Public Health England

Protecting and improving the nation's health

# Response modelling

## *The practical use of models during the emergency response to chemical incidents and fires*

ADMLC seminar, 12/03/20
Jim Stewart-Evans, Environmental Hazards & Emergencies Department

# Contents

- Use in practice of dispersion modelling during the response to typical chemical incidents and fires – the ‘standard’ approach
- Current asks, capabilities, resources and practice
- Some recent work
- Future aspirations

# The demands of emergency response…

- Instant prediction
- Instant interpretation
- Instant decision-making
- Instant action!

- Exact location
- Meteorological factors
- Substance(s) involved
- Incident scenario
- Release rate
- Release period
- Fire-fighting / mitigation

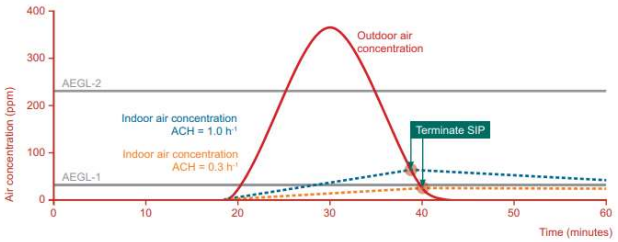
# …versus inevitable uncertainties

# US Emergency Response Guidelines


**TABLE 3 - INITIAL ISOLATION AND PROTECTIVE ACTION DISTANCES FOR LARGE SPILLS FOR DIFFERENT QUANTITIES OF SIX COMMON TIH (PIH in the US) GASES**

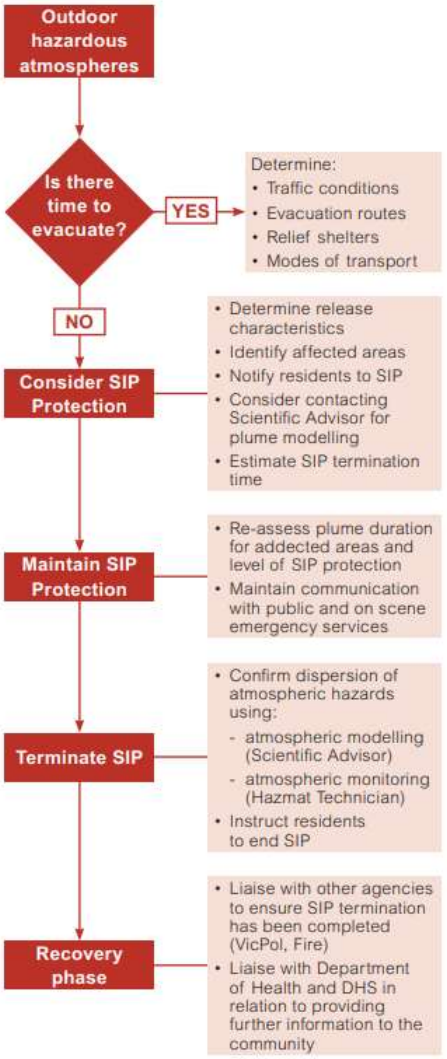
| | First ISOLATE in all Directions | | Then **PROTECT** persons Downwind during | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | DAY | | | | | | NIGHT | | | | | |
| | | | Low wind (< 6 mph = < 10 km/h) | | Moderate wind (6-12 mph = 10 - 20 km/h) | | High wind (> 12 mph = > 20 km/h) | | Low wind (< 6 mph = < 10 km/h) | | Moderate wind (6-12 mph = 10 - 20 km/h) | | High wind (> 12 mph = > 20 km/h) | |
| | Meters | (Feet) | km | (Miles) | km | (Miles) | km | (Miles) | km | (Miles) | km | (Miles) | km | (Miles) |
| **TRANSPORT CONTAINER** | **UN1005 Ammonia, anhydrous: Large Spills** | | | | | | | | | | | | | |
| Rail tank car | 300 | (1000) | 1.7 | (1.1) | 1.3 | (0.8) | 1.0 | (0.6) | 4.3 | (2.7) | 2.3 | (1.4) | 1.3 | (0.8) |
| Highway tank truck or trailer | 150 | (500) | 0.9 | (0.6) | 0.5 | (0.3) | 0.4 | (0.3) | 2.0 | (1.3) | 0.8 | (0.5) | 0.6 | (0.4) |
| Agricultural nurse tank | 60 | (200) | 0.5 | (0.3) | 0.3 | (0.2) | 0.3 | (0.2) | 1.3 | (0.8) | 0.3 | (0.2) | 0.3 | (0.2) |
| Multiple small cylinders | 30 | (100) | 0.3 | (0.2) | 0.2 | (0.1) | 0.1 | (0.1) | 0.7 | (0.5) | 0.3 | (0.2) | 0.2 | (0.1) |

