APPENDIX H7: POOL SPREAD AREAS FOR INSTANTANEOUS TANK FAILURE

H7.1   Introduction

H7.1.1.1 The extent of flow of liquid from a instantaneous tank failure has been assessed based on the physical modelling tests undertaken by HR Wallingford. Physical modelling tests were undertaken at 1/30th scale based on a failure of T-001, with the unzipping scenario being in the direction of SWS. The following tests were conducted for Tank 001:

Test	Description
A	Instantaneous tank removal (100% fill level)
B	Unzipping (100% fill level)
C	Unzipping (80% fill level)
D	Panel failure of 1m high by 10m wide (100% fill level)
E	Panel failure of 1m high by whole perimeter (100% fill level)

H7.1.1.2 The analysis is based on the physical tests, and assessment of likely differences for the other tanks and releases in different directions. This is considered to provide the best basis for the assessment.

H7.1.1.3 Results, in terms of percentages of the initial liquid content of the tank that ended up in different locations, are summarised below. The locations are shown in Figure 10.3.
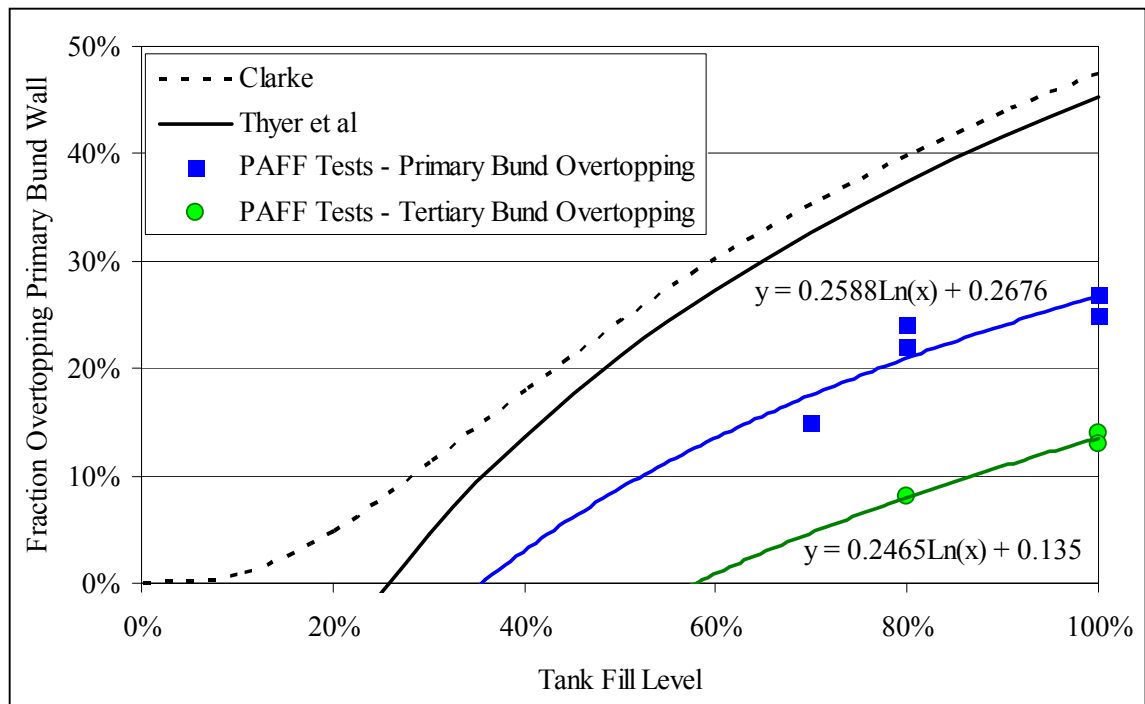
Measured Location[1]	Test	Percentage of Initial Liquid for Test				
		A	B	C	D	E
Retained in primary bund[3]		75	73	78	98	93
Between primary and tertiary wall (Area A)		11	14	14	0	3
Drainage from EVA Road[2]		1	1	1	1	1
Overtopping onto public road & beyond (Area B[2])		5	9	6.7	1	2
Overtopping secondary containment towards Sea (Loc A and Area C)		8	0.5	0.1	0	1
Overtopping step within the SWS building		0	2.5	0.2	0	0
1 Locations are defined in Figure 10.3						
2 Estimate that <2% in Area B is from EVA Road - 1% is assumed here						
3 Two further tests were conducted for 80% fill level with instantaneous tank removal and 70% fill level with unzipping with a slightly different arrangement. These gave 76% and 85% retained in the primary bund respectively, but other results are not relevant.						

