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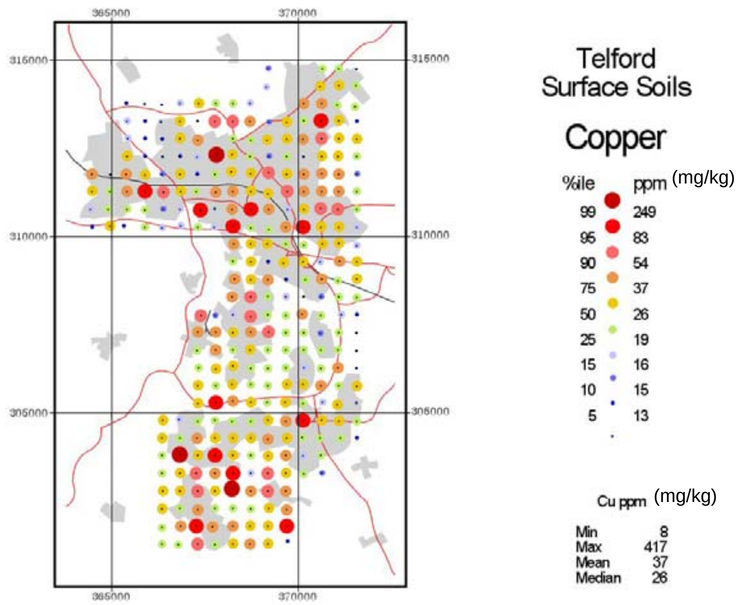
Geochemical baseline data for the urban area of Telford

Urban Geoscience & Geological Hazards Programme

Internal Report IR/02/86



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/01/86

Geochemical baseline data for the urban area of Telford

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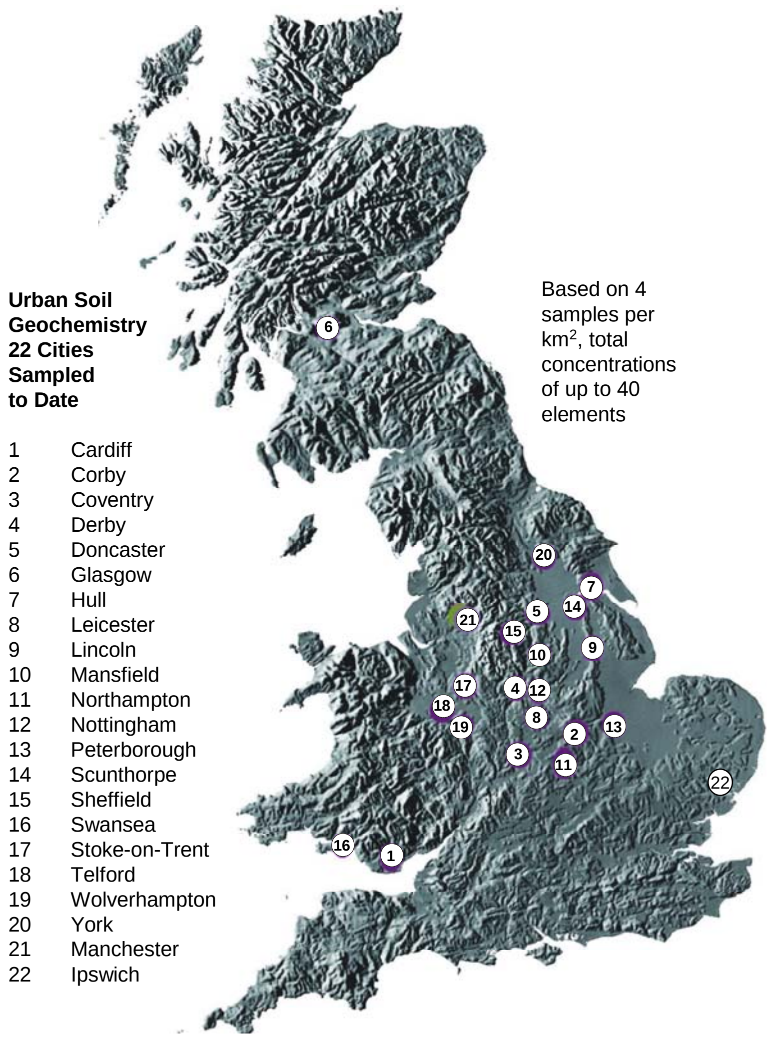
Foreword

This report is a product of the British Geological Survey's (BGS) Geochemical Surveys of Urban Environments (GSUE) project. The work is funded by the UK Government Office of Science and Technology and is part of the national Geochemical Baseline Survey of the Environment (G-BASE) programme. The report forms part of a publication series, which aims to make GSUE urban soil chemistry data publicly available with a minimum of interpretation, displaying the data as a series of graduated symbol maps.

A number of urban centres have been surveyed to date using systematic soil sampling procedures. These are indicated in the figure below. Wolverhampton, Manchester and Glasgow were sampled as part of larger multi-disciplinary projects.



Urban centres sampled to date by the GSUE project

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Summary

This report presents the results of an urban soil geochemical survey of Telford carried out by the British Geological Survey (BGS) during 1994. The study was undertaken as part of the BGS systematic Geochemical Surveys of Urban Environments (GSUE) project. The concentrations of many potentially harmful elements (PHE) such as As, Cd, Cr, Ni and Pb are enhanced in city environments as a result of urbanisation and industrial processes and their distribution is of concern under current UK environmental legislation.

The GSUE data provide an overview of the urban geochemical signature and because they are collected as part of a national baseline programme, can be readily compared with soils in the rural hinterland to assess the extent of urban contamination. The aim of the present study was to generate urban soil geochemistry information for Telford to aid planning and development.

Urban surveying was based upon the collection of samples on a systematic 500 m grid. Soils were sampled at a density of 4 per km^2 across the built-up area. Samples were collected from open ground as close as possible to the centre of each 500 m grid cell.

Preliminary interpretations of the data in relation to the underlying geology and past and present industrial history of Telford are presented in this report and demonstrate that several metal elements are elevated over the Coal Measures which underlie much of the built-up area, however, several of these elements are also found in high concentration in proximity to the transport network. However, in general contaminant levels in Telford are similar to other city environments in the region.

1 Introduction

This report summarises the results and methodology of a soil geochemical survey of the urban area of Telford, undertaken by the British Geological Survey (BGS) during 1994 as part of the Geochemical Survey of Urban Environments (GSUE) project. The GSUE project forms part of the national strategic geochemical survey of Great Britain and Northern Ireland, the Geochemical Baseline Survey of the Environment (G-BASE) programme (Johnson and Breward, 2004).

The programme is undertaking a systematic regional geochemical survey of soils, stream sediments and stream waters of the British Isles at a sample density in rural areas of 1 per 1.5 – 2 km^2. The data provide information on the surface chemical environment, which can be used to define environmental baselines and the extent of surface contamination and are published as a series of regional geochemical atlases for the country (see for example British Geological Survey, 2001). The distribution of chemical elements in the environment is of concern because although many are essential to life, several including As, Cd, Cr, Ni and Pb are potentially harmful to plants and animals in high doses. Concentrations at any location are often controlled by factors such as geology, vegetation, soil forming processes and climate. In addition to natural sources of these elements, environmental concentrations can be enhanced by anthropogenic activities such as mining, industrialisation, urbanisation and waste disposal. The G-BASE data have a wide range of applications, including the assessment of risks to human health, with respect to potentially harmful elements (PHE) through environmental exposure.

The concentrations of many potentially harmful elements (PHE) are enhanced in urban environments as a result of atmospheric and terrestrial contamination and the nature of urban ground, which is often disturbed and in-filled and bears little relation to the soils, bedrock and superficial cover of the surrounding rural hinterland.

As part of the G-BASE programme, the GSUE project undertakes systematic soil surveys to define citywide geochemical signatures over selected urban areas including that of Telford (Figure 1).

Figure 1 Telford location map

Telford is a town in the Borough of Telford and Wrekin. It is located in the West Midlands approximately 30 miles to the west of Birmingham and covers an area of 112 square miles (Borough of Telford and Wrekin, 2003). It was designated as a New Town over twenty-five years ago (Foxcroft, 2002) and has a population of over 150,000. Past industry include coal minig, ironmaking and agriculture.

The distributions of approximately 17 major and trace elements including several PHE in the surface environment of Telford are described in this report in relation to present and historical land use. The concentrations of the elements are also considered in terms of the underlying geology and placed in context with respect to the typical rural background concentrations obtained from G-BASE regional stream sediment data sets from the surrounding area.

2 Study area

2.1 INDUSTRIAL HISTORY

Telford is a New Town, formed over 25 years ago by drawing a ring around the existing towns of Wellington, Oakengates, Donnington, Dawley, Madeley and Ironbridge, together with many smaller villages.

The area is most famous for the iron making industry. Abraham Darby I was the first ironmaster to smelt iron using coke rather than charcoal, thus developing a relatively small iron industry into the worlds leading ironworks, earning the town the modern nickname of “The Birthplace of the Industrial Revolution”. His grandson Abraham Darby III built the World famous iron bridge at Ironbridge, across the River Severn in 1779. The transport needs of the iron making industry resulted in the development of a complex network of canals, railways and tramways in the area.

2.2 AREA SAMPLED

An area of 73km^2 was surveyed during the summer of 1994, in which a total of 293 surface soils (0.05 - 0.20 m depth) and 287 profile soils (0.35 – 0.50 m depth) were sampled. This extends from grid references 364200m east to 371800m east and from 301200m north to 314800m north, and covers Telford city centre and the surrounding suburbs. The survey area is shown in Figure 2 and Figure 3.

2.3 BEDROCK AND SUPERFICIAL GEOLOGY

Geological information for the Telford area was obtained from the BGS 1:50 000 series maps for the area and the BGS digital DigmapGB® data (British Geological Survey, 1971; British Geological Survey, 1932). The solid and superficial deposits of the region are shown in Figures 4 and 5.

Silurian shales underlie the western edge of the survey area but the area is dominated by Carboniferous formations, with Coal Measures trending north to south. To the north-west of the area are Permian sandstones. The solid geology is shown in Figure 4.

Superficial deposits are predominately till in the central and southern sections of the survey area with glaciofluvial deposits in the north and north-west. There are small deposits of head in the river valleys. In the south of the region there are large areas with no superficial cover (British Geological Survey, 1968). See Figure 5.

2.4 SOIL TYPE

The National Soil Resources Institute (formerly the Soil Survey of England and Wales) produces soil maps for much of the UK landmass, however urban and industrial areas have not been surveyed for soil type. Therefore no information exists on soil type for the main urban area of Telford.

Some soil characteristics are reported as part of the GSUE survey. Basic information for the urban soils of Telford was recorded on computer-compatible field cards (see Appendix A), which are completed at site during sampling according to standard procedures (Johnson et al., 2003). These contain data such as soil colour, texture, sample depth, clasts that are contained within the soil, as well as land use and any physical contamination that is observed. The field cards are completed using a set of standard database-compatible codes (Harris and Coats, 1992) and the information is held on the BGS corporate geochemistry database.

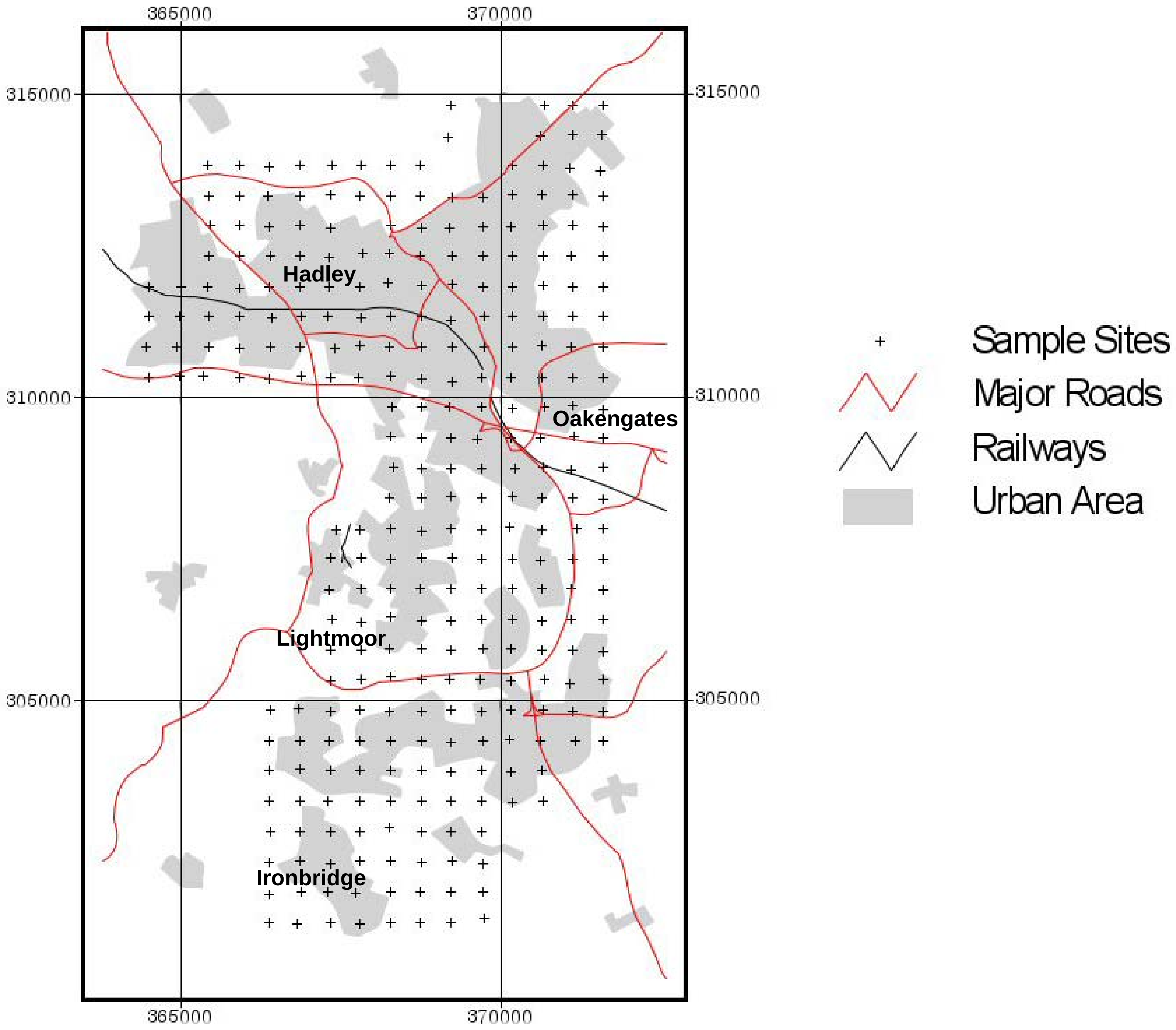


Figure 2 Location of sample sites in Telford

+ Sample sites

Figure 3 Topographic map of Telford (1:50,000 Ordnance Survey©)

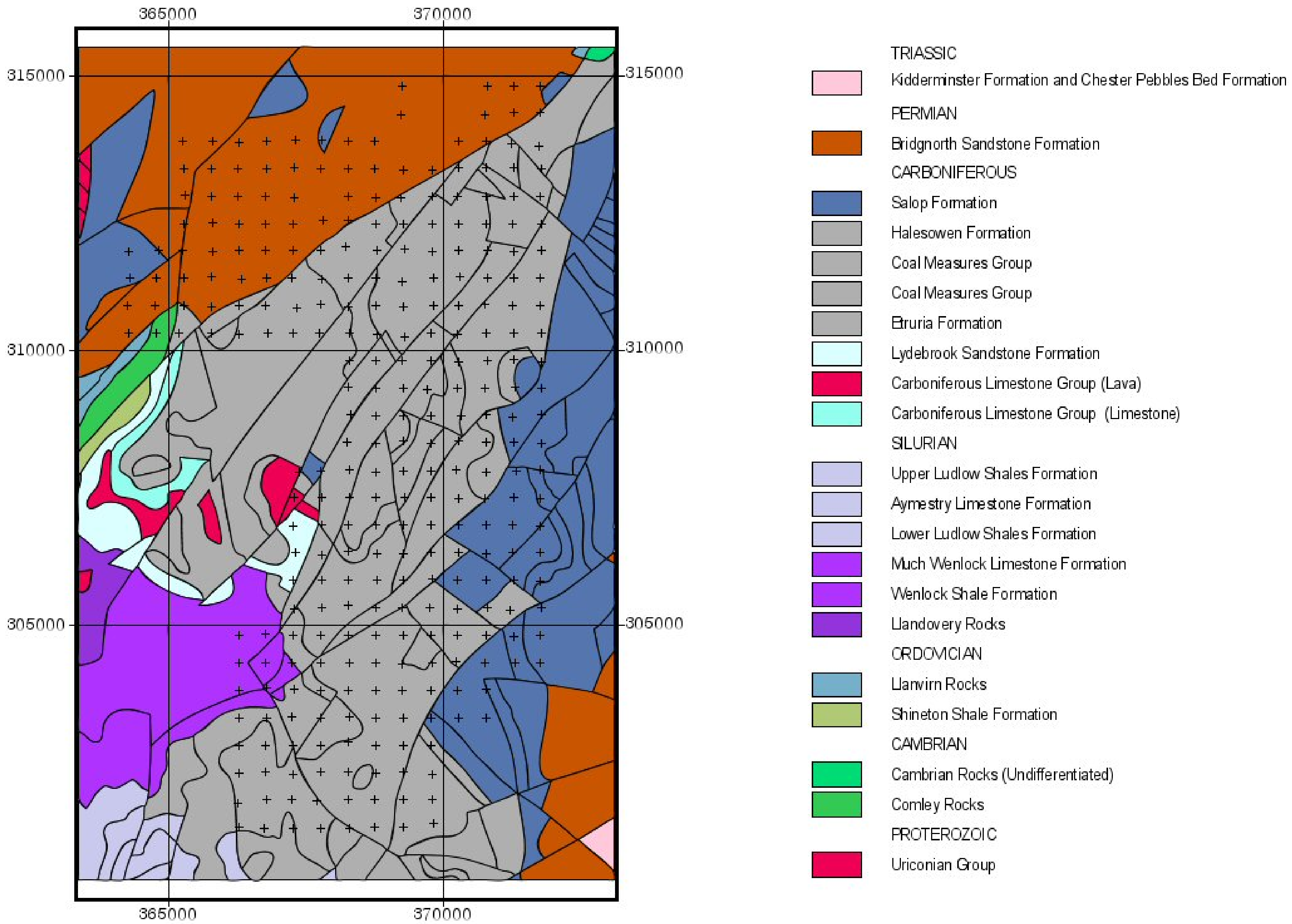


Figure 4 Solid Geology Map of Telford (1:50 000 British Geological Survey©)

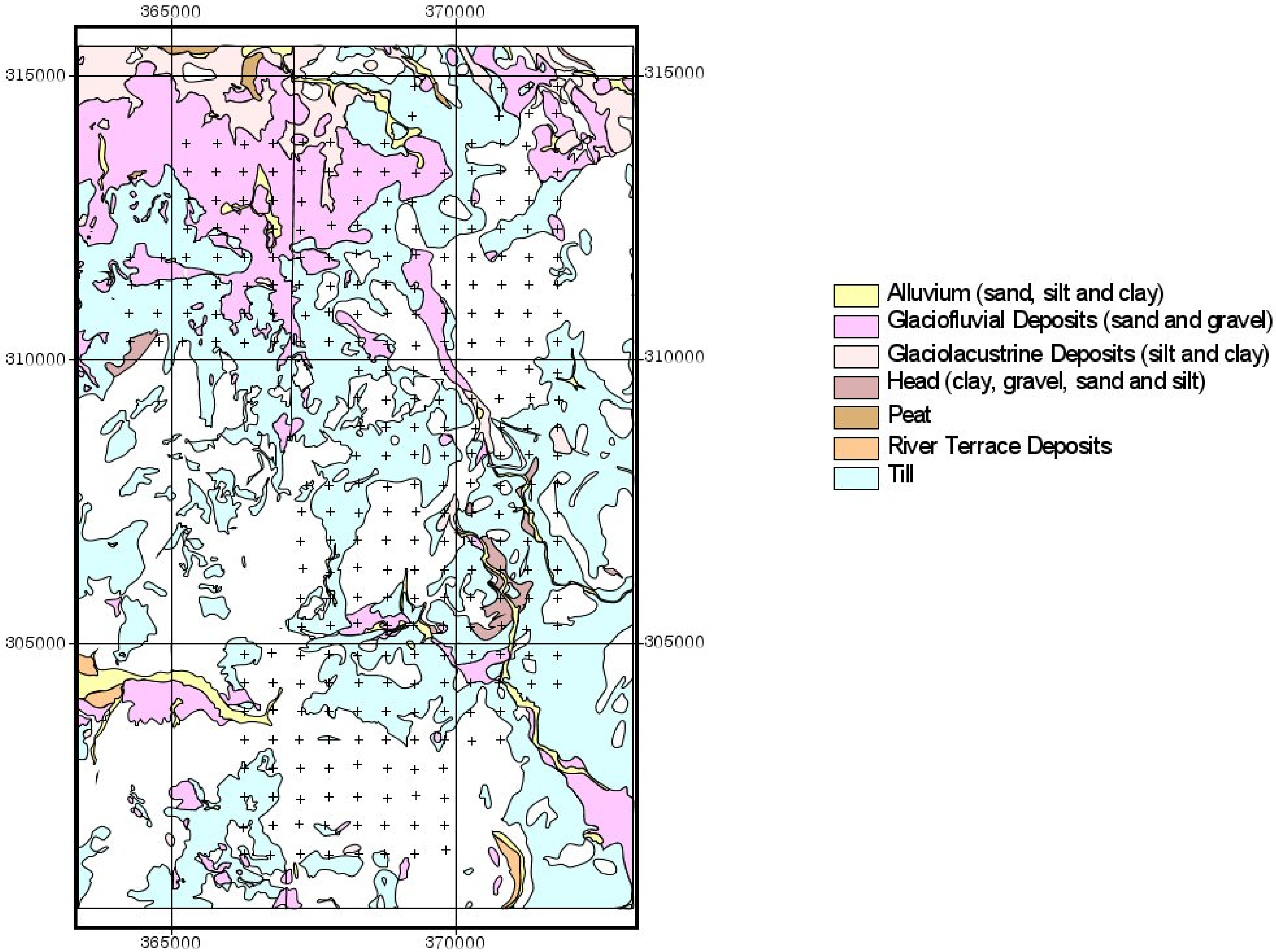


Figure 5 Superficial deposit map of Telford (1:50,000 British Geological Survey©)

3 Methodology

3.1 SOIL SAMPLING

Sample sites were arranged on a systematic grid pattern at a density of 4 samples per km^2 across the built-up area whereby each BNG kilometre square as defined from 1:25 000 scale topographic maps (Ordnance Survey®) was split into four 500 m x 500 m sub-cells. Samples were collected from open ground as close as possible to the centre of each 500 m cell. Sample spacing was kept as regular as possible, namely 500 m apart, but was constrained by the actual conditions that were encountered on the ground (such as buildings and other constructions). Typical locations for sampling included gardens, parks, sports fields, road verges, allotments, open spaces, schoolyards and waste ground. Whilst attempts were made to select the least disturbed area of open ground as close as possible to the centre of the 500 m cell, contamination was not purposefully avoided as the aim of the survey was to provide an overview of the urban geochemistry and not to establish a 'near natural' geochemical baseline.

