THIRD PARTY RISK CONTOURS FOR 2000 AND 2015 MOVEMENTS FOR POSSIBLE RUNWAY CONFIGURATIONS AT FRANKFURT AIRPORT

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1 INTRODUCTION

1.1 This report describes the results of third party risk calculations for Frankfurt Airport. The work was performed by the Department of Analysis and Research (A&R) of National Air Traffic Services (NATS) Ltd under contract to Fraport AG who are the owners and operators of Frankfurt Airport.

1.2 The work is an extension to an initial piece of work done for Fraport AG, which was reported in Reference 1. For the initial piece of work NATS were tasked with calculating the risk to third parties in the vicinity of the airport based on the proposed set of movements for 2015. The data included the movements that would occur on the proposed new runway 07N / 25N, sited to the North West of the present runways. In addition, an assessment was made of the size and shape of the Public Safety Zones (PSZ) that would be applied to each runway if the UK policy were adopted. The UK policy defines a simple geometric shape for the PSZ that contains the 10^{-5} third party risk contour at the end of a runway.

1.3 This follow-up piece of work re-calculates the original scenario (referred to as the "*2015 four runway scenario*") but with slight modifications to the movement numbers, and calculates the third party risk contours for a further two scenarios:

- actual 2000 movements
- proposed 2015 movements assuming that no new runway is built (referred to as the "*2015 three runway scenario*").

1.4 For these three scenarios, only the locations in which third parties would be subject to risks of death greater than 10^{-4} and 10^{-5} were calculated. The 10^{-5} contour is used to determine the size and shape of PSZs in the UK. The risks were assessed by estimating the risk of death per year from aircraft crashes to a nominal individual residing permanently at a particular location. The risks to airline passengers and people whilst working at the airport have not been considered.

1.5 Fraport provided detailed movements for all scenarios. The movements were broken down for each individual runway into the number of landings and take-offs by aircraft type, classifying each movement into one of the following five operations: passenger, cargo, ferry, search & rescue or executive[1]. Some of the search and rescue movements were conducted by helicopters. However, in the UK the third party risk is calculated from crashes only attributable to fixed wing aircraft, so these movements were not included in the calculations. Fraport also provided the co-ordinates of all actual and proposed runway thresholds.

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[1] For the actual movements in 2000, the breakdown contained a further six categories of movements. The movements within the additional classes were assigned to the most closely compatible class from the original five classes.

2 METHODOLOGY FOR INDIVIDUAL RISK CALCULATION

2.1 Individual risk is generally defined in safety literature as the risk of death per year to a representative or specified individual as the result of the realisation of specific hazards. For airport third party risk assessment the risk considered is death as a direct result of an aircraft crash. Individual risk at a particular location in the vicinity of an airport is assessed for a nominal individual who is assumed to reside at that location for 24 hours a day, every day of the year. This clearly results in an overestimate of the risk actually experienced by a real individual, but this approach is consistent with the methods used when assessing third party risk from industrial activities.

2.2 In order to calculate the individual risk at a given location near to an airport, three quantities are needed:

(i) the annual statistical expectation that an aircraft crash occurs in the vicinity of the airport (crash frequency);

(ii) the probability, given that a crash has occurred, that it affects a particular location (crash location model); and

(iii) the size of the area likely to be damaged as a result of a particular crash and the proportion of people in this area likely to be killed (crash consequence model).

2.3 The crash frequency at an airport is determined by the number of aircraft movements that occur and the crash rates of the aircraft performing those movements. Crash rates have been calculated for generic groups of aircraft dependent upon the type of operation they are undertaking.

2.4 Two types of crash location and crash consequence models have been produced by NATS, one for commercial aircraft and one for general aviation (GA) aircraft. Both crash location models were produced from analysing historical crash data. The commercial model consists of four separate mathematical location probability distributions for different types of crashes:

- landing overruns (including veer-offs)
- landing crashes from flight
- take-off overruns (including veer-offs)
- take-off crashes from flight

2.5 The GA model has two probability distributions, one each for take-off and landing crashes. The models for each include both crashes from flight and overruns.

