Health and Safety
Executive

HSE

SESSION 2: MODELLING in PLANNING and PREPAREDNESS

(Current approaches for different contaminants)

How dispersion modelling informs public safety decision making for risks presented by major hazards installations

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Major Hazards Risk Assessment

ADMLC: Workshop March 2020

What are major hazards?

- Example of flammables released at high-pressure
  - How big was vessel/leak/radius? Very little information released!!

  https://www.youtube.com/watch?v=xQX8yWwLX2Q
- Example of toxic gas release (Chlorine)
  - How big was vessel: US 10 ton/leak 6” (~150mm) diameter hole

  Chlorine_Jack Rabbit II Trial 7_9,000kg - https://www.youtube.com/watch?v=kPyc68ZR13E

Context:

1974 Flixborough, North Lincolnshire

- Saturday 1st June ~16:53
- Release of flammable cyclohexane followed by a huge explosion
- On-site

  28 dead

  36 injured
- Off-site

  53 injured
- Significant damage to homes nearby

The regulatory response:

Advisory Committee on Major Hazards (ACMH)

HSE

- Identified a three-part strategy:
  - **Identification** of hazardous installations which had the potential for major accidents
  - **Prevention** of accidents through controls over the design, operation and maintenance of the installation
  - Recognizing that zero risk is unattainable **mitigation** of the consequences of any accidents
    - ***emergency planning*** & information to the public
    - control of off-site populations at risk through ***land-use planning***

Control of Major Accident Hazards (COMAH) regulations

- **Aim**: Prevent or mitigate the impact of major accidents from industrial processes that could harm people and/or the environment
- Duties for Site Operators, Competent Authority, Local Authority/ Emergency Services
- Higher risk “Upper Tier” Site Operators must prepare a Safety Report that demonstrates their understanding of the hazards and the potential consequences of a major accident (performance-based regulation)

Enschede, Netherlands (2000)
23 killed, 1000 injured

Toulouse, France (2001)
30 killed, 2242 injured, $1.6 billion

Buncefield, UK (2005)
0 killed, 43 injured, $1.3 billion

Land-Use Planning Legislation

- **Aim**: To manage population growth around major hazard sites and help mitigate the consequences of major accidents
- HSE's roles:
  - Statutory Consultee to the Planning System
  - Hazardous substances consent
  - Advice on land-use planning to planning authorities and property developers

HSE provides three-zone maps of residual risk for:

- Around 2,000 major hazard sites
- 28,000 km of major accident hazard pipelines

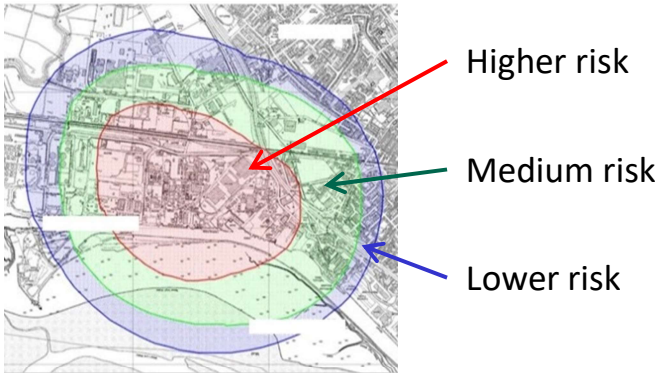


Figure for illustration purposes only

Major Hazards Sites - M62 Corridor

Dispersion modelling for land-use planning

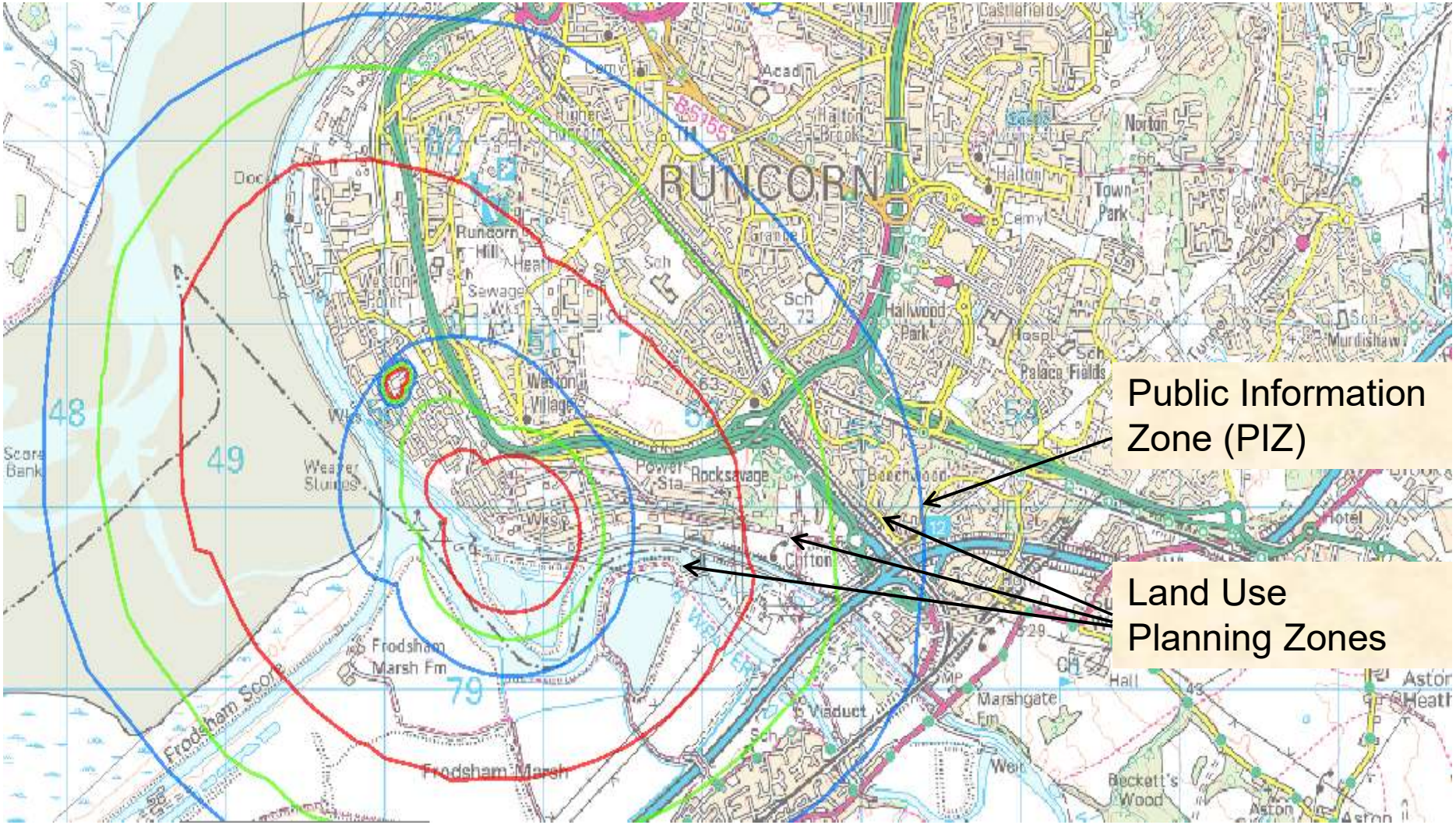
- Simulations performed by HSE using the DRIFT integral dispersion model
- Dispersion modelling scenarios chosen based on maximum inventory of hazardous substances that an operator is permitted to have onsite by virtue of their hazardous substances consent
  - Generic classes of hazardous substances (acute toxic, flammable gas etc.)
  - Named hazardous substances (chlorine, carbonyl dichloride, phosphine, etc.)
  - Catastrophic releases and range of hole sizes, based on failure frequency model, depending on vessel type
- Weather: four categories (D2.4, D4.3, D6.7 and F2.4) and wind directions with probabilities assigned from Met Office weather data near the major hazards site
- Obstructions (e.g. buildings) modelled as surface roughness
- Three-zone maps defined by HSE will typically remain the same for the duration of the operations on the major hazards site, which can be 20 – 30 years

