Environmental Permit Application - Hayden Sewage Treatment Works

Air Quality Impact Assessment

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Severn Trent Water Limited

Environmental Permit Application - Hayden Sewage Treatment Works

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Document history and status

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Contents

Executive Summary

Under the Industrial Emissions Directive (IED) the existing anaerobic digestion assets at Hayden Sewage Treatment Works (STW) require an Environmental Permit (EP). The scope of anaerobic digestion activities includes all treatment stages and incorporates directly associated activities such as a combined heat and power (CHP) gas engine and boilers.

Severn Trent Water Limited operate a STW near the town of Cheltenham, (GL51 0FJ). These operations include one existing ENER-G 499B CHP engine (with a thermal input capacity of 1.3 MW_{th}) and two existing Strebel boilers (each with a thermal input capacity of 0.8 MW_{th}).

Assessed Combustion Plant

Medium Combustion Plant (MCP) Information			
MCP specific identifier*	Hayden- CHP 1	Hayden – Boiler 1	Hayden – Boiler 2
12-digit grid reference or latitude/longitude	E 390623 N 223034	E 390646 N 223042	E 390661 N 223033
Rated thermal input (MW) of the MCP	1.3	0.8	0.8
Type of MCP (diesel engine, gas turbine, other engine or other MCP)	Gas engine	Boiler	Boiler
Type of fuels used: gas oil (diesel), natural gas, gaseous fuels other than natural gas	Biogas	Dual fuelled (biogas / gas-oil). Modelled with biogas.	Dual fuelled (biogas / gas-oil). Modelled with biogas.
Date when the new MCP was first put into operation (DD/MM/YYYY)	20/03/2018	Pre 2010	Pre 2010
Sector of activity of the MCP or the facility in which it is applied (NACE code**)	E.37.00	E.37.00	E.37.00
Expected number of annual operating hours of the MCP and average load in use	8,760 (modelled)	8,760 (modelled)	8,760 (modelled)
Where the option of exemption under Article 6(8) is used the operator (as identified on Form A) should sign a declaration here that the MCP will not be operated more than the number of hours referred to in this paragraph	N / A	N / A	N / A

The Environmental Permit application is collated to include the required forms: Part A, B2.5 and F1. As the site has a CHP engine, the information required to complete Appendix 1 of application form Part B2.5 is included within this document.

The Air Quality Impact Assessment presented within this report is required to support the EP application and assesses the potential for significant air quality effects from the operation of the CHP engine and boilers at the Hayden STW.

The potential impacts were determined for the following aspects.

- The potential impact on human health due to emissions of pollutants. The pollutants considered include nitrogen dioxide (NO_2); carbon monoxide (CO); sulphur dioxide (SO_2), total volatile organic compounds (TVOC's) and particulate matter (PM_{10}, particles with an aerodynamic diameter of 10 microns or less and $PM_{2.5}$, particles with an aerodynamic diameter of 2.5 microns or less).
- The potential impact on vegetation and ecosystems due to emissions of oxides of nitrogen (NOx) and SO_2.

This assessment has been carried out on the assumption that the CHP engine would operate continuously at maximum load throughout the year (i.e. 8,760 hours) and the boilers will operate simultaneously for 1,500 hours per year. In practice, the boilers only ever operate simultaneously when the CHP engine is not operating. Furthermore, during the summer months, the boilers rarely operate and during the winter months, only one boiler is operational for approximately 12 hours each day. Furthermore, the assessed plant may not always operate at maximum load.

Human receptors

The assessment indicates that the predicted modelled off-site concentrations and predicted concentrations at sensitive human receptors do not exceed any relevant long-term or short-term air quality objective or guideline. At sensitive human receptor locations, the predicted long-term (i.e. annual mean) NO_2 and particulate (PM_{10} and $PM_{2.5}$) contributions are considered 'not significant'. For short-term NO_2, PM_{10}, SO_2 and CO concentrations at modelled off-site locations and sensitive human receptor locations, the contributions are also considered 'not significant'.

In the absence of an Environmental Quality Standard (EQS) for TVOC's, comparison of the annual mean and 24-hour mean predicted concentrations have been made against the annual mean and 24-hour mean environmental quality standard for benzene (C_6H_6). This represents a worst-case scenario for VOCs because it assumes all VOC contributions comprise benzene. For annual mean and maximum 24-hour mean TVOC concentrations at a sensitive human receptor location, the respective PECs exceed the relevant standard for benzene.

However, TVOC emissions from the assessed combustion plant will largely comprise unburnt methane gas from the biogas fuel (up to 75% composition (Naskeo Environment, 2009)), which is not directly harmful to human health. If the contribution of methane (CH_4) is removed from the process contribution, there would be no exceedance of the relevant standard. Therefore, when considering the conservative approach to the assessment and based on professional judgement, the contribution of TVOC's is considered 'not significant'.

This assessment has been carried out on the assumption that the CHP engine and boilers would operate continuously at maximum load throughout the year (i.e. 8,760 hours). However, the boilers are unlikely to operate simultaneously and for more than 6,000 hours per year. Furthermore, the assessed plant may not always operate at maximum load.

Protected conservation areas

For critical levels at the assessed Cotswold Beechwoods Special Area of Conservation (SAC), the results indicate that the annual mean NOx and SO_2 PCs are less than 1% of the long-term environmental standard and the impact can be described as 'insignificant' as per Environment Agency guidance (Environment Agency, 2021a).

For the 24-hour mean critical level for NOx, the results indicate that the short-term NOx PC is less than 10%, of the short-term environmental standard and can be described as 'insignificant'. The conservative approach adopted throughout this assessment means that, based on professional judgement, it is not considered likely that there would be unacceptable impacts to air quality at the assessed Cotswold Beechwoods SAC as a consequence of the operation of the assessed CHP engine and boilers with regard to ambient concentrations of NOx and SO_2.

For acid deposition and nutrient nitrogen deposition, the results indicate that at the assessed Cotswold Beechwoods SAC, the respective PCs are less than 1% of the long-term environmental standard for protected conservation areas and the impact can be described as 'insignificant' as per Environment Agency guidance (Environment Agency, 2021a).

As discussed above, the conservative approach adopted for this assessment means the predicted concentrations presented are likely to be higher than would reasonably be expected.

Summary

Based on the above assessment, it is concluded that the assessed CHP engine and boilers are acceptable from an air quality perspective.

1. Introduction

1.1 Background

Under the Industrial Emissions Directive (IED)[1] the anaerobic digestion assets at Hayden Sewage Treatment Works (STW) are required to be included in an Environmental Permit (EP). The scope of anaerobic digestion activities includes all treatment stages and incorporates directly associated activities such as a combined heat and power (CHP) gas engine and boilers.

Severn Trent Water Limited (hereafter 'Severn Trent') currently operates one biogas fuelled ENER-G 499B CHP engine (with a thermal input capacity of 1.3 MW_{th}) and two duel-fuelled[2] Strebel boilers (each with thermal input capacity of 0.8 MW_{th}) at the Hayden STW (GL51 0FJ) (hereafter 'the site'). Jacobs UK Limited (hereafter 'Jacobs') has carried out an Air Quality Impact Assessment (AQIA) on behalf of Severn Trent to assess the potential impact of emissions from the existing CHP engine and boilers.

1.2 Study Outline

This AQIA is required to support the EP application and assesses the likely significant air quality effects of emissions to air from the CHP engine and boilers at the site. The air quality assessment has been carried out following the relevant Environment Agency guidance (Environment Agency, 2021a; 2021b). The AQIA considers the following.

- The potential impact on human health due to emissions of pollutants. The pollutants considered include nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), total volatile organic compounds (TVOC's) and particulate matter (PM_{10}, particles with an aerodynamic diameter of 10 microns or less and $PM_{2.5}$, particles with an aerodynamic diameter of 2.5 microns or less).
- The potential impact on vegetation and ecosystems due to emissions of oxides of nitrogen (NOx) and SO_2.

In order to support the Medium Combustion Plant Directive (MCPD) EU/2015/2193[3] and Specified Generators (Schedule 25A and 25B) Environment Permit (EP) application, the site was previously modelled in 2018. The previous assessment only considered the existing CHP engine. This assessment now includes the existing on-site boilers.

The site boundary (represented by the approximate site fenceline) is presented in Figure 1.

This report draws upon information provided from the following parties:

- Severn Trent;
- ADM Ltd;
- Centre for Ecology and Hydrology (CEH);
- Centrica Business Solutions (Centrica)
- Tewkesbury Borough Council (TBC);
- Cheltenham Borough Council (CBC); and
- Department for Environment, Food and Rural Affairs (Defra).

This report includes a description of the emission sources, description of methodology and significance criteria, a review of the baseline conditions including an exploration of the existing environment of the site and

[1] European Directive 2010/75/EU.
2 Dual fuelled utilising biogas (primary fuel) or gas-oil.
[3] European Parliament and the Council of the European Union, Medium Combustion Plant Directive EU/2015/2193 of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants.

surrounding area, an evaluation of results and the potential impact of emissions on human health and protected conservation areas during operation and, finally, conclusions of the assessment.

2. Emission Sources

2.1 Emission Sources to Air

The location of the assessed CHP engine (emission point reference A1) and boilers (emission point reference A2 and A3) are presented in Figure 1.

The CHP engine and boilers (when utilising biogas) are fuelled by biogas generated from the sites' anaerobic digestion process and emissions were modelled on this basis. As discussed previously, the boilers are a dual-fuel design and can run on biogas or gas-oil. However, for this assessment they have been modelled utilising biogas as this gives a worst-case scenario for emissions of NOx, typically the pollutant of main concern. The modelling only considers emissions from the CHP engine and boilers and no other emission points to air at the site have been included in the assessment.

Table 1 presents the emission sources to air considered in this assessment.

Table 1: Combustion plant to be assessed

Parameters	ENER-G 499B CHP engine (1.3 MW_{th})	Strebel boiler (0.8 MW_{th})	Strebel boiler (0.8 MW_{th})
Modelled fuel	Biogas	Biogas	Biogas
Emission point	A1	A2	A3

This assessment has been carried out on the assumption that the CHP engine and boilers would operate continuously at maximum load throughout the year (i.e. 8,760 hours). This is a conservative assumption as, in practice, the CHP engine will have periods of shut-down and maintenance and may not always operate at maximum load. Furthermore, the boilers are unlikely to operate simultaneously and for more than 6,000 hours per year. This approach ensures that the worst-case or maximum long-term and short-term modelled concentrations are quantified (further consideration of this is provided in Appendix A).

2.2 Emissions Data

It should be noted from the 1st January 2030, certain pollutant emission concentrations from the assessed combustion plant must adhere to emission concentration limits as set out in the Medium Combustion Plant Directive (MCPD) EU/2015/2193[3] (European Union, 2015) and as transposed into Schedule 25A of The Environmental Permitting (England and Wales) (Amendment) Regulations 2018 (UK Government, 2018).

For the assessed CHP engine, the NOx, CO and TVOC emission concentrations were derived from the Environment Agency's '*Guidance for monitoring landfill gas engine emissions*' (Environment Agency, 2010). For SO_2, in the absence of a specific emission limit value, the SO_2 emission concentration typically used in similar permit applications for biogas fuelled engines has been applied. This is a conservative approach to the assessment as in practice, the SO_2 emission concentration is likely to be lower than that applied in the model. For particulates, in the absence of a specific emission limit value, the emission concentration was derived from a previous study of landfill gas engines (Land Quality Management Ltd, 2002).

For the boilers, as a worst-case approach to the assessment, the modelled NOx and SO_2 emission concentration are based on the respective emission limit value for existing MCP other than engines and gas turbines as regulated under the MCPD[3]. For CO and TVOC, in the absence of a specific emission limit value, the CO emission concentration was obtained from Defra's Process Guidance Note 1/3, *'Statutory Guidance for Boilers and Furnaces 20-50MW thermal input'* (Defra, 2012) and the TVOC emission concentration was derived from the Environment Agency's '*Guidance for monitoring landfill gas engine emissions*' (Environment Agency, 2010).

For the assessed CHP engine, the exhaust gas volumetric flow and exhaust gas temperature were obtained from the ENER-G 499B biogas engine Technical Datasheet (Centrica, 2018). In the absence of information regarding oxygen and moisture content, the data used in the model is based on professional judgment acquired from previous work involving biogas fuelled CHP engines of a similar thermal input capacity.

For the boilers, the exhaust gas volumetric flow was determined using stoichiometric calculations based on the combustion of biogas at the maximum thermal input rating of the respective boiler. In the absence of information regarding temperature, oxygen and moisture content of the boilers, the data used in the model is based on professional judgement acquired from previous work involving biogas fuelled boilers of a similar thermal input capacity.

The emissions inventory of releases to air from the CHP engine and boilers is provided in Appendix A.

3. Assessment Methodology

This section presents a summary of the methodology used for the assessment of the potential impacts of the site. A full description of the study inputs and assumptions are provided in Appendix A.

3.1 Assessment Location

For this assessment, 20 of the closest sensitive human receptors (such as residential properties, schools, residential care homes and Public Rights of Way (PRoW)) near the site were identified for modelling purposes. The location of these receptors are presented in Figure 2. Furthermore, the nearby Cheltenham Whole Borough Air Quality Management Area (AQMA) (see Section 4.2) was also considered in the assessment.

In line with the Environment Agency guidance '*Air emissions risk assessment for your environmental permit*' (Environment Agency, 2021a), it is necessary to identify protected conservation areas within the following distances from the site:

- European sites (i.e. Special Area of Conservation (SAC), Special Protection Area (SPA) and Ramsar sites) within 10 km; and
- Site of Special Scientific Interest (SSSI) and local nature sites (i.e. ancient woodlands, local wildlife sites (LWS) and national and local nature reserves (NNR and LNR)) within 2 km.

Based on these criteria, Cotswold Beechwoods SAC has been included in the assessment. No other protected conservation areas have been identified within this distances.

The location of the assessed protected conservation area is presented in Figure 3 and further details are set out in Appendix A.

3.2 Overall Methodology

The assessment was carried out using an atmospheric dispersion modelling technique. Atmospheric Dispersion Modelling System (ADMS) version 5.2.4 was used to model releases of the identified substances. The ADMS model predicts the dispersion of operational emissions from a specific source (e.g. a stack), and the subsequent concentrations over an identified area (e.g. at ground level across a grid of receptor points) or at specified points (e.g. a residential property). ADMS was selected because this model is fit for the purpose of modelling the emissions from the type of sources on-site (i.e. point source emissions from a combustion source) and is accepted as a suitable assessment tool by local authorities and the Environment Agency.

The modelling assessment was undertaken in accordance with the Environment Agency guidance '*Air emissions risk assessment for your environmental permit*' (Environment Agency, 2021a).

A summary of the dispersion modelling procedure is set out below.

1) Information on plant location and stack parameters were supplied by Severn Trent (Severn Trent, 2022). Information on the CHP engine and the boilers were obtained from various sources as described in Section 2.2.
2) Five years of hourly sequential data recorded at the Pershore meteorological station (2016 – 2020 inclusive) were used for the assessment (ADM Ltd, 2022).
3) Information on the main buildings located on-site, which could influence dispersion of emissions from the CHP engine and boiler stacks, were estimated from Defra's environmental open-data applications and datasets (Defra, 2022a) and Google Earth (Google Earth, 2022).
4) The maximum predicted concentrations (at a modelled height of 1.5 m or 'breathing zone') at the assessed sensitive human receptor locations R1 – R15 (representing long-term exposure at residential properties) were considered for the assessment of annual mean, 24-hour mean, 8-hour mean, 1-hour mean and 15-minute mean pollutant concentrations within the study area. For receptors R16 – R20 (representing a

PRoW), only the 1-hour mean and 15-minute mean concentrations were considered. The maximum predicted concentrations at an off-site location in the vicinity of the site were considered for the assessment of short-term (1-hour and 15-minute mean) concentrations. Furthermore, the nearby Cheltenham Whole Borough AQMA (see Section 4.2) was considered for predicted annual mean NO_2 concentrations only.