# Best practice? An Australian perspective



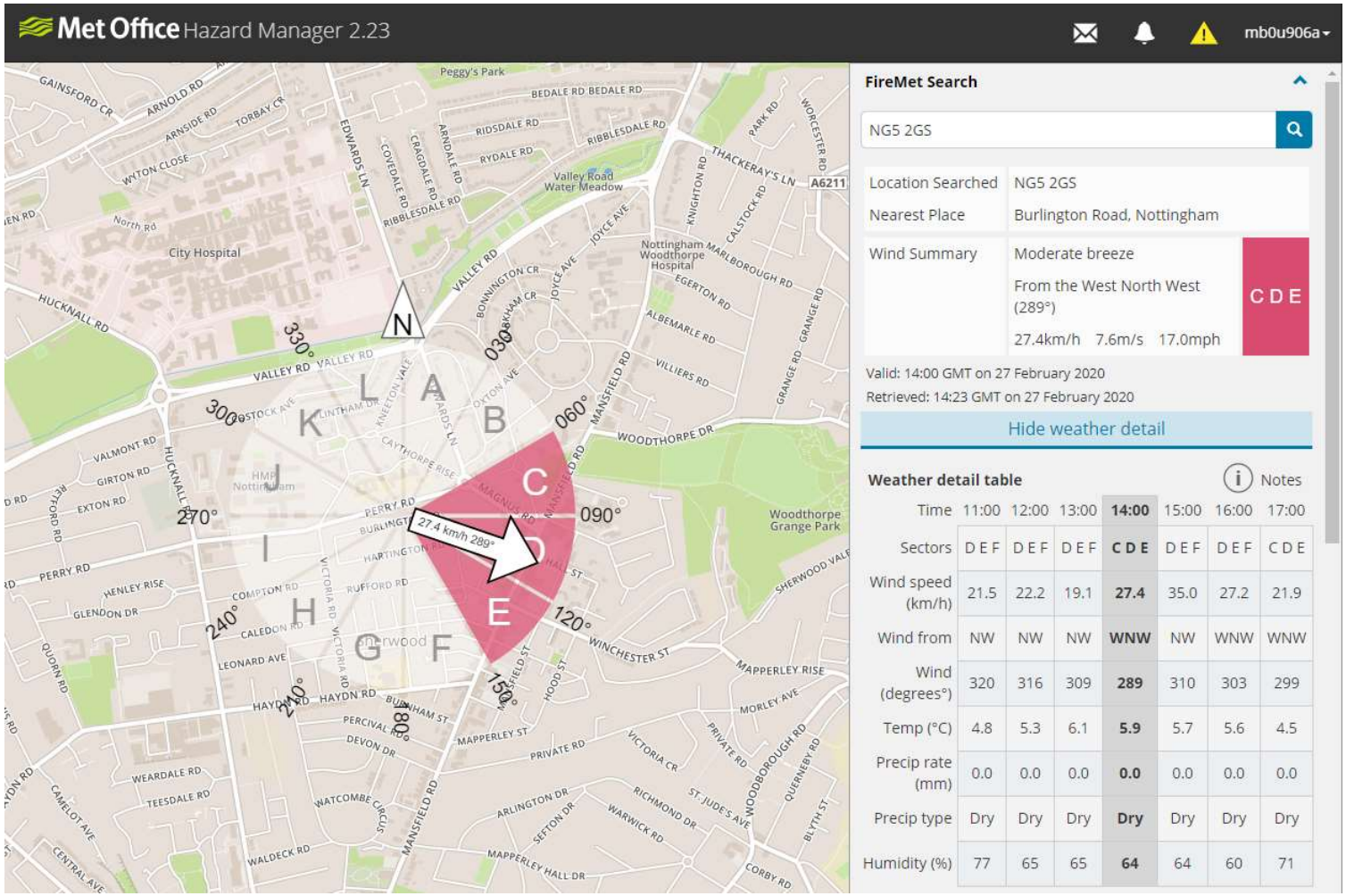

| Threat Zone | Footprint Red | Footprint Orange | Footprint Yellow | Confidence Limit Yellow |
|---|---|---|---|---|
| Value (ppm) | 3000 | 1200 | 250 | 250 |
| Length Downwind (km) | 1.7 | 3.0 | 7.2 | 7.2 |
| Area (ha) | 73 | 160 | 571 | 1281 |
| **Dwellings** | | | | |
| Semi Detatched | 6 | 10 | 63 | 251 |
| Separate House | 592 | 971 | 3962 | 6878 |
| Flats Units | 34 | 98 | 551 | 1063 |
| Other Dwellings | 0 | 0 | 16 | 29 |
| Total Dwellings | 632 | 1079 | 4592 | 8221 |
| **People** | | | | |
| Age 0 - 4 | | | | |
| Age 5 - 14 | | | | |
| Age 15 - 19 | | | | |
| Age 20 - 24 | | | | |
| Age 25 - 34 | | | | |
| Age 35 - 44 | | | | |
| Age 45 - 54 | | | | |
| Age 55 -64 | | | | |
| Age 65 - 74 | | | | |
| Age 75 - 84 | | | | |
| Age 85+ | | | | |
| Persons Working | | | | |
| Persons Not Working | | | | |
| Total Persons | | | | |

