

**Health and Safety Executive  
Nuclear Directorate**

**LAND USE PLANNING AND  
THE SITING OF NUCLEAR INSTALLATIONS  
IN THE UNITED KINGDOM**

A note by the Health & Safety Executive's (HSE) Nuclear Installations Inspectorate (NII) , describing the basis for its advice on demographics in relation to developments around existing nuclear licensed sites, and on the siting of proposed nuclear installations

## Summary

Since the start of the civil nuclear power programme in the 1960s, the government has applied a policy of siting new nuclear power plants in areas where the population density does not exceed certain thresholds, and where the growth of that population can be monitored and controlled. This is done by means of land use planning policies which require local planning authorities to carefully consider the impact of new developments within 'consultation zones' around each nuclear site. The aim was to avoid the population around the station steadily rising to an undesirable level. The policy and its application is now extended to all nuclear installations.

The UK Government's policy on the siting of nuclear power stations was, in the 1960's, based on the advice and recommendations of its Nuclear Safety Advisory Committee. Responsibility for the implementation of this policy was vested in the Nuclear Installations Inspectorate (NII), who developed methods and criteria on which advice could be provided in relation to the siting of new nuclear plants, and subsequently on the control of population around such site after they had begun operation.

This note describes HSE's current approach to providing advice in relation to the population distribution (or 'demographics') near to proposed or existing nuclear sites. This is particularly pertinent at the moment with the growth of interest in the siting of new nuclear power stations and the note explains how HSE's advice has informed the Government's Strategic Siting Assessment process. The main part of this note is descriptive and is intended to be of interest to non-technical readers. Two annexes provide more technical detail and a worked example which will be of interest to those with a more technical background.

## **A Note on Land Use Planning and the Siting of Nuclear Installations in the United Kingdom**

### **Background**

HSE's regulation of UK health and safety laws require that the Nuclear Site Licensees operate their nuclear installations in such a way that risks to employees and to the general public are as low as reasonably practicable (ALARP). HSE applies a range of regulatory procedures, including inspection and assessment to make judgements about the licensee's compliance with the law, through their safety cases and licensing conditions which are benchmarked against international requirements and standards. Although Licensees put in place arrangements to demonstrate compliance with legal controls to ensure that the chances of an accident leading to the release of radioactivity into the environment are very low, the risk of such an accident cannot be eliminated. Measures, to reduce the chance of a release, and control any that occur are based on the reliability and control systems for complex plant and equipment, which is supported by operator procedures. Additionally, emergency preparedness and response arrangements are put in place to minimise and mitigate the health consequences of any significant radiological release that might occur. Emergency arrangements cover the actions to be taken by the local emergency authorities and services, to assist and protect people living in the vicinity of the nuclear installation. The key objective is to ensure that all these planned actions would operate effectively during the course of a potential accident and the subsequent recovery phase. Emergency planning arrangements are regularly practised and tested, with the efficiency and effectiveness of response being related to the assumptions made about population density and controls.

For that reason, since the start of the civil nuclear power programme in the 1960s, the government has applied a policy of siting new nuclear power plants in areas where the population density does not exceed certain thresholds, and where the growth of that population can be monitored and controlled. This is done by means of land use planning policies which require local councils to carefully consider the impact of new developments within 'consultation zones' around each nuclear site. The aim was to avoid the population around the station steadily rising to an undesirable level. This policy has been reinforced at public inquiries in the 1980s for the development of the Sizewell B and proposed Hinkley Point C power stations. Consultation criteria are in place around all licensed nuclear sites with arrangements for planning authorities to consult NII about planning applications (details can be found at:

<http://www.hse.gov.uk/landuseplanning/nuclear.htm> )

