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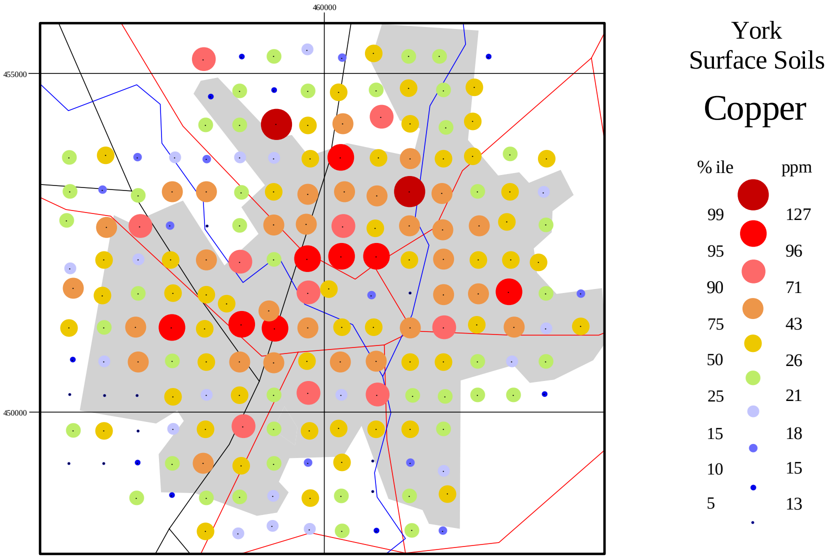
# Geochemical baseline data for the urban area of York

Urban Geoscience and Geological Hazards Programme

Internal Report IR/02/085



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/02/085

# Geochemical baseline data for the urban area of York

K.E. O'Donnell

*Contributor/editor*

N. Breward and C.C. Johnson

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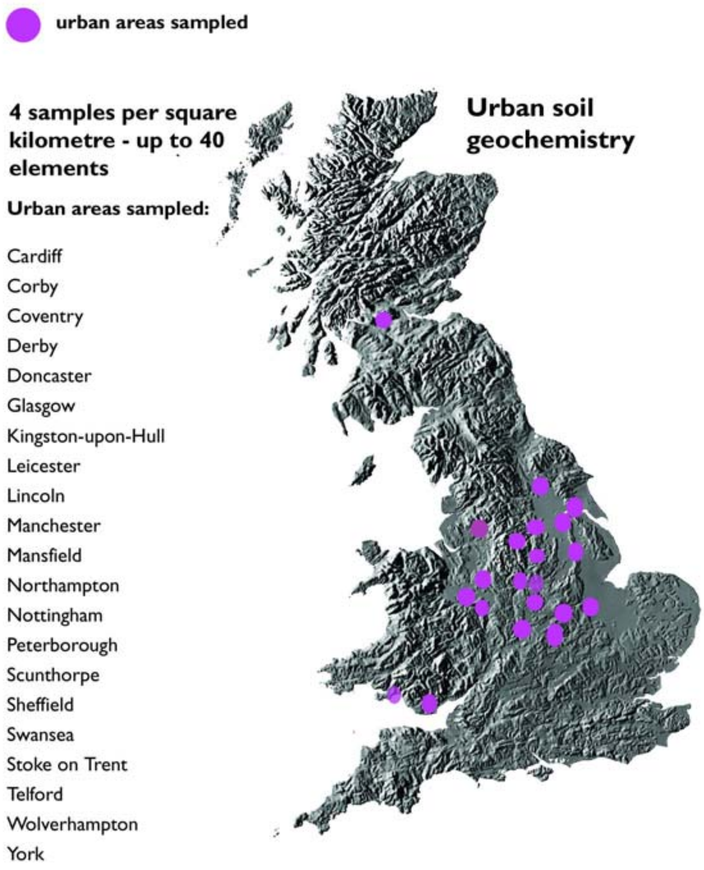
*The soil geochemical data presented in this report (and other urban reports from this series) are from individual sites which were sampled as part of a baseline geochemical survey. The results should only be used to set a regional context, not as the basis for interpretations concerning specific sites. Interpretations relating to specific sites should be based on follow-up investigations. The data in this report, in addition to all geochemical data held by BGS, are available under licence. Its use is subject to the terms of a licensing agreement.*

# Foreword

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

A number of urban centres have been surveyed using the same sampling procedures; the status of completed sampling is indicated by the figure below. Wolverhampton, Manchester and Glasgow have been sampled as part of larger multi-disciplinary projects.



***Map showing urban areas that have been soil sampled (end of 2003)***

# Contents

## FIGURES

## TABLES

# Summary

This report describes and interprets the results of a systematic geochemical baseline survey carried out in the urban area of York.

The concentrations of trace elements vary widely over different rock types. Baseline geochemical data enables natural concentrations to be determined and these provide a benchmark with which to compare the levels of contaminants in industrialised and urban areas.

Soil samples were taken at a density of four per square kilometre. Sampling was carried out on the least disturbed area of unbuilt ground, such as domestic gardens, allotments, parks or (in the worst instance) road verges or made ground. Details of the sampling and analysis of York soils are summarised in Table 1.

Preliminary interpretation of the data can then be carried out and related back to the past and present industrial history of York.

**Table 1 Summary of York soil sampling information**

| | |
|---|---|
| **Date Sampled:** | Summer 1995 |
| **Area Sampled:** | 48 km$^2$ (min E 456200; max E 463770; min N 448210; and max N 455340) |
| **Number of Samples:** | 191 surface and 187 profile soils |
| **Elements determined by XRFS:** | Sb, As, Ba, Cd, Cr, Co, Cu, $Fe_2O_3$, Pb, MnO, Mo, Ni, Sn, $TiO_2$, U, V, Zn |

# 1 Introduction

This report summarises the results and methodology of a soil geochemical survey of the urban area of York, undertaken by the British Geological Survey as part of the Geochemical Surveys of the Urban Environment Project (GSUE), which is funded by the Office of Science and Technology. The project is part of a much wider national survey known as the Geochemical Baseline Survey of the Environment Project (G-BASE).

The G-BASE Programme is undertaking a systematic regional geochemical survey of soils, stream sediments and stream waters of the British Isles. The data obtained provide information on the surface chemical environment, which can be used to define the soil geochemical baseline and the extent of surface contamination. The data has a range of applications, including the modelling of risk to human health with respect to potentially harmful elements through environmental exposure.

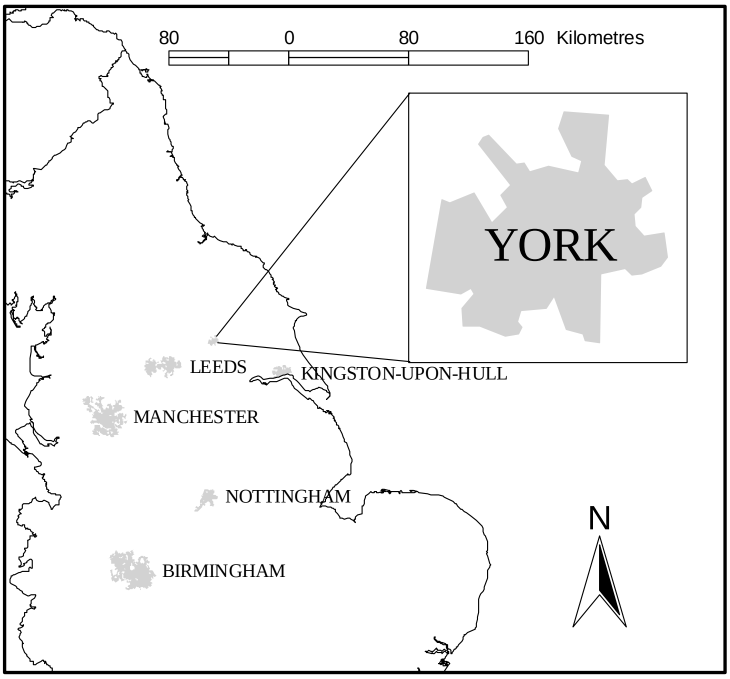


**Figure 1 Location map for York**

York is a historic city, located in central England, close to the Humber Estuary (Figure 1). The most important industries are related to the railway, manufacturing and tourism. The central part of York is protected for its historical interest.

The distributions of trace metals in the surface environment of York are described in this report in the context of present and historical land use. The concentrations of the trace metals are also considered in relation to the underlying geology and placed in context with respect to the typical background concentrations obtained from G-BASE regional data sets.

# 2 Study area

## 2.1 HISTORICAL LAND USE

The Yorkshire Dales observed a long history of lead mining, however, the lead mining fields are found in the upland areas in the northwest of the county. To the southeast of this region, York overlies Quaternary deposits, principally exploited for aggregates, such as sand and gravel.

Industrially, York benefited greatly from the arrival of the railway in 1839 and the city rapidly became a major railway centre, with over 5,500 people employed on the railway by the early 20th century. The heart of York's railway network is located directly to the west of the central ring road, with a significant amount of railway infrastructure, including York railway station (Figure 3).

The principal areas of manufacturing in York are located next to the main railway lines as they leave the city towards the north. Rowntree's Cocoa Works (now owned by Nestlé) and Terry's Confectionery Works both observed significant expansion following the arrival of the railway and, along with the railway, are the city's biggest employers.

Tourism is another important industry in York and the historic core of the city has been protected as a conservation area since 1968[1].

## 2.2 AREA SAMPLED

An area of 48 km$^2$ was surveyed during the summer of 1995, in which a total of 191 surface and 187 profile soils were sampled (Table 1). This extends from grid references 456200 m east to 463770 m east and from 448210 m north to 455340 m north. The survey area is shown in Figure 2.

## 2.3 SOLID AND DRIFT GEOLOGY

Geological information for the York area was obtained from the BGS 1:50 000 series maps for the area and BGS DigmapGB data[2]. York overlies Quaternary parent materials, dominated by silts and clays. Sands, till and hummocky glacial deposits also feature across the area, as do small, isolated areas of peat. The arc-shaped York moraine extends eastwards from the centre of the city and is largely comprised of hummocky glacial deposits. This is the main relief feature of the area surrounding York, rising 25-30 m above a poorly-drained plain. The moraine trends NE-SW and provides a foundation for part of the A166. The Quaternary deposits are entirely underlain by the Sherwood Sandstone Group. As this geological unit does not outcrop anywhere in the York area, it is unlikely to have been directly involved in the formation of the soils in York and is therefore not considered to be a parent material for any of the samples collected. The drift and solid geology can be seen in Figure 4 and Figure 5 respectively.

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[1] http://www.york.gov.uk/heritage/heritage/history.html

[2] Ew062_harrogate; Ew063_york; Ew070_leeds; Ew071_selby. Drift and solid geology.

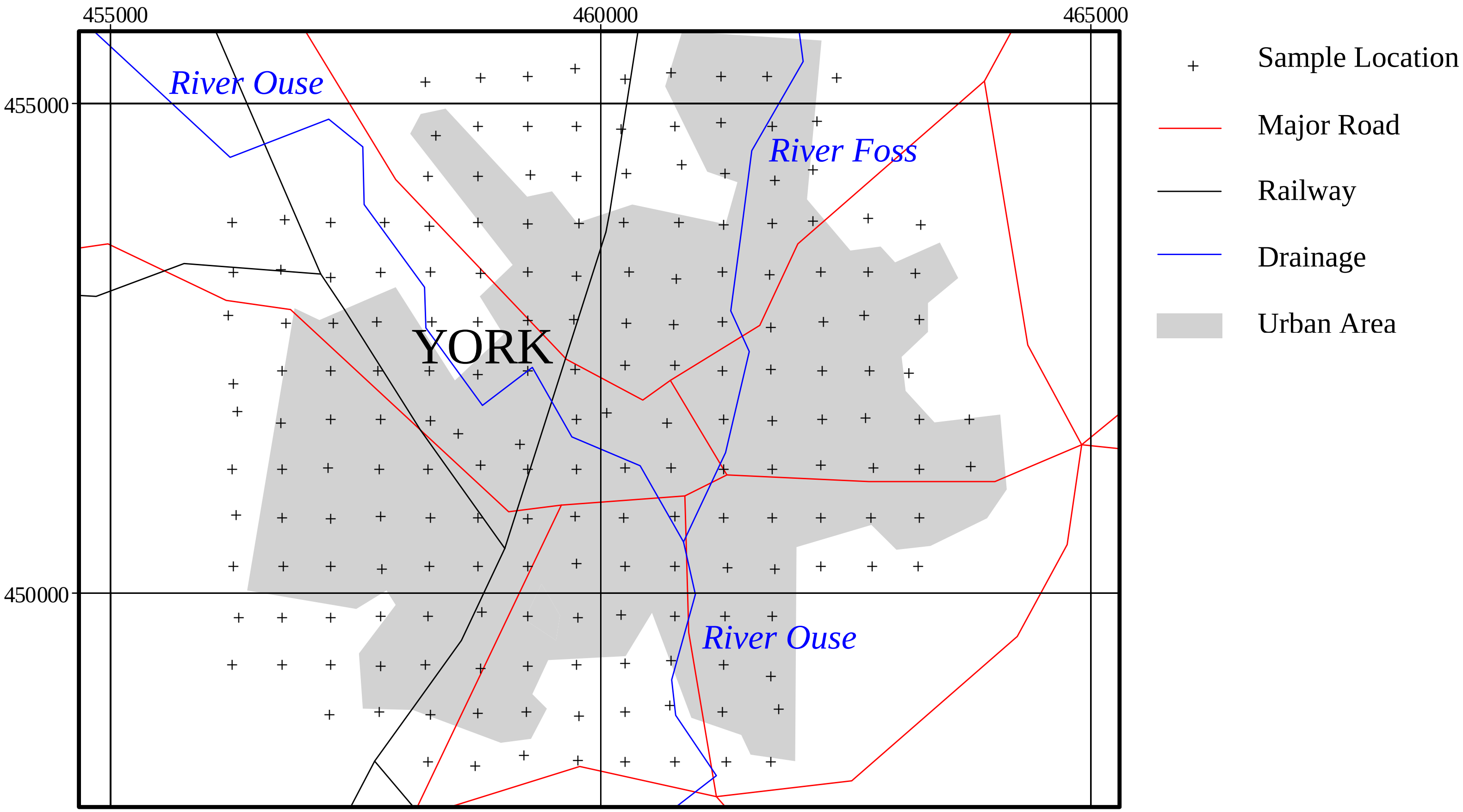

**Figure 2 Map of York sampling area (Grid squares shown at 5 km intervals)**

**Figure 3 Topographical map of sampling area (Grid squares shown at 1 km intervals, sample locations indicated by black crosses)**

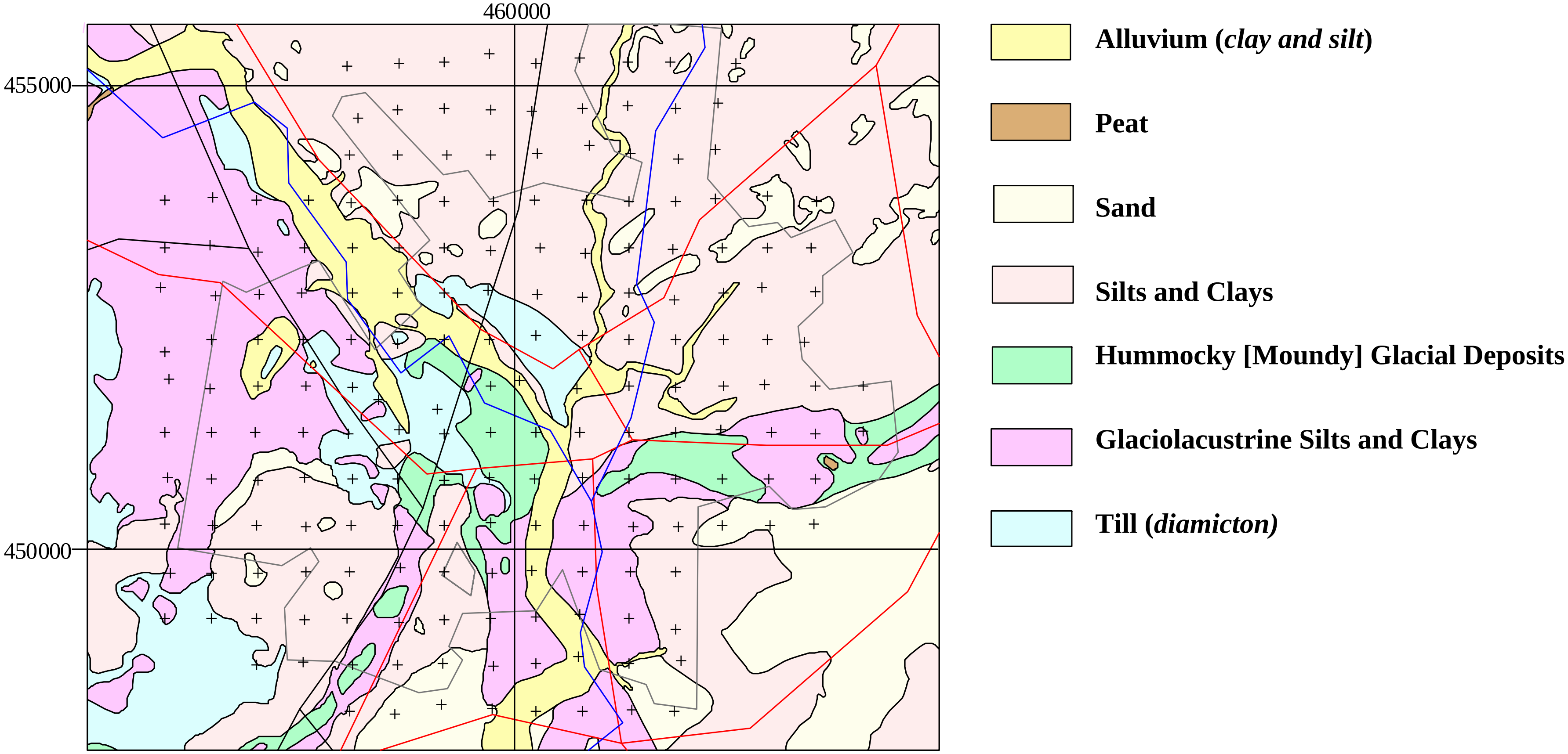

**Figure 4 Drift cover of York and surrounding area (Grid squares shown at 5km intervals, sample locations indicated by black crosses)**

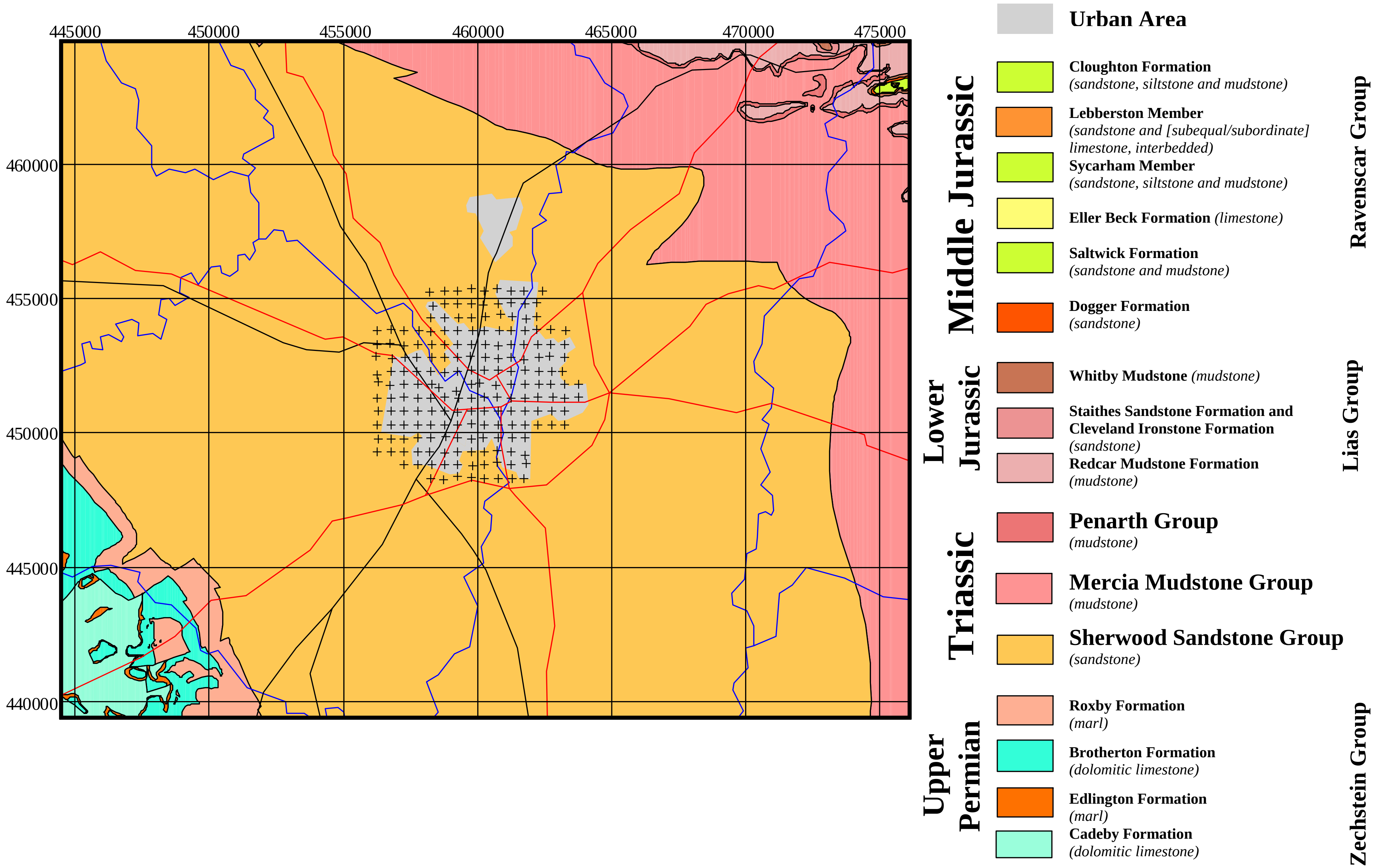

**Figure 5** **Solid geology of York and surrounding area (Grid squares shown at 5km intervals, sample locations indicated by black crosses)**

### 2.4 SOIL TYPE

Urban and industrial areas have not been surveyed for soil type by the Soil Survey and Land Research Centre (formerly the Soil Survey of England and Wales). No information therefore exists on soil type for the main city area of York, although limited data is available for the outskirts of the urban area (Soil Survey of England and Wales, 1970; Matthews, 1971).

Basic information for the urban soils of York is available from the G-BASE field cards (see Appendix A), which are filled in “on-site” during sampling. These contain data such as soil colour, texture, sample depth, clasts that are contained in the soil, as well as land use and any physical contamination that is observed. The field codes used were extracted from Harris and Coats (1992).

The soil map available for the area around York, at a scale of 1:25 000, excludes the outskirts to the far west and south of the city (Soil Survey of England and Wales, 1970). Soils around York are representative of the glacial and post-glacial (Flandrian) deposits of the Vale of York. To the north and north-east of York, non-calcareous gley soils dominate, largely derived from lacustrine clay. Soils of this parent material are classed as undifferentiated, with combined features of both surface-water and ground-water gley soils. These soil types are poorly drained; surface-water gley soils retain water seasonally in the upper horizons, while ground-water gley soils become waterlogged in lower horizons. Non-calcareous ground-water gley soils derived from fluvio-glacial drift are also common to the north and east of York and gleyed brown earth, from sandy fluvio-glacial drift is also observed.

Soils overlying the moraine feature to the east of York (Figure 4) differ from the soils further north; the dominant soil type is argillic brown earth, derived from morainic loamy drift and stony coarse loamy drift over gravel. Argillic brown earths are well-drained, brown and reddish-brown in colour and contain illuvial accumulations of clay in the B-horizon below a zone of depleted clay. Morainic loamy drift has also given rise to non-calcareous surface-water gley soils in this area.

At a scale of 1:250 000 (Soil Survey of England and Wales, 1983), the soil map for northern England also includes the York region. The dominant soil type to the south and south-west of York is argillic brown earth, while non-calcareous gley soils are predominant to the west of the city.

# 3 Methodology

### 3.1 SOIL SAMPLING

Sample sites were arranged on a regular grid pattern at a density of 4 samples per $km^2$. 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). Soil samples were collected from the closest area of open ground to the allocated sample point. Care was taken to avoid contamination from roads, buildings, fences, pylon lines, etc., an ideal sample being collected at least 50 m from any of these contaminating sources. In urban areas it is often difficult to find sample sites that obey this ideal, but wherever possible samples were taken so as to preserve as near as possible the regular sampling grid.

Soil samples were collected using a Dutch style hand auger with a 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 0-15 cm. They were made up of a three point composite sample based on a 2 x 2 m square. The deeper “profile” samples were labelled “S” and were collected at a standard depth of 30-45 cm. These were composed of 3 sub-samples from the same 2 x 2 m square as the “A” sample. Duplicate sampling is described in section 3.3.2.

Information from the field cards is entered onto a database and sample positions are recorded on a stable base map and archived. This data is then stored in the corporate geochemical database (Harris and Coats, 1992).

## 3.2 SAMPLE PREPARATION

Samples were dried in an oven 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. 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 (XRFS) (see section 3.4).

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

## 3.3 ERROR CONTROL PROCEDURES

The accuracy and precision of the geochemical data was 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 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 of the duplicate samples were split to obtain a sub-sample. Each sub-sample was assigned a different number and treated as a separate sample for analytical purposes.

The collection of duplicate samples enables the sampling error, or sampling variation, to be estimated, thus providing a measure of the between-sample variance. Sub-sampling allows the analytical error or variance to be estimated. The variation in the results between original and sub-sample gives an indication of the variation introduced by sample preparation and analysis.

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 natural variation in element concentrations across the survey area). All of the analyses form part of a single randomised dataset and a random nested model of ANOVA was therefore 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 horizons) and $TiO_2$ (surface soils) were log transformed to produce a distribution approaching the required Gaussian. The ANOVA calculations were performed using the NESTED procedure from the statistical software package, MINITAB$^{TM}$. The results of the ANOVA indicate that for most elements the between-site variability is greater than 80% of the total variance (Table 2). This suggests that geochemical variation is the principal control over element concentrations in urban areas. The between-site variance of cadmium 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.

### 3.3.3 Standards

G-BASE internal reference standards were analysed within each batch of field samples in order to monitor analytical instrument performance, and to provide continuity of data between different analytical campaigns. Internal standards were assigned unique sample ID's and inserted into each batch of field samples. In the case of York, G-BASE internal reference standards S13 and S15 were inserted during analysis of surface (A) and profile (S) soil samples. Each reference standard was analysed in duplicate, and mean concentrations for all elements in S13 and S15 are illustrated in Table 3.

