# APPROXIMATION OF POPULATION DISTRIBUTION UNDER AN ACCIDENT RELEASE PLUME FOR RADTRAN ACCIDENT RISK ANALYSIS OF COMPLETE ROUTES

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## ABSTRACT

Previously, semi-automated population tabulating tools have been developed at SNL as additions to the capabilities of a commercial geographic information system (GIS). One of these tools tabulates population within 0.8 km (1/2 mile) of the route centerline, in increments as short as 1 km, for input to RADTRAN incident-free dose calculations. The other tool tabulates population under individual isopleths of a dispersion plume extending from a hypothetical accident in a user-specified wind direction; it has been useful for analysis of consequences and risks associated with limited numbers of specific accident sites and conditions. A practical means of determining the distribution of population perpendicular to extended route segments, for RADTRAN accident-risk analysis, was not available.

A method, that employs the inherent capabilities of the GIS, for tabulating population within bands parallel to both sides of a chosen portion of a shipment route (e.g. across a single state) is presented. The widths of the bands were chosen to equal the lengths of the ellipses describing a set of 15 isopleths commonly employed in RADTRAN accident-risk analysis. Population data were tabulated in this manner for potential routes across several western and mid-western states. They were compared with the corresponding incident-free population data normally entered in the RADTRAN accident-risk model. To evaluate the effects on risk calculations, the two sets of data were used as inputs to RADTRAN for the route segments investigated.

Results revealed that the distributions of population density perpendicular to the route centerline vary noticeably from state to state. RADTRAN calculations for each state, with both sets of data, did not reveal a consistent bias and generally agreed within a factor of two. In conclusion, a change to the distributed population model is not necessary for suitable accuracy in evaluating accident risks relating to entire shipment routes. This new model promises to be most useful to analysts who need to consider populations at distances from a route that are comparable to plume extent.

* Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE- ACO4-94AL85000.

## DESCRIPTION OF GRAPHICS and TABLES

Figure 1 demonstrates the manner in which the GIS incident-free population tool tabulates population within 0.8 km (1/2 mile) of the route centerline, breaking the route portion into 1-km-long segments.

Figure 2 illustrates use of the second GIS tool, which tabulates population under a dispersion plume that originates at a selected point on the route and aligns with a specified wind direction. The set of isopleths (contours of equal concentration) is described quantitatively in Table 1.

Figure 3 illustrates some of the bands employed in tabulating population data for the present approximation. This method is an approximation in that it describes the aggregate population distribution perpendicular to a route portion (entire states in the cases in Table 3).

Figure 4 compares the RADTRAN calculations of accident dose-risks employing the population density within 0.8 km of the route centerlines and distributed population densities for each of the states in Table 2.

Table 1 lists the isopleth numbers, areas, lengths and time-integrated concentrations for a representative set of isopleths frequently employed in RADTRAN.

Table 2 gives the tabulated population data generated by the GIS tool for the set of isopleths shown in Figure 2. Population densities for input to RADTRAN are calculated differentially, i.e. $PD_N = (Pop_N - Pop_{N-1})/(Area_N - Area_{N-1})$, as shown in the three right-hand columns.

Table 3 lists the differential population densities within each band for four states along Interstates 70 and 80. The distance-weighted average population density within 0.8 km (1/2 mile) of the route centerline for each state would lie between the values for band half-widths of 0.57 and 1.02 km.

## Discussion and Conclusions

The manner in which population densities vary with distance from the route is clearly different among the four states; this may be expected on the basis of the difference in proportions of urban versus rural population areas in these states. However, it is generally true that population density decreases at the largest distances from the route; there is also a slight decrease at the very closest distances. The first characteristic results from the fact that Interstate highways link major cities and pass through or near towns in between, none of which typically has an extent of 40 or more kilometers. The second characteristic is due to the fact that people seldom reside in immediate proximity to Interstate highways.

The values in Figure 4 reveal no consistent pattern in the relationship of accident risks calculated with the two different sets of population data. The calculations from the distributed densities resulted in maximum and minimum values, dependent on whether they were designated as Rural or Urban. The standard RADTRAN calculations employing the population densities within 0.8 km of the route centerline summed Rural, Suburban and Urban values calculated separately. The latter values lie between the maximum and minimum values or are within a factor of two of the maximum values, apparently depending on the occurrence of major metropolitan areas on the route.