| Feature Type | Feature Subtype | Address | LOC: 1000ppm = ERPG-3 Colour: Red — Footprint | LOC: 1000ppm = ERPG-3 Colour: Red — CFD Limit | LOC: 150 ppm = ERPG-2 Colour: Orange — CFD Limit | LOC: 50 ppm ERPG-1 Colour: Yellow — CFD Limit |
|---|---|---|---|---|---|---|
| Barrabool CFA | fire station | 15 Wheat Sheaf Rd Ceres 3221 | | | ✓ | |
| Ceres Primary School | primary school | 40 Cochranes Rd Ceres 3221 | | | | ✓ |
| Geelong West CFA | fire station | 67B McCurdy Rd Herne Hill | | ✓ | | |
| Herne Hill Primary School | primary school | 194 Church St Hamlyn Heights | ✓ | | | |
| Belmont Grange | aged care | Church St Hamlyn Heights | ✓ | | | |
| Manifold Heights Primary School | primary school | 20 Strachan Ave Manifold Heights | | ✓ | | |




A Best Practice Approach to Shelter-in-Place for Victoria (2011) (hyperlink)

# Met Office: models on-demand




| Time | 11:00 | 12:00 | 13:00 | **14:00** | 15:00 | 16:00 | 17:00 |
|---|---|---|---|---|---|---|---|
| Sectors | D E F | D E F | D E F | **C D E** | D E F | D E F | C D E |
| Wind speed (km/h) | 21.5 | 22.2 | 19.1 | **27.4** | 35.0 | 27.2 | 21.9 |
| Wind from | NW | NW | NW | **WNW** | NW | WNW | WNW |
| Wind (degrees°) | 320 | 316 | 309 | **289** | 310 | 303 | 299 |
| Temp (°C) | 4.8 | 5.3 | 6.1 | **5.9** | 5.7 | 5.6 | 4.5 |
| Precip rate (mm) | 0.0 | 0.0 | 0.0 | **0.0** | 0.0 | 0.0 | 0.0 |
| Precip type | Dry | Dry | Dry | **Dry** | Dry | Dry | Dry |
| Humidity (%) | 77 | 65 | 65 | **64** | 64 | 60 | 71 |

# Chemet

Met Office — CHEMET Forecast

**Wolverton Fire CHEMET 329_002**

**Issued by Met Office Environment Monitoring and Response Centre (EMARC)**

Tel: 01392 447947 Email: emarc@metoffice.gov.uk Link to Hazard Manager

**Plume forecast below 100m** - map will be sent separately

Forecast Issued on Thursday, 27 February 2020 at 07:27 local

| | |
|---|---|
| **To:** Duty Officer | *of* Environment Agency |
| **Tel:** 07795 223431 | **Email:** robin.musk@environemnt-agency.gov.uk |
| **Forecast for:** Wolverton | *due to* Fire |
| **Incident ongoing since:** 26/02/2020 07:30 | |
| **Forecast valid between:** 07:30 26/02/2020 | *and* 19:30 26/02/2020 |

**Surface wind direction/speed:** *Blowing from WNW towards ESE at 10 mph.*

**Weather conditions and effect on plume:** A cloudy morning with outbreaks of rain, sleet and snow. This clearing around midday to leave the afternoon dry. Light winds early on will cause the plume direction to be variable, however a brisk west/northwesterly breeze will develop from mid-morning.

**If incident continues beyond the validity period, the following weather conditions will affect the plume**

Dry overnight with winds easing. The plume will generally blow from west to east overnight but will lower close to the ground.