The inclusion of G-BASE internal reference standards throughout all G-BASE and GSUE projects maintains data integrity between such projects. York lies within the Humber-Trent regional atlas area, and it is therefore essential that data for the urban centre of York is compatible with that of the surrounding regional dataset, which consists of the XRFS analyses of approximately 7000 soil sample sites (British Geological Survey, In Prep). A number of G-BASE standards, including S13 and S15, were routinely analysed throughout the entire duration of analysis of samples from the Humber-Trent area. Mean element concentrations determined for standards S13 and S15 during analysis of York urban samples may be compared with those generated for S13 and S15 during analysis of Humber-Trent regional samples (Table 3).

Where values differed significantly, conditioning of the data was carried out. Simple X-Y plots and regression calculations were generated in Excel in order to carry out this task.

**Table 2 Percentage of variance in surface and profile soils 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 |

**Table 3 Comparison of G-BASE bulk soil standards**

| Sample Type Standard ID | Units | Humber-Trent S13 | York A S13 | York S S13 | Humber-Trent S15 | York A S15 | York S S15 |
|---|---|---|---|---|---|---|---|
| Sb | ppm | 0.1 | <1 | <1 | 1.1 | <1 | 1 |
| As | ppm | 15 | 15 | 15 | 9 | 9 | 9 |
| Ba | ppm | 1704 | 1796 | 1834 | 291 | 382 | 378 |
| Cd | ppm | <1 | <1 | 1 | <1 | <1 | <1 |
| Cr | ppm | 98 | 96 | 100 | 41 | 34 | 37 |
| Co | ppm | 29 | 23 | 23 | 9 | 4 | 6 |
| Cu | ppm | 17 | 16 | 15 | 6 | 4 | 4 |
| $Fe_2O_3$ | % | 6.88 | 6.93 | 7.14 | 1.88 | 1.93 | 2.03 |
| Pb | ppm | 109 | 108 | 110 | 24 | 24 | 23 |
| MnO | % | 0.128 | 0.109 | 0.122 | 0.082 | 0.063 | 0.07 |
| Mo | ppm | 1.6 | 1.6 | 1 | 0.7 | <0.3 | 0.9 |
| Ni | ppm | 36 | 35 | 35 | 12 | 10 | 11 |
| Sn | ppm | 3 | 2 | 2 | 5 | 4 | 4 |
| $TiO_2$ | % | 0.817 | 0.896 | - | 0.392 | 0.431 | - |
| U | ppm | 2.5 | 3.3 | 3 | 1.2 | 1.9 | 2.3 |
| V | ppm | 97 | 85 | 94 | 35 | 23 | 32 |
| Zn | ppm | 113 | 112 | 113 | 30 | 28 | 29 |

## 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 results for trace elements are reported in parts per million (ppm). One part per million is equivalent to one microgram per gram (µg/g or µg $g^{-1}$) or one milligram per kilogram (mg/kg or mg $kg^{-1}$). Major elements are reported as weight percent of the element in its oxide form (WT % oxide).

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 4.

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 4 Lower limits of detection (LLD) and upper reporting limit (URL) values for XRFS analysis of G-BASE urban soil samples, Humber-Trent region**

| Analyte | LLD (ppm) | LLD (%) | URL (ppm) | URL (%) |
|---|---|---|---|---|
| Sb | 1.2 | - | 10000 | - |
| As | 0.9 | - | 10000 | - |
| Ba | 2.9 | - | 600000 | - |
| Cd | 0.9 | - | 500 | - |
| Cr | 3 | - | 250000 | - |
| Co | 1.9 | - | 10000 | - |
| Cu | 0.9 | - | 6500 | - |
| $Fe_2O_3$ | - | 0.01 | - | 100.0 |
| Pb | 1.2 | - | 10000 | - |
| MnO | - | 0.01 | - | 10.0 |
| Mo | 0.3 | - | 1000 | - |
| Ni | 0.9 | - | 4000 | - |
| Sn | 1.1 | - | 10000 | - |
| $TiO_2^*$ | - | 0.01 | - | 100.0 |
| U | 0.5 | - | 650 | - |
| V | 2.4 | - | 20000 | - |
| Zn | 1 | - | 10000 | - |

*A horizon only.

## 3.5 DATA INTERPRETATION

Once full error control and data quality procedures were completed, the York geochemical and location data were loaded into an Arcview© GIS software package. Proportional symbol geochemical maps for surface and profile soils were then generated (see Appendix C).

# 4 Geochemical Interpretation

## 4.1 BACKGROUND LEVELS

In order to aid the interpretation of the geochemical data for York, it is useful to be aware of typical background concentrations in the local environment. This should put the concentrations seen in York into context. Regional soil data is available for the Humber-Trent region, in which York is located (British Geological Survey, In Prep). The median elemental concentrations for 6561 surface soil samples are shown in Table 5 and the concentrations for 6877 profile soils are displayed in Table 6. These data can be used to give an indication of the typical magnitude of the elemental concentrations throughout the Humber-Trent region as a whole.

**Table 5 Comparison of median concentrations in regional surface soil samples, Humber-Trent atlas area and in York surface soil samples**

| Analyte | Units | Median Regional | Median York |
|---|---|---|---|
| Sb | ppm | 0.5 | 2 |
| As | ppm | 13 | 10 |
| Ba | ppm | 376 | 340 |
| Cd | ppm | 1 | 1 |
| Cr | ppm | 71 | 59 |
| Co | ppm | 19 | 15 |
| Cu | ppm | 18 | 26 |
| $Fe_2O_3$ | wt% | 4.66 | 3.43 |
| Pb | ppm | 43 | 106 |
| MnO | wt% | 0.080 | 0.072 |
| Mo | ppm | 2.2 | 1.3 |
| Ni | ppm | 22 | 19 |
| Sn | ppm | 4 | 8 |
| $TiO_2$ | wt% | 0.680 | 0.424 |
| U | ppm | 2.1 | 1.1 |
| V | ppm | 83 | 61 |
| Zn | ppm | 72 | 81 |

**Table 6 Comparison of median concentrations in regional profile soil samples, Humber-Trent atlas area and in York profile soil samples**

| Analyte | Units | Median Regional | Median York |
|---|---|---|---|
| Sb | ppm | 3 | 1 |
| As | ppm | 12 | 12 |
| Ba | ppm | 388 | 354 |
| Cd | ppm | 0.35 | 1 |
| Cr | ppm | 83 | 67 |
| Co | ppm | 21 | 17 |
| Cu | ppm | 20 | 29 |
| $Fe_2O_3$ | wt% | 5.04 | 4.00 |
| Pb | ppm | 38 | 80 |
| MnO | wt% | 0.104 | 0.073 |
| Mo | ppm | 1.8 | 1.6 |
| Ni | ppm | 27 | 24 |
| Sn | ppm | 4 | 6 |
| $TiO_2$ | wt% | 0.735 | - |
| U | ppm | 2.5 | 1.9 |
| V | ppm | 88 | 67 |
| Zn | ppm | 77 | 76 |

## 4.2 KEY GEOCHEMICAL CHARACTERISTICS OF THE YORK DATASET

In a comparison of surface and profile soils, it should again be noted that during sample preparation the two horizons are sieved to different size fractions. Surface soils are sieved to <2 mm, while profile soils are sieved to <150 µm. The sieved profile soil therefore has a much larger surface area and will contain more clay particles (which possess the ability to attract and bind heavy metal ions (Brady and Weil, 1999)). In an urban area, higher concentrations of elements derived from anthropogenic sources would typically be expected in the surface soils, however, the surface values may be underestimated with respect to the profile soil concentrations to some extent, due to the difference in size fraction.

A total of 17 major and trace elements were measured in York top-soils; antimony (Sb), arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (expressed as $Fe_2O_3$), lead (Pb), manganese (expressed as MnO), molybdenum (Mo), nickel (Ni), tin (Sn), titanium (expressed as $TiO_2$), uranium (U), vanadium (V) and zinc (Zn). All elements except $TiO_2$ were additionally measured in the profile soils. Of these 16 elements, a total of 13 demonstrate either very little change in concentration with depth (Sb, Cd, Cr, $Fe_2O_3$, Ni, V and Zn), or are present in higher concentrations within the profile soils (As, Ba, Co, Mo, Mn and U). This could reflect an underestimation of surface-soil concentrations, due to the difference in size fraction, or remediation of contaminated soils by the addition of fresh top-soil. It seems likely, however, that these elements are not significant contaminants in the York area. With the exception of Sb and Zn in surface soils and Cd in profile soils, the median concentrations of these elements are found to be similar to or lower than the regional average values, obtained from data for the Humber-Trent region (Tables 5 and 6). Despite this, the images produced demonstrate significant relationships between elevated concentrations of these elements and the main industrial areas of the city.

The highest concentrations of Ba in both horizons are found close to the rivers running through York (reaching over 3000 ppm in the surface soils and over 4500 ppm in the profile soils). This pattern is very similar for Cd in the profile soil (where concentrations exceed 4 ppm), but is less evident in the surface soil. This perhaps reflects a decline in the uses of cadmium in modern industry, prompted by the significant environmental concerns associated with this element. The highest overall levels of Cd (6 ppm and 9 ppm) are, however, found in the surface soils, with the former value located in close proximity to the River Foss.

Higher concentrations of Sb, As and Co are apparent in both horizons to the north of York centre, between the railway line and the River Foss. This area has been identified as a major industrial area of the city (largely manufacturing). Arsenic concentrations reach 93 ppm in the surface soils and 160 ppm in the profile soils in this area. Elevated levels of As are also observed at the confluence of the rivers Ouse and Foss (around 20 ppm). This only occurs in the surface soils and may therefore represent recent contamination.

The elements Mn and Zn show generally elevated concentrations over central York, extending towards the north and east and to the far south of the mapped area, but not into the western part of the city. Concentrations of U are also lowest to the far west of York in both horizons (generally less than 1 ppm in the surface soils and less than 2 ppm in the profile soils). However, while the upper percentile values of U are fairly widespread in the surface soils, a cluster of high values is evident in the north-east corner of the mapped area in the profile soils (up to 4.3 ppm). The area involved is sufficiently large to eliminate the possibility of localised contamination; however, a more widespread source, such as smelter stack emissions may be responsible. It is likely however, that a natural geochemical signature causes U enrichment in the profile soils of this area. The soils in the north-east corner of the area are largely derived from lacustrine clays (section 2.4). The results obtained indicate an enrichment of U in the fine fraction (the profile soils are sieved to <150 µm), which is likely to be clay-rich.

Chromium, $Fe_2O_3$, Ni, $TiO_2$ and V have lower median concentrations in the York urban soils than those obtained for the wider Humber-Trent region (Tables 5 and 6). They are, however, largely elevated in concentration at two points close to industrial activity along the River Ouse and over the manufacturing area to the north of York centre. In particular, V and profile soil Cr are significantly elevated in concentration in the north-eastern corner of the area mapped. This is similar to the unusual pattern observed for U in the profile soils, suggesting that these elements are also concentrated in the clay-rich soils.

There are just three elements in York that seem to be generally elevated above the regional average: Cu, Pb, and Sn. Lead exceeds the regional average in York surface and profile soils by more than double at the 50th percentile and concentrations are significantly higher in the surface soils than in the profile soils (median values are 106 ppm and 80 ppm respectively). This element seems to be a significant contaminant in York, with the highest concentrations associated with transport routes and industrial areas. Concentrations of >1250 ppm were identified in two locations around the industrial area to the north of York centre (which includes the Nestlé chocolate factory). Levels of Cu and Sn are also higher in this area and these elements again seem to be elevated in proximity to the main transport routes (railways, roads, rivers).

The results for selected elements from surface soils in York are presented in Figure 6 in the context of six other urban areas from the Humber-Trent region (Doncaster, Hull, Lincoln, Mansfield, Scunthorpe and Sheffield) and the results from the regional survey for the Humber-Trent region. Eight elements that may be affected by anthropogenic contamination in urban areas (Sb, As, Cd, Cu, Pb, Mo, Sn and Zn) were selected, while $TiO_2$ was included to represent the closest approximation to a conservative element, unaffected by contamination.

While concentrations of $TiO_2$ are normally distributed in each urban area and fall within the range in concentration found on the regional scale, the levels of the other selected elements are in general positively skewed (indicated by a mean value significantly exceeding the median) and are higher than the regional values. This may reflect the influence of anthropogenic contamination, elevating the concentrations of certain elements above the typical regional levels and generating anomalously high values, which create skewed distributions. In the case of Mo, however, this pattern is only observed in Sheffield.

The main controls over variation in concentrations between different urban areas include population and past and present industrial activities. Recent work carried out by the British Geological Survey (Rawlins et al., 2003) has demonstrated the importance of parent material type in determining the geochemical composition of soils. This work is, however, largely outside the scope of this report.

Soil Guideline Values (SGV) produced by the Contaminated Land Exposure Assessment (CLEA) model (Department of the Environment Food and Rural Affairs and the Environment Agency, 2002a, Department of the Environment Food and Rural Affairs and the Environment Agency, 2002b) for residential areas with plant uptake are shown on Figure 6 for Cd and As. The SGV for Pb (450 ppm) is outside the plot area, suggesting that the levels found in soils are not of significant risk to human health in any of the Humber-Trent urban areas sampled. From the 75th percentile, cadmium concentrations in York are above the SGV value for soils with a pH of 6, but are largely below the level given for pH 7 soils. The levels are comparable with Sheffield and Mansfield, but are higher than the remaining four urban areas, which are very low in Cd. Excluding outliers, levels of As are below the SGV for residential land use in the soils collected from York, and are also lower than the values obtained from the other six urban areas (which all exceed the SGV in the upper ranges of their distributions). This may be related to lower levels of anthropogenic As contamination in York than in the other urban areas. The levels of As are, however also lower in York than on a regional, non-urban scale. This suggests that the specific parent materials underlying York may be poor in As, relative to other parent material types in the area.

According to Figure 6, the main contaminants in York appear to be Pb, Zn, Sn and Cd. Concentrations of Pb and Cd are high in relation to a number of other urban areas in the Humber-Trent region. A possible explanation may be higher levels of traffic pollution in York. Prior to 2000, tetra-ethyl Pb was added to petrol as an anti-knocking agent, while Cd is present in car tyres.

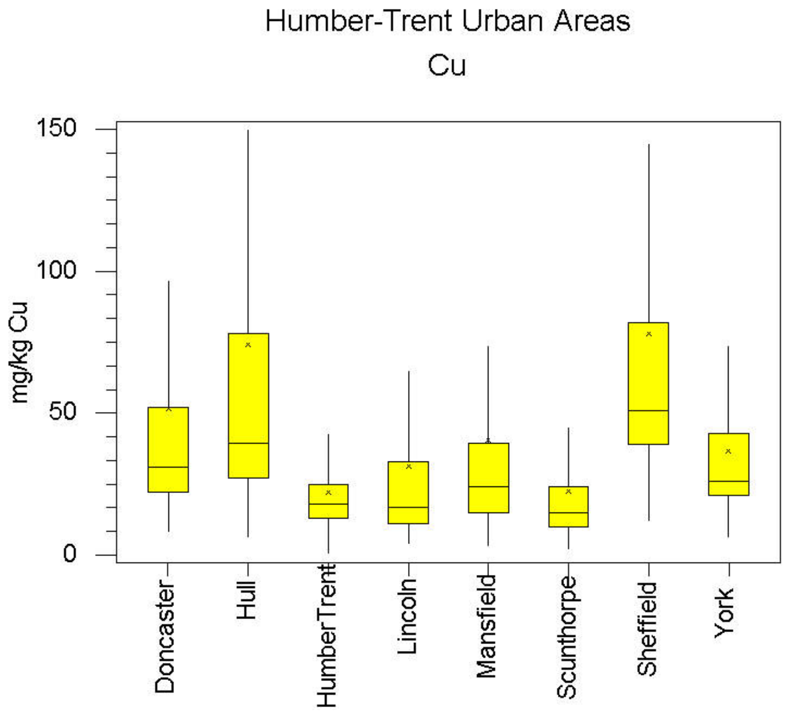

Figure 6: (a) Copper in surface soil

**Figure 6 ((*a*) - (*i*)) Box and Whisker Plots for selected elements in surface soils from six urban areas in the Humber-Trent region presented with the regional Humber-Trent data. Soil Guideline Values (SGVs) for soils in residential areas involving plant uptake (derived using the CLEA model) are shown in red for As and Cd. Note that for Pb (450 mg/kg) and Cd (pH = 8, 8 mg/kg) SGV values are outside plot area (boxes show inter-quartile range, median is a straight line and the mean value a cross)**