5) The above information was entered into the dispersion model.

6) The dispersion model was run to provide the Process Contribution (PC). The PC is the estimated maximum environmental concentration of substances due to releases from the process alone. The results were then combined with baseline concentrations (see Section 4) to provide the total Predicted Environmental Concentration (PEC) of the substances of interest.

7) The PECs were then assessed against the appropriate environmental standards for air emissions for each substance set out in the Environment Agency's guidance (Environment Agency, 2021a) document to determine the nature and extent of any potential adverse effects.

8) Modelled concentrations were processed using geographic information system (GIS) software (ArcMap 10.8.1) to produce contour plots of the model results. These are provided for illustrative purposes only; assessment of the model results was based on the numerical values outputted by the dispersion model on the model grid (see Figure 2) and at the specific receptor locations and were processed using Microsoft Excel.

9) The predicted concentrations of NOx and SO_2 (at ground level) were also used to assess the potential impact on critical levels and critical loads (i.e. acid and nutrient nitrogen deposition) (see Section 3.3.2) at the assessed protected conservation area. Details of the deposition assessment methodology are provided in Appendix B.

In addition to the above, a review of existing ambient air quality in the area was undertaken to understand the baseline conditions at the site and at receptors within the study area. These existing conditions were determined by reviewing the monitoring data already available for the area and other relevant sources of information. The review of baseline air quality is set out in Section 4.

Where appropriate, a conservative approach has been adopted throughout the assessment to increase the robustness of the model predictions. In addition, an analysis of various sensitivity scenarios has also been carried out (see Section 5.3) to determine how changes to model parameters (e.g. differing surface roughness values or modelling without considering buildings) may impact on predicted concentrations at sensitive human receptors and off-site locations.

3.3 Assessment Criteria

3.3.1 Environmental Quality Standards: Human Receptors

In the UK, the focus on local air quality is reflected in the air quality objectives (AQOs) set out in the *Air Quality Strategy for England, Scotland, Wales and Northern Ireland* (AQS) (Defra and the Devolved Administrations, 2007). The AQS stipulates a number of air quality objectives for nine main air pollutants with respect to ambient levels of air quality (Defra, 2007). The AQOs are similar to the limit values that were transposed from the relevant EU directives into UK legislation by *The Air Quality Standards Regulations 2010* (UK Government, 2010). The objectives are based on the current understanding of health effects of exposure to air pollutants and have been specified to control health and environmental risks to an acceptable level. They apply to places where people are regularly present over the relevant averaging period. The objectives set for the protection of human health and vegetation of relevance to the project are summarised in Table 2. Relevant Environmental Assessment Levels (EALs) set out in the Environment Agency guidance (Environment Agency, 2021a) are also included in Table 2 where these supplement the AQOs.

For the purposes of reporting, the AQOs and EALs have been collectively termed as Environmental Quality Standards (EQSs).

Table 2: Air quality objectives and environmental assessment levels

Pollutant	EQS (µg/m³)	Concentration measured as
NO_2	40	Annual mean
	200	1-hour mean, not to be exceeded more than 18 times a year (99.79th percentile)
CO	10,000	Maximum daily 8 hour running mean (100th percentile)
	30,000	Maximum 1-hour mean (100th percentile)
SO_2	125	24-hour mean not to be exceeded more than 3 times a year (99.18th percentile)
	350	1-hour mean not to be exceeded more than 24 times a year (99.73rd percentile)
	266	15-minute mean not to be exceeded more than 35 times a year (99.9th percentile)
PM_{10}	40	Annual mean
	50	24-hour mean, not to be exceeded more than 35 times a year (90.41st percentile)
$PM_{2.5}$	20[3]	Annual mean
TVOC[1]	5[2]	Annual mean
	30	Maximum 24-hour mean (100th percentile)

Note 1: VOCs may contain a wide range of organic compounds and it is often difficult to determine or identify each and every compound present. The TVOC emissions from the assessed combustion plant will largely comprise methane which is not directly harmful to human health.
Note 2: For the purposes of this assessment, the annual mean and 24-hour mean AQO for benzene (C_6H_6) has been applied as it is a standard substitute that adequately represents a worst-case scenario for VOCs.
Note 3: Amendment to the Air Quality Standards Regulations 2010 as per the Environment (Miscellaneous Amendments) (EU Exit) Regulations 2020 (UK Government, 2020).

For the assessment of long-term average concentrations (i.e. the annual mean concentrations) at human receptors, impacts were described using the following criteria:

- if the PC is less than 1% of the long-term EQS, the contribution can be considered as 'insignificant' and not representative of a significant effect (i.e. not significant) (Environment Agency, 2021b);
- if the PC is greater than 1% of the EQS but the PEC is less than 70% of the long-term air quality objective, based on professional judgement, this would be classed as 'not significant'; and
- where the PC is greater than 1% of the EQS and the PEC is greater than 70% of the EQS, professional judgement is used to determine the overall significance of the effect (i.e. whether the effect would be 'not significant' or 'significant'), taking account of the following:
  - the scale of the changes in concentrations;
  - whether or not an exceedance of an EQS is predicted to arise in the study area where none existed before, or an exceedance area is substantially increased as a result of the development; and
  - uncertainty, including the influence and validity of any assumptions adopted in undertaking the assessment.

For the assessment of short-term average concentrations (e.g. the 1-hour mean NO_2 concentrations, and the 15-minute, 1-hour and 24-hour mean SO_2 concentrations etc.), impacts were described using the following criteria:

- if the PC is less than 10% of the short-term EQS, this would be classed as 'insignificant' and not representative of a significant effect (i.e. not significant) (Environment Agency, 2021b);
- if the PC is greater than 10% of the EQS but less than 20% of the headroom between the short-term background concentration and the EQS, based on professional judgement, this can also be described as not significant; and
- where the PC is greater than 10% of the EQS and 20% of the headroom, professional judgement is used to determine the overall significance of the effect (i.e. whether the effect would be not significant or significant) in line with the approach specified above for long-term average concentrations.

Environment Agency guidance recommends that further action will not be required if proposed emissions comply with Best Available Techniques Associated Emission Levels (BAT AELs) and resulting PECs do not exceed the relevant EQS (Environment Agency, 2021a).

3.3.2 Environmental Quality Standards: Protected Conservation Areas

Critical levels

The environmental standards set for protected conservation areas of relevance to the project are summarised in Table 3 (Environment Agency, 2021a).

Table 3: Air Quality Objectives and Environmental Assessment Levels for protected conservation areas

Pollutant	EQS (µg/m^3)	Concentration measured as
NOx	30	Annual mean limit value for the protection of vegetation (referred to as the “critical level”)
	75	Maximum 24-hour mean for the protection of vegetation (referred to as the “critical level”)
SO_2	10	Annual mean limit value for the protection of vegetation (referred to as the “critical level”) where lichens or bryophytes are present
	20	Annual mean limit value for the protection of vegetation (referred to as the “critical level”) where lichens or bryophytes are not present

Critical loads

Critical loads for pollutant deposition to statutorily designated habitat sites in the UK and for various habitat types have been published by the CEH and are available from the APIS website. Critical Loads are defined on the APIS website (Centre for Ecology and Hydrology, 2022) as:

"a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge".

Compliance with these benchmarks is likely to result in no significant adverse effects on the natural environment at these locations. For the assessed protected conservation area, the Site Relevant Critical Loads tool function on the APIS website was used to determine the relevant critical loads based on the likely vegetation type inhabiting Cotswold Beechwoods SAC. The critical load data is set out in Table 4. Where both short and tall vegetation type is assumed to inhabit the protected conservation area, the most sensitive habitat feature was selected on the APIS website irrespective of whether the habitat feature is present at the modelled receptor location.

Table 4: Critical loads for modelled protected conservation areas

Receptor ref	Protected conservation area	Habitat feature applied	Vegetation type (for deposition velocity)	Critical load			
				Acid deposition (kEqH+/ha/year)			Nitrogen deposition (kg N/ha/year)
				CLMaxS	CLMinN	CLMaxN	Minimum
H1	Cotswood Beechwoods SAC	Sub-atlantic semi-dry calcareous grassland	Short	4.000	0.856	4.856	15
		Fagus woodland	Tall	2.527	0.142	2.768	10

Critical load functions for acid deposition are specified on the basis of both nitrogen and sulphur derived acid. The critical load function contains a value for sulphur derived acid and two values for nitrogen derived acid deposition (a minimum and maximum value). The APIS website provides advice on how to calculate the process contribution (PC – emissions from the modelled process alone) and the predicted environmental concentrations (PEC – the PC added to the existing deposition) as a percentage of the acid critical load function and how to determine exceedances of the critical load function. This guidance was adopted for this assessment. The minimum of the range of nitrogen critical loads was used for the assessment in line with the advice on the APIS website (Centre for Ecology and Hydrology, 2022).

Significance Criteria – SAC

With regard to concentrations at the assessed designated habitat sites, the Environment Agency guidance (Environment Agency, 2021a) states emissions can be described as insignificant and no further assessment is required (including the need to calculate PECs) if:

- the short-term PC is less than 10% of the short-term environmental standard for protected conservation areas; or
- the long-term PC is less than 1% of the long-term environmental standard for protected conservation areas.

Where appropriate, the significance of the predicted long-term (annual mean) concentrations or deposition at protected conservation areas were determined in line with Environment Agency guidance (Environment Agency, 2021a) summarised as follows:

- where the PC is less than 1% of the relevant critical level or critical load, the emission is not likely to have a significant effect alone or in combination irrespective of the existing concentrations or deposition rates;
- where the PC is above 1%, further consideration of existing background concentrations or deposition rates is required, and where the total concentration or deposition is less than 70% of the critical level or critical load, calculated in combination with other committed projects or developments as appropriate, the emission is not likely to have a significant effect; and
- where the contribution is above 1%, and the total concentration or deposition rate is greater than 70% of the critical level or critical load, either alone or in combination with other committed projects or developments, then this may indicate a significant effect and further consideration is likely to be required.

The above approach is used to give a clear definition of what effects can be disregarded as insignificant, and which need to be considered in more detail in relation to the predicted annual mean concentrations or deposition.

For short-term mean concentrations (i.e. the 24-hour mean critical level for NOx) where the PC is less than 10% of the critical level then it would be regarded as 'insignificant'. A potentially significant effect would be identified where the short-term PC from the modelled sources would lead to the total concentration exceeding the critical level. Further consideration is likely to be required in this situation.

4. Existing Environment

4.1 Site Location

The site is situated approximately 3.5 km west-northwest from the centre of the town of Cheltenham, Gloucestershire. The eastern boundary of the site is located on the administrative boundary between TBC and CBC. The area surrounding the site generally comprises open grassland with infrequent residential properties.

There are several sensitive human receptors in the vicinity of the site in respect of potential air emissions from the process. The most relevant sensitive receptors have been identified from local mapping and are summarised in Appendix A and presented in Figure 2. The nearest modelled residential property is approximately 180 m west-northwest of the CHP engine (based on the CHP engine stack location NGR E 390623 N 223034). The nearest modelled receptor represents a PRoW approximately 120 m west-southwest of the CHP engine stack.

4.2 Local Air Quality Management

A review of baseline air quality was carried out prior to undertaking the air quality assessment. This was carried out to determine the availability of baseline air quality data recorded in the vicinity of the site and also if data from other regional or national sources such as the UK Air Information Resource (UK-AIR) (Defra, 2022b) website could be used to represent background concentrations of the relevant pollutants in the vicinity of the site.

As part of the Local Air Quality Management (LAQM) process, TBC has declared a single AQMA which encompasses an area of Tewkesbury town centre. This AQMA (termed 'Tewkesbury Town Centre AQMA') is approximately 7.9 km north-northwest of the site and is not considered further in the assessment. However, the neighbouring CBC has declared a borough-wide AQMA termed 'Cheltenham Whole Borough AQMA'. This AQMA, declared in 2011 for elevated annual mean concentrations of NO_2 in 2011, is adjacent to the eastern boundary of the site and therefore, has been considered in the assessment.

TBC and CBC also carry out regular assessments and monitoring of air quality within their respective administrative borough as part of the LAQM process. The most recent Air Quality Annual Status Report (Cheltenham Borough Council, 2021) and TBC air quality website (Tewkesbury Borough Council, 2022) were reviewed to determine concentrations of NO_2 in the vicinity of the site. It should be noted that none of the other assessed pollutants are monitored by TBC and CBC[4]. Table 5 presents information on the nearest monitoring locations to the site.

Table 5: Nearest monitoring locations to the site

Site ID	Description	Site type	Location	Distance and direction from CHP engine	Pollutants monitored	2020 Annual mean concentration (µg/m³)
Tewkesbury Borough Council (diffusion tubes)						
15N	Comus, Bamfurlong	Urban	E 389714 N 221845	1.5 km, SW	NO_2	18.1 µg/m³
16N	15 Withybridge Gardens	Urban	E 390461 N 225544	2.5 km, N	NO_2	20.3 µg/m³
Cheltenham Borough Council (diffusion tubes)						
22	Hatherley Lane	Roadside	E 391178 N 221641	1.5 km, SSE	NO_2	25.2 µg/m³
29	Princess Elizabeth	Roadside	E 392066 N 222540	1.5 km, ESE	NO_2	24.7 µg/m³
37	A40 PE Way	Roadside	E 391869 N 222084	1.6 km, SE	NO_2	23.9 µg/m³

These monitoring locations are not considered representative of the site and surrounding area due to the roadside and urban monitoring location type and respective distance from the site.

[4] From August 2020, Cheltenham Borough Council installed nine Air Quality Mesh Pods in order to monitor real-time localised NOx, PM_{10} and $PM_{2.5}$. Due to the impacts of COVID-19, the calibration of recorded data is still being finalised.

For the assessed pollutants, information on background air quality in the vicinity of the site was obtained from Defra background map datasets (Defra, 2022b). The 2018-based background maps by Defra are estimates based upon the principal local and regional sources of emissions and ambient monitoring data. For SO_2 and CO concentrations, the 2001-based background maps were used. For TVOC concentrations, the 2010-based background maps for C_6H_6 were used. These background concentrations are presented in Table 6.

As it is necessary to determine the potential impact of emissions from the site on the assessed protected conservation area, the background concentrations of NOx and SO_2 were also identified for the assessed protected conservation area. These background concentrations were also obtained from Defra background map datasets (Defra, 2022b) and are displayed in Table 6.

Table 6: Background concentrations: adopted for use in assessment for assessed human receptors and protected conservation areas

Pollutant	Annual mean concentration (μg/m³)	Description
Human receptors		
NO_2	9.2 – 11.2	Defra 1 km x 1 km background map value for the assessed sensitive human receptor locations, 2022 map concentration
CO	137 - 150	Defra 1 km x 1 km background map value for the assessed sensitive human receptor locations, scaled from 2001-based map to 2022 concentration
PM_{10}	12.9 – 13.5	Defra 1 km x 1 km background map value for the assessed sensitive human receptor locations, 2022 map concentration
$PM_{2.5}$	8.4 – 9.0	Defra 1 km x 1 km background map value for the assessed sensitive human receptor locations, 2022 map concentration
SO_2	2.2 – 2.3	Defra 1 km x 1 km background map value for the assessed sensitive human receptor locations, 2001 map concentration
C_6H_6	0.28 – 0.34	Defra 1 km x 1 km background map value for the assessed sensitive human receptor locations, 2010 map concentration for benzene
Protected conservation areas		
NOx	8.2	Defra 1 km x 1 km background map value for the assessed sensitive human receptor locations, 2022 map concentration
SO_2	2.0	Defra 1 km x 1 km background map value for the assessed sensitive human receptor locations, 2001 map concentration

The long-term background concentrations were doubled to estimate the short-term background concentrations in line with the Environment Agency guidance (Environment Agency, 2021a).

