CRESTWOOD ENVIRONMENTAL LTD

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Wessex Water Services Ltd.

Sampling and Enumeration of Bioaerosols from:

Trowbridge Bioresources Centre
Bradford Road,
Trowbridge,
Wiltshire,
BA14 9BJ

Report Reference: CE-TB-2228-RP01-Final

Report Date: 12 April 2023

Produced by Crestwood Environmental Ltd.

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ECOLOGY	HERITAGE	WATER	TREES
MINERALS / WASTE	AIR QUALITY	LAND QUALITY	VISUALISATION

Crestwood Report Reference: CE-TB-2228-RP01-Final:

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1 INTRODUCTION

1.1 BACKGROUND

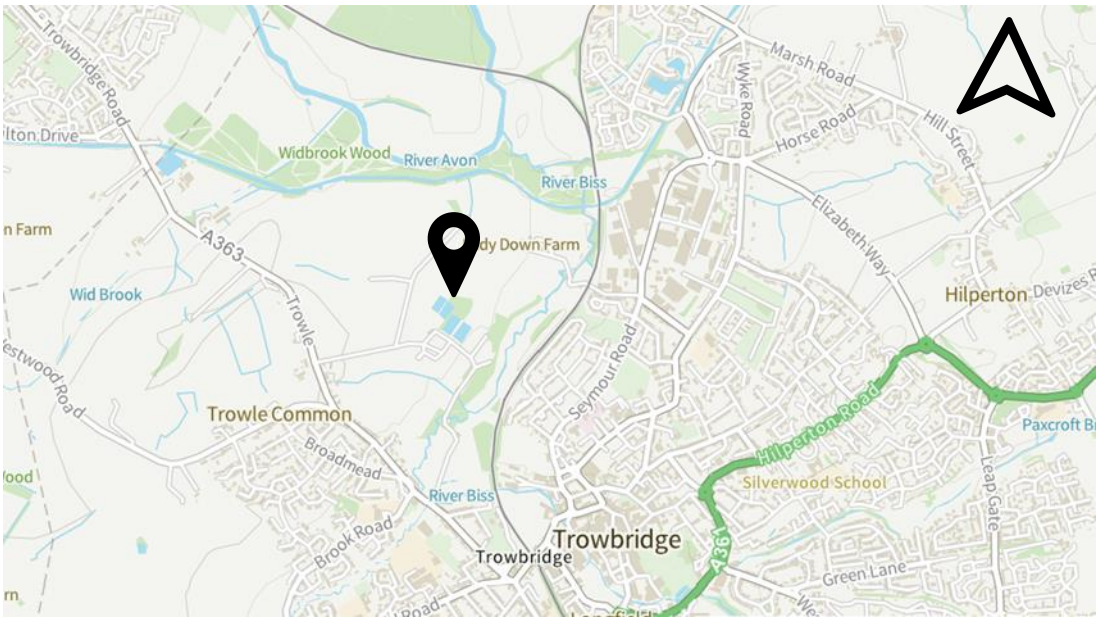
1.1.1 Crestwood Environmental Ltd., a firm of environmental consultants based in Wolverhampton, has been commissioned by Wessex Water Services Ltd. ('the Client') to undertake an examination of the bioaerosol concentrations at locations around the new installation boundary of their Trowbridge Bioresources Centre (BC) ('the Site') in Trowbridge, BA14 9BJ.

1.1.2 The purpose of the investigation is to obtain measurements of bioaerosols present at a number of locations around the boundary of the new installation to support an Environmental Permit application for the Site. The monitoring was undertaken by Kat Okon of Crestwood Environmental Ltd on 14th of February 2023 whilst the Site was operational.

1.2 THE SITE

1.2.1 Trowbridge BC is located approximately 2.5km northwest of the town of Trowbridge, with the closest dwelling being located about 200m from the Site. The river Biss flows approximately 100m east of the Site. The solar farm is located approximately 50m north and northwest of the Site, beyond which Wildbrook Wood, Kennet & Avon Canal and River Avon are located about 600m north. The site borders the agricultural land to the south and southwest. The residential area of Trowle Common is located approximately 400m southwest of the Site (see Figure 1).

Figure 1. Site location



1.2.2 The closest housing estate to Trowbridge BC is located approximately 200 m southeast of the Site's cake skip holding area, and therefore, it is regarded as the nearest sensitive receptor (NSR).

