Yorkshire Water Services Ltd

Huddersfield Wastewater Treatment Works

Odour assessment

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Job number 264427-00

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Executive summary

Ove Arup and Partners Ltd (Arup) has been commissioned by Yorkshire Water Services Ltd. (YW) to undertake a detailed odour assessment in order to assess the potential impacts of changing the sludge processing at the Huddersfield Wastewater Treatment Works.

Odour emissions

The assessment scenarios are two base cases of existing sources and two future project cases. Base case 1 includes all the existing sources and Base case 2 contains the subset of assets that are associated with the existing Sludge Treatment Facility (STF). Project case 1 includes all potential future sources: 10 of the existing sources unchanged from the base case, the drum thickeners modified from the base case, 16 new sources and two new Odour Control Units (OCUs). Project case 2 assesses the odour impact from the future STF assets only.

The annual average odour emission rates of each scenario are calculated as:

- Base case 1 (all existing sources): 126,945ou_E/s;
- Base case 2 (STF assets only): 66,667 ou_E/s;
- Project case 1 (all potential future sources 126,511ou_E/s; and
- Project case 2 (STF assets only): 66,233ou_E/s.

In each of the future project cases, the emissions from all sources are essentially the same as the emissions from all sources in the comparative base cases. Therefore there would not be expected to be a large change in predicted odour concentrations. Any differences in predicted concentrations between the base and future project cases would largely arise from differences in the location and nature of the source.

Predicted odour concentrations

The results show that the maximum predicted odour concentrations for project cases 1 and 2 are lower than the base cases at the most affected residential properties (high sensitivity receptors). The final results can be summarised as follows:

Base case

- Base case 1, the maximum predicted odour concentration at a high sensitivity receptor was 6.5ou_E/m^3 at R3, on the A62.
- Base case 2, the maximum predicted odour concentration at a high sensitivity receptor was 4.4ou_E/m^3 at R3, on the A62.

Future

- Project case 1, the maximum predicted odour concentration at a high sesnsitvy receptor was $5.0ou_E/m^3$ at R3, on the A62, where a reduction of $1.5ou_E/m^3$ is experienced.
- Project case 2: the maximum predicted odour concentration at a high sensitivity receptor was $3.4ou_E/m^3$ at R3, residential property on A62, where a reduction of $1.0ou_E/m^3$ is experienced.

The modelling demonstrated there was a negligible or beneficial impact between the base case and comparative project case at all discrete receptors.

1 Introduction

Arup has been commissioned by Yorkshire Water Service Ltd. (YW) to undertake a detailed odour assessment in order to assess the potential impacts of changing the sludge processing at the Huddersfield Wastewater Treatment Works. YW has requested that Arup assesses the potential odour impact of two current baseline scenarios (all existing sources; sources associated with the existing Sludge Treatment Facility (STF)) and two future project scenarios (all future sources; all future STF sources) to assess the impact of a future design and proposed mitigation.

This report presents the findings of the study. In Section 1.2 guidance on odour nuisance is outlined, while Section 3 describes the assessment methodology. The results are presented in Section 4 and the conclusions are presented in the final section, Section 5.

1.1 Proposed development and surroundings

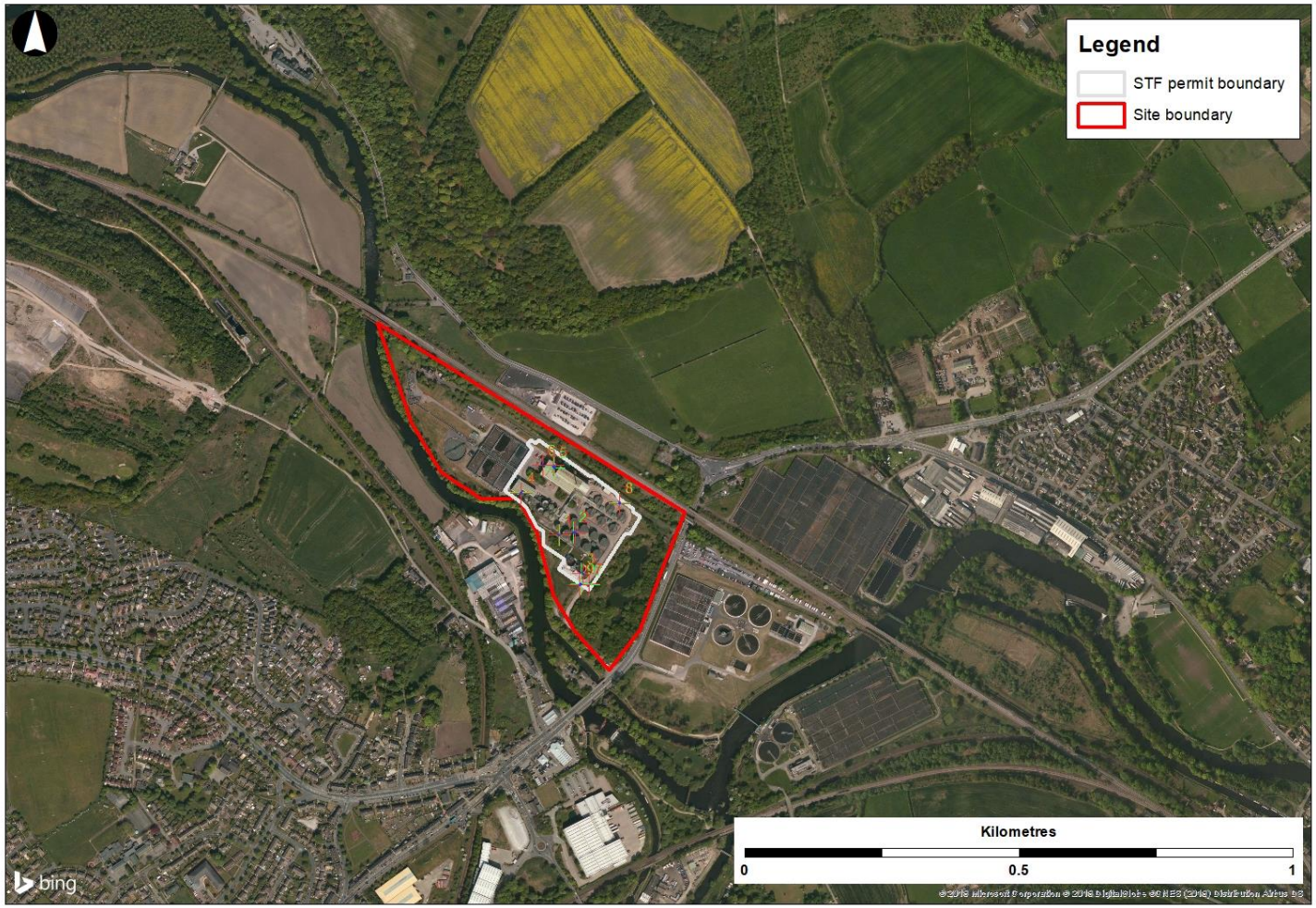
Huddersfield Wastewater Treatment Works is located on the north-east outskirts of Huddersfield; its location is shown in Figure 1. The site is surrounded by a mixture of agricultural and urban land-uses. There is a large residential area 400m to the south-east of the site, and the nearest residential receptor is 200m east of the site.

YW has reviewed options for upgrading the sludge processing at the Wastewater Treatment Works. A summary of the scenarios considered in this assessment is provided below:

- Base case 1: all odour sources on the existing works (modelled as 17 sources);
- Base case 2: all odour sources in the STF (modelled as 10 sources);
- Project case 1 (to be compared to base case 1): all potential future sources comprising of 10 of the existing sources which remain unchanged from the baseline, a change to the drum thickeners from the base case, 16 new sources and two new OCUs; and
- Project case 2 (to be compared to base case 2): all odour sources associated with the future STF. This comprises of three sources which remain unchanged, a change to the drum thickeners from the base case, 16 new sources and two new OCUs.

The assessment scenarios are described in detail in Section 4.1.

Figure 1: Location of site and STF permit boundary



1.2 Overview of complaint history

The site was formally a sludge incinerator facility (commissioned in 1995), which also contained numerous sludge storage and processing plant. During the 20 years that the incinerator was in operation, YW received a single odour complaint from a local business, which was found to be caused by a broken roller-shutter door on a cake import reception unit and was subsequently resolved immediately with no further issues. Since the incinerator was taken out of service, following flooding in 2015, the site has continued to process and dewater sludges using mobile centrifuges for export from site as sludge cake. To date, YW have received no further odour complaints relating to this activity.

2 Background guidance

2.1 Defra odour guidance

Odour is due to a mixture of volatile chemical compounds or a single compound that triggers a reaction in the olfactory organ, generally at very low concentrations. Any odour, whether considered to be pleasant or unpleasant, can result in a loss of amenity for occupiers of property if it is unwanted. If the odour is perceived sufficiently often above a threshold level, a statutory nuisance can be considered to exist. Odour can therefore be an important issue in planning when a proposal is made to locate sensitive uses close to an existing odorous process. The National Planning Policy Framework in paragraph 120 also notes that "planning decisions should ensure that new development is appropriate for its location" and "the potential sensitivity of the area or proposed development to adverse effects from pollution should be taken into account".

As noted in the Defra Code of Practice on Odour Nuisance from Sewage Treatment Works[1] (which was withdrawn in 2017, but has not been replaced) odour can be characterised by four attributes:

- Concentration: the "amount" of odour present in a sample of air. It can be expressed in terms of parts per million, parts per billion or in mg/m^3 of air for a single odorous compound. More usually a mixture of compounds is present and the concentration of the mixture can be expressed in odour units per cubic metre. Odour concentration is measured in European odour units (ou_E/m^3). The odour concentration at the detection threshold is defined to be $1ou_E/m^3$. If an odour sample has been diluted in an olfactometer by a factor of 10,000 to reach the detection threshold, then the concentration of the original sample is 10,000 odour units;
- Intensity: is the magnitude (strength) of perception of an odour (from faint to strong). Intensity increases as concentration increases but the relationship is logarithmic rather than linear so increases or decreases in concentration of an odour do not always produce a corresponding proportional change in the odour strength as perceived by the human nose;
- Quality/Characteristics: this is a qualitative attribute which is expressed in terms of "descriptors", e.g. "fruity", "almond", "fishy". This can be of use when establishing an odour source from complainants' descriptions; and
- Hedonic tone: this is a judgement of the relative pleasantness or unpleasantness of an odour made by assessors in an odour panel. This provides a method to differentiate odours considered to be pleasant (e.g. bakeries) from those considered to be unpleasant (e.g. rotting fish).

The Defra Odour Guidance for Local Authorities[2] (also withdrawn in 2017) notes that $5ou_E/m^3$ would be a 'faint' odour whilst $10ou_E/m^3$would be considered a 'distinct' odour. Generally, an average person would be able to recognise the

[1] Defra (2006) Code of Practice on Odour Nuisance from Sewage Treatment Works (withdrawn 2017),
[2] Defra (2010) Odour Guidance for Local Authorities (withdrawn 2017)

source of an odour at about $3ou_E/m^3$ although this can depend on the relative offensiveness of the odour.

It should be noted that there is no statutory limit in England and Wales for ambient odour concentrations[1], whether set for individual chemical species or for mixtures. However, guideline limits and custom-and-practice standards have been used in some circumstances and there is some experience from other planning decisions.