### **NII's Approach to Demographic Assessment**

In 2008, the Nuclear Installations Inspectorate (NII) produced a paper to the then Health & Safety Commission's Nuclear Safety Advisory Committee (NuSAC) <sup>(9&10)</sup>. The aim was to refresh and update the published demographic criteria for the siting of nuclear installations in the UK, not least to inform UK Government policy on the suitability of sites for proposed new power stations, in terms of their compatibility with surrounding distribution of populations (known as demographics). NII's suggested method for assessing demographics in

relation to siting new installations is based on international best practice and guidelines, including those produced by the International Atomic Energy Agency (IAEA) and the NII's Safety Assessment Principles (SAPs)<sup>8</sup> for Nuclear Facilities. These approaches seek to limit the scale of harmful effects of radiation in the remote chance of an accident at a nuclear facility by limiting the number of people living and working in the vicinity. The approach also acknowledges that new nuclear 'power stations' will be designed and constructed to engineering standards that have been developed from international operating experience over the last 50 years and are therefore expected to be safer than those existing power stations which are nearing the end of operation.

### **Demographics and Advice to Local Planning Authorities about new development in the vicinity of nuclear installations**

The NuSAC paper also reinforced the basis of the method for assessing the significance of population growth arising from new developments in the vicinity of existing nuclear installations. As stated above controls over development have been in place for many years and seek to preserve the desirable population characteristics from the time a nuclear installation is first licensed, and throughout its operating life. NII is consulted by Local Planning Authorities (LPAs) and provides advice about certain types of development before the LPA decides on planning permission. NII's advice takes into account the significance of any increase in population and impact on the capability of local emergency arrangements.

### **Strategic Siting Assessment (SSA) for new Nuclear Power Stations**

The Government's proposed approach to the assessment and decision making process on the potential suitability of sites for new nuclear power stations will take into account a number of social, environmental and operational factors. Further details about the Government's SSA process can be found at the web site of the Department of Energy and Climate Change (DECC) <http://www.nuclearpowersiting.decc.gov.uk/nominations/>

### **SSA Criteria & those for Demographic Assessment**

One of the SSA criteria places a restriction on the local population density and distribution which if exceeded will categorically exclude a site from further consideration. For the purpose of the Strategic Siting Assessment SSA, the Government has decided to adopt an established "semi urban" siting criteria as an 'exclusionary' limit. Because of NII's expertise and experience in demographic analysis, DECC asked NII to undertake an assessment of the sites nominated as part of the SSA process against the "semi-urban" criteria. In this assessment, should areas of a nominated site exceed the semi-urban criteria the Government would consider further advice from the regulators to see whether the site remains viable. Such flexibility is possible, because at the stage of nuclear licensing it would be stipulated that the nuclear island, ie those elements which have a direct potential to cause radiological hazard would be in the area of the site which does not exceed the semi-urban criteria.

Furthermore this assessment process is independent of any knowledge about the design of the nuclear reactor; the only purpose is to determine whether a

proposed site should be excluded, because the near site population density is too high. The semi-urban 'limiting criterion' derives from cumulative weighted populations present in a given area (ie population density – or number of people per square kilometre). A weighting factor is attached to take account of the reduction in radiation dose, with distance from a possible accident situation. The population is measured out to various radial distances all around the nominated site, and in any 30 degree sector, then compared to constraint limits. Technical details of the basis for the demographics assessment are given in Annex 1. A worked example is given in Annex 2.

### **New Nuclear Power Stations - Site Specific Assessment**

If a nominated site meets the Strategic Siting Assessment criteria then it may be included in the Government's Nuclear National Policy Statement. Developers wishing to construct a power station on one of those sites must obtain a site licence from NII. As part of its licensing assessment, NII will undertake a more detailed consideration of viability of the site on the basis of the risk to persons off the site presented by the proposed reactor design. That risk will be compared with risk targets contained within NII's Safety Assessment Principles (SAPs)<sup>8</sup>.

### **Control of Future Population at Developments around Nuclear Sites**

The recently published Nuclear National Policy Statement from the Department of Energy and Climate Change (DECC) restates the Government's longstanding policy regarding local demographics which would limit the radiological consequences to the public in the unlikely event of an accident involving the spread of radioactive materials beyond the site boundary. This policy is a measure of prudence over and above the stringent regulatory requirements imposed on nuclear operators to prevent such accidents. The Health and safety Executive, through the Nuclear Installations Inspectorate administers the Government's policy on the control of population around existing licensed nuclear sites. Planning Authorities take this advice into account in considering whether or not to approve planning applications. Furthermore once a new power station receives planning consent, and a nuclear site license, arrangements will be put in place with Local Planning Authorities and Nuclear Site Licensees, which place constraints on development around nuclear sites. These constraints are designed to control residential, industrial and commercial developments. The aim is to preserve the general characteristics of the area around the nuclear site throughout its lifecycle, and to ensure that the basis on which the site is licensed is not undermined.