2.6 Two crash consequence models have also been derived from historical crash data, one for commercial aircraft and one for GA. They relate the mean Maximum Take-off Weight Authorised (MTWA) to the destroyed area. It is pessimistically assumed that for a commercial crash all people in the destroyed area would be killed, whereas for a GA crash 30% are assumed to be killed. (This percentage is derived from the ratio of third party injuries to third party fatalities that have occurred on the ground in previous GA crashes.)

2.7 The details of the techniques and data used to create the three model components can be found in Reference 2. The report describes the first version of the model created. Although the techniques used to create the model sub-components have remained the same, the model has been improved on two occasions since the production of this report. The following changes have been made:

- All aircraft crash rates have been changed to include accidents up to and including the year 2000;
- The category of Western Jets Class II-IV has been sub-divided into Class II, Class III and Class IV jets, each with their own appropriate crash rate;
- Separate crash rates have been produced for jet and turboprop aircraft, dependant on whether they conduct passenger or non-passenger operations;
- The probability distributions underlying the commercial crash location models were changed to incorporate additional crash location data;
- A new GA crash location model has been developed by NATS to replace the older AEA model;
- The parameters in the crash consequence model have been changed to include additional crashes;
- A separate GA crash consequence model, for aircraft with a MTWA < 4 tonnes has been added;

2.8 The methodology described above is the same as that used by NATS to determine the sizes and shapes of Public Safety Zones (PSZs) at UK airports for the Department for Transport (DfT) (see Refs 3 and 4). The method has also previously been used to estimate the effects on the risk from aircraft crashes to people living in the vicinity of Heathrow Airport as part of the Terminal 5 Public Inquiry (Ref 5).

2.9 It should be noted that no GA movements are contained in the traffic forecasts for Frankfurt Airport. Therefore, only the commercial crash rate, location and consequence models have been used in calculating the third party risk in the vicinity of the new airport.

3 RESULTS

Model Input Parameters

3.1 The traffic forecasts provided by Fraport have a different forecast traffic mix for each runway in all scenarios. Therefore, the crash frequency and the average destroyed area from a crash were calculated separately for each runway. These input parameters are shown in Tables 1 - 3. In general the size of the crash frequency reflects the number of movements assigned to that runway. However, the crash frequency will be higher than the average for that number of movements, if the proportions of non-passenger movements or proportion of older planes are large. The destroyed area will be relatively small if the mix of aircraft using the runway is lighter than the average as is the case for runway 7N/25N in the 2015 four runway scenario.

3.2 For each scenario, three sets of movements were supplied for runway 18, based upon where the take-off roll was likely to begin. However, as the location of take-off crashes is measured relative to the runway end, not the beginning of the runway, the three sets of movements were combined together.

Crash Location Models

3.3 The probability of a crash occurring at a particular position depends on the type of crash. The distribution of crashes due to landing crashes from flight, landing overruns, take-off crashes from flight and take-off overruns are all different.

3.4 Landing crashes from flight are tightly distributed about the extended runway centre-line, 69% of crashes occurring before the threshold and 31% after. Landing overruns all occur after the runway landing threshold: historically, the location of these crashes reduce in likelihood as one travels away from the runway centre-line and away from the landing threshold.

3.5 Take-off crashes from flight are more widely distributed about the runway centre-line as commercial aircraft usually follow standard departure routes, which deviate from the runway centre-line after only a short distance. 63% of crashes occur after the runway end. The wreckage location from take-off overruns is narrowly distributed about the runway end, 75% located after the threshold, 25% located before it.

3.6 The impact of different crash location models manifests itself in the shape of third party risk contours produced for landing and take-off crashes. If the risk from each were equal, the landing crash contours would be longer and narrower than the take-off crash contours. However, it should be noted that historically 72% of all crashes have been landing crashes, hence for a similar number of landings and take-offs the landing crash contours are always much larger.

