



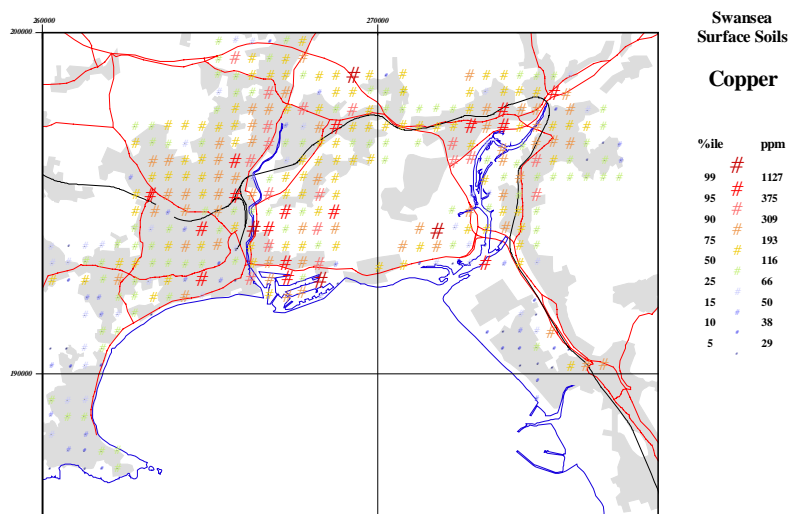
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# Geochemical baseline data for the urban area of Swansea

Integrated Geoscience Surveys (South) Programme

Internal Report IR/01/36R





BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/01/36R

# Geochemical baseline data for the urban area of Swansea

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# Foreword

This report is a published product of a study by the British Geological Survey's (BGS) Geochemical Baseline Survey of the Environment (G-BASE). G-BASE is funded by the Office of Science and Technology. It contains a brief interpretation of geochemical data collected in the Swansea urban area and displays the data as a series of proportional symbol maps.

A number of urban centres have been surveyed using the same sampling procedures, and, in due course reports in the same format will be released for the following cities: Cardiff, Telford, Kingston-upon-Hull, York, Scunthorpe, Sheffield, Doncaster, Mansfield, Lincoln, Derby, Nottingham, Peterborough, Corby, Leicester, Coventry, Northampton and Glasgow.

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# Summary

This report describes and interprets the results of a systematic urban geochemical baseline survey carried out in the Swansea, Neath and Port Talbot area.

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

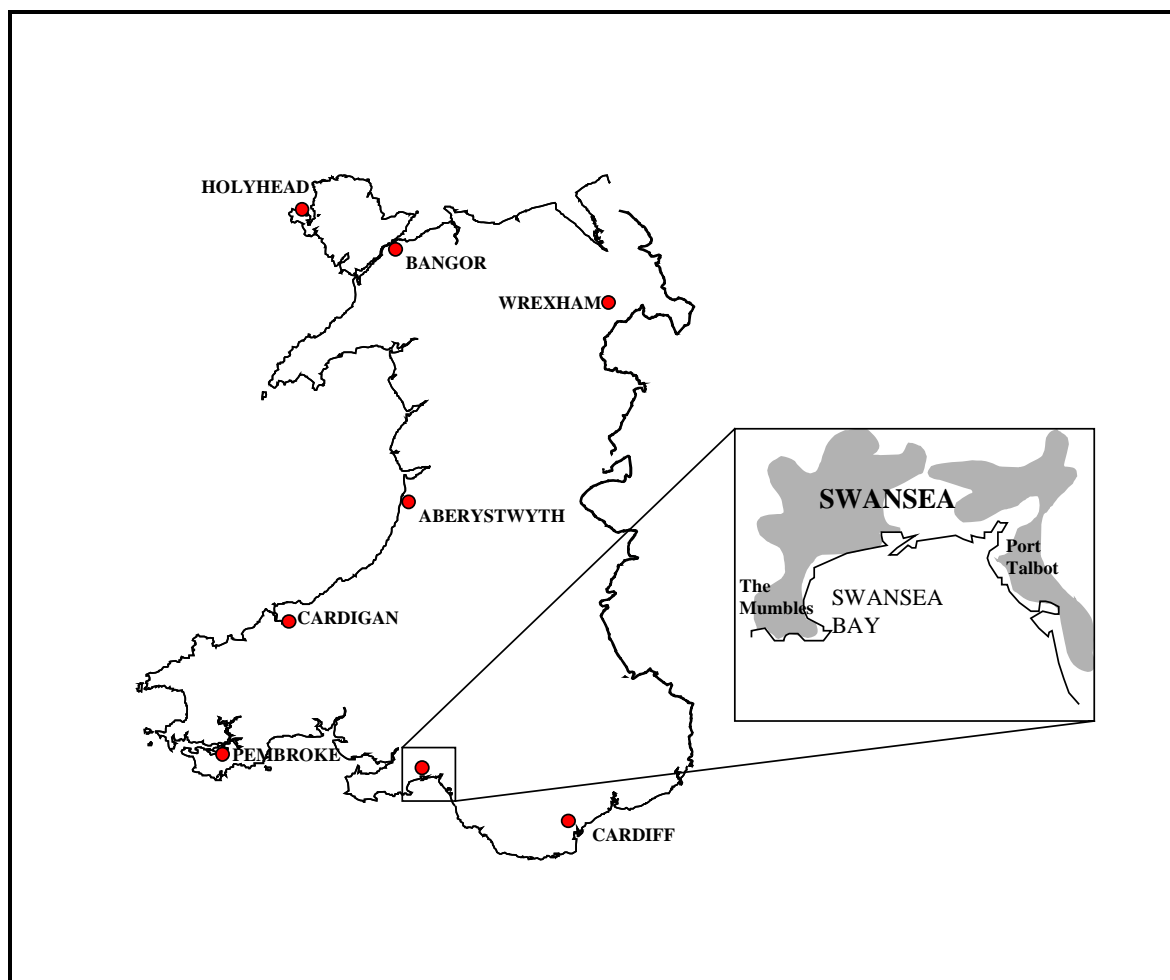
Soil samples were taken at a density of four per square kilometre. Sampling was carried out on the least disturbed area of unbuilt ground such as, domestic gardens, allotments, parks or (in the worst instance) road verges or made ground.

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

# 1 Introduction

This report summarises the results and methodology of a soil geochemical survey of the urban area of Swansea, undertaken by the British Geological Survey as part of the Geochemical Baseline Survey of the Environment Programme (G-BASE), which is funded by the Office of Science and Technology.

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 environmental baselines 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. During the course of the systematic regional survey of the UK, more detailed soil surveys are undertaken over selected urban areas, including that of Swansea (Figure 1)



**Figure 1** Location map for Swansea

Swansea is a port situated on the southern outcrop of the South Wales coalfield which has had a varied industrial history, related to coal mining, steel production, associated metal processing (especially tin, copper and nickel smelting) and chemical manufacture.

The distributions of trace metals in the surface environment of Swansea 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

Coal has played a major part in the industrial development of Swansea, having been mined within the region from both the Upper and Lower Coal Measures (Balchin, 1971). Consequently there is a legacy of coal spoil and coal combustion waste, including fly ash, which is likely to have a strong influence on the surface geochemistry of the region.

In the 19th Century the industry of the Swansea area was almost entirely based on metal manufacture, which in turn was based on the primary coal industry and good port facilities. Activities included the smelting of non-ferrous metals such as lead, copper, tin and zinc, and the manufacture of iron and steel. Other metal processing was also carried out and the area was an important centre for tinplating.

By the 20th Century copper was no longer smelted, although zinc and lead were still being produced in the 1970's and metal manufacture continues to be important up until the present day. Developments in the metal manufacturing industries in the early 20th Century led to the production of nickel, aluminium, titanium and other metals used in modern processes and fabrication. Steel production remained one of the primary industries in the Swansea and Port Talbot area throughout much of this period. These activities are likely to have resulted in the distribution of metal processing waste throughout the area, and, in the atmospheric deposition of metallic dusts in the region as a whole.

In the early 19th century Swansea was the principle port of Wales, but today it is the 3rd largest of the principality. It is the terminal for the main ferry route to Cork in Ireland, and also has a large container facility. Past and present activities in the port area have included oil, fuel and chemical processing and the manufacture of plastic, textiles and toiletries (City and County of Swansea, 1999).

### 2.2 AREA SAMPLED

An area of 93km<sup>2</sup> was surveyed during the summer of 1994, in which a total of 373 sites were sampled. This extends from grid references 260000m east to 280000m east and from 185000m north to 200000m north, and includes Swansea, Neath and Port Talbot and The Mumbles area of the Gower Peninsula. The survey area is shown in Figure 2 and Figure 3. The central area of Swansea was not sampled, as this is Crymlyn Bog nature reserve and therefore wasn't considered an urban area. Part of the Port Talbot area was not sampled due to access restrictions.

### 2.3 SOLID AND DRIFT GEOLOGY

Geological information for the Swansea area was obtained from the BGS 1:50 000 series map for the area (British Geological Survey, 1978). The area sampled is entirely underlain by the sedimentary rocks of the Carboniferous period. It is dominated by the Coal Measures sequence of the South Wales Coalfield. The succession generally increases in age towards the south, with the only pre-Coal Measures strata occurring around The Mumbles in the extreme south-west of the study area. Here Carboniferous Limestone around Mumbles is overlain by Millstone Grit

facies in the Black Pill area. The drift and solid geology can be seen on Figure 4 and Figure 5 respectively.

Approximately 60% of Swansea is covered by Quaternary deposits. These are predominantly glacial, glaciofluvial and tidal flats with peat deposits to the centre and north of the Swansea urban conurbation. The drift underlying the Tawe Valley consists of alluvium deposits, whereas the River Neath to the east of Swansea is underlain by tidal flat deposits. Both rivers lead out to large beach and tidal flat deposit, which run around the Swansea Bay.

Figure 2 Map of sampling area

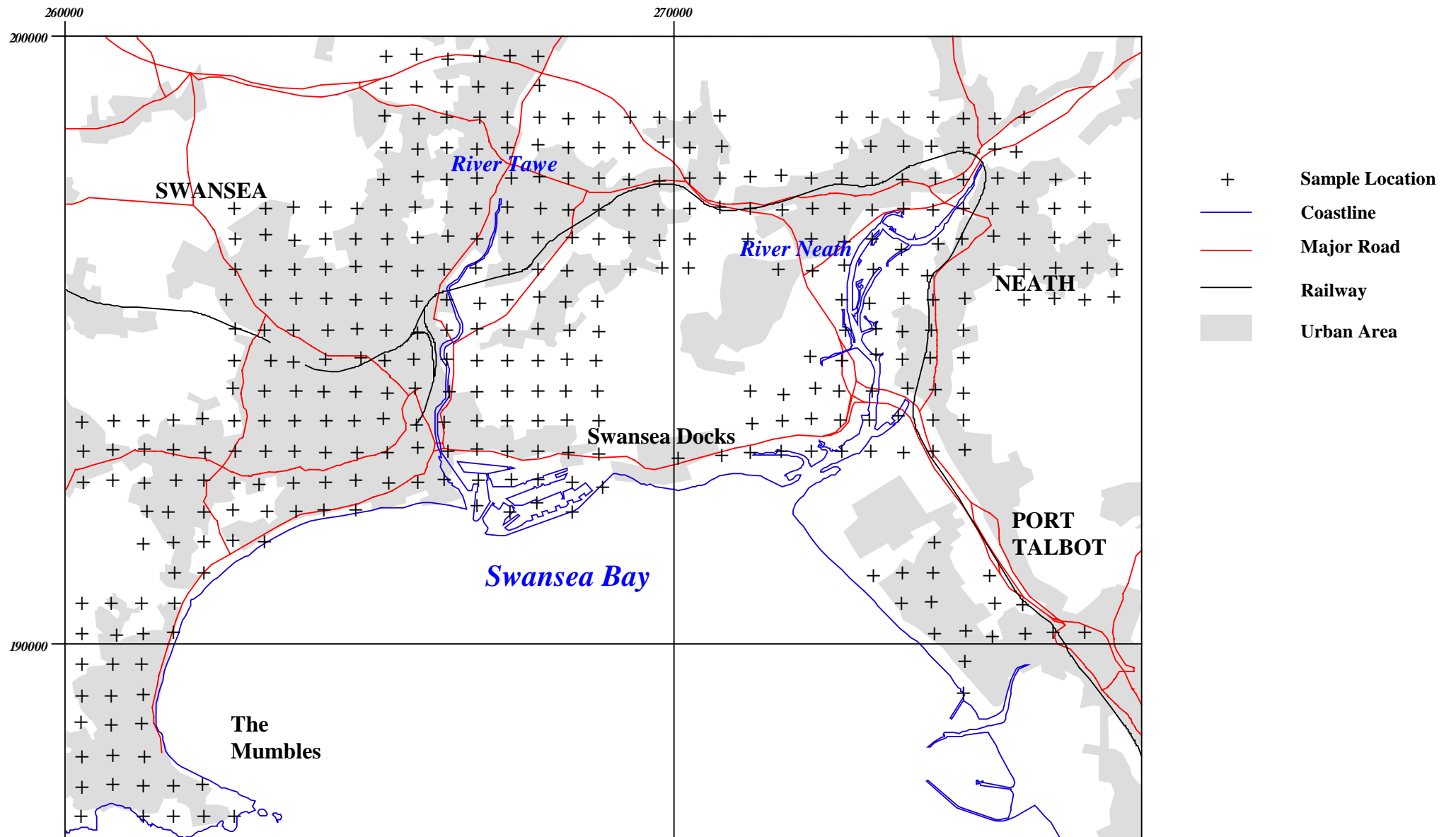




Figure 3 Topographical map of sampling area

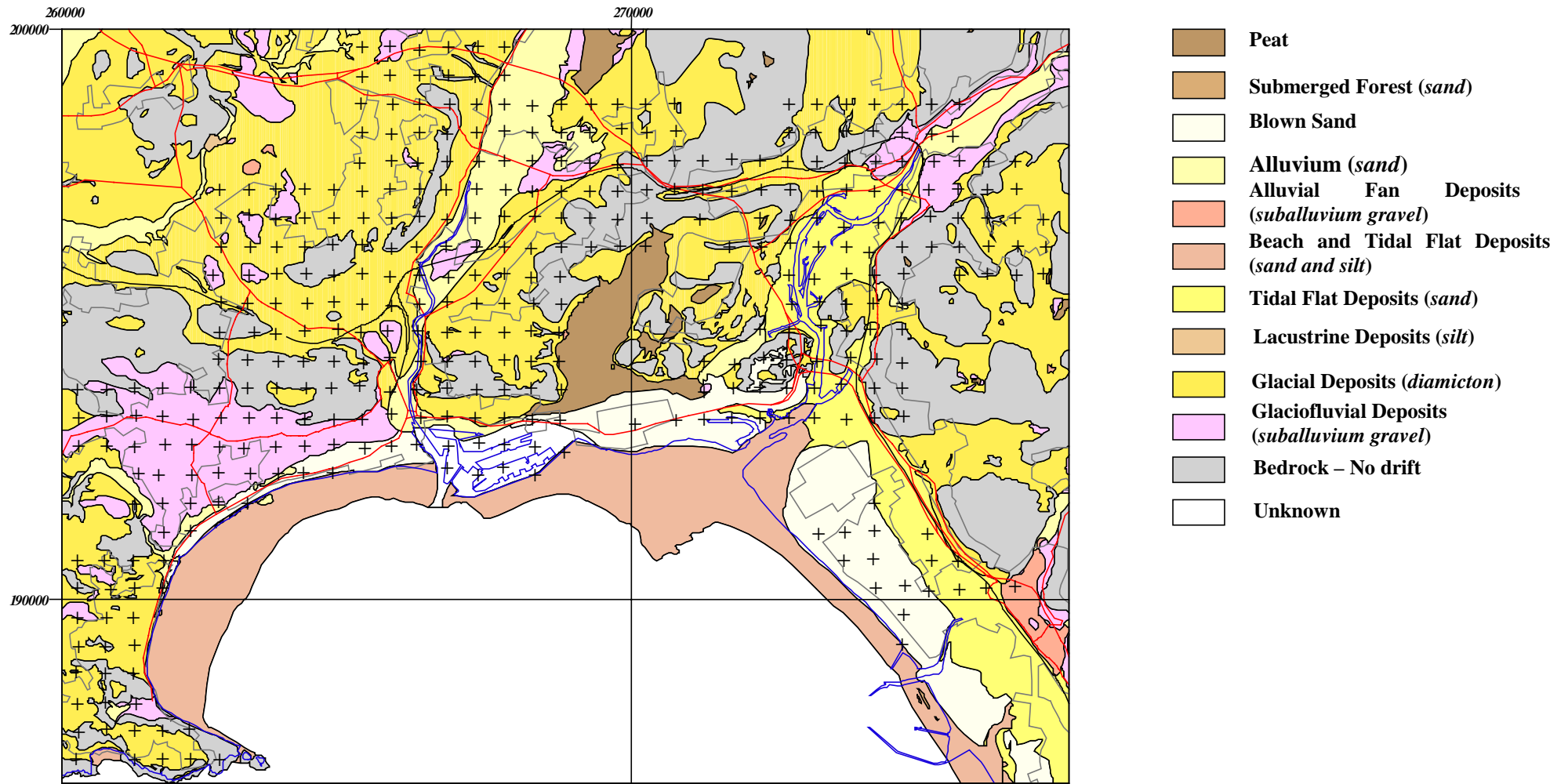


Figure 4 Drift cover of Swansea and surrounding area

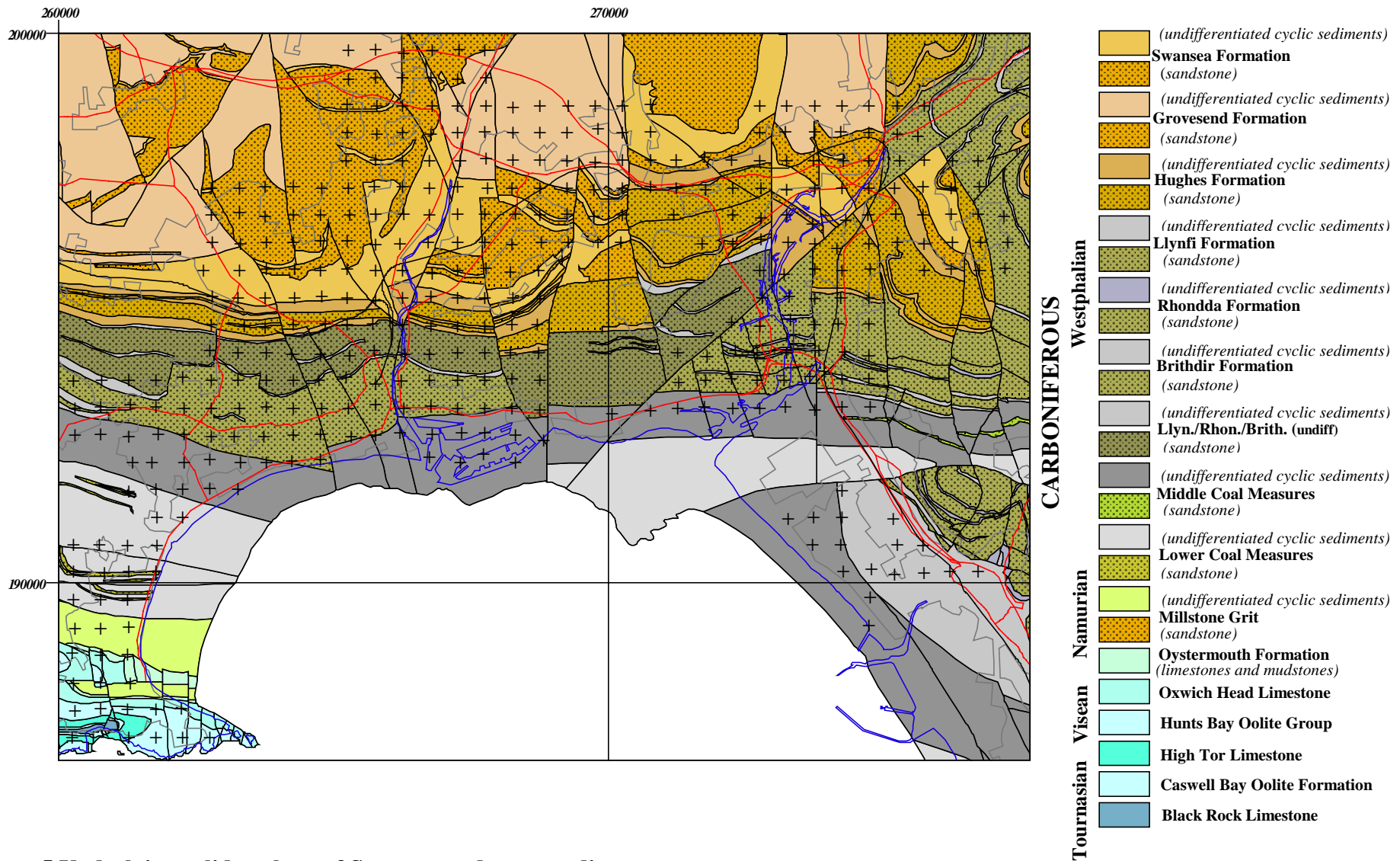


Figure 5 Underlying solid geology of Swansea and surrounding area

## **2.4 SOIL TYPE**

Urban and industrial areas have not been surveyed for soil type by the Soil Survey of England and Wales. No information therefore exists on soil type for the main city area of Swansea, although limited data is available for the outskirts of the urban area. This was obtained from a map of the Soils of Wales (Soil Survey of England and Wales, 1983).