**Please call 01392 447947 to request further updates if this incident is likely to continue or to discuss further.**

**Additional Information for Science and Health Agencies**

**Precipitation (type and intensity):** Outbreaks of rain and snow until midday, unlikely to produce washout.

**Total Cloud amount:** 7 becoming 4 oktas

**Height of lowest significant cloud:** 800 becoming 2500 feet

**Air temperature:** 2 becoming 6 °C

**Relative humidity:** 75 %

**Depth of mixing layer:** 500 metres

**Wind at top of mixing layer:** Blowing from 340 to 160 degrees at 40 km/h

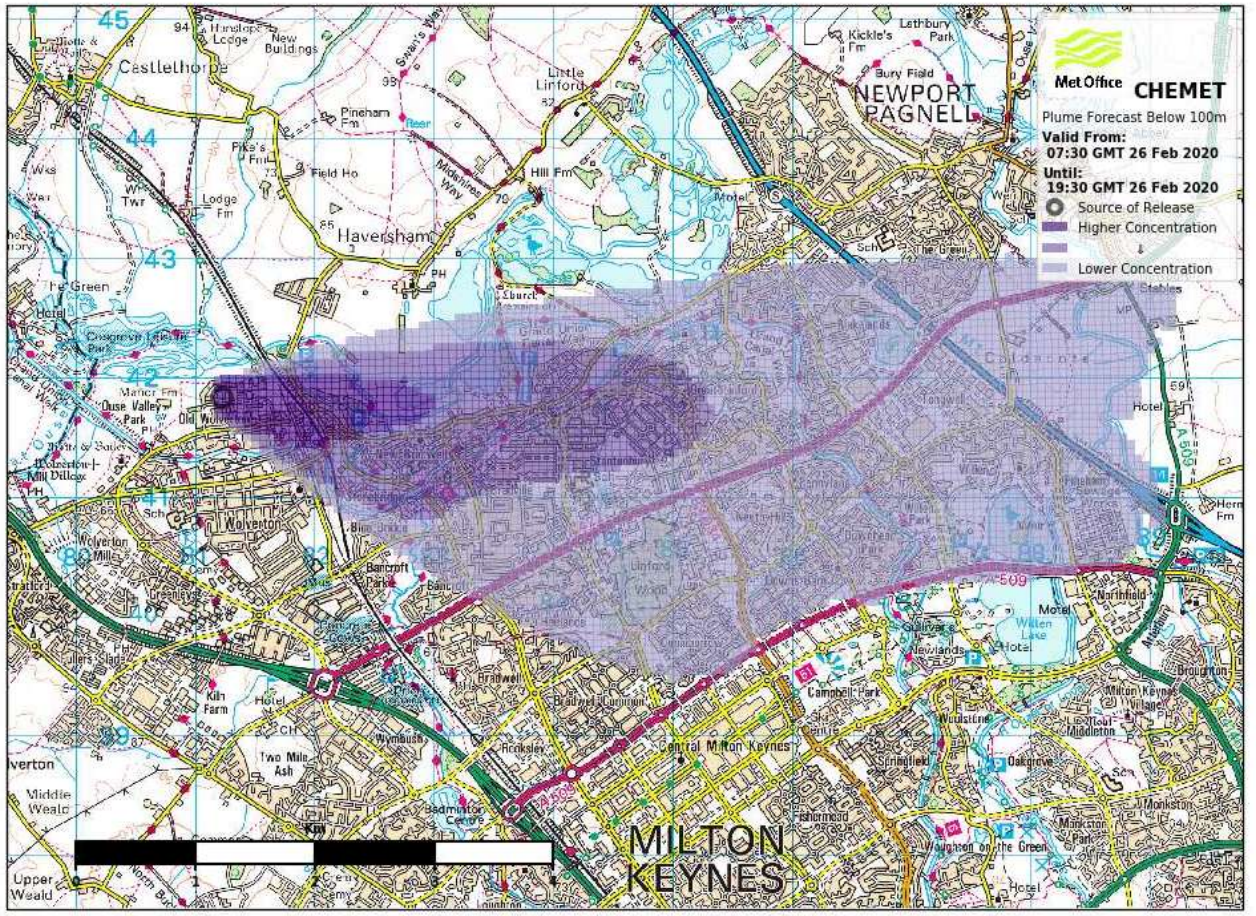
**Air stability:** D *(A=unstable, G=stable)*

**Latitude and Longitude of source:** 52.069 N, 0.815 W

**Sensible heat flux:** 35 W/m²



ID = 329_002_Wolverton_Fire For further advice, call EMARC on 01392 447947.