Soil samples were collected using a Dutch style hand auger with a 15 x 3 cm bore. Two samples were collected from different depths at each site. Surface samples were labelled A and were collected from a depth of 0.05 – 0.20 m. Deeper 'profile' samples were labelled S and were collected from the same auger holes as the A samples from a depth of 0.35 – 0.50 m (Johnson et al, 2003). Both A and S samples comprised a composite of 3 sub-samples collected on the diagonal of a 2 x 2 m square. Duplicate sampling is described in section 3.3.2 of this report.

As indicated in section 2.5 above, information about the soils recorded at each site on field cards and the sample locations are stored in the BGS corporate geochemical database where they can be retrieved via a user-friendly PC software interface (Harris and Coats, 1992).

3.2 SAMPLE PREPARATION

Samples were air and then oven dried at temperatures below 20ºC and then sieved. Surface soils were sieved to obtain the <2 mm fraction and profile soils to obtain the <150 µm fraction to be compatible with G-BASE regional <150 µm stream sediment data. The sieved material was coned and quartered and a split of the sample was ground using an agate ball mill until 95% reached a grain size finer than 53 µm. A 12 g split of the ground material was combined with 3 g of elvacite binder and pressed into a pellet for analysis by X-Ray Fluorescence Spectrometry analysis (XRFS) (see section 3.4).

Excess sieved and ground sample material is retained in the National Geoscience Records Centre at the BGS.

3.3 ERROR CONTROL PROCEDURES

The accuracy and precision of the geochemical data were monitored using the methods of (Plant et al, 1975) which are briefly described below.

3.3.1 Random numbering of samples

Samples were allocated numbers according to a random numbering system (Plant, 1973), but were analysed in numerical order. This allows any systematic error in either sampling or analytical methodologies to be identified and attributed to the appropriate process. At each site the A and the S samples were assigned unique numbers according to the random number lists. Therefore, within each batch of one hundred samples there were 50 A and 50 S samples.

3.3.2 Duplicate and sub-samples

Within each batch of one hundred samples, a pair of sample numbers were assigned to a sampling duplicate, resulting in a field duplicate pair for both A and S samples. Duplicate samples were collected using identical sampling methodology adjacent to the original sample. At the sample preparation stage each field duplicate sample was split to obtain an analytical replicate sub-sample. Each sub-sample was assigned a different number and treated as a separate sample for analytical purposes.

The collection of field duplicate samples enables the sampling error, or sampling variation, to be estimated, thus providing a measure of the between-sample variance. Analytical replicate sub-sampling allows the analytical error or variance to be estimated as differences in results between the original and the sub-sample may indicate the influence of the sample preparation and analytical process.

The components of variance were estimated using analysis of variance (ANOVA). This statistical technique is used to determine the residual variance (introduced by sub-sampling, sample preparation and chemical analysis); the between-sample variance (attributed to within-site variation and variability introduced during sample collection); and between-site variance (representing the environmental variation in element concentrations across the survey area). All of the analyses considered were part of a single randomised dataset and therefore a random nested model of ANOVA was used (Snedecor and Cochran, 1989).

Due to the relatively low number of duplicate samples collected in a single urban area, the ANOVA calculations were performed using replicate soils collected from 11 different urban centres: Cardiff, Swansea, Stoke, Telford, York, Hull, Doncaster, Mansfield, Scunthorpe, Lincoln and Sheffield (Lister, 2002; Lister, In Prep). A total of 50 replicate sets were measured for urban profile soils, while up to 37 were measured for urban surface soils. All elements except Cd and U (both depths) and TiO_2 (surface soils) were log transformed to improve the fit of the data to a Gaussian distribution. The ANOVA calculations were performed using the NESTED procedure from the statistical software package, MINITAB™. The results of the ANOVA indicate that for most elements the between-site variability is greater than 80% of the total variance (see Table 1). This suggests that geochemical variation is the principal control on element concentrations in urban areas. The between-site variance of Cd is significantly lower than the other elements, with nearly half the variation in the surface soils attributed to residual factors. This is an indication of analytical error, most likely to result from low overall concentrations with respect to the detection limit.

Table 1 ANOVA percentage of variance in surface and profile soils from 11 urban centres attributable to between-site, between-sample and residual variance

Surface Soils	Variance				Profile Soils	Variance			
Element	Number of Replicate Sets	Between Site (%)	Between Sample (%)	Residual (%)	Element	Number of Replicate Sets	Between Site (%)	Between Sample (%)	Residual (%)
Sb	16	88.03	1.15	10.82	Sb	50	87.68	3.05	9.27
As	37	97.69	2.02	0.29	As	50	97.87	1.82	0.31
Ba	37	97.63	1.79	0.58	Ba	50	97.39	2.56	0.05
Cd	27	47.88	6.77	45.35	Cd	50	65.44	3.95	30.61
Cr	37	94.14	3.07	2.79	Cr	50	93.46	5.55	0.99
Co	37	96.35	0.00	3.65	Co	50	94.00	5.62	0.38
Cu	37	97.63	1.66	0.72	Cu	50	98.87	1.08	0.06
Fe_2O_3	37	97.69	2.06	0.25	Fe_2O_3	50	96.62	3.36	0.01
Pb	27	97.48	2.23	0.29	Pb	50	96.51	3.43	0.06
MnO	37	98.28	1.39	0.33	MnO	50	96.03	3.92	0.05
Mo	33	94.24	0.71	5.05	Mo	50	93.59	3.23	3.17
Ni	37	98.06	1.59	0.34	Ni	50	95.96	3.83	0.21
Sn	36	93.45	2.91	3.63	Sn	50	95.77	2.42	1.81
TiO_2	37	96.58	2.65	0.77	TiO_2	-	-	-	-
U	37	85.95	1.24	12.81	U	47	76.92	10.99	12.09
V	37	97.89	1.79	0.32	V	50	97.85	2.09	0.06
Zn	37	94.77	5.16	0.07	Zn	50	92.64	7.34	0.02

3.3.3 Standards

Standards were included in the analytical runs to monitor the accuracy of the results. These were assigned a unique number at the sample preparation stage and were treated identically to the other samples. For the Telford data set 14 standards were included in the analysis of the A samples and 7 were included with the S samples. The standards used were the G-BASE in-house bulk soil standards S13, S15 and S 24.

The inclusion of standards allows the data to be normalised to the G-BASE regional data set for Wales, which, consists of the XRFS analyses of approximately 21,000 samples (British Geological Survey, 2001).

3.4 ANALYTICAL PROCEDURES

All samples were analysed at the BGS laboratories for a range of elements by Wavelength Dispersive X-ray Fluorescence Spectrometry (Ingham and Vrebos, 1994). Three sequential XRF spectrometers were used. A Philips PW1480 fitted with a 216 position sample changer and a 3 kW/100kV tungsten anode X-ray tube was used to determine Cd, Sn and Sb. Two Philips PW2400 spectrometers fitted with 102 position sample changers and with 3 kW/60 kV rhodium anode x-ray tubes were used to determine TiO_2, MnO, Fe_2O_3, V, Cr, Co, and Ba in one suite and Ni, Cu, Zn, As, Mo, Pb, and U in another.

The elements determined and the lower limits of detection (LLD) and upper and lower reporting limits (URL and LLR) for each analyte are shown in Table 2.

The quoted LLDs are theoretical values for the concentration equivalent to three standard deviations above the background count rate for the analyte in a pure silica matrix. High instrumental stability results in practical values for these materials approaching the theoretical.

Table 2 Lower (LLD) and upper reporting limit (URL) values for XRFS analysis of GSUE urban soil samples

Analyte	LLD (mg/kg)	LLR (wt %)	URL (mg/kg)	URL (wt %)
TiO_2*	-	0.010	-	100.0
MnO	-	0.010	-	10.0
Fe_2O_3	-	0.01	-	100.0
V	2	-	20000	-
Cr	3	-	250000	-
Co	2	-	10000	-
Ni	1	-	4000	-
Cu	1	-	6500	-
Zn	1	-	10000	-
As	1	-	10000	-
Mo	0.4	-	1000	-
Cd	1	-	500	-
Sn	1	-	10000	-
Sb	1	-	10000	-
Ba	3	-	600000	-
Pb	1	-	10000	-
U	1	-	650	-

* A soils only.

3.5 DATA INTERPRETATION

Once full error control and data quality procedures were completed, the spatially registered Telford geochemical data were loaded into an Arcview© GIS software package. Graduated symbol geochemical maps for surface and profile soils categorised according to percentiles of the data distribution (Appendix B) were then generated (see Appendix C).

4 Geochemical Interpretation

4.1 BACKGROUND LEVELS

In order to aid the interpretation of the geochemical data for Telford it is useful to be aware of typical background concentrations of elements in the surrounding rural environment to place the urban data in context. Regional soil sampling was not carried out routinely in the G-BASE survey of Wales, although direct comparisons of soil and stream sediment data are not possible, the G-BASE stream sediment data set for Wales none-the-less provides a useful overview of background concentrations of elements in the surface environment. The median elemental concentrations for 18,927 Welsh stream sediment samples are shown in Table 3. For comparison, Table 4 shows the median elemental concentrations of the surface and profile soils from the urban area of Telford.

The median value of a geochemical dataset provides an indication of the typical concentrations for elements across the area, removing the influence of outliers caused by isolated regions of contamination. However, it should be noted that background values in the urban environment, as well as the rural environment (to a lesser extent), are likely to be elevated by some level of diffuse pollution.

Taking into account the regional trends, the levels of heavy metals within the Telford urban area are not particularly elevated, although zinc and lead are slightly higher than the regional levels suggest (see Table 3 and Table 4).

Table 3 Median concentrations in < 150 µm stream sediment samples **(British Geological Survey, 2001)**

Analyte	Units	Mean Value
As	mg/kg	14
Ba	mg/kg	540
Cd	mg/kg	<1
Co	mg/kg	31
Cr	mg/kg	92
Cu	mg/kg	22
Fe_2O_3	wt%	6.84
MnO	wt%	0.182
Mo	mg/kg	1.6
Ni	mg/kg	38
Pb	mg/kg	36
Sb	mg/kg	4
Sn	mg/kg	5
TiO_2	wt%	0.869
U	mg/kg	2.3
V	mg/kg	110
Zn	mg/kg	130

Table 4 Median concentrations of surface and profile soils from Telford

Analyte	Units	Median (Surface)	Median (Profile)
As	mg/kg	10	12
Ba	mg/kg	425	458
Cd	mg/kg	1	2
Co	mg/kg	22	26
Cr	mg/kg	65	85
Cu	mg/kg	26	30
Fe_2O_3	wt%	4.29	5.06
MnO	wt%	0.098	0.109
Mo	mg/kg	1.2	2.5
Ni	mg/kg	28	35
Pb	mg/kg	92	82
Sb	mg/kg	2	1
Sn	mg/kg	5	5
TiO_2	wt%	0.590	N/A
U	mg/kg	2	2
V	mg/kg	82	99
Zn	mg/kg	264	238

4.2 CHEMICAL VARIATION WITH DEPTH

In a comparison of surface and profile soils, it should again be noted that during sample preparation the two sample types are sieved to different size fractions. The surface soils are sieved to <2 mm whilst the profile soils are sieved to <150 µm. This means that the sieved profile soil has a much larger surface area and will contain more clay particles (which possess the ability to attract and bind many metal elements (Brady and Weil, 1999) and this may affect the geochemical results.

The majority of analytes (Mn, Fe, V, Cr, Co, Ba, Ni, Cu, As, Mo, and Cd) show higher concentrations in the profile soil rather than the surface soil. This is probably due to the difference in size fraction.

There could also be other explanations why the profile soils show elevated levels of some heavy metals. For example, in areas of contamination, fresh topsoil could have been brought in for a remediation exercise, resulting in the contaminated soil being buried.

Certain soil properties such as pH and redox potential can affect the mobility of potentially toxic elements, such as As and Cd. Under appropriate conditions, elements can go into solution and leach downwards, taking elements from the upper soil horizon and re-precipitating them into the deeper soils, or into groundwaters in the underlying strata. Leaching may also reach surface waters i.e. rivers.

There is also evidence of contamination. For example Pb shows higher levels in the surface soils rather than profile soils and is much higher than the regional median. This is probably due to pollution from car emissions. U and Sn show the same median values in both the surface and profile soils, this is probably due to the fact that the values are close to the detection limit.

4.3 GEOCHEMICAL DISTRIBUTIONS IN TELFORD SOILS

There are generally higher levels of trace elements such as As, V, Ni, Cu and Pb over the coal measures, which dominate the greatest part of the area sampled. Coal measures have a naturally high abundance of numerous trace elements, therefore indicating that specific elevations in trace metals are natural rather than anthropogenic.

To the north of Telford in Hadley (mainly Hadley junction and Hadley Brook), there are comparatively high levels of elements such as As, Cd, Cr, Cu, Fe, Pb, Mn and Sn. Hadley junction is at the intersection of a dismantled railway and road, which could explain the higher levels of these trace elements. Railway embankments are often filled with furnace slags and waste that are notoriously high in the above trace elements. This area also housed steel pressing and brickmaking factories that could have contributed to the contamination.

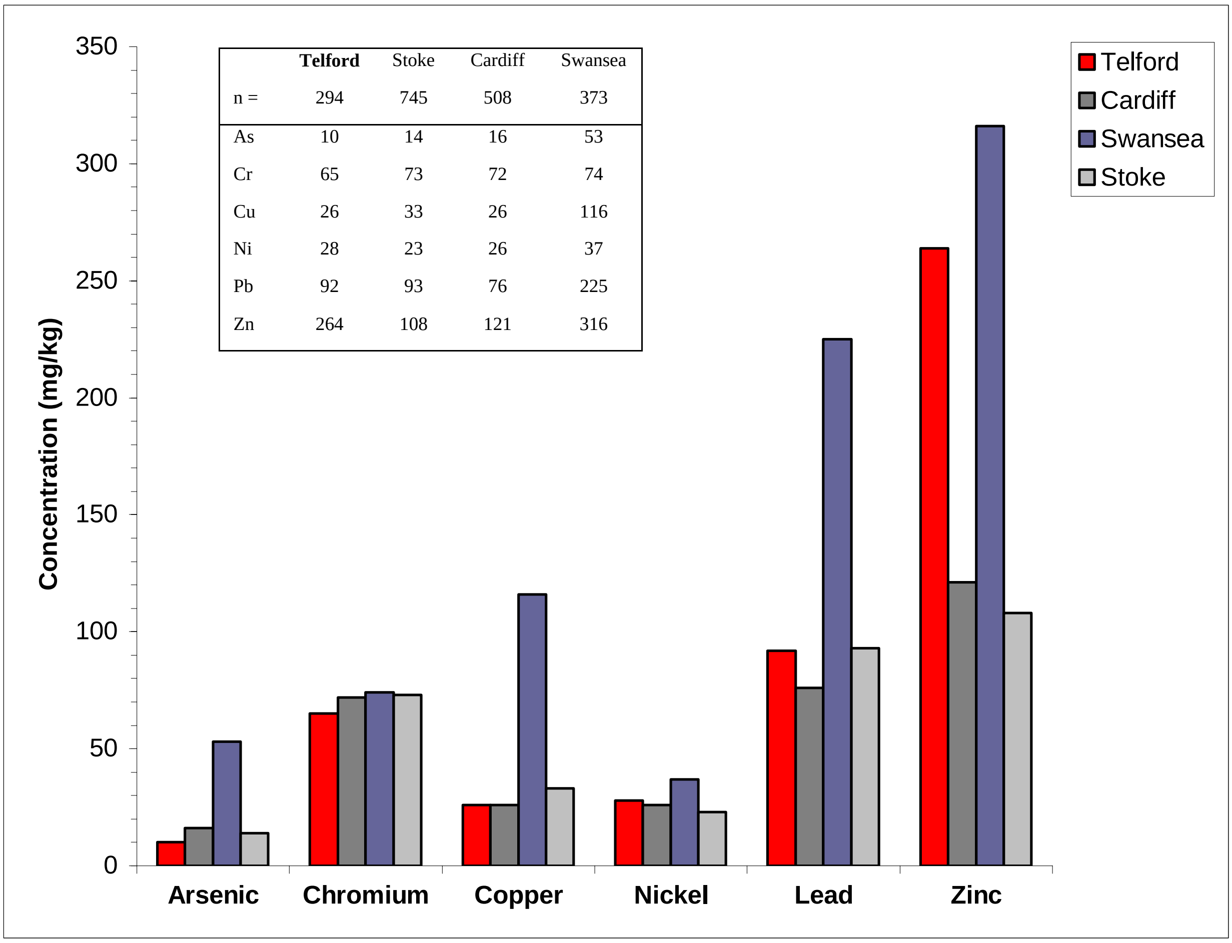
In the Oakengate area to the N-E of Telford there are elevated levels of all trace elements analysed with the exception of Mn, Ti and U. This could be due to the fact that it the sample sites were situated very near to disused workings and and industrial estate at Snedshill Way. The enrichment factors of most elements at this particular site were between 2 and 4 times that of the regional median, with the exception of Zn and Pb that have enrichment factors of 20 and 31 respectively. Both of these elements can be linked to road traffic usage as Pb used to be an additive in petrol and was deposited from vehicle emissions and Zn is used in tyre manufacture and could be enriched due to the use of road vehicles.

Other areas where there were obvious enrichments in trace element concentrations were to the southwest in Lightmoor, which showed highs in elements such as Cd, Sn and Sb that are indicative of industrial processes. These elevated levels could therefore be linked to the many disused mineshafts dotted around the Lightmoor area. This is an area that is currently being redeveloped.

Further south along the footpaths of the River Severn towards Ironbridge there are anomalies of elements such as Fe, Cu, Zn and tin that could be associated with the Ironworks at Ironbridge and also the transportation of industrial products along the river.

4.4 SOIL GEOCHEMISTRY OF TELFORD IN RELATION TO OTHER WELSH ATLAS URBAN AREAS

Six elements that may be affected by anthropogenic contamination in urban areas (As, Cr, Cu, Ni, Pb, and Zn) from Telford surface soils are presented in the context of three other urban areas from the Welsh atlas region in Figure 6. On the basis of median values, concentrations of elements such as As, Ni and Cr in Telford compare with those of Cardiff and Stoke, but are considerably lower than Swansea, which has a history of heavy metal smelting.



	Telford	Stoke	Cardiff	Swansea
n =	294	745	508	373
As	10	14	16	53
Cr	65	73	72	74
Cu	26	33	26	116
Ni	28	23	26	37
Pb	92	93	76	225
Zn	264	108	121	316

Figure 6 Comparisons of surface soil As, Cr, Cu, Ni, Pb and Zn median values between cities within the Welsh atlas area

References

BOROUGH OF TELFORD AND WREKIN. 2003. Borough of Telford and Wrekin.

BRADY, N, C, and WEIL, R, R. 1999. *The nature and properties of soils.* (New Jersey: Prentice Hall.)

BRITISH GEOLOGICAL SURVEY. 1932. Shrewsbury (S & D). 1:50K. (Ordnance Survey Office.)

BRITISH GEOLOGICAL SURVEY. 1968. Wolverhampton (Drift). 1:50K. 2nd. (Ordnance Survey Office.)

BRITISH GEOLOGICAL SURVEY. 1971. Wolverhampton (Solid). 1:50K. 3rd. (Ordnance Survey Office.)

BRITISH GEOLOGICAL SURVEY. 2001. *Regional geochemistry of Wales and part of west-central England: Stream sediment and soil*. (Keyworth, Nottingham: British Geological Survey.)

FOXCROFT, R. 2002. Exploring Telford.

HARRIS, J R, and COATS, J S. 1992. Geochemistry database: data analysis and proposed design. *British Geological Survey*, Technical Report WF/92/5 (BGS Mineral Reconnaissance Programme Report 125).

INGHAM, M N, and VREBOS, B A R. 1994. High productivity geochemical XRF analysis. *Advances in X-ray Analysis*, Vol. 37, 717-724.

JOHNSON, C C, and BREWARD, N B. 2004. G-BASE Geochemical Baseline Survey of the Environment. *British Geological Survey Commissioned Report*, CR/04/016N.

JOHNSON, C C, BROWN, S E, and LISTER, T R. 2003. G-BASE Field Procedures Manual version 1.1. *British Geological Survey Internal Report*, IR/03/096N.

LISTER, T R. 2002. Analysis of Variance (ANOVA) of G-BASE Sub-Surface Soil Data from 11 Urban Centres in England and Wales. *British Geological Survey Internal Report*, IR/02/009.

LISTER, T R. In Prep. Analysis of Variance (ANOVA) of G-BASE Surface Soil Data from 11 Urban Centres in England and Wales. *British Geological Survey Internal Report*.

PLANT, J A. 1973. A random numbering system for geochemical samples. *Transactions of the Institution of Mining and Metallurgy (Section B: Applied earth science)*, Vol. 83, B64.

PLANT, J A, JEFFREY, K, GILL, E, and FAGE, C. 1975. The systematic determination of error, accuracy and precision in geochemical exploration data. *Journal of Geochemical Exploration*, Vol. 4, 467-486.

SNEDECOR, G W, and COCHRAN, W G. 1989. *Statistical Methods* (8th edition). (Ames, Iowa, USA: Iowa State University Press.)

Appendix A: Examples of urban surface and profile field cards from Telford.

URBAN SOIL/WATER

CODE	SAMPLE NO	TYPE	EASTING	NORTHING	O/S MAP	COLLECTORS	DAY	MONTH	YEAR
6Ø	2692	A	36625	3Ø125	127	JRRMHS	24	Ø8	94

DUPLICATE SAMPLE NO

CODE	SAMPLE NO	WEA	LAND USE	SITE/DRAINAGE CONTAMINATION A	B	C	D	E	F	G	H	I	OBS B/R	DRIFT
		1	PA										1	C1

SITE LOCALITY DETAILS

120m S OF TRK X/RD IN BILL'S ROUGH (WOOD)
450m ESE OF POSENHALL FM.

SOIL DATA

COLOUR	TEXTURE	HORIZON	DEPTH	SOIL CLAST LITHOLOGY	BEDROCK LITHOLOGY
BR	SiCL	A	Ø.15	3DØØ 3TØØ COAL	4PØØ

WATER SAMPLE DATA

STM ORD	DRN TYP	DRN CON	WATER COLOUR C	Y	B	SS	DRAINAGE CLAST LITHOLOGY

SOIL GASES

RADON: Unit: C Pot: 149

B G	Count 1	Count 2	Count 3	CO2	OXYGEN	METHANE
36	34Ø	229	138			

FIELD DATA COMMENTS

LCM/S&G

APPLIED GEOCHEMISTRY GROUP, BRITISH GEOLOGICAL SURVEY, 1994.