1.2.3 According to Technical Guidance Note (Monitoring); M9: Environmental monitoring of bioaerosols at regulated facilities (Environment Agency, Version 2, July 2018), the nearest sensitive receptor (NSR) is the closest location to the permitted activities where people are likely to be for a prolonged period of time but not less than 6 hours and falls within 250m of the Site.

1.2.4 However, in accordance with the M9 Guidance rule, at sites with several separate widely spread sources, the sources located more than 250m away from the NSR should be discounted from the monitoring because they are not likely to affect the NSR.

1.2.5 Because of the Site's unusual shape, bioaerosol sources on the west corner of the Site are located

further away from the NSR than 250 m, and therefore they were eliminated from the monitoring.

1.2.6 It was assumed that the only source of bioaerosol that may affect the NSR is the cake skip holding area (see Appendix 1).

1.3 SLUDGE TREATMENT PROCESS

1.3.1 The Trowbridge BC treats indigenous sewage sludges arising from sewage treatment processes operated within the wider Trowbridge Water Recycling Centre (WRC), as well as sewage sludges generated by smaller WW 'satellite' sewage works. The main activities undertaken within the installation include:

- Sludge reception and screening;
- Raw sludge thickening;
- Anaerobic digestion (including associated heat generation from Digester Boiler to support AD activities);
- Liquor balancing;
- Digested sludge dewatering;
- Storage and maturation of digested sludge prior to transfer off site for land spreading as an agricultural soil conditioning agent;
- Raw material storage and use;
- Surface water and process liquor collection and transfer to Trowbridge WRC for treatment; and
- Waste storage and transfer off site.

1.3.2 Imported sludge is transferred from tankers into sludge reception tank and primary indigenous sludge. The storage tank is also where the site's indigenous primary sludge is discharged. The sludge from the reception tank flow is pumped forward to the 2 no. strain presses.

1.3.3 The strained sludge is delivered to 2 no gravity belt thickeners (GBT) feed tanks via two holding tanks (strained transfer tank and pre-thickener tank). The 2 no. GBTs liquors are transferred to the head of the works via return liquor PS.

1.3.4 The thickened sludge is pumped to the post-thickened tank before being forwarded for digestion.

1.3.5 The digestion process is made up of two phases; acid phase digestion (APD) and mesophilic anaerobic digestion (MAD) which make up the first phase, and secondary digester making up the second phase. The "digester boiler" supplies heat to the APD, which is currently operated at around 30^{0}C. Residual heat is used in the MAD to facilitate biological activity.

1.3.6 Digested sludge is pumped from the secondary digester to two sludge dewatering belts. Filtrate generated by dewatering is forwarded to two liquor balancing tanks (concentration tanks) before being pumped via filtrate return pumps to the head of works for treatment at Trowbridge WRC. The digested cake ("sludge cake") from the dewatering activity is conveyed into skips in the skip storage area before being sent off the Site for disposal.

1.3.7 The biogas is mainly utilised by the gas to grid system. If the gas does not meet the required standard or the gas-to-grid system has failed, the biogas is utilised by the waste gas burner (CHP) and the boilers.

1.3.8 The waste gas burner design includes the provision of the gas holder with sufficient capacity and the use of high-integrity relief valves. Plant management includes balancing the gas system and

using advanced process control.

1.3.9 The CHP process is designed to optimise the use of biogas and minimise the potential for releases to air. When biogas is available it is preferentially used to power the CHP engine and provide energy to be used by the Site or resold to the National Grid with excess heat being used to maintain the optimum operating temperature of the primary digesters.

1.3.10 Under normal operating conditions, biogas is burned in the CHP or dual-fuel boilers. When biogas volumes are in excess of operational requirements and cannot be reduced by the operation of the engine and boilers, it is abated by the flare stack. The flare stack is designed and operated in accordance with Landfill Guidance Note (LFTGN) 05.

2 BIOAEROSOLS

2.1.1 Bioaerosols are airborne particles consisting of, or originating from micro-organisms (i.e., bacteria, viruses, and fungi), metabolites, toxins or fragments of micro-organisms. These particles come from organic matter, plants, soil, animals and humans. They may be put into suspension in the air, adhere to organic dust particles and tiny droplets of water with which they come into contact and then may be transported, creating bioaerosols.

2.1.2 Typically, bioaerosols consist of very fine particles measuring less than 20 microns in diameter. These particles can be inhaled and held in the nose and mouth while the smallest, less than 10 microns, are respirable and can penetrate deep into the lungs.

