REDROW

BAE SYSTEMS

ROYAL ORDNANCE, BISHOPTON

REMEDIATION AND RECLAMATION EARTHWORKS

ENVIRONMENTAL STATEMENT

APPENDIX 9.2

BUILDING DECONTAMINATION BURN ASSESSMENT

October 2006

A REPORT BY ENVIROS CONSULTING LIMITED: MAY 2006

BAE SYSTEMS

AIR QUALITY IMPACT ASSESSMENT: FORMER MUNITIONS FACTORY, BISHOPTON, RENFREWSHIRE

QUALITY CONTROL SHEET

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3. BACKGROUND AIR QUALITY

EXECUTIVE SUMMARY

BAE Systems are currently in the planning stages of the remediation of a site in Bishopton, Renfrewshire. The site is a former explosives and propellants and armaments factory and the buildings on the site are potentially contaminated with traces of propellants and explosives. In order to remove any residual contamination from the buildings prior to demolition BAE Systems are planning to undertake a programme of controlled burning within the buildings in order to destroy any residual explosive material.

An investigation has been undertaken to assess whether there are likely to be any adverse impacts on air quality arising at local receptors as a consequence of the burning programme. The investigation has been undertaken using a detailed dispersion modelling programme. The analysis includes assessing the impacts of burning typically sized buildings and the largest buildings on site. In addition the assessment includes the impacts of burning several buildings concurrently and the influence of local conditions including meteorology, terrain and land use. Throughout the assessment a number of worst case assumptions were made to ensure that the impacts are more likely to be overestimated than underestimated.

The assessment investigated impacts of a number of scenarios:

- Scenario 1 assessed the impacts of burning one building per day for five days per week throughout the year. This situation is likely to be representative of the short term and long term impacts arising from the burning.

- Scenario 2 assessed the impacts of burning two buildings per day for five days per week throughout the year. This situation is likely to be representative of the short term and long term impacts arising from the burning.

- Scenario 3 assessed the impacts of burning two, three, four, five and six buildings in close proximity to one another (approximately 30m apart) per day. Occasionally there may be the requirement to burn up to six buildings in a single day, although the normal pattern would be to burn a maximum of two buildings in any one day. The assessment was undertaken for short term impacts only, as this scenario is not applicable to long term impacts.

- Scenario 4 assessed the impacts of burning of the large buildings at the northern end and centre of the site. In this case, the buildings will be burned individually and at a maximum rate of one per day. The assessment was based upon burning of the largest of these buildings and was undertaken for short term impacts only, as this scenario is not applicable to long term impacts.

The investigation concluded that, with appropriate mitigation measures in place, the remedial burning is unlikely to result in adverse impacts on air quality at local sensitive receptors.

The mitigation measures were developed on the basis of the results of the dispersion modelling assessment. The mitigation measures include a margin of safety whereby even if the impact from the fires at sensitive receptors were double that predicted by the dispersion model, the air quality objectives and guidelines would not be predicted to be exceeded.

The mitigation measures identified are:

- For scenario 1 where only a single typically sized building is burned, or buildings are widely dispersed across the site (at a minimum distance of 500m between each) the burning should only be undertaken when the wind direction is such that the nearest sensitive receptors to any of the buildings are at least 300m downwind. This scenario takes into account both long term and short term impacts;

- For scenario 2 where two buildings are burned in close proximity, the burning should only be undertaken when the wind direction is such that the nearest sensitive receptors to any of the buildings are at least 500m downwind. This scenario takes into account both long term and short term impacts;

- For Scenario 3, where groups of buildings in close proximity (less than 500m apart) are due to be burned, the wind direction should be such that the nearest sensitive receptor locations are at least:

    - 150m downwind for two buildings;

    - 200m downwind for three buildings;

    - 300m downwind for four buildings;

    - 300m downwind for five buildings; and

    - 400m downwind for six buildings.

- For scenario 4, the large buildings at the north end and centre of the site should be burned singly and should only be burned when the wind direction is such that the nearest sensitive receptor locations are at least 100m downwind of the building to be burned.

1. INTRODUCTION

BAE Systems are currently in the planning stages of the remediation of a site in Bishopton, Renfrewshire. The site is a former explosives and propellants and armaments factory and the buildings on the site are potentially contaminated with traces of propellants and explosives. In order to remove any residual contamination from the buildings prior to demolition BAE Systems are planning to undertake a programme of controlled burning within the buildings in order to destroy any residual explosive material.

The local authority has raised the possibility that the burning of the buildings on site may have adverse impacts on local air quality. In order to assess the nature and extent of impacts on air quality, BAE Systems commissioned Enviros Consulting Limited (Enviros) to undertake an assessment of the impacts on air quality of the burning programme.

This has been carried out by comparing predicted ground level concentrations of released substances with standards and guidelines for ambient air quality, taking existing background levels of these substances into account.

Information has been obtained from several third parties, including:

- BAE Systems (Ref. 1)
- The Meteorological Office (Ref. 2);
- Renfrewshire District Council (Ref. 3);
- The UK Air Quality Information Archive (Ref. 4);
- The Ordnance Survey (Ref. 5);
- A site walkover, including inspection of a demonstration burn building and other typical buildings on site (Ref. 6).

All information supplied by third parties either directly or indirectly has been accepted *de facto* by Enviros.

The main body of this report sets out: a summary of the assessment inputs; the assessment methodology; background air quality; assessment results and mitigation recommendations. More details of the background information used and the assessment methodology are set out in the appendices.

2. SUMMARY BACKGROUND INFORMATION

2.1 Site description

The site is situated immediately to the southwest of the large village of Bishopton, Renfrewshire, as illustrated in Figure 1. The area surrounding the site is rural to the north, west and south with scattered residential properties around the site boundary, and built up area of Bishopton to the west.

The site was formerly used for the manufacture and processing of propellants and explosives and ammunition. This site covers approximately 800 hectares and has approximately 600 buildings in which explosive materials were handled and processed.

2.2 Sources of emissions

During the burning of the buildings there are several potential sources of emissions to air. The main source of emissions is the straw and wood fuel used to set the fire. Residual oils, explosive materials, fixtures and fittings within the buildings may also give rise to emissions.

2.3 Emissions of interest

There are a number of potential emissions to air that may arise as a result of the burning activities undertaken on site. These are summarised in Table 1.

Table 1 Emissions of interest

Emission		
Ammonia	Carbon monoxide	Hydrogen chloride
Hydrogen cyanide	Methane	Nitric acid
Nitric oxide	Oxides of nitrogen	Sulphuric acid
Sulphur dioxide	Particulate matter (including fine particulate matter, PM_{10})	Polychlorinated dibenzo dioxins and Polychlorinated dibenzo furans (known as dioxins and furans)
Non-methane Volatile Organic Compounds (VOCs) including: acetaldehyde; acetonitrile; acrolein; acrylonitrile; benzene; 1,3-butadiene; t-butyl alcohol; chloromethane; dichlorodifluoromethane1,2-dichloroethane; ethylbenzene; ethylene; formaldehyde; hexane; dichloromethane; methyl ethyl ketone; 2 methylactonitrile propionaldehyde; propylene; styrene; toluene; 1,1,1,trichloroethane; 1,2,4 trimethylbenzene; xylenes	Polycyclic aromatic hydrocarbons (PAHs) (17 species)	Metals (including aluminium, antimony, barium, copper, lead, selenium, zinc)

The assessment does not assess the impacts of every one of the substances set out in Table 1. Instead, a list of priority substances of interest to be investigated was developed as following:

- Eight substances regulated by statutory air quality objectives or proposed air quality objectives (1,3-butadiene, benzene, carbon monoxide, lead, nitrogen dioxide, particulate matter, sulphur dioxide and benzo[a]pyrene);

- The five most significant substances released, identified by calculating the estimated quantity released as a percentage of the Environmental Assessment Level for each substance. This is described in more detail in Section 2.5. This approach allowed the most important substances from an environmental perspective to be identified (cadmium, chromium, copper, formaldehyde and hydrogen chloride);

- In addition the impacts from emissions of dioxins and furans were also assessed. Whilst no EALs exist from these substances, emissions of dioxins and furans are important from the perspective of impacts on health.

The emissions data used in the assessment are set out in detail in Appendix 1.

2.4 Meteorological considerations

Careful consideration of the weather conditions at the time of the fires is important for two reasons:

- Ensuring the optimum conditions for the burning process; and
- Minimising the potential for unacceptable off site impacts.

Meteorological data obtained from the Bishopton Weather Station has been used in the assessment. The influence of weather conditions has been considered in detail.

2.5 Assessment criteria

The impacts of emissions from the burning buildings are assessed by comparison to air quality objectives and guidelines set out in UK law and other guidance. These objectives and guidelines are collectively known as Environmental Assessment Levels (EALs). The EALs are based upon health impact research and represent the airborne concentration below or at which no significant adverse health effects are likely to occur in the most sensitive receptors. The EALs used in this assessment are UK air quality objectives (Ref. 7), other guidelines set out in the H1 guidance (Ref. 8) or recommendations from the Expert Panel on air Quality Standards (EPAQS) (Ref. 9). Table 2 sets out the EALs relevant to this study.

