Technical Note

Project:	Vantage Data Centre CWL11/12
Subject:	Air quality management plan
Author:	Atkins
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Document history

Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
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1. Introduction

1.1. Background and regulatory guidance

This document presents the air quality management plan (AQMP) to be followed in the event of an unplanned power loss at the Vantage Data Centers Ltd (Vantage, formerly Next Generation Data (NGD)) facility in Newport, Wales.

The Newport data centre facility is a Schedule 1 listed activity under the Industrial Emissions Directive (IED) and operates under an environmental permit (EPR/BB3599CW/V003). An AQMP[1] for CWL11 was requested by Natural Resources Wales (NRW), in support of the original environmental permit application. An AQMP is required for managing a response to potential exposure to standby diesel generator emissions during an emergency power outage. An environmental permit variation application for the extension of CWL11/12 to add a further 125 engines has been duly made by NRW. The AQMP for the installation has been updated to account for the extension to CWL11 and CWL12 (a total of 202 engines).

NRW stated in the Environmental Permit Decision Document for CWL11 that the emergency outage operating scenario could pose a risk to local air quality at identified receptors for short term nitrogen dioxide (NO_2), albeit such an occurrence would be for a very short period of time and the probability of there being a full power outage is extremely unlikely. This is because Vantage manages the risk of an emergency power outage through having in place dual connections to the Super Grid, measures to prevent on-site power failures including regular switchgear and engine testing and maintenance, testing of rapid load-shedding procedures, all of which minimise the potential effects of grid power failures. A conservative estimate is that a ‘full’ two hour grid outage is a one in twenty year event. There have been only two power outages since the facility commenced operation, neither of these were ‘full’ grid outages and on each occasion only a small number of cells / engines were running.

In line with the Environment Agency’s “*Data centre FAQ Headline Approach*”[2], a written action plan is required to manage prolonged emergency running of the plant in the rare event of a grid failure. The plan includes identification of sensitive receptors, assessment and impact evaluation against modelled risk conditions, i.e. those periods of most concern in the year for potential emergency occurrences, the number of cells of engines operational and the outage duration) and proposed actions to ensure mitigation and monitoring is in place.

In response to the Schedule 5 notice issued by NRW (PAN-015219, 1 June 2022) this plan also captures:

- findings from modelling of different degrees of incident severity[3];
- proposals for monitoring to assess the actual impact to determine a suitable response;
- incident review and future prevention.

The areas identified for further investigation and investment by Vantage will be reported in an updated version of this AQMP which is expected to be issued within 12 months of the variation of the permit.

1.2. Site Information

Permit Number	EPR/BB3599CW/V003
Address	Newport Data Centre, Imperial Park, Celtic Way, Marshfield, Newport
Post Code	NP10 8BE
Local authority	Newport City Council
OS – grid coordinates	328200, 184600

[1] Atkins, Air quality management plan_issue 14.10.20_v3.0.doc
[2] Environment Agency draft guidance released to industry, version 11, dated 11/5/20
[3] The original AQMP was prepared in relation to the worst case emergency scenario - i.e. grid failure resulting in all cells operating. However, the AQMP is being used by Vantage to manage all emergency scenarios, including those where only a small number of cells / engine operate. Consequently the AQMP will benefit from consideration of these lower severity events (in addition to the worst case emergency incident).

1.3. Headline scale of standby onsite

The backup power facilities for the Vantage Newport facility known as CWL11 and CWL12 (CWL11/12) are provided by 37 cells of diesel[4] engine powered standby generators (202 engines in total) with a combined thermal input of 520 MW_{th}.

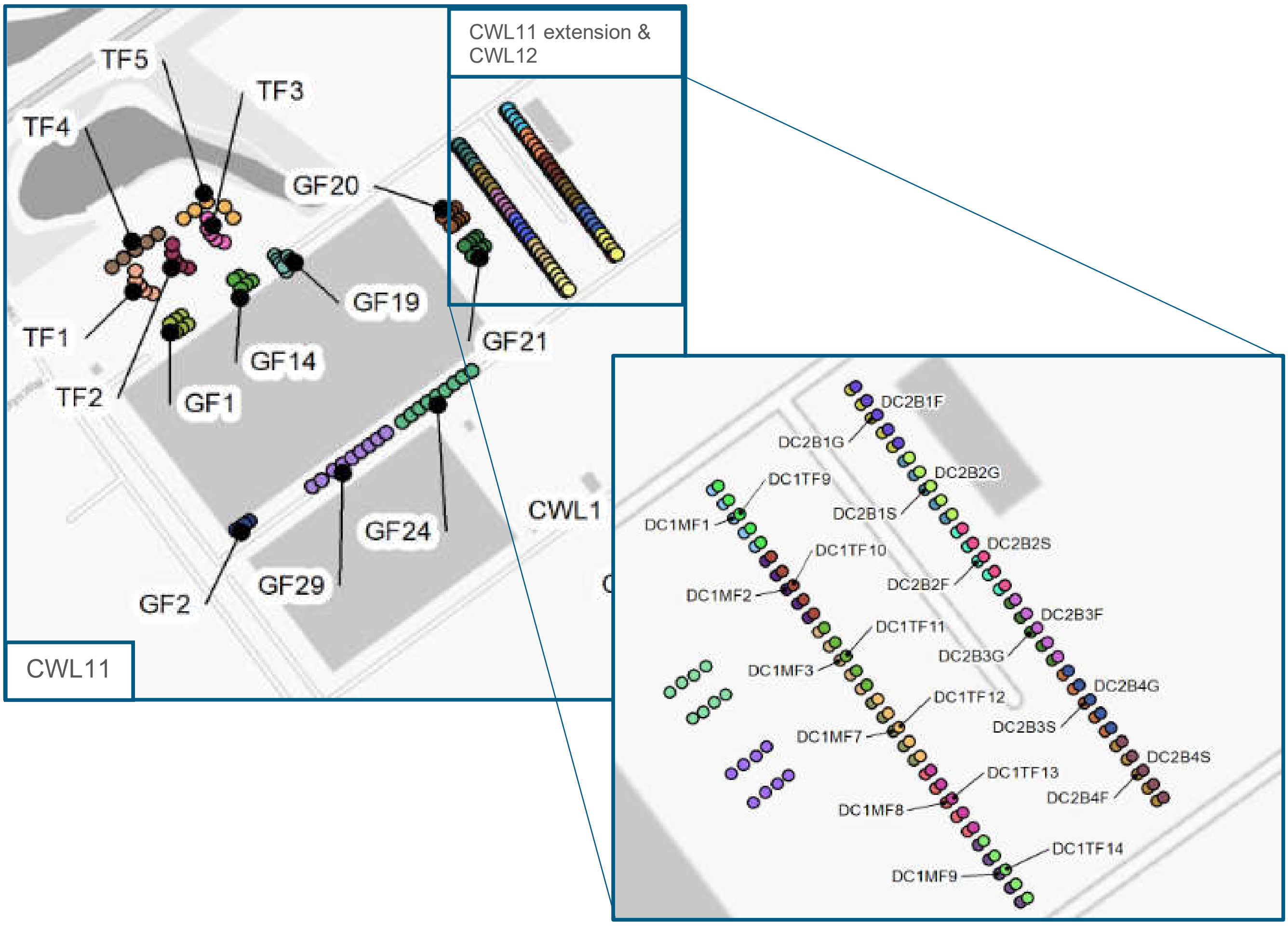
At CWL11/12 there are six generator types in total with varying thermal inputs; each cell is composed of a group of one generator type:

- GF1 and GF2 - Perkins 4006-23TAG3A (1.970 MW_{th}) (10 in total);
- GF14 and GF19 to GF21 - Kohler MTU 12V1600G20F-E (X715C2) (1.457 MW_{th}) (29 in total);
- GF24 and GF29 - Volvo PentaTAD 1642GE (1.311 MW_{th}) (18 in total);
- TF1 - Mitsubishi S12R-F1PTAW2 (T1650C) (3.226 MW_{th}) (5 in total);
- TF2 to TF4 - Kohler KD45V20-5DEP (2.987 MW_{th}) (15 in total);
- TF5, plus CWL11 extension (TF9 to TF14, MF1 to MF9) - Kohler KV45V20-DES (2.987 MW_{th} limited to 75% output) installed at 13 cells of 5 engines (65 in total).
- CWL12 - Kohler KV45V20-DES (2.987 MW_{th} limited to 75% output) installed at 12 cells of 5 engines.

The locations of the engines and cells are shown in Figure 1-1.

Stack heights range from approximately three to four metres above ground level for the CWL11 engines located around the main building (including TF5). The new Kohler engines forming the CWL11 extension to the east will each discharge through individual vertical stacks, 9.3 metres above ground level. Once CWL12 is constructed, all 120 engine stacks forming the CWL11/12 extension will discharge at a height of 12.3 metres.

Figure 1-1 - Vantage Newport engine cell layout



4 N.B. Vantage can also use hydrotreated vegetable oil (HVO) as an alternative to diesel fuel.

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1.4. Hierarchy of engine numbers and outage durations of concern

This AQMP sets out the conditions that could give rise to an emergency scenario with a greater likelihood of short-term average NO_2 concentrations above acute exposure guideline thresholds (see Table 1-1), the severity of an incident according to different intensity and duration outages (Section 3.2), and the actions to be taken in such an event in terms of monitoring and reporting (Section 4.1).

1.4.1. Assessment criteria

The key pollutant of concern during a power outage is nitrogen dioxide (NO_2) which is formed by the conversion of NO to NO_2 following release from the engine stacks. Exceedences of the hourly mean criterion for NO are not anticipated based on modelling undertaken for the permit variation application.

The assessment criteria most applicable to emergency exposures are the Acute Exposure Guidance Levels (AEGL). These are threshold exposure limits i.e. short-term exposure levels below which adverse health effects are not likely to occur in the general public. The values are intended to protect most individuals in the general population, including those that might be particularly susceptible to the harmful effects of the chemical.

There are three AEGL levels for nitrogen dioxide, shown in Table 1-1; these vary according to the severity of toxic effects and the duration of the exposure.

The AEGL-1 is the atmospheric concentration of a substance above which the general population, including sensitive individuals, could experience notable discomfort, irritation, or asymptomatic effects. However, the effects are transient and reversible upon cessation of exposure. The AEGL-1 for nitrogen dioxide is 940 µg/m^3 (0.5 ppm) and is the same for exposures of 10 minutes to 8 hours duration.

Significant concern for public health and non-reversible damage for nitrogen dioxide starts at 38,000 µg/m^3 (20 ppm) over 1 hour reducing to 12,600 µg/m^3 (6.7 ppm) over an 8-hour period. This AEGL-2 value is two orders of magnitude higher than AEGL-1.

The Health and Safety Executive (HSE) occupational exposure level (OEL) over 15 minutes is 1,910 µg/m^3 as nitrogen dioxide, approximately twice the AEGL-1 criterion.

The AEGL-2 value is not applicable to the scale of results seen for the CWL11/12 emergency scenario for a full site outage as the maximum modelled hourly concentrations were less than half the AEGL-2 threshold in a five year modelled period.

Table 1-1 - Assessment criteria for nitrogen dioxide[5]

	Unit	10 mins	30 mins	1 hour	4 hours	8 hours
AQS Objective	mg/m^3	-	-	0.20	-	-
HSE OEL	mg/m^3	1.91	-	-	-	-
AEGL 1 (non disabling)	ppm	0.50	0.50	0.50	0.50	**0.50**
	mg/m^3	0.94	0.94	0.94	0.94	**0.94**
AEGL 2 (disabling)	ppm	20	15	12	8.2	6.7
	mg/m^3	38	28	23	15	13
AEGL 3 (lethal)	ppm	34	25	20	14	11
	mg/m^3	64	47	38	26	21

The UK air quality strategy (AQS) objective for hourly mean NO_2 is 200 µg/m^3, not to be exceeded more than 18 times in a calendar year. This is intended for management of ambient air quality to which members of the public are regularly exposed and is not therefore a focus of this AQMP for emergency engine operation. The anticipated number of engine operating hours in an emergency scenario (a few hours) means there is a very low likelihood of the engine emissions resulting in an exceedance of the health-based objective in a calendar year.

[5] https://www.epa.gov/sites/production/files/2015-09/documents/nitrogen_oxides_volume_11_1.pdf

1.4.2. Full emergency power outage

The emergency operational scenario addressed in the permit variation application was based on running all 202 engines (i.e. the 142 engines forming CWL11 and 60 engines forming CWL12). This represents the maximum outage that may occur in the event of a catastrophic power failure (loss of offsite power or LOOP event) which has a very low probability of occurring (a two hour LOOP has a 1 in 20 year frequency[6]).

In the unlikely event of an emergency outage, all standby generators would be brought into operation followed by load shedding to the required load after an initial 10 minutes. This entails certain engines within each engine cell being powered down or turned off after approximately 10 minutes. Vantage has confirmed that load ramp down will occur under all power outage scenarios. It is not possible for Vantage to select which engines would operate following ramp down, and there is no flexibility in operation of different banks of engines. The priority will be to immediately understand the risk presented by the prevailing meteorological conditions and throughout the likely duration of the power outage.

Air dispersion modelling undertaken for the permit variation application[7] considered the hypothetical scenario of continuous emergency operation throughout a whole year. The findings demonstrated a potential (although an extremely low likelihood) risk of hourly exceedances of the AEGL-1 (see Table 1-1) for nitrogen dioxide at sensitive receptors for local air quality downwind of the engines when unfavourable conditions occur at the time of the outage (wind speed and time of day).

For the full site outage scenario, the maximum modelled hourly average NO_2 concentration at a sensitive human health receptor (Sir Briggs Avenue to the east) was several times the AEGL-1 of 940 µg/m^3 but an order of magnitude below the AEGL-2 threshold. The highest value was modelled during summer, at night-time and under low wind speeds (less than 1.54 m/s).

The dispersion modelling (described in Appendix B) has been designed to highlight the most extreme results, having been undertaken assuming an emergency situation could occur at any time i.e. all hours of the year were modelled. This has been reported as a cumulative total of exceedences of the AEGL-1, which in certain cases gives over 1000 exceedences for a hypothetical continuous outage, in order to determine the event probability. There are actually very few occasions in a year when consecutive hours in the year would give rise to the most adverse meteorological conditions for dispersion.

The likelihood of exceedences occurring under different dispersion conditions is presented in Section 3.1, based on the total number of hours in a year exceeding, as a percentage of the number of hours modelled.

Therefore, while there is the potential for very high concentrations of nitrogen dioxide (NO_2) from the simultaneous operation of all of the CWL11 and CWL12 engines to result in concentrations above AEGL-1 acute air quality criterion, the anticipated duration of any emergency power outage event is in the order of a few hours, therefore the probability of such high values coinciding with continuously poor dispersion conditions, and persistently so, is very low.

1.4.3. Partial site outage

Lower intensity events involving partial site outages of substantially lower intensity (e.g. a few engines or cells) may typically be of longer duration (over 8 hours) than a full outage scenario. Two less "intense" power outages affecting a small number cells have occurred at the Vantage Newport facility in the last few years:

- a phase failure relay fault occurred, simulating mains failures and transferring the load to the backup generators - this resulted in 1 cell of 5 engines operated for 4 hours and 34 minutes; and
- a solar flare resulted in a power dip on the National Grid, the systems worked as intended but when the power stabilised Vantage was unable to return fully to mains supply as a result of a component failure with the 3-phase failure relay - this resulted in the operation of 1 cell (4 engines) for less than twenty minutes, 1 cell (5 engines) for less than 4 hours and 1 cell (6 engines) for less than 5 hours.

The AQMP must be able to reflect the range of outages that may occur, to ensure a proportionate response. An incident "severity" has been defined (Section 3.2), which can be combined with the likelihood of an exceedence under the AEGL-1 under prevailing conditions (wind speed, direction, season, time of day) to determine the risk of high concentrations at receptors (Section 3.3), that can be communicated to the regulator.

[6] Office for Nuclear Regulation [ONR] loss of off-site power event frequencies for use in nuclear power station safety assessments to support the UK Generic Design Assessment process

[7] CWL11/CWL12 Permit Variation Application Air Quality Assessment, April 2021

Further modelling to support the approach to this AQMP (see Appendix D) has indicated that the AEGL-1 is not exceeded where three or fewer cells (or equivalent number of engines) operate, regardless of the duration of the event. For the engines on the CWL11 extension and CWL12, there are no modelled exceedences of the AEGL-1 when up to six cells operate.