## **ANNEX 1: Technical Basis for HSE's Demographics Assessments**

### **Historical Approach to Demographic Assessment**

The early approach for considering demographic siting criteria in the UK was developed from the work of Charlesworth and Gronow<sup>(7)</sup>, and was based on a consideration of the dispersion characteristics of the generalized Gaussian Plume Model for estimating the dispersion of a prolonged, accidental release of radioactive material. This approach was developed in a series of papers by the Health & Safety Commission's Advisory Committee on the Safety of Nuclear Installations (ACSNI) from 1978 to 1988, leading to the definition of a "semi-urban" siting criterion which was described in a ministerial statement to Parliament in March 1988. Further details are provided in NuSAC P12 (2008)<sup>9</sup> and its Addendum (2008)<sup>10</sup> which includes the historical development of demographic siting criteria.

### **Approach for Generic Screening Demographic Assessment**

The current approach considers the population in the vicinity of an installation which is compared with standard reference population distributions. A Generic Site Population Factor (SPF)<sup>11</sup> is calculated based on the maximum of the actual weighted population density around the site divided by the reference weighted population density. The absolute value of the Generic SPF provides a simple indication of the relative risks associated with different sites, based on an assessment of 30 degree sectors, and also the total population all around the site. In both cases, the cumulative weighted populations are considered for each radial distance band out to 30 km. Sector rotations of 5 degree intervals ie 72 distinct sectors, is used to identify the most densely populated 30 degree sector.

On the basis of HSE's advice the Government has decided that if a SPF for any location proposed new site exceeds the semi-urban demographic siting criteria previously used for Advanced Gas-Cooled Reactors (AGRs), then the local population density is too high to permit the siting of a nuclear power station at that location. This led to the adoption of an Exclusionary Criterion, in the Government's Strategic Siting Assessment process, based on the 'semi-urban' criterion. It is emphasised that the generic SPF does not take into account any features of the design of any particular type of station, but simply gives a measure of the population density in the vicinity. Whilst this provides a useful measure for comparing sites, and for providing an initial assessment, the actual risks associated with any particular station will be site specific, and will depend on the extent to which the installation meets the relevant targets in the Safety Assessment Principles, which would be considered by NII during the process of nuclear site licensing.

## ANNEX 2: Example Calculation of Generic Site Population Factor (SPF) for a Particular Site

### A1 Introduction

This appendix provides a fully worked example illustrating the calculation of the generic SPF for a particular site. This applies to any potential source of release of radioactive material from within the nominated site boundary, and is taken as the origin for the polar grid. The worked example is based on a hypothetical power station located 'close' to urban populations, although it is emphasised that the numerical analysis (described in References 9 and 10) has been somewhat simplified for ease of presentation in this document.

### A2 Step by Step Example

The main steps in the calculation of the generic SPF are illustrated in Tables A1 to A4 and are summarised below. Each table considers the population in each of the twelve 30° sectors, and the total for all around the site. The values in bold below can be traced through the tables.

Table A1 shows the population distribution around the site in terms of 1 km radial bands out to 30 km and in each 30° sector. For example, the total population between 2 and 3 km in the sector bearing 30° to 60° from the site is **4945**, and the total population in the 2-3 km radial band is **5410**.

Table A2 shows the weighted population, where the data in Table A1 has been multiplied by a weighting factor of  $1/r^{1.5}$ , (see Note 1) where  $r$  has been taken as the average of the inner and outer radial distances for that band. For example, the 2-3 km 30°-60° weighted population is  $4945/2.5^{1.5} = 1251.0$ , and the total weighted population in the 2-3 km radial band is  $5410/2.5^{1.5} = 1368.6$ .