Third Party Risk Contours

3.7 Tables 1 - 3 show that the crash frequency and average destroyed area for each runway are different. Consequently, the third party risk associated with each runway was modelled separately. The third party risk at each location was then calculated as the sum of the risk at that point from all the runways modelled in the scenario.

3.8 The approximate lengths of the risk contours for each runway are shown in Tables 4 - 6. Figures 1 – 3 show the calculated third party risk contours (10^{-4} and 10^{-5}) for the airport as a whole.

3.9 Tables 4 - 6 show that the lengths of the risk contours differ for each runway. These differences are caused by the interaction between the various input parameters to the risk model i.e. the crash frequency, average destroyed area and the numbers and direction of the landing/take-off operations on a given runway. This interaction is complex so that only general information can be provided on the size and shape of the contours for the runways in each scenario.

2015 Four Runway Scenario

3.10 On runways 7N/25N and 7R/25L the shape of the risk contours relate mainly to the distribution of landing crashes. The contours are therefore long and narrow. They are longer at the 25 thresholds due to the higher proportion of landings on the 25 runways. The contours are larger for runways 7R/25L compared to 7N/25N as on average heavier planes will use these runways to land. The risk adjacent to both runways is high due to the contribution from those landing overruns that occur off the sides of the runways (i.e. veer-offs).

3.11 On runway 7L/25R the shape of the risk contours relates mainly to the distribution of take-off crashes. The contours are shorter than for the other two parallel runways. There are two factors contributing to this: historically, take-off crashes have occurred less frequently than landing crashes and also take-off crashes have been more broadly dispersed around the extended runway centre-line.

3.12 The risk contours at the southern end of runway 18 are entirely due to the take-offs from this runway. The large quantity of movements results in wide contours.

2015 Three Runway Scenario

3.13 In this scenario runway 18 is again dedicated to departures. Most of the remaining departures occur on runway 25R/7L, with only a few occurring on runway 25L/7R. The landings are relatively evenly split between 25R/7L and 25L/7R.

3.14 The shape of the risk contours on 25L/7R is mainly determined by landing crashes. The crash frequency and average destroyed area for this runway is similar to 25N/7N in the four runway scenario and hence the contours are similar in size and shape.

3.15 Over 30% of the movements on Runway 25R/7L are departures, in addition to a similar number of landings as 25L/7R. Consequently, there is a significant contribution to the risk from take-off crashes. This has the effect of making the contours wider than if the risk were all due to landing crashes. Although there are more movements on 25R/7L than on 25L/7R, due to the mix of the aircraft on these runways the crash frequency for both runways is similar. However, the aircraft on 25R/7L are much heavier, so the contours are considerably longer.

3.16 There are only 3 runways available, hence the number of departures on runway 18 is higher than for the four runway scenario. Consequently, although the contours on runway 18 are of a similar shape, they are longer in the three runway scenario compared to the four runway scenario.

Actual Movements 2000

3.17 The concept of operation in 2000 is similar to the future proposed concept in 2015 if no additional runway is built. In general, the aircraft operating in 2015 will be of a more modern design, with on average lower crash rates. Additionally on the parallel runways in 2015, there is predicted to be a reduction in large aircraft conducting non-passenger operations, which have on average higher crash rates and larger consequence areas. Consequently, the risk contours for the parallel runways in 2000 are longer than those proposed for the 2015 three runway scenario, although of a similar shape.

3.18 In 2000 there were fewer departures on runway 18 than proposed for the 2015 three runway scenario, and these planes had a lower average weight. Hence, the risk contours are shorter in 2000 compared to 2015.

4 THIRD PARTY RISK AND PSZ POLICY

4.1 In the UK, areas that will be subject to a third party risk of greater than 10^{-5} per year in 2015 have been designated PSZs. To aid planning, the area of each PSZ is based on a simple geometrical shape. The shapes are usually elongated isosceles triangles but can be slightly, "modified," triangles (pentagons formed by pinching inwards the two longer sides of the triangle). The dimensions of these shapes are determined by the smallest area that encloses the majority of the 10^{-5} third party risk contour. The bases of the shapes are on the landing threshold for each end of the runway and taper away along the extended runway centre-line. Inside the PSZ new or replacement developments are prevented. The control of development within PSZs in the UK is described in Reference 6.