Basic information for the urban soils of Swansea 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 Mumbles area is characterised by well-drained loamy soil. Information is also available for the ground directly north of the Swansea dock area where well-drained loamy soil overlies sandstone. Directly east of this there is an area of thick, very acidic amorphous raw peat soil underlying the marshy area of Crymlyn Bog nature reserve, and east of this on both sides of the River Neath deep, well drained calcareous and non-calcareous sandy soils are the predominant type. North of these lying on the eastern side of the River Tawe the main soil type is fine loam.

# **3 Methodology**

## **3.1 SOIL SAMPLING**

Sample sites were arranged on a regular grid pattern at a density of 4 samples per km<sup>2</sup>. Sample spacing was kept as regular as possible, namely 500m 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 50m 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 at 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 nine point composite sample based on a 2 x 2m square. The deeper “profile” samples were labelled S and collected at a standard depth of 35-45 cm. These were composed of 3 sub-samples from the same 2 x 2m square as the A sample. Duplicate sampling is described in section 3.2.2.

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

## **3.2 SAMPLE PREPARATION**

Samples were dried in an oven at temperatures below 20°C and then sieved. Surface soils were sieved to obtain the <math>-2\text{mm}</math> fraction and profile soils to obtain the <math>-150\mu\text{m}</math> 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 <math>53\mu\text{m}</math>. A 12g split of the ground material was combined with 3g 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 was monitored using the methods of Plant (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 considered were part of a single randomised dataset and therefore a random nested model of ANOVA was used (Snedecor and Cochran, 1989). The results of the ANOVA indicate that for all elements, with the exception of uranium, the between-site variance is greater than 90% of the total variance. Variations in the distribution of element concentrations can thus be attributed principally to the inherent variability in the environment rather than to variation introduced by the sampling and analytical procedures. In the case of uranium the between-site variance is approximately 70% indicating probable analytical variation, which may be attributed to the overall low concentrations of uranium being very close to the analytical detection limits.

#### **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 Swansea data set 17 standards were included in the analysis of the A samples and 9 were included with the S samples (see Table 2).

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).

**Table 1** Percentage of variance in surface and profile soils attributable to between-site, between sample and residual variance.

Element (surface)	Between site	Between sample	Residual	Element (profile)	Between site	Between sample	Residual
TiO <sub>2</sub>	97.44	2.17	0.39	V	95.06	4.91	0.04
V	97.68	2.29	0.03	Cr	95.66	3.95	0.39
Cr	94.95	3.53	1.52	MnO	95.06	4.91	0.37
MnO	93.88	6.06	0.07	Fe <sub>2</sub> O <sub>3</sub>	96.61	3.39	0.01
Fe <sub>2</sub> O <sub>3</sub>	89.81	10.11	0.08	Co	96.79	3.13	0.08
Co	99.31	0.31	0.38	Ni	95.74	4.23	0.04
Ni	98.46	1.38	0.16	Cu	98.37	1.62	0.01
Cu	80.93	18.51	0.56	Zn	93.14	6.84	0.13
Zn	98.38	1.61	0.01	As	95.93	4.05	0.03
As	98.80	1.14	0.06	Mo	96.27	3.65	0.09
Mo	98.12	1.70	0.18	Cd	68.94	0.00	31.06
Cd	47.89	6.77	45.35	Sn	94.47	5.52	0.01
Sn	83.11	5.54	11.35	Sb	90.35	8.90	0.75
Sb	89.20	6.23	4.57	Ba	91.70	8.27	0.02
Ba	98.15	1.39	0.46	Pb	92.81	7.19	0.01
Pb	97.67	1.99	0.34	U	74.67	12.63	12.70
U	80.16	2.74	17.10				

**Table 2** Comparison of G-BASE bulk soil standards

Sample Type Standard ID	Profile	Surface	Profile	Surface	Profile	Surface
	S13	S13	S15	S15	S24	S24
Cd	1.1	0.5	0.9	0.5	1.9	0.5
Sn	2.6	3.0	4.5	4.0	5.8	5.9
Sb	0.5	0.6	1.6	0.9	7.8	7.8
TiO <sub>2</sub>	N/A	0.774	N/A	0.372	N/A	1.101
MnO	0.119	0.120	0.067	0.066	0.487	0.487
Fe <sub>2</sub> O <sub>3</sub>	6.86	6.87	1.89	1.89	10.18	10.18
V	96	97	34	34	140	140
Cr	97	98	36	35	123	124
Co	28	28	8	8	97	97
Ba	1593	1603	391	402	979	958
Ni	36	36	12	12	45	45
Cu	16	17	6	6	64	63
Zn	113	113	30	30	387	387
As	15	15	9	9	123	124
Mo	1	0.5	1	1.2	2	0.6
Pb	113	114	22	21	1111	1111
U	2.6	2.6	1.4	1.4	1.5	1.5

### 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<sub>2</sub>, MnO, Fe<sub>2</sub>O<sub>3</sub>, 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 3.

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 3 Lower limits of detection (LLD) and upper reporting limit (URL) values for XRF analysis of G-BASE urban soil samples**

Analyte	LLD (ppm)	LLR (%)	URL (ppm)	URL (%)
TiO <sub>2</sub> *	-	0.010	-	100.0
MnO	-	0.010	-	10.0
Fe <sub>2</sub> O <sub>3</sub>	-	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	1	-	1000	-
Cd	1	-	500	-
Sn	1	-	10000	-
Sb	1	-	10000	-
Ba	3	-	600000	-
Pb	1	-	10000	-
U	1	-	650	-

\* A horizon only.

### 3.5 DATA INTERPRETATION

Once full error control and data quality procedures were completed, the Swansea geochemical and location data were loaded into 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 Swansea it is useful to be aware of typical background concentrations in the environment in order to put the concentrations seen in Swansea into context. Regional soil sampling was not carried out routinely in the G-BASE survey of Wales, but, soil samples over the Coal Measures in the Humber Trent Atlas area were collected and have been used in comparison with the Swansea urban soils which were collected over the South Wales Coal Measures. The mean elemental concentrations for the 958 profile soil samples in the data set are shown in Table 4. Although direct comparisons of soil and stream sediment data are not possible, the G-BASE stream sediment data set for Wales represents a complete background survey of the surface environment. The mean elemental concentrations for 18,927 stream sediment samples are shown in Table 5, these data can be used to give an indication of the typical magnitude of the elemental concentrations throughout Wales as a whole.

**Table 4** Mean concentrations in regional soil samples over Coal Measures in Humber Trent atlas area

Analyte	Units	Mean Value
As	ppm	15
Ba	ppm	504
Cd	ppm	2
Co	ppm	24
Cr	ppm	77
Cu	ppm	38
Fe <sub>2</sub> O <sub>3</sub>	wt%	4.68
MnO	wt%	0.140
Mo	ppm	3.0
Ni	ppm	25
Pb	ppm	104
Sb	ppm	1
Sn	ppm	8
TiO <sub>2</sub>	wt%	0.66
U	ppm	1.7
V	ppm	99
Zn	ppm	115

**Table 5** Mean concentrations in stream sediment samples (**British Geological Survey, 2001**)

Analyte	Units	Mean Value
As	ppm	14
Ba	ppm	542
Cd	ppm	1
Co	ppm	31
Cr	ppm	92
Cu	ppm	22
Fe <sub>2</sub> O <sub>3</sub>	wt%	6.84
MnO	wt%	0.182
Mo	ppm	1.6
Ni	ppm	38
Pb	ppm	36
Sb	ppm	4
Sn	ppm	5
TiO <sub>2</sub>	wt%	0.869
U	ppm	2.3
V	ppm	114
Zn	ppm	125

### 4.2 KEY GEOCHEMICAL CHARACTERISTICS OF THE SWANSEA DATASET

The majority of analytes show higher concentrations in the profile soil rather than the surface soil. This could be due to the fact that during sample preparation the two horizons are sieved to a different size fraction. The surface soils are sieved to <2mm whilst the profile soils are sieved to <150µm. This means that the sieved profile soil has a much larger surface area and will contain more clay particles. Clay minerals possess the ability to attract and bind heavy metal

ions, which could explain why the profile soils show higher levels of these (Brady and Weil, 1999).

There could also be other explanations why the profile soils show elevated levels of 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.

#### **4.2.1 Tawe Valley**

The Tawe Valley housed the great majority of Swansea's smelting factories. The main metals smelted in the area were Fe, Cu, Zn and Sn, and as a result this area clearly shows deposition of these. The factories also left a legacy of a great many spoil tips. As a result many of the analytes that are associated with metal smelting such as, Sb, Mo, Pb and As, also show anomalies running along this area.

Coal mining also played a substantial part in the industry of Swansea both in the Tawe Valley and the other industrial areas of the city. Many trace metals, such as Ni, Cu and Pb, occur at naturally elevated levels in the Coal Measures which could explain their elevated levels in soils. The combustion product of coal and other fossil fuels have more trace metals (e.g. Sn, Cr, Co) associated with them and therefore could also contribute to the high level through atmospheric deposition (Alloway, 1995).

#### **4.2.2 Port Talbot and Neath**

Port Talbot and Neath are two of the more heavily industrialised areas of the region with industries such as steel manufacture and chemical production. Many of the elements associated with steel making, such as V, Ni, Cu and Pb (Alloway, 1995), show higher levels in and around these areas.

Port Talbot has a railway line running through it and also houses a railway station and sidings where there seem to be higher levels of heavy metals. This could be where the products of industry, such as ore materials, were loaded and unloaded to and from freightliners, resulting in spillage, therefore explaining the elevated levels.

#### **4.2.3 Swansea Docks**

The dock area has elevated levels of many trace elements, such as As, Cd, Cr and Co, typically those related to the processing of oil, fuel and chemicals. It also houses a large container facility, which could explain the anomalies in most trace elements, as it would have exported all of Swansea's main industrial products.

As well as exportation Swansea docks were also one of the main importers of Cu and Sn ores. These analytes show significantly elevated levels in this area.

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

**URBAN SOIL/WATER**

CODE	SAMPLE NO	TYPE	EASTING	NORTHING	OS MAP	COLLECTORS	DAY	MONTH	YEAR					
	601971	A	26224	19176	159	MFP/CS	29	07	94					
DUPLICATE SAMPLE NO		SITE DRAINAGE CONTAMINATION												
CODE	SAMPLE NO	W/L	LAND USE	A	B	C	D	E	F	G	H	I	OS	DRIFT
			7URRE											1C1
SITE LOCALITY DETAILS														
ALLOTMENTS TO N KING GEORGE V PLAYING FIELD, 140M N W END PAVILION, 110M SSW S CNR GROSVENOR NURSERIES GREENHOUSE														
SOIL DATA														
COLOUR		TEXTURE		HORIZON		DEPTH		SOIL CLAST LITHOLOGY					BEDROCK LITHOLOGY	
DB		SASICL		A		0.5		3L 4P 3D 4P					4P	
WATER SAMPLE DATA														
WATER COLOUR										SOIL GASES				
										RADON Unit: B Pet 353 RATE = 1.5				
FIELD DATA COMMENTS														
+3500 dsb														

APPLIED GEOCHEMISTRY GROUP, BRITISH GEOLOGICAL SURVEY, 1994

**URBAN SOIL/WATER**

CODE	SAMPLE NO	TYPE	EASTING	NORTHING	OS MAP	COLLECTORS	DAY	MONTH	YEAR					
	601968	S	26224	19176	159	MFP/CS	29	07	94					
DUPLICATE SAMPLE NO		SITE DRAINAGE CONTAMINATION												
CODE	SAMPLE NO	W/L	LAND USE	A	B	C	D	E	F	G	H	I	OS	DRIFT
			7URRE											1C1
SITE LOCALITY DETAILS														
ALLOTMENTS TO N KING GEORGE V PLAYING FIELD, 140M N W END PAVILION, 110M SSW S CNR GROSVENOR NURSERIES GREENHOUSE.														
SOIL DATA														
COLOUR		TEXTURE		HORIZON		DEPTH		SOIL CLAST LITHOLOGY					BEDROCK LITHOLOGY	
LB		SASICL		A		0.5		3L 3D 4P 3S 4P					4P	
WATER SAMPLE DATA														
WATER COLOUR										SOIL GASES				
										RADON Unit: B Pet				
FIELD DATA COMMENTS														
dsb														

APPLIED GEOCHEMISTRY GROUP, BRITISH GEOLOGICAL SURVEY, 1994

## Appendix B: Percentile calculations for Swansea soil

Percentile	TiO <sub>2</sub> wt %	MnO wt %	MnO wt %	Fe <sub>2</sub> O <sub>3</sub> wt %	Fe <sub>2</sub> O <sub>3</sub> wt %	V ppm	V ppm	Cr ppm	Cr ppm	Co ppm	Co ppm	Ba ppm	Ba ppm	Ni ppm	Ni ppm	Cu ppm	Cu ppm
99	0.847	0.352	0.433	14.90	15.55	201	207	188	233	70	108	1717	2918	224	261	1127	1884
95	0.776	0.251	0.277	10.85	12.30	146	149	126	129	54	66	1113	1563	110	138	375	703
90	0.715	0.205	0.220	8.86	9.49	123	133	111	117	41	50	843	1020	81	88	309	476
75	0.667	0.154	0.166	6.89	7.12	98	106	88	95	30	32	524	578	57	54	193	221
50	0.604	0.122	0.125	5.92	5.92	85	91	74	83	23	24	398	383	37	36	116	118
25	0.536	0.088	0.089	5.15	5.30	75	81	67	76	19	19	324	314	27	26	66	62
15	0.488	0.068	0.071	4.52	4.85	70	77	64	73	17	18	303	285	23	22	50	46
10	0.429	0.056	0.055	4.16	4.45	67	73	60	70	14	16	289	265	21	20	38	34
5	0.328	0.036	0.027	3.26	3.64	61	66	50	66	12	14	265	243	19	17	29	27
Max	0.92	0.463	7.237	21.23	22.1	298	351	565	757	238	141	2941	20867	349	966	1447	3321
Min	0.097	0.012	0.005	1.12	0.98	27	44	20	24	5	7	197	167	8	8	7	10
Median	0.604	0.122	0.124	5.92	5.92	85	91	74	83	23	24	397	383	36	35	115	113
Mean	0.097	0.012	0.157	1.12	6.57	27	99	20	92	5	30	197	606	8	54	7	225

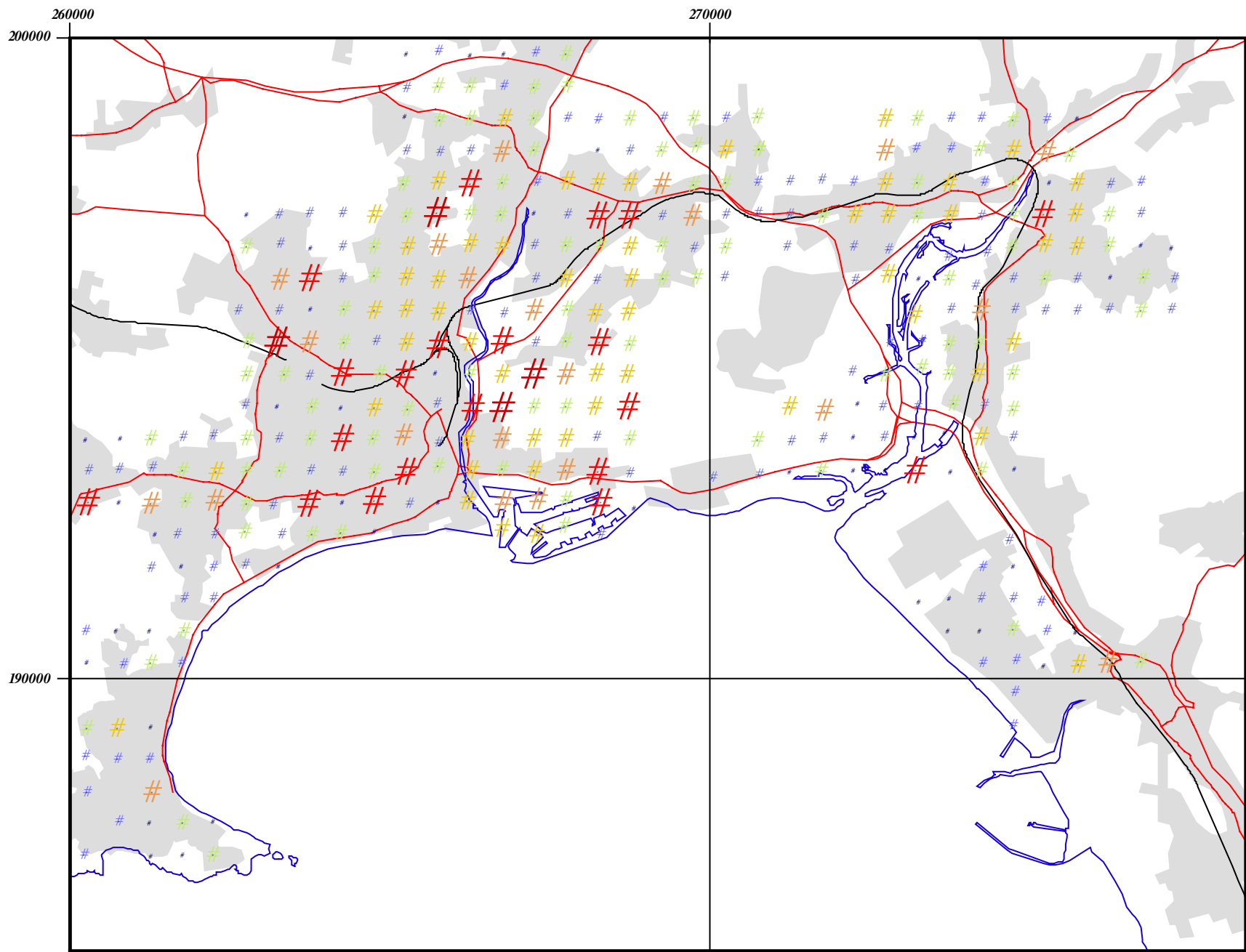
Percentile	Zn ppm	Zn ppm	As ppm	As ppm	Mo ppm	Mo ppm	Pb ppm	Pb ppm	U ppm	U ppm	Cd ppm	Cd ppm	Sn ppm	Sn ppm	Sb ppm	Sb ppm
99	4425	9556	400	358	15.3	31.4	2990	5434	4	6	21	8	466	799	34	81
95	1788	3023	187	199	7.7	11.4	1275	1979	3	4	9	4	178	231	17	30
90	1250	1476	129	137	5.9	8.5	921	1296	2	3	6	3	113	128	13	20
75	608	741	81	83	3.6	4.4	435	455	2	3	4	2	65	53	9	10
50	316	267	53	47	2.3	2.7	225	159	2	2	2	1	31	21	7	6
25	164	129	32	31	1.5	2.0	122	65	1	2	1	1	16	11	5	5
15	123	99	25	24	1.2	1.6	91	45	1	1	1	1	11	8	5	5
10	106	85	22	20	1.0	1.5	70	34	1	0	1	1	10	6	4	4
5	82	67	18	16	0.7	1.3	54	26	0	0	1	1	7	5	4	4
Max	19047	30305	2047	1319	31.8	48.5	14714	23795	6	9	61	32	919	2009	93	103
Min	41	33	8	1	0.2	0.2	20	13	0	0	1	1	3	2	4	3
Median	315	263	53	47	2.2	2.7	224	157	2	2	2	1	31	21	7	6
Mean	41	808	8	71	0.2	4.3	20	552	0	2	1	2	3	67	4	10