*(Note1: this inverse power law is derived from the dispersion coefficients used in the classical Gaussian Plume Model used to estimate the concentration of radionuclides, and hence effective 'per capita' radiation dose at a given distance from the source of an accidental release)*

Table A3 shows the cumulative weighted population out to each radial band, which is simply the sum total of all the weighted populations out to that radial band. For example, the cumulative weighted population in 30°-60° sector out to 3 km is  $0 + 1224.2 + 1251.0 = 2475.2$ , and the total cumulative weighted population out to 3 km is **3148.1**.

Table A4 shows the results of dividing this cumulative weighted population by the relevant sector or site cumulative limit. The cumulative sector limits for a particular radial distance (R) are calculated as the cumulative weighted population associated with a uniform population density of 1667 persons per square km (see note 2) for all radii up to 30km.

$$\text{Cumulative sector limit} = \int_{r=1}^{r=R} \frac{1667}{r^{1.5}} \frac{2\pi r dr}{12} = \frac{1667\pi}{3} (R^{0.5} - 1)$$

Hence, the cumulative sector limit out to 3 km is  $1667\pi(3^{0.5} - 1)/3 = 1277.9$

The cumulative *site* limits for a particular radial distance (R) are calculated as the cumulative weighted population associated with a uniform population density of 417 persons per square km from 1 to R km over all sectors all around the site. This can be calculated analytically as:

$$\text{Cumulative site limit} = \int_{r=1}^{r=R} \frac{417}{r^{1.5}} 2 \pi r dr = 1668 \pi (R^{0.5} - 1)$$

Hence, the cumulative *site* limit out to 3 km is  $1668\pi(3^{0.5} - 1) = \mathbf{3836.1}$

( *Note 2: these population limits approximate to 1000 people per square mile all around the site*)

The ratio of the cumulative weighted population for the 30°-60° sector out to 3 km to the cumulative *sector* limit out to 3 km is therefore  $2475.2/1277.9 = \mathbf{1.937}$ . Inspection of Table A4 shows that this is the largest ratio for any of the twelve sectors for any radial distance.

Similarly, the ratio of the *total* cumulative weighted population out to 3 km to the cumulative *site* limit out to 3 km is therefore  $3148.1/3836.1 = \mathbf{0.821}$ . Inspection of Table A4 shows that this is the largest ratio for any radial distance.

The generic SPF is defined as the maximum of the sector or site ratios, and so in this example the generic SPF is **1.937** based on the cumulative weighted population out to 3 km in the 30°-60° sector.

### **A3 Further Refinement of Calculations**

As previously noted, the calculations described above have been somewhat simplified for the purposes of this example. More accurate calculations may need to take into account a number of additional refinements, as outlined below.

- 1) The example above did not include any population within 1 km of the site. If there is any such population, then it should be included in the analysis and included in the various cumulative totals. However, it is noted that the cumulative site and sector limits are theoretically zero at 1 km, the boundary of the assumed generic exclusion zone.
- 2) The example above was based on residential population data from the National Population Database (NPD)<sup>14</sup>. This data is regularly updated and so the raw population data in Table A1 above may be somewhat out of date. Any detailed analysis should use the latest available and most accurate population data.
- 3) In some cases, the residential population data may not provide a complete representation of the population at risk, and so it may also be necessary to take account of additional populations in the vicinity of the site, such as industrial/workplace populations, schools, transport routes, and transient populations.