URBAN SOIL/WATER

CODE	SAMPLE NO	TYPE	EASTING	NORTHING	O/S MAP	COLLECTORS	DAY	MONTH	YEAR
6Ø	26Ø2	S	36625	3Ø125	127	JRRMHS	24	Ø8	94

DUPLICATE SAMPLE NO

CODE	SAMPLE NO	WEA	LAND USE	SITE/DRAINAGE CONTAMINATION A	B	C	D	E	F	G	H	I	OBS B/R	DRIFT
		1	PA										1	C1

SITE LOCALITY DETAILS

120m S OF X/RD OF TRKS IN BILL'S ROUGH
(WOOD). 450m ESE OF POSENHALL FM.

SOIL DATA

COLOUR	TEXTURE	HORIZON	DEPTH	SOIL CLAST LITHOLOGY	BEDROCK LITHOLOGY
LB	SiCL	B	Ø.35	3DØØ COAL 3SØØ 3TØØ	4PØØ

WATER SAMPLE DATA

STM ORD	DRN TYP	DRN CON	WATER COLOUR C	Y	B	SS	DRAINAGE CLAST LITHOLOGY

SOIL GASES

RADON: Unit: Pot:

B G	Count 1	Count 2	Count 3	CO2	OXYGEN	METHANE

FIELD DATA COMMENTS

LCM/S&G

APPLIED GEOCHEMISTRY GROUP, BRITISH GEOLOGICAL SURVEY, 1994.

Appendix B: Percentile calculations for Telford soils

*surface soils in yellow.

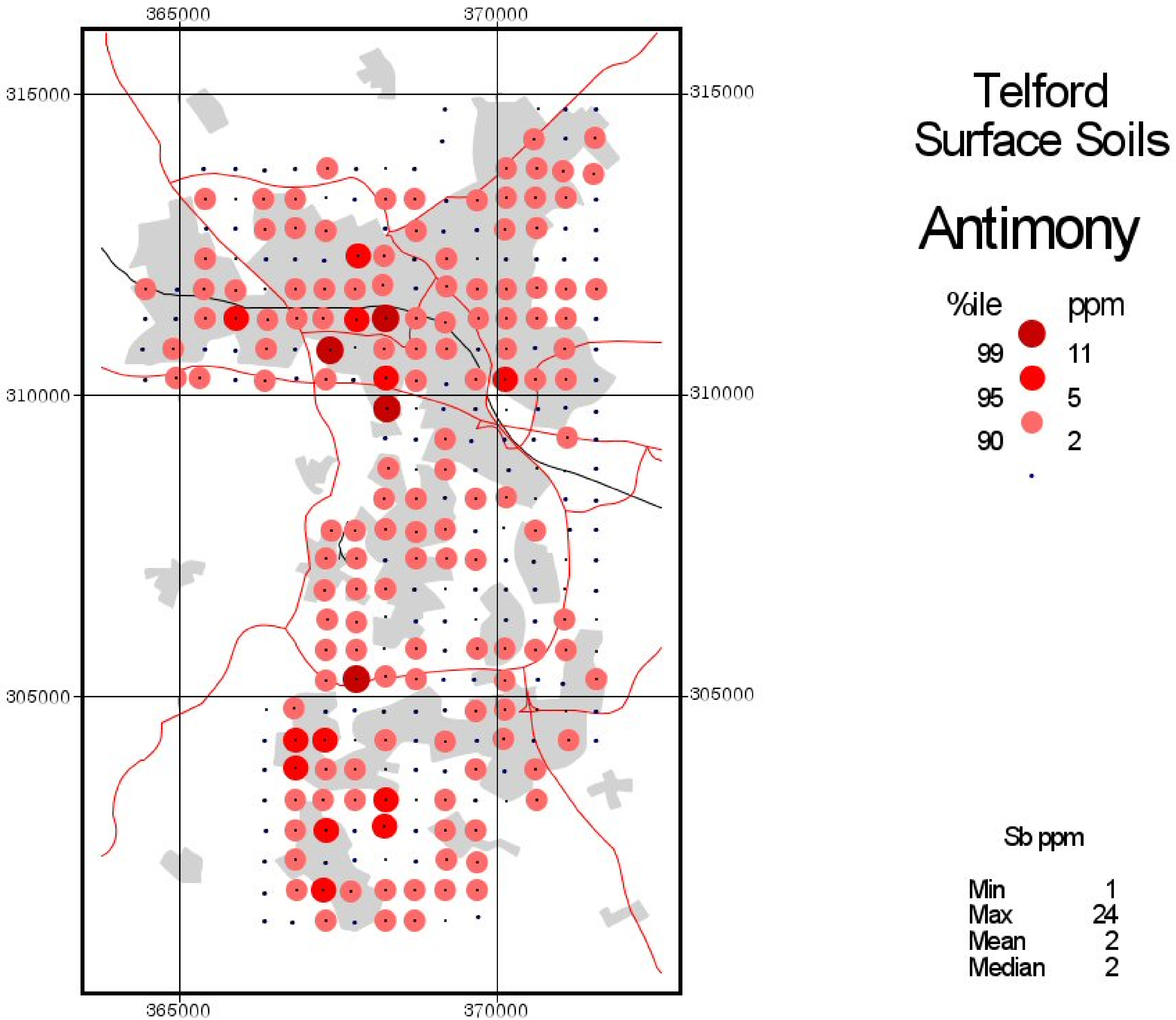
Percentiles	TiO_2 wt %	MnO wt %	MnO wt %	Fe_2O_3 wt %	Fe_2O_3 wt %	V mg/kg	V mg/kg	Cr mg/kg	Cr mg/kg	Co mg/kg	Co mg/kg	Ba mg/kg	Ba mg/kg	Ni mg/kg	Ni mg/kg	Cu mg/kg	Cu mg/kg
99	1.196	0.423	0.397	11.65	14.64	228	340	132	157	87	117	753	1136	129	226	249	305
95	1.078	0.228	0.269	7.71	8.25	185	211	114	121	48	74	585	694	76	108	83	91
90	0.965	0.182	0.228	6.49	6.77	168	180	108	115	39	43	547	609	51	60	54	69
75	0.768	0.135	0.151	5.17	5.87	117	133	86	101	31	31	479	534	38	44	37	41
50	0.590	0.098	0.109	4.29	5.06	82	99	65	85	22	26	425	458	28	35	26	30
25	0.497	0.071	0.080	3.25	4.29	67	84	54	76	16	22	384	407	21	27	19	23
15	0.447	0.060	0.060	2.85	3.91	60	78	51	73	14	20	365	379	18	24	16	19
10	0.420	0.053	0.052	2.69	3.57	56	74	47	71	13	17	347	350	16	22	15	17
5	0.361	0.044	0.035	2.35	3.12	48	66	42	65	11	15	326	305	14	20	13	14
Min	0.252	0.005	0.005	1.13	1.82	32	47	25	45	4	8	251	141	7	12	8	9
Max	1.442	0.533	0.562	15.57	18.67	329	414	164	211	102	181	1490	3333	153	349	417	572
Mean	0.644	0.113	0.126	4.47	5.34	98	117	72	90	25	31	441	489	33	44	37	43
Median	0.590	0.098	0.109	4.29	5.06	82	99	65	85	22	26	425	458	28	35	26	30

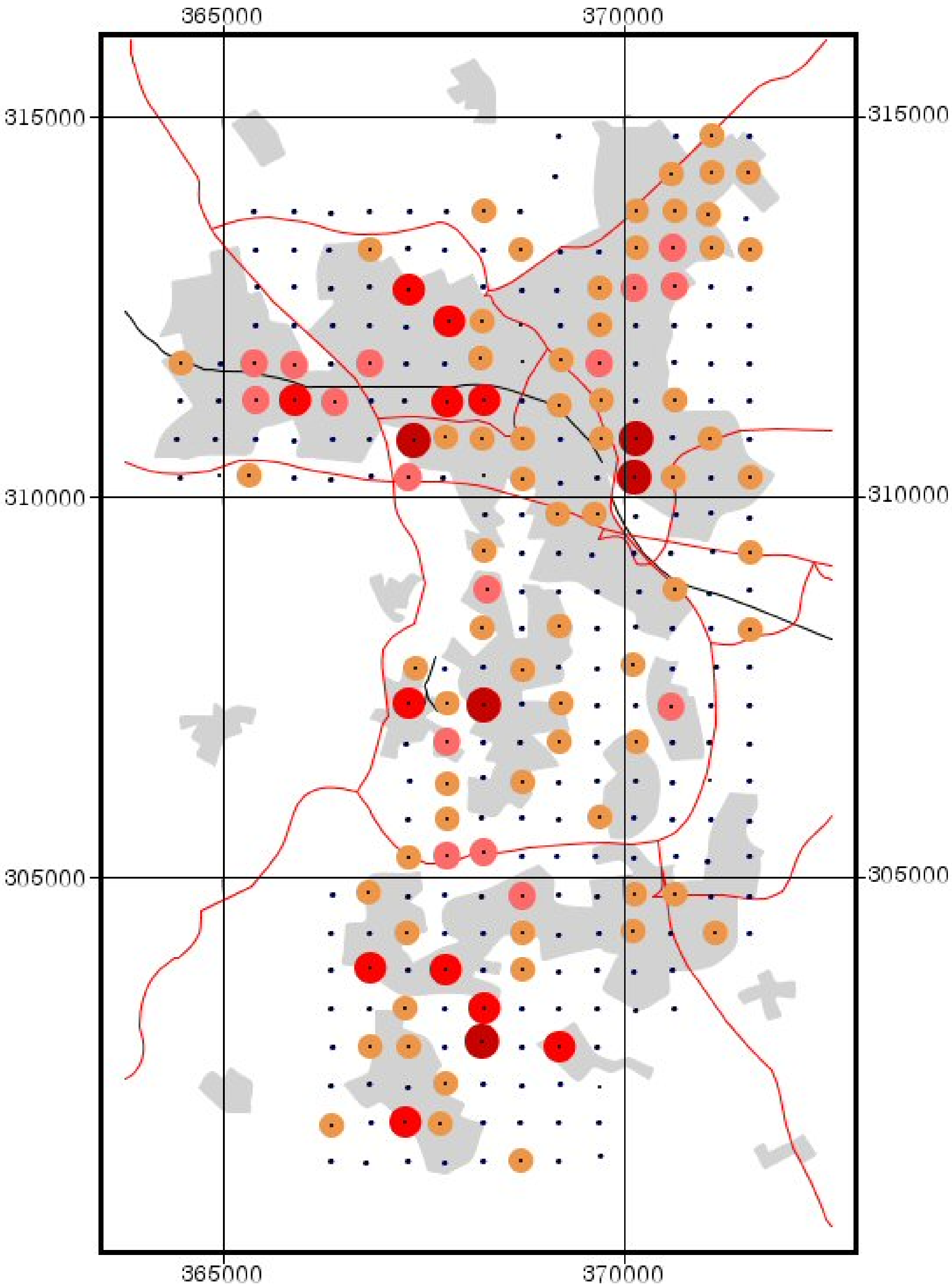
Percentiles	Zn mg/kg	Zn mg/kg	As mg/kg	As mg/kg	Mo mg/kg	Mo mg/kg	Pb mg/kg	Pb mg/kg	U mg/kg	U mg/kg	Cd mg/kg	Cd mg/kg	Sn mg/kg	Sn mg/kg	Sb mg/kg	Sb mg/kg
99	2660	3528	36	73	6.4	17.6	1081	1523	3	3	15	18	35	84	11	12
95	1222	1794	24	32	3.6	9.0	431	520	3	3	7	9	13	29	5	6
90	883	935	19	23	2.7	5.1	286	342	2	3	5	6	11	18	2	4
75	466	430	13	15	1.8	3.5	169	162	2	2	3	3	7	8	2	2
50	264	238	10	12	1.2	2.5	92	82	2	2	1	2	5	5	2	1
25	153	121	8	10	0.8	1.7	54	44	1	2	1	2	4	3	1	1
15	121	95	7	9	0.6	1.4	45	31	1	2	1	1	3	3	1	1
10	105	79	7	8	0.5	1.2	39	26	1	2	1	1	3	3	1	1
5	82	65	6	7	0.4	1.0	33	20	1	2	1	1	3	2	1	1
Min	46	38	5	3	0.2	0.2	20	11	1	1	1	1	2	1	1	1
Max	4943	6849	54	120	9.7	39.1	1236	2975	4	4	30	44	68	241	24	19
Mean	417	455	12	15	1.5	3.4	150	164	2	2	2	3	7	10	2	2
Median	264	238	10	12	1.2	2.5	92	82	2	2	1	2	5	5	2	1

Appendix C: Graduated symbol geochemical maps for Telford surface and profile soils

Antimony
Arsenic
Barium
Cadmium
Chromium
Cobalt
Copper
Iron
Lead
Manganese
Molybdenum
Nickel
Tin
Titanium
Uranium
Vanadium
Zinc

Note ppm = mg/kg


365000
370000
315000
310000
305000
Telford
Surface Soils
Antimony
%ile
ppm
99
11
95
5
90
2
Sb ppm
Min 1
Max 24
Mean 2
Median 2



