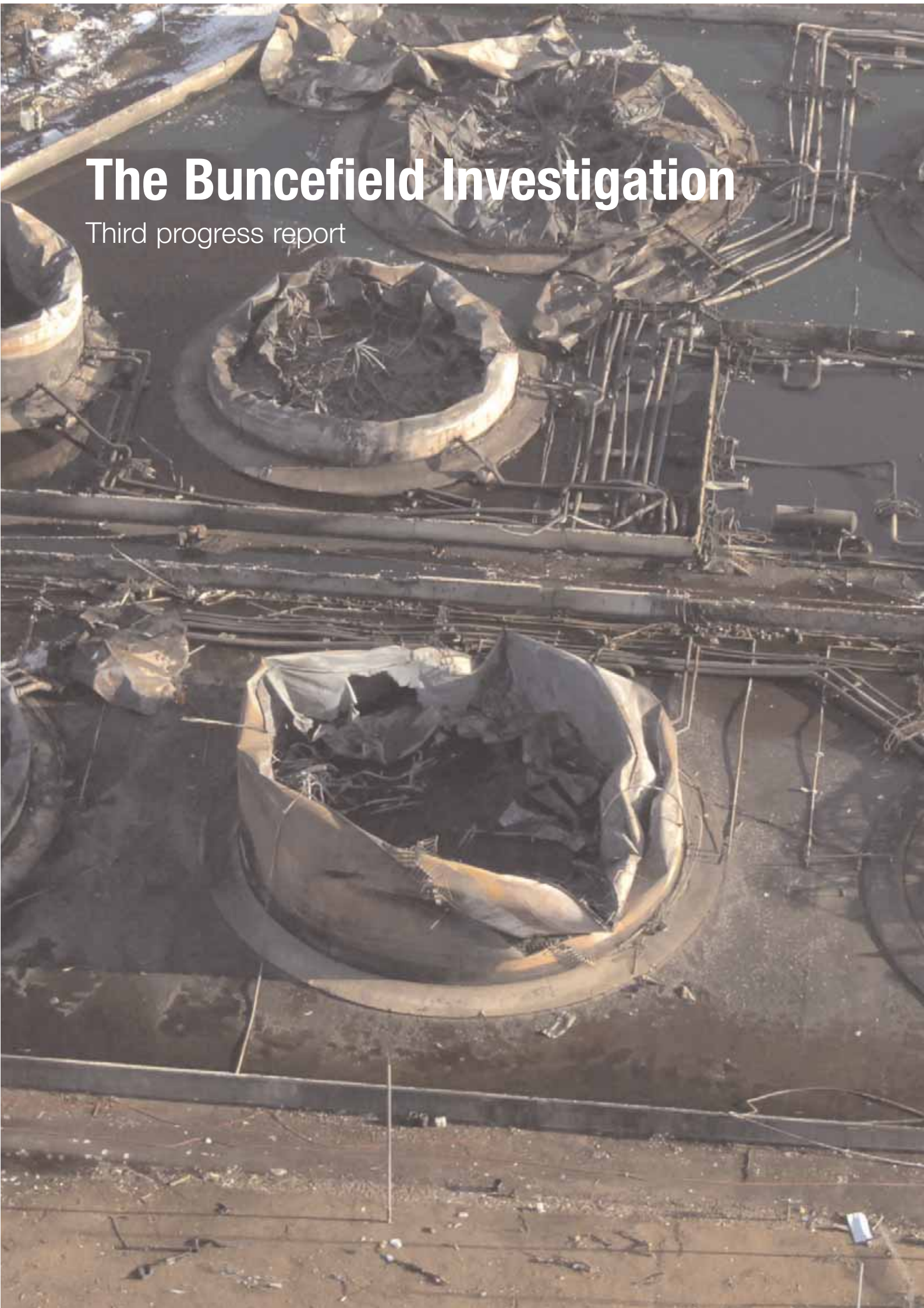


The Buncefield Investigation

Third progress report



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Photograph on front cover shows Tank 912 and is courtesy of the Chiltern Air Support Unit

Foreword

This is my third progress report into the explosions, fires and aftermath at Buncefield. In this report I am able to explain with reasonable clarity and confidence that Tank 912 in bund A on the Hertfordshire Oil Storage Ltd (HOSL) West site overflowed at around 05.30 hours on 11 December while being filled at a high rate.

The environmental conditions, flow rate of fuel, and physical configurations of the tank top and wall provide a suitable mechanism for rapid formation of a fuel-rich vapour that flowed off site following the ground topography.

As the vapour flowed off site, driven by gravity and the formation of more vapour in bund A, it would have mixed with more air and by the time it reached the Fuji and Northgate car parks, may have become an almost ideal flammable mixture.

Several likely sources of ignition are discussed, a primary one on site and another in the Northgate car park. The explosion sequence is also discussed, but here there is far less confidence in the mechanism for the high overpressures seen and modelling of this may take some time. Nonetheless I believe the most important facts leading up to the explosions at Buncefield are known with reasonable confidence and they are presented below.

Updates are also given on environmental issues, and on further contacts with local businesses and residents, though the main focus is on the important information about how fuel escaped and vaporised leading to the explosions.

The ongoing investigation and other work are briefly described.



Taf Powell

Buncefield Investigation Manager and Member of Buncefield Major Incident Investigation Board