4.3 Existing Deposition Rates

Existing acid and nutrient nitrogen deposition levels were obtained from APIS (Centre for Ecology and Hydrology, 2022). As a conservative approach to the assessment, it is assumed the vegetation type selected is present at the specific modelled location (see Appendix A) within the assessed protected conservation area.

The existing deposition values at the assessed protected conservation area are set out in Table 7.

Table 7: Existing deposition at Cotswold Beechwood SAC

Receptor ref	Protected conservation area	Vegetation type (for deposition velocity)	Existing deposition rates		
			Acid deposition (kEqH+/ha/year)		Nutrient N deposition (kg N/ha/year)
			Nitrogen	Sulphur	Nitrogen
H1	Cotswold Beechwood SAC	Short	1.32	0.17	18.48
		Tall	2.18	0.21	30.48

5. Results

5.1 Human Receptors

The results presented below are the maximum modelled concentrations predicted at any of the 20 assessed sensitive human receptor locations, the assessed Cheltenham Whole Borough AQMA and the maximum modelled concentration at any off-site location for the five years of meteorological data used in the study.

The results of the dispersion modelling are set out in Table 8, which presents the following information:

- EQS (i.e. the relevant air quality standard);
- estimated annual mean background concentration (see Section 4) that is representative of the baseline;
- PC, the maximum modelled concentrations due to the emissions from the assessed combustion plant;
- PEC, the maximum modelled concentration due to process emissions combined with estimated baseline concentrations;
- PC and PEC as a percentage of the EQS; and
- PC as a percentage of headroom (i.e. the PC as a percentage of the difference between the short-term background concentration and the EQS, for short-term predictions only).

The full results at assessed human receptor locations are presented in Appendix C.

Table 8: Results of detailed assessment

Pollutant	Averaging period	Assessment location	Maximum receptor	EQS (µg/m³)	Baseline air quality level (µg/m³)	PC (µg/m³)	PEC (µg/m³)	PC / EQS (%)	PEC / EQS (%)	PC as a percentage of headroom (%)
CO	Maximum 8-hour running mean	Sensitive locations	R11	10,000	274	129.3	403.4	1.3%	4.0%	1.3%
	Maximum 1-hour mean	Maximum off-site	-	30,000	274	306.2	580.4	1.0%	1.9%	1.0%
		Sensitive locations	R18	30,000	280	242.2	522.6	0.8%	1.7%	0.8%
NO_2	Annual mean	Sensitive locations	R1	40	9.5	3.2	12.6	8.0%	31.6%	-
		Cheltenham Whole Borough AQMA	-		9.5[2]	1.2	10.7	3.1%	26.7%	-
	1-hour mean (99.79th percentile)	Maximum off-site	-	200	18.9	41.3	60.2	20.6%	30.1%	22.8%
		Sensitive locations	R18	200	19.8	27.4	47.3	13.7%	23.6%	15.2%
SO_2	24-hour mean (99.18th percentile)	Sensitive locations	R1	125	4.4	13.5	17.9	10.8%	14.3%	11.2%
	1-hour mean (99.73rd percentile)	Maximum off-site	-	350	4.4	92.0	96.4	26.3%	27.5%	26.6%
		Sensitive locations	R18	350	4.6	54.8	59.4	15.7%	17.0%	15.9%
	15-minute mean (99.9th percentile)	Maximum off-site	-	266	4.4	126.3	130.7	47.5%	49.1%	48.3%
		Sensitive locations	R18	266	4.6	78.7	83.3	29.6%	31.3%	30.1%
PM_{10}	Annual mean	Sensitive locations	R1	40	13.5	0.08	13.6	0.2%	34.0%	-
	24-hour mean (90.41st percentile)	Sensitive locations	R1	50	27.1	0.20	27.2	0.4%	54.5%	0.9%
$PM_{2.5}$	Annual mean	Sensitive locations	R1	20	8.5	0.08	8.6	0.4%	43.1%	-
TVOC	Annual mean	Sensitive locations	R1	5 (Benzene)	0.3	16.4	16.7	327.5%	333.0%	-
	Maximum 24-hour mean	Sensitive locations	R13	30 (Benzene)	0.6	76.6	77.1	255.3%	257.1%	260.1%

Note 1: For annual mean NO_2, PM_{10} and $PM_{2.5}$ and TVOC concentrations, 24-hour mean PM_{10} and SO_2 concentrations and 8-hour mean CO concentrations, R16 and R20 have been omitted from analysis as these receptor locations represent a PRoW (i.e. short-term exposure only). The full results are presented in Appendix C.

Note 2: The Defra background map concentration applied (Defra, 2022b) is based on the location where the highest PC was predicted within Cheltenham Whole Borough AQMA.

The results in Table 8 indicate that the predicted off-site concentrations and predicted concentrations at sensitive human receptors do not exceed any relevant long-term or short-term air quality objective or guideline.

Table 8 indicates that the maximum PC for annual mean NO_2 at a sensitive human receptor location is 3.2 µg/m^3 (equating to 8.0% of the relevant EQS) and is predicted at R1, which represents a residential property approximately 0.20 km east-northeast of the CHP engine stack. The PC is above 1% of the relevant EQS but the PEC is less than 70% of the EQS (i.e. 31.6%) and based on professional judgement, the impact can be classed as 'not significant'. As discussed previously, this assessment assumes the assessed combustion plant operate simultaneously and continuously all year. In practice, the assessed boilers are not likely to operate simultaneously and the assessed plant may not always operate at maximum load.

For the Cheltenham Whole Borough AQMA, the maximum PC for annual mean NO_2 is 1.2 µg/m^3 (equating to 3.1% of the relevant EQS) and was predicted at NGR E 390943 N 223114. It should be noted that the PC's at the closest sensitive human receptors to the site that are located within the AQMA (i.e. R2 – R6), are all below 1% of the relevant long-term EQS and are considered 'insignificant' as per Environment Agency guidance (Environment Agency, 2021a) and therefore 'not significant'.

For the assessment of 1-hour mean (99.79th percentile) NO_2 concentrations at a sensitive human receptor location, the maximum PC of 27.4 µg/m^3 (which equates to 13.7% of the relevant EQS) is predicted at R18, which represents a PRoW approximately 0.1 km west-southwest of the CHP engine stack. The PC is just above 10% of the short-term EQS but less than 20% of the headroom between the short-term background concentration and the EQS and is considered 'not significant'. For the assessment of 1-hour mean (99.79th percentile) NO_2 concentrations at a modelled off-site location, the maximum PC is 41.3 µg/m^3, which equates to 20.6% of the relevant EQS. The PC is greater than 10% of the short-term EQS and greater than 20% of the headroom. However, the PEC of 60.2 µg/m^3 equates to 30.1% of the EQS and based on professional judgement, the impact is considered 'not significant'. This concentration is predicted at NGR E 390713 N 223174, which is adjacent to the northern boundary of the site in an agricultural field and is not likely to be frequented by members of the public.

For long-term PM_{10} and $PM_{2.5}$ concentrations, the respective PCs are less than 1% of the relevant long-term EQS and are considered 'insignificant' as per Environment Agency guidance (Environment Agency, 2021a) and therefore 'not significant'. For 24-hour mean (90.41st percentile) PM_{10} concentrations, the maximum PC is less than 10% of the relevant short-term EQS (i.e. 0.4%) and its impact can be described as 'insignificant' and therefore 'not significant'.

For short-term CO concentrations at both sensitive human receptor locations and modelled off-site locations, the respective PCs are less than 10% of the relevant short-term EQS and their impact is considered 'insignificant' and not representative of a significant effect (i.e. not significant).

For 24-hour mean (99.18th percentile) SO_2 concentrations at a sensitive human receptor location, the highest PC of 13.5 µg/m^3 is predicted at R1. The PC is just above 10% of the short-term EQS but less than 20% of the headroom and based on professional judgement, the impact is considered 'not significant'.

For 1-hour mean (99.73rd percentile) SO_2 concentrations at a sensitive human receptor location, the maximum PC of 54.8 µg/m^3 is above 10% of the short-term EQS but less than 20% of the headroom between the short-term background concentration and the EQS and is considered 'not significant'. At a modelled off-site location, the maximum PC of 92.0 µg/m^3 is greater than 10% of the short-term EQS and greater than 20% of the headroom. However, the PEC of 96.4 µg/m^3 equates to 27.5% of the EQS and based on professional judgement, is considered 'not significant'. This concentration is predicted at NGR E 390713 N 223174, which is adjacent to the northern boundary of the site in an agricultural field and is not likely to be frequented by members of the public.

For 15-minute mean (99.9th percentile) SO_2 concentrations at a sensitive human receptor location and modelled off-site location, the respective PCs of 78.7 µg/m^3 (predicted at R18) and 126.3 µg/m^3 are greater than 10% of the short-term EQS and greater than 20% of the headroom. However, the respective PEC's are well within the relevant EQS and based on professional judgement, the impact is considered 'not significant'. The maximum 15-minute mean (99.9th percentile) SO_2 concentration at an off-site location is predicted at NGR E 390743 N 223154, which is adjacent to the northern boundary of the site in an agricultural field and is not likely to be frequented by members of the public.

For annual mean TVOC concentrations at a sensitive human receptor location, the maximum PC is 16.4 µg/m^3 and is predicted at R1. When comparing the PEC against the annual mean EQS for benzene, there is an exceedance of the standard.

For maximum 24-hour mean TVOC concentrations at a sensitive human receptor location, the maximum PC is 76.6 µg/m^3. This PC is predicted at R13 which represents a residential property 0.2 km west-northwest of the CHP engine stack. The PEC of 77.1 µg/m^3 exceeds the benzene 24-hour mean standard.

In the absence of an EQS for TVOC's, comparison of the annual mean and 24-hour mean predicted concentrations have been made against the annual mean and 24-hour mean environmental quality standard for benzene (C_6H_6). This represents a worst-case scenario for VOCs because it assumes all VOC contributions comprise benzene. TVOC emissions from the assessed combustion plant will largely comprise unburnt methane gas from the biogas fuel (up to 75% composition (Naskeo Environment, 2009)), which is not directly harmful to human health. If the contribution of methane (CH_4) is removed from the process contribution, there would be no exceedance of the short-term relevant standard. Therefore, when considering the conservative approach to the assessment and based on professional judgement, the contribution of TVOC's is considered 'not significant'.

Summary

The results in Table 8 indicate that the predicted modelled off-site concentrations and predicted concentrations at sensitive human receptors do not exceed any relevant long-term or short-term air quality objective or guideline. Furthermore, the conservative approach adopted throughout the assessment means the predicted concentrations presented in Table 8 are likely to be considerably higher than would reasonably be expected.

Isopleths (see Figures 4 - 7) have been produced for annual mean and 1-hour mean (99.79th percentile) NO_2 concentrations, 1-hour mean (99.73rd percentile) and 15-minute mean (99.9th percentile) SO_2 concentrations. The figures are based on the year of meteorological data which resulted in the highest PC at a sensitive human receptor location.

5.2 Protected Conservation Areas

5.2.1 Assessment against Critical Levels

The environmental effects of releases from the site at the assessed protected conservation areas have been determined by comparing predicted concentrations of released substances with the EQSs for the protection of vegetation (critical levels) (see Table 3). The results of the detailed modelling at the assessed protected conservation area are shown in Table 9. The results presented are the maximum predicted concentration for the five years of meteorological data used in the study.

For SO_2, the relevant EQS is based on the assumption that lichens and bryophytes were present at Cotswold Beechwoods SAC, therefore adopting a further conservative approach.

Table 9: Results of detailed assessment at Cotswold Beechwoods SAC for annual mean NOx and SO_2 concentrations and for maximum 24-hour mean NOx concentrations

Ref	Protected Conservation Area	EQS (µg/m^3)	Background concentration (µg/m^3)	PC (µg/m^3)	PEC (µg/m^3)	PC/EQS (%)	PEC/EQS (%)
Annual mean NOx concentrations							
H1	Cotswold Beechwoods SAC	30	8.2	0.02	8.3	0.1%	27.5%
Annual mean SO_2 concentrations							
H1	Cotswold Beechwoods SAC	10	2.0	0.01	2.0	0.1%	19.7%
Maximum 24-hour mean NOx concentrations							
H1	Cotswold Beechwoods SAC	75	16.5	0.4	16.8	0.5%	22.4%

The results in Table 9 indicate that the respective annual mean NOx and SO_2 PCs are less than 1% of the long-term environmental standard and the impact can be described as 'insignificant' as per Environment Agency guidance (Environment Agency, 2021a).

The maximum short-term mean concentrations which were assessed against the 24-hour mean critical level for NOx (i.e. 75 µg/m^3) are also presented in Table 9. The results indicate that the short-term NOx PC is less than 10% of the short-term environmental standard and can also be described as 'insignificant' as per Environment Agency guidance (Environment Agency, 2021a).

Summary

The conservative approach adopted throughout this assessment means that, based on professional judgement, it is not considered likely that there would be unacceptable impacts to air quality at Cotswold Beechwoods SAC as a consequence of the operation of the assessed CHP engine and boilers with regard to ambient concentrations of NOx and SO_2.

5.2.2 Assessment against Critical Loads

The rate of deposition of acidic compounds and nitrogen containing species have been estimated at the assessed Cotswold Beechwoods SAC. This allows the potential for adverse effects to be evaluated by comparison with critical loads for acid and nutrient nitrogen deposition. The assessment took account of emissions of NOx and SO_2 only.

Critical load functions for acid deposition are specified on the basis of both nitrogen-derived acid and sulphur-derived acid. This information, including existing deposition levels at habitat sites, is available from APIS (Centre for Ecology and Hydrology, 2022). Further information on the assessment of deposition is provided in Appendix B. The full detailed modelled results are displayed in Table 10 and Table 11.

Table 10: Modelled acid deposition at Cotswold Beechwoods SAC

Ref	Habitat	Vegetation type (for deposition velocity)	Critical load (CL) (kEqH+/ha/year)			Existing acid deposition (kEqH+/ha/year)		PC	PEC	PC/CL (%)	PEC/CL(%)
			CLMaxS	CLMinN	CLMaxN	Existing deposition (N)	Existing deposition (S)				
H1	Cotswold Beechwoods SAC	Short	4.000	0.856	4.856	1.32	0.17	0.002	1.49	<0.1%	31%
		Tall	2.527	0.142	2.768	2.18	0.21	0.004	2.39	0.1%	87%

Table 11: Modelled nitrogen deposition at Cotswold Beechwoods SAC

Ref	Habitat	Vegetation type (for deposition velocity)	Existing nutrient deposition (kgN/ha-year)		PC	PEC	PC/CL (%)	PEC/CL(%)
			Minimal Critical Load (CL)	Existing deposition				
H1	Cotswold Beechwoods SAC	Short	15	18.48	0.002	18.48	<0.1%	123%
		Tall	10	30.48	0.004	30.48	<0.1%	305%

The results in Table 10 and Table 11 indicate that for the assessed Cotswold Beechwoods SAC, the respective PCs for acid and nutrient nitrogen deposition are less than 1% of the relevant long-term environmental standard for protected conservation areas and the impact can be described as 'insignificant' as Environment Agency guidance (Environment Agency, 2021a).

