for the erection of 101 dwellings on land between Upthorne Road and Hepworth Road, Stanton, Suffolk, for reasons including the proximity of the site to an existing small rural sewage treatment works and the potential effects on the living conditions of future residents of the dwellings. On the basis of odour dispersion modelling submitted by experts acting for both parties, the inspector considered an appropriate threshold to be more than $C_{98,\ 1\text{-hour}}$ = 1.5 ou_E/m^3, and that $C_{98,\ 1\text{-hour}}$ = 3 - 5 ou_E/m^3 was a more appropriate threshold (the inspector could see no reason to expect a significant loss of amenity to the occupiers of the proposed dwellings where Anglian Water’s modelling predicted exposure levels below $C_{98,\ 1\text{-hour}}$ = 3 ou_E/m^3).

- **Appeal against Corby Borough Council (2012)**. This appeal concerned land at Ashley Road, Middleton, Leicestershire. The inspector concluded in this case “I believe that it is reasonable to take account of the 1.5 ou_E/m^3 contour map in determining odour impact. In my view areas subject to such concentrations are unlikely to provide a reasonable permanent living environment.”

- **Appeal by Lakeland Leisure Ltd. against Allerdale Borough Council, 2012.** This appeal concerned the development of dwellings in Cockermouth, Cumbria in the vicinity of a sewage treatment works. The inspector concluded that development within the area predicted to experience odour exposure levels of $C_{98,\ 1\text{-hour}}$ = 3 ou_E/m^3 or less would be appropriate due to the anticipated medium offensive nature of the odours from the sewage works.

- **Thames Water vrs Dobson 2011.** This nuisance action was brought against Thames Water Mogden Sewage Treatment Works by a group of residents claiming odour nuisance caused by this large municipal sewage works in London. The inspector concluded that he would be reluctant to find nuisance if the modelled odour concentration was only $C_{98,\ 1\text{-hour}}$ > 1.5 ou_E/m^3 but as the odour concentration rises to $C_{98,\ 1\text{-hour}}$ = 5 ou_E/m^3 he considered that this was the area where nuisance from the works would start and that by the time that $C_{98,\ 1\text{-hour}}$ > 5 ou_E/m^3 or above is reached nuisance would certainly be established.

- **Appeal by JS Bloor (Northampton) Ltd 2010.** This appeal concerned a proposed residential development on land near an existing sewage treatment works in Leighton Linslade. The inspector noted that the water company used a standard of $C_{98,\ 1\text{-hour}}$ > 5 ou_E/m^3 which they indicated would be a “concentration level above which odour might be a potential nuisance”, and stated that the approach seemed reasonable and had been accepted at a previous appeal.

- **Extract from CIWEM policy statement.** CIWEM issued a position statement on odour in 2012 stating that the following framework is the most reliable that can be defined on the basis of the limited research undertaken in the UK at the time of writing:

  - $C_{98,\ 1\text{-hour}}$ >10 ou_E/m^3 - complaints are highly likely and odour exposure at these levels represents an actionable nuisance;

  - $C_{98,\ 1\text{-hour}}$ >5 ou_E/m^3, - complaints may occur and depending on the sensitivity of the locality and nature of the odour this level may constitute a nuisance;

  - $C_{98,\ 1\text{-hour}}$ <3 ou_E/m^3, - complaints are unlikely to occur and exposure below this level is unlikely to constitute significant pollution or significant detriment to amenity unless the locality is highly sensitive or the odour highly unpleasant in nature.

It should be noted that the majority of the guidance and legal/planning cases relating to odour focus on the risk of impact at <u>residential</u> premises which are considered as high sensitivity receptors. There is much less available data regarding odour impact at potentially less sensitive non-residential receptors, and there is no clear precedent for what constitutes a suitable criterion.

As a general concept, the application of less stringent odour impact criterion may be suitable for users of less sensitive receptors (such as commercial or industrial premises). However complaints of odour are often documented from non-residential premises such as places of work so the issue is far from clear.

As there is no definitive precedent as to which criterion is suitable for either residential or non-residential premises, the criteria selected for planning purposes is open to challenge. Ultimately the decision on which criteria to apply is for the Council based on their risk appetite.

For this study, the assessment of risk of impact associated with the operations conducted at the WRC has been conducted by consideration of the $C_{98,\ 1\text{-hour}} = 3\ ou_E/m^3$ and $5\ ou_E/m^3$ criteria. The $C_{98,\ 1\text{-hour}} = 6$ and $10\ ou_E/m^3$ isopleths are also presented for reference.

3 Overview of sewage treatment operations

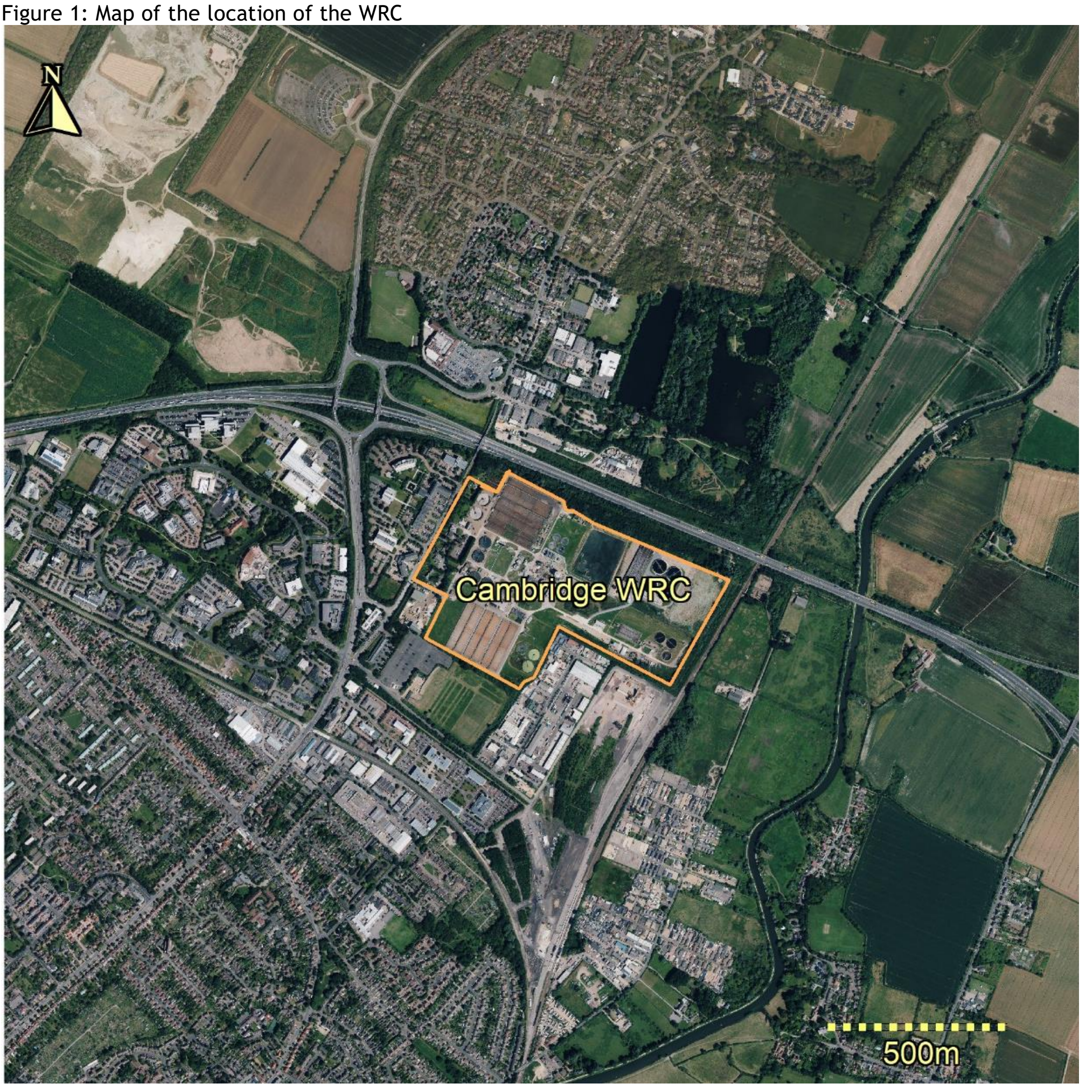
3.1 Location of works

The Water Recycling Centre is a medium to large sized sewage treatment works located on the north eastern edge of the city of Cambridge. The works serves a population equivalent of approximately 165,000, with an influent dry weather flow of 650 l/s.