The first conclusion drawn from this study is that use of representative population distributions in the calculation of accident risks for a route-length of hundreds of kilometers will not lead to differences from the standard method that are significant (greater than a factor of two). This is due to the fact that variations in population are averaged along the route in both cases and if the averages are over route distances that are long compared to 20 to 40 km, variation of population perpendicular to the route becomes less significant.

It also can be concluded that the current approximation will be useful to the risk analyst interested in examining the risks associated with transportation accident-risks in large metropolitan areas or along route portions that pass within a few kilometers of smaller concentrations of population, e.g. small cities of towns.

**Table 1 - Isopleth Areas, Centerline Distances and Time-Integrated Concentrations for National Average Meteorology**

| Isopleth Number | Area ($m^2$) | Length (km.) | Integrated Concentration* |
|---|---|---|---|
| 1 | 4.590E+02 | 0.0334 | 3.420E-03 |
| 2 | 1.530E+03 | 0.0680 | 1.720E-03 |
| 3 | 3.940E+03 | 0.105 | 8.580E-04 |
| 4 | 1.250E+04 | 0.244 | 3.420E-04 |
| 5 | 3.040E+04 | 0.360 | 1.720E-04 |
| 6 | 6.850E+04 | 0.561 | 8.580E-05 |
| 7 | 1.760E+05 | 1.018 | 3.420E-05 |
| 8 | 4.450E+05 | 1.628 | 1.720E-05 |
| 9 | 8.590E+05 | 2.308 | 8.580E-06 |
| 10 | 2.550E+06 | 4.269 | 3.420E-06 |
| 11 | 4.450E+06 | 5.468 | 1.720E-06 |
| 12 | 1.030E+07 | 11.136 | 8.580E-07 |
| 13 | 2.160E+07 | 13.097 | 3.420E-07 |
| 14 | 5.520E+07 | 21.334 | 1.720E-07 |
| 15 | 1.770E+08 | 40.502 | 8.580E-08 |
| 16 | 4.890E+08 | 69.986 | 5.420E-08 |
| 17 | 8.120E+08 | 89.860 | 4.300E-08 |
| 18 | 1.350E+09 | 120.878 | 3.420E-08 |

* Units are (Ci-sec/$m^3$/Ci-released).

**Table 2 – Population Data from the Plume in Figure 2**

| Iso-pleth # | # Census Blocks | Total Population | Total Land Area | Differential Population | Differential Area | Differential Pop. Density |
|---|---|---|---|---|---|---|
| 6* | 1 | 11 | 1.36 | 11 | 1.36 | 8.08 |
| 7 | 1 | 11 | 1.36 | 11 | 1.36 | 8.08 |
| 8 | 2 | 37 | 3.01 | 26 | 1.64 | 15.82 |
| 9 | 2 | 37 | 3.01 | 26 | 1.64 | 15.82 |
| 10 | 10 | 53 | 11.96 | 16 | 8.95 | 1.79 |
| 11 | 11 | 287 | 14.14 | 234 | 2.18 | 107.19 |
| 12 | 22 | 2031 | 33.80 | 1744 | 19.66 | 88.72 |
| 13 | 49 | 7783 | 49.40 | 5752 | 15.60 | 368.79 |
| 14 | 127 | 17375 | 112.24 | 9592 | 62.84 | 152.64 |
| 15 | 309 | 23849 | 275.71 | 6474 | 163.48 | 39.60 |
| 16 | 596 | 38536 | 497.46 | 14687 | 221.74 | 66.23 |
| 17 | 895 | 54125 | 788.56 | 15589 | 291.10 | 53.55 |
| 18 | 1229 | 65526 | 975.64 | 11401 | 187.08 | 60.94 |

* Isopleths 1 – 5 are given the same population density as 6 because their extent is less 0.8 km (Table 1).