It should be noted acid and nitrogen deposition rates currently exceed their relevant critical loads in the majority of the assessed protected conservation areas. However, this is a relatively common situation at protected conservation areas across the UK due to the high baseline deposition rates.

5.3 Sensitivity Analysis

A sensitivity study was undertaken to see how changes to the surface roughness and omission of the buildings in the 2017 model (which predicted the highest annual mean NO_2 concentrations at a sensitive human receptor location) and 2019 model (which predicted the highest 1-hour mean (99.79th percentile) NO_2 concentrations at a sensitive human receptor location and modelled off-site location) may impact on predicted concentrations at sensitive human receptors and off-site locations. The results of the sensitivity analysis are presented in Table 12, Table 13 and Table 14.

Table 12: Sensitivity analysis - fixed surface roughness of 0.1 m

Pollutant	Averaging period	Assessment location	Original PC (surface roughness 0.5 m) (µg/m^3)	Surface roughness length 0.1 m				
				PC (µg/m^3)	PEC (µg/m^3)	PC/EQS	PEC/EQS	% difference in PC/EQS compared to original
NO_2	Annual mean	Sensitive locations	3.2	3.5	12.9	8.6%	32.3%	0.7%
	1 hour mean (99.79th percentile)	Maximum off-site	41.3	51.4	70.3	25.7%	35.2%	5.1%
		Sensitive locations	27.4	35.3	55.2	17.7%	27.6%	3.9%

The results in Table 12 indicate that the change to maximum predicted annual mean concentrations for NO_2 is higher when using a surface roughness value of 0.1 m compared to the original value of 0.5 m. For 1-hour mean (99.79th percentile) NO_2 concentrations at a sensitive human receptor location and modelled off-site location, the PCs were also higher when using a reduced surface roughness value of 0.1 m. However, a surface roughness of 0.1 m (representing root crops) is not considered representative of the site and surrounding area.

Table 13: Sensitivity analysis - fixed surface roughness of 1 m

Pollutant	Averaging period	Assessment location	Original PC (surface roughness 0.5 m) (µg/m^3)	Surface roughness length 1 m				
				PC (µg/m^3)	PEC (µg/m^3)	PC/EQS	PEC/EQS	% difference in PC/EQS compared to original
NO_2	Annual mean	Sensitive locations	3.2	3.2	12.7	8.1%	31.7%	0.1%
	1 hour mean (99.79th percentile)	Maximum off-site	41.3	29.1	48.0	14.5%	24.0%	-6.1%
		Sensitive locations	27.4	23.0	42.8	11.5%	21.4%	-2.2%

The results in Table 13 indicate that the change to maximum predicted annual mean concentrations for NO_2 is negligible when using a surface roughness value of 1 m compared to the original value of 0.5 m. For 1-hour mean (99.79th percentile) NO_2 concentrations at an off-site location and sensitive human receptor location, the PCs were lower when modelling with an increased surface roughness value of 1 m. However, a surface roughness of 1 m (representing a large city centre location with built up areas and tall buildings) is not considered representative of the site and surrounding area.

Table 14: Sensitivity analysis - no buildings

Pollutant	Averaging period	Assessment location	Original PC (with buildings) (µg/m³)	No buildings				
				PC (µg/m³)	PEC (µg/m³)	PC/EQS	PEC/EQS	% difference in PC/EQS compared to original
NO_2	Annual mean	Sensitive locations	3.2	3.0	12.4	7.4%	31.1%	-0.5%
	1 hour mean (99.79th percentile)	Maximum off-site	41.3	26.7	45.6	13.4%	22.8%	-7.3%
		Sensitive locations	27.4	20.0	39.8	10.0%	19.9%	-3.7%

The results in Table 14 indicate that the differences between the maximum predicted concentrations with and without the buildings is such that including buildings within the model is the preferred option for this study, to maintain a more realistic, and conservative, approach.

6. Conclusions

This report has assessed the potential air quality impacts associated with the operation of the biogas fuelled CHP engine and boilers at the Hayden STW. The predicted impacts were assessed against the relevant air quality standards and guidelines for the protection of human health (referred to in the report as EQSs) and protected conservation areas (referred to as critical levels and critical loads).

Human receptors

The assessment indicates that the predicted modelled off-site concentrations and predicted concentrations at sensitive human receptors do not exceed any relevant long-term or short-term air quality objective or guideline. At sensitive human receptor locations, the predicted long-term (i.e. annual mean) NO_2 and particulate (PM_{10} and $PM_{2.5}$) contributions are considered 'not significant'. For short-term NO_2, PM_{10}, SO_2 and CO concentrations at modelled off-site locations and sensitive human receptor locations, the contributions are also considered 'not significant'.

In the absence of an EQS for TVOC's, comparison of the annual mean and 24-hour mean predicted concentrations have been made against the annual mean and 24-hour mean environmental quality standard for benzene (C_6H_6). This represents a worst-case scenario for VOCs because it assumes all VOC contributions comprise benzene. For annual mean and maximum 24-hour mean TVOC concentrations at a sensitive human receptor location, the respective PECs exceed the relevant standard for benzene.

However, TVOC emissions from the assessed combustion plant will largely comprise unburnt methane gas from the biogas fuel (up to 75% composition (Naskeo Environment, 2009)), which is not directly harmful to human health. If the contribution of methane (CH_4) is removed from the process contribution, there would be no exceedance of the relevant standard. Therefore, when considering the conservative approach to the assessment and based on professional judgement, the contribution of TVOC's is considered 'not significant'.

This assessment has been carried out on the assumption that the CHP engine and boilers would operate continuously at maximum load throughout the year (i.e. 8,760 hours). However, the boilers are unlikely to operate simultaneously and for more than 6,000 hours per year. Furthermore, the assessed plant may not always operate at maximum load.

Protected conservation areas

For critical levels at the assessed Cotswold Beechwoods SAC, the results indicate that the annual mean NOx and SO_2 PCs are less than 1% of the long-term environmental standard and the impact can be described as 'insignificant' as per Environment Agency guidance (Environment Agency, 2021a).

For the 24-hour mean critical level for NOx, the results indicate that the short-term NOx PC is less than 10%, of the short-term environmental standard and can be described as 'insignificant'. The conservative approach adopted throughout this assessment means that, based on professional judgement, it is not considered likely that there would be unacceptable impacts to air quality at the assessed Cotswold Beechwoods SAC as a consequence of the operation of the assessed CHP engine and boilers with regard to ambient concentrations of NOx and SO_2.

For acid deposition and nutrient nitrogen deposition, the results indicate that at the assessed Cotswold Beechwoods SAC, the respective PCs are less than 1% of the long-term environmental standard for protected conservation areas and the impact can be described as 'insignificant' as per Environment Agency guidance (Environment Agency, 2021a).

As discussed above, the conservative approach adopted for this assessment means the predicted concentrations presented are likely to be higher than would reasonably be expected.

Summary

Based on the above assessment, it is concluded that the assessed CHP engine and boilers are acceptable from an air quality perspective.

7. References

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8. Figures

Figure 1: Approximate site fenceline, modelled stack locations and modelled buildings

Figure 2: Extent of modelled grid, assessed AQMA and sensitive human receptor locations

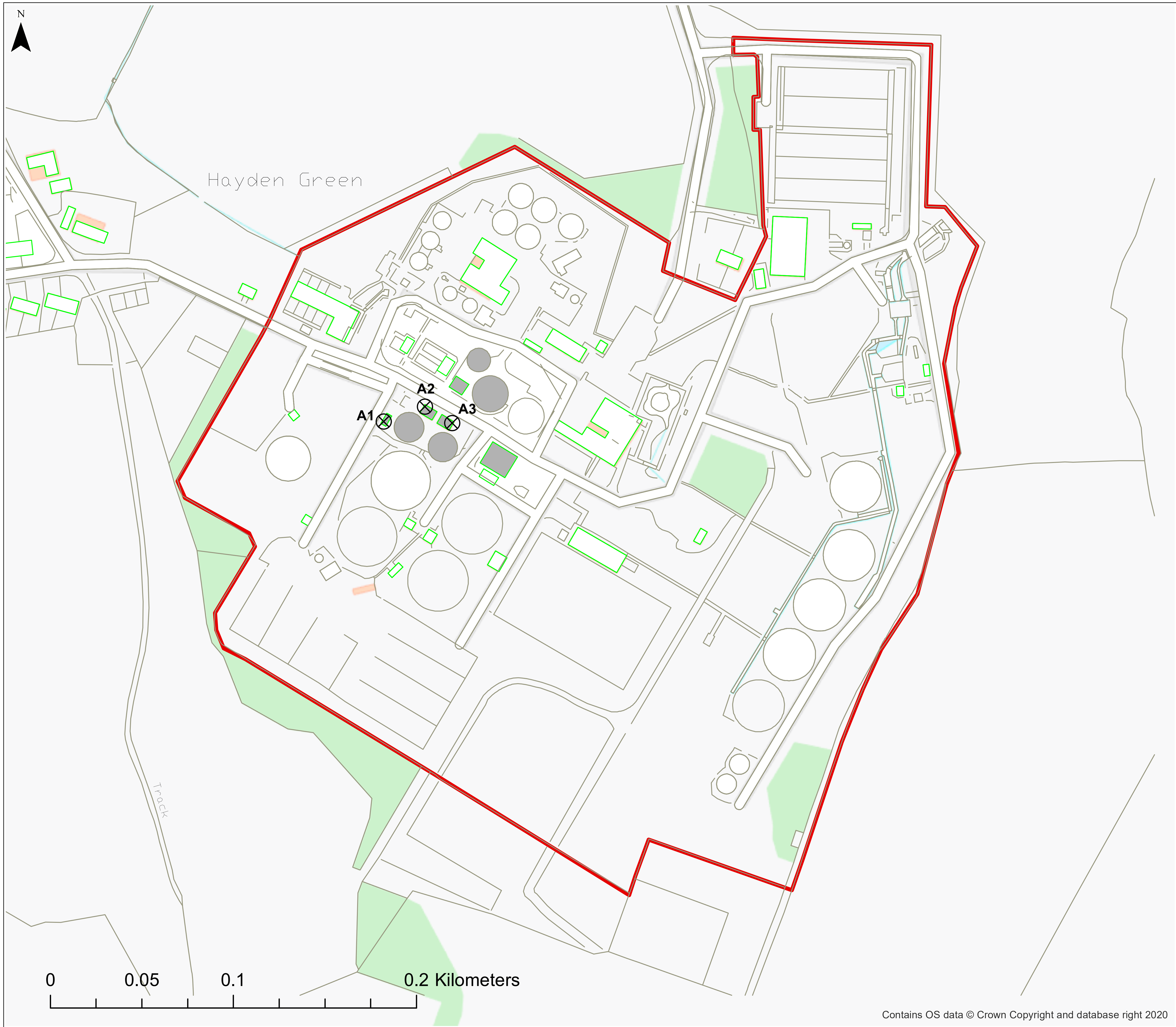
Figure 3: Assessed protected conservation area

Figure 4: Annual mean nitrogen dioxide process contributions, 2017 meteorological data

Figure 5: 1-hour mean (99.79th percentile) nitrogen dioxide process contributions, 2019 meteorological data

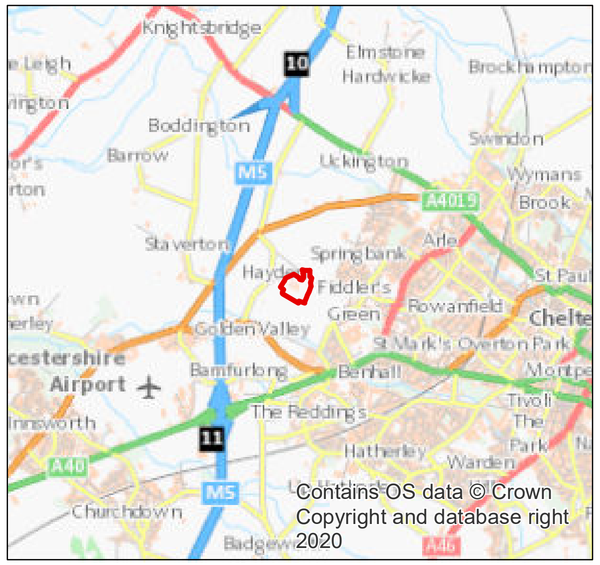
Figure 6: 1-hour mean (99.73rd percentile) sulphur dioxide process contributions, 2019 meteorological data

Figure 7: 15-minute mean (99.9th percentile) sulphur dioxide process contributions, 2016 meteorological data



Legend

- Approximate site fenceline
- Modelled stack locations
- Modelled buildings



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	10/01/2022	Initial Issue	DH	GW	GW	MM

Jacobs

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Project

ENVIRONMENTAL PERMIT APPLICATION - HAYDEN SEWAGE TREATMENT WORKS AIR QUALITY IMPACT ASSESSMENT

Drawing Title

APPROXIMATE SITE FENCELINE, MODELLED STACK LOCATIONS AND MODELLED BUILDINGS

Drawing Status

FINAL

Scale @ A3	1:2,000	DO NOT SCALE	
Jacobs No.	B1958992	Rev	0
Client No.			