2.2 Environment Agency H4 guidance

The Environment Agency H4 Odour Management document[3] gives "Benchmark Levels" for odour modelled over a year at the site/installation boundary. The benchmarks are based on the 98th percentile of hourly mean concentrations over a year and are as follows:

- $1.5ou_E/m^3$ for most offensive odours;
- $3.0ou_E/m^3$ for moderately offensive odours;
- $6.0ou_E/m^3$ for less offensive odours.

The 98th percentile value is the parameter used for all currently applied odour standards and unless otherwise stated, all odour concentrations within this report are expressed as the 98th percentile value.

The H4 document states that "*any modelled results that project exposures above these benchmark levels, after taking into account uncertainty, indicates the likelihood of unacceptable odour pollution*".

The guidance provides examples of the different levels of offensive odours which are detailed in Table 1.

The document also notes factors that are relevant to sewage treatment works, in particular, odours from processes likely to become anaerobic or septic are more offensive and, the character of odours from different parts of a process may differ, for example it may only be the sludge handling part of a sewage works that attracts the highest score. On the basis of the H4 guidance, the level of acceptable odour is likely to lie in the range $1.5\text{-}3.0ou_E/m^3$.

[3] Environment Agency (2011) H4 Odour Management

Table 1: Examples of activities and their offensiveness

Level of offensiveness	Activities
Most offensive	Processes involving decaying animal or fish remains Processes involving septic effluent or sludge Biological landfill odours
Moderately offensive	Intensive livestock rearing Fat frying (food processing) Sugar beet processing Well aerated green waste composting
Less offensive	Brewery Confectionery Coffee roasting Bakery
Note: Source Environment Agency H4 Guidance	

These standards are derived from research carried out in Holland mainly during the period 1980-2000. This research examined the relationship between the reported annoyance in the community caused by exposure to pig farming odours with modelled odour concentrations. However, the underlying research used to derive the H4 odour benchmarks did not examine the effect of offensiveness of odours on annoyance[4]. The research examined how three different types of community responded to odours, these were (1) respondents where pig odours were not a common feature of the area, (2) respondents where pig odours were a common feature of the area, and (3) respondents who had an economic interest in pig farming.

The three H4 odour benchmarks were based on the factors detailed in Table 2.

[4] A P van Harreveld (2004) How much odour is annoying, Paper presented at Conference, Current Best Practice for Odour Control, London.

Table 2: Basis of H4 odour benchmarks

H4 Standard	Basis
Most offensive - 1.5ou_E/m^3	10% of the respondents in an area where pig odours were not a common feature of the area reported being "annoyed" by odours at an exposure level of 1.3ou_E/m^3.
Moderately offensive – 3.0ou_E/m^3	10% of the respondents in an area where pig odours were a common feature of the area were reported as being annoyed by odours at a concentration of 3.2ou_E/m^3
Less offensive – 6.0ou_E/m^3	This value was not based entirely on the same research. It is stated that this was based on the pig farm study "*combined with data from a dozen dose-effect studies for industrial sectors in the Netherlands where the 10% annoyance level corresponded with approximately 5ou_E/m^3. As supporting indicative evidence, the observation from a number of consultancy projects in the UK was used, indicating that between 90-95% of complaints registered for wastewater treatment and solid waste management occur in a range of exposure of 5-10 ou_E/m^3*". It is important to note that the Netherlands research referenced above examined the proportion of the population that was "highly annoyed" by odours, this is different to those considered to be "annoyed".

Experience in the application of these standards is that there is frequently a problem in determining the most appropriate standard for sewage works, essentially, do the odours fall into the "most offensive" or "moderately offensive" category. However, when the derivation of the H4 benchmarks is examined, even the application of the most stringent standard (i.e. 1.5ou_E/m^3 for most offensive odours) could result in 10% of the population being annoyed by odours.

2.3 Relevant planning appeals

Numerical odour criteria have been applied for planning purposes in the UK on numerous occasions. Such an approach appears to have been first applied at an appeal by Newbiggin-by-the-Sea v Northumbrian Water. The evidence presented to the inquiry details the results of research in Holland undertaken at over 200 sites to assess the relationship between odour and nuisance. The research concluded that a level of 5ou_E/m^3 was an appropriate indicator of nuisance. It should be noted that this study was based on Dutch odour units that are twice the value of European units so therefore this standard is equivalent to 2ou_E/m^3. However, the background to this study appears to be obscure and there is little information regarding the methods applied or the study sites.

Experience from other more recent planning appeals concerning residential development near sewage works suggest that levels of odour considered to be acceptable are below $5ou_E/m^3$ as a 98th percentile; on three recent occasions (including most recently in 2016) a level of $3ou_E/m^3$ has been accepted and on one occasion a level of $1.5ou_E/m^3$ was used and accepted. These include:

- Land at Stoke Road, Leighton Linslade, APP/P0240/A/09/2110667, in this inquiry the Inspector considered that a level of $5ou_E/m^3$ "could be a risk of regular and unacceptable odour annoyance to such an extent that it would detract from the future resident's living conditions";
- Low Road, Cockermouth, Cumbria CA13 0XE, APP/G0908/A/11/2151737, the inspector concluded that "should odours fall within medium offensiveness, rather than low, (i.e. $3ou_E/m^3$) level modelled by the appellant indicates that it would not impinge on the appeal dwellings" (i.e. $3ou_E/m^3$ represented acceptable odour conditions).
- Land between Upthorpe Road and Hepworth Road, Stanton, APP/E3525/A/11/2162837, the inspector concluded that "I consider that a more appropriate threshold in this case is 3 - $5ou_E/m^3$, the level of the DEFRA guidance's "faint odour". He did note that this was for a small sewage works.
- Land at Ashley Road, Middleton, Leicestershire, APP/U2805/A/11/2162384. The Inspector concluded in this case "I believe that it is reasonable to take account of the $1.5ou_E/m^3$ contour map in determining odour impact. In my view areas subject to such concentrations are unlikely to provide a reasonable permanent living environment."
- The Planning Inspectorate, Appeal Ref: APP/N1215/W/15/3005513, Land South of Le Neubourg Way, Gillingham, Dorset, March 2016. The Inspector wrote: "…..I conclude that the appropriate parameter to apply in this case is the 3 ou_E/m^3 contour line; a more restrictive approach would preclude from development areas which are comparable in odour terms with extensive areas of existing housing in Gillingham."

It should be noted that evidence presented at these appeals does not contain any new fundamental research on the relationship between odour concentrations and perceived annoyance. Therefore, these appeal decisions can only be regarded as interpretations of other studies.

2.4 Other relevant guidance and research

CIWEM has produced a Policy Position Statement[5] on odours which states that for a level of less than $3ou_E/m^3$, "complaints are unlikely to occur and exposure below this level are unlikely to constitute significant pollution or significant detriment to amenity unless the locality is highly sensitive or the odour highly unpleasant in nature".

UK Water industry Research (UKWIR)[6] published a study in 2001 that examined modelled odour concentrations and their relationship to complaints around sewage works. This was based on a review of the correlation between reported odour

[5] https://www.ciwem.org/assets/pdf/Policy/Policy%20Position%20Statement/Control-of-odour.pdf
[6] UKWIR (2001) Odour Control in Wastewater Treatment – A Technical Reference Document Report 01/ww/13/3

complaints and modelled odour impacts in relation to nine Wastewater Treatment Works in the UK with ongoing odour complaints. The findings of this research indicated the following:

- At modelled exposures of below $5ou_E/m^3$, complaints are relatively rare, at only 3% of the total registered;
- At modelled exposures between $5\text{-}10ou_E/m^3$, a significant proportion of total registered complaints occur (38% of the total); and
- The majority of complaints occur in areas of modelled exposure greater than $10ou_E/m^3$ (59% of the total).

While this study is frequently cited as a justification for a less stringent odour standard of $5ou_E/m^3$ examination of the research report shows that it provides very little information regarding the methodology for the research and no information is provided at all regarding the sites included in the research. It is also important to note that the UKWIR research is based on complaints whilst the Netherlands research used to derive the H4 odour benchmarks were based on reported annoyance from social surveys in the community. Evidence suggests that only a very low percentage of a community exposed to odours will complain. Arup has been involved in one case where a detailed study was carried out examining the percentage of population that complained and this was 0.1-1.1%.

There is some consistency between these sources but it must be recognised that all these studies are based on limited information. As noted in the H4 guidance, any assessment not only has to take into account the applicable standard but also the uncertainty inherent within the assessment.

In a another study[7], the ability of odour modelling to predict complaints around sewage works was examined and it was found that this was not a reliable approach and should only be used with caution and taking into account model uncertainty. This reflects the general uncertainty regarding odour assessments.

The concept of an undeveloped buffer zone between an odorous process and sensitive receptors has been used for Wastewater Treatment Works for instance, a water company may look for a 400m undeveloped zone around their works to allow odours to disperse. In the Defra Code of Practice on Odour Nuisance from Sewage Treatment Works it notes (p16):

> *"individual buffer zones can offer a practical means of preventing the exacerbation of existing problems and the occurrence of new ones".*

The code of practice also notes that a fixed distance for the buffer zone such as 400m is inappropriate and individual site circumstances should be taken into account. Anglian Water has taken a similar approach when assessing odour risks around its sites, developing its odour encroachment policy. This sets different distances based on the size and some operational features of the works[8], these

[7] Bull M A and Fromant E L (2013) The performance of the numerical odour assessment for the prediction of odour complaints from wastewater treatment works, Water and Environment Journal.
[8] Anglian Water (2013) Asset Encroachment Risk Assessment Methodology http://www.anglianwater.co.uk/developers/encroachment.aspx

distances do not define where odour nuisance is likely but used as a threshold where a more detailed odour study would be required.

Water companies will often define a "consultation zone" within which development must take the existence of the works into account.

2.5 IAQM Odour and Planning guidance

The Institute of Air Quality Management (IAQM) has published guidance[9] for assessing odour impacts (on amenity) for planning purposes. This includes information on various assessment methods to be used to undertaken odour assessments for planning.

The guidance states that for assessing site suitability of proposed development land (e.g. residential) around an existing odour source, the odour effect would normally be assessed using predictive methods (which may be qualitative or modelling). Atmospheric dispersion modelling should use source terms that have been measured by dynamic dilution olfactometry or if not available, use literature values.

The modelling will provide predicted concentrations (ou_E/m^3) as a 98^{th} percentile of 1-hour means. The guidance recommends that in terms of comparing predicted concentrations with odour assessment criteria, practitioners should observe from the various scientific studies, case law and practical examples of the investigation of odour annoyance cases and then determine an appropriate criterion. This criterion could lie somewhere in the range of 1 to $10ou_E/m^3$ as a 98^{th} percentile of hourly mean odour concentrations.

The document provides guidance on the assessment of impacts related to change in odour concentrations from odour. The change in odour concentration is assessed differently, depending on the level of sensitivity of the receptor, so the levels of receptor sensitivity according to the IAQM guidance shown in Table 3 should be considered in assessment methodology.

Odours from sewage treatment works plant operating normally, i.e. non-septic conditions, would not be expected to be at the 'most offensive' end of the spectrum. Therefore the impact descriptors proposed for a 'moderately offensive' odour presented in Table 4 should be taken into account with the different receptor sensitivities.