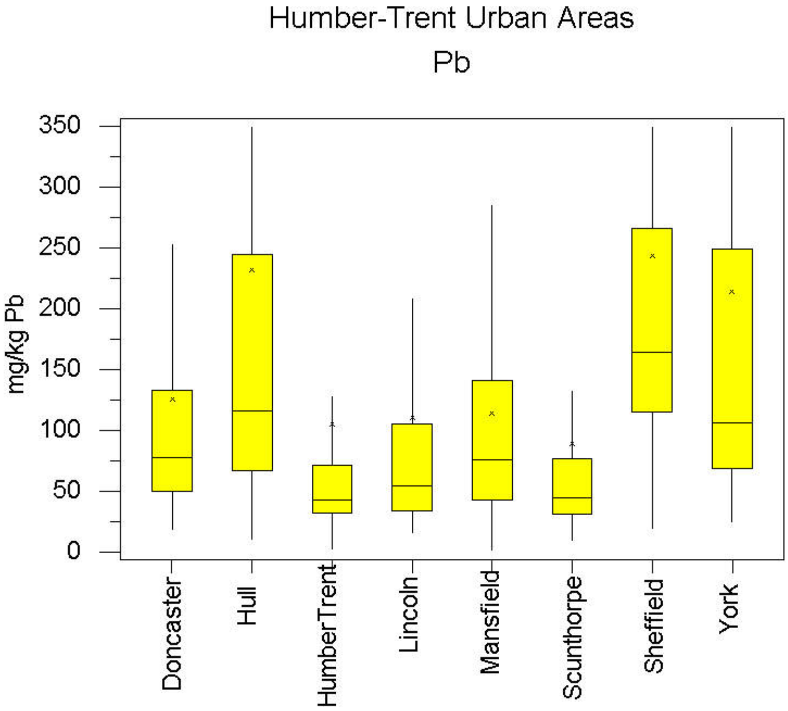

Figure 6: (b) Lead in surface soil

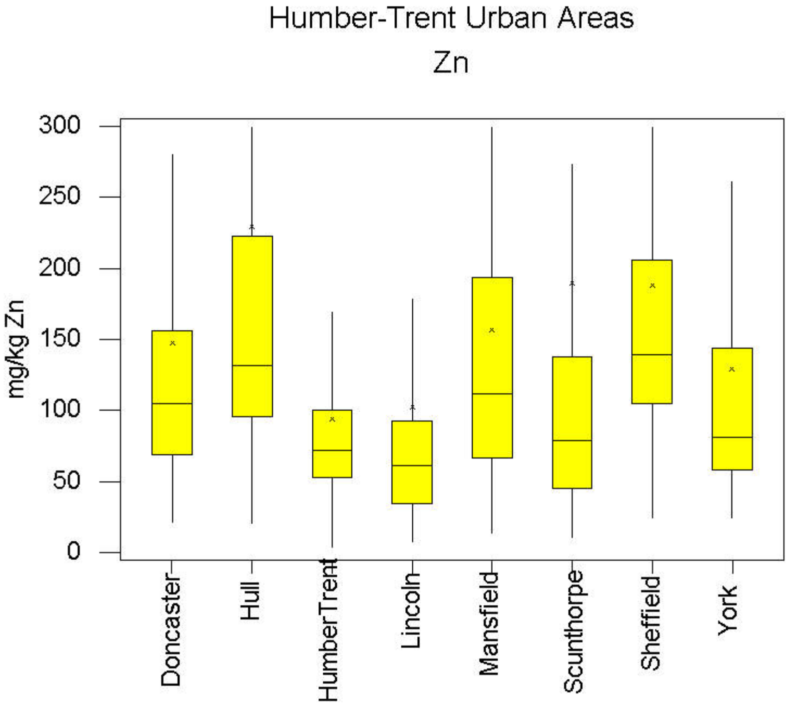

Figure 6: (c) Zinc in surface soil

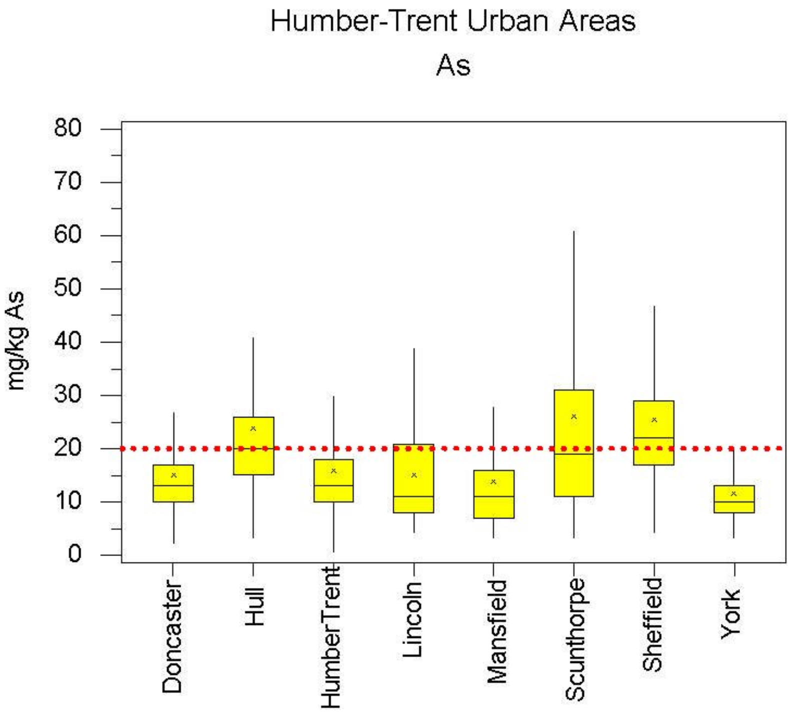

Figure 6: (d) Arsenic in surface soil

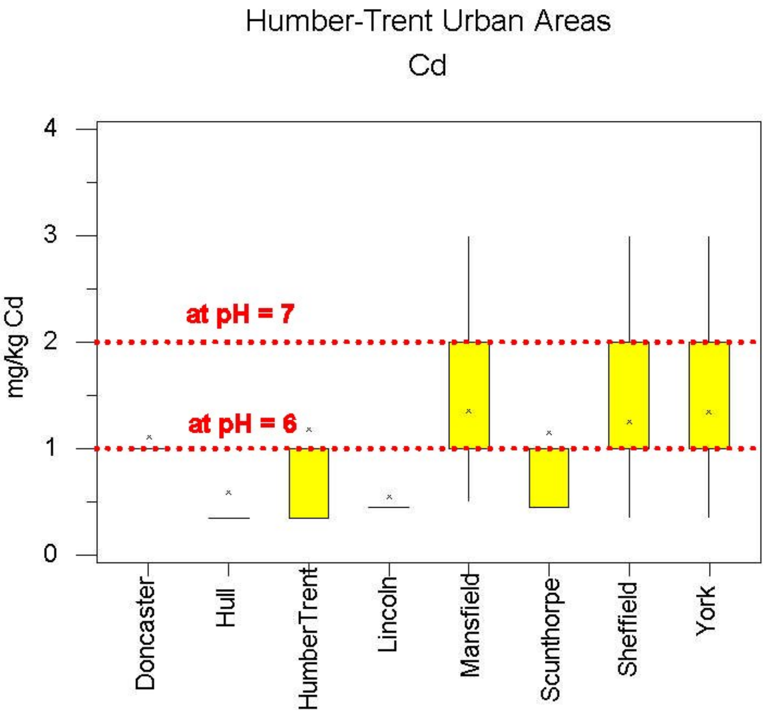

Figure 6: (e) Cadmium in surface soil

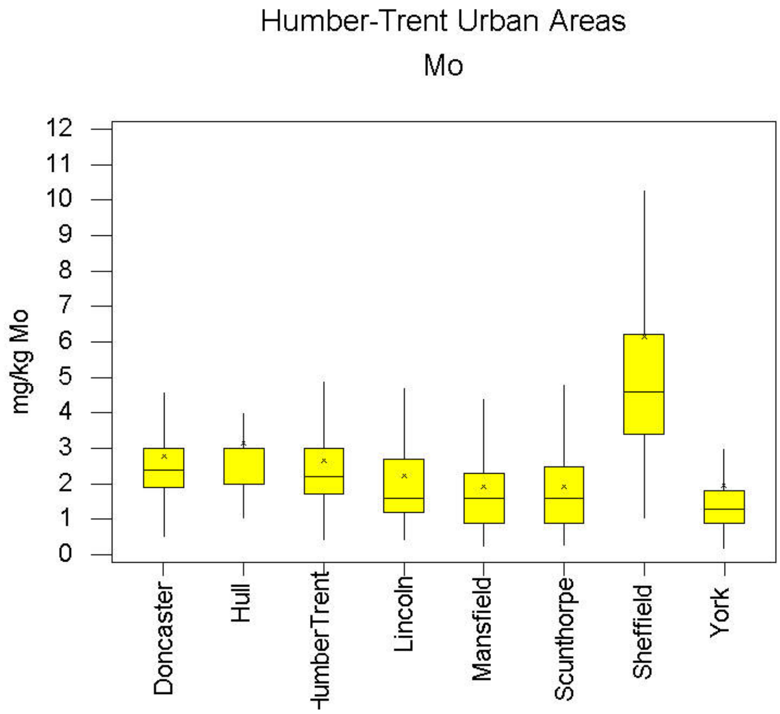

Figure 6: (f) Molybdenum in surface soil

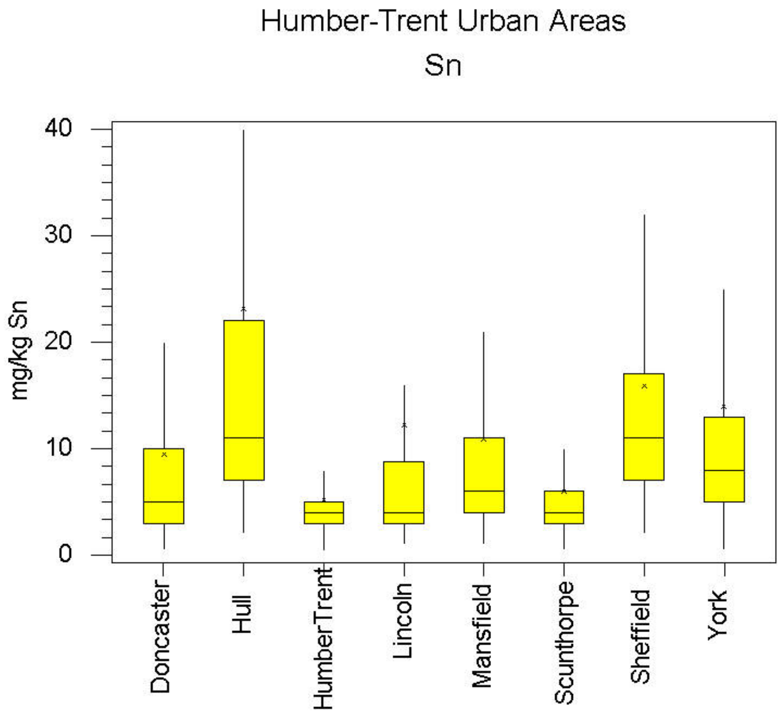

Figure 6: (g) Tin in surface soil

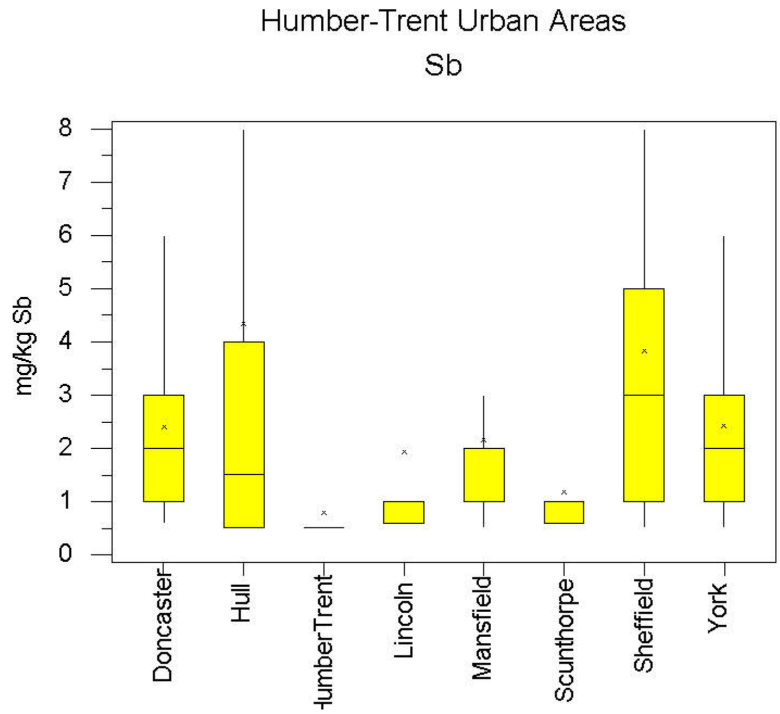

Figure 6: (h) Antimony in surface soil

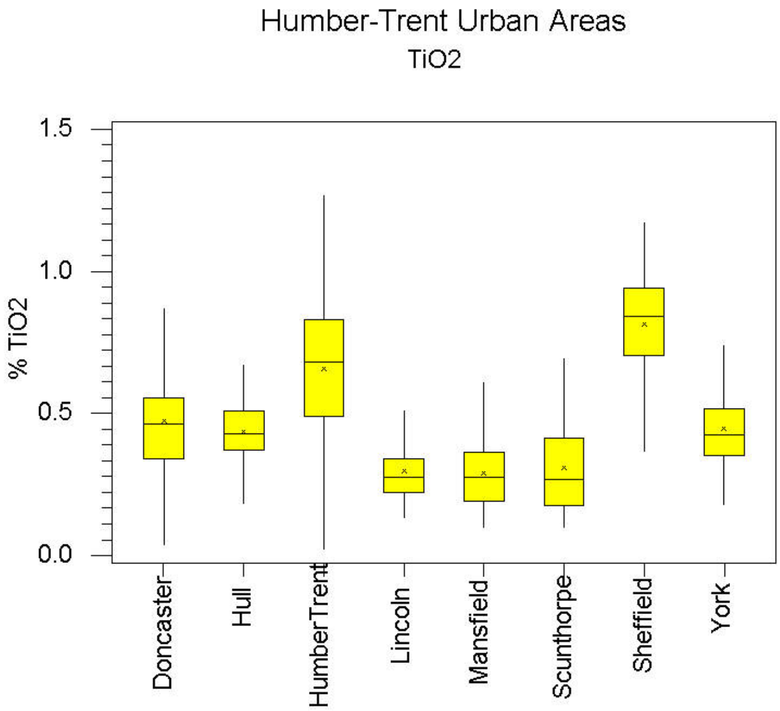

Figure 6: (i) Titanium oxide in surface soil

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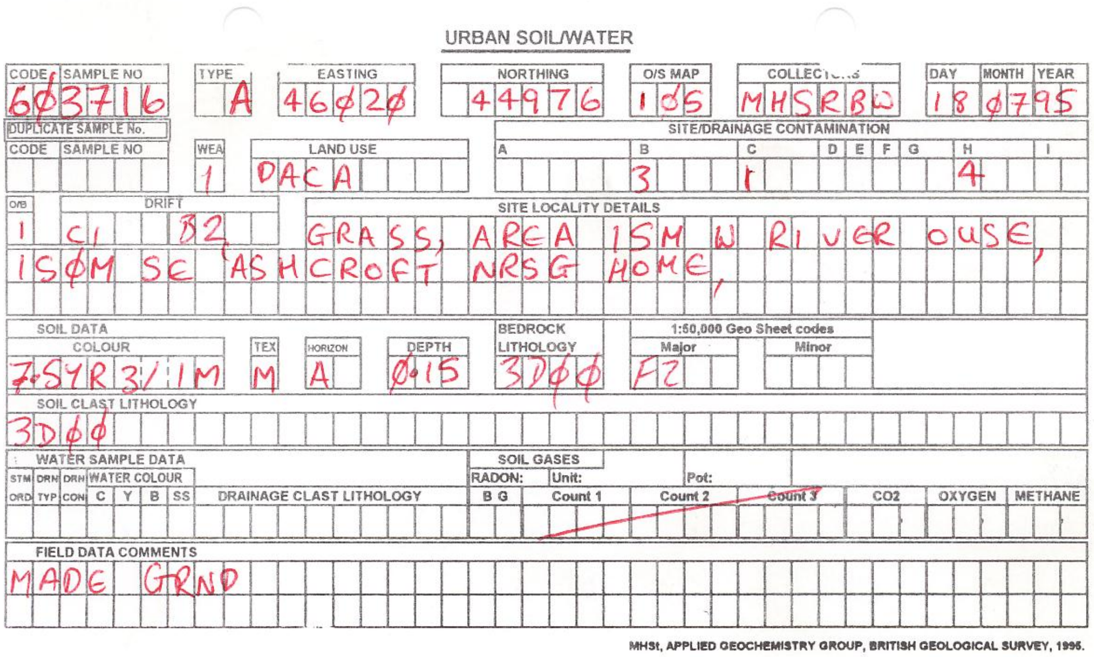
# Appendix A: Examples of urban surface and profile field cards from York.



## URBAN SOIL/WATER

CODE, SAMPLE NO: 603716
TYPE: A
EASTING: 46020
NORTHING: 44976
O/S MAP: 105
COLLECTORS: MHSRBW
DAY: 18 MONTH: 07 YEAR: 95

DUPLICATE SAMPLE No.: CODE: SAMPLE NO:
WEA: 1
LAND USE: DACA
SITE/DRAINAGE CONTAMINATION: A: B: 3 C: 1 D: E: F: G: H: 4 I:

O/B: 1
DRIFT: C1 B2
SITE LOCALITY DETAILS: GRASS, AREA 15M W RIVER OUSE, 150M SE 'ASHCROFT NRSG HOME,'

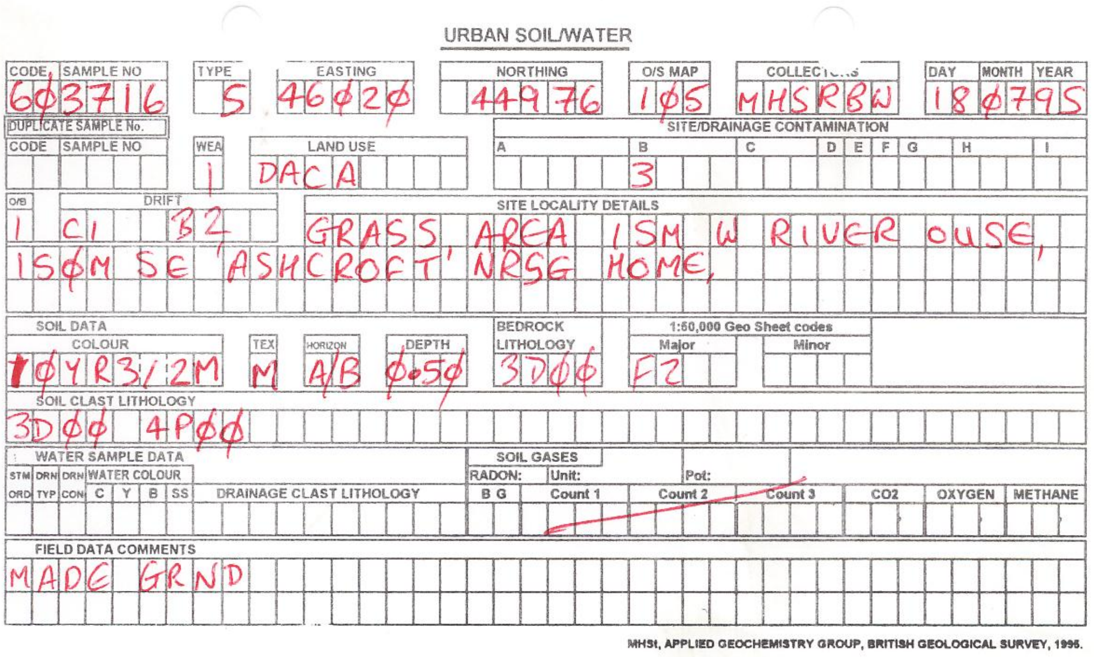
SOIL DATA
COLOUR: 7.5YR 3/1M
TEX: M
HORIZON: A
DEPTH: 0.15
BEDROCK LITHOLOGY: 3D00
1:50,000 Geo Sheet codes: Major: FZ Minor:
SOIL CLAST LITHOLOGY: 3D00

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: MADE GRND

MHSt, APPLIED GEOCHEMISTRY GROUP, BRITISH GEOLOGICAL SURVEY, 1995.



## URBAN SOIL/WATER

CODE, SAMPLE NO: 603716
TYPE: 5
EASTING: 46020
NORTHING: 44976
O/S MAP: 105
COLLECTORS: MHSRBW
DAY: 18 MONTH: 07 YEAR: 95

DUPLICATE SAMPLE No.: CODE: SAMPLE NO:
WEA: 1
LAND USE: DACA
SITE/DRAINAGE CONTAMINATION: A: B: 3 C: D: E: F: G: H: I:

O/B: 1
DRIFT: C1 B2
SITE LOCALITY DETAILS: GRASS, AREA 15M W RIVER OUSE, 150M SE 'ASHCROFT' NRSG HOME,

SOIL DATA
COLOUR: 10YR3/2M
TEX: M
HORIZON: A/B
DEPTH: 0.50
BEDROCK LITHOLOGY: 3D00
1:50,000 Geo Sheet codes: Major: FZ Minor:
SOIL CLAST LITHOLOGY: 3D00 4P00

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: MADE GRND

MHSt, APPLIED GEOCHEMISTRY GROUP, BRITISH GEOLOGICAL SURVEY, 1995.

# Appendix B: Percentile calculations for York A-soils

| **A-Soils:** | **Sb*** | **As** | **Ba** | **Cd*** | **Cr** | **Co** | **Cu** | **$Fe_2O_3$** | **Pb** | **MnO** | **Mo*** | **Ni** | **Sn** | **$TiO_2$** | **U*** | **V** | **Zn** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Percentile** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **wt %** | **ppm** | **wt %** | **ppm** | **ppm** | **ppm** | **wt %** | **ppm** | **ppm** | **ppm** |
| **99th** | 16.0 | 32 | 3110 | 5.10 | 122 | 33 | 127 | 8.74 | 1250 | 0.178 | 10.4 | 57 | 83 | 0.837 | 3.14 | 141 | 682 |
| **95th** | 6.5 | 18 | 1263 | 2.00 | 99 | 25 | 96 | 5.91 | 671 | 0.127 | 3.7 | 39 | 42 | 0.717 | 2.20 | 111 | 365 |
| **90th** | 5.0 | 17 | 723 | 2.00 | 90 | 21 | 71 | 4.93 | 510 | 0.111 | 2.6 | 30 | 25 | 0.651 | 1.70 | 100 | 262 |
| **75th** | 3.0 | 13 | 461 | 2.00 | 70 | 18 | 43 | 4.24 | 246 | 0.091 | 1.8 | 25 | 13 | 0.516 | 1.40 | 79 | 144 |
| **50th** | 2.0 | 10 | 340 | 1.00 | 59 | 15 | 26 | 3.43 | 106 | 0.072 | 1.3 | 19 | 8 | 0.424 | 1.10 | 61 | 81 |
| **25th** | 1.0 | 8 | 276 | 1.00 | 48 | 12 | 21 | 2.60 | 69 | 0.056 | 0.9 | 14 | 5 | 0.352 | 0.80 | 50 | 58 |
| **15th** | 1.0 | 7 | 254 | 1.00 | 42 | 11 | 18 | 2.28 | 55 | 0.050 | 0.8 | 12 | 4 | 0.320 | 0.60 | 43 | 50 |
| **10th** | 0.5 | 6 | 236 | 1.00 | 41 | 10 | 15 | 2.13 | 46 | 0.047 | 0.7 | 12 | 4 | 0.293 | 0.50 | 41 | 44 |
| **5th** | 0.5 | 6 | 209 | 0.35 | 37 | 9 | 13 | 1.93 | 38 | 0.039 | 0.4 | 10 | 3 | 0.270 | 0.25 | 38 | 40 |
| **Minimum** | 0.5 | 3 | 72 | 0.35 | 27 | 5 | 6 | 0.73 | 24 | 0.026 | 0.15 | 6 | 1 | 0.102 | 0.25 | 29 | 24 |
| **Maximum** | 26.0 | 93 | 3612 | 9.00 | 639 | 47 | 227 | 10.08 | 2400 | 0.208 | 69.6 | 84 | 253 | 0.910 | 3.70 | 230 | 898 |
| **Median** | 2.0 | 10 | 340 | 1.00 | 59 | 15 | 26 | 3.43 | 106 | 0.072 | 1.3 | 19 | 8 | 0.424 | 1.10 | 61 | 81 |
| **Mean** | 2.4 | 12 | 496 | 1.34 | 64 | 15 | 37 | 3.55 | 214 | 0.076 | 2.0 | 21 | 14 | 0.449 | 1.13 | 67 | 129 |

*Minimum value reported as half detection limit

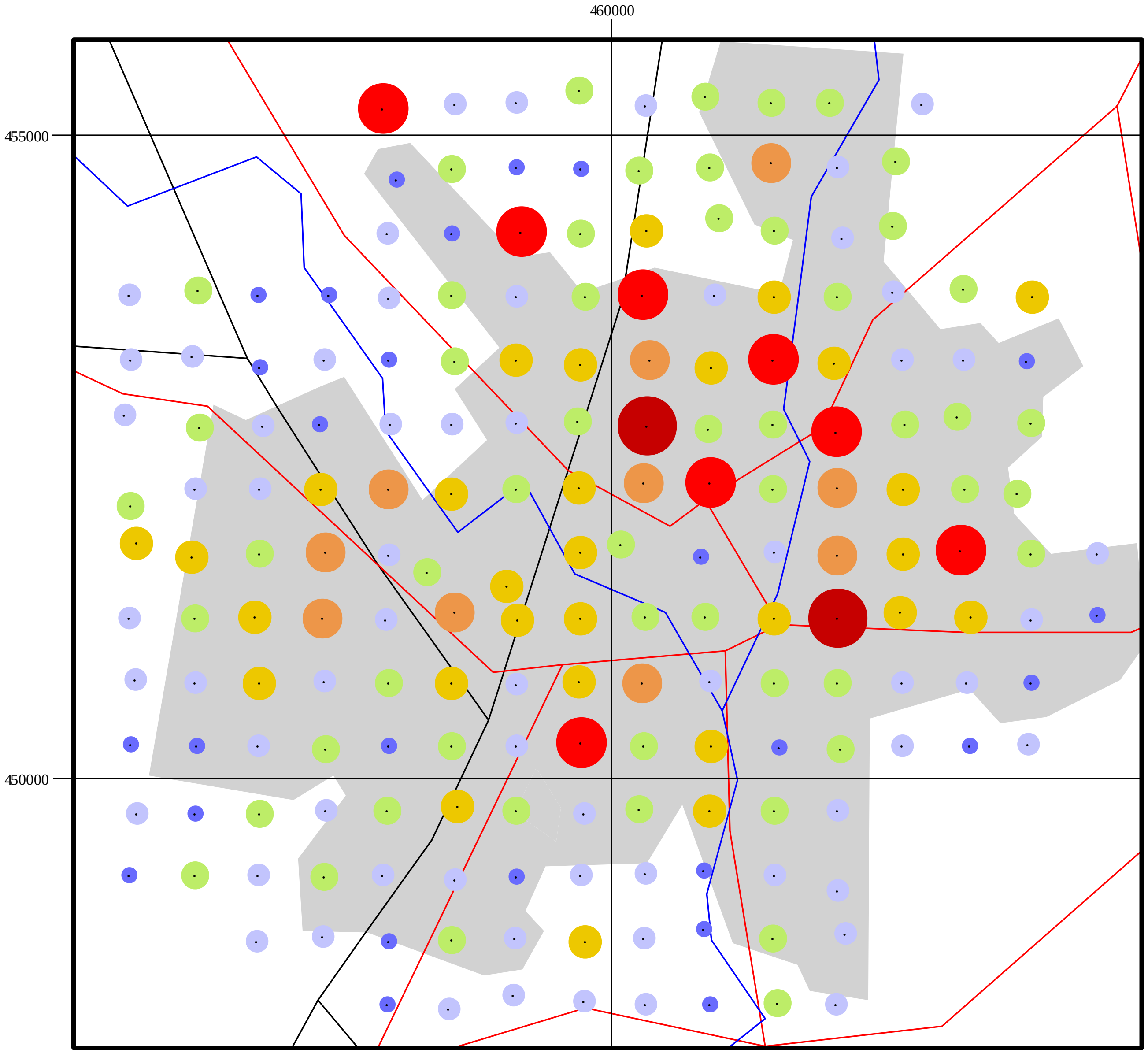
# Appendix B: Percentile calculations for York S-soils

| S-Soils: | Sb* | As | Ba | Cd* | Cr | Co | Cu | $Fe_2O_3$ | Pb | MnO | Mo | Ni | Sn | $TiO_2$ | U* | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Percentile** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **wt %** | **ppm** | **wt %** | **ppm** | **ppm** | **ppm** | **wt %** | **ppm** | **ppm** | **ppm** |
| **99th** | 16.0 | 44 | 4759 | 4.14 | 117 | 38 | 167 | 8.45 | 1090 | 0.279 | 5.0 | 52 | 67 | - | 3.64 | 134 | 622 |
| **95th** | 6.7 | 24 | 992 | 3.00 | 103 | 27 | 118 | 6.37 | 627 | 0.156 | 3.4 | 42 | 32 | - | 2.77 | 109 | 357 |
| **90th** | 5.0 | 21 | 700 | 2.00 | 94 | 25 | 94 | 5.74 | 425 | 0.121 | 2.7 | 38 | 26 | - | 2.44 | 101 | 230 |
| **75th** | 2.0 | 15 | 467 | 2.00 | 80 | 21 | 44 | 4.80 | 183 | 0.095 | 1.9 | 29 | 11 | - | 2.20 | 85 | 126 |
| **50th** | 1.0 | 12 | 354 | 1.00 | 67 | 17 | 29 | 4.00 | 80 | 0.073 | 1.6 | 24 | 6 | - | 1.90 | 67 | 76 |
| **25th** | 1.0 | 10 | 301 | 1.00 | 57 | 14 | 22 | 3.13 | 49 | 0.044 | 1.2 | 17 | 4 | - | 1.60 | 53 | 57 |
| **15th** | 0.5 | 9 | 279 | 1.00 | 52 | 13 | 18 | 2.77 | 37 | 0.029 | 1.0 | 14 | 4 | - | 1.30 | 47 | 52 |
| **10th** | 0.5 | 9 | 263 | 1.00 | 51 | 12 | 17 | 2.46 | 33 | 0.025 | 0.9 | 13 | 3 | - | 1.30 | 45 | 46 |
| **5th** | 0.5 | 8 | 251 | 0.35 | 45 | 10 | 16 | 2.17 | 28 | 0.016 | 0.7 | 11 | 2 | - | 1.10 | 39 | 39 |
| **Minimum** | 0.5 | 5 | 125 | 0.35 | 38 | 7 | 8 | 1.52 | 17 | 0.012 | 0.3 | 8 | 2 | - | 0.25 | 34 | 26 |
| **Maximum** | 17.0 | 160 | 5456 | 5.00 | 147 | 39 | 251 | 8.63 | 1955 | 0.303 | 14.0 | 84 | 85 | - | 4.30 | 190 | 1100 |
| **Median** | 1.0 | 12 | 354 | 1.00 | 67 | 17 | 29 | 4.00 | 80 | 0.073 | 1.6 | 24 | 6 | - | 1.90 | 67 | 76 |
| **Mean** | 2.1 | 14 | 538 | 1.49 | 70 | 18 | 41 | 4.08 | 176 | 0.076 | 1.8 | 24 | 10 | - | 1.88 | 71 | 119 |

*Minimum value reported as half detection limit

# Appendix C: Proportional symbol geochemical maps for York surface and profile soils

**Antimony**
**Arsenic**
**Barium**
**Cadmium**
**Chromium**
**Cobalt**
**Copper**
**Iron**
**Lead**
**Manganese**
**Molybdenum**
**Nickel**
**Tin**
**Titanium** (not determined in profile soils)
**Uranium**
**Vanadium**
**Zinc**

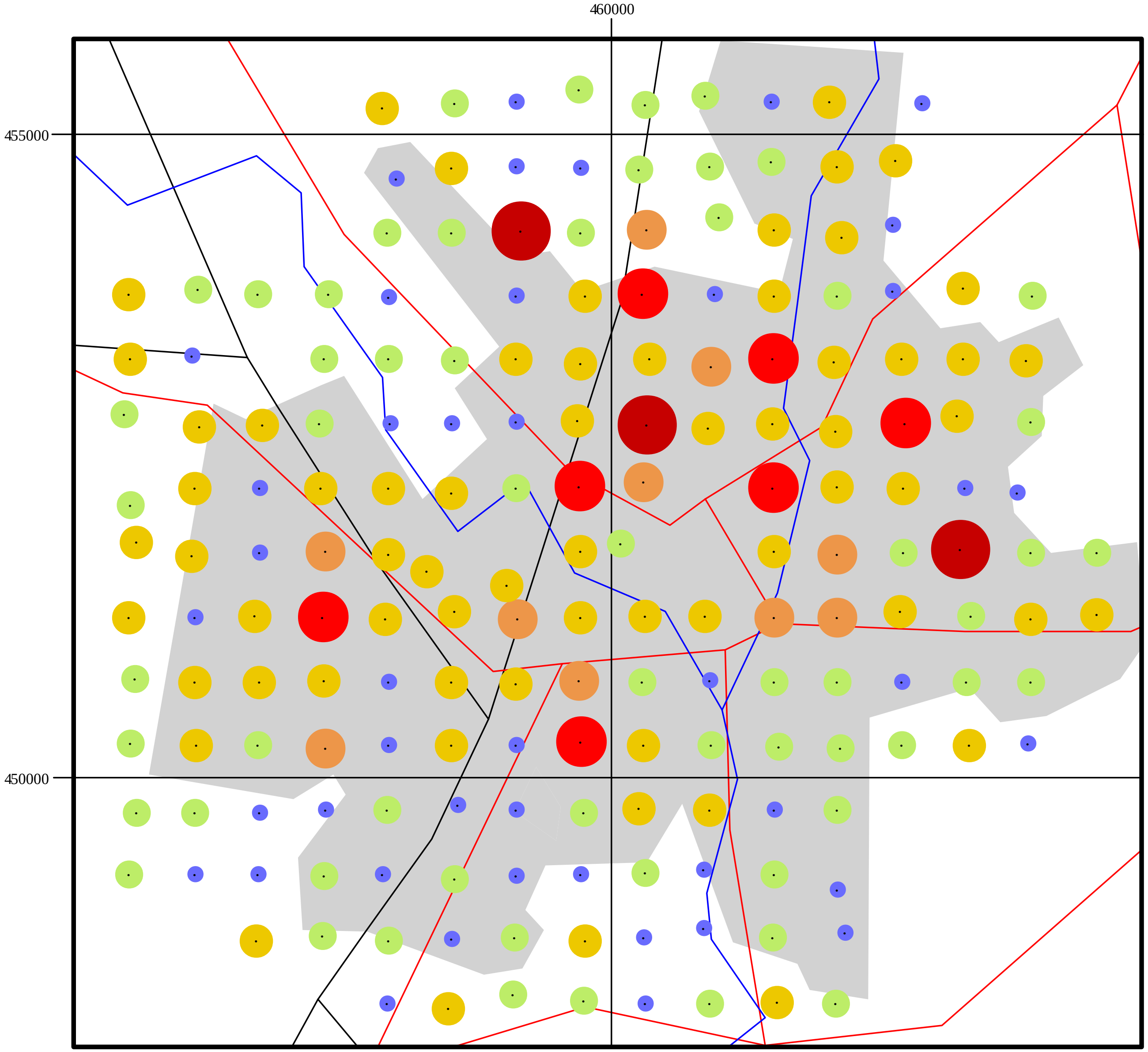


# York
# Surface Soils

# Antimony

| % ile | ppm |
|---|---|
| 99 | 16.0 |
| 95 | 6.5 |
| 90 | 5.0 |
| 75 | 3.0 |
| 50 | 2.0 |
| 25 | 1.0 |
| 10 | 0.5 |

| surface soil | **Sb** (ppm) |
|---|---|
| number | 191 |
| minimum | 0.5 |
| maximum | 26.0 |
| median | 2.0 |
| mean | 2.4 |