Drawing Number

FIGURE 1

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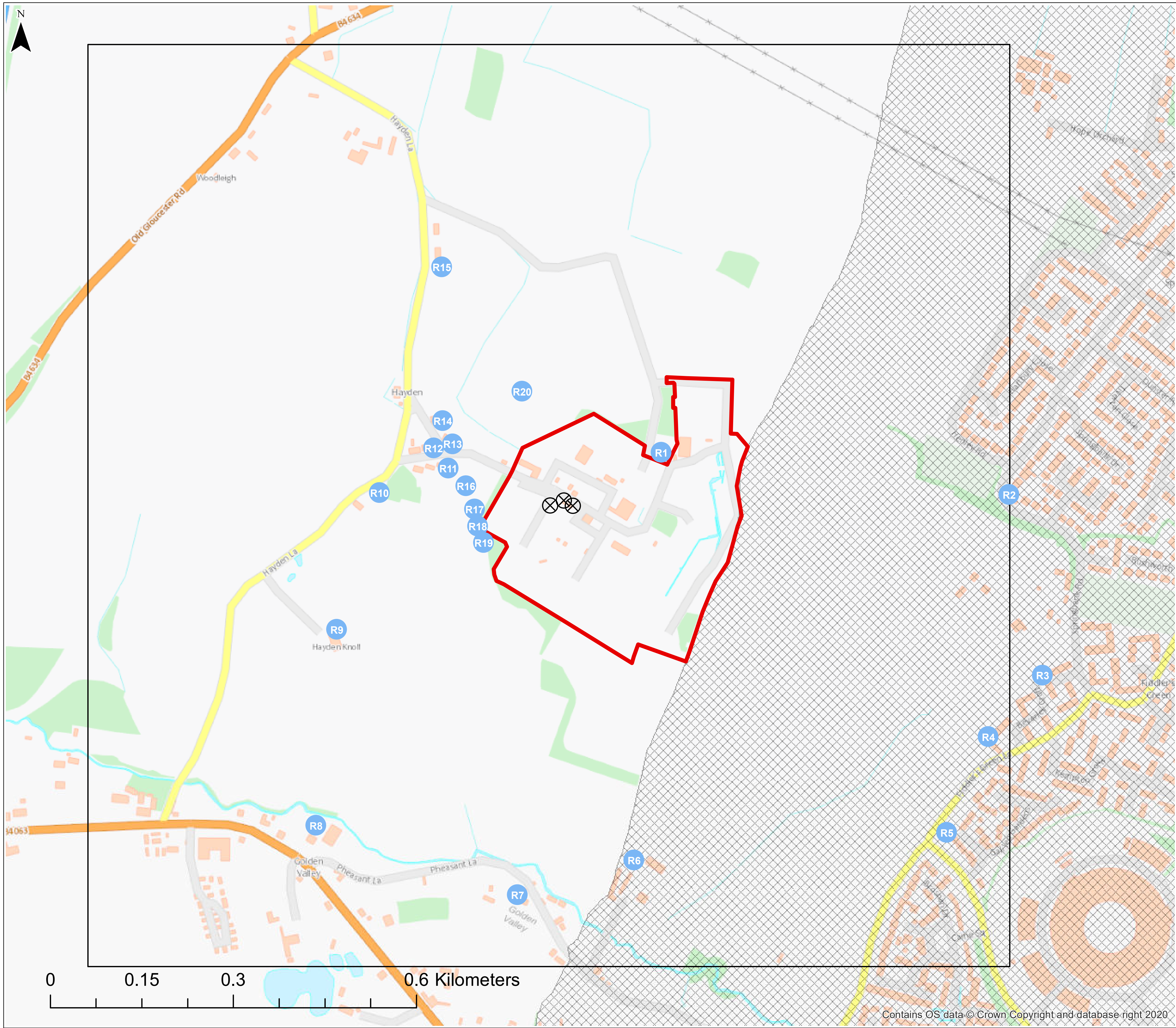
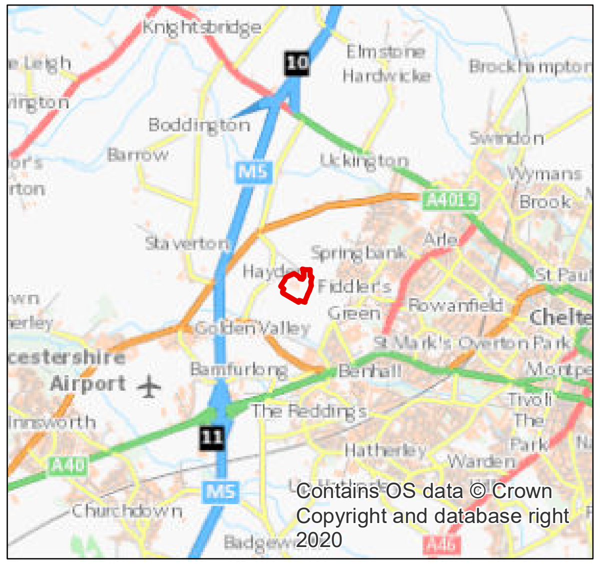


Legend

- Approximate site fenceline
- Modelled stack locations
- Extent of modelled grid
- Cheltenham Whole Borough AQMA
- R1 Sensitive human receptor locations



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	10/01/2022	Initial Issue	DH	GW	GW	MM

Jacobs

Client

SEVERN TRENT

Project

ENVIRONMENTAL PERMIT APPLICATION - HAYDEN SEWAGE TREATMENT WORKS AIR QUALITY IMPACT ASSESSMENT

Drawing Title

EXTENT OF MODELLED GRID, ASSESSED AQMA AND SENSITIVE HUMAN RECEPTOR LOCATIONS

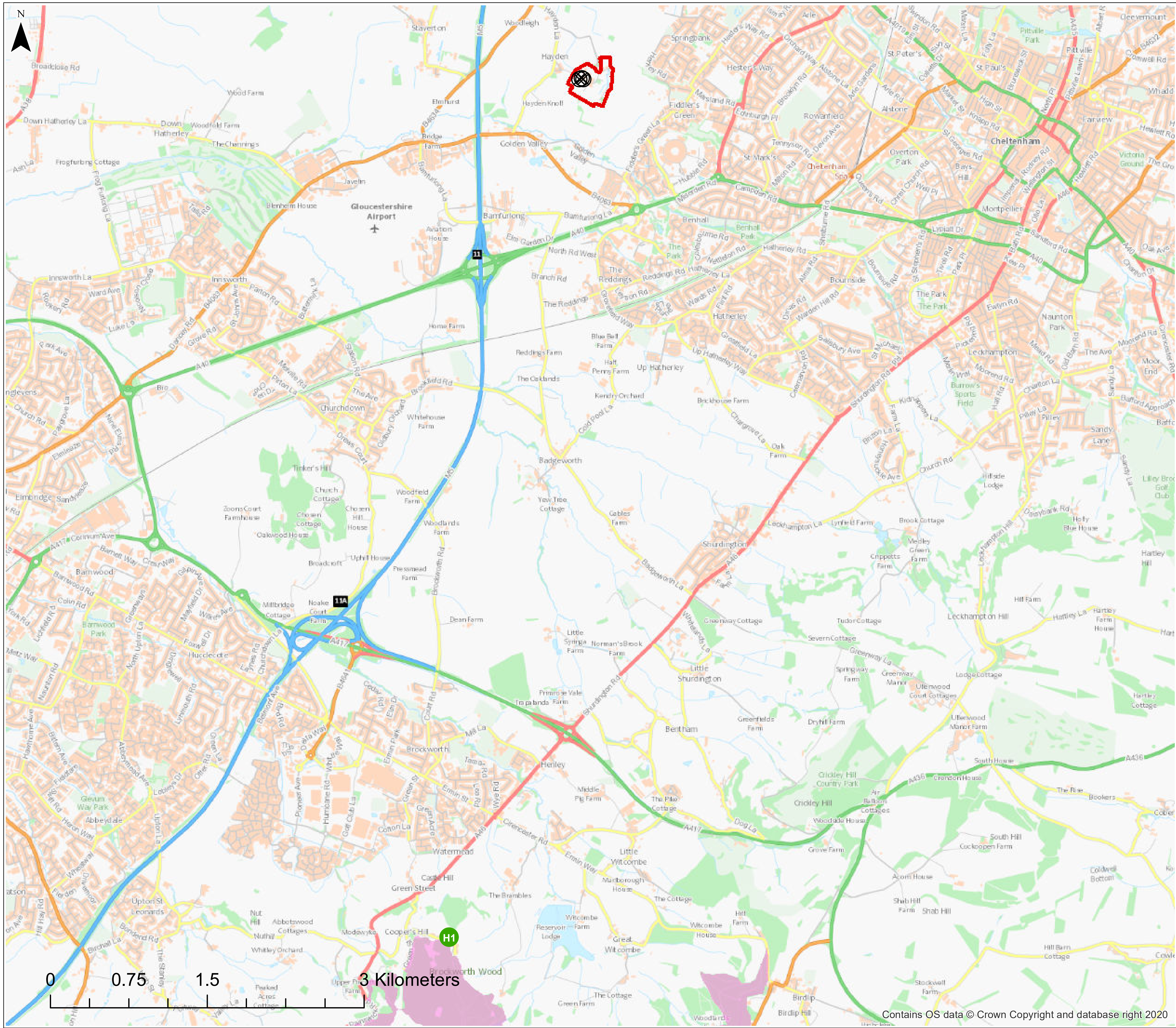
Drawing Status

FINAL

Scale @ A3	1:6,000	DO NOT SCALE
Jacobs No.	B1958992	Rev 0
Client No.		

Drawing Number

FIGURE 2



Legend

- Approximate site fenceline
- Modelled stack locations
- Cotswold Beechwoods SAC
- H1 Assessed protected conservation area location

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	10/01/2022	Initial Issue	DH	GW	GW	MM

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Client: SEVERN TRENT

Project: ENVIRONMENTAL PERMIT APPLICATION - HAYDEN SEWAGE TREATMENT WORKS AIR QUALITY IMPACT ASSESSMENT

Drawing Title: ASSESSED PROTECTED CONSERVATION AREA

Drawing Status: FINAL

Scale @ A3	1:35,000	DO NOT SCALE
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Client No.		

Drawing Number: FIGURE 3

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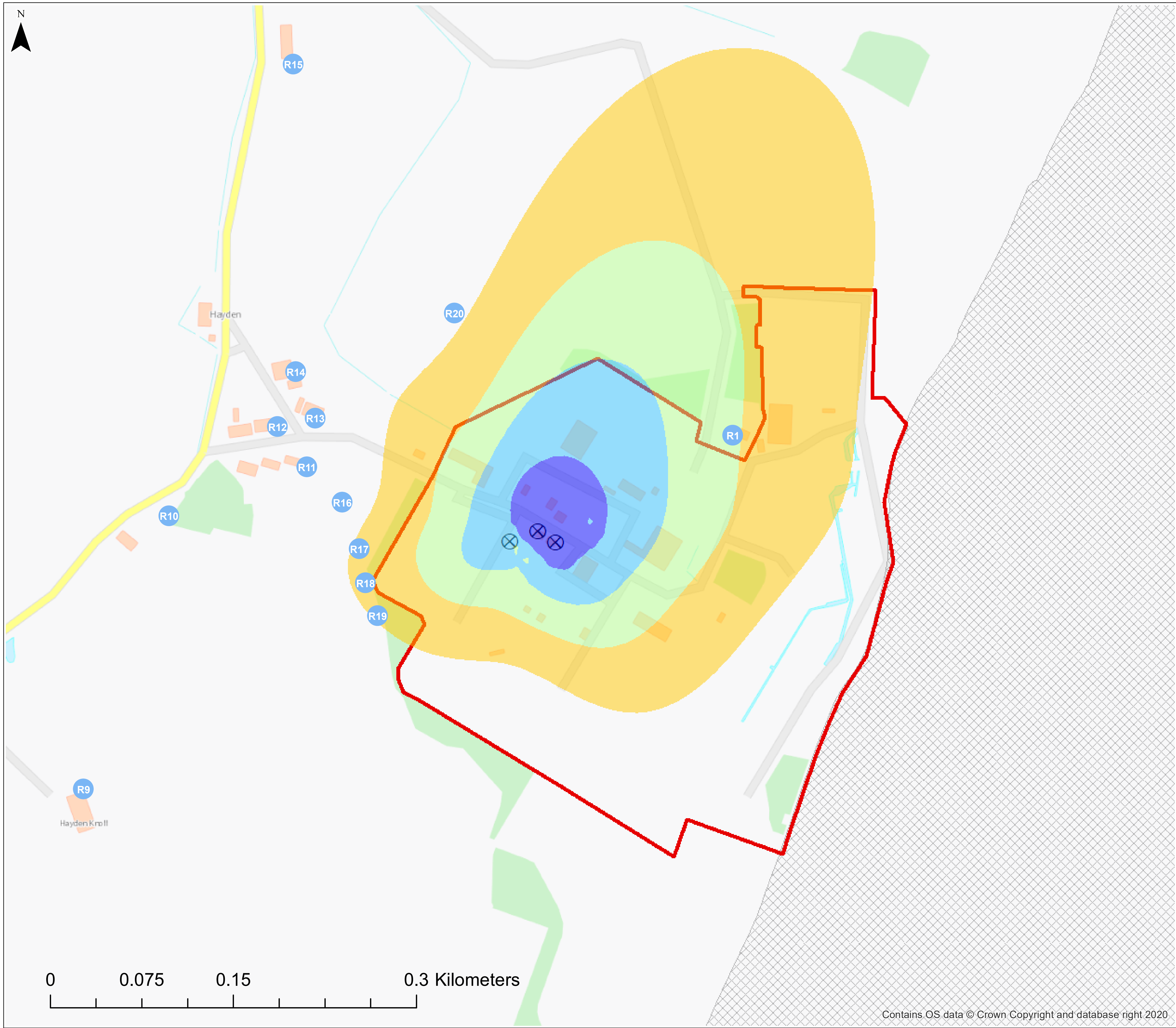

Legend

- Approximate site fenceline
- Modelled stack locations
- Cheltenham Whole Borough AQMA
- Sensitive human receptor locations

Annual mean nitrogen dioxide process contributions (µg/m³)

- 0 - 1.5
- 1.5 - 3
- 3 - 6
- 6 - 16
- 16 - 125

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
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Jacobs

Client: SEVERN TRENT

Project: ENVIRONMENTAL PERMIT APPLICATION - HAYDEN SEWAGE TREATMENT WORKS AIR QUALITY IMPACT ASSESSMENT

Drawing Title: ANNUAL MEAN NITROGEN DIOXIDE PROCESS CONTRIBUTIONS, 2017 METEOROLOGICAL DATA

Drawing Status: FINAL

Scale @ A3	1:3,000	DO NOT SCALE	
Jacobs No.	B1958992	Rev	0
Client No.			

Drawing Number: FIGURE 4

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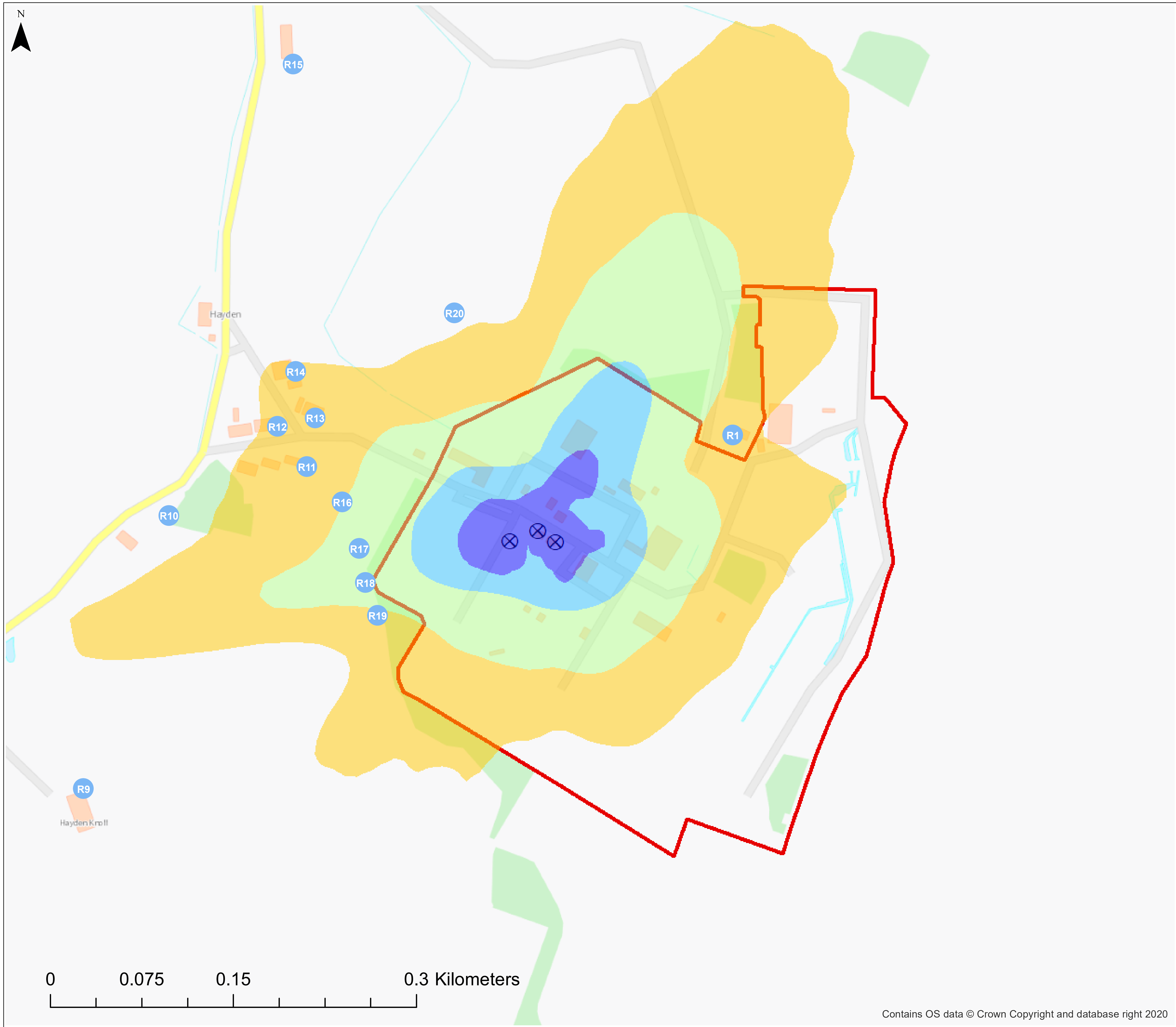