2.1.3 Bioaerosols could potentially cause ill heath in the people exposed to them either by infection, or through an allergic reaction. The main route of exposure to bioaerosols is by inhalation. Mean and median background levels are highly variable and can range from 1 to 100,000 colony-forming units per cubic metre (cfu/m^3) (Pearson. C et al, 2015). Many micro-organisms grow and are released into the air at irregular intervals or depend on some form of air turbulence or material disturbance to make them airborne. Because there is a large variation in size, shape and mass of microbial particles, some remain airborne for extended periods, while others fall back to the ground rapidly. In outdoor situations, temperature, humidity and wind speed are all critical factors in determining the airborne concentration of bacteria and fungi as well as their metabolic products. In indoor situations, micro-organisms are more likely to be aerosolised following jet washing or high levels of turbulence from the unloading of biodegradable waste (Mette Madsen and Matthiesen, 2013).

2.1.4 Signs such as respiratory symptoms, nausea and headaches have been reported at concentrations of 10^5 or 10^6 cfu/m^3 for total bacteria. Fungi are known to cause the same symptoms at concentrations >10^4 cfu/m^3. Review of Health Risks for Workers in the Waste and Recycling Industry (Searl and Crawford, 2012), states:

"Bacterial exposures have not been widely measured in epidemiological studies of the waste industry. Adverse effects on respiratory and more general health (excessive tiredness) have been reported in waste workers exposed to concentrations exceeding 10^6 total bacteria/m^3 or 10^5 cfu/m^3. There are few data from studies in other sectors relevant to the waste industry. "

"The exposure-response information available for airborne fungi is highly inconsistent and the use of a variety of measurement metrics limits inter-study comparison, as does the variation of the species present in different environments. Adverse effects on respiratory health have been generally reported in workers in the waste and other industries at concentrations exceeding 10^4 cfu/m^3 with limited data suggesting that gastrointestinal effects may arise at concentrations of less than 10^5 cfu/m^3. More severe respiratory symptoms including hypersensitivity pneumonitis have been reported at concentrations of 10^6-10^9 cfu/m^3."

3 METHODOLOGY AND METHODS

3.1 BIOAEROSOLS MONITORING METHODOLOGY

3.1.1 British Standard 13098:2001 Workplace Guidelines for Measurement of Airborne Micro-Organisms and Endotoxins provides guidelines for the assessment of workplace exposure to airborne micro-organisms including the determination of total number and culturable number of micro-organisms in the workplace atmosphere (BSI, 2001).

3.1.2 In line with these guidelines Crestwood Environmental follows Technical Guidance Note (Monitoring); M9: Environmental monitoring of bioaerosols at regulated facilities (Environment Agency, Version 2, July 2018).

3.2 METHODS AND PROCEDURES

3.2.1 The Technical Guidance Note M9 was applied to determine the sampling locations and methodology.

3.2.2 For the monitoring of bioaerosols, sterile filters and sterile filter holders are used for the measurements. The sterile filter holders and sterile filters are carefully mounted on the sampling apparatus using sterile gloves to avoid any risk of cross-contamination. Sampling air is drawn into the sampling apparatus by a vacuum pump with a calibrated flow rate of 2 litres/min.

3.2.3 Downwind concentrations are determined to assess the level of emission directly from the Site. Upwind data provides information on the concentration of specified bioaerosols that are present in the air blowing onto the operational area of the Site. The upwind concentration should be measured at a distance of 50m from the Site.

3.2.4 Sampling is carried out downwind of the Site, using a fan like shape arrangement to detect the position of the plume. The orientation of the measurement area is determined by the prevailing mean wind direction and the accessibility.

3.2.5 A central traverse is determined based on the mean wind direction. A sampling traverse line is run through these points at an angle of 30° (±3) to the centre traverse.

3.2.6 The distance of the downwind locations from the active operational area should be the same as the distance of the NSR from the source of bioaerosol.

3.2.7 Comparison of the concentrations in air unaffected by the activities of the facility (background air sampled upwind of the Site) with the concentration of bioaerosols in air downwind of the Site enables an assessment of the Site related contribution over a specified area to be made. The difference between the upwind and downwind concentration caused by bioaerosol emissions from the Site is known as the process contribution.