Table 2 Environmental Assessment Levels

Substance	Information Source	Statistic	Value ($\mu g/m^3$)
Carbon monoxide	H1 guidance	Annual mean	350
	UK Air Quality Strategy objective	8 hour rolling mean	10,000
Hydrogen chloride	H1 guidance	Annual mean	20
	EPAQS recommendation	1 hour maximum	750
Nitrogen dioxide	UK Air Quality Strategy objective	Annual mean	40
	UK Air Quality Strategy objective	1 hour mean not to be exceeded more than 18 times per year	200
PM_{10}	UK Air Quality Strategy objective	Annual mean	40
	UK Air Quality Strategy objective	24 hour mean not to be exceeded more than 35 times per year	50
Sulphur dioxide	H1 guidance	Annual mean	50
	UK Air Quality Strategy objective	24 hour mean not to be exceeded more than 3 times per year	125
		1 hour mean not to be exceeded more than 24 times per year	350
		15 minute mean not to be exceeded more than 35 times per year	266
Benzene	UK Air Quality Strategy objective	Annual mean	3.25
	H1 guidance	1 hour maximum	208
1,3-butadiene	UK Air Quality Strategy objective	Annual mean	2.25
	H1 guidance	1 hour maximum	1320
Benzo[a]pyrene	UK Air Quality Strategy objective	Annual mean	0.00025
Formaldehyde	H1 guidance	Annual mean	5
		30 minute maximum	100
Cadmium	H1 guidance	Annual mean	0.005
		1 hour maximum	1.5
Chromium	H1 guidance	Annual mean	0.1
		1 hour maximum	3.0
Copper	H1 guidance	Annual mean	2
		1 hour maximum	60
Lead	H1 guidance	Annual mean (to be achieved by 2004)	0.5
		Annual mean (to be achieved by 2008)	0.25

Notes:

For the purposes of the assessment the impact of emissions at human receptors, 50% of NO_x emissions are assumed to occur as NO_2. The rationale for this assumption is explained in more detail in appendix 2.

No EALs exist for dioxins and furans

2.6 Baseline air quality

In order to assess the total environmental concentrations of the substances of interest, information is required on the baseline levels in air in the vicinity of the site, with no contribution from the fires. The availability of suitable baseline data varies with the significance of each substance in the national context and the existence of local sources of the pollutant. Appendix 3 sets out the derivation of baseline air quality data. This is summarised in Table 3.

Table 3 Summary of baseline air quality

Substance	Baseline value		Source
	Long term	Short term	
Carbon monoxide	319	637	Glasgow centre AURN
Hydrogen chloride	0.30	0.60	Centre for Ecology and Hydrology
Nitrogen dioxide	14.7	29.3	Renfrewshire Council
PM_{10}	12.7	22.7	Glasgow centre AURN
Sulphur dioxide	1.9	3.9	Glasgow centre AURN
Benzene	1.57	3.14	Glasgow centre AURN
1,3-butadiene	0.30	0.60	Glasgow centre AURN
Benzo[a]pyrene	0.000071	N/A	Glasgow centre AURN
Formaldehyde	1.4	2.7	A to Z of air quality
Cadmium	0.18	0.36	Glasgow centre AURN
Copper	0.012	0.024	Glasgow centre AURN
Chromium	0.0024	0.0047	Glasgow centre AURN
Lead	0.015	N/A	Glasgow centre AURN
Dioxins and furans	1.2×10^{-8}	N/A	Average of monitoring at three UK rural sites

3. ASSESSMENT METHODOLOGY

The impact of emissions from the fires was assessed using a dispersion modelling technique. Full details of the study methodology and study inputs for the dispersion modelling assessment are shown in Appendix 3. A summary is provided below.

3.1 Summary

Information on emissions from the fires was combined with information on meteorological conditions. A dispersion model was then used to predict the concentrations which would arise in the vicinity of the site due to these emissions. A current industry standard atmospheric dispersion model ADMS version 3.3 was used to model releases of the substances identified. The dispersion modelling procedure was as follows:

1. Emissions data associated with the fires was estimated from the USEPA AP42 document and other relevant published information (Ref. 10, Ref. 11, Ref. 12);

2. Appropriate meteorological data were obtained from The Meteorological Office (Ref. 2);

3. Information on fire characteristics, buildings, site layout and sensitive receptor locations was obtained from BAE Systems (Ref. 1) and during the site walkover (Ref. 6);

4. In the first instance, the impact from the fires was modelled on a grid of all off-site locations. This approach was adopted to assess the maximum impacts arising due to the fires;

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

6. The dispersion model was run and the results combined with background data to provide predicted environmental concentrations of the substances of interest. The interpretation of the model results was based on the highest modelled concentration at any off site location in the first instance;

7. The study results were assessed against air quality standards and guidelines to determine the nature and extent of any adverse effects;

8. Further scenarios were run to assist in identifying candidate control measures;

9. Sensitivity cases were carried out to assist in understanding the sensitivity of the study design to the main inputs.

3.2 Scenarios

The burning will be undertaken as a staged process across the site during a three to four year period. In order to reflect the most significant potential impacts on air quality, the assessment of short term impacts was based upon the assumption that no more than six ‘average sized’ buildings would be burned in any one 24 hour period. This assumption is a worst case because normally one or two buildings only would be burned. In addition, short term impacts were assessed for the burning of a single large building in any one day.

Long term impacts were assessed on the basis that a maximum of two buildings per working day are burned, a maximum of ten buildings per week. Again, this represents an overestimation of the likely burning rate which is more likely to be five buildings per week as a maximum.

On this basis, three scenarios were investigated. A more detailed description of the model inputs for these scenarios is set out in Appendix 3.

3.2.1 Scenario 1

This scenario assessed the impacts of burning one building per day for five days per week throughout the year. This situation is likely to be representative of the short term and long term impacts arising from the burning.

3.2.2 Scenario 2

This scenario assessed the impacts of burning two buildings per day for five days per week throughout the year. This situation is likely to be representative of the short term and long term impacts arising from the burning.

3.2.3 Scenario 3

This scenario assessed the impacts of burning two, three, four, five and six buildings in close proximity to one another (approximately 30m apart) per day. During normal burning operations, a maximum two buildings would be burned in any one day. However, occasionally there may be the requirement to burn up to six buildings. The assessment was undertaken for short term impacts only, , as this scenario is not applicable to long term impacts.

3.2.4 Scenario 4

This scenario assessed the impacts of burning of the large buildings at the northern end and centre of the site. In this case, the buildings will be burned individually and at a maximum rate of one per day. The impacts are based upon burning of the largest of these buildings and was undertaken for short term impacts only, as this scenario is not applicable to long term impacts.

3.2.5 Sensitivity cases

A number of sensitivity cases were run which included the investigation of the following parameters:

- Surface roughness with values of 0.3m and 0.5m;
- Release height with values of 0m, 0.25m, 0.5m, 0.75m, 1m, 2m, 3m and 20m;
- Emission temperature with values of 800 Celsius and 1400 Celsius;
- Meteorological effects including the analysis of the differences observed for various dispersion conditions based upon a set of seven dispersion conditions; in using three different years of meteorological data; using wind speed and direction limited meteorological data.
- The effect of complex terrain upon the dispersion of emissions; and
- The effect of the presence of buildings on site of the dispersion of emissions.

4. RESULTS SUMMARY

A summary of the main findings of the assessment are set out below. A more detailed breakdown of the results is set out in appendix 1. Following on from the summary a number of mitigation measures are recommended to ensure that the possibility of any unacceptable risks to air quality is minimal.

In all cases the substances with the highest impacts on air quality, in terms of the Predicted Environmental Concentration (PEC, that is, the predicted contribution from the process contribution with background levels) are particulate matter and oxides of nitrogen.

In order to provide an additional level of confidence that the EALs are not likely to be exceeded, the results presented below incorporate an additional margin for error. The distances downwind at which impacts to air quality are predicted to be acceptable set out below, are the distances downwind at which the baseline added to double the Process Contribution is predicted below the relevant EALs for all substances. Utilising this approach provides confidence that the impacts to air quality of the fires are unlikely to be any higher than those predicted.

This approach also allows a margin of error in the event that the buildings burned are larger than the typically sized buildings. It is important to note that where larger buildings are to be burned a doubling of the building footprint does not equate to a doubling of the process contribution, as the fuel load for the building is less than doubled and the source of emissions is also more diffuse.

4.1 Scenario 1

The burning of a single building of 200m^2 footprint each weekday throughout the year is predicted to result in an acceptable air quality in compliance with all standards and guidelines at distances greater than 300m downwind.

4.2 Scenario 2

The burning of a two buildings of 200m^2 footprint each weekday throughout the year is predicted to result in an acceptable air quality in compliance with all standards and guidelines at distances greater than 500m downwind.

4.3 Scenario 3

The burning of several buildings in close proximity to one another will lead to greater short term impacts on air quality than burning a single building. The assessment indicated that the burning of buildings each with a footprint of 200m^2 simultaneously in close proximity to one another (< 50m apart), is predicted to result in no unacceptable impacts:

- For two buildings burned, impacts are predicted to be acceptable at a distance of 150m or more downwind;
- For three buildings burned, impacts are predicted to be acceptable at a distance of 200m or more downwind;
- For four buildings burned, impacts are predicted to be acceptable at a distance of 300m or more downwind;

- For five buildings burned, impacts are predicted to be acceptable at a distance of 300m or more downwind; and
- For six buildings burned, impacts are predicted to be acceptable at a distance of 400m or more downwind;

4.4 Scenario 4

The burning of a single large building of approximately 3250m^2 footprint is predicted to not result in an unacceptable impact to air quality at a distance greater than 100m downwind over an annual mean period or short term period.

4.5 Dioxins and furans

The predicted concentrations of dioxins and furans are predicted to reach 10% of the background levels within 400m of the fires for scenario 1 and within 100m of the fires for scenario 4. On this basis and with due regard to the mitigation measures outlined above, emissions of dioxins and furans from the fires are not considered likely to substantially increase exposure at sensitive receptor locations.

5. MITIGATION

On the basis of the results of the assessment, the following measures are recommended to ensure that no unacceptable impacts to air quality arise at sensitive human receptors.

The mitigation measures were specified on the basis of the results of the dispersion modelling assessment. The mitigation measures include a margin of safety whereby even if the impact from the fires at sensitive receptors were double that predicted by the dispersion model, the air quality objectives and guidelines would not be predicted to be exceeded.

- For scenario 1 where only a single typically sized building is burned, or buildings are widely dispersed across the site (at a minimum distance of 500m between each) the burning should only be undertaken when the wind direction is such that the nearest sensitive receptors to any of the buildings are at least 300m downwind. This scenario takes into account both long term and short term impacts;

- For scenario 2 where two buildings are burned in close proximity, the burning should only be undertaken when the wind direction is such that the nearest sensitive receptors to any of the buildings are at least 500m downwind. This scenario takes into account both long term and short term impacts;

- For Scenario 3, where groups of buildings in close proximity (less than 500m apart) are due to be burned, the wind direction should be such that the nearest sensitive receptor locations are at least:

    - 150m downwind for two buildings;

    - 200m downwind for three buildings;

    - 300m downwind for four buildings;

    - 300m downwind for five buildings; and

    - 400m downwind for six buildings.