[9] IAQM (2014) Guidance on the assessment of odour for planning

Table 3: Receptor sensitivity to odours

Receptor sensitivity	Description of land	Example land use
High	Users can reasonably expect enjoyment of a high level of amenity and people would reasonably be expected to be present here continuously, or at least regularly for extended periods, as part of the normal pattern of use of the land.	Residential dwellings, hospitals, schools/education and tourist/cultural.
Medium	Users would expect to enjoy a reasonable level of amenity, but wouldn't reasonably expect to enjoy the same level of amenity as in their home; or people wouldn't reasonably be expected to be present here continuously or regularly for extended periods as part of the normal pattern of use of the land.	Places of work, commercial/retail premises and playing/recreation fields.
Low	The enjoyment of amenity would not reasonably be expected or there is transient exposure, where the people would reasonably be expected to be present only for limited periods of time as part of the normal pattern of use of the land.	Industrial use, farms, footpaths and roads.

Table 4: Proposed odour effect descriptors for impacts predicted by modelling - 'moderately offensive' odours

Odour exposure level (ou_E/m^3)	Receptor sensitivity		
	Low	Medium	High
≥ 10	Moderate	Substantial	Substantial
5 - <10	Slight	Moderate	Moderate
3 - <5	Negligible	Slight	Moderate
1.5 - <3	Negligible	Negligible	Slight
0.5 - <1.5	Negligible	Negligible	Negligible
<0.5	Negligible	Negligible	Negligible
Note: it should be noted that the table applies equally to cases where there are increases and decreases in odour exposure as a result of this development, in which case the appropriate terms 'adverse' or 'beneficial' should be added to the descriptors			

2.6 Local Air Quality Management Technical guidance

The 2016 technical guidance note from the Department for Environment, Food and Rural Affairs (Defra), Local Air Quality Management (LAQM) Technical Guidance 2016 (TG (16))[10] is designed to support local authorities in carrying out their duties to review and assess air quality in their area. TG (16) is published at the UK level and is relevant to England, Scotland, Wales and Northern Ireland. It

[10] Defra (2016) LAQM Technical Guidance

provides detailed guidance on how to assess air quality. Much of the advice on modelling air quality is relvant to modelling odour. Where relevant, this guidance has been taken in to account in this assessment.

2.7 Assessment criteria used for this study

This assessment has modelled the predicted odour concentrations (ou_E/m^3) as a 98^{th} percentile of 1-hour means. The IAQM guidance states that the appropriate assessment criterion could lie somewhere in the range of 1 to $10ou_E/m^3$ as a 98^{th} percentile of hourly mean odour concentrations. The guidance also provides guidance on the assessment of impacts related to change in odour concentrations from the 'modertely offensive' odours. This study assesses the impacts related to change in odour concentrations using these descriptors. The contour plots of predicted odour concentrations, show the 1.5, 3 and $5ou_E/m^3$ isopleths for reference.

3 Assessment methodology

This section details the odour emission sources identified for the existing (base case) and proposed future (project case) process. It then details the assessment secnarios considered and the methodology applied.

3.1 Emission sources and scenarios

3.1.1 Base case emission sources

Table 5 summarises the emission sources included in each base case and the sources are shown in Figure 2. The emissions shown in Table 6 are the average odour emission rates, taking into account the operating hours of the sources. Table 7 shows the percentage contribution of each source to the odour emissions from the site for each of the base case scenarios.

The two case scenarios examined were:

- Base case 1: all 17 existing odour sources (B1 to B5, B7 to B17 and P36);
- Base case 2: all 10 existing sources in the STF (B9 to B17 and P36);

The total average odour emission rate (averaged over a day to account for time variable sources) for the two base case scenarios are as follows:

- Base case 1: 126,945ou_E/s; and
- Base case 2: 66,667ou_E/s.

The main sources of odour for each of the base cases are summarised below.

- Base case 1:
  - B1, Inlet works: 38.3% of total odour emissions; and
  - B12, Liquors and imported sludge pumping station - 2 sections liquors: 24.2% of total odour emission
- Base case 2:
  - B12, Liquors and imported sludge pumping station - 2 sections liquors: 46.0% of base case 2 odour emissions;
  - B17, Cake trailer: 15.0% of base case 2 odour emissions;
  - B16, Dewatered cake bunded area: 12.7% of base case 2 odour emissions; and
  - P36, Thickened liquors pumping station (existing filtrate pumping station): 11.5% of base case 2 odour emissions.

Table 5: Emission sources included in each base case

ID	Description	Base case	
		1	2
B1	Inlet works	✓	
B2	Skips screenings	✓	
B3	Skips- grit	✓	
B4	Crude sewage channel	✓	
B5	Storm tank	✓	
B7	FFT pumping station	✓	
B8	CASS Plant	✓	
B9	Drum thickeners	✓	✓
B10	Gravity belt thickeners	✓	✓
B11	SAS tanks (existing next to building)	✓	✓
B12	Liquors and imported sludge pumping station - 2 sections liquors	✓	✓
B13	Liquors and imported sludge pumping station - 1 section imported sludge	✓	✓
B14	SAS tank (air mixed)	✓	✓
B15	Sludge bend tank. Air mixed	✓	✓
B16	Dewatered cake bunded area	✓	✓
B17	Cake trailer	✓	✓
P36	Thickened liquors pumping station (existing filtrate pumping station)	✓	✓

Table 6: Base case source properties and area odour emission rates

ID	Description	Number	Height (m)	Open (O) or covered (C)	% odour capture	Total area (m^2)	Odour emission rate ($ou_E/m^2/s$)	Odour emission rate (ou_E/s)	Operating hours
B1	Inlet works	1	1.5	O	0%	666.0	73.0	48,618.0	
B2	Skips screenings	2	1.5	O	0%	24.0	15.0	360.0	
B3	Skips- grit	2	1.5	O	0%	24.0	15.0	360.0	
B4	Crude sewage channel	1	1.5	O	0%	205.3	25.0	5,132.5	
B5	Storm tank	1	1.5	O	0%	1,341.1	0.8	1,072.9	
B7	FFT pumping station	1	1.5	O	0%	42.0	25.0	1,050.0	
B8	CASS Plant	8	6	O	0%	7,369.0	0.5	3,684.5	
B9	Drum thickeners	2	8.8	C	80%	204.7	3.3	683.7	07:00 to 23:00
B10	Gravity belt thickeners	2	8.8	O	0%	204.7	10.7	2,190.3	07:00 to 23:00
B11	SAS tanks (existing next to building)	3	8	C	80%	160.2	1.3	208.3	
B12	Liquors and imported sludge pumping station - 2 sections liquors	1	0	C	80%	100.0	307	30,679.5	
B13	Liquors and imported sludge pumping station - 1 section imported sludge	1	0	C	80%	50.0	16	799.5	12:00 to 14:00
B14	SAS tank (air mixed)	2	8	O	0%	412.0	6.5	2,678.0	
B15	Sludge bend tank. Air mixed	1	4	C	80%	206.0	24	4,944.0	
B16	Dewatered cake bunded area	1	0	O	0%	20.0	425	8,500.0	
B17	Cake trailer	4	3	O	0%	100.0	100	10,000.0	
P36	Thickened liquors PS (existing filtrate PS)	1	0	C	80%	25.0	307	7,675.0	

Figure 2: Base case odour sources

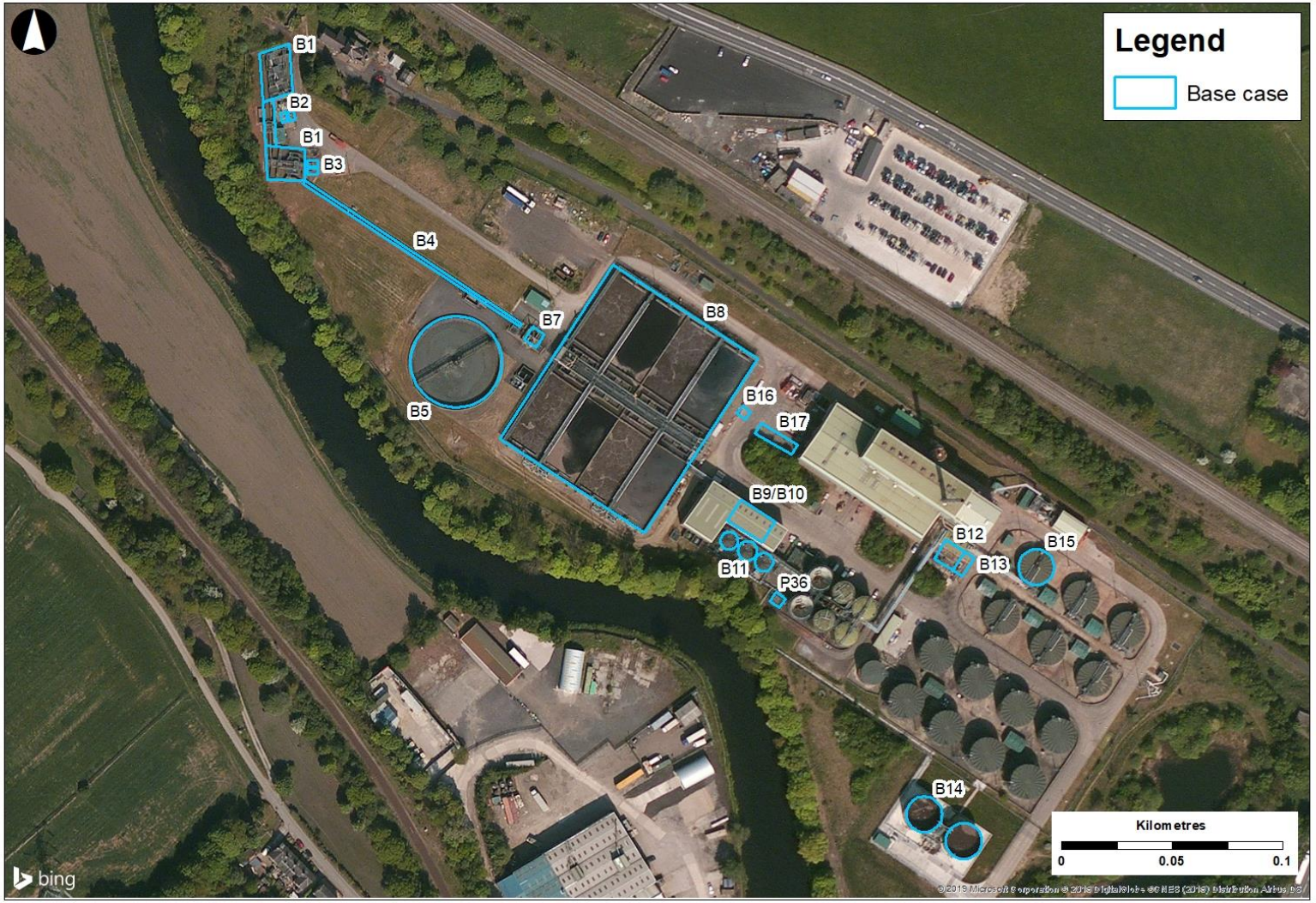


Table 7: Contribution of emission sources to total odour emission rate in each base case

ID	Description	Source contribution (%)	
		Base case 1	Base case 2
B1	Inlet works	38.3	
B2	Skips screenings	0.3	
B3	Skips- grit	0.3	
B4	Crude sewage channel	4.0	
B5	Storm tank	0.8	
B7	FFT pumping station	0.8	
B8	CASS Plant	2.9	
B9	Drum thickeners	0.4	0.7
B10	Gravity belt thickeners	1.2	2.2
B11	SAS tanks (existing next to building)	0.2	0.3
B12	Liquors and imported sludge pumping station - 2 sections liquors	24.2	46.0
B13	Liquors and imported sludge pumping station - 1 section imported sludge	0.1	0.1
B14	SAS tank (air mixed)	2.1	4.0
B15	Sludge bend tank. Air mixed	3.9	7.4
B16	Dewatered cake bunded area	6.7	12.7
B17	Cake trailer	7.9	15.0
P36	Thickened liquors pumping station (existing filtrate pumping station)	6.0	11.5
Total		**100.0**	**100.0**

3.1.2 Project case emission sources

Table 8 summarises the emission sources included in each project case. The area source parameters are detailed in Table 9, the OCU stack parameters in Table 10 and the odour sources are shown in Figure 3. YW provided the OCU parameters and emission rates. The emissions shown in Table 9 and Table 10 are the average odour emission rates, taking into account the operating hours of the sources. Table 11 shows the percentage contribution of each source to the odour emissions from the site for each of the project case scenarios.

