Appendix 12.4

Application of Chlorine Dispersion Modelling Results in QRA

A12.4-1 APPLICATION OF CHLORINE DISPERSION MODELLING RESULTS IN QRA

This appendix presents the details of how the chlorine dispersion modelling results from the wind tunnel testing, CFD modelling and DRIFT flat terrain dispersion modelling have been applied in the QRA. It complements the discussion in *Section 12.10* of the *Main Report*.

In the wind tunnel testing (*Appendix 12.2*) 36 separate simulations of chlorine releases were undertaken. However in the QRA it is necessary to consider a much large number of possible release scenarios corresponding to various combinations of chlorine release rate/quantity, release location, wind speed, wind direction and atmospheric stability. This appendix describes how the results of the wind tunnel testing, in combination with those from the CFD modelling and DRIFT modelling have been used to generate all the cloud shapes required for the QRA.

The aspects covered are as follows:

- scaling of the wind tunnel results for different chlorine release rates/quantities;
- scaling of the wind tunnel results for different wind speeds;
- simulation of releases at different locations along the site access road;
- interpolation of the wind tunnel results for different wind directions (i.e. the method of 'wind smoothing'); and
- the influence of atmospheric stability on the chlorine hazard range.

Table 1.1 below lists each of the key parameters of interest and details how the results of the various strands of the dispersion modelling work have been applied in the QRA.

Table 1.1 Application of Chlorine Dispersion Modelling Results in QRA

Parameter	Details of Application of Dispersion Modelling Results
1. Chlorine release rate/quantity	The wind tunnel testing considered only a limited range of chlorine release rates/quantities, ie typically one instantaneous release case and one or two continuous release cases per site. However in the DRIFT flat terrain modelling a much greater range of chlorine release rates/quantities was considered (*Appendix 12.1*). From the DRIFT results it is possible to derive a relationship between the chlorine release rate/quantity and the hazard range. These relationships are used to scale the LD contours generated by the wind tunnel according to the release rate/quantity of interest. A method of uniform scaling is used, which is undertaken mathematically within the GIS*Risk* software. This method of scaling is sufficiently accurate provided that the range of extrapolation is not too great and that the topography surrounding the WTW is reasonably flat. For Sha Tin WTW the topography surrounding the WTW is not flat and this introduces potential errors when scaling the wind tunnel results for 1 tonne instantaneous releases up to the largest releases of interest. The method of uniform scaling has therefore been adapted to take into account the effects of the topography. This has been achieved by constraining the cloud to follow the topographic contours (i.e. the LD90 contour is constrained to 50m PD, based on observed behaviour in the wind tunnel), whilst preserving the cloud area. This method of scaling provides a conservative assessment of the number of fatalities arising from the large release cases, as it results in the cloud penetrating into the populated areas around the Hin Keng Estate. For the LD03 and LD50 contours the scaling is achieved by applying the scale factors (in the normal way). Unlike the LD90 contour, the LD03 and LD50 contours are allowed to expand without regard to the local topography. An adjustment is then made to ensure that the contours still fit with the (modified) LD90 contour, i.e. to avoid any discontinuities. The scale factors used in the QRA for Sha Tin WTW are as follows: 1. Continuous releases ('Base case' continuous release: 1.4 kg/s) Event RU1TMML (4.2 kg/s continuous release) Scale factor = 1.8 (from *Appendix 12.1*, *Figure A1*) 2. Instantaneous Releases ('Base case' instantaneous release: 1 tonne) Events EU1TMRU and EU1TMRU1G (instantaneous release) Scale factor = 4.5 for a storage of 190 tons (from *Appendix 12.1,Figure A2*) Scale factor = 4.1 for a storage of 158 tons (from *Appendix 12.1,Figure A2*) Scale factor = 4.0 for a storage of 150 tons (from *Appendix 12.1,Figure A2*)
2. Wind speed	In the wind tunnel testing for each WTW, most simulations were undertaken at a 2m/s wind speed, which is typical of the weather conditions in Hong Kong. However a small number of tests were undertaken at the higher wind speed of 5 m/s, usually for critical wind directions such as towards the nearest population. The results of the 2 m/s and 5 m/s wind tunnel tests have been compared for all sites to determine a simple scaling factor. This scaling factor is then applied to all the 2 m/s LD contours to generate the corresponding 5 m/s contours. The calculated scaling factor is 0.7.

Parameter	Details of Application of Dispersion Modelling Results
3. Release locations	Accidents associated with the transport of chlorine along the site access road may occur at any location along the access road and it is important to take this into account in the QRA. In the wind tunnel testing for each WTW, releases were typically modelled at two locations - the store and one location on the access road. In the QRA however releases are considered to occur at several points along the access road (typically one release location every 50m). The cloud contours for each location are generated by simply translating the clouds generated from the nearer of the two locations modelled in the wind tunnel. For Sha Tin WTW the number of release locations considered for both the existing and alternative access roads is nine (for continuous releases) and four (for instantaneous releases). It is not necessary to consider as many release locations for the instantaneous releases, because the clouds are large and the spatial resolution need not be as great.
4. Wind direction	In the wind tunnel testing for each WTW, up to eight wind directions were simulated for the most important release scenarios (e.g. a 1 tonne instantaneous release). However in the QRA it is necessary to consider a much larger number of possible wind directions, in order to avoid any numerical error in the risk results. The means interpolating between modelled wind directions is called 'wind smoothing'. For the case of flat terrain, wind smoothing can be achieved with sufficient accuracy by the simple method of cloud 'rotation', i.e. rotating adjacent clouds to fill the directional 'gaps' left by the wind tunnel testing (see *8 WTW Project Technical Note 1, ERM, 1998*). The cloud rotation is achieved mathematically within the GIS*Risk* software. For the case of complex terrain, however, it is necessary to ensure that, within the raw wind tunnel data, the effects of nearby topography (including any high rise buildings) are adequately represented, such that further wind smoothing is either not necessary or can be achieved easily using the method of cloud rotation. For Sha Tin WTW it was demonstrated in *Technical Note 1 (see 8 WTW Project Technical Note 1, ERM, 1998)* that sufficient directions had been considered in the original wind tunnel testing, such that further wind smoothing was not necessary. The above discussion applies to the instantaneous chlorine releases at Sha Tin WTW. For the continuous releases on the access road the results from the CFD modelling (1.4 kg/s continuous release case) have been used in the QRA in preference to the wind tunnel results, as explained in *Section 12.10* of the *Main Report*. For this release case wind smoothing has been achieved by simple rotation of the cloud shape from the CFD study for a total of 16 wind directions at each release location on the access road.
5. Atmospheric stability	The CFD modelling for Sha Tin WTW and Tai Po Tau WTW shows that atmospheric stability is not a significant factor influencing the chlorine hazard range, when comparing D (neutral) and F (stable) atmospheric conditions, which are the most important in Hong Kong. Therefore atmospheric stability is not a parameter which is considered in the QRA and the probability of unstable (B) or stable (F) conditions is simply combined with that for D (neutral) conditions.