The modelling has also shown that for events lasting 8 hours or more, with up to 12 cells emitting concurrently, the AEGL-1 is unlikely to be exceeded when expressed as an 8 hour average concentration. This appears counterintuitive, i.e. the longer the duration of an outage, the lower the probability of a high NO_2 concentration occurring at a receptor. This is because, although there are many more than eight hours within a year that may be at more at risk of exceeding the AEGL-1, the probability of more than one of these adverse hours occurring close to another is very low (see results for different source groups and event durations in Appendix D).

1.5. Mitigation

1.5.1. Design

The key mitigation measures for the limitation of air quality impacts of the data centre facility are embedded within the design and include:

- dual grid connections and a dedicated substation to minimise the likelihood of a significant power outage affecting the site;
- generator engines that can achieve the TA Luft emissions benchmark of 2000 mg/Nm^3;
- taller stacks to improve dispersion for engines associated with the extension to CWL11 and CWL12.

Further abatement measures such as retrofitting SCR to the engines or further increases in stack height are not deemed to be BAT in light of the extremely low probability of an incident; however, this will be kept under regular review by Vantage (see Section 6.1). Research into alternative fuels with lower emissions e.g. HVO, will also be undertaken as part of the AQMP review cycle.

1.5.2. Maintenance

The following measures are in place to minimise engine emissions to atmosphere during an incident and to minimise the duration of such an incident where the cause is due to internal malfunctions rather than external factors that are outwith the control of Vantage (e.g. grid outages):

- Equipment is maintained in line with the manufacturers' recommendations / industry standards. Robust service level agreements for the critical supply chain ensure rapid respond to business-critical incidents.
- The engines are tested throughout the year on a quarterly cycle both individually, and twice a year as cells;
  - The number of times that engines are tested for and the duration of the test has been minimised as far as is practicable;
  - No cell testing can be undertaken concurrently across the CWL11/12 facility, so as to reduce impacts on local air quality;
- Intervals between equipment servicing and replacement have been minimised where practicable;
  - For example, the frequency of replacement of the 3-phase relay has been reduced from a 5 year programme to 3 years - this change was made recently as a result of the 'After-Action Report' following one of the small scale emergency operation incidents.
- Significant volume of critical spares kept on site to minimise engine down time due to malfunctioning;
  - £500,000 worth of critical spares held on site, which are maintained and the holdings regularly checked for mean time before failure instance holdings, succession management of the spares to ensure they do not exceed use by date.
- Engineers on site 24 hours a day to ensure a timely response and investigation of any alarms;
  - An on-call engineering Chief or Manager can respond to site out of hours and escalate any outages or major instances to the Senior Management Team (SMT).

1.5.3. Operation

Typically, engine load shedding is applied in an emergency outage after initial startup, to bring the power output down to the minimum requirement in accordance with data centre customer's use at the time of an incident.

It is not currently feasible to determine which specific engines within a cell can be turned down; each cell is specific to a data hall and a customer, therefore the engines that operate are determined by customer requirements at the time. Given the geographical arrangement and proximity of the cells of engines on the extension to CWL11 and CWL12, the specific engines that operate are not considered to materially affect the risk to receptors.

2. Local environs

2.1. Offsite receptors

Receptors relevant to the consideration of risks during an emergency outage at CWL11/12, in terms of exposure to air emissions from multiple standby diesel generators, are the surrounding residential areas, industrial/commercial operations which would not be protected by enclosed structures, schools and other locations of short term exposure such as hotels and nurseries. The industrial units close to the Vantage Newport data centre are considered of low sensitivity due to the enclosed nature of these buildings and the expectation of them being fitted with mechanical ventilation systems and filters.

The nearest sensitive receptors considered in the emergency scenario modelling are numbered 1 to 12 in Table 2-1.

These discrete receptors are shown in plan view in **Figure 2-1** as numbered blue (residential) and purple (commercial) triangles. The CWL11/12 site is highlighted in sand colour and the building itself is grey with the stacks denoted by red dots. Other surrounding industrial facilities are also shown in grey.

When determining the risk matrix for the AQMP, receptors were considered more broadly by sector, as illustrated in **Figure 2-2**.

Figure 2-1 - Selected local human health receptors

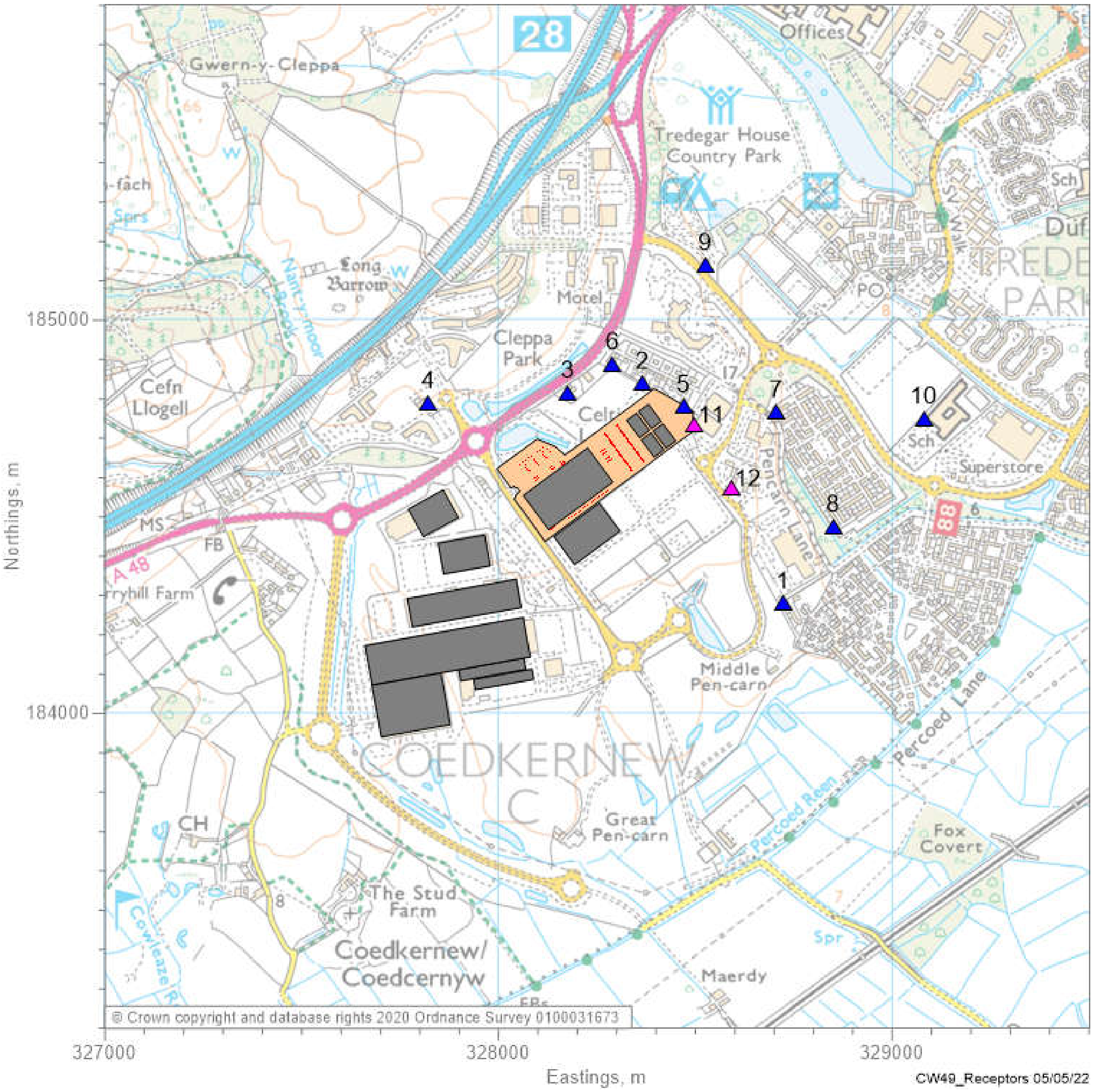
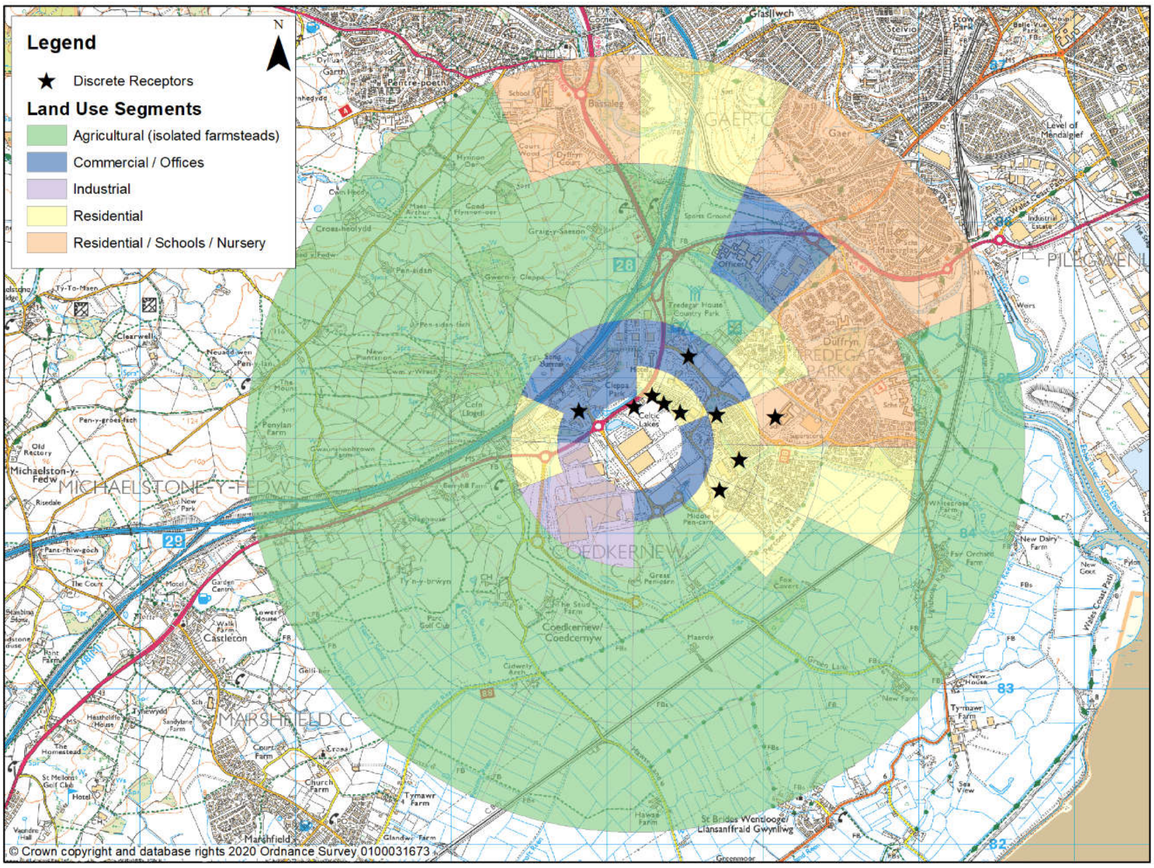
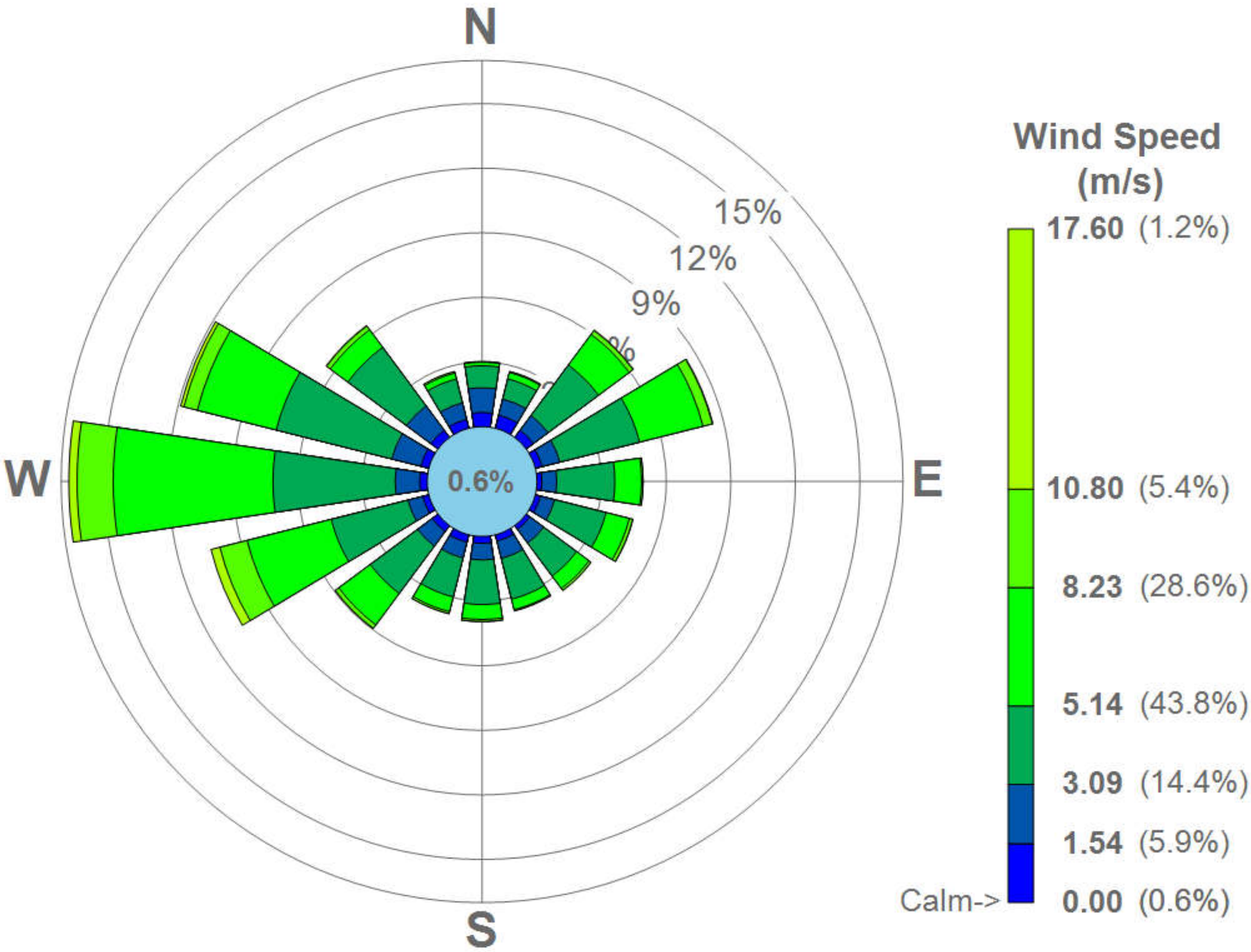


Figure 2-2 – Broad land-use segments for human health receptor risk classification



2.2. Meteorological conditions

Figure 2-3 - Windrose showing five-year distribution of wind speeds and directions for Cardiff, 2011 to 2015



3. Risk Assessment

For the purposes of this AQMP, a **likelihood** and **severity** rating are applied to determine the **risk** of an incident resulting in exceedances of the AEGL-1 health based threshold for NO_2.

These ratings are defined as:

Likelihood

- Low – An incident that is highly unlikely to occur.
- Medium – A reasonably likely incident.
- High – An incident that is highly likely to occur.

Severity

- Low – An incident that would cause a negligible impact on receptors.
- Medium – An incident that would cause a slight impact on receptors.
- High – An incident that could cause a serious threat to human health or the environment.

The likelihood and severity of an incident and thus the associated risk, can change over time and need to be frequently reviewed during an outage.

3.1. Likelihood

For the purposes of this AQMP, the **likelihood** refers to the how likely an outage occurring is in the first place, but how likely the conditions at the time of the outage are to result in ineffective dispersion and thus whether an increased risk of exceedances of the **AEGL-1** health-based threshold for NO_2.