**Table A1 - Population Distribution**

	0°-30°	30°-60°	60°-90°	90°-120°	120°-150°	150°-180°	180°-210°	210°-240°	240°-270°	270°-300°	300°-330°	330°-360°	All around site
0-1km	0	0	0	0	0	0	0	0	0	0	0	0	0
1-2km	18	2249	955	45	2	0	0	0	0	0	0	0	3269
2-3km	7	<b>4945</b>	17	421	13	7	0	0	0	0	0	0	<b>5410</b>
3-4km	611	3942	2	355	6	0	0	0	0	0	0	0	4916
4-5km	574	8154	19	578	57	0	0	0	0	0	0	0	9382
5-6km	0	8840	2	3	340	0	0	0	0	0	0	0	9185
6-7km	0	10744	4136	82	46	3	0	0	0	0	0	0	15011
7-8km	0	6160	13993	845	69	3	0	0	0	0	0	0	21070
8-9km	0	177	22131	4127	76	0	0	0	0	0	0	0	26511
9-10km	0	2609	3258	1306	243	31	18	0	0	0	0	0	7465
10-11km	0	1442	77	113	180	139	203	0	0	0	0	0	2154
11-12km	0	1808	1286	167	427	719	1903	0	0	0	0	0	6310
12-13km	0	1395	925	82	760	277	3407	0	0	0	0	0	6846
13-14km	0	2012	985	430	423	93	4332	2619	0	0	0	0	10894
14-15km	0	3613	1515	46	533	89	3020	7082	0	0	0	0	15898
15-16km	43	1959	234	31	766	34	2173	6132	0	0	0	199	11571
16-17km	1053	1509	134	20	4076	553	1515	1621	0	105	338	2884	13808
17-18km	1659	161	78	75	1630	202	15580	0	0	419	389	1232	21425
18-19km	1920	525	141	12	556	506	16687	0	0	7	730	519	21603
19-20km	1891	339	37	12	1732	2921	12130	0	0	513	1255	474	21304
20-21km	1171	208	610	6	78	239	14743	0	0	5182	7020	573	29830
21-22km	1135	1264	479	3	187	1266	16721	0	0	14310	11218	1246	47829
22-23km	345	1210	82	0	205	1143	13814	0	0	16252	11923	216	45190
23-24km	1082	593	151	0	197	376	19454	0	0	9469	3801	239	35362
24-25km	1677	194	189	8	172	860	15157	0	0	3267	130	868	22522
25-26km	600	407	126	14	205	862	19221	0	0	494	3162	716	25807
26-27km	391	485	662	19	286	3337	20557	0	0	0	475	550	26762
27-28km	939	271	364	120	1635	8897	15071	0	0	0	248	474	28019
28-29km	806	1709	2516	52	1195	4423	14981	0	0	0	532	378	26592
29-30km	1335	445	233	23	1439	19490	3907	0	0	0	680	79	27631
<b>Total</b>	<b>17257</b>	<b>69369</b>	<b>55337</b>	<b>8995</b>	<b>17534</b>	<b>46470</b>	<b>214594</b>	<b>17454</b>	<b>0</b>	<b>50018</b>	<b>41901</b>	<b>10647</b>	<b>549576</b>