4.2 For each of the airport runways, where the third party risk behind the landing threshold is greater than 10^{-5}, a PSZ based on the UK criteria has been proposed[2]. Each PSZ is a "modified" triangle shape. The dimensions of the PSZs are shown in Tables 7 - 9. The length L1 represents the overall length of the shape from the runway threshold to the vertex of the "triangle". The width W1 represents the widest dimension of the shape, which is the base perpendicular to the runway. The length L2 is the distance from the runway threshold to the point at which the pentagon is pinched inwards; the

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[2] For example, 25N PSZ encloses the 10^{-5} risk contour *behind* the 25N landing threshold. The PSZ at the southern end of runway 18 has been artificially designated as being behind runway "36", as there is no runway 36 in operation at Frankfurt.

width W2 is the width of the shape at this point. Figure 5 illustrates these dimensions relative to a nominal PSZ.

4.3 It should be noted that due to the configuration of the runways at Frankfurt (i.e. closely spaced parallel runways etc) there are areas off the end of the runways where the risk is greater than 10^{-5} but which are not in the suggested PSZs. In view of this the proposed shapes may not be the most suitable for Frankfurt airport.

5 SUMMARY

5.1 Third party risk contours have been calculated for the proposed movements for three operational scenarios at Frankfurt airport. None of the scenarios contain runways where the third party risk of death exceed a value of 10^{-5} per year at a distance of further than 6 km from the runway ends; in addition no PSZ exceeds 6km in length.

5.2 The longest 10^{-5} third party risk contours occur on the parallel runways for the 2000 movements. If no new runway is built, it is predicted that by 2015 the contours will become shorter on the parallel runways. Further reductions in the length of the contours is predicted if a new runway is built.

5.3 For a new fourth runway the 10^{-5} contour is a length of 4km for runway 25N and a length of 2.6 km for runway 7N. The length of the corresponding recommended PSZs are 4.1 km and 2.9 km respectively. This is shorter than the corresponding contours for the dominant existing landing runway in all scenarios.

References:

1 Wilson E and Bullock A: Third Party Risk Contours For Proposed 2015 Movements at Frankfurt Airport: SAPT 0313: May 2003

2 Department for Transport: Third Party Risk Near Airports and Public Safety Zone Policy: October 1997

3 Kent D and Mason S: Individual Risk Contours as a Method for Determining Public Safety Zones at UK Airports: National Air Traffic Services Limited, R&D Report 0101: February 2001.

4 Wilson E and Bullock A: Update to Individual Risk Contours Used to Determine Public Safety Zones at UK Airports: National Air Traffic Services Limited, R&D Report 0215: August 2002.

5 Foot PB et al: Third Party Risk in the Vicinity of Heathrow Airport: R&D Report 9805: March 1998.

6 Control of Development in Airport Public Safety Zones: Department for Transport Circular 1/2002: July 2002.

TABLE 1
CRASH FREQUENCIES AND DESTROYED AREAS – 2015 FOUR RUNWAY SCENARIO

Runway	Landings	Take-offs	Landing Crash Frequency (y^{-1})	Take-Off Crash Frequency (y^{-1})	Destroyed Area (m^2)
7N	43,362	0	0.0106	0	3,594
25N	122,862	0	0.0299	0	3,594
7L	3,569	39,704	0.0008	0.0033	5,842
25R	9,661	113,316	0.0021	0.0095	5,842
7R	39,971	3,537	0.0103	0.0004	6,032
25L	108,743	9,691	0.0281	0.0010	6,032
18	0	161,919	0	0.0190	4,328

TABLE 2
CRASH FREQUENCIES AND DESTROYED AREAS – 2015 THREE RUNWAY SCENARIO

Runway	Landings	Take-offs	Landing Crash Frequency (y^{-1})	Take-Off Crash Frequency (y^{-1})	Destroyed Area (m^2)
7L	34,165	16,225	0.0087	0.0016	6,995
25R	96,381	43,041	0.0244	0.0042	6,995
7R	31,043	2,585	0.0097	0.0003	3,212
25L	87,573	7,299	0.0272	0.0009	3,212
18	0	180,011	0	0.0217	5,338