Mitigation to reduce the likelihood of a power outage resulting in the use of emergency diesel generators is embedded within the design of the CWL11/12 facility which has a dual grid connection (see Section 1.5). Once cells are operating, load shedding is typically enabled to meet the power demand for each cell. This has been incorporated into the modelling for the permit variation application and the AQMP.

The likelihood of an event resulting in an exceedence of the AEGL-1 (the definition of an "incident" for the purposes of this AQMP) is therefore determined assuming no further mitigation is practicable under the circumstances and is dependent upon the dispersion of emissions in the atmosphere according to prevailing meteorological conditions.

The dispersion modelling, details of which are presented in Appendix B, has considered a range of time periods and dispersion conditions (wind speed and direction) throughout the year.

Table 3-1 summarises the outcome of the evaluation of an emergency scenario affecting under each of these condition categories. The contour plots in Appendix C show:

- Modelled hourly concentrations above the hourly AEGL-1 extend up to a few kilometres from the site boundary in some directions, for a full site outage;
- There is a higher risk of exceedences at receptors at night-time when wind speeds are low (< 5.14 m/s) or in the day-time when wind speeds are low and have a southerly or westerly component.

Table 3-1 presents the likelihood of AELG-1 exceedences during day time and night time hours, for an emergency power outage event independent of the event duration. While this table is based on modelling for a full outage across both sites CWL11 and CWL12 in combination, the same principles of effective dispersion would apply to less "intense" outages e.g. smaller subsets of cells.

The terms "high", "medium" and "low" in the table describe the likelihood of exceedences of AEGL-1 based on the modelling findings, relative to the maximum for this specific facility; they do not imply likelihood of a direct toxicological risk to a receptor.

The assigned likelihood of exceedence captures whether a sensitive receptor is present downwind (see land use segments in Figure 2-2) within the area subject to exceedences, and the number of times exceedances were modelled under certain conditions.

The classification assists the site / operations manager in identifying the likelihood of AEGL-1 exceedences at receptors and, once combined with incident **severity** (see Table 3-2), the relevant steps to be taken for the risk.

Table 3-1 – Likelihood of day and night-time hourly AEGL-1 exceedances at sensitive offsite receptors

DAY	Wind from	N	NE	E	SE	S	SW	W	NW
Season	Spring								
	Summer								
	Autumn								
	Winter								
NIGHT	Wind from	N	NE	E	SE	S	SW	W	NW
Season	Spring								
	Summer								
	Autumn								
	Winter								

Key to likelihood

HIGH	> 90 hours of exceedances and medium to high sensitivity receptors	~ 1% of modelled hours
MEDIUM	10 - 90 hours of exceedences or >90 hours and low sensitivity receptors	~ 0.1 to 1% of modelled hours
LOW	1 - 10 hours of exceedances or no sensitive receptors downwind	~ 0.1% of modelled hours

Season	Month	Day time (hour commencing)	Night time (hour commencing)
Spring	Mar, Apr, May	07:00 to 18:00	19:00 to 06:00
Summer	Jun, Jul, Aug	07:00 to 19:00	20:00 to 06:00
Autumn	Sep, Oct, Nov	09:00 to 17:00	18:00 to 08:00
Winter	Dec, Jan, Feb	08:00 to 15:00	16:00 to 07:00

The supporting dispersion plots are shown in Appendix C for each of the seasons and wind speeds considered; the contours have been set to match the three categories of likelihood (high, medium and low). Note that, given the four-year meteorological data set used in the assessment, each season contains approximately 8,760 hours, meaning the counts of exceedances can be directly considered as an approximate annual frequency. The three bands stratify the exceedance count data for this specific facility, to allow a hierarchy of responses in the AQMP i.e. the definitions are applied relative to the total modelled number, and it is not implying that 1% of modelled hours relates to a "high" likelihood of exceedences occurring in reality.

3.2. Severity

Three levels of incident severity have been defined based on the potential for harm i.e. how likely concentrations are to be above the AEGL-1 in the event of an outage. As for likelihood, this is a relative rather than absolute term for a theoretical outage scenario.

A **high** severity incident is defined as one involving all 202 diesel generators, where there is a risk this may last for two hours or more. This is due to the number of maximum modelled hourly concentrations several times the AEGL-1. Modelled concentrations are, however, an order of magnitude below the AEGL-2 therefore even a full outage is not anticipated to result in concentrations that may be disabling to human health.

Incident severity will be proportionately lower for the more frequent (albeit still uncommon) outage scenarios i.e. when a power failure does not cause a full site outage but some generators are required to operate. Work has commenced to define these severity levels based on dispersion modelling for a range of engine cell combinations (see Appendix D, which presents results for initial groupings of smaller numbers of cells operating concurrently, covering different areas of the CWL11/12 facility, over different event durations).

Regardless of the prevailing conditions or event duration, the initial modelling has shown that the AEGL-1 is rarely, if ever, exceeded for:

- outages of up to three cells on the original CWL11 groups of cells (GF and TF) or;
- outages of up to six cells on the expanded CWL11/12 facility;

Incidents involving such low numbers of cells (or equivalent numbers of engines) can be considered of **negligible** severity and thus of **low risk** independent of consideration of the likelihood of exceedences.

Incidents involving four to eight cells on the original CWL11 site or seven to 12 cells on the expanded site, are assigned a **low** severity for events of 2 to 4 hours duration, and **medium** severity for 4 to 8 hours. Beyond this time, although modelling shows that the AEGL-1 is not exceeded as an 8 hour average, such prolonged outages are undesirable in terms of the AQS standard of 200 µg/m^3. Therefore any incident with more than 8 cells operating is assigned a **medium** severity regardless of the duration.

Table 3-2 presents an initial classification of incident severity. Further work (Section 6.1) will be undertaken to refine these subsets of scenarios that have a low or medium incident severity to ensure that in the event of an incident, the approach is logical and practicable i.e. can be applied rapidly by staff, and in future planned improvements, automated within the Scada system.

Table 3-2 – Initial classification of severity of outages based on intensity and duration

		No. cells running (or equivalent no. engines)		
		CWL11 original	CWL11 extension	CWL12
Duration	Any	3	6	6
	<2	Any	Any	Any
	2-4	4-8	7-12	7-12
	4-8	4-8	7-12	7-12
	>8	4-8	7-12	7-12
		9-13	9-12	9-12
	>2	All		

3.3. Risk

Likelihood and severity are combined to give the classification of risk shown in **Table 3-3**.

Table 3-3 – Risk Rating Matrix

Risk Matrix		Severity			
		High	Medium	Low	Negligible
Likelihood	High	HIGH	HIGH	MEDIUM	LOW
	Medium	HIGH	MEDIUM	LOW	
	Low	MEDIUM	LOW	LOW	

The risk should be checked every two hours as operating and meteorological conditions can change over time.

If a **HIGH** risk incident is identified, it is proposed that ambient air quality monitoring is undertaken to verify whether AEGL-1 exceedences are occurring at sensitive receptor locations. The detail of the approach will be included in the next update to the AQMP (planned within 12 months, see Section 6.1) following completion of a study to identify viable monitoring methods (see Section 0).

4. Emergency procedure

4.1. Actions

In the event of a power outage at CWL11/12, the Vantage incident manager will immediately open a Microsoft Teams channel to coordinate the incident response. This acts as the incident diary and the information will include the number of engines / cells operating and, where appropriate in light of customer demands at the time, what load shedding has been activated. If known, the cause of and expected duration of the outage is provided. An incident proforma template is provided in Appendix A, which can be sent to the regulator following an outage as a record of actions taken.

If the outage is likely to last more than two hours, the operator will check the prevailing meteorological conditions and time/season to define the **likelihood**, and define **severity** based on the number of engines/cells operating. These are entered into the risk matrix to determine whether there is a low, medium or high risk for air quality (i.e. risk of exceedences of the AEGL-1). These steps are outlined in Section 4.2 and **Figure 4-1**. Vantage is undertaking to automate this step within the Scada system to ensure an efficient response.

- **Low** risk: the operator continues to monitor the situation every 2 hours to update risk definition;
- **Medium** risk: the operator or nominated responsible person will undertake visual inspections or subjective assessment of emissions either at source or the downwind site boundary;
- **High** risk: the operator informs the regulator and completes the further information in the high risk incident proforma template provided in Appendix A. Where appropriate, dependent on the anticipated event duration, further action may need to be undertaken:
  - Within 4 to 8 hours of the incident starting, ambient monitoring of concentrations at downwind receptors to obtain a more detailed understanding on the actual conditions rather than the theoretical risk;
  - If the event is likely to be of prolonged duration (over 8 hours), and concentrations are close to or above the AEGL-1, the operator will discuss with the regulator any actions to be taken and, where appropriate, engage with the local authority;

N.B. Any decision regarding community liaison should be made in consultation with the regulator and the local authority according to the risk to receptors identified at the time of the event (i.e. according to the conditions prevailing at the time) and likely duration of the outage. Direct community engagement, in terms of raising local awareness of emergency operational equipment and understanding of local sensitivities (e.g. existing health conditions), is not deemed to be appropriate at this time, given the extremely low likelihood of an emergency power outage event, even of short duration, coinciding with the least favourable meteorological conditions.

4.2. Notification

The following steps will be put in place in the event of an emergency power outage at the CWL11/12 site:

- Open an incident diary on Teams;
  - Note start time of outage, local conditions;
  - Record actions taken to address outage;
- Identify likely duration of outage and enact load shedding;
  - Check with UKPN, normal repair times for works, how critical is the fault;
  - Check load shedding of generators has begun (within initial ten minutes, where appropriate);
- Notify regulator of outage
  - Number of engines run initially, number that have load shed and likely duration of outage;
- If the incident may last more than **2 hours**, identify air quality **risk** category
  - Check number of cells running and likely duration, to determine **severity;**
  - Screen out low risk incidents (wind speed >8.23 or no. of cells <3 / 6)
  - Check weather conditions (wind speed, direction) to identify **likelihood** of exceeding AEGL-1;
- Report a High Outage Impacts Risk;
  - Use appropriate proforma in Appendix A to record actions, according to risk;

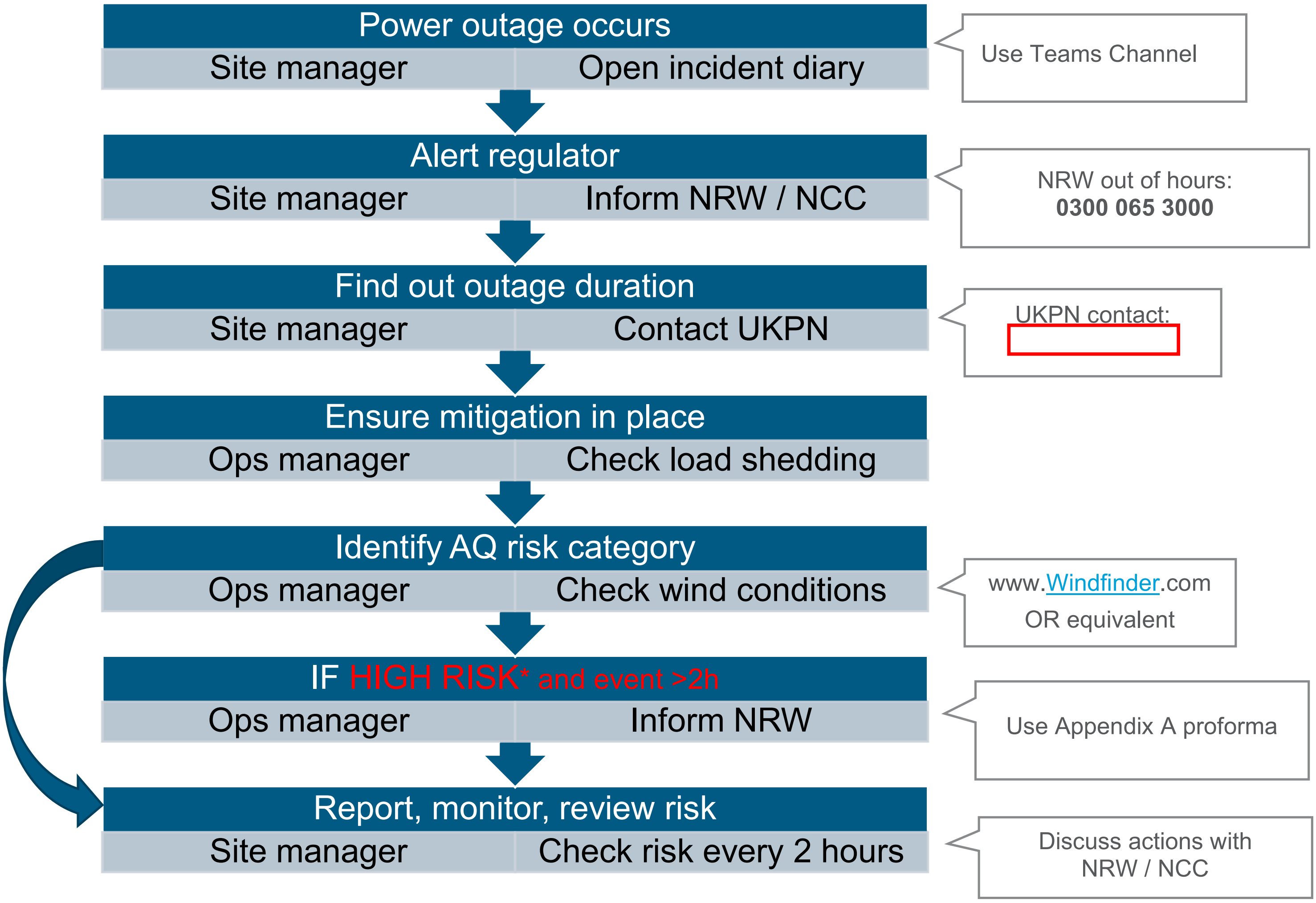
- Report high risk to the NRW permitting officer and if unavailable the National Incident Help Line;
- Notify Local Authority Environmental Health Team of high risk incident;
- Undertake appropriate monitoring for **medium** and **high** risk outages:
  - Observations at source or areas downwind, in case diesel fume or odour is noticeable there;
  - Monitoring of ambient conditions at sensitive receptors;
  - Log complaints relating to smoke/fumes/visible emissions.
- Keep up to date on changing circumstances:
  - Check likelihood and severity **every 2 hours** and revise risk category if appropriate, e.g. if outage continues into a different time period i.e. night time, or if number of cells operating changes;
  - In the extremely unlikely event of a full outage and where UKPN advises of a potential **prolonged** interruption to mains power **(> 8 hours)** under continued **high risk** conditions, Vantage will discuss relevant and proportionate actions with NRW and if appropriate, the Local Authority;

4.3. Responsibilities

One manager within Vantage shall be nominated for responsibility for the execution of the AQMP in an emergency outage situation, including monitoring and reporting to the regulator, with one named deputy.

The flow chart in **Figure 4-1** shows the actions required and the responsible person for incident reporting. This procedure is to be adopted as part of the Vantage Emergency Management Procedure PM03-01, within Vantage's Integrated Management Plan.

Figure 4-1 - Flow chart of actions and responsibilities



<u>*HIGH RISK</u>
Wind speed <8.23 m/s (except **W→** winds, in which case all speeds apply)
PLUS wind direction <u>FROM:</u>
S↑, SW↗, W→ NW↘ (day time) OR E←, SE↖, S↑, SW↗, W→, NW↘ (night time)

Day-time periods		**Night-time periods**	
Spring (March to May)	07:00 to 18:59	Spring (March to May)	19:00 to 06:59
Summer (June to Aug)	07:00 to 19:59	Summer (June to Aug)	20:00 to 06:59
Autumn (Sept to Nov)	09:00 to 17:59	Autumn (Sept to Nov)	18:00 to 08:59
Winter (Dec to Feb)	08:00 to 15:59	Winter (Dec to Feb)	16:00 to 07:59

4.4. Key Contacts

Table 4-1 - Useful Contact Information

Contact	Description	[redacted]
Vantage	Principle of Facilities	
UK Power Networks	Power provider	
NRW	Incident Helpline	
	Permit officer	
Newport City Council	Local authority	

5. Monitoring

There are multiple factors to consider in determining the probability of high NO_2 concentrations and thus the risk that a full or partial emergency outage presents to neighbouring sensitive receptors. These include: the number of cells or engines operating, the location and type of cells, the prevailing conditions at the time and the anticipated duration of the incident.