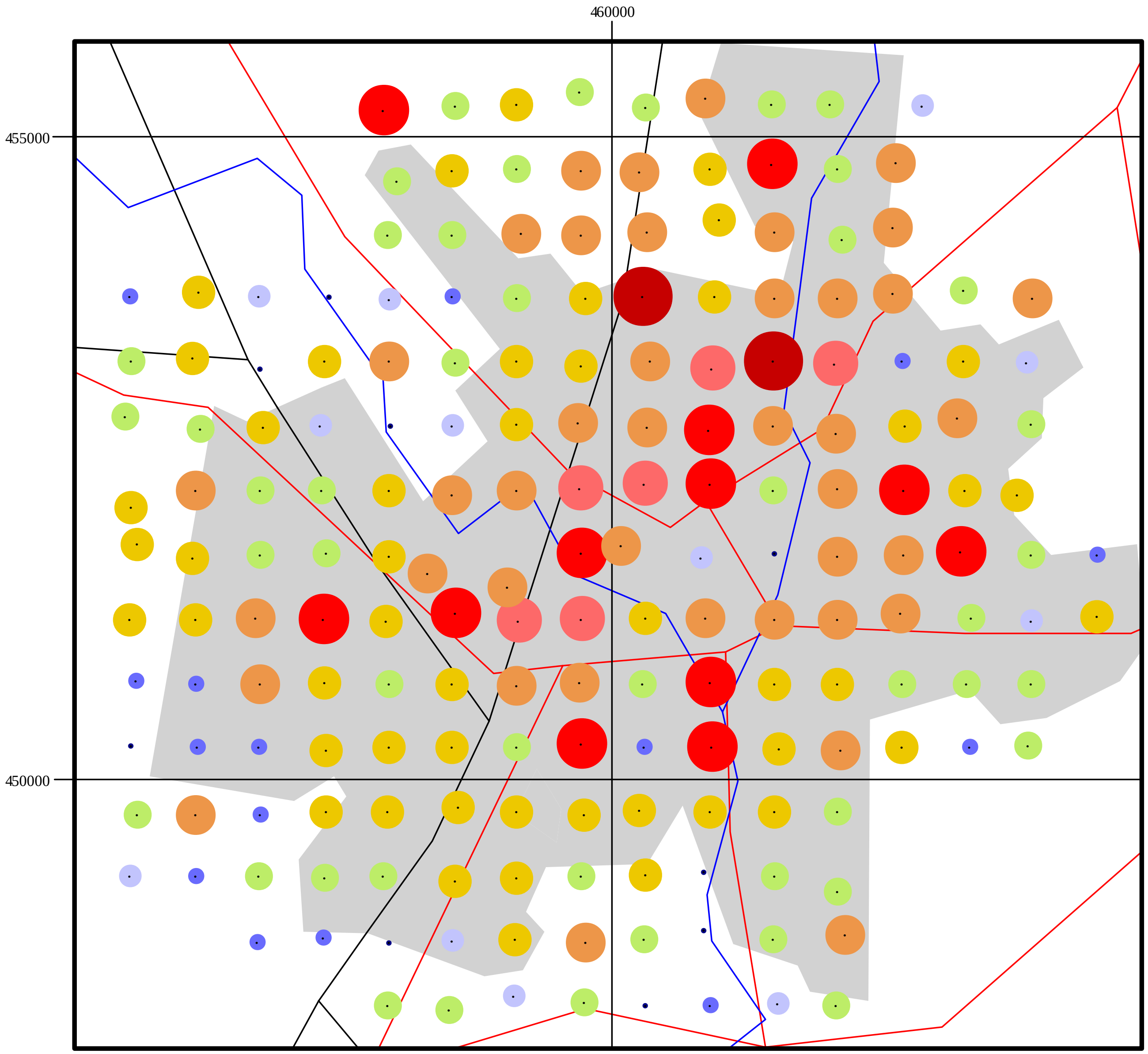


# York
# Profile Soils

## Antimony

| % ile | ppm |
|---|---|
| 99 | 16.0 |
| 95 | 6.7 |
| 90 | 5.0 |
| 75 | 2.0 |
| 50 | 1.0 |
| 15 | 0.5 |

| profile soil | **Sb** (ppm) |
|---|---|
| number | 187 |
| minimum | 0.5 |
| maximum | 17.0 |
| median | 1.0 |
| mean | 2.1 |



# York
# Surface Soils

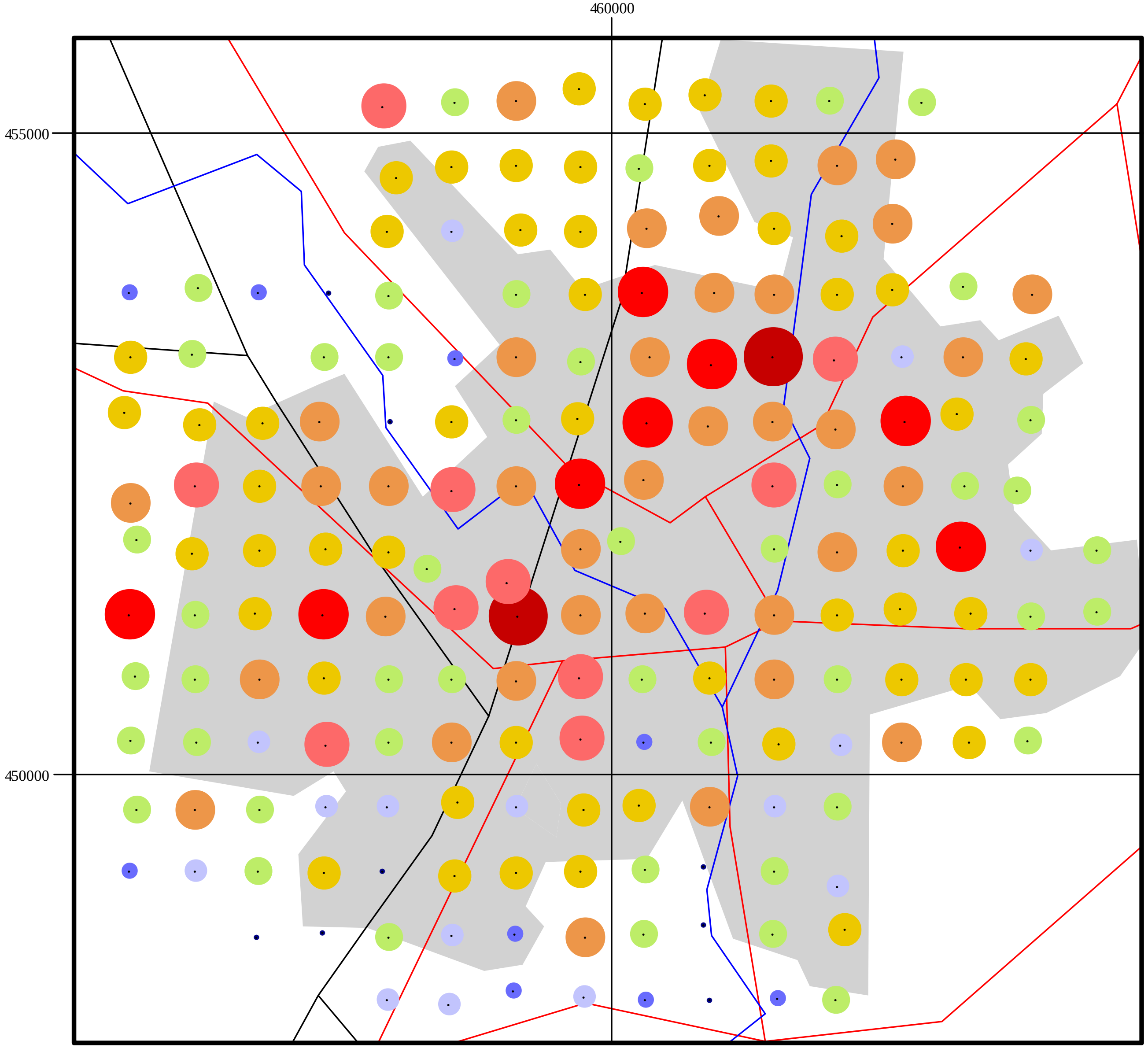
## Arsenic

| % ile | ppm |
|---|---|
| 99 | 32 |
| 95 | 18 |
| 90 | 17 |
| 75 | 13 |
| 50 | 10 |
| 25 | 8 |
| 15 | 7 |
| 10 | 6 |

| surface soil | As (ppm) |
|---|---|
| number | 191 |
| minimum | 3 |
| maximum | 93 |
| median | 10 |
| mean | 12 |

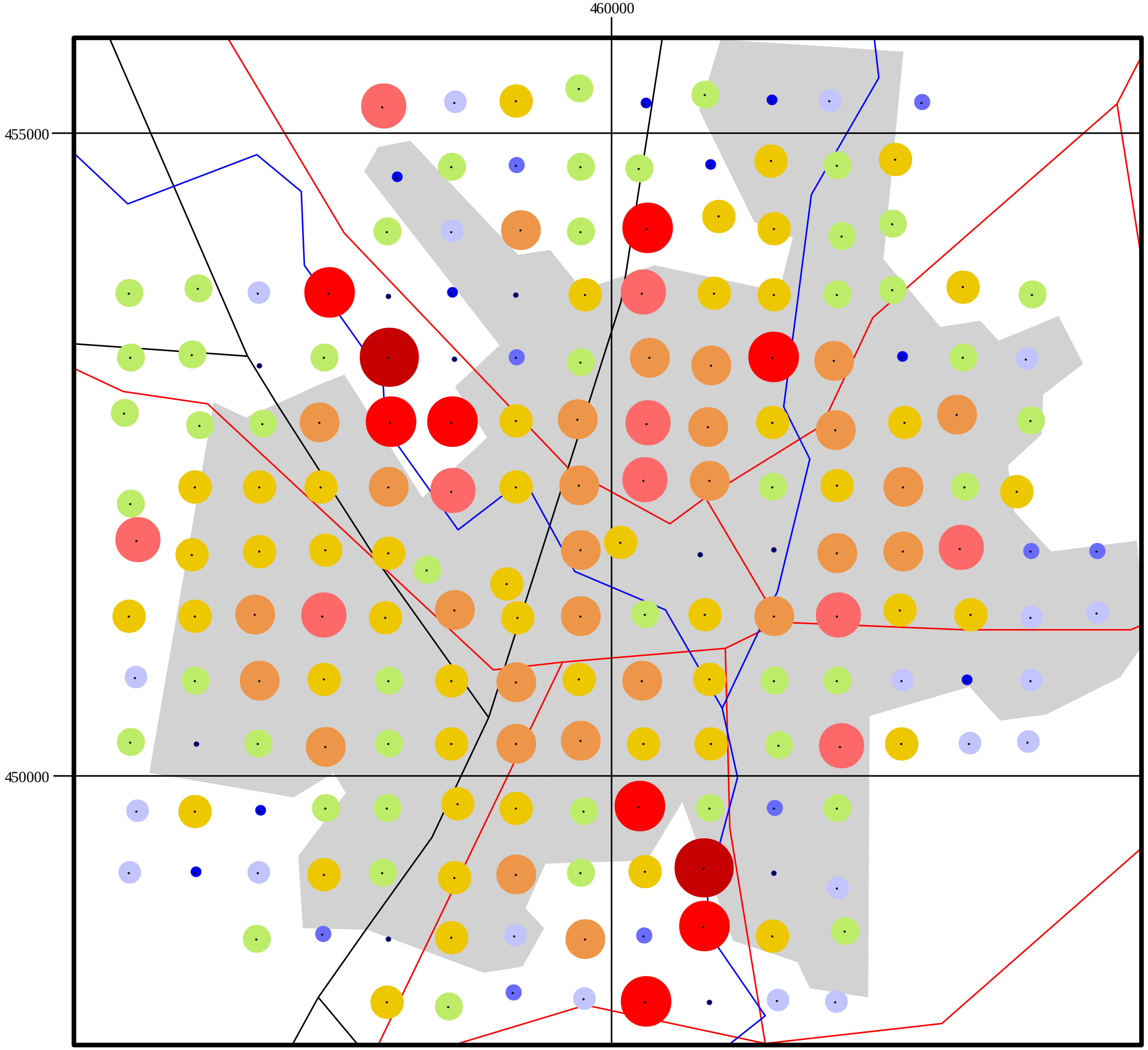
# York
# Profile Soils

## Arsenic



| % ile | ppm |
|---|---|
| 99 | 44 |
| 95 | 24 |
| 90 | 21 |
| 75 | 15 |
| 50 | 12 |
| 25 | 10 |
| 15 | 9 |
| 5 | 8 |

| profile soil | As (ppm) |
|---|---|
| number | 187 |
| minimum | 5 |
| maximum | 160 |
| median | 12 |
| mean | 14 |

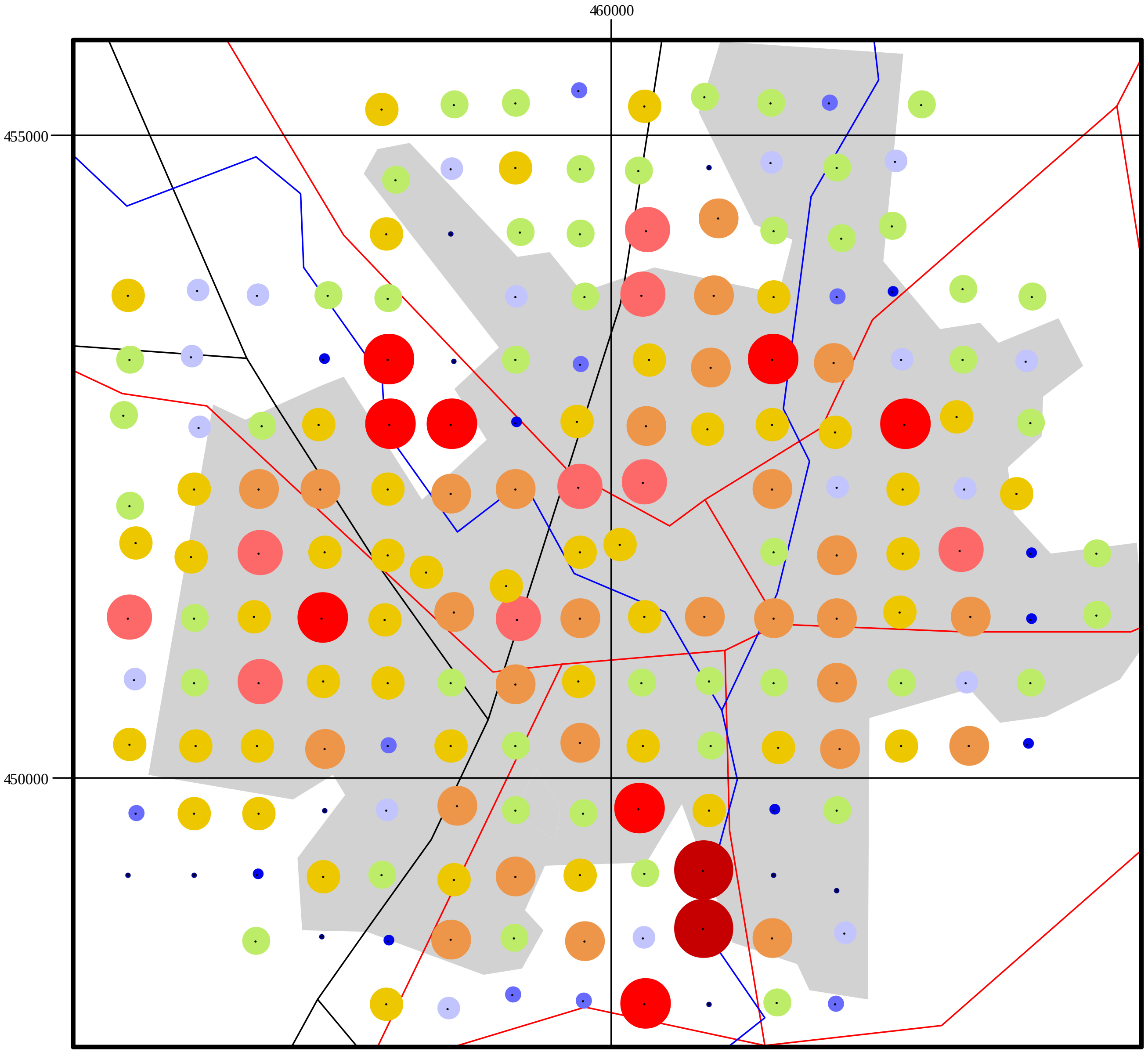


# York
# Surface Soils

# Barium

| % ile | ppm |
|---|---|
| 99 | 3110 |
| 95 | 1263 |
| 90 | 723 |
| 75 | 461 |
| 50 | 340 |
| 25 | 276 |
| 15 | 254 |
| 10 | 236 |
| 5 | 209 |

| surface soil | **Ba** (ppm) |
|---|---|
| number | 191 |
| minimum | 72 |
| maximum | 3612 |
| median | 340 |
| mean | 496 |

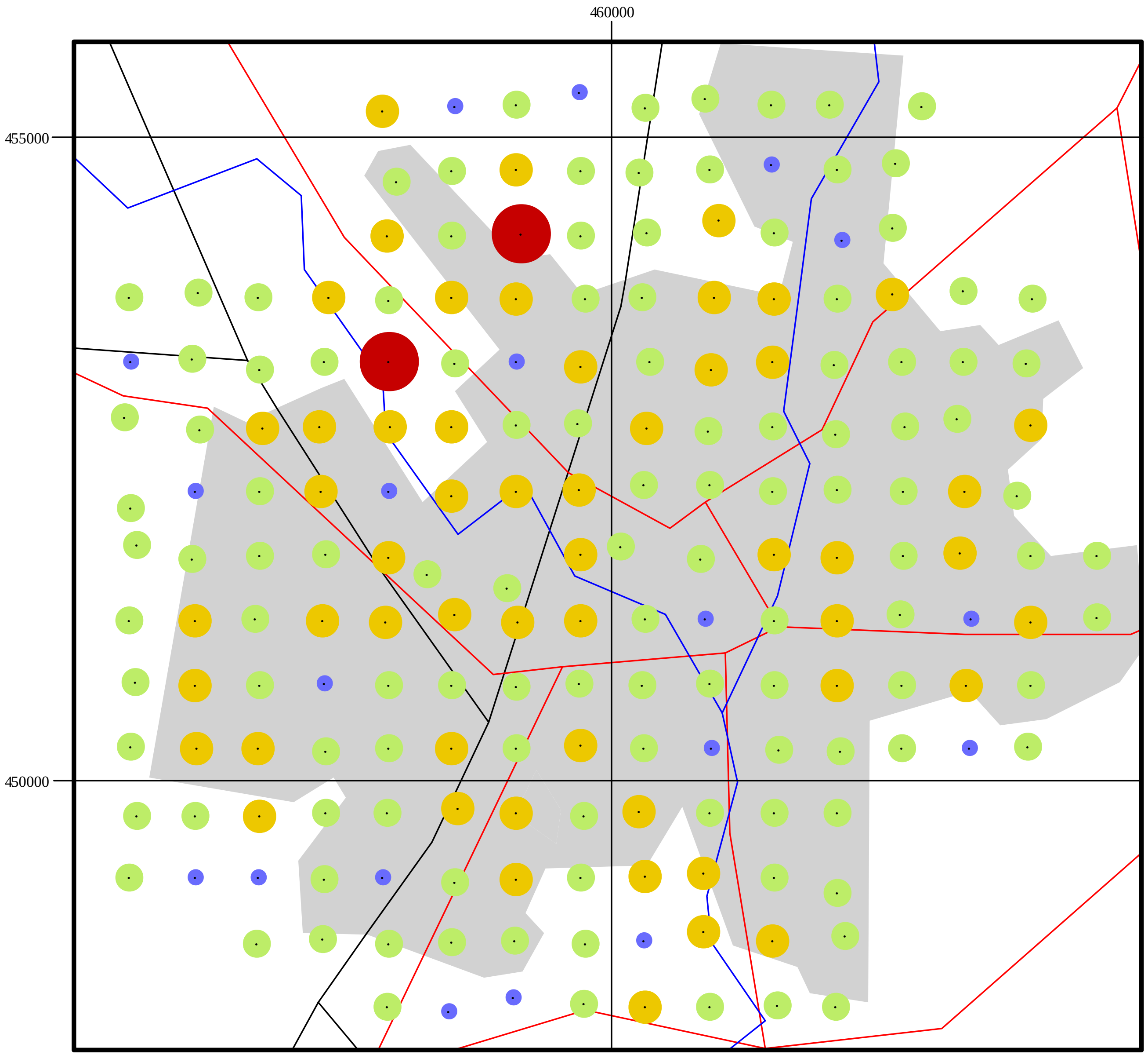


# York
# Profile Soils

## Barium

| % ile | ppm |
|---|---|
| 99 | 4759 |
| 95 | 992 |
| 90 | 700 |
| 75 | 467 |
| 50 | 354 |
| 25 | 301 |
| 15 | 279 |
| 10 | 263 |
| 5 | 251 |

| profile soil | **Ba** (ppm) |
|---|---|
| number | 187 |
| minimum | 125 |
| maximum | 5456 |
| median | 354 |
| mean | 538 |

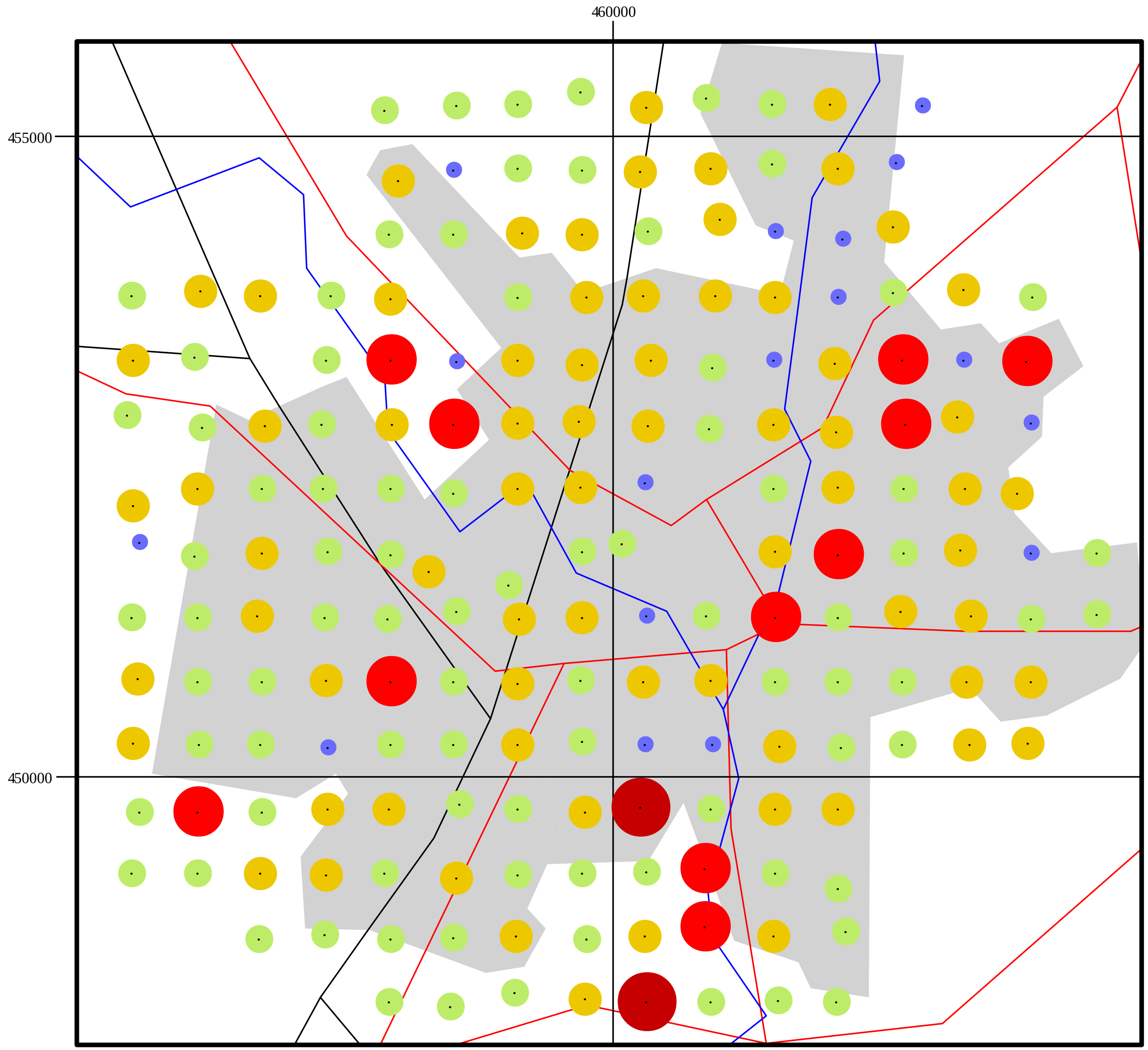


# York
# Surface Soils

# Cadmium

| % ile | ppm |
|---|---|
| ● | |
| 99 | 5.10 |
| ● | |
| 95 | 2.00 |
| ● | |
| 50 | 1.00 |
| ● | |
| 5 | 0.35 |
| • | |

| surface soil | Cd (ppm) |
|---|---|
| number | 191 |
| minimum | 0.35 |
| maximum | 9 |
| median | 1 |
| mean | 1.34 |