TABLE 3
CRASH FREQUENCIES AND DESTROYED AREAS – 2000 SCENARIO

Runway	Landings	Take-offs	Landing Crash Frequency (y^{-1})	Take-Off Crash Frequency (y^{-1})	Destroyed Area (m^2)
7L	31,579	24,910	0.0118	0.0036	5,409
25R	88,592	60,808	0.0331	0.0088	5,409
7R	29,102	1,661	0.0146	0.0003	3,954
25L	80,899	6,978	0.0405	0.0014	3,954
18	0	134,205	0	0.0194	4,194

TABLE 4

LENGTHS OF THIRD PARTY RISK CONTOURS – 2015 FOUR RUNWAY SCENARIO

Behind Runway Threshold	Approximate Length of Third Party Risk Contours From Runway Thresholds (m)	
	10^{-4}	10^{-5}
07N	460	2570
25N	715	4040
07L	655	1690
25R	380	1350
07R	465	2980
25L	880	4990
(36)	780	1930

TABLE 5

LENGTHS OF THIRD PARTY RISK CONTOURS – 2015 THREE RUNWAY SCENARIO

Behind Runway Threshold	Approximate Length of Third Party Risk Contours From Runway Thresholds (m)	
	10^{-4}	10^{-5}
07L	655	3290
25R	895	5200
07R	255	1825
25L	550	3415
(36)	850	2385

TABLE 6

LENGTHS OF THIRD PARTY RISK CONTOURS – 2000 SCENARIO

Behind Runway Threshold	Approximate Length of Third Party Risk Contours From Runway Thresholds (m)	
	10^{-4}	10^{-5}
07L	810	3800
25R	1035	5680
07R	490	2920
25L	930	5020
(36)	805	1890

TABLE 7
DIMENSIONS OF SUGGESTED PUBLIC SAFETY ZONES – 2015 FOUR RUNWAY SCENARIO #

Behind Runway Threshold	Overall Length (L1) of modified triangle/ metres	Length (L2) from Base to 'flared' point/ metres	Width (W1) at base of triangle/ metres	Width (W2) at 'flared' point/ metres	Total Area of modified triangle (Hectares)
07N	2880	940	230	140	31.4
25N	4100	1200	340	180	57.3
07L	1800	255	440	330	34.7
25R	1500	225	315	240	21.5
07R	3340	1150	310	155	43.7
25L	5700	1840	480	200	101.2
(36)*	2000	720	500	215	39.5

TABLE 8
DIMENSIONS OF SUGGESTED PUBLIC SAFETY ZONES - 2015 THREE RUNWAY SCENARIO #

Behind Runway Threshold	Overall Length (L1) of modified triangle/ metres	Length (L2) from Base to 'flared' point/ metres	Width (W1) at base of triangle/ metres	Width (W2) at 'flared' point/ metres	Total Area of modified triangle (Hectares)
07L	3540	1140	375	180	53.2
25R	5480	1620	560	240	111.1
07R	2175	925	220	130	24.3
25L	3960	1300	280	170	51.9
(36)*	2460	1005	600	220	57.2

Assuming the UK policy was adopted

* Runway (36) indicates southern end of runway 18.

TABLE 9

DIMENSIONS OF SUGGESTED PUBLIC SAFETY ZONES – 2000 SCENARIO#

Behind Runway Threshold	Overall Length (L1) of modified triangle/ metres	Length (L2) from Base to 'flared' point/ metres	Width (W1) at base of triangle/ metres	Width (W2) at 'flared' point/ metres	Total Area of modified triangle (Hectares)
07L	3915	1380	450	180	66.3
25R	5850	1950	550	225	119.4
07R	3350	1140	300	150	42.2
25L	5550	2225	450	175	98.6
(36)*	1950	720	495	210	38.3

Assuming the UK policy was adopted

* Runway (36) indicates southern end of runway 18.