Further modelling has shown that exceedances of the AEGL-1 threshold may occur at sensitive receptors in proximity to the site boundary, under unfavourable meteorological conditions when the number of cells operational is more than just a few (typically three to six, according to the location and type of engines).

For all incidents, Vantage monitors the number of engines operating in an outage situation to define the **severity** and identifies the prevailing meteorological conditions to assess the **likelihood** of AEGL-1 exceedences based on modelling for a full emergency outage.

Suggested approaches to monitoring that are deemed proportionate to the medium and high risk levels are presented in Table 5-1. These are explored further in the following subsections.

Table 5-1 – Monitoring for different incident risk levels

Incident risk	What	When	How
Low	Meteorological conditions	Every 2 hours	Check websites
Medium	Visual inspections	After 2 to 4 hours	Inspection at site boundary downwind of affected engines
High	Ambient concentrations of NO_x and/or NO_2	After 4 to 8 hours	Handheld, automatic sensors or other technique to be confirmed

5.1.1. Check wind conditions

Vantage plans to make site specific meteorological data available through an onsite integrated meteorological station. The definition of likelihood will be automated through the meteorological station data linked in to the Scada control system.

In the event that onsite systems are unavailable to check direction and speed, websites such as Windfinder, Met Office or other reliable online source can be used.

On the Windfinder website, navigate to the site location (NP10 8BE) and left click on the page:

In this example, the arrows ↙ show the wind is coming from the **NE** direction and speed is **8 m/s**.

A forecast can also be viewed https://www.windfinder.com/forecast/cardiff

A widget can be added to the operator's homepage so the local forecast is constantly visible: https://www.windfinder.com/widget/configurator/cardiff

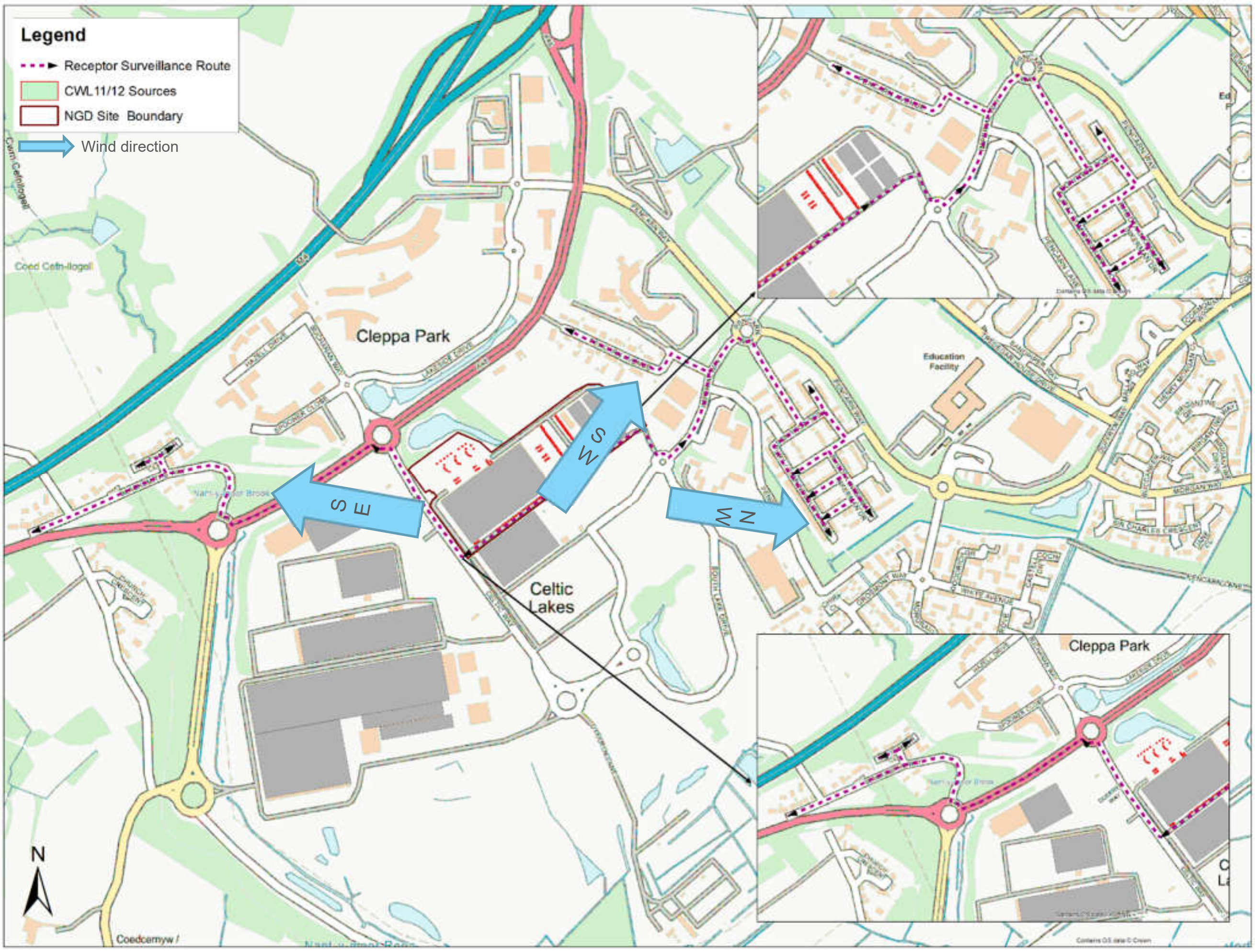
5.1.2. Subjective observations

The need for and type of further monitoring should be proportionate to the risk of AEGL-1 exceedences occurring. Any proposed monitoring must be practicable given the operational constraints including the availability of personnel at the time of an incident. It is proposed that subjective/visual inspection is undertaken but if this is not possible, then this could be substituted with automated air quality monitoring.

If outages are assigned a **medium or high risk**, between two and four hours after the commencement of the incident, the operator or other nominated person will:

- check wind direction, to determine the closest site boundary location where the observable plume may be detectable;
- inspect the site boundary in the downwind direction of the source to assess whether or not the plume may be detectable at off-site receptors (according to strength of odour/visible plume);
- if detectable, e.g. visible/odours/smoke or other indicator of high pollution is suspected, or a complaint received from an off-site receptor, off-site surveillance should be undertaken in the absence of other means to verify concentrations (Figure 5-1 provides suggested routes according to prevailing wind direction);
- in the event that the plume is verified at the site boundary and/or at nearby sensitive receptors, this should be logged in the incident diary and appropriate action agreed with the regulator.

Figure 5-1 - Receptor Surveillance Route



5.1.3. Ambient monitoring

The longer an incident continues, the lower the probability of exceedences of the AEGL-1 occurring over an extended period of time (e.g. 4 to 8 hours). Nevertheless, in the event of a prolonged, high severity incident i.e. an outage occurring under high risk conditions, which may continue for 8 hours or more, monitoring of ambient NO_2 concentrations would support Vantage and NRW in understanding the impact on air quality at sensitive receptor locations and therefore inform whether any further actions are required to protect human health or providing reassurance that local conditions are acceptable.

Under this plan, Vantage is committed to investigating an appropriate and practicable means of monitoring or measuring ambient NOx/NO_2 concentrations in the event of there being a risk of a prolonged, high risk outage for an extended duration. It is anticipated that monitoring would be commenced after four hours of the commencement of the outage event.

As an example of an approach that may be taken in the event of a prolonged high risk outage:

- monitoring of ambient NO_2 concentrations at the downwind receptors
  - e.g. handheld monitoring device or automatic sensors to check concentrations at nearest properties;
- compare findings to the health based thresholds for NO_2
  - see AEGL criteria in Table 1-1;
- where concentrations are found to be above the AEGL-1, as a last course of action, the downwind receptors may be advised to close windows and to remain indoors until such time as the incident severity decreases or likelihood of exceedences drops to medium.
  - to be agreed in discussion with NRW/NCC according to prevailing conditions at the time, including the time of day which may influence background concentrations.

Proposed approach for selection of monitoring technique

In an emergency loss of power event, the first priority of Vantage operational staff and engineers will be providing an immediate response to the issues arising from the incident and ensuring customer services are restored. Therefore the selected approach may need to be one that is independent of site staff intervention and therefore outsourcing options will also be considered.

The review of the potential monitoring techniques for determining air quality impacts during a high risk incident will consider:

- Spatial and temporal variability of the impacts;
- Limit of detection, resolution and concentration range of the technique;
- Timescales for obtaining results, accessibility and format of data;
- Power requirements, access, safety and security;
- Level of operator involvement, training requirements;
- Storage, maintenance and calibration requirements.

Monitoring techniques that are expected to form part of the investigation of appropriate measures include:

- Continuous monitoring using an electrochemical sensor at single or multiple locations on or beyond the site boundary;
- Handheld monitoring using an electrochemical sensor at receptor locations or within the site boundary;
- Indicative sampling by drawing air through an appropriate medium in a diffusion tube.

It is not considered that MCERTs certified monitoring or that using reference techniques such as chemiluminescence is necessary given the main objective is for an indication of whether concentrations are approaching an order of magnitude above that of concern i.e. 0.1, 1.0 or 10 ppm; nevertheless, the selected equipment will need to be stored, maintained and calibrated in line with the manufacturer’s recommendations to ensure accuracy in the event that monitoring is undertaken.

The selected technique must be able to verify the concentrations at receptors, or equivalent locations, at an appropriate resolution and order of magnitude in order to allow a meaningful comparison against the wide range of heath based thresholds (0.1 ppm to 38 ppm). Because of this range of interest, certain of the simpler techniques may also need to be disregarded.

The findings of the study will be incorporated in a future update of the AQMP.

6. Review & Training

6.1. Further actions

When	What
Within 12 months of permit determination	• Refine the definition of low, medium and high severity incidents through further dispersion modelling; • Identify and install practicable ambient air quality monitoring method; • Review the potential for further viable mitigation techniques.

6.2. AQMP review

When	What
After an incident of any magnitude	• Produce an "After-Action Report" with timelines and investigation into the event including the "5 whys" and lessons learnt; - Record lessons learned and share with relevant staff with responsibility under the AQMP; • Update associated documentation and if necessary, train staff any key changes to approach.
After a major outage / high risk incident	• Formal review of all systems, including the AQMP, in accordance with the PM05A Major Incident Procedure; - an investigation into the cause and effects - identification of further practicable measures that could be taken to prevent significant impacts; - identify requirement for updates or changes to mitigating / monitoring such as maintenance regimes, reporting mechanism or location/type of monitoring.
If plant reconfigured	• Review effectiveness and suitability of the AQMP.
Every four years	• Review viable measures to reduce emissions from an emergency outage, including alternative fuels and abatement technology.

6.3. Training

When	What
Release of AQMP update	Present a toolbox talk to Vantage staff with responsibility under the AQMP to raise awareness of potential impacts of an emergency outage, and the actions in the AQMP for incident management to ensure: • knowledge of sensitive receptor locations; • identifying prevailing meteorological conditions; • determination of incident risk categories; • familiarity with AQMP reporting procedures; • interpretation of monitoring data (if / when applicable).
Once a year	• Undertake an annual drill or equivalent exercise to: - check reporting procedures are appropriate and practicable, - ensure monitoring equipment and software systems are working correctly and any required calibration is up-to-date
After an incident	• Share lessons learned

Relevant documents and forms will be made available on Vantage's internal Sharepoint site.

Appendices

Appendix A. Incident Diary

A.1. Low or medium risk incident

Simple incident diary reporting format using below template and/or embedded in a Teams Channel

Include the following information

Item	Format	Comment
Permit reference	EPR/XXXXXX	EPR/BB3599CW
Date of outage	DD/MM/YYYY	
Start time	xx:xx	
Number of engines operating upon outage, no. data halls affected	X no.	
Load shedding actioned	Y / N or n/a	
Number of engines operating after two hours	X no. full load X no. part load	
Anticipated duration of outage (hours) *("prolonged" if >2 hours)*		

A.2. High risk incident

Detailed incident diary reporting format using below template and/or embedded in a Teams Channel

Include the following information

Item	Format	Comment
Type of incident	Free text	*This is a self-reported potentially polluting event to air quality caused by an NRW permitted installation.* *We are a data centre needing to run a significant number of standby diesel engines that may lead to ambient air quality breaches*
Permit reference	EPR/XXXXXX	EPR/BB3599CW
Date of outage	DD/MM/YYYY	
Start time	xx:xx	
Number of engines operating upon outage, no. data halls affected	X no.	
Load shedding actioned	Y / N or n/a	
Number of engines operating after two hours	X no. full load X no. part load	

Item	Format	Comment
UK Power Network contacted?	Y / N	
Anticipated duration of outage (hours) ***("prolonged" if >2 hours)***		
Wind direction	N / E / S / W NE / SE / SW / NW	
Wind speed	Low (<5 m/s) / High (> 5 m/s)	
Season	Spring / Summer / Autumn / Winter	
Time category **(*check seasonal differences in timings*)**	Day / Night	
Air quality risk category **(AEGL-1 exceedences in full outage)**	Low / Medium / High	
Regulator informed? ***(state NRW and/or Local Authority)***	NRW Y / N LA Y/ N	
Initial actions taken	Text field	*We have initiated the agreed AQMP (this will be logged in your document management system DMS under the permit reference). The AQMP includes the requirement to make this notification as soon as practical.*
Further action required? ***(Y if high risk, >2 hours and sensitive receptors)***	Y / N	
Sensitive receptors nearby ***(give type & locations)***		
Visual impact (fumes etc)	Y / N (if Y) description of where	
Further action agreed with regulator and/or LA ***(give detail)***	Y / N	
Outage end time & date	xx:xx DD/MM/YY	
Total number of hours' outage		

Appendix B. Evaluation of risks

B.1. Emergency Operation

Dispersion modelling was undertaken for a hypothetical emergency operational scenario of all engines operating in the event of a full site power outage. The emergency condition considered in the modelling undertaken for the permit application was for a period of up to one hour; although emergency outages may last longer the impact of subsequent hours may be assumed to be lower than the maximum reported modelled concentrations. This is because the emissions were modelled for each hour of the year to identify the highest hourly average concentration, so necessarily relate to the initial hour of an emergency. Were the emergency conditions to persist beyond one hour, the subsequent hours do not reflect the actual stable site demand load and hence would overestimate by an amount approximately equivalent to five additional engines running continuously.

A four year meteorological data set has been used in the modelling for the AQMP for the purposes of determining the likelihood under different seasons, thus analysing a composite of twelve months of data (approximately 8760 hours) for each of four seasons. As in the previous regulatory submissions, the modelled oxides of nitrogen concentrations were factored by 0.35 to convert to NO_2 concentrations, and a value of 40 $\mu g/m^3$ was added to derive the total concentration or "Predicted Environmental Concentration, (PEC)" which comprises the plant contribution and an allowance for local background concentrations.

The PEC results were evaluated with respect to the selected short term AEGL-1; or more precisely, the counts of modelled exceedences of that criterion at each of the receptor points. These exceedance counts are displayed graphically to enable the relative risks of an exceedance to be determined in the downwind area.

B.2. Approach to development of the AQMP

Dispersion of pollutants from stacks is primarily influenced by wind direction and wind speed. There are seasonal differences in such weather conditions. Another important factor is the degree of turbulence in the atmosphere acting to dilute the exhaust plumes, which may differ markedly between daytime and night time unless local conditions are overcast. The broad categories of atmospheric conditions are classified using the Pasquill stability classes of stable, neutral and unstable, and further categorised with reference to wind speed and cloud cover into six or seven classes; A to G/F.

The dispersion model scenario for an initial hour of emergency operation with load shedding, as addressed in the permit application, has been further evaluated for the purposes of developing a risk matrix to inform the operator's understanding of the potential for exceedances of public health criteria, under different specific classes of meteorological conditions. A comparison with this criterion allows for identification of potentially affected areas.

