Hydraulics Research
Wallingford

HEAVY METAL TRANSPORT AND DISPERSAL BY MAINTENANCE DREDGING

A study of the River Tees and the Inner Disposal Site

A P Diserens, BSc
E A Delo, BSc, PhD, CEng, MICE, MIWEM

Report SR 235

March 1990

Registered Office: Hydraulics Research Limited,
Wallingford, Oxfordshire OX10 8BA.
Telephone: 0491 35381. Telex: 848552

CONTRACT

This report describes work funded by the Department of the Environment under Research contract PECD 7/7/224 for which the nominated officer was Mr C E Wright. It is published on behalf of the Department of the Environment, but any opinions expressed in the report are not necessarily those of the Funding Department. The work was carried out by Mr A P Diserens in Dr E A Delo's Section in the Tidal Engineering Department of Hydraulics Research, Wallingford under the management of Mr M F C Thorn.

ABSTRACT

The annual quantity of dredged material released into the coastal waters of the UK is in the order of 50 million tonnes per year. This quantity of material has the potential for considerable effect on the environment. Firstly the sediment itself is likely to have an adverse effect on the coastal environment by burying turbidite dwelling organisms and by changing substantially the sediment regime of the area. The pollutants associated with the sediment, in particular heavy metals, could also have considerable effect on the coastal environment. There is current concern over possible effects on the flora and fauna in the area of disposal activities. One area of particular concern is whether the metals adsorbed onto sediment dissolve in a fully saline environment. The United Kingdom has obligations, under international agreements to limit marine pollution resulting from disposal at sea of dredged material. The Food and Environment Protection Act (Part II) 1985 and through it, the Oslo and London Dumping Conventions will continue to have an increasing impact on the dredging contractors in the UK.

Metal pollutants enter an estuary in dissolved and particulate form, as a consequence of both natural processes and anthropogenic activities. The principal sources are river input at the tidal limits, freshwater run off and outfalls discharging from the banks and also from coastal waters on incoming tides. Sediments from areas of intense shipping and industrial activity tend to have higher metal concentrations of metals than those from less active areas. The increased concentration of metals can have adverse effects on the flora and fauna of the disposal site if it is 'bioavailable' (attached to ion exchange sites or incorporated into the organic or poorly crystalline phases of the sediment). The proportion of the metal which dissolves after disposal has been shown by previous workers to be insignificant. The bioavailable fraction however is of particular importance since anthropogenic metal input is often in a bioavailable form.

The Department of the Environment (DoE) commissioned Hydraulics Research (HR) to study the estuarine transmission of heavy metal pollutants in an attempt to determine the extent to which they are accumulated within an estuary or are passed out to sea and the factors affecting their transmission. This report is one of a series covering several aspects of this investigation.

The objective of the study was to monitor the concentration of metals in the bed sediments of the River Tees dredged channel and the associated disposal site and surrounding area, and to draw conclusions on whether or not the metals become dispersed after disposal in the coastal environment.

The River Tees is located in the North East of England on the North Sea coast. The estuary is of the partially mixed type, hence the estuarine sediments are likely to be a mix of fluviatile and marine origin. Dredging is carried out from 500m downstream of Newport bridge to the turning circle at the seaward end of the approach channel. The dredged material from maintenance dredging is disposed of at the inner disposal site and the dredged material from capital dredging is disposed of at the outer disposal site.

On recommendations from the earlier work, sampling on a grid of 10 by 10 at 1km intervals orientated north-east/south-west with an inner grid of 10 by 10 at 0.5km intervals was carried out. Samples from this grid were split into four size fractions <20µm, 20-63µm, 63-90µm and >90µm. Heavy metal analysis for the six metals studied previously, cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), lead (Pb) and zinc (Zn), was conducted on all except the greater than 90µm fraction.

Two subsequent surveys of the disposal area were undertaken, together with a comprehensive set of river samples. The <90µm fraction was analysed for ten metals, the six investigated previously Co, Cu, Fe, Mn, Pb and Zn, plus cadmium (Cd), chromium (Cr), nickel (Ni), and mercury (Hg).

A sequential extraction analysis was also carried out on a number of samples on the final survey to determine the amount of metal associated with each chemical phase of the sediment.

Copper, zinc, lead, cadmium, chromium and mercury were found to have higher concentrations in the dredged channel of the River Tees compared to the background metal concentrations. The concentration of each of these metals was higher in the bed sediment at the 2km by 2.5km Inner Disposal Site compared to the background metal concentration, but, lower than the average metal concentration on the disposed dredged material. The concentration of each metal was also higher than background outside the disposal site. Except, for mercury the metal concentration decreased with distance from the disposal site to the background level within the 10km by 10km survey area.

Iron, Manganese, Cobalt and Nickel were found to have similar concentrations to the background in the dredged channel of the River Tees and in and around the disposal site.

The study showed that the disposed material was transported from the disposal site. This was indicated by the distribution of <90µm fraction of the sediment. The high proportion of fines in the disposed dredged material was not found in the disposal site. Uncontaminated sediment was also being transported across the disposal site and mixing with the dredged material. The transport and mixing of sediment was considered to the cause of the reduction in metal concentration observed for copper, zinc, lead, cadmium, chromium and mercury with distance from the disposal site.

The change in speciation of metals on the sediments from the dredged river channel to the disposal site could not be accounted for by desorption or phase changes within the sediment. The increase in the residual fraction was probably due to the mixing with cleaner sediments and transport processes at the disposal site.

CONTENTS

TABLES

FIGURES

1 INTRODUCTION

1.1 Background

The annual quantity of dredged material released into the coastal waters of the UK is in the order of 50 million tonnes per year. This quantity of material has the potential for considerable effect on the environment. Firstly the sediment itself is likely to have an adverse effect on the coastal environment by burying turbidite dwelling organisms and by changing substantially the sediment regime of the area. The pollutants associated with the sediment, in particular heavy metals, could also have considerable effect on the coastal environment.

There is current concern over possible effects on the flora and fauna in the area of disposal activities. One area of particular concern is whether the metals adsorbed onto sediment dissolve in a fully saline environment. The United Kingdom has obligations, under international agreements to limit marine pollution resulting from disposal at sea of dredged material. The Food and Environment Protection Act (Part II) 1985 and through it, the Oslo and London Dumping Conventions will continue to have an increasing impact on the dredging contractors in the UK.

Metal pollutants enter an estuary in dissolved and particulate form, as a consequence of both natural processes and anthropogenic activities. The principal sources are river input at the tidal limits, freshwater run off and outfalls discharging from the banks and also from coastal waters on incoming tides. Sediments from areas of intense shipping and industrial activity tend to have higher metal concentrations of metals than those from less active areas. The increased concentration of metals can have adverse effects on the flora and fauna of the disposal site if it is 'bioavailable' (attached to ion exchange sites or incorporated into the organic or poorly crystalline phases of the sediment). The proportion of the metal which dissolves after disposal has been shown by previous workers to be insignificant (Ref 5). The bioavailable fraction however is of particular importance since anthropogenic metal input is often in a bioavailable form.

The Department of the Environment (DoE) commissioned Hydraulics Research (HR) to study the estuarine transmission of heavy metal pollutants in an attempt to determine the extent to which they are accumulated within an estuary or are passed out to sea and the factors affecting their transmission. This report is one of a series covering several aspects of this investigation.

Previous research by HR into the estuarine transmission of heavy metals includes extensive field studies in two contrasting estuaries-; that of the River Parret in Somerset (Ref 3) and that of the River Conway in North Wales (Ref 2). During 1981 HR carried out a pilot study of the River Tees followed by three further field studies of the estuary and disposal site during 1985 and 1986. These studies and a literature review are presented in Hydraulics Research Report SR 142 (Ref 4). This study is a continuation and development from the previous study of the river Tees.

1.2 Outline of study

The River Tees is located in the North East of England on the North Sea coast (Fig 1). The estuary is of the partially mixed type, hence the estuarine sediments are likely to be a mix of fluviatile and marine origin.

Dredging is carried out from 500m downstream of Newport bridge to the turning circle at the seaward end of the approach channel (Fig 2). The channel is dredged by Tees and Hartlepool Port Authority using two trailing suction hopper dredgers and a grab dredger. The dredged material from maintenance dredging is disposed of at the inner disposal site and the dredged material from capital dredging is disposed of at the outer disposal site (Fig 2). The annual dredged quantities from each section along the channel over the 10 year period from 1979 to 1988 area given in Table 1. The ten year average dredged quantity for the channel was 1.8 million in-situ cubic metres per year most of which is from maintenance dredging.

The objective of the study was to monitor the concentration of metals in the bed sediments of the River Tees dredged channel and the associated disposal site and surrounding area (Fig 2), and to draw conclusions on whether or not the metals become dispersed after disposal in the coastal environment.

Metals are not evenly distributed throughout the particle size range of the sediment, the metal concentration being found mainly in the clay and silt fraction (Ref 5). To enable a comparison of different samples some compensation has to be made for grain size differences between samples. There are a number of possible methods of compensating for grain size, these include: extrapolation from regression curves of concentration with percent below a certain grain size; correction for inert constituents eg. quartz; treatment with dilute acid and analysis of mobile fraction; comparison with conservative element; or separation of grain size by sieving.

It was decided that separation of grain size by sieving at 90µm would be the most cost effective method of compensating for grain size differences. 90µm was chosen since this is the break point used by MAFF (Ministry of Agriculture Fisheries and Food) in its sediment analysis and would enable comparison of results.

On recommendations from the earlier part of this study (Ref 3), sampling on a grid of 10 by 10 at 1km intervals orientated north-east/south-west with an inner grid of 10 by 10 at 0.5km intervals was carried out. Samples from this grid were split into four size fractions <20µm, 20-63µm, 63-90µm and >90µm. Heavy metal analysis for the six metals studied previously, cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), lead (Pb) and zinc (Zn), was conducted on all except the greater than 90µm fraction.

Two subsequent surveys of the disposal area were undertaken, together with a comprehensive set of river samples. The <90µm fraction was analysed for ten metals, the six investigated previously Co, Cu, Fe, Mn, Pb and Zn, plus cadmium (Cd), chromium (Cr), nickel (Ni), and mercury (Hg).

A sequential extraction analysis was also carried out on a number of samples on the final survey to determine the amount of metal associated with each chemical phase of the sediment.

2 DETAILS OF SURVEYS

2.1 Methodology

All samples in the study were taken using a 0.5L Van Veen Grab. Since the disposed sediment is likely to spread out on the sea bed as a thin layer a sub sample of the surface 20mm of the 100mm deep grab sample was taken for analysis. The samples were stored in plastic bags prior to analysis. Samples taken for speciation analysis were sealed in plastic bags and frozen to inhibit chemical processes such as the breakdown of organic material and the oxidation of sulphide compounds.

A four transmitter position fixing system operated by Tees and Hartlepool Port Authority was used for position fixing on all surveys.

2.2 Descriptions of surveys

Samples from the dredged channel and the disposal site and surrounding area had been taken during the previous study, from 1981 to 1986 (Ref 1). The concentrations of Cu, Zn, Pb, Fe, Mn, Co were found in the total sample. In the present study three sampling exercises were conducted. These took place in September 1987, September 1988 and March 1989.

The disposal site and surrounding area was sampled in September 1987 over a 10 by 10 grid orientated north-east/south-west. Samples were taken at 1km intervals covering a physical area of $81km^2$ centred on the disposal site (Fig 3). Samples were also taken over a finer grid with positions at 0.5km intervals located over the central $25km^2$ of the coarser grid. Samples of the dredged material were also taken from the dredger hoppers at the time of the survey. The samples were split into four size fractions, $<20\mu m$, $20-60\mu m$, $60-90\mu m$ and $>90\mu m$. The %mass of each fraction was found and the concentration of Co, Cu, Fe, Pb, Mn and Zn in each of the three finer fractions was determined.

In September 1988 the area was sampled over a 7 by 6km grid with similar sampling positions used for the 1987 survey extending over an area of $42km^2$ (Fig 4). The inner area once again was sampled at 0.5km intervals. Samples were also obtained from the dredged channel of the River Tees and approaches at 150m intervals along the centre line of the dredged channel from Newport Road Bridge to the Fairway Buoy. In addition, a number of samples were also taken from the dredgers. The samples were split at 90µm and the finer fraction analysed for concentration of 10 metals Co, Cu, Pb, Mn, Fe, Zn, Hg, Ni, Cd and Cr. The percent mass <90µm was also found for each sample.

The March 1989 sampling grid covered the same area as the 1987 survey, however the distance between the sampling points was increased from 1km to 1.5km on the outer grid and from 0.5km to 0.75km on the inner grid, thus halving the number of samples (Fig 5).

Samples were taken from a 7km dredged section of the estuary and also from the dredgers. Each sample was split at 90µm and the finer fraction analysed for metal concentration of 10 metals; Cd, Co, Cu, Pb, Mn, Fe, Hg, Ni, Zn and Cr. The percent mass of each sample <90µm was also found. A number of samples from both the estuary and disposal site were selected for speciation analysis. The samples were analysed for the percentage distribution of Cr, Cu, Pb, Zn and Mn in 6 chemical phases (see Appendix A).

3 SPATIAL DISTRIBUTIONS

3.1 Introduction

3.1.1 Form of presentation

The concentrations of each metal and percentage of each sediment size fraction were represented by three-dimensional isometric projections for the survey grid area (Figs 6-23). This enabled a visual assessment to be made of the distribution of each metal in each survey.

A representation of the metal concentrations along the centre line of the dredged channel was combined with the isometric projection for the March 1988 samples (Figs 14-23). The concentration of metal is denoted by height on the vertical axis. A running average of 3 samples was used.

Neighbouring samples in the river often had widely different concentrations. To compare the concentration of each metal along the dredged channel the average concentration within the area of each THPA chart (Fig 2) was calculated.

To enable trends within the disposal site and surrounding area to be seen more clearly the area was divided up into 9 smaller regions (Fig 2). These regions were: the disposal site, four inner regions (north east inner, north west inner, south east inner and south west inner) and four outer regions (north east outer, north west outer, south east outer and south west outer). The mean concentration of each metal in the <90µm fraction of the samples in each area was calculated.

3.1.2 Purpose of analysis

The visual comparison of the isometric plots enabled identification of anomalies in distribution. In particular any trend towards increased metal concentration in and around the disposal site was looked for as well as identification of local areas of high metal concentration.

The mean concentrations of metals within each of the 9 smaller regions were calculated to show general trends more clearly and to enable a comparison of each section of the river with the average concentration on dredged material. In addition this spatially averaged data enabled time effects to be shown more clearly.

A statistical summary of the metal distribution results is presented (Tables 10 and 11). The following statistics are given for the each metal in each data set: average concentration; standard deviation; coefficient of variation (standard deviation/mean); minimum concentration; maximum concentration and the ratio of the minimum to the maximum concentration.

3.2 Sediment size

3.2.1 Distribution in dredged channel

The bed sediments of the dredged channel of the River Tees were composed principally of fine material (<90µm) except for an area around the mouth of the river where some of the samples consisted of below 20% fine material (Table 7 and Fig 6). During storms large amounts of sand are deposited in this area. As a consequence the volume of material dredged from this section varies from year to year depending on the frequency and severity of storms.

3.2.2 Inner disposal site and surrounding area

The percentage of particles of <90μm diameter in the samples varied greatly over the surveyed area (Tables 1, 6 and 8). The samples nearest the coast (south west) consisted of more than 20% <90μm (Fig 6). The bed became increasingly fine grained towards 7km off shore from which it became more coarse again towards the north east edge of the survey area. The inner disposal site had on average less fines than the north west and south east regions. The disposal site had the largest variation in particle size with samples containing under 20% <90μm to over 80% <90μm. The percentage less than 90μm at any particular point was found to vary from year to year.

The distributions of the 0 to 20μm, 20 to 63μm, and 63 to 90μm fractions (Tables 2, 3 and 4 and Fig 7) showed similar trends in the survey area to that of the <90μm (Fig 6). The <90μm content of the samples varied from less than 5% on the south west edge of the survey area to greater than 75% south east and north west of the disposal site. The maximum proportion of the samples in the intermediate size ranges (20-63μm and 63-90μm) was approximately 40%.

The average percentage of <90μm sediment within each of the 9 regions (Fig 24) decreased towards the disposal site on a north west to south east transect. The north west inner region in which there are rock outcrops on the bed had around 25% fines. The percentage of fines was constant at approximately 30% on a south west south east transect except for the south west outer area (the area nearest the coast) where the percentage fines was between 10 and 20%.

3.3 Metal Concentrations

3.3.1 River Tees dredged channel

The metal concentrations in the dredged channel were highest in chart numbers 5 to 7. The concentrations decreased towards the river mouth. The lowest concentrations were found in the open water part of the dredged channel (charts 11 to 13) between the river mouth and the turning circle.

The metals showed two types of distribution. The concentrations of Fe, Mn, Co and Ni had low variation with coefficients of variation (standard deviation/mean) up to 0.45 whereas the concentrations of Cu, Zn, Pb, Hg, Cr and Cd had coefficients of variation above 0.55 (Table 7).

The concentration of each metal in each section of the river was averaged and represented as histograms (Figs 25 to 34). The concentrations of all metals, decreased from chart number 7 to chart number 13. Cu, Zn, Co, Ni, Fe and Mn all had highest concentration in the river between chart numbers 5 and 7. Pb, Hg, Cr and Cd had highest concentration near the upstream dredging limit (chart number 1).

3.3.2 Inner disposal site and surrounding area

The disposal site and surrounding area had lower coefficients of variation for Fe, Mn, Co and Ni, (below 0.35) whereas for Cu, Zn, Pb, Hg, Cr and Cd the coefficient of variation in concentration was generally higher (above 0.35). Hg showed the greatest variation.