    This scenario takes into account short term impacts only;

- For scenario 4, the large buildings at the north end and centre of the site should be burned singly and should only be burned when the wind direction is such that the nearest sensitive receptor locations are at least 100m downwind of the building to be burned. This scenario takes into account short term impacts only.

6. CONCLUSIONS AND DISCUSSION

The results of the assessment of the impacts on air quality indicate that the burning of buildings at the Bishopton site are unlikely to result in any unacceptable impacts on air quality at nearby sensitive human receptors, providing good control is maintained on the combustion process and the recommended mitigation measures are implemented.

The recommended mitigation measures require the fires to be set during periods of suitable meteorological conditions, such that sensitive human receptors around the boundary of the site are at a sufficient distance downwind of the fire to avoid unacceptable impacts. This mainly means considering wind direction, but wind speed and rainfall will also need to be taken into account to ensure efficiency of the combustion process.

The greater distance downwind recommended for scenario 1 and scenario 2 in comparison to scenario 3 reflects the fact that Scenarios 1 and 2 take into account long term impacts, whereas Scenario 3 is only applicable to short-term impacts.

The modelling methodology was based upon a number of worst case assumptions which ensure that the predicted impacts from the remedial fires are more likely to be over estimated than underestimated. These include:

- Assessment of impacts based upon all meteorological conditions rather than ideal conditions;
- Overestimation of the number of buildings to be burned in any one day or over a year;
- Overestimation of the size of buildings and fuel quantities;
- Overestimation of the quantities of oil and propellant and explosives remaining in the buildings structures; and
- Specification of the mitigation measures such that Process Contribution values twice those obtained from the model study would not be forecast to result in levels of airborne pollutants above the EALs.

7. REFERENCES

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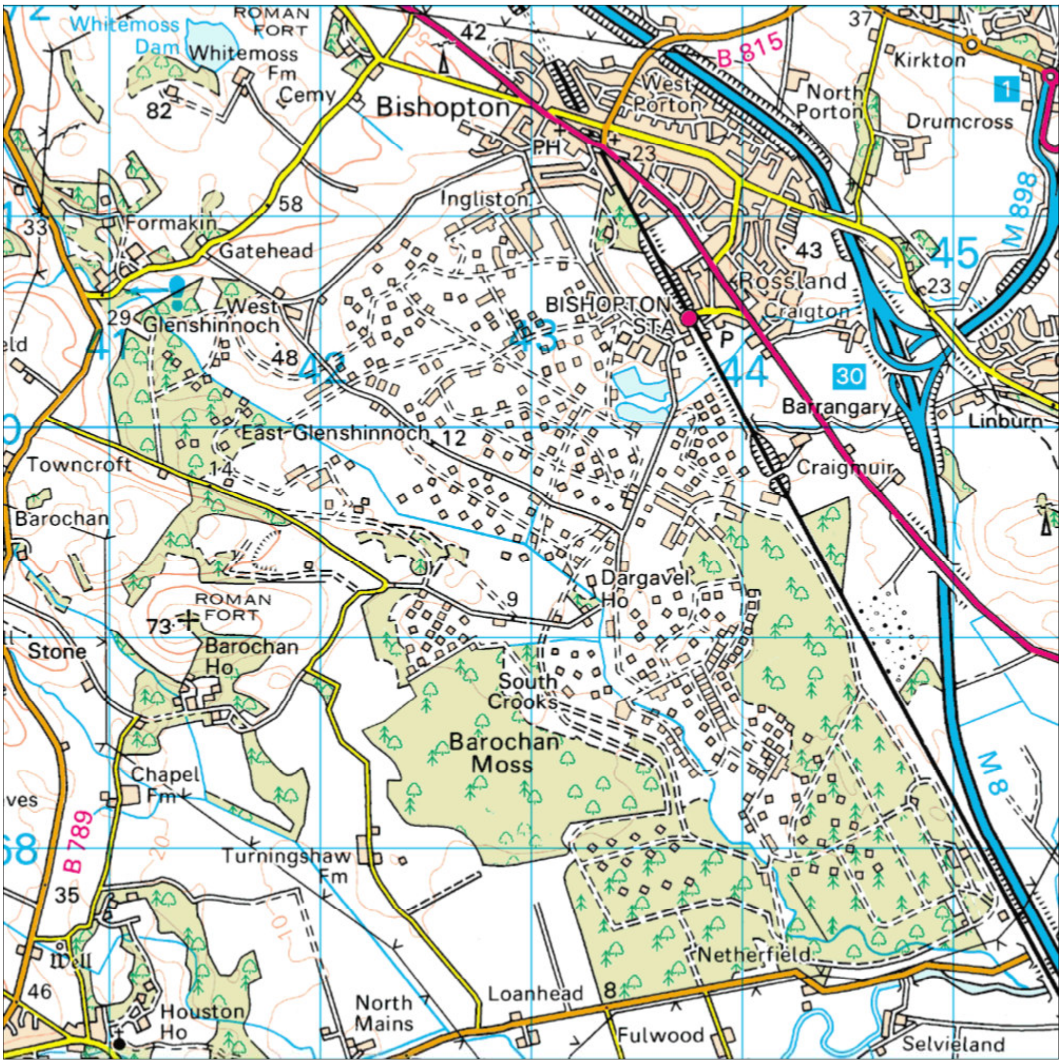
FIGURES

Figure 1 Site location plan



SCALE: Approx 1:50000

CONTENT: CHL

CHECKED: DMB

CAN: CA1440004A

DRAWN: CHL

DATE: May 2006

Air quality impact assessment: former munitions factory, Bishopton, Renfrewshire

FIGURE 1

Site location plan

ENVIROS

Figure 2 Demonstration burn building

SCALE: n/a	CAN: CA1440004A	Air quality impact assessment: former munitions factory, Bishopton, Renfrewshire
CONTENT: CHL	DRAWN: CHL	**FIGURE 2**
CHECKED: DMB	DATE: May 2006	Demonstration burn building

ENVIROS

Figure 3 Two small buildings

SCALE: n/a

CONTENT: CHL

CHECKED: DMB

CAN: CA1440004A

DRAWN: CHL

DATE: May 2006

Air quality impact assessment: former munitions factory, Bishopton, Renfrewshire

FIGURE 3

Two small buildings

ENVIROS

Figure 4 Building interior

SCALE: n/a	CAN: CA1440004A	Air quality impact assessment: former munitions factory, Bishopton, Renfrewshire
CONTENT: CHL	DRAWN: CHL	**FIGURE 4**
CHECKED: DMB	DATE: May 2006	Building interior

ENVIROS

Figure 5 Building interior

SCALE: n/a

CAN: CA1440004A

Air quality impact assessment: former munitions factory, Bishopton, Renfrewshire

CONTENT: CHL

DRAWN: CHL

FIGURE 5

Building interior

CHECKED: DMB

DATE: May 2006

ENVIROS

Figure 6 Ammunition and rocket magazine

SCALE: n/a

CONTENT: CHL

CHECKED: DMB

CAN: CA1440004A

DRAWN: CHL

DATE: May 2006

Air quality impact assessment: former munitions factory, Bishopton, Renfrewshire

FIGURE 6

Ammunition and rocket magazine

Figure 7 **Magazine interior**

SCALE: n/a

CONTENT: CHL

CHECKED: DMB

CAN: CA1440004A

DRAWN: CHL

DATE: May 2006

Air quality impact assessment: former munitions factory, Bishopton, Renfrewshire

FIGURE 7

Magazine interior

ENVIROS

Figure 8 Interior of large processing building

SCALE: n/a	CAN: CA1440004A	Air quality impact assessment: former munitions factory, Bishopton, Renfrewshire
CONTENT: CHL	DRAWN: CHL	**FIGURE 8**
CHECKED: DMB	DATE: May 2006	Interior of large processing building

ENVIROS

APPENDICES

1. DETAILED MODEL RESULTS

A detailed breakdown of the results of the dispersion modelling assessment of the three scenarios is set out below in Table A1 to Table A8.

Table A1 Scenario 1- detailed results

Substance	Averaging period	EAL (µg/m^3)	Background concentration (µg/m^3)	PC/EAL (%)			PEC/EAL (%)		
				All locations	>100m	>200m	All locations	>100m	>200m
Benzene	Annual mean	3.25	1.6	0.0000072%	0.0000012%	0.00000057%	48%	48%	48%
	1 hour maximum	208	3.1	0.000028%	0.0000017%	0.00000060%	1.5%	1.5%	1.5%
Benzo[a]pyrene	Annual mean	0.00025	0.000071	562%	93%	45%	590%	121%	74%
1,3-butadiene	Annual mean	2.25	0.30	0.0000032%	0.000000059%	0.000000029%	13%	13%	13%
	1 hour maximum	1320	0.60	0.00000015%	0.0000000092%	0.0000000033%	0.046%	0.046%	0.046%
Cadmium	Annual mean	0.005	0.00018	0.21%	0.0039%	0.0019%	3.8%	3.6%	3.6%
	1 hour maximum	1.5	0.00036	0.020%	0.0012%	0.00042%	0.044%	0.025%	0.025%
Carbon monoxide	Annual mean	350	136	103%	5.4%	2.6%	142%	44%	41%
	8 hour rolling mean	10000	272	69%	11%	4.1%	72%	14%	6.8%
Chromium	Annual mean	0.1	0.0024	0.022%	0.0037%	0.0018%	2.4%	2.4%	2.4%
	1 hour maximum	3	0.0047	0.083%	0.011%	0.0040%	0.24%	0.17%	0.16%
Copper	Annual mean	2	0.012	0.0022%	0.000041%	0.000020%	0.60%	0.59%	0.59%
	1 hour maximum	60	0.024	0.0021%	0.00013%	0.000045%	0.042%	0.040%	0.040%
Dioxins and furans (PC expressed as a percentage of background)	No EAL	N/A	0.000000012	290%	48%	23%			
Formaldehyde	Annual mean	5	1.4	0.013%	0.0021%	0.0010%	28%	28%	28%
	30 minute maximum	100	2.7	0.072%	0.010%	0.0035%	2.8%	2.7%	2.7%
Hydrogen chloride	Annual mean	20	0.30	0.78%	0.015%	0.0071%	2.3%	1.5%	1.5%
	1 hour maximum	750	0.60	0.26%	0.036%	0.013%	0.34%	0.12%	0.093%