**Figure 4 – Comparison of RADTRAN Total Accident Dose-Risk for Population Density Within 0.8 km of the Route Centerline and Distributed Population Density**

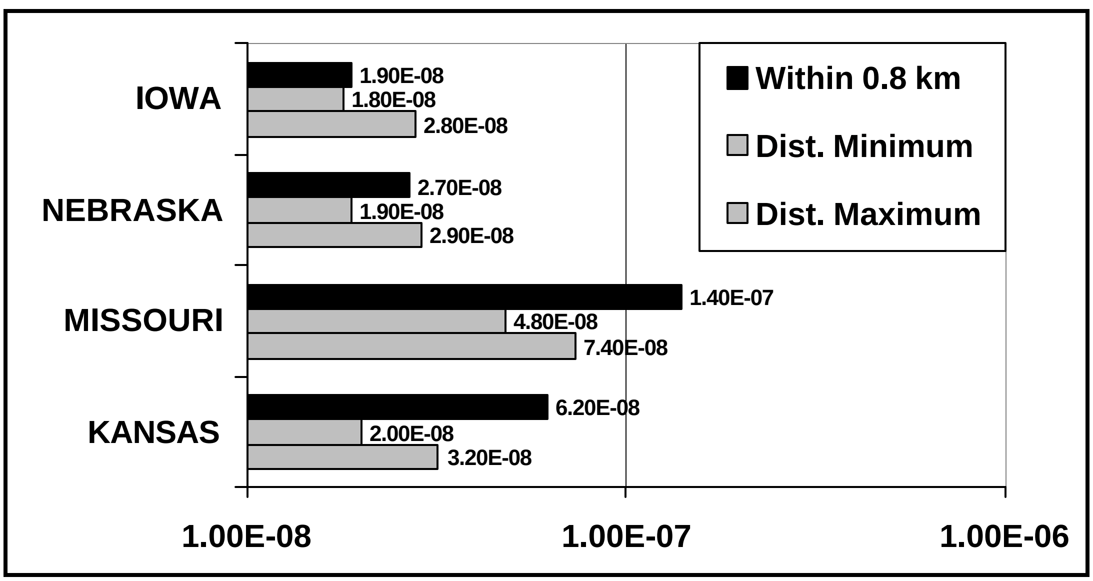

**Figure 1 – Sample of Incident-Free Population Data Collection (West of St. Louis, MO)**

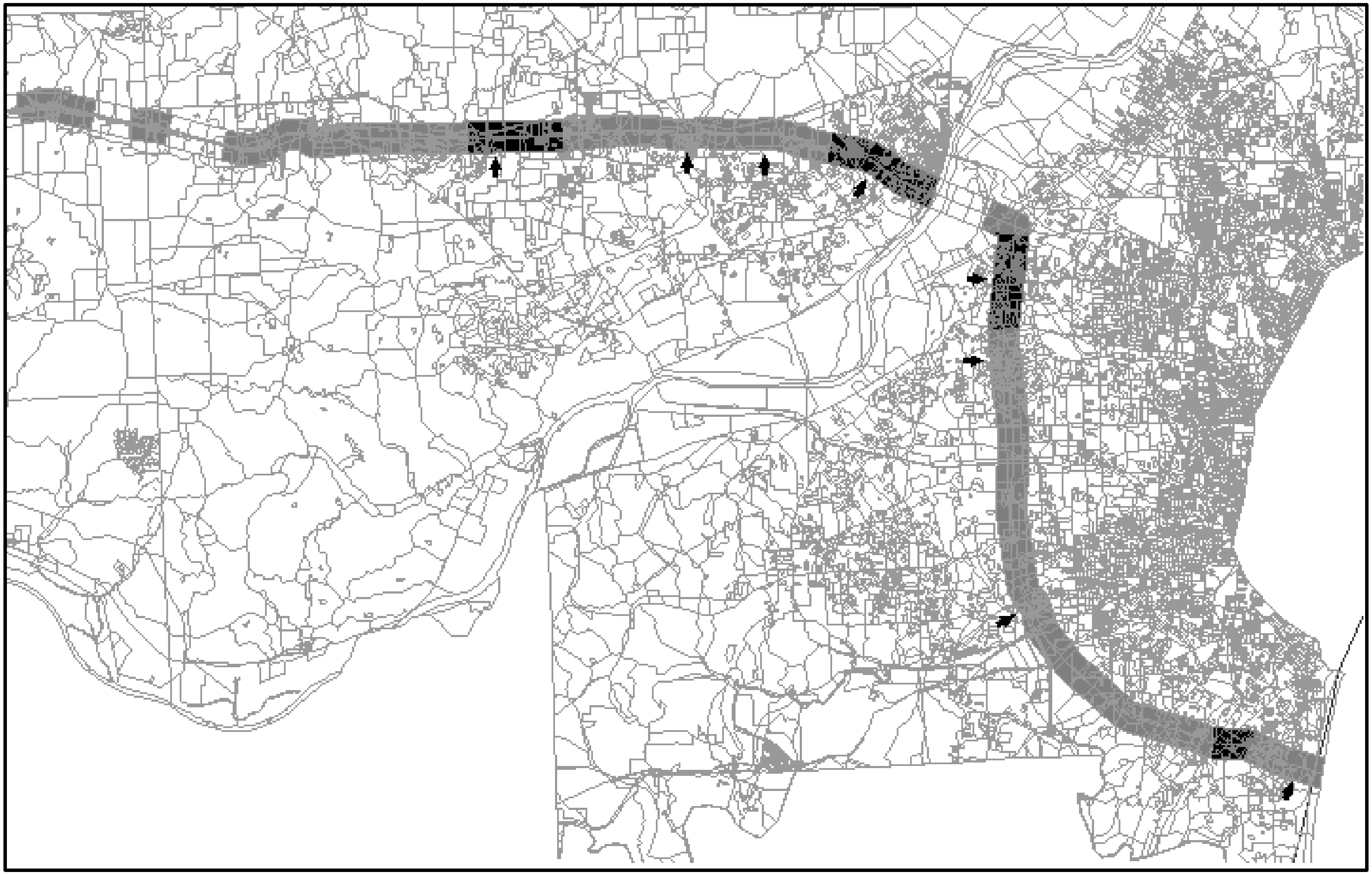

**Figure 2 – Example of a Hypothetical Accident Plume (West of St. Louis, MO)**

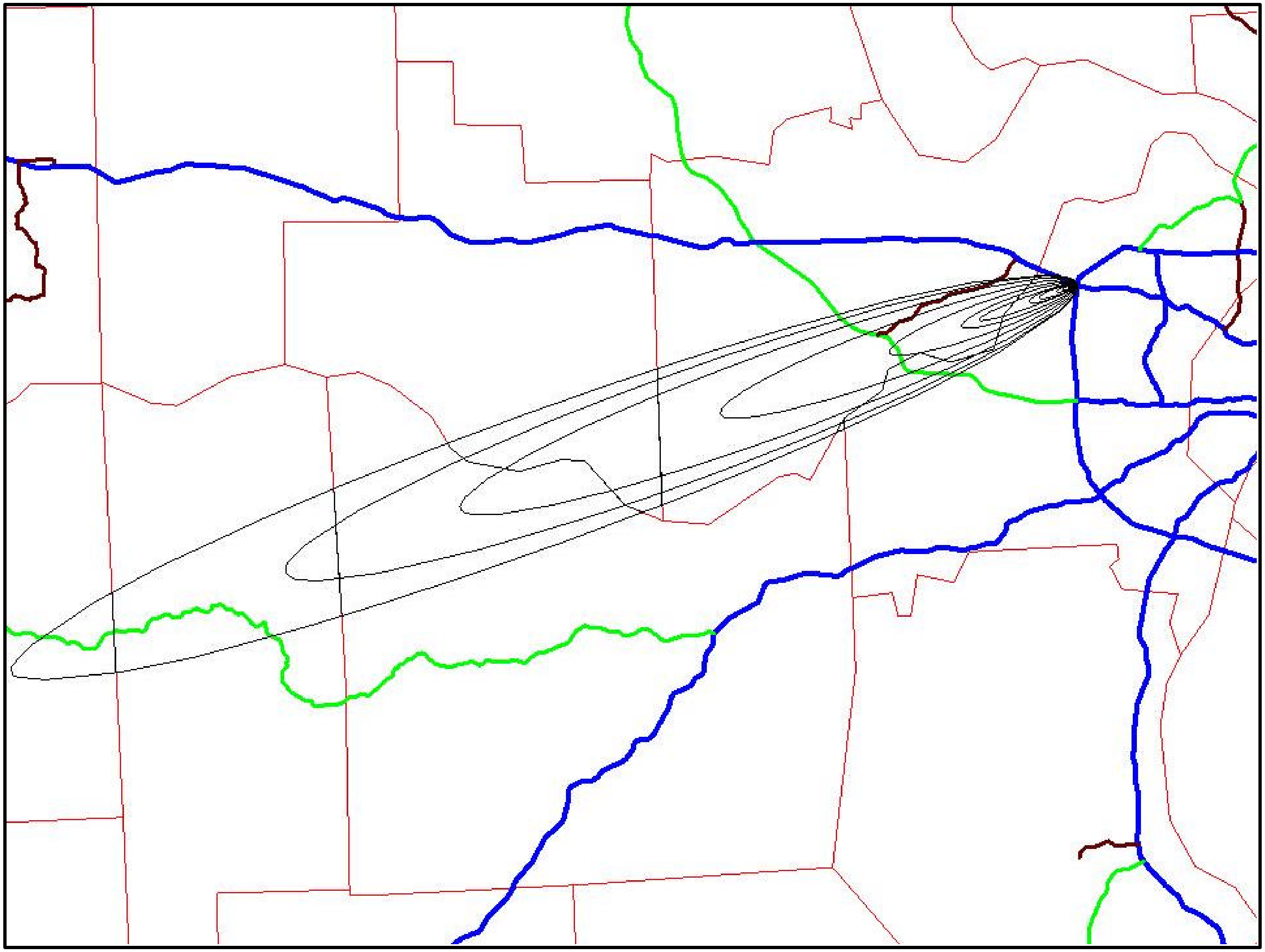

**Figure 3 – Sample Bands along I70 near Topeka, KS. Maximum Half-Width is 21.3 km.**

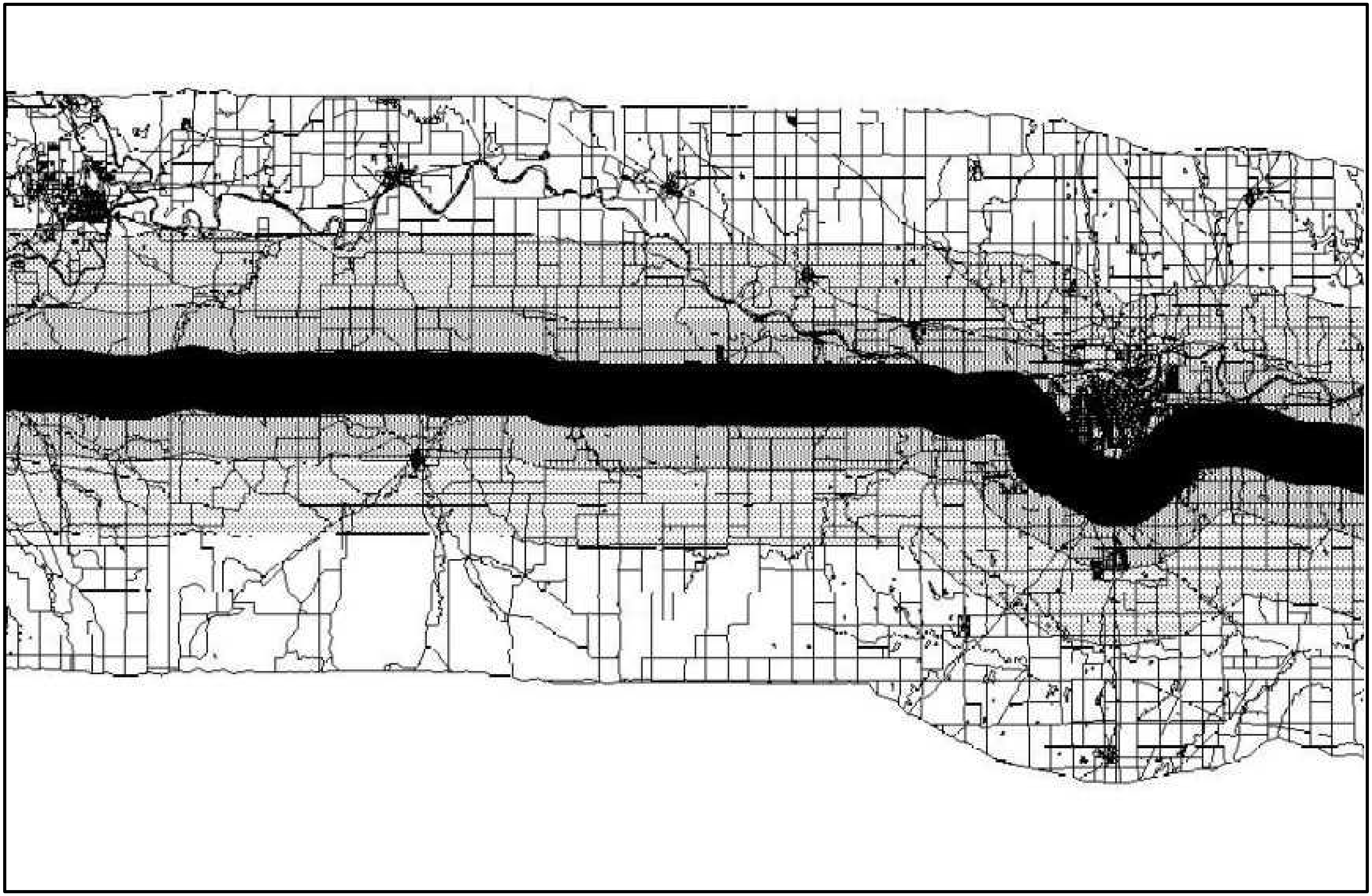

**Table 3a – Differential Population Densities by Band Half-Width for I70 in Kansas and Missouri**

| | KANSAS | | | | MISSOURI | | | |
