APPENDIX 8.2

Description of the AERMOD Model

The AERMOD (version 18081) dispersion model has been developed, in part, by the U.S. Environmental Protection Agency (USEPA)(3). The model is a steady-state Gaussian model used to assess pollutant concentrations associated with industrial sources. The model is an enhancement on the Industrial Source Complex-Short Term 3 (ISCST3) model which has been widely used for emissions from industrial sources. The Guidelines on Air Quality Models has promulgated AERMOD as the preferred model for a refined analysis from industrial sources, in all terrains(1).

Improvements over the ISCST3 model include the treatment of the vertical distribution of concentration within the plume. ISCST3 assumes a Gaussian distribution in both the horizontal and vertical direction under all weather conditions. AERMOD, however, treats the vertical distribution as non-Gaussian under convective (unstable) conditions while maintaining a Gaussian distribution in both the horizontal and vertical direction during stable conditions. This treatment reflects the fact that the plume is skewed upwards under convective conditions due to the greater intensity of turbulence above the plume than below. The result is a more accurate portrayal of actual conditions using the AERMOD model. AERMOD also enhances the turbulence of night-time urban boundary layers thus simulating the influence of the urban heat island.

In contrast to ISCST3, AERMOD is widely applicable in all types of terrain. Differentiation of the simple versus complex terrain is unnecessary with AERMOD. In complex terrain, AERMOD employs the dividing-streamline concept in a simplified simulation of the effects of plume-terrain interactions. In the dividing-streamline concept, flow below this height remains horizontal, and flow above this height tends to rise up and over terrain. Extensive validation studies have found that AERMOD performs better than ISCST3 for many applications and as well or better than CTDMPLUS for several complex terrain data sets(3)

AERMOD has made substantial improvements in the area of plume growth rates in comparison to ISCST3(3). ISCST3 approximates turbulence using six Pasquill-Gifford-Turner Stability Classes and bases the resulting dispersion curves upon surface release experiments. This treatment, however, cannot explicitly account for turbulence in the formulation. AERMOD is based on the more realistic modern planetary boundary layer (PBL) theory which allows turbulence to vary with height. This use of turbulence-based plume growth with height leads to a substantial advancement over the ISCST3 treatment.

Improvements have also been made in relation to mixing height(3). The treatment of mixing height by ISCST3 is based on a single morning upper air sounding each day. AERMOD, however, calculates mixing height on an hourly basis based on the morning upper air sounding and the surface energy balance, accounting for the solar radiation, cloud cover, reflectivity of the ground and the latent heat due to evaporation from the ground cover. This more advanced formulation provides a more realistic sequence of the diurnal mixing height changes.

AERMOD also contains improved algorithms for dealing with low wind speed (near calm) conditions. As a result, AERMOD can produce model estimates for conditions when the wind speed may be less than 1 m/s, but still greater than the instrument threshold.

AERMET

AERMOD incorporates a meteorological pre-processor AERMET[36]. AERMET allows AERMOD to account for changes in the plume behaviour with height. AERMET calculates hourly boundary layer parameters for use by AERMOD, including friction velocity, Monin-Obukhov length, convective velocity scale, convective (CBL) and stable boundary layer (SBL) height and surface heat flux. AERMOD uses this information to calculate concentrations in a manner that accounts for changes in dispersion rate with height, allows for a non-Gaussian plume in convective conditions, and accounts for a dispersion rate that is a continuous function of meteorology.

The AERMET meteorological preprocessor requires the input of surface characteristics, including surface roughness (z_0), Bowen Ratio and albedo by sector and season, as well as hourly observations of wind speed, wind direction, cloud cover, and temperature. A morning sounding from a representative upper air station, latitude, longitude, time zone, and wind speed threshold are also required.

Two files are produced by AERMET for input to the AERMOD dispersion model. The surface file contains observed and calculated surface variables, one record per hour. The profile file contains the observations made at each level of a meteorological tower, if available, or the one-level observations taken from other representative data, one record level per hour.

From the surface characteristics (i.e. surface roughness, albedo and amount of moisture available (Bowen Ratio)) AERMET calculates several boundary layer parameters that are important in the evolution of the boundary layer, which, in turn, influences the dispersion of pollutants. These parameters include the surface friction velocity, which is a measure of the vertical transport of horizontal momentum; the sensible heat flux, which is the vertical transport of heat to/from the surface; the Monin-Obukhov length which is a stability parameter relating the surface friction velocity to the sensible heat flux; the daytime mixed layer height; the nocturnal surface layer height and the convective velocity scale which combines the daytime mixed layer height and the sensible heat flux. These parameters all depend on the underlying surface.

The values of albedo, Bowen Ratio and surface roughness depend on land-use type (e.g., urban, cultivated land etc) and vary with seasons and wind direction. The assessment of appropriate land-use type was carried out to a distance of 10km from the location of the meteorological station in line with USEPA recommendations[4-6] for albedo and Bowen ratio with a 1km geometric determination undertaken for the surface roughness. In relation to wind direction, a minimum sector arc of 30 degrees is recommended. In the current model, the surface characteristics of Cork Airport were assessed and two sectors identified with distinctly varying land use characteristics.

Surface roughness

Surface roughness length is the height above the ground at which the wind speed goes to zero. Surface roughness length is defined by the individual elements on the landscape such as trees and buildings. In order to determine surface roughness length, the USEPA recommends that a representative length be defined for each sector, based on an upwind area-weighted average of the land use within the sector, by using the eight land use categories outlined by the USEPA. The inverse-distance weighted surface roughness length derived from the land use classification within a radius of 1km from Cork Airport Meteorological Station is shown in Table A8.81.

Table A8.81 Surface Roughness based on an inverse distance weighted average of the land use within a 1km radius of Cork Airport Meteorological Station.

Sector	Area Weighted Land Use Classification	Spring	Summer	Autumn	Winter Note 1
350-50	60% Urban, 40% Grassland	0.213	0.305	0.093	0.093
50-350	100% Grassland	0.050	0.100	0.010	0.010

(1) Winter defined as periods when surfaces covered permanently by snow whereas autumn is defined as periods when freezing conditions are common, deciduous trees are leafless and no snow is present (Iqbal (1983))[(4)]. Thus for the current location autumn more accurately defines "winter" conditions in Ireland.

Albedo

Noon-time albedo is the fraction of the incoming solar radiation that is reflected from the ground when the sun is directly overhead. Albedo is used in calculating the hourly net heat balance at the surface for calculating hourly values of Monin-Obuklov length. A 10km x 10km square area is drawn around the meteorological station to determine the albedo based on a simple average for the land use types within the area independent of both distance from the station and the near-field sector. The classification within 10km from Cork Airport Meteorological Station is shown in Table A8.82.

Table A8.82 Albedo based on a simple average of the land use within a 10km × 10km grid centred on Cork Airport Meteorological Station.

Area Weighted Land Use Classification	Spring	Summer	Autumn	Winter Note 1
19% Urban, 81% Grassland	0.17	0.18	0.20	0.20

(1) For the current location autumn more accurately defines "winter" conditions in Ireland.

Bowen Ratio

The Bowen ratio is a measure of the amount of moisture at the surface of the earth. The presence of moisture affects the heat balance resulting from evaporative cooling which, in turn, affects the Monin-Obukhov length which is used in the formulation of the boundary layer. A 10km x 10km square area is drawn around the meteorological station to determine the Bowen Ratio based on geometric mean of the land use types within the area independent of both distance from the station and the near-field sector. The classification within 10km from Cork Airport Meteorological Station is shown in Table A8.83.

Table A8.83 Bowen Ratio based on a geometric mean of the land use within a 10km × 10km grid centered on Cork Airport Meteorological Station.

Area Weighted Land Use Classification	Spring	Summer	Autumn	Winter Note 1
19% Urban, 81% Grassland	0.47	0.95	1.14	1.14

(1) For the current location autumn more accurately defines "winter" conditions in Ireland.

Detailed Meteorological Data – Cork Airport 2014 - 2018

Cork Airport 2014

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	34	38	168	46	12	0	298
22.5	20	32	81	9	0	0	142
45.0	30	43	70	18	1	0	162
67.5	37	26	58	21	1	0	143
90.0	52	74	185	131	43	2	487
112.5	49	58	119	93	23	8	350
135.0	39	45	115	70	20	20	309
157.5	35	82	152	91	34	32	426
180.0	109	150	333	272	79	20	963
202.5	88	103	251	213	122	46	823
225.0	60	134	551	239	103	43	1,130
247.5	45	89	350	194	61	14	753
270.0	52	148	351	271	91	39	952
292.5	51	109	255	166	18	7	606
315.0	41	90	318	257	31	0	737
337.5	36	66	173	141	16	3	435
Total	778	1,287	3,530	2,232	655	234	8,716
Calms							44
Missing							0
Total							8,760

Cork Airport 2015

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	32	40	155	47	0	0	274
22.5	10	24	104	12	0	0	150
45.0	24	23	102	3	0	0	152
67.5	22	21	83	24	0	0	150
90.0	51	94	174	111	24	0	454
112.5	49	96	141	67	14	1	368
135.0	26	58	149	144	36	13	426
157.5	36	59	159	145	49	22	470
180.0	54	90	253	231	80	47	755
202.5	44	83	249	279	158	146	959
225.0	47	102	507	375	129	72	1,232
247.5	33	83	337	251	76	31	811
270.0	46	99	240	283	101	23	792
292.5	34	65	234	177	52	9	571
315.0	33	96	301	204	32	15	681
337.5	19	84	244	137	7	2	493
Total	560	1,117	3,432	2,490	758	381	8,738
Calms							22
Missing							0
Total							8,760

Cork Airport 2016

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	24	31	167	85	17	1	325
22.5	24	35	104	46	1	0	210
45.0	19	47	109	33	1	0	209
67.5	27	36	84	34	9	0	190
90.0	57	98	258	213	31	14	671
112.5	42	71	182	72	14	7	388
135.0	32	45	138	48	34	16	313
157.5	33	79	119	69	32	2	334
180.0	79	128	246	204	107	15	779
202.5	85	106	318	210	88	31	838
225.0	51	131	557	262	84	22	1,107
247.5	46	98	352	201	69	18	784
270.0	65	144	330	207	52	11	809
292.5	45	137	248	190	31	14	665
315.0	36	78	283	176	38	7	618
337.5	31	56	182	188	54	2	513
Total	696	1,320	3,677	2,238	662	160	8,753
Calms							31
Missing							0
Total							8,784

Cork Airport 2017

Dir \ Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	22	25	85	88	24	0	244
22.5	13	17	22	27	8	0	87
45.0	14	23	31	19	12	0	99
67.5	18	16	18	33	2	2	89
90.0	39	73	137	82	54	15	400
112.5	29	58	84	38	9	3	221
135.0	29	35	92	54	36	17	263
157.5	45	72	178	113	55	40	503
180.0	91	108	287	272	50	7	815
202.5	78	109	352	236	106	23	904
225.0	63	164	678	355	55	15	1,330
247.5	57	134	372	243	49	4	859
270.0	70	125	373	289	71	22	950
292.5	54	126	325	181	50	27	763
315.0	46	125	333	180	59	18	761
337.5	47	64	186	121	22	4	444
Total	715	1,274	3,553	2,331	662	197	8,732
Calms							28
Missing							0
Total							8,760