Figure 1 FRANKFURT 2015 FOUR RUNWAY SCENARIO

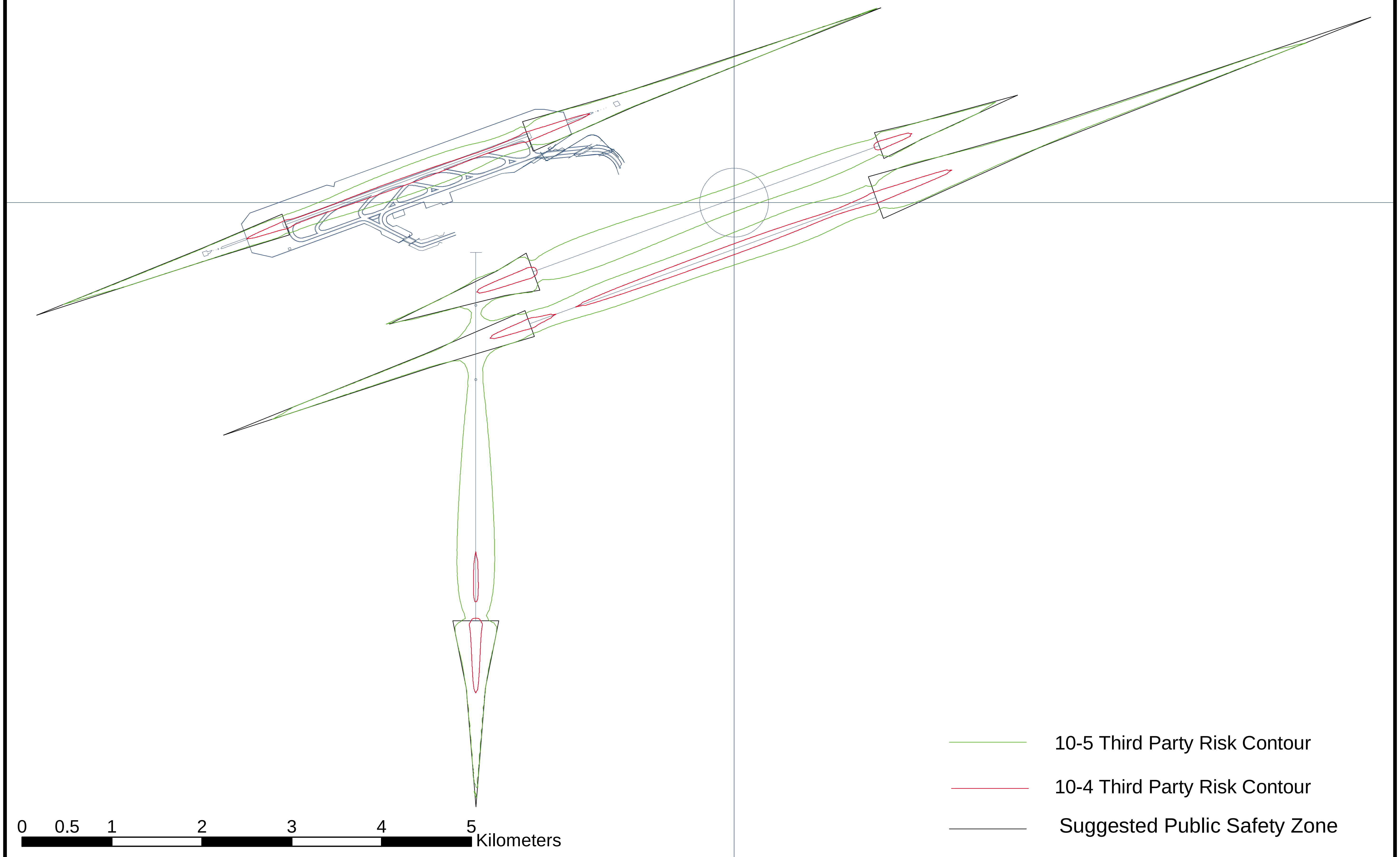

Figure 2 FRANKFURT 