\*surface soils in yellow



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

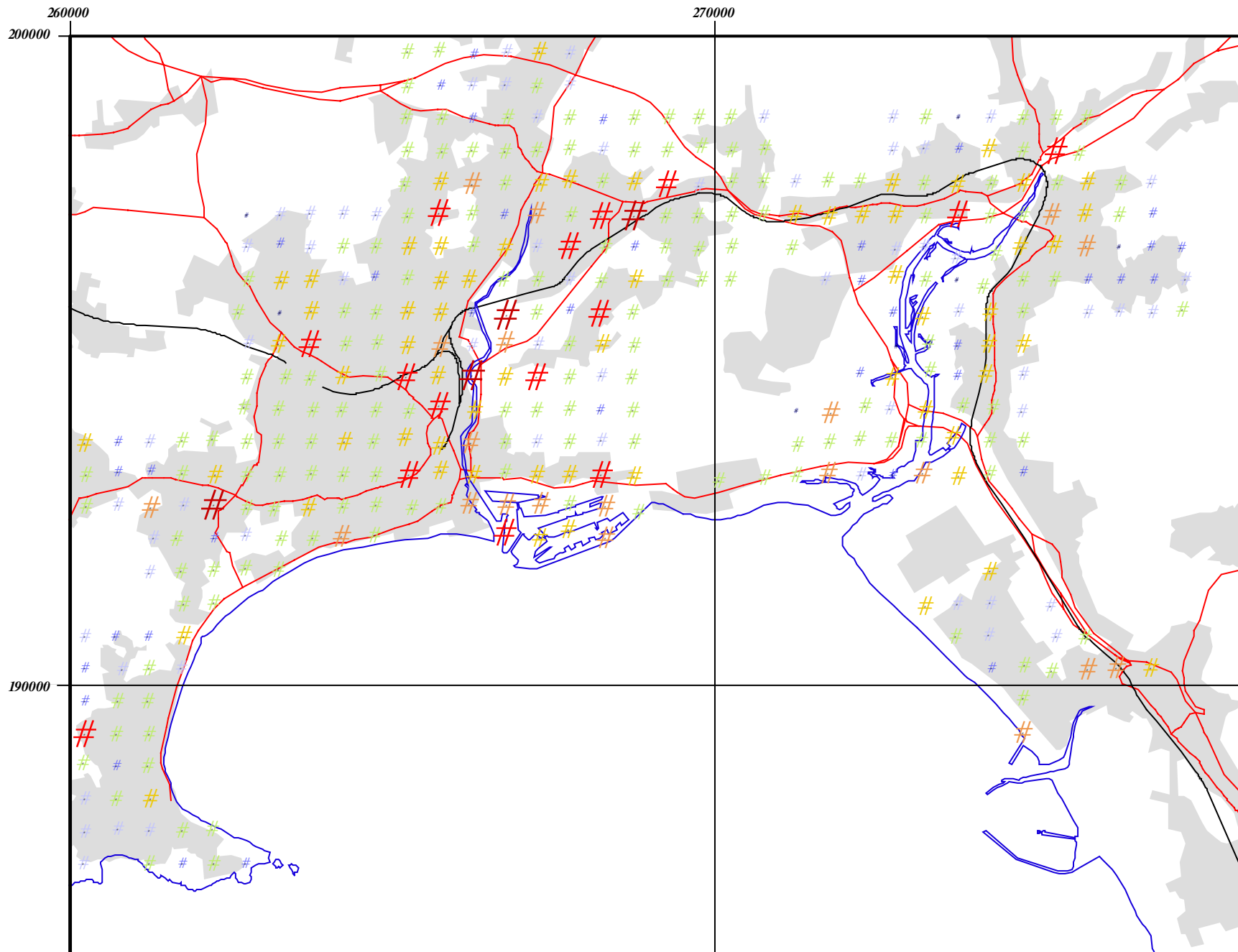
**Antimony**  
**Arsenic**  
**Barium**  
**Cadmium**  
**Chromium**  
**Cobalt**  
**Copper**  
**Iron**  
**Lead**  
**Manganese**  
**Molybdenum**  
**Nickel**  
**Tin**  
**Titanium**  
**Uranium**  
**Vanadium**  
**Zinc**



# Swansea Surface Soils

## Antimony

%ile	#	ppm
99	#	34
95	#	17
90	#	13
75	#	9
50	#	7
25	#	5
	#	



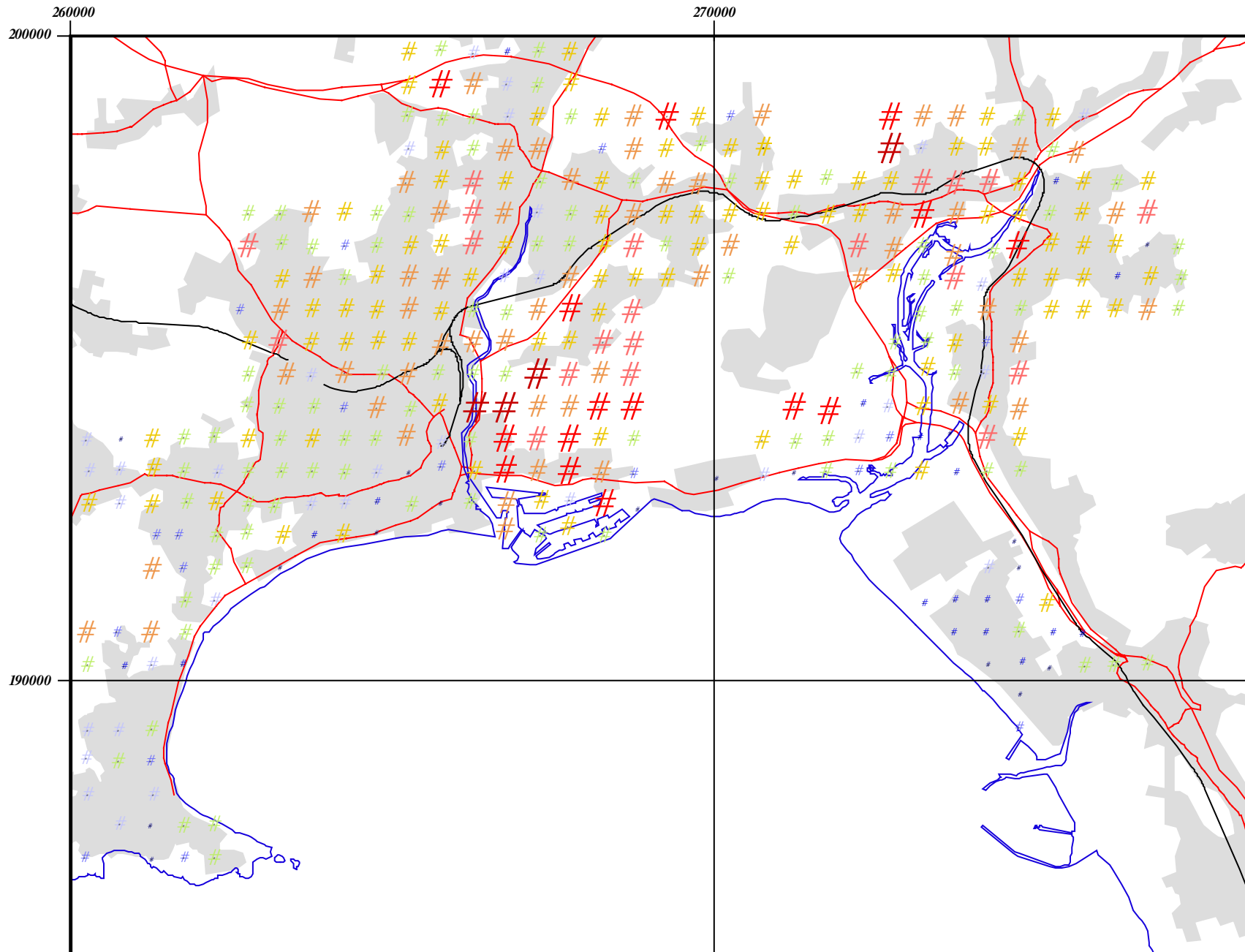
# Swansea Profile Soils

## Antimony

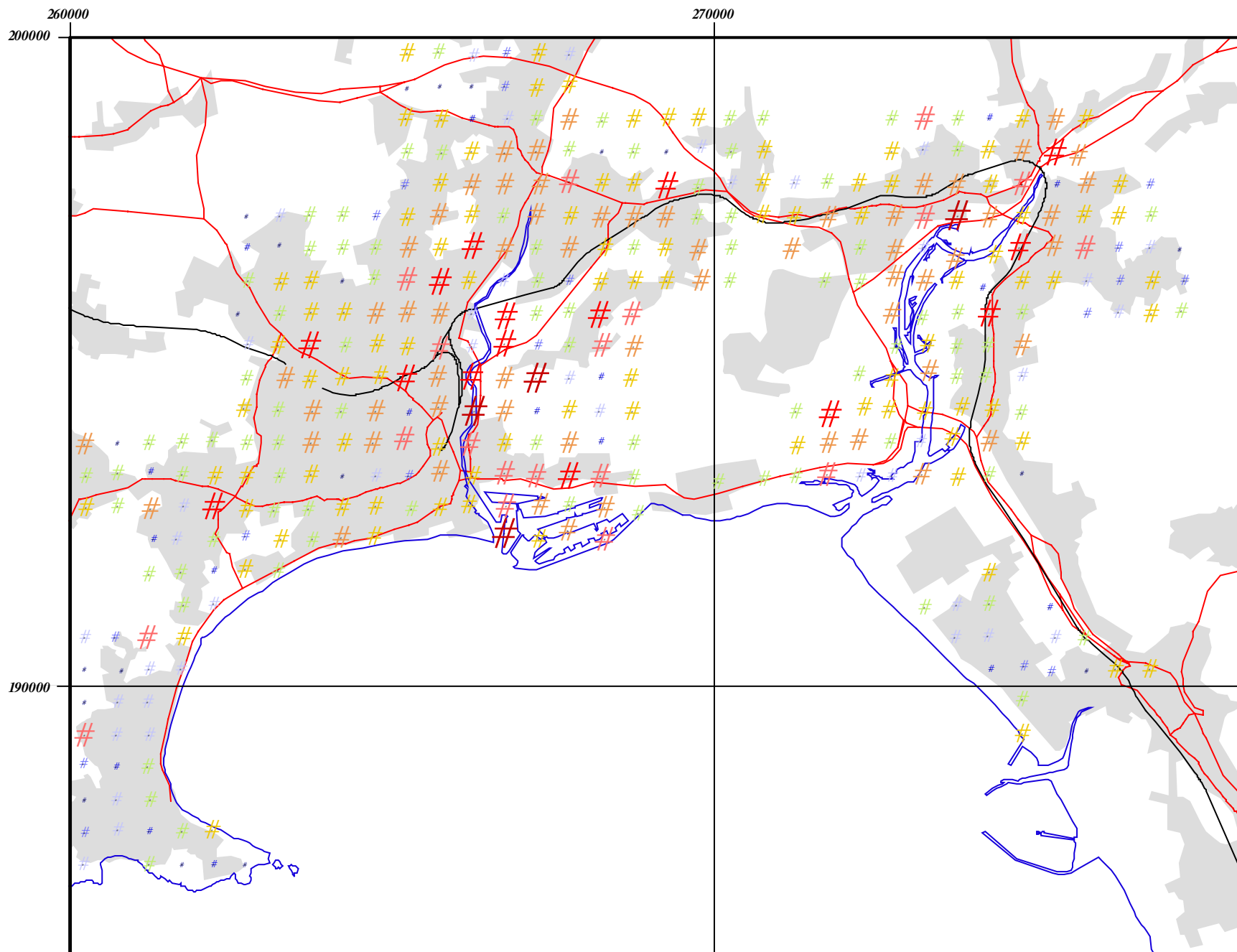
%ile	#	ppm
99	#	81
95	#	30
90	#	20
75	#	10
50	#	6
25	#	5
10	#	4

# Swansea Surface Soils

## Arsenic



%ile	#	ppm
99	#	400
95	#	187
90	#	129
75	#	81
50	#	53
25	#	32
15	#	25
10	#	22
5	#	18



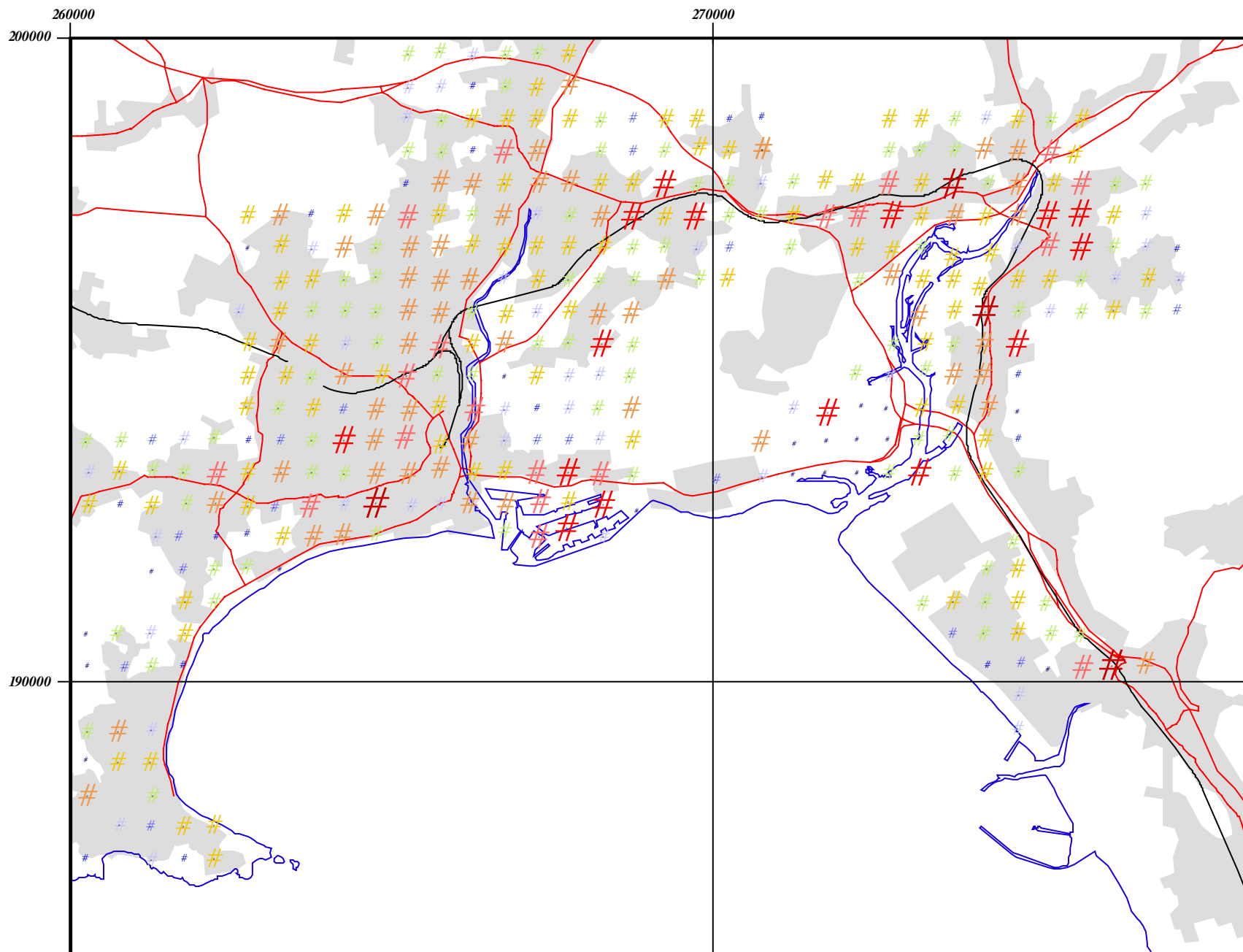
# Swansea Profile Soils

## Arsenic

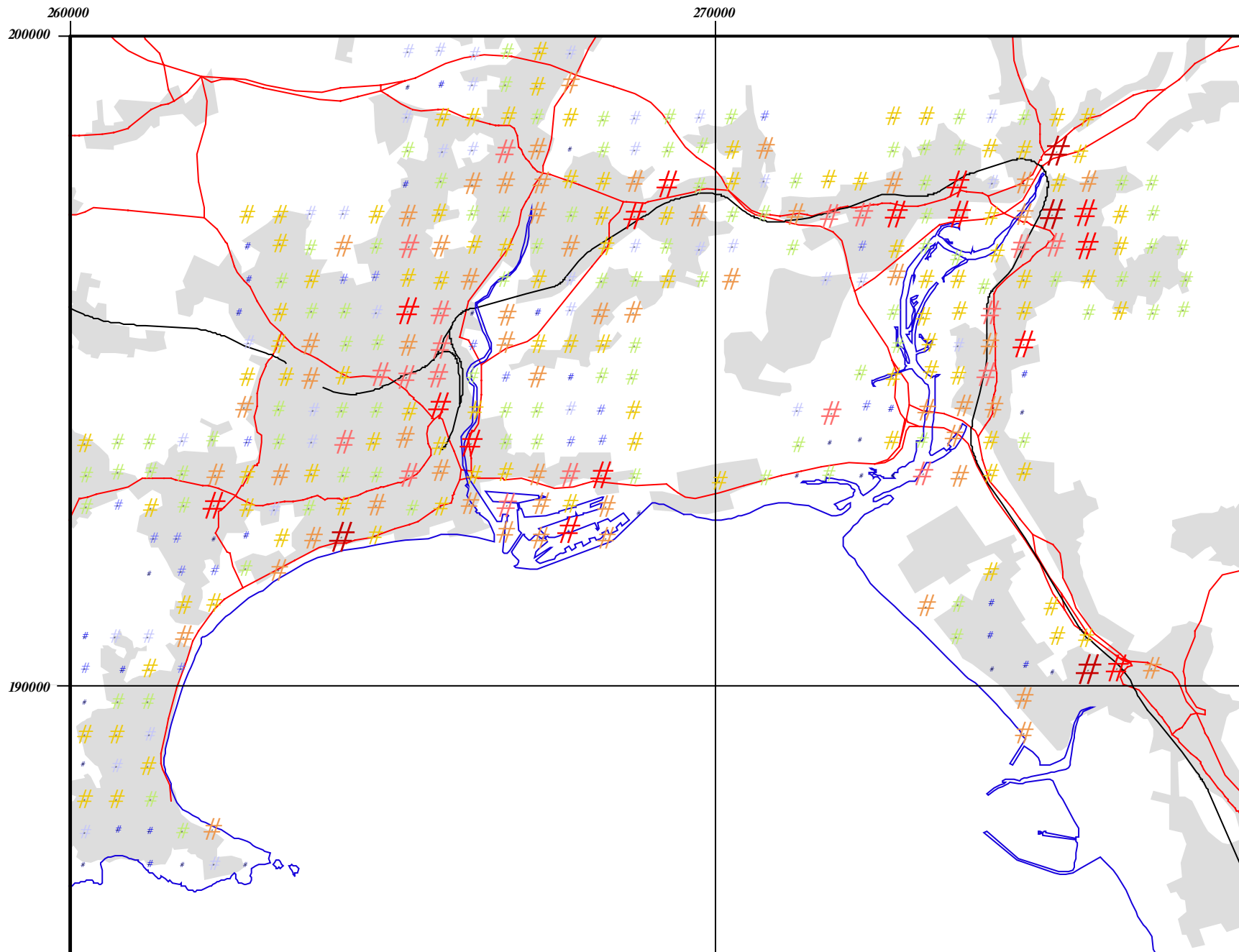
%ile	#	ppm
99	#	358
95	#	199
90	#	137
75	#	83
50	#	47
25	#	31
15	#	24
10	#	20
5	#	16