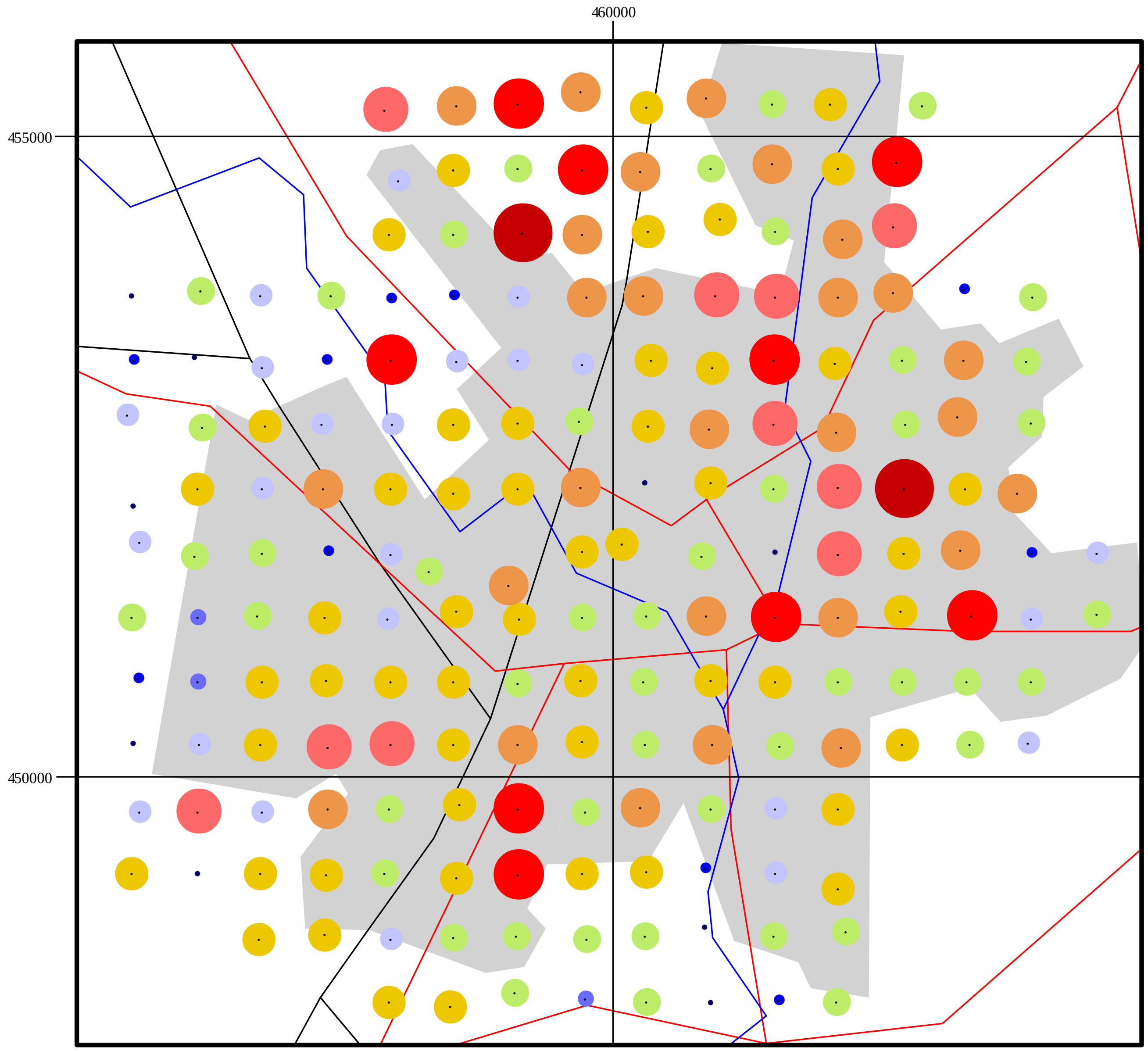


# York
# Profile Soils

# Cadmium

| % ile | ppm |
|---|---|
| 99 | 4.14 |
| 95 | 3.00 |
| 90 | 2.00 |
| 50 | 1.00 |
| 5 | 0.35 |

| profile soil | **Cd** (ppm) |
|---|---|
| **number** | **187** |
| **minimum** | **0.35** |
| **maximum** | **5** |
| **median** | **1** |
| **mean** | **1.49** |

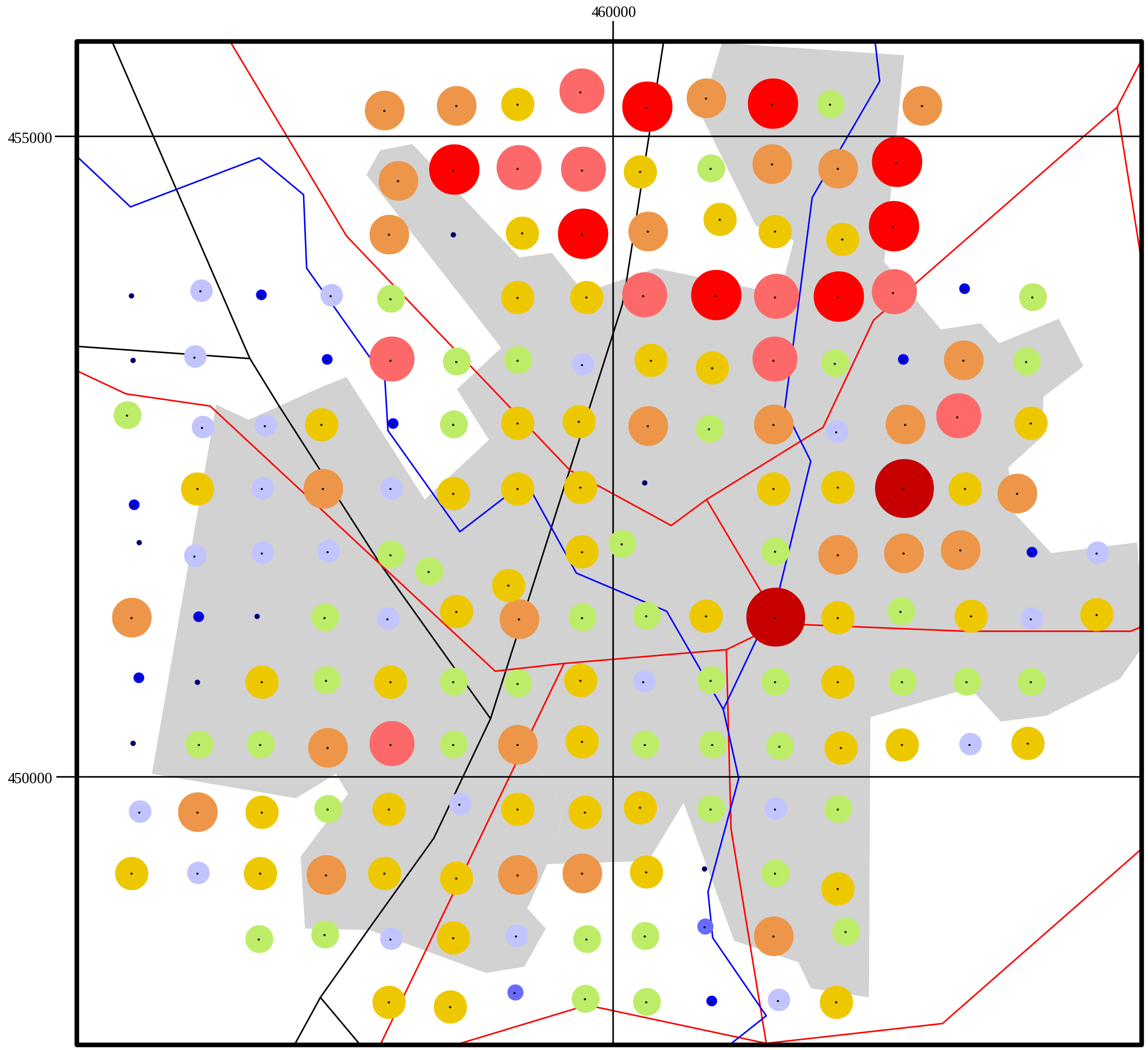


# York
# Surface Soils

# Chromium

| % ile | ppm |
|---|---|
| 99 | 122 |
| 95 | 99 |
| 90 | 90 |
| 75 | 70 |
| 50 | 59 |
| 25 | 48 |
| 15 | 42 |
| 10 | 41 |
| 5 | 37 |

| surface soil | Cr (ppm) |
|---|---|
| number | 191 |
| minimum | 27 |
| maximum | 639 |
| median | 59 |
| mean | 64 |

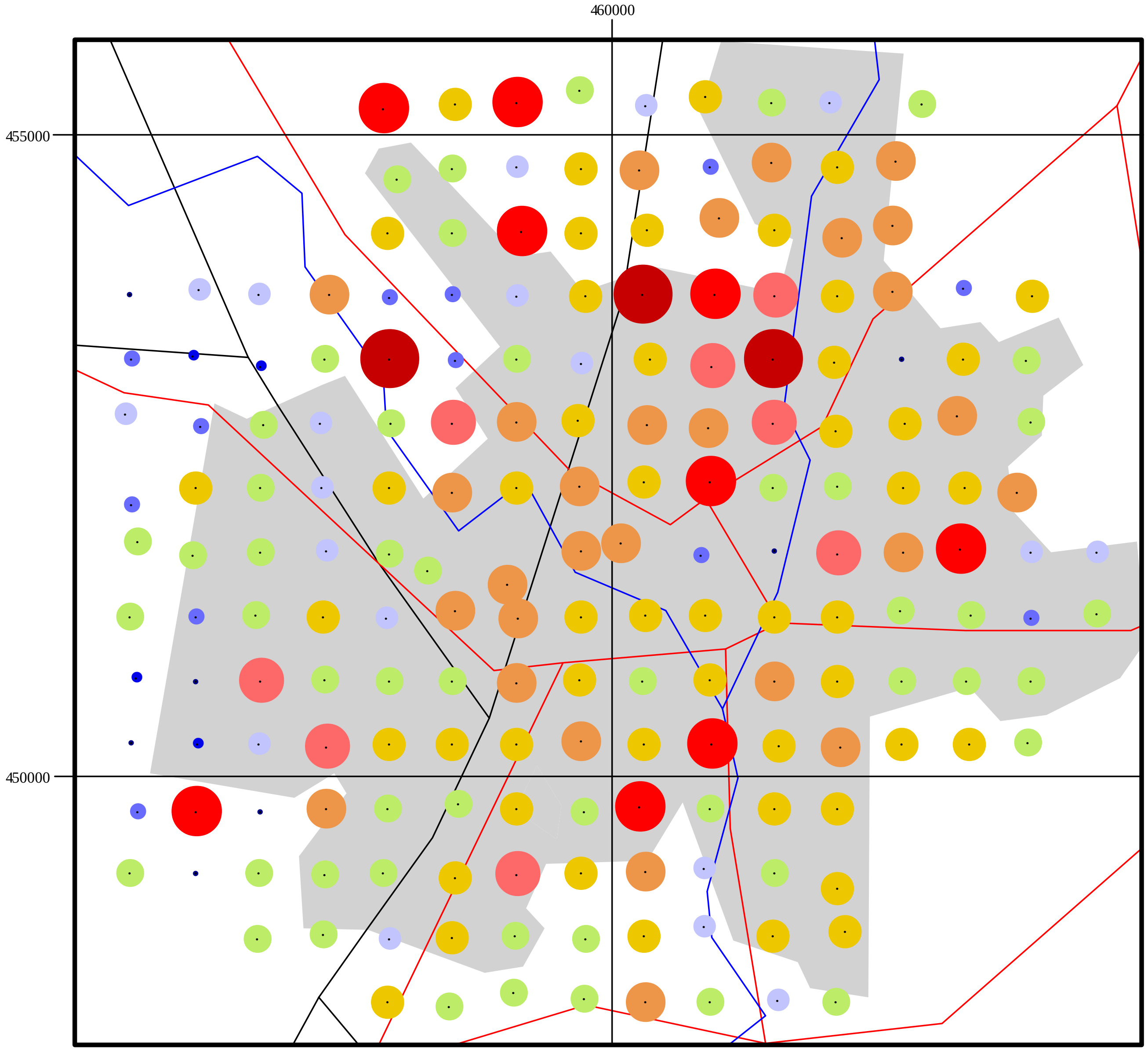


# York
# Profile Soils

# Chromium

| % ile | ppm |
|---|---|
| 99 | 117 |
| 95 | 103 |
| 90 | 94 |
| 75 | 80 |
| 50 | 67 |
| 25 | 57 |
| 15 | 52 |
| 10 | 51 |
| 5 | 45 |

| profile soil | Cr (ppm) |
|---|---|
| number | 187 |
| minimum | 38 |
| maximum | 147 |
| median | 67 |
| mean | 70 |

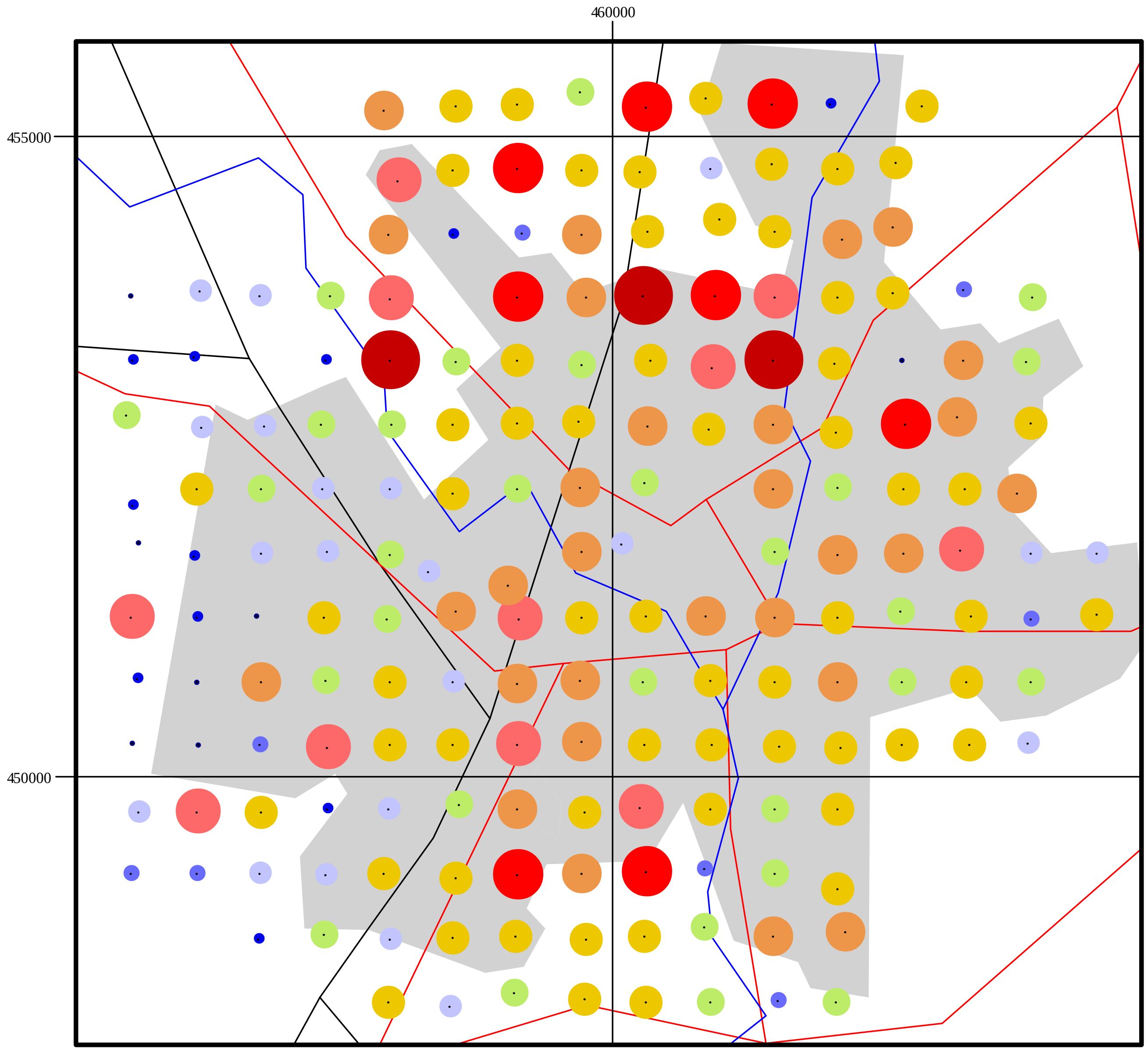


# York
# Surface Soils

## Cobalt

| % ile | ppm |
|---|---|
| 99 | 33 |
| 95 | 25 |
| 90 | 21 |
| 75 | 18 |
| 50 | 15 |
| 25 | 12 |
| 15 | 11 |
| 10 | 10 |
| 5 | 9 |

| surface soil | Co (ppm) |
|---|---|
| number | 191 |
| minimum | 5 |
| maximum | 47 |
| median | 15 |
| mean | 15 |



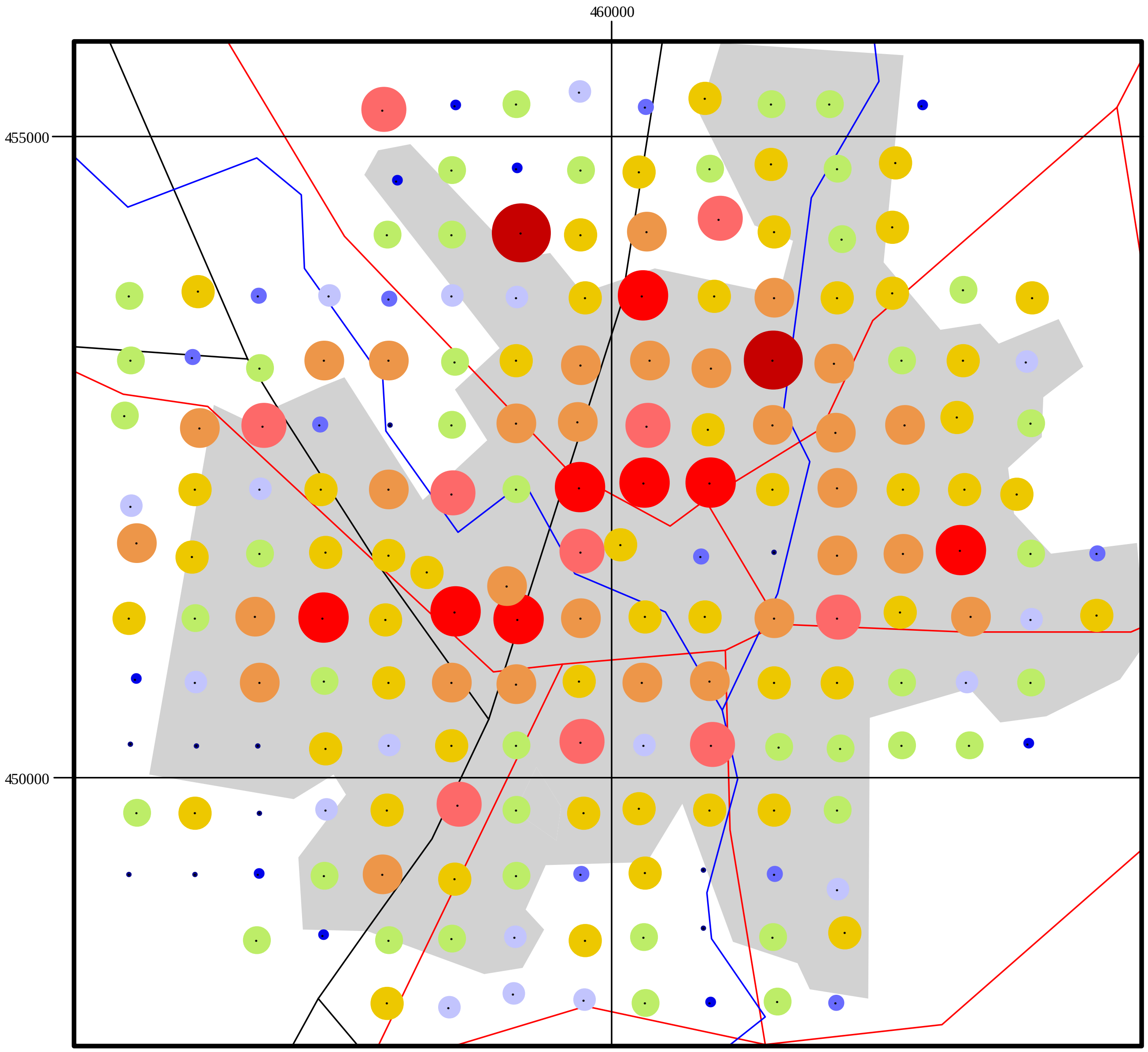
# York
# Profile Soils

## Cobalt

| % ile | ppm |
|---|---|
| 99 | 38 |
| 95 | 27 |
| 90 | 25 |
| 75 | 21 |
| 50 | 17 |
| 25 | 14 |
| 15 | 13 |
| 10 | 12 |
| 5 | 10 |

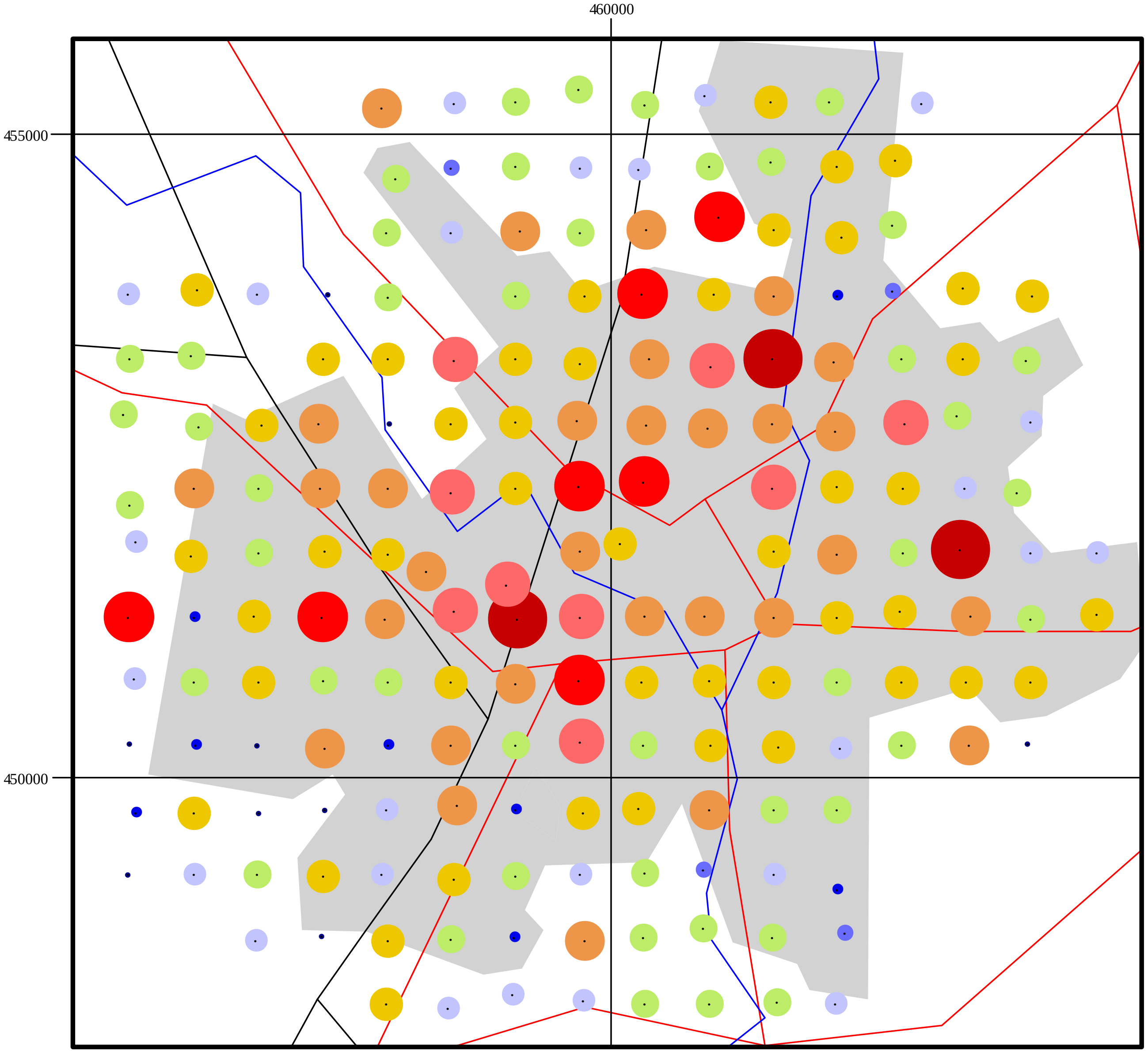
| profile soil | Co (ppm) |
|---|---|
| number | 187 |
| minimum | 7 |
| maximum | 39 |
| median | 17 |
| mean | 18 |

# York
# Surface Soils
# Copper



| % ile | ppm |
|---|---|
| 99 | 127 |
| 95 | 96 |
| 90 | 71 |
| 75 | 43 |
| 50 | 26 |
| 25 | 21 |
| 15 | 18 |
| 10 | 15 |
| 5 | 13 |

| surface soil | Cu (ppm) |
|---|---|
| number | 191 |
| minimum | 6 |
| maximum | 227 |
| median | 26 |
| mean | 37 |