A four year hourly meteorological data set was used to evaluate the number of potential exceedances in winter, spring, summer and autumn; hence providing a count for each season comprising twelve months of meteorological data. The cumulative total counts for four years provide a robust estimate for conditions at the CWL11/12 site. These findings were subsequently broken down to evaluate the day time and night time exceedance counts within each of the four seasons. In the context of the Pasquill stability classes, night time is defined as the period from one hour before sunset to one hour after sunrise.

The analyses are presented as a series of isopleth plots showing the counts of exceedances of the adopted threshold concentration, by day and night for each season, overlaid on a local map showing receptors.

A further investigation of the effect of wind speeds was carried out for the four year meteorological dataset. This looked at the number of exceedances for the four-year period in several wind speed bands. Again, the results are presented as a series of isopleth plots, in this case showing the counts of exceedances in the entire four-year period for the wind speed band in question.

B.3. Assessing Impacts

An outage occurrence has been modelled for all hours of meteorological data based on fundamentals of dispersion under the following scenarios to identify the number of exceedences of AEGL-1 threshold during:

- Seasonal variation:

  - Winter (Dec, Jan, Feb);
  - Spring (Mar, Apr, May);
  - Summer (June, July, Aug);
  - Autumn (Sept, Oct, Nov);
- Seasonal and diurnal variation:
  - based on Pasquill stability classes;
  - night time refers to the period from 1 hour before sunset to 1 hour after sunrise;
  - specified for each season using Newport sunrise and sunset data and cross referenced to initial seasonal model output;
- Wind speed categories:
  - < 1.54 m/s;
  - 1.54 to 3.09 m/s;
  - 3.09 to 5.14 m/s;
  - 5.14 to 8.23 m/s;
  - > 8.23 m/s.

The three bands of likelihood categories proposed are based on stratifying the exceedance count data, as modelled for this specific facility, to allow a hierarchy of responses in the AQMP.

The modelling shows no significant difference in the maximum hourly mean NO_2 concentration in terms of the nearfield maxima under different seasons. In no scenario does the maximum approach the higher AEGL-2 therefore the relevant health threshold for action is AEGL-1, which concerns non-disabling, reversible impacts.

B.4. Application of findings

In developing an AQMP it has been necessary to consider how to feasibly manage what is an emergency event, to limit the potential for significant effects on sensitive receptors. This document identifies in further detail the areas at most risk of breaches in the initial hours of a power outage and sets out appropriate actions by the Vantage site team to inform NRW and where appropriate, to minimise harm.

The exceedance count contour plots (Appendix C) have been used to define relative likelihoods of exceedences (Table 3-1) which will be fed into a set of simple steps to be incorporated within Vantage's integrated management system. The set of tiered operator actions has been designed to be capable of implementation within a few minutes of a power outage. This will enable a rapid understanding of the relative risks, given the prevailing meteorological conditions at the time of the event.

In the event of an emergency, the existing wind speed and direction will be established from consultation of online sources (Vantage are planning to automate this step within Scada using an on site meteorological station). The operator will use the prevailing conditions to identify if the event is a low, medium or high risk of exceedance of air quality exposure criteria and report to the regulator.

If the outage is potentially of long duration (over two hours), and the number of cells of engines is above a minimum value, the contour plots can provide further detail for the regulator with regard to the potential extent of the downwind region that may be subject to exceedances of the criterion during the emergency event and the density of sensitive receptors. With reference to the plots and the actual conditions at the time e.g. through continued review of meteorological data or inspection of the site boundary, the initial apparent potential for exceedances may be either discounted or confirmed by the operator in discussion with the regulator.

Appendix C. Exceedance plots

C.1. Risk plots

The following plots show the counts of exceedances of the AEGL-1 for nitrogen dioxide of 940 μg/m^3, based on the calculated total concentration (the PEC), under different conditions (season, time of day and wind speed category). The colours correspond to the three risk categories (low, medium, high) according to the probability of exceedences more than 1% of the modelled hours.

C.1.1. Spring

Spring daylight hours were modelled as hour commencing 07:00 to 18:00 inclusive for day time, and 19:00 to 06:00 inclusive for night time.

Figure C-1 - Summary risk plot for Spring and day time outage

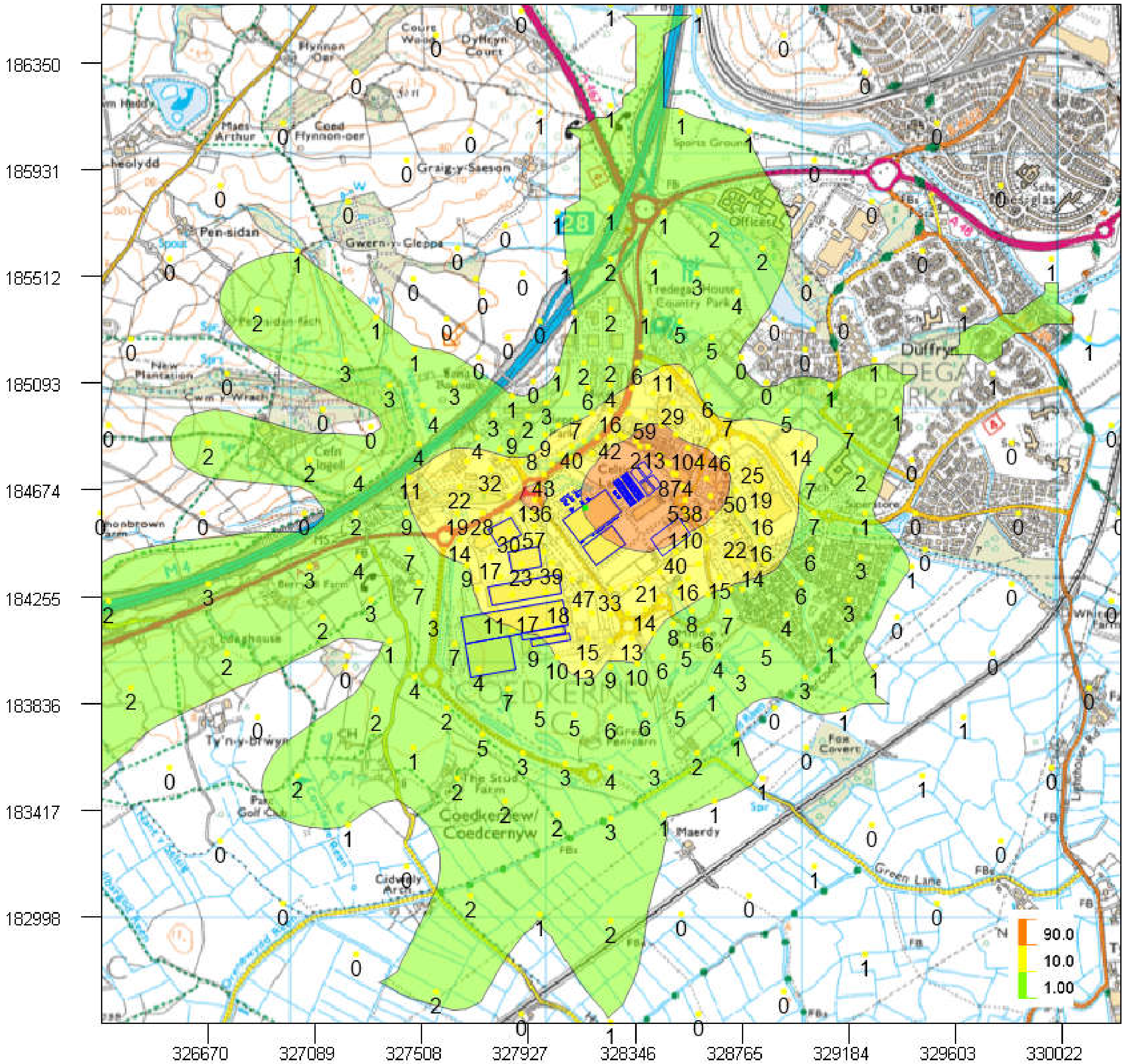
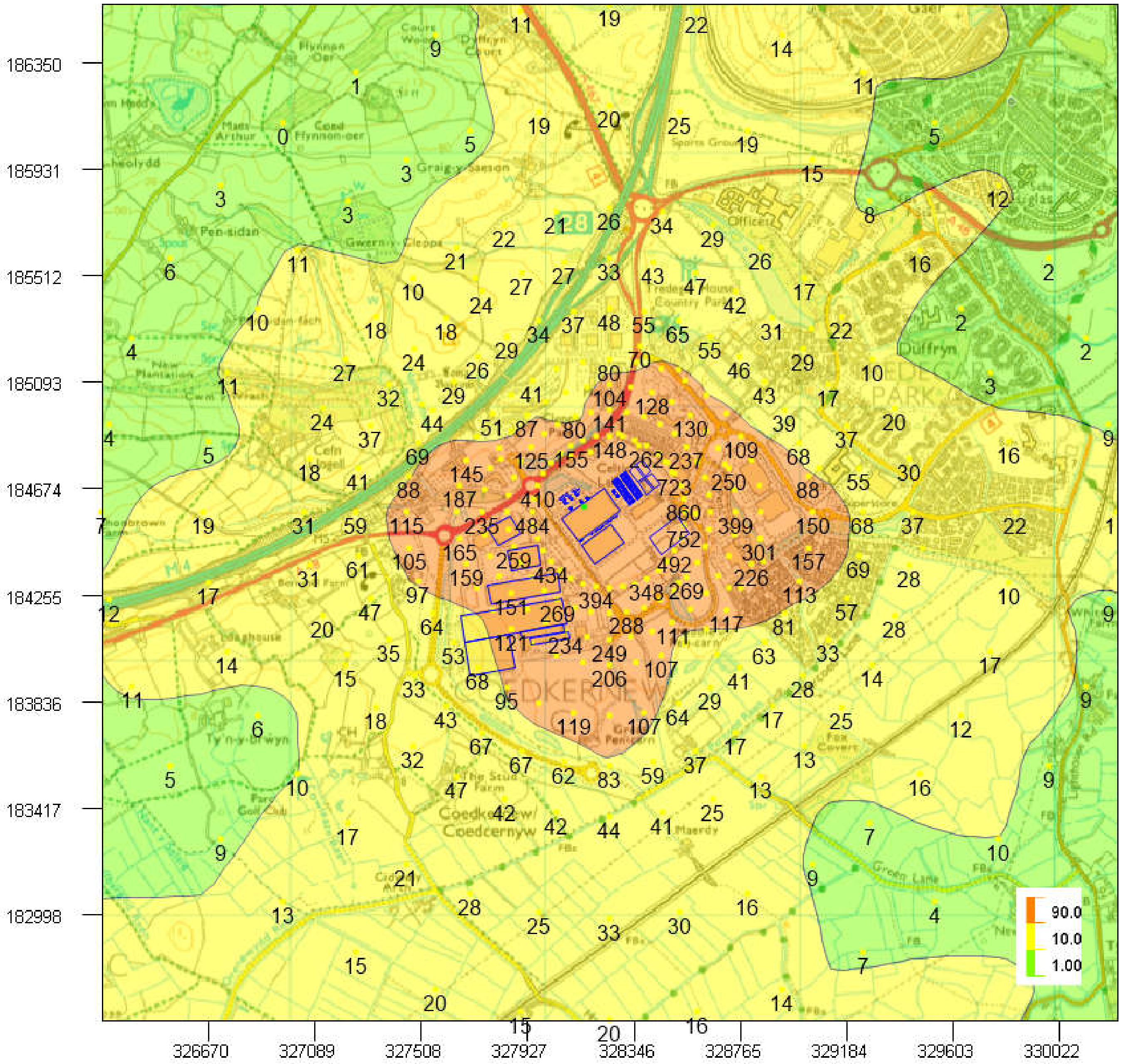


Figure C-2 - Summary risk plot for spring and night time outage



C.1.2. Summer

Summer daylight hours were modelled as 07:00 to 19:00 inclusive for day time, and 20:00 to 06:00 inclusive for night time.

Figure C-3 - Summary risk plot for summer and day time outage

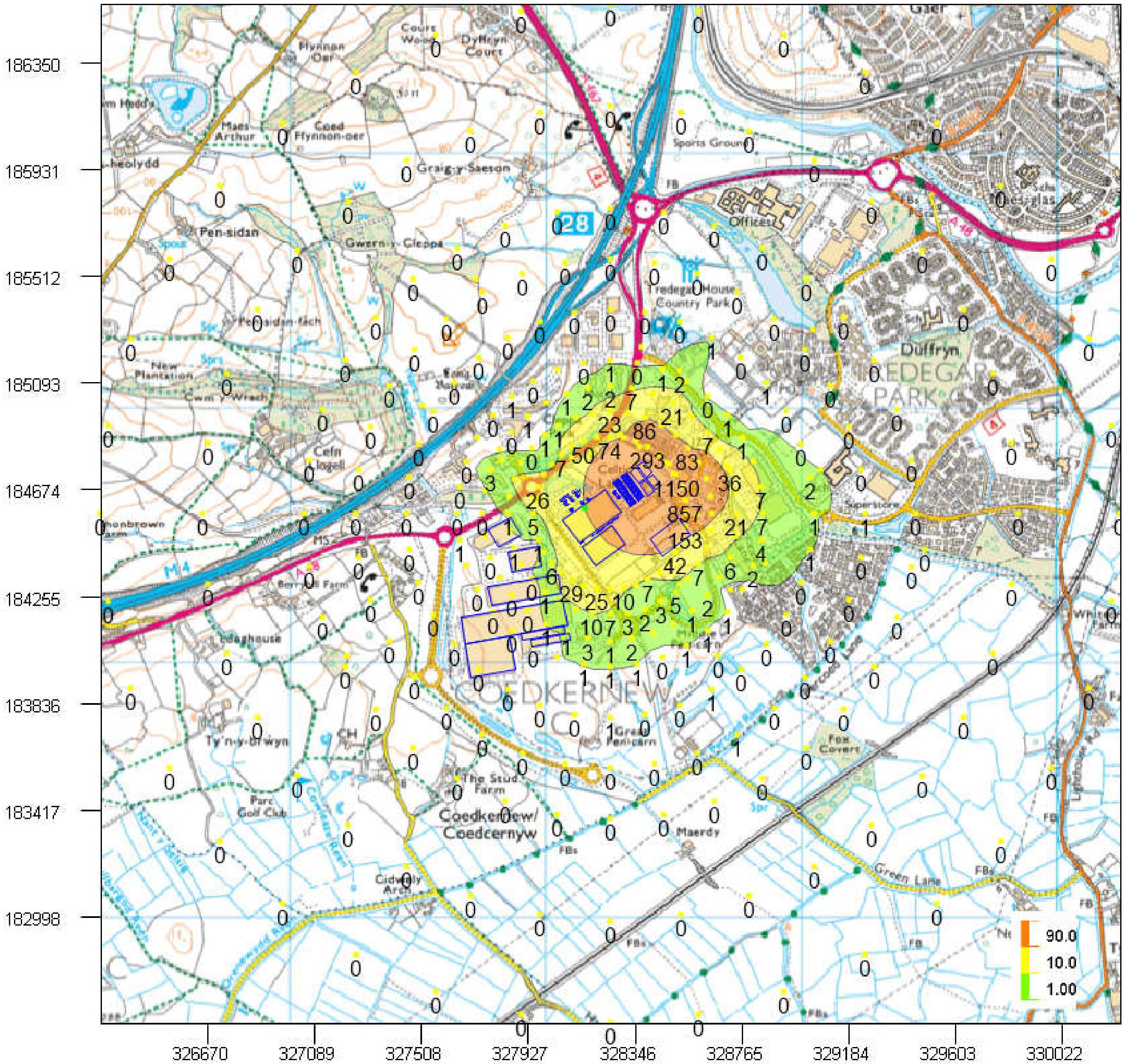
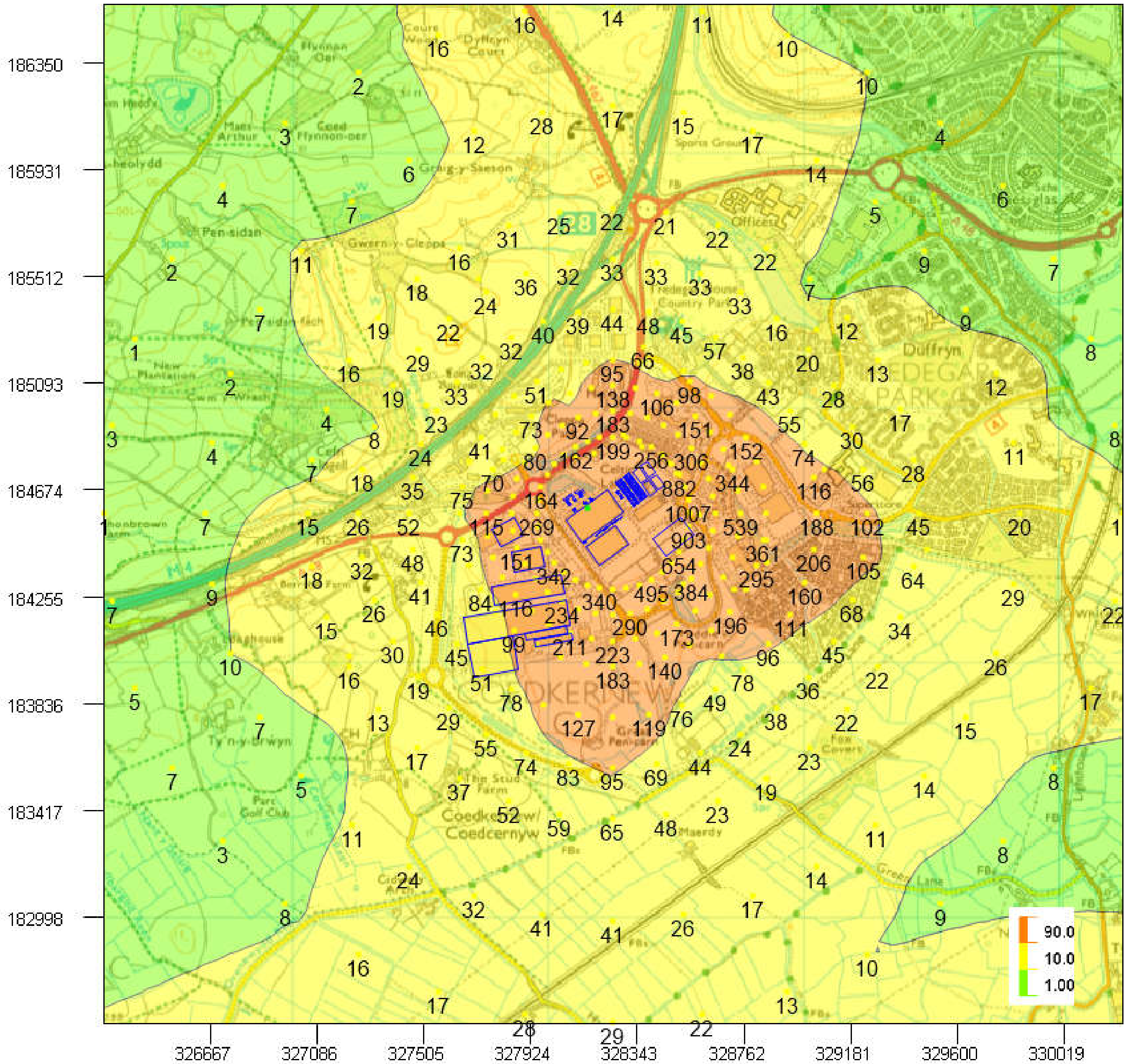