**Table A2 - Weighted Population**

	0°-30°	30°-60°	60°-90°	90°-120°	120°-150°	150°-180°	180°-210°	210°-240°	240°-270°	270°-300°	300°-330°	330°-360°	All around site	Weighting factor
0-1km	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.828
1-2km	9.8	1224.2	519.8	24.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1779.4	0.544
2-3km	1.8	<b>1251.0</b>	4.3	106.5	3.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	<b>1368.6</b>	0.253
3-4km	93.3	602.0	0.3	54.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	750.8	0.153
4-5km	60.1	854.2	2.0	60.5	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	982.8	0.105
5-6km	0.0	685.3	0.2	0.2	26.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	712.1	0.078
6-7km	0.0	648.3	249.6	4.9	2.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	905.8	0.060
7-8km	0.0	299.9	681.3	41.1	3.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1025.8	0.049
8-9km	0.0	7.1	893.0	166.5	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1069.8	0.040
9-10km	0.0	89.1	111.3	44.6	8.3	1.1	0.6	0.0	0.0	0.0	0.0	0.0	254.9	0.034
10-11km	0.0	42.4	2.3	3.3	5.3	4.1	6.0	0.0	0.0	0.0	0.0	0.0	63.3	0.029
11-12km	0.0	46.4	33.0	4.3	10.9	18.4	48.8	0.0	0.0	0.0	0.0	0.0	161.8	0.026
12-13km	0.0	31.6	20.9	1.9	17.2	6.3	77.1	0.0	0.0	0.0	0.0	0.0	154.9	0.023
13-14km	0.0	40.6	19.9	8.7	8.5	1.9	87.3	52.8	0.0	0.0	0.0	0.0	219.6	0.020
14-15km	0.0	65.4	27.4	0.8	9.7	1.6	54.7	128.3	0.0	0.0	0.0	0.0	287.9	0.018
15-16km	0.7	32.1	3.8	0.5	12.6	0.6	35.6	100.5	0.0	0.0	0.0	3.3	189.6	0.016
16-17km	15.7	22.5	2.0	0.3	60.8	8.3	22.6	24.2	0.0	1.6	5.0	43.0	206.0	0.015
17-18km	22.7	2.2	1.1	1.0	22.3	2.8	212.8	0.0	0.0	5.7	5.3	16.8	292.7	0.014
18-19km	24.1	6.6	1.8	0.2	7.0	6.4	209.7	0.0	0.0	0.1	9.2	6.5	271.5	0.013
19-20km	22.0	3.9	0.4	0.1	20.1	33.9	140.9	0.0	0.0	6.0	14.6	5.5	247.4	0.012
20-21km	12.6	2.2	6.6	0.1	0.8	2.6	158.8	0.0	0.0	55.8	75.6	6.2	321.4	0.011
21-22km	11.4	12.7	4.8	0.0	1.9	12.7	167.7	0.0	0.0	143.5	112.5	12.5	479.8	0.010
22-23km	3.2	11.3	0.8	0.0	1.9	10.7	129.4	0.0	0.0	152.3	111.7	2.0	423.4	0.009
23-24km	9.5	5.2	1.3	0.0	1.7	3.3	170.8	0.0	0.0	83.1	33.4	2.1	310.4	0.009
24-25km	13.8	1.6	1.6	0.1	1.4	7.1	125.0	0.0	0.0	26.9	1.1	7.2	185.7	0.008
25-26km	4.7	3.2	1.0	0.1	1.6	6.7	149.3	0.0	0.0	3.8	24.6	5.6	200.4	0.008
26-27km	2.9	3.6	4.9	0.1	2.1	24.5	150.7	0.0	0.0	0.0	3.5	4.0	196.2	0.007
27-28km	6.5	1.9	2.5	0.8	11.3	61.7	104.5	0.0	0.0	0.0	1.7	3.3	194.3	0.007
28-29km	5.3	11.2	16.5	0.3	7.9	29.1	98.5	0.0	0.0	0.0	3.5	2.5	174.8	0.007
29-30km	8.3	2.8	1.5	0.1	9.0	121.6	24.4	0.0	0.0	0.0	4.2	0.5	172.5	0.006
<b>Total</b>	<b>328.4</b>	<b>6010.6</b>	<b>2615.7</b>	<b>526.0</b>	<b>269.1</b>	<b>367.2</b>	<b>2175.2</b>	<b>305.7</b>	<b>0.0</b>	<b>478.9</b>	<b>405.9</b>	<b>121.0</b>	<b>13603.7</b>	