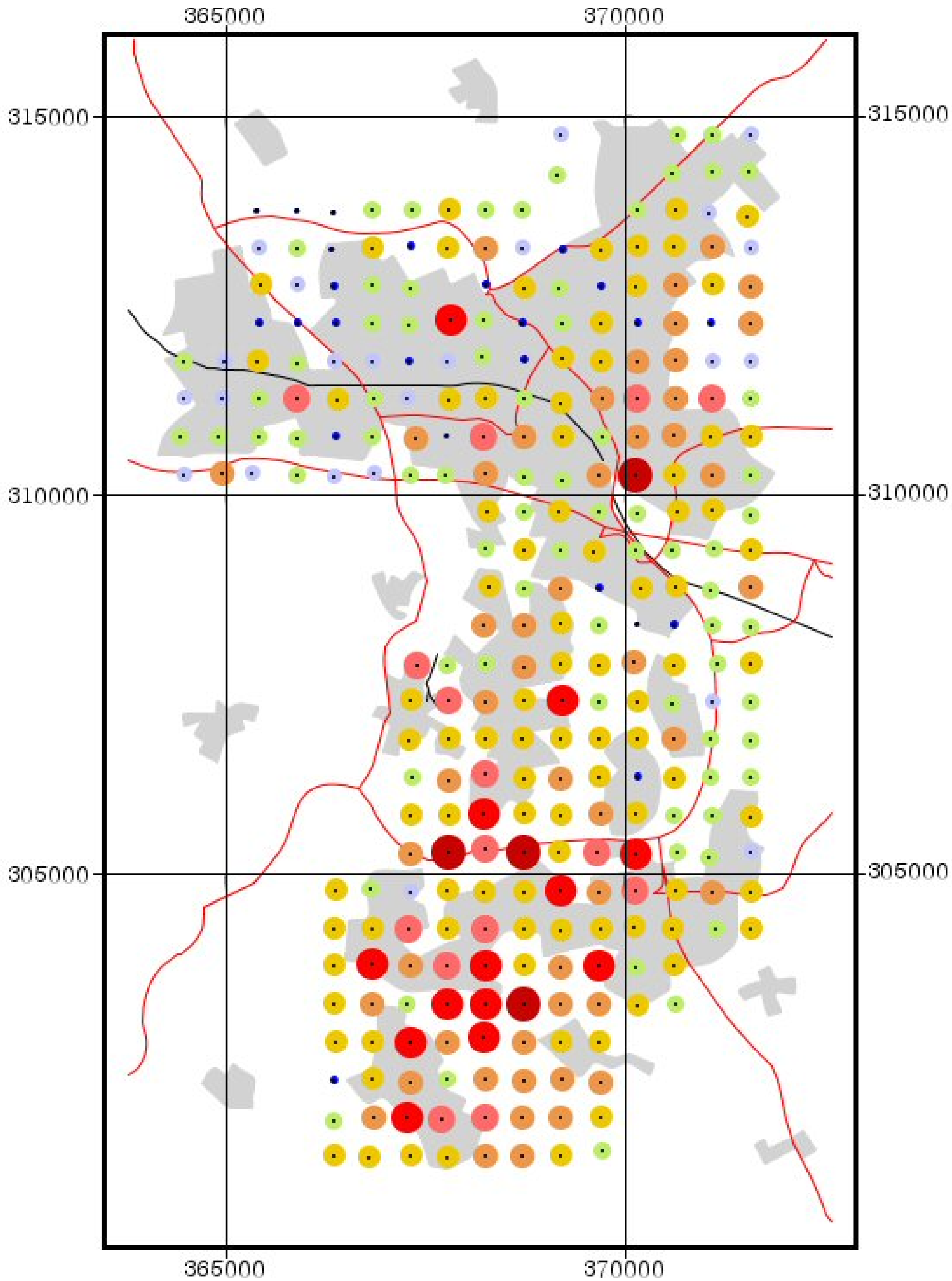
Telford Profile Soils

Antimony

%ile	ppm
99	12
95	6
90	4
75	2

Sb ppm

Min	1
Max	19
Mean	2
Median	1



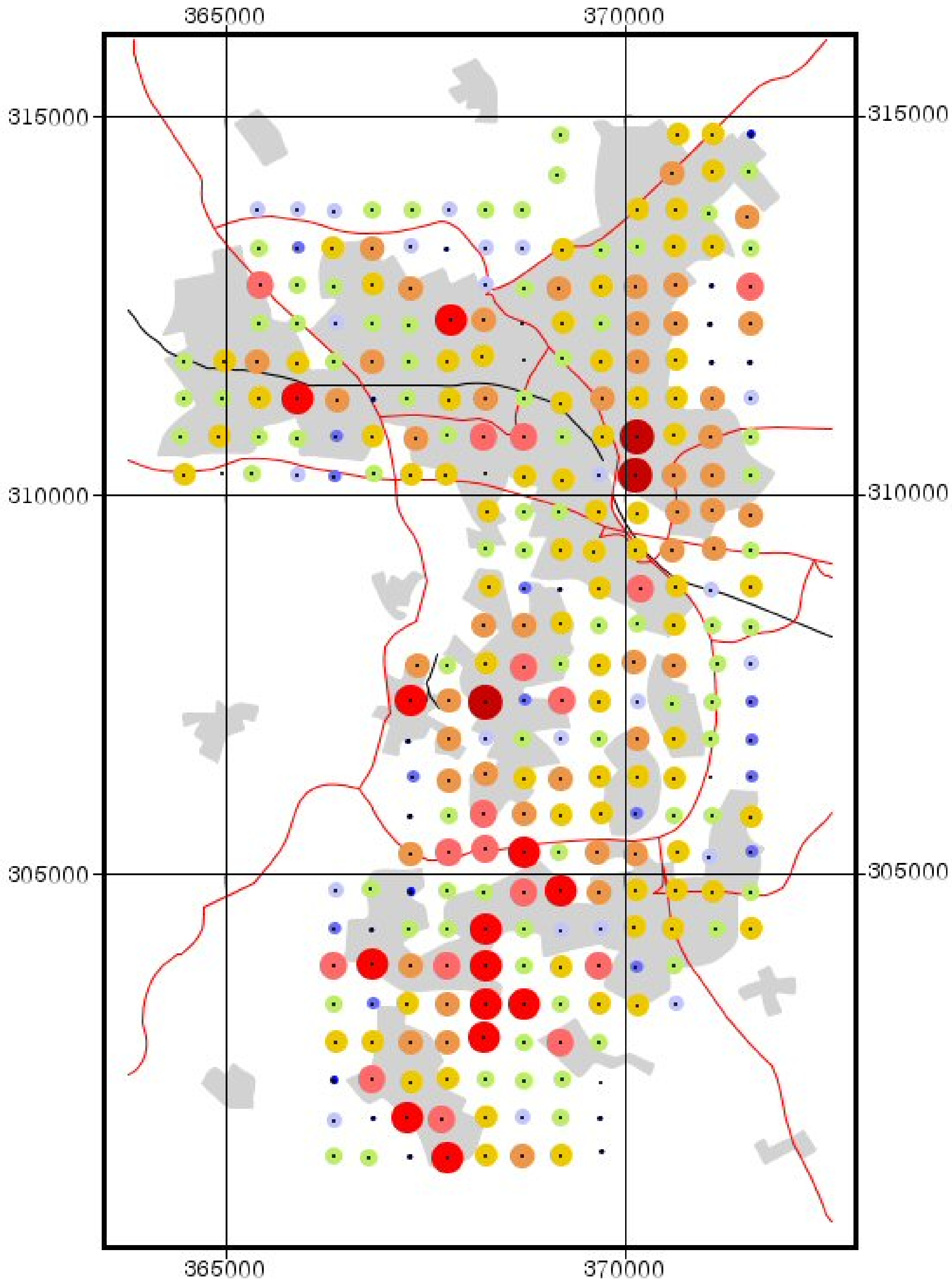
Telford
Surface Soils

Arsenic

%ile	ppm
99	36
95	24
90	19
75	13
50	10
25	8
15	7
5	6

As ppm

Min	5
Max	54
Mean	12
Median	10



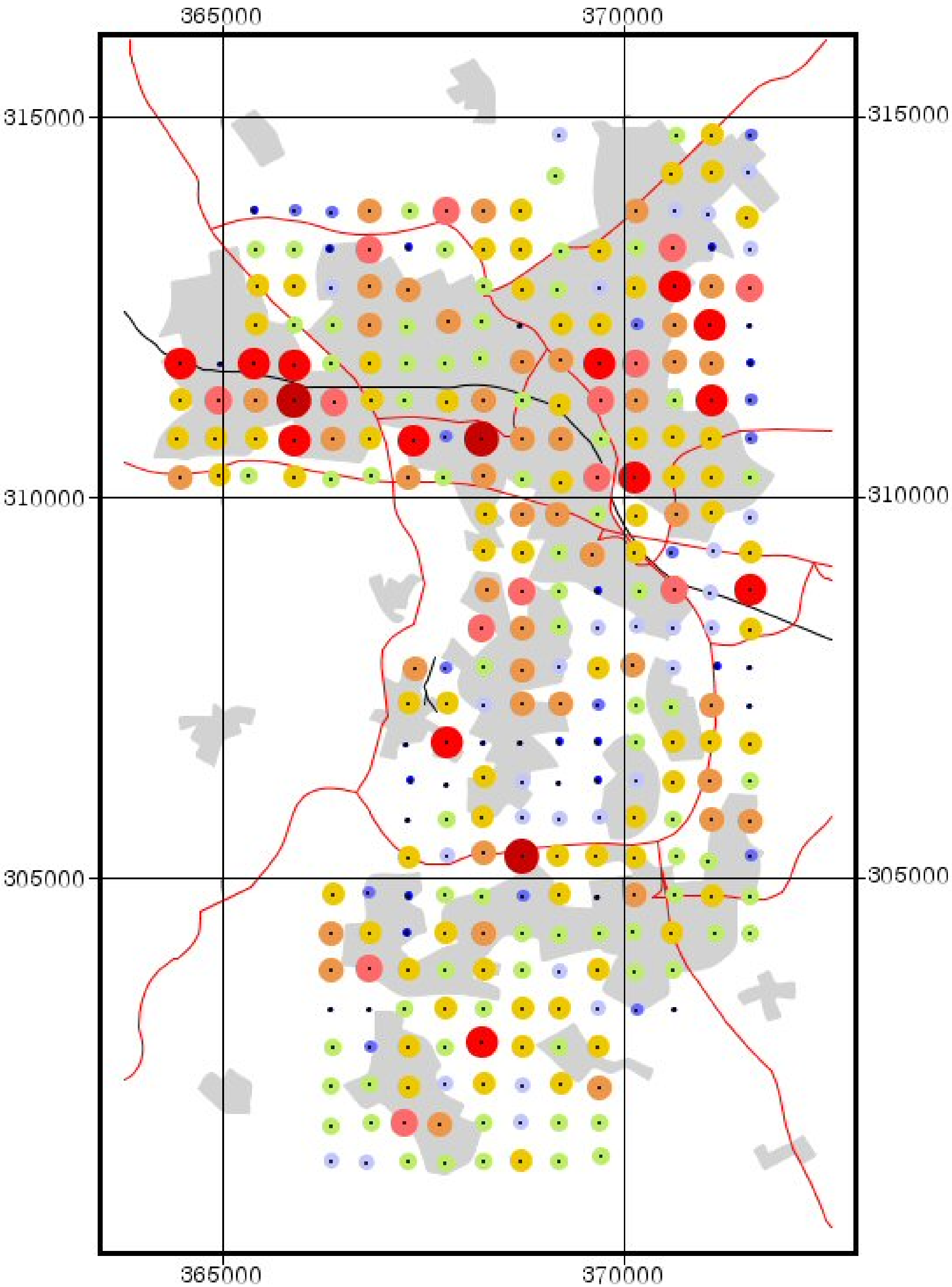
Telford Profile Soils

Arsenic

%ile	ppm
99	73
95	32
90	23
75	15
50	12
25	10
15	9
10	8
5	7

As ppm

Min	3
Max	120
Mean	15
Median	12



Telford Surface Soils

Barium

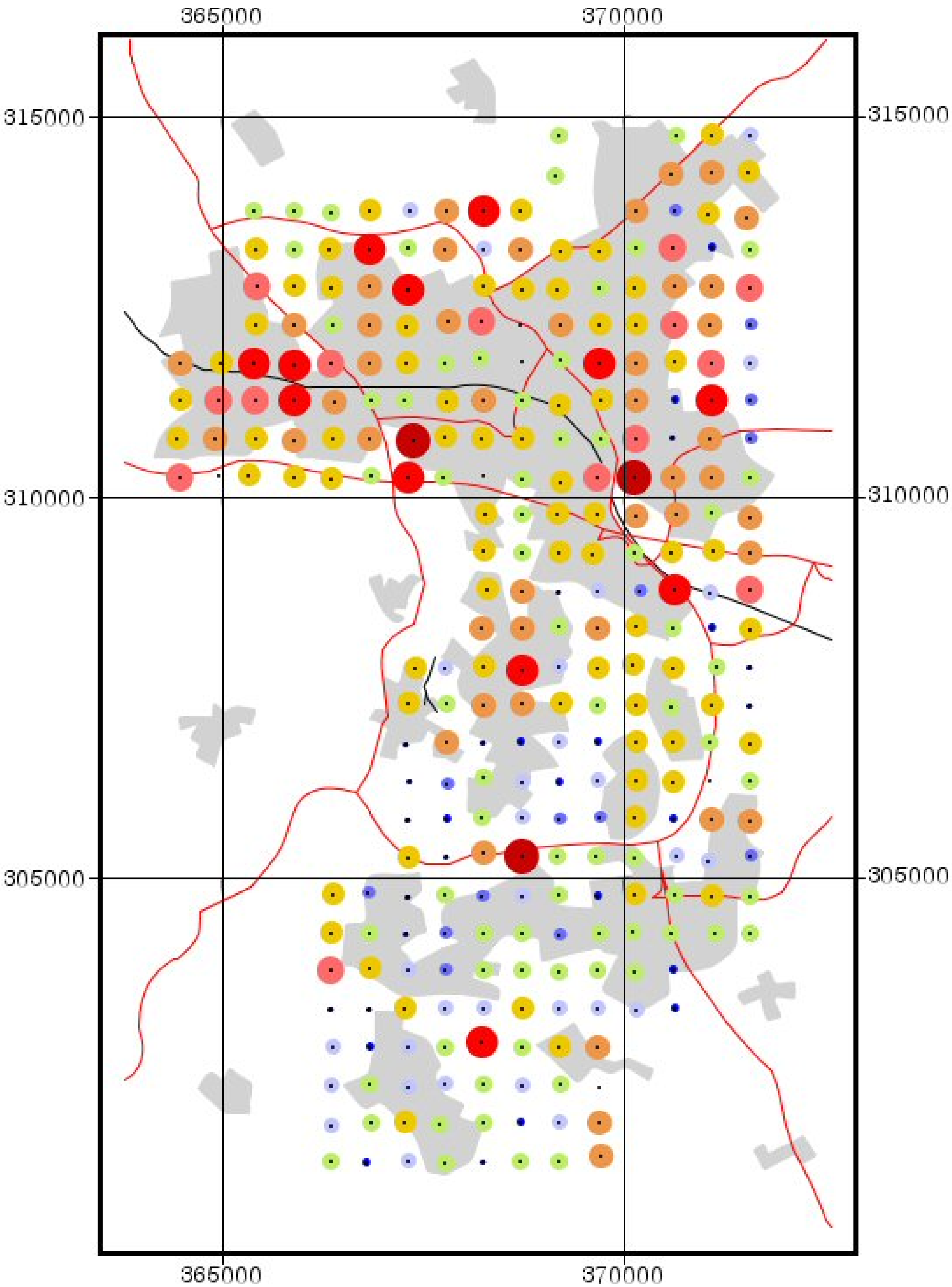
%ile	ppm
99	753
95	585
90	547
75	479
50	425
25	384
15	365
10	347
5	326

Ba ppm

Min	251
Max	1490
Mean	441
Median	425

Telford Profile Soils

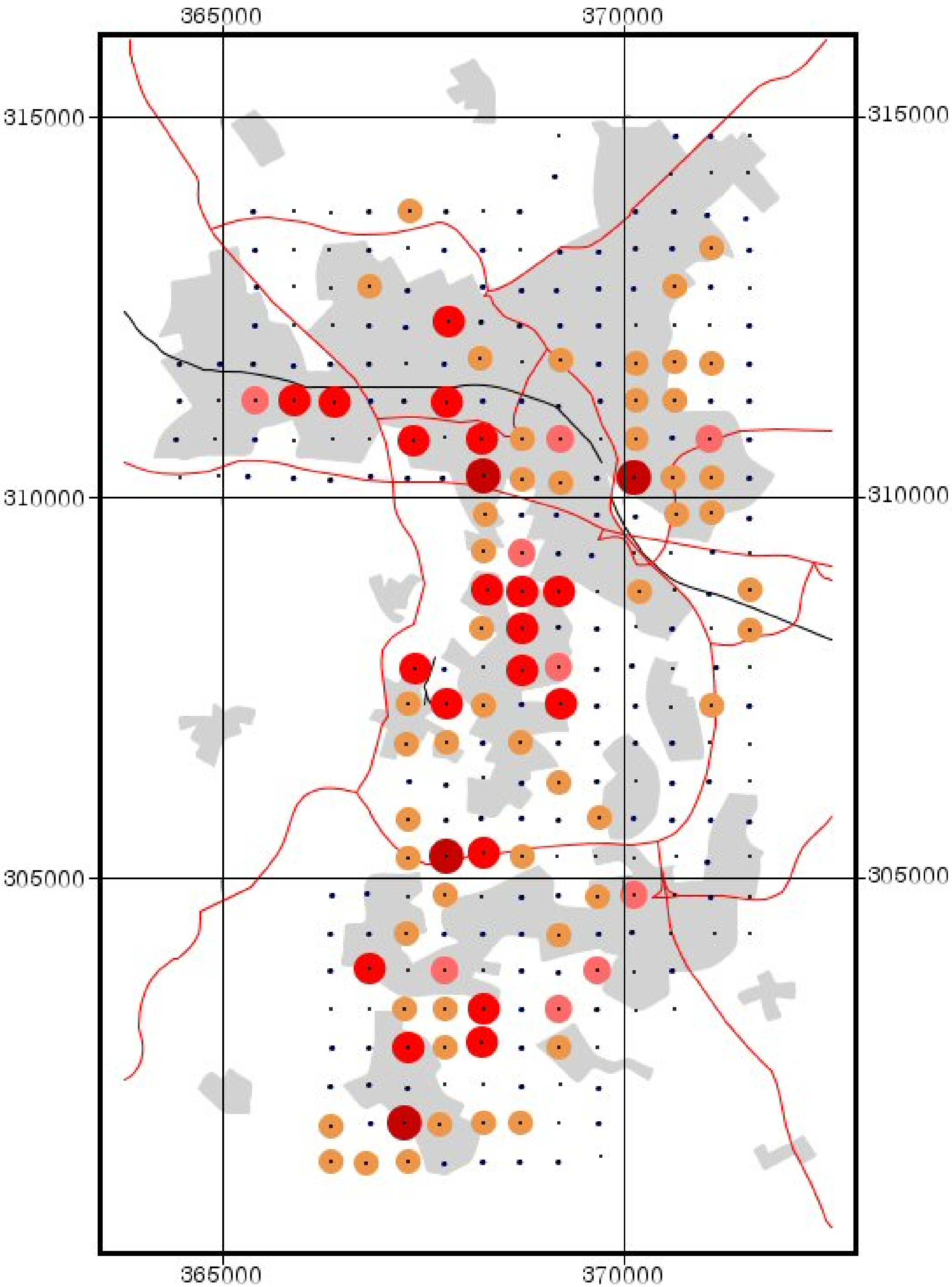
Barium



%ile	ppm
99	1136
95	694
90	609
75	534
50	458
25	407
15	379
10	350
5	305

Ba ppm

Min	141
Max	3333
Mean	489
Median	458



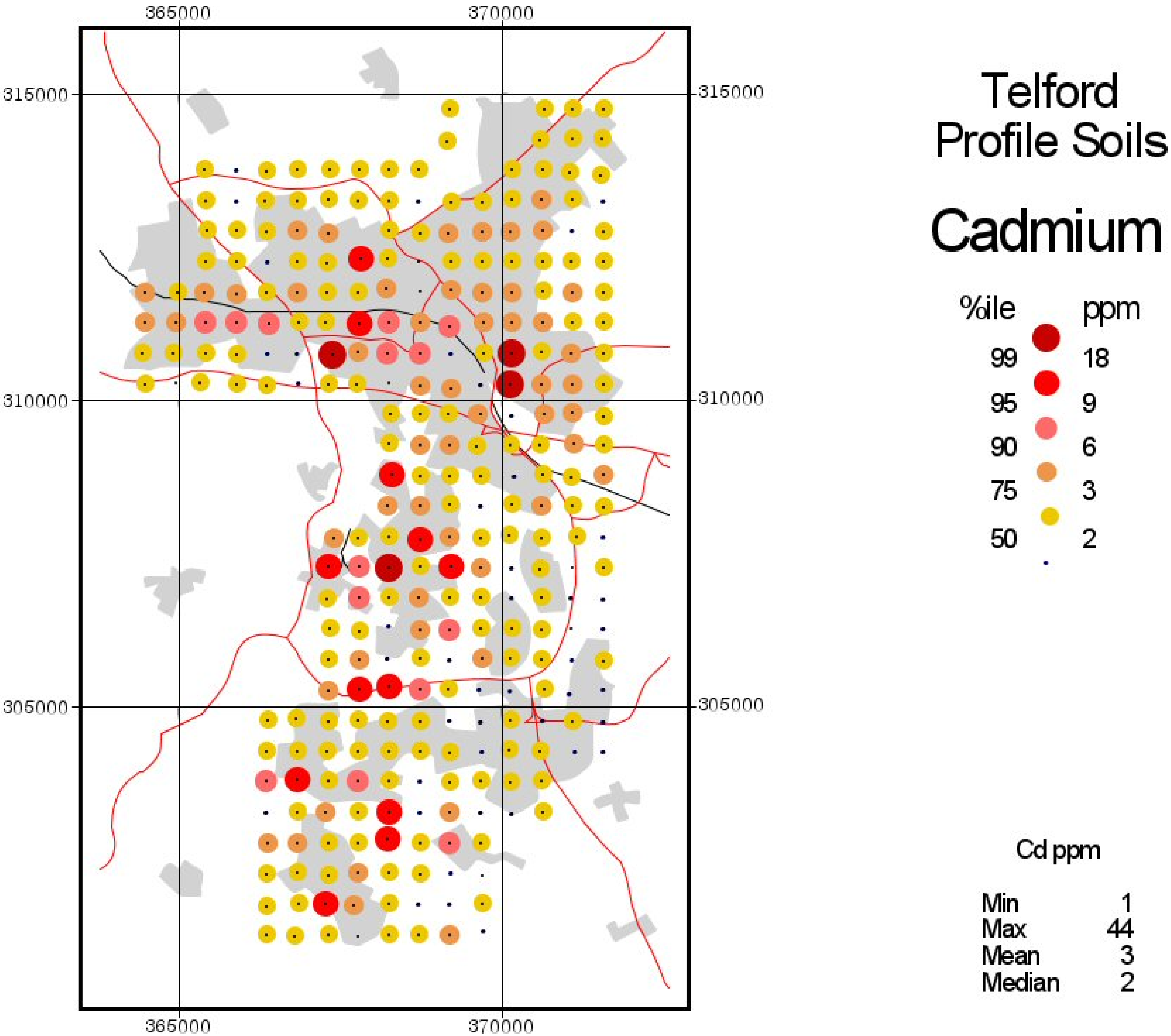
Telford Surface Soils

Cadmium

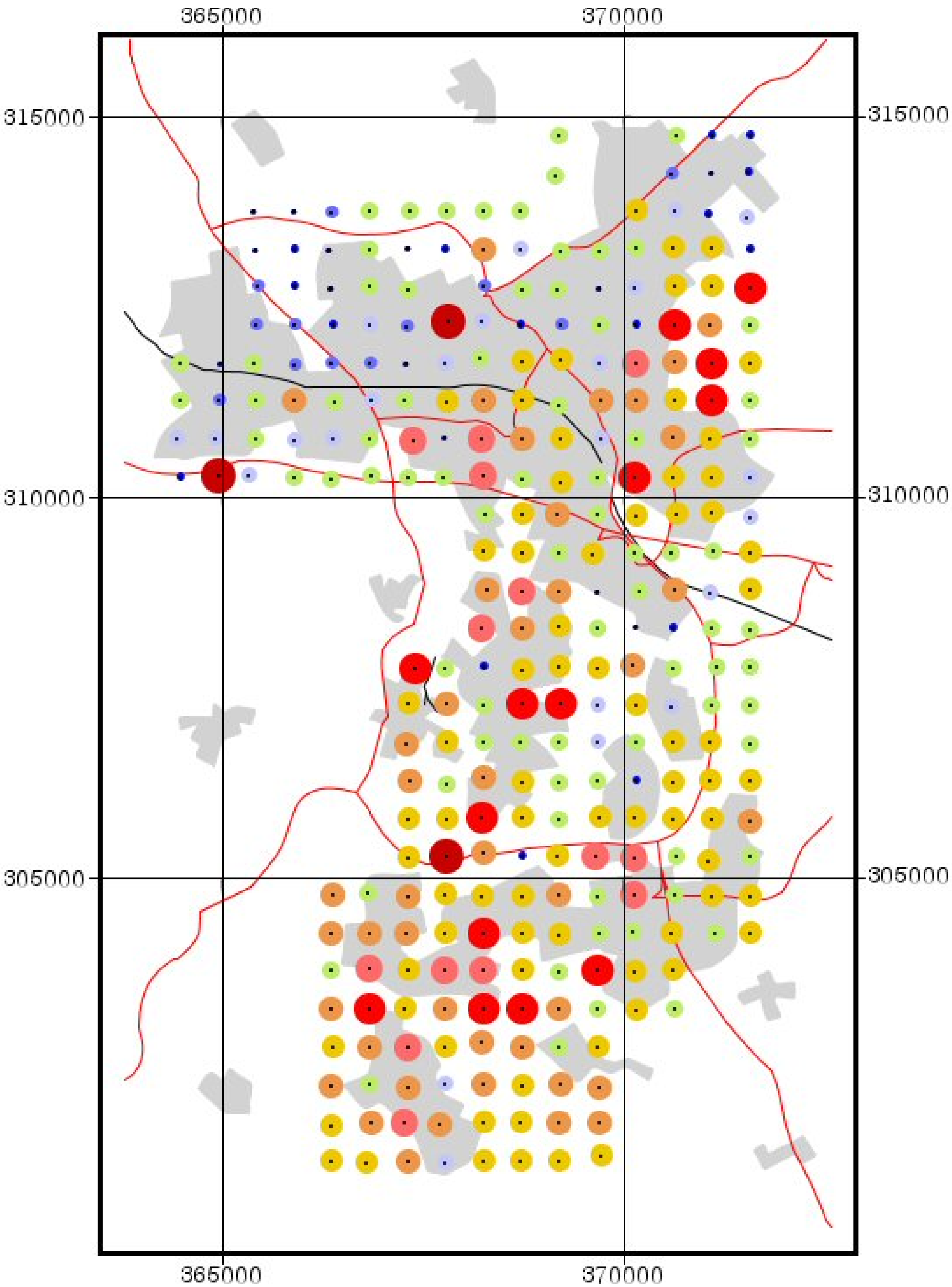
%ile	ppm
99	15
95	7
90	5
75	3

Cd ppm

Min	1
Max	30
Mean	2
Median	1



365000
370000
315000
310000
305000
Telford
Profile Soils
Cadmium
%ile
ppm
99
18
95
9
90
6
75
3
50
2
Cd ppm
Min 1
Max 44
Mean 3
Median 2