|---|---|---|---|---|---|---|---|---|
| Half-Width (km) | # Census Blocks | Total Population | Total Area | Differential Pop. Den. | # Census Blocks | Total Population | Total Area | Differential Pop. Den. |
| 0.56 | 2095 | 65806 | 2199.729 | 29.92 | 2889 | 185,744 | 1446.22 | 128.43 |
| 1.02 | 3495 | 113387 | 3230.621 | 46.16 | 4322 | 270,265 | 1832.924 | 218.57 |
| 1.63 | 5199 | 172214 | 3893.89 | 88.69 | 6218 | 391,750 | 2312.184 | 253.48 |
| 2.31 | 7164 | 239794 | 4577.025 | 98.93 | 8144 | 522,059 | 2926.654 | 212.07 |
| 4.27 | 12646 | 440543 | 8182.986 | 55.67 | 13567 | 880,611 | 4656.738 | 207.25 |
| 5.47 | 14922 | 536139 | 9371.97 | 80.40 | 16957 | 1,074,152 | 5558.563 | 214.61 |
| 11.14 | 23320 | 829089 | 17429.904 | 36.36 | 31023 | 1,839,960 | 10505.41 | 154.81 |
| 13.1 | 25753 | 888795 | 20074.437 | 22.58 | 34717 | 2,073,880 | 12092.432 | 147.40 |
| 21.33 | 33359 | 1031039 | 30731.201 | 13.35 | 48127 | 2,734,702 | 18764.334 | 99.05 |
| 40.5 | 47576 | 1157653 | 55176.956 | 5.18 | 67181 | 3,152,051 | 33842.693 | 27.68 |

**Table 3b – Differential Population Densities by Band Half-Width for I80 in Nebraska and Iowa**

| | NEBRASKA | | | | IOWA | | | |
|---|---|---|---|---|---|---|---|---|
| Half-Width (km) | # Census Blocks | Total Population | Total Area | Differential Pop. Den. | # Census Blocks | Total Population | Total Area | Differential Pop. Den. |
| 0.56 | 1668 | 41827 | 2414.994 | 17.32 | 1233 | 30734 | 1252.36 | 24.54 |
| 1.02 | 2671 | 72026 | 3373.147 | 31.52 | 2053 | 59306 | 2159.39 | 31.50 |
| 1.63 | 4258 | 121792 | 4377.227 | 49.56 | 3014 | 96916 | 2549.40 | 96.43 |
| 2.31 | 6093 | 180807 | 5279.453 | 65.41 | 4216 | 143660 | 3006.61 | 102.24 |
| 4.27 | 11340 | 342400 | 9001.141 | 43.42 | 7830 | 299203 | 5215.24 | 70.43 |
| 5.47 | 14584 | 455577 | 10555.22 | 72.83 | 9885 | 384122 | 6068.67 | 99.50 |
| 11.14 | 25462 | 800826 | 19334.294 | 39.33 | 18162 | 643053 | 11389.46 | 48.66 |
| 13.10 | 27955 | 867294 | 21782.548 | 27.15 | 20660 | 710017 | 13086.48 | 39.46 |
| 21.33 | 34830 | 966242 | 32622.239 | 9.13 | 27571 | 833486 | 20802.85 | 16.00 |
| 40.50 | 49829 | 1113197 | 57178.23 | 5.98 | 47268 | 1234839 | 38108.16 | 23.19 |