Dispersion modelling for land-use planning & emergency planning

- Three-zone maps contours are set on the risk of receiving a HSE Dangerous Dose
  - Risk expressed in Chances Per Million per Year (CPM)
  - Inner Zone 10CPM
  - Middle Zone 1CPM
  - Outer Zone 0.3CPM
- The COMAH Competent Authority is required to set a Public Information Zone (PIZ)
  - The land use planning 0.3CPM Outer Zone Contour is used to set the PIZ
- HSE Dangerous Dose is defined as one that produces all the following effects:
  - severe distress to almost everyone
  - a substantial fraction requires medical attention
  - some people are seriously injured, requiring prolonged treatment
  - any highly susceptible people might be killed
- Public Information Zone (PIZ) Safety Advice

Go in ... Stay in ...Tune in

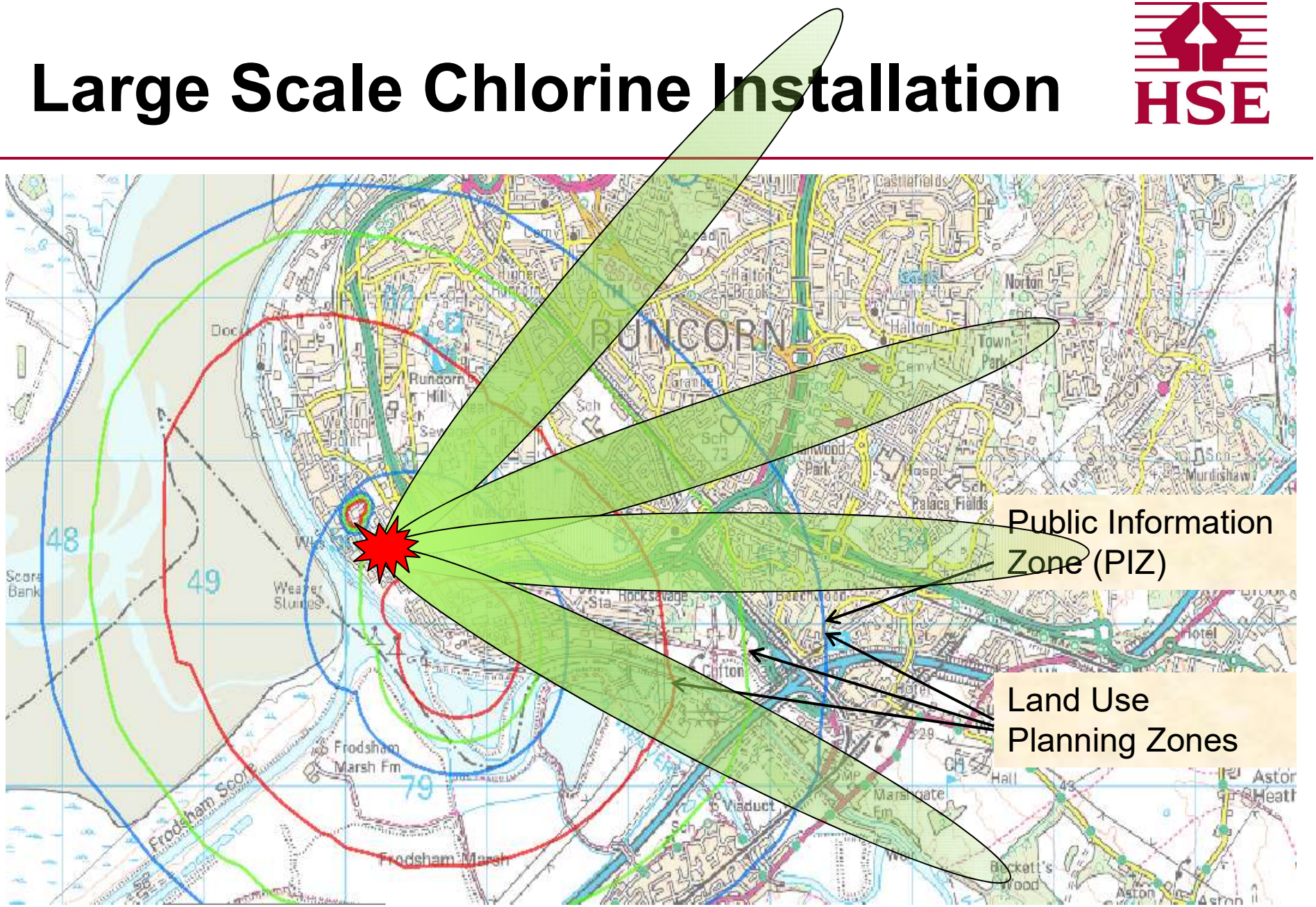
Large Scale Chlorine Installation



Risk (likelihood) vs Consequence

- Public Information Zone (PIZ)
  - Risk based 0.3 CPM/yr
  - Underpinned by consequence (dispersion modelling) & Event & Met likelihoods
  - Potential for consequences to far exceed the PIZ
- PIZ
  - Representative of ***Reasonable Worst Cases***??
  - Good for smaller more likely events
  - There is an expectation actions will be taken on site to reduce consequences
    - On-site Emergency Plan
    - Water sprays?
    - Application of vapour suppression foams?