3.2.8 To allow for collection of meteorological data during bioaerosols monitoring at the Site, a portable weather station (Kestrel 4500) was employed with inbuilt remote data storage capability.

4 MONITORING AND RESULTS

4.1 SITE INFORMATION (DAY OF MONITORING)

4.1.1 Bioaerosol monitoring was carried out on 14th February 2023.

4.1.2 On the day of monitoring, the upwind and downwind locations were based on conditions observed at the time of actual set up, which indicated that the predominant wind direction was variable but mainly from the southeast. The sampling locations were based on the prevailing wind direction and on the distance from the operational area. The physical restrictions at the Site,

accessibility and the structural setup of the Site were also taken into consideration.

4.1.3 The meteorological conditions on the day of monitoring were mostly sunny (1/8 cover) and cold (~11°C), with an average wind speed of 11 km/h, which is classed as 'Light breeze' on the Beaufort scale descriptions (see Appendix 3 for meteorological data).

4.1.4 On the day of monitoring, the odour of sludge was not detected.

4.2 BIOAEROSOL MONITORING LOCATIONS

4.2.1 A total of 12 boundary bioaerosol samples were taken from locations around the Site. Monitoring included two additional "blank" samples.

4.2.2 Boundary bioaerosol monitoring was undertaken at four separate locations around the Site and three samples were taken at each location. The locations were chosen according to the Technical Guidance Note (Monitoring) M9 (i.e., based on the wind direction in the area at the time of monitoring, the location of the nearest sensitive receptor and accessibility).

4.2.3 Samples were referenced 'UW', DW1', 'DW2' and 'DW3'. The first part of the reference indicates the location of the samplers, i.e., 'UW' for 'Upwind' and 'DW' for 'Downwind'. Three samples were each taken at `UW`, `DW1`, `DW2 and`DW3`.

4.2.4 The nearest sensitive receptor, i.e., the closest housing estate of Trowbridge BC, is located approximately 200 m southeast of the Site's cake skip holding area. As recommended in Technical Guidance Note M9, the distance of the downwind locations from the centre of the active operational area should be the same as the distance of the nearest sensitive receptor.

4.2.5 The downwind locations were conducted as close as possible to the nearest sensitive receptor while maintaining the fan shape arrangement to detect the position of the plume. The downwind DW1 monitoring point was situated approximately 180m from the Site's cake skip holding area, DW2 - 200m and DW3 - 145m. Reaching the ideal distance of 200 m was impossible for the samples DW1 and DW3 due to restricted access to the sample locations i.e., the pond to the north of the Site and the structure to the northwest of the Site.

4.2.6 Sampling was carried out downwind of the Site, using a fan-like shape arrangement to detect the position of the plume. A central traverse was determined based on the mean wind direction blowing to 315° from the true north (DW1). Sampling points DW2 and DW3 were located at an angle of 30° to the centre traverse; see Appendix 1.

4.2.7 The upwind monitoring point (UW) was positioned 50 m from the Site's cake skip holding area as recommended in Technical Guidance Note M9; see Appendix 1.

4.2.8 Table 1 below gives a full description of the monitoring locations.

Table 1 Description of Monitoring Locations

Location Number	Ref.	Location Description
Location 1 (Upwind)	UW	Approximately 50 m from the centre of the operational area.
Location 2 (Downwind 1)	DW1	Approximately 180 m from the centre of the operational area.
Location 3 (Downwind 2)	DW2	Approximately 200 m from the centre of the operational area and 30° from central downwind location.
Location 4 (Downwind 3)	DW3	Approximately 145 m from the centre of the operational area and 30° from central downwind location.

4.3 LABORATORY PROCEDURES

4.3.1 All samples were stored and transported to the Crestwood Environmental laboratory at 3-5°C where processing was carried out within 24-hours of the sampling.

4.3.2 Crestwood Environmental laboratory follows the guidelines of Technical Guidance Note (Monitoring); M9: Environmental monitoring of bioaerosols at regulated facilities (Environment Agency, Version 2, July 2018).

4.3.3 In the Crestwood Environmental laboratory, quantitative determination of the concentrations of Aspergillus fumigatus and mesophilic bacteria is performed by counting visually recognisable colonies following cultivation.

4.3.4 The filters were washed and starting with the highest dilution step, the resulting fluid was spread onto 3 plates (parallels) of the appropriate media and incubated in the laboratory. Inoculation of at least 3 parallel plates for each dilution step is required for quality assurance.