Substance	**Averaging period**	**EAL (µg/m^3)**	**Background concentration (µg/m^3)**	**PC/EAL (%)**			**PEC/EAL (%)**		
				All locations	**>100m**	**>200m**	**All locations**	**>100m**	**>200m**
Lead	Annual mean	0.25	0.015	22%	0.41%	0.20%	28%	6.3%	6.1%
Oxides of nitrogen	Annual mean	40	15	5.2%	0.85%	0.41%	42%	38%	37%
	1 hour mean, not to be exceeded more than 18 times per annum	200	29	72%	11%	4.5%	86%	26%	19%
PM_{10}	Annual mean	40	13	137%	5.0%	2.4%	168%	37%	34%
	24 hour mean, not to be exceeded more than 35 times per annum	50	23	337%	17%	9.3%	382%	62%	55%
Sulphur dioxide	Annual mean	50	1.9	13%	0.76%	0.37%	17%	4.6%	4.2%
	24 hour mean, not to be exceeded more than 3 times per annum	125	3.9	25%	4.2%	1.8%	28%	7.3%	4.9%
	1 hour mean not to be exceeded more than 24 times per annum	350	3.9	37%	6.7%	2.7%	39%	7.8%	3.8%
	15 minute mean, not to be exceeded more than 35 times per year	266	3.9	60%	10%	3.9%	61%	12%	5.4%

Table A2 Scenario 2- detailed results

Substance	Averaging period	EAL (µg/m^3)	Background concentration (µg/m^3)	PC/EAL (%)			PEC/EAL (%)		
				>100m	>300m	>500m	>100m	>300m	>500m
Benzene	Annual mean	3.25	1.6	0.0036%	0.0013%	0.00067%	28%	28%	28%
	1 hour maximum	208	3.1	0.013%	0.0035%	0.0018%	2.7%	2.7%	2.7%
Benzo[a]pyrene	Annual mean	0.00025	0.000071	0.0000020%	0.00000070%	0.00000037%	48%	48%	48%
1,3-butadiene	Annual mean	2.25	0.30	0.0000022%	0.00000060%	0.00000030%	1.5%	1.5%	1.5%
	1 hour maximum	1320	0.60	155%	55%	29%	184%	83%	58%
Cadmium	Annual mean	0.005	0.00018	0.0062%	0.0022%	0.0012%	2.4%	2.4%	2.4%
	1 hour maximum	1.5	0.00036	0.015%	0.0040%	0.0020%	0.17%	0.16%	0.16%
Carbon monoxide	Annual mean	350	136	0.00000010%	0.000000035%	0.000000019%	13%	13%	13%
	8 hour rolling mean	10000	272	0.000000012%	0.0000000033%	0.0000000016%	0.046%	0.046%	0.046%
Chromium	Annual mean	0.1	0.0024	0.0065%	0.0023%	0.0012%	3.6%	3.6%	3.6%
	1 hour maximum	3	0.0047	0.0016%	0.00042%	0.00021%	0.026%	0.025%	0.024%
Copper	Annual mean	2	0.012	9.1%	3.2%	1.7%	48%	42%	41%
	1 hour maximum	60	0.024	17%	4.8%	2.6%	20%	7.5%	5.4%
Dioxins and furans (PC expressed as a percentage of background)	No EAL	N/A	0.000000012	0.000069%	0.000024%	0.000013%	0.59%	0.59%	0.59%
Formaldehyde	Annual mean	5	1.4	0.00016%	0.000045%	0.000022%	0.040%	0.040%	0.040%
	30 minute maximum	100	2.7	N/A	N/A	N/A	N/A	N/A	N/A
Hydrogen chloride	Annual mean	20	0.30	0.025%	0.0087%	0.0046%	1.5%	1.5%	1.5%
	1 hour maximum	750	0.60	0.047%	0.013%	0.0063%	0.13%	0.1%	0.086%

Substance	**Averaging period**	**EAL (µg/m^3)**	**Background concentration (µg/m^3)**	**PC/EAL (%)**			**PEC/EAL (%)**		
				>100m	**>300m**	**>500m**	**>100m**	**>300m**	**>500m**
Lead	Annual mean	0.25	0.015	0.69%	0.24%	0.13%	6.6%	6.1%	6.0%
Oxides of nitrogen	Annual mean	40	15	1.4%	0.50%	0.27%	38%	37%	37%
	1 hour mean, not to be exceeded more than 18 times per annum	200	29	16%	4.8%	2.5%	31%	19%	17%
PM_{10}	Annual mean	40	13	8.3%	2.9%	1.6%	40%	35%	33%
	24 hour mean, not to be exceeded more than 35 times per annum	50	23	30%	11%	6.1%	76%	56%	51%
Sulphur dioxide	Annual mean	50	1.9	1.3%	0.45%	0.24%	5.1%	4.3%	4.1%
	24 hour mean, not to be exceeded more than 3 times per annum	125	3.9	6.2%	1.9%	1.0%	9.3%	5.0%	4.1%
	1 hour mean not to be exceeded more than 24 times per annum	350	3.9	10%	2.9%	1.5%	11%	4.0%	2.6%
	15 minute mean, not to be exceeded more than 35 times per year	266	3.9	15%	4.3%	2.2%	16%	5.7%	3.6%

Table A3 Scenario 3 detailed results- assessment of impacts from 2 buildings (short-term concentrations only)

Substance	**Averaging period**	**EAL (μg/m^3)**	**Background concentration (μg/m^3)**	**PC/EAL (%)**		**PEC/EAL (%)**	
				>100m	**>200m**	**>100m**	**>200m**
Benzene	1 hour maximum	208	3.1	0.0000022%	0.0000010%	1.5%	1.5%
1,3-butadiene	1 hour maximum	1320	0.60	0.000000012%	0.0000000057%	0.046%	0.046%
Cadmium	1 hour maximum	1.5	0.00036	0.0016%	0.00074%	0.026%	0.025%
Carbon monoxide	8 hour rolling mean	10000	272	17%	7.6%	20%	10%
Chromium	1 hour maximum	3	0.0047	0.37%	0.17%	4.3%	4.1%
Copper	1 hour maximum	60	0.024	0.00016%	0.000078%	0.040%	0.040%
Formaldehyde	30 minute maximum	100	1.4	0.013%	0.0061%	1.4%	1.4%
Hydrogen chloride	1 hour maximum	750	0.60	0.047%	0.022%	0.13%	0.10%
Oxides of nitrogen	1 hour mean, not to be exceeded more than 18 times per annum	200	29	16%	8.1%	31%	23%
PM$_{10}$	24 hour mean, not to be exceeded more than 35 times per annum	50	23	30%	18%	76%	64%
Sulphur dioxide	24 hour mean, not to be exceeded more than 3 times per annum	125	3.1	6.2%	3.3%	9%	6.4%
	1 hour mean not to be exceeded more than 24 times per annum	350	3.1	10%	5.0%	11%	6.1%
	15 minute mean, not to be exceeded more than 35 times per year	266	3.1	14%	7.1%	16%	9%

Table A4 Scenario 3 detailed results- assessment of impacts from 3 buildings (short-term concentrations only)

Substance	Averaging period	EAL (µg/m^3)	Background concentration (µg/m^3)	PC/EAL (%)		PEC/EAL (%)	
				>100m	>200m	>100m	>200m
Benzene	1 hour maximum	208	3.1	0.0000031%	0.0000015%	1.5%	1.5%
1,3-butadiene	1 hour maximum	1320	0.60	0.000000017%	0.000000008%	0.046%	0.046%
Cadmium	1 hour maximum	1.5	0.00036	0.00218%	0.0010%	0.026%	0.025%
Carbon monoxide	8 hour rolling mean	10000	272	24%	11%	27%	13%
Chromium	1 hour maximum	3	0.0047	0.51%	0.24%	4.4%	4.2%
Copper	1 hour maximum	60	0.024	0.00023%	0.00011%	0.040%	0.040%
Formaldehyde	30 minute maximum	100	1.4	0.018%	0.0086%	1.4%	1.4%
Hydrogen chloride	1 hour maximum	750	0.60	0.065%	0.031%	0.15%	0.11%
Oxides of nitrogen	1 hour mean, not to be exceeded more than 18 times per annum	200	29	23%	11%	38%	26%
PM$_{10}$	24 hour mean, not to be exceeded more than 35 times per annum	50	23	42%	26%	87%	72%
Sulphur dioxide	24 hour mean, not to be exceeded more than 3 times per annum	125	3.1	8.8%	4.6%	12%	7.7%
	1 hour mean not to be exceeded more than 24 times per annum	350	3.1	14%	7.0%	15%	8.2%
	15 minute mean, not to be exceeded more than 35 times per year	266	3.1	21%	10%	23%	11%

Table A5 Scenario 3 detailed results- assessment of impacts from 4 buildings (short-term concentrations only)

Substance	Averaging period	EAL (µg/m^3)	Background concentration (µg/m^3)	PC/EAL (%)		PEC/EAL (%)	
				>100m	>200m	>100m	>200m
Benzene	1 hour maximum	208	3.1	0.0000037%	0.0000019%	1.5%	1.5%
1,3-butadiene	1 hour maximum	1320	0.60	0.000000020%	0.000000010%	0.046%	0.046%
Cadmium	1 hour maximum	1.5	0.00036	0.0026%	0.0013%	0.027%	0.026%
Carbon monoxide	8 hour rolling mean	10000	272	28%	14%	31%	17%
Chromium	1 hour maximum	3	0.0047	0.62%	0.31%	4.5%	4.2%
Copper	1 hour maximum	60	0.024	0.00028%	0.00014%	0.040%	0.040%
Formaldehyde	30 minute maximum	100	1.4	0.022%	0.011%	1.4%	1.4%
Hydrogen chloride	1 hour maximum	750	0.60	0.079%	0.039%	0.16%	0.12%
Oxides of nitrogen	1 hour mean, not to be exceeded more than 18 times per annum	200	29	29%	14%	43%	29%
PM_{10}	24 hour mean, not to be exceeded more than 35 times per annum	50	23	52%	31%	97%	76%
Sulphur dioxide	24 hour mean, not to be exceeded more than 3 times per annum	125	3.1	11%	5.9%	14%	9%
	1 hour mean not to be exceeded more than 24 times per annum	350	3.1	17%	9%	18%	10%
	15 minute mean, not to be exceeded more than 35 times per year	266	3.1	24%	13%	25%	14%