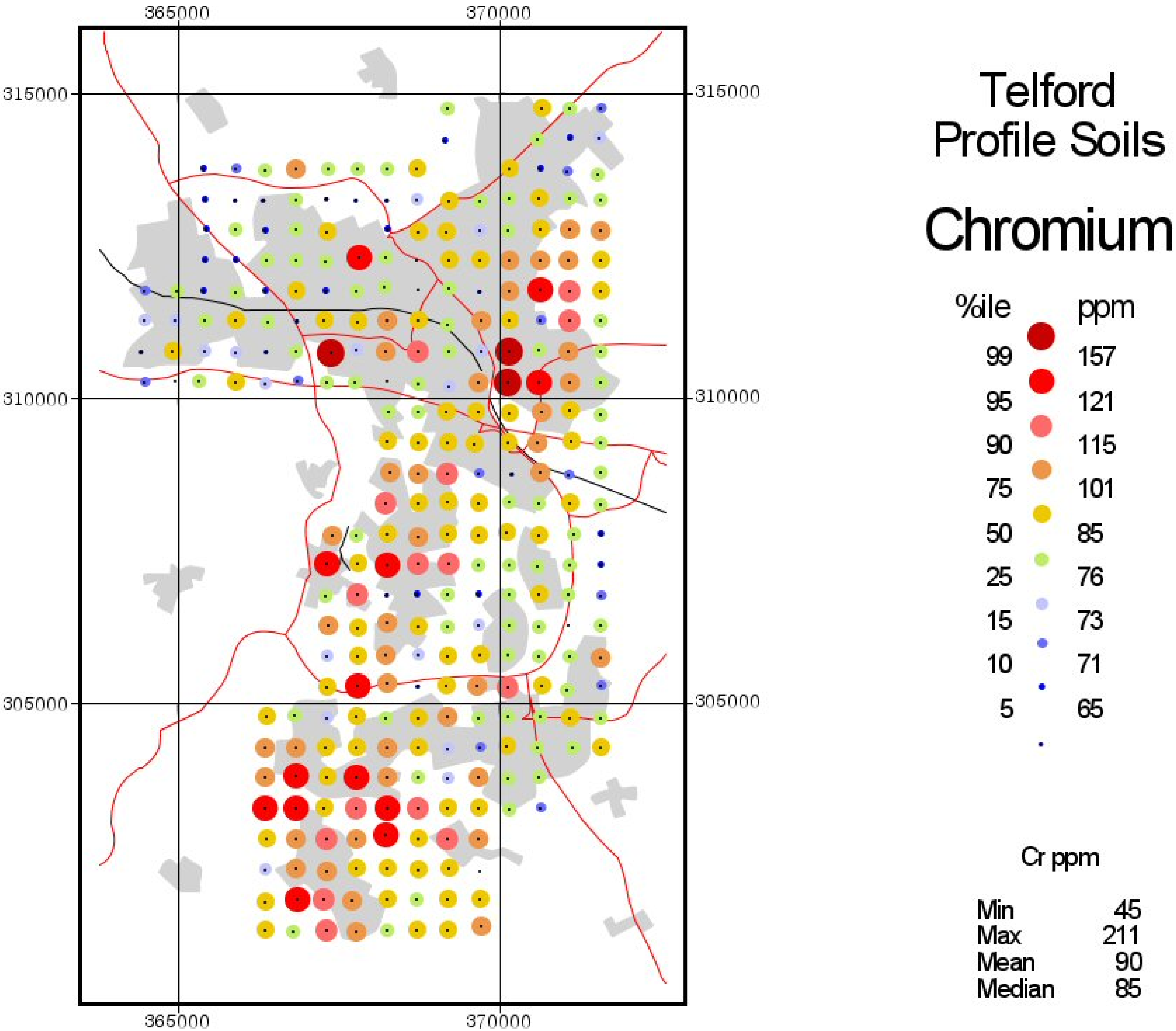
Telford Surface Soils

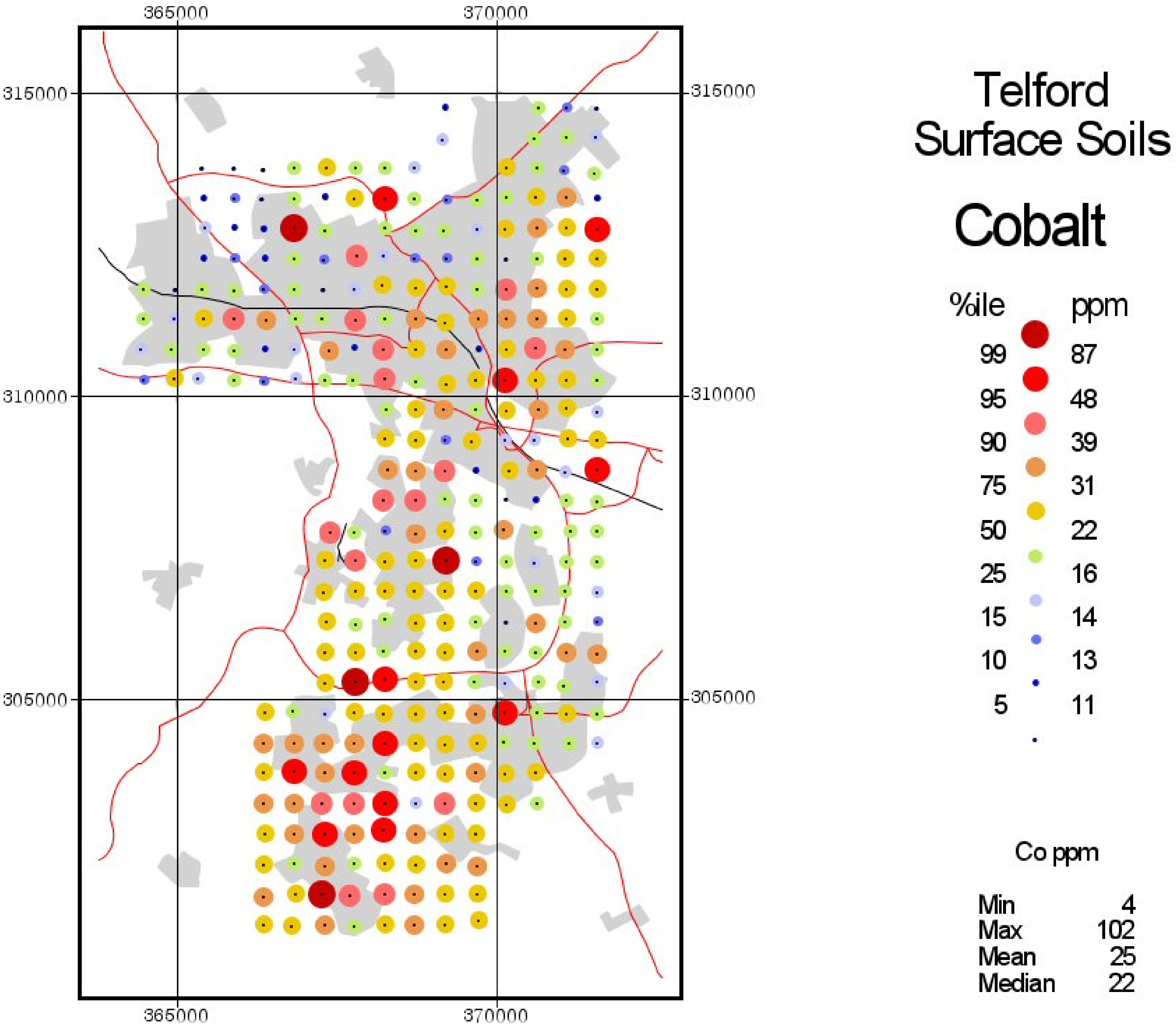
Chromium

%ile	ppm
99	132
95	114
90	108
75	86
50	65
25	54
15	51
10	47
5	42

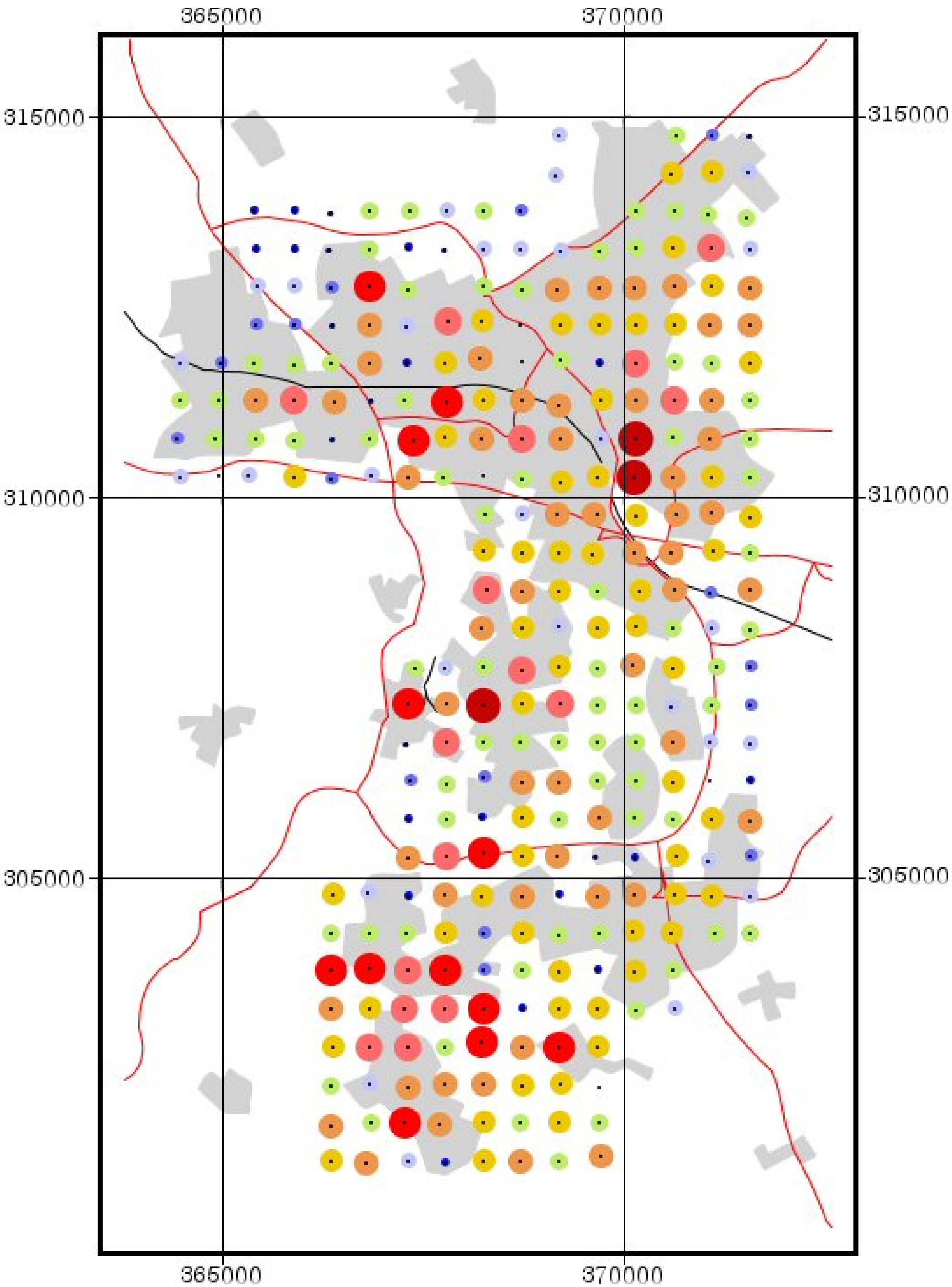
Cr ppm

Min	25
Max	164
Mean	72
Median	65


365000
370000
315000
310000
305000
Telford
Profile Soils
Chromium
%ile
ppm
99
157
95
121
90
115
75
101
50
85
25
76
15
73
10
71
5
65
Cr ppm
Min 45
Max 211
Mean 90
Median 85



365000
370000
315000
310000
305000
Telford
Surface Soils
Cobalt
%ile
ppm
99 87
95 48
90 39
75 31
50 22
25 16
15 14
10 13
5 11
Co ppm
Min 4
Max 102
Mean 25
Median 22



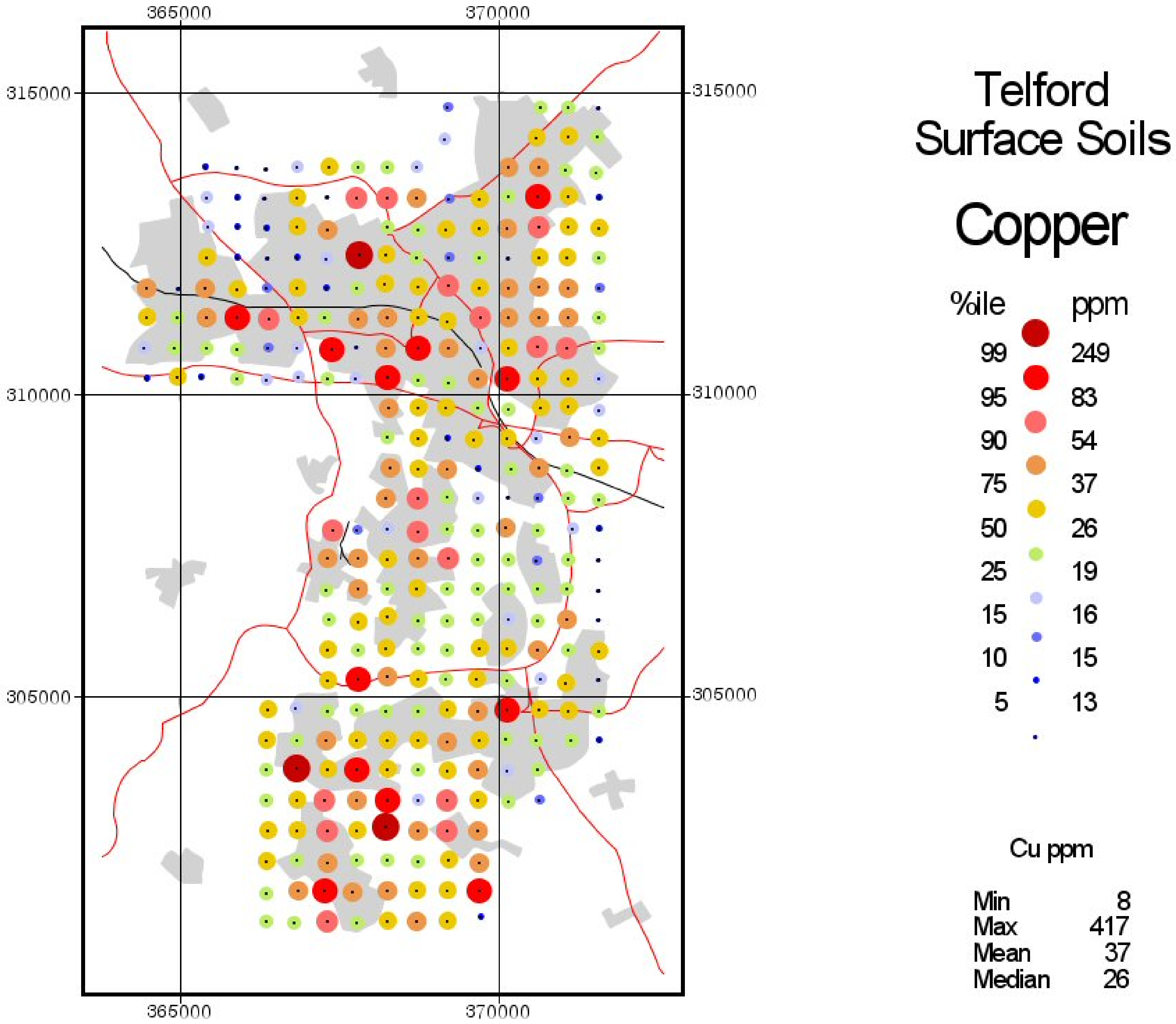
Telford Profile Soils

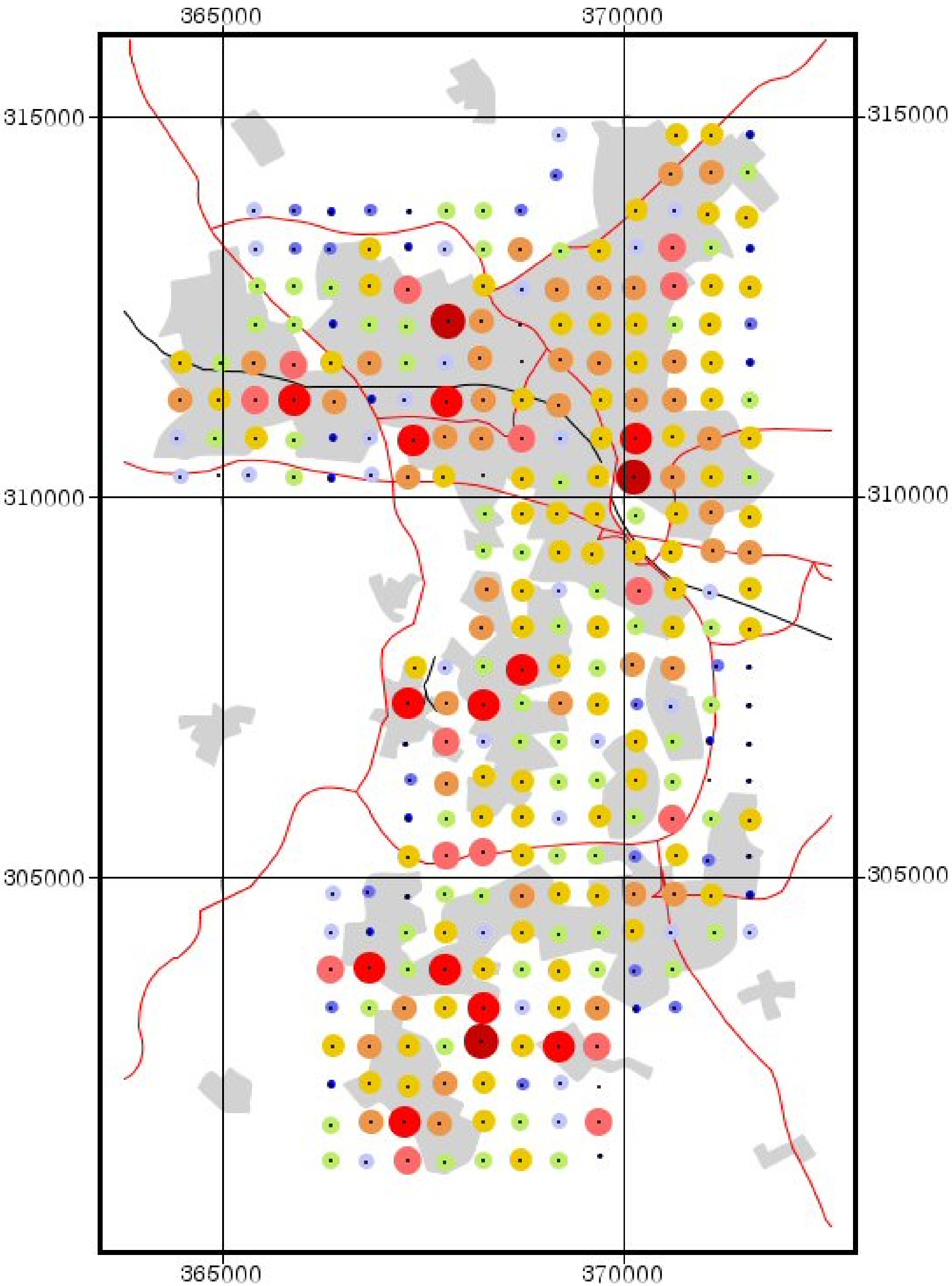
Cobalt

%ile	ppm
99	117
95	74
90	43
75	31
50	26
25	22
15	20
10	17
5	15

Co ppm

Min	8
Max	181
Mean	31
Median	26


Telford
Surface Soils
Copper
%ile ppm
99 249
95 83
90 54
75 37
50 26
25 19
15 16
10 15
5 13
Cu ppm
Min 8
Max 417
Mean 37
Median 26
365000
370000
315000
310000
305000



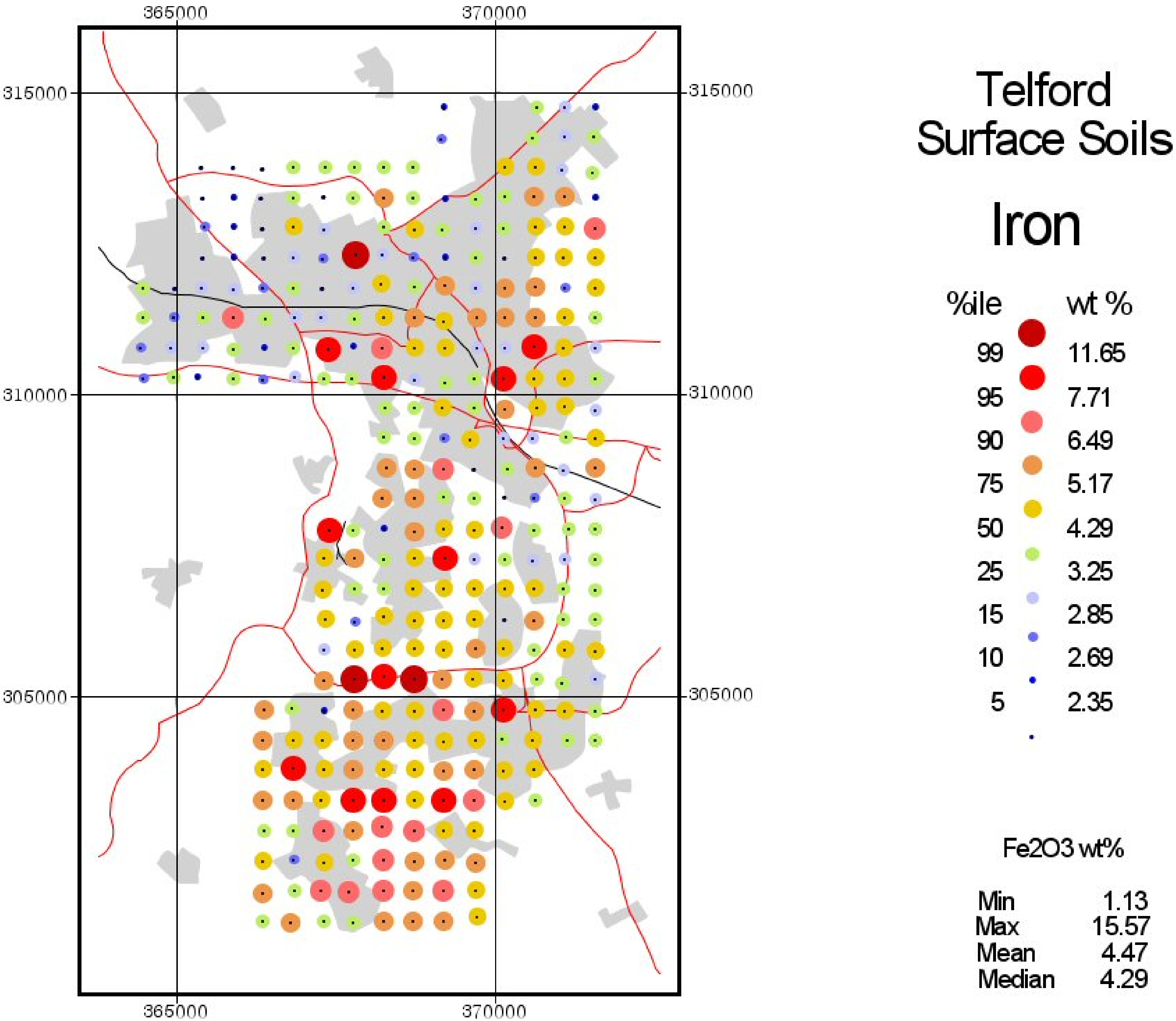
Telford Profile Soils

Copper

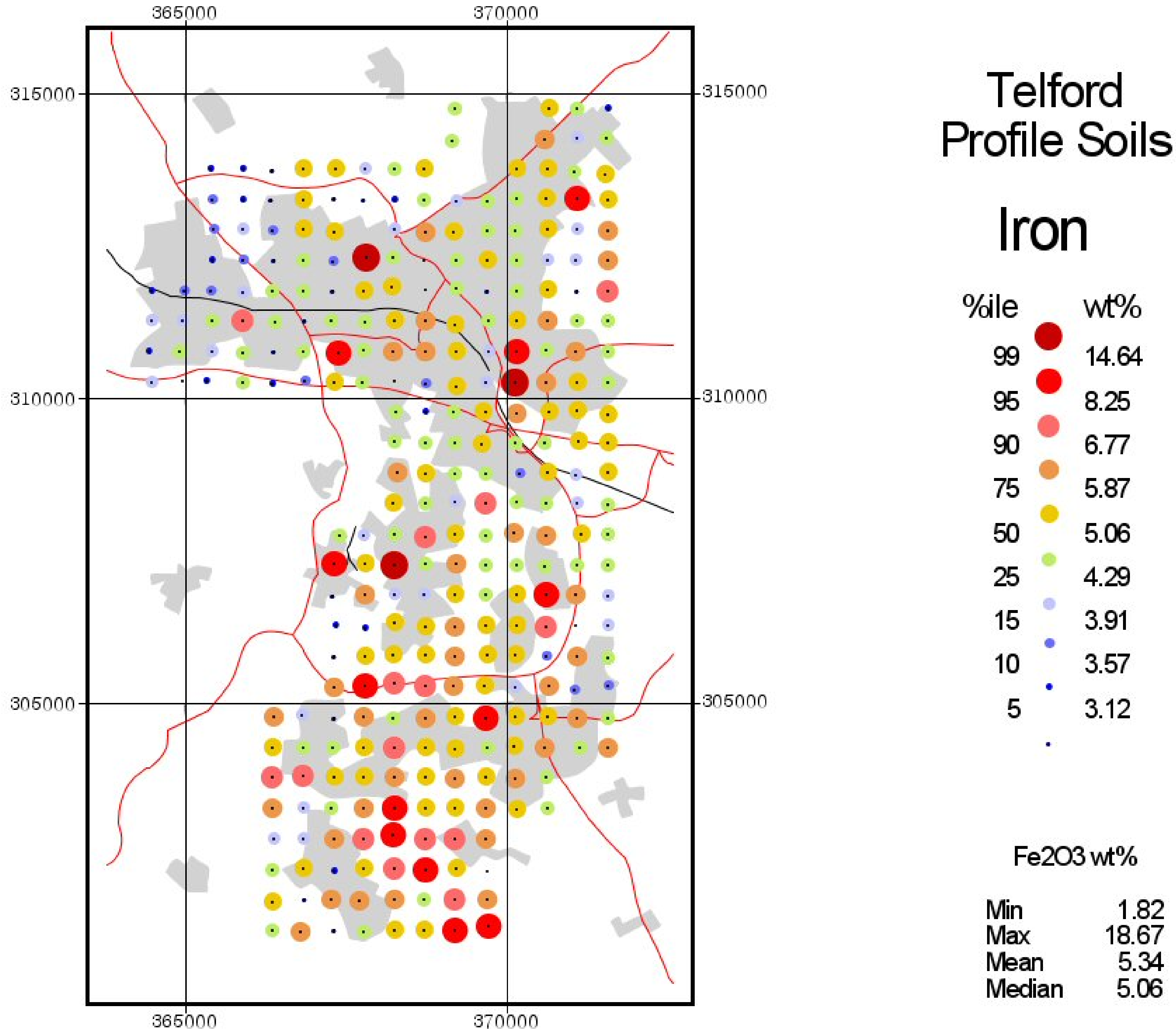
%ile	ppm
99	305
95	91
90	69
75	41
50	30
25	23
15	19
10	17
5	14