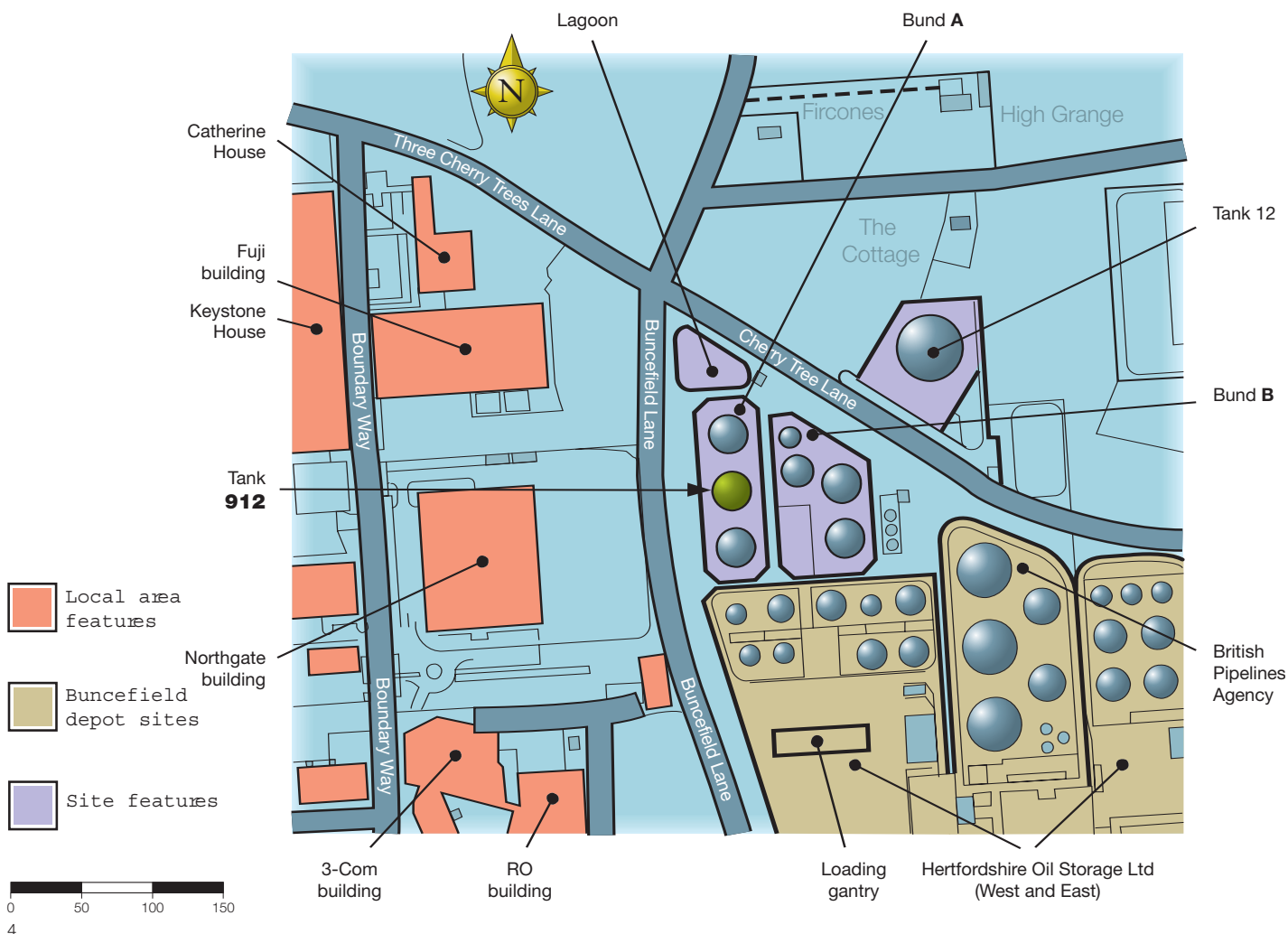
Introduction

1 This report describes where and how fuel escaped from storage at the Buncefield Oil Storage Depot on 11 December 2005 and how it vaporised, forming a flammable mixture that subsequently ignited at around 06.00 that morning with devastating consequences. It summarises the work carried out to analyse the electronic records that were recovered from site and experimental work undertaken by the Health and Safety Laboratory (HSL) to explain what happened to the fuel after it was released. So the heart of this report is a narrative, setting out the sequence of events leading up to the explosions.

2 For the complete picture of what is now known, this report should be read in conjunction with its predecessors, the details of which are not repeated here (see www.buncefieldinvestigation.gov.uk). The first progress report, published on 21 February, described in some depth the incident and emergency response. It concluded that the escape of fuel came from the area around bund A at the north west of the site and set out what was then known about the nature of the explosions and fire. The second progress report, published on 11 April, focused mainly on the environmental impact of the incident, and reported on the failure of some of the bunds to contain the fuel, foam and fire run-off water. It also set out the measures in hand to monitor any potential pollution levels.

3 The values and other data presented in this report are subject to ongoing rechecking as is usual in an investigation of this kind. They are presented as indicative and should be used in that context.

Figure 1 Layout of depot and surroundings



Timeline of events

10 December 2005

Around 19.00, Tank 912 in bund A at the HOSL West site started receiving unleaded motor fuel from the T/K South pipeline, pumping at about 550 m³/hour (flow rates are variable within limits).

11 December 2005

At approximately midnight, the terminal was closed to tankers and a stock check of products was carried out. When this was completed at around 01.30, no abnormalities were reported.

From approximately 03.00, the level gauge for Tank 912 recorded an unchanged reading. However, filling of Tank 912 continued at a rate of around 550 m³/hour.

Calculations show that at around 05.20, Tank 912 would have been completely full and starting to overflow. Evidence suggests that the protection system which should have automatically closed valves to prevent any more filling did not operate.

From 05.20 onwards, continued pumping caused fuel to cascade down the side of the tank and through the air, leading to the rapid formation of a rich fuel/air mixture that collected in bund A.

At 05.38, CCTV footage shows vapour from escaped fuel start to flow out of the north-west corner of bund A towards the west. The vapour cloud was about 1 m deep.

At 05.46, the vapour cloud had thickened to about 2 m deep and was flowing out of bund A in all directions.

Between 05.50 and 06.00, the pumping rate down the T/K South pipeline to Tank 912 gradually rose to around 890 m³/hour.

By 05.50, the vapour cloud had started flowing off site near the junction of Cherry Tree Lane and Buncefield Lane, following the ground topography. It spread west into Northgate House and Fuji car parks and towards Catherine House.

At 06.01, the first explosion occurred, followed by further explosions and a large fire that engulfed over 20 large storage tanks. The main explosion event was centred on the car parks between the HOSL West site and the Fuji and Northgate buildings. The exact ignition points are not certain, but are likely to have been a generator house in the Northgate car park and the pump house on the HOSL West site.

At the time of ignition, the vapour cloud extended to the west almost as far as Boundary Way in the gaps between the 3-Com, Northgate and Fuji buildings; to the north west it extended as far as the nearest corner of Catherine House. It may have extended to the north of the HOSL site as far as British Pipelines Agency (BPA) Tank 12 and may have extended south across part of the HOSL site, but not as far as the tanker filling gantry. To the east it reached the BPA site.

Part 1 Loss of fuel containment

1.1 Overview of Buncefield operations

4 Fuel products were supplied by three discrete pipeline systems:

- 10" pipeline (FinaLine) from Lindsay Oil Refinery on Humberside, which terminates in the HOSL West site;
- 10" pipeline from Merseyside via Blisworth, (M/B North), which terminates in the BPA's Cherry Tree Farm site;
- 14" pipeline from Thameside via a tee junction close to the site – the Hemel Tee (T/K South), which terminates in the BPA main site.

5 The three pipelines all operated in a similar way by transporting fuel oils and motor spirit in discrete batches, of known volume, under pressure. These batches were separated by an interface or buffer, which are small amounts of mixed product. The volume of this interface mix varies dependant on the flow rate and operating conditions prevalent while the product batches are being transported through the pipeline.

6 On arrival at site, the batches of product were diverted into dedicated tanks for each product type. The interface mix when it entered the site system, being a mix of two products, was either re-injected in small quantities into the large tanks of specific product if the product specification allowed, or it was transported back to a refinery as 'slops' for reprocessing.

7 The fuel stored in the tanks at Buncefield was then either transported off site in road tankers for distribution, or in the case of the majority of aviation fuel, via two BPA-operated 6" pipelines to London airports.

1.2 The escape of fuel

8 Evidence from CCTV footage reported in the first progress report pointed clearly to the vapour mist emanating from bund A on the HOSL West site. The investigation has therefore concentrated on finding out how the site was operating in the crucial period leading up to the explosion and what was happening in the vicinity of bund A.

9 At the time of the incident, approximately 06.00 on 11 December 2005, the pipelines were transporting the following products into the HOSL West site:

- FinaLine was delivering unleaded petrol at a flow rate of approximately 220 m³/hour into Tank 915 at HOSL West (also in bund A);
- M/B North line was delivering diesel oil at a flow rate of approximately 400 m³/hour into Tank 908 in bund D;
- T/K South line was delivering unleaded petrol at a flow rate of approximately 890 m³/hour into Tank 912.

10 All reasonable avenues of investigation have been and continue to be explored but information obtained to date allows stating with some confidence that the initial loss of containment occurred from Tank 912 in bund A, and that this was most likely due to an overfill of unleaded petrol.

11 In order to appreciate the way the fuel escaped, it is important to understand how the tank and its control and instrumentation systems functioned at the time.