Table A6 Scenario 3 detailed results- assessment of impacts from 5 buildings (short-term concentrations only)

Substance	Averaging period	EAL (µg/m^3)	Background concentration (µg/m^3)	PC/EAL (%)		PEC/EAL (%)	
				>100m	>200m	>100m	>200m
Benzene	1 hour maximum	208	3.1	0.0000043%	0.0000022%	1.5%	1.5%
1,3-butadiene	1 hour maximum	1320	0.60	0.000000024%	0.000000012%	0.046%	0.046%
Cadmium	1 hour maximum	1.5	0.00036	0.0030%	0.0016%	0.027%	0.026%
Carbon monoxide	8 hour rolling mean	10000	272	33%	16%	35%	19%
Chromium	1 hour maximum	3	0.0047	0.025%	0.013%	1.4%	1.4%
Copper	1 hour maximum	60	0.024	0.00032%	0.00016%	0.040%	0.040%
Formaldehyde	30 minute maximum	100	1.4	0.025%	0.013%	1.4%	1.4%
Hydrogen chloride	1 hour maximum	750	0.60	0.091%	0.047%	0.17%	0.13%
Oxides of nitrogen	1 hour mean, not to be exceeded more than 18 times per annum	200	29	34%	17%	48%	32%
PM$_{10}$	24 hour mean, not to be exceeded more than 35 times per annum	50	23	60%	37%	105%	82%
Sulphur dioxide	24 hour mean, not to be exceeded more than 3 times per annum	125	3.1	13%	7.0%	16%	10%
	1 hour mean not to be exceeded more than 24 times per annum	350	3.1	20%	10%	21%	11%
	15 minute mean, not to be exceeded more than 35 times per year	266	3.1	28%	15%	30%	16%

Table A7 Scenario 3 detailed results- assessment of impacts from 6 buildings (short-term concentrations only)

Substance	Averaging period	EAL (µg/m^3)	Background concentration (µg/m^3)	PC/EAL (%)			PEC/EAL (%)		
				>100m	>150m	>200m	>100m	>150m	>200m
Benzene	1 hour maximum	208	3.1	0.0000048%	0.0000035%	0.0000025%	1.5%	1.5%	1.5%
1,3-butadiene	1 hour maximum	1320	0.60	0.000000027%	0.00000000030%	0.000000014%	0.046%	0.046%	0.046%
Cadmium	1 hour maximum	1.5	0.00036	0.0034%	0.000038%	0.0018%	0.028%	0.024%	0.026%
Carbon monoxide	8 hour rolling mean	10000	272	36%	26%	20%	39%	29%	23%
Chromium	1 hour maximum	3	0.0047	0.80%	0.57%	0.015%	4.7%	4.5%	1.4%
Copper	1 hour maximum	60	0.024	0.00036%	0.00026%	0.00019%	0.040%	0.040%	0.040%
Formaldehyde	30 minute maximum	100	1.4	0.028%	0.020%	0.015%	1.4%	1.4%	1.4%
Hydrogen chloride	1 hour maximum	750	0.60	0.036%	0.020%	0.013%	0.12%	0.10%	0.093%
Oxides of nitrogen	1 hour mean, not to be exceeded more than 18 times per annum	200	29	36%	26%	19%	51%	40%	34%
PM_{10}	24 hour mean, not to be exceeded more than 35 times per annum	50	23	67%	54%	44%	112%	99%	89%
Sulphur dioxide	24 hour mean, not to be exceeded more than 3 times per annum	125	3.1	14%	11%	7.9%	17%	14%	11%
	1 hour mean not to be exceeded more than 24 times per annum	350	3.1	22%	16%	12%	23%	17%	13%
	15 minute mean, not to be exceeded more than 35 times per year	266	3.1	33%	23%	17%	34%	24%	18%

Table A8 Scenario 4- detailed results

Substance	Averaging period	EAL (µg/m^3)	Background concentration (µg/m^3)	PC/EAL (%)		PEC/EAL (%)	
				All locations	>100m	All locations	>100m
Benzene	Annual mean	3.25	1.6	0.000063%	0.00000058%	48%	48%
	1 hour maximum	208	3.1	0.000028%	0.0000037%	1.5%	1.5%
Benzo[a]pyrene	Annual mean	0.00025	0.000071	1550%	14%	1578%	43%
1,3-butadiene	Annual mean	2.25	0.30	0.0000032%	0.000000029%	13%	13%
	1 hour maximum	1320	0.60	0.00000015%	0.000000020%	0.046%	0.046%
Cadmium	Annual mean	0.005	0.00018	0.21%	0.0019%	3.8%	3.6%
	1 hour maximum	1.5	0.00036	0.020%	0.0026%	0.044%	0.027%
Carbon monoxide	Annual mean	350	136	103%	0.95%	142%	40%
	8 hour rolling mean	10000	272	69%	5.4%	72%	8.1%
Chromium	Annual mean	0.1	0.0024	4.9%	0.045%	64%	59%
	1 hour maximum	3	0.0047	4.7%	0.62%	8.6%	4.5%
Copper	Annual mean	2	0.012	0.0022%	0.000020%	0.60%	0.59%
	1 hour maximum	60	0.024	0.0021%	0.00028%	0.042%	0.040%
Dioxins and furans (PC expressed as a percentage of background)	No EAL		0.000000012	799%	7.4%		
Formaldehyde	Annual mean	5	1.4	0.11%	0.0011%	28%	27%
	30 minute maximum	100	2.7	0.16%	0.022%	2.9%	2.8%
Hydrogen chloride	Annual mean	20	0.30	0.78%	0.0072%	2.3%	1.5%
	1 hour maximum	750	0.60	0.26%	0.036%	0.34%	0.12%
Lead	Annual mean	0.25	0.015	22%	0.20%	28%	6.1%

Substance	**Averaging period**	**EAL ($\mu g/m^3$)**	**Background concentration ($\mu g/m^3$)**	**PC/EAL (%)**		**PEC/EAL (%)**	
				All locations	**>100m**	**All locations**	**>100m**
Oxides of nitrogen	Annual mean	40	15	10%	0.091%	47%	37%
	1 hour mean, not to be exceeded more than 18 times per annum	200	29	44%	5.8%	59%	21%
PM_{10}	Annual mean	40	13	137%	1.3%	168%	33%
	24 hour mean, not to be exceeded more than 35 times per annum	50	23	337%	2.0%	382%	47%
Sulphur dioxide	Annual mean	50	1.5	13%	0.12%	17%	4.0%
	24 hour mean, not to be exceeded more than 3 times per annum	125	3.1	25%	1.2%	28%	4.3%
	1 hour mean not to be exceeded more than 24 times per annum	350	3.1	37%	2.1%	39%	3.2%
	15 minute mean, not to be exceeded more than 35 times per year	266	3.1	60%	4.7%	61%	6.2%

2. DESCRIPTION OF MODEL METHODOLOGY AND MODEL INPUTS

Introduction

This appendix describes the background information used in the assessment; the methodology of the detailed dispersion modelling; and other relevant background information.

Background information

Description of the burning process

The purpose of the remedial fire is to ensure that sufficient temperature will be reached at all potentially contaminated areas to destroy any residual explosive or propellant contaminants. These areas will include the floor, roof, walls (which may include potentially explosive dusts between layers of paint), ventilation systems and machinery.

Straw is used as an initial starter fuel and wood as the main combustion material in the majority of buildings. However, in the smaller buildings straw will be used alone as the fuel source. The fuel is positioned based upon the optimum wind direction, the dimensions and construction of the building and the ventilation arrangements.

Preparation of a building for burning will take 1-2 days in the majority of cases depending upon the size of the building. The preparation process will include:

- Removal of any non-contaminated ancillary equipment and plant, asphalt flooring, roofing felt and doors;
- Severing sealed pipe and duct work;
- Removal of oil and lubricants from sumps or tanks;
- Removal of any external ventilation or duct work and the placement of these items into the buildings;
- Removal of any fixtures or fittings from buildings, where practical, including light fittings and uncontaminated equipment;
- Installation and positioning of fuel.

The fires are usually ignited mid to late morning. This allows personnel on site to supervise the fire during the day and allow combustion to cease before personnel leave the site at the end of the working day.

The fires have four primary phases. These phases will vary depending upon the specific conditions of the fire and the building and the times set out here represent the typical for average sized buildings:

Phase 1.	Ignition phase - 10 to 20 minutes;
Phase 2.	Heat phase - 1 to 2 hours;
Phase 3.	Smoulder phase - 1 to 2 hours;
Phase 4.	Cooling phase - 4 to 12 hours.

The initial ignition phase occurs immediately after ignition whilst the fire is taking hold in cold fuel. Some smoking will occur due to the incomplete combustion of carbon in the fuel. In some cases buildings are surrounded by a mound and in this case some local 'pooling' of smoke may occur in the mound until the temperature within the fire increases sufficiently to allow thermal uplift to occur.

The second 'heat phase' is when the high temperatures required to decontaminate the buildings are achieved. During this phase there will be little or no visible smoke from the fire and a heat haze is apparent over the fire. The absence of visible smoke indicates good combustion conditions with the large majority of carbon being oxidised to carbon dioxide with minimal ash and smoke.

The third 'smoulder phase' takes place once the majority of fuel has been consumed and the temperature of the fire decreases. No damping of the fire with water is undertaken for two reasons: it can be hazardous to access the buildings at this stage for the purposes of damping; and damping has the potential to create a contaminated water problem.