- Off-site Emergency Plan (Local Authority)
  - Plans put in place based on the extent of the PIZ
  - Relies on information provided by the Major Hazard Site Operator in helping draw up the plan

Large Scale Chlorine Installation



Public Safety Decisions

- A level of confidence is required in Dispersion Model predictions?
  - Setting of land use planning zones
  - Planning for emergencies
- Need to put into context with all other assumptions (uncertainties)
  - Estimates of accident/event likelihoods
  - Met Data
  - Source Term Models
  - Human response to toxic substance exposure
  - Inherent unknowns
- Consequences of getting it ***wrong*** (land use planning zones too large/small)
  - Too large - Leads to planning blight
  - Too small - Introduce and impose populations to elevated risk
- Fail to put in place appropriate plans for emergencies
  - Too large - Create fear/anxiety for ***impossible*** events
  - Too small – Mass casualties in the event of an accident

Dispersion Modelling Tools

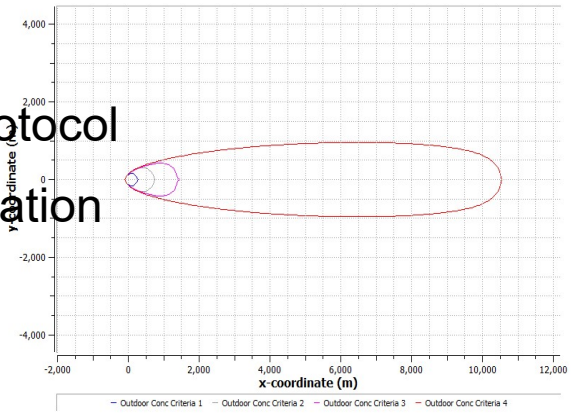
- Integral dispersion models
  - ESR Technology **DRIFT**
  - DNV GL **PHAST**
- Computational Fluid Dynamics (CFD)
  - Ansys **CFX**, **Fluent**, **Autodyn**
  - GexCon **FLACS**
- Source models (examples)
  - **GASP** evaporating spills
  - **STAWaRS** water reactive spills
  - **PiRRaM** pipeline model
  - **SPLOT** shallow-layer model for liquid spills