Figure C-4 – Summary risk plot for summer and night time outage



C.1.3. Autumn

Autumn daylight hours were modelled as 09:00 to 17:00 inclusive for day time, and 18:00 to 08:00 inclusive for night time.

Figure C-5 – Summary risk plot for autumn and day time outage

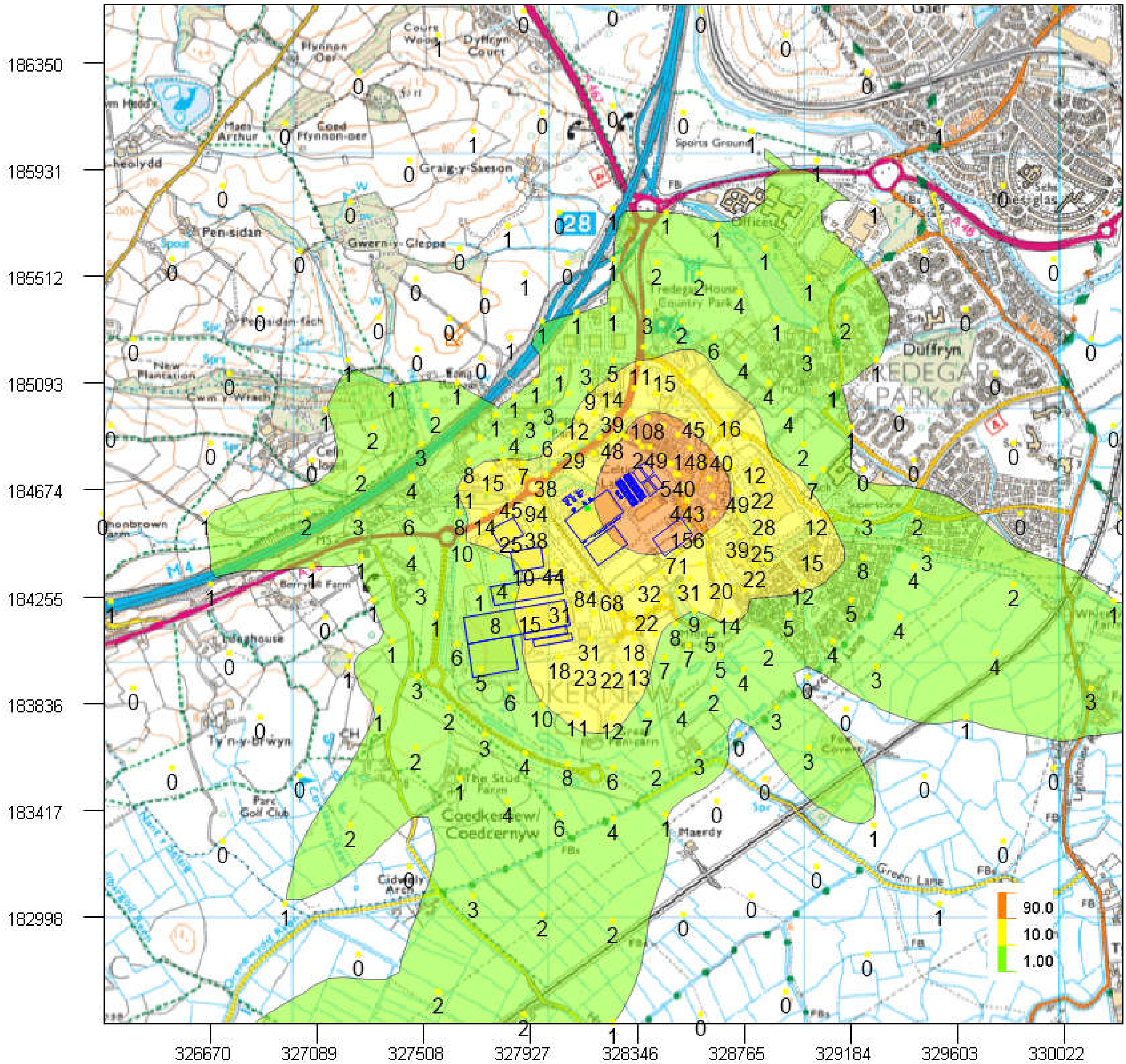
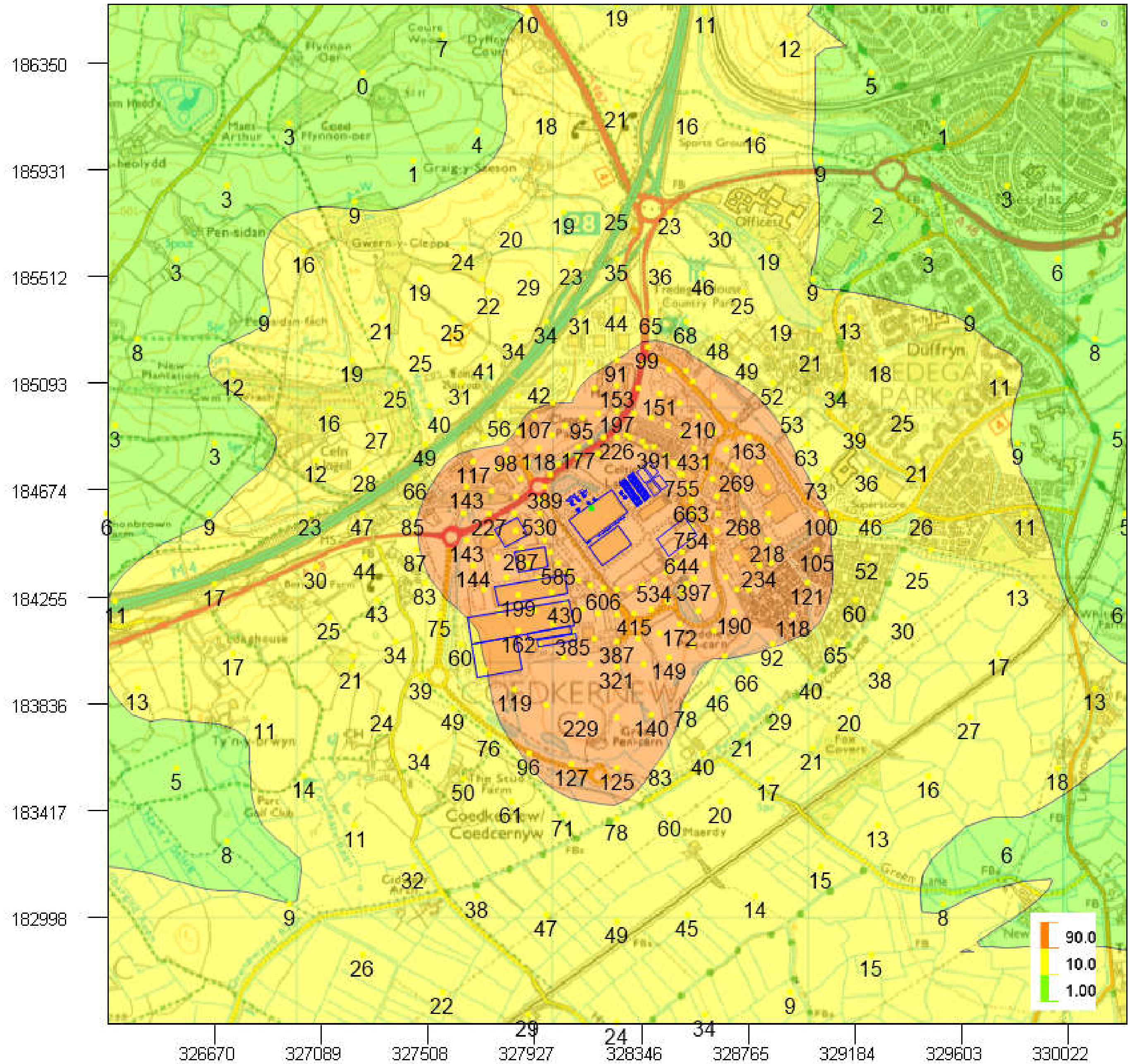


Figure C-6 - Summary risk plot for Autumn and night time outage



C.1.4. Winter

Winter daylight hours were modelled as 08:00 to 15:00 inclusive for day time, and 16:00 to 07:00 inclusive for night time.

Figure C-7 – Summary risk plot for Winter and day time outage

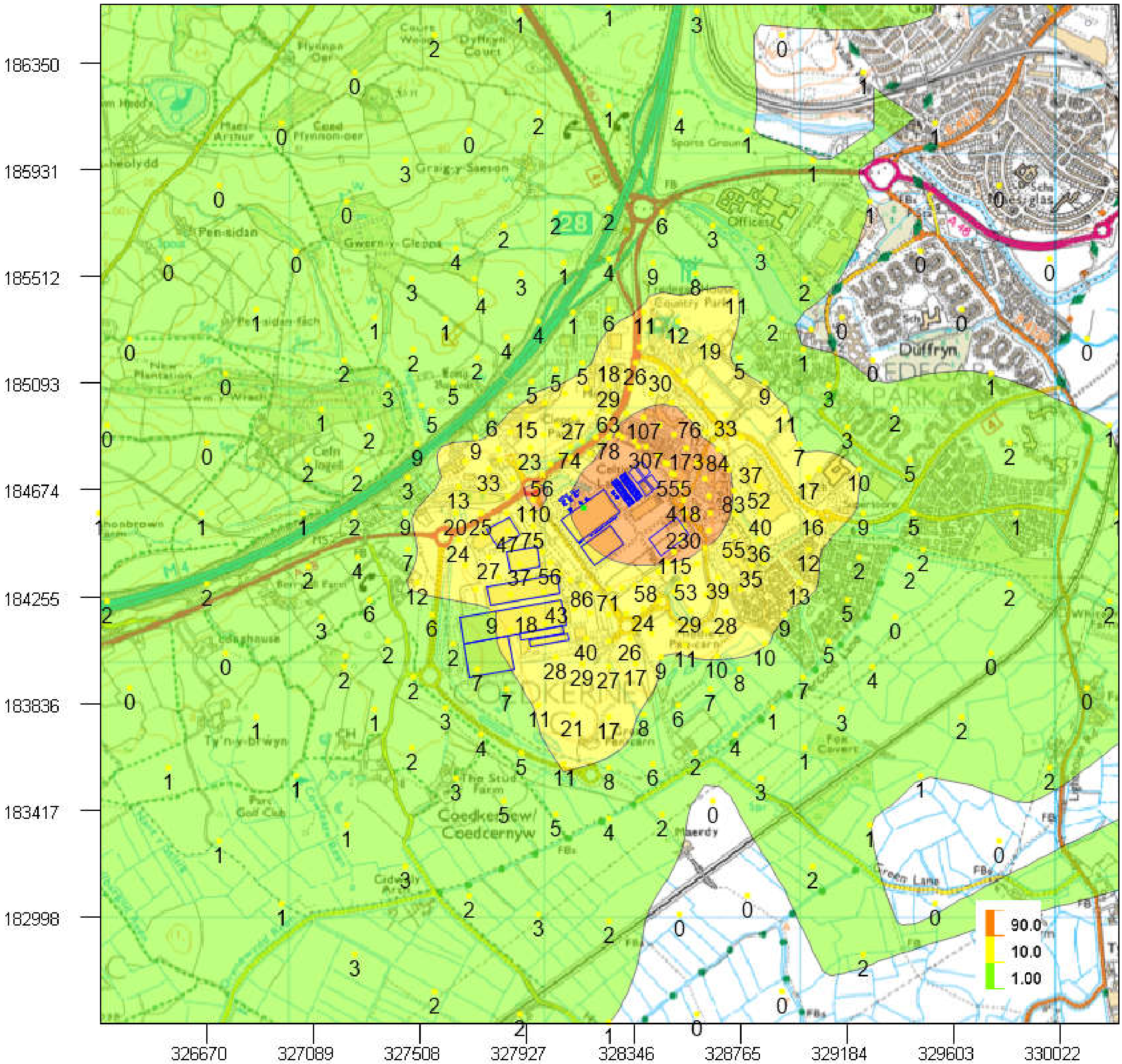
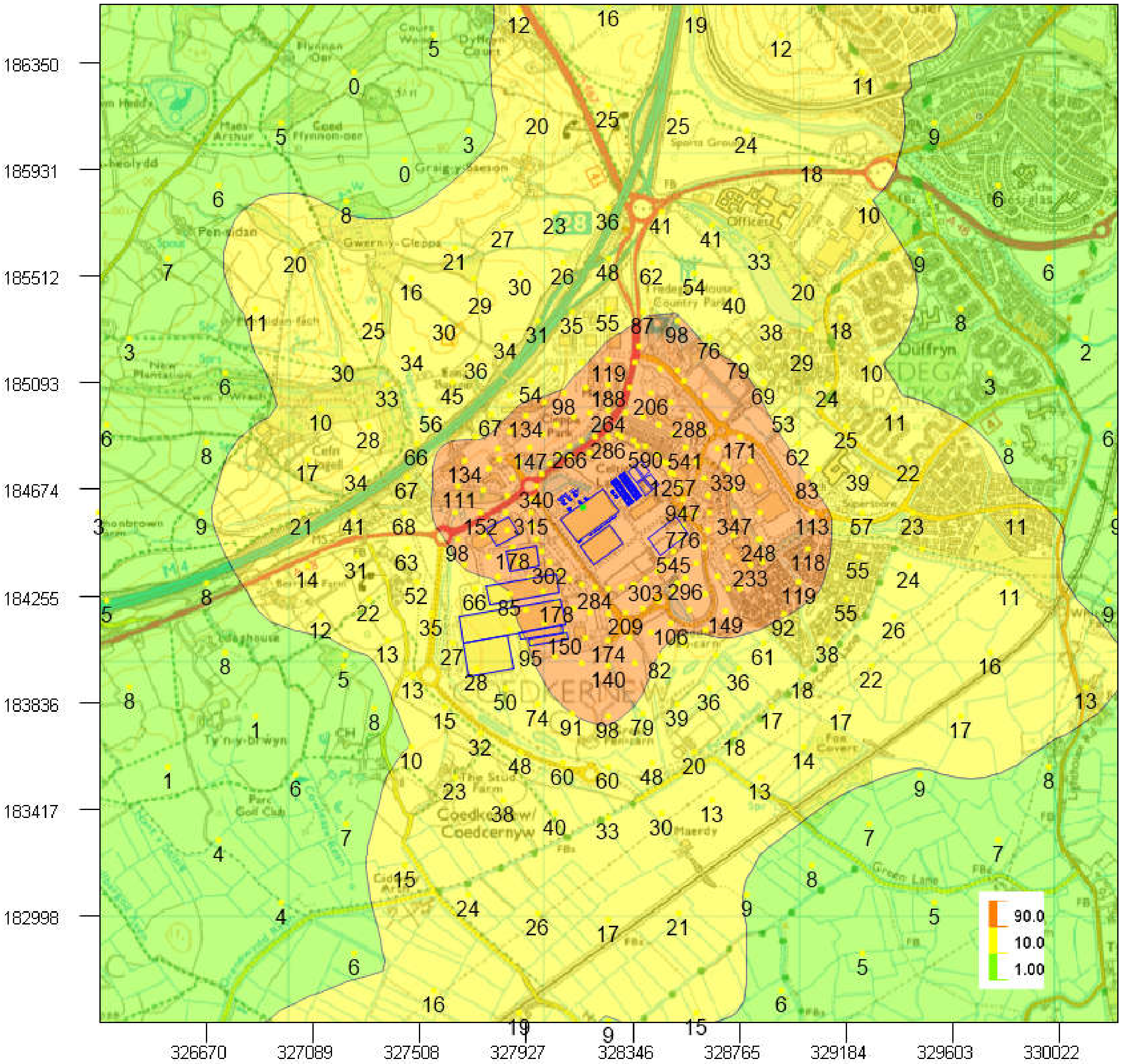