H7.1.1.4 Correlations to the bund overtopping fractions have been published elsewhere [84] based primarily on the work of Greenspan and co-workers ([85], [86]) and recent studies [87] have largely confirmed these relationships for simple geometries. Thyer et al. [84] give the following correlation for the bund overtopping fraction Q over vertical bund walls:

$$Q = 0.044 - 0.229 \ln(h/H) - 0.116 \ln(r/H)$$

Where h is the bund wall height, H is the tank liquid height, and r is the distance from the centre of the tank to the bund wall. An alternative correlation due to Clarke is also stated (Q = exp(-3.89h/H)).

H7.1.1.5 For the PAFF tanks, we have h = 4.8m, H = 25.05m (100% fill level of 23.55m plus an additional 1.5m for the tank foundations) and r = 31.75m. Predictions based on these correlations are provided together with the test results in Figure H7.1.

Figure H7.1: Bund Overtopping Estimates For PAFF Tank Configuration

H7.1.1.6 Simple correlations to the test data are provided in Figure H7.1 in the same form as the correlation of Thyer et al. The fractions of the tank contents overtopping the bund wall remain consistent between the instantaneous tank removal and unzipping tests, with the overtopping fractions in the tests for the PAFF configuration consistently about half those of from the Thyer correlations. In part this may be due to the wave wall on the bund and in part due the correlations being for single tank bunds.

H7.1.1.7 An additional correlation is shown for the fraction observed in the tests that overtopped the tertiary containment wall at the PAFF; i.e. the fraction that would flow outside the PAFF boundary. It may be noted that extrapolation of the data suggests that no liquid would overtop the tertiary bund wall for fill levels below ~60%.

H7.1.1.8 At 80% fill level, the fraction of the initial volume overtopping the tertiary wall is estimated at 8%, which is 6.4% of the full 100% fill volume. This compares to 13.5% of the volume for 100% fill level. For the 80% fill level, the predicted volume overtopping onto the road is therefore ~50% of the volume that would overtop in the case of the 100% fill level.

H7.1.1.9 For the assessment of liquid spread outside the PAFF due to an instantaneous failure, we consider 4 cases:

- 90-100% fill level based on tests A and B (100% fill level)

- 60-90% fill level based on 50% of the flow area identified in Test A and the results of Test C (80% fill level) directly for unzipping.

- <60% fill level: confined to the PAFF tertiary bund.

- <35% fill level: confined to the PAFF primary bund.

H7.1.1.10 The last two cases are considered to relate to confined fires rather than fires spreading outside the site.

H7.2 Liquid Spread Outside the PAFF

H7.2.1.1 The extent of liquid spread is based on interpreting the results of the physical model tests undertaken. Results from tests A and B are used to estimate the extent of pool spread for all instantaneous tank failure cases with 90-100% fill level, although clearly they are most applicable to failures of the tanks closest to SWS with failures (for the unzipping case) directed straight at SWS. For 60-90% fill levels, the estimates are based on either scaling the volume released over the tertiary wall (floor seam failure) or the results of Test C for unzipping.

H7.2.1.2 In the final configuration, twelve tanks are intended for the PAFF and unzipping failures are considered for each tank in directions at 45° intervals. 0° is defined as directly towards SWS, as was the case for Test B. Account is taken of the characteristics of the bund wall local to the tank in question as well as the orientation of the unzipping scenario relative to the bund wall. Whilst this involves approximation, the use of a physical model as a basis is considerably beyond what would normally be undertaken in a QRA of this type.

H7.2.2 Instantaneous Tank Removal

H7.2.2.1 The results of Test A showed that the spill outside the PAFF boundary for an instantaneous floor to wall seam failure with 90-100% fill level for Tank 001 would cross the SWS plot boundary and impact on the lorry parking areas and the storage areas within the SWS building. However, it does not lead to liquid overtopping the step within the SWS building. The flow outside the PAFF covered about 12,600 m^2 with the maximum extent reaching around half the distance from the tank to the sea between the PAFF and SWS and approximately in line with the Tank 001 bund wall furthest from the sea.

H7.2.2.2 For the 60-90% fill level cases, the unconstrained flow area is estimated as 50% of the flow area for the 100% fill level case (see H7.1.1.8).

H7.2.2.3 To estimate the potential extent of any release from each of the different tanks, the following rule set is applied:

- Tanks adjacent to SWS (T-01-001, T-01-003, T-01-007, T-01-009). The distance extended towards the SWS site from the centre of tanks closest to the SWS site will be equal to that calculated for Tank 001 from the results of the physical modelling.

For Tank 009, the spill area is multiplied by the ratio of the tank volumes (i.e. assuming the overtopping fractions and depths remain the same).

