



Jack Rabbit II 2015 trials: preliminary comparison using Drift and Phast

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Jack Rabbit

- United States led initiative to address concerns about risks to public from accidents or terrorist attacks on railcars containing chlorine or other toxics
- Around 3.5 million tonnes of chlorine transported by railcar annually in the USA
- Previous incidents, e.g. Graniteville (2005): railcar collision, 9 fatalities, 554 injured, 5400 evacuated

Jack Rabbit II

- Chlorine release experiments from pressurised vessel: large scale 4.5–18 tonnes
- Follows on from smaller Jack Rabbit I experiments (2010)
- Experiments carried out over two years
- Phase 1 (2015) directly downward with mock urban grid
- Phase 2 (2016) various release orientations without mock urban grid

Jack Rabbit II sponsors

- U.S. Department of Homeland Security, Chemical Security Analysis Center
- U.S. Defense Threat Reduction Agency
- Transport Canada
- Defence Research and Development Canada



**Homeland
Security**

Science and Technology



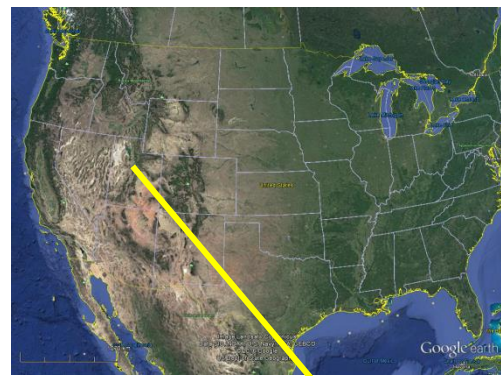
Transport
Canada



Jack Rabbit II Phase 1 (2015)

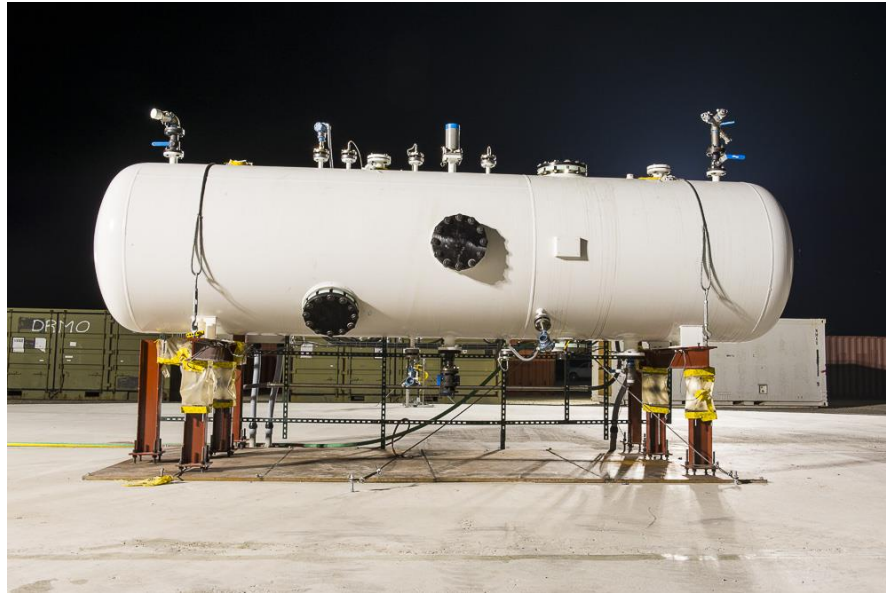
- Chlorine releases of 4.5 to 8 tonnes
- Release from a pressure vessel through a 6 inch diameter hole, 1 m above ground level
- Release orientation directly downwards
- Mock urban array of obstacles
- Dispersion measurements up to 11 km downwind
- Infiltration measurements into buildings and vehicles
- Measurements of source terms and weather conditions

Dugway Proving Ground



Tank/Pad Instrumentation

Photo © U.S. Department of Homeland Security



- Load cells and pressure sensors
- Thermocouples for vessel and pad
- Guided wave radars for liquid depth of vessel and pad
- Ambient temperature and humidity measurements
- Infrared and visible cameras