# Swansea Surface Soils

## Barium



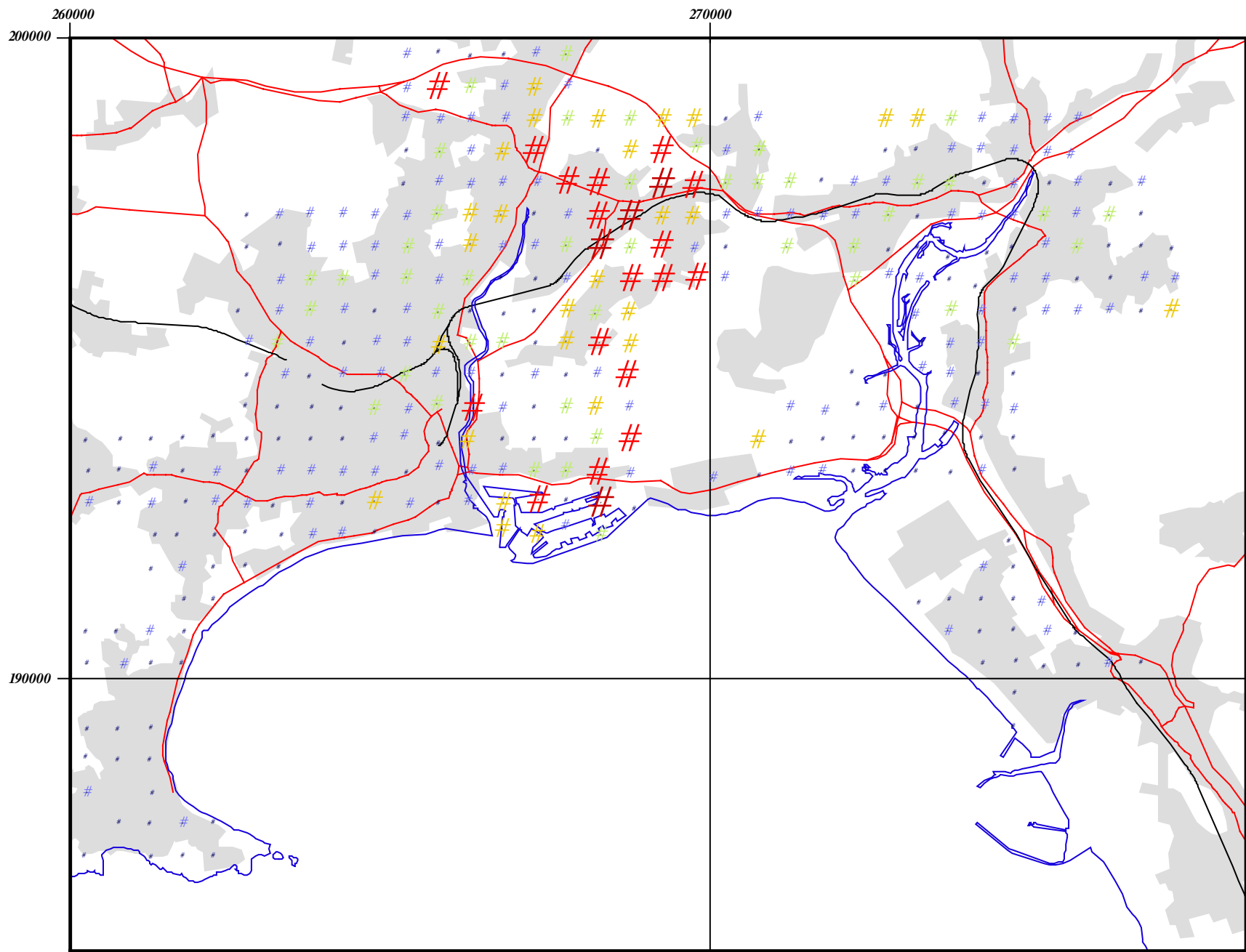
%ile	Color	ppm
99	Red	1717
95	Red-Orange	1113
90	Orange	843
75	Yellow-Orange	524
50	Yellow	398
25	Yellow-Green	324
15	Light Blue	303
10	Blue	289
5	Dark Blue	265



# Swansea Profile Soils

## Barium

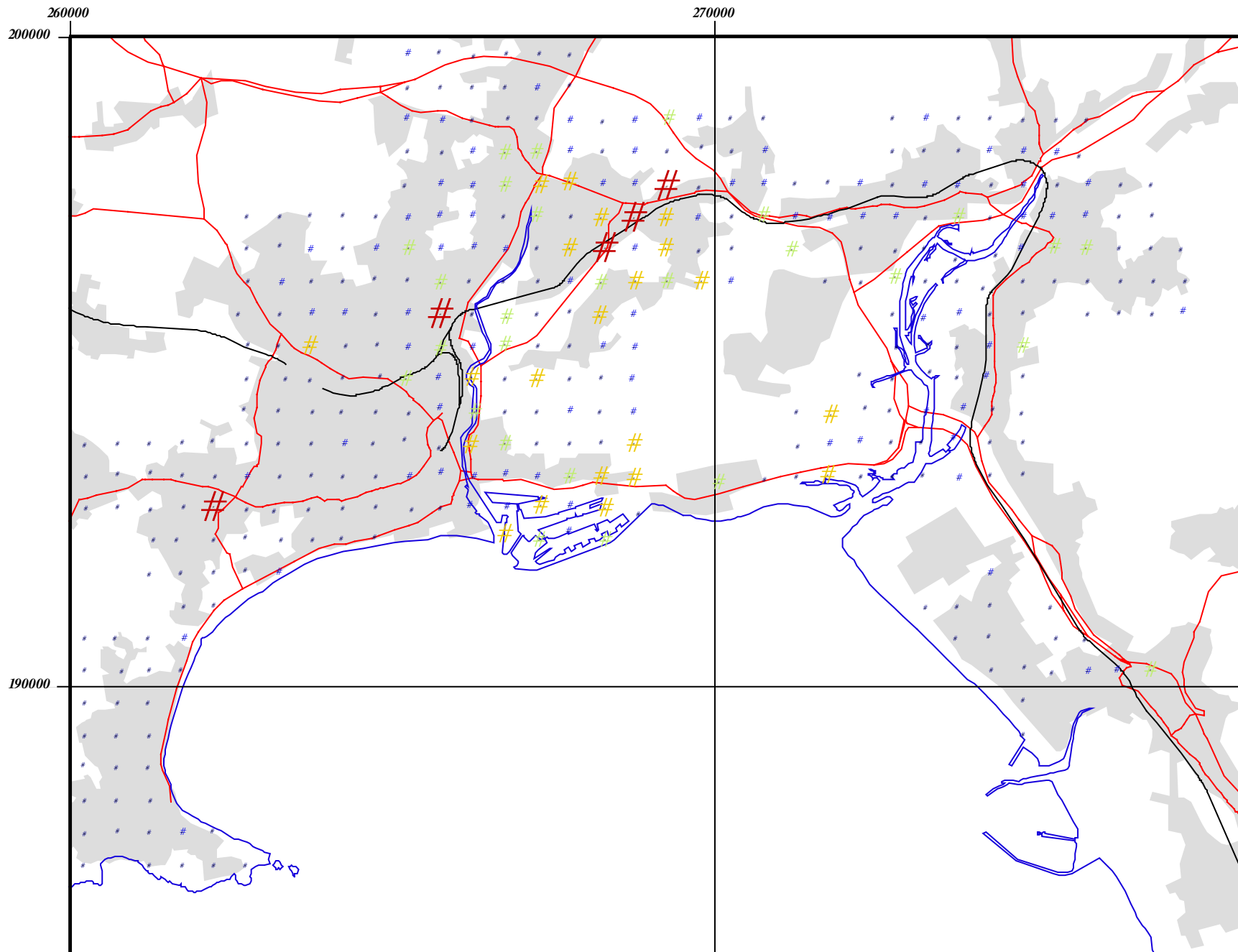
%ile	#	ppm
99	#	2918
95	#	1563
90	#	1020
75	#	578
50	#	383
25	#	314
15	#	285
10	#	265
5	#	243



# Swansea Surface Soils

## Cadmium

%ile		ppm
99	#	21
95	#	9
90	#	6
75	#	4
50	#	2
	.	



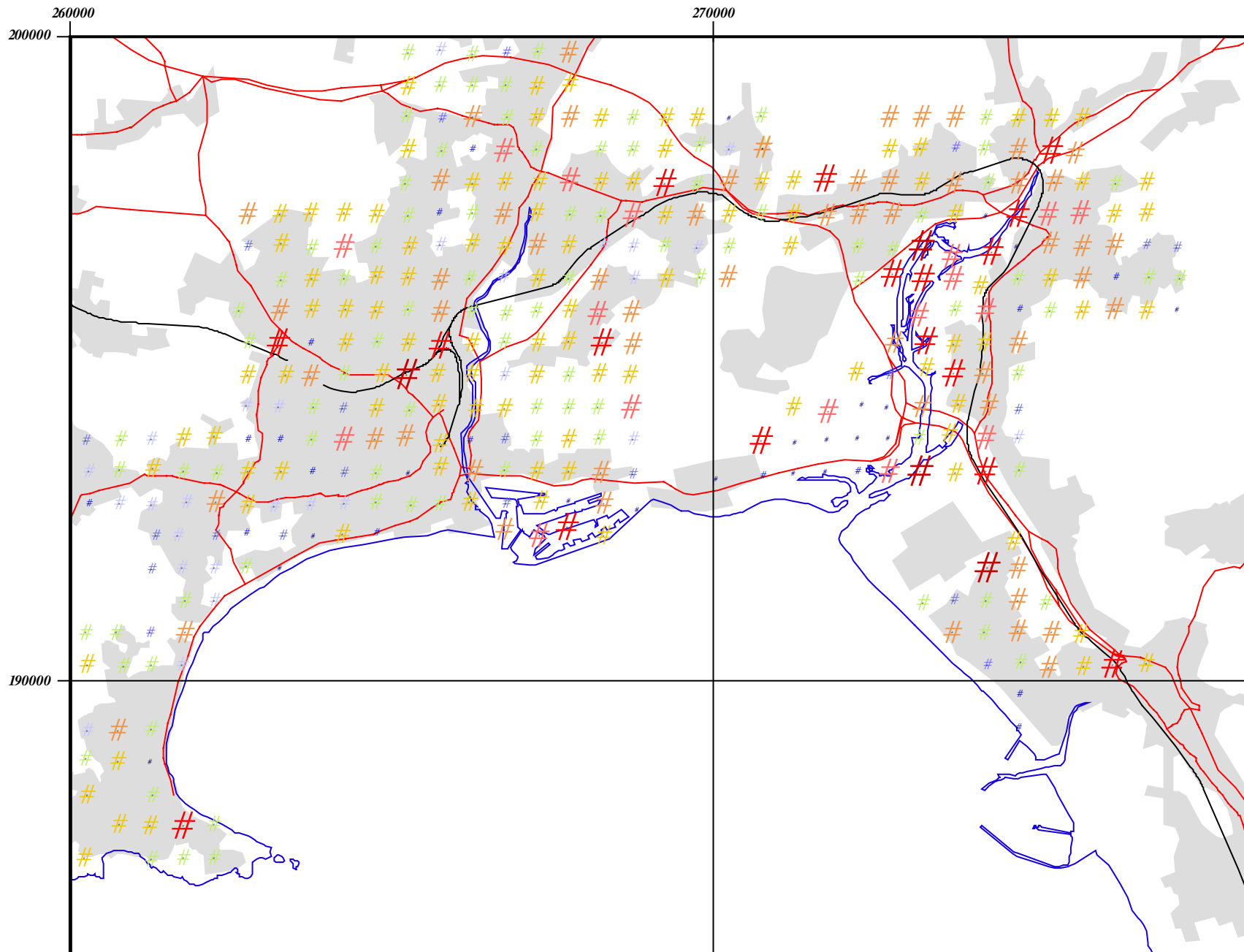
# Swansea Profile Soils

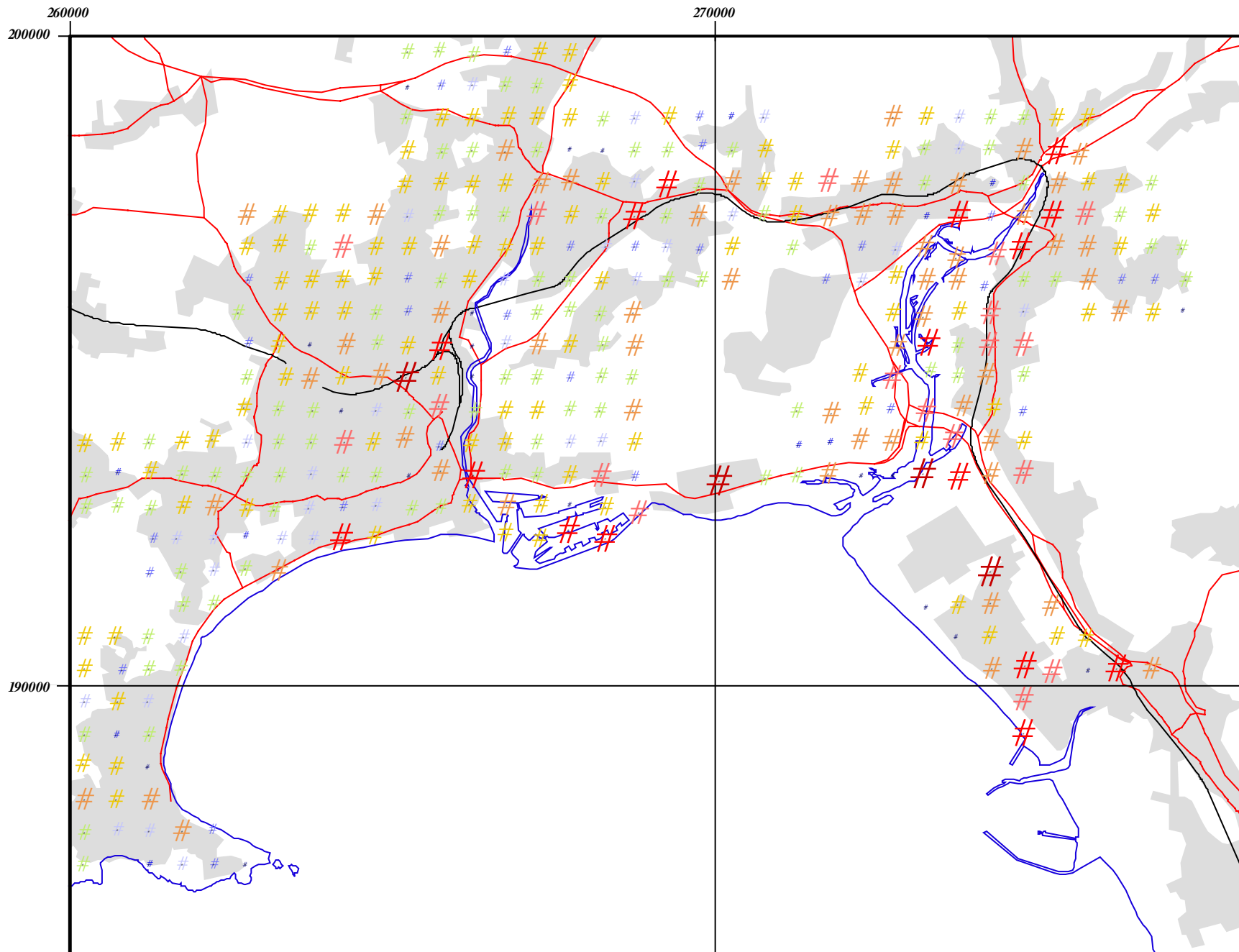
## Cadmium

%ile		ppm
99	#	6
95	#	4
90	#	3
75	#	2
	#	

# Swansea Surface Soils

## Chromium



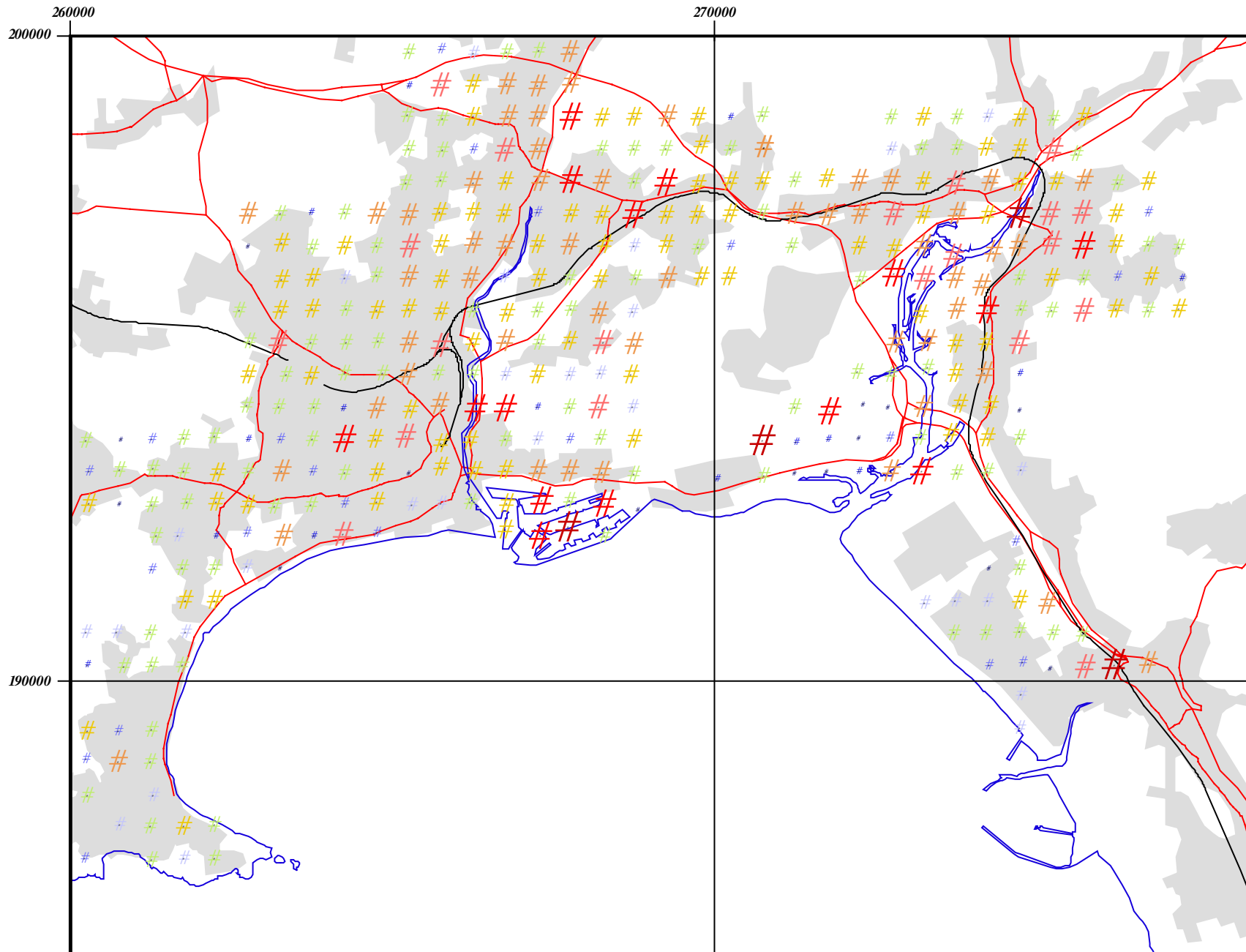


# Swansea Profile Soils Chromium

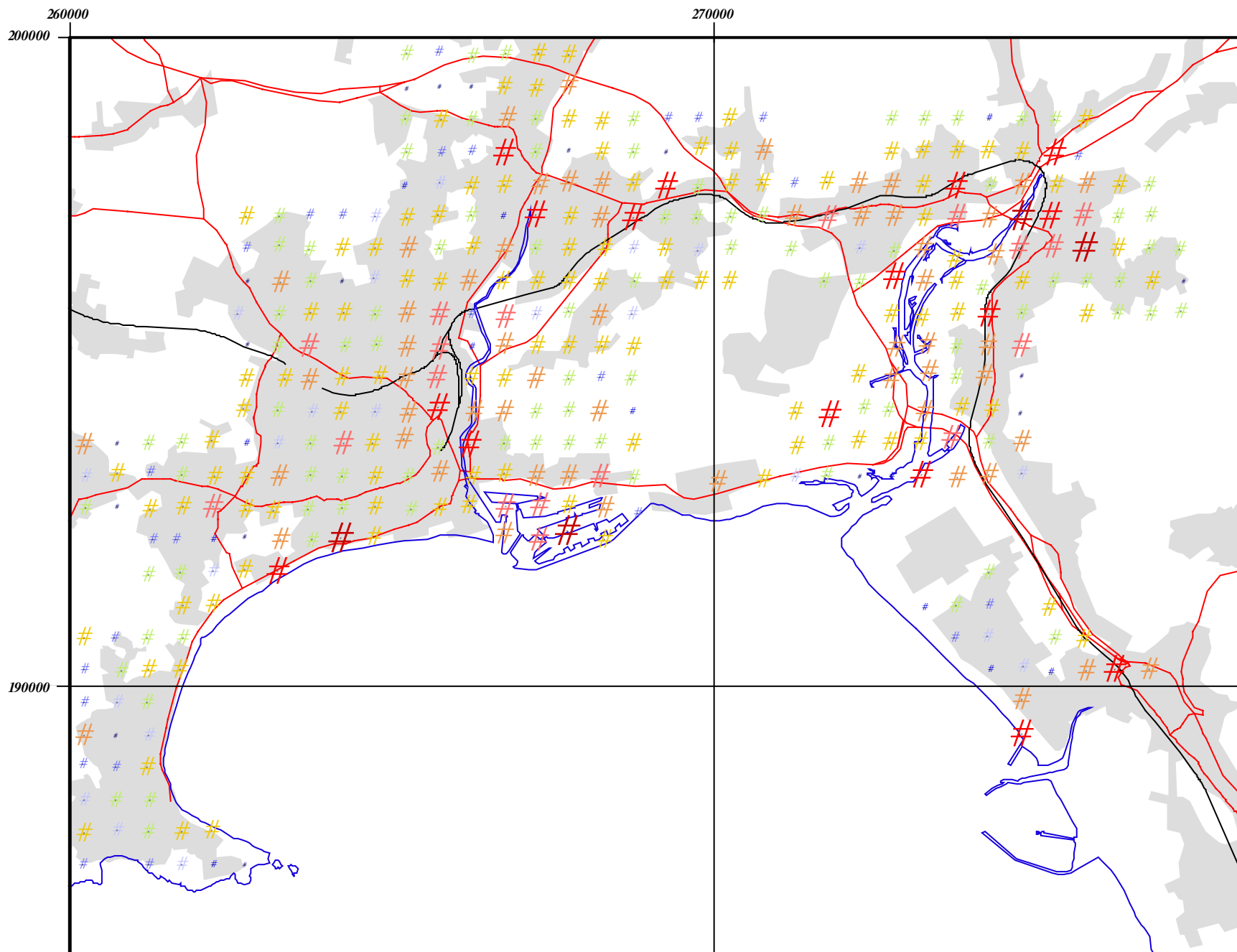
%ile	#	ppm
99	#	233
95	#	129
90	#	117
75	#	95
50	#	83
25	#	76
15	#	73
10	#	70
5	#	66