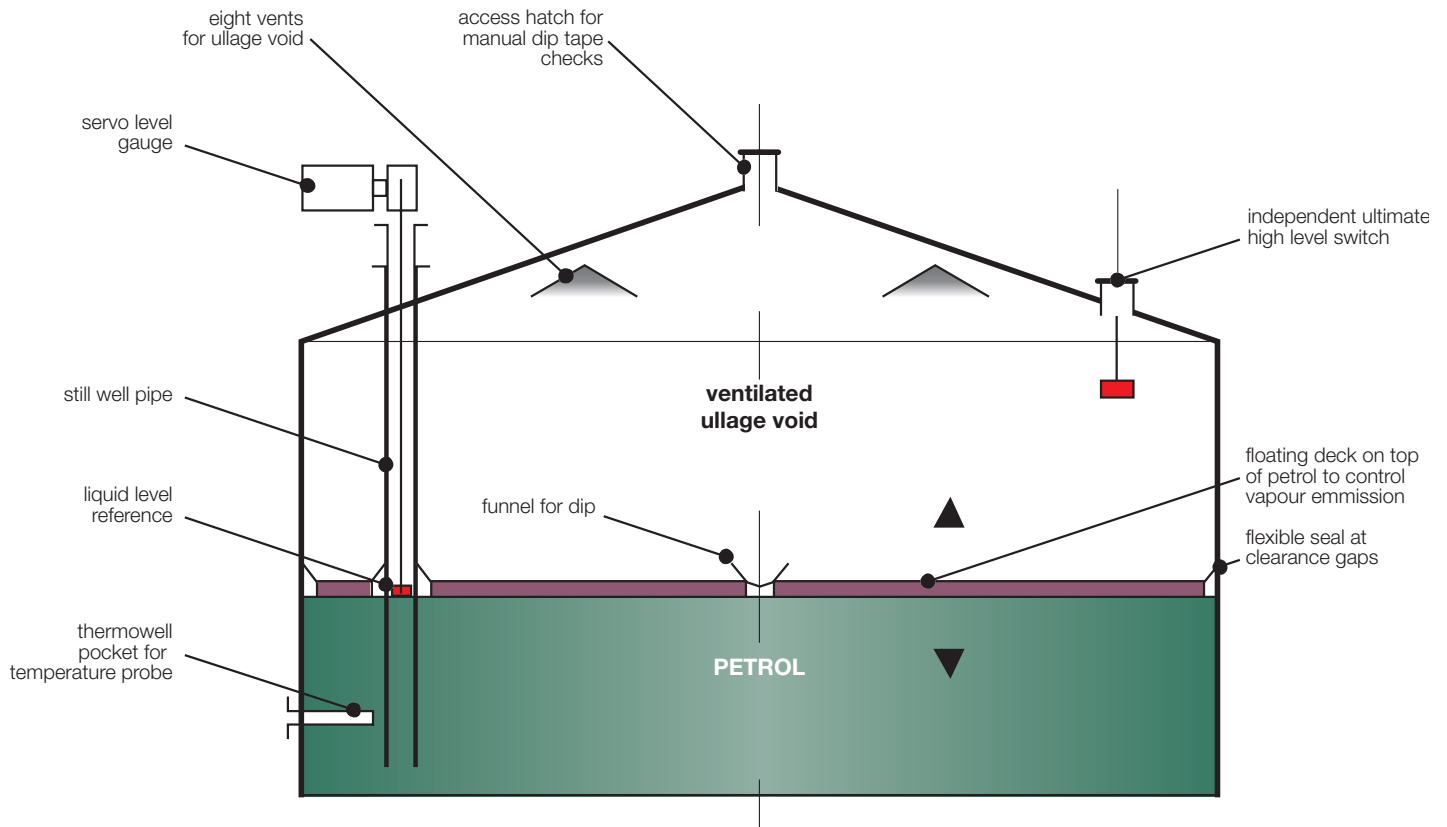


Figure 2 Basic layout of Tank 912

12 Figure 2 depicts the basic layout of Tank 912. This was a floating deck tank whereby in addition to the fixed roof, there is a deck inside the tank which floats on the fuel, thus minimising the emission of vapour from the fuel surface.

1.3 Instrumentation and control systems

13 Tank 912 was fitted with instrumentation that (among other things) measured and monitored levels and temperatures of the liquid in the tank. The instruments were connected to an automatic tank gauging (ATG) system in common with all the other tanks on the site. Tank levels were normally controlled from a control room using the ATG system.

14 A servo level gauge measured the liquid level. The temperature of liquid in Tank 912 was measured using a temperature sensor.

15 The ATG system enabled the operator to monitor levels, temperatures and tank valve positions, and to initiate the remote operation of valves all from the control room on HSOL West site. The ATG system was also able to trend data and had an event logging system, integrated with the alarm system. The ATG contained a large database which recorded levels, temperatures, alarms, valve positions, and other related information indexed against times and dates for a user-configurable period, which can be several months. The records from this database are providing valuable information for the investigation.

16 The tank also had an independent safety switch, which provided the operator with a visual and audible alarm in the control room when the level of liquid in the tank reached its specified maximum level (the 'ultimate' high level). This alarm also initiated a trip function to close valves on relevant incoming pipelines. The ultimate high level safety switch on the tank sensed when the liquid reached its specified maximum level, should all other alarms and controls fail to prevent this. Its purpose was to provide an alarm to operators in the control room and to initiate automatic shutdown of delivery once the maximum level was reached. The switch was intended to alert the control room operator via a flashing lamp (one for each tank) and an audible buzzer. In addition, the ultimate high level safety switch alarm signal from any overflowing tank in HOSL West would be sent to computer control and instrumentation relating to both the FinaLine and BPA pipelines.

17 When the BPA site received an alarm/trip signal from the HOSL West site, the BPA computer control system should have closed the relevant pipeline manifold valve feeding in product to the tank(s) on the HOSL West site. BPA also had a high-level supervisory control and data acquisition (SCADA) system, which had the facility for alarm and event logging both locally at Buncefield and remotely at the BPA control centre at Kingsbury, Warwickshire.

18 An override keyswitch in the HOSL West control room could be used to inhibit the alarm/trip signal to BPA during testing of the ultimate high level safety switches. Putting the keyswitch in the override position would illuminate a red lamp on the annunciator panel.

1.4 Evidence from control systems records

19 Examination of the records for Tank 912 from the ATG system suggest an anomaly. A little after 03.00 on 11 December, the ATG system indicated that the level remained static at about two thirds full. This was below the level at which the ATG system would trigger alarms.

20 However, the printouts from the BPA SCADA systems indicate that the T/K South line was delivering a batch of 8400 m³ of unleaded petrol, starting around 19.00 the previous evening (10 December). The delivery was being split between Tank 912 at the HOSL West site and BPA's site at Kingsbury, giving a flow rate to Tank 912 of around 550 m³/hour. These SCADA printouts further indicate that approximately seven minutes before the incident, the Kingsbury line was closed, leading to a sharp increase in the flow rate to Tank 912 to around 890 m³/hour.

21 At the time of the incident, automatic shutdown did not take place.

22 Examination of the valve positions shown by the ATG database confirm that the inlet valve to Tank 912, which was connected to the BPA petrol manifold, was open at the time of the incident. Based on this evidence, it is concluded that Tank 912 was still filling after 03.00.

23 Temperature records also provide evidence that the inflowing fuel was warmer than the tank contents. Records for Tank 912 show the tank temperature continuing to rise after 03.00, supporting the above conclusion that the product was still feeding into the tank from the pipeline.

24 The evidence to date is consistent with continued filling of Tank 912 after 03.00, despite the ATG system showing a static level reading. On the basis of calculations, Tank 912 would have been completely full at approximately 05.20, overflowing thereafter. This timing is entirely consistent with CCTV evidence and eyewitness accounts reporting on a dense vapour cloud at various times between 05.38 and 06.00. The overflow of unleaded petrol would therefore have been in the order of over 300 tonnes by 06.00.

1.5 Alarm systems testings

25 Simulation of the ultimate high level tank alarms (from the relevant electrical substation on site) and tests on the annunciator panel and the link to BPA prove that they worked normally. Tests on the override switch found that it had no effect on the audible and visual alarms from the annunciator, but it did, when switched to override, inhibit the alarm/trip signals being sent to BPA.

26 Information from the BPA SCADA system indicates that no ultimate high level alarm was received from HOSL West, but it has not been possible to test the ultimate high level safety switch or intervening wiring between Tank 912 and the substation, as they have been damaged in the fire. However, the switch has very recently been located, but it has not yet been possible to recover it. When it is, it will be subject to forensic examination.