The two project case assessement scenarios examined were:

- Project case 1: all potential future sources, including 10 existing sources (B1 to B5, B7, B8, B11, B14 and P36), the drum thickeners modified from the base case (P35) and 16 new sources (P19 to P24, P26 to P28, P30, P31, P33, P34, P37, P38 and two OCU stacks); and
- Project case 2: as per project case 2 but only the STF assets, including three existing sources (B11, B14 and P36), the drum thickeners modified from the

base case (P35) and 16 new sources (P19 to P24, P26 to P28, P30, P31, P33, P34, P37, P38 and two OCU stacks).

The total average odour emission rate (averaged over a day to account for time variable sources) for the project case scenarios are as follows:

- Project case 1: 126,511ou_E/s; and
- Project case 2: 66,233ou_E/s.

In each of the future project cases, the emissions from all sources were essentially the same as the emissions from all sources in their comparative base cases.The main sources of odour for each of the project cases are given below..

- Project case 1:
  - B1, Inlet works: 38.4% of project case 1 odour emissions;
  - P22, Cake barn limed - disturbed: 21.5% of project case 1 odour emissions; and
  - P23, Cake barn limed - undisturbed: 13.8% of project case 1 odour emissions.
- Project case 2:
  - P22, Cake barn limed - disturbed: 41.1% of project case 2 odour emissions;
  - P23, Cake barn limed - undisturbed: 26.3% of project case 2 odour emissions;
  - P38, Digested sludge tanks: 8.9% ; and
  - P34, Thickeners feed tank: 7.6%.

Table 8: Emission sources included in each project case

ID	Description	Project case	
		Project case 1	Project case 2
B1	Inlet works	✓	
B2	Skips screenings	✓	
B3	Skips- grit	✓	
B4	Crude sewage channel	✓	
B5	Storm tank	✓	
B7	FFT pumping station	✓	
B8	CASS Plant	✓	
B11	SAS tanks (existing next to building)	✓	✓
B14	SAS tank (air mixed)	✓	✓
P19	Skips - liquid sludge screenings	✓	✓
P20	Skips - cake screenings	✓	✓
P21	Dewatering liquors well	✓	✓
P22	Cake barn limed - disturbed	✓	✓
P23	Cake barn limed - undisturbed	✓	✓
P24	Dewatering liquors balance tank	✓	✓
P26	LTP - treatment tank	✓	✓
P27	LTP - final settlement tank	✓	✓
P28	Sludge screens feed tank - primary & liquid imported	✓	✓
P30	Screened sludge wet well	✓	✓
P31	Cake hoppers	✓	✓
P33	Rewetted & screened sludge tank	✓	✓
P34	Thickeners feed tank	✓	✓
P35*	Drum thickeners	✓	✓
P36	Thicker liquors pumping station (existing filtrate pumping station)	✓	✓
P37	Digester feed tanks	✓	✓
P38	Digested sludge tanks	✓	✓
OCU1	Odour Control Unit	✓	✓
OCU2		✓	✓
Note: *Corresponds to B9 in the base case but source parameters have changed between base and future cases and hence it has been renamed			

Table 9: Project case area source properties and area odour emission rates

ID	Description	Number	Height (m)	Open (O) or covered (C)	% odour capture	Total area (m^2)	Odour emission rate ($ou_E/m^2/s$)	Odour emission rate (ou_E/s)	Operating hours
B1	Inlet works	1	1.5	O	0%	666.0	73.0	48,618.0	
B2	Skips screenings	2	1.5	O	0%	24.0	15.0	360.0	
B3	Skips- grit	2	1.5	O	0%	24.0	15.0	360.0	
B4	Crude sewage channel	1	1.5	O	0%	205.3	25.0	5,132.5	
B5	Storm tank	1	1.5	O	0%	1,341.1	0.8	1,072.9	
B7	FFT pumping station	1	1.5	O	0%	42.0	25.0	1,050.0	
B8	CASS Plant	8	6	O	0%	7,369.0	0.5	3,684.5	
B11	SAS tanks (existing next to building)	3	8	C	80%	160.2	1.3	208.3	
B14	SAS tank (air mixed)	2	8	O	0%	412.0	6.5	2,678.0	
P19	Skips - liquid sludge screenings	2	1.5	O	0%	24.0	15.0	360.0	
P20	Skips - cake screenings	2	1.5	O	0%	24.0	15.0	360.0	
P21	Dewatering liquors well	1	0	O	0%	15.0	14.0	210.0	
P22	Cake barn limed - disturbed	1	2	O	0%	100.0	37.0	3,700.0	00:00 to 08:00
							390.0	39,000.0	08:00 to 00:00
P23	Cake barn limed - undisturbed	1	2	O	0%	471.0	37.0	17,427.0	
P24	Dewatering liquors balance tank	1	8	C	80%	210.0	2.8	588.0	
P26	LTP - treatment tank	2	4	O	0%	742.0	0.5	371.0	
P27	LTP - final settlement tank	1	4	O	0%	199.0	0.5	99.5	
P28	Sludge screens feed tank - primary & liquid imported	1	6	C	80%	70.3	16.0	1,124.8	08:00 to 20:00
P30	Screened sludge wet well	1	0	C	80%	5.2	16.0	83.2	

ID	Description	Number	Height (m)	Open (O) or covered (C)	% odour capture	Total area (m^2)	Odour emission rate ($ou_E/m^2/s$)	Odour emission rate (ou_E/s)	Operating hours
P31	Cake hoppers	1	7.3	C	50%	35.6	153.1	5,448.6	09:00 to 10:00 and 12:00 to 13:00
					95%		3.8	136.2	00:00 to 09:00; 10:00 to 12:00 and 13:00 to 00:00
P33	Rewetted & screened sludge tank	1	3	C	80%	25.6	16.0	409.6	
P34	Thickeners feed tank	1	12.5	C	80%	210.0	24.0	5,040.0	
P35*	Drum thickeners	6	8.8	C	100%	204.7	0.0	0.0	07:00 to 23:00
P36	Thicker liquors pumping station (existing filtrate pumping station)	1	0	C	95%	25.0	76.8	1,918.8	
P37	Digester feed tanks	2	8.8	C	99%	420.0	1.2	504.0	
P38	Digested sludge tanks	2	8.8	O	0%	420.0	14.0	5,880.0	
Note: *Corresponds to B9 in the base case but source parameters and containment rate have changed between base and future cases, hence it has been renamed									

Table 10: Project case point source properties and odour emission rates

ID	Description	Number	Stack height (m)	Stack diameter (m)	Exit velocity (m/s)	Exit temperature (°C)	Odour emission rate (ou_E/s)
OCU1	Odour control unit 1	1	15	0.200	17.6	15.0*	556
OCU2	Odour control unit 2	1	15	0.315	14.9	15.0*	1,165
Note: *Assumed ambient temperature.							

Figure 3: Project case odour sources

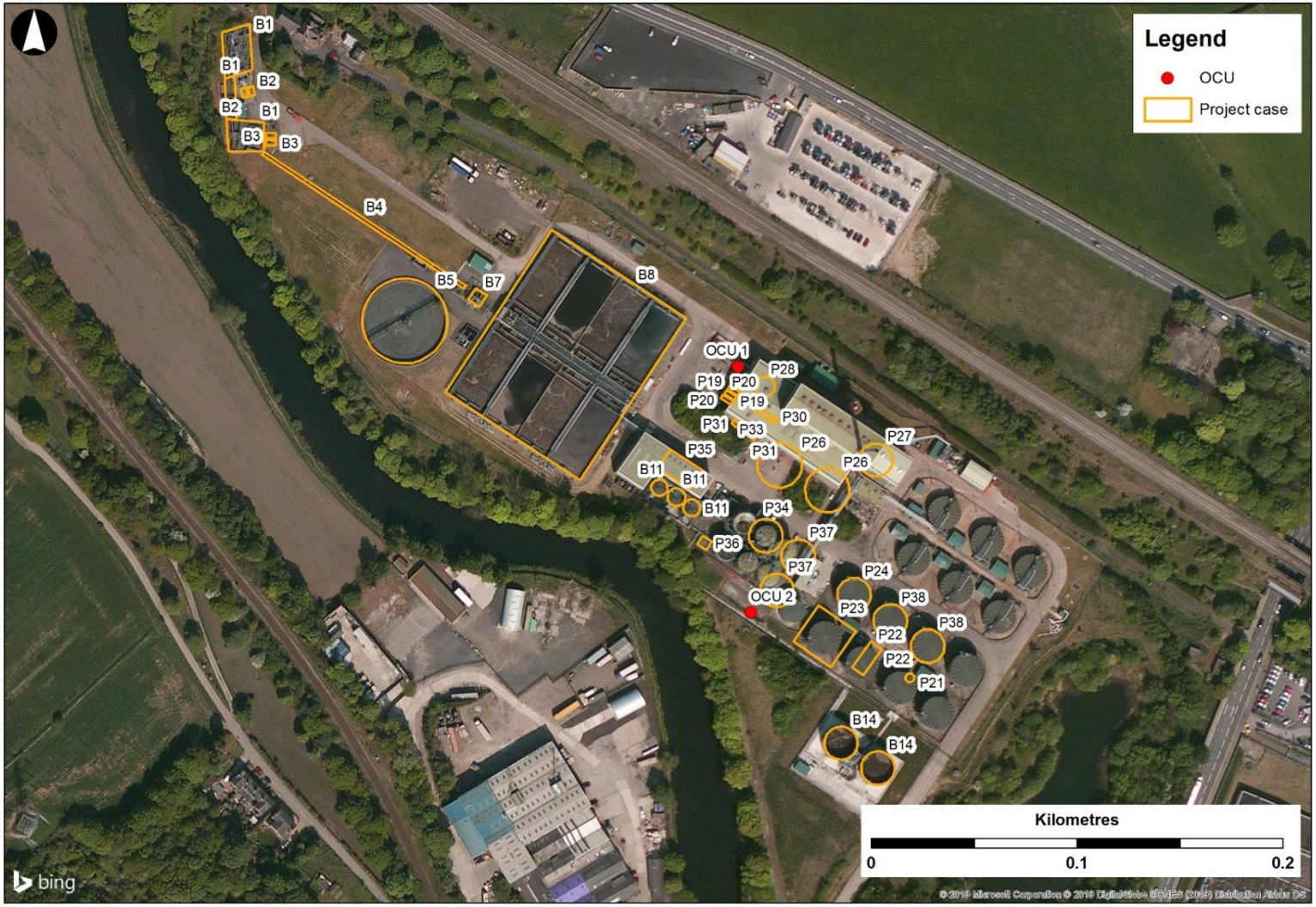


Table 11: Contribution of emission sources to total odour emission rate in each project case