In close proximity to the northern, south eastern and western boundaries of the WRC are located commercial premises. To the east and north east is located undeveloped land (agricultural land and Milton Country Park). Residential areas are located further afield to the north and south west.

The location of the site is indicated in Figure 1 below.

Figure 1: Map of the location of the WRC



In broad terms, the works has been operating in its current configuration since 2015. In 2015 Anglian Water completed a £20 million upgrade of the WRC to meet the Greater Cambridgeshire growth needs up to 2031. The key elements of the upgrade focussed on the secondary treatment operations, and involved decommissioning two percolating filter beds (known as Stream A and Stream B filters) and associated humus tanks. To replace these plant new biological treatment plant with a smaller footprint (Stream D activated sludge plant) and final settlement tanks were commissioned.

3.2 Overview of sewage treatment operations

The sewage received at the WRC is made up of primarily domestic influent (there are no notably odorous trade discharges). The majority of the influent received at the works is delivered via gravity sewer, although a small proportion of the influent is delivered via pumped rising mains. Septicity dosing is undertaken at the pumping stations of the rising mains to reduce the risk of the development of septic conditions within the sewage.

Sewage arrives at the WRC into a large open below ground chamber from where it is pumped to the head of a raised inlet works. Tankered cess and other liquid wastes delivered to the works by road are also discharged into the below ground chamber.

At the head of the raised inlet works a number of bellmouths discharge the influent into a turbulent chamber prior to it flowing through open channels to 3 No. enclosed fine screens (operated in duty-assist-standby configuration). The screens remove rag from the influent which is then washed and compacted prior to deposit in 2 No. open skips which are replaced approximately once per week.

Following screening the flows pass through an open channel into an open circular detritor where grit is removed prior to being washed and deposited into an open skip which is replaced approximately once per week.

The screened and degritted flows are then conveyed along an open channel and turbulent mixing section. Works returns primarily consisting of liquors from the sludge treatment centre (liquors from the raw sludge gravity belt thickeners and centrate from the digested sludge centrifuges) and any road drainage are returned into an open chamber downstream of the detritor prior to combining with the influent in the open channel. Ferric sulphate is dosed into this channel.

Storm flows received at the works (those above 3x dry weather flow) are removed via storm weirs located downstream of the screens and diverted into 2 No. open circular storm tanks via enclosed pipework. Once the incoming flow rate into the works subsides the storm water within the tanks is returned to the works for treatment. The storm tanks are fitted with scrapers which are designed to prevent the accumulation of potentially odorous sediment on the base of the tanks after emptying. In extreme rainfall events the storm tanks fill and overspill (via enclosed pipework) into a large (approximately 100m x 140m) storm lagoon which is designed to store storm effluent which then soaks into the ground. Once the effluent has soaked away a residual sediment layer is left on the base of the lagoon which (according to site operators) typically results in a notable odour in the immediate area for between 10 and 14 days. Site operators believe that the lagoon is typically filled once per year on average.

Flows from the inlet works are conveyed via 2 No. open turbulent distribution chambers into 5 No. circular primary settlement tanks (PSTs) for solids settlement and removal. Each tank is fitted with automatic sludge scrapers and scum removal plant. Site operators state that between four and five of the tanks are routinely in use, dependent on the magnitude of flows received at the works.

Following primary treatment, the settled sewage is conveyed via an open distribution chamber into one of 2 No. secondary treatment streams. Stream D is an activated sludge process which includes a highly turbulent distribution/mixing chamber at the head of the works where settled sewage and return activated sludge (RAS) are mixed. The mixed liquors are conveyed to one of 4 No. lanes each comprising an anoxic and an aerobic section. A turbulent outlet channel collects the treated sewage from all 4 No. lanes and conveys it to 4 No. circular final treatment tanks (FSTs) for final clarification.

Stream C receives settled sewage from the PSTs which is mixed with RAS in a turbulent open chamber and then diverted into 4 No. lanes, each comprising anoxic and aerobic stages. Final clarification is provided by 3 No. open circular final settlement tanks.

Final tertiary treatment of all flows is provided by sand filters.

3.3 Overview of sludge treatment operations

Indigenous raw sludge from the primary settlement tanks is pumped via enclosed pipework into a circular covered sludge buffer tank, the air from which is extracted for treatment in an odour control unit.

Imported raw sludge is delivered to the site by road tanker and passed through a strainpress (to remove rag and other materials which are deposited into an open skip) into an enclosed imported sludge holding tank. This tank is served by an odour control unit. Imported sludge from this tank is conveyed into the sludge buffer tank where it is mixed with the indigenous raw sludge.

Mixed raw sludge from the sludge buffer tank is thickened in 2 No. gravity belt thickeners located on the ground floor of a sludge thickening building. The belts are locally enclosed and the captured odours are vented to atmosphere via 2 No. dispersion stacks. The liquors from the belts are discharged into an open sump prior to return the head of the works as described above.

Surplus activated sludge (SAS) from the Stream D activated sludge plant is stored in an open above ground SAS holding tank prior to thickening within 1 of 2 No. aquabelts (only one belt can run at any time and each is locally enclosed and vented to atmosphere via short dispersion stack) located in a SAS thickening building. Liquors from the belts are diverted into the distribution chamber at the head of the D stream secondary treatment plant.