2015 THREE RUNWAY SCENARIO

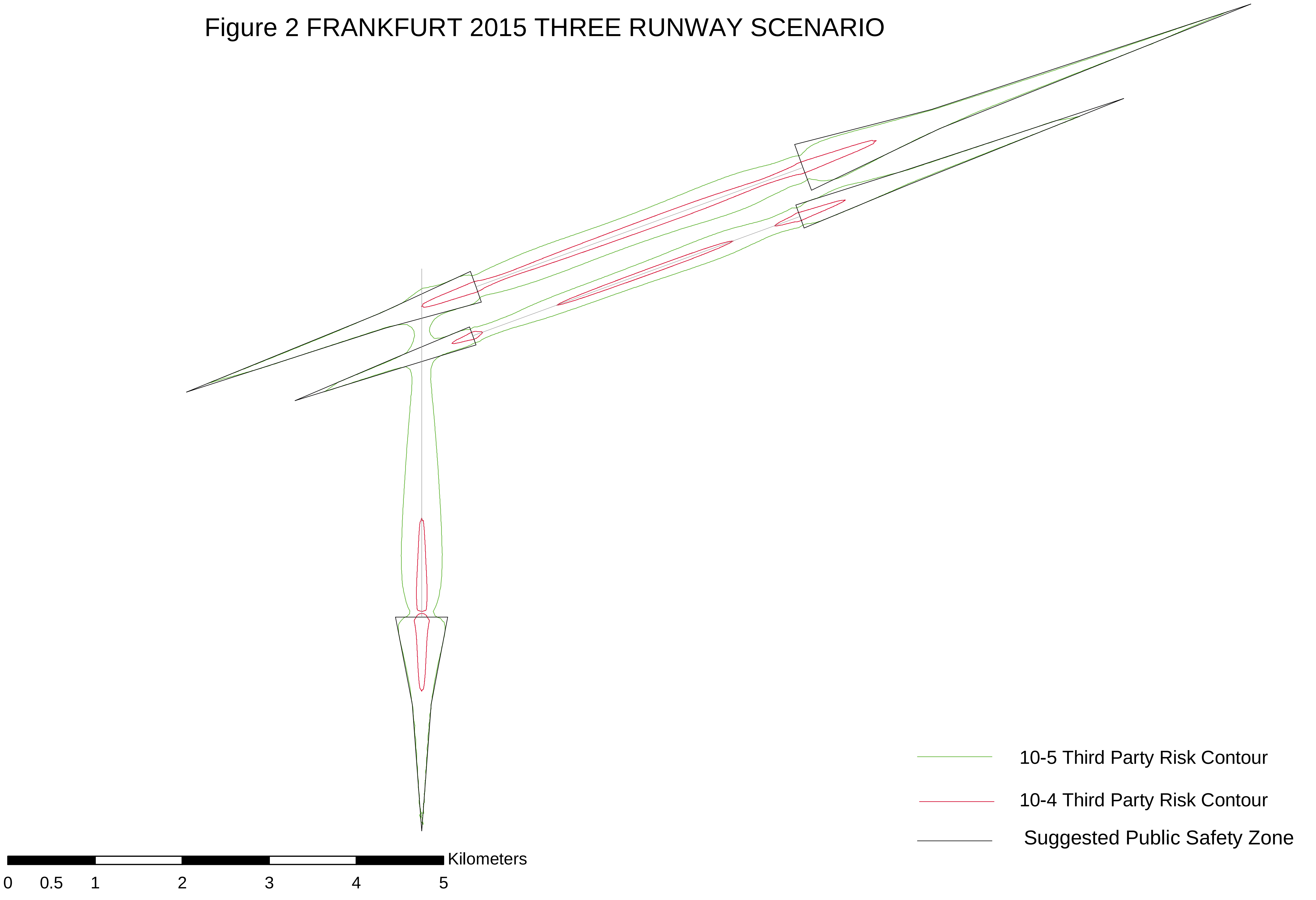

Figure 3 FRANKFURT ACTUAL MOVEMENTS 2000