- Tanks in centre of PAFF (T-01-004, T-01-008). Tanks located centrally in the PAFF are much further from the bund wall than Tank 001 and have tanks between them and the bund wall obscuring much of the potential flow paths. From a review of Test A photographs, looking particularly at the flows around Tank 003, it is clear that any overtopping will be on a much smaller scale than for T-001 in this situation. The extent of the flow from the centre of the source tank is assumed to be equal to that observed in Test A for Tank 001, reducing the extent of the modelled flow over the bund wall by a distance equivalent to the distance between the tank centres.

- Tanks at edge of PAFF away from SWS (T-01-002, T-01-005, T-01-006, T-01-011, T-01-012, T-01-010). For these tanks the release will be predominantly into the EcoPark area. The details of the landscaping, walls, etc. for this area are not known, although there is a clearly identified elevated planting area between Phase I and Phase II of the EcoPark (Figure 2.3a of [10]). Based on the flows identified in the tests, this feature would be expected to prevent flow of Jet A1 into Phase II of the EcoPark. It is assumed that the spill area will be the same as evaluated for Tank 001, but in the corresponding direction of the closest bund wall. For Tank 012, the spill area is multiplied by the ratio of the tank volumes (i.e. assuming the overtopping fractions and depths remain the same).

H7.2.2.4 Broadly, the same spill areas outside the PAFF as for Tank 001, appropriately displaced and rotated, are used for the tanks around the edge of the PAFF, and a smaller spill area is assumed for the two central tanks.

H7.2.3 Unzipping Failures

H7.2.3.1 The results of Test B showed that the spill outside the PAFF boundary for an unzipping failure directed towards the nearest bund wall and SWS with 100% fill level for Tank 001 would cross the SWS plot boundary and impact on the lorry parking areas and the storage areas within the SWS building. It also results in a fraction of the initial tank contents (2.5%, 875 m^3) splashing over the step within the SWS building. The flow outside the PAFF covered about 14,000 m^2 up to the step with the maximum extent reaching around half the distance from the tank to the sea between the PAFF and SWS and about 40m further up the road than the Tank 001 bund wall furthest from the sea.

H7.2.3.2 For the unzipping scenario at 60-90% fill level (Test C), the spread towards the sea is reduced by 10-20m and is reduced to approximately in line with the Tank 001 bund wall furthest from the sea, covering a area outside the PAFF of about 12,000 m^2. The quantity overtopping the step within the SWS building is also reduced to 56 m^3.
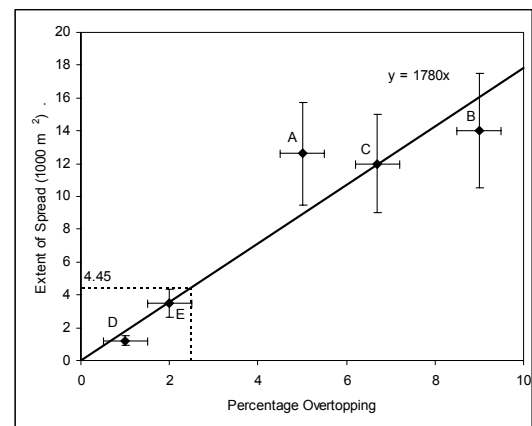
H7.2.3.3 The spread of this flow within the mill building was not modelled in the physical tests, so an approximation is made based on the available information. A review of available photographs of the mill building [21] and information from the site visit to SWS by ESR shows that the area is generally flat concrete with little impediment to flow except for the control building, a cable trench (~0.5m wide) in the floor between the control room and the rolling mill and extensive grated drainage areas around the rolling mill. The level of drainage available is similar or greater than that on the road, and is more distributed along the mill building floor than on the road. The extent of the spreading of

the liquid overtopping the step is therefore estimated based on the other physical model test results for spread on the road.

H7.2.3.4 Physical Model Test E simulates a 1m high failure all the way around the base of the tank. The flow impinges the primary bund wall below the top of the bund level and the fluid spread over the road splashes high over the bund wall. The splashed liquid lands primarily on the road area from above rather than flowing over primary, secondary and tertiary walls. The flow spreads over the flat area of the road which slopes down towards SWS at the far side of the road and back toward the PAFF on the near side of the road. The initial flow is therefore not dissimilar to the flow splashing over the step within the mill building in Test B. In Physical Model Test E, ~2% of the tank contents overtopped onto the road (see H7.1.1.3), which is similar to the quantities overtopping the step within the mill building in Test B (2.5%).