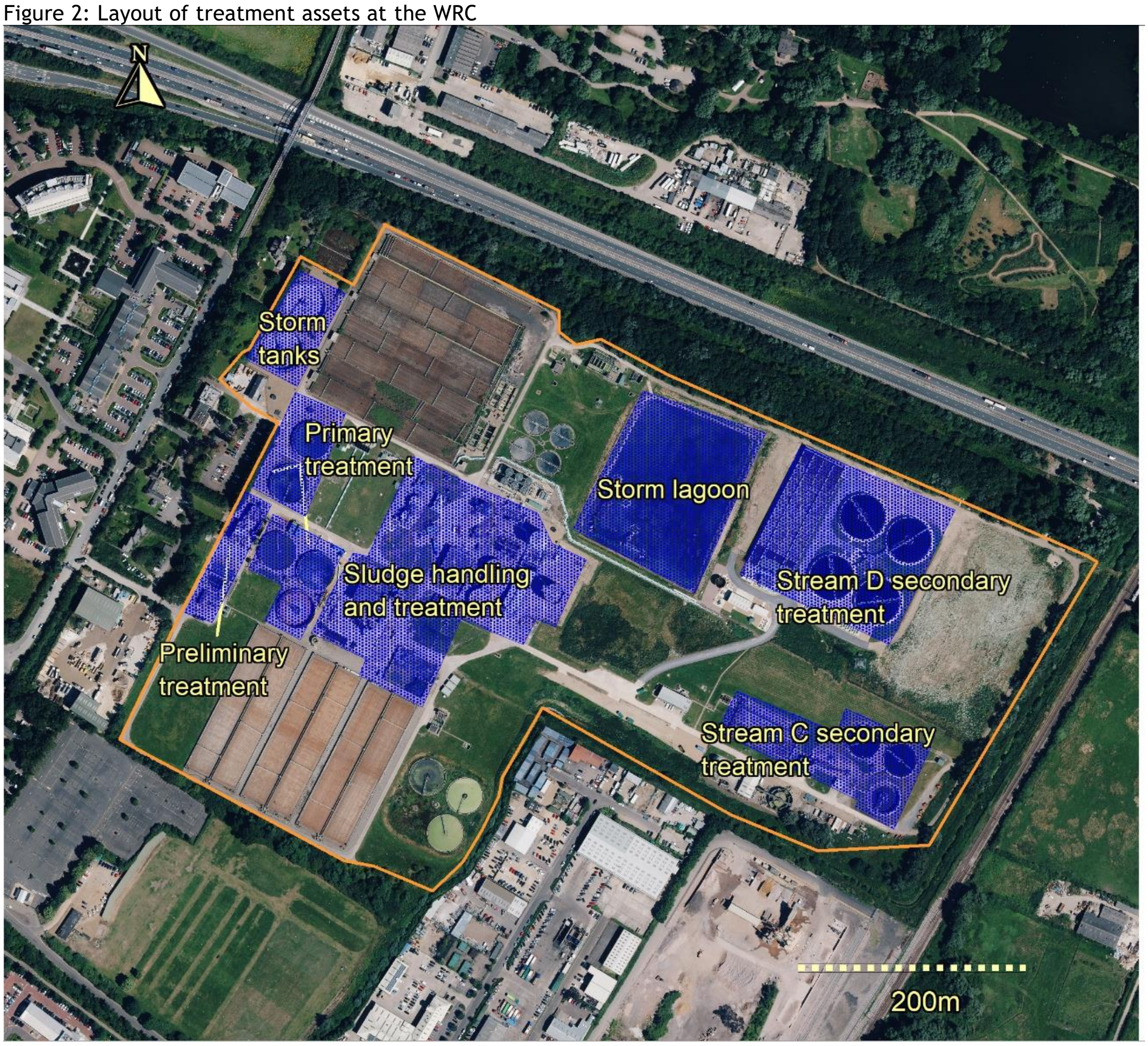
Imported SAS and indigenous SAS from the Stream C secondary treatment plant is stored in a circular covered SAS buffer tank which is served by an odour control unit. The SAS is thickened in a SAS drum thickener prior to delivery into a circular covered above ground sludge blend tank where it is mixed with the thickened SAS from the D stream secondary treatment plant and the thickened raw sludge. The air from the sludge blend tank is extracted for treatment in the same odour control unit as the SAS buffer tank.

Mixed thickened sludge from the sludge blend tank is processed in the enclosed Monsal plant and then digested in enclosed primary anaerobic digesters with associated gas capture and combustion plant. At the time of the site audit there were a number of operational issues with the normal gas collection system and gas flare and some degree of gas leakage was occurring from the primary digester Whessoe valves. Anglian Water have indicated that these issues are being resolved and the routine release of unburnt biogas will not be anticipated from the site over the long term. Following digestion the sludge is transferred to one of 2 No. open secondary digestion tanks, sections of which are aerated in specific locations to avoid the accumulation of grit and silt, resulting in turbulence in these areas. The second tank is not in use, but contains a quantity of digested sludge. Anglian Water have indicated that the second tank will be cleaned in September 2017 and brought back into operation at some future stage.

Sludge from the secondary digestion tank is transferred via enclosed pipework to a number of centrifuges located in the upper level of the sludge thickening building. Centrate is discharged into the same sump as the GBT liquors. The trailers are typically removed after several days of storage, and in summer four or five trailers are typically stored onsite, and in winter this can increase up to nine. In addition, an emergency bund typically contains a quantity of cake that hasn't been deposited in a trailer.

The layout of the treatment assets at the WRC is shown in Figure 2.

Figure 2: Layout of treatment assets at the WRC



3.4 Overview of complaints

Complaints data provided by Cambridge City Council indicates that between 2005 and 2014 18 No. complaints of odour relating the WRC were received by the Council, from both residential and commercial premises. From completion of the upgrade in 2015 to the present (September 2017), 5 No. complaints of odour have been received. Detailed information regarding the nature of each complaint is not available. For three of the complaints the postcode is provided and these appear to have been received from residential locations. These locations have been plotted on the map below.

Figure 3: Location of odour complaints (2015-present)

4 Identification of odour sources

4.1 Overview of the mechanisms for odour generation from sewage treatment operations.

The generation of odour from the processing of sewage is primarily associated with the release of odorous Volatile Organic Compounds (VOCs) that are generated as a result of the anaerobic breakdown of organic matter by micro-organisms. Anaerobic breakdown starts within the human bowel and may continue within the sewerage network and treatment works if conditions (i.e. a lack of oxygen) allow.

The key objectives of the sewage treatment process are to remove solid organic matter which is responsible for the generation of the majority of sewage odours and to provide treatment to remove any residual contaminants from the wastewater so that it can be returned back into the environment.

Since the main source of odour and VOCs is the solid organic matter, the most intense and offensive odours tend to be generated from the operations involving the handling of sludge i.e. the processes applied to dewater and store raw sludge. These processes are generally considered to present the greatest risk of odour impact offsite, unless adequate controls are put in place. Depending upon the quality of the sewage presented to the works, the aspects of the treatment process involved in the handling of raw sewage (e.g. preliminary and primary treatment stages) may also generate substantial levels of offensive odours.

Odours generated from the sewage treatment processes downstream of the primary sludge removal stage (e.g. the activated sludge processes and final settlement) present a significantly reduced risk of odour impact. This is due to the fact that the majority of odorous biogenic material has been removed from the flow at this point, and the treatment processes applied to remove any remaining contaminants in the sewage are aerobic which inhibits the formation of the majority of the reduced sulphur compounds which are responsible for offensive sewage odours.

The rate of odour release from sewage and sludge sources is influenced by the temperature of the material and the surface area exposed to the atmosphere. As a result, odorous emissions from sewage treatment operations tend to be highest during the summer months. Furthermore, activities that lead to increase in the surface area of odorous material exposed to the atmosphere (e.g. due to turbulence generated by sewage handling processes and agitation of sludge) will inevitably lead to an increase in the magnitude of odour released.

4.2 Identification of sources of odour emission

A range of odour sources were identified at the WRC. These sources are summarised below.

Table 2: Identification of odour sources for the WRC

Stage of treatment	Source	Nature of odorous material/level of enclosure	Frequency and duration of release
Preliminary Treatment	Inlet works chambers, detritor and channels	Raw sewage / open	Continuous
	Screenings plant and skips	Screenings / enclosed and open	Continuous
	Grit skips and dewatering plant	Grit storage / open	Continuous
	Works return channel	Works returns (dewatering liquors, site drainage)	Continuous
Storm water	Storm weirs and tanks	Raw sewage (storm water) / open	Intermittent (1 day per month in summer, 2 days per month winter)

	Storm lagoon	Raw sewage (storm water) and sediment / open	Intermittent (very infrequent, typically 1 to 2 weeks per year)
Primary Treatment	Distribution chambers	Raw sewage / open	Continuous
	Primary settlement tanks	Raw sewage / open	Continuous
	Settled sewage distribution chambers	Raw sewage / open	Continuous
Secondary Treatment	Distribution/mixing chambers	Settled sewage and return activated sludge / open	Continuous
	Activated sludge plant - anoxic and aerobic sections	Mixed liquors / open	Continuous
Sludge treatment and handling	Sludge buffer tank OCU	Treated odours - stack emissions	Continuous
	Imported sludge strain press skip	Sludge screenings / open skip	Continuous
	Imported sludge tank OCU	Treated odours - stack emissions	Continuous
	Raw sludge gravity belt thickeners	Enclosed thickeners with vented emissions	Continuous
	Raw sludge thickening building	Fugitive emissions from building	Continuous
	Sludge liquors sump	Raw & digested sludge liquors / open chamber	Continuous
	SAS thickening building	Enclosed belts with vented emissions	Intermittent (10 hours per day)
	SAS holding tank	SAS / open tank	Continuous
	SAS buffer & sludge blend tank OCU	Treated odours - stack emissions	Continuous
	Secondary digestion tanks	Digested sludge / open tanks	Continuous
	Sludge cake	Digested sludge cake / open bay and trailers	Continuous

5 Odour survey results

5.1 Olfactometry and hydrogen sulphide measurement results

The results of Odournet's 2017 odour survey are summarised in the tables below and presented in full in Annex B, along with a record of the operational conditions at the works at the time of sampling.