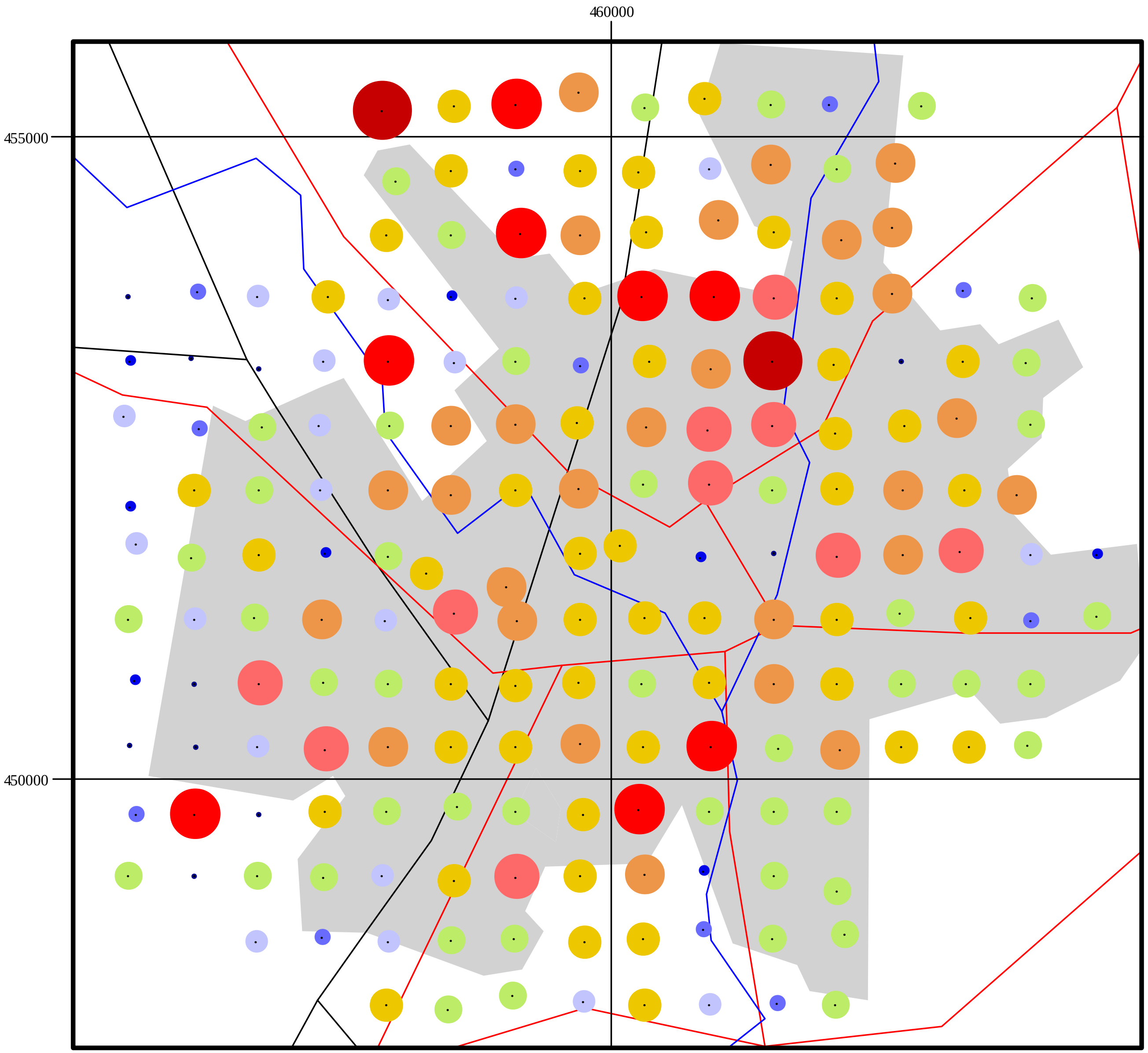


# York
# Profile Soils

## Copper

| % ile | ppm |
|---|---|
| 99 | 167 |
| 95 | 118 |
| 90 | 94 |
| 75 | 44 |
| 50 | 29 |
| 25 | 22 |
| 15 | 18 |
| 10 | 17 |
| 5 | 16 |

| profile soil | Cu (ppm) |
|---|---|
| number | 187 |
| minimum | 8 |
| maximum | 251 |
| median | 29 |
| mean | 41 |

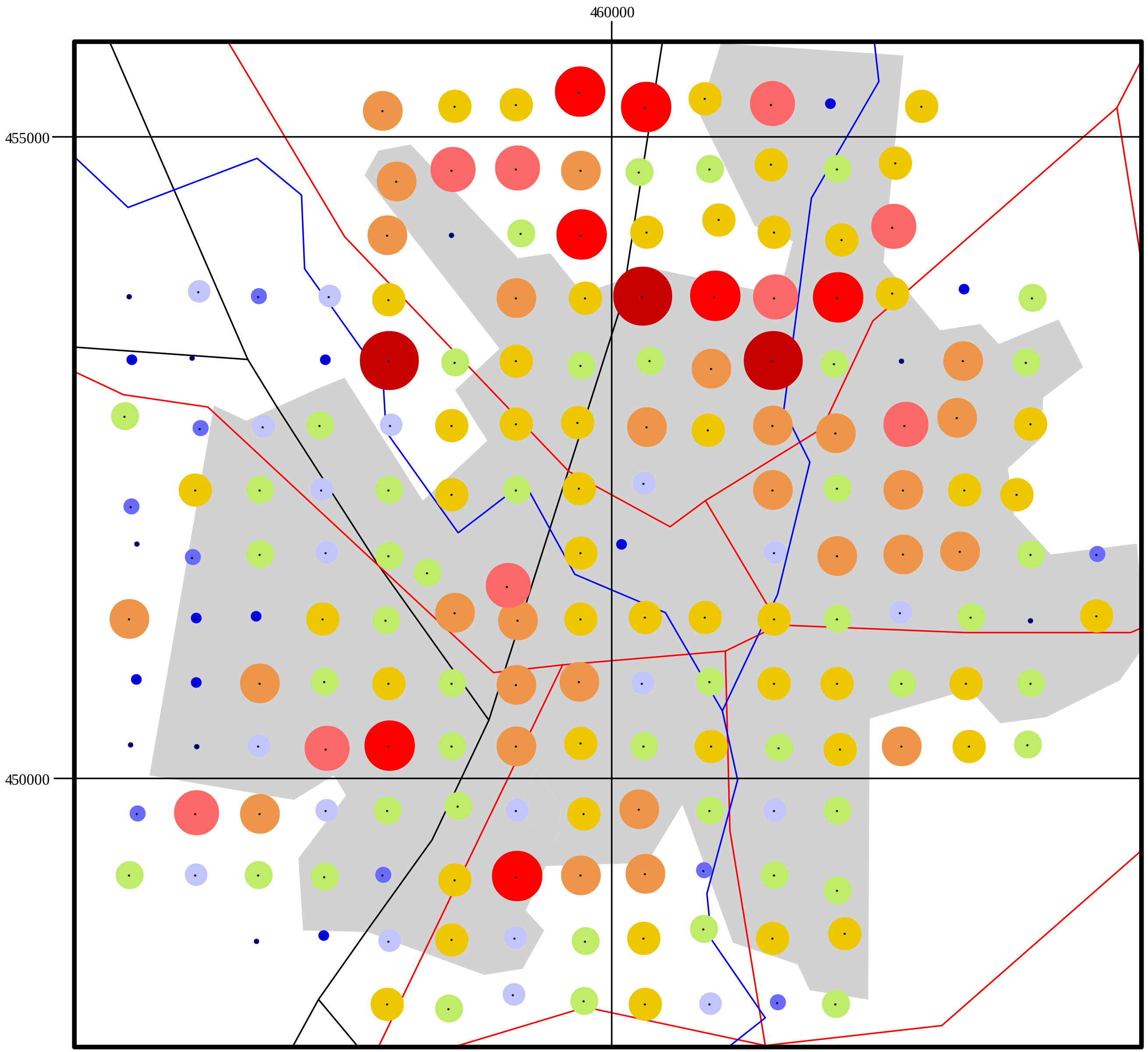


# York
# Surface Soils

## Iron

| % ile | wt % |
|---|---|
| 99 | 8.74 |
| 95 | 5.91 |
| 90 | 4.93 |
| 75 | 4.24 |
| 50 | 3.43 |
| 25 | 2.60 |
| 15 | 2.28 |
| 10 | 2.13 |
| 5 | 1.93 |

| surface soil | $Fe_2O_{3(wt\%)}$ |
|---|---|
| number | 191 |
| minimum | 0.73 |
| maximum | 10.08 |
| median | 3.43 |
| mean | 3.55 |

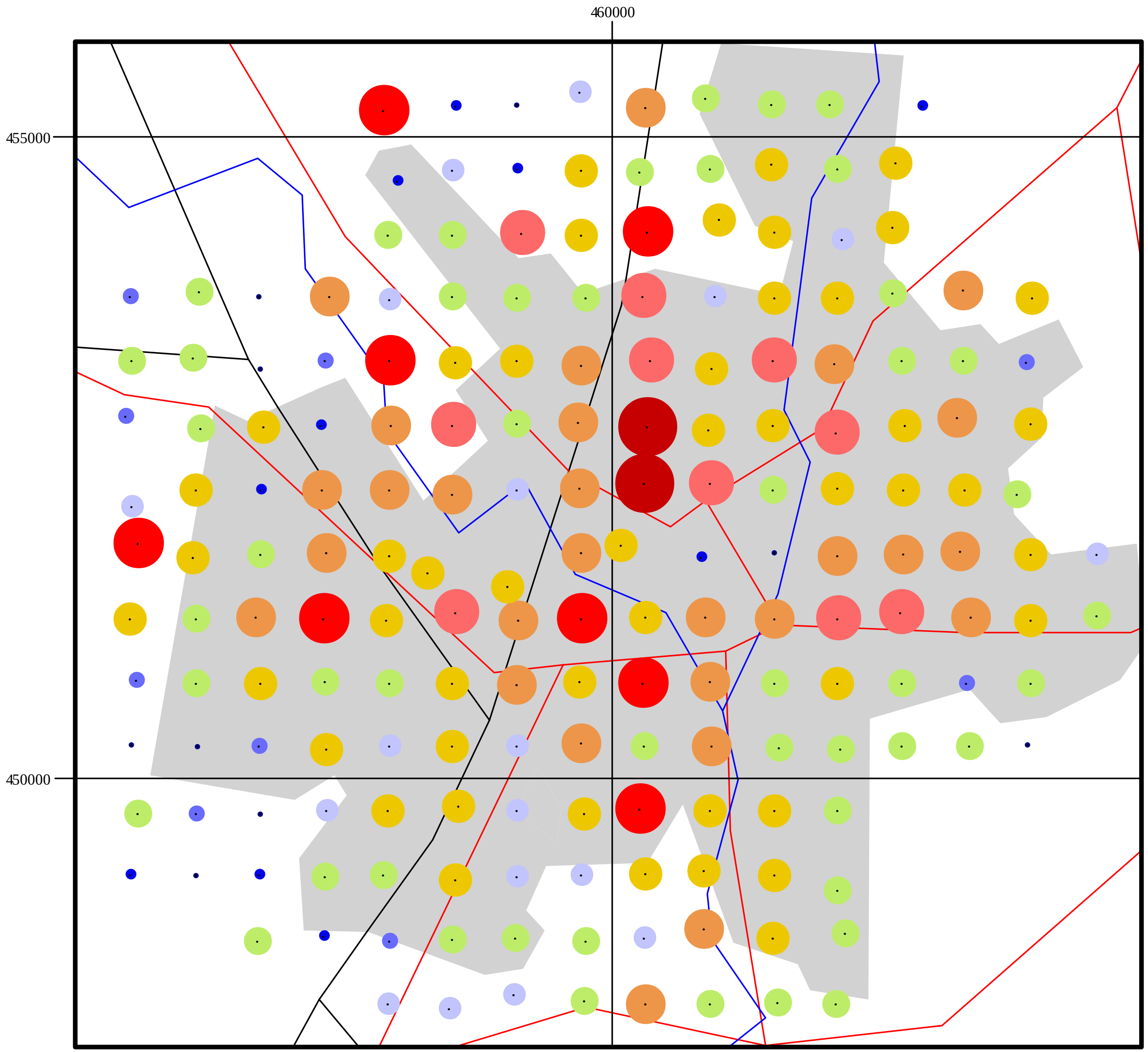


# York
# Profile Soils

# Iron

| % ile | wt % |
|---|---|
| 99 | 8.45 |
| 95 | 6.37 |
| 90 | 5.74 |
| 75 | 4.80 |
| 50 | 4.00 |
| 25 | 3.13 |
| 15 | 2.77 |
| 10 | 2.46 |
| 5 | 2.17 |

| profile soil | $Fe_2O_{3(wt\%)}$ |
|---|---|
| number | 187 |
| minimum | 1.52 |
| maximum | 8.63 |
| median | 4.00 |
| mean | 4.08 |

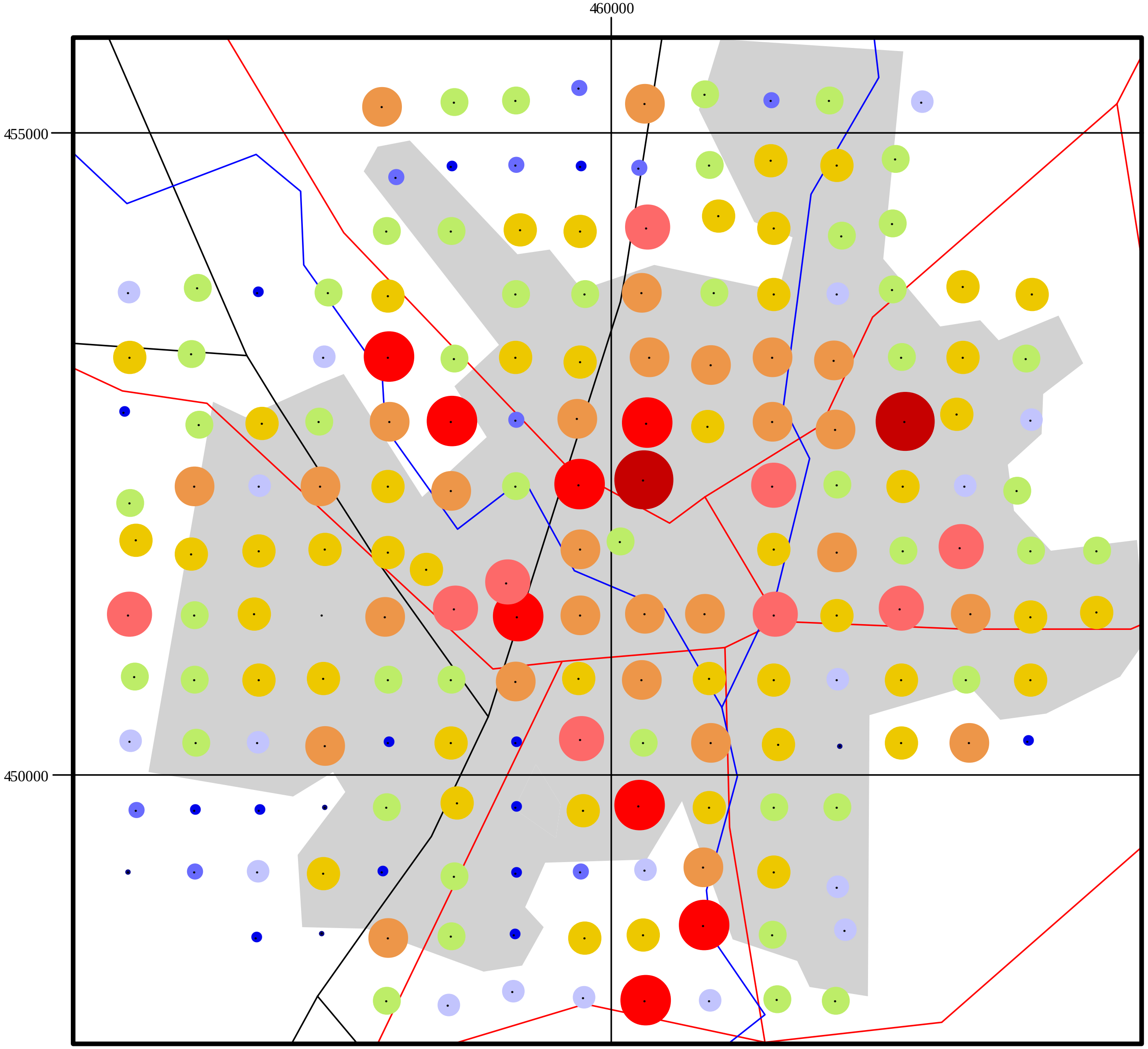


# York
# Surface Soils

## Lead

| % ile | ppm |
|---|---|
| 99 | 1250 |
| 95 | 671 |
| 90 | 510 |
| 75 | 246 |
| 50 | 106 |
| 25 | 69 |
| 15 | 55 |
| 10 | 46 |
| 5 | 38 |

| surface soil | **Pb** (ppm) |
|---|---|
| number | 191 |
| minimum | 24 |
| maximum | 2400 |
| median | 106 |
| mean | 214 |

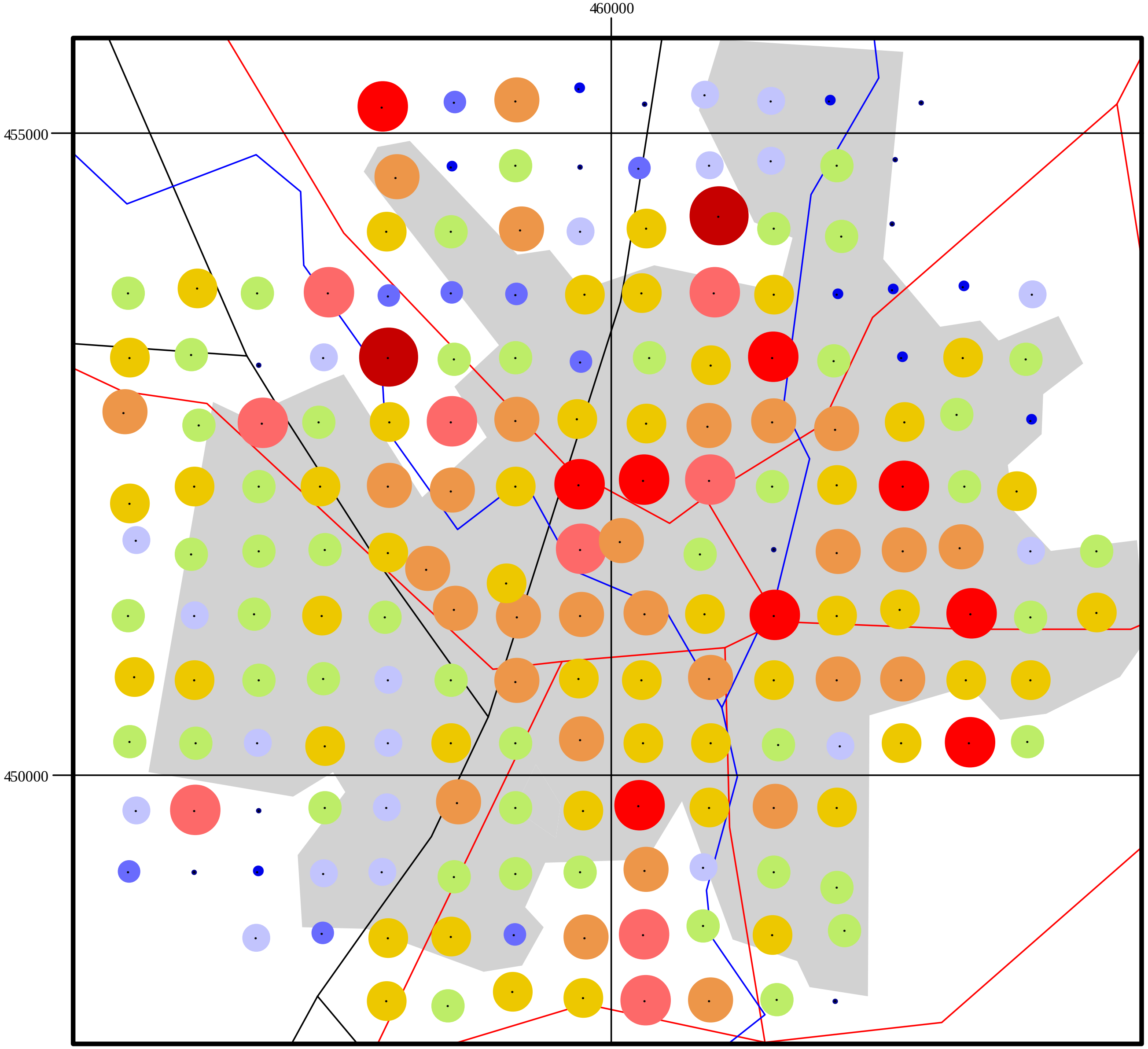


# York
# Profile Soils

## Lead

| % ile | ppm |
|---|---|
| 99 | 1090 |
| 95 | 627 |
| 90 | 425 |
| 75 | 183 |
| 50 | 80 |
| 25 | 49 |
| 15 | 37 |
| 10 | 33 |
| 5 | 28 |

| profile soil | **Pb** (ppm) |
|---|---|
| number | 186 |
| minimum | 17 |
| maximum | 1955 |
| median | 80 |
| mean | 176 |

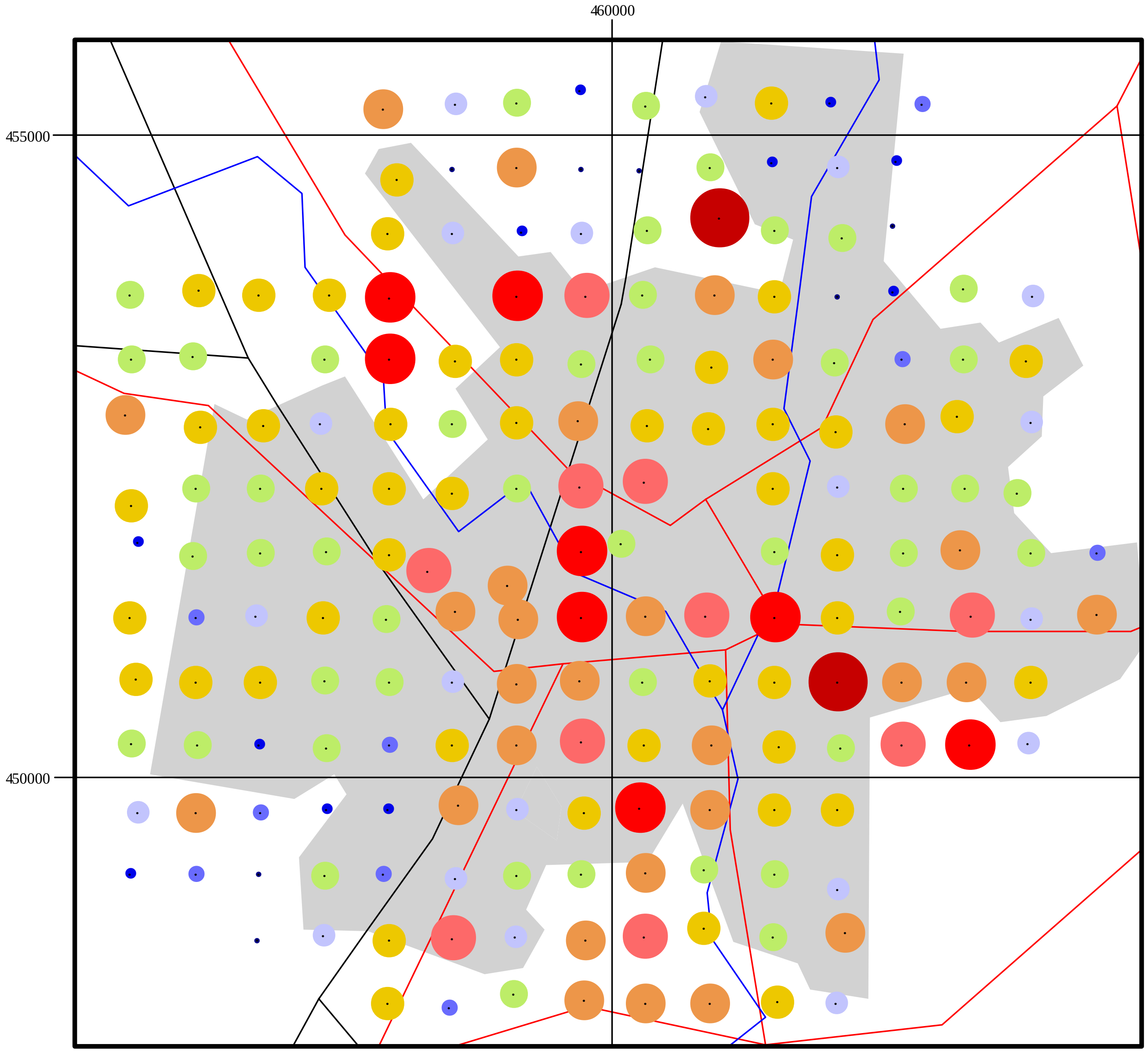


# York
# Surface Soils

## Manganese

| % ile | wt % |
|---|---|
| 99 | 0.178 |
| 95 | 0.127 |
| 90 | 0.111 |
| 75 | 0.091 |
| 50 | 0.072 |
| 25 | 0.056 |
| 15 | 0.050 |
| 10 | 0.047 |
| 5 | 0.039 |

| surface soil | MnO (wt%) |
|---|---|
| number | 191 |
| minimum | 0.026 |
| maximum | 0.208 |
| median | 0.072 |
| mean | 0.076 |

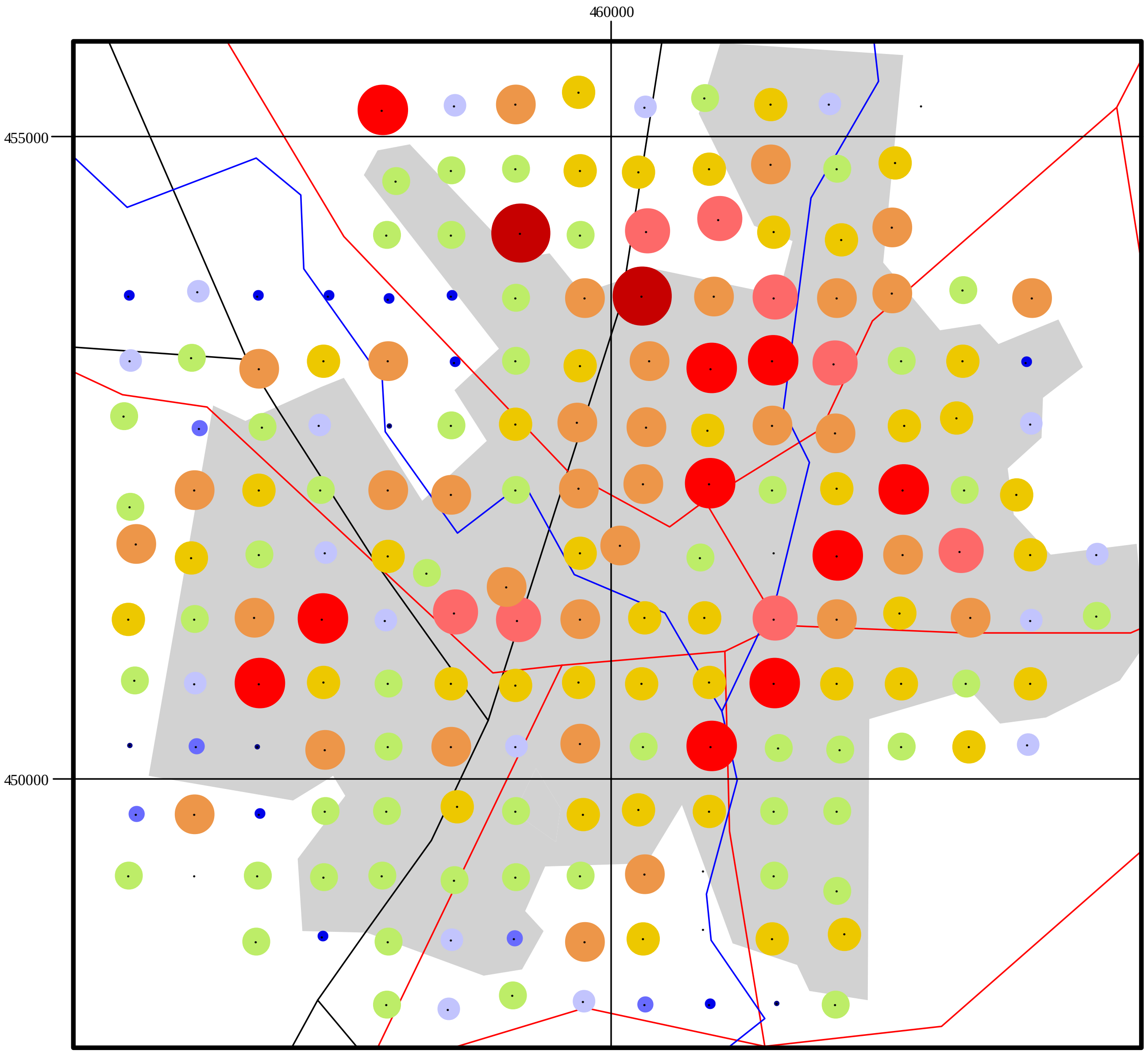


# York
# Profile Soils

# Manganese

| % ile | wt % |
|---|---|
| 99 | 0.279 |
| 95 | 0.156 |
| 90 | 0.121 |
| 75 | 0.095 |
| 50 | 0.073 |
| 25 | 0.044 |
| 15 | 0.029 |
| 10 | 0.025 |
| 5 | 0.016 |

| profile soil | **MnO** (wt%) |
|---|---|
| number | 187 |
| minimum | 0.012 |
| maximum | 0.303 |
| median | 0.073 |
| mean | 0.076 |