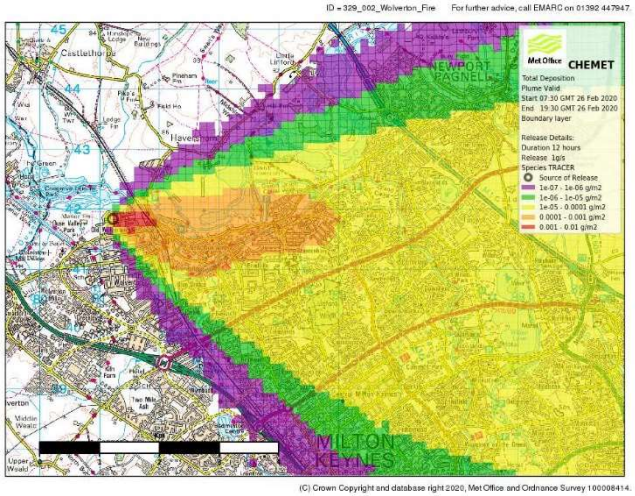



Few users consider model assumptions and applicability…

# So what can we do right now?

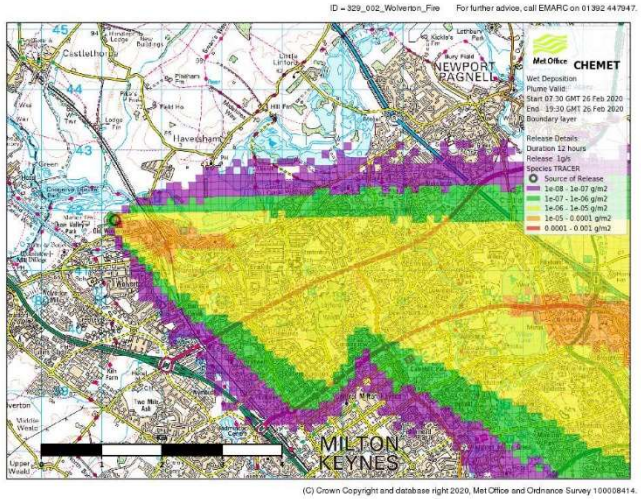
- ✓ "We can quickly predict at-risk areas downwind”
- ✓ "We can predict how at-risk areas will change with the weather over time”
- ✓ "We can predict **where** highest ground-level concentrations occur, but may not be able to predict **what** they are…“
  - ❑ “We can only predict concentrations **if** we can characterise the release (amount and duration)”
  - ❑ “We might be able to back-calculate a source-term **if** we have environmental monitoring data”
  - ❑ “We **might** be able to use models to predict concentrations, but it is the exception rather than the rule”

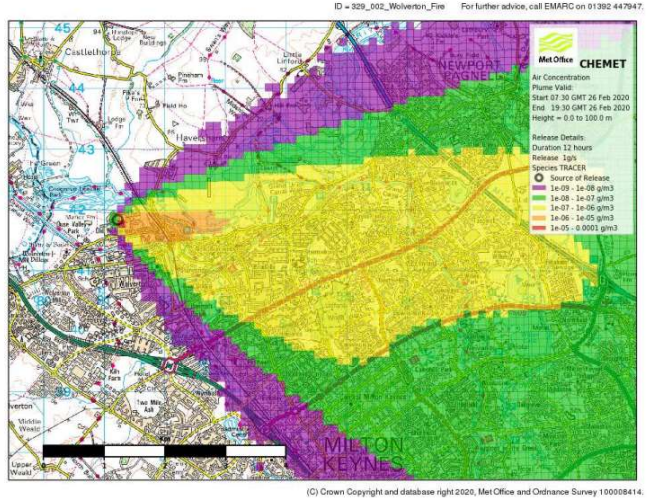
# Going further: ChemetPro




- Total deposition, dry deposition, wet deposition ($gm^{-2}$)
- Air concentration ($gm^{-3}$)
- Dosage ($gs^{-1}m^{-3}$) *not commonly used for chemical exposures*

- Can be scaled to give *absolute* levels **if** the release rate is known

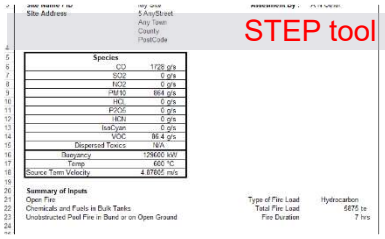


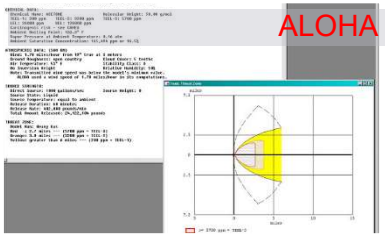
# Source-term information: a challenge?

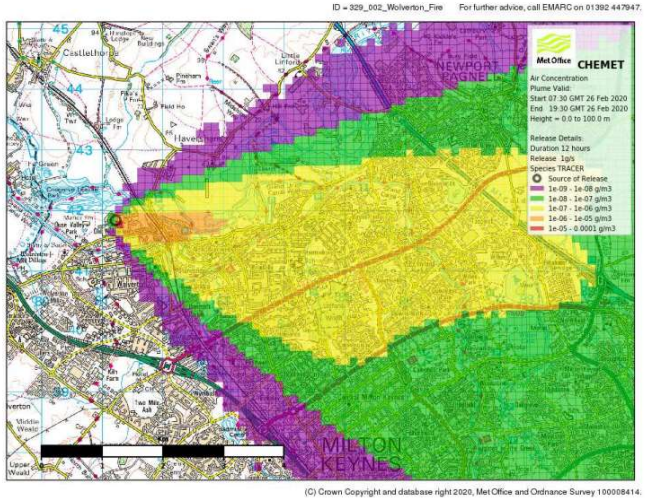
Focus: Fire & Rescue Services










Quick wins that can help:

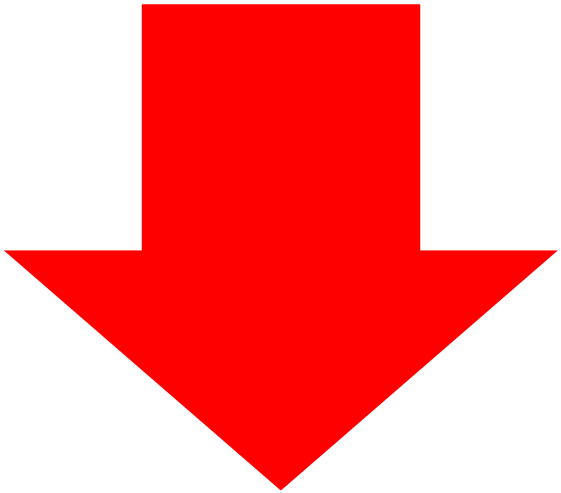
- ❑ Photos
- ❑ Observed plume height
- ❑ Observed plume behaviour

# Predict the hazard range?

"**If** we can predict chemical concentrations and exposure durations at different locations…

…we can comment on expected signs and symptoms"

…we can compare them to health standards"



Predict an exact protective action distance

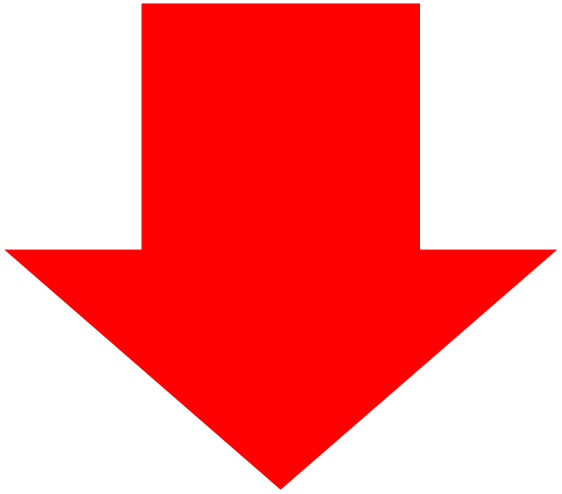
Predict near-field dispersion with confidence (ie, ranges of 100s of metres)

Predict thermal or blast hazards

# Predict population level impacts?

"**If** we can predict chemical concentrations and exposure durations at different locations…

…we can compare GIS maps with model outputs to get an idea of the number and types of people who might be affected"



Calculate the number or severity of injuries

Calculate the number of casualties

# Predict indoor exposures? INGRESS

**INGRESS Tool - Indoor Concentration for Specified Hourly Outdoor Pollutant Concentration (Max 24 Hours)**

**Data Input**

BUILDING

**Building Data Input**

| | |
|---|---|
| Building Type | Detached/Semi |
| Region Type | Urban/City |
| Building Age | Old Pre 2000 |
| Chimney | Yes |

WEATHER

**Weather Data Input**

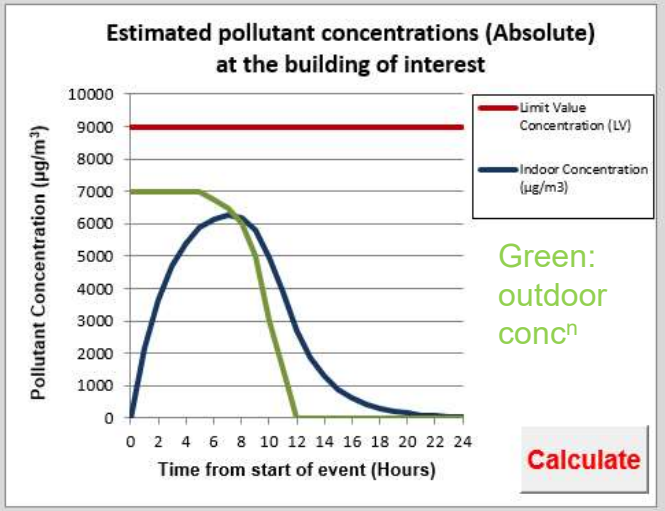
| | | |
|---|---|---|
| Wind Speed | 18 | (km/h) |
| Wind Direction | 190 to 010 | (Deg) |
| Outdoor Temperature | 15 | (Deg C) |
| Indoor Temperature | 20 | (Deg C) |