Table 3: Olfactometry and H_2S measurements from open sources

Source	Date of Sampling	Geomean emission rate [$ou_E/m^2/s$]	H_2S emission rate [$ug/m^2/s$]
Detritor (morning)	22.08.2017	22.2	5.664
Detritor (afternoon)	24.08.2017	23.4	1.680
Works return chamber	22.08.2017	26.8	1.338
PST #1	22.08.2017	3.9	0.654
PST #5	23.08.2017	1.1	0.134
Settled sewage chamber	23.08.2017	8.0	0.539
Stream D Anoxic zone	23.08.2017	22.4	0.414
Stream D Aerobic zone	23.08.2017	0.2*	<LLOD
Stream C Anoxic zone	23.08.2017	0.5	<LLOD
Stream C Aerobic zone	23.08.2017	0.2*	<LLOD
Secondary digestion tank (in use)	24.08.2017	5.7	3.342
Secondary digester (disused)	24.08.2017	0.6	5.739
Fresh sludge cake	24.08.2017	5.7	4.475
Digested sludge centrate sump	24.08.2017	2.4	0.677

*Estimated result as some sample results fell below the lower limit of detection of the analysis technique

Table 4: Olfactometry and H_2S measurements from volume sources

Source	Date of sampling	Geomean odour concentration [ou_E/m^3]	H_2S conc. [ppm]	Flow rate (m^2/s)	Odour emission rate (ou_E/s)
SAS buffer & sludge blend tank OCU	22.08.2017	31	<LLOD	0.03	1
Raw sludge thickening building	22.08.2017	231	<LLOD	n/a	n/a
Imported raw sludge holding tank OCU outlet	24.08.2017	2831	<LLOD	0.02	50
Raw sludge gravity belt outlet stack	22.08.2017	47557	10.7	0.36	19023

The raw sludge buffer tank OCU was not operating at the time of the 2017 odour survey. Anglian Water have indicated that the performance of this unit is likely to be broadly comparable to the performance of the OCU which serves the sludge blend and SAS buffer tanks.

5.2 Hedonic tone analysis results

Table 5: Hedonic tone analysis results

Source	Date of sampling	Concentration at which odours were perceived as 'mildly offensive' [ou_E/m_3]
Detritor	22.08.2017	2.1
Stream D anoxic zone*	23.08.2017	1.8

Imported raw sludge holding tank OCU outlet	24.08.2017	2.0
Secondary digestion tank	24.08.2017	2.1

*due to the low concentration of the sample collected from the stream D aerobic zone, hedonic tone analysis could not be undertaken.

5.3 Discussion

Review of the odour measurement results presented above prompts the following observations:

- The odour emission rates measured from the influent in the detritor at the WRC are indicative of a moderately odorous influent. The comparability of the measured emission rates from the morning of the first day of sampling and the afternoon of the third day indicate a relatively consistent influent emission rate. The hydrogen sulphide emission rates do not indicate a substantial problem of septicity within the sewage received at the works at the time of sampling.
- The measurements of the odour emission rate from the works return chamber confirm that the material which is returned to the works for treatment is also moderately odorous.
- In comparison the emission rates of odour and hydrogen sulphide from the primary settlement tanks (PSTs) are low and are indicative of well operated tanks. The maintenance of the sludge blankets in the tanks at minimal levels is likely to result in the minimisation of odour generation within the tanks.
- The odour emission rates measured from the secondary treatment plant (filter beds, humus tanks and activated sludge plant) were all low and indicative of a well treated sewage, with the exception of the D stream anoxic zone. The measured emission rate at this location is higher than would typically be expected, and the reason for this is unknown.
- Review of the emission rates from the secondary digestion tanks indicates that the retained digested sludge within the disused tank is not a particularly odorous material. The sludge within the tank that is in use is more odorous, and measurements of the ammonia concentration of the collected samples indicates that this is likely to be a key component of the odours released. The same is the case for the sludge cake.
- At the time of sampling the sludge liquors sump was unlikely to have contained liquors due to the temporary suspension of the use of the thickening plant. On this basis the emission rate measured from this location is unlikely to be representative of the long term emissions.
- The odour concentration of the treated air from the SAS buffer & sludge blend tank OCU is very low, and indicates that the unit is likely to be providing a high level of treatment.
- The odour concentration of the treated air from the imported raw sludge holding tank OCU is substantially higher and indicates that the unit is unlikely to be performing as well. However due to the low flow rate of air through this OCU the resulting odour emission is small. The untreated air extracted from the raw sludge gravity belt thickeners is extremely odorous.
- Review of the results of the hedonic tone analysis indicates that the odour panel found the offensiveness of the odours from the various areas of the works to be broadly comparable.

6 Estimation of odour emissions

6.1 Assumptions applied to estimate odour emissions

The assumptions applied to estimate odour emissions from the works for the current operational conditions are presented below. This reflects the current operational conditions at the works, but assuming that the biogas leakage has been resolved and both of the secondary sludge digestion tanks are brought into use (indicated by Anglian Water to be the long term plan).

- The odour emission rates for open odour sources for summer conditions were calculated by multiplying the plan area of the treatment process by the area odour emission rates defined in the table below.

Table 6: Estimated summer odour emission rates applied for current operational conditions

Stage of treatment	Source	Estimated odour emission rate ($ou_E/m^2/s$)	Turbulence factor	Note
Preliminary Treatment	Inlet works chamber, screens detritor and channels	23	1 - 6	Measured
	Screenings skips	35	1	Estimated (reference data)
	Grit skips and dewatering plant	25	1	Estimated (reference data)
	Works return channel	27	1	Measured
Storm water	Storm weirs and tanks	8	1-6	Measured influent emission rate divided by 3 (3xDWF)
Primary Treatment	Distribution chambers	23	1-3	Measured (influent)
	Primary settlement tanks	2.1	1-3 (weirs)	Measured
	Settled sewage distribution chamber	8	1-6	Measured
Secondary Treatment	Distribution/mixing chambers	5	1-20	Estimated based on SS distribution measurement and estimate of RAS
	Stream D anoxic zone	22	1	Measured
	Stream D aerobic zone	0.2	1	Measured
	Stream C anoxic zone	0.5	1	Measured
	Stream C aerobic zone	0.2	1	Measured
	Outlet channels	0.2	1-20	Estimated based on aerobic zone measurements
Sludge treatment and handling	Imported sludge strain press skip	50	1	Estimated (reference data)
	Sludge liquors sump	350	3	Estimated (reference data)
	SAS holding tank	4	1	Estimated (reference data)
	Secondary digestion tank	6	1-6	Measured
	Sludge cake	6	1	Measured

- The emission rate of odour from all aspects of the works involved in handling raw liquid sewage (e.g. the preliminary and primary treatment) were reduced by a factor of 5 during autumn/winter to reflect the reduction in emissions due to lower sewage/ambient temperature and dilution effects of rainwater. Emissions from aspects of the operations including the secondary treatment stage, sludge handling, screenings handling and storage were assumed to remain relatively constant during summer and winter conditions.