ID	Description	Contribution to total odour emission rate (%)	
		Project case 1	Project case 2
B1	Inlet works	38.4	NA
B2	Skips screenings	0.3	NA
B3	Skips- grit	0.3	NA
B4	Crude sewage channel	4.1	NA
B5	Storm tank	0.8	NA
B7	FFT pumping station	0.8	NA
B8	CASS Plant	2.9	NA
B11	SAS tanks (existing next to building)	0.2	0.3
B14	SAS tank (air mixed)	2.1	4.0
P19	Skips - liquid sludge screenings	0.3	0.5
P20	Skips - cake screenings	0.3	0.5
P21	Dewatering liquors well	0.2	0.3
P22	Cake barn limed - disturbed	21.5	41.1
P23	Cake barn limed - undisturbed	13.8	26.3
P24	Dewatering liquors balance tank	0.5	0.9
P26	LTP - treatment tank	0.3	0.6
P27	LTP - final settlement tank	0.1	0.2
P28	Sludge screens feed tank - primary & liquid imported	0.4	0.8
P30	Screened sludge wet well	0.1	0.1
P31	Cake hoppers	0.5	0.9
P33	Rewetted & screened sludge tank	0.3	0.6
P34	Thickeners feed tank	4.0	7.6
P35	Drum thickeners	0.0	0.0
P36	Thicker liquors pumping station (existing filtrate pumping station)	1.5	2.9
P37	Digester feed tanks	0.4	0.8
P38	Digested sludge tanks	4.6	8.9
OCU1	Odour Control Unit 1	0.4	0.8
OCU2	Odour Control Unit 1	0.9	1.8
Total		**100.0**	**100.0**

3.1.3 Assessment scenarios

The assessment scenarios are summarised as follows:

- Base case 1: all 17 existing odour sources (B1 to B5, B7 to B17 and P36);
- Base case 2: all 10 existing sources in the STF (B9 to B17 and P36);
- Project case 1: all potential future sources, including 10 existing sources (B1 to B5, B7, B8, B11, B14 and P36), the drum thickeners modified from the base case (P35) and 16 new sources (P19 to P24, P26 to P28, P30, P31, P33, P34, P37, P38 and two OCU stacks); and
- Project case 2: as per project case 1 but only the STF assets, including three existing sources (B11, B14 and P36), the drum thickeners modified from the base case (P35) and 16 new sources (P19 to P24, P26 to P28, P30, P31, P33, P34, P37, P38 and two OCU stacks).

A detailed description of the sources and the modelled parameters is provided in the sections 3.1.1 and 3.1.2. Table 5 to Table 11 shows the sources included in the assessment scenarios and the information applied for each source. Information on source areas, asset heights, operating hours, capture/reduction percentage of OCUs, building reduction factor and odour emission rates were supplied by YW. The key assumptions made in the base cases and project cases were:

- All odour emission rates are assumed to be reduced by 50% in the winter months (December to February inclusive);
- Emissions from sources in buildings are assumed to occur at the building height.

3.2 Dispersion modelling set-up

The detailed dispersion modelling was undertaken using the ADMS 5 modelling software which is developed by Cambridge Environmental Research Consultants (CERC) Ltd. All the odour sources were modelled as area sources, except for the two OCUs which were modelled as point sources.

3.2.1 Meteorological data

The meteorological data used in this assessment was recorded at Emley Moor meteorological station, located approximately 8.5km south-east of the Wastewater Treatment Works. The assessment uses five years of meteorological data, over the period 1st January 2014 to 31st December 2018 (inclusive), to account for inter-annual variability.

Defra's LAQM.TG16[10] guidance recommends that the meteorological data file be tested in a dispersion model and the relevant output log file checked to confirm the number of missing hours and calm hours that cannot be used by the dispersion model. This is important when considering predictions of high percentiles and the number of exceedances. The guidance recommends that meteorological data should only be used if the percentage of usable hours is greater than 75% and

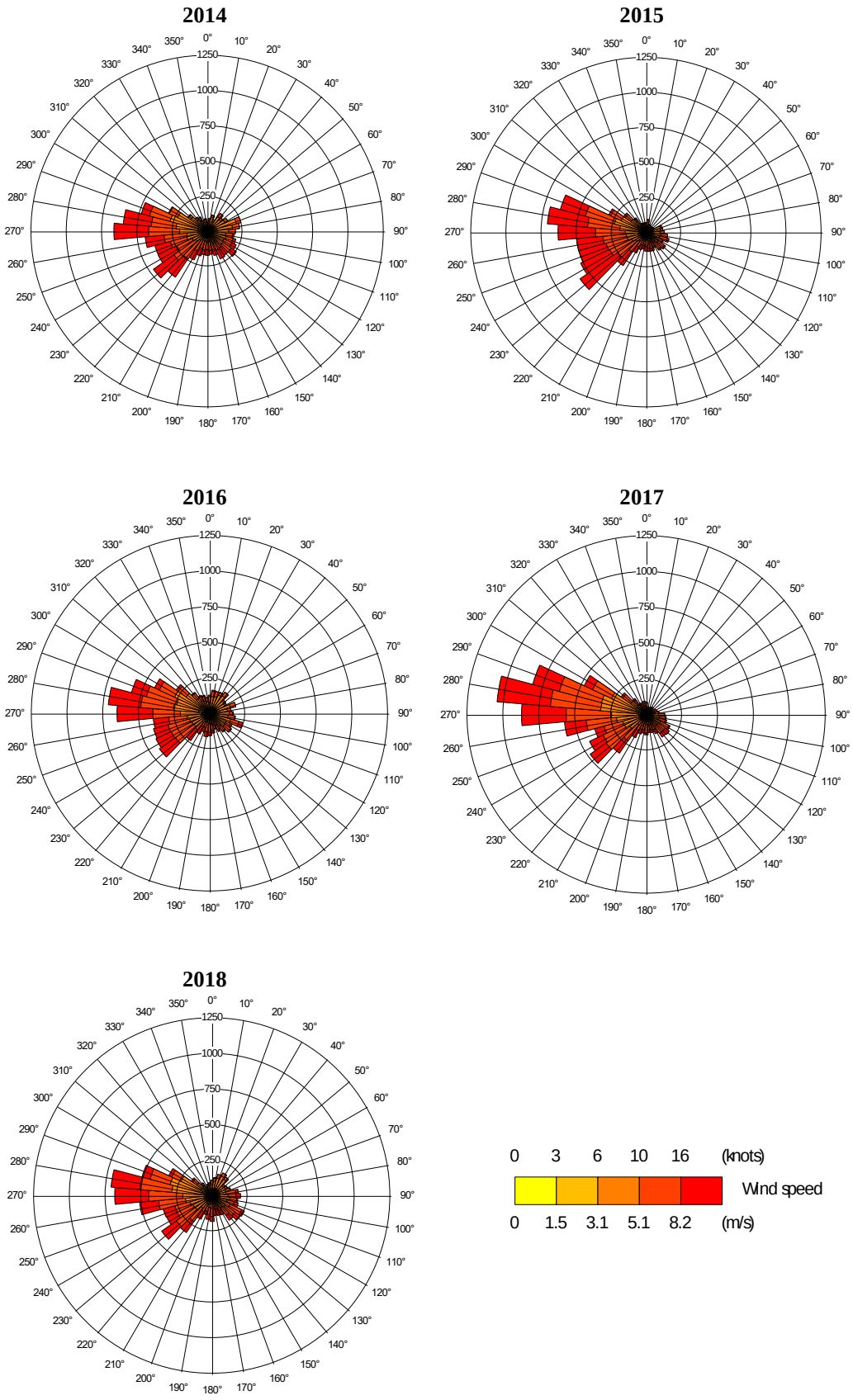
preferably 90%. Table 12 shows that each year of the meteorological data used includes enough useable data to correspond with more than 90% of the year, meeting the Defra guidance and are therefore suitable for dispersion modelling.

The windroses derived from the Emley Moor meteorological data are shown in Figure 4. They show the predominant wind direction is westerly.

Table 12: Useable lines of Emley Moor meteorological data (2014 to 2018)

Year	Number of lines of useable data	Total number of lines	% of usable data
2014	8,541	8,760	98
2015	8,610	8,760	98
2016	8,725	8,784	99
2017	8,668	8,760	99
2018	8,346	8,760	95

Figure 4: Windroses for Emley Moor (2014 to 2018)



3.2.2 Other model parameters

The extent of mechanical turbulence (and hence, mixing) in the atmosphere is affected by the roughness of the surface/ground over which the air is passing. Typical surface roughness values range from 0.0001m (for water or sandy deserts) to 1.5m (for cities, forests and industrial areas).

In this assessment, the general land use in the area around the site can be described as 'agricultural area max' with a corresponding surface roughness of 0.3m. The general land use in the area around the meterological station (Emley Moor) can be described as rural which is defined in ADMS as 'agricultural area min' with a corresponding surface roughness of 0.2m. The minimum Monin-Obukhov length was set 10m, described in the model as suitable for "small town <50,000".

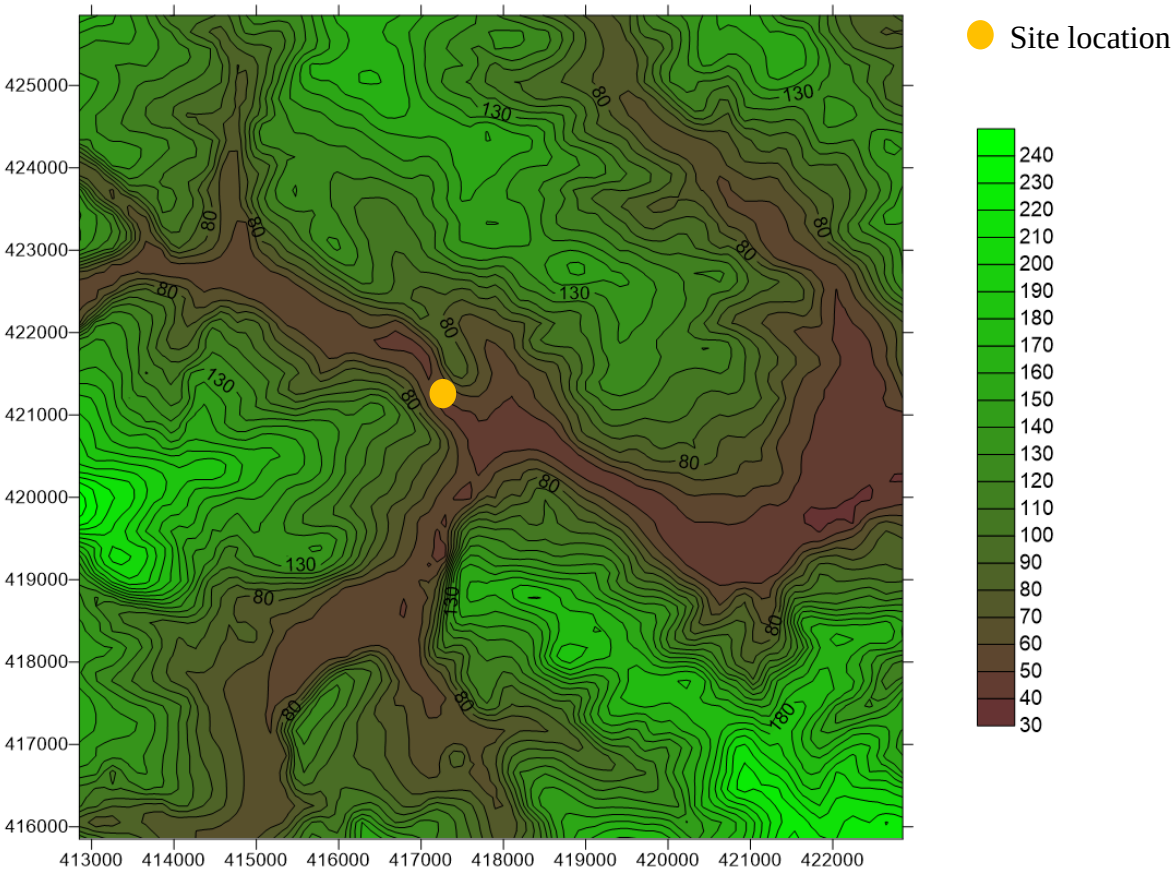
3.2.3 Time-varying emissions

A seasonal factor has been applied to adjust for seasonal variation in emission rates. All odour emission rates have been assumed to be reduced by 50% in the winter months (December to February inclusive). The seasonal adjustment reflects that odour emission rates from some processes are likely to vary with temperature and therefore be lower in cooler weather.