Comparison of the averaged concentrations in the 9 regions of the disposal site and surrounding area

(Table 12, Figs 25 to 34) showed that in general the concentration of Cu, Pb, Zn, Hg, Cr and Cd decreased with distance from the disposal site. The concentration of Fe, Mn, Co and Ni however, showed no tendency to decrease away from the disposal site. The concentration of Fe, Mn, Co and Ni had only slight variation from region to region. This confirmed the visual observations of the isometric plots.

3.3.3 Influence of particle size

The average concentration of each metal on each size fraction is shown in Table 14. The average concentrations of Cu, Pb and Zn were higher in the finest fraction than in the coarser fractions, by a factor of 5 for Pb, 3 for Zn and 2 for Cu. In contrast the concentrations of Mn, Fe and Co showed less difference between size fractions of within a factor of two.

The samples from the dredger (Table 5) showed similar ratios; there was 6 times the concentration of Pb and Cu on the 0-20μm fraction than on the 63-90μm fraction, 4 times the concentration of Zn, 3 times the concentration of Co and less than twice the concentration of Mn and Fe.

The implications of this distribution are that the total concentration on the <90 micron fraction is dependant on the size distribution of the particles. This is more so for Pb, Zn and Cu than for Fe, Mn, and Co. Samples with a high proportion of sediment of 0-20μm size fraction will have proportionally higher concentrations of Cu, Zn and Pb when presented as concentration in <90μm fraction.

The isometric plots of metal concentration on each size fraction (Figs 7-12) showed that peaks of higher concentration existed in and near the disposal site for Cu, Pb and Zn for all size fractions, whereas, for Fe, Mn and Ni the distribution was more uniform. The peaks of high concentration were more pronounced in the <20μm fraction than the 20-63μm and 63-90μm fractions. The concentration of Cu, Zn and Pb in the 0-20μm fraction was higher in the disposal site than in the outlying areas, by a factor of 2 for Cu and Pb and by a factor of 1.5 for Zn (Figs 25 to 34). The concentration of Fe and Mn on the 0-20μm fraction was 10% higher in the disposal site than in the outlying areas. In the coarser fractions there was no trend to higher concentrations of Fe and Mn in the disposal site in these metals. Co showed no trend to higher concentrations in the disposal site in any size fraction.

3.3.4 <u>Comparison with dredged material</u>

From the 1988 survey, detailed information on the metal concentration in the dredged river was obtained. This information was used to derive an average concentration of each metal on the dredged material. The average concentration of each metal on the dredged material was calculated from the 1979-1988 average dredged quantity (Table 9) and average metal concentrations for each section of the river, represented by a THPA chart number (Fig 2), using a weighted average method.

A background metal concentration of each metal was estimated from the metal concentrations in the samples from the dredged channel between the mouth of the River Tees and Fairway Buoy (ie chart numbers 10 to 13). This material was assumed to have originated from the coastal area and would be likely to be lower in pollutants than the river. The background metal concentration was assumed to be representative of the natural metal concentrations in the disposal site and surrounding area.

The average concentration of each metal in the disposal site was compared with the average concentration on the dredged material and the background metal concentration in order to evaluate the degree of dispersal or mixing.

The average concentration of Hg, Pb, Cu, Cd, Cr and Zn in the dredged material was far greater than the background concentration (Table 12 and Figs 25a-34a). The average concentration of Fe, Mn, Ni and Co on the dredged material was only slightly higher than the background concentration (Table 12).

The average metal concentration in the disposal site for all the metals was between the average metal concentration on the dredged material and the background concentration. The metal concentration in the disposal site can be given as:

$$C_s = C_b + E_f\,(C_d - C_b)$$

where

C_s = metal concentration in the disposal site

C_b = background concentration

C_d = average metal concentration on the dredged material

E_f = enrichment factor (typically between 0 and 1).

The enrichment factor of the metals Cu, Zn, Pb, Cd, Cr and Hg in each of the regions are given in Table 13. Hg had the highest enrichment factors which in some instances exceeded 1. The enrichment factor for these metals on average decreased in magnitude away from the disposal site and reached values close to zero in the outer regions.

3.4 Discussion

3.4.1 General

Natural spatial variation in the concentration of metals in bed sediments is expected. Variation in metal concentration within source material of the sediment, sorting of the sediment by transport processes, chemical and biological effects can all influence the spatial distribution (Ref 5).

The average concentration of the metals investigated (Cu, Zn, Pb, Fe, Mn, Co, Cd, Cr, Ni and Hg) were in the same order of magnitude as the natural occurrence concentration (Ref 6) of the metals (Table 15). Fe being present in highest quantities followed by Mn, Zn, Pb, Cu, Cr, Ni, Co, Cd and Hg. The chemical properties of each particular metal influence the concentration of the metal in each particle size fraction and the concentration of the metal in each chemical phase of the sediment. A high concentration of metal in the silt fraction of a particular sample does not necessarily indicate anthropogenic contamination, it may simply be due to natural processes (Ref 5).

Natural chemical effects can concentrate metals in the surface layers of deposited sediments. Metal ions can diffuse through and be transported by upward moving pore water in consolidating sediments. When the dissolved ions reach oxic surface layers of sediment a change in the chemical conditions results in precipitation of the metal. As the sediment accretes the oxic layer moves up within the sediment and the metals move up with it. Hence, surface layers of sediment very often have higher concentrations of metals than the underlying layers.

3.4.2 <u>Particle size distribution</u>

The particle size distribution in the dredged channel is in itself caused by a combination of both physical and chemical effects. Fine sediment will accumulate in the tidal part of the river where the hydrodynamic environment is less energetic than the river above the tidal limit and the wave influenced coastal area. The changing chemical conditions where fresh river water mixes with saline water can result in precipitation from solution of dissolved particles and the flocculation and deposition of suspended material adding to the fine fraction of the sediments.

In the disposal site and surrounding area a more even distribution of fine sediment would be expected if there was no disposal of dredged material since chemical and hydrodynamic conditions vary little over the area. The south west area nearest the coast had the lowest percentage of fine particles. This is most likely because it is the shallowest area and would consequently be subjected to the highest hydrodynamic energy from wave effects. The higher percentage of fines found in the north west and south east areas is less easily explained but is likely to be due to a combination of bathymetric effects and the characteristics of underlying material.

The most notable characteristic of the distribution of fine material was that the percentage of fines in the disposal site was only half that in the dredged material. This could be due to one or all of three factors: the dredged material is mixing quickly with the surrounding sediments; the dredged material is removed from the area by mass erosion; and, the true proportion of fines in the dredged material is far lower than that estimated. A combination of the first two is considered to be resulting in the observed effect.

3.4.3 Spatial distribution of metal concentrations

The higher concentration of all metals within the finer fraction of each sample was also found in river sediments by Salomons and Forstner (Ref 5). This trend is likely to be enhanced by anthropogenic input since pollution is often in the form of fine particles or solution.

The distribution of metals on the fine fraction of sediments from the dredged channel showed a peak of higher concentration for all metals studied between chart numbers 5 and 7 (Fig 2). Generally lower concentrations were observed at the seaward end of the dredged channel (chart number 13). Hg, Cr and Cd had highest concentrations at the landward end of the dredged channel (chart numbers 1 and 2).

The peak concentration of Fe and Mn oxides in chart numbers 5 to 7 may be explained by the cycling of these metals noted by Salomons and Forstner (Ref 5). Fe and Mn are transported landward by a combination of chemical and hydrodynamic processes and are deposited at the freshwater salt water interface as hydrous oxides. The peaks of the other metals, Cu, Zn, Pb, Hg, Co, Ni, Cr and Cd, in these sections of the river can be attributed to the scavenging of these metals by the Fe and Mn hydrous oxides.

Pb, Hg, and Cr had particularly high concentrations in chart number 1, the upstream end of the dredged channel. This could be due to sediments containing high concentrations of these metals being brought down the river from far upstream. The lower concentrations at the seaward end of the river could be due to mixing of the river sediments with marine sediments containing lower concentrations.

The metals which have significantly higher average concentrations in the dredged channel compared with assumed background metal concentrations also have high concentration in the disposal site and surrounding area. This is most likely a result of the disposal of dredged material.

The calculated enrichment factors indicated that the area of elevated concentrations of Hg, Pb, Cu, Cd, Cr and Zn were generally contained within the boundary of the 10km by 10km survey area.

3.4.5 Changes over monitoring period

The peaks of high concentration in and close to the inner and outer disposal sites were not consistent in size or position from one year to the next. This is possibly due to unrepresentative samples (in some instances the peaks were due to one sample). The change of position of the peaks could be accounted for by movement of the polluted sediment. The disappearance of peaks could be due to desorption of ions into solution, mass erosion of the polluted sediment or recent disposal of unpolluted sediment. Appearance of new peaks could be caused by disposal of polluted sediments or re-exposure of previously polluted sediment. It is unlikely that sediment containing high concentrations of sediment is being brought into the area by natural processes.

Processes which can account for this are the release of metals from the sediment into solution or mass erosion of the polluted sediment out of the area.

4 SPECIATION OF METALS

4.1 Scope of work

Teesside Polytechnic conducted a sequential extraction analysis on selected samples from the dredged channel and the disposal site and surrounding area (March 1989 survey). The objective was to determine the species in which the metals were present before and after disposal. The speciation in samples from the dredged channel (assumed to be representative of sediment before disposal) was compared with the speciation of samples from the disposal site and surrounding area.

The percentages of Cu, Cr, Pb, Zn, Mn, Ni and Co were determined on each chemical fraction. The concentrations of Co however proved to be too small to detect.

4.2 Analysis and results

A five stage extraction procedure was used for which the details and results are given in Appendix A. The results of the speciation indicated that the bulk of the metals in the dredged channel were incorporated into the easily reducible fraction of the sediment. In the samples from the disposal site and surrounding areas greater diversity was found. Metal concentration in the residual phase varied between 5% and 60%, in the oxidizable phase from between 2% to 50%, in the moderately reducible phase from between 2% to 60%, and in the easily reducible from between 5% to 80%. The proportion present as exchangeable ions was never greater than 5% in any of the samples.

The average total concentrations of each metal in the samples from the dredged channel, dredger hoppers and the disposal site and surrounding area are given in

Table 2 of Appendix A. The disposal site samples had almost the same concentrations of Ni and Mn as the dredged channel. The average concentrations of Cu, Zn, Pb and Cr were much less in the disposal site than the dredged channel (0.3, 0.2, 0.3 and 0.1 times respectively).

4.3 Discussion

In the dredged channel samples a high proportion of the metals was associated with the easily reducible phase of the sediment. This is contrary to what has been found in other estuaries (Refs 7 and 8). The March 1989 samples were taken from a part of the dredged channel where the majority of the sediment was fine grained. Fine grained particles consist of hydrous oxides of Fe and magnesium with clay minerals. A possible explanation for the majority of the metals being incorporated into the easily reducible fraction is that oxidising conditions prevail in the upper layers of the sediment, which was sampled only to a depth of 100mm. Hence, any Fe and Mn present in the fine particles occur as hydrous oxides. These hydrous oxides would be rich in other metals, which would be incorporated into their lattice structure and attached to ion exchange sites on the particle surfaces. In addition any carbonates present would be included in this phase since the extraction involved use of weak acid.

A lower proportion of the metal was found in the easily reducible fraction of the sediment in the disposal site and surrounding area. The possible chemical processes which can account for the change are that the easily reducible fraction becomes dissolved and released from the sediment or undergoes reduction and becomes part of the oxidizable fraction. These processes however cannot account for the large increase in metal associated with the residual fraction, particularly in the case of Mn and Ni where the total concentration of metal is no different in the disposal site than the dredged channel. The most likely processes accounting for the differences in speciation are mass erosion of the fine grained disposed sediment and mixing of the disposed sediment with sediment from the surrounding area which has a higher proportion of sand (residual and moderately reducible fractions).

5 CORRELATION OF METAL CONCENTRATIONS

5.1 Analysis

Linear regression analysis was carried out on metal concentrations on the samples from the disposal site and surrounding area for the September 1987, June 1988 and March 1989 surveys as well as the dredged channel samples taken in June 1988.

The degree of correlation was expressed a probability percentage that the there is a relationship between the two data sets. The degree of correlation of the distribution of each metal with each other metal and with particle size was found for each data set.

5.2 Results

5.2.1 <u>River Tees dredged channel</u>

Tables 16 and 17 give the results of the regression analysis of the dredged channel samples taken in June 1988.

The metals which displayed the lowest variation in concentration (Fe, Mn, Co, Ni), had in most instances high correlation with each other. Co and Ni showed high correlation with each other as did Mn with Co and Ni. In contrast, there was no significant correlation between Co and Fe and a high negative correlation between Ni and Fe in this data set.

The metals which had highest variation and peaks in metal concentration charts 5 to 7 of the river (Cu, Zn, Pb and Cd) had high correlation with each other. Cu, Zn and Cd also had high correlation with Mn. Hg and Cr which had peaks of high concentration in charts 1 and 2 had high correlation with each other. In contrast, high negative correlation of Hg and Cr with Co and Ni occurred.

There was also high correlation between the %silt and Cu, Zn, Pb, Cd, Co and Ni.

5.2.2 Disposal site

The samples from the September 1987 and June 1988 were consistent in having high correlation between Cu, Zn and Pb. There was also high correlation between Fe and Mn. Fe had high correlation with Cu, Zn and Pb, whereas, Mn had low correlation with these three metals in both data sets. Mn had low correlation with all metals except Co, Ni and Fe in 1988 (Tables 16 and 17).

The March 1989 data set was characterized by low correlation between most pairs of metals, in contrast the September 1988 data set had high degrees of correlation in most instances (Tables 16 and 17).

5.2.3 Disposal site and surrounding area

Cu, Zn and Pb had high correlation with each other in all three data sets except for Cu and Pb in March 1989. Mn, Fe, Co and Ni also had high correlation with each other, except for Mn with Co and Mn with Ni in the March 1989 data set. Co and Cd had high correlation with Cu, Zn and Ni in both the 1988 and 1989 samples. Cr and Hg were characterised by high correlation with Cu, Zn, Pb and Cd and high correlation with each other in 1988, but, low or no correlation with any metal including each other in 1989 (Tables 16 and 17).

5.3 Discussion

In nature, the modes of occurrence and chemical behaviour of all the metals are broadly similar. The most common form of all the metals is as divalent or trivalent cations. Fe and Mn are exceptions in that they can change their oxidation state. They are stable in oxidation state 2+ at low Eh, whereas at high Eh, Fe is stable as 3+ and Mn as 4+. Fe and Mn are the most abundant of the metals studied and are usually in the form of hydrous oxides.

Common secondary minerals such as clay minerals and hydrous oxides of Fe and aluminium can incorporate ions of other metals within their lattice structure as they form as well as on surface exchange sites. Hence, samples with high proportions of these secondary minerals (present as fine particles) will also have relatively high concentrations of other metals, this would explain high correlations between Fe, Mn and other metals.

The correlation between Fe and Mn was consistently high and shows that both metals have similar distribution which was expected from similarity of their chemical behaviour described above.

The correlation of Fe and Mn with Co and Ni was generally also high. The correlation with the other metals Cu, Zn, Pb, Cr, Cd and Hg was much lower.

The metals with higher concentrations in the river than the background, Cu, Zn, Pb, Cr, Cd and Hg, had generally quite high correlation with each other in all data sets. The most likely reason for this is that the high concentrations are on the same samples in the river for many of the metals and that the paths of dispersion, once disposed are the same for all of the metals. The low correlation of Hg and Cr with other metals in March 1989 could be due to the disposal of material with exceptionally high concentrations of these two metals. Such material is found at the upstream end of the dredged channel (Figs 29 and 32).

6 CONCLUSIONS

1. Copper, zinc, lead, cadmium, chromium and mercury had higher concentrations in the dredged channel of the River Tees compared to the background metal concentrations. The concentration of each of these metals was higher in the bed sediment at the 2km by 2.5km Inner Disposal Site compared to the background metal concentration, but, lower than the average metal concentration on the disposed dredged material. The concentration of each metal was also higher than background outside the disposal site. Except, for mercury the metal concentration decreased with distance from the disposal site to the background level within the 10km by 10km survey area.

2. Iron, Manganese, Cobalt and Nickel were found to have similar concentrations to the background in the dredged channel of the River Tees and in and around the disposal site.

3. The differences in concentration of Copper, Zinc and Lead were excentuated in the 0-20μm fraction. However, the overall trend was the same as in the <90μm fraction is the same. The concentrations of Iron, Manganese and Cobalt showed no particular trend, i.e. they were reasonably constant across the survey area.

4. The study showed that the disposed material was transported from the disposal site. This was indicated by the distribution of <90μm fraction of the sediment. The high proportion of fines in the disposed dredged material was not found in the disposal site. Uncontaminated sediment was also being transported across the disposal site and mixing with the dredged material. The transport and mixing of sediment was considered to the cause of the reduction in metal concentration observed for copper, zinc, lead, cadmium, chromium and mercury with distance from the disposal site.

5. The change in speciation of metals on the sediments from the dredged river channel to the disposal site could not be accounted for by desorption or phase changes within the sediment. The increase in the residual fraction was probably due to the mixing with cleaner sediments and transport processes at the disposal site.

7 ACKNOWLEDGEMENTS

The cooperation and assistance given by the Tees and Hartlepool Port Authority in carrying out the sample retrieval and their general support throughout this study is gratefully acknowledged.

Carolyn Davis under the supervision of
Dr Tom Stephenson carried out the metal speciation analysis at Teesside Polytechnic.