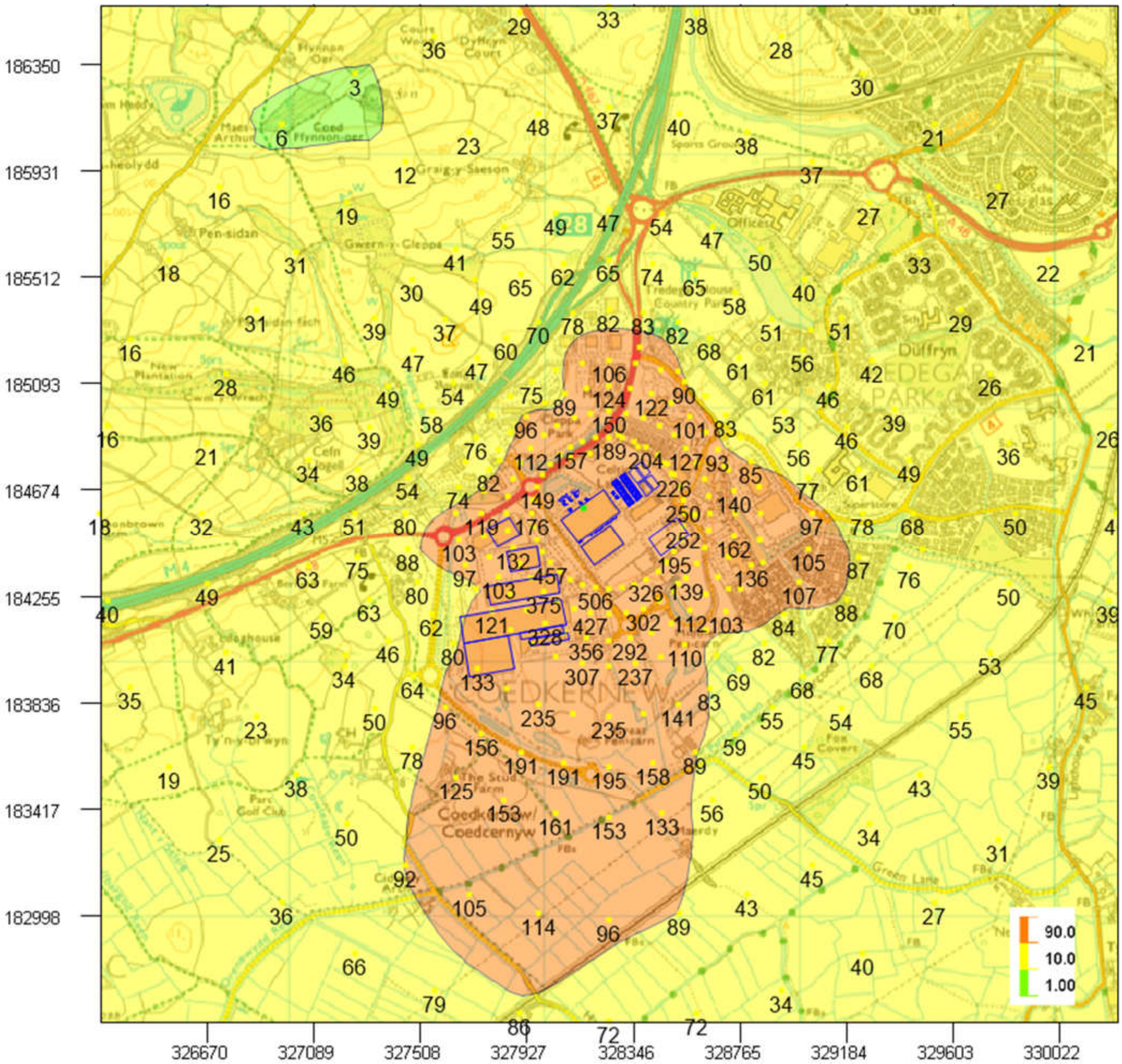
Figure C-8 - Summary risk plot for Winter and night time outage



C.2. Wind speed

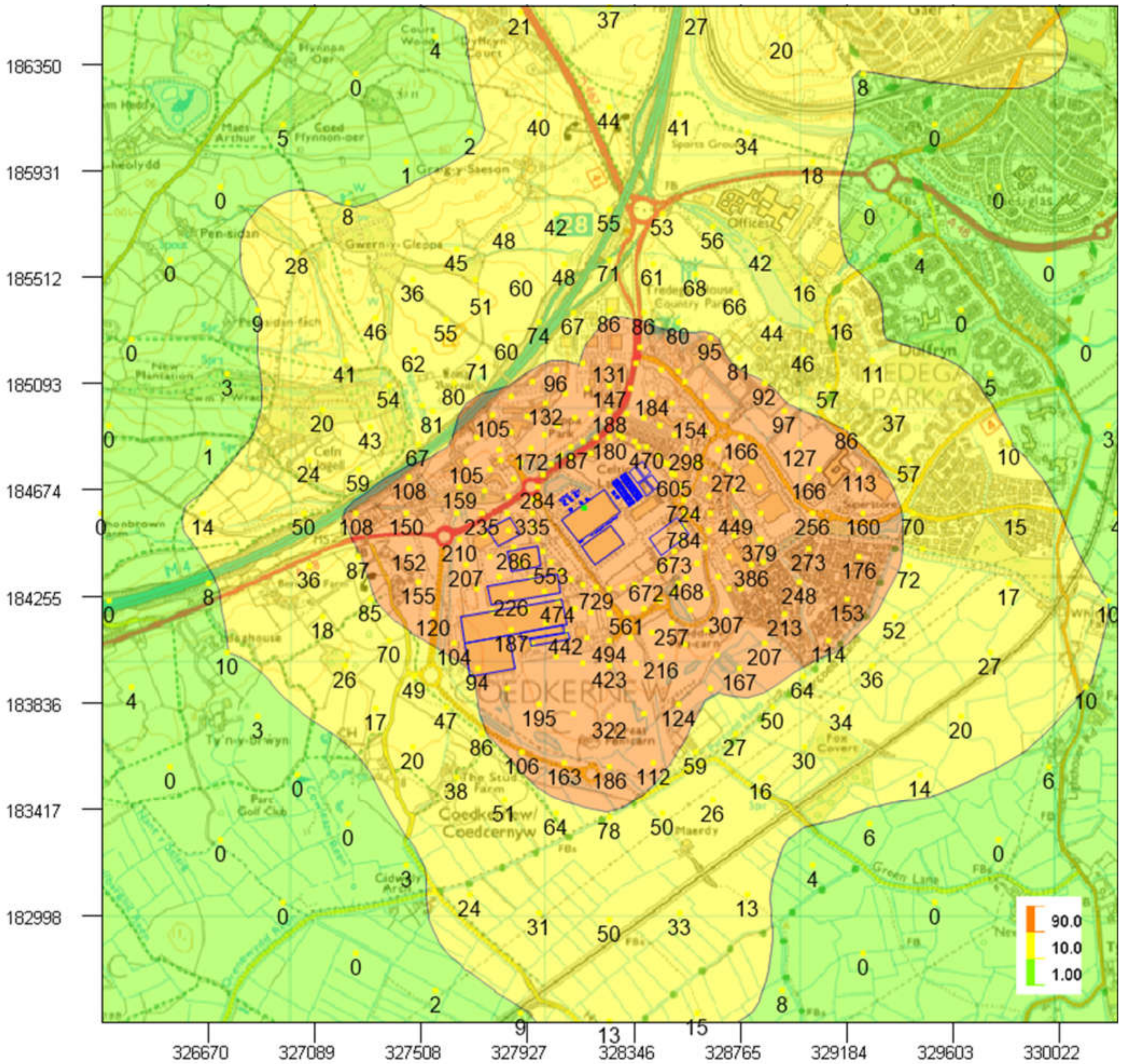
C.2.1. Category 1

Figure C-9 - Summary risk plot for wind speed <1.54 m/s (<3 knots)



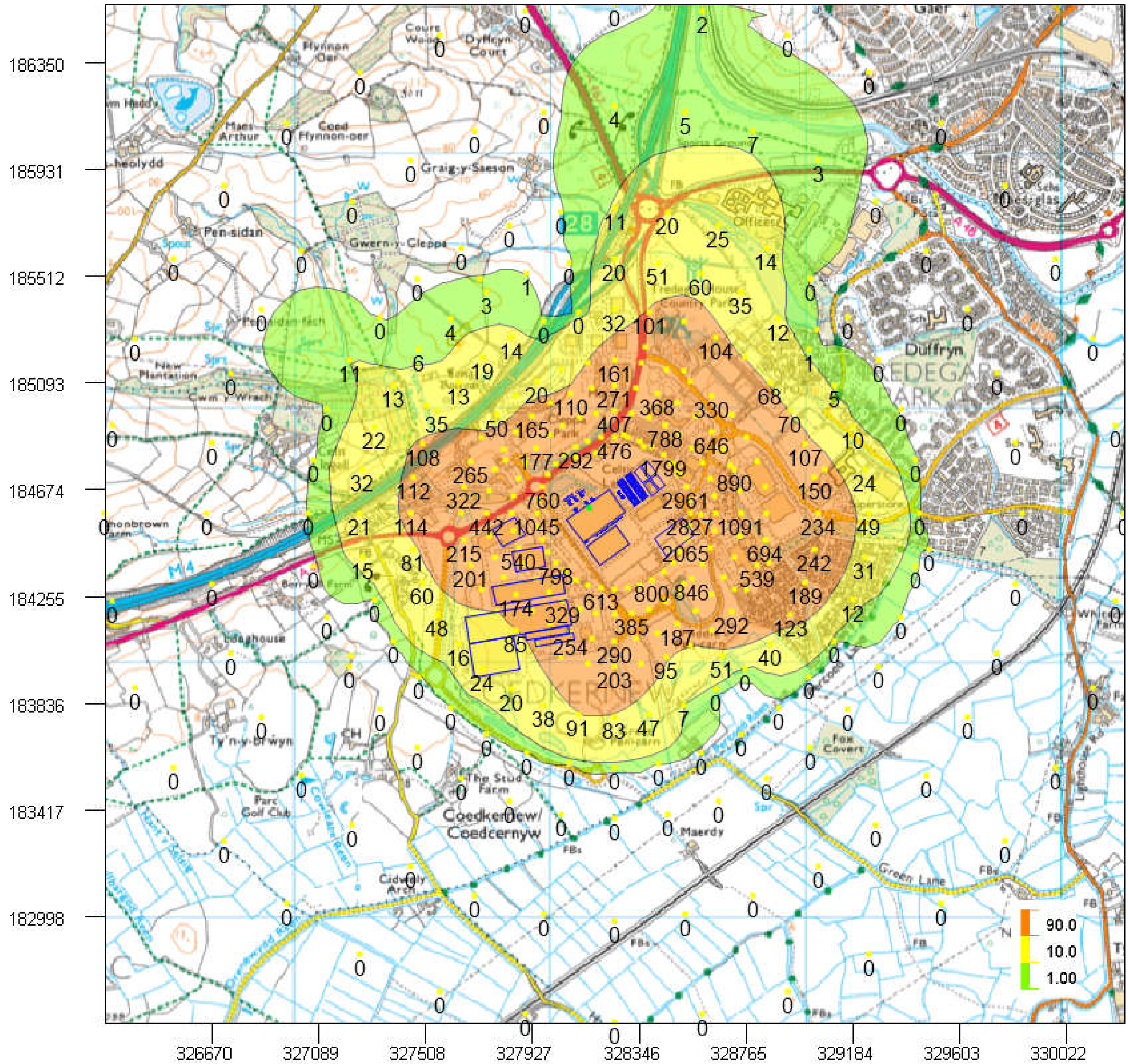
C.2.2. Category 2

Figure C-10 - Summary risk plot for wind speed 1.54 to 3.09 m/s (3 to 6 knots)