Photos of Dugway

Photo © U.S. Department of Homeland Security



Photos of Dugway

Photo © U.S. Department of Homeland Security

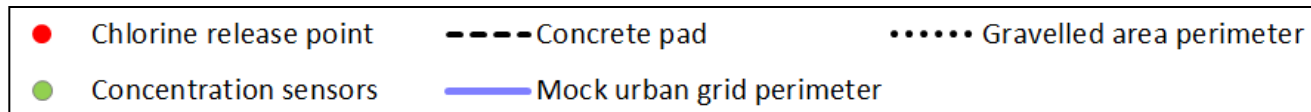
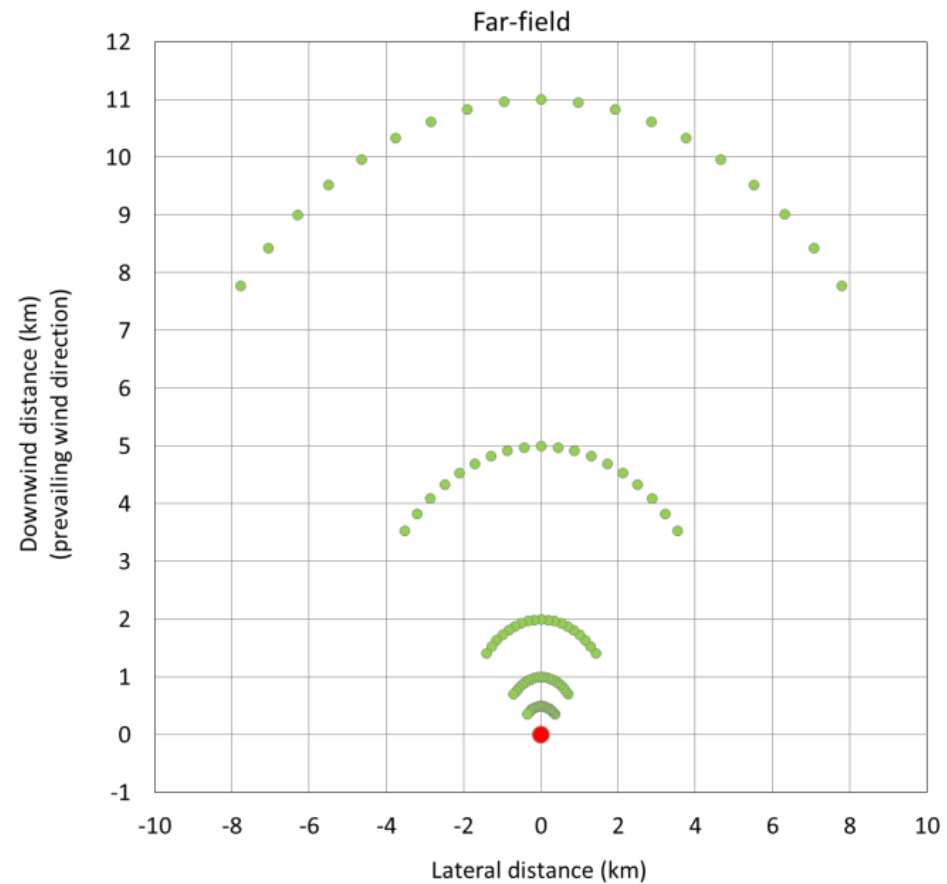
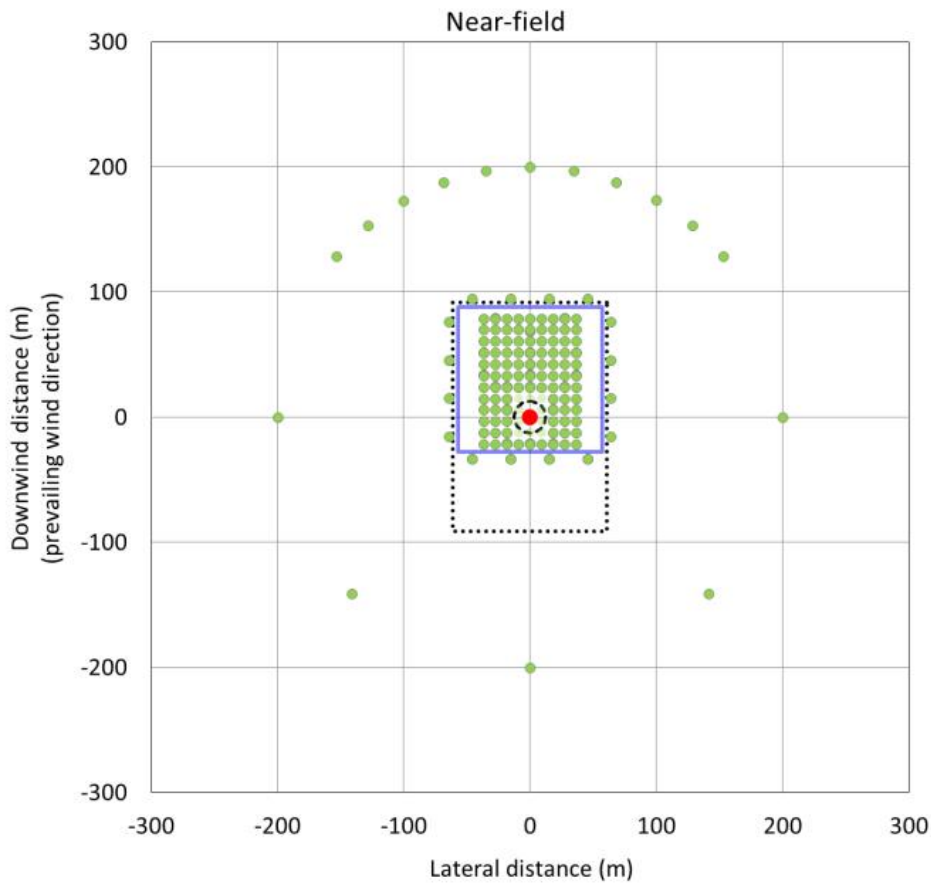