# Swansea Surface Soils

## Cobalt



%ile	#	ppm
99	#	70
95	#	54
90	#	41
75	#	30
50	#	23
25	#	19
15	#	17
10	#	14
5	#	12



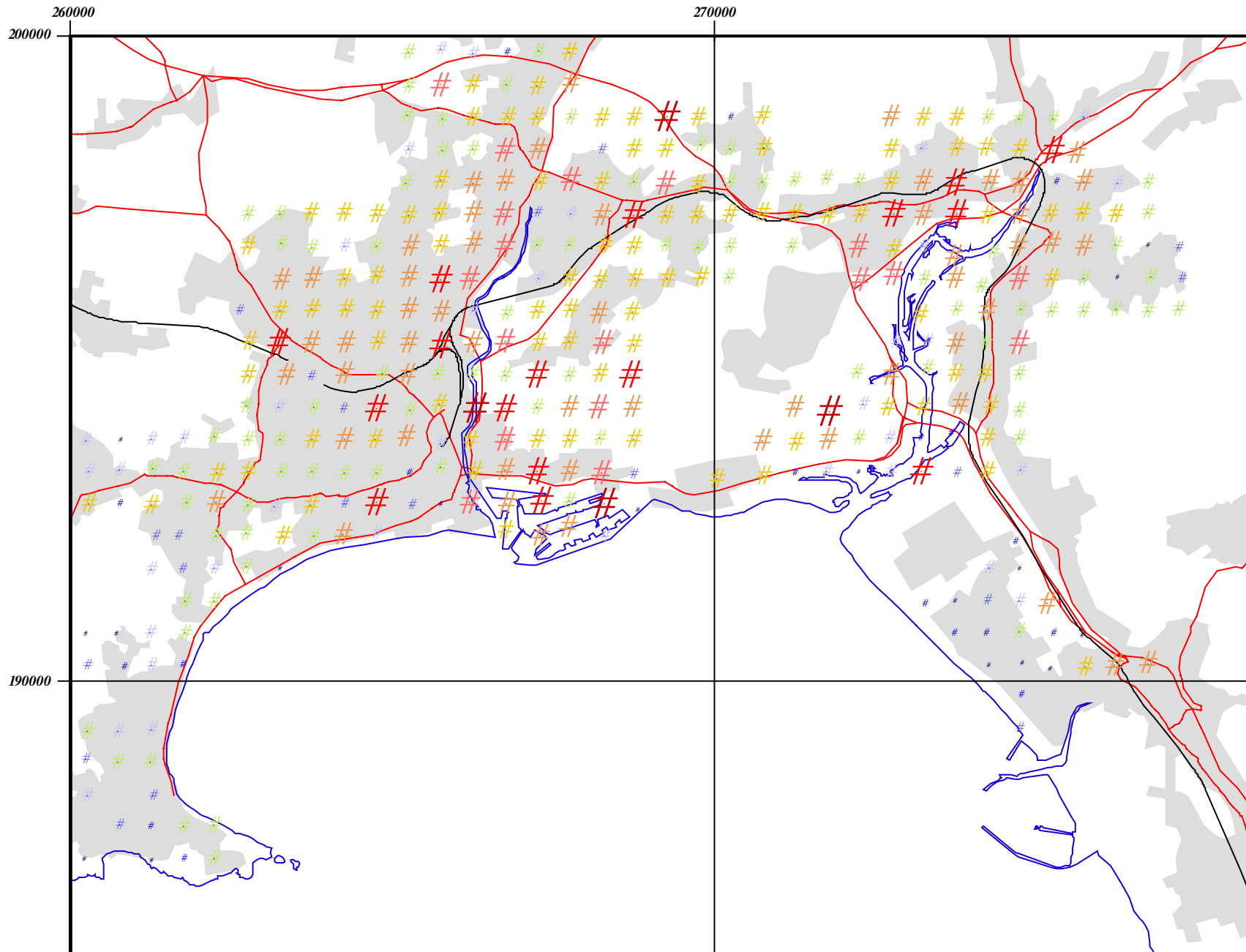
# Swansea Profile Soils

## Cobalt

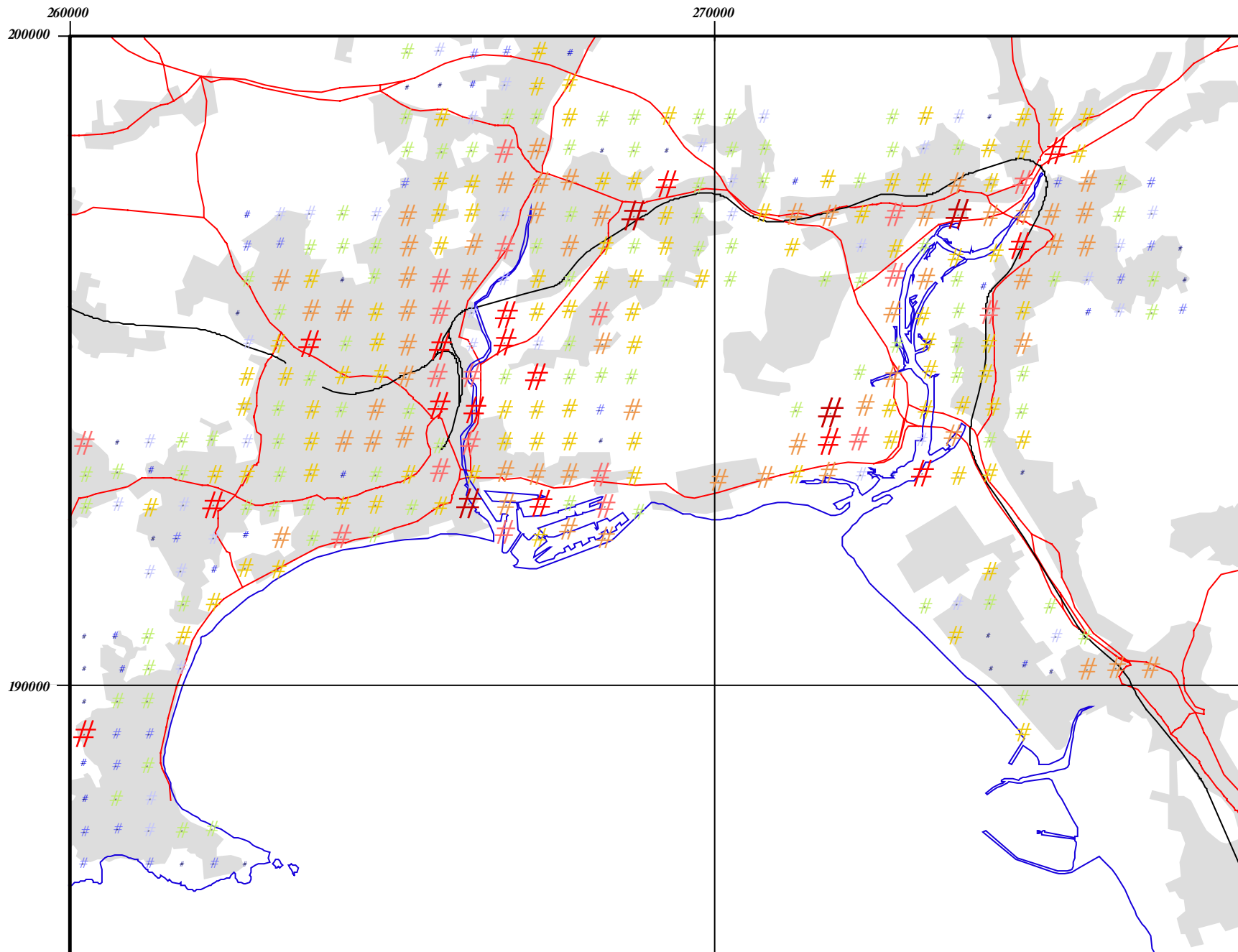
%ile	#	ppm
99	#	108
95	#	66
90	#	50
75	#	32
50	#	24
25	#	19
15	#	18
10	#	16
5	#	14

# Swansea Surface Soils

## Copper



%ile	#	ppm
99	#	1127
95	#	375
90	#	309
75	#	193
50	#	116
25	#	66
15	#	50
10	#	38
5	#	29



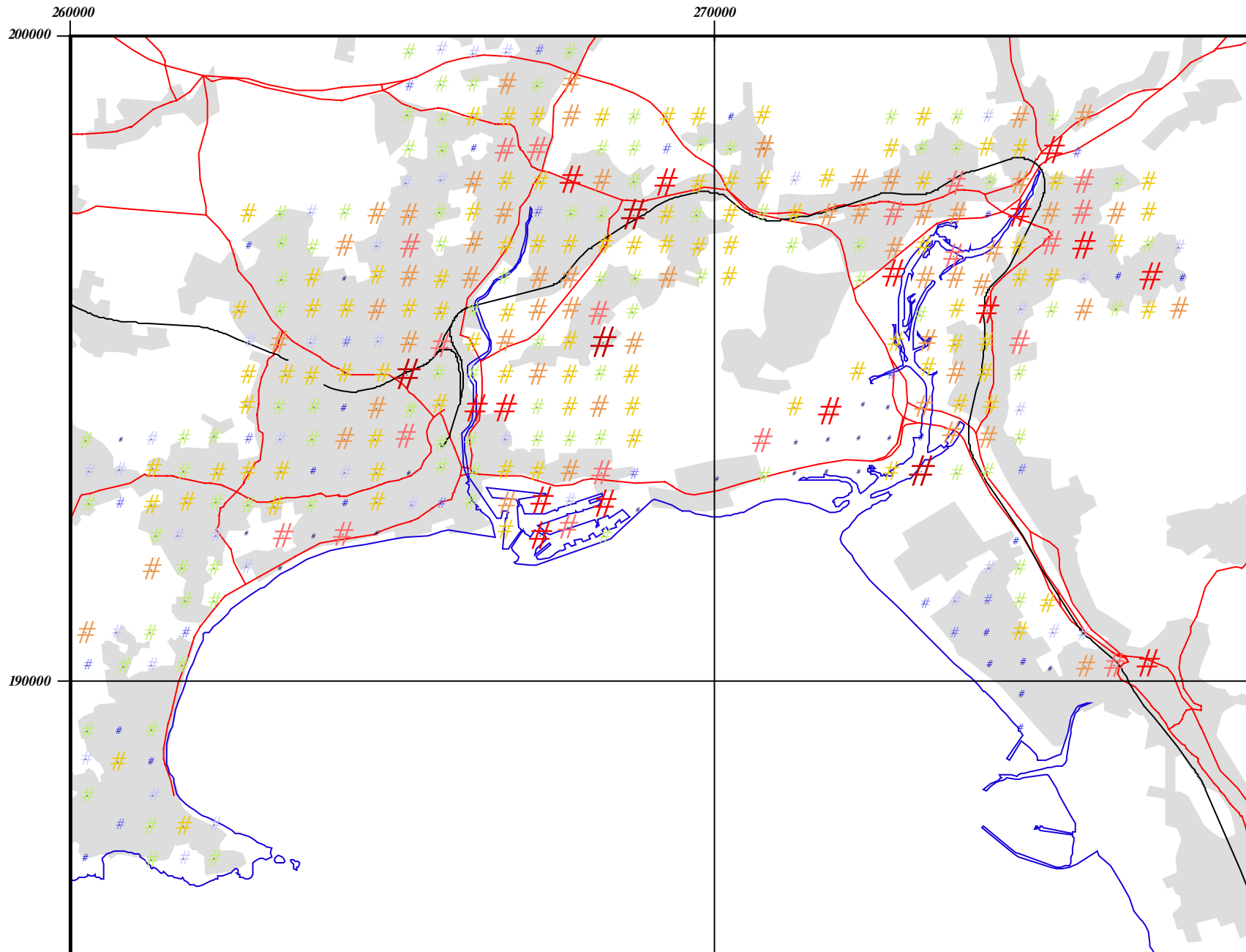
# Swansea Profile Soils

## Copper

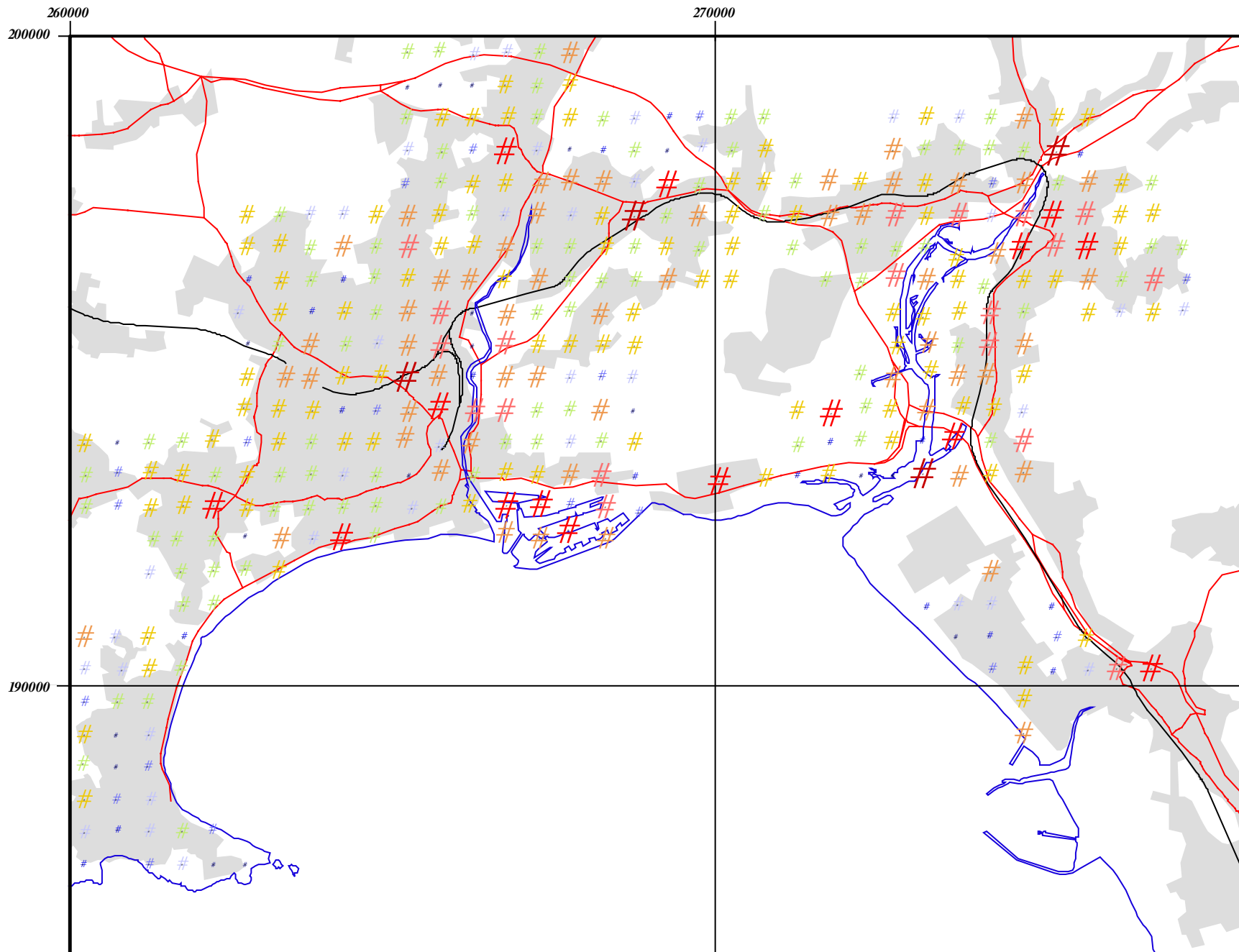
%ile	#	ppm
99	#	1884
95	#	703
90	#	476
75	#	221
50	#	118
25	#	62
15	#	46
10	#	34
5	#	27

# Swansea Surface Soils

## Iron



%ile	#	wt%
99	#	14.90
95	#	10.85
90	#	8.86
75	#	6.89
50	#	5.92
25	#	5.15
15	#	4.52
10	#	4.16
5	#	3.26