Legend

- Approximate site fenceline
- Modelled stack locations
- Sensitive human receptor locations

1-hour mean (99.79th percentile) nitrogen dioxide process contributions (µg/m³)

- 0 - 14
- 14 - 22
- 22 - 38
- 38 - 65
- 65 - 509

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
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Jacobs

Client: SEVERN TRENT

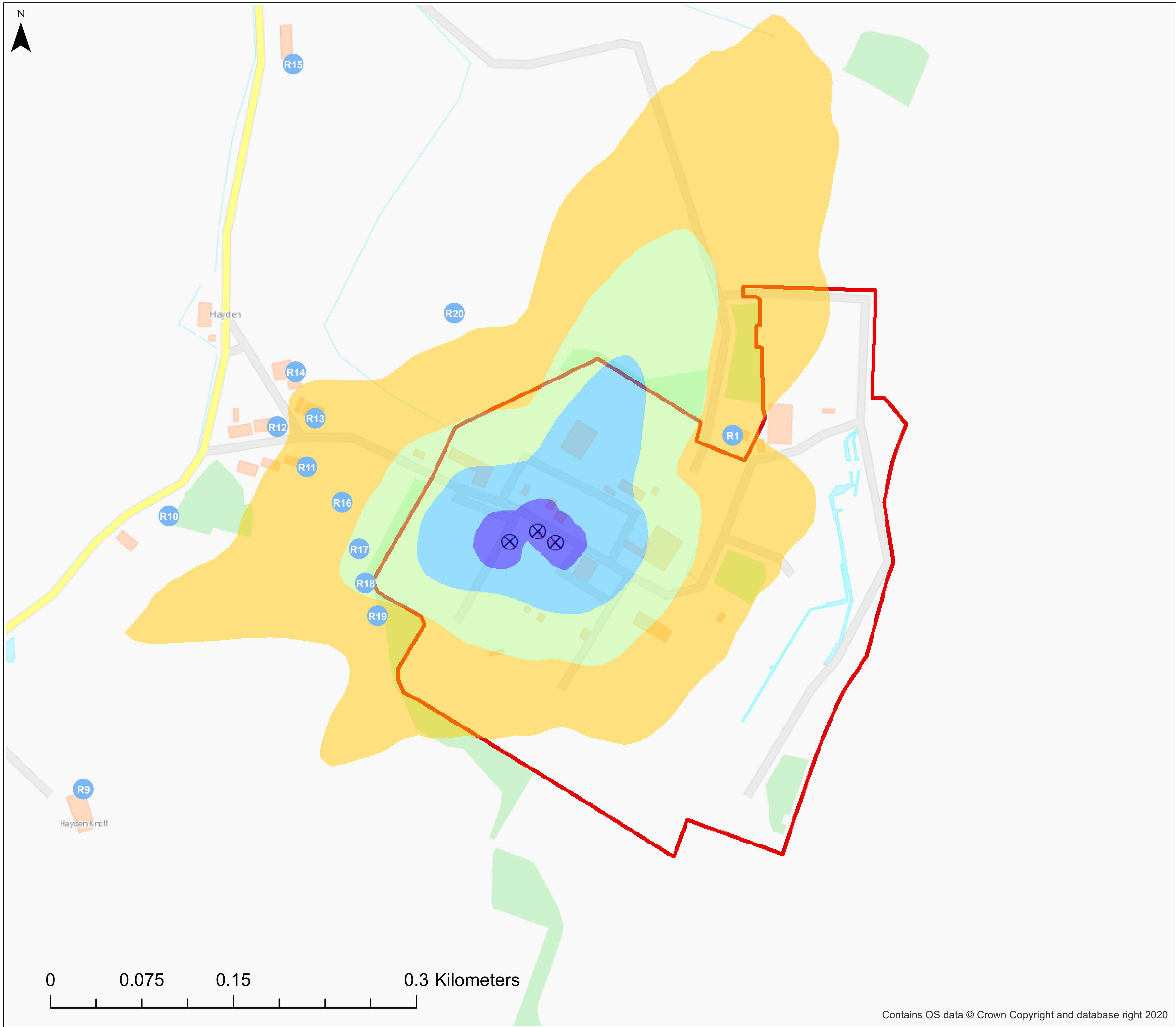
Project: ENVIRONMENTAL PERMIT APPLICATION - HAYDEN SEWAGE TREATMENT WORKS AIR QUALITY IMPACT ASSESSMENT

Drawing Title: 1-HOUR MEAN (99.79th PERCENTILE) NITROGEN DIOXIDE PROCESS CONTRIBUTIONS, 2019 METEOROLOGICAL DATA

Drawing Status: FINAL

Scale @ A3	1:3,000	DO NOT SCALE
Jacobs No.	B1958992	Rev 0
Client No.		

Drawing Number: FIGURE 5



Legend

- Approximate site fenceline
- Modelled stack locations
- Sensitive human receptor locations

1-hour mean (99.73rd percentile) sulphur dioxide process contributions (µg/m³)

- 0 - 30
- 30 - 50
- 50 - 80
- 80 - 200
- 200 - 1,002

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	10/01/2022	Initial Issue	DH	GW	GW	MM

Jacobs

Client: SEVERN TRENT

Project: ENVIRONMENTAL PERMIT APPLICATION - HAYDEN SEWAGE TREATMENT WORKS AIR QUALITY IMPACT ASSESSMENT

Drawing Title: 1-HOUR MEAN (99.73rd PERCENTILE) SULPHUR DIOXIDE PROCESS CONTRIBUTIONS, 2019 METEOROLOGICAL DATA

Drawing Status: FINAL

Scale @ A3	1:3,000	DO NOT SCALE
Jacobs No.	B1958992	Rev 0
Client No.		

Drawing Number: FIGURE 6

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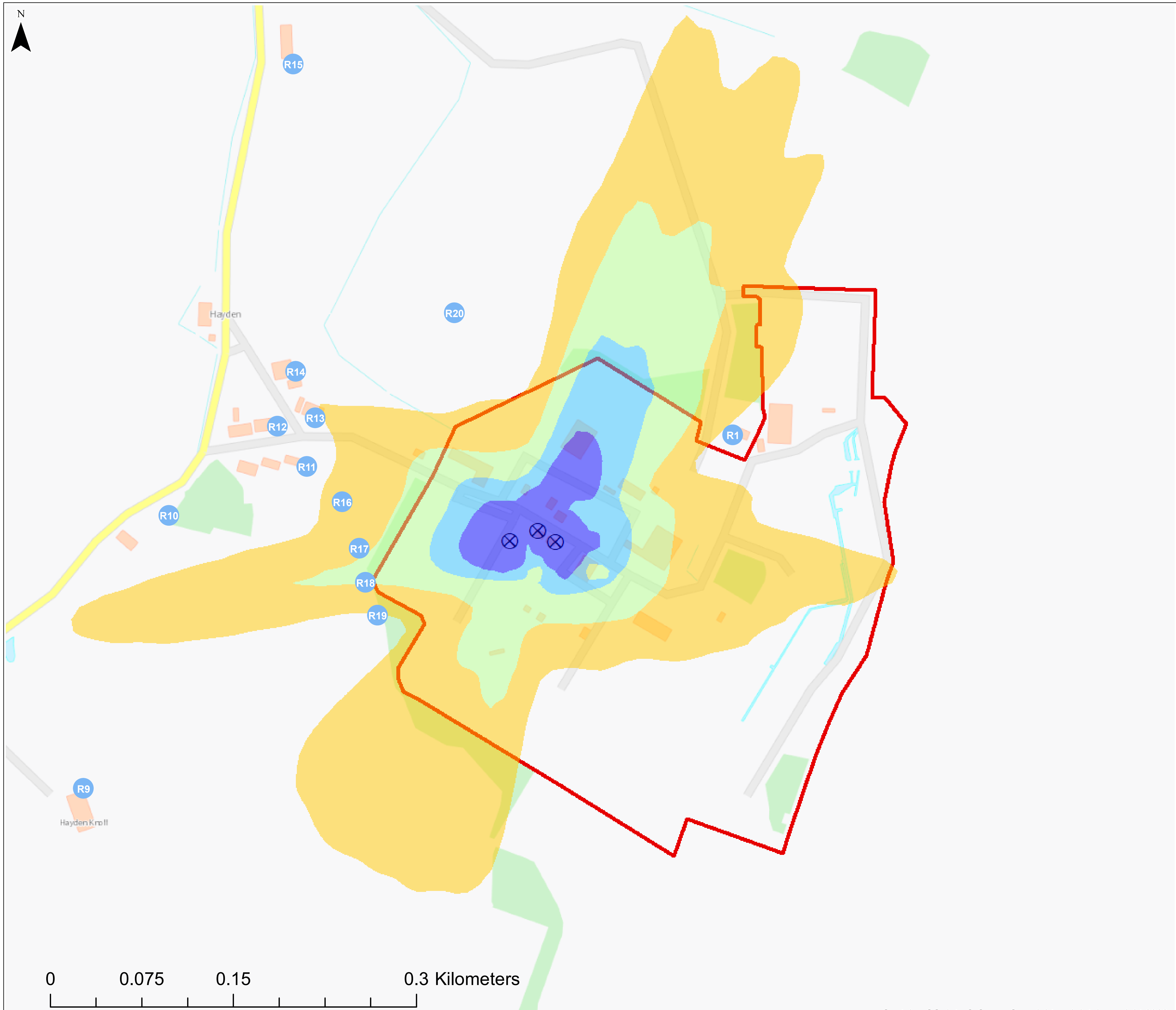

Legend

- Approximate site fenceline
- Modelled stack locations
- R1 Sensitive human receptor locations

15-minute mean (99.9th percentile) sulphur dioxide process contributions (µg/m³)

- 0 - 52
- 52 - 75
- 75 - 110
- 110 - 161
- 161 - 1,076

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	10/01/2022	Initial Issue	DH	GW	GW	MM

Jacobs

Client

SEVERN TRENT

Project

ENVIRONMENTAL PERMIT APPLICATION - HAYDEN SEWAGE TREATMENT WORKS AIR QUALITY IMPACT ASSESSMENT

Drawing Title

15-MINUTE MEAN (99.9th PERCENTILE) SULPHUR DIOXIDE PROCESS CONTRIBUTIONS, 2016 METEOROLOGICAL DATA

Drawing Status

FINAL

Scale @ A3	1:3,000	DO NOT SCALE	
Jacobs No.	B1958992	Rev	0
Client No.			

Drawing Number

FIGURE 7

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Appendix A. Dispersion Model Input Parameters

A.1 Emission Parameters

The emissions data used to represent the site for the scenario described in Section 2 is set out in Table A.1. Emission limits as set out in the MCPD[3] for existing combustion plant are also presented in Table A.1 where relevant.

Table A.1 Dispersion modelling parameters

Parameters	Unit	ENER-G 499B CHP engine (1.3 MW_{th})	Strebel boiler (0.8 MW_{th})	Strebel boiler (0.8 MW_{th})
Modelled fuel	-	Biogas	Biogas	Biogas
Emission point	-	A1	A2	A3
Assessed operation hours	Hours	8,760	8,760	8,760
Stack location	m	E 390623 N 223034	E 390646 N 223042	E 390661 N 223033
Stack position	-	Vertical	Vertical	Vertical
Stack height	m	5.14	4.75	4.75
Stack diameter	m	0.25	0.40	0.40
Flue gas temperature	°C	180	150	150
Efflux velocity	m/s	20.4	5.6	5.6
Moisture content of exhaust gas	%	11.4	10.0	10.0
Oxygen content of exhaust gas (dry)	%	8.4	3.0	3.0
Volumetric flow rate (actual)	m^3/s	1.003	0.702	0.702
Volumetric flow rate (normal)[1]	Nm^3/s	1.135	0.407	0.407
NOx emission concentration[1]	mg/Nm^3	186 (190 after 1st January 2030)	250 (250 after 1st January 2030)	250 (250 after 1st January 2030)
NOx emission rate	g/s	0.211	0.102	0.102
CO emission concentration[1]	mg/Nm^3	519	100	100
CO emission rate	g/s	0.589	0.041	0.041
PM_{10} / $PM_{2.5}$ emission concentration[1]	mg/Nm^3	2.7	5.0	5.0
PM_{10} / $PM_{2.5}$ emission rate	g/s	0.003	0.002	0.002
SO_2 emission concentration[1]	mg/Nm^3	130 (60 after 1st January 2030)	200 (200 after 1st January 2030)	200 (200 after 1st January 2030)
SO_2 emission rate	g/s	0.147	0.081	0.081
TVOC emission concentration[1]	mg/Nm^3	371	1,126	1,126
TVOC emission rate	g/s	0.421	0.459	0.459

Note 1: Normalised flows and concentrations presented at 273 K, 101.3 kPa, dry gas and oxygen content of 15% (CHP engine) or 3% (boilers).

A.2 Dispersion Model Inputs

A.2.1 Structural influences on dispersion

The main structures within the site which have been included in the model to reflect the existing site layout are identified within Table A.2. A sensitivity study has been carried out to assess the sensitivity of the model to using the buildings module.

Table A.2 Modelled building parameters

Building	Modelled building shapes	Length / diameter (m)	Width (m)	Height (m)	Angle of length to north	Centre point co-ordinates	
						Easting	Northing
Boiler House	Rectangular	7.63	5.39	3.75	120	390648	223039
Boiler House	Rectangular	7.63	5.39	3.75	121	390657	223033
Digester[1]	Circular	16.20	16.2	18.69	-	390637	223031
Digester[2]	Circular	15.90	15.9	17.71	-	390656	223020
CHP engine housing	Rectangular	6.50	3.12	2.90	30	390625	223035
Tank	Circular	19.70	19.70	9.90	-	390682	223049
Storage warehouse	Rectangular	15.80	13.30	5.70	121	390686	223013
Building	Rectangular	7.15	8.18	2.55	33	390664	223053
Gas holder	Circular	12.94	12.94	8.30	-	390675	223067

Note 1: Modelled as the main building for emission point A1 and A2.
Note 2: Modelled as the main building for emission points A3.