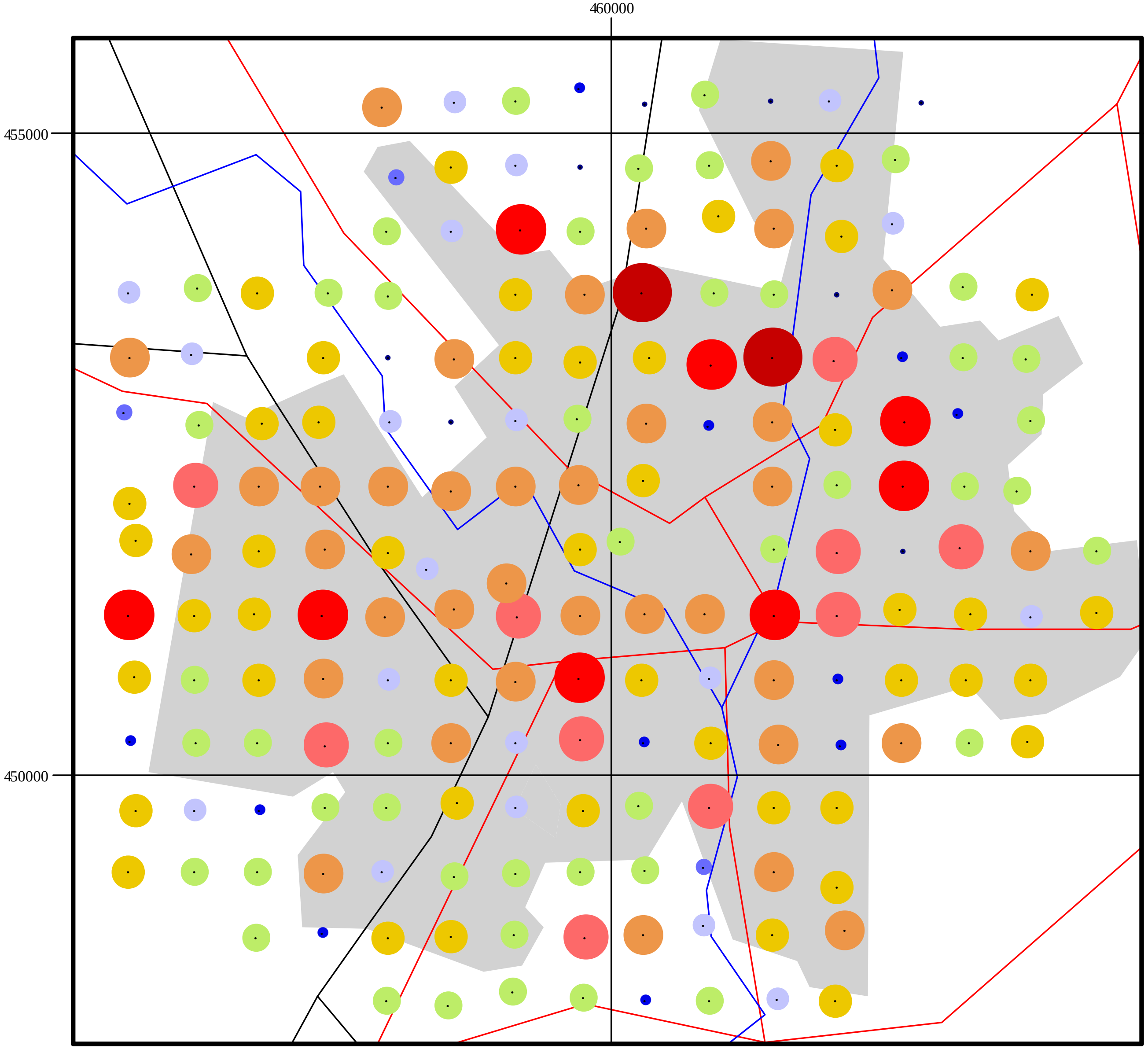


# York
# Surface Soils

# Molybdenum

| % ile | ppm |
|---|---|
| 99 | 10.4 |
| 95 | 3.7 |
| 90 | 2.6 |
| 75 | 1.8 |
| 50 | 1.3 |
| 25 | 0.9 |
| 15 | 0.8 |
| 10 | 0.7 |
| 5 | 0.4 |

| surface soil | **Mo** (ppm) |
|---|---|
| number | 191 |
| minimum | 0.15 |
| maximum | 69.6 |
| median | 1.3 |
| mean | 2.0 |

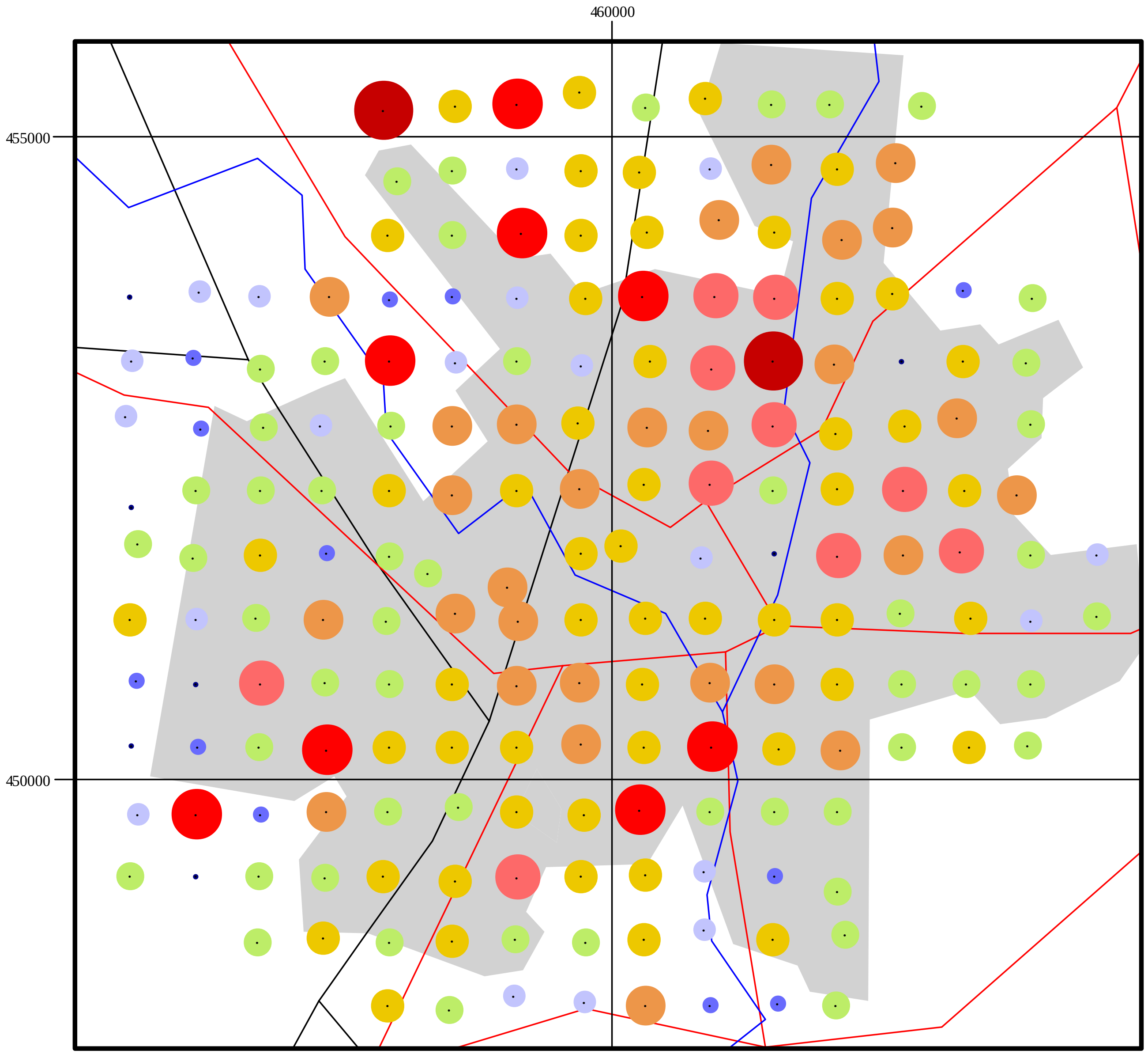


# York
# Profile Soils

# Molybdenum

| % ile | ppm |
|---|---|
| 99 | 5.0 |
| 95 | 3.4 |
| 90 | 2.7 |
| 75 | 1.9 |
| 50 | 1.6 |
| 25 | 1.2 |
| 15 | 1.0 |
| 10 | 0.9 |
| 5 | 0.7 |

| profile soil | **Mo** (ppm) |
|---|---|
| number | 187 |
| minimum | 0.3 |
| maximum | 14.0 |
| median | 1.6 |
| mean | 1.8 |

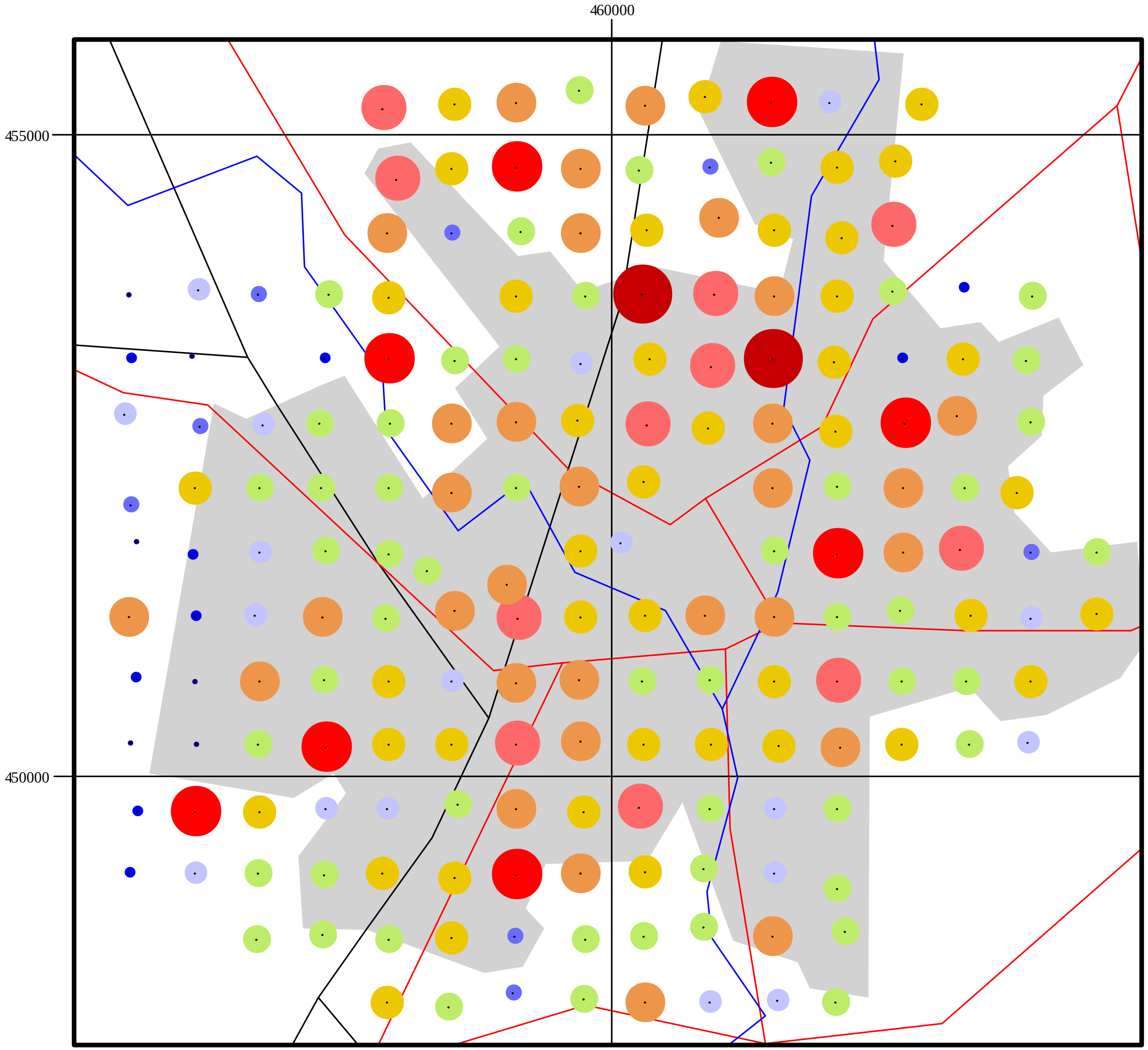


# York
# Surface Soils

# Nickel

| % ile | ppm |
|---|---|
| 99 | 57 |
| 95 | 39 |
| 90 | 30 |
| 75 | 25 |
| 50 | 19 |
| 25 | 14 |
| 15 | 12 |
| 5 | 10 |

| surface soil | Ni (ppm) |
|---|---|
| number | 191 |
| minimum | 6 |
| maximum | 84 |
| median | 19 |
| mean | 21 |



# York
# Profile Soils

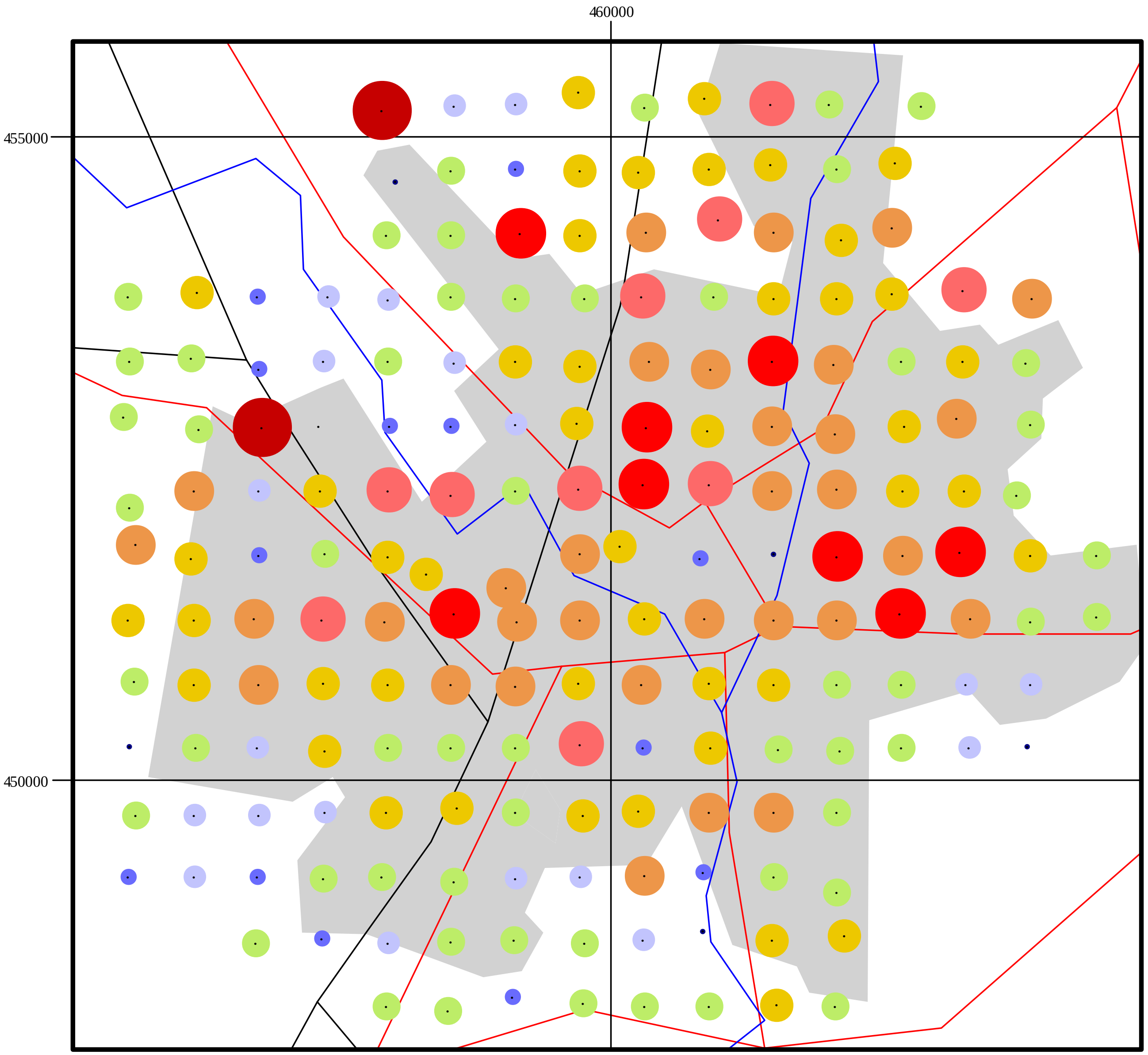
# Nickel

| % ile | ppm |
|---|---|
| 99 | 52 |
| 95 | 42 |
| 90 | 38 |
| 75 | 29 |
| 50 | 24 |
| 25 | 17 |
| 15 | 14 |
| 10 | 13 |
| 5 | 11 |

| profile soil | Ni (ppm) |
|---|---|
| number | 187 |
| minimum | 8 |
| maximum | 84 |
| median | 24 |
| mean | 24 |

# York
# Surface Soils

# Tin

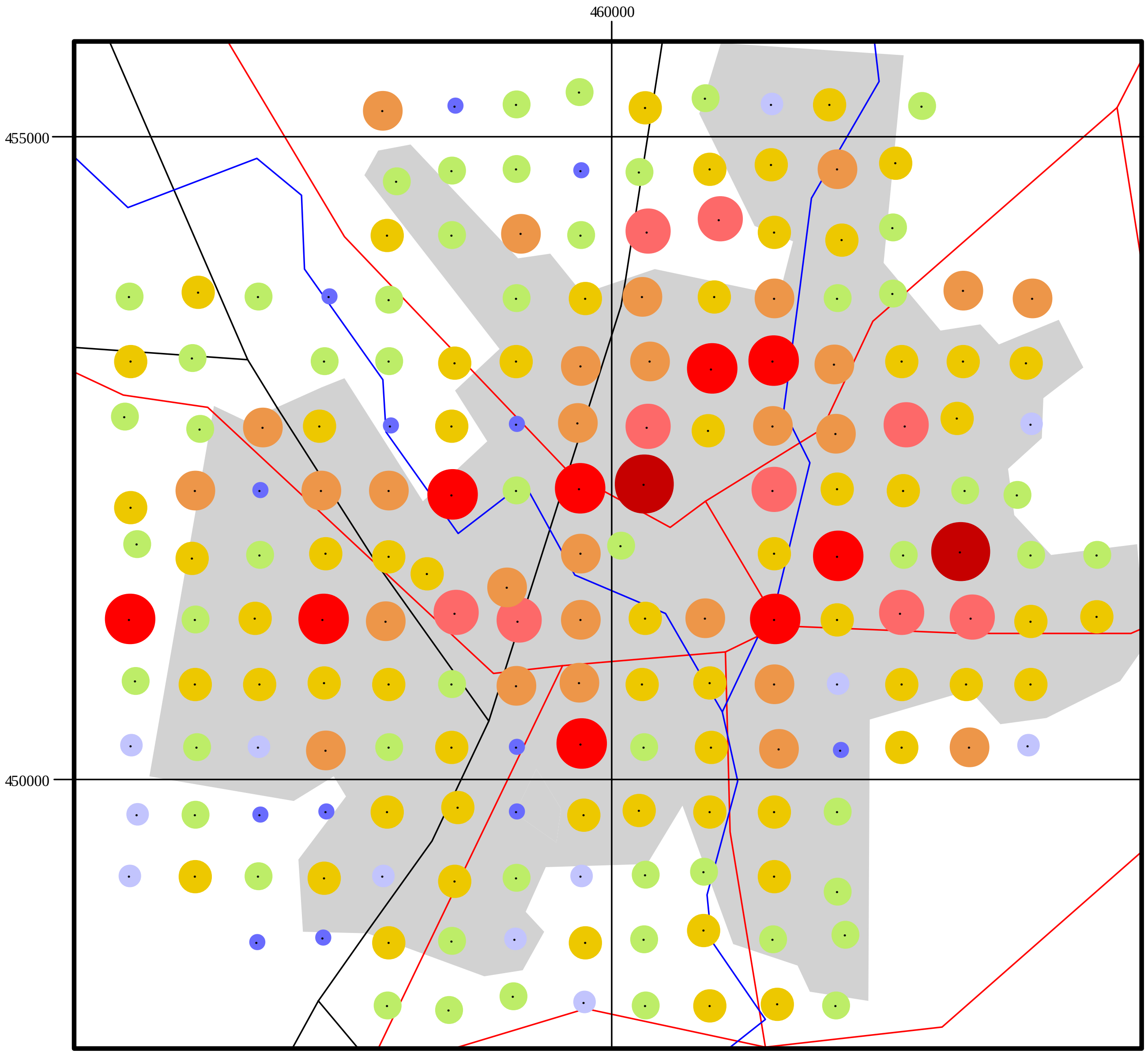


| % ile | | ppm |
|---|---|---|
| | ● | |
| 99 | | 83 |
| | ● | |
| 95 | | 42 |
| | ● | |
| 90 | | 25 |
| | ● | |
| 75 | | 13 |
| | ● | |
| 50 | | 8 |
| | ● | |
| 25 | | 5 |
| | ● | |
| 15 | | 4 |
| | ● | |
| 5 | | 3 |
| | • | |

| surface soil | **Sn** (ppm) |
|---|---|
| number | 191 |
| minimum | 1 |
| maximum | 253 |
| median | 8 |
| mean | 14 |

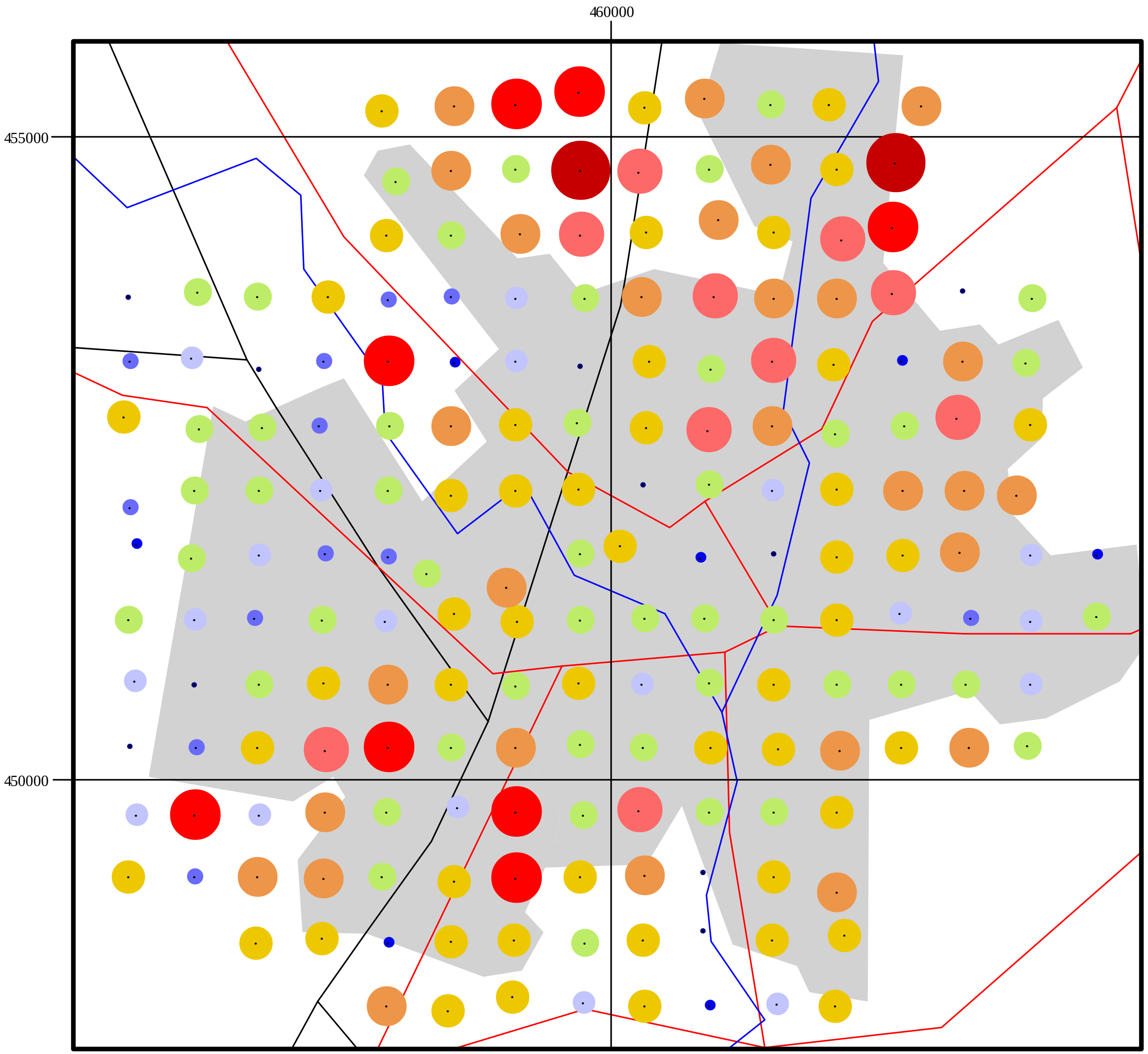
# York
# Profile Soils

## Tin



| % ile | ppm |
|---|---|
| 99 | 67.1 |
| 95 | 32.0 |
| 90 | 26.0 |
| 75 | 11.0 |
| 50 | 6.0 |
| 25 | 4.0 |
| 10 | 3.0 |
| 5 | 2.0 |

| profile soil | Sn (ppm) |
|---|---|
| number | 187 |
| minimum | 2 |
| maximum | 85 |
| median | 6 |
| mean | 10 |