Photos of Dugway

Photo © U.S. Department of Homeland Security



Geometric layout of experiments



Release conditions

Trial	Mass of Chlorine (kg)	Initial Tank Pressure (barg)	Wind direction offset to urban array (deg)	Wind Speed (m/s)	Atmospheric Temperature (°C)	Relative Humidity (%)	Atmospheric Pressure (bar)	Pasquill Stability Class
1	4509	6.50	-18	2.0	17.7	39.2	0.87	?
2	8151	6.06	-7	4.2	22.7	33.6	0.87	C → B
3	4512	5.71	+4	3.9	22.5	30.3	0.87	D
4	6970	5.16	+18	2.3	22.5	26.9	0.87	D → C → B
5	8303	5.87	+17	2.7	22.2	26.5	0.87	D

Modelling methodology

- Meta-stable liquid flow through orifice (sensitivity with flashing)
- Surface roughness for the mock urban grid 0.4 m
- Surface roughness for desert 1 mm
- Two simulations run and blended together 100 m downwind
- Base case assuming no rainout
- Sensitivity including full rainout
- Used source and weather data from experiments
- Short averaging times used in dispersion models to predict peak concentrations

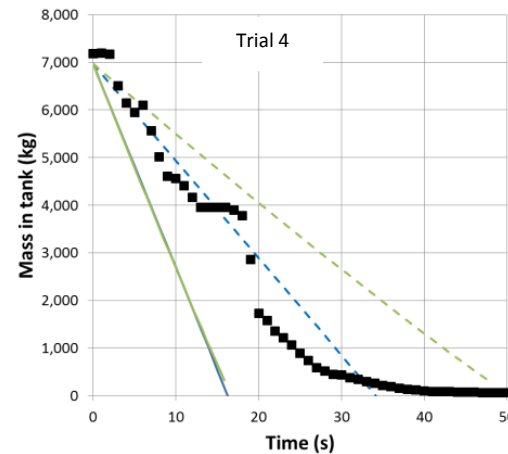
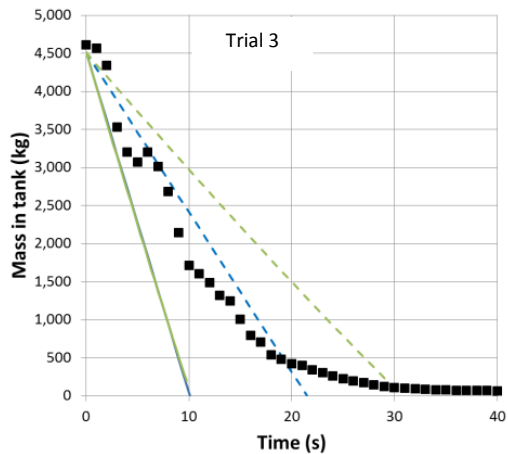
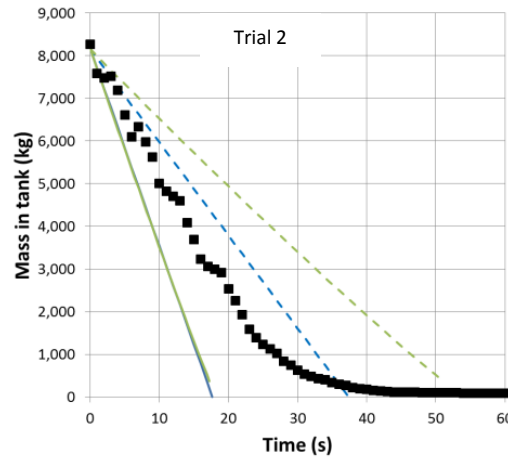
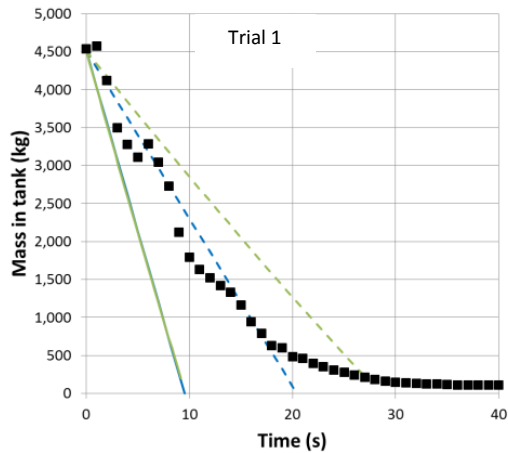
Drift 3.7.2 (ESR Technology)

- STREAM (HSE) was used to model the release rate
- Drift's two-phase jet model was used to predict conditions at impact point with the ground
- Drift's low momentum area source model was used with the finite duration model
- GASP (ESR Technology) was used for pool evaporation and the results combined with Drift for the dispersion studies involving rainout
- Drift accounts for along-wind diffusion and gravity spreading

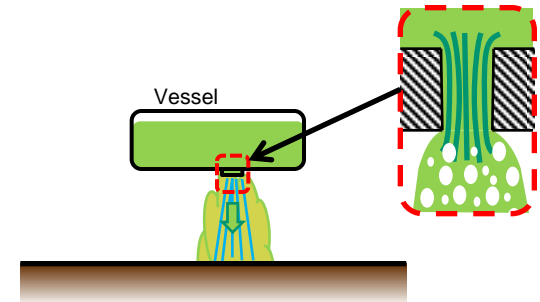
Phast 7.11 (DNV GL)

- Time-varying leak option was used in Phast. This model does not account for along-wind diffusion or gravity spreading. Phast 8.0 will include these effects and is scheduled to be released by the end of this year
- Source modelled as a number of time steps. For each of these release segments, a corresponding dispersion calculation is performed
- Release was angled -90° from the horizontal
- For the rainout cases, Phast uses the default pool evaporation model and accounts for the addition of chlorine vapour from the pool back into the dispersing cloud