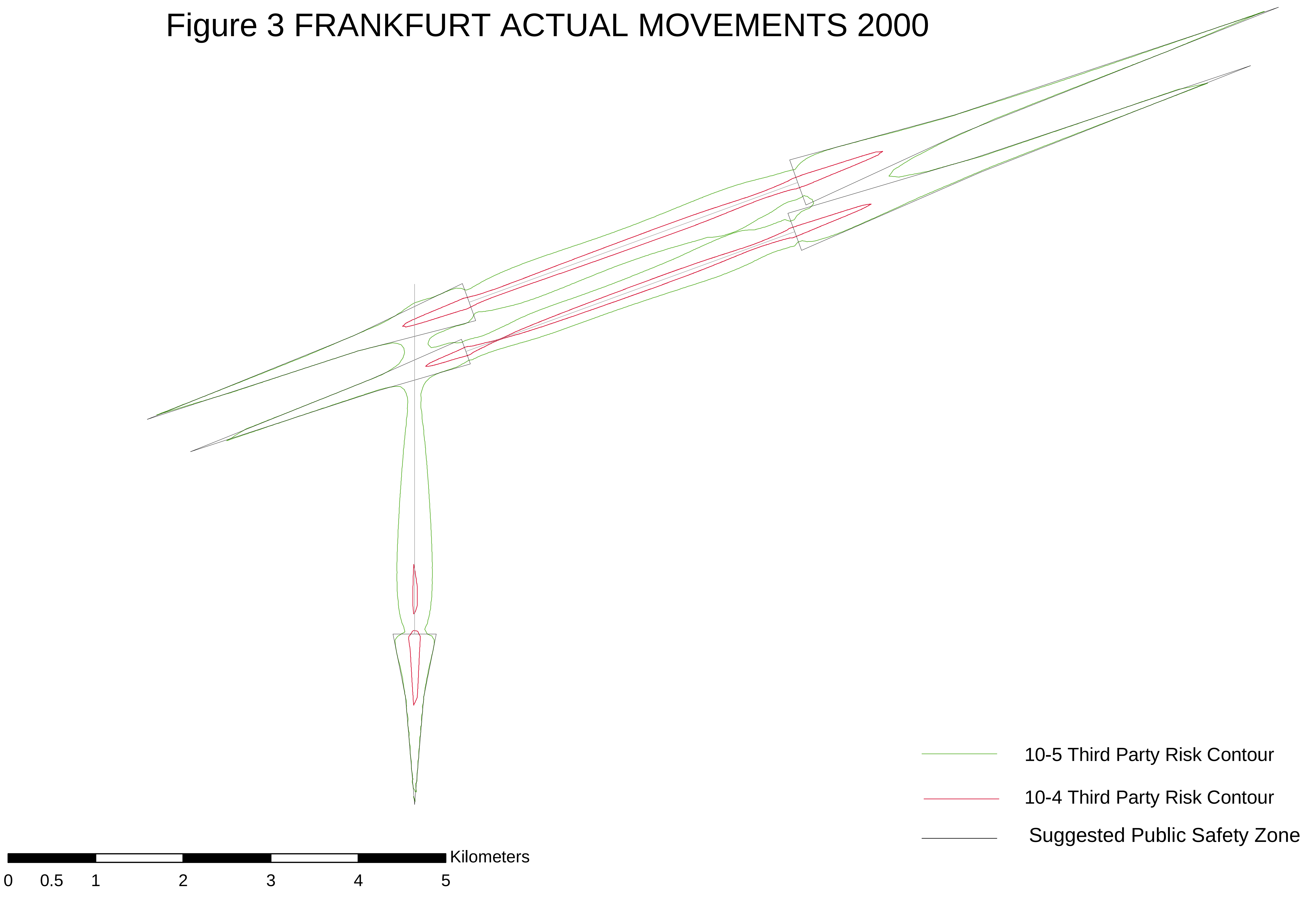

Figure 4 Example of a 'Slightly Modified' Triangular PSZ