3.2.4 Complex terrain

A terrain file was created to assess the influence of terrain on predicted odour concentrations. The terrain file was generated over a 10km x 10km domain, 5km in each direction of the site. Figure 5 shows the heights in the terrain file; the site is located in the centre of the figure. The terrain file has been included in all assessment scenarios.

Figure 5: Modelled terrain heights (metres)



3.2.5 Study area and receptors

3.2.5.1 Study area

The study area for this assessment has been defined as a 2km x 2km domain centred on the Wastewater Treatment Works. This defined grid was used to produce the contours provided in Appendix A.

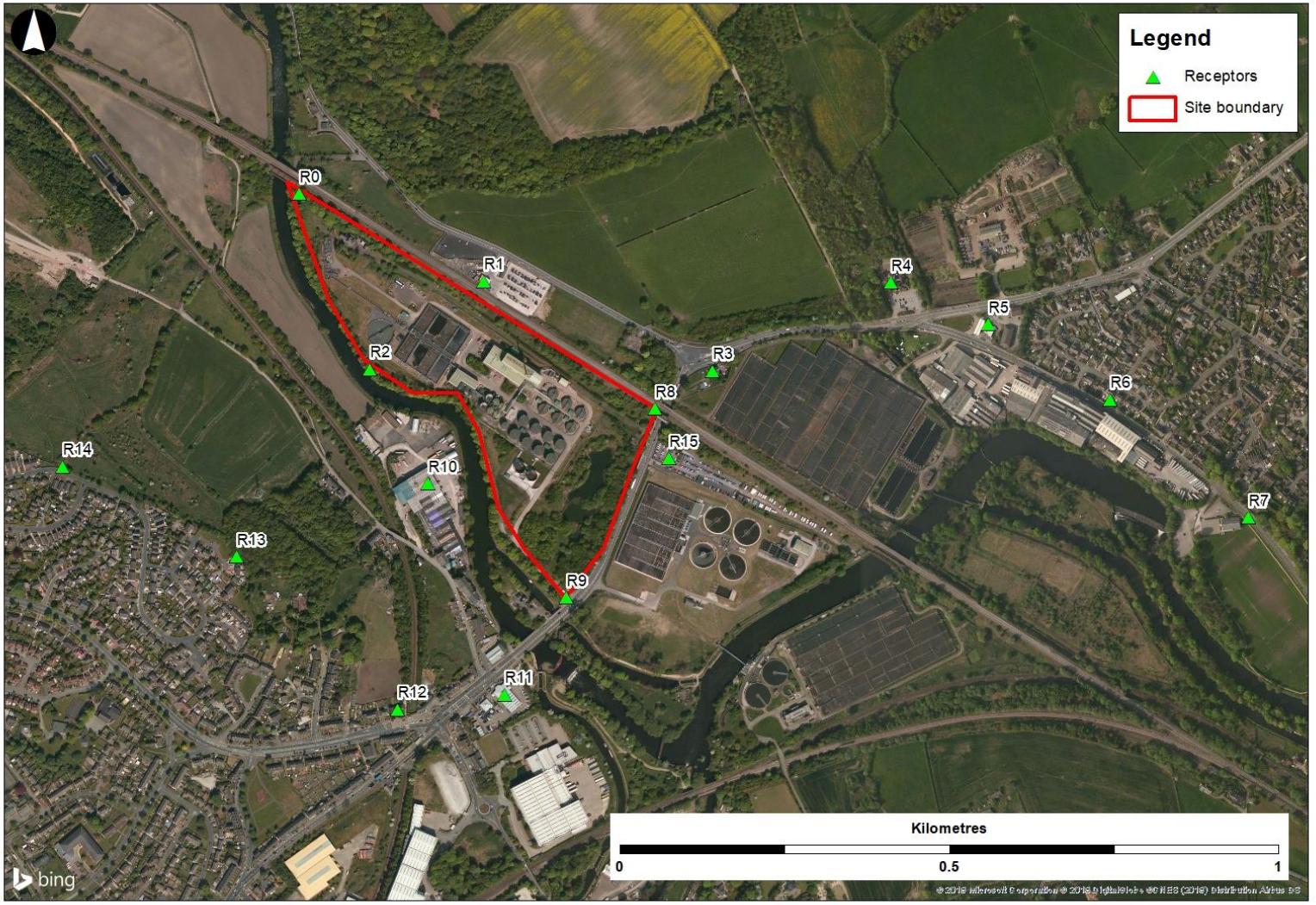
3.2.5.2 Discrete receptors

The receptors included in the detailed modelling were supplied by YW. They include receptors on the site boundary and at the closest residential and commercial (Other) locations. The locations of the receptors are given in Table 13 and are shown in Figure 6. The receptor sensitivity has been selected by following the IAQM guidance[9]. All residential receptors are considered high sensitivity receptors. They have all been modelled at a height of 1.5m corresponding to typical inhalation height for ground level receptors.

Table 13: Details of discrete receptors

Receptor ID	Description	Type	Receptor sensitivity	OS Grid Reference (m)		Height (m)
				X	Y	
R0	Site boundary - north	Boundary	Low	417242	421310	1.5
R1	Scrap yard	Other	Medium	417522	421177	1.5
R2	Site boundary - south-west	Boundary	Low	417350	421044	1.5
R3	Residential property A62	Residential	High	417870	421041	1.5
R4	Miller & Carter Mirfield	Other	Medium	418141	421175	1.5
R5	Three Nuns Service Station	Other	Medium	418288	421112	1.5
R6	Residential Property A644	Residential	High	418473	420998	1.5
R7	The Radcliff Residential Home	Residential	High	418683	420819	1.5
R8	Site boundary - east	Boundary	Low	417783	420984	1.5
R9	Site boundary - south	Boundary	Low	417647	420697	1.5
R10	Light industrial mill and warehouses	Other	Medium	417438	420871	1.5
R11	Residential and commercial properties	Residential	High	417554	420550	1.5
R12	Residential properties on Bradley Road	Residential	High	417392	420528	1.5
R13	Residential properties on Woodlands close	Residential	High	417147	420760	1.5
R14	Residential properties on Park Lea Road	Residential	High	416884	420896	1.5
R15	Car sales yard	Other	Medium	417804	420908	1.5

Figure 6: Discrete receptor locations



4 Results

The predicted 98th percentile hourly odour concentrations at all receptors for each assessment scenario and year of meteorological data have been modelled. The maximum predicted concentrations (for the years 2014 to 2018) at all receptors for each assessment scenario are shown in Table 14. Tables A1 to A4 in Appendix A present the complete results for the base case and the project cases.

Base case

In base case 1, the maximum predicted odour concentration was 23.8ou$_E$/m^3, which was predicted at a low sensitivity receptor (R0 on the northern site boundary). The maximum predicted odour concentration at a high sensitivity receptor was 6.5ou$_E$/m^3 at R3, on the A62.

In base case 2, the maximum predicted odour concentration was 9.9ou$_E$/m^3, which was predicted at a low sensitivity receptor (R8 on the eastern site boundary). The maximum predicted odour concentration at a high sensitivity receptor was 4.4ou$_E$/m^3 at R3, on the A62.

Future

In project case 1, the maximum predicted odour concentration was 23.9ou$_E$/m^3, which was predicted at a low sensitivity receptor (R0 on the northern site boundary). The maximum predicted odour concentration at a high sensitivity receptor was 5.0ou$_E$/m^3 at R3, on the A62. The concentration at R3 reduced by 1.5ou$_E$/m^3 (slight beneficial) as a result of the scheme. Receptor R1 is also predicted to experience a slight beneficial improvement with a 4.8ou$_E$/m^3 reduction.

In project case 2, the maximum predicted odour concentration was 8.0ou$_E$/m^3, which was predicted at a medium sensitivity receptor (R15, the car sales yard). The maximum predicted odour concentration at a high sensitivity receptor was 3.4ou$_E$/m^3 at R3, residential property on A62. The concentration at R3 reduced by 1.0ou$_E$/m^3 (which is an improvement but is considered negligible following IAQM guidance) as a result of the scheme. Receptor R1 is predicted to experience a moderate beneficial improvement with a 5.8ou$_E$/m^3 reduction.

Table 14 shows that at all discrete receptors there is a negligible or beneficial impact between the base case and comparative project case.

Figures A1 to A4 in Appendix A show the contours of odour concentrations at ground level (1.5m) for the years giving the highest concentrations: 2014 for base cases 1 and 2, 2016 for project case 1 and 2015 for project case 2. The 1.5ou$_E$/m^3, 3ou$_E$/m^3 and 5ou$_E$/m^3 contours are shown as dark blue, light blue and green respectively.

Table 14: Maximum predicted odour concentrations (from 2014 to 2018) at each receptor for all assessment scenarios (ou_E/m^3)

Receptor ID	Receptor sensitivity	Maximum 98th percentile odour concentration for all sources (ou_E/m^3)			Impact descriptor for all sources	Maximum 98th percentile odour concentration for STF sources (ou_E/m^3)			Impact descriptor for all sources in STF
		Base case 1	Project case 1	Change		Base case 2	Project case 2	Change	
R0	Low	23.8	23.9	0.1	Negligible	3.0	1.5	-1.5	Negligible
R1	Medium	15.7	11.0	-4.8	Slight beneficial	9.7	3.9	-5.8	Moderate beneficial
R2	Low	13.7	10.8	-2.9	Negligible	5.8	5.5	-0.2	Negligible
R3	High	6.5	5.0	-1.5	Slight beneficial	4.4	3.4	-1.0	Negligible
R4	Medium	2.5	2.0	-0.6	Negligible	1.3	1.2	-0.1	Negligible
R5	Medium	1.8	1.6	-0.2	Negligible	1.0	0.8	-0.2	Negligible
R6	High	1.4	1.1	-0.3	Negligible	0.9	0.6	-0.3	Negligible
R7	High	1.0	0.9	-0.1	Negligible	0.6	0.5	-0.2	Negligible
R8	Low	12.2	8.5	-3.7	Negligible	9.9	6.5	-3.4	Negligible
R9	Low	3.3	4.1	0.8	Negligible	2.5	3.1	0.6	Negligible
R10	Medium	8.8	8.1	-0.7	Negligible	6.6	6.5	-0.1	Negligible
R11	High	2.0	2.5	0.4	Negligible	1.6	1.8	0.1	Negligible
R12	High	1.7	1.9	0.2	Negligible	1.0	1.4	0.3	Negligible
R13	High	1.8	1.7	-0.1	Negligible	0.7	0.9	0.2	Negligible
R14	High	1.0	1.0	-0.1	Negligible	0.3	0.4	0.1	Negligible
R15	Medium	10.9	9.6	-1.3	Negligible	8.5	8.0	-0.6	Negligible

5 Conclusions

Odour emissions

The assessment scenarios are two base case scenarios of existing sources and two future scenarios. The modelling scenarios are in pairs, with one pair including all sources and the second including only the STF assets.