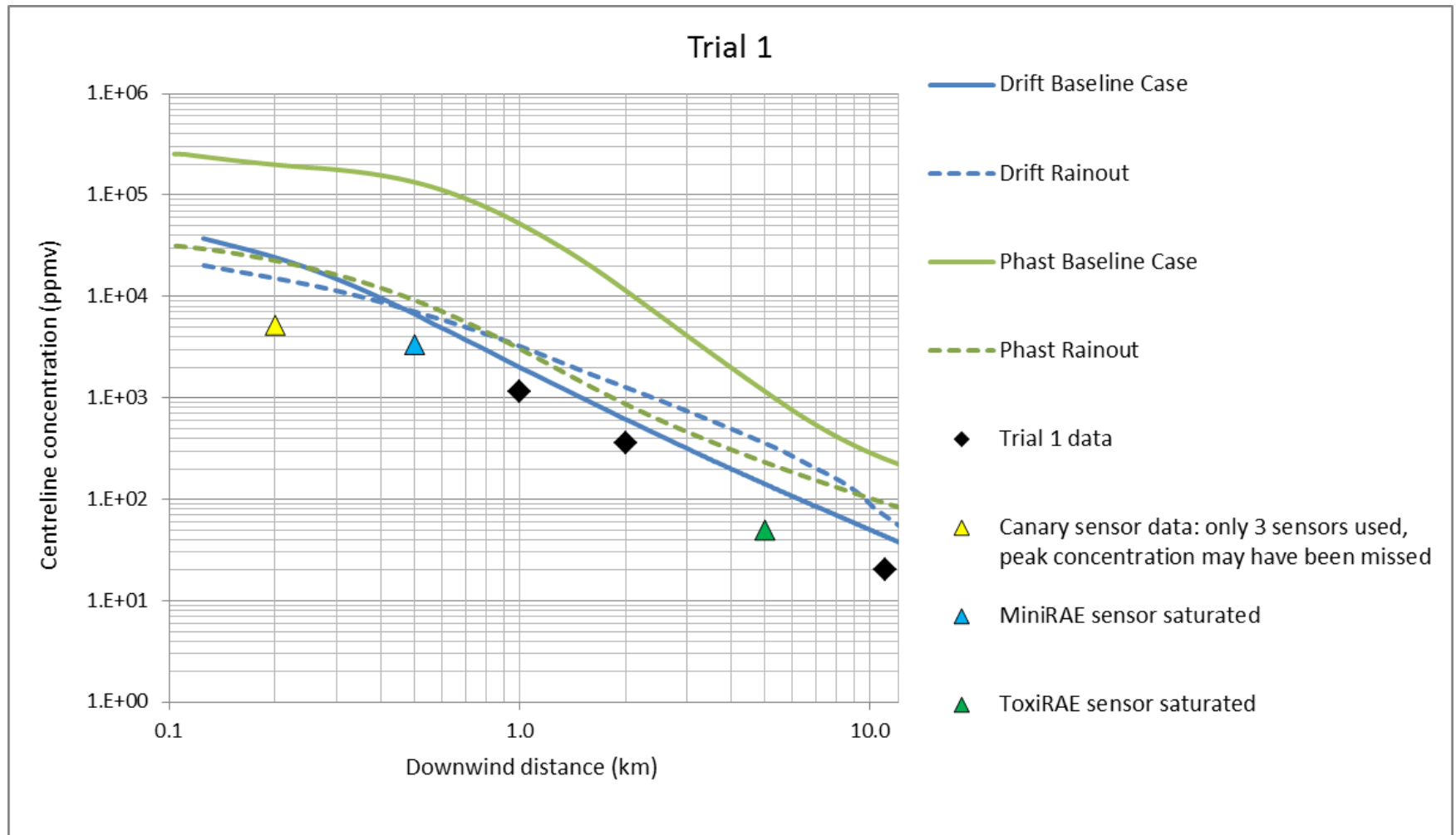
Discharge results



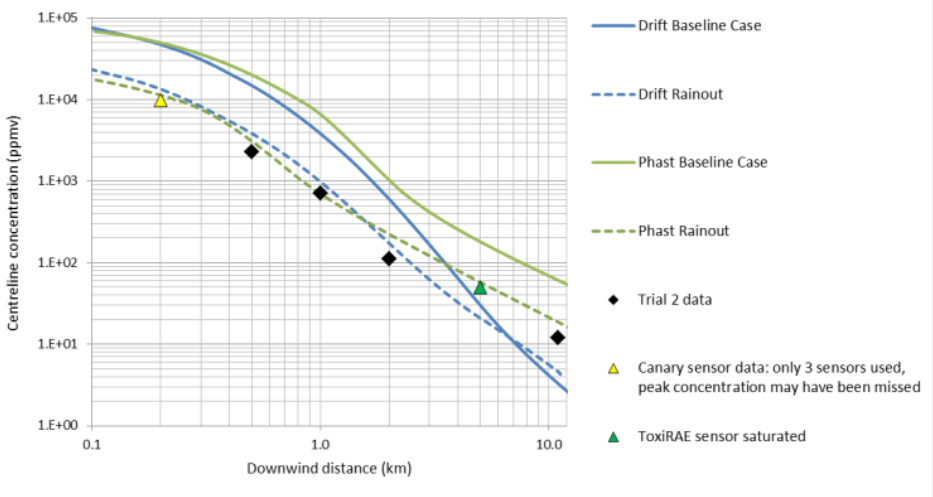
- Stream (metastable liquid) - - Stream (flashing in orifice)
- Phast (metastable liquid) - - Phast (flashing in orifice)
- Experiment