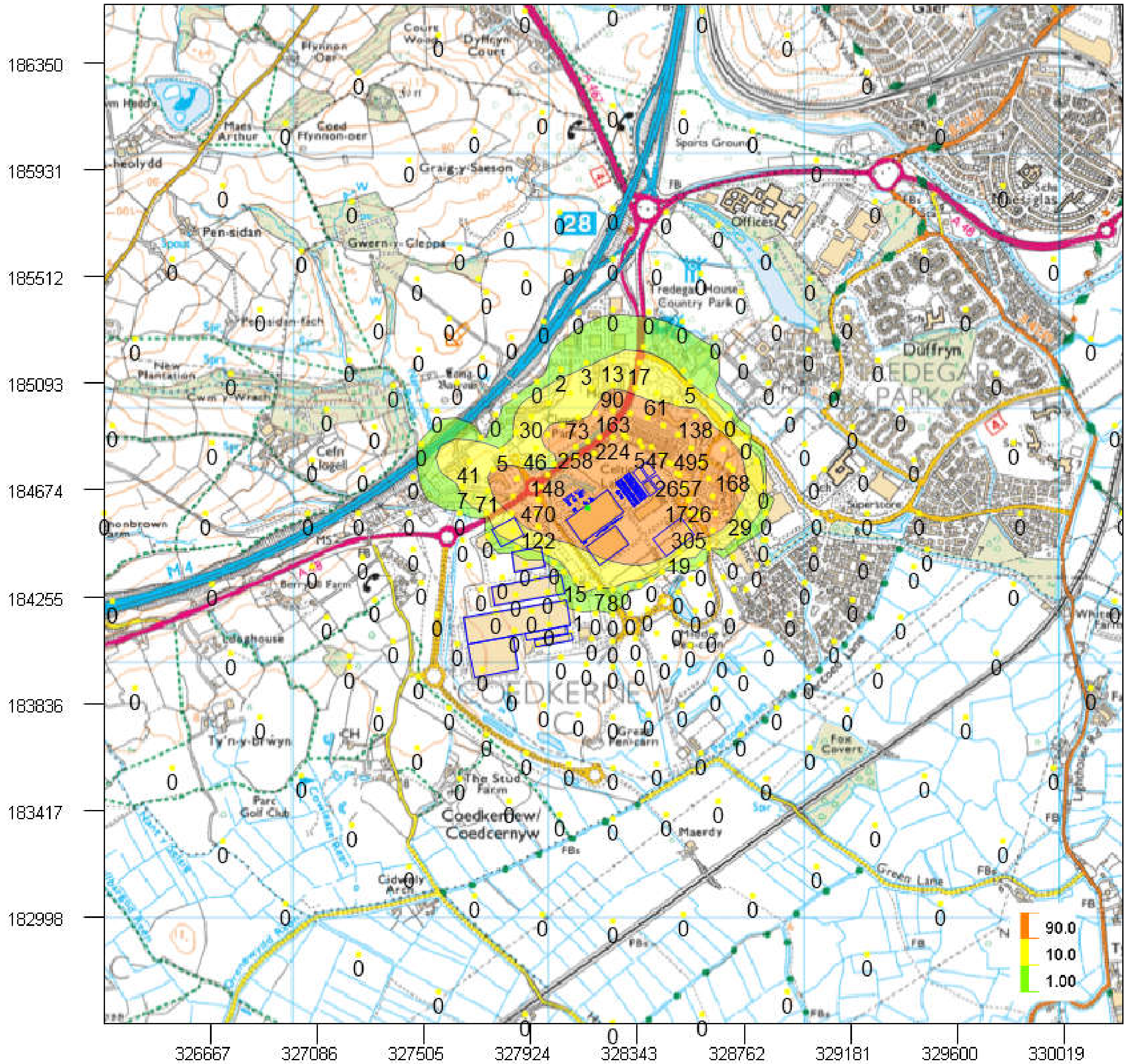
C.2.3. Category 3

Figure C-11 - Summary risk plot for wind speed 3.09 to 5.14 m/s (6 to 10 knots)



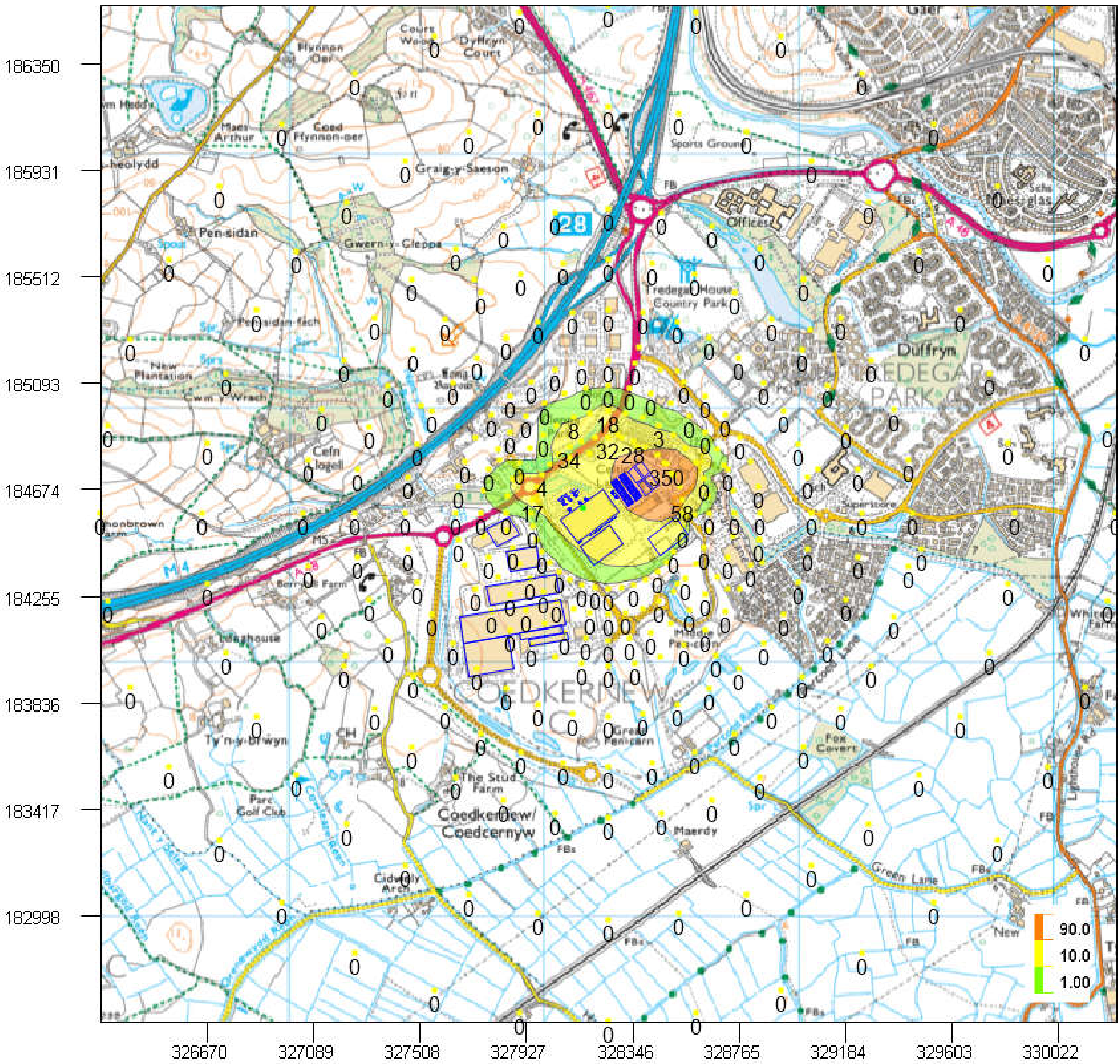
C.2.4. Category 4

Figure C-12 - Summary risk plot for wind speed 5.14 to 8.23 m/s (10 to 16 knots)



C.2.5. Categories 5 & 6

Figure C-13 - Summary risk plot for wind speed above 8.23 m/s (> 16 knots)



Appendix D. Extended outages

D.1. Modelling of different incident intensity and duration

The results from a dispersion modelling exercise to identify maximum NO_2 concentrations over a range of short-term averaging periods (from 1 to 8 hours), for different incident intensities i.e. number of cells operational concurrently, are presented in Table D-2 to Table D-5.

The cell groupings were selected based on a review of the most frequent wind directions, the position of cells within the installation boundary and their alignment with off-site receptors numbered 1 to 12.

Table D-1 - Source groups used in modelling

Group	No. Cells	Cells Running											
CWL11 GF	2	GF1	GF14										
	3	GF1	GF14	GF19									
	4	GF1	GF14	GF19	GF20								
	5	GF1	GF14	GF19	GF20	GF21							
	6	GF1	GF14	GF19	GF20	GF21	GF24						
	7	GF1	GF14	GF19	GF20	GF21	GF24	GF29					
	8	GF1	GF14	GF19	GF20	GF21	GF24	GF29	GF2				
CWL11 TF	2	TF1	TF2										
	3	TF1	TF2	TF3									
	4	TF1	TF2	TF3	TF4								
	5	TF1	TF2	TF3	TF4	TF5							
CWL 11/12	2	GF20	GF21										
	4	GF20	GF21	MF3	TF11								
	6	GF20	GF21	MF3	TF11	B2FF	B2SF						
	8	GF20	GF21	TF3	MF3	TF11	TF12	B2FF	B2SF	B2GF			
CWL11 extension	3	MF2	MF3	MF7									
	6	MF2	MF3	MF7	TF10	TF11	TF12						
	9	MF1	MF2	MF3	MF7	TF9	TF10	TF11	TF12	TF13			
	12	MF1	MF2	MF3	MF7	MF8	MF9	TF9	TF10	TF11	TF12	TF13	TF14
CWL12	3	B1SF	B2FF	B3GF									
	6	B1SF	B2FF	B3GF	B2GF	B2SF	B3FF						
	9	B1SF	B2FF	B3GF	B2GF	B2SF	B3FF	B1GF	B1FF	B3SF			
	12	B1SF	B1GF	B1FF	B2FF	B2SF	B2GF	B3GF	B3FF	B3SF	B4GF	B4FF	B4SF

Table D-2 - Maximum modelled NO_2 concentrations at different incident intensities – 1 hour average

1 h	CWL11_GF							CWL11_TF				CWL11/12				CWL11_ext				CWL 12			
Receptor	2	3	4	5	6	7	8	2	3	4	5	2	4	6	9	3	6	9	12	3	6	9	12
1	553	772	815	947	1341	1502	1605	668	986	1289	1516	346	346	356	671	115	190	263	344	268	544	755	755
2	699	1064	1211	1335	1590	1879	2297	383	441	442	442	764	1310	1394	1827	714	1367	1629	2065	573	1110	1288	1745
3	1112	1535	1535	1536	1596	1862	2223	992	1270	1388	1613	525	525	525	539	241	409	669	825	446	869	1116	1216
4	717	912	1111	1401	1669	1756	1934	1082	1480	2041	2425	967	1309	1561	1965	424	821	1122	1408	470	908	1294	1609
5	715	1047	1453	1711	1846	2019	2252	832	953	1334	1430	860	993	1342	1532	473	902	1009	1239	514	996	1246	1440
6	711	1036	1048	1179	1582	1966	2320	346	755	756	791	855	1060	1257	1366	390	713	1064	1546	508	993	1229	1831
7	532	762	1047	1331	1473	1624	1792	722	1039	1414	1498	627	904	1270	1894	425	841	967	1243	575	1102	1515	1916
8	535	730	906	1201	1382	1480	1549	707	1031	1334	1585	629	745	959	1297	261	472	778	1142	472	906	1319	1546
9	500	749	927	1063	1222	1408	1713	198	468	468	489	560	789	1170	1517	450	872	1181	1529	591	1141	1512	1830
10	418	596	825	1054	1166	1235	1343	578	823	1116	1217	498	713	977	1453	327	633	725	977	439	830	1178	1553
11	698	1012	1365	1751	1853	1990	2191	877	1271	1725	1827	782	934	1251	1982	468	914	1056	1275	539	1030	1359	1546
12	755	1084	1234	1593	1725	1850	1983	917	1339	1736	2065	895	1169	1282	1846	442	843	1078	1389	609	1183	1715	2012

Table D-3 - Maximum modelled NO_2 concentrations at different incident intensities – 2 hour average

2 h	CWL11_GF							CWL11_TF				CWL11_mix				CWL11_ext				CWL 12			
Receptor	2	3	4	5	6	7	8	2	3	4	5	2	4	6	9	3	6	9	12	3	6	9	12
1	489	671	699	791	1126	1298	1393	592	858	1126	1304	265	265	288	547	111	183	252	331	196	378	522	562
2	538	858	1066	1171	1289	1478	1771	212	241	247	291	653	1039	1231	1606	597	1158	1359	1536	537	1042	1196	1605
3	576	804	805	805	869	1010	1266	544	846	847	1071	365	419	432	493	230	393	592	759	340	648	915	1087
4	517	871	1105	1388	1664	1756	1781	845	1257	1655	2134	710	978	1140	1431	336	640	842	1044	303	572	822	1090
5	693	1014	1361	1631	1741	1861	2021	534	620	687	735	657	769	978	1168	257	471	524	639	444	853	1087	1182
6	524	793	860	898	986	1146	1338	281	563	563	618	610	742	883	1033	285	520	701	920	469	910	1076	1524
7	374	543	746	960	1056	1125	1196	477	629	788	863	457	620	862	1239	305	583	663	924	398	757	1067	1386
8	387	546	675	851	1032	1124	1196	495	743	955	1125	401	495	695	907	204	350	618	798	374	707	1024	1215
9	421	602	652	736	856	987	1214	119	254	254	266	442	665	974	1265	388	741	1045	1296	489	937	1259	1489
10	281	385	509	648	747	852	991	379	521	700	796	330	467	646	957	241	443	509	670	305	572	822	1017
11	528	745	945	1260	1539	1765	2048	632	833	989	1106	555	630	952	1491	385	757	831	946	481	923	1287	1432
12	588	814	926	1221	1344	1454	1539	764	1071	1388	1594	618	796	884	1280	316	594	787	1025	519	1009	1443	1570

Table D-4 - Maximum modelled NO_2 concentrations at different incident intensities – 4 hour average

4 h	CWL11_GF							CWL11_TF				CWL11_mix				CWL11_ext				CWL 12			
Receptor	2	3	4	5	6	7	8	2	3	4	5	2	4	6	9	3	6	9	12	3	6	9	12
1	383	520	541	583	823	952	1029	445	639	833	963	190	195	211	379	111	182	252	331	121	210	286	361
2	314	479	714	862	1035	1223	1510	146	214	214	251	442	689	953	1296	428	819	975	1247	447	859	994	1255
3	377	572	579	586	714	904	1111	372	576	576	712	332	413	430	476	200	344	536	694	297	572	805	916
4	304	464	623	782	906	962	988	516	683	975	1096	404	532	667	865	188	340	478	611	215	394	561	740
5	475	690	921	1101	1174	1254	1361	369	427	523	567	451	526	743	1012	216	392	461	537	357	681	942	1032
6	476	690	700	704	768	872	982	206	492	492	515	442	546	682	778	255	461	621	757	429	835	983	1317
7	271	399	553	697	752	791	828	369	514	647	684	338	477	682	1012	235	446	524	684	331	620	891	1112
8	277	371	437	565	639	697	740	349	488	626	728	305	377	518	675	163	269	469	644	257	481	692	804
9	313	466	608	711	804	909	1083	131	289	289	301	289	391	548	721	239	436	617	758	299	561	733	975
10	248	346	465	583	675	745	830	326	452	599	632	277	383	498	728	181	330	382	527	214	383	530	737
11	366	510	660	854	1039	1190	1379	467	653	816	863	384	509	693	1096	273	519	624	750	350	662	938	1108
12	350	473	612	801	850	878	1084	461	639	821	1001	420	544	671	867	229	411	620	771	427	822	1164	1280

Table D-5 - Maximum modelled NO_2 concentrations at different incident intensities – 8 hour average

	CWL11_GF							CWL11_TF				CWL11_mix				CWL11_ext				CWL 12			
Receptor	2	3	4	5	6	7	8	2	3	4	5	2	4	6	9	3	6	9	12	3	6	9	12
1	187	260	276	301	411	463	496	224	325	395	465	111	127	163	269	89	137	184	240	102	167	230	282
2	206	313	386	460	521	615	760	106	145	173	198	278	435	595	787	271	502	627	773	329	621	722	940
3	291	393	396	398	463	567	671	226	339	341	437	287	315	323	423	181	302	436	554	273	522	747	890
4	203	314	415	524	605	639	654	297	433	567	703	269	363	425	530	145	254	330	401	124	209	295	389
5	274	392	564	701	749	795	850	278	350	388	413	348	434	649	846	162	285	362	412	334	633	861	964
6	242	347	390	435	514	596	682	131	245	248	268	298	351	468	566	246	445	592	719	304	574	676	910
7	197	281	376	475	540	587	642	242	329	425	454	234	318	441	633	175	316	375	488	217	391	538	720
8	163	214	273	343	398	427	451	199	283	358	423	193	231	316	434	120	195	297	403	168	295	415	513
9	162	223	284	336	388	442	523	79	147	147	152	184	262	350	488	158	280	374	463	184	330	442	528
10	146	196	259	319	371	413	467	185	250	325	343	163	221	282	402	117	197	228	310	132	223	306	410
11	269	397	527	639	728	807	908	332	443	538	578	322	408	544	811	221	410	509	644	299	562	763	947
12	273	367	406	494	589	690	820	329	451	577	658	275	354	487	644	183	322	480	595	258	479	679	840