A.2.2 Other Model Inputs

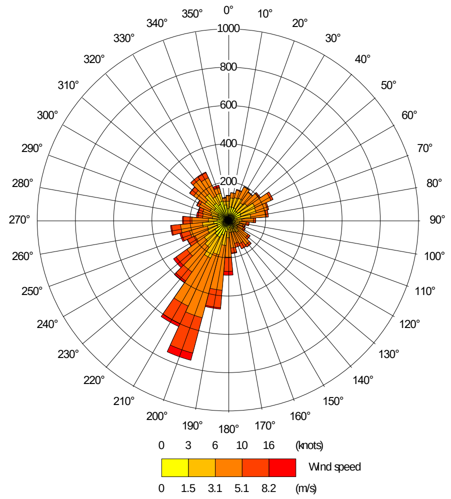
Table A.3: Other model inputs applied

Parameter	Value used	Comments
Surface roughness length for dispersion site	0.5 m	This is appropriate for the dispersion site where the local land-use ranges from open grassland to suburban areas. A sensitivity study has been carried out with fixed surface roughness values of 0.1 m and 1.0 m.
Surface roughness length at meteorological station site	0.3 m	This is appropriate for an area where the local land-is relatively open such as at the location for the Pershore meteorological station.
Minimum Monin-Obukhov Length	1 m	Typical values for the dispersion site
Surface Albedo	0.23 m	Typical values for the dispersion site
Priestley-Taylor Parameter	1 m	Typical values for the dispersion site
Terrain	Not included	Guidance for the use of the ADMS model suggests that terrain is normally incorporated within a modelling study when the gradient exceeds 1:10. As the gradient in the vicinity of the site does not exceed 1:10, a terrain file was not included in the modelling.
Meteorological data	Pershore meteorological station, 2016 - 2020	Pershore meteorological station is located approximately 28.1 km north-northeast of the site and is considered the closest most representative meteorological monitoring station to the site.

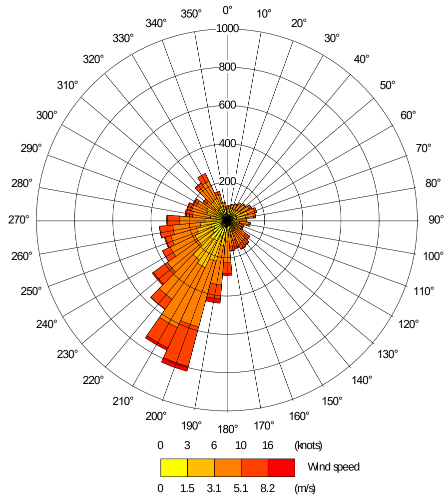
A.2.3 Meteorological Data – Wind Roses

The wind roses for each year of meteorological data utilised in the assessment are shown below.

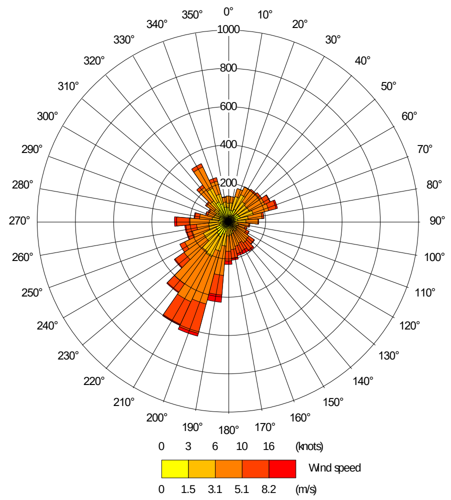
Pershore meteorological station, 2016



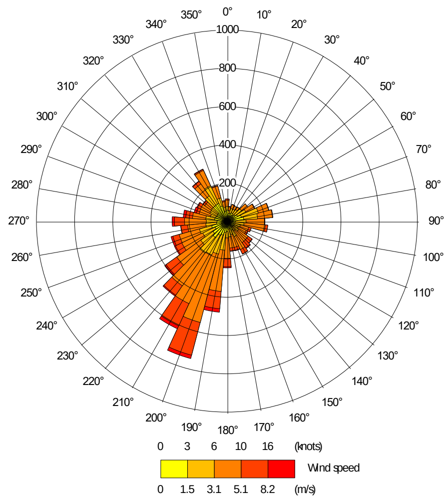
Pershore meteorological station, 2017



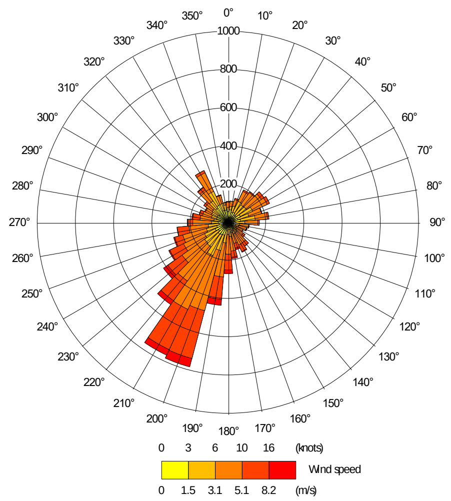
Pershore meteorological station, 2018



Pershore meteorological station, 2019



Pershore meteorological station, 2020



A.2.4 Model Domain/Study Area

The ADMS model calculates the predicted concentrations based on a user defined grid system. Generally, the larger the study area, the greater the distance between the grid calculation points and the lower the resolution of the dispersion model predictions. This is to be offset against the need to encompass an appropriately wide area within the dispersion modelling study to capture the dispersion of the stack emissions.

The modelled grid was specified as a 1.5 km x 1.5 km grid with calculation points every 10 m (i.e. 151 points along each grid axis) with a grid height of 1.5 m. This size of grid was selected to provide a good grid resolution and also encompass a sufficient area so that the maximum predicted concentrations would be determined. The area within the site boundary was excluded from the modelled grid as it is not accessible to the general public. The modelled grid parameters are presented in Table A.4

Table A.4: Modelled grid parameters

	Start	Finish	Number of grid points	Grid spacing (m)
Easting	389873	391373	151	10
Northing	222284	223784	151	10
Grid height	1.5	1.5	1	-

As Cheltenham Whole Borough AQMA is adjacent to the eastern boundary of the site, those grid points described above which encompass the AQMA were used to quantify the maximum annual mean NO_2 process contributions.

As well as the modelled grid, the potential impact at 20 sensitive human receptors (e.g. exposure locations such as residential properties and a PRoW) and Cotswold Beechwoods SAC were assessed. The receptor locations are shown in Figure 2 and Figure 3 and further details of the receptor locations are provided in Table A.5 and Table A.6.

Table A.5: Assessed sensitive human receptor locations

Receptor	Description	Grid reference		Distance from CHP engine stack (km)	Direction from CHP engine stack
		Easting	Northing		
R1	Residential property off Hayden Lane	390806	223120	0.20	ENE
R2	Residential property on Springbank Road	391376	223051	0.75	E
R3	Residential property on Laburnum Court	391431	222755	0.85	ESE
R4	Residential property on Alder Curt	391342	222654	0.81	ESE
R5	Residential property on Galileo Gardens	391274	222497	0.84	SE
R6	Residential property on Fiddlers Green Road	390761	222452	0.60	SSE
R7	Residential property on Pheasant Lane	390570	222395	0.64	S
R8	Residential property on Pheasant Lane	390240	222509	0.65	SW
R9	Residential property on Hayden Lane	390274	222830	0.40	WSW
R10	Residential property on Hayden Lane	390344	223054	0.28	W
R11	Residential property off Hayden Lane	390457	223094	0.18	WNW
R12	Residential property off Hayden Lane	390433	223127	0.21	WNW
R13	Residential property off Hayden Lane	390464	223134	0.19	WNW
R14	Residential property off Hayden Lane	390448	223172	0.22	NW
R15	Residential property on Hayden Lane	390446	223424	0.43	NNW
R16	PRoW	390486	223065	0.14	WNW
R17	PRoW	390500	223027	0.12	W

Receptor	Description	Grid reference		Distance from CHP engine stack (km)	Direction from CHP engine stack
		Easting	Northing		
R18	PRoW	390505	222999	0.12	WSW
R19	PRoW	390515	222972	0.12	WSW
R20	PRoW	390578	223220	0.19	NNW

Table A.6: Assessed protected conservation area location

Receptor	Description	Grid reference		Distance from CHP engine stack (km)	Direction from CHP engine stack
		Easting	Northing		
H1	Cotswold Beechwoods SAC	389381	214827	8.3	S

A.2.5 Treatment of oxides of nitrogen

It was assumed that 70% of NOx emitted from the assessed combustion plant will be converted to NO_2 at ground level in the vicinity of the site, for determination of the annual mean NO_2 concentrations, and 35% of emitted NOx will be converted to NO_2 for determination of the hourly mean NO_2 concentrations, in line with guidance provided by the Environment Agency (Environment Agency, 2022b). This approach is likely to overestimate the annual mean NO_2 concentrations considerably at the most relevant assessment locations close to the site.

A.2.6 Calculation of PECs

In the case of long-term mean concentrations, it is relatively straightforward to combine modelled process contributions with baseline air quality levels, as long-term mean concentrations due to plant emissions could be added directly to long-term mean baseline concentrations.

It is not possible to add short-period peak baseline and process concentrations directly. This is because the conditions which give rise to peak ground-level concentrations of substances emitted from an elevated source at a particular location and time are likely to be different to the conditions which give rise to peak concentrations due to emissions from other sources.

As described in the Environment Agency guidance (Environment Agency, 2021a), for most substances the short-term peak PC values are added to twice the long-term mean baseline concentration to provide a reasonable estimate of peak concentrations due to emissions from all sources.

A.2.7 Modelling Uncertainty

There are always uncertainties in dispersion models, in common with any environmental modelling study, because a dispersion model is an approximation of the complex processes which take place in the atmosphere. Some of the key factors which lead to uncertainty in atmospheric dispersion modelling are as follows:

- The quality of the model output depends on the accuracy of the input data enter the model. Where model input data are a less reliable representation of the true situation, the results are likely to be less accurate;
- The meteorological data sets used in the model are not likely to be completely representative of the meteorological conditions at the site. However, the most suitable available meteorological data was chosen for the assessment;
- Models are generally designed on the basis of data obtained for large scale point sources and may be less well validated for modelling emissions from smaller scale sources;

- The dispersion of pollutants around buildings is a complex scenario to replicate. Dispersion models can take account of the effects of buildings on dispersion; however, there will be greater uncertainty in the model results when buildings are included in the model;
- Modelling does not specifically take into account individual small-scale features such as vegetation, local terrain variations and off-site buildings. The roughness length (z_o) selected is suitable to take general account of the typical size of these local features within the model domain; and
- To take account of these uncertainties and to ensure the predictions are more likely to be over-estimates than under-estimates, the conservative assumptions described below have been used for this assessment.

A.2.8 Conservative Assumptions

The conservative assumptions adopted in this study are summarised below.

- The CHP engine and boilers were assumed to operate at maximum load for 8,760 hours each calendar year but in practice, the CHP engine will have periods of shut-down and maintenance and may not always operate at maximum load. Furthermore, in practice, the boilers are not likely to operate simultaneously are for more than 6,000 hours per year.
- The study is based on emissions being continuously at the emission limits and calculated emissions specified.
- The maximum predicted concentrations at any residential areas as well as off-site locations were considered for the assessment of short-term concentrations and the maximum predicted concentrations at any residential areas were considered for assessment of annual mean concentrations within the air quality study area. Concentrations at other locations will be less than the maximum values presented.
- The highest predicted concentrations obtained using any of the five different years of meteorological data have been used in this assessment. During a typical year the ground level concentrations are likely to be lower.
- It was assumed that 100% of the particulate matter emitted from the plant is in the PM_{10} size fraction. The actual proportion will be less than 100%.
- It was assumed that 100% of the particulate matter emitted from the plant is in the $PM_{2.5}$ size fraction. The actual proportion will be less than 100%.
- It was assumed the vegetation type selected at the Cotswold Beechwoods SAC is present at the specific modelled location.

Appendix B. Calculating Acid and Nitrogen Deposition

B.1 Methodology

Nitrogen and acid deposition have been predicted using the methodologies presented in the Air Quality Technical Advisory Group (AQTAG) guidance note: AQTAG 06 "*Technical Guidance on Detailed Modelling Approach for an Appropriate Assessment for Emissions to Air* (AQTAG, 2014).

When assessing the deposition of nitrogen, it is important to consider the different deposition properties of nitric oxide (NO) and NO_2. It is generally accepted that there is no wet or dry deposition arising from NO in the atmosphere. Thus, it is normally necessary to distinguish between NO and NO_2 in a deposition assessment. In this case, the conservative assumption that 70% of the NOx are in the form of NO_2 was adopted.

Information on the existing nitrogen and acid deposition was obtained from the APIS database (Centre for Ecology and Hydrology, 2021). Information on the deposition critical loads for each habitat site was also obtained from the APIS database using the Site Relevant Critical Load function.

The annual dry deposition flux can be obtained from the modelled annual average ground level concentration via use of the formula:

Dry deposition flux (μg/m^2/s) = ground level concentration (μg/m^3) x deposition velocity (m/s)

(where μg refers to μg of the chemical species under consideration).

The deposition velocities for various chemical species recommended for use in the AQTAG guidance note (AQTAG, 2014) are shown below in Table B.1.

Table B.1: Recommended dry deposition velocities

Chemical species	Recommended deposition velocity (m/s)	
NO_2	Grassland (short)	0.0015
	Forest (tall)	0.003
SO_2	Grassland (short)	0.012
	Forest (tall)	0.024

To convert the dry deposition flux from units of μg/m^2/s (where μg refers to μg of the chemical species) to units of kg N/ha/yr (where kg refers to kg of nitrogen), multiply the dry deposition flux by the conversion factors shown in Table B.2. To convert dry deposition flux to acid deposition (keq/ha/yr), multiply the concentrations by the factors shown in Table B.3.