**Table A3 - Cumulative Weighted Population**

	0°-30°	30°-60°	60°-90°	90°-120°	120°-150°	150°-180°	180°-210°	210°-240°	240°-270°	270°-300°	300°-330°	330°-360°	All around site
0-1km	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-2km	9.8	1224.2	519.8	24.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1779.4
2-3km	11.6	<b>2475.2</b>	524.1	131.0	4.4	1.8	0.0	0.0	0.0	0.0	0.0	0.0	<b>3148.1</b>
3-4km	104.9	3077.2	524.4	185.2	5.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	3898.8
4-5km	165.0	3931.4	526.4	245.8	11.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	4881.7
5-6km	165.0	4616.8	526.6	246.0	37.6	1.8	0.0	0.0	0.0	0.0	0.0	0.0	5593.7
6-7km	165.0	5265.1	776.2	250.9	40.4	2.0	0.0	0.0	0.0	0.0	0.0	0.0	6499.6
7-8km	165.0	5565.0	1457.4	292.1	43.8	2.1	0.0	0.0	0.0	0.0	0.0	0.0	7525.4
8-9km	165.0	5572.1	2350.5	458.6	46.8	2.1	0.0	0.0	0.0	0.0	0.0	0.0	8595.2
9-10km	165.0	5661.2	2461.7	503.2	55.1	3.2	0.6	0.0	0.0	0.0	0.0	0.0	8850.1
10-11km	165.0	5703.6	2464.0	506.5	60.4	7.2	6.6	0.0	0.0	0.0	0.0	0.0	8913.4
11-12km	165.0	5750.0	2497.0	510.8	71.4	25.7	55.4	0.0	0.0	0.0	0.0	0.0	9075.2
12-13km	165.0	5781.5	2517.9	512.7	88.6	31.9	132.5	0.0	0.0	0.0	0.0	0.0	9230.1
13-14km	165.0	5822.1	2537.8	521.4	97.1	33.8	219.8	52.8	0.0	0.0	0.0	0.0	9449.8
14-15km	165.0	5887.5	2565.2	522.2	106.7	35.4	274.5	181.1	0.0	0.0	0.0	0.0	9737.7
15-16km	165.7	5919.6	2569.0	522.7	119.3	36.0	310.1	281.5	0.0	0.0	0.0	3.3	9927.3
16-17km	181.4	5942.2	2571.0	523.0	180.1	44.2	332.7	305.7	0.0	1.6	5.0	46.3	10133.3
17-18km	204.1	5944.4	2572.1	524.0	202.4	47.0	545.5	305.7	0.0	7.3	10.4	63.1	10426.0
18-19km	228.2	5951.0	2573.9	524.2	209.4	53.4	755.2	305.7	0.0	7.4	19.5	69.6	10697.5
19-20km	250.2	5954.9	2574.3	524.3	229.5	87.3	896.1	305.7	0.0	13.3	34.1	75.1	10944.9
20-21km	262.8	5957.1	2580.9	524.4	230.3	89.9	1054.9	305.7	0.0	69.2	109.7	81.3	11266.3
21-22km	274.2	5969.8	2585.7	524.4	232.2	102.6	1222.7	305.7	0.0	212.7	222.3	93.8	11746.0
22-23km	277.4	5981.1	2586.5	524.4	234.1	113.3	1352.1	305.7	0.0	365.0	334.0	95.8	12169.5
23-24km	286.9	5986.4	2587.8	524.4	235.8	116.6	1522.9	305.7	0.0	448.1	367.3	97.9	12479.9
24-25km	300.7	5988.0	2589.3	524.5	237.3	123.7	1647.9	305.7	0.0	475.0	368.4	105.1	12665.6
25-26km	305.4	5991.1	2590.3	524.6	238.9	130.4	1797.1	305.7	0.0	478.9	393.0	110.7	12866.0
26-27km	308.3	5994.7	2595.2	524.7	240.9	154.8	1947.8	305.7	0.0	478.9	396.5	114.7	13062.2
27-28km	314.8	5996.5	2597.7	525.5	252.3	216.5	2052.3	305.7	0.0	478.9	398.2	118.0	13256.5
28-29km	320.1	6007.8	2614.2	525.9	260.1	245.6	2150.8	305.7	0.0	478.9	401.7	120.5	13431.2
29-30km	328.4	6010.6	2615.7	526.0	269.1	367.2	2175.2	305.7	0.0	478.9	405.9	121.0	13603.7