The fourth 'cooling phase' will take place when all combustion has ceased The building structure is allowed to cool to such a temperature where it can be safely entered.

Combustion temperature

No direct information on the combustion temperature and therefore the emissions release temperature is available. However, on inspection of the demonstration burn building it was noted that window glass and an aluminium panel had melted. The glass used in this case was commercially available wired glass and has a melting point of approximately 1200 to 1400 Celsius. In addition, aluminium has a melting point of 660 Celsius. This indicates that the fire has a combustion temperature of 1400 Celsius or more during the main heat phase of the fire.

Sources of emissions

Fuel

The main sources of emissions will be the straw and wood used to set the fires.

The straw used is either wheat straw or oil seed rape straw depending upon availability. Oil seed rape straw is preferred as this results in a higher temperature.

The large majority of the wood will be untreated timber from a variety of sources including waste wood from demolition of older buildings (to avoid use of preservative treated woods) or waste virgin wood from sawmills. Some painted and treated waste wood arising from the site may be used, for example, doors or fixtures from the buildings and roofing timbers. In addition there are some trees on site which are scheduled to be removed and the possibility exists that some of this wood may be utilised in the burning. However, this wood is green and is not ideal for burning. If this unseasoned wood is used, it will only represent a small percentage of the total wood used.

Fixtures, fittings and building structures

The majority of the buildings do not have substantial fittings and fixtures. However, some fixtures and fittings remain, including plastic and rubber coated electrical wiring, some light fittings, wooden work benches and painted doors. Fluorescent tubes will be removed, where practicable. In addition any asbestos cladding or lead lined doors which were used where x-ray sources were present. This study does not address the assessment of radiologically active materials. If safe and practicable to do so rooftop ventilation and extraction systems will be removed and placed within the building for decontamination.

The majority of glass in windows will be removed prior to burning to maximise ventilation. Additional ventilation will be provided where necessary by creating holes in walls to ensure sufficient air flow and thereby ensure that optimum combustion conditions are achieved. In the majority of buildings the flooring is bare or painted concrete. Where other flooring or roofing materials are present, for example plastic, linoleum or asbestos cladding, these will be removed where required and stripped to concrete. Some small quantities of residual binding substances may remain. Where wooden roofs are in place these will be left in place and will be burnt in the combustion. However, in the majority of cases the roof is concrete and will remain in place.

Whilst the interiors of the majority of buildings are painted, it is unlikely that lead containing paints have been used at the site at any time as lead can react with the explosives in a hazardous manner (Ref. 1). On this basis emissions of lead are anticipated to be negligible.

Not all areas of the buildings will be burned. Several buildings are designed with separate rooms where ancillary systems, for example water tanks or electrical switch gear, are situated away from the main process areas. In these areas there is no significant risk of contamination and the room will not be burned.

Residual contamination

During the building preparation any concentrated areas of explosives and propellants are removed manually. As a consequence, it is likely that contamination with explosives would be minimal. It is estimated that the quantity of explosive contamination in a building is, at most, 100 grams, depending on size of building and use (Ref. 1). Consideration was made of emissions of substances evolved from combustion of these contaminants, but these are unlikely to contribute significantly to impacts on air quality.

Some traces of oil and lubricants may remain in machinery. However, oil in sumps and pipework has been drained during building preparation and only trace contamination is likely to remain.

The temperature of the fire is estimated to reach 1200 to 1400 Celsius. At this temperature the possibility exists that metal fumes may be evolved from metals within the buildings, such as zinc from galvanised steel and aluminium fume. It is anticipated that quantities would be low compared to other emissions and on this basis no detailed consideration has been made of metal fume.

Figures 2 to 8 illustrate various buildings on site and these illustrate the nature of building interiors and the types of materials contained within the buildings:

Figure 2 illustrates the demonstration burn building after burning had taken place. Note the lack of black ‘charring’ around windows and doors illustrating that the large majority of carbon in the fuel has been burnt to carbon dioxide or char. This building is of a smaller size than the ‘typical’ building of 200m^2 used in the assessment.

Figure 3 illustrates two buildings of much smaller size also present on site.

Figure 4 illustrates the interior of a building used for the production of explosives. The wooden work benches will remain in the building during the fire as these may be contaminated. Doors will be removed to provide additional ventilation and will be burned. The explosion proof light fittings will be removed along with the fluorescent tubes.

Figure 5 illustrates the interior of the building described in figure 3. The interior condition of the building is typical of those on site to be burned.

Figure 6 illustrates a magazine used for the storage of ammunition and rockets.

Figure 7 illustrates the interior of the magazine illustrated in figure 5. In this case the floor covering will be removed and if required additional ventilation will be provided in the far wall.

Figure 8 illustrates the interior of one of the large processing buildings in the northeast sector of the site. The figure illustrates some of the large items of processing equipment within the building, which will remain during the burning for the purposes of decontamination.

Emissions Data

In total, 93 substances were identified as being released in potentially significant quantities from the fires. However, rather than consider each substance separately, 14 substances were identified as priority on the following basis:

- Eight substances regulated by statutory air quality objectives or proposed air quality objectives (1,3-butadiene, benzene, carbon monoxide, lead, nitrogen dioxide, particulate matter, sulphur dioxide and benzo[a]pyrene);

- The five most significant substances released, identified by calculating the estimated quantity released as a percentage of the Environmental Assessment Level (this is described in more detail in section 2.5) for each substance. This approach allowed the most important substances from an environmental perspective to be identified (cadmium, copper, chromium, formaldehyde and hydrogen chloride);

- In addition the impacts from emissions of dioxins and furans were also assessed. Whilst no EALs exist from these substances, emissions of dioxins and furans are important from the perspective of impacts on health.

Table A9 below summarises the process by which the five most significant substances were identified.

Table A9 Derivation of five most significant substances

Substance	Emissions factor (g/kg)	EALs		Significance index (emission rate (g/kg) divided by lower EAL value (µg/m^3))
		Short term	Long Term	
1,1,1-Trichloroethane	8.5 × 10^{-5}	11100	222000	7.6 x10^{-9}
1,2,4-Trimethylbenzene	8.47 x 10^{-5}	1250	37500	6.8 x10^{-8}
1,2-Dichloroethane	6.6x 10^{-4}	42	700	1.6 x10^{-5}
2,2,4-Trimethylpentane	1.4 x 10^{-4}	N/A		
2-Methyllactonitrile	1.6 x 10^{-3}	N/A		
Acenaphthene	3.7 x10^{-6}	N/A		
Acenaphthylene	2.3 x10^{-5}	N/A		
Acetaldehyde	0.013	370	9200	3.4 x10^{-5}
Acetonitrile	9.1x10^{-3}	8.8	264	1.0 x10^{-3}
Acetophenone	2.7 x10^{-4}	N/A		
Acrolein	2.2	N/A		
Acrylonitrile	1.7x10^{-3}	8.8	264	1.9 x10^{-4}
Aluminum	9.8 x10^{-3}	20	600	4.9 x10^{-4}
ammonia	2.0	180	2500	1.1 x10^{-2}
Anthracene	2.7 x10^{-6}	N/A		
Antimony	0.041	5.0	150	8.2 x10^{-3}
Arsenic	0.0059	0.20	15	2.9 x10^{-2}
Barium	0.025	5.0	150	5.0 x10^{-3}
Benz(a)anthracene/chrysene	3.9 x10^{-4}	N/A		
Benzo[a]anthracene	1.0 x10^{-5}	N/A		
Benzo[b]fluoranthene	1.7 x10^{-5}	N/A		
Benzo[e]pyrene	2.3 x10^{-5}	N/A		
Benzo[g,h,i]perylene	5.6 x10^{-5}	N/A		
Benzo[k]fluoranthene	7.9 x10^{-6}	N/A		
Beryllium	1.8 x10^{-4}	0.0040	0.12	4.6 x10^{-2}
Bis(2-ethylhexyl)phthalate	2.2 x10^{-4}	50	1000	4.3 x10^{-6}
Butanal	1.2 x10^{-4}	N/A		
Butylbenzylphthalate	2.2 x10^{-4}	N/A		
Cadmium	**3.4 x10^{-3}**	**0.0050**	**1.5**	**6.8 x10^{-1}**
Carbon disulphid	2.1 x10^{-3}	64	100	3.2 x10^{-5}
Carbon tetrachloride	5.6 x10^{-6}	130	3900	4.3 x10^{-8}
Carbonyl sulphide	1.3 x10^{-4}	N/A		
Chlorine	6.8 x10^{-5}	15	290	4.5 x10^{-6}

Substance	**Emissions factor (g/kg)**	**EALs**		**Significance index (emission rate (g/kg) divided by lower EAL value (µg/m^{3})**
		Short term	**Long Term**	
Chloromethane	6.0 x10^{-5}	1050	21000	5.7 x10^{-8}
Chromium	**0.018**	**0.10**	**3.0**	**1.8 x10^{-1}**
Chrysene	1.1 x10^{-5}	N/A		
Cobalt	5.7 x10^{-4}	0.20	6.0	2.9 x10^{-3}
Copper	**0.39**	**2.0**	**60**	**2.0 x10^{-1}**
Cyclohexane	1.9 x10^{-5}	3500	105000	5.4 x10^{-9}
Dibenz[a,h]anthracene	2.1 x10^{-6}	N/A		
Dibutyl phthalate	3.3 x10^{-4}	50	1000	6.7 x10^{-6}
Dichlorobenzene	7.8 x10^{-8}	1530	30600	5.1 x10^{-11}
Dichlorodifluoromethane	1.9 x10^{-5}	50300	628000	3.8 x10^{-10}
Ethylbenzene	1.8 x10^{-4}	4410	55200	4.0 x10^{-8}
Ethylene	2.2 x10^{-2}	N/A		
Fluoranthene	2.0 x10^{-5}	N/A		
Fluorene	1.2 x10^{-5}	N/A		
Formaldehyde	**0.5**	**5.0**	**100**	**1.0 x10^{-1}**
Freon 113	1.6 x10^{-6}	N/A		
Hexane	8.9 x10^{-3}	720	21600	1.2 x10^{-5}
Hydrogen chloride	**14**	**20**	**800**	**7.0 x10^{-1}**
Hydrogen cyanide	19	N/A	220	8.6 x10^{-2}
Indeno[1,2,3-cd]pyrene	1.8 x10^{-5}	N/A		
Manganese	6.7 x10^{-3}	1.0	1500	6.7 x10^{-3}
Mercury	4.1 x10-^{7}	0.25	75	1.7 x10^{-6}
Methyl ethyl ketone	2.9 x10^{-4}	N/A	150	2.0 x10^{-6}
Methyl tert butyl ether	7.0 x10^{-6}	N/A		
Methylene chloride	0.030	N/A		
m-Xylene,p-Xylene	1.7 x10^{-4}	4410	66200	3.7 x10^{-8}
Naphthalene	1.2 x10^{-3}	530	8000	2.2 x10^{-6}
Nickel	5.2 x10^{-3}	10	300	5.2 x10^{-4}
Nitric acid	0.023	52	1000	4.4 x10^{-4}
o-Xylene	1.5 x10^{-4}	4410	66200	3.4 x10^{-8}
Particulate cyanide	4.3 x10^{-3}	N/A		
Phenanthrene	6.7 x10^{-5}	N/A		
Phenanthrene/anthracene	5.4 x10^{-4}	N/A		
Phenol	1.2 x10^{-4}	200	3900	5.9 x10^{-7}
Phosphorous	3.5 x10^{-3}	1.0	30	3.5 x10^{-3}