- For turbulent sources, a multiplier was applied to the emission rate to reflect the elevation in emissions that occurs due to the increase in surface area exposed to the atmosphere. The following turbulence factors were used which are based on Odournet's broader experience in the wastewater sector and the findings of research:

Table 7: Turbulence factors

Level of turbulence	Turbulence multiplier
Low	3
Medium	6
High	12
Extreme	20

- The emission rates applied for volume and point sources were also based on the results of Odournet's 2017 measurement survey, and where relevant, reference data obtained by Odournet from comparable sources at UK sewage treatment works using accredited odour sampling and analysis techniques. For the raw sludge buffer tank OCU, the flow rates and odour emission rate were estimated based on the results of the testing of the SAS buffer and sludge blend tank OCU.

Table 8: Estimated emission rates for point and volume sources

Stage of treatment	Source	Estimated flow rate (m^3/s)	Estimated odour emission rate (ou_E/s)	Note
Sludge treatment and handling	Raw sludge buffer tank OCU	0.03	1	Assumed to be the same as SAS buffer & sludge blend tank OCU
	Imported sludge OCU	0.02	50	Measured
	SAS buffer & sludge blend tank OCU	0.03	1	Measured
	SAS thickening belt vent	0.4	250	Estimated (reference data)
	Raw sludge thickening building	0.625	144	Estimate based on measured odour concentration and estimated 3 building air changes per hour
	Raw sludge gravity belt thickener vents	0.4	19023	Measured

- It is assumed that at any given time three of the bellmouths at the head of the elevated inlet works are discharging.
- It is assumed that 2 No. screenings skips, 1 No. grit skip and 1 No. sludge strainpress skip are in use.
- It is assumed that the 2 No. circular storm tanks are in use for 2 No. days per month in winter and 1 No. day per month in summer. The emission rate from the storm water has been estimated as a third of the influent emission rate, to account for the fact the storm flows are directed to the tanks at 3x dry weather flow. It is assumed that the cleaning systems within the tanks are effective and that no odorous sediment is retained in the tanks after emptying.
- It is assumed that 4 No. PSTs are in use during summer, and 5 No. PSTs are in use in winter.
- It is assumed that one of the raw sludge gravity belt thickeners is in operation 24 hours per day.
- It is assumed that one of the SAS belts is in operation for 10 No. hours per day.

- It is assumed that both of the secondary digestion tanks are in use, and that each is fitted with an aeration system which constantly aerates approximately 10% of the surface.
- It is assumed that 5 No. sludge cake trailers were in place in summer, and 9 No. trailers were present in winter.
- Emissions from the filling of the storm lagoon (which typically only happens once per year) were not included in the model.

6.2 Breakdown of estimated emissions

A breakdown of the summer odour emissions generated from each aspect of the sewage treatment process is presented in Table 9 below. The emission rates presented in the table have been adjusted to reflect the frequency of occurrence of each odour source and are 'time-weighted'.

Table 9: Summer time weighted emissions from each aspect of the treatment process

Stage of treatment	Source	Odour emission rate [ou_E/s]	% of total emissions
Preliminary treatment	Inlet works screens, detritor & channels	13283	18.2%
	Screenings skips	315	0.4%
	Grit skips and dewatering plant	190	0.3%
	Works return channel	398	0.5%
Storm water	Storm weirs and tanks	557	0.8%
Primary treatment	Distribution chambers	2235	3.1%
	Primary settlement tanks	7271	10.0%
	Settled sewage	1744	2.4%
Secondary treatment	Distribution/mixing chambers	1435	2.0%
	Activated sludge plant - anoxic zones	13705	18.8%
	Activated sludge plant - aerobic zones	1264	1.7%
Sludge treatment and handling	Sludge buffer tank OCU	1	0.0%
	Imported sludge strain press skip	225	0.3%
	Imported sludge tank OCU	50	0.1%
	Raw sludge gravity belt thickener vent	19023	26.1%
	Raw sludge thickening building	144	0.2%
	Sludge liquors sump	350	0.5%
	SAS thickening vent	104	0.1%
	SAS holding tank	278	0.4%
	SAS buffer & sludge blend tank OCU	1	0.0%
	Secondary digestion tanks	9855	13.5%
	Sludge cake	416	0.6%
TOTAL		72843	100

Based on a review of the above table, the total time weighted summer odour emission from the works is approximately 73,000 ou_E/s. Of these emissions approximately 20% are generated by the preliminary treatment stage, 1% from storm water handling, 15% by the primary treatment stage, 22% by the secondary treatment stage and 42% from the sludge handling and treatment operations.

Within the preliminary treatment area, the handling and treatment of odorous raw sewage results in this area contributing approximately one fifth of the total emissions from the WRC.

Storm water handling emissions account for a very small percentage of site emissions due to fact that the storm tanks are used relatively infrequently, and also due to the cleaning systems which prevent the retention of sediment in the base of the tanks after emptying.

For the primary treatment stage, the majority of emissions (10%) are released from the surface of the primary settlement tanks which have a relatively large surface area.

For the secondary treatment stage, the elevated odour emission rate measured from the anoxic zones of the D stream activated sludge plant means that they account for almost 19% of the total emissions from the WRC as a whole. Despite the large surface area of the aerobic stages of the secondary treatment plant, the low odour emission rate from the partially treated sewage means that emissions from this area only account for approximately 1% of overall emissions.

The high contribution of the sludge treatment and handling operations is due primarily to two key odour sources; the vent which emits odours from the raw sludge gravity belt thickener and the open secondary digestion tanks. The large contribution of the raw sludge belt thickener (26% of total emissions) is due to the very high odour concentration of the air extracted and vented to atmosphere untreated. For the secondary digestion tanks the 14% contribution to total emissions results primarily from the large surface area of the tanks and the areas of turbulence caused by the aeration mixing.

7 Odour impact assessment

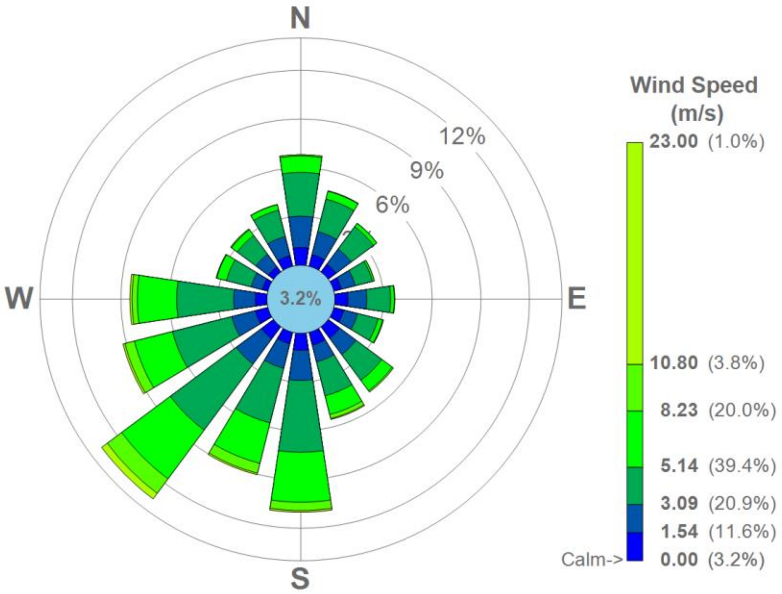
7.1 Dispersion modelling assumptions

The assumptions applied for the dispersion model were as follows:

- The meteorological data used by the model to simulate the dispersion and dilution effects generated by the atmosphere has been selected with reference to the AERMOD Implementation Guide[7], which advises that the most representative meteorological dataset should be utilised (this will be influenced by both proximity to the study site and the representativeness of the surface characteristics of the meteorological station in comparison to the study site).

- Sequential hourly average meteorological data was obtained from the recording station located at Cambridge Airport for the years 2012 to 2016, with missing data imported from RAF Mildenhall. Cambridge Airport is located approximately 3km to the south of the WRC and is located in an area of broadly comparable landuse (semi rural/urban area located on the eastern edge of the city of Cambridge). The meteorological data was adjusted to reflect the surface characteristics of the study site in accordance with the guidelines in the AERMOD Implementation Guide. The windrose for the meteorological data utilised in the study is presented below.