CHEM

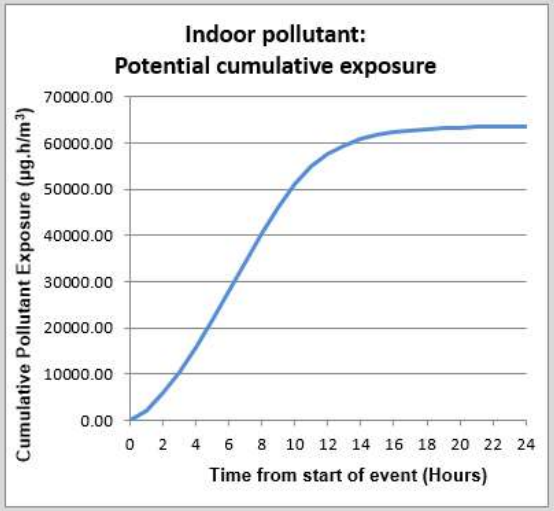
**Pollutant Data Input**

| | | |
|---|---|---|
| Pollutant Type | Chlorine | |
| Start Indoor Concentration | 0 | ($\mu g/m^3$) |
| Limit Value Concentration (LV) | 9000 | ($\mu g/m^3$) |
| Pollutant Ingress Factor (Value 0 to 1) | 1 | |

Purging when Outdoor Conc < Indoor Conc: No




Pollutant Type: Chlorine




**Results**

Monitored Outdoor Concentration
Insert in Column H
Starting at Cell H36

| Time (Hours) | Wind Speed (m/s) | Wind Direction | Outside Temperature (Deg C) | Inside Temperature (Deg C) | Ventilation Rate (L/s) | Outdoor Concentration ($\mu g/m^3$) | Indoor Concentration ($\mu g/m^3$) | Limit Value (LV) ($\mu g/m^3$) | Potential Cumulative Pollutant Exposure ($\mu g.h/m^3$) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 2.1 | 190 to 010 | 15 | 20 | 40.51 | 7000.00 | 0.00 | 9000 | 0.00 |
| 1 | 2.1 | 190 to 010 | 15 | 20 | 40.51 | 7000.00 | 2156.46 | 9000 | 2156.46 |
| 2 | 2.1 | 190 to 010 | 15 | 20 | 40.51 | 7000.00 | 3648.59 | 9000 | 5805.04 |

# Characterising incidents

PHE reviewed its waste fire database and 2017-18 incidents that led to CHEMET requests

- **Chemical incidents**: short-lived (most <4h), normally a single Chemet requested, natural gas / chlorine / ammonia were most prevalent (but there were few incidents)
- **Fires**: much more common, most out within a day with a single forecast issued , but a *wide range of durations* with up to 10s of forecasts over months, most impacts reported within 2km

Some potential areas of work:

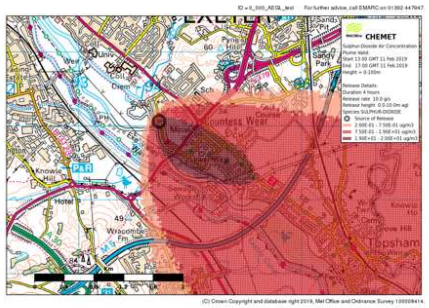
- Improving data capture / scope of future reviews
- Filtering requests (flagging indoor, small-scale, complex environments etc)
- Customising forecast spatial resolutions and timescales
- Developing approaches to source-term prediction and suites of outputs

# Developing ChemetPro

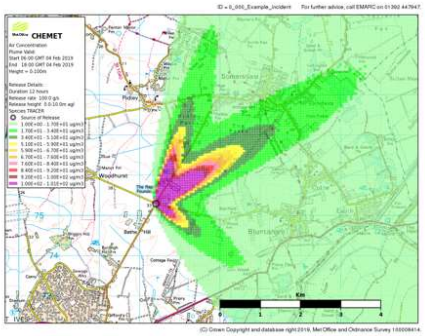
The Met Office have made many improvements to a working prototype:

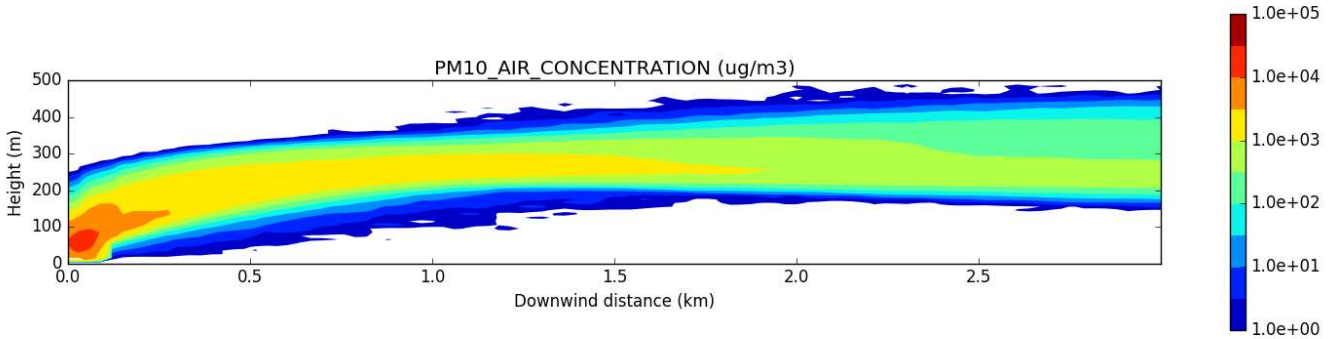
- Incorporation of health standards
- Time series at specified locations
- Near-field dispersion
- Cross-sections along and downwind (vertical information)
- … and more to be discussed in a future user workshop

AEGL



DAQI (recent real event)





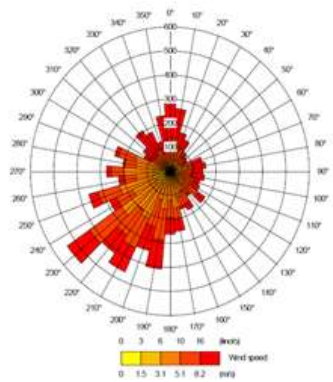
# Waste fire rules of thumb?

◄General … …vs site specific ▼

Potential template for protective action look-up table for fires based on past monitoring data and model predictions:

| Waste fire: buoyant plume | 100m downwind | 500m downwind | 1km downwind | 2.5km downwind | 5km downwind | 10km downwind |
|---|---|---|---|---|---|---|
| Typical 24h PM | Above AQS | Below AQS | Below AQS | Below AQS | Below AQS | Below AQS |
| Worst-case 24h PM | Above 1st trigger | Below AQS | Below AQS | Below AQS | Below AQS | Below AQS |
| Typical dioxin | Below TDI | Below TDI | Below TDI | Below TDI | Below TDI | Below TDI |
| Worst-case dioxin | Below TDI | Below TDI | Below TDI | Below TDI | Below TDI | Below TDI |

| Waste fire: smouldering | 100m downwind | 500m downwind | 1km downwind | 2.5km downwind | 5km downwind | 10km downwind |
|---|---|---|---|---|---|---|
| Typical 24h PM | Above AQS | Above AQS | Above AQS | Below AQS | Below AQS | Below AQS |
| Worst-case 24h PM | Above 2nd trigger | Above 2nd trigger | Above 1st trigger | Above AQS | Below AQS | Below AQS |
| Typical dioxin | Above TDI | Below TDI | Below TDI | Below TDI | Below TDI | Below TDI |
| Worst-case dioxin | Above TDI | Above TDI | Below TDI | Below TDI | Below TDI | Below TDI |



**Traditional classification of common atmospheric conditions**

| Surface wind speed | Day - Solar Radiation | | | | Night Cloudiness | | |
|---|---|---|---|---|---|---|---|
| (m/s) | strong | moderate | slight | overcast | overcast | cloudy | clear |
| <2 | A | A-B | B | D | D | E | F |
| 2-3 | A-B | B | C | D | D | E | F |
| 3-5 | B | B-C | C | D | D | D | E |
| 5-6 | C | C-D | D | D | D | D | D |
| >6 | C | D | D | D | D | D | D |

A = very unstable
B = moderately unstable
C = slightly unstable
D = neutral
E = slightly stable
F = stable

Notes:
- Surface wind is measured 10m above ground.
- A 'cloudy night' is one with more than half cloud cover.
- A 'clear night' is one with less than half cloud cover.

# Concluding thoughts

- Fires and chemical incidents differ in nature (and their demands on modellers) – needs related to both must be considered
- We can do more to join-up and optimise use of our default options
- With limited resources, we are looking for quick wins and rules of thumb for operational practice
- We are focussing on the *protection* of people before thinking about the detailed *prediction* of impacts
- How can we develop and ‘operationalise’ some of the existing but little-used tools and resources for chemical incidents and fires…?

# The bigger picture

Modelling and exposure assessment is one part of risk assessment and incident management. We must also consider:

- Operational procedures
- Organisational roles
- Staff skills and training
  - Capabilities/understanding across levels from decision-makers to specialist advisors
- Information flows
  - Between organisations
  - From new technologies and other sources of information
- Decision-making and decision frameworks
- Decision support tools
- Public warning and informing (protective actions)