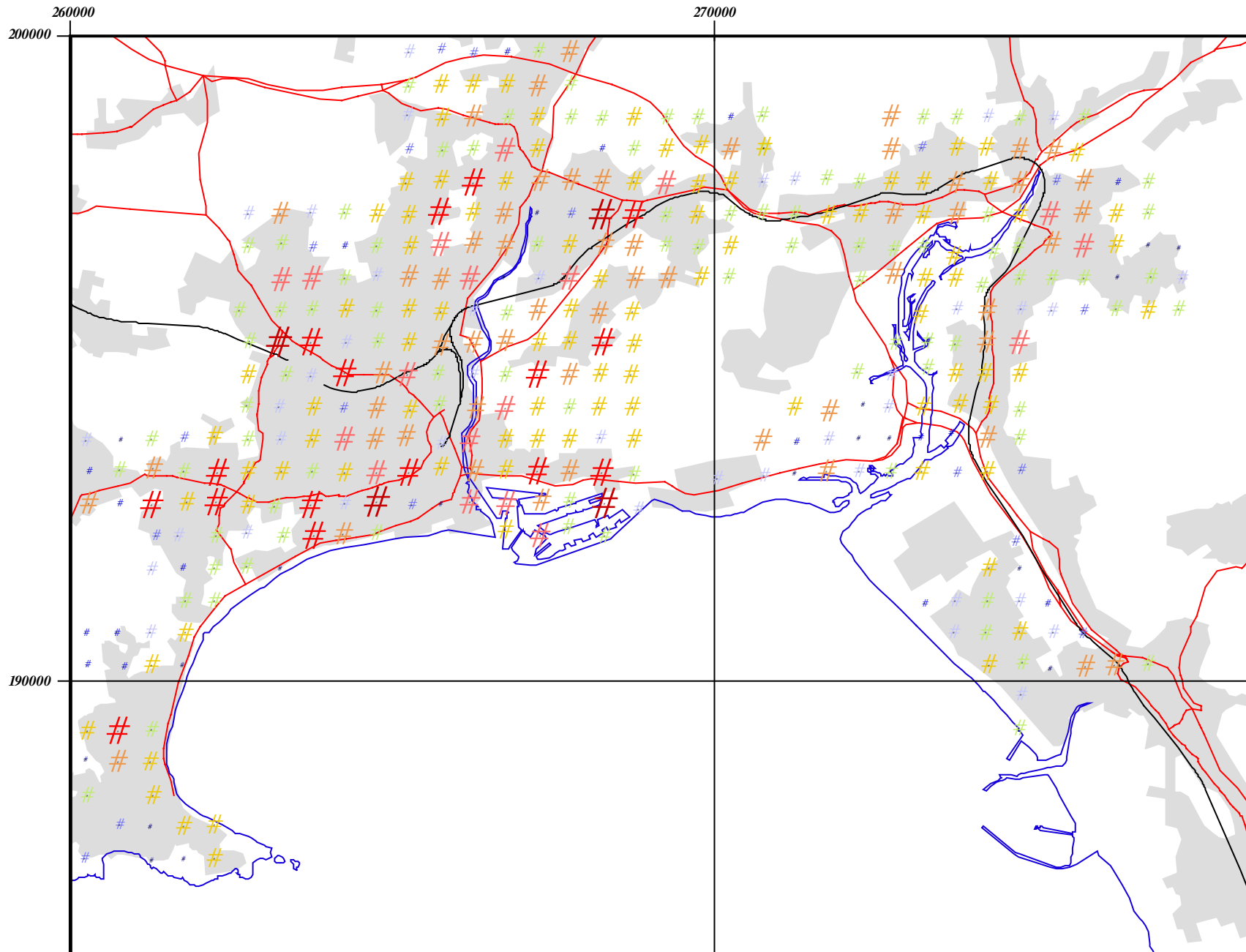
# Swansea Profile Soils

## Iron

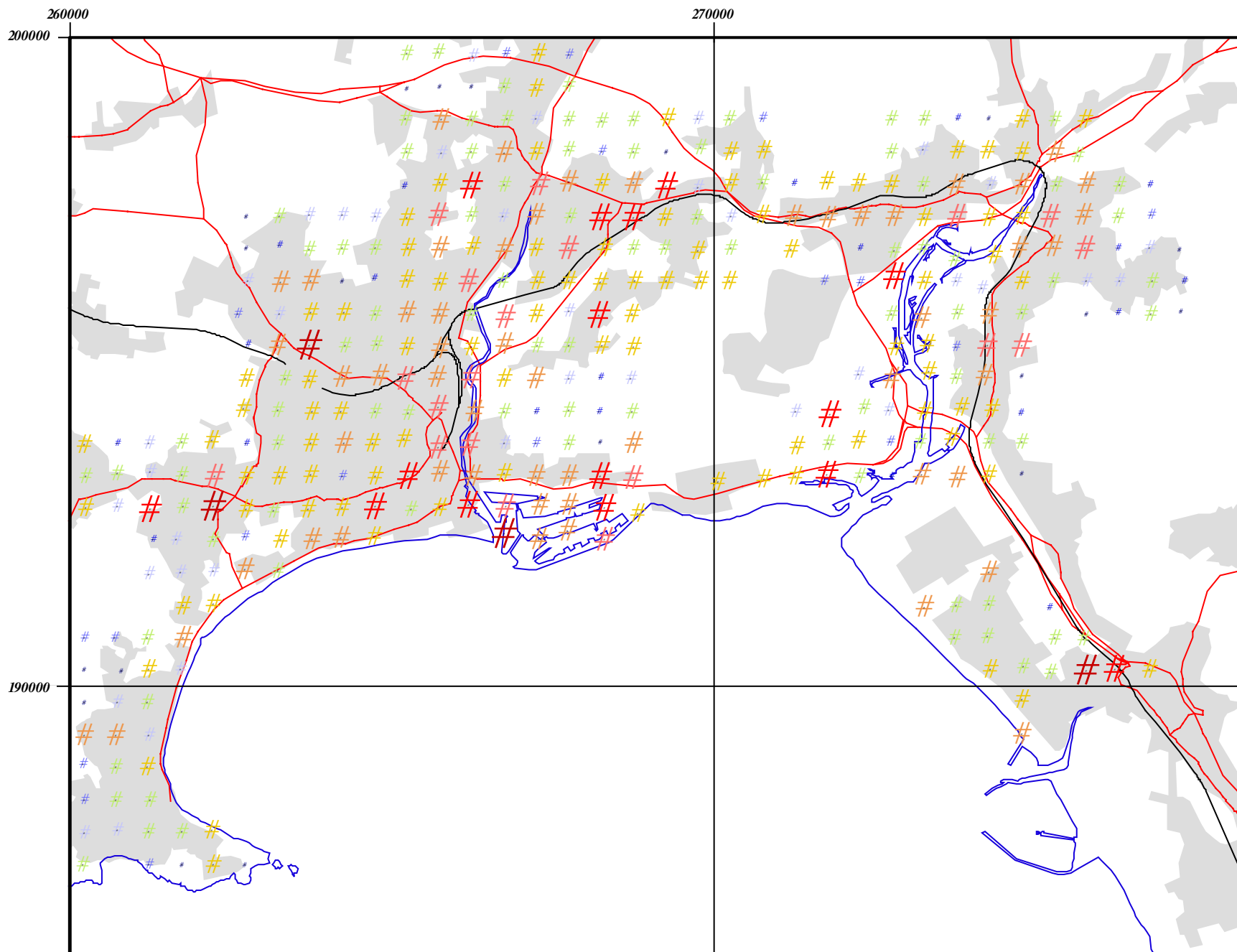
%ile	#	wt%
99	#	15.55
95	#	12.30
90	#	9.49
75	#	7.12
50	#	5.92
25	#	5.30
15	#	4.85
10	#	4.45
5	#	3.64

# Swansea Surface Soils

## Lead



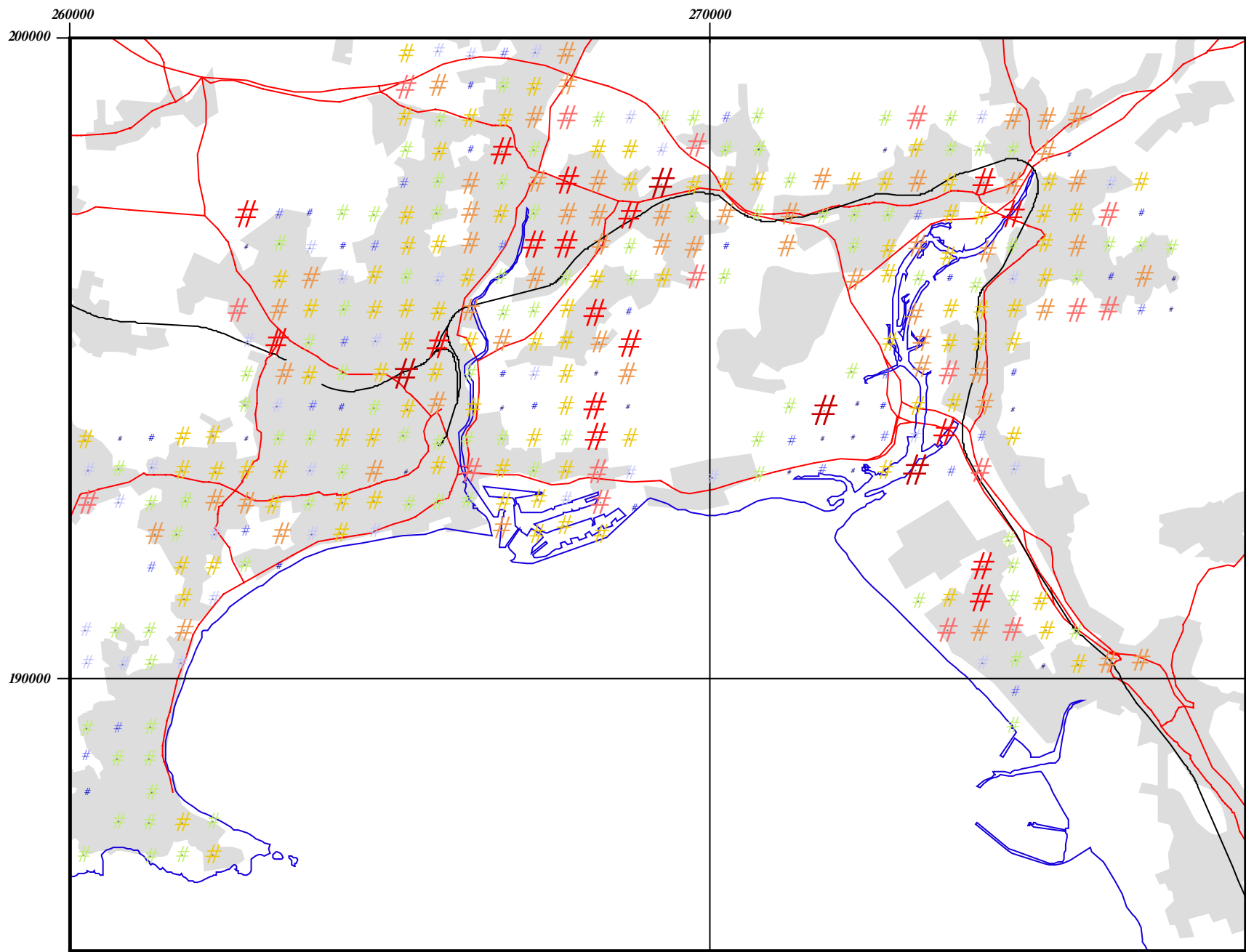
%ile	#	ppm
99	#	2990
95	#	1275
90	#	921
75	#	435
50	#	225
25	#	122
15	#	91
10	#	70
5	#	54



# Swansea Profile Soils

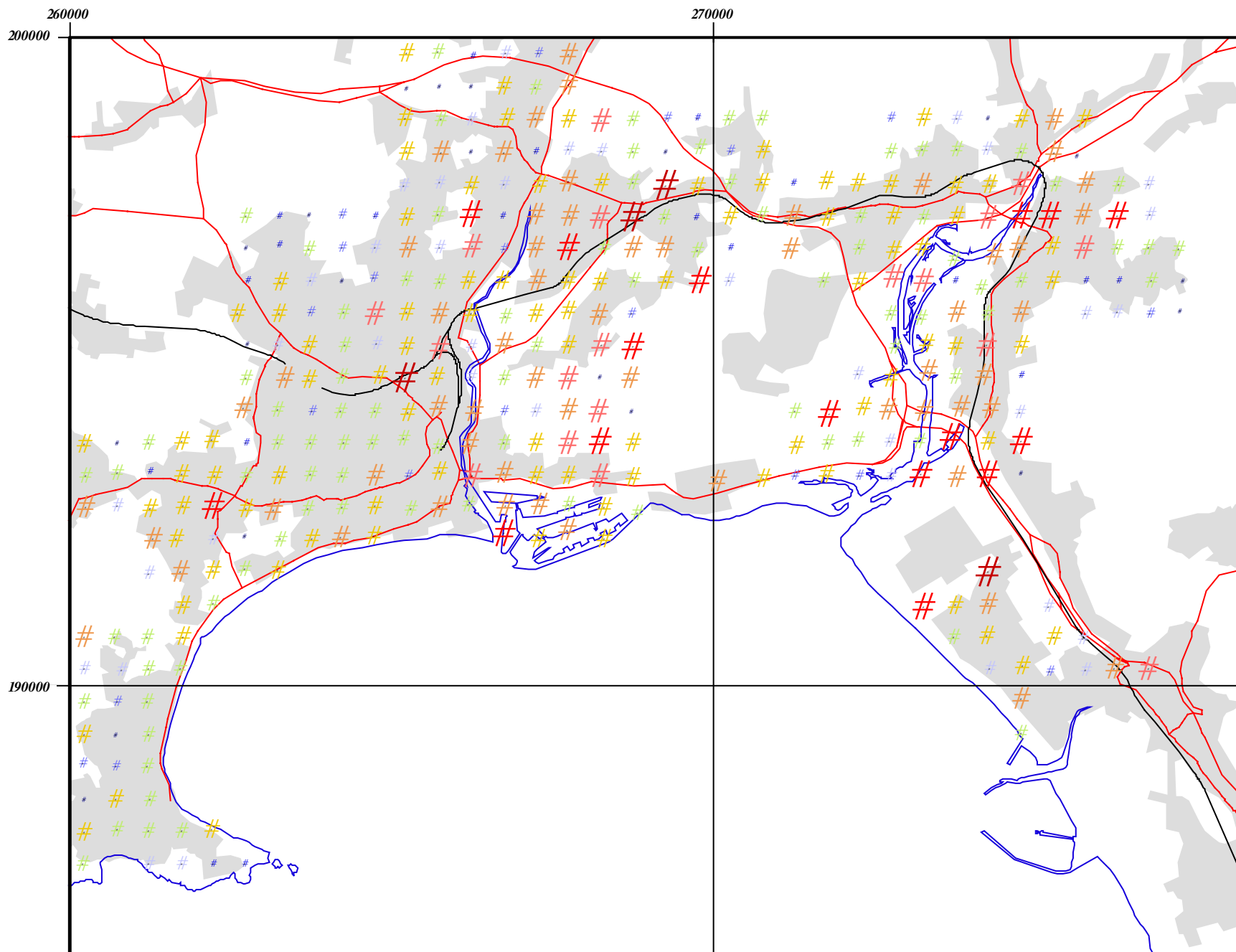
## Lead

%ile	#	ppm
99	#	5434
95	#	1979
90	#	1296
75	#	455
50	#	159
25	#	65
15	#	45
10	#	34
5	#	26



**Swansea  
Surface Soils  
Manganese**

%ile	#	wt%
99	#	0.352
95	#	0.251
90	#	0.205
75	#	0.154
50	#	0.122
25	#	0.088
15	#	0.068
10	#	0.056
5	#	0.036



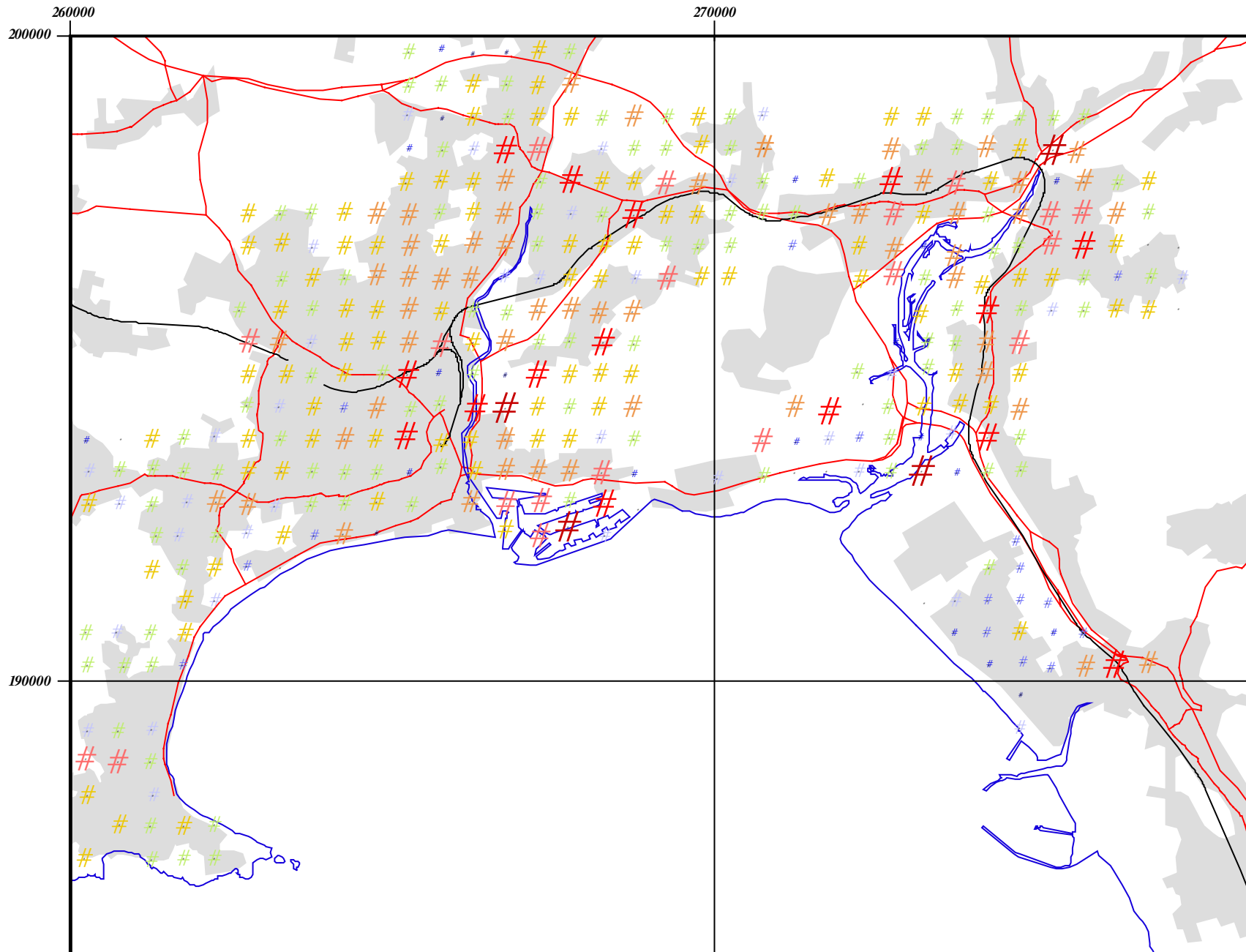
# Swansea Profile Soils

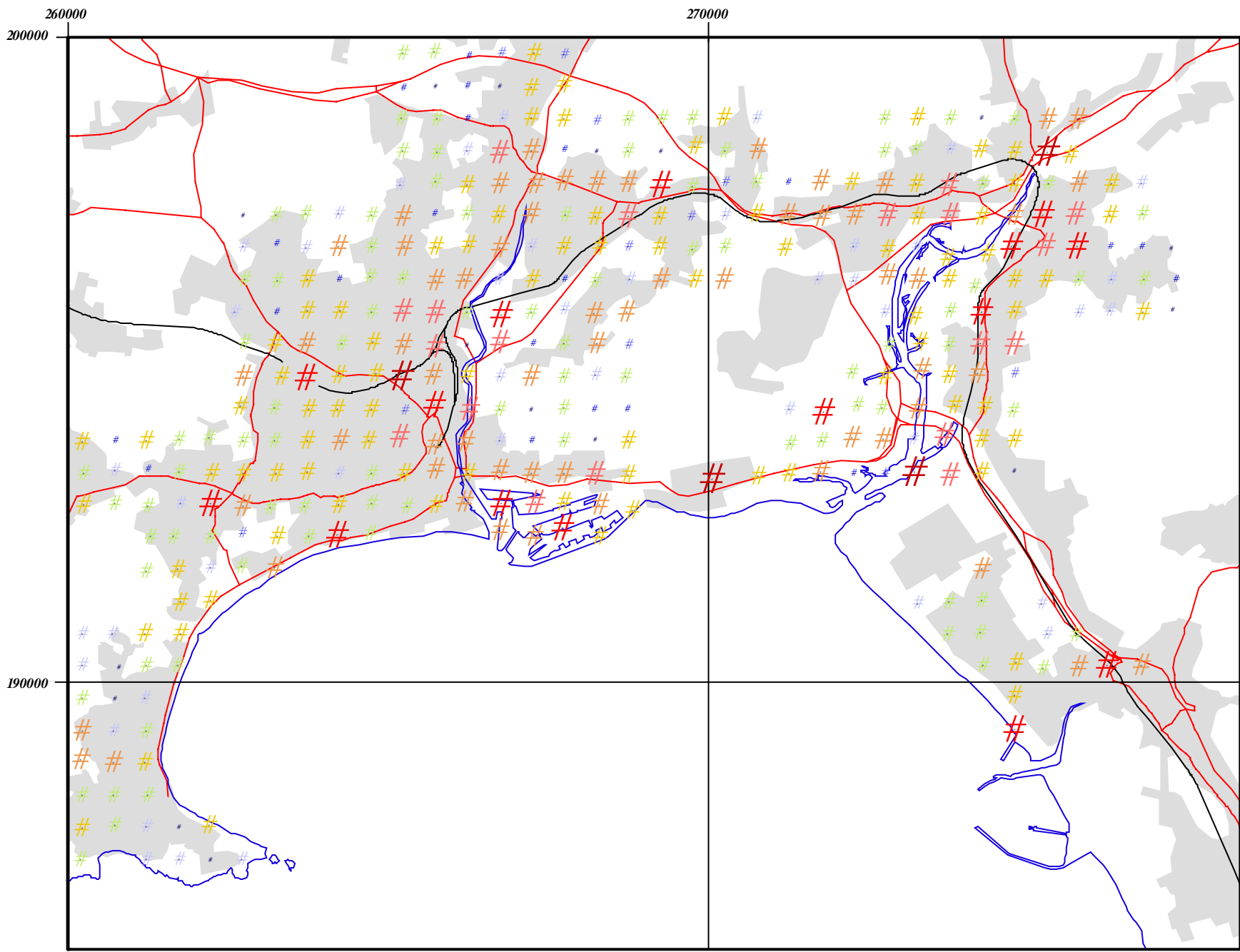
## Manganese

%ile	#	wt%
99	#	0.433
95	#	0.277
90	#	0.220
75	#	0.166
50	#	0.125
25	#	0.089
15	#	0.071
10	#	0.055
5	#	0.027