Table B.2: Dry deposition flux conversion factors for nutrient nitrogen deposition

μg/m^2/s of species	Conversion factor to kg N/ha/yr
NO_2	95.9

Table B.3: Dry deposition flux conversion factors for acidification

μg/m^2/s of species	Conversion factor to keq/ha/yr
NO_2	6.84
SO_2	9.84

Appendix C. Results at Sensitive Human Locations

Table C.1: Results of detailed assessment at sensitive human receptor locations for maximum 8-hour mean and 1-hour mean CO predicted concentrations

Receptor ID	Baseline air quality level (µg/m³)	Maximum 8-hour running mean					Maximum 1-hour mean				
		EQS (µg/m³)	PC (µg/m³)	PEC (µg/m³)	PC/EQS (%)	PEC/EQS (%)	EQS (µg/m³)	PC (µg/m³)	PEC (µg/m³)	PC/EQS (%)	PEC/EQS (%)
R1	274	10,000	49.4	323.6	0.5%	3.2%	30,000	80.1	354.3	0.3%	1.2%
R2	293		19.1	312.1	0.2%	3.1%		46.3	339.3	0.2%	1.1%
R3	299		28.2	327.4	0.3%	3.3%		39.2	338.4	0.1%	1.1%
R4	299		32.6	331.8	0.3%	3.3%		40.2	339.4	0.1%	1.1%
R5	299		19.5	318.8	0.2%	3.2%		36.5	335.7	0.1%	1.1%
R6	280		16.1	296.5	0.2%	3.0%		29.5	309.9	0.1%	1.0%
R7	280		11.3	291.8	0.1%	2.9%		27.7	308.1	0.1%	1.0%
R8	280		14.6	295.1	0.1%	3.0%		28.4	308.8	0.1%	1.0%
R9	280		21.0	301.4	0.2%	3.0%		40.2	320.6	0.1%	1.1%
R10	274		88.2	362.4	0.9%	3.6%		106.7	380.9	0.4%	1.3%
R11	274		129.3	403.4	1.3%	4.0%		173.7	447.9	0.6%	1.5%
R12	274		109.8	384.0	1.1%	3.8%		145.2	419.4	0.5%	1.4%
R13	274		94.9	369.1	0.9%	3.7%		175.4	449.5	0.6%	1.5%
R14	274		73.0	347.1	0.7%	3.5%		161.9	436.1	0.5%	1.5%
R15	274		17.8	291.9	0.2%	2.9%		39.2	313.3	0.1%	1.0%
R16	274		144.7	418.8	1.4%	4.2%		208.8	482.9	0.7%	1.6%
R17	274		169.6	443.7	1.7%	4.4%		222.1	496.2	0.7%	1.7%
R18	280		177.9	458.3	1.8%	4.6%		242.2	522.6	0.8%	1.7%
R19	280		86.3	366.7	0.9%	3.7%		147.5	428.0	0.5%	1.4%
R20	274		52.6	326.8	0.5%	3.3%		65.8	340.0	0.2%	1.1%

Table C.2: Results of detailed assessment at sensitive human receptor locations for annual mean and 1-hour mean (99.79th percentile) NO_2 predicted concentrations

Receptor ID	Annual mean						99.79th percentile of 1-hour mean					
	Baseline air quality level (µg/m³)	EQS (µg/m³)	PC (µg/m³)	PEC (µg/m³)	PC/EQS (%)	PEC/EQS (%)	EQS (µg/m³)	Baseline air quality level (µg/m³)	PC (µg/m³)	PEC (µg/m³)	PC/EQS (%)	PEC/EQS (%)
R1	9.5	40	3.2	12.6	8.0%	31.6%	200	18.9	15.8	34.7	7.9%	17.3%
R2	9.9		0.3	10.2	0.7%	25.5%		19.8	5.1	24.9	2.6%	12.5%
R3	9.5		0.2	9.6	0.4%	24.1%		18.9	4.5	23.5	2.3%	11.7%
R4	9.5		0.2	9.6	0.4%	24.1%		18.9	4.6	23.5	2.3%	11.7%
R5	9.5		0.2	9.6	0.4%	24.1%		18.9	3.9	22.8	1.9%	11.4%
R6	9.5		0.2	9.6	0.5%	24.1%		18.9	3.7	22.6	1.8%	11.3%
R7	9.5		0.2	9.7	0.5%	24.2%		18.9	6.0	24.9	3.0%	12.4%
R8	9.5		0.3	9.7	0.7%	24.3%		18.9	6.1	25.0	3.1%	12.5%
R9	9.5		0.6	10.0	1.4%	25.0%		18.9	8.1	27.0	4.1%	13.5%
R10	9.5		0.8	10.3	2.1%	25.7%		18.9	12.6	31.5	6.3%	15.7%
R11	9.5		1.3	10.7	3.2%	26.8%		18.9	17.0	35.9	8.5%	17.9%
R12	9.5		0.9	10.4	2.3%	26.0%		18.9	14.8	33.7	7.4%	16.8%
R13	9.5		1.1	10.6	2.8%	26.4%		18.9	17.0	35.9	8.5%	18.0%
R14	9.5		0.9	10.3	2.2%	25.8%		18.9	14.7	33.6	7.4%	16.8%
R15	9.5		0.3	9.8	0.9%	24.5%		18.9	6.1	25.0	3.0%	12.5%
R16	9.5		1.9	11.3	4.7%	28.3%		18.9	21.5	40.4	10.8%	20.2%
R17	9.5		2.8	12.2	6.9%	30.5%		18.9	26.8	45.7	13.4%	22.8%
R18	9.9		2.8	12.7	6.9%	31.7%		19.8	27.4	47.3	13.7%	23.6%
R19	9.9		2.7	12.6	6.8%	31.6%		19.8	19.9	39.7	9.9%	19.9%
R20	9.5		1.4	10.9	3.5%	27.2%		18.9	13.1	32.0	6.6%	16.0%

Table C.3: Results of detailed assessment at sensitive human receptor locations for 24-mean (99.18th percentile) and 1-hour mean (99.73rd percentile) SO_2 predicted concentrations

Receptor ID	99.18th percentile of 24-hour mean						99.73rd percentile of 1-hour mean					
	Baseline air quality level (µg/m^3)	EQS (µg/m^3)	PC (µg/m^3)	PEC (µg/m^3)	PC/EQS (%)	PEC/EQS (%)	EQS (µg/m^3)	Baseline air quality level (µg/m^3)	PC (µg/m^3)	PEC (µg/m^3)	PC/EQS (%)	PEC/EQS (%)
R1	4.4	125	13.5	17.9	10.8%	14.3%	350	4.4	34.1	38.5	9.7%	11.0%
R2	4.5		2.0	6.5	1.6%	5.2%		4.5	10.2	14.7	2.9%	4.2%
R3	4.5		1.6	6.2	1.3%	4.9%		4.5	8.9	13.4	2.5%	3.8%
R4	4.5		1.6	6.1	1.2%	4.9%		4.5	9.1	13.7	2.6%	3.9%
R5	4.5		2.0	6.5	1.6%	5.2%		4.5	7.7	12.2	2.2%	3.5%
R6	4.6		1.9	6.5	1.5%	5.2%		4.6	7.4	12.0	2.1%	3.4%
R7	4.6		3.5	8.1	2.8%	6.5%		4.6	13.2	17.8	3.8%	5.1%
R8	4.6		3.1	7.7	2.5%	6.2%		4.6	13.6	18.2	3.9%	5.2%
R9	4.6		5.9	10.5	4.7%	8.4%		4.6	15.7	20.3	4.5%	5.8%
R10	4.4		7.8	12.3	6.3%	9.8%		4.4	24.7	29.1	7.1%	8.3%
R11	4.4		12.3	16.7	9.8%	13.4%		4.4	33.7	38.1	9.6%	10.9%
R12	4.4		9.9	14.3	7.9%	11.4%		4.4	28.6	33.0	8.2%	9.4%
R13	4.4		10.9	15.3	8.7%	12.2%		4.4	33.0	37.4	9.4%	10.7%
R14	4.4		9.3	13.7	7.4%	10.9%		4.4	28.6	33.0	8.2%	9.4%
R15	4.4		3.9	8.3	3.1%	6.6%		4.4	12.5	16.9	3.6%	4.8%
R16	4.4		18.1	22.5	14.4%	18.0%		4.4	42.9	47.3	12.3%	13.5%
R17	4.4		24.3	28.7	19.4%	23.0%		4.4	54.2	58.7	15.5%	16.8%
R18	4.6		27.2	31.8	21.8%	25.4%		4.6	54.8	59.4	15.7%	17.0%
R19	4.6		24.9	29.5	19.9%	23.6%		4.6	42.1	46.7	12.0%	13.3%
R20	4.4		12.0	16.4	9.6%	13.1%		4.4	27.5	31.9	7.9%	9.1%

Table C.4: Results of detailed assessment at sensitive human receptor locations for 15-minute mean (99.9th percentile) SO_2 predicted concentrations

Receptor ID	99.9th percentile of 15-minute mean					
	Baseline air quality level (µg/m³)	EQS (µg/m³)	PC (µg/m³)	PEC (µg/m³)	PC/EQS (%)	PEC/EQS (%)
R1	4.4	266	57.4	61.9	21.6%	23.3%
R2	4.5		21.8	26.3	8.2%	9.9%
R3	4.5		18.6	23.2	7.0%	8.7%
R4	4.5		18.1	22.6	6.8%	8.5%
R5	4.5		17.7	22.3	6.7%	8.4%
R6	4.6		13.1	17.7	4.9%	6.6%
R7	4.6		22.1	26.7	8.3%	10.0%
R8	4.6		25.0	29.6	9.4%	11.1%
R9	4.6		29.9	34.5	11.2%	13.0%
R10	4.4		46.4	50.8	17.4%	19.1%
R11	4.4		59.3	63.7	22.3%	24.0%
R12	4.4		57.4	61.8	21.6%	23.2%
R13	4.4		58.0	62.4	21.8%	23.5%
R14	4.4		56.4	60.8	21.2%	22.9%
R15	4.4		19.0	23.4	7.2%	8.8%
R16	4.4		67.5	72.0	25.4%	27.1%
R17	4.4		71.4	75.9	26.9%	28.5%
R18	4.6		78.7	83.3	29.6%	31.3%
R19	4.6		48.3	52.9	18.2%	19.9%
R20	4.4		35.3	39.7	13.3%	14.9%

Table C.5: Results of detailed assessment at sensitive human receptor locations for annual mean and 24-hour mean (90.41st) percentile) PM_{10} predicted concentrations

Receptor ID	Annual mean						90.41st percentile of 24-hour mean					
	Baseline air quality level (µg/m³)	EQS (µg/m³)	PC (µg/m³)	PEC (µg/m³)	PC/EQS (%)	PEC/EQS (%)	EQS (µg/m³)	Baseline air quality level (µg/m³)	PC (µg/m³)	PEC (µg/m³)	PC/EQS (%)	PEC/EQS (%)
R1	13.5	40	0.08	13.6	0.20%	34.0%	50	27.1	0.20	27.2	0.4%	54.5%
R2	13.4		0.01	13.4	0.02%	33.4%		26.7	0.02	26.7	0.0%	53.4%
R3	13.4		0.00	13.4	0.01%	33.5%		26.8	0.01	26.8	0.0%	53.6%
R4	13.4		0.00	13.4	0.01%	33.5%		26.8	0.01	26.8	0.0%	53.6%
R5	13.4		0.00	13.4	0.01%	33.5%		26.8	0.02	26.8	0.0%	53.6%
R6	12.9		0.00	12.9	0.01%	32.2%		25.8	0.02	25.8	0.0%	51.6%
R7	12.9		0.01	12.9	0.01%	32.2%		25.8	0.02	25.8	0.0%	51.6%
R8	12.9		0.01	12.9	0.02%	32.2%		25.8	0.03	25.8	0.1%	51.6%
R9	12.9		0.01	12.9	0.03%	32.3%		25.8	0.05	25.8	0.1%	51.7%
R10	13.5		0.02	13.5	0.05%	33.9%		27.1	0.08	27.1	0.2%	54.3%
R11	13.5		0.03	13.6	0.07%	33.9%		27.1	0.12	27.2	0.2%	54.3%
R12	13.5		0.02	13.5	0.06%	33.9%		27.1	0.09	27.1	0.2%	54.3%
R13	13.5		0.03	13.6	0.06%	33.9%		27.1	0.10	27.2	0.2%	54.3%
R14	13.5		0.02	13.5	0.05%	33.9%		27.1	0.08	27.1	0.2%	54.3%
R15	13.5		0.01	13.5	0.02%	33.8%		27.1	0.03	27.1	0.1%	54.2%
R16	13.5		0.04	13.6	0.11%	33.9%		27.1	0.18	27.2	0.4%	54.5%
R17	13.5		0.06	13.6	0.16%	34.0%		27.1	0.28	27.3	0.6%	54.7%
R18	12.9		0.06	13.0	0.16%	32.4%		25.8	0.25	26.0	0.5%	52.1%
R19	12.9		0.06	13.0	0.16%	32.4%		25.8	0.28	26.1	0.6%	52.1%
R20	13.5		0.03	13.6	0.08%	33.9%		27.1	0.13	27.18	0.3%	54.4%

Table C.6: Results of detailed assessment at sensitive human receptor locations for annual mean $PM_{2.5}$ predicted concentrations

Receptor ID	Annual mean					
	Baseline air quality level (µg/m³)	EQS (µg/m³)	PC (µg/m³)	PEC (µg/m³)	PC/EQS (%)	PEC/EQS (%)
R1	8.5	20	0.08	8.6	0.4%	43.1%
R2	9.0		0.01	9.0	0.0%	45.0%
R3	9.0		0.00	9.0	0.0%	45.1%
R4	9.0		0.00	9.0	0.0%	45.1%
R5	9.0		0.00	9.0	0.0%	45.1%
R6	8.4		0.00	8.4	0.0%	42.1%
R7	8.4		0.01	8.4	0.0%	42.1%
R8	8.4		0.01	8.4	0.0%	42.1%
R9	8.4		0.01	8.4	0.1%	42.1%
R10	8.5		0.02	8.6	0.1%	42.8%
R11	8.5		0.03	8.6	0.1%	42.8%
R12	8.5		0.02	8.6	0.1%	42.8%
R13	8.5		0.03	8.6	0.1%	42.8%
R14	8.5		0.02	8.6	0.1%	42.8%
R15	8.5		0.01	8.5	0.0%	42.7%
R16	8.5		0.04	8.6	0.2%	42.9%
R17	8.5		0.06	8.6	0.3%	43.0%
R18	8.4		0.06	8.5	0.3%	42.4%
R19	8.4		0.06	8.5	0.3%	42.4%
R20	8.5		0.03	8.6	0.2%	42.8%

Table C.7: Results of detailed assessment at sensitive human receptor locations for annual mean and maximum 24-hour mean TVOC predicted concentrations

Receptor ID	Annual mean						100th percentile of 24-hour mean					
	Baseline air quality level	EQS (µg/m³)	PC (µg/m³)	PEC (µg/m³)	PC/EQS (%)	PEC/EQS (%)	EQS (µg/m³)	Baseline air quality level	PC (µg/m³)	PEC (µg/m³)	PC/EQS (%)	PEC/EQS (%)
R1	0.3	5 (Benzene)	16.4	16.7	327.5%	333.0%	30 (Benzene)	0.6	72.7	73.3	242.4%	244.3%
R2	0.3		1.3	1.6	26.3%	32.6%		0.6	14.2	14.8	47.3%	49.4%
R3	0.3		0.8	1.1	15.5%	22.3%		0.7	10.3	11.0	34.4%	36.7%
R4	0.3		0.8	1.1	15.9%	22.6%		0.7	12.0	12.7	40.0%	42.2%
R5	0.3		0.8	1.2	16.6%	23.4%		0.7	12.3	12.9	40.9%	43.1%
R6	0.3		0.9	1.2	18.0%	23.9%		0.6	16.9	17.4	56.2%	58.1%
R7	0.3		1.1	1.4	22.5%	28.4%		0.6	21.0	21.6	70.1%	72.1%
R8	0.3		1.5	1.8	29.5%	35.4%		0.6	22.3	22.9	74.3%	76.2%
R9	0.3		2.7	3.0	54.4%	60.3%		0.6	29.6	30.2	98.6%	100.5%
R10	0.3		3.6	3.9	72.8%	78.3%		0.6	66.3	66.9	221.1%	223.0%
R11	0.3		5.6	5.8	111.4%	116.9%		0.6	68.0	68.5	226.6%	228.4%
R12	0.3		4.1	4.4	82.0%	87.5%		0.6	56.4	56.9	187.9%	189.7%
R13	0.3		4.8	5.1	96.1%	101.7%		0.6	76.6	77.1	255.3%	257.1%
R14	0.3		3.8	4.1	75.9%	81.4%		0.6	64.0	64.6	213.4%	215.2%
R15	0.3		1.6	1.9	32.5%	38.0%		0.6	24.6	25.1	81.8%	83.7%
R16	0.3		8.2	8.5	164.9%	170.4%		0.6	91.9	92.4	306.3%	308.2%
R17	0.3		11.7	11.9	233.1%	238.6%		0.6	192.1	192.7	640.4%	642.3%
R18	0.3		11.7	12.0	234.6%	240.5%		0.6	143.8	144.4	479.2%	481.2%
R19	0.3		12.1	12.4	242.6%	248.5%		0.6	117.3	117.9	391.0%	392.9%
R20	0.3		6.5	6.7	129.1%	134.7%		0.6	94.9	95.5	316.4%	318.3%