The total average odour emission rate (averaged over a day) for each scenario are:

Base case

- Base case 1 (all existing sources): 126,945ou_E/s;
- Base case 2 (STF assets only): 66,667 ou_E/s;

Future 1

- Project case 1 (all potential future sources): 126,511ou_E/s; and
- Project case 2 (STF assets only): 66,233ou_E/s.

In each of the future project cases, the emissions from all sources are essentially the same as the emissions from all sources in their comparative base cases.

Predicted odour concentrations

The results show that the maximum predicted odour concentrations for project cases 1 and 2 are lower than the base cases at the most affected residential properties (high sensitivity receptors). The final results can be summarised as follows:

Base case

- Base case 1, the maximum predicted odour concentration at a high sensitivity receptor was 6.5ou_E/m^3 at R3, on the A62.
- Base case 2, the maximum predicted odour concentration at a high sensitivity receptor was 4.4ou_E/m^3 at R3, on the A62.

Future

- Project case 1, the maximum predicted odour concentration at a high sesnsitvy receptor was 5.0ou_E/m^3 at R3, on the A62, where a reduction of 1.5ou_E/m^3 is experienced.
- Project case 2: the maximum predicted odour concentration at a high sensitivity receptor was 3.4ou_E/m^3 at R3, residential property on A62, where a reduction of 1.0ou_E/m^3 is experienced.

The modelling demonstrated there was a negligible or beneficial impact between the base case and comparative project case at all discrete receptors.

Appendix A

Predicted odour concentrations

A1 Predicted odour concentrations at receptors

Table A1: Base case 1 predicted odour concentrations (ou_E/m^3)

Receptor ID	Description	Receptor sensitivity	OS grid reference (m)		98th percentile odour concentration (ou_E/m^3)					
			X	Y	2014	2015	2016	2017	2018	Maximum
R0	Site boundary - north	Low	417242	421310	23.8	18.1	20.9	18.8	18.6	23.8
R1	Scrap yard	Medium	417522	421177	15.7	13.5	13.4	12.9	12.9	15.7
R2	Site boundary - south-west	Low	417350	421044	13.7	11.8	12.8	6.6	11.1	13.7
R3	Residential property A62	High	417870	421041	6.0	6.5	5.7	5.8	5.9	6.5
R4	Miller & Carter Mirfield	Medium	418141	421175	1.9	2.5	1.9	1.8	2.0	2.5
R5	Three Nuns Service Station	Medium	418288	421112	1.7	1.8	1.4	1.5	1.5	1.8
R6	Residential Property A644	High	418473	420998	1.2	1.3	1.2	1.4	1.4	1.4
R7	The Radcliff Residential Home	High	418683	420819	0.7	0.8	0.8	0.8	1.0	1.0
R8	Site boundary - east	Low	417783	420984	12.0	12.2	11.8	10.9	12.1	12.2
R9	Site boundary - south	Low	417647	420697	3.0	2.9	3.3	1.9	2.8	3.3
R10	Light industrial mill and warehouses	Medium	417438	420871	7.6	4.5	8.8	2.8	6.7	8.8
R11	Residential and commercial properties	High	417554	420550	1.6	1.5	2.0	0.9	1.8	2.0
R12	Bradley Road residential properties	High	417392	420528	1.3	1.0	1.7	0.6	1.5	1.7
R13	Woodlands close residential properties	High	417147	420760	1.7	0.9	1.8	0.7	1.3	1.8
R14	Park Lea Road residential properties	High	416884	420896	1.0	0.6	0.9	0.4	0.6	1.0
R15	Car sales yard	Medium	417804	420908	10.9	9.9	9.8	8.7	9.2	10.9

Table A2: Base case 2 predicted odour concentrations (ou_E/m^3)

Receptor ID	Description	Receptor sensitivity	OS grid reference (m)		98th percentile odour concentration (ou_E/m^3)					
			X	Y	2014	2015	2016	2017	2018	Maximum
R0	Site boundary - north	Low	417242	421310	3.0	2.5	2.4	2.1	2.3	3.0
R1	Scrap yard	Medium	417522	421177	9.7	6.4	8.3	7.8	7.1	9.7
R2	Site boundary - south-west	Low	417350	421044	5.8	4.6	5.5	3.6	4.4	5.8
R3	Residential property A62	High	417870	421041	4.0	4.4	3.8	4.1	3.9	4.4
R4	Miller & Carter Mirfield	Medium	418141	421175	1.1	1.3	1.1	1.1	1.2	1.3
R5	Three Nuns Service Station	Medium	418288	421112	0.8	1.0	0.7	0.8	0.8	1.0
R6	Residential Property A644	High	418473	420998	0.6	0.7	0.7	0.9	0.7	0.9
R7	The Radcliff Residential Home	High	418683	420819	0.4	0.5	0.5	0.5	0.6	0.6
R8	Site boundary - east	Low	417783	420984	9.2	9.7	9.4	9.2	9.9	9.9
R9	Site boundary - south	Low	417647	420697	1.9	2.1	2.5	1.3	2.2	2.5
R10	Light industrial mill and warehouses	Medium	417438	420871	5.7	2.7	6.6	2.1	4.6	6.6
R11	Residential and commercial properties	High	417554	420550	1.0	1.1	1.6	0.6	1.4	1.6
R12	Bradley Road residential properties	High	417392	420528	0.8	0.5	1.0	0.4	0.9	1.0
R13	Woodlands close residential properties	High	417147	420760	0.7	0.4	0.7	0.3	0.5	0.7
R14	Park Lea Road residential properties	High	416884	420896	0.3	0.2	0.3	0.1	0.2	0.3
R15	Car sales yard	Medium	417804	420908	8.5	7.7	7.6	7.2	7.4	8.5

Table A3: Project case 1 predicted odour concentrations (ou_E/m^3)

Receptor ID	Description	Receptor sensitivity	OS grid reference (m)		98th percentile odour concentration (ou_E/m^3)					
			X	Y	2014	2015	2016	2017	2018	Maximum
R0	Site boundary - north	Low	417242	421310	23.9	17.4	20.5	18.3	18.2	23.9
R1	Scrap yard	Medium	417522	421177	10.0	11.0	9.6	8.1	8.5	11.0
R2	Site boundary - south-west	Low	417350	421044	10.3	9.6	10.8	6.4	9.8	10.8
R3	Residential property A62	High	417870	421041	4.4	5.0	4.5	4.1	4.4	5.0
R4	Miller & Carter Mirfield	Medium	418141	421175	1.7	2.0	1.8	1.6	1.8	2.0
R5	Three Nuns Service Station	Medium	418288	421112	1.4	1.6	1.4	1.4	1.3	1.6
R6	Residential Property A644	High	418473	420998	1.1	1.1	1.1	1.1	1.1	1.1
R7	The Radcliff Residential Home	High	418683	420819	0.7	0.8	0.8	0.8	0.9	0.9
R8	Site boundary - east	Low	417783	420984	8.3	8.5	8.2	7.2	7.3	8.5
R9	Site boundary - south	Low	417647	420697	3.4	3.4	4.1	2.6	3.4	4.1
R10	Light industrial mill and warehouses	Medium	417438	420871	8.1	5.5	8.1	3.9	6.0	8.1
R11	Residential and commercial properties	High	417554	420550	2.0	1.9	2.5	1.1	2.0	2.5
R12	Bradley Road residential properties	High	417392	420528	1.6	1.1	1.9	0.7	1.7	1.9
R13	Woodlands close residential properties	High	417147	420760	1.6	1.0	1.7	0.7	1.2	1.7
R14	Park Lea Road residential properties	High	416884	420896	1.0	0.6	0.9	0.4	0.6	1.0
R15	Car sales yard	Medium	417804	420908	9.6	9.5	9.6	8.9	9.2	9.6

Table A4: Project case 2 predicted odour concentrations (ou_E/m^3)

Receptor ID	Description	Receptor sensitivity	OS grid reference (m)		98th percentile odour concentration (ou_E/m^3)					
			X	Y	2014	2015	2016	2017	2018	Maximum
R0	Site boundary - north	Low	417242	421310	1.5	1.3	1.2	1.2	1.4	1.5
R1	Scrap yard	Medium	417522	421177	3.8	3.0	3.9	3.6	3.2	3.9
R2	Site boundary - south-west	Low	417350	421044	5.5	4.5	4.6	3.7	4.5	5.5
R3	Residential property A62	High	417870	421041	2.9	3.4	3.2	3.0	3.1	3.4
R4	Miller & Carter Mirfield	Medium	418141	421175	0.9	1.2	1.0	0.9	1.0	1.2
R5	Three Nuns Service Station	Medium	418288	421112	0.7	0.8	0.7	0.7	0.7	0.8
R6	Residential Property A644	High	418473	420998	0.5	0.6	0.5	0.6	0.6	0.6
R7	The Radcliff Residential Home	High	418683	420819	0.4	0.4	0.4	0.5	0.5	0.5
R8	Site boundary - east	Low	417783	420984	5.8	6.5	6.2	6.1	6.1	6.5
R9	Site boundary - south	Low	417647	420697	2.5	2.5	3.1	2.1	2.8	3.1
R10	Light industrial mill and warehouses	Medium	417438	420871	6.5	4.5	6.3	3.4	5.1	6.5
R11	Residential and commercial properties	High	417554	420550	1.2	1.3	1.8	0.8	1.4	1.8
R12	Bradley Road residential properties	High	417392	420528	1.1	0.7	1.4	0.5	1.1	1.4
R13	Woodlands close residential properties	High	417147	420760	0.9	0.6	0.9	0.4	0.6	0.9
R14	Park Lea Road residential properties	High	416884	420896	0.4	0.3	0.4	0.2	0.3	0.4
R15	Car sales yard	Medium	417804	420908	7.4	8.0	7.6	7.3	7.5	8.0

A2 Contours of predicted odour concentrations

Figure A 1: Base case 1 predicted odour concentrations (ou_E/m^3) at ground level (1.5m) in 2014