Part 2 Creation of the vapour cloud

2.1 Liquid behaviour during overfilling

27 The investigation considered the effect of the floating deck arising from overfilling of Tank 912. This deck is constructed from relatively lightweight alloy tubes. It is unlikely that the integrity of the tank would have been breached when this floating deck became pressed up against the top of the tank by the rising liquid. Drawings of it show several places where fluid could flow upwards through it with minimal backpressure. These locations include freely hinged man-ways, the dip-tube diaphragm and the accommodation plate around the level gauge pipe.

28 Therefore overfilling of Tank 912 would have resulted in flow from the breather holes at the top of the tank. There were eight of these, each triangular in section with an area of 0.07 m^2 , as can be seen in Figure 3 which is a photograph of one of the tanks in bund A taken shortly after construction.

Figure 3 Tank top details before the incident



29 CCTV records from the HOSL West site show the first appearance of a mist from Bund A at about 05.38, supporting the view that the overflow began at around 05.20. For most of the time between the onset of loss of containment and ignition, the flow rate from vents would have been around $550 \text{ m}^3/\text{hour}$. Approximately seven minutes before the incident, shutting down of the flow from the BPA line to Kingsbury led to a sharp increase in the rate of delivery to Buncefield with a corresponding increase in the overflow rate.

30 To simulate a loss of containment from Tank 912, a full-scale model of one eighth of the whole tank top, including one of the breather vents, has been built at HSL in Buxton, Derbyshire (see Figure 4). It includes a 'deflector plate' at the edge of the tank top, visible in the third and fourth pictures in Figure 4. The original plate was designed to direct water from sprinklers on the top of the tank onto the sides of the tank to provide cooling in the event of fire engulfment. Liquid running off the top of the tank strikes this plate and is directed back onto the side of the tank.

31 Considerable work has been carried out on this model, pumping water through the breather hole at a flow rate equivalent to $550 \text{ m}^3/\text{hour}$ for an entire tank top. These flows are sufficiently high that differences in viscosity and surface tension between water and petrol will make little difference to the results as regards observing initial flow behaviour.

Figure 4a-d Liquid flow from the breather holes on the tank top



Figure 4a



Figure 4b

32 These tests demonstrate that the deflector plate was effective in channelling the majority but not all of the liquid onto the tank wall, but only spread it laterally over approximately one third of the wall. Images captured from video records are shown in Figure 4.

2.2 Generation of hydrocarbon-rich vapour

33 The differences in physical characteristics between water and petrol become more important for processes of droplet formation and additional work with petrol will be needed to investigate the subsequent behaviour of the escaped fuel. These tests are therefore a less reliable indicator of behaviour. However, it seems likely that the proportion of the liquid flowing over the top of the deflector plate will not reattach to the wall. This free cascade of liquid will naturally divide into small droplets.

34 Much of the liquid directed back to the wall by the deflector plate will hit the wind girder which can be seen running round the tank about a third of the way down in Figure 3. It is likely that this liquid flow will be further fragmented on impact with this girder to form a second free cascade.

35 There would be an impact zone in the bund where there is further splashing of falling liquid. There is also likely to have been a vigorous mixing of the heavy downward vapour flow with air.



Figure 4c



Figure 4d

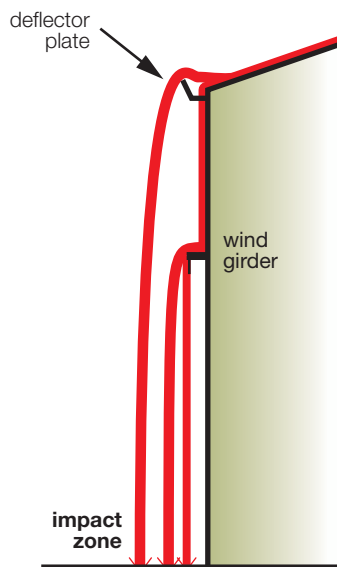


Figure 5 Liquid flow during overfilling of a tank with deflector plate and wind girder

36 The general features of these processes during an overflow are illustrated schematically in Figure 5.

37 The conclusion of this work is that the flow is likely to be very efficiently fragmented, and would create relatively small droplets falling freely through air around the tank. These conditions would promote the evaporation of the lighter chemical components of petrol, eg butanes, pentanes and hexanes.

38 The free fall of fuel droplets through the air also leads to entrainment of air and mixing between the air and fuel vapour. Calculations based on a simplified composition of unleaded petrol suggest that the ambient air already at 0 °C and fully saturated with water vapour, would have cooled below zero by a further 7-8 °C from fuel evaporation. As a result, roughly half the initial water content of the air would precipitate as an ice mist, and this mist would persist even as the vapour is diluted. This is consistent with the cloud of mist highly visible on CCTV cameras. It supports the contention that the mist can be used as an indicator for determining the size of the fuel/air vapour mixture created by the overfilling and how it was dispersed.

2.3 Dispersion of vapour

39 Aerial pictures of the site have confirmed preliminary conclusions about the extent of the burn damage shown in Figure 5 of the first progress report. This is also shown by the dotted line in Figure 6. This is indicative of the extent of the flammable vapour cloud.

40 As described in the first progress report, eyewitness accounts and CCTV footage show a white mist or thick fog on the north and west sides of the HOSL West site, spreading out from bund A (around Tanks 910, 912 and 915). By the time of the main explosion, the edge of this cloud had almost reached Boundary Way to the west of bund A and wisps of mist had just started to arrive at the tanker loading gantry to the south. To the north, it had flowed beyond Cherry Tree Lane. To the east, the mist can be seen on CCTV at the BPA site, but not further east at the

Figure 6 Extent of burn damage (indicated by dotted line)



HOSL East site. This is a little way beyond the extent of the burn damage shown in Figure 6. According to witnesses, the depth of the visible mist varied from about 1 m in the area between bund A and the loading gantry to between 5 and 7 m in Three Cherry Trees Lane.

41 In addition to defining the overall extent and location of the flammable vapour cloud, dispersion modelling is being used to analyse how concentrations of hydrocarbons vary within the cloud. In the meantime some features of dispersion of the hydrocarbon-rich vapour can be deduced from observations of burn damage at the site. Figures 7 and 8 illustrate this.

42 The telegraph pole shown in Figure 7 is in Buncefield Lane relatively close to the wall of bund A containing Tank 912. The bottom part of the pole shows soot blackening, characteristic of objects exposed to burning of a very rich vapour mixture. Video records of the fire confirm that this area was not affected by the smoke plume during the fire.

43 The tree trunk in the Northgate car park shown in Figure 8 is much further from the site and has been exposed to an explosion propagating in a more dilute vapour mixture with a composition close to the optimum for complete combustion. There is no soot on exposed surfaces but the left-hand side facing the camera has been deeply abraded by grit driven into it at high speed by the explosion. Examples of this kind of damage were found across most of the area covered by the Northgate and Fuji car parks.

44 Such observations of burn damage support the conclusion that additional air mixed with the rich vapour as it flowed out across the Northgate and Fuji car parks. This reduced the vapour concentration to the point where it could support an explosion.

Figure 7 A telegraph pole in Buncefield Lane, showing sooting on lower half



Figure 8 Part of a tree trunk in the Northgate car park showing abrasion



Part 3 The explosions

3.1 Description

45 From analysis of seismic records, the British Geological Survey (BGS) has calculated that the main explosion occurred at 06.01:32. Eyewitness accounts and media reports refer to a very large explosion followed by a number of lesser ones. The other explosions were not detected seismically, confirming that they were significantly smaller than the main explosion. Because of this it is not possible to say how many smaller explosions occurred, or much about their timing. The first of the smaller subsequent explosions was probably some minutes after the main explosion and probably all occurred within about half an hour. It cannot be ruled out that there were one or more smaller explosions immediately before the main explosion.

46 The delay of some minutes between the main and subsequent explosions suggests the latter were more likely to be due to internal tank explosions or further release of fuel from damaged tanks and pipework, rather than further explosions of parts of the vapour cloud.