8 REFERENCES

1. Dredged spoil in tidal waters, research summary. Hydraulics Research Report SR 199, January 1989.

2. Estuarine transmission of heavy metal pollutants: data collection from the River Conwy, North Wales, Hydraulics Research Report SR 15, January 1985.

3. Burt T N. Estuarine Transmission of Pollutants, Progress report on studies of the River Parret, Hydraulics Research, 1981.

4. Delo E A and Burt T N. Heavy metal transport and dispersal by maintenance dredging: A study of the Tees. Hydraulics Research Report SR 142, May 1988.

5. In Metals in the hydrocycle, Ed Salomons W, Forstner U, Springer Verlag, 1984.

6. Krauskopf K B. Untraced. 1967.

7. Calmano W and Wellershaus S, Dredging of Contaminated Sediments in the Weser Estuary: Chemical forms of some metals, Environmental Technology Letters Vol. 3, pp199-208, 1982.

8. Salomons W and Forstner U, Trace Metal Analysis on Polluted Sediments, Part II: Evaluation of environmental impact. Environmental Technology Letters Vol. 1, pp506517, 1980.

TABLES

Table 1 Sample positions and metal concentrations, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%<90	CU	ZN	PB	FE	MN	CO	REGION
462470	534336	R0	19	136	274	152	35104	406	15	2
462117	533983	R1	75	112	263	149	35947	425	14	2
461763	533629	R2	29	91	226	110	35082	386	12	8
461410	533276	R3	39	191	361	185	37668	456	15	8
461056	532922	R4	37	117	229	123	34220	395	13	8
460703	532569	R5	15	115	243	116	31413	385	9	8
460349	532215	R6	5	103	223	61	30176	458	8	8
462824	533983	R10	28	124	218	132	33028	375	13	2
462470	533629	R11	66	42	120	24	41328	464	13	2
462117	533276	R12	82	351	382	133	38761	599	20	1
461763	532922	R13	32	258	574	248	39490	561	12	1
461410	532569	R14	27	218	439	203	35222	428	15	1
461056	532215	R15	17	123	251	116	31571	406	10	1
460703	531862	R16	13	83	186	77	31370	425	8	6
463177	533629	R20	53	79	203	119	33991	366	10	2
462824	533276	R21	41	85	201	125	34062	403	13	2
462470	532922	R22	35	151	340	205	33641	389	9	1
462117	532569	R23	34	322	224	90	32341	414	15	1
461763	532215	R24	25	192	332	147	32342	452	11	1
461410	531862	R25	6	98	224	65	30298	422	6	1
461056	531508	R26	10	82	216	69	30165	391	9	6
463531	533276	R30	37	79	193	112	34001	380	12	2
463177	532922	R31	68	48	154	44	38337	582	6	2
462824	532569	R32	18	89	226	110	36841	413	6	1
462470	532215	R33	15	130	299	137	34126	412	6	1
462117	531862	R34	28	223	539	256	39766	465	8	1
461763	531508	R35	10	127	259	112	33959	414	6	1
461410	531155	R36	3	113	224	69	38773	459	4	6
463884	532922	R40	8	121	274	153	38161	401	11	2
463531	532569	R42								
463177	532215	R43	10	101	233	122	32443	427	10	1
462824	531862	R44	20	218	390	186	37617	433	17	1
462470	531508	R45	27	125	270	131	34597	400	12	1
462117	531155	R46	15	114	286	149	35358	407	14	6
461763	530801	R47								
464238	532569	R50	22	88	230	135	35271	379	10	2
463884	532215	R51	4	177	393	130	39408	597	11	1
463531	531862	R52	7	95	247	86	31997	472	14	1
463177	531508	R53	9	101	225	77	34691	427	8	1
462824	531155	R54	12	123	354	134	38771	426	11	1
462470	530801	R55								
462117	530448	R56								
464591	532215	R60	28	76	109	120	31094	378	11	4
464238	531862	R61	13	89	233	103	33347	487	9	4
463884	531508	R62								

TABLE 1 (contd.) Sample positions and metal concentrations, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%<90	CU	ZN	PB	FE	MN	CO	REGION
463531	531155	R63	14	124	245	107	38397	423	11	4
463177	530801	R64								
462824	530448	R65								
462470	530094	R66								
462510	538607	B11	35	63	181	107	27476	290	8	3
461766	537908	B12	47	66	165	104	28848	322	10	9
461049	537134	B13	40	43	139	71	27222	315	10	9
460354	536484	B14	60	64	152	89	27458	309	10	9
459672	535815	B15								
458980	535053	B16	89	103	182	118	32329	296	12	9
458241	534357	B17	67	60	148	78	31013	387	8	9
457555	533663	B18	64	58	146	76	30906	430	12	9
456806	532958	B19	48	102	137	68	32949	428	9	9
456147	532246	B20	26	40	167	56	32758	525	9	9
463194	537897	B21	40	48	158	83	27478	316	7	3
462464	537172	B22	50	56	162	94	28101	277	11	3
461770	536474	B23	40	63	153	78	29228	385	13	9
461059	535774	B24	59	61	176	93	29659	371	12	9
460387	535053	B25	43	101	225	114	35856	394	13	9
459661	534357	B26	38	91	235	119	36316	376	15	9
458949	533658	B27	58	98	234	129	31485	325	14	9
458205	532973	B28	40	54	158	77	29732	341	13	9
457538	532296	B29	26	72	171	86	34303	386	15	9
456788	531619	B30	4	133	259	107	36237	505	16	7
463927	537224	B31	50	53	155	86	26999	330	12	3
463177	536455	B32	51	69	193	102	29492	325	13	3
462475	535758	B33	17	80	201	109	32167	376	12	2
461788	535080	B34	20	74	197	117	35238	423	16	8
461063	534368	B35	15	100	237	125	33523	371	17	8
460365	533667	B36	38	78	206	106	34561	397	13	8
459656	532948	B37	4	112	242	81	35300	503	9	8
458916	532244	B38								
458271	531564	B39								
457547	530813	B40	10	58	156	64	34310	642	8	7
464593	536479	B41	5	104	236	100	32584	682	11	3
463884	535725	B42	31	61	160	87	35443	429	13	3
463177	535043	B43	45	56	128	52	35241	478	14	2
459653	531480	B48	9	79	172	52	35243	530	11	6
458926	530829	B49	5	81	196	58	34863	534	8	7
458251	530104	B50	3	169	332	113	36687	503	9	7
465332	535807	B51	37	63	184	112	30747	342	10	3
464608	535046	B52	65	66	163	90	29581	349	10	3
463868	534350	B53	81	40	110	25	37751	383	14	2
460396	530845	B58								

TABLE 1 (contd.) Sample positions and metal concentrations, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%<90	CU	ZN	PB	FE	MN	CO	REGION
459664	530118	B59	6	69	199	85	39218	655	11	7
458969	529404	B60	33	64	175	96	34366	465	10	7
466043	535074	B61	33	68	223	111	32896	431	13	3
465289	534348	B62	12	67	183	85	31350	420	11	3
464609	533648	B63	66	45	120	37	37066	390	13	2
461085	530097	B68	10	77	207	88	42660	582	9	6
460385	529381	B69	26	74	201	97	39679	538	9	7
459686	528683	B70	17	67	171	108	38273	535	9	7
466714	534464	B71	12	76	215	120	33213	453	12	3
466001	533667	B72	20	84	224	110	32318	391	10	3
465291	533016	B73	27	64	184	109	33901	391	13	2
461816	529402	B78	97	103	236	167	36739	601	18	6
461100	528688	B79	16	58	175	87	34377	510	12	7
460397	527974	B80	17	75	176	91	40442	604	13	7
467487	533644	B81	44	74	213	130	34515	389	12	3
466726	532890	B82	38	66	187	112	31803	385	11	3
466016	532179	B83	25	82	223	132	35983	381	13	4
465344	531504	B84	12	112	229	123	35690	442	14	4
464617	530785	B85	37	69	202	95	34162	422	11	4
463998	530070	B86								
463217	529360	B87	82	73	176	111	34198	383	14	4
462523	528677	B88	60	69	168	69	36914	500	12	6
461811	527962	B89	5	92	223	132	37649	630	14	7
461086	527272	B90	21	83	216	131	37738	445	14	7
468174	532937	B91	31	62	183	117	31612	381	13	3
467450	532190	B92	43	75	217	126	33268	312	14	5
466727	531496	B93	54	77	228	125	35321	404	13	5
466042	530786	B94	49	80	225	131	33533	371	13	5
465343	530076	B95	64	87	260	136	34581	408	12	5
464636	529378	B96	52	79	205	117	34354	394	12	5
463933	528670	B97	45	67	172	92	34418	404	11	5
463216	527944	B98	25	71	145	70	30285	408	11	5
462493	527251	B99	3	76	179	61	34610	600	9	7
461799	526544	B100								
468898	532234	B101	25	73	187	123	31277	376	9	5
468155	531490	B102	52	72	169	97	30376	423	10	5
467431	530792	B103	49	67	178	108	30523	344	7	5
466730	530071	B104	67	78	214	119	28806	363	6	5
466030	529359	B105	83	68	171	97	30719	408	6	5
465330	528653	B106	80	63	158	96	31092	374	9	5
464626	527978	B107	62	62	162	105	28344	341	8	5
463905	527251	B108	15	57	146	75	33996	491	6	5
463206	526575	B109	4	78	179	83	35472	534	7	5
462524	525867	B110								

TABLE 1 (contd.) Sample positions and metal concentrations, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%<90	CU	ZN	PB	FE	MN	CO	REGION
461410	532569	C1-14	32	97	168	40	26796	582	11	1
462117	532569	C1-23	39	269	458	237	41689	407	17	1
461763	532215	C1-24	10	253	483	231	53266	515	13	1
461410	531862	C1-25	11	107	235	91	38030	465	9	1
462117	531862	C1-34	7	203	394	193	42620	435	12	1
461763	532451	C1-71	19	153	299	160	40578	477	10	1
461940	532392	C1-72	23	96	207	76	39260	456	10	1
461999	532215	C1-73	13	139	263	117	39460	479	7	1
461940	532038	C1-74	14	108	242	115	34816	485	8	1
461763	531979	C1-75	47	67	147	66	29278	416	5	1
461586	532038	C1-76	8	175	282	113	41480	397	8	1
461527	532215	C1-77	8	197	334	110	38766	495	8	1
461586	532392	C1-78	14	220	254	99	40160	503	14	1
461763	532686	C1-81	36	142	211	76	40619	501	11	1
462175	532215	C1-82	10	95	204	92	35526	452	3	1
461763	531744	C1-83	44	123	240	131	39461	481	9	1
461292	532215	C1-84	24	104	213	101	34495	413	6	1
Mean			32	101	224	109	34498	434	11	
Standard deviation			22	55	80	40	4010	80	3	
Coefficient of variation			0.70	0.54	0.36	0.37	0.12	0.18	0.28	
Minimum			3	40	80	24	4010	80	3	
Maximum			97	351	574	256	53266	682	20	

Table 2 Sample positions and metal concentrations, 0-20microns, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%0-20	CU	ZN	PB	FE	MN	CO	REGION
462470	534336	R0	13.1	179	343	205	38100	413	17	2
462117	533983	R1	44.4	153	347	211	42500	489	16	2
461763	533629	R2	7.2	208	440	248	40500	396	18	8
461410	533276	R3	27.5	254	467	248	41600	486	18	8
461056	532922	R4	17.7	194	344	210	41800	414	16	8
460703	532569	R5	3.3	310	540	282	42200	417	18	8
460349	532215	R6	1.2	274	507	142	35500	576	14	8
462824	533983	R10	11.2	168	294	198	40200	356	16	2
462470	533629	R11	51.0	48	136	28	47300	472	15	2
462117	533276	R12	58.6	452	480	168	39500	670	23	1
461763	532922	R13	17.8	405	881	390	46600	690	14	1
461410	532569	R14	13.1	376	726	350	43100	485	18	1
461056	532215	R15	6.8	244	456	228	40800	457	14	1
460703	531862	R16	4.1	195	365	178	41400	477	15	6
463177	533629	R20	28.3	104	258	168	37500	366	10	2
462824	533276	R21	20.4	116	270	184	41900	436	15	2
462470	532922	R22	16.1	276	577	370	40000	421	13	1
462117	532569	R23	16.3	518	305	118	39400	442	24	1
461763	532215	R24	9.8	375	593	282	41600	544	14	1
461410	531862	R25	0.7	452	932	212	33900	556	15	1
461056	531508	R26	2.0	268	574	191	43300	481	14	6
463531	533276	R30	18.6	119	273	174	41200	384	13	2
463177	532922	R31	52.8	57	180	53	44100	628	7	2
462824	532569	R32	6.8	170	378	212	43000	460	7	1
462470	532215	R33	7.1	225	492	232	42400	448	7	1
462117	531862	R34	11.3	428	1014	500	49500	534	12	1
461763	531508	R35	4.1	216	429	215	43800	473	7	1
461410	531155	R36	0.8	235	428	153	45200	511	7	6
463884	532922	R40	5.4	143	330	199	40800	400	13	2
463531	532569	R42	2.6	269	543	268	45100	526	18	1
463177	532215	R43	10.0	343	567	277	43400	460	21	1
462824	531862	R44	10.9	225	448	238	42400	450	15	1
462470	531508	R45	8.8	155	382	209	41300	431	17	6
462117	531155	R46								
461763	530801	R47								
464238	532569	R50	14.7	109	285	182	38300	387	10	2
463884	532215	R51	2.2	276	584	200	41500	714	14	1
463531	531862	R52	4.8	120	300	106	28500	495	17	1
463177	531508	R53	1.4	363	637	242	43400	575	13	1
462824	531155	R54	4.5	262	451	249	40900	412	17	1
462470	530801	R55								
462117	530448	R56								
464591	532215	R60	16.2	100	104	143	36300	392	15	4
464238	531862	R61	4.7	167	411	199	39600	595	12	4
463884	531508	R62								

TABLE 2 (contd.) Sample positions and metal concentrations, 0-20microns, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%0-20	CU	ZN	PB	FE	MN	CO	REGION
463531	531155	R63	5.0	197	450	224	42400	458	16	4
463177	530801	R64								
462824	530448	R65								
462470	530094	R66								
462510	538607	B11	15.0	99	267	171	37400	332	12	3
461766	537908	B12	19.9	115	254	185	39700	365	13	9
461049	537134	B13	12.0	88	241	158	37700	331	15	9
460354	536484	B14	24.7	107	225	146	35500	330	15	9
459672	535815	B15								
458980	535053	B16	52.4	103	232	171	38500	282	14	9
458241	534357	B17	24.4	94	218	148	39500	406	11	9
457555	533663	B18	29.6	77	185	119	35600	405	15	9
456806	532958	B19	14.7	243	205	131	38000	366	15	9
456147	532246	B20	3.4	112	271	150	39300	432	13	9
463194	537897	B21	17.0	87	262	159	38300	333	9	3
462464	537172	B22	23.6	84	235	159	38000	268	14	3
461770	536474	B23	12.0	105	263	182	43400	499	17	9
461059	535774	B24	23.7	102	275	178	39700	420	15	9
460387	535053	B25	20.9	126	314	188	38800	393	15	9
459661	534357	B26	15.8	129	319	179	40200	327	18	9
458949	533658	B27	42.8	108	249	142	31300	310	15	9
458205	532973	B28	18.3	92	216	125	36100	328	16	9
457538	532296	B29	12.0	105	231	131	39500	346	17	9
456788	531619	B30	1.6	152	313	149	33100	444	17	7
463927	537224	B31	12.7	110	285	182	42100	395	16	3
463177	536455	B32	24.7	96	270	148	35900	333	15	3
462475	535758	B33	10.3	92	238	140	35200	368	13	2
461788	535080	B34	10.9	98	253	168	39400	443	20	8
461063	534368	B35	10.0	117	276	140	36700	368	19	8
460365	533667	B36	12.5	148	354	228	44000	417	21	8
459656	532948	B37	1.1	212	437	163	41500	670	12	8
458916	532244	B38								
458271	531564	B39								
457547	530813	B40	1.3	159	327	141	42900	928	17	7
464593	536479	B41	2.0	162	332	147	40600	804	15	3
463884	535725	B42	19.6	75	198	117	44200	452	17	3
463177	535043	B43	28.1	67	161	68	45700	530	20	2
459653	531480	B48	4.0	95	212	71	39700	566	16	6
458926	530829	B49	1.0	188	337	130	36800	541	14	7
458251	530104	B50	2.1	182	399	146	43300	556	11	7
465332	535807	B51	19.3	90	253	170	38600	361	14	3
464608	535046	B52	30.9	97	234	145	38700	372	13	3
463868	534350	B53	67.3	42	116	26	41200	375	15	2
460396	530845	B58	2.1	118	277	138	38200	668	12	7