Figure 4: Windrose for Cambridge Airport (with missing data imported from RAF Mildenhall) for 2012 to 2016



- Data describing the topography of the area surrounding the works was obtained from Ordnance Survey in Landform Panorama™ format.

- The model was run assuming rural dispersion characteristics, as defined in the AERMOD implementation guide

- Buildings and structures in the vicinity of the odour control units were included in the model.

- A 2.7km by 3.2 km uniform Cartesian receptor grid was defined for the study area. The model was run using a receptor point spacing of 100 m for all years. The model for the 'worst case'

[7] AERMOD Implementation Guide, Published by the US EPA, Revised August 2015

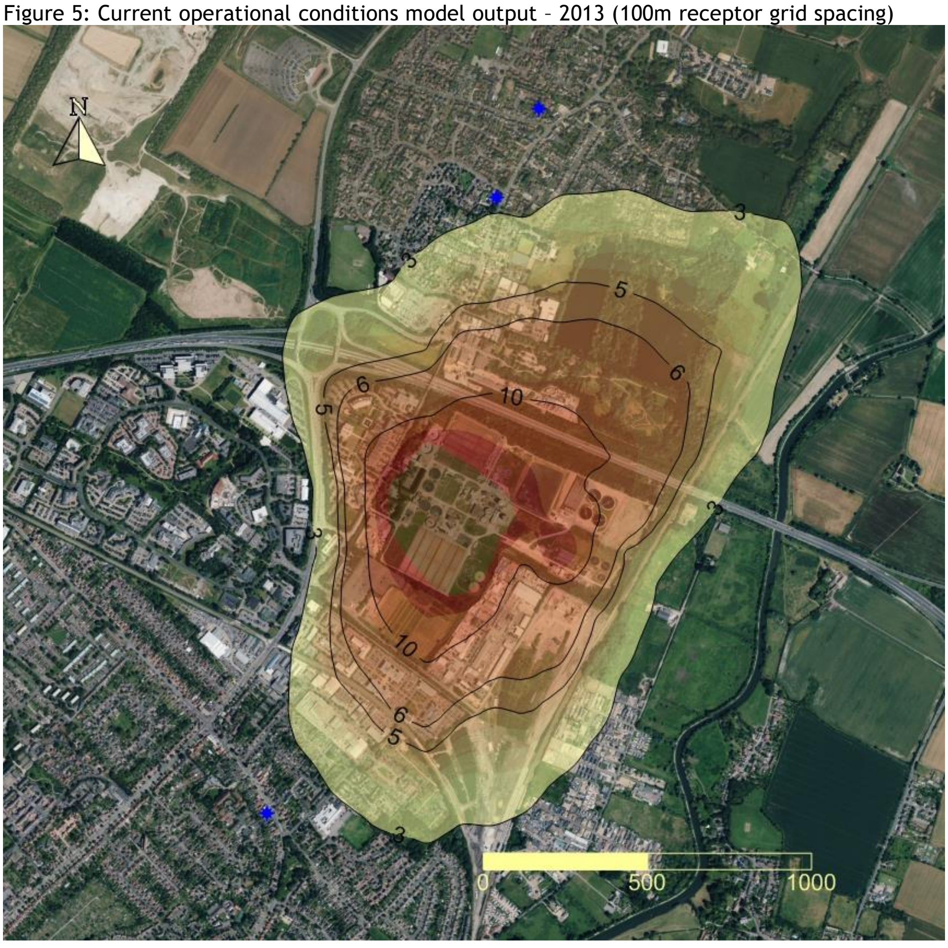
year was also rerun using a spacing of 40 m, and this is presented in Annex C. Receptor heights of 1.5m were assumed.

- The model only considers normal operational occurrences. Short term events such as plant breakdown, maintenance and repair could potentially impact considerably on the odorous emissions from time to time. Such short term variations have not been considered within the model.
- The model reflects the current operational conditions, with the exception that the both secondary digestion tanks are assumed to be in use and the issues with gas collection are assumed to have been addressed. From discussions with Anglian Water it is understood that there are currently no other planned changes to the works operations that are likely to substantially change odour emissions and that this reflects the likely foreseeable long term operation of the WRC.

7.2 Dispersion modelling results

Current practice for odour assessment for planning is for the model to be run using five individual meteorological years, and for the assessment conclusions to be based on the results of the worst case year. In this case the worst case year is likely to be 2013, although this is dependent on which specific offsite location is being assessed. The model output for 2013 (100 m receptor grid spacing) is presented in Figure 5 below. The model outputs for all years modelled (including the 2013 model output with a 40 m receptor grid spacing) are presented in Annex C so that the variation in predicted odour exposure levels can be understood. The figures present isopleths defining the area where predicted odour exposure levels will exceed $C_{98,\ 1\text{-hour}}$ = 3, 5, 6 and 10 ou_E/m^3.

Figure 5: Current operational conditions model output – 2013 (100m receptor grid spacing)



7.3 Discussion of model output:

Review of the model output presented above indicates that under the likely foreseeable long term operations at the WRC, predicted odour exposure levels in the area immediately surrounding the works exceed the $C_{98,\ 1\text{-hour}}$ = 3, 5 and 6 ou_E/m^3 criteria discussed in section 2.3. On this basis any residential developments in these areas are likely to be at risk of odour impact. For any commercial or industrial developments in these areas, the degree to which odour impact is likely to occur is less clear for the reasons discussed in section 2.3.

Clearly if the operations at the works vary substantially going forwards in comparison to those assumed for the model then the risk of odour impact will vary.

Review of the model output indicates that the predicted exposure levels at the 3 No. residential locations from which odour complaints were received range fall below the $C_{98,\ 1\text{-hour}}$ = 3 ou_E/m^3 exposure level. However the absence of detailed complaint information means that it is unclear whether these complaints resulted from 'normal' odour emissions from the works or abnormal emissions, such as those associated with the gas collection system problems. Overall the value of the complaint data in assessing the forseeable level of odour impact risk is limited.

It should be noted when reviewing the model output that the odour emissions associated with the use of the storm overflow lagoon are not included within the model. As described in section 3.2 the lagoon is typically only used approximately once per year with the resulting sediment causing a notable odour in the immediate area for between 10 and 14 days. On this basis it is considered likely that any receptors located in close proximity to the lagoon would experience elevated odours and increased risk of annoyance during these times. This could be confirmed by undertaking sniff testing in the area at a time when the lagoon contains odorous material.

8 Summary of findings

The key findings of the study are summarised as follows:

1. The odour survey identified a range of odour sources at the WRC under the current operational conditions. These sources include the raw sewage reception and screenings/grit removal plant, the stormwater storage tanks, the primary settlement tanks, the anoxic and aerobic secondary treatment plant, and the sludge handling and storage operations.
2. The estimated time weighted summer odour emissions from the WRC are approximately 73,000 ou_E/s. Of these emissions approximately 20% are generated by the preliminary treatment stage, 1% from storm water handling, 15% by the primary treatment stage, 22% by the secondary treatment stage and 42% from the sludge handling and treatment operations.
3. The largest individual contributors to the total site emissions are the emissions from the raw sludge belt thickening plant, the secondary sludge digestion tanks, the D stream anoxic plant and the primary settlement tanks.
4. The results of dispersion modelling which was undertaken to assess the level of odour impact risk under the foreseeable long term operational conditions at the works (current operations plus both secondary digestion tanks assumed to be in use and gas collection issues addressed) indicate that odour exposure levels in the area immediately surrounding the works exceed the $C_{98,\ 1\text{-hour}}$ = 3, 5 and 6 ou_E/m^3 odour impact criteria discussed in section 2.3 of this report. On this basis any residential developments in these areas are likely to be at risk of odour impact. For any commercial or industrial developments in these areas, the degree to which odour impact is likely to occur is less clear for the reasons discussed within this report.
5. The likely increase in exposure to odours that would be experienced periodically in the vicinity of the storm overflow lagoon should be considered if the suitability of this land for development is to be reviewed.