47 For instance, part of a tank roof believed to come from Tank 910 in bund A was found in the Northgate car park. This is consistent with an internal explosion in the tank. It is understood that this tank was empty of liquid fuel and not in use at the time. Internal explosions in other empty tanks or tank ullage spaces could have accounted for the remaining explosions.

3.2 Ignition sources

48 The dispersion of vapour mixture is described earlier in Part 2.3. The extent of the visible mist cloud by the time of the main explosion very closely matches the extent of visible burning to vulnerable surfaces. Within this extensive area of about 80 000 m² there would have been a number of potential ignition sources. It is not possible to identify the ignition source for this explosion with any degree of certainty, because of the resulting destruction of evidence. However, there are some potential candidates.

49 There is some evidence of an internal explosion in the fire pump house, located on the east side of the lagoon on the HOSL West site. This is indicated by the doors, which are the only remaining part of the cladding. The left-hand door has been blown open, and the top half of the right-hand door folded outwards. It is believed that the pumps should have started when the emergency fire alarm was activated just before the explosion occurred.

50 There is also evidence of an internal explosion in the emergency generator cabin located on the south side of the Northgate Building. It is understood that there were thermostatically controlled heaters in the cabin and the air intakes for the diesel generator would have allowed vapour to enter the cabin. If the heaters were switched on, the spark generated at any electrical contacts would have been capable of igniting a surrounding flammable atmosphere. Like the pump house, the venting of an internal explosion within the generator cabin would have also been a very powerful ignition source.

51 Car engines are another potential source. A number of witnesses describe how their cars began to run erratically. For at least one vehicle in Three Cherry Trees Lane, the engine continued to race even after the ignition had been turned off and the driver had left the vehicle.

52 Other sources of ignition cannot be ruled out, given that off site there would have been no precautions in place to control ignition sources. There is also the possibility that there were near-simultaneous ignitions at a number of locations.

3.3 Explosion development and magnitude

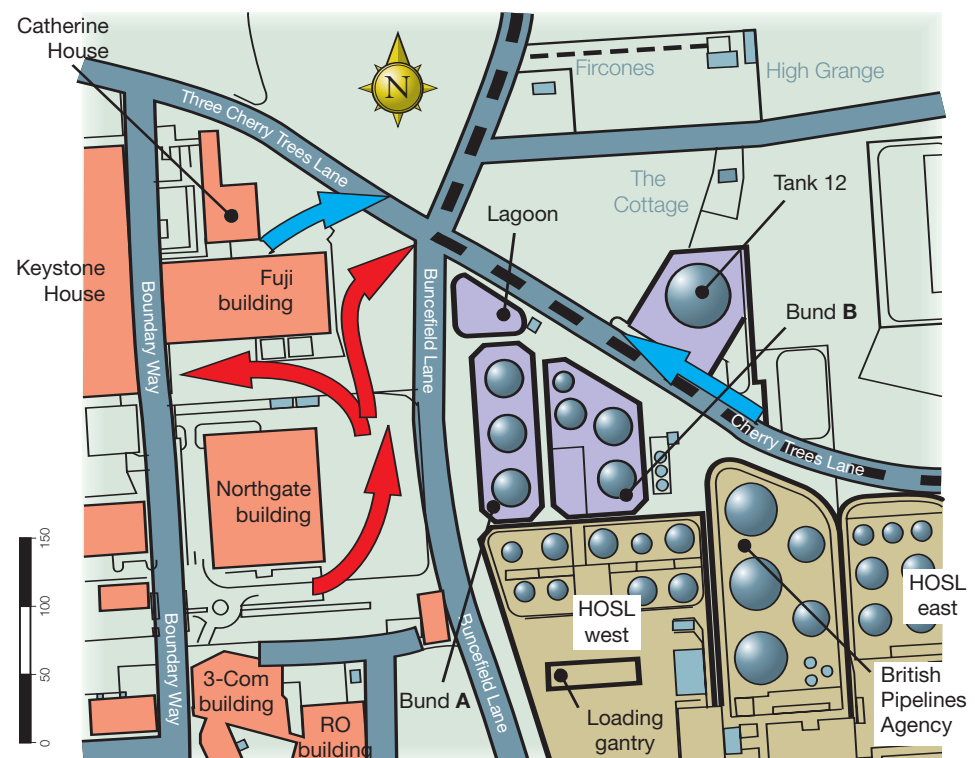
53 A preliminary assessment of the blast damage has been carried out. Estimates have been made of the overpressures required to cause the observed damage, based on the published tables derived from wartime bomb damage and solid explosive and nuclear bomb testing. Due to the very different characteristics of a blast wave produced by a vapour cloud explosion, there is considerable uncertainty in the estimated overpressures, and work is ongoing to resolve these uncertainties. But it is clear from a purely qualitative assessment of the damage that the highest overpressures were generated in the area of the Northgate and Fuji car parks.

54 Subject to these uncertainties, the current best estimates of the overpressures are of the order of:

- 700–1000 mbar in the Northgate and Fuji car parks, leading to extensive damage to adjacent buildings;
- decaying to 7–10 mbar at 2 km distant, causing breakage of some windows in local homes and premises.

55 The magnitude of the overpressures generated in the open areas of the Northgate and Fuji car parks is not consistent with current understanding of vapour cloud explosions. For example, a method in current usage would predict overpressures in this sort of environment of 20–50 mbar. The investigation has, so far, been unable to establish why the ignition of the vapour cloud and the explosion propagation in the relatively uncongested environment of the adjacent car parks caused significant overpressures that produced the severe damage to property.

Figure 9 Showing main and secondary explosion propagation



56 Furthermore there is evidence, from erosion/abrading on just one side of posts and tree trunks, of a powerful explosion having propagated northwards across the Northgate and Fuji car parks, as shown in Figure 8. The movement of objects like fence posts, tree branches etc indicate explosions of lesser magnitude having propagated through other areas bordering on the Buncefield site. The directions of explosion propagation are shown on Figure 9. The main explosion propagation is shown in red with secondary effects in blue.

Part 4 Environmental monitoring

4.1 Air quality and health surveillance

57 The second progress report explained that the Department for Environment, Food and Rural Affairs (DEFRA) is planning to publish a report on *Initial review of air quality aspects of the Buncefield Oil Depot explosion* in May, and this is still the case. The Health Protection Agency (HPA) is also closely involved with this work. DEFRA and HPA are continuing to keep the Investigation Board informed of progress with their findings.

4.2 Water quality monitoring

58 In the period from 12 December 2005 and up until 19 April, 125 river water samples and 76 ground water samples have been taken as part of a monitoring programme. On site, 190 solid and liquid samples from bunds, tanks, boreholes, lagoons and outfalls have been taken.

59 These samples were monitored for fuels and fire-fighting foam, or other chemicals which act as indicators for them. The indicators for foam include fluoro-surfactants including perfluorooctane sulphonate (PFOS) and zinc.

4.3 Ground water monitoring

60 Ground water and ground water abstraction boreholes have been monitored up to 9 km from the site, including six pumping stations operated by Three Valleys Water Company. Private boreholes have been sampled in a wider survey of the ground water for contamination, but not as part of the routine programme.

61 Three new observation boreholes have been drilled closer to the Buncefield site to provide an early detection of any ground water pollution: Butlers Farm (between Buncefield and Bow Bridge pumping station); Breakspear House (south of Buncefield) and Hogg End Lane (on the east boundary of Buncefield). This is part of an ongoing regime of monitoring that will provide further boreholes in the vicinity of the site.

62 In addition to the observation boreholes, two new ones have been installed in the vicinity of Tank 12, in the northern part of the site, to determine the level of ground water and any contamination. The first of these has been installed adjacent to the Cherry Tree Lane deep road drain. A second new borehole has been installed to the north west of Tank 12, which is believed to be upstream of the Cherry Tree Lane road drain.