TABLE 2 (contd.) Sample positions and metal concentrations, 0-20microns, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%0-20	CU	ZN	PB	FE	MN	CO	REGION
459664	530118	B59	14.6	102	238	164	36600	398	12	7
458969	529404	B60	17.5	98	316	169	41900	464	18	3
466043	535074	B61	6.6	92	253	125	40100	494	15	3
465289	534348	B62	55.9	47	127	40	40400	391	14	2
464609	533648	B63								
461085	530097	B68	2.4	176	351	196	42800	598	13	6
460385	529381	B69	8.7	138	293	192	40000	392	15	7
459686	528683	B70	5.4	133	250	229	38200	395	13	7
466714	534464	B71	6.2	107	294	185	41500	536	15	3
466001	533667	B72	11.9	108	291	154	38900	419	13	3
465291	533016	B73	21.1	70	203	129	35500	381	14	2
461816	529402	B78	79.4	111	255	183	38600	625	19	6
461100	528688	B79	4.6	127	289	200	42900	477	18	7
460397	527974	B80	5.0	154	257	171	39900	517	16	7
467487	533644	B81	22.5	118	310	207	44700	421	17	3
466726	532890	B82	17.9	103	280	193	40100	411	16	3
466016	532179	B83	14.2	110	297	190	41400	381	15	4
465344	531504	B84	6.2	155	315	197	42700	474	17	4
464617	530785	B85	11.5	138	348	199	44400	419	21	4
463998	530070	B86								
463217	529360	B87	53.9	86	205	139	37000	392	16	4
462523	528677	B88	12.2	136	304	196	22600	442	19	6
461811	527962	B89	2.3	140	312	223	40700	705	20	7
461086	527272	B90	13.7	112	266	181	39200	389	16	7
468174	532937	B91	13.8	105	287	214	42200	432	19	3
467450	532190	B92	18.7	124	334	219	44700	273	15	5
466727	531496	B93	28.7	116	328	202	41800	406	16	5
466042	530786	B94	20.4	142	358	241	42800	396	16	5
465343	530076	B95	36.8	124	353	201	39200	451	15	5
464636	529378	B96	26.4	117	284	188	37200	351	16	5
463933	528670	B97	22.1	104	228	151	37500	370	14	5
463216	527944	B98	7.4	138	227	137	38000	418	16	5
462493	527251	B99	0.4	169	354	117	33900	589	15	7
461799	526544	B100								
468898	532234	B101	12.7	106	260	193	38400	385	12	5
468155	531490	B102	24.9	101	232	136	36600	498	12	5
467431	530792	B103	20.7	113	280	195	37000	318	13	5
466730	530071	B104	28.6	130	327	207	36600	379	7	5
466030	529359	B105	39.8	91	212	143	35800	420	8	5
465330	528653	B106	35.3	97	231	166	37200	359	13	5
464626	527978	B107	31.3	97	226	165	37100	385	13	5
463905	527251	B108	5.0	106	234	155	36100	403	8	5
463206	526575	B109	1.2	149	288	153	39800	518	9	5
462524	525867	B110								

TABLE 2 (contd.) Sample positions and metal concentrations, 0-20microns, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%0-20	CU	ZN	PB	FE	MN	CO	REGION
461410	532569	C1-14	11.4	105	175	35	35600	548	16	1
462117	532569	C1-23	21.3	394	635	342	48500	422	22	1
461763	532215	C1-24	6.6	305	592	290	61200	508	13	1
461410	531862	C1-25	2.6	223	394	178	46900	464	11	1
462117	531862	C1-34	2.8	316	611	328	59200	489	14	1
461763	532451	C1-71	13.3	170	335	195	44800	478	12	1
461940	532392	C1-72	13.5	122	262	100	48800	449	14	1
461999	532215	C1-73	4.6	264	480	239	58900	518	10	1
461940	532038	C1-74	5.8	167	374	188	42900	495	10	1
461763	531979	C1-75	11.0	135	266	155	41700	477	11	1
461586	532038	C1-76	6.3	161	282	117	43500	396	9	1
461527	532215	C1-77	3.3	329	520	154	49100	486	9	1
461586	532392	C1-78	9.0	255	300	119	46300	493	14	1
461763	532686	C1-81	22.9	171	254	90	46700	483	13	1
462175	532215	C1-82	3.0	186	375	194	51500	517	4	1
461763	531744	C1-83	22.2	145	333	190	50500	506	13	1
461292	532215	C1-84	7.8	231	402	224	48500	488	10	1
Mean			15.9	166	340	182	40909	456	14	4
Standard deviation			14.6	93	149	66	5024	103	3.5	2.8
Coefficient of variation			0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Minimum			0.4	42	104	26	22600	268	4	1
Maximum			19.4	518	1014	500	61200	928	24	9

Table 3 Sample positions and metal concentrations, 20-63microns, September 1987 survey (disposal ground and surrounding area)

POSITION				CONCENTRATION IN 20-63 MICRON FRACTION EACH METAL						
East	North	Sample	%20-63	CU	ZN	PB	FE	MN	CO	REGION
462470	534336	R0	4.4	49	138	45	28600	418	10	2
462117	533983	R1	25.9	56	143	58	26700	345	12	2
461763	533629	R2	14.5	67	184	78	38200	421	11	8
461410	533276	R3	8.1	53	120	43	30400	386	11	8
461056	532922	R4	12	56	137	45	31200	420	13	8
460703	532569	R5	7.2	85	203	95	33200	422	9	8
460349	532215	R6	2.1	67	150	37	29300	471	8	8
462824	533983	R10	14.2	107	180	97	29500	406	12	2
462470	533629	R11	11.3	22	64	13	21600	476	8	2
462117	533276	R12	19.8	100	140	45	38000	440	14	1
461763	532922	R13	8.2	102	238	88	36600	464	10	1
461410	532569	R14	7.7	88	195	74	31100	416	13	1
461056	532215	R15	5.2	54	128	42	28500	409	9	1
460703	531862	R16	4.6	44	111	30	29600	447	6	6
463177	533629	R20	20.1	56	148	69	32000	387	10	2
462824	533276	R21	13.4	61	142	70	28700	412	13	2
462470	532922	R22	8.2	52	139	64	31100	389	7	1
462117	532569	R23	9.4	204	188	82	28900	457	11	1
461763	532215	R24	8.9	93	201	73	29600	427	9	1
461410	531862	R25	2.1	86	196	73	41800	538	8	1
461056	531508	R26	2.2	63	166	49	32500	458	12	6
463531	533276	R30	13.5	38	109	49	27600	404	12	2
463177	532922	R31	8.8	16	56	10	17600	516	5	2
462824	532569	R32	3.8	56	156	59	35900	440	9	1
462470	532215	R33	2.9	69	161	58	31900	433	3	1
462117	531862	R34	8.3	99	248	100	37800	462	3	1
461763	531508	R35	3.2	105	186	48	30500	421	6	1
461410	531155	R36	1.1	135	213	50	38900	492	2	6
463884	532922	R40	1.4	102	179	60	31800	436	6	2
463531	532569	R42	3.8	57	139	103	30600	424	9	1
463177	532215	R43	8.7	96	215	99	32600	415	14	1
462824	531862	R44	9.3	66	157	62	31100	395	12	1
462470	531508	R45	3.7	79	186	87	30500	413	12	6
462117	531155	R46								
461763	530801	R47								
464238	532569	R50	4.6	59	129	43	28400	363	12	2
463884	532215	R51	0.9	62	148	40	26300	469	6	1
463531	531862	R52	0.9	73	179	67	27000	412	6	1
463177	531508	R53	3.6	72	181	55	31400	438	10	1
462824	531155	R54	3.6	57	464	77	42300	480	8	1
462470	530801	R55								
462117	530448	R56								
464591	532215	R60	9.5	46	111	99	23200	360	6	4
464238	531862	R61	3.6	54	128	46	29300	462	5	4
463884	531508	R62								

TABLE 3 (contd.) Sample positions and metal concentrations, 20-63microns, September 1987 survey (disposal ground and surrounding area)

POSITION			CONCENTRATION IN 20-63 MICRON FRACTION EACH METAL							
East	North	Sample	%20-63	CU	ZN	PB	FE	MN	CO	REGION
463531	531155	R63	3.8	49	122	35	32600	407	9	4
463177	530801	R64								
462824	530448	R65								
462470	530094	R66								
462510	538607	B11	8.3	56	140	76	27000	342	7	3
461766	537908	B12	13.5	43	120	60	27300	399	8	9
461049	537134	B13	12.8	36	103	40	27600	368	9	9
460354	536484	B14	17.1	42	109	65	26500	359	8	9
459672	535815	B15								
458980	535053	B16	30.6	51	109	40	24200	331	9	9
458241	534357	B17	24.8	52	110	31	30900	440	7	9
457555	533663	B18	12.5	61	124	40	33000	452	10	9
456806	532958	B19	16.1	54	129	47	37900	501	7	9
456147	532246	B20	5	57	175	46	38200	613	10	9
463194	537897	B21	9.6	34	102	31	26000	423	7	3
462464	537172	B22	10	49	119	44	24900	372	10	3
461770	536474	B23	16.2	63	117	36	27200	400	12	9
461059	535774	B24	20.1	43	111	37	25300	385	11	9
460387	535053	B25	13.9	104	146	48	35100	419	13	9
459661	534357	B26	15	78	194	92	34000	440	14	9
458949	533658	B27	7.9	108	249	142	31300	310	15	9
458205	532973	B28	10.5	29	138	45	32700	427	11	9
457538	532296	B29	6.8	52	112	42	30900	418	14	9
456788	531619	B30	1.6	153	257	89	41000	561	17	7
463927	537224	B31	17.9	53	148	78	28500	405	11	3
463177	536455	B32	19	53	140	69	27000	358	13	3
462475	535758	B33	4.3	74	157	71	29300	401	12	2
461788	535080	B34	5.6	51	132	61	30700	432	14	8
461063	534368	B35	3.3	77	165	115	27400	398	15	8
460365	533667	B36	15.9	47	137	45	33300	415	10	8
459656	532948	B37	1.6	84	153	43	27100	408	7	8
458916	532244	B38								
458271	531564	B39								
457547	530813	B40	2.6	85	178	54	41300	735	12	7
464593	536479	B41	1.8	89	214	92	33800	770	11	3
463884	535725	B42	7.7	46	104	38	22500	451	7	3
463177	535043	B43	12.8	42	79	27	19100	437	6	2
459653	531480	B48	3.4	86	152	39	30500	504	8	6
458926	530829	B49	2.5	77	164	43	29500	463	8	7
458251	530104	B50	0.6	152	243	50	23600	369	6	7
465332	535807	B51	11.7	40	122	56	25600	372	7	3
464608	535046	B52	26.6	41	105	44	23700	356	8	3
463868	534350	B53	9.1	30	84	17	20000	462	6	2
460396	530845	B58	2.4	57	157	63	35800	617	11	7

TABLE 3 (contd.) Sample positions and metal concentrations, 20-63microns, September 1987 survey (disposal ground and surrounding area)

POSITION			CONCENTRATION IN 20-63 MICRON FRACTION EACH METAL							
East	North	Sample	%20-63	CU	ZN	PB	FE	MN	CO	REGION
459664	530118	B59	9.7	49	148	52	39500	585	9	7
458969	529404	B60	12.4	37	122	50	24600	415	9	3
466043	535074	B61	3.8	43	95	34	20600	329	6	3
465289	534348	B62	7.6	30	74	20	16900	408	6	2
464609	533648	B63								
461085	530097	B68	2.8	78	178	73	43500	631	11	6
460385	529381	B69	3.9	71	168	44	42300	531	12	7
459686	528683	B70	5.3	58	165	57	48300	719	9	7
466714	534464	B71	3.5	51	131	51	25500	395	9	3
466001	533667	B72	5.1	63	139	52	24000	379	4	3
465291	533016	B73	3.6	58	144	48	35800	544	11	2
461816	529402	B78	15.1	62	137	89	27600	477	15	6
461100	528688	B79	4.1	49	139	45	27300	452	11	7
460397	527974	B80	2.9	94	164	59	41800	648	12	7
467487	533644	B81	10.9	36	133	62	30000	432	11	3
466726	532890	B82	14.7	40	114	47	27400	404	6	3
466016	532179	B83	8.2	50	134	62	30400	397	11	4
465344	531504	B84	3.6	91	138	43	30000	433	11	4
464617	530785	B85	5	53	134	48	32600	444	5	4
463998	530070	B86								4
463217	529360	B87	25.9	50	123	59	27500	373	10	6
462523	528677	B88	26.6	69	133	40	44600	491	9	7
461811	527962	B89	1.6	79	175	73	33300	562	12	7
461086	527272	B90	2.5	53	136	59	37000	510	12	3
468174	532937	B91	9.5	38	108	42	26800	401	10	5
467450	532190	B92	14.4	51	151	68	28600	403	15	5
466727	531496	B93	15.5	42	127	42	33300	474	12	5
466042	530786	B94	13.7	43	137	54	29600	395	11	5
465343	530076	B95	13.3	51	150	57	33300	417	12	5
464636	529378	B96	16.9	48	129	48	33600	462	11	5
463933	528670	B97	15.3	37	126	34	36300	488	10	5
463216	527944	B98	6.6	67	120	34	28800	445	11	7
462493	527251	B99	1.6	91	191	66	35000	587	10	
461799	526544	B100								
468898	532234	B101	8.8	47	123	57	26900	407	7	5
468155	531490	B102	17.6	62	133	79	29600	418	10	5
467431	530792	B103	16.7	42	103	39	28800	391	3	5
466730	530071	B104	23.6	48	143	56	26800	404	4	5
466030	529359	B105	33.7	47	128	51	27600	422	2	5
465330	528653	B106	29.7	44	110	42	31000	452	7	5
464626	527978	B107	1	81	175	124	29500	323	14	5
463905	527251	B108	4.8	41	105	33	34300	520	4	5
463206	526575	B109	1.1	76	165	68	34200	505	6	5
462524	525867	B110								

TABLE 3 (contd.) Sample positions and metal concentrations, 20-63microns, September 1987 survey (disposal ground and surrounding area)

POSITION			CONCENTRATION IN 20-63 MICRON FRACTION EACH METAL							
East	North	Sample	%20-63	CU	ZN	PB	FE	MN	CO	REGION
461410	532569	C1-14	17.7	99	169	40	21600	640	9	1
462117	532569	C1-23	8.4	104	217	84	31400	390	11	1
461763	532215	C1-24	2.4	212	368	170	44700	641	16	1
461410	531862	C1-25	3.9	113	277	91	45600	613	10	1
462117	531862	C1-34	3.1	168	308	134	36800	410	12	1
461763	532451	C1-71	4.4	127	235	84	33700	507	5	1
461940	532392	C1-72	4.5	87	163	53	30200	547	8	1
461999	532215	C1-73	2.9	151	248	97	35100	522	4	1
461940	532038	C1-74	3.1	124	237	111	36500	613	11	1
461763	531979	C1-75	6.9	81	175	70	32000	484	7	1
461586	532038	C1-76	1.5	241	310	98	33700	404	3	1
461527	532215	C1-77	2.1	185	306	118	44300	725	10	1
461586	532392	C1-78	3.2	165	196	75	35100	615	14	1
461763	532686	C1-81	9.2	89	138	52	31500	583	8	1
462175	532215	C1-82	2.2	120	237	86	42000	594	5	1
461763	531744	C1-83	12	128	144	63	26200	453	5	1
461292	532215	C1-84	6.1	71	157	50	33800	473	6	1
Mean			9	73	159	61	31280	457	9	
Standard deviation			7	38	57	26	5907	88	3	
Coefficient of variation			0.79	0.53	0.36	0.43	0.19	0.19	0.34	
Minimum			1	16	56	10	16900	310	2	
Maximum			34	241	464	170	48300	770	17	

Table 4 Sample positions and metal concentrations, 63-90microns, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%63-90	CU	ZN	PB	FE	MN	CO	REGION
462470	534336	R0	1.80	38	107	32	29200	330	8	2
462117	533983	R1	4.70	41	130	58	25000	264	6	2
461763	533629	R2	7.40	24	101	39	23700	306	10	8
461410	533276	R3	3.80	31	104	35	24700	389	6	8
461056	532922	R4	7.70	35	110	46	21500	311	8	8
460703	532569	R5	4.70	25	95	33	21100	305	3	8
460349	532215	R6	1.70	27	112	34	27500	359	5	8
462824	533983	R10	2.90	37	108	48	22600	296	11	2
462470	533629	R11	3.90	22	65	12	20400	318	8	2
462117	533276	R12	3.30	67	98	30	30200	291	12	1
461763	532922	R13	6.20	43	138	50	22900	317	10	1
461410	532569	R14	5.80	34	115	44	22900	313	9	1
461056	532215	R15	4.60	23	86	33	21400	329	6	1
460703	531862	R16	4.30	19	96	32	23700	352	4	6
463177	533629	R20	4.30	28	94	36	20200	268	10	2
462824	533276	R21	7.30	45	118	63	22000	294	6	2
462470	532922	R22	10.40	34	131	60	25800	339	6	1
462117	532569	R23	8.00	60	103	42	22000	308	3	1
461763	532215	R24	5.90	39	95	36	21100	337	7	1
461410	531862	R25	2.90	22	73	24	21100	305	2	1
461056	531508	R26	6.20	28	119	37	25100	338	7	6
463531	533276	R30	4.70	37	118	51	23900	294	5	2
463177	532922	R31	6.30	21	71	16	19000	290	2	2
462824	532569	R32	7.60	33	125	44	31800	357	3	1
462470	532215	R33	4.70	25	92	43	23000	346	6	1
462117	531862	R34	8.10	63	173	74	28200	371	8	1
461763	531508	R35	3.00	30	104	38	24200	327	4	1
461410	531155	R36	1.40	25	115	35	35000	403	3	6
463884	532922	R40	1.10	34	118	48	33300	358	6	2
463531	532569	R42								
463177	532215	R43	3.90	31	119	44	25800	363	6	1
462824	531862	R44	1.20	65	178	63	25800	332	6	1
462470	531508	R45	7.20	49	146	59	27300	331	7	1
462117	531155	R46	2.80	34	118	40	23100	324	6	6
461763	530801	R47								
464238	532569	R50	3.10	31	120	47	31100	363	9	2
463884	532215	R51	0.90	52	172	50	47400	438	9	1
463531	531862	R52	1.60	32	127	37	45300	436	9	1
463177	531508	R53	3.80	33	116	36	34600	362	5	1
462824	531155	R54	4.00	25	146	55	33200	394	7	1
462470	530801	R55								
462117	530448	R56								
464591	532215	R60	2.40	37	134	48	27200	350	7	4
464238	531862	R61	4.30	34	125	47	29900	391	9	4
463884	531508	R62								