4.3.5 Half strength nutrient agar medium was used to culture total mesophilic bacteria. The agar plates were incubated for 7 days in 37°C. Colonies of Aspergillus fumigatus was growing on malt extract agar for 2 days at 45°C.

4.3.6 After incubation, colonies were enumerated, in accordance with the Protocol and BS IS0 7218:2007 and presented as raw data, before CFU/m^3 calculations were undertaken.

4.3.7 The “Blank” samples were included in the incubation and enumeration process in an identical manner to exposed samples. Due to the fact that there is no measurable flow rate, the colonies were enumerated but are not displayed as CFU/m^3.

4.3.8 Three control plates of each medium were also plated out and incubated as controls.

4.4 BOUNDARY BIOAEROSOL MONITORING RESULTS

4.4.1 Results for all samples were converted to 60 minutes to provide standardised results for all samples.

4.4.2 The median results for the estimated concentration of bioaerosols are included in Appendix 2 ‘Estimated Concentration of Bioaerosols’. Detailed information is summarised in Table 2 below.

Table 2 Sampling information and raw laboratory results

Location	Flowrate (m^3/min)	Mean flowrate	Duration [mins]	Dilution	Number of Aspergillus fumigatus (cfu/m^3)	Number of mesophilic bacteria (cfu/m^3)
UW1	0.002	0.12	60	NEAT	Not detected	Not detected
UW2	0.002	0.12	60	NEAT	Not detected	Not detected
UW3	0.002	0.12	60	NEAT	Not detected	Not detected
DW1A	0.002	0.12	60	NEAT	417	Not detected
DW1B	0.002	0.12	60	NEAT	Not detected	Not detected
DW1C	0.002	0.12	60	NEAT	139	139
DW2A	0.002	0.12	60	NEAT	Not detected	556
DW2B	0.002	0.12	60	NEAT	556	Not detected
DW2C	0.002	0.12	60	NEAT	Not detected	694
DW3A	0.002	0.12	60	NEAT	Not detected	Not detected
DW3B	0.002	0.12	60	NEAT	139	417
DW3C	0.002	0.12	60	NEAT	Not detected	Not detected

4.4.3 The results in Table 2 represent bioaerosol concentrations for the locations sampled on the day that monitoring took place. Concentrations of bioaerosols fluctuate significantly depending on the prevailing weather conditions and activities taking place in the area. Sampling air was drawn into the sampling apparatus by a vacuum pump with a flow rate of 2 litres/min for 60 minutes.

4.4.4 The additional "blank" samples are required as per the sampling guidance for quality control purposes in relation to the loading and unloading process of the samples and the presence of bioaerosols in the surrounding atmosphere. The blank is a filter treated in an identical manner as the real sample, but without drawing air through the sampling pump. The resulting blank represents the bioaerosols entering the sample simply by handling the filter during sampling.

4.4.5 Table 3 shows the number of individual colonies on the "blank" samples after incubation.

Table 3 Mean number of bioaerosols colonies on the blank samples

Samples no	Aspergillus fumigatus (cfu/plate)	Mesophilic bacteria (cfu/plate)
Blank 1	Not detected	Not detected
Blank 2	Not detected	Not detected

5 DISCUSSION AND CONCLUSIONS

5.1 RESULTS OBTAINED FOR BOUNDARY BIOAEROSOL MONITORING AT UPWIND AND DOWNWIND LOCATIONS

5.1.1 Concentrations of boundary bioaerosols are subject to large variations due to factors such as meteorological conditions, individual site characteristics, neighbouring sites and other local activities. Variation in bioaerosol concentrations is likely to be due to a heterogeneous distribution of bioaerosols in the air.

5.1.2 The Environment Agency Position Statement 031 (Version 1.0), 2010 states that in relation to composting activities, acceptable levels of mesophilic bacteria and Aspergillus fumigatus at the site boundary are 1,000 and 500 cfu/m^3 respectively.

5.1.3 Because of the broad scatter inherent in the measurement of bioaerosol concentrations, the median of replicate samples is used to assess the result for each sample location. Use of the median reduces the effect of extreme values, and any outliers present will have much less influence on the measurement result.

5.1.4 When using the simplified fan approach for routine compliance monitoring, the maximum median result of the 3 downwind sample locations is used to assess the impact of bioaerosols at the nearest sensitive receptor.