Annex A Odour sampling and analysis techniques

A.1 Collection of odour samples from sources with no measurable flow

Collection of samples from area sources where there is no measurable flow such as open liquid tanks or channels and piles of sludge cake was conducted using a ventilated canopy known as a 'Lindvall hood'. The canopy was placed on the odorous material and ventilated at a known rate with clean odourless air. A sample of odour was collected from the outlet port of the hood using the 'Lung' principle as described above.

The rate of air blown into the hood was monitored for each sample and used to calculate a specific odour emission rate per unit area per second (E_{sp}) as follows:

$$E_{sp}\ (ou_E/m^2/s) = C_{hood} \times L \times V$$

Where:

C_{hood} is the concentration result from the laboratory analysis.

V is the flow presented to the hood.

L is the $\dfrac{\text{flow path cross section of the hood } (m^2)}{\text{Covered area } (m^2)}$

A.2 Collection of odour samples from odour control plant and buildings

Collection of samples from vents and odour control plant stacks vents were conducted using the 'Lung' principle. A 60 l Nalophan sample bag was placed in a rigid container and connected to the sample location using a PTFE sample line. Air was withdrawn from this container using a pump which caused a sample of the odorous air to be drawn through the line into the bag.

If necessary, samples were pre-diluted with nitrogen at the point of collection to prevent condensation from forming in the sampling lines and odour bag, which may influence the odour concentration prior to analysis.

For samples undertaken from vents or odour control plant stacks, the temperature and velocity of the airflow at each point was also determined using suitable monitoring techniques.

The emission rate of odour was then calculated by multiplying the measured odour concentration by the volume flow rate (m^3/s) as measured in the duct.

For samples collected from within buildings, the lung principle was applied to collect the sample, and the volume escape rate of building air estimated to enable an estimation of the emission rate of odour from the building to be made.

A.3 Measurement of odour concentration using olfactometry

Odour measurement is aimed at characterising environmental odours, relevant to human beings. As no methods exist at present that simulates and predict the responses of our sense of smell satisfactorily, the human nose is the most suitable 'sensor'. Objective methods have been developed to establish odour concentration, using human assessors. A British standard applies to odour concentration measurement:

- BSEN 13725:2003, *Air quality - Determination of odour concentration by dynamic olfactometry*.

The odour concentration of a gaseous sample of odorants is determined by presenting a panel of selected and screened human subjects with that sample, in varying dilutions with neutral gas, in order to determine the dilution factor at the 50% detection threshold (D_{50}). The odour concentration of the examined sample is then expressed as multiples of one European Odour Unit per cubic meter [ou_E/m^3] at standard conditions.

Annex B Odour and H_2S measurement results

B.1 Odour and H_2S measurement results from 2017 survey

Table 10 Odour emission measurements for open sources

Source	Date of Sampling	Area odour emission rate [$ou_E/m^2/s$]			
		Geomean	Sample 1	Sample 2	Sample 3
Detritor (morning)	22.08.2017	22.2	36.4	13.4	22.3
Detritor (afternoon)	24.08.2017	23.4	23.2	23.5	23.4
Works return chamber	22.08.2017	26.8	20.0	36.7	26.2
PST #1	22.08.2017	3.9	3.3	4.0	4.6
PST #5	23.08.2017	1.1	1.2	1.2	0.9
Stream D Anoxic zone	23.08.2017	22.4	22.2	20.4	24.9
Stream D Aerobic zone	23.08.2017	0.2*	0.2*	0.2*	0.2*
Stream C Anoxic zone	23.08.2017	0.5	0.5	0.6	0.4
Stream C Aerobic zone	23.08.2017	0.2*	0.3	0.2*	0.2*
Settled sewage chamber	23.08.2017	8.0	6.6	6.5	11.8
Secondary digestion tank (in use)	24.08.2017	5.7	12.1	4.9	3.1
Secondary digester (disused)	24.08.2017	0.6	0.9	0.6	0.4
Fresh sludge cake	24.08.2017	5.7	5.1	5.9	6.0
Digested sludge centrate sump	24.08.2017	2.4	1.6	3.6	2.2

*Result is estimated as actual result fell below the Lower limit of detection of the analysis technique

Table 11 Odour concentration measurements for volume sources

Source	Date of sampling	Odour concentration [ou_E/m^3]			
		Geomean	Sample 1	Sample 2	Sample 3
SAS buffer & sludge blend tank OCU	22.08.2017	31	32	30	32
Raw sludge thickening building	22.08.2017	231	277	216	206
Imported raw sludge holding tank OCU outlet	24.08.2017	2831	4012	2779	2036
Gravity belts outlet stack	22.08.2017	47557	48699	45353	48699

B.2 Operational conditions at the time of the odour survey

Date	Incoming flow rate to works (m^3/day)	PST dip levels	GBTs in operation1	Centrifuges in operation	Rainfall in 3 days prior to survey (mm)
22.08.2017	53049	#1: 3.0m water (<1m sludge)	1 of 2	1	0
23.08.2017	51016	#5: 3.2m water (<0.8m sludge)	1 of 2	1	0
24.08.2017	49943	NA	0 of 2	1	0

Annex C Dispersion model outputs

Figure 6: Current operational conditions model output – 2012 Met data (100m receptor grid spacing)

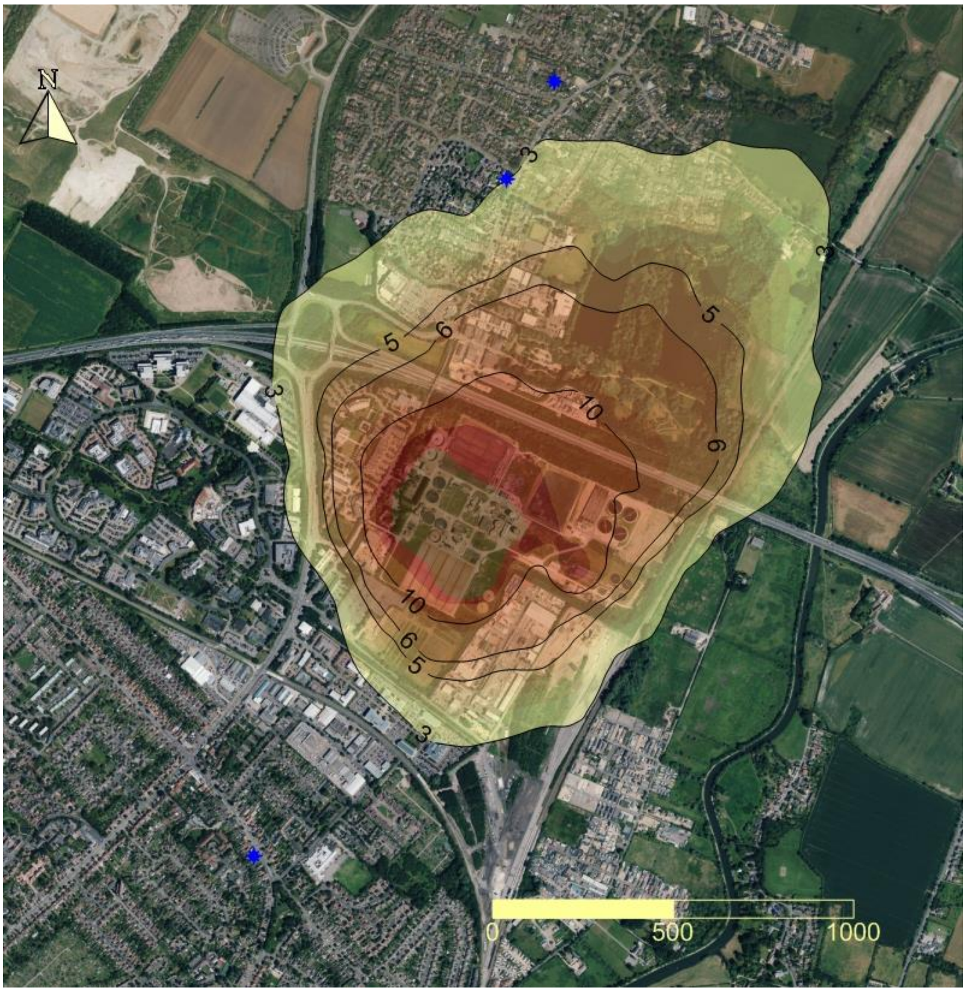


Figure 7: Current operational conditions model output – 2013 Met data (40m receptor grid spacing)