Substance	**Emissions factor (g/kg)**	**EALs**		**Significance index (emission rate (g/kg) divided by lower EAL value (μg/m^3)**
		Short term	**Long Term**	
Propene	1.4 x10^{-3}	N/A		
Propionaldehyde	5.4 x10^{-4}	N/A		
Propylene	6.2 x10^{-3}	N/A		
Pyrene	4.0 x10^{-4}	N/A		
Selenium	5.2 x10^{-4}	1.0	30	5.2 x10^{-4}
Styrene	4.3 x10^{-4}	800	800	5.4 x10^{-7}
Sulfuric acid	1.5 x10^{-2}	10	300	1.5 x10^{-3}
t-Butyl alcohol	1.5 x10^{-4}	N/A		
Toluene	1.2 x10^{-3}	1910	8000	6.3 x10^{-7}
Trichloromonofluoromethane	4.3 x10^{-6}	57100	714000	7.6 x10^{-11}
Zinc	0.071	50	1000	1.4 x10^{-3}

Those substances highlighted in bold are the five substances assessed.

The emissions data was derived from a number of published information sources, primarily the AP-42 document supplied by the United States Environmental Protection Agency (USEPA) (Ref. 10), the National Atmospheric Emissions Inventory (Ref. 11) and McMahon and Tsoukalas (Ref. 12). Based upon the data provided in this document, emissions concentrations were derived for combustion of straw, wood, explosive residues, oils and building materials. The total emissions arising during a fire were then calculated based upon the quantities of fuel likely to be used for each fire and estimates of the maximum quantities of residual explosives, oils and other fittings remaining in the buildings prior to the fire.

The emissions data used in the assessment is summarised in Table A10 below.

Table A10 Summary of emissions data

Substance	Emissions (grams emission per kilogram substance burned)					
	Hay	**Wood**	**Explosives/ propellants**	**Residual oil**	**Building structure**	**Total**
Benzene			0.018			0.018
Benzo[a]pyrene	*0.00074*	0.00074	0.000015	0.00039		0.0019
1,3-butadiene			0.00064			0.00064
Cadmium			0.0025	0.00091		0.0034
Carbon monoxide	70	56	44	0.21		170
Chromium			0.00023	0.018		0.018
Copper			0.39			0.39
Dioxins and furans	*1.9 x 10^{-8}*	1.9x 10^{-8}				3.7x10^{-8}
Formaldehyde			0.0097		0.51	0.52
Hydrogen chloride				6.5	7.6	14
Lead			0.14	4.9		5.0
Oxides of nitrogen	1.42	2.6	3.8	1.6		9.4
PM$_{10}$	11	4.0	52	5.3		72
Sulphur dioxide	*1.2*	1.2	0.093	10		13

Notes: Where figures are shown in italics for hay, no emissions data has been identified and emissions are assumed to be similar to those for burning wood.

The emissions data used in the assessment are a reasonable representation of the likely emissions from the fires. Because of the limitations in the data available and the variability in the combustion process, the assessment took a pessimistic approach in order to ensure that emissions are more likely to be overestimated than underestimated. For example, the emissions factors for wood and straw burning are based upon forest fires and burning of waste wood piles, for which the combustion conditions are likely to be less controlled and occur at a lower temperature. This will result in emissions of the substances of interest being higher than those from the more controlled and higher temperature combustion conditions of the remedial fires.

Meteorological conditions

The fires would be set during periods when meteorological conditions ensure the optimum burn conditions and minimise the impacts to local sensitive receptors.

Optimum conditions for combustion

There are two primary considerations when considering the optimum meteorological conditions for combustion. Whilst these parameters represent an optimum situation, combustion may be undertaken during other meteorological conditions if required for operational reasons. Optimum meteorological conditions are:

- A wind speed of between 5 and 25 mph, as this will assist both the combustion of fuel and the dispersion of emissions;

- Burning should not be undertaken during periods of heavy precipitation. The buildings may be prepared several days or weeks in advance of the burning whilst awaiting optimum meteorological conditions. The fuel will be kept dry either by use of pre-existing concrete or other roof structures or in some cases by temporary roofing.

The days on which burning would take place would be selected on the basis of the weather forecast, with final confirmation by consideration of the forecast and prevailing conditions made on the morning of the burn.

Optimum conditions for minimising local impacts

In addition to selecting meteorological conditions to optimise combustion conditions, the burning would be planned to be undertaken on days where the meteorology would also assist in minimising impacts at local sensitive receptors. Again, whilst these parameters represent an optimum situation, combustion may be undertaken during other meteorological conditions.

Optimum conditions would include:

- Clear or sunny days with a wind speed of greater than 5mph. These conditions would assist in the dispersion of emissions from the fires as in these conditions an inversion layer is less likely to form.

- Wind direction corresponding with the mitigation measures set out in Section 5 of this report.

However, for operational reasons, fires may be set on days when the optimum conditions are not met. In order to reflect this and ensure than no unacceptable impacts to air quality arise at sensitive receptor locations the assessment was undertaken utilising meteorological data that reflected all weather conditions. On this basis, the mitigation measures recommended take into account that dispersion conditions may not be optimum.

Meteorological data source

Meteorological data for the dispersion modelling study were obtained from the Meteorological Office (Ref. 2). The most appropriate meteorological station to represent weather conditions at the site is the Bishopton weather station.

Three years of hourly sequential data recorded in 2003-2005 inclusive at the Bishopton weather station have been used in this study. All data have been accepted *de facto* and it has been assumed that the data are representative of conditions at the site. Predicted pollutant concentrations presented are for the maximum obtained using any of these three years.

Detailed modelling approach and assumptions

Description of Dispersion Model

The dispersion modelling study was carried out using ADMS, (Atmospheric Dispersion Modelling System). ADMS is widely accepted as the current industry standard model for dispersion from point sources such as this plant. The most recent version of the model, version 3.3 was used for the updated assessment. This model is able to incorporate the influence of buildings on the dispersion of material released from the source.

ADMS is a computer based model of dispersion in the atmosphere of passive, buoyant, or slightly dense, continuous or finite duration releases from single or multiple sources. The development of ADMS was supported by the Environment Agency. A key improvement in ADMS over older models is its use of the most recent scientific understanding of the structure of the atmospheric boundary layer. In the ADMS approach, the boundary layer structure is defined in terms of measurable physical parameters obtained from meteorological readings, which allow for a more realistic representation of the changing characteristics of dispersion with height. The result is a more accurate and soundly based prediction of the concentrations of pollutants.

The presence of buildings close to the release point can significantly affect the dispersion of material from a source. This influence can be taken into account by the use of an appropriate module in ADMS. The potential effect of buildings on site on the dispersion of emissions from the fires was investigated in the sensitivity testing described in this appendix.

Models of atmospheric dispersion processes are generally more reliable for long period means than short period means. Models are usually more reliable over intermediate distances (100m to 1000m) than very close to the source, or more distant from the source. This reflects the range of data that have been used to compile the models. Where emissions data are less reliable, or averaging periods are shorter, the results are likely to be less accurate. The ADMS model is able to model sources such as the building fires in this case as area sources.

To acknowledge this potential for variability in dispersion model results, a worst-case approach has been adopted throughout the study. This means that modelled results are likely to be over-estimates of the levels that will arise in practice.

In summary, ADMS was considered to be the most suitable model for this application for the following reasons:

- Industry standard model for atmospheric dispersion modelling; and

- Advanced understanding of boundary layer meteorology.

Modelling methodology

The dispersion modelling has been undertaken as staged process:

1. Initially a number of sensitivity tests were undertaken to identify critical model inputs; establish realistic model inputs; and develop model scenarios;

2. Based upon the results of the sensitivity testing and model inputs three scenarios were assessed.

Sensitivity testing

Sensitivity testing of a number of model parameters was undertaken. This testing was designed to ensure that the model approach was pessimistic, whilst not unrealistic, and allowed identification of the model parameters to which the results are particularly sensitive:

- The surface roughness is a factor which defines the degree of turbulent mixing of the air at ground level. This parameter depends upon the surrounding land use including the presence of buildings, trees, vegetation and other obstructions. The sensitivity analysis tested surface roughness heights of 0.3m (the maximum defined values for flat agricultural areas) and 0.5m (the maximum defined values for parkland and open suburbia similar to the area surrounding the majority of the Bishopton site). On the basis of the sensitivity testing the higher of these two values was selected for use in the assessment, as this resulted in the higher predicted ground level values.

- The temperature of emissions from the fires is a factor in defining the thermal buoyancy of the plume and therefore the plume rise away from the fire. Sensitivity tests were undertaken for emission temperatures of 800 Celsius (the temperature observed during the final smoulder stages of the fire) and 1400 Celsius (the temperature established from the melting of glass in the demonstration burn building). The sensitivity testing demonstrated that whilst the lower emission temperature resulted in greater ground level concentrations, the difference was marginal. On this basis the higher temperature was used in the assessment as this is more realistic for the main combustion phase of the fire when the majority of the emissions will arise.