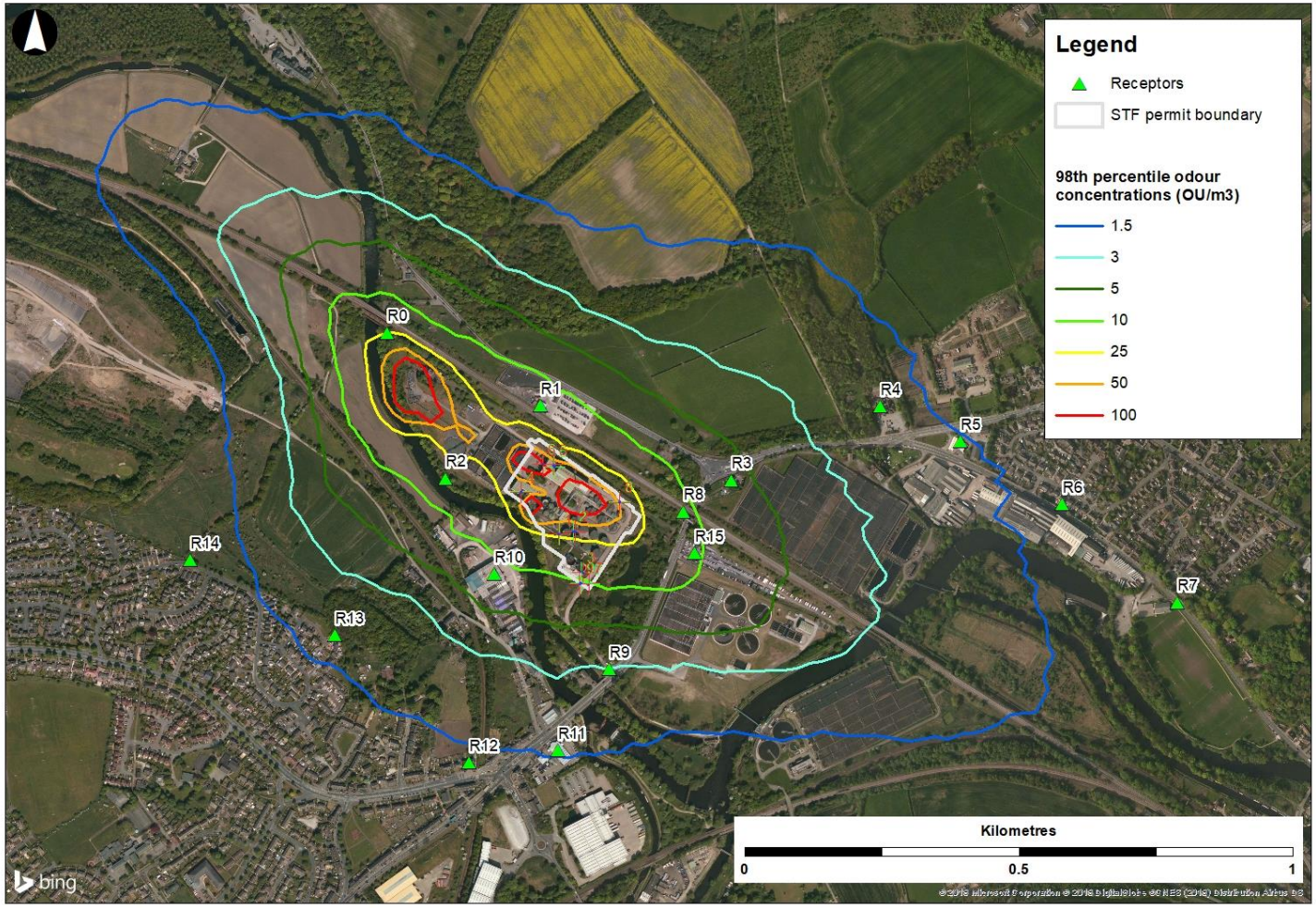


Figure A 2: Base case 2 predicted odour concentrations (ou_E/m^3) at ground level (1.5m) in 2014

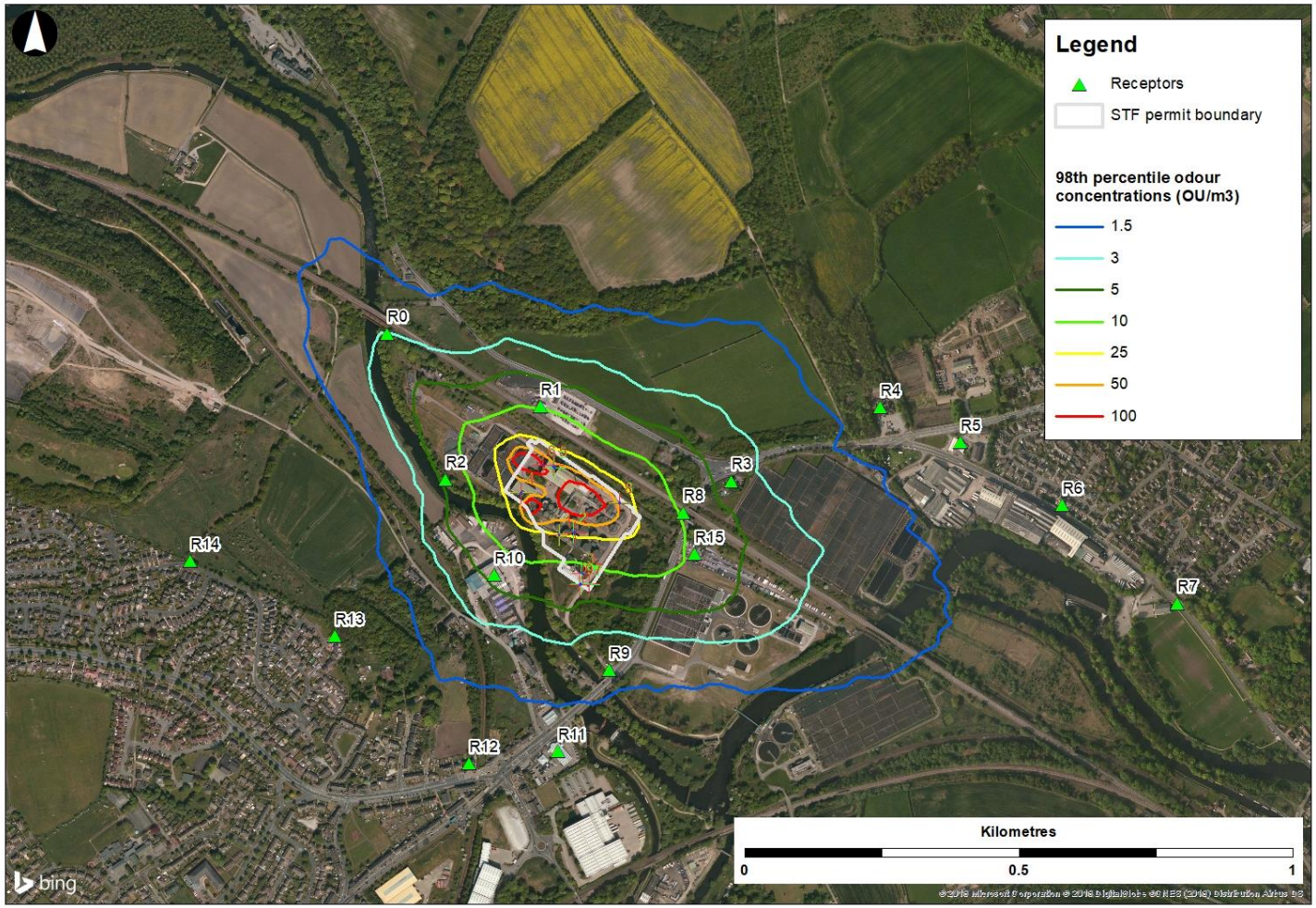


Figure A 3: Project case 1 predicted odour concentrations (ou_E/m^3) at ground level (1.5m) in 2016

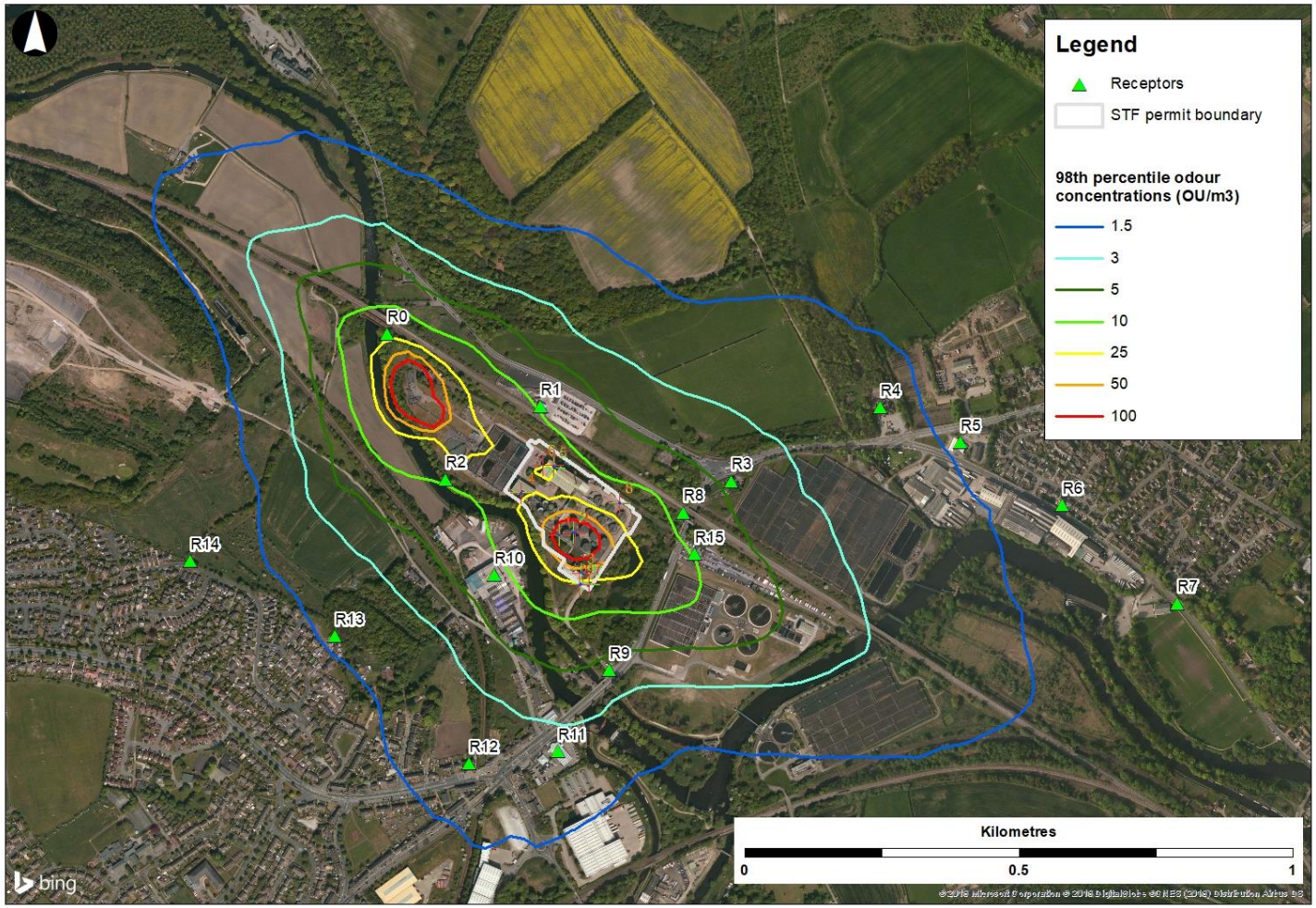


Figure A 4: Project case 2 predicted odour concentrations (ou_E/m^3) at ground level (1.5m) in 2015