Cu ppm

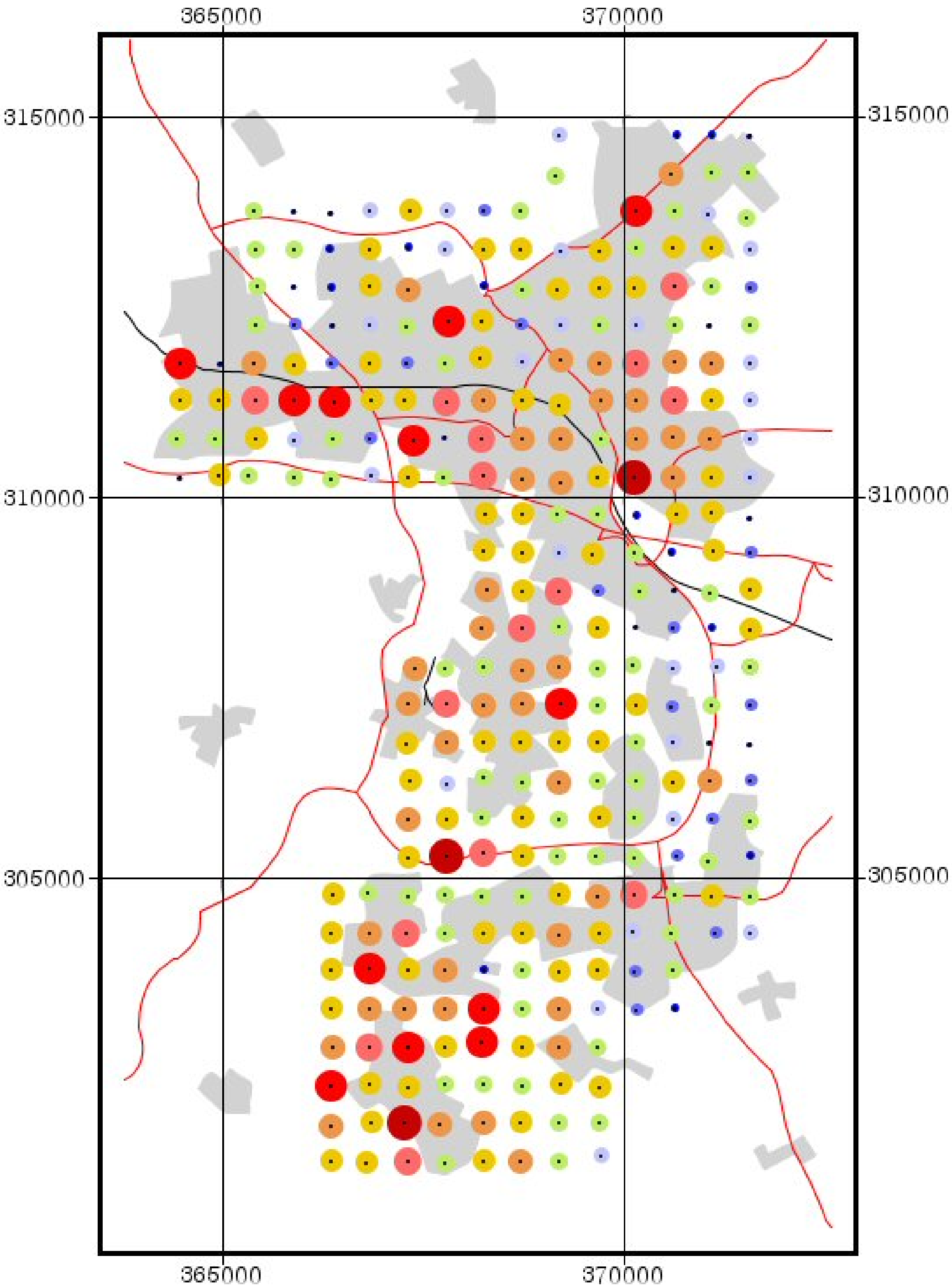
Min	9
Max	572
Mean	43
Median	30



365000
370000
315000
310000
305000
Telford
Surface Soils
Iron
%ile
wt %
99
11.65
95
7.71
90
6.49
75
5.17
50
4.29
25
3.25
15
2.85
10
2.69
5
2.35
Fe2O3 wt%
Min 1.13
Max 15.57
Mean 4.47
Median 4.29



365000
370000
315000
310000
305000
365000
370000
315000
310000
305000
Telford
Profile Soils
Iron
%ile
wt%
99
14.64
95
8.25
90
6.77
75
5.87
50
5.06
25
4.29
15
3.91
10
3.57
5
3.12
Fe2O3 wt%
Min 1.82
Max 18.67
Mean 5.34
Median 5.06



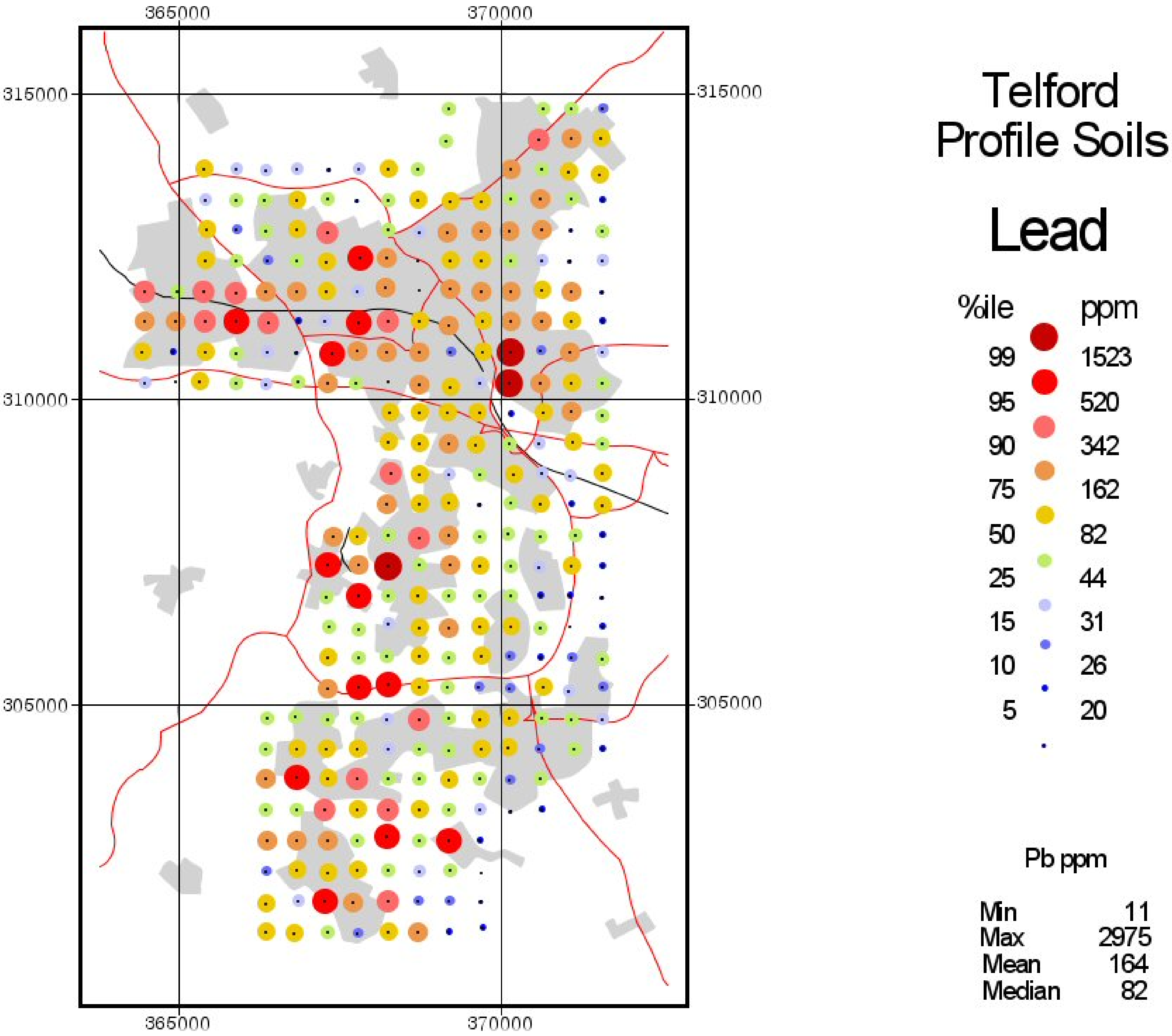
Telford Surface Soils

Lead

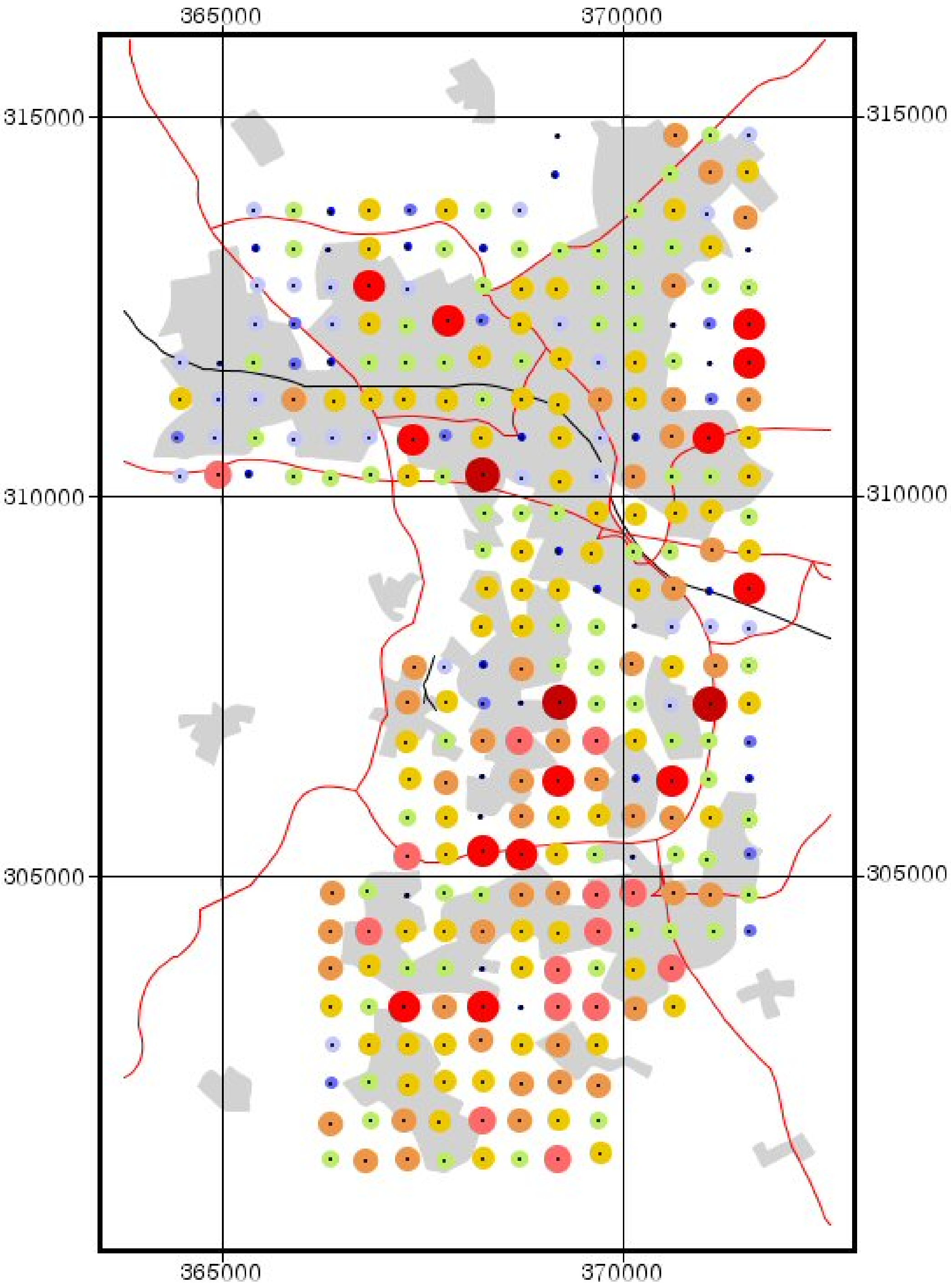
%ile	ppm
99	1081
95	431
90	286
75	169
50	92
25	54
15	45
10	39
5	33

Pb ppm

Min	20
Max	1236
Mean	150
Median	92



365000
370000
315000
310000
305000
Telford
Profile Soils
Lead
%ile
ppm
99
1523
95
520
90
342
75
162
50
82
25
44
15
31
10
26
5
20
Pb ppm
Min 11
Max 2975
Mean 164
Median 82



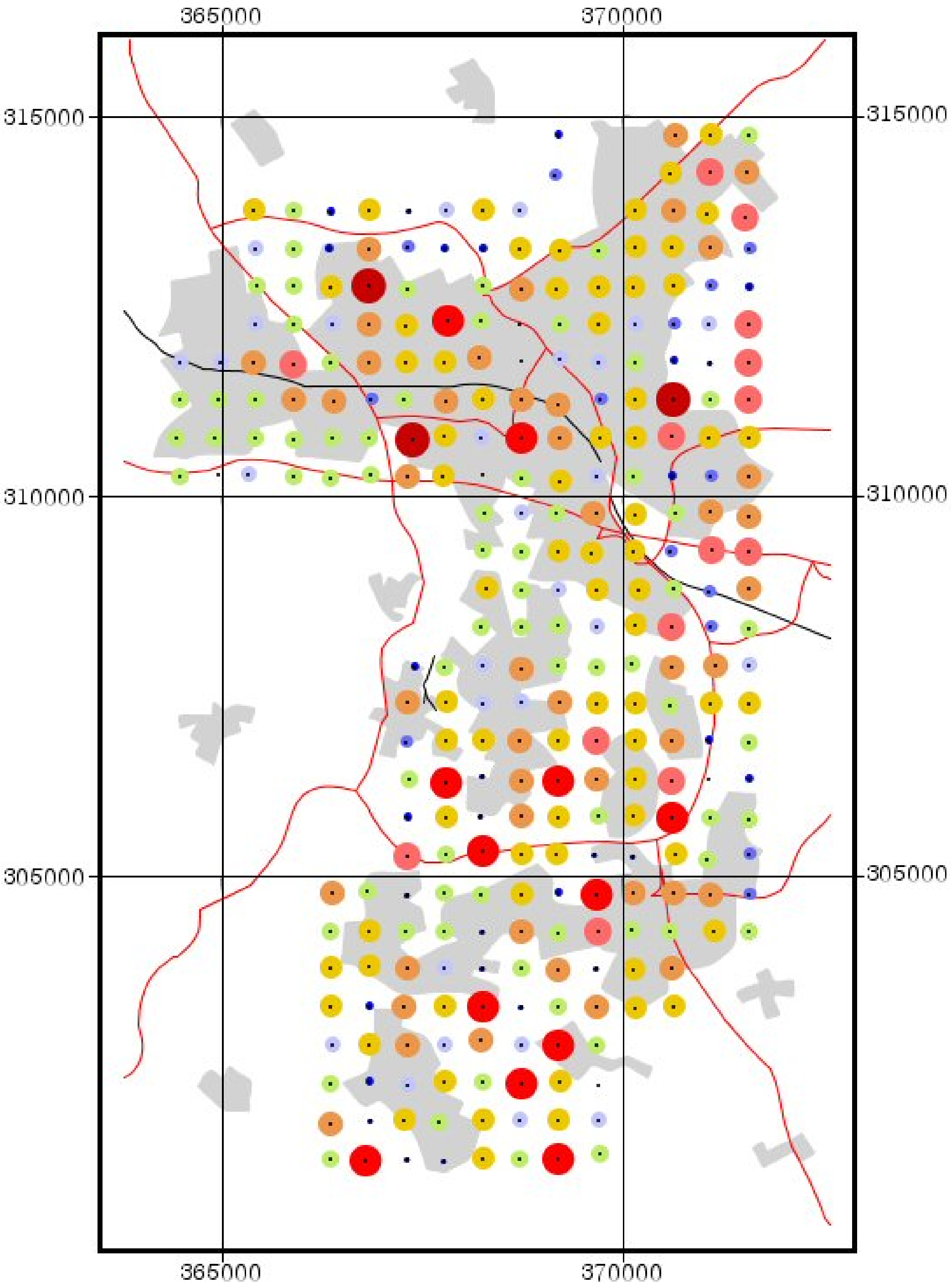
Telford Surface Soils

Manganese

%ile	wt %
99	0.423
95	0.228
90	0.182
75	0.135
50	0.098
25	0.071
15	0.060
10	0.053
5	0.044

MnO wt%

Min	0.005
Max	0.533
Mean	0.113
Median	0.098



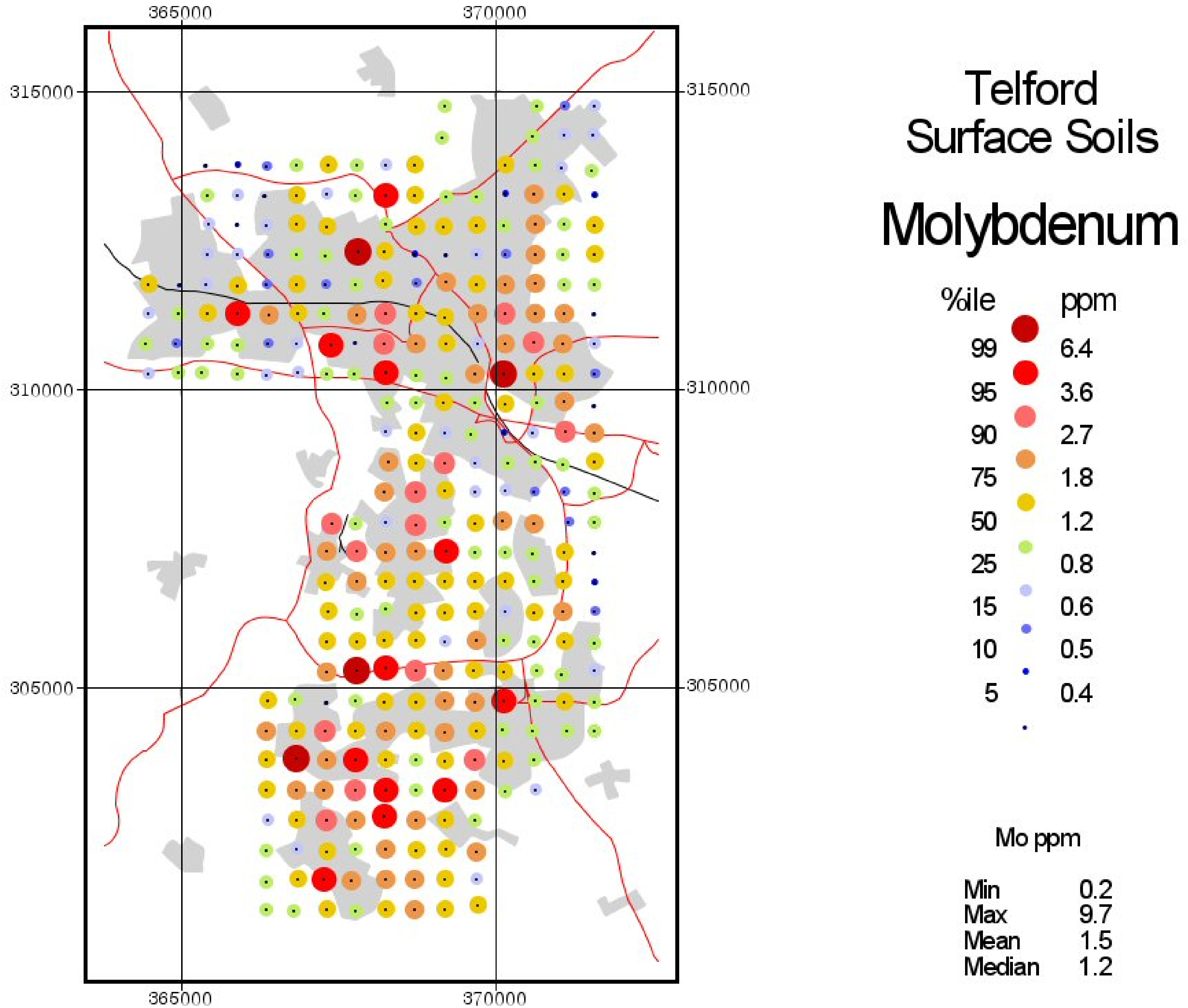
Telford Profile Soils

Manganese

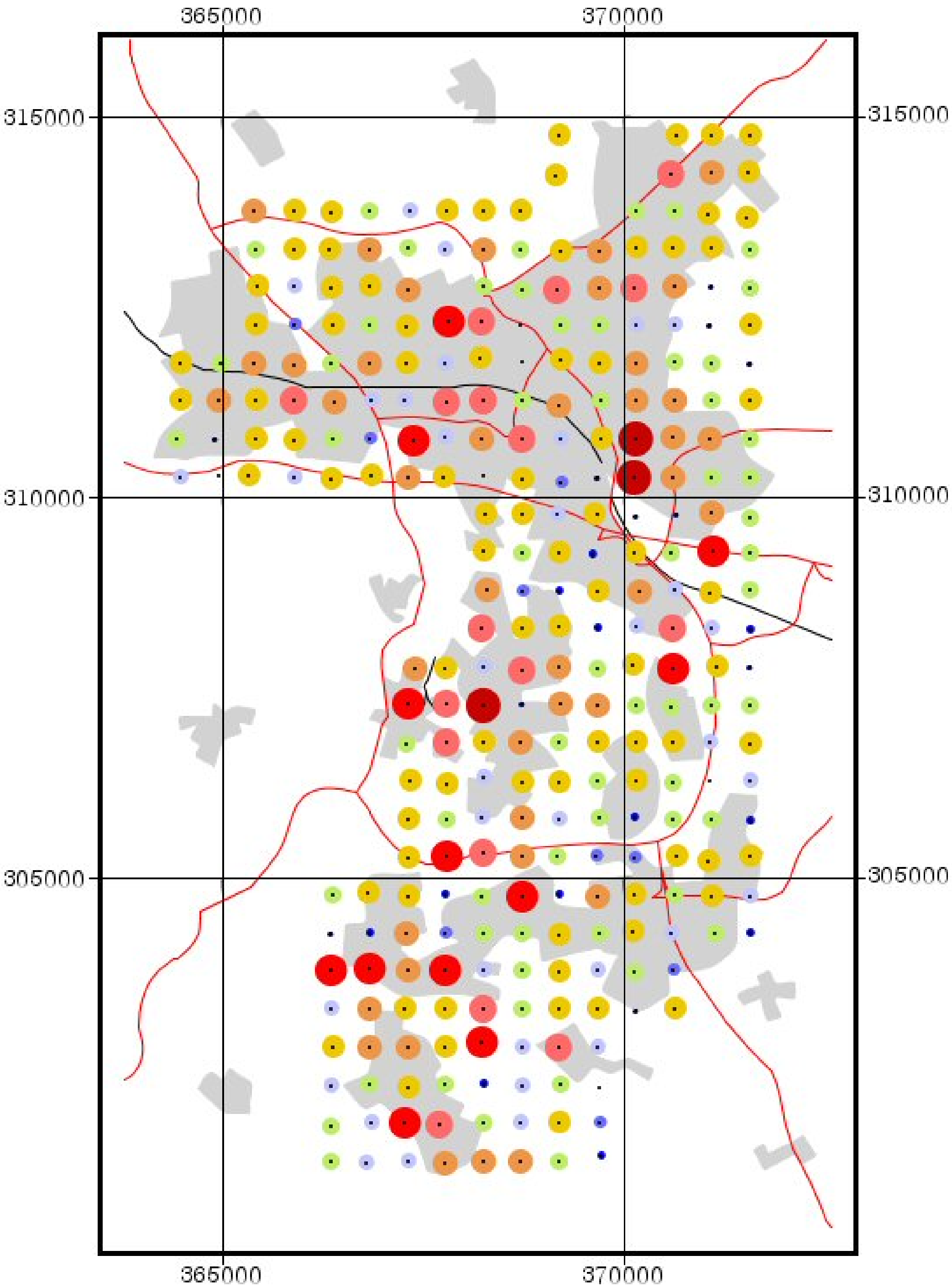
%ile	wt%
99	0.397
95	0.269
90	0.228
75	0.151
50	0.109
25	0.080
15	0.060
10	0.052
5	0.035