**Table A4 - Cumulative Weighted Population Divided by Sector or Site Limit**

	0°-30°	30°-60°	60°-90°	90°-120°	120°-150°	150°-180°	180°-210°	210°-240°	240°-270°	270°-300°	300°-330°	330°-360°	All around site	Sector limit (based on 1667/km <sup>2</sup> )	Site limit (based on 417/km <sup>2</sup> )
0-1km															
1-2km	0.014	1.693	0.719	0.034	0.002	0	0	0	0	0	0	0	0.820	723.1	2170.6
2-3km	0.009	<b>1.937</b>	0.410	0.103	0.003	0.001	0	0	0	0	0	0	<b>0.821</b>	<b>1277.9</b>	<b>3836.1</b>
3-4km	0.060	1.763	0.300	0.106	0.003	0.001	0	0	0	0	0	0	0.744	1745.7	5240.2
4-5km	0.076	1.822	0.244	0.114	0.005	0.001	0	0	0	0	0	0	0.754	2157.8	6477.2
5-6km	0.065	1.825	0.208	0.097	0.015	0.001	0	0	0	0	0	0	0.736	2530.3	7595.6
6-7km	0.057	1.833	0.270	0.087	0.014	0.001	0	0	0	0	0	0	0.754	2873.0	8624.0
7-8km	0.052	1.744	0.457	0.092	0.014	0.001	0	0	0	0	0	0	0.785	3191.8	9581.3
8-9km	0.047	1.596	0.673	0.131	0.013	0.001	0	0	0	0	0	0	0.820	3491.4	10480.4
9-10km	0.044	1.500	0.652	0.133	0.015	0.001	0	0	0	0	0	0	0.781	3774.6	11330.7
10-11km	0.041	1.410	0.609	0.125	0.015	0.002	0.002	0	0	0	0	0	0.734	4044.1	12139.5
11-12km	0.038	1.337	0.580	0.119	0.017	0.006	0.013	0	0	0	0	0	0.703	4301.5	12912.3
12-13km	0.036	1.271	0.554	0.113	0.019	0.007	0.029	0	0	0	0	0	0.676	4548.5	13653.5
13-14km	0.034	1.216	0.530	0.109	0.020	0.007	0.046	0.011	0	0	0	0	0.658	4786.1	14366.8
14-15km	0.033	1.174	0.511	0.104	0.021	0.007	0.055	0.036	0	0	0	0	0.647	5015.3	15054.9
15-16km	0.032	1.130	0.491	0.100	0.023	0.007	0.059	0.054	0	0	0.001	0.631	5237.0	15720.5	
16-17km	0.033	1.090	0.472	0.096	0.033	0.008	0.061	0.056	0	0	0.001	0.008	0.619	5451.9	16365.6
17-18km	0.036	1.050	0.454	0.093	0.036	0.008	0.096	0.054	0	0.001	0.002	0.011	0.614	5660.6	16992.0
18-19km	0.039	1.015	0.439	0.089	0.036	0.009	0.129	0.052	0	0.001	0.003	0.012	0.608	5863.6	17601.2
19-20km	0.041	0.982	0.425	0.087	0.038	0.014	0.148	0.050	0	0.002	0.006	0.012	0.602	6061.2	18194.6
20-21km	0.042	0.953	0.413	0.084	0.037	0.014	0.169	0.049	0	0.011	0.018	0.013	0.600	6254.0	18773.3
21-22km	0.043	0.927	0.401	0.081	0.036	0.016	0.190	0.047	0	0.033	0.035	0.015	0.607	6442.3	19338.4
22-23km	0.042	0.903	0.390	0.079	0.035	0.017	0.204	0.046	0	0.055	0.050	0.014	0.612	6626.3	19890.8
23-24km	0.042	0.880	0.380	0.077	0.035	0.017	0.224	0.045	0	0.066	0.054	0.014	0.611	6806.4	20431.3
24-25km	0.043	0.858	0.371	0.075	0.034	0.018	0.236	0.044	0	0.068	0.053	0.015	0.604	6982.7	20960.7
25-26km	0.043	0.837	0.362	0.073	0.033	0.018	0.251	0.043	0	0.067	0.055	0.015	0.599	7155.6	21479.6
26-27km	0.042	0.818	0.354	0.072	0.033	0.021	0.266	0.042	0	0.065	0.054	0.016	0.594	7325.1	21988.6

<b>27-28km</b>	0.042	0.800	0.347	0.070	0.034	0.029	0.274	0.041	0	0.064	0.053	0.016	0.589	7491.6	22488.2
<b>28-29km</b>	0.042	0.785	0.342	0.069	0.034	0.032	0.281	0.040	0	0.063	0.052	0.016	0.584	7655.1	22979.0
<b>29-30km</b>	0.042	0.769	0.335	0.067	0.034	0.047	0.278	0.039	0	0.061	0.052	0.015	0.580	7815.8	23461.5

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