H7.2.3.5 In Test B, the flow overtopping the step was caught within containers for measurement. In reality some of the overtopping flow would be expected to flow back over the step towards the PAFF once the initial overtopping had occurred and this would reduce the total quantity spreading out within the mill. The flow back towards the PAFF in Test E is therefore not dissimilar to the flow that would occur back over the step for the case of interest.

H7.2.3.6 The maximum extent of the flow spread outside the PAFF boundary in Test E covers an area of approximately 3,500 m^2. This is shown adjacent together with the other test results and indicative uncertainties. Based on interpolation between the available results, the estimated flow area for 2.5% of the tank contents is 4,450 m^2. This is taken as the flow area for the liquid that overtops the step within the mill building, rather than relying only on Test E.

H7.2.3.7 In Test B (100% fill), the flow overtops the step in the mill building over a length of approximately 100-120m, The flow area of 4,450 m^2 could therefore be represented as a semicircle of radius 53m or a rectangle of 40-50m across by 90-110m long. Either flow will approximately cover the width of the rolling mill platform within the mill building.

H7.2.3.8 Where the flow is largely unconstrained by the step within the mill building (e.g. when directed into the EcoPark area) the total area is estimated based on the impact area for Test A (largely unconstrained) scaled up to the fraction of the tank volume overtopping onto the road (including that overtopping the step), to give 12,600 m^2 × (9%+2.5%) / 5% = 29,000 m^2 (this is a 57% increase over the flow area when constrained by the step within SWS). For the 60-90% fill case, half this area is taken.

H7.2.3.9 For the 60-90% fill level case (Test C) 0.2% of the tank volume (56 m^3 or 0.16% of the 100% fill volume) overtopped the step within the mill. In this case the estimated spread area is 285 m^2. The overtopping occurs over a front of 90-110m, so represents a spread of only a few metres (approximately 5m allowing for the lip in the physical model). The

overtopping front is therefore considered to be approximately 5m wide and occur over around 100m, with a total area of around 500m^2.

H7.2.3.10 To estimate the potential extent of releases at different angles, the following rules are applied:

- The profile of the release towards the SWS site in Test B has been rotated in 45° intervals and the area coverage approximated. No reduction in overtopping of the bund has been applied, although this is likely for an oblique impact. Only the profile has been rotated, which is expected to be conservative.

- For unzipping scenarios directed inwards from the bund wall, the release is assumed to be contained within the bund.

- Where the flow is in the correct direction to overtop the step within SWS, an additional approximately semi-circular flow over an area of 4,450 m^2 is included unless only part of the flow would overtop the step and the remainder run beyond SWS due to the angle of the failure. In these cases (Tank 001 unzipping at -45° and Tank 007 unzipping at +45°) the area covered above the step is reduced in proportion to the length of the overtopping front estimated.

H7.2.3.11 To provide estimates for all the tanks, the following rules are also applied:

- Tanks closest to SWS (T-01-001, T-01-003, T-01-007, T-01-009). The distance extended towards the SWS site from the centre of tanks closest to the SWS site will be equal to that calculated for Tank 001. For Tank 009, the spill area is multiplied by the ratio of the tank volumes (i.e. assuming the overtopping fractions and depths remain the same).

- Tanks in centre of PAFF (T-01-004, T-01-008). Tanks located centrally in the PAFF are much further from the bund wall than Tank 001 and have tanks between them and the bund wall obscuring much of the potential flow paths. It is expected that any overtopping will be on a much smaller scale than for T-001 in this situation. The extent of the flow from the centre of the source tank is assumed to be equal to that observed in Test A for Tank 001, reducing the extent of the modelled flow over the bund wall by a distance equivalent to the distance between the tank centres.

- Tanks at edge of PAFF away from SWS (T-01-002, T-01-005, T-01-006, T-01-010, T-01-011, T-01-012). For these tanks the release will be predominantly into the EcoPark area. The details of the landscaping, walls, etc. for this area are not known, although there is a clearly identified elevated planting area between Phase I and Phase II of the EcoPark (Figure 2.3a of [10]). Based on the flows identified in the tests, this feature would be expected to prevent flow of Jet A1 into Phase II of the EcoPark. The total area covered by the flow for the 90-100% fill case is taken as 29,000 m^2 (see H7.2.3.8). For the total overtopping volume of 4025 m^3, this gives an average depth of 14 cm, which is considered reasonable allowing for typical elevation changes at kerbs, drainage, etc. For Tank 012, the spill area is multiplied by the ratio of the tank volumes (i.e. assuming the overtopping fractions and depths remain the same). Direction is less important here since a uniform population density and ignition probability is assumed for the EcoPark since the details are not yet available.