# Swansea Surface Soils

## Molybdenum



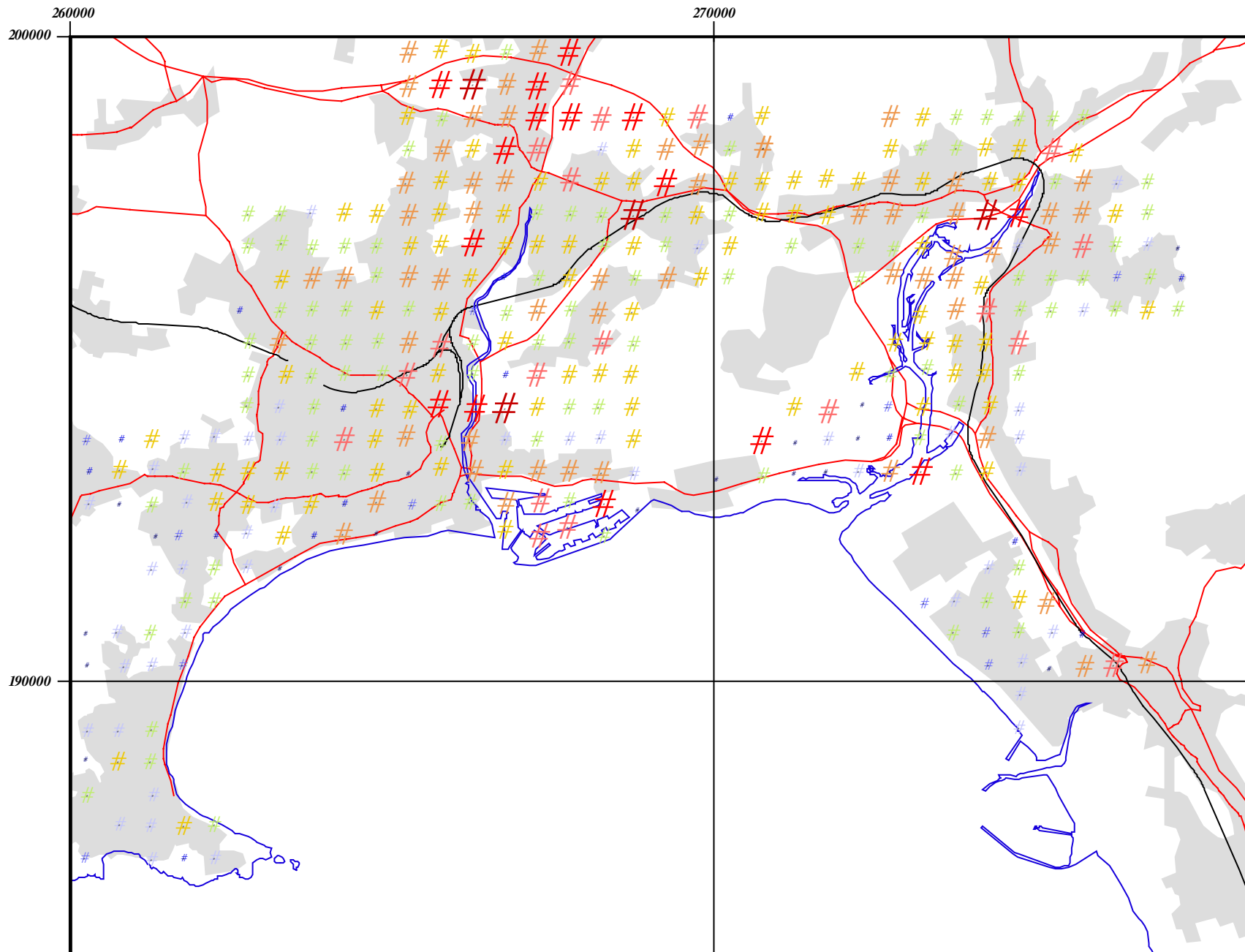


**Swansea  
Profile Soils  
Molybdenum**

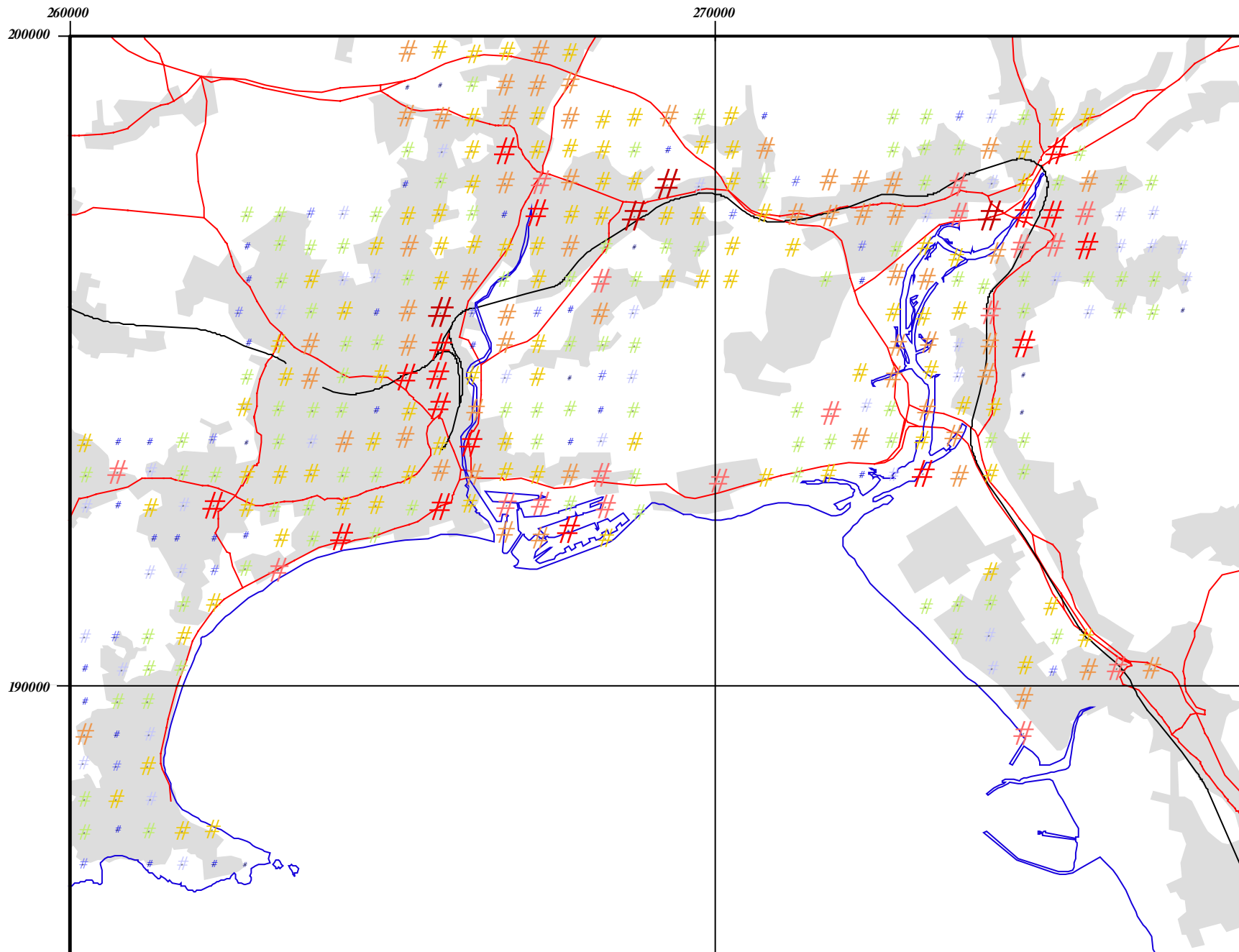
%ile	#	ppm
99	#	31.4
95	#	11.4
90	#	8.5
75	#	4.4
50	#	2.7
25	#	2.0
15	#	1.6
10	#	1.5
5	#	1.3

# Swansea Surface Soils

## Nickel



%ile	#	ppm
99	#	224
95	#	110
90	#	81
75	#	57
50	#	37
25	#	27
15	#	23
10	#	21
5	#	19



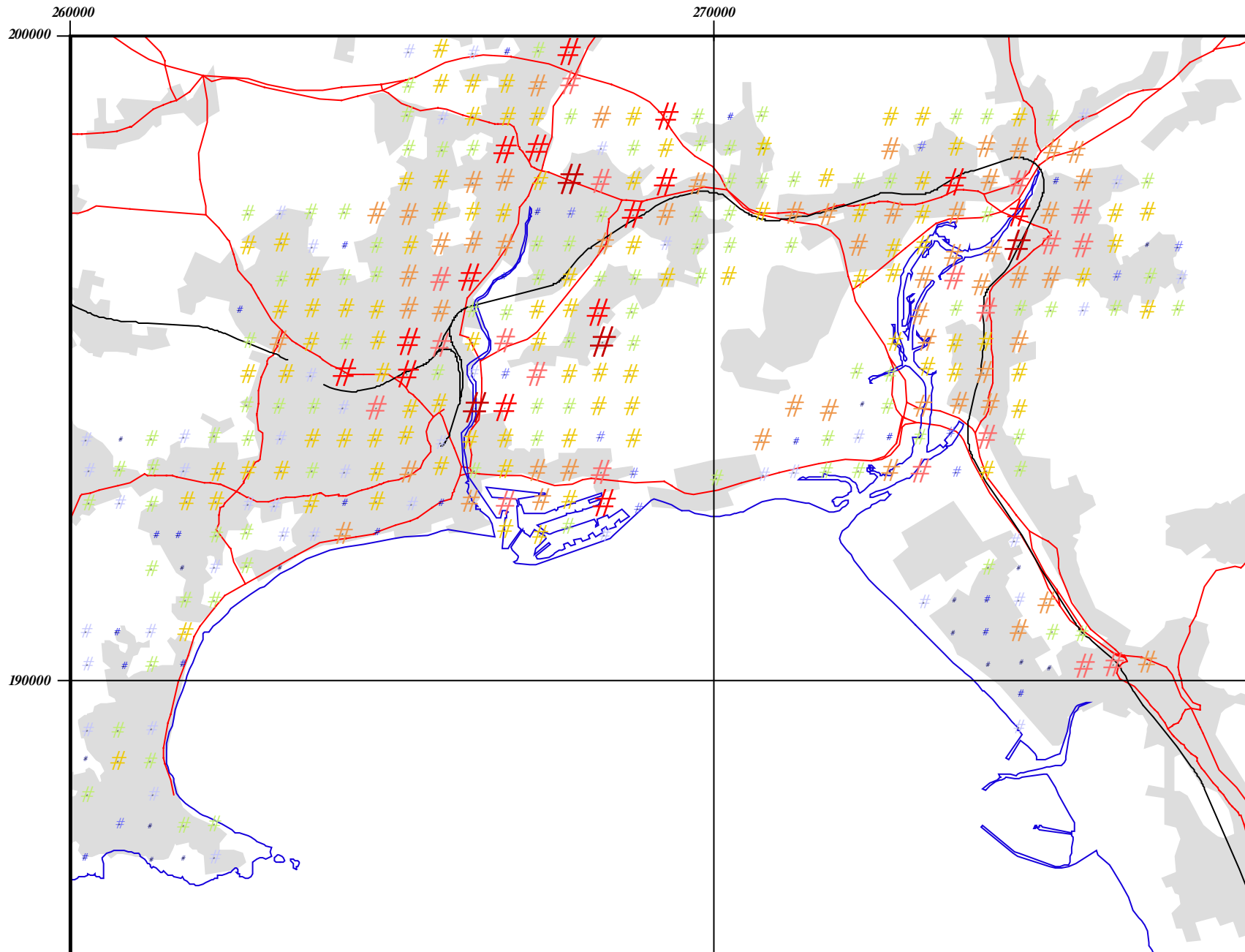
# Swansea Profile Soils

## Nickel

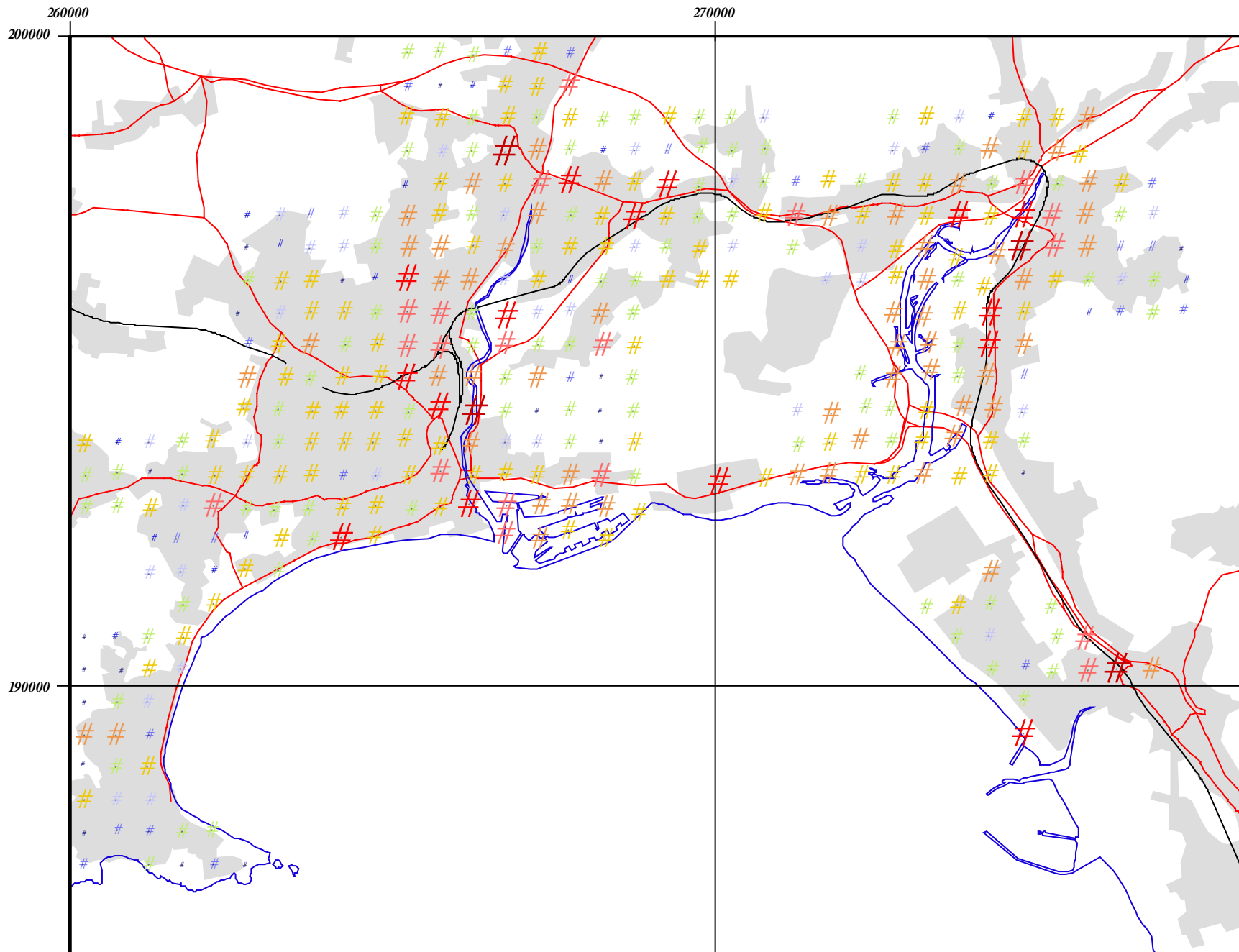
%ile	#	ppm
99	#	261
95	#	138
90	#	88
75	#	54
50	#	36
25	#	26
15	#	22
10	#	20
5	#	17

# Swansea Surface Soils

## Tin



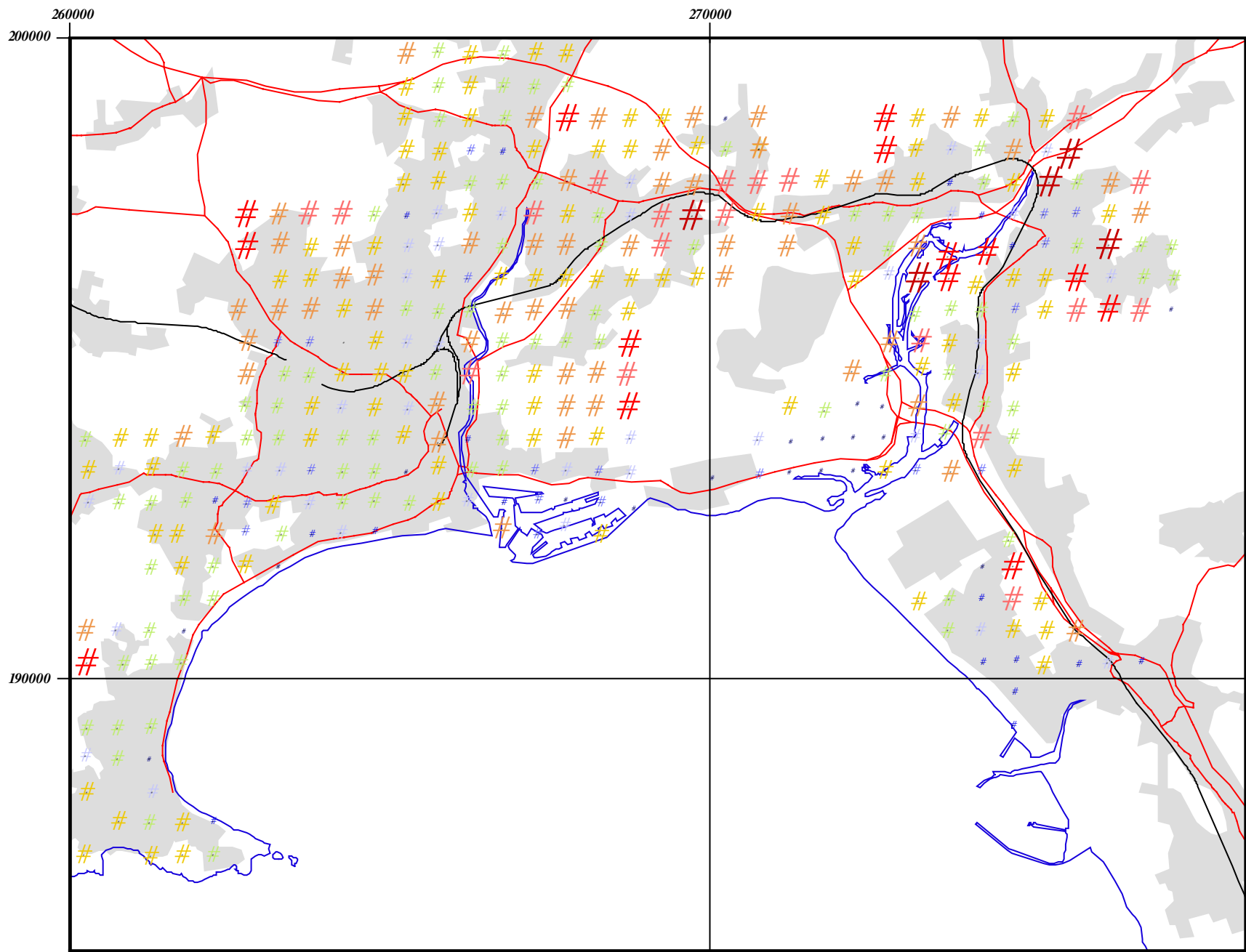
%ile	#	ppm
99	#	466
95	#	178
90	#	113
75	#	65
50	#	31
25	#	16
15	#	11
10	#	10
5	#	7



# Swansea Profile Soils

## Tin

%ile	#	ppm
99	#	799
95	#	231
90	#	128
75	#	53
50	#	21
25	#	11
15	#	8
10	#	6
5	#	5



# Swansea Surface Soils

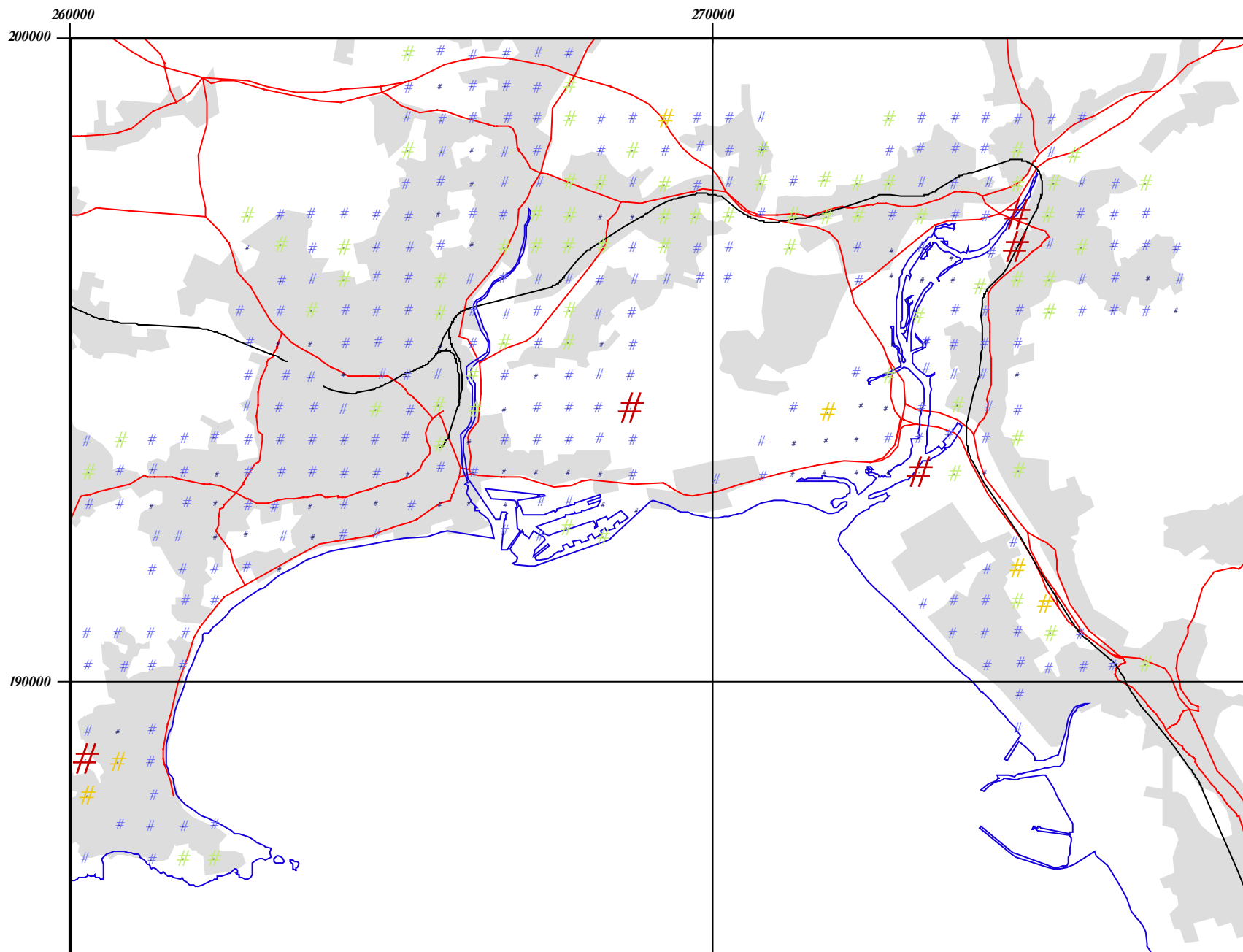
## Titanium

%ile	#	wt%
99	#	0.847
95	#	0.776
90	#	0.715
75	#	0.667
50	#	0.604
25	#	0.536
15	#	0.488
10	#	0.429
5	#	0.328