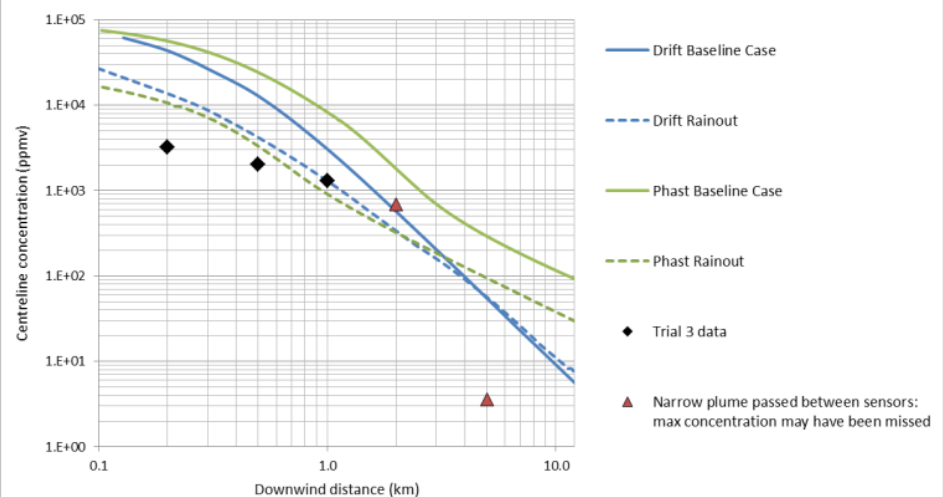
Trial 1: Drift and Phast results



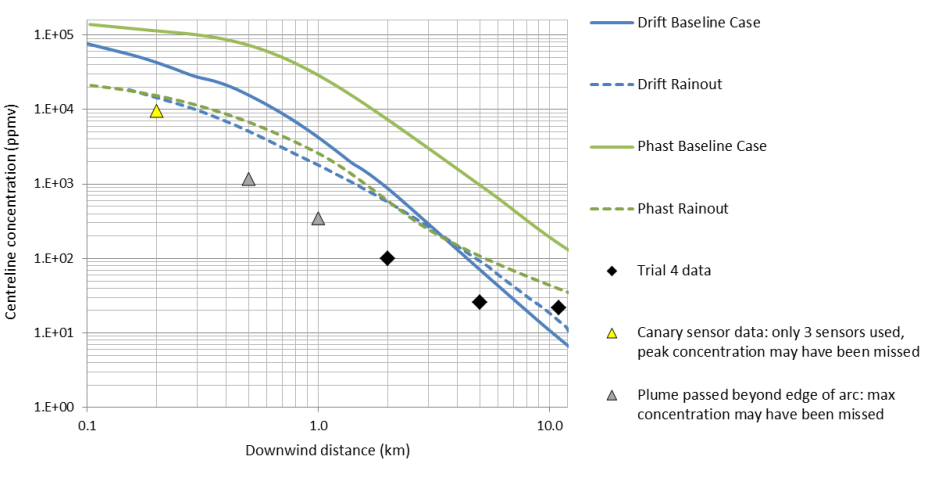
Trial 2



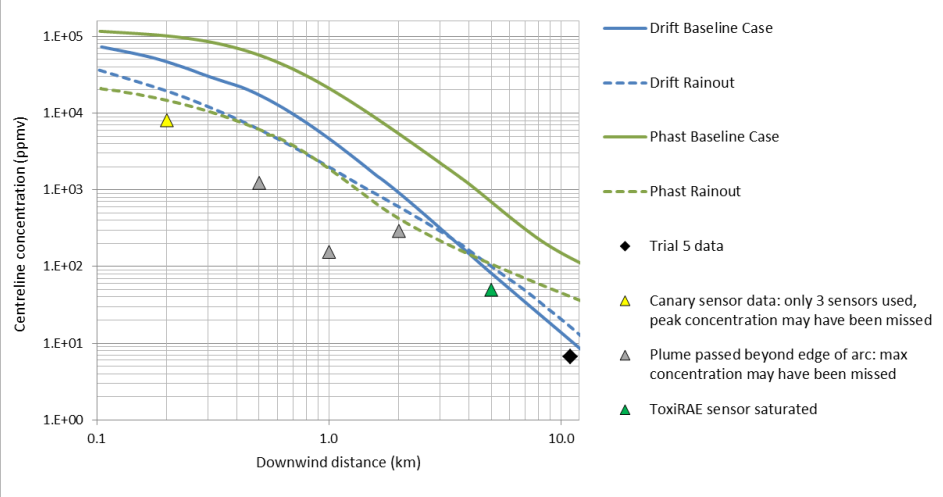
Trial 3



Trial 4



Trial 5



Jack Rabbit II Video

- Jack Rabbit II video courtesy of Utah Valley University (UVU)



- Videos are available to view online:
<https://www.uvu.edu/esa/jackrabbit/>

Summary

- Drift and Phast have both been compared against the Jack Rabbit II Phase 1 trials (2015)
- Sensitivity tests were performed with:
 - (a) a discharge model that allowed flashing in the orifice
 - (b) the liquid impinging upon the ground to rainout
- The rainout simulations predicted concentrations that agreed better with the experimental data
- The above finding is consistent with video footage which showed a pool of liquid chlorine forming
- The experimental data is preliminary

Some of our future planned work includes...

- Similar work is planned to compare models against Jack Rabbit II Phase 2 (2016) experiments
- Compare toxic loads, calculated from the integral of the time-varying measured concentrations
- Wind speed, wind direction and atmospheric stability conditions

Further analysis of weather data required

Conditions changed during the experiments (cloud typically took 1 hour to reach 11 km), whereas models assumed constant conditions

Sensitivity tests currently ongoing

Acknowledgements

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Disclaimer

The experimental data presented in this paper is preliminary, pending further analysis by the Jack Rabbit II Data Quality Working Group.

GT Science & Software contributed towards the work on Drift, and DNV GL Software contributed towards the work on Phast, but the Drift and Phast simulations presented in this paper were performed by HSE and have not been independently checked by the software developers.

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