63 The location of the monitoring borehole network was provided in the second progress report.

Results of ground water monitoring

64 Some results from the samples, taken from the ground water monitoring network, have shown very low levels of PFOS. Follow-up samples however, have not always shown PFOS to be still present. It is therefore not possible to draw conclusions as to the extent and origin of the PFOS. Further monitoring is continuing to establish if the results are directly attributable to the incident.

65 The Drinking Water Inspectorate (DWI) has established an advisory level for PFOS in drinking water of no greater than 3 micrograms/litre. This advice follows consultation with health professionals at HPA. HPA has stated that: 'It appears unlikely that a lifetime's consumption of drinking water containing concentrations up to 3 micrograms/litre would harm human health'. In all cases, the levels at which PFOS has been detected has been below this advisory level.

66 Fuel products, fuel-related contaminants and surfactants have been detected in soakaways, boreholes and chambers in the verges of Cherry Tree Lane.

67 Latest results suggest that the fuels and fire waters that formed a large pool in Cherry Tree Lane during the incident have passed into the deep road drain, and from there into the underlying water table. The extent of the movement of this pollution off the site will be the focus for the continuing investigations.

68 Work is continuing to characterise the contaminants found to establish if they relate to the loss of containment during this incident.

4.4 Surface water

69 Extensive sampling of surface water around the site continues to assess the environmental impact of the incident. The samples have been sent to Environment Agency laboratories around the country for analysis.

70 Monitoring of surface water has concentrated on the River Ver as it received surface water from the Buncefield site. Two balancing tanks which provided a buffer to prevent uncontrolled surges of water, known as the Maylands and Redbourn lagoons, received surface water from the site and the surrounding area. These tanks subsequently discharged into the River Ver and River Red respectively.

71 The River Ver was monitored daily in the first two weeks after the incident. Two sites were tested, one upstream and one downstream of the Maylands' tank outfall. Additionally, the balancing tanks and outfalls were subject to daily sampling and analyses. The initial focus was directed to oil contamination and fire-fighting foam, which could have caused oil pollution and as the foam degraded, oxygen depletion. This could have impacted on the ability of fish and other organisms to live in the river.

72 Two additional monitoring sites were sampled routinely on the River Ver at the end of December, downstream of St Albans, 7 and 11 km downstream of the Maylands' outfall.

73 These sites were sampled for oils and fluoro-surfactants such as PFOS.

Results of surface water monitoring

74 No direct impact of the loss of containment was found in the first days after the incident. By the third day of the incident, low concentrations of PFOS were noted in the balancing lagoons, at the Maylands' outfall and in the River Ver downstream of the outfall. In addition, there was an increase in zinc levels above background concentrations (zinc is often used together with PFOS in fire-fighting foams).

75 PFOS concentrations started to drop in the River Ver in the middle of January, one month after the incident, to below detectable levels in February. Occasionally, low concentrations of surfactants are found in the River Ver. The flow of water from the Maylands' outfall stopped in February. The Redbourn outfall started to flow in February, with low concentration of PFOS, feeding into the River Ver. The Maylands' tank contains low PFOS concentrations. Results to date indicate the levels to be generally below the DWI advisory limit (3 micrograms/litre).

76 PFOS has been identified at all monitoring points, including during a survey on the River Colne. The PFOS concentrations, however, have not exceeded the DWI advisory limit and no identifiable environmental consequences have been observed in the river habitat. More recently, fluoro-surfactants (other than PFOS), which may be associated with fire-fighting foam, have been detected in the river at low concentrations.

4.5 Impact on the environment and drinking water

77 Although there have been elevated levels of surfactants and other contaminants found in the surface waters in the proximity of the Buncefield site, there has been no evidence (to date) of an adverse impact to the environment. The results from the monitoring to date are below levels that would cause concern to the health of humans or wildlife. Monitoring will continue for the foreseeable future.

78 Public drinking water supply in the area is the responsibility of Three Valleys Water Company, which has the detailed operational knowledge required to manage the local response. The regulation of public drinking water quality is the responsibility of DWI. Both Three Valleys Water Company and DWI are working closely together to ensure that drinking water supplies remain of the highest quality.

79 The monitoring boreholes that have shown evidence of fuel and fire water contamination are not used to abstract water for drinking water purposes. The nearest drinking water abstraction point operated by Three Valleys Water Company, some 3 km from the Buncefield site, has not been used for abstraction since the incident in December.

80 The purpose of the Environment Agency monitoring is to determine the severity and extent of ground water contamination and advise on any remediation that may be necessary. The Environment Agency is in regular contact with Three Valleys Water Company and should there be evidence that pollution is migrating towards any of its abstraction boreholes, the Environment Agency will advise Three Valleys Water Company so that they can put in place appropriate measures to safeguard the quality of drinking water supplies.

4.6 Disposal of contaminated fire waters

81 The contaminated fire waters have been removed from the site and are being safely stored at a number of sites around the country. The largest single storage site is at the Thames Water Maple Cross Sewage Treatment Works.

82 The fire waters are a mixture of water, oils and fire-fighting foam.

83 The oil companies are responsible for the safe disposal of the fire waters. They are continuing to investigate suitable techniques. The Environment Agency is responsible for ensuring that any proposals will provide proper protection of the environment.

84 The current storage does not present a significant environmental risk and measures are in place to protect the environment.

85 In response to the significant loss of primary and secondary containment after the incident, the Environment Agency issued specific advice to its officers to ensure that operators have assessed and provided suitable containment, primarily bunding (secondary containment) at fuel depots over the next three months. Some of these investigations will take place at the same time as Competent Authority (HSE and Environment Agency) investigations, following the safety alert issued to industry by HSE following publication of the first progress report (see www.buncefieldinvestigation.gov.uk). A copy of the Environment Agency advice is at Annex 1.

Part 5 Continuing business and community issues

86 Both local residents and businesses affected by the incident continue to face a variety of difficulties.

87 At this time a number of residents have still not been able to return to their homes. The continuing uncertainty about the future of the depot is a cause of anxiety and stress to those living in the area. Businesses and residents are also concerned to know the root causes of the explosions and fires as soon as possible.

88 Investigation Board members met the Maylands Business Network in April, to listen to views and concerns of the local business community. Some businesses continue to have challenging operating conditions and face difficult decisions about whether to reinstate their premises.

89 According to a recent report, around 100 official redundancies have occurred since December, although it is likely that further jobs have been lost but have been unreported. A variety of agencies are working towards the recovery of the area. The Maylands Task Force, a group of key business leaders and local agencies, is seeking to rejuvenate and develop the area. A number of high profile companies have committed to remain while longer-term decisions about whether to rebuild their previous buildings are made.

90 In late May, Board members will be meeting with local residents in Adeyfield, and follow-up meetings with residents at Woodhall Farm and Leverstock Green will be arranged in the near future. In June, Board members will be represented at the Young People's Forum to hear the views and concerns of local school children.

Part 6 The continuing Investigation

91 The investigation team will continue investigation of the computer records and testing and examination of the wiring and instrumentation circuits that remain after the fire. In particular, the team wish to establish why the safety switch and associated trip instrumentation of Tank 912 did not prevent an overfill. The team will then be looking at factors that may have contributed to any underlying causes to the incident.

92 Additional work will be carried out at HSL to measure what proportion of the liquid flows over the deflector plate and what proportion is brought back to the wall, and to investigate other factors associated with vapour cloud formation and dispersion.

93 Further detailed work is still being considered in order to ascertain why the ignition of the vapour cloud and explosion propagation in the relatively uncongested environment of the adjacent car parks caused significant overpressures that produced the severe damage to property.

94 Investigations into the loss of control of the fuel in Tank 912 continue apace.

95 The evidence obtained to date supports the initial conclusions regarding the physical process and the mechanisms that led to the explosions, while not yet understanding why the main explosion was so violent. Term of Reference 5 requires recommendations to be made for future action to ensure the effective management and regulation of major accident risk at COMAH sites. The investigation is in a position, subject to ongoing inquiries, to direct attention to the effective management and regulation of both the on-site and off-site major accident risks presented by such sites. This work will include the prevention of incidents, preparation for response to incidents, and mitigation of their effects. The investigation will pursue those issues in order to assist the Investigation Board to make its Initial Report to the Health and Safety Commission and the Environment Agency in line with its Terms of Reference.