TABLE 4 (contd.) Sample positions and metal concentrations, 63-90microns, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%63-90	CU	ZN	PB	FE	MN	CO	REGION
463531	531155	R63	5.00	107	134	44	38800	399	8	4
463177	530801	R64								
462824	530448	R65								
462470	530094	R66								
462510	538607	B11	12.00	22	103	47	15400	202	3	3
461766	537908	B12	13.50	17	78	29	14400	180	6	9
461049	537134	B13	14.80	13	88	26	18400	257	7	9
460354	536484	B14	18.30	25	93	36	17500	234	6	9
459672	535815	B15								
458980	535053	B16	6.20	363	113	50	20300	244	9	9
458241	534357	B17	17.90	25	106	48	19600	287	4	9
457555	533663	B18	22.00	31	105	39	23400	452	9	9
456806	532958	B19	17.60	27	87	34	24200	414	7	9
456147	532246	B20	17.30	21	144	40	29900	518	8	9
463194	537897	B21	13.50	10	67	24	14900	219	3	3
462464	537172	B22	16.00	18	81	30	15500	231	8	3
461770	536474	B23	11.80	20	91	31	17600	250	9	9
461059	535774	B24	15.10	21	106	33	19700	277	8	9
460387	535053	B25	7.90	32	127	35	29400	350	10	9
459661	534357	B26	6.80	31	128	38	32400	349	10	9
458949	533658	B27	7.70	29	138	45	32700	427	11	9
458205	532973	B28	11.60	18	84	31	17000	283	11	9
457538	532296	B29	7.00	34	125	51	28700	425	11	9
456788	531619	B30	0.60	26	121	41	31900	521	11	7
463927	537224	B31	19.70	16	77	31	15900	221	10	3
463177	536455	B32	7.50	21	76	33	14700	214	5	3
462475	535758	B33	2.50	41	123	46	24600	368	10	2
461788	535080	B34	3.10	29	115	38	28800	339	6	8
461063	534368	B35	1.60	43	139	52	26300	334	9	8
460365	533667	B36	9.10	34	124	45	23800	337	7	8
459656	532948	B37	1.00	48	171	51	41600	472	9	8
458916	532244	B38								
458271	531564	B39								
457547	530813	B40	6.10	25	110	52	29500	542	5	7
464593	536479	B41	1.20	30	109	33	17400	345	5	3
463884	535725	B42	3.80	18	76	30	16500	263	4	3
463177	535043	B43	4.40	22	64	26	15400	265	3	2
459653	531480	B48	1.80	28	123	35	34300	500	7	6
458926	530829	B49	1.90	29	165	41	40900	625	6	7
458251	530104	B50	0.40	124	116	35	21600	423	3	7
465332	535807	B51	5.80	19	80	30	15000	217	4	3
464608	535046	B52	7.70	24	78	32	13300	236	4	3
463868	534350	B53	4.60	24	77	19	22400	341	7	2
460396	530845	B58								

TABLE 4 (contd.) Sample positions and metal concentrations, 63-90microns, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%63-90	CU	ZN	PB	FE	MN	CO	REGION
459664	530118	B59	1.70	25	163	51	45300	693	8	7
458969	529404	B60	8.80	19	102	33	25000	445	9	7
466043	535074	B61	3.20	22	107	35	15800	308	5	3
465289	534348	B62	2.00	28	120	48	22900	349	8	3
464609	533648	B63	2.10	52	115	30	21300	291	2	2
461085	530097	B68	4.80	27	151	42	42100	546	5	6
460385	529381	B69	13.30	33	150	51	38700	635	5	7
459686	528683	B70	6.70	21	112	50	30400	503	7	7
466714	534464	B71	2.10	25	123	43	21600	305	8	3
466001	533667	B72	3.20	27	111	38	21100	308	9	3
465291	533016	B73	2.60	21	86	27	18300	265	4	2
461816	529402	B78	2.30	106	230	142	32500	580	16	6
461100	528688	B79	7.40	21	124	39	33000	563	8	7
460397	527974	B80	8.60	22	133	56	40300	640	11	7
467487	533644	B81	10.10	16	82	31	16700	272	3	3
466726	532890	B82	5.70	17	80	27	17100	257	7	3
466016	532179	B83	3.00	40	116	52	25600	335	5	4
465344	531504	B84	2.30	29	139	49	25700	372	9	4
464617	530785	B85	20.50	34	136	49	28800	418	7	4
463998	530070	B86								
463217	529360	B87	2.20	37	107	38	44400	277	11	4
462523	528677	B88	21.10	29	134	31	35500	544	12	6
461811	527962	B89	1.20	16	118	37	37600	577	6	7
461086	527272	B90	5.00	19	120	30	34100	567	8	7
468174	532937	B91	7.60	14	86	35	18400	262	7	3
467450	532190	B92	9.60	16	87	34	18000	251	10	5
466727	531496	B93	9.90	19	95	32	19700	286	7	5
466042	530786	B94	14.80	30	122	51	24400	315	11	5
465343	530076	B95	13.80	21	118	40	23500	285	6	5
464636	529378	B96	9.10	25	115	38	27500	391	5	5
463933	528670	B97	7.50	21	99	37	21500	335	6	5
463216	527944	B98	11.30	29	106	47	26100	379	7	5
462493	527251	B99	1.10	19	98	32	34300	624	6	7
461799	526544	B100								
468898	532234	B101	3.40	16	81	30	16000	265	3	5
468155	531490	B102	9.50	13	72	27	15500	235	4	5
467431	530792	B103	11.80	22	107	54	21600	324	2	5
466730	530071	B104	14.50	22	105	46	16700	266	7	5
466030	529359	B105	9.60	50	148	70	20600	305	10	5
465330	528653	B106	15.00	20	83	37	16900	257	2	5
464626	527978	B107	30.10	26	96	42	19200	295	2	5
463905	527251	B108	5.00	23	98	34	31600	550	5	5
463206	526575	B109	1.60	27	108	41	33100	565	5	5
462524	525867	B110								

TABLE 4 (contd.) Sample positions and metal concentrations, 63-90microns, September 1987 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)						
East	North	Sample	%63-90	CU	ZN	PB	FE	MN	CO	REGION
461410	532569	C1-14	17.70	49	134	60	23900	357	3	1
462117	532569	C1-23	8.40	125	262	128	35100	385	11	1
461763	532215	C1-24	2.40	65	144	46	28800	319	9	1
461410	531862	C1-25	3.90	32	101	38	25800	332	7	1
462117	531862	C1-34	3.10	62	165	61	23700	385	6	1
461763	532451	C1-71	4.40	64	131	46	19000	352	2	1
461940	532392	C1-72	4.50	33	100	31	22000	395	3	1
461999	532215	C1-73	2.90	28	90	26	25500	424	6	1
461940	532038	C1-74	3.10	32	96	34	24600	397	4	1
461763	531979	C1-75	6.90	38	95	31	23900	377	2	1
461586	532038	C1-76	1.50	115	81	96	36300	392	8	1
461527	532215	C1-77	2.10	55	143	53	23000	340	6	1
461586	532392	C1-78	3.20	160	152	54	22400	382	12	1
461763	532686	C1-81	9.20	87	125	44	24800	405	9	1
462175	532215	C1-82	2.20	26	79	30	22300	343	2	1
461763	531744	C1-83	12.00	67	145	79	30600	458	3	1
461292	532215	C1-84	6.10	27	103	37	24200	319	3	1
Mean			6.8	37	114	42	25490	360	7	
Standard deviation			5.4	37	30	17	7427	103	3	
Coefficient of variation			0.79	0.79	0.79	0.79	0.79	0.79	0.79	
Minimum			0.4	10	64	12	13300	180	2	
Maximum			30.1	363	262	142	47400	693	16	

Table 5 Hopper samples, metal concentrations, September 1987

0-20 micron fraction

Sample	Cu	Pb	Zn	Fe	Mn	Co
R1DB1	112	90	240	41700	425	14
R1DB2	151	117	286	40800	434	11
R1DB3	161	131	326	38300	396	14
R1DB4	126	125	237	37400	409	5
R1DB1	373	529	917	49100	547	16
R1DB2	406	539	1018	48200	549	15
R1DB3	349	473	804	44500	575	15
R2DB1	161	114	242	34400	392	7
R2DB2	108	131	217	37800	392	12
R2DB3	127	124	227	34300	370	12
R2DB4	166	143	278	38100	454	12
R2DB6	137	134	217	34000	416	7
R2DB7	111	122	207	34600	384	7
R2DB1	339	455	784	43800	532	17
R2DB2	390	523	955	48500	555	17
R2DB3	347	449	836	46600	600	12
R2DB4	441	644	1520	50800	732	16
R3DB1	370	499	907	45000	530	17
R3DB2	297	363	765	46600	675	14
R3DB3	265	367	612	48900	676	11
Mean	247	304	580	42170	502	13
S D	120	194	380	5719	111	4
C V	0.49	0.64	0.66	0.14	0.22	0.29
Min	108	90	207	34000	370	5
Max	441	644	1520	50800	732	17

20-63 micron fraction

Sample	Cu	Pb	Zn	Fe	Mn	Co
R1DB1	51	36	117	23100	431	8
R1DB2	55	45	152	28000	475	9
R1DB3	54	45	145	30700	524	5
R1DB4	61	39	124	26100	446	8
R1DB1	41	52	152	21200	366	3
R1DB2	81	115	250	26400	409	5
R1DB3	64	88	204	25500	402	6
R2DB1	56	29	134	28600	461	3
R2DB2	55	39	129	29300	480	5
R2DB3	48	1370	120	28700	478	8
R2DB4	61	52	148	30400	484	8
R2DB6	65	50	124	30000	483	8
R2DB7	58	44	127	27700	453	8
R2DB1	55	63	177	25700	424	6
R2DB2	49	56	467	26100	415	6
R2DB3	95	118	261	32000	506	5
R2DB4	116	146	367	43600	591	10
R3DB1	123	162	360	38000	544	12

Table 5 (contd.) Hopper samples, metal concentrations, September 1987

R3DB2	148	113	315	28800	517	6
R3DB3	79	93	230	40000	504	11
Mean	71	138	205	29495	470	7
S D	29	293	101	5480	54	2
C V	0.40	2.12	0.49	0.19	0.11	0.35
Min	41	29	117	21200	366	3
Max	148	1370	467	43600	591	12

63-90 micron fraction

Sample	Cu	Pb	Zn	Fe	Mn	Co
R1DB1	26	30	80	21400	329	2
R1DB2	31	31	88	20200	323	5
R1DB3	22	32	90	20700	343	2
R1DB4	31	35	99	21800	356	4
R1DB1	37	56	161	17900	275	3
R1DB2	45	58	163	16200	231	6
R1DB3	59	84	208	16500	240	7
R2DB1	25	29	81	21200	384	2
R2DB2	29	32	84	21700	376	3
R2DB3	22	27	80	18400	365	2
R2DB4	27	35	74	20100	323	2
R2DB6	18	25	65	15200	286	4
R2DB7	29	30	82	20800	362	6
R2DB1	59	91	201	20500	319	4
R2DB2	37	47	153	18100	302	2
R2DB3	77	119	246	31600	438	7
R2DB4	87	119	324	49800	496	9
R3DB1	32	32	110	22500	498	4
R3DB2	76	100	245	34800	481	7
R3DB3	41	69	227	27800	329	3
Mean	41	54	143	22860	353	4
S D	20	32	75	8001	77	2
C V	0.50	0.59	0.53	0.35	0.22	0.51
Min	18	25	65	15200	231	2
Max	87	119	324	49800	498	9

Table 6   Sample positions and metal concentrations, <90microns, June 1988 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)									
North	East	SAMPLE	%<90	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg
462593	534572	P 0	20.35	56	142	98	38200	380	11	40	1	38	0.86
462251	534199	P 1	56.63	64	170	107	40300	430	12	52	1	40	1.13
461866	533904	P 2	20.5	51	142	90	33400	380	8	72	1	27	1.25
461518	533542	P 3	29.13	59	168	107	35700	380	9	72	2	29	1.57
461171	533188	P 4	25.86	120	246	145	38700	470	12	77	2	35	1.73
460874	532853	P 5	13.72	50	141	81	28400	400	8	47	1	23	0.65
460537	532512	P 6	0.44	77	203	101	41400	570	9	93	1	33	1.48
462849	534311	P 10	70.24	29	89	31	41400	410	14	15	1	50	0.04
462662	533874	P 11	76.74	41	100	34	45000	390	16	20	1	54	0.07
462360	533478	P 12	28.44	106	459	292	40800	450	11	75	3	38	3.66
461855	533135	P 13	12.23	92	239	115	42500	440	10	142	2	32	1.81
461601	532824	P 14	45.17	85	209	146	32800	380	11	52	2	34	2.28
461210	532517	P 15	15.68	73	173	111	33500	410	9	56	2	29	0.93
460860	532094	P 16	45.72	62	172	127	33300	380	10	39	2	36	1.19
463230	533921	P 20											
463052	533524	P 21	74.17	26	85	28	43600	470	14	24	1	48	0.04
462687	533113	P 22	20.7	35	110	63	30200	400	8	31	1	28	0.37
462307	532741	P 23	34.21	91	211	135	33000	380	10	45	2	32	1.40
461974	532459	P 24	45.7	112	276	162	38400	430	12	83	2	39	2.80
461581	532122	P 25	26.26	102	287	159	35000	440	10	78	2	33	2.28
461185	531792	P 26	13.25	50	131	84	34600	430	9	69	1	27	0.47
463563	533569	P 30	64.39	25	64	19	35700	350	11	20	1	40	0.03
463351	533113	P 31	49.32	48	138	88	37800	400	12	42	1	41	0.98
462983	532725	P 32	95.24	13	49	14	22100	310	7	16	1	23	0.03
462655	532457	P 33	28.99	63	196	103	34400	380	10	49	2	33	1.32
462298	532128	P 34	18.57	96	271	227	33000	400	10	66	2	31	2.06
461926	531711	P 35	16.09	69	185	103	33700	410	9	46	2	29	0.74
461637	531445	P 36	15.72	67	164	110	39600	450	10	63	1	31	1.43
463935	533336	P 40	5.81	56	168	150	38500	550	9	62	1	30	0.42
463654	532782	P 41											
463315	532415	P 42											
462959	532077	P 43	40.1	350	478	311	41200	450	14	449	4	41	10.33
462624	531759	P 44	43.14	57	159	103	28500	340	8	77	1	27	1.04
462252	531388	P 45	9.14	45	142	77	36400	430	7	93	1	24	0.41
461919	530999	P 46	1.92	62	162	102	35400	570	7	69	1	23	1.12
464350	532958	P 48	3.77	50	131	79	50600	510	7	119	1	25	0.53
464163	532419	P 50	7.28	59	149	117	37400	420	10	86	1	33	1.19
463822	532050	P 51	10.17	58	164	113	38500	640	10	55	1	36	0.89

Table 6 (cont.) Sample positions and metal concentrations, <90microns, June 1988 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)									
North	East	SAMPLE	%<90	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg
463532	531609	P 52	10.0	78	226	153	40300	490	11	75	2	40	1.53
463059	531332	P 53	12.48	69	203	128	42600	590	11	85	1	42	1.15
462739	530918	P 54	9.97	239	710	278	50300	680	12	234	4	37	4.68
462399	530645	P 56	83.6	57	167	95	32800	520	9	67	1	29	0.69
464666	532495	P 60											
464336	532170	P 61	94.35	26	77	25	44700	420	15	27	1	53	0.02
463935	531722	P 62											
463655	531386	P 63											
463273	531160	P 64											
462888	530799	P 65											
462666	530372	P 66											
461860	536720	Y 23	76.27	41	124	85	30600	350	10	41	1	33	0.33
461181	535981	Y 24	44.29	52	144	123	33100	360	10	58	1	34	0.82
460494	535361	Y 25	34.54	54	159	127	36300	360	10	65	1	34	1.09
459747	534584	Y 26	4.51	82	223	157	62000	680	12	188	1	38	0.84
458223	533993	Y 27	77.67	51	147	98	39700	480	11	74	2	35	0.41
457449	533342	Y 28	9.28	56	144	109	36900	520	12	60	1	40	0.44
457741	532547	Y 29	17.26	61	158	117	42200	520	12	107	1	41	0.49
462524	535990	Y 33	39.85	48	148	110	37600	410	11	58	1	37	0.52
461855	535313	Y 34	2.51	45	139	90	55200	560	11	113	1	36	0.16
461193	534623	Y 35	48.31	39	148	62	48100	460	15	54	1	49	0.71
460483	533882	Y 36	20.48	52	160	87	44400	470	9	113	1	29	0.51
459784	533194	Y 37	4.24	67	164	105	49400	590	12	111	1	36	0.30
459163	532633	Y 38	2.77	60	190	114	35200	520	11	66	2	35	0.60
463278	535313	Y 43	3.59	60	168	121	48700	720	12	53	1	44	0.77
459794	531729	Y 48											
464076	534567	Y 53	11.29	121	380	361	73900	1040	18	54	3	57	2.36
460542	531020	Y 58	2.23	75	242	108	101000	1340	13	519	1	41	0.50
464676	533868	Y 63	23.54	50	149	102	38600	490	11	71	1	40	0.72
461247	530356	Y 68	2.67	84	250	166	42800	670	11	123	3	34	0.74
465398	533175	Y 73	4.81	99	281	171	43900	600	13	78	2	42	1.60
461956	529615	Y 78											
466095	532445	Y 83	44.91	54	179	124	37600	330	11	60	1	38	1.16
465437	531693	Y 84	55.36	51	210	142	41900	440	11	77	1	40	1.01
464684	531025	Y 85	18.03	27	122	77	38700	490	7	177	1	23	0.24
464016	530298	Y 86	4.35	73	223	169	53500	570	13	97	2	41	1.85
463345	529633	Y 87	14.45	70	200	151	41600	550	12	42	2	40	1.19
462629	528852	Y 88	46.84	47	149	115	40400	440	11	82	2	35	0.46
Mean			29.4	69	190	120	40723	488	11	85	1	36	1.18
Standard deviation			25.3	47	100	63	10918	158	2	81	1	7	1.42
Coefficient of variation			0.86	0.68	0.53	0.52	0.27	0.32	0.20	0.96	0.49	0.21	1.21
Minimum			0.4	13	49	14	22100	310	7	15	1	23	0.02
Maximum			95.2	350	710	361	101000	1340	18	519	4	57	10.33