5.1.5 The median results for the estimated concentration of bioaerosols are included in Appendix 2 'Estimated concentration of bioaerosols'. The results indicate that:

- **Median of upwind location**:

- Aspergillus fumigatus = 0 cfu/m^3,

- Mesophilic bacteria = 0 cfu/m^3.

- **Median of downwind locations**:

- Aspergillus fumigatus median results for downwind locations were 0 cfu/m^3 at DW2 and DW3 and 139 cfu/m^3 at DW1,

- Mesophilic bacteria median results for downwind locations were 0 cfu/m^3 at DW1 and DW3 and 556 cfu/m^3 and DW2.

5.1.6 Median bioaerosol monitoring results showed that levels were below the Environment Agency threshold levels for Aspergillus fumigatus and mesophilic bacteria at upwind monitoring location and at all downwind locations. In summary,

- **For the upwind location:**

- Level of Aspergillus fumigatus was below Environment Agency's threshold limit of 500 cfu/m^3,

- Level of Mesophilic bacteria was below Environment Agency threshold limit of 1,000 cfu/m^3.

- **For downwind locations:**

- Levels of Aspergillus fumigatus were below Environment Agency's threshold limit of 500 cfu/m^3,

- Levels of Mesophilic bacteria were below Environment Agency's threshold limit of 1,000 cfu/m^3.

5.2 CONCLUSIONS

5.2.1 The bioaerosol monitoring results reported represent bioaerosol concentrations for locations upwind and downwind around the boundary of the Site.

5.2.2 Aspergillus fumigatus and mesophilic bacteria were not detected at the upwind location, which reflects the background concentration at that time.

5.2.3 The maximum median result of the 3 downwind sample locations is used to assess the impact of bioaerosols at the nearest sensitive receptor. The highest result was detected at location DW1 for Aspergillus fumigatus and DW2 for mesophilic bacteria however all median results for all downwind locations were within Environment Agency threshold limits of 500 and 1,000 cfu/m^3 respectively.

5.2.4 The difference between the upwind and downwind concentration caused by bioaerosol emissions from the Site is known as the process contribution. Median bioaerosol monitoring results for the downwind locations showed that the process contribution was low or none.

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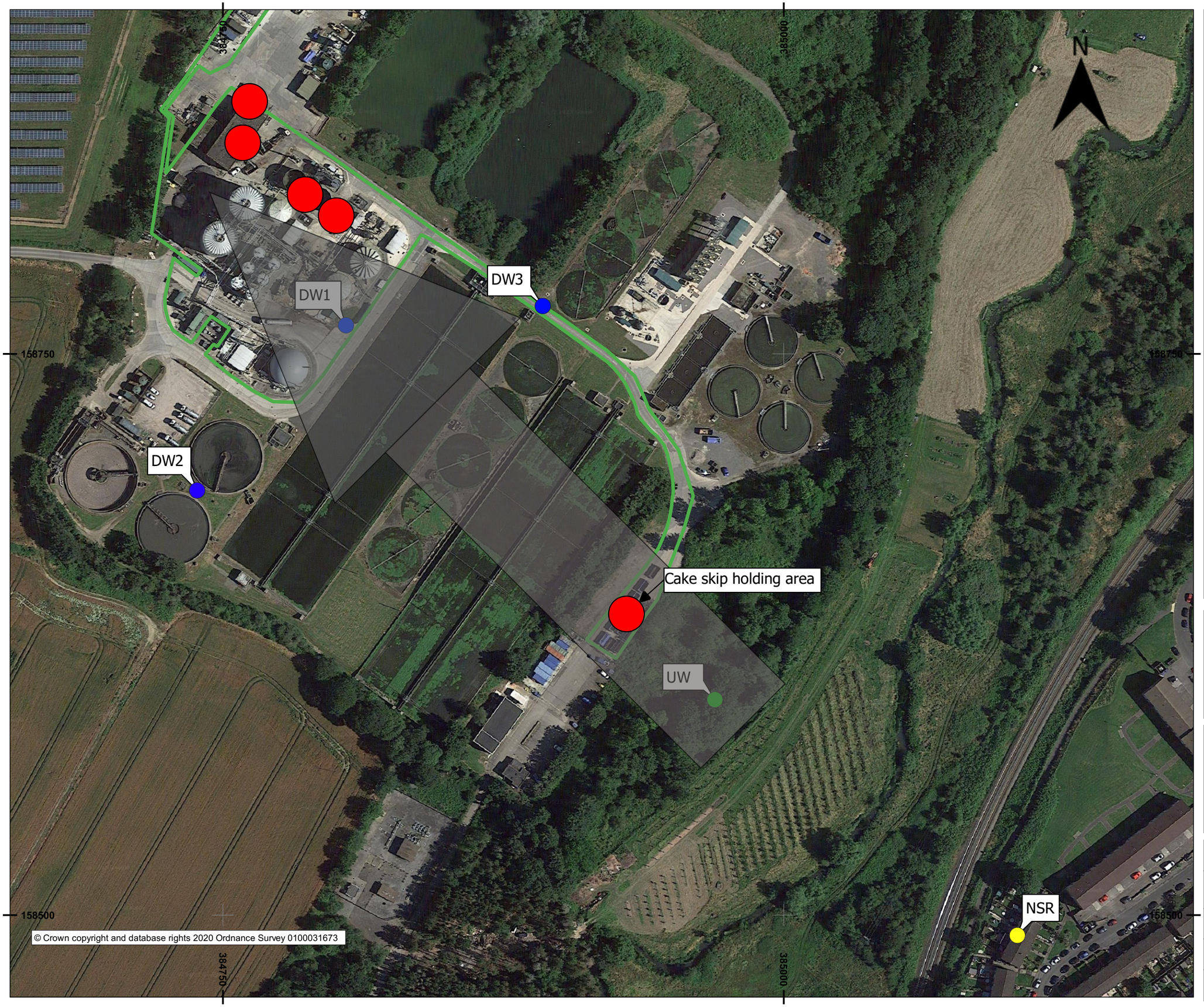
APPENDICES:

APPENDIX 1 BOUNDARY BIOAEROSOLS MONITORING LOCATIONS



LEGEND:

- New instalation boundary
- Source of bioaerosol
- Upwind monitoring location
- Downwind monitoring locations
- Nearest sensitive receptor
- Predominant wind direction

Consultant:

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Client:

Wessex Water Services Ltd.

Trowbridge WRC

Drawing Title:

Bioaerosol Monitoring Locations

Date:	Scale	Paper Size:
11 April 2023	1:1,600	A3 (420×297mm)

Drawn By:	Checked By:	Status:	Final Revision:
KO	AA	FINAL	-

Drawing Ref:	Drawing No:
CE-TB-2228-DW01-Final	**Figure 1**

APPENDIX 2 ESTIMATED CONCENTRATION OF BOUNDARY BIOAEROSOLS

Estimated concentration of boundary bioaerosols:

Site: Trowbridge BC

Commissioning laboratory: Crestwood Environmental Ltd.

Site Operator: Wessex Water Services Ltd.

Sampling Date: 14/02/2023

Type of materials on Site: Sewage

Operations ongoing during sampling: Sludge Anaerobic Digestion

Location	Distance from the centre of active area (m)	Sampling start/end times (hh:mm:ss)	Median of upwind samples (CFU/m³)		Median of downwind replicate field samples (CFU/m³)	
			Aspergillus fumigatus	Mesophilic bacteria	Aspergillus fumigatus	Mesophilic bacteria
UW	50	13:07/14:10	0	0	-	-
DW1	180	13:11/14:17	-	-	139	0
DW2	200	13:05/14:05			0	556
DW3	145	13:00/14:30			0	0

APPENDIX 3 METEOROLOGICAL DATA

Meteorological data:

Site: Trowbridge BC

Commissioning laboratory: Crestwood Environmental Ltd.

Site Operator: Wessex Water Services Ltd.

Sampling Date: 14/02/2023

Type of materials on Site: Sewage

Operations ongoing during sampling: Sludge Anaerobic Digestion

Location	Bearing of samplers from centre of operational area or turning / screening operation (° from true north)	Mean direction the wind blows to during the sampling period (each individual sample) (° from true north)	Difference in bearing between location of samplers from centre of operational area and mean direction wind blows to (°)	Mean wind speed during sampling (m/s)	Arithmetic mean of air temperature (°C)	Arithmetic mean of relative humidity (%)	Prevailing weather conditions (cloud cover in 8ths)
UW	130	315	185	3.0	11	76	1/8
DW1	315	315	0	3.0	11	76	1/8
DW2	285	315	30	3.0	11	76	1/8
DW3	345	315	30	3.0	11	76	1/8

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