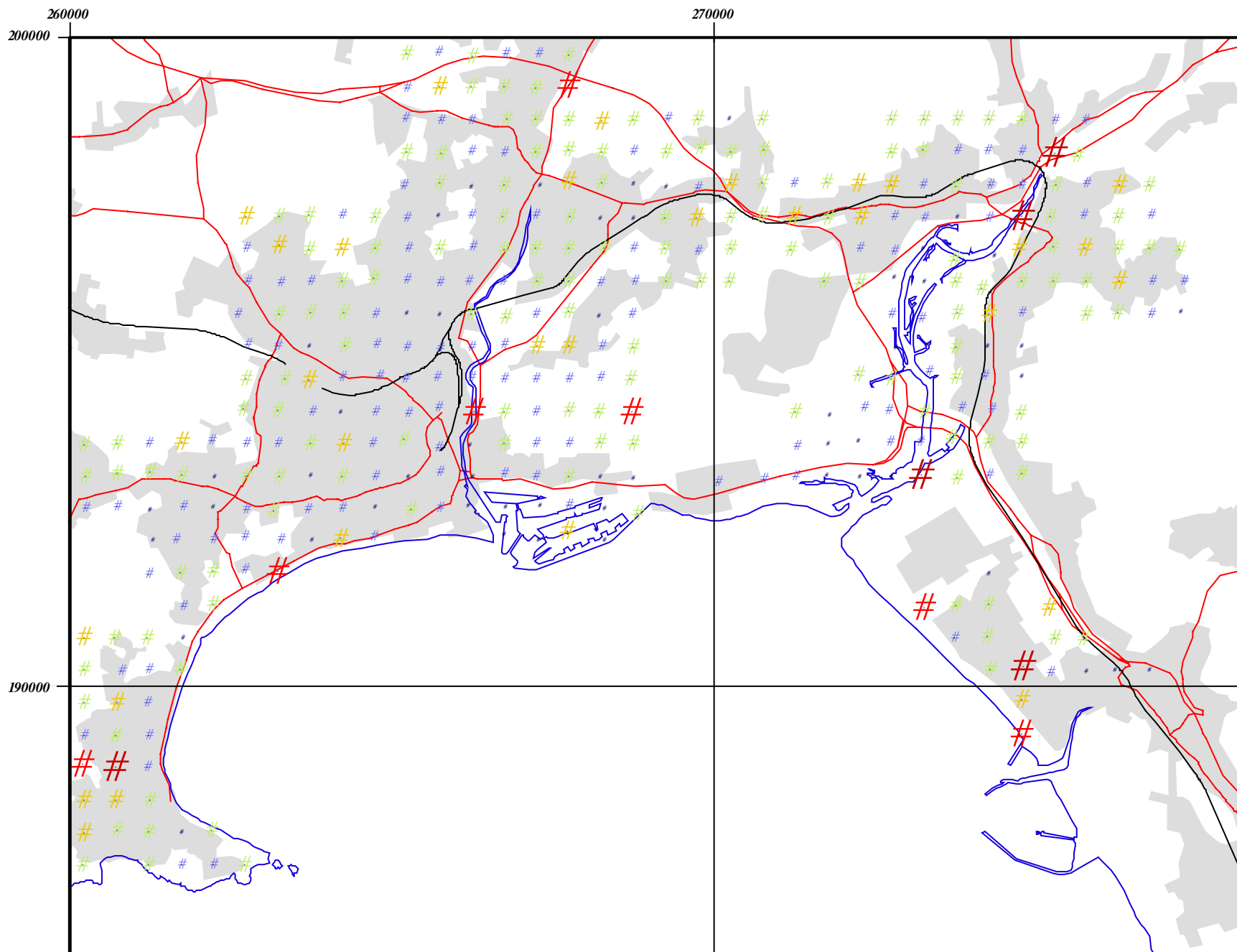
**Titanium Oxide has not been determined in the Profile Soils**

# Swansea Surface Soils

## Uranium



%ile	#	ppm
99	#	4
95	#	3
90	#	2
25	#	1



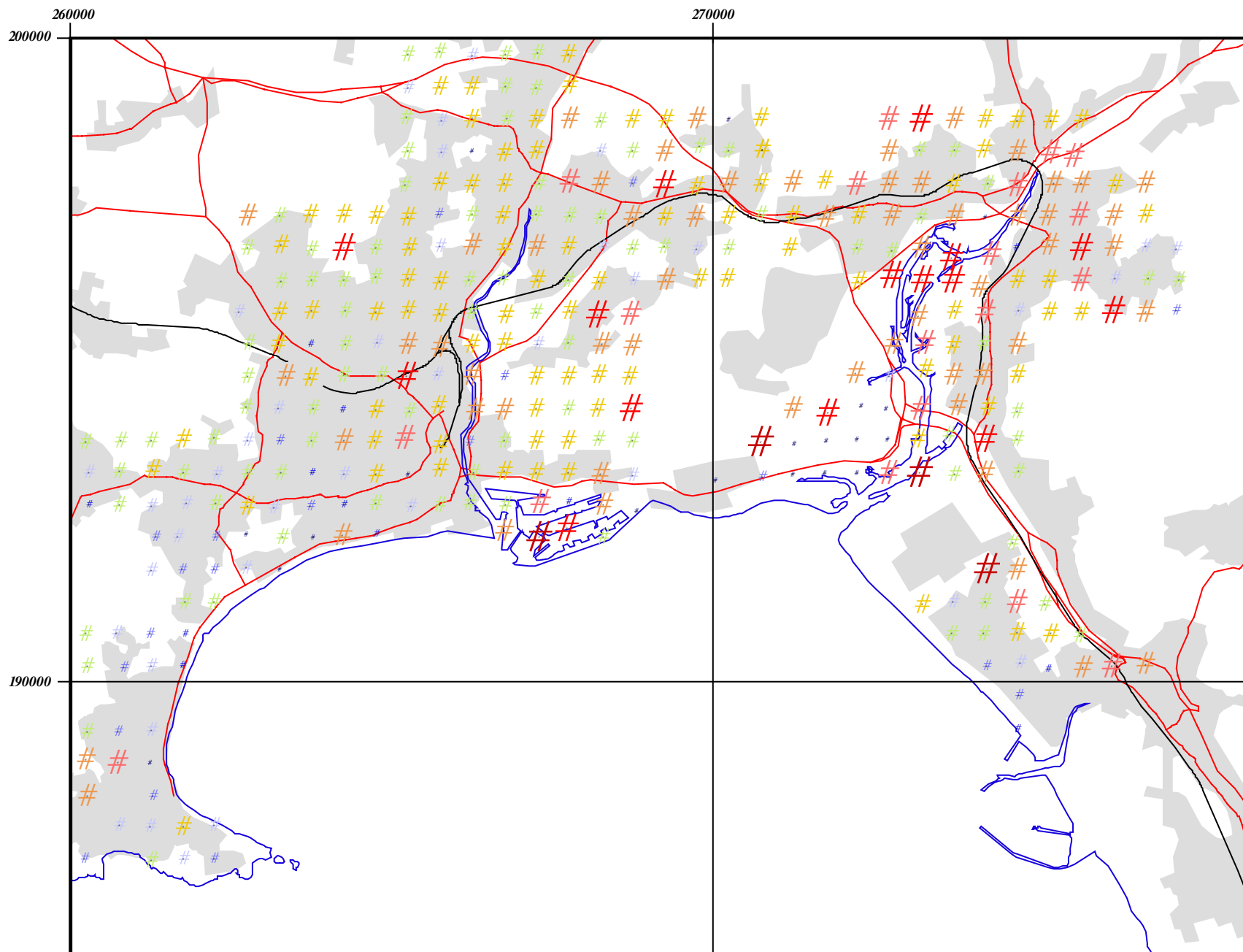
# Swansea Profile Soils

## Uranium

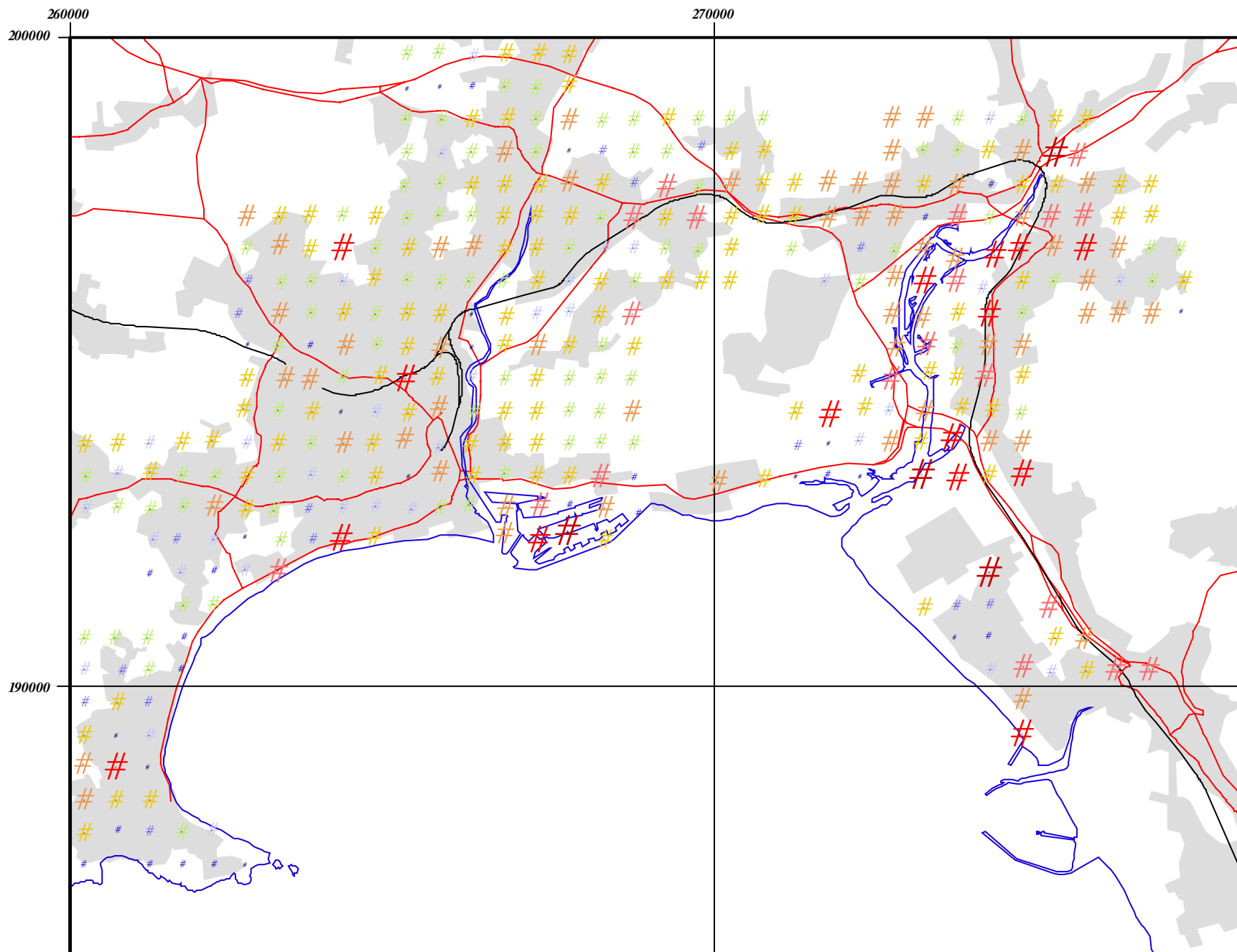
%ile		ppm
99	#	6
95	#	4
90	#	3
50	#	2
15	#	1

# Swansea Surface Soils

## Vanadium



%ile	#	ppm
99	#	201
95	#	146
90	#	123
75	#	98
50	#	85
25	#	75
15	#	70
10	#	67
5	#	61



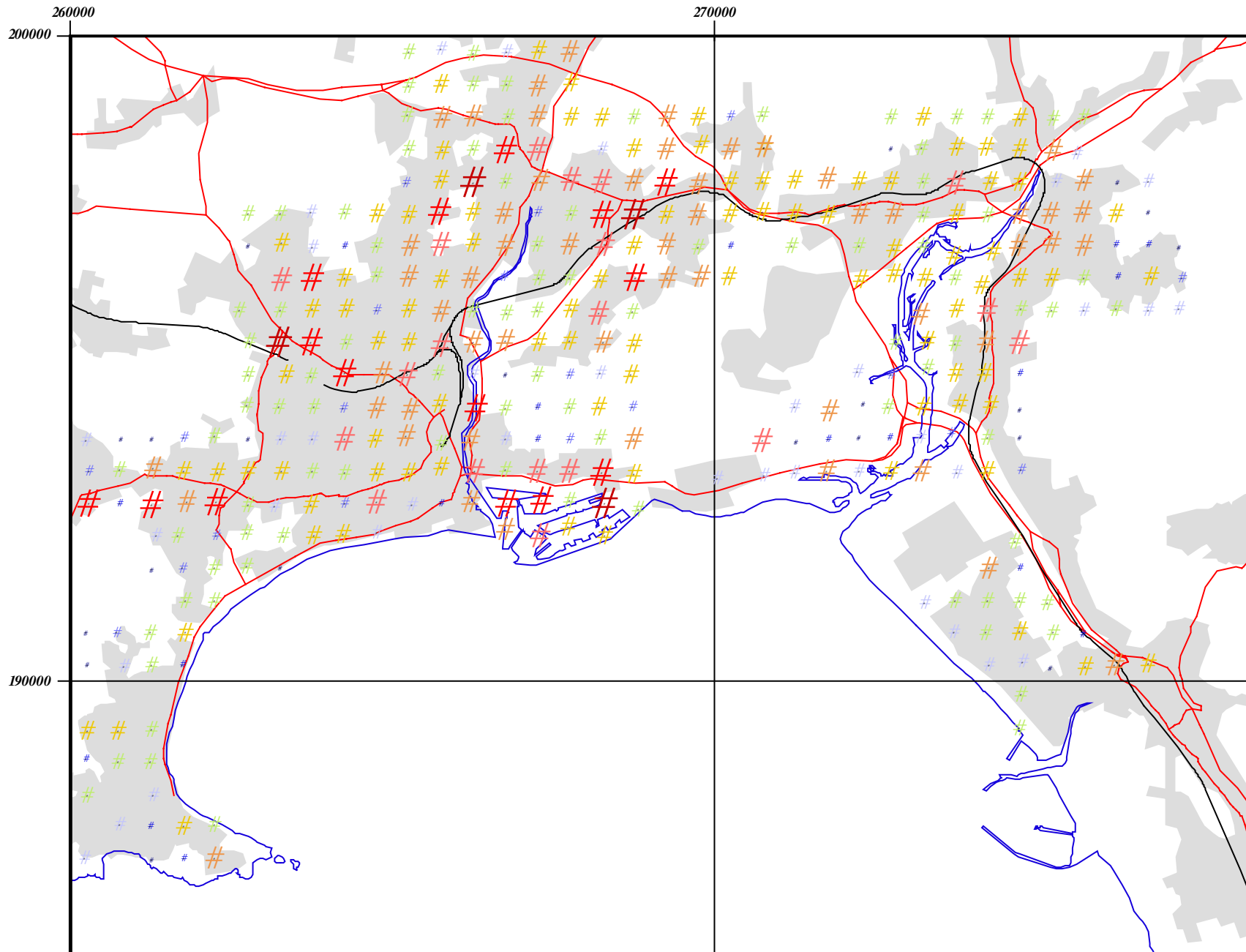
# Swansea Profile Soils

## Vanadium

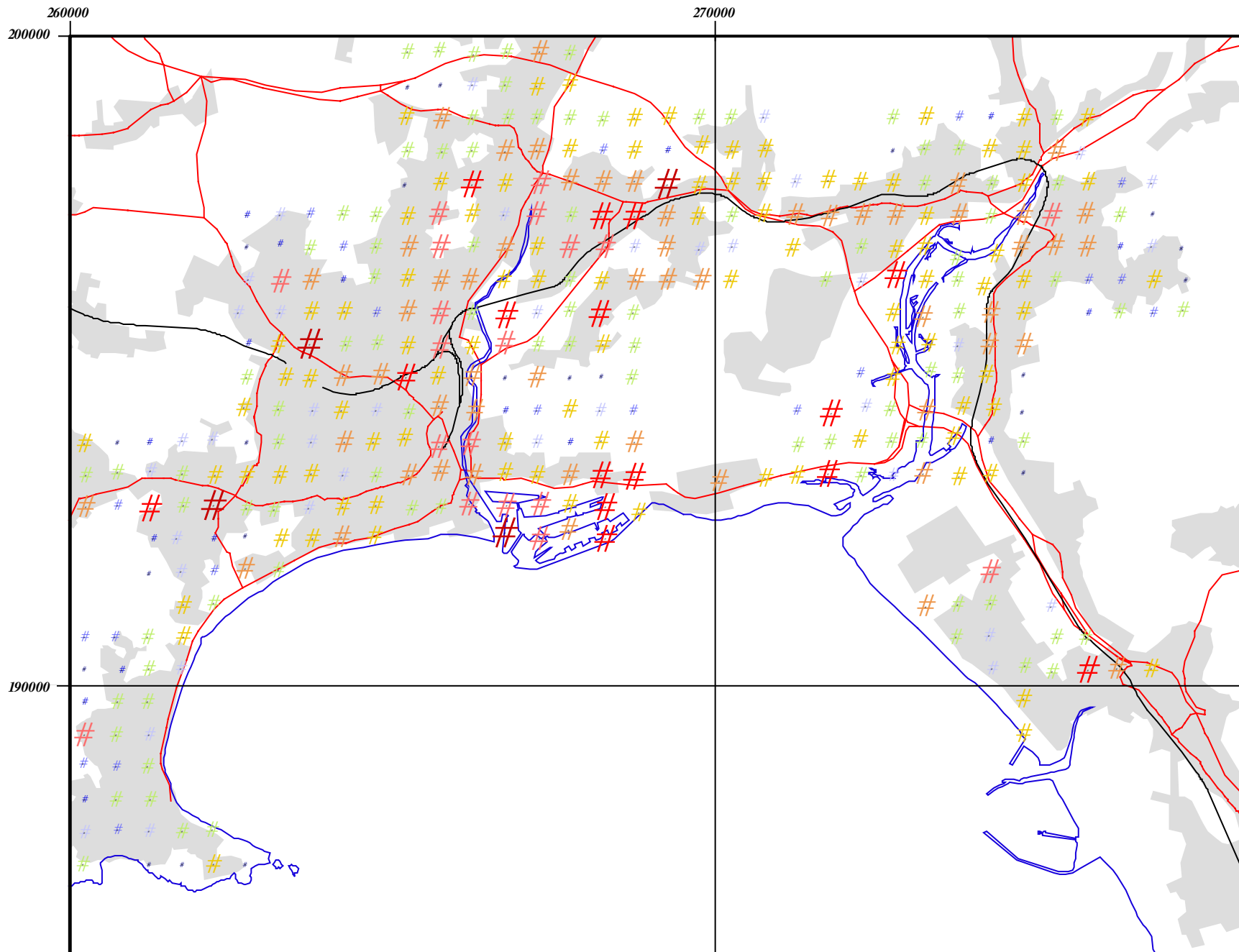
%ile	#	ppm
99	#	207
95	#	149
90	#	133
75	#	106
50	#	91
25	#	81
15	#	77
10	#	73
5	#	66

# Swansea Surface Soils

## Zinc



%ile	#	ppm
99	#	4425
95	#	1788
90	#	1250
75	#	608
50	#	316
25	#	164
15	#	123
10	#	106
5	#	82



# Swansea Profile Soils

## Zinc

%ile	#	ppm
99	#	9556
95	#	3023
90	#	1476
75	#	741
50	#	267
25	#	129
15	#	99
10	#	85
5	#	67