Table 7 Sample positions and metal concentration, <90microns, June 1988 river samples

Distance (m)	Sample	%<90	Cu	Zn	Pb	Co	Ni	Cr	Fe	Mn	Cd	Hg
			METAL CONCENTRATIONS (ppm)									
150	1	3.3	147	850	1300	15	63	850	55000	520	7	4.05
300	2	81.1	190	680	710	14	68	560	48500	410	5	33.95
450	3	22.9	135	459	512	12	49	391	45300	350	4	3.58
600	4	88.4	103	409	513	11	42	202	42500	290	4	2.19
750	5	42.9	92	481	418	17	58	278	46100	360	4	6.35
900	6	98.5	50	473	710	15	45	94	43800	610	4	1.00
1050	7	94.0	417	351	510	15	48	1380	48100	510	6	21.93
1200	8	39.4	130	497	483	12	44	310	42000	380	5	4.67
1350	9	86.6	71	372	381	13	42	100	40200	580	3	1.88
1500	10	89.4	226	524	521	16	50	570	46100	390	6	9.94
1650	11	94.6	98	408	476	13	48	191	46000	430	4	2.52
1800	12	99.2	512	427	387	14	60	1300	43200	390	6	18.27
1950	13	95.5	96	406	398	12	46	164	39000	340	4	2.23
2100	14	96.6	160	494	463	12	47	249	42200	360	5	4.51
2250	15	91.0	227	670	580	13	53	515	45800	390	6	9.35
2400	16	95.9	125	458	431	13	46	195	45700	340	4	3.87
2550	17	91.8	125	462	439	13	47	209	40700	330	5	3.69
2700	18	94.6	199	556	486	14	50	331	49100	430	6	5.55
2850	19	95.1	159	534	570	13	45	201	43300	370	5	3.61
3000	20	95.1	143	509	429	14	51	139	47500	340	5	4.28
3150	21	90.7	181	536	399	13	45	143	47100	350	5	4.28
3300	22	54.0	152	514	385	14	51	144	54100	410	5	2.98
3450	23	82.7	231	570	453	12	45	190	40000	360	6	5.77
3600	24	98.4	177	489	314	12	42	143	36200	320	5	4.10
3750	25	85.6	216	750	505	14	46	340	46700	420	7	8.12
3900	26	85.1	228	620	371	14	45	436	51700	490	5	9.66
4050	27	82.6	196	590	399	14	47	234	49600	430	5	5.41
4200	28	91.9	189	527	336	13	50	133	48900	400	4	4.41
4350	29	89.9	227	585	401	12	46	162	45200	380	6	5.47
4500	30	80.4	229	670	452	14	53	181	55700	440	6	4.95
4650	31	91.2	247	650	464	13	51	204	48500	440	6	6.74
4800	32	91.6	198	660	406	13	44	180	50100	390	5	6.23
4950	33	88.3	180	650	386	14	46	200	52200	420	5	5.44
5100	34	91.1	202	650	432	15	53	221	52200	430	6	5.23
5250	35	91.2	196	590	364	13	44	163	50100	430	5	5.16
5400	36	93.3	222	690	412	14	46	178	51900	400	5	7.20
5550	37	88.4	218	620	359	14	47	121	50100	450	5	5.13
5700	38	87.4	256	650	456	14	52	174	54400	460	5	5.48
5850	39	91.5	106	345	187	13	42	68	33700	420	3	2.64
6000	40	5.0	229	740	387	14	49	287	41300	430	6	9.99
6150	41	82.1	256	700	435	14	52	152	51400	530	6	6.56
6300	42	86.6	120	352	197	13	43	112	43300	530	3	3.25
6450	43	83.7	235	700	401	13	50	201	50000	470	6	6.61
6600	44	76.8	284	850	525	15	52	292	62400	600	7	9.03
6750	45	83.9	296	650	389	14	45	445	58200	450	6	13.32

TABLE 7 (cont.) Sample positions and metal concentration, <90microns, June 1988 river samples

Distance (m)	Sample	%<90	Cu	Zn	Pb	Co	Ni	Cr	Fe	Mn	Cd	Hg
				METAL CONCENTRATIONS (ppm)								
6900	46	73.8	252	680	437	14	50	265	54400	480	5	5.71
7050	47	84.1	197	650	394	14	47	184	48100	450	4	5.59
7200	48	75.2	240	720	416	14	54	217	54600	630	6	7.17
7350	49	70.9	200	740	459	13	46	208	50600	470	4	6.05
7500	50	76.5	218	650	393	14	45	266	49400	510	5	5.40
7650	51	72.8	239	630	358	15	51	192	49100	540	5	5.38
7800	52	72.2	247	675	349	14.5	47.5	140	57900	650	4.5	5.62
7950	53	85.8	244	690	350	15	47	136	55500	680	4	4.57
8100	54	77.0	220	570	325	14	47	131	49200	540	4	4.34
8250	55	77.7	207	650	332	16	48	144	60100	640	5	4.99
8400	56	83.9	252	650	332	15	46	176	54500	690	5	4.63
8550	57	89.6	201	660	294	17	49	131	55000	620	4	3.42
8700	58	90.3	206	730	304	16	47	146	62700	920	5	3.70
8850	59	93.5	224	890	436	15	42	156	100000	2440	8	8.79
9000	60	95.2	175	610	250	19	48	72	55700	710	4	3.45
9150	61	97.6	156	600	227	17	44	64	51600	600	3	2.84
9300	62	96.5	202	560	235	19	49	85	54000	650	4	2.09
9450	63	96.9	238	650	262	21	51	132	56800	670	4	2.81
9600	64	94.9	202	541	223	19	53	108	51800	720	4	2.66
9750	65	69.4	196	620	252	23	55	139	59800	710	4	1.70
9900	66	71.0	153	459	190	15	47	84	50900	630	3	2.11
10050	67	61.4	173	404	179	20	46	94	47900	580	3	1.80
10200	68	92.3	181	535	211	18	52	96	50300	640	3	2.27
10350	69	92.2	208	419	191	19	48	106	49500	670	3	2.34
10500	70	94.8	131	371	162	19	47	80	59900	590	3	1.54
10650	71	90.7	129	304	150	15	45	61	43000	500	2	1.25
10800	72	89.6	108	201	120	14	41	53	38000	460	2	1.49
10950	73	87.1	126	297	124	18	57	67	44100	480	2	1.12
11100	74	85.9	146	234	146	15	43	64	41400	430	2	1.85
11250	75	92.6	114	230	130	17	45	57	42500	480	2	1.27
11400	76	89.1	262	830	493	13	49	372	56100	520	7	9.28
11550	77	86.3	110	206	129	20	45	57	43600	550	2	1.16
11700	78	93.6	56	130	96	12	42	31	36800	400	2	4.80
11850	79	77.2	133	194	107	20	41	48	39200	470	2	1.27
12000	80	78.4	115	172	103	15	48	46	39900	520	2	1.06
12150	81	76.3	83	179	122	15	45	65	42000	430	2	1.35
12300	82	81.1	28	77	22	14	48	26	41700	380	1	0.11
12450	83	58.7	79	198	114	16	46	63	45100	500	1	0.90
12600	84	17.1	75	167	89	12	37	59	35800	400	1	0.67
12750	85	35.9	50	126	81	11	34	58	34600	430	1	0.62
12900	86	28.4	52	121	86	11	36	45	31800	300	1	0.59
13050	87	8.8	90	171	106	13	39	59	37300	380	1	1.04
13200	88	8.6	50	123	76	9	29	57	32000	400	1	0.37
13350	89	10.5	69	167	100	12	37	49	36900	420	1	0.88
13500	90	27.8	74	181	112	14	40	52	40500	470	1	0.68

TABLE 7 (cont.) Sample positions and metal concentration, <90microns, June 1988 river samples

Distance (m)	Sample	%<90	Cu	Zn	Pb	Co	Ni	Cr	Fe	Mn	Cd	Hg
			METAL CONCENTRATIONS (ppm)									
13650	91	42.9	75	190	115	14	44	51	43200	530	1	1.02
13800	92	18.0	70	166	97	12	38	49	37000	460	1	0.66
13950	93	60.0	59	132	96	11	35	48	31700	410	1	0.74
14100	94	59.2	66	176	118	12	37	52	35500	390	1	1.39
14250	95	47.6	58	131	96	12	40	42	34700	390	1	0.55
14400	96	70.4	60	146	104	12	41	43	37600	490	1	1.24
14550	97	85.4	70	164	121	14	43	40	39300	460	1	0.84
14700	98	32.6	44	119	77	10	33	47	33100	420	1	0.17
14850	99	89.7	55	141	113	12	44	24	35900	400	1	0.86
15000	100	76.5	66	153	121	13	43	34	39100	560	1	1.62
15150	101	85.1	46	119	92	12	41	26	35500	340	1	0.34
15300	102	86.5	50	127	96	13	46	27	41200	380	1	0.83
15450	103	64.6	41	110	68	10	35	30	32300	360	1	0.37
15600	104	72.3	41	102	81	11	39	27	31800	310	1	0.83
15750	105	36.0	39	103	59	9	30	43	30900	390	1	0.12
15900	106	66.9	45	101	71	11	38	15	31400	310	1	0.24
16050	107	48.9	38	92	60	8	33	26	27600	370	1	0.90
16200	108	86.3	46	105	86	11	39	14	36400	350	1	0.30
16350	109	79.7	46	98	66	11	38	17	27100	360	1	0.31
16500	110	30.9	25	78	40	6	20	40	24600	720	1	0.60
16650	111	12.0	39	97	46	7	19	122	35300	780	1	0.21
16800	112	50.5	31	79	46	7	24	32	26300	1110	1	0.04
16950	113	52.3	112	334	182	12	42	108	48900	580	3	2.44
17100	114	14.2	33	85	56	8	28	25	28500	310	1	0.22
17250	115	8.6	28	80	47	5	17	78	28200	480	1	0.04
17400	116	13.6	37	91	44	6	19	96	27400	400	1	0.47
17550	117	15.1	27	98	48	7	22	139	33000	460	1	0.14
17700	118	14.3	20	82	39	6	19	85	28800	390	1	0.09
	Average	71	145	411	279	13	44	167	44568	493	3.4	3.82
	S D	28	87	239	196	3	9	203	10289	223	2.0	5
	C V	0.39	****	0.58	0.70	0.23	0.20	1.22	0.23	0.45	0.6	1.18
	Maximum	99	512	890	1300	23	68	1380	100000	2440	8.0	33.95
	Minimum	3	20	77	22	5	17	14	24600	290	1.0	0.04
	Max/Min	30	26	12	59	5	4	99	4	8	8.0	849

Table 8 Sample locations and metal concentrations, <90microns, March 1989 survey (disposal ground and surrounding area)

POSITION					METAL CONCENTRATIONS (ppm)									
East	North	Sample	%<90	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg
462646	530323	A 1	11.8	88	234	142	49200	441	15	161	2	43	1.41
463193	530902	A 2	STONES										
460542	528226	A 3	12.5	39	128	83	43300	493	11	274	1	24	0.52
461645	529259	A 4	STONES										
463766	531374	A 5	8.6	83	205	127	37300	361	13	110	2	37	4.31
464248	531925	A 6	24.7	77	217	129	44600	409	12	132	2	40	32.70
464813	532415	A 7	87.8	144	540	121	43900	422	35	144	3	51	1.52
465889	533524	A 8	29.3	55	175	116	41800	353	12	113	1	45	1.23
466951	534504	A 9	10.4	46	151	105	36100	383	11	101	1	43	22.21
465858	535600	A 10	29.6	43	162	119	38800	292	13	113	2	42	1.81
464791	534566	A 11	13.4	89	174	123	34900	317	13	102	2	45	2.06
463741	533471	A 12	55.0	51	131	59	45100	393	15	86	3	51	0.82
464249	532966	A 13	5.4	62	193	127	38500	418	13	100	2	45	1.87
463748	532422	A 14	3.9	83	221	133	55500	411	13	228	2	42	1.71
463157	533006	A 15	52.8	98	263	174	43600	339	15	129	3	38	3.43
462640	532456	A 16	13.1	91	222	115	51100	407	13	142	1	33	1.95
463182	531929	A 17	11.1	85	233	135	52300	444	11	278	1	32	2.14
462638	531400	A 18	56.9	98	242	139	35800	356	12	162	2	40	2.24
462138	531866	A 19	50.7	101	245	122	38600	343	14	145	2	43	2.12
461571	531399	A 20	69.3	117	242	141	34000	203	15	174	2	41	2.16
462132	530860	A 21	24.0	96	225	141	36300	392	13	139	2	41	2.01
460534	530310	A 22	18.0	50	170	106	50300	578	13	310	2	36	0.81
459436	529256	A 23	29.3	43	132	89	41700	463	13	249	1	34	0.72
458430	530268	A 24	2.5	90	500	142	37000	453	11	97	1	36	2.68
459505	531404	A 25	58.8	61	150	115	36500	421	14	114	2	42	1.41
460547	532463	A 26	8.8	45	115	42	47500	545	15	58	1	47	0.71
461066	531925	A 27	32.0	89	188	105	36200	383	14	132	2	37	1.73
461620	532453	A 28	25.8	126	480	163	39700	341	15	167	3	44	2.94
461060	532975	A 29	51.3	106	249	140	39200	379	15	124	3	39	2.15
461602	533515	A 30	29.2	91	222	142	38300	412	14	109	2	38	2.34
462146	532993	A 31	29.7	48	141	160	41700	471	17	65	2	41	0.83
462662	533517	A 32	32.2	281	620	335	55600	462	18	320	4	57	8.66
462148	534064	A 33	25.2	178	500	179	46300	529	18	136	3	48	3.11
462659	534556	A 34	31.4	360	214	84	43200	500	20	88	3	44	3.92
463192	534066	A 35	16.6	69	141	93	37100	257	13	89	1	30	1.24
463762	535694	A 36	32.6	67	171	116	32700	241	9	82	1	35	2.38
464794	536741	A 37	16.8	56	191	160	37100	531	13	88	1	48	1.26
463683	537737	A 38	38.8	45	173	117	38400	454	13	75	0	52	0.91

Table 8 (cont.) Sample locations and metal concentrations, <90microns, March 1989 survey (disposal ground and surrounding area)

POSITION				METAL CONCENTRATIONS (ppm)									
East	North	Sample	%<90	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg
462633	536702	A 39	60.0	46	146	108	29100	323	11	93	0	36	1.81
461596	535665	A 40	31.9	47	154	95	40200	382	13	127	1	33	1.01
460490	534601	A 41	70.5	76	212	139	38900	356	15	88	1	42	1.32
459449	533532	A 42	46.2	56	159	92	41600	413	15	133	2	32	0.91
458447	532449	A 43	52.2	57	143	96	36700	392	14	102	2	33	1.21
457307	531384	A 44	6.2	38	140	68	43600	675	13	239	2	21	0.80
456312	532427	A 45	28.4	43	138	84	41300	489	15	198	2	28	0.61
457387	533499	A 46	33.8	58	143	106	36700	355	16	101	2	34	0.90
458464	534585	A 47	STONES										
459507	535599	A 48	STONES										
460549	536640	A 49	91.5	63	172	132	41600	342	18	73	2	47	1.13
461598	537756	A 50	70.6	45	140	104	32600	327	15	70	1	31	1.06
462665	538821	A 51	45.5	14	44	29	39300	101	9	61	1	9	0.80
467935	533504	A 52	25.9	38	140	102	28700	302	15	74	2	28	1.01
468991	532407	A 53	28.0	46	145	123	32100	256	15	202	1	31	1.34
467962	531375	A 54	12.9	45	142	102	31400	335	15	88	2	28	0.90
466879	532439	A 55	41.4	45	148	102	33300	347	14	81	2	28	3.77
465807	531370	A 56	50.6	56	172	114	38300	322	16	91	2	33	1.31
466933	530298	A 57	60.5	55	171	112	34700	290	16	85	2	29	1.12
465845	529154	A 58	STONES										
464780	530340	A 59	28.8	47	150	105	44400	513	14	186	2	28	1.00
463714	529229	A 60	42.0	92	232	92	51800	484	19	144	2	47	1.90
464752	528173	A 61	81.3	56	149	56	39200	368	15	151	2	36	0.70
463709	527145	A 62	48.0	66	167	66	37800	334	17	102	1	34	11.50
462641	528205	A 63	47.4	44	132	44	39400	365	8	108	1	25	0.81
461638	527090	A 64	4.5	32	106	32	35600	555	7	279	1	14	0.52
Average			34.9	77	203	114	40127	394	14	136	2	37	2.8
Standard deviation			22.0	55	109	44	6051	97	4	65	1	9	5.1
Coefficient of variation			0.6	0.72	0.54	0.39	0.15	0.25	0.26	0.48	0.43	0.24	1.84
Minimum			2.5	14	44	29	28700	101	7	58	0	9	0.5
Maximum			91.5	360	620	335	55600	675	35	320	4	57	32.7

Table 9 Calculation of 10 year average dredged quantity

DREDGED QUANTITY (In situ cubic metres)

CHART	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	AVERAGE
1	47089	169302	61781	34267	46901	63928	113676	126425	113346	180640	95735.5
2	247661	526472	183687	177195	44707	41415	55461	109141	104423	57551	154771
3	100699	201405	116807	78444	83318	71552	98064	181249	145966	108843	118635
4	153305	109502	142402	133017	105748	134140	124573	167103	128768	123103	132166
5	78911	104078	55431	75992	377319	328776	451338	276356	380293	396558	252505
6	65879	115392	127176	81352	172231	123616	137318	158050	156505	150140	128766
7	103992	119913	165918	139007	213402	125837	87860	113497	112705	64456	124659
8	34241	165702	187951	156214	124183	76158	41464	49306	51924	147384	103453
9	332321	411038	226463	320440	75253	26556	65394	56821	97206	133660	174515
10	152366	128016	159775	113396	137895	91768	190168	64824	83998	74456	119666
11	253340	128017	159777	83790	95999	73590	181790	131962	93990	94680	129694
12	35779	94048	68874	40529	207579	273984	233573	318568	314748	153680	174136
13	50518	94049	68875	0	43928	46136	30985	195682	191627	126074	84787.4
Total	1656101	2366934	1724917	1433643	1728463	1477456	1811664	1948984	1975499	1811225	1793489

Table 10 Statistical summary of results

1987 DATA

	<90	Cu	Zn	Pb	Fe	Mn	Co
Average	32	101	224	109	34498	434	11
Standard deviation	22	55	80	40	3995	80	3
Coefficient of variation	0.70	0.54	0.35	0.37	0.12	0.18	0.28
Minimum	3	40	109	24	26796	277	3
Maximum	97	351	574	256	53266	682	20

1988 DATA

	<90	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg
Average	29	69	190	120	40723	488	11	85	1.48	36	1.18
Standard deviation	25	47	100	63	10918	158	2	81	0.73	7	1.42
Coefficient of variation	0.86	0.68	0.53	0.52	0.27	0.32	0.20	0.96	0.49	0.21	1.21
Minimum	0	13	49	14	22100	310	7	15	1.00	23	0.02
Maximum	95	350	710	361	101000	1340	18	519	4.00	57	10.33

1989 DATA

	<90	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg
Average	35	77	203	114	40127	394	14	136	1.77	37	2.8
Standard deviation	22	55	109	44	6051	97	4	65	0.75	9	5.1
Coefficient of variation	0.63	0.72	0.54	0.39	0.15	0.25	0.26	0.48	0.43	0.24	1.84
Minimum	3	14	44	29	28700	101	7	58	0.25	9	0.5
Maximum	92	360	620	335	55600	675	35	320	4.00	57	32.7

1988 RIVER DATA

	<90	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg
Average	71	145	411	279	44568	493	13	167	3.42	44	3.82
Standard deviation	28	87	239	196	10289	223	3	203	2.00	9	5
Coefficient of variation	0.39	0.60	0.58	0.70	0.23	0.45	0.23	1.22	0.59	0.20	1.18
Minimum	3	20	77	22	24600	290	5	14	1.00	17	0.04
Maximum	99	512	890	1300	100000	2440	23	1380	8.00	68	33.95

Table 11 Statistical summary of results, 0-20, 20-63 and 63-90 microns (September 1987 samples)

0-20 micron fraction (disposal ground and surrounding area)

		METAL CONCENTRATIONS (ppm)					
	%size	Cu	Zn	Pb	Fe	Mn	Co
Mean	15.9	166	340	182	40909	456	14
Standard deviation	14.6	93	149	66	5024	103	3.5
Coefficient of variation	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Minimum	0.4	42.0	104.0	26.0	22600.0	268.0	4.0
Minimum	0.4	42	104	26	22600	268	4
Maximum	79.4	518	1014	500	61200	928	24

20-63 micron fraction (disposal ground and surrounding area)

		METAL CONCENTRATIONS (ppm)					
	%size	Cu	Zn	Pb	Fe	Mn	Co
Mean	9	73	159	61	31280	457	9
Standard deviation	7	38	57	26	5907	88	3
Coefficient of variation	0.79	0.53	0.36	0.43	0.19	0.19	0.34
Minimum	1	16	56	10	16900	310	2
Maximum	34	241	464	170	48300	770	17

63-90 micron fraction (disposal ground and surrounding area)

		METAL CONCENTRATIONS (ppm)					
	%size	Cu	Zn	Pb	Fe	Mn	Co
Mean	6.8	37	114	42	25490	360	7
Standard deviation	5.4	37	30	17	7427	103	3
Coefficient of variation	0.79	0.98	0.26	0.39	0.29	0.28	0.42
Minimum	0.4	10	64	12	13300	180	2
Maximum	30.1	363	262	142	47400	693	16

TABLE 11 Statistical summary of results, 0-20, 20-63 and 63-90 microns

0-20 micron fraction (disposal ground and surrounding area)

		METAL CONCENTRATIONS (ppm)					
	%size	Cu	Zn	Pb	Fe	Mn	Co
Mean	15.9	166	340	182	40909	456	14
Standard deviation	14.6	93	149	66	5024	103	3.5
Coefficient of variation	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Minimum	0.4	42.0	104.0	26.0	22600.0	268.0	4.0
Minimum	0.4	42	104	26	22600	268	4
Maximum	79.4	518	1014	500	61200	928	24

Table 11 (contd.) Statistical summary of results, 0-20, 20-63 and 63-90 microns (September 1987 samples)

20-63 micron fraction (disposal ground and surrounding area)

		METAL CONCENTRATIONS (ppm)					
	%size	Cu	Zn	Pb	Fe	Mn	Co
Mean	9	73	159	61	31280	457	9
Standard deviation	7	38	57	26	5907	88	3
Coefficient of variation	0.79	0.53	0.36	0.43	0.19	0.19	0.34
Minimum	1	16	56	10	16900	310	2
Maximum	34	241	464	170	48300	770	17

63-90 micron fraction (disposal ground and surrounding area)

		METAL CONCENTRATIONS (ppm)					
	%size	Cu	Zn	Pb	Fe	Mn	Co
Mean	6.8	37	114	42	25490	360	7
Standard deviation	5.4	37	30	17	7427	103	3
Coefficient of variation	0.79	0.98	0.26	0.39	0.29	0.28	0.42
Minimum	0.4	10	64	12	13300	180	2
Maximum	30.1	363	262	142	47400	693	16

Table 12 <90 micron fraction regional averages

		METAL CONCENTRATION (ppm)									
Area	%<90	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg
September 1987 samples											
SWO	13	84	205	95	36804	551	11				
SWI	27	90	212	92	35903	487	11				
DG	22	160	301	131	36783	459	10				
NEI	45	81	192	98	35818	415	12				
NEO	35	67	189	103	30975	387	11				
NWO	50	72	172	90	31338	373	12				
NWI	22	109	240	114	34131	419	13				
DG	22	160	301	131	36783	459	10				
SEI	31	86	200	112	33793	401	11				
SEO	48	72	189	106	32273	397	10				
June 1988 samples											
SWI	37.7	56.7	157.0	116.6	40114.3	467.1	11.0	84.7	1.1	36.4	0.6
DG	28.5	99.3	255.8	150.9	36155.6	445.6	10.2	95.2	2.0	33.6	2.2
NEI	36.3	55.9	159.4	109.8	42900.0	504.3	12.4	48.2	1.2	42.4	0.8
NWO	37.7	56.7	157.0	116.6	40114.3	467.1	11.0	84.7	1.1	36.4	0.6
NWI	16.8	62.0	170.1	98.2	40990.0	480.0	10.4	81.8	1.3	33.2	0.9
DG	28.5	99.3	255.8	150.9	36155.6	445.6	10.2	95.2	2.0	33.6	2.2
SEI	38.6	50.2	168.5	114.7	43000.0	466.7	11.5	80.0	1.3	39.2	0.9
DR AV	70.2	159.2	459.6	276.7	46476.9	531.9	13.9	148.3	3.7	44.6	3.8
BGRD	43.7	47.9	123.4	78.7	33351	455.7	9.8	53.4	1.1	32.5	0.6
March 1989 samples											
SWO	18	49	202	75	39460	502	10	194	1.2	26	1.1
SWI	36	82	204	129	41260	407	14	180	2.0	41	1.6
DG	31	91	248	138	43833	388	14	161	2.0	39	2.1
NEI	26	143	269	140	42813	404	15	129	2.4	46	2.9
NEO	32	44	147	107	35025	328	12	86	1.1	37	4.0
NWO	54	54	149	102	38417	386	16	113	1.8	34	1.0
NWI	38	73	190	112	40820	415	14	101	1.6	40	1.5
DG	31	91	248	138	43833	388	14	161	2.0	39	2.1
SEI	34	80	245	110	44217	447	17	165	2.0	38	7.0

Table 13 <90micron fraction, enrichment factor of regions

Area	Cu	Zn	Pb	Cr	Cd	Hg
September 1987 samples						
SWO	0.33	0.24	0.08			
SWI	0.38	0.26	0.07			
DG	1.01	0.53	0.27			
NEI	0.30	0.20	0.10			
NEO	0.18	0.19	0.12			
NWO	0.21	0.15	0.06			
NWI	0.55	0.35	0.18			
DG	1.01	0.53	0.27			
SEI	0.34	0.23	0.17			
SEO	0.22	0.19	0.14			
June 1988 samples						
SWI	0.08	0.10	0.19	0.33	0.03	0.02
DG	0.46	0.39	0.36	0.44	0.35	0.50
NEI	0.07	0.11	0.16	-0.05	0.06	0.06
NWO	0.08	0.10	0.19	0.33	0.03	0.02
NWI	0.13	0.14	0.10	0.30	0.09	0.10
DG	0.46	0.39	0.36	0.44	0.35	0.50
SEI	0.02	0.13	0.18	0.28	0.10	0.10
DR AV	1.00	1.00	1.00	1.00	1.00	1.00
BGRD	0.00	0.00	0.00	0.00	0.00	0.00
March 1989 samples						
SWO	0.01	0.23	-0.02	1.49	0.05	0.16
SWI	0.31	0.24	0.25	1.33	0.35	0.30
DG	0.39	0.37	0.30	1.13	0.35	0.48
NEI	0.86	0.43	0.31	0.80	0.50	0.71
NEO	-0.03	0.07	0.14	0.34	0.00	1.07
NWO	0.05	0.08	0.12	0.63	0.29	0.12
NWI	0.23	0.20	0.17	0.50	0.20	0.29
DG	0.39	0.37	0.30	1.13	0.35	0.48
SEI	0.29	0.36	0.16	1.18	0.35	1.99
SEO	0.04	0.10	0.09	0.64	0.25	0.74

Table 14 0-20micron, 20-63micron, 63-90micron, fractions regional average (September 1987 samples)

Area	%size	Cu	Zn	Pb	Fe	Mn	Co
0-20microns							
SWO	5	144	301	168	38900	538	15
SWI	14	171	359	172	39363	516	15
DG	10	269	483	222	44817	501	14
NEI	30	103	240	134	41029	428	14
NEO	16	102	273	165	40200	427	15
NWO	22	114	247	156	38187	369	15
NWI	10	202	402	203	40356	465	17
DG	10	269	483	222	44817	501	14
SEI	16	132	300	183	40150	430	16
SEO	23	116	275	178	38488	396	13
20-63microns							
SWO	5	30	124	41	33415	553	7
SWI	6	37	135	50	30700	436	8
DG	5	51	125	49	27020	361	6
NEI	4	33	101	38	22821	305	6
NEO	7	21	91	33	17875	271	6
NWO	13	48	109	38	23633	338	9
NWI	4	33	121	42	27467	374	7
DG	5	51	125	49	27020	361	6
SEI	8	39	116	44	27938	327	7
SEO	11	25	105	42	22569	338	6
63-90microns							
SWO	5	31	126	42	34046	566	7
SWI	6	37	136	49	31413	448	8
DG	7	51	125	49	26942	360	6
NEI	4	34	102	38	23600	310	7
NEO	8	20	91	34	17013	263	6
NWO	13	47	108	38	23013	330	8
NWI	4	33	119	41	26556	350	7
DG	7	51	125	49	26942	360	6
SEI	6	43	124	47	29475	343	7
SEO	11	24	103	41	21994	332	6

Table 15 Naturally occuring concentrations

Metal	Earths crust	Granite	Basalt	Shale
	CONCENTRATION (ppm)			
Fe	56000	27000	86000	47000
Mn	950	400	1500	850
Cr	100	4	200	100
Ni	75	0.5	150	95
Zn	70	40	100	80
Cu	55	10	100	57
Co	25	1	48	20
Pb	12.5	20	5	100
Cd	0.2	0.2	0.2	0.3
Hg	0.08	0.08	0.08	0.4

Table 16 Correlation of metals 1987, 1988 and 1989 samples

Symbol	% Probability of significant correlation
+++	>99.9
++	99 to +99.9
+	90 to +99
o	-90 to +90
-	-90 to -99
--	-99 to -99.9
---	<-99.9

September 87 survey Disposal site and surrounding area

	Cu	Zn	Pb	Fe	Mn	Co	%size
Cu		+++	+++	+++	+	++	---
Zn	>99.9		+++	+++	+	+	---
Pb	>99.9	>99.9		+++	---	++	---
Fe	>99.9	>99.9	>99.9		+++	+	---
Mn	90-+99	90-+99	<-99.9	>99.9		---	---
Co	99-+99.	90-+99	99-+99.	90-+99	<-99.9		+
%size	<-99.9	<-99.9	<-99.9	<-99.9	<-99.9	90-+99	

June 88 survey Disposal site and surrounding area

	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg	%silt
Cu		+++	+++	o	o	+	+++	+++	o	+++	-
Zn	<99.9		+++	+	++	+	+++	+++	o	+++	-
Pb	<99.9	<99.9		+	++	+	++	+++	o	+++	-
Fe	-90-+90	90-+99	90-+99		+++	+++	+++	o	+++	o	-
Mn	-90-+90	99-+99.	99-+99.	<99.9		++	+++	o	+	o	---
Co	90-+99	90-+99	90-+99	<99.9	99-+99.		o	+	+++	o	o
Cr	<99.9	<99.9	99-+99.	<99.9	<99.9	-90-+90		+	o	+++	-
Cd	<99.9	<99.9	<99.9	-90-+90	-90-+90	90-+99	90-+99		o	+++	o
Ni	-90-+90	-90-+90	-90-+90	<99.9	90-+99	<99.9	-90-+90	-90-+90		o	+
Hg	<99.9	<99.9	<99.9	-90-+90	-90-+90	-90-+90	<99.9	<99.9	-90-+90		o
%silt	-90--99	-90--99	-90--99	-90--99	>-99.9	-90-+90	-90--99	-90-+90	90-+99	-90-+90	

March 1989 survey Disposal site and surrounding area

	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg	%silt
Cu		++	o	o	-	o	o	o	o	++	o
Zn	90--90		o	o	-	o	o	o	o	+	o
Pb	90--90	90-99		o	o	o	o	+	o	o	o
Fe	90--90	90--90	90--90		o	o	+	o	o	o	-
Mn	90--90	90--90	90--90	90-99		o	o	-	o	-	-
Co	99-+99.9	90--90	90--90	90--90	90--90		-	+	o	o	o
Cr	90--90	90--90	90--90	90--90	90--90	90--90		o	o	o	o
Cd	90--90	90--90	90--90	90--90	90--90	90--90	90--90		+	o	o
Ni	90--90	90--90	90--90	90--90	90--90	90--90	90--90	90--90		o	o
Hg	90--90	90--90	90--90	90--90	90--90	90--90	90--90	90--90	90--90		o
%silt	90--90	90--90	90--90	90--90	90--90	90--90	90--90	90--90	90--90	90--90	

Table 16 Correlation of metals 1987, 1988 and 1989 samples

1988 survey Tees River Dredged Cannel

	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg	%SILT
Cu		+++	++	++	+	o	++	+++	o	++	o
Zn	>99.9		+++	++	+	o	++	+++	o	++	o
Pb	99-99.9	>99.9		o	o	--	+++	+++	o	+++	o
Fe	99-99.9	99-99.9	-99-99		+++	o	+	++	o	o	o
Mn	90-99	90-99	-99-99	>99.9		++	o	+	o	o	o
Co	-99-99	>99.9	-99--90	-99--90	99-99.9		--	o	o	--	o
Cr	>99.9	99-99.9	>99.9	90-99	-99--90	-99--90		+++	o	+++	o
Cd	>99.9	>99.9	>99.9	99-99.9	90-99	-99-99	>99.9		o	++	o
Ni	-99-99	-99-99	-99-99	-99-99	-99-99	-99-99	-99-99	-99-99		o	o
Hg	90-99	90-99	>99.9	-99-99	-99-99	-99--90	>99.9	99-99.9	-99-99		o
%SILT	-99-99	-99-99	-99-99	-99-99	-99-99	-99-99	-99-99	-99-99	-99-99	-99-99	

September 87 survey Disposal site

	Cu	Zn	Pb	Fe	Mn	Co	%size
Cu		+++	+++	o	+	+++	o
Zn	>99.9		+++	o	+	o	---
Pb	>99.9	>99.9		+	o	o	---
Fe	-90-+90	-90-+90	90-+99		---	---	---
Mn	90-+99	90-+99	-90-+90	<-99.9		o	o
Co	>99.9	-90-+90	-90-+90	<-99.9	-90-+90		++
%size	-90-+90	<-99.9	<-99.9	<-99.9	-90-+90	99-+99.	

June 88 survey Disposal site

	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg	%silt
Cu		+++	+++	++	o	+++	+++	+++	+	+++	o
Zn	<99.9		+++	+++	+	+++	++	+++	+	+++	o
Pb	<99.9	<99.9		++	o	+++	++	+++	++	+++	o
Fe	99-+99.	<99.9	99-+99.		+++	+++	+	++	+++	+	-
Mn	-90-+90	90-+99	-90-+90	<99.9		+	o	o	++	o	-
Co	<99.9	<99.9	<99.9	<99.9	90-+99		+++	+++	+++	+++	o
Cr	<99.9	99-+99.	99-+99.	90-+99	-90-+90	<99.9		+++	+	+++	o
Cd	<99.9	<99.9	<99.9	99-+99.	-90-+90	<99.9	<99.9		+	+++	o
Ni	90-+99	90-+99	99-+99.	<99.9	99-+99.	<99.9	90-+99	90-+99		+	-
Hg	<99.9	<99.9	<99.9	90-+99	-90-+90	<99.9	<99.9	<99.9	90-+99		o
%silt	-90-+90	-90-+90	-90-+90	-90--99	-90--99	-90-+90	-90-+90	-90-+90	-90--99	-90-+90	

March 1989 survey Disposal site

	Cu	Zn	Pb	Fe	Mn	Co	Cr	Cd	Ni	Hg	%silt
Cu		++	o	o	-	o	o	o	o	++	o
Zn	-90-+90		o	o	-	o	o	o	o	+	o
Pb	-90-+90	90-99		o	o	o	o	+	o	o	o
Fe	-90-+90	-90-+90	-90-+90		o	o	+	o	o	o	-
Mn	-90-+90	-90-+90	-90-+90	90-99		o	o	-	o	-	-
Co	99-+99.9	-90-+90	-90-+90	-90-+90	-90-+90		-	+	o	o	o
Cr	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90		o	o	o	o
Cd	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90		+	o	o
Ni	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90		o	o
Hg	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90		o
%silt	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	-90-+90	

Table 17 Correlation of metals on each size fraction, 1987 samples

Symbol	% Probability of significant correlation
+++	>99.9
++	99 to +99.9
+	90 to +99
o	-90 to +90
-	-90 to -99
--	-99 to -99.9
---	<-99.9

0-20micron fraction
Disposal site and surrounding area

	Cu	Zn	Pb	Fe	Mn	Co	%size
Cu		+++	+++	+++	+++	o	---
Zn	>99.9		+++	+++	+++	o	---
Pb	>99.9	>99.9		+++	o	o	---
Fe	>99.9	>99.9	>99.9		+	---	---
Mn	>99.9	>99.9	-90-+90	90-+99		o	---
Co	-90-+90	-90-+90	-90-+90	<-99.9	-90-+90		o
%size	<-99.9	<-99.9	<-99.9	<-99.9	<-99.9	-90-+90	

0-20micron fraction
Disposal site

	Cu	Zn	Pb	Fe	Mn	Co	%size
Cu		+++	+++	o	+	+++	o
Zn	>99.9		+++	o	+	o	---
Pb	>99.9	>99.9		+	o	o	---
Fe	-90-+90	-90-+90	90-+99		---	---	---
Mn	90-+99	90-+99	-90-+90	<-99.9		o	o
Co	>99.9	-90-+90	-90-+90	<-99.9	-90-+90		++
%size	-90-+90	<-99.9	<-99.9	<-99.9	-90-+90	99-+99.9	

20-63micron fraction
Disposal site and surrounding area

	Cu	Zn	Pb	Fe	Mn	Co	Cr
Cu		+++	+++	o	o	+	---
Zn	>99.9		+++	+++	+++	+++	---
Pb	>99.9	>99.9		+++	++	+++	---
Fe	-90-+90	>99.9	>99.9		+++	+++	---
Mn	-90-+90	>99.9	99-+99.9	>99.9		+	---
Co	90-+99	>99.9	>99.9	>99.9	90-+99		---
%size	<-99.9	<-99.9	<-99.9	<-99.9	<-99.9	<-99.9	

20-63micron fraction
Disposal site

	Cu	Zn	Pb	Fe	Mn	Co	%size
Cu		++	+++	o	o	+++	o
Zn	99-+99.9		+++	+	o	++	o
Pb	>99.9	>99.9		+	o	+	+
Fe	-90-+90	90-+99	90-+99		+++	+	---
Mn	-90-+90	-90-+90	-90-+90	>99.9		o	o
Co	>99.9	99-+99.9	90-+99	90-+99	-90-+90		---
%size	-90-+90	-90-+90	90-+99	<-99.9	-90-+90	<-99.9	

Table 17 (contd.) Correlation of metals on each size fraction, 1987

63-90micron fraction
Disposal site and surrounding area

	Cu	Zn	Pb	Fe	Mn	Co	%size
Cu		+++	+++	o	o	+	---
Zn	>99.9		+++	+++	+++	+++	---
Pb	>99.9	>99.9		+++	++	+++	o
Fe	-90-+90	>99.9	>99.9		+++	+++	---
Mn	-90-+90	>99.9	99-+99.9	>99.9		+	---
Co	90-+99	>99.9	>99.9	>99.9	90-+99		---
%size	<-99.9	<-99.9	-90-+90	<-99.9	<-99.9	<-99.9	

63-90micron fraction
Disposal site

	Cu	Zn	Pb	Fe	Mn	Co	%size
Cu		++	+++	o	o	+++	++
Zn	99-+99.9		+++	+	o	++	+
Pb	>99.9	>99.9		+	o	+	++
Fe	-90-+90	90-+99	90-+99		+++	+	---
Mn	-90-+90	-90-+90	-90-+90	>99.9		o	+
Co	>99.9	99-+99.9	90-+99	90-+99	-90-+90		---
%size	99-+99.9	90-+99	99-+99.9	<-99.9	90-+99	<-99.9	

FIGURES

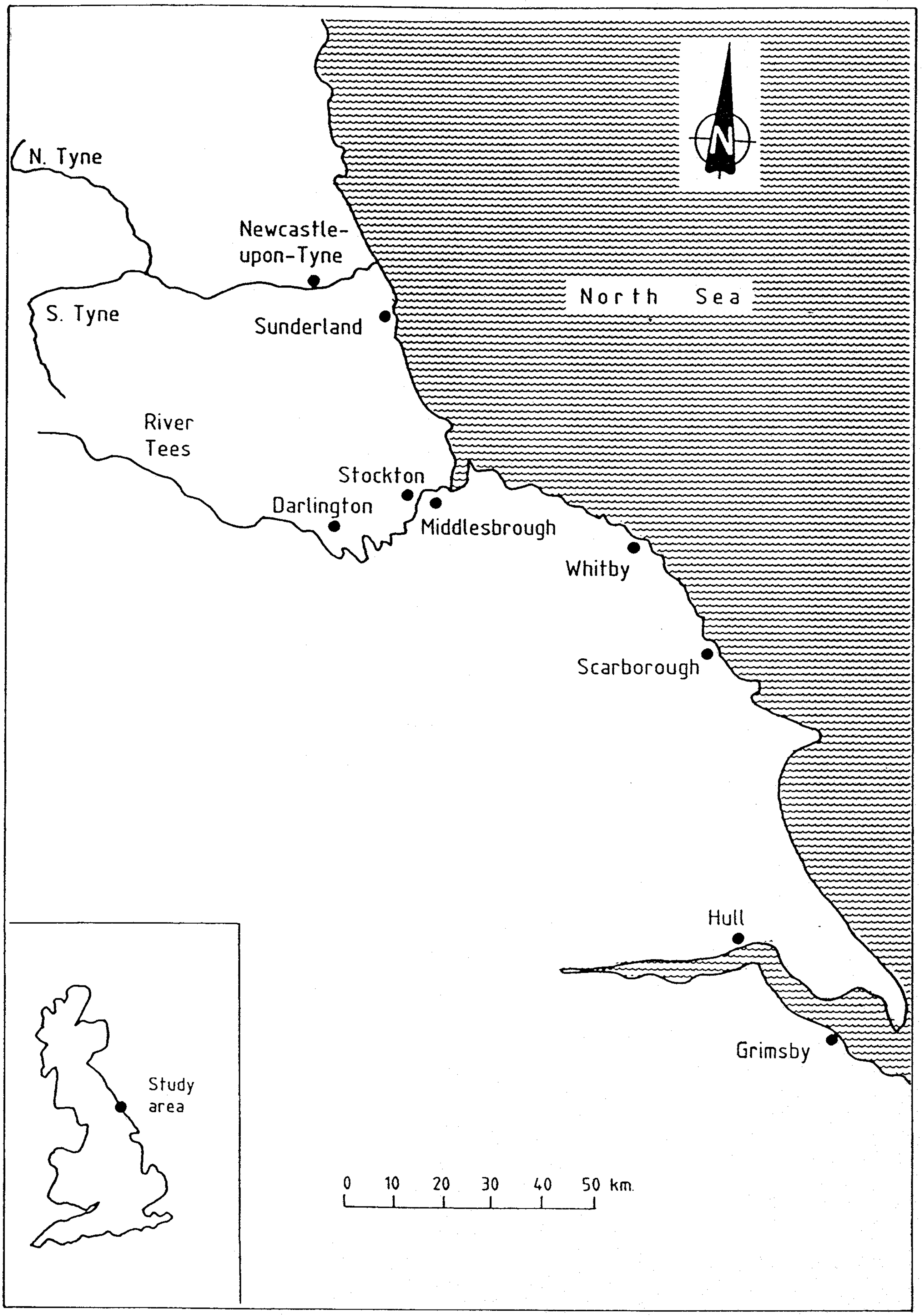


Fig 1 Location map of River Tees

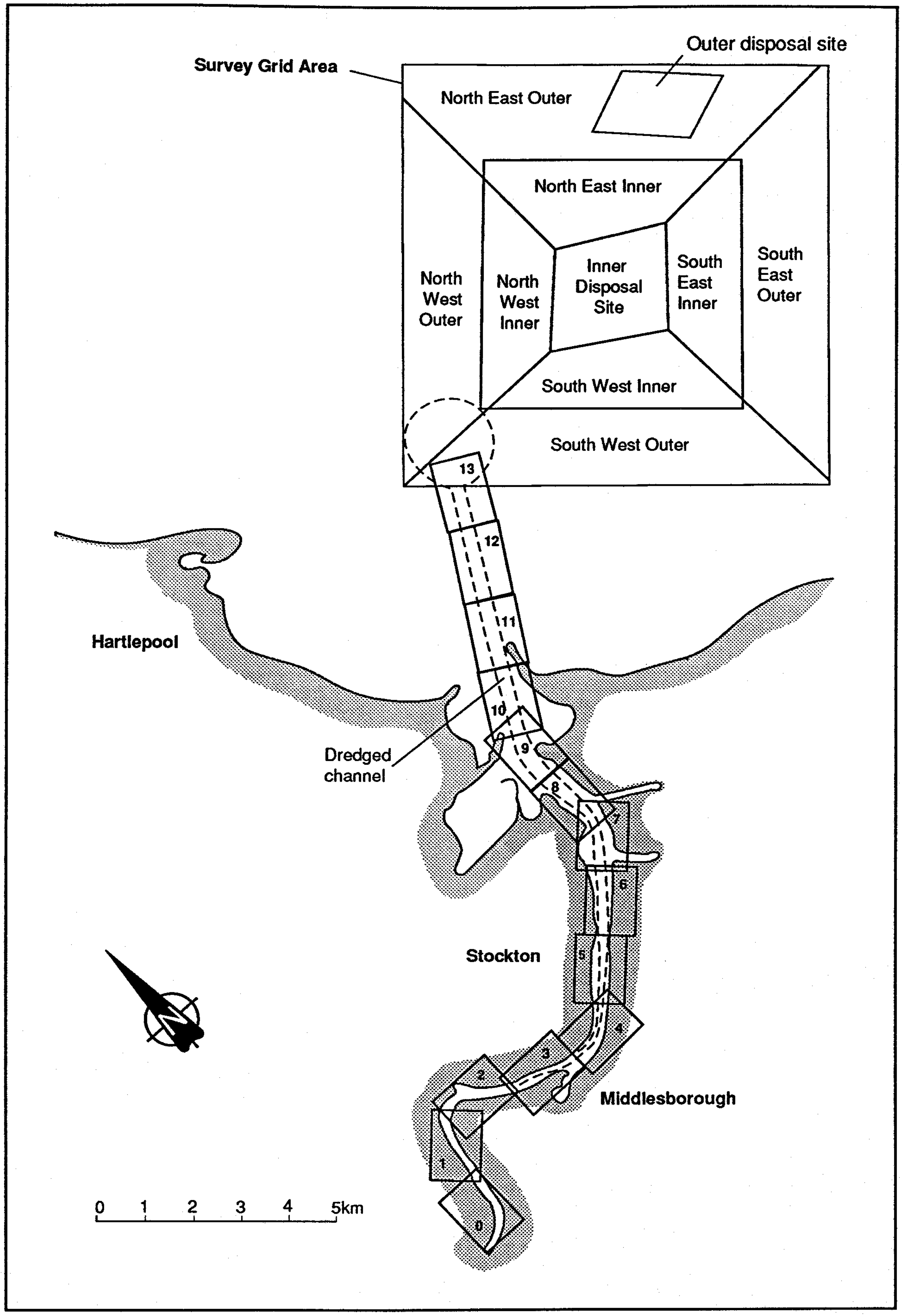


Fig 2. Map of Study Area

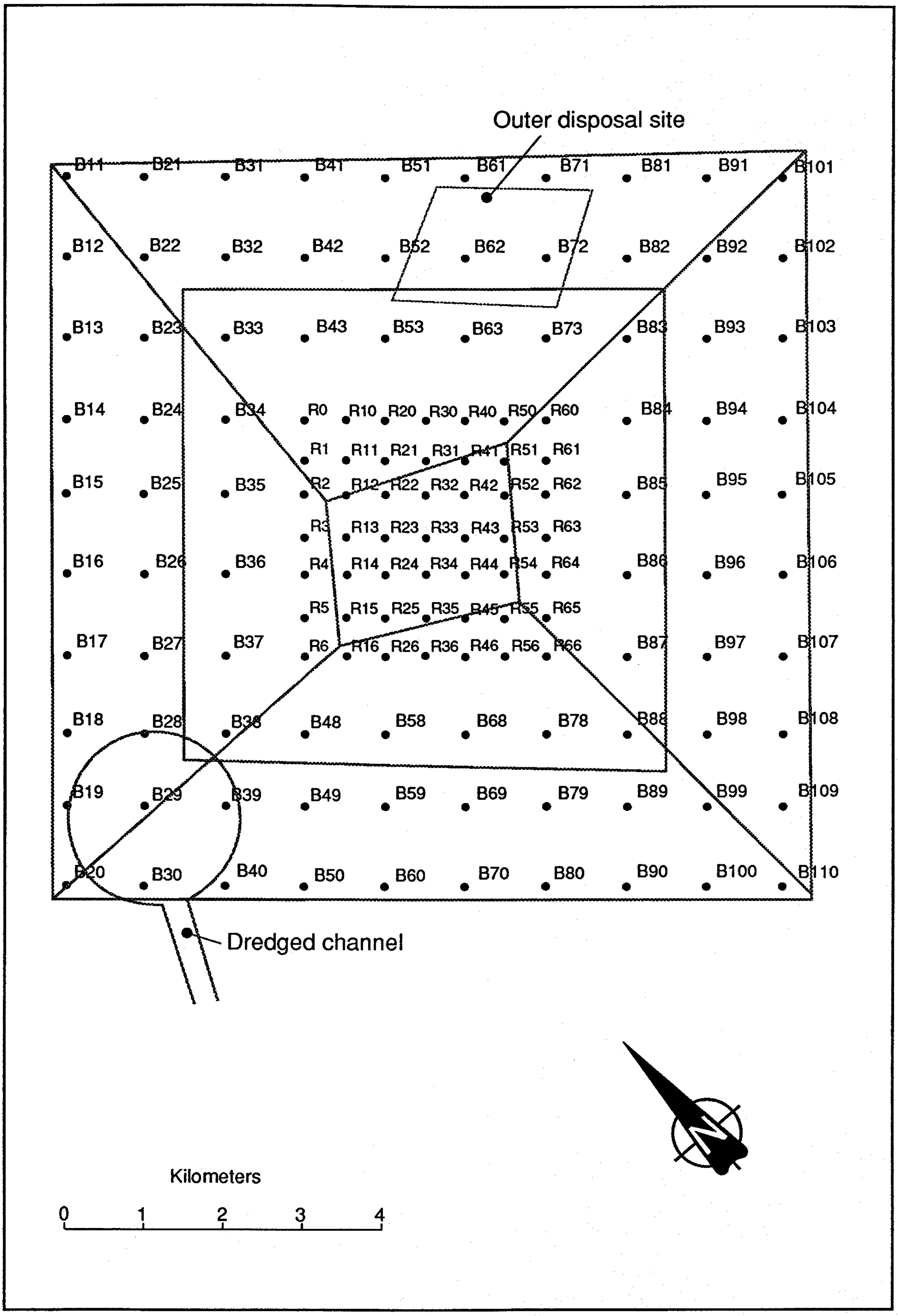


Fig 3. 1987 survey sampling positions