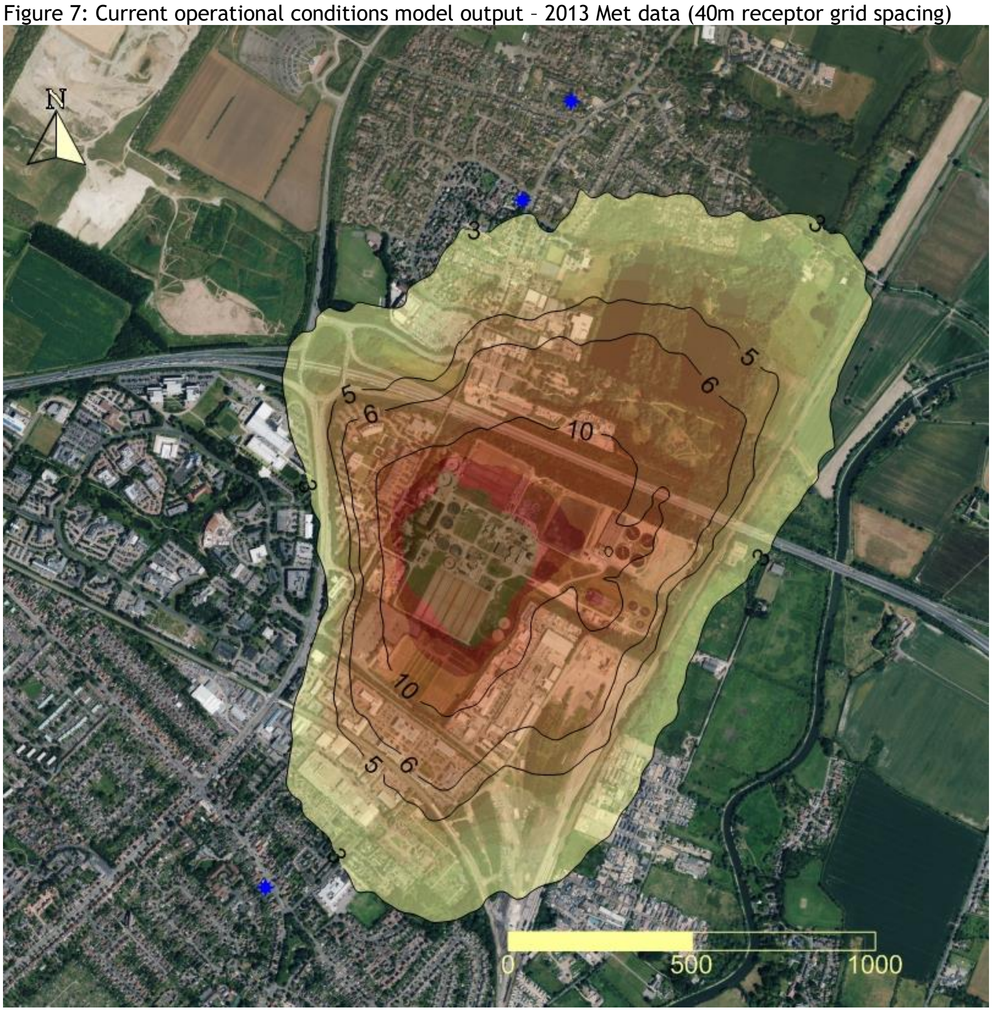


Figure 8: Current operational conditions model output – 2014 Met data (100m receptor grid spacing)

Figure 9: Current operational conditions model output – 2015 Met data (100m receptor grid spacing)

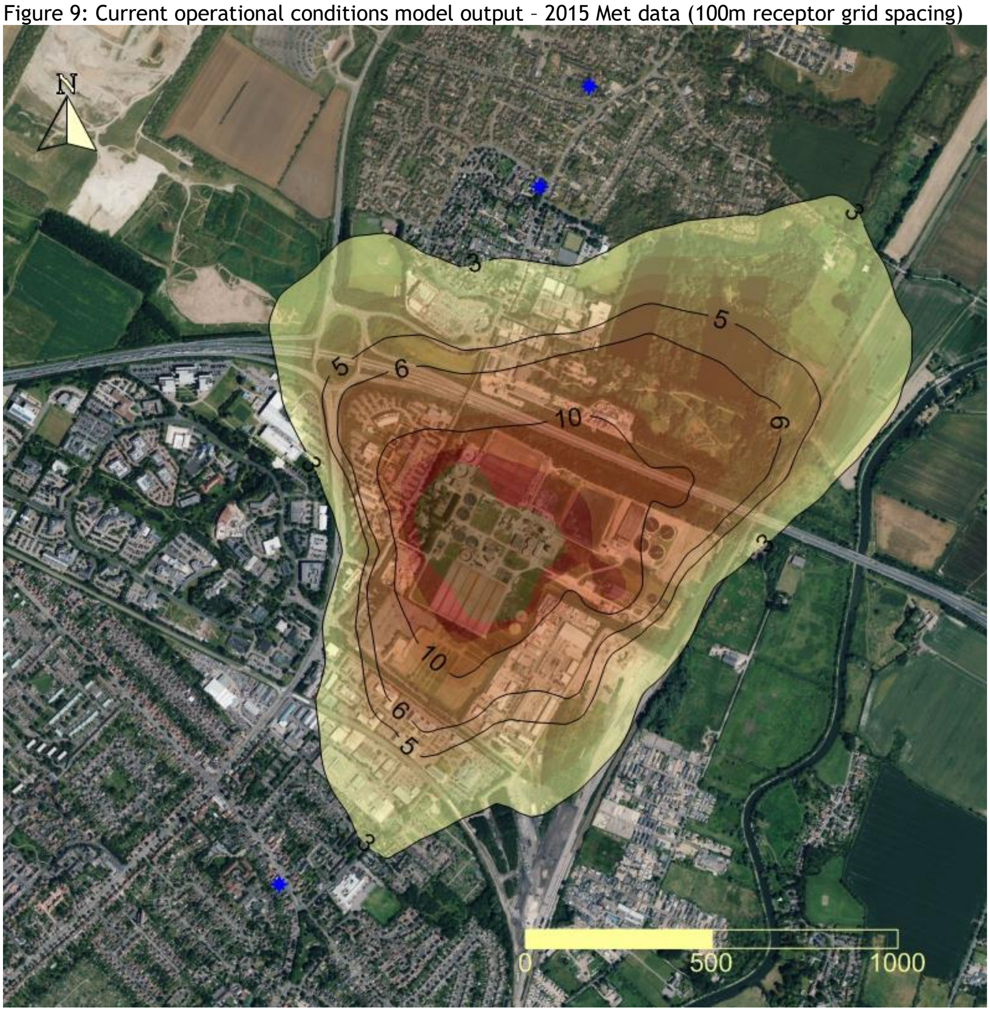


Figure 10: Current operational conditions model output – 2016 Met data (100m receptor grid spacing)