DRIFT integral dispersion model

- **D**ispersion of **R**eleases **I**nvolving **F**lammables or **T**oxics (DRIFT)
- Originally developed by UK Atomic Energy Authority (UKAEA) in late 1980's
- Developed with support from HSE over last 30 years
- Capabilities:
  - Passive, buoyant and dense gas dispersion
  - Instantaneous, steady, time-varying releases
  - Two-phase flashing releases, droplet evaporation
  - Condensation of atmospheric water vapor (HF, ammonia)
  - Rainout and pool evaporation (using GASP)
  - Along-wind diffusion effects
- Validated using the NFPA LNG Model Evaluation Protocol
- Currently being subject to further Jack Rabbit II validation

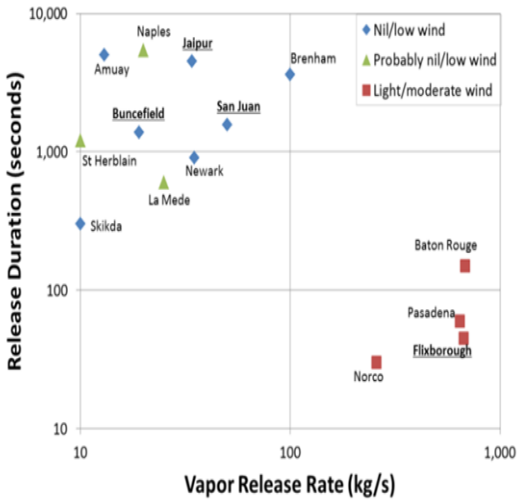
ESR Technology
Engineering, Safety & Risk

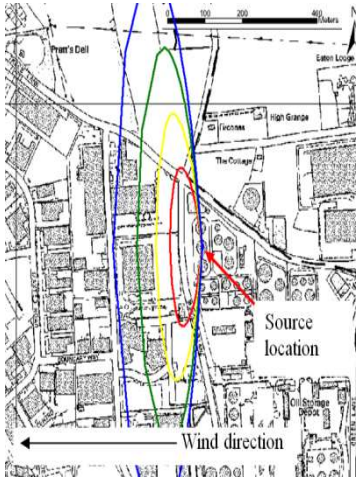
GT Science & Software



Gaps and Challenges

- Addressing hitherto unforeseen events (Buncefield 2005)
- Dense-gas dispersion in low/zero wind speeds
  - Common factor in severe vapor cloud explosion incidents
  - Cannot use common integral models, e.g. DRIFT/Phast
  - Terrain effects/vapor fences potentially important
  - Full CFD is costly, complex, user-variability issues
- CFD modelling of atmospheric dispersion





Links to some relevant information

- NFPA LNG Model Evaluation Protocol
  - https://www.nfpa.org/News-and-Research/Data-research-and-tools/Hazardous-Materials/LNG-model-evaluation-protocol-and-validation-database-update
- DRIFT model validation
  - http://www.hse.gov.uk/research/rrhtm/rr1100.htm
- Gant S.E. and Tucker, H (2018) "CFD modelling of atmospheric dispersion for land-use planning around major hazards sites in Great Britain", Journal of Loss Prevention in the Process Industries, 54, p340-345 (https://doi.org/10.1016/j.jlp.2018.03.015)
- Gant S.E., Weil J., Delle Monache L., McKenna B., Garcia M.M., Tickle G., Tucker H., Stewart J., Kelsey A., McGillivray A., Batt R., Witlox H. and Wardman M. (2018) "Dense gas dispersion model development and testing for the Jack Rabbit II Phase 1 Chlorine Release Experiments", Atmospheric Environment, 192, p218-240 (https://doi.org/10.1016/j.atmosenv.2018.08.009)