MnO wt%

Min	0.005
Max	0.562
Mean	0.126
Median	0.109



365000
370000
315000
310000
305000
Telford
Surface Soils
Molybdenum
%ile
ppm
99
6.4
95
3.6
90
2.7
75
1.8
50
1.2
25
0.8
15
0.6
10
0.5
5
0.4
Mo ppm
Min 0.2
Max 9.7
Mean 1.5
Median 1.2



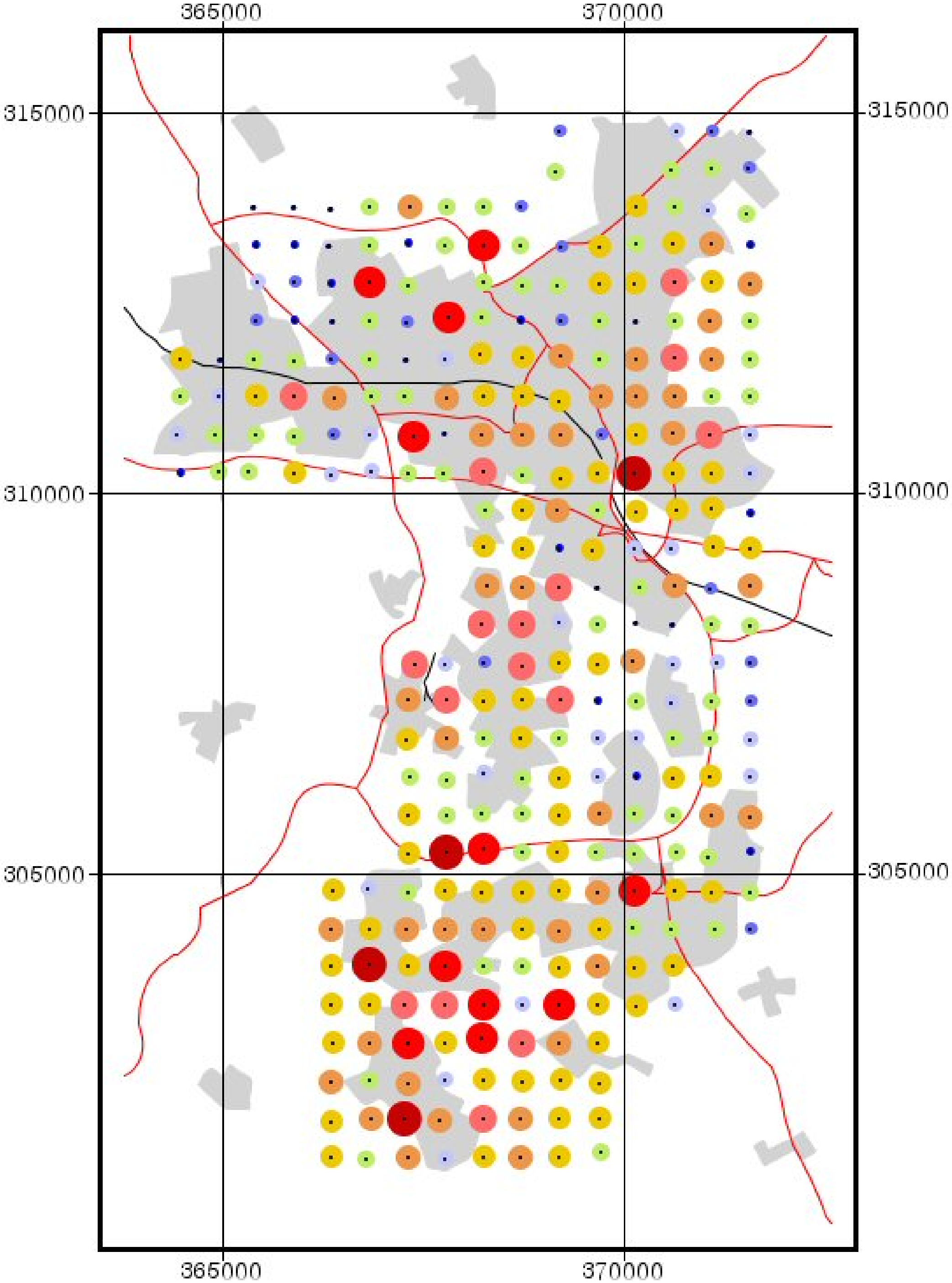
Telford
Profile Soils

Molybdenum

%ile	ppm
99	17.6
95	9.0
90	5.1
75	3.5
50	2.5
25	1.7
15	1.4
10	1.2
5	1.0

Mo ppm

Min	0.2
Max	39.1
Mean	3.4
Median	2.5



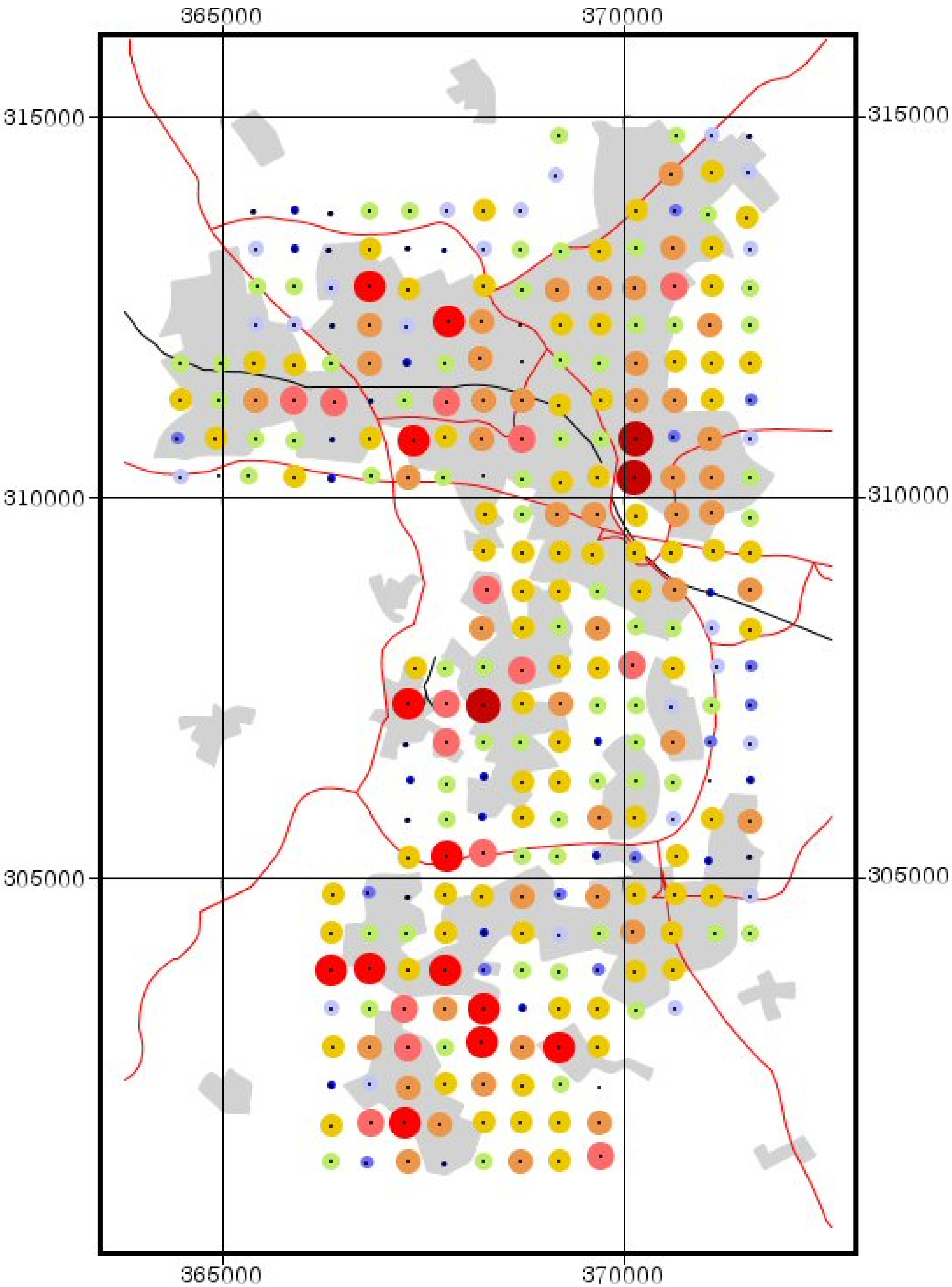
Telford Surface Soils

Nickel

%ile	ppm
99	129
95	76
90	51
75	38
50	28
25	21
15	18
10	16
5	14

Ni ppm

Min	7
Max	153
Mean	33
Median	28



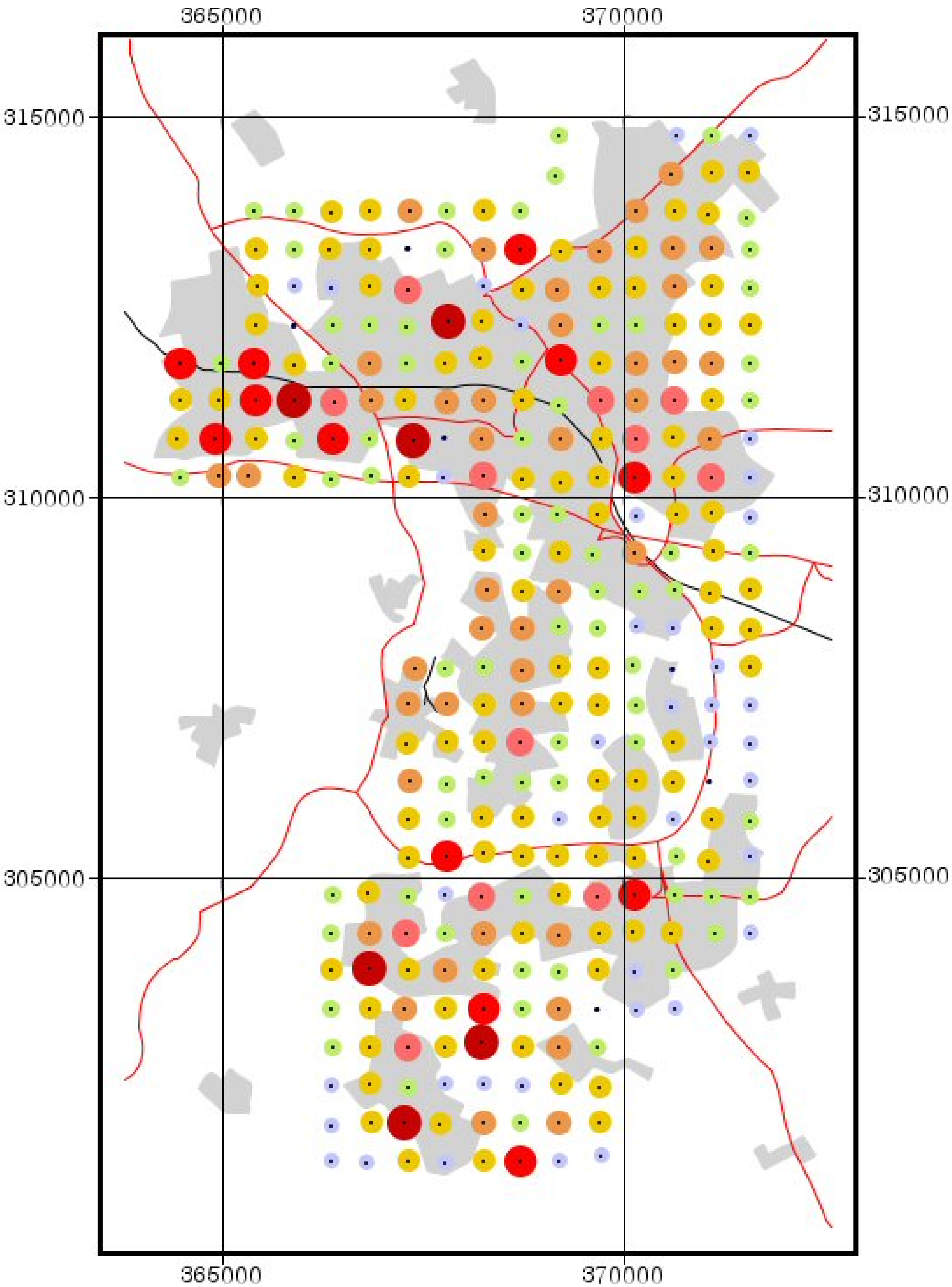
Telford Profile Soils

Nickel

%ile	ppm
99	226
95	108
90	60
75	44
50	35
25	27
15	24
10	22
5	20

Ni ppm

Min	12
Max	349
Mean	44
Median	35



Telford Surface Soils

Tin

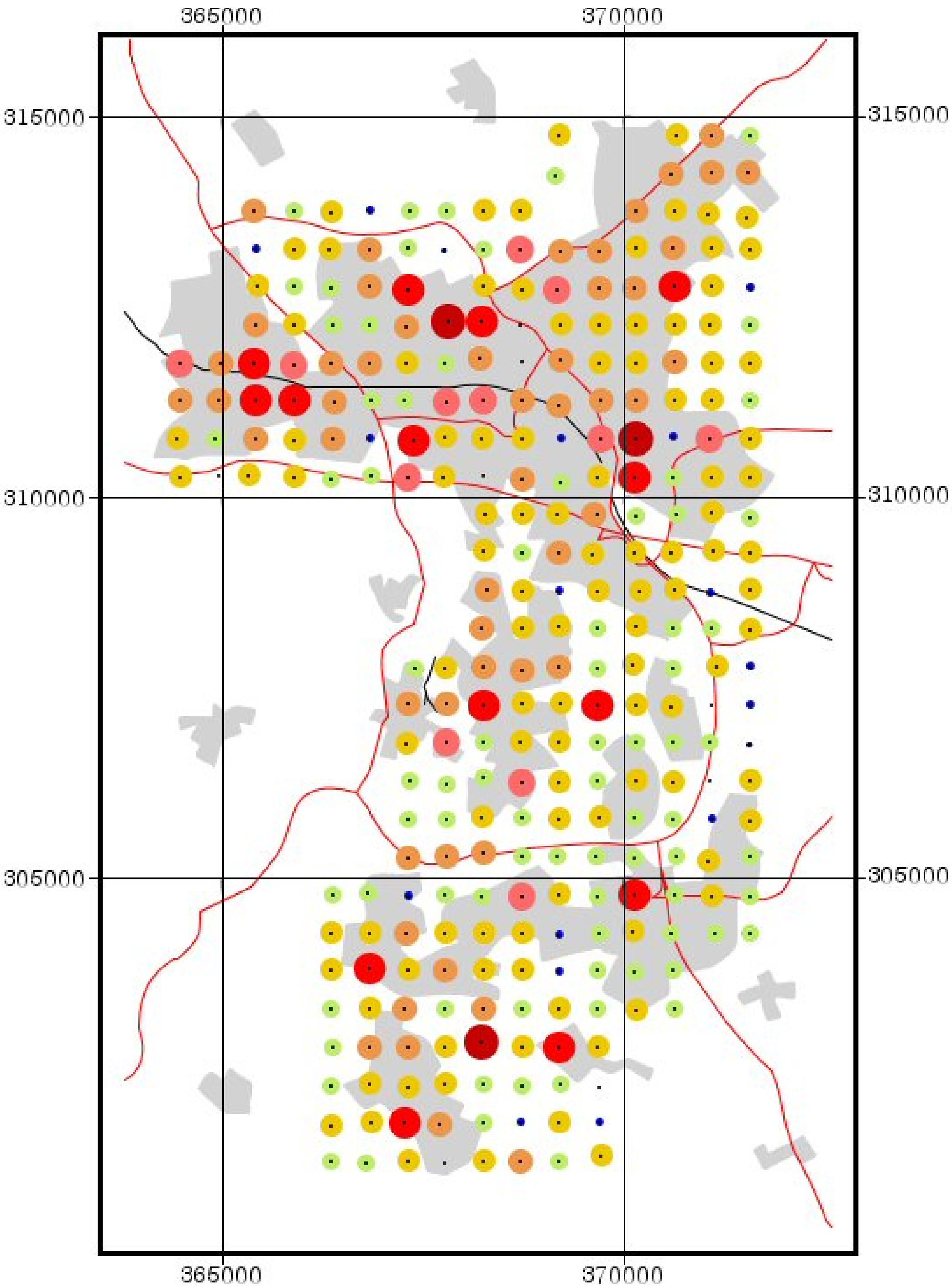
%ile	ppm
99	35
95	13
90	11
75	7
50	5
25	4
15	3

Sn ppm

Min	2
Max	68
Mean	7
Median	5

Telford Profile Soils

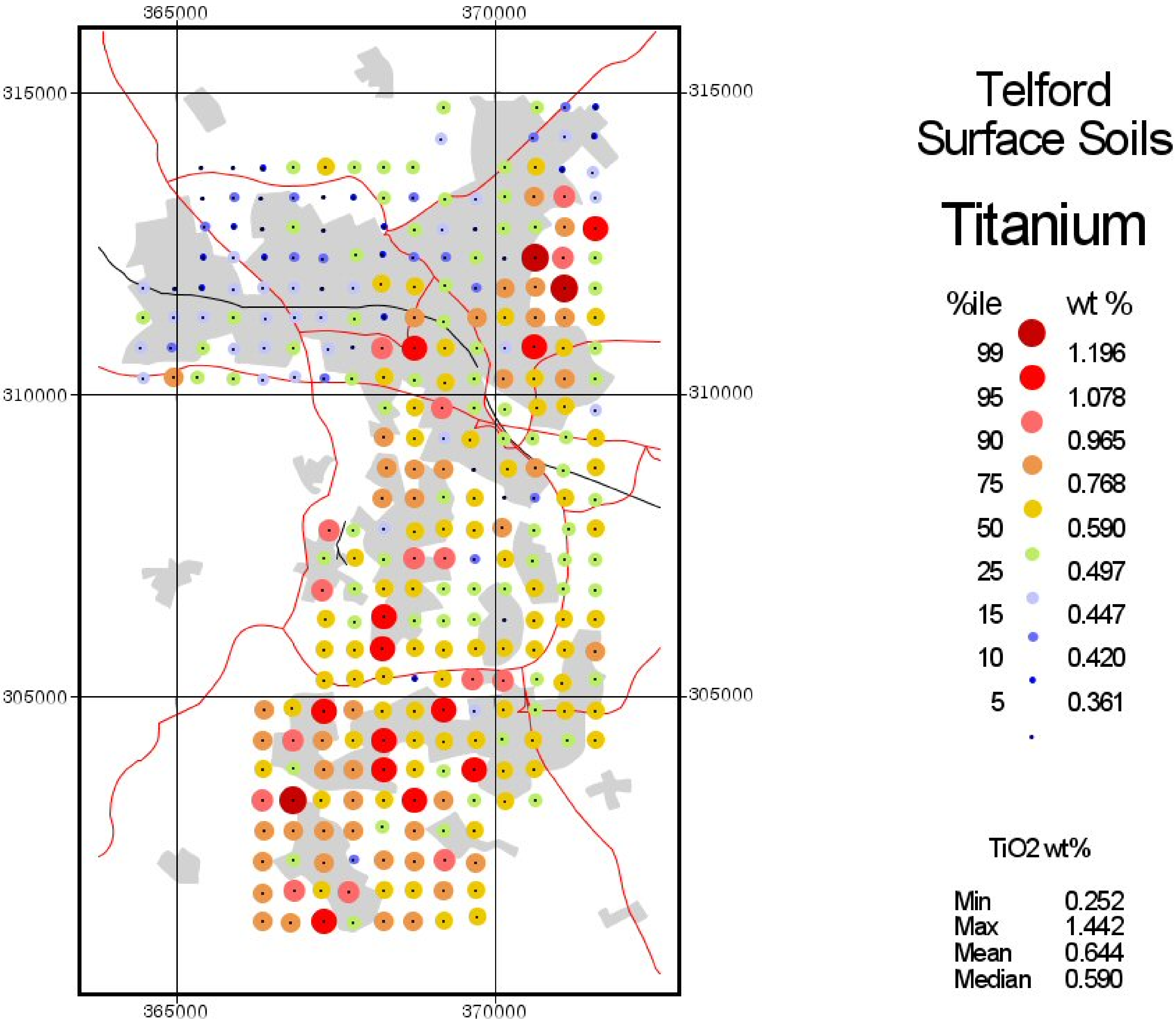
Tin



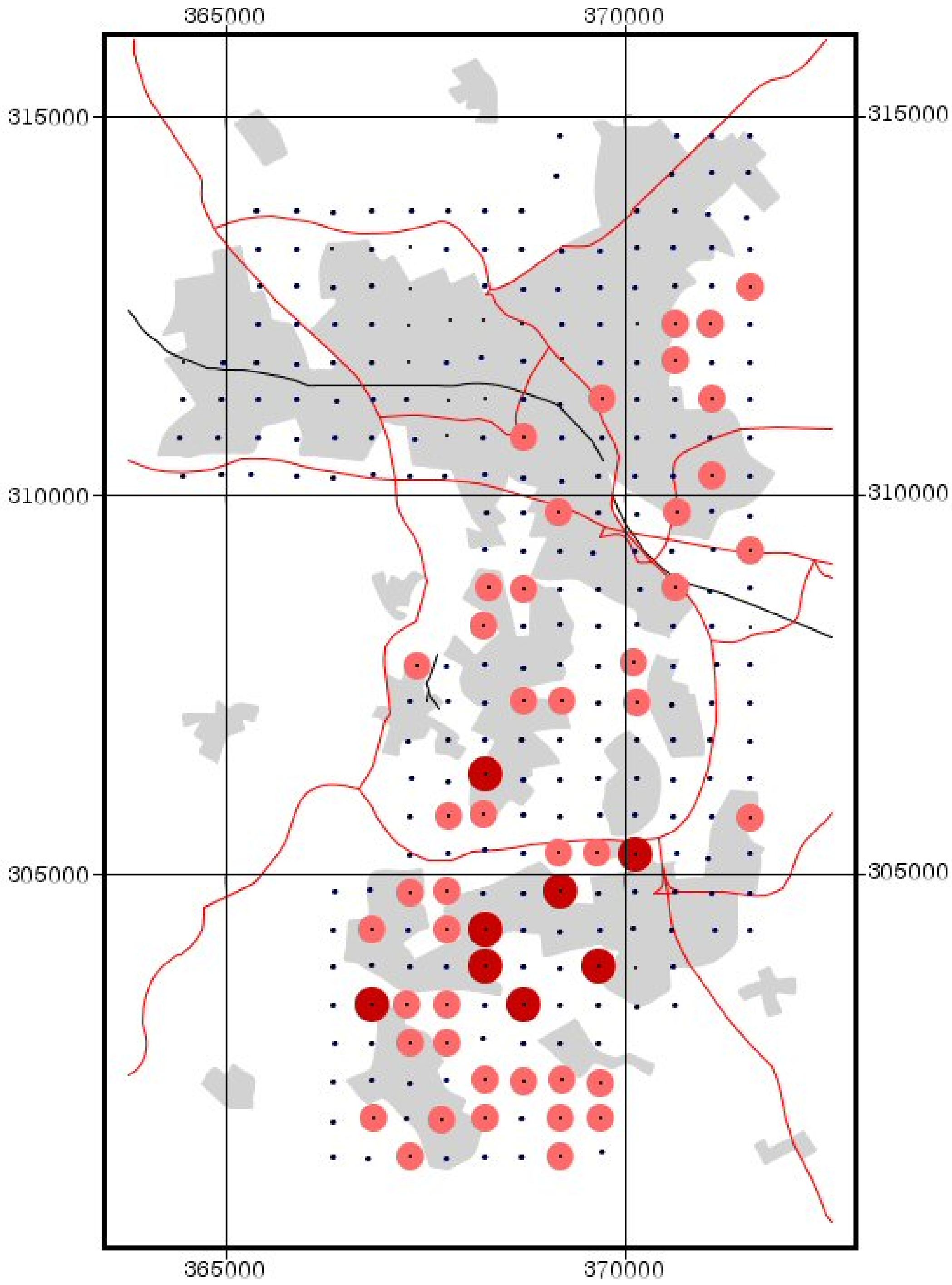
%ile	ppm
99	84
95	29
90	18
75	8
50	5
25	3
5	2

Sn ppm

Min	1
Max	241
Mean	10
Median	5


Telford
Surface Soils
Titanium
%ile
wt %
99
1.196
95
1.078
90
0.965
75
0.768
50
0.590
25
0.497
15
0.447
10
0.420
5
0.361
TiO2 wt%
Min 0.252
Max 1.442
Mean 0.644
Median 0.590
365000
370000
315000
310000
305000

No Profile Soil Data for TiO_2



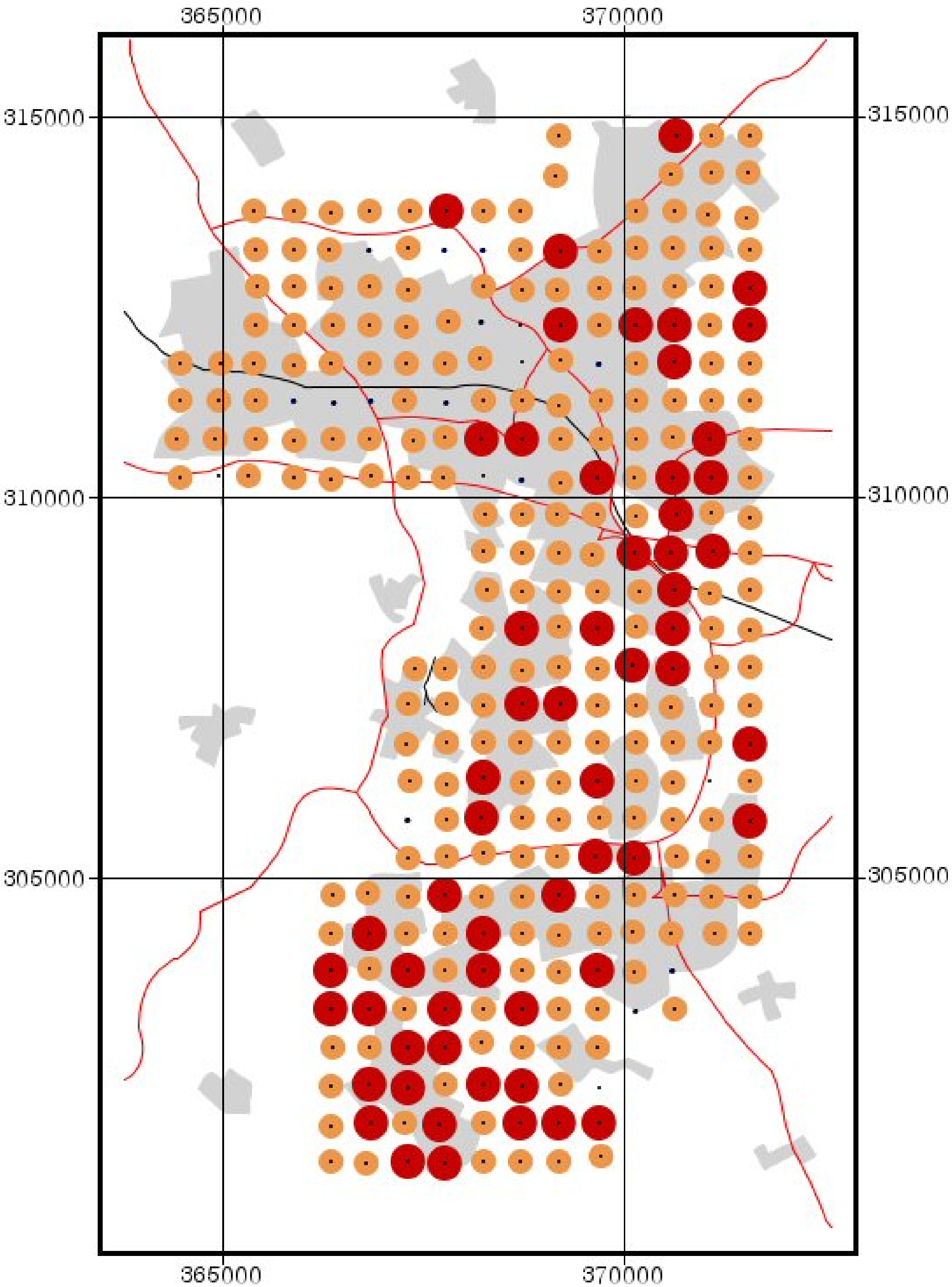
Telford Surface Soils

Uranium

%ile		ppm
99		3
90		2

U ppm

Min	1
Max	4
Mean	2
Median	2



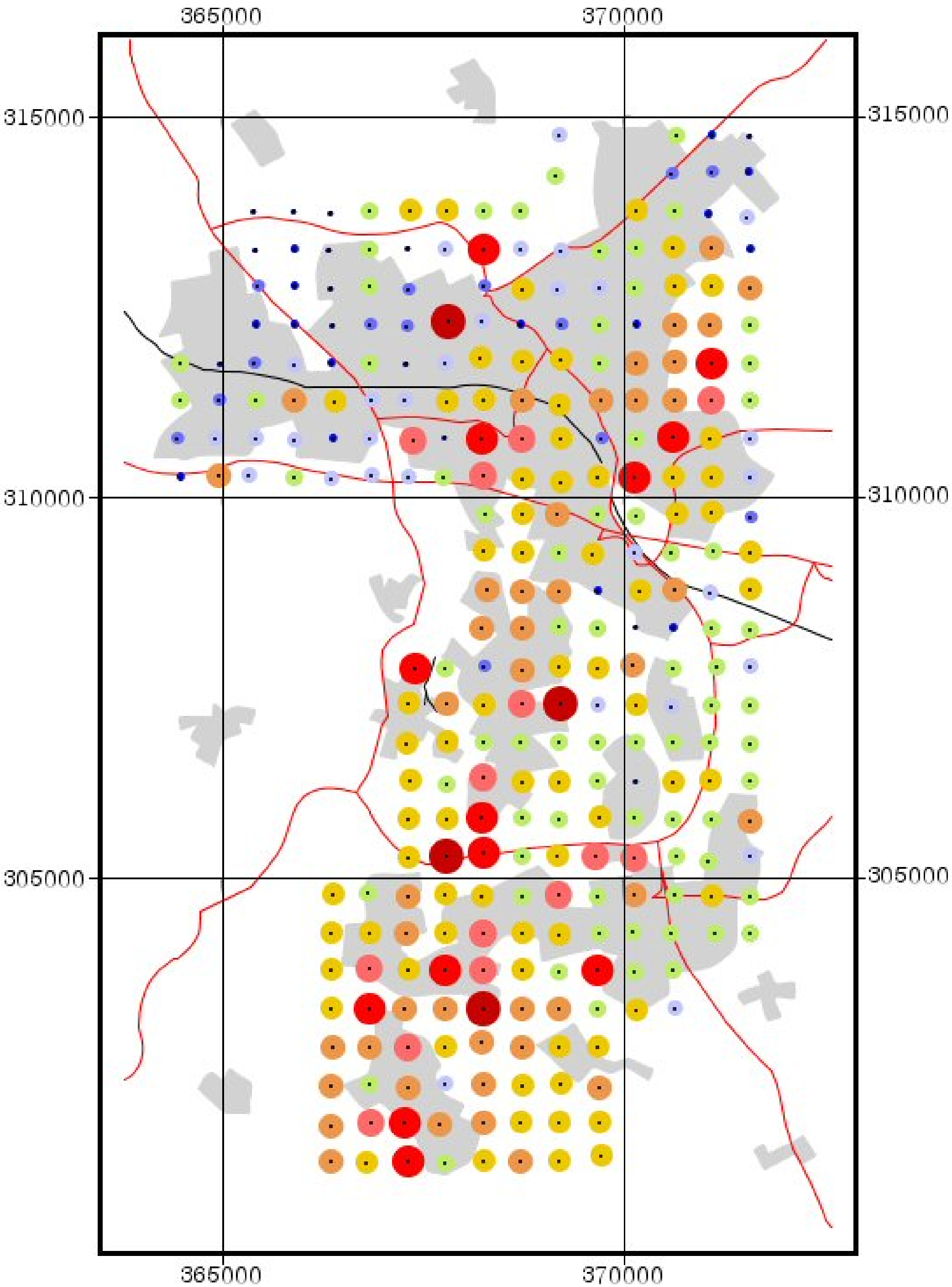
Telford Surface Soils

Uranium

%ile	ppm
99	3
75	2

U ppm

Min	1
Max	4
Mean	2
Median	2



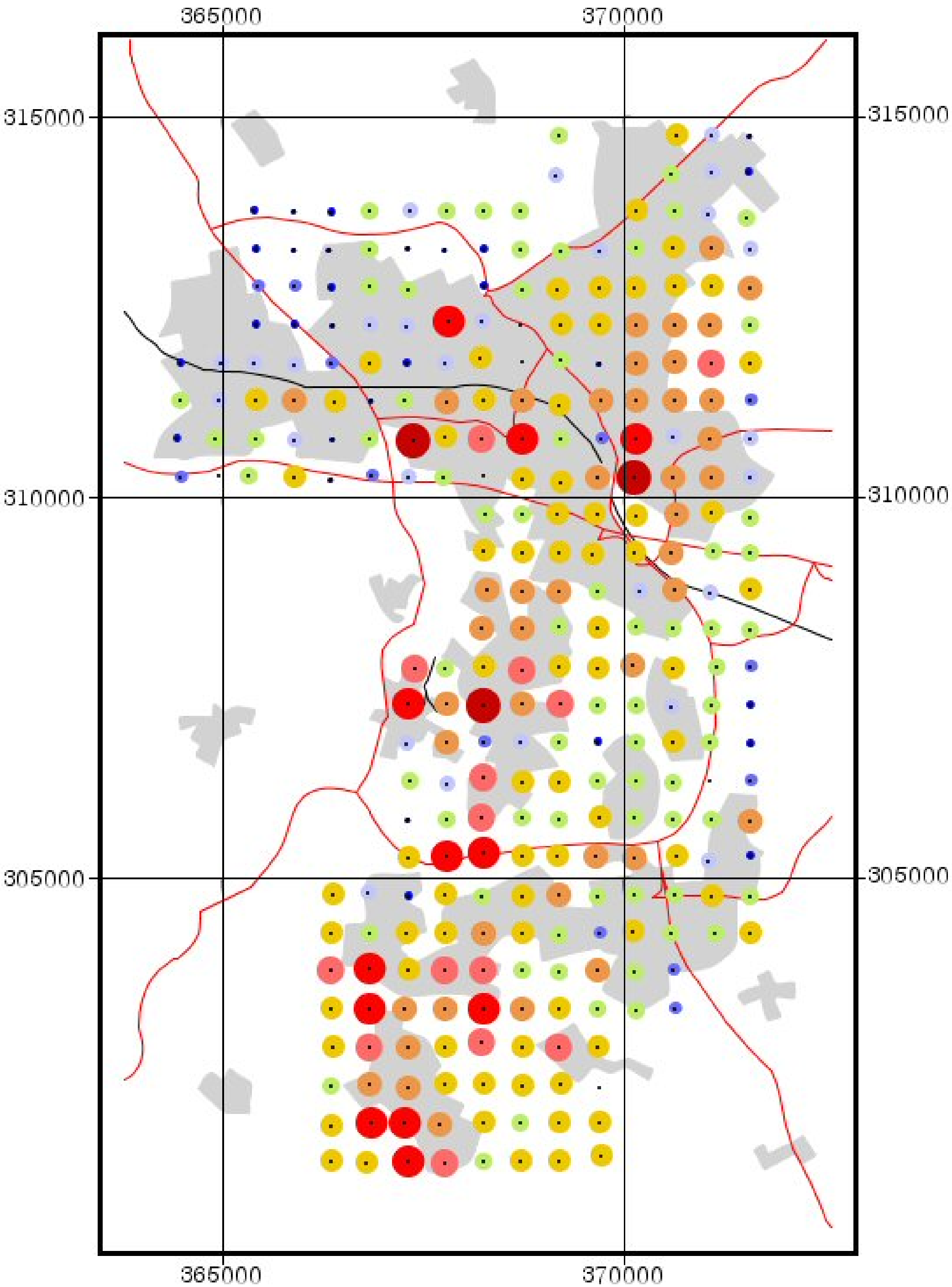
Telford Surface Soils

Vanadium

%ile	ppm
99	228
95	185
90	168
75	117
50	82
25	67
15	60
10	56
5	48

V ppm

Min	32
Max	329
Mean	98
Median	82



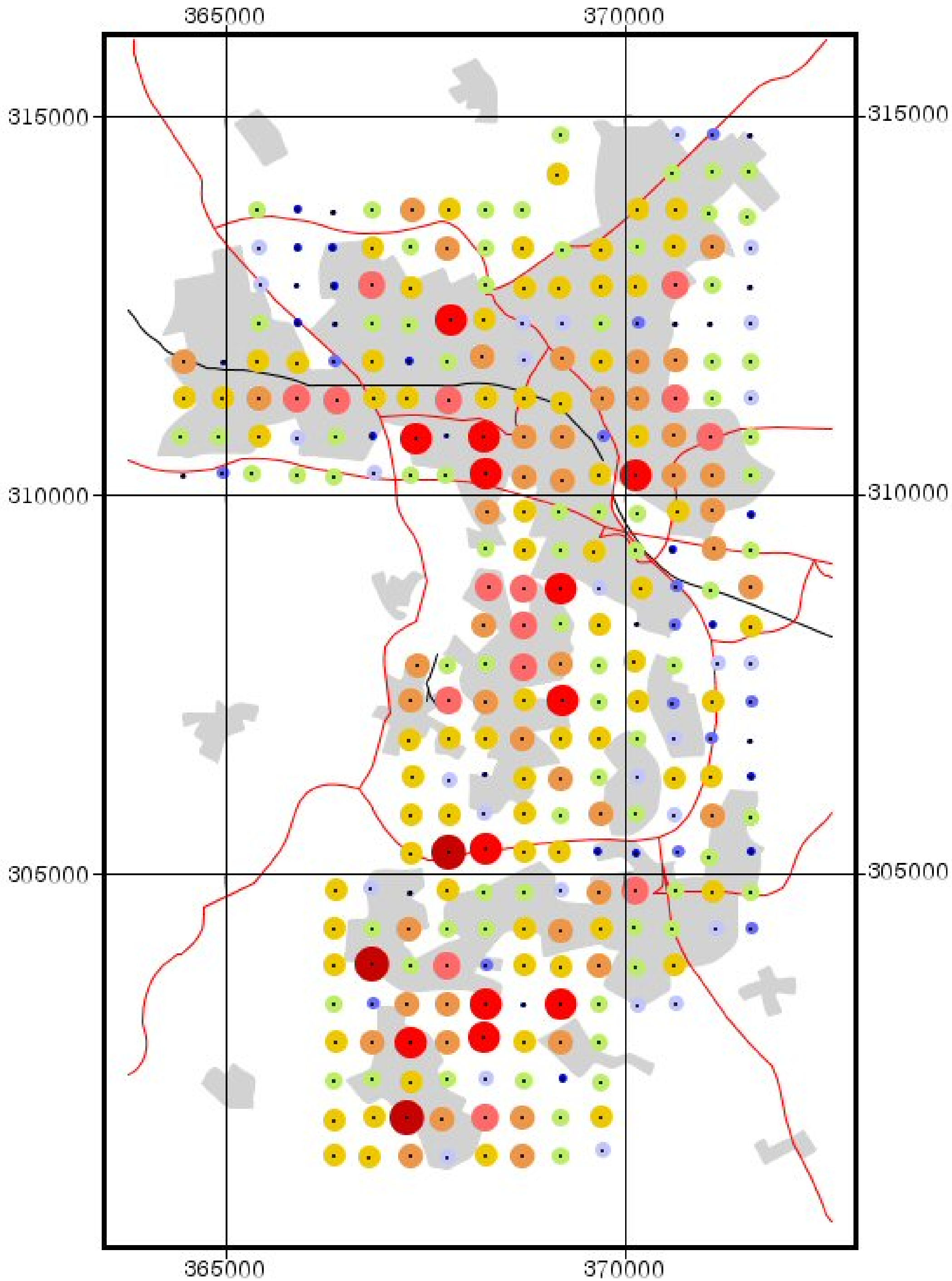
Telford Profile Soils

Vanadium

%ile	ppm
99	340
95	211
90	180
75	133
50	99
25	84
15	78
10	74
5	66

V ppm

Min	47
Max	414
Mean	117
Median	99



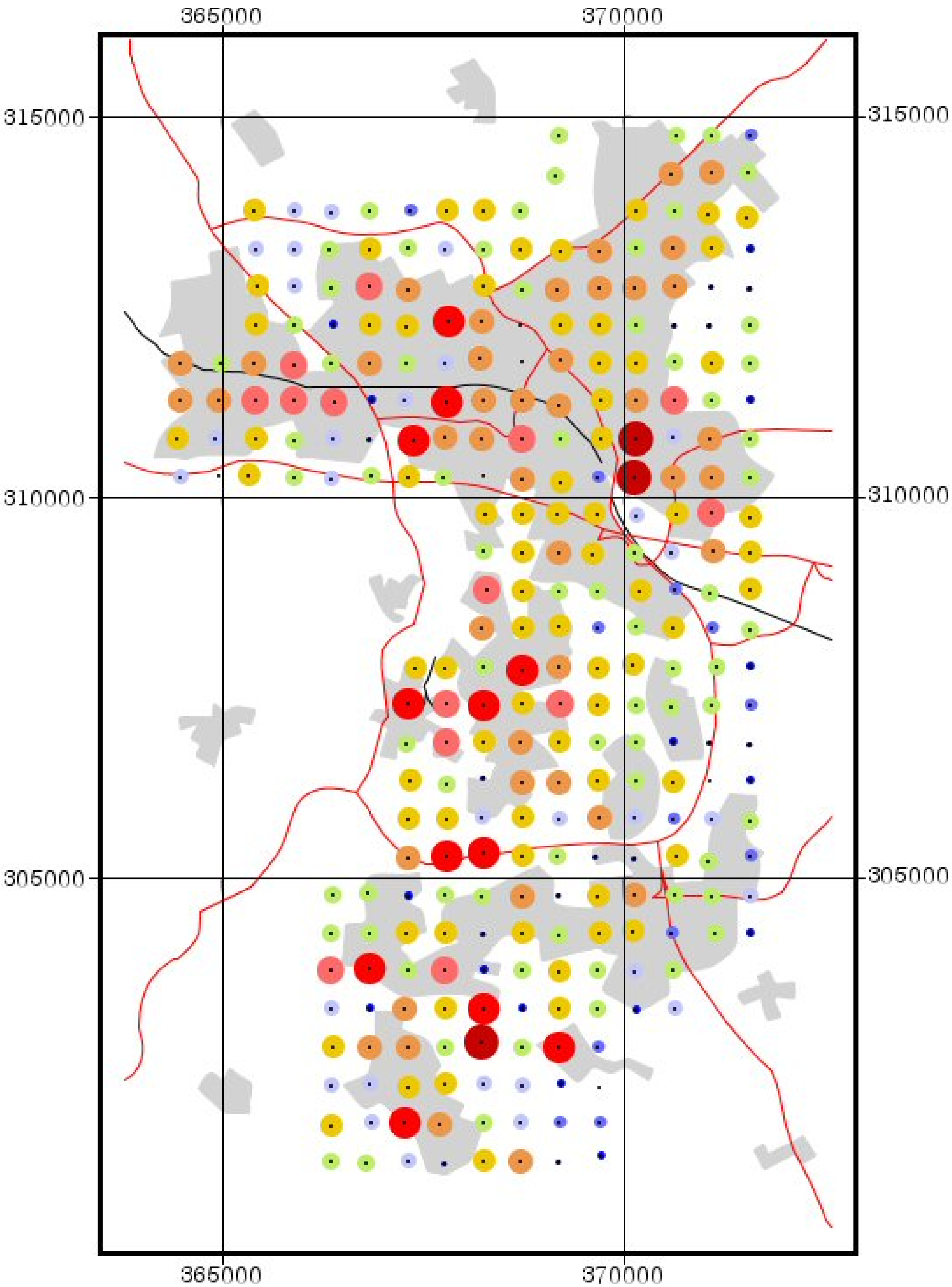
Telford
Surface Soils

Zinc

%ile	ppm
99	2660
95	1222
90	883
75	466
50	264
25	153
15	121
10	105
5	82

Zn ppm

Min	46
Max	4943
Mean	417
Median	264



Telford Profile Soils

Zinc

%ile	ppm
99	3528
95	1794
90	935
75	430
50	238
25	121
15	95
10	79
5	65

Zn ppm

Min	38
Max	6849
Mean	455
Median	238