Annex 1

Memo to Area PIR Team Leaders from Martin Bigg, Head of Industry Regulation, Environment Agency dated 10 April 2006

BUNCEFIELD INVESTIGATION UPDATE – 11 April 2006
ENVIRONMENT REVIEW AT OIL/FUEL STORAGE SITES

Introduction

On 11 April 2006 the Buncefield Major Incident Investigation Board (BMIIIB) will publish its second progress report on the investigation. This memo identifies actions to be taken by Environment Agency staff with responsibility for the regulation of oil/fuel storage sites under the COMAH Regulations.

At this stage nothing can be said in relation to the causes leading to the loss of primary containment. Some information relating to issues of secondary and tertiary containment will be made available, though it is recognised that not all the details, which would be normally be used to inform inspections, will be available.

Given this situation, at this stage, our actions should be limited to a basic risk assessment of the secondary and tertiary containment measures across the sector, with the aim of identifying those sites with obvious basic deficiencies. This basic risk screening will inform further inspection and actions when conclusions from the Buncefield investigation are known.

Second progress report

In summary the BMIIIB second progress report raised the following points regarding secondary and tertiary containment:

Secondary containment

- While the concrete bunds substantially remained standing, their ability to contain fuel and fire water was lost due to damage to the sealant in the construction and expansion joints;
- sealant around penetrating pipework was also lost resulting in leakage;
- seepage through the walls of the concrete bunds also occurred; and
- the concrete panels forming the floor of the bunds underwent significant heave, opening up holes and cracks which acted as a pathway for fuel and fire water into the environment.

Tertiary containment

- Following loss of containment, fuel and fire water found numerous pathways into the environment. These included a number of shallow boreholes and one deep borehole within the site and flow across site roadways and overtopping of kerbs onto public roads and consequent escape via surface water gullies.

Implications for the programme of sector inspections

The key issues to be addressed by Environment Agency staff within the next three months are listed below. Where inspections have already taken place, either by joint teams of inspectors from the HSE and the Environment Agency or unilaterally by either, please review the findings of these inspections against the key issues.

- Are the tanks holding oil/fuel within a bund or bunds of such integrity that they would contain any leak of the tank and fire water, and prevent loss including into the ground?

- Is the bund capacity at least 110% of largest tank in the bund or at least 25% of all the tanks in the bund?
- Is the bund capable of holding the significant volumes of imported fire water used during an incident for either direct fire fighting and/or cooling of adjacent tanks?
- Is the bund design sufficiently robust to remain serviceable following a pool fire that may last for a considerable period of time? This assessment should take account of whether sealants¹ and waterstops² have been used as part of the construction and expansion joints.
- Is there any pipework penetrating the bund which could cause the containment to fail including when subject to fire?
- Given that pumps and powered valves will be lost if site power is lost due to fire or explosion, the behaviour of liquids flowing under gravity should be considered. This includes the loss of liquids from secondary containment. Has a study been made of the directions and volumes of flow and are provisions in place to contain these liquids within the boundaries of the site?
- Has an assessment been made of drainage paths to the environment and are the plans available to the off-site emergency response teams? This should include all on-site and near-off-site drainage and its relationship to the surface water systems, geology and hydrogeology.

Please contact Mark Maleham (Tel: 0117 914 2813) if clarification is required.

Martin G Bigg

Head of Industry Regulation

- 1 British Standard BS 6213: 2000 *Selection of construction sealants. Guide* (First published May 1982 Second edition July 2000) British Standards Institution ISBN 0 580 33168 7
- 2 Waterstops are preformed strips of durable impermeable material that are wholly or partially embedded in the concrete during construction. BS 8007: 1987 *Code of practice for design of concrete structures for retaining aqueous liquids* British Standards Institution ISBN 0 580 16134 X

Annex 2 Further information

Useful links

Buncefield Investigation

Buncefield Major Incident Investigation
Marlowe Room, Rose Court
2 Southwark Bridge
London, SE1 9HS
Tel: 020 7717 6909
Fax: 020 7717 6082
E-mail: buncefield.inforequest@hse.gsi.gov.uk
Web: www.buncefieldinvestigation.gov.uk

Business support

Dacorum Business Contact Centre
Tel: 01442 867 805

Business Link Helpline
Tel: 01727 813 813

Hertfordshire Chamber of Commerce
Tel: 01727 813 680

Residents' support

Dacorum Community Trust Mayors' Fund
To apply, call the freephone helpline on 0800 131 3351. Lines are open from 9.30 am – 4.30 pm, Monday to Friday.

Dacorum Borough Council
www.dacorum.gov.uk
Tel: 01442 228 000

Citizens Advice Bureau

Hemel Hempstead Citizens Advice Bureau, based in Hillfield Road, offers free, impartial, practical and confidential advice on a range of subjects.

Local authorities and emergency services

Dacorum Borough Council
www.dacorum.gov.uk
Tel: 01442 228 000

St Albans District Council
www.stablans.gov.uk
Tel: 01727 866 100

Hertfordshire County Council
www.hertsdirect.org
Tel: 01483 737 555

Hertfordshire Fire and Rescue Service
www.hertsdirect.org/yrccouncil/hcc/fire/buncefield

Hertfordshire Constabulary
www.herts.police.uk/news/buncefield/main.htm

Hertfordshire Chamber of Commerce
www.hertschamber.com
Tel: 01727 813 680

Government links

Office of the Deputy Prime Minister
Fire and Resilience Directorate: www.odpm.gov.uk

Government Office for the East of England
www.go-east.gov.uk

Environment Agency
www.environment-agency.gov.uk

Department of Trade and Industry
Oil and Gas Directorate: www.og.dti.gov.uk

Health and Safety Executive
Hazardous Installations Directorate: www.hse.gov.uk/hid
Control of Major Accident Hazards: www.hse.gov.uk/comah

Department for the Environment, Food and Rural Affairs
www.defra.gov.uk

Health Protection Agency
www.hpa.org.uk

Food Standards Agency
www.food.gov.uk

Drinking Water Inspectorate
www.dwi.gov.uk

Industry links

United Kingdom Petroleum Industry Association (UKPIA)
www.ukpia.com
Tel: 020 7240 0289

Chemical Industries Association
www.cia.org.uk
Tel: 020 7834 3399

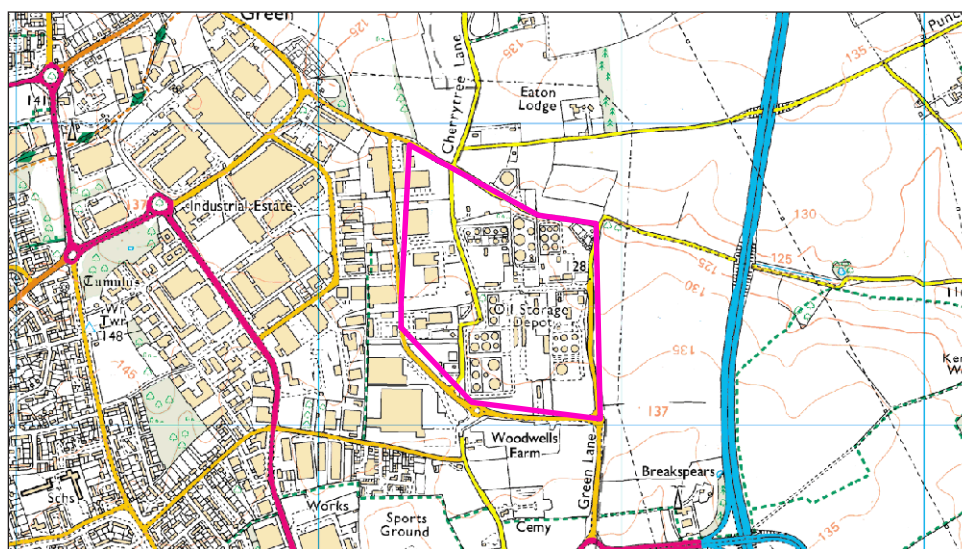
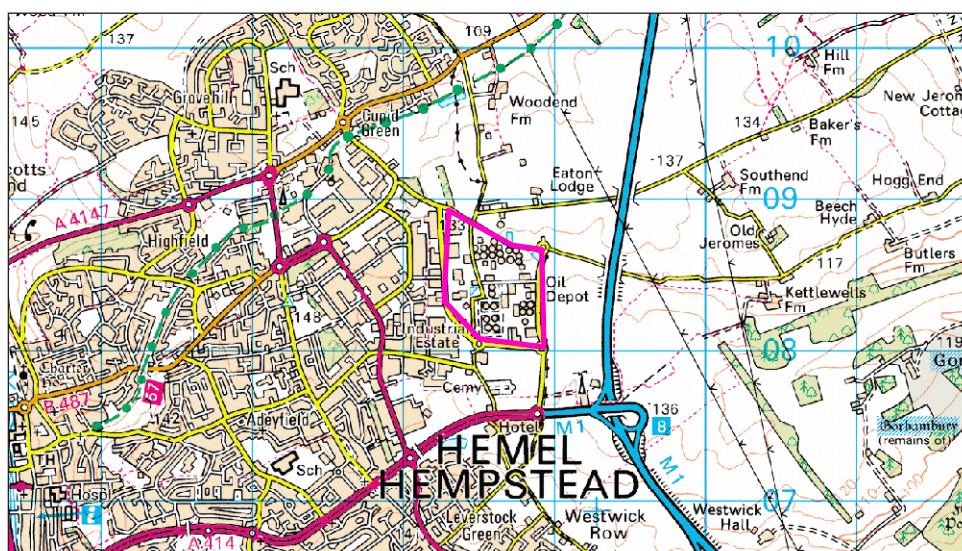
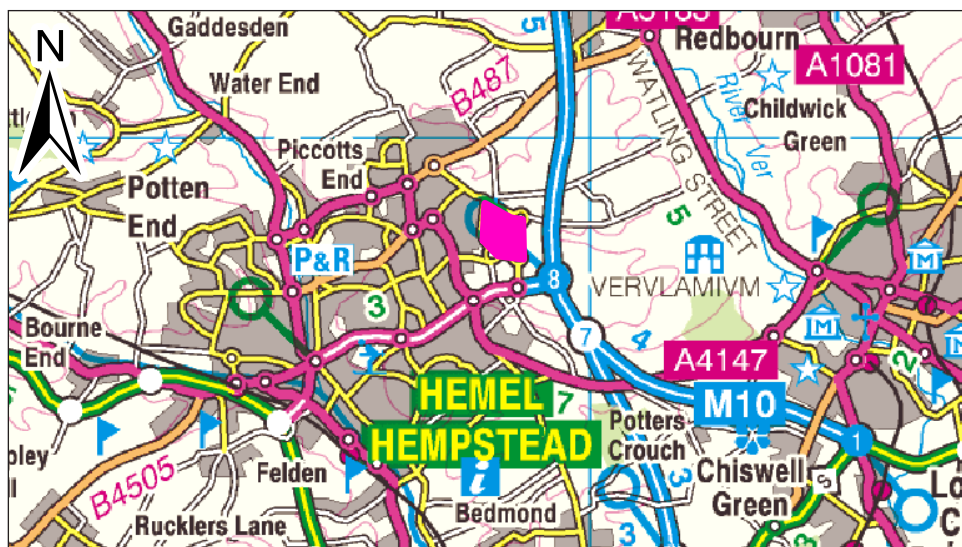
Other useful sources of information

Dacorum Borough Council *Digest* newsletter, available monthly
Dacorum Borough Council *Buncefield Update* Newsletter

Annex 3 Investigation terms of reference

- 1 To ensure the thorough investigation of the incident, the factors leading up to it, its impact both on and off site, and to establish its causation including root causes.
- 2 To identify and transmit without delay to duty holders and other appropriate recipients any information requiring immediate action to further safety and/or environmental protection in relation to storage and distribution of hydrocarbon fuels.
- 3 To examine the Health and Safety Executive's and the Environment Agency's role in regulating the activities on this site under the COMAH Regulations, considering relevant policy guidance and intervention activity.
- 4 To work closely with all relevant stakeholders, both to keep them informed of progress with the investigation and to contribute relevant expertise to other inquiries that may be established.
- 5 To make recommendations for future action to ensure the effective management and regulation of major accident risk at COMAH sites. This should include consideration of off-site as well as on-site risks and consider prevention of incidents, preparations for response to incidents, and mitigation of their effects.
- 6 To produce an initial report for the Health and Safety Commission and the Environment Agency as soon as the main facts have been established. Subject to legal considerations, this report will be made public.
- 7 To ensure that the relevant notifications are made to the European Commission.
- 8 To make the final report public.

Annex 4 Site maps



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Glossary

The Health and Safety Commission (HSC) is responsible for health and safety regulation in Great Britain. The Health and Safety Executive and local authorities are the enforcing authorities who work in support of the HSC. Both are statutory bodies, established under the Health and Safety at Work etc Act 1974.

The Environment Agency is the lead regulator in England and Wales with responsibility for protecting and enhancing the environment. It was set up by the Environment Act 1995 and is a non-departmental public body, largely sponsored by the Department for Environment, Food and Rural Affairs (DEFRA) and the National Assembly for Wales (NAW). The Environment Agency's prime responsibilities include flood risk management, tackling pollution incidents, reducing industry's impact on the environment, restoring and improving rivers, coastal waters, contaminated land, and wildlife habitats. The Environment Agency also advises on sustainable drainage, water conservation and management, planning issues, nature conservation and waste management.

ATG	Automatic tank gauging system
bund	An enclosure designed to contain fluids should they escape from the tank or vessel inside the bund
COMAH Regulations	The Control of Major Accident Hazards Regulations 1999 (COMAH)
COMAH sites	Sites to which the COMAH Regulations apply
Competent Authority	The COMAH Regulations are enforced by a joint Competent Authority comprising HSE and EA in England and Wales, and HSE and the Scottish Environment Protection Agency (SEPA) in Scotland. The Competent Authority operates to a Memorandum of Understanding which sets out arrangements for joint working
containment	Barriers which, in the event of a spill, can prevent spilled materials from reaching the environment
contaminants	Substances that have an adverse effect on air, water or soil
fire waters	A mix of waters, oils and fire-fighting foam
hazard	Anything with the potential to cause harm
hydrocarbon	An organic chemical compound of hydrogen and carbon. There are a wide variety of hydrocarbons such as crude oil (basically a complex mixture of hydrocarbons), methane, propane, butane etc. They are often used as fuels
Northgate	A business whose premises were affected by the Buncefield incident
Overpressure	For a pressure pulse (or blast wave), the pressure developed above atmospheric pressure is called the overpressure
PFOS	Perfluorooctane sulphonate

Prohibition Notice	Issuing Improvement or Prohibition Notices are some of the range of means which enforcing authorities use to achieve the broad aim of dealing with serious risks, securing compliance with health and safety law and preventing harm. A Prohibition Notice stops work in order to prevent serious personal injury
risk	The likelihood that a hazard will cause a specified harm to someone or something
safety reports	The COMAH Regulations require operators of top-tier sites to submit written safety reports to the Competent Authority
SCADA system	High-level supervisory control and data acquisition system
servo level gauge	Measures the liquid level in tanks
ullage	The volume in the tank between the normal maximum operating volume and when the tank is completely full of liquid
wind girder	Structural stiffening ring attached to the tank side wall