  The dispersion modelling predicted that the greatest process Contribution occurred within 100m of the fire. This indicates that in close proximity to the fire the thermal buoyancy, and therefore the emission temperature, is not a critical factor in determining the dispersion of the emissions from the fire;

- The meteorological data used in the assessment is critical in defining the direction and degree of the dispersion of emissions. Sensitivity testing was undertaken using:

  - a set of seven meteorological conditions representing atmospheric conditions from stable to neutral to unstable;

  - three years full meteorological data from Bishopton weather station; and

  - three years limited meteorological data from Bishopton weather station. This dataset was manipulated to remove meteorological conditions where the wind direction was between 140^o and 320^o and the wind speed was between 2.2m/s (5mph) and 13.3m/s (25mph). This data represented conditions where the wind direction was away from Bishopton village and is at optimum burn conditions.

  The sensitivity testing identified that, as expected, the model is sensitive to the meteorological data. On the basis of the sensitivity testing, the full meteorological datasets were used in the dispersion modelling as this is likely to result in the most realistic estimation of impacts;

- The release height of emissions from the fire is an important factor in the dispersion of emissions from the fire. The sensitivity testing demonstrated that defining the emission source with a release height of 0m (ground level source) greatly increased the predicted impacts. However, these impacts occurred in very close proximity to the fire and when compared to a release height of 2m the predicted impacts further away from the fire were lower. On this basis a release height of 2m was used in the assessment as this was likely to be a realistic release height and also result in higher impacts away from the immediate vicinity of the fire.

- The terrain in the area surrounding the site can have a significant impact upon the dispersion of emissions from the fires. Terrain effects are likely to be important where sustained gradients of greater than 1:10 are present. In this case gradients of greater than 1:10 are present in the wider area surrounding the site. However, gradients of greater than 1:10 are not sustained on the site, or between the site and the nearest receptors to the site. The effects of terrain were investigated in more detail. The effects of terrain were not included in the main assessment as the effects of terrain are dependent upon the relative positions of the source term and sensitive receptors. In the initial stage of the assessment no specific consideration is made of either of these as the modelling is conceptual, rather than based on actual buildings on site.

The effects of terrain were investigated during the sensitivity analysis. The sensitivity analysis indicated that inclusion of terrain data within the model can lead to elevated concentrations at locations where steep gradients occur. However, the study findings were that the area of concern is within five hundred metres of the fires. At this distance from the fires there are no gradients of greater than 1:10 and therefore, the study approach provides a robust evaluation of the highest levels of airborne pollutants.

- The presence of buildings on site can adversely affect the dispersion of emissions from the fires. However, the effects of adjacent buildings are only important where buildings are in close proximity to the source and are likely to represent a significant obstruction to the passage of air. In this case, the majority of buildings are, by design, situated remote from one another. Sensitivity analysis was undertaken to assess the effect of a large building such as those located in the north and centre of the site, and a number of small buildings downwind of the fire. This sensitivity analysis demonstrated that the presence of the building was minimal on the predicted impact of the fire.

Assessment assumptions

The assessment was undertaken using a number of worst case assumptions:

1. Impacts were predicted on a grid to identify the maximum impacts occurring at any off site location. This approach was adopted rather than identifying discrete sensitive receptor locations to identify the maximum impact. The EALs based on air quality objectives are applicable at all off-site locations, however those EALs based on guideline air quality values from the H1 document or EPAQS are applicable only at locations where members of the public might reasonably be exposed for the duration of the averaging period. On this basis, assessing impacts at all off-site locations represents the worst case;

2. The assessment was based upon three complete annual meteorological datasets. In reality burning would only take place during favourable meteorological conditions as described in section 2.7. The use of full meteorological datasets therefore overestimates impacts. Time varying emission factors were used to represent the fact that the fires would be set at mid or late morning and no burning would be undertaken during the night-time;

3. The period of time for which the fire would burn varies depending upon building size, dimensions and ventilation. The modelling is based upon estimates of the longest periods of burning. In reality for the majority of buildings the period of burning will be less.

4. For assessing short term impacts, the assumption is made that a maximum of six ‘typical’ buildings would be burning in any one day. In reality it is unlikely that more than two buildings would be burned as this would consequently lead to an overestimation of impacts;

5. For assessing long term impacts, the assumption was made that five ‘typical’ buildings are burned per week throughout the year. In reality it is more likely that a maximum of three buildings would be burning in a week and no burning would be undertaken during holiday periods, for example at Christmas or bank holidays;

6. The modelling assumes that the buildings are in close proximity to one another. However, in reality the buildings to be burned are not necessarily in close proximity and may be spread across the site. This approach overestimated impacts as the plume from the burning is more concentrated.

7. It was assumed that at ground level, 100% of the oxides of nitrogen released are in the form of nitrogen dioxide for calculations of annual mean and one-hour mean concentrations at human sensitive receptors, respectively. However a percentage of the emissions will occur as less toxic NO and the actual proportion is likely to be less than 50%.

8. It was assumed that 100% of the particulate matter emitted is in the PM_{10} size fraction. The actual proportion will be less than 100%;

9. The highest predicted concentrations obtained using any of the three different years of meteorological data have been used in this assessment. During a typical year the highest ground level concentrations would be lower; and

10. The highest reasonable background air quality levels were used in the assessment, with the exception of dioxins and furans, where the assessment was based on a comparison of the effects of the burning programme with background levels. In this case, to ensure that impacts are properly controlled, the average concentration from three UK rural sites was used.

Other model considerations

In order to complete the assessment, it was necessary to combine modelled concentrations of substances emitted from the plant with baseline concentrations of the substances present in the environment due to emissions from other sources. In the case of long-term mean concentrations, this was relatively straightforward, as long-term mean concentrations due to plant emissions could be added directly to long-term mean baseline concentrations.

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

This point is addressed in the H1 guidance (Ref. 8) which advises that an estimate of the short-term combined pollutant concentration can be obtained by adding the maximum short term concentration due to emissions from the source to twice the annual mean baseline concentration. In the case of PM_{10} the short term mean is calculated from the annual mean by multiplying by 1.79. This procedure was adopted in the present study for short term concentrations.

3. BACKGROUND AIR QUALITY

In order to assess the total environmental concentrations of the substances of interest, information is required on the baseline levels in air in the vicinity of the site that would occur with no contribution from the site. The availability of suitable baseline data will vary with the significance of a substance in the national context. For example, there is good local data on levels of nitrogen dioxide, whereas there is only limited or no data available for some volatile organic compounds and metals of interest.

There are several sources of baseline air quality data available which are, in order of relevance:

- Monitoring data obtained in Bishopton by Renfrewshire Council (Ref. 3);
- Interpolated mapping data (Ref. 4);
- Automatic monitoring data obtained from nearby Automatic Urban and Rural Network sites (Ref. 4);
- Data obtained by Centre for Ecology and Hydrology (CEH) (Ref. 13); and
- The A to Z of air quality (Ref. 14).

The baseline air quality is set out in Table A11.

Table A11 Derivation of baseline air quality

Substance	**Baseline value**		**Source**
	Long term	**Short term**	
Carbon monoxide	319	637	Based upon interpolated mapping data for the kilometre grid square for Bishopton station. In addition consideration was made of monitoring from Glasgow centre AURN. However, this data is likely to overestimate background levels at the site.
Hydrogen chloride	0.30	0.60	Based upon monitoring data obtained from the Centre for Ecology and Hydrology at Bush House, Midlothian, 1999-2001. This site is the nearest monitoring location to Bishopton
Nitrogen dioxide	14.7	29.3	Based upon diffusion tube monitoring data obtained from Bishopton by Renfrewshire Council, 2002-2004. In addition consideration was made of monitoring from Glasgow centre AURN. However, this data is likely to overestimate background levels at the site. The interpolated mapping data for the Bishopton site was substantially lower than this value, and the data from Renfrewshire Council was used in preference.
PM_{10}	12.7	22.7	Based upon interpolated mapping data for the kilometre grid square for Bishopton station. In addition consideration was made of monitoring from Glasgow centre AURN. However, this data is likely to overestimate background levels at the site.

Substance	Baseline value		Source
	Long term	Short term	
Sulphur dioxide	1.9	3.9	Based upon interpolated mapping data for the kilometre grid square for Bishopton station. In addition consideration was made of monitoring from Glasgow centre AURN. However, this data is likely to underestimate background levels at the site, which is not in a smoke control zone and is likely to have a higher percentage of households burning coal.
Benzene	1.57	3.14	Based upon monitoring data from Glasgow centre AURN, 2002-2005. This is the nearest and most appropriate monitoring site.
1,3-butadiene	0.30	0.60	Based upon monitoring data from Glasgow centre AURN, 2002-2005. This is the nearest and most appropriate monitoring site.
Benzo[a]pyrene	0.000071	0.00014	Based upon monitoring data from Glasgow centre AURN, 2004. This is the nearest and most appropriate monitoring site.
Formaldehyde	1.4	2.7	Based upon monitoring at a rural site in Harwell, Oxfordshire. Limited monitoring data exists for this substance and this data is the most appropriate available.
Cadmium	0.18	0.36	Based upon monitoring data from Glasgow centre AURN, 2004. This is the nearest and most appropriate monitoring site.
Chromium	0.0024	0.0047	Based upon monitoring data from Glasgow centre AURN, 2004. This is the nearest and most appropriate monitoring site.
Copper	0.012	0.024	Based upon monitoring data from Glasgow centre AURN, 2002-2004. This is the nearest and most appropriate monitoring site.
Lead	0.015	0.029	Based upon monitoring data from Glasgow centre AURN, 2002-2004. This is the nearest and most appropriate monitoring site.
Dioxins and furans	1.2×10^{-8}	2.4×10^{-8}	Based upon monitoring results from three UK rural monitoring sites. This data was considered preferable to data obtained in the vicinity of specific industrial sources of emissions