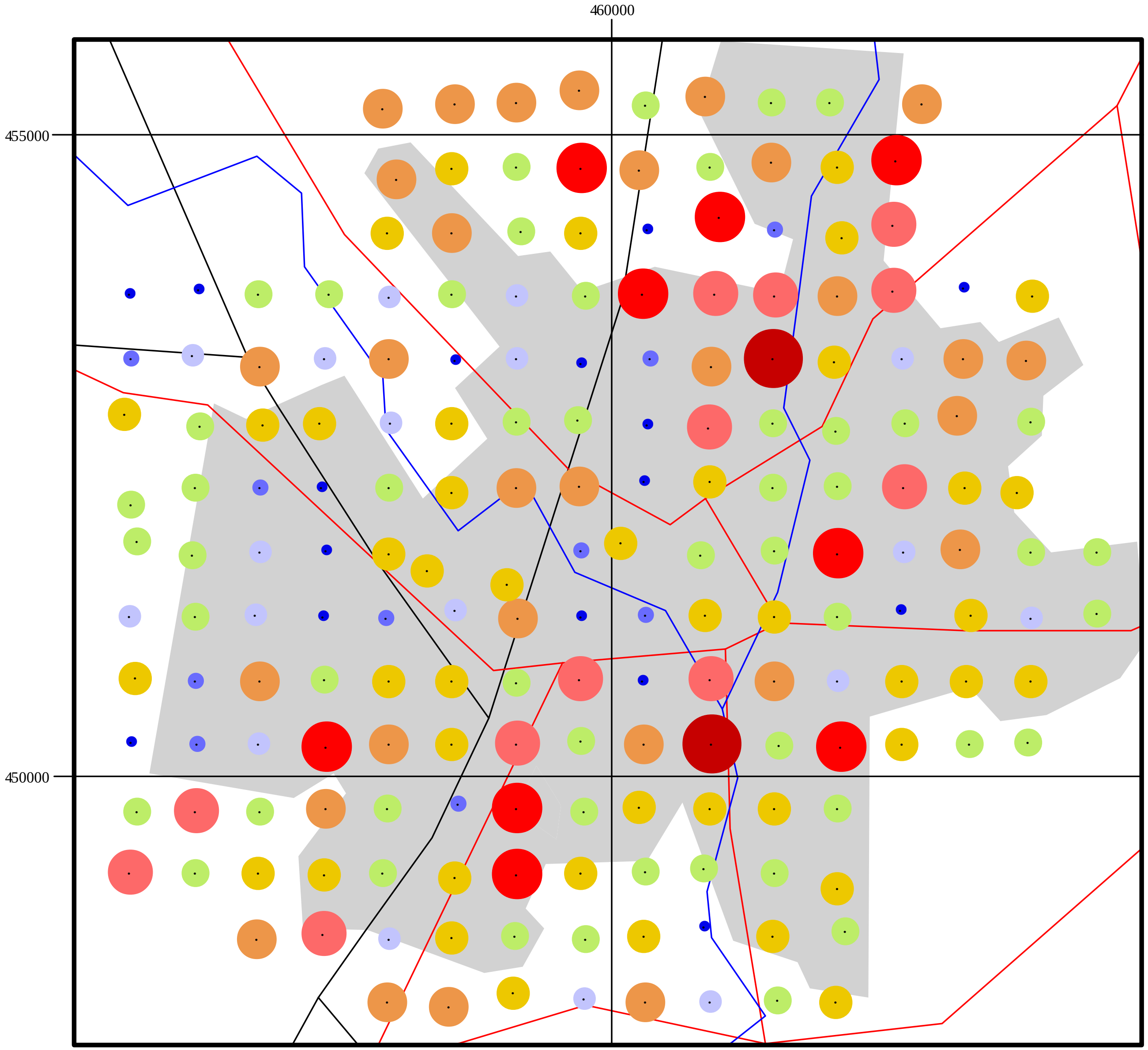
# York
# Surface Soils

# Titanium

| % ile | wt % |
|---|---|
| 99 | 0.837 |
| 95 | 0.717 |
| 90 | 0.651 |
| 75 | 0.516 |
| 50 | 0.424 |
| 25 | 0.352 |
| 15 | 0.320 |
| 10 | 0.293 |
| 5 | 0.270 |

| surface soil | $TiO_{2 (wt\%)}$ |
|---|---|
| number | 191 |
| minimum | 0.102 |
| maximum | 0.910 |
| median | 0.424 |
| mean | 0.449 |

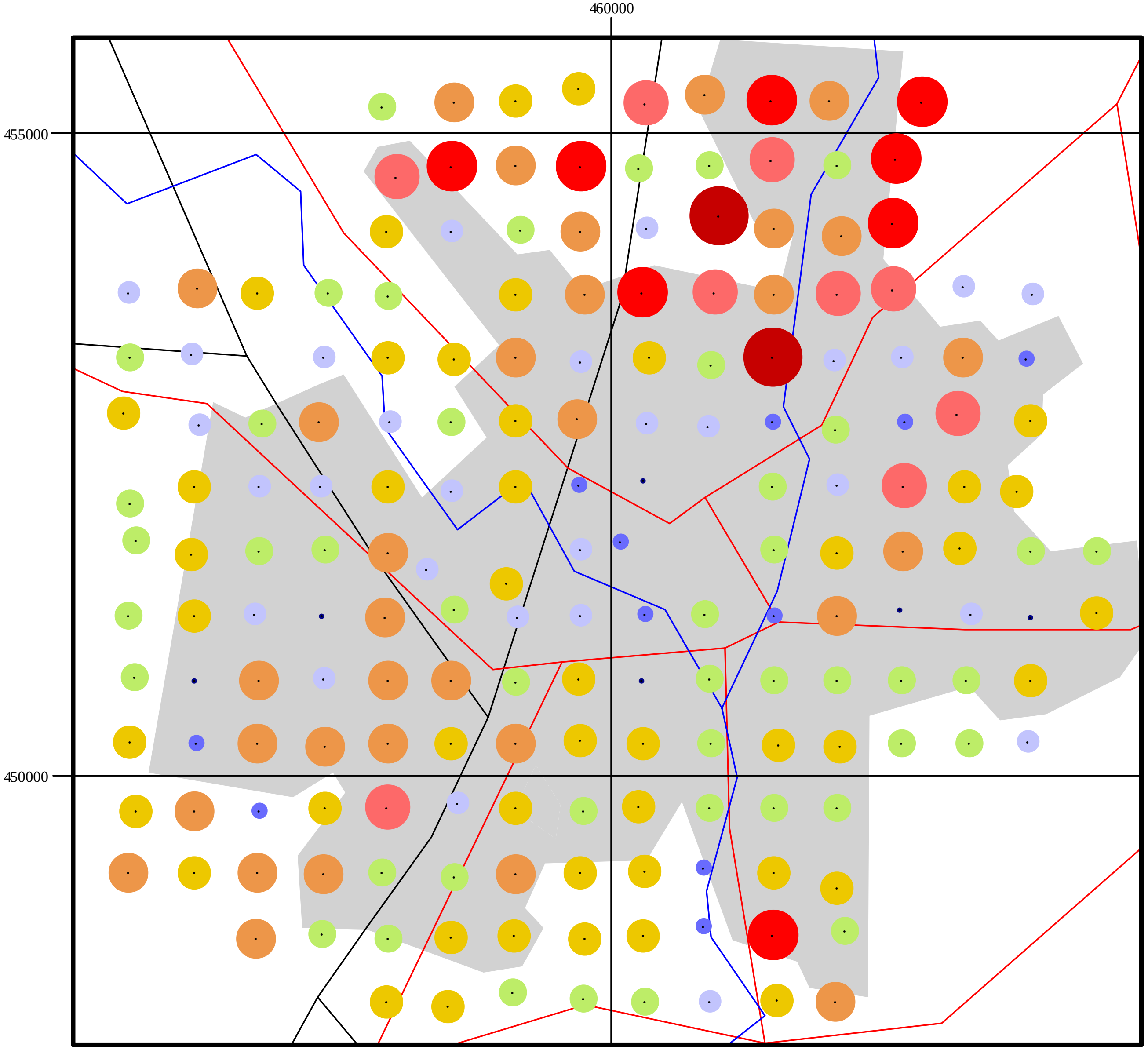
**Titanium oxide has not been determined in the profile soils**



# York
# Surface Soils
# Uranium

| % ile | ppm |
|---|---|
| 99 | 3.14 |
| 95 | 2.20 |
| 90 | 1.70 |
| 75 | 1.40 |
| 50 | 1.10 |
| 25 | 0.80 |
| 15 | 0.60 |
| 10 | 0.50 |
| 5 | 0.25 |

| surface soil | U (ppm) |
|---|---|
| number | 191 |
| minimum | 0.25 |
| maximum | 3.70 |
| median | 1.10 |
| mean | 1.13 |



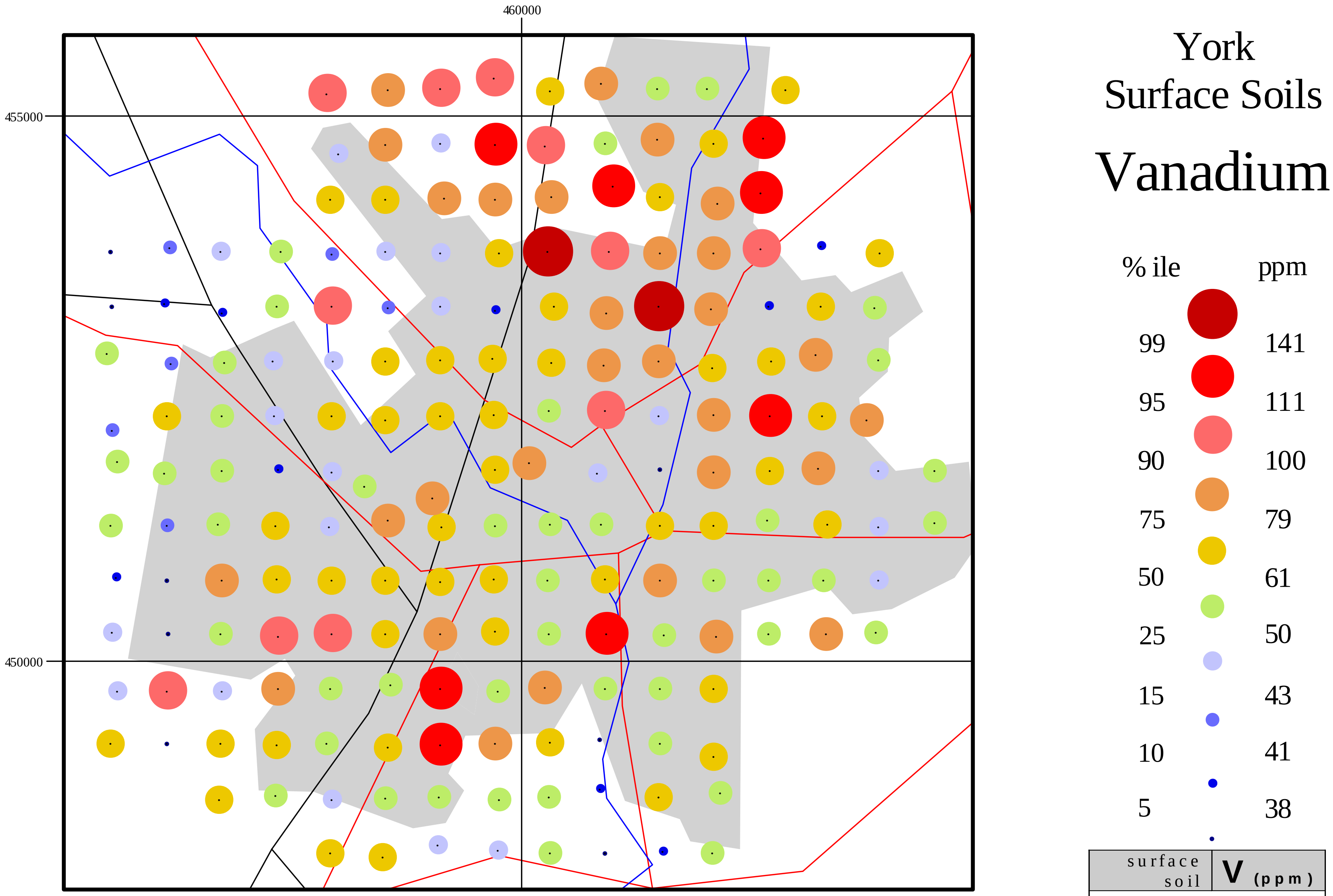
# York
# Profile Soils

# Uranium

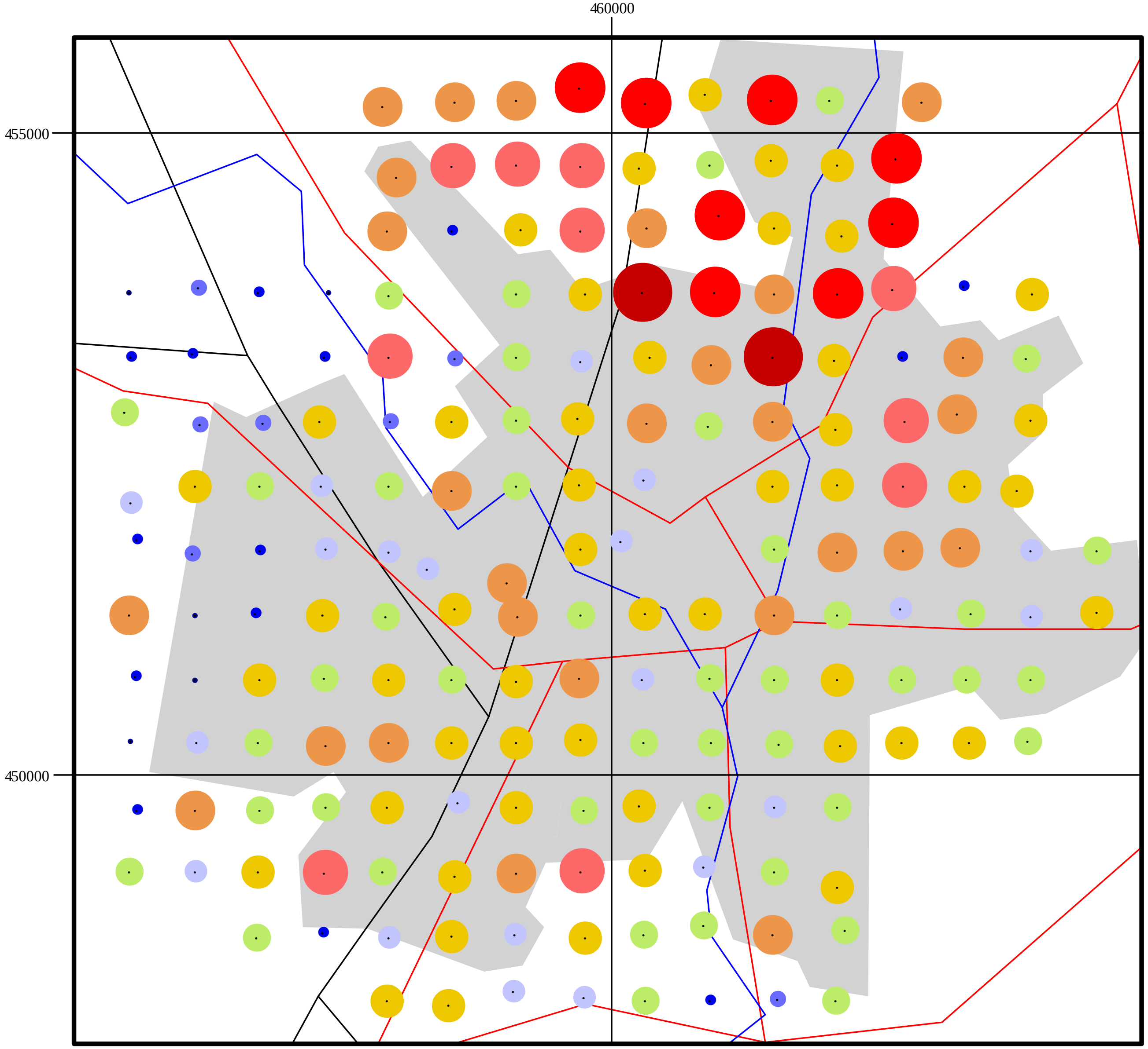
| % ile | ppm |
|---|---|
| | ● |
| 99 | 3.64 |
| | ● |
| 95 | 2.77 |
| | ● |
| 90 | 2.44 |
| | ● |
| 75 | 2.20 |
| | ● |
| 50 | 1.90 |
| | ● |
| 25 | 1.60 |
| | ● |
| 15 | 1.30 |
| | ● |
| 5 | 1.10 |
| | • |

| profile soil | U (ppm) |
|---|---|
| number | 187 |
| minimum | 0.25 |
| maximum | 4.30 |
| median | 1.90 |
| mean | 1.88 |

# York
# Surface Soils
# Vanadium



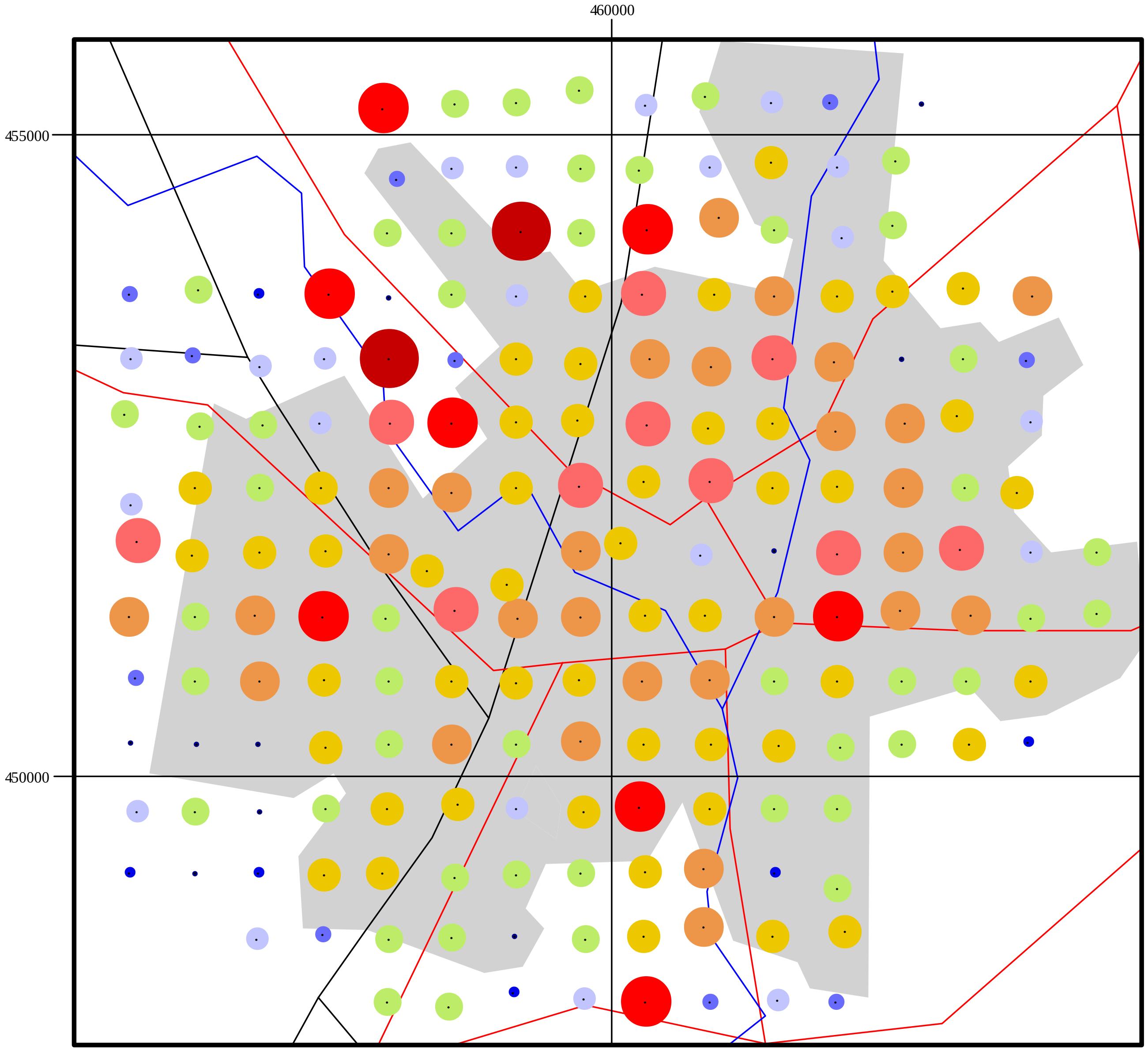
| surface soil | V (ppm) |
|---|---|
| number | 191 |
| minimum | 29 |
| maximum | 230 |
| median | 61 |
| mean | 67 |



# York
# Profile Soils
## Vanadium

| % ile | ppm |
|---|---|
| 99 | 134 |
| 95 | 109 |
| 90 | 101 |
| 75 | 85 |
| 50 | 67 |
| 25 | 53 |
| 15 | 47 |
| 10 | 45 |
| 5 | 39 |

| profile soil | **V** (ppm) |
|---|---|
| number | 187 |
| minimum | 34 |
| maximum | 190 |
| median | 67 |
| mean | 71 |

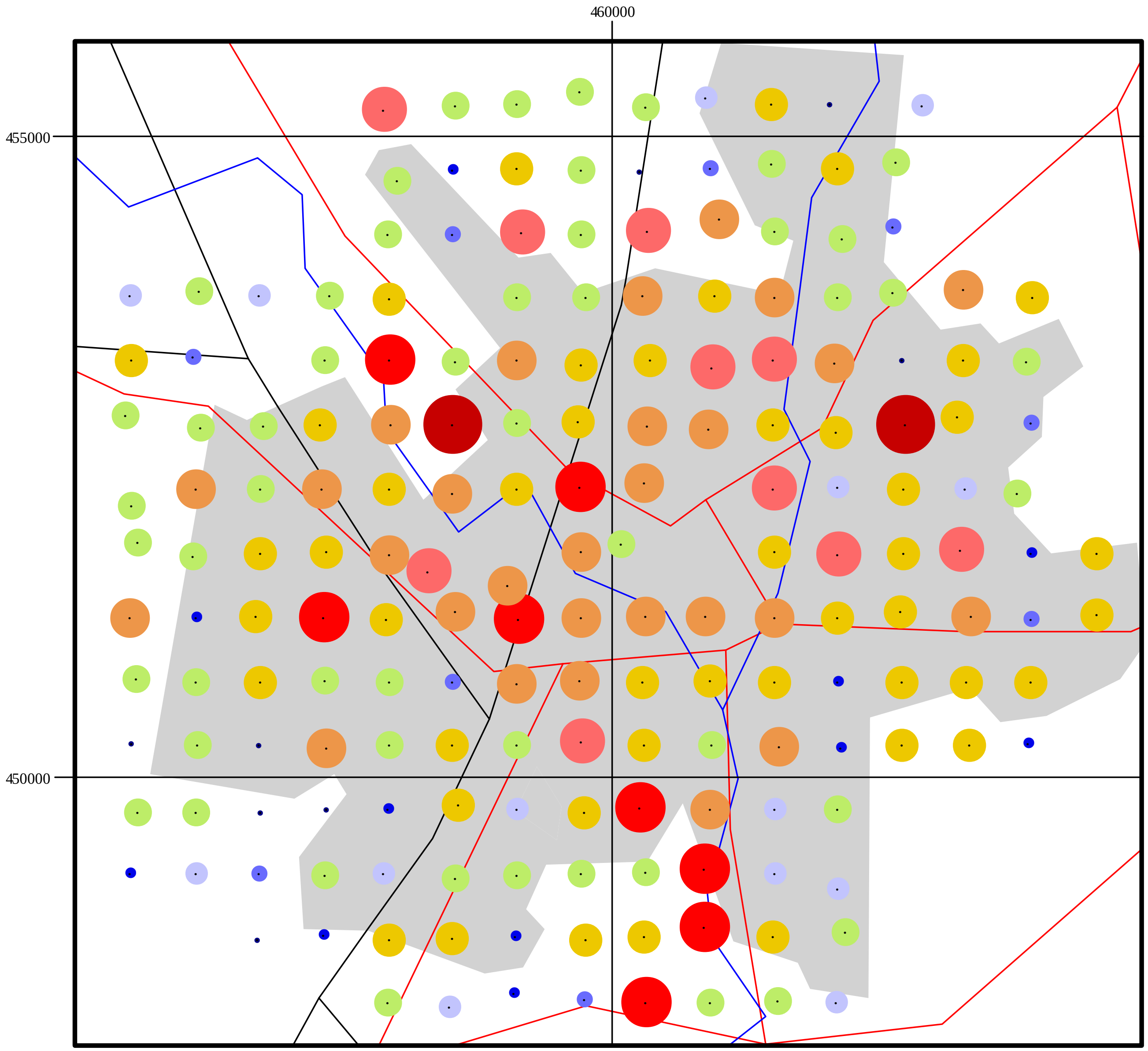


# York
# Surface Soils

# Zinc

| % ile | ppm |
|---|---|
| 99 | 682 |
| 95 | 365 |
| 90 | 262 |
| 75 | 144 |
| 50 | 81 |
| 25 | 58 |
| 15 | 50 |
| 10 | 44 |
| 5 | 40 |

| surface soil | **Zn** (ppm) |
|---|---|
| number | 191 |
| minimum | 24 |
| maximum | 898 |
| median | 81 |
| mean | 129 |



# York
# Profile Soils

## Zinc

| % ile | ppm |
|---|---|
| 99 | 622 |
| 95 | 357 |
| 90 | 230 |
| 75 | 126 |
| 50 | 76 |
| 25 | 57 |
| 15 | 52 |
| 10 | 46 |
| 5 | 39 |

| profile soil | **Zn** (ppm) |
|---|---|
| number | 187 |
| minimum | 26 |
| maximum | 1100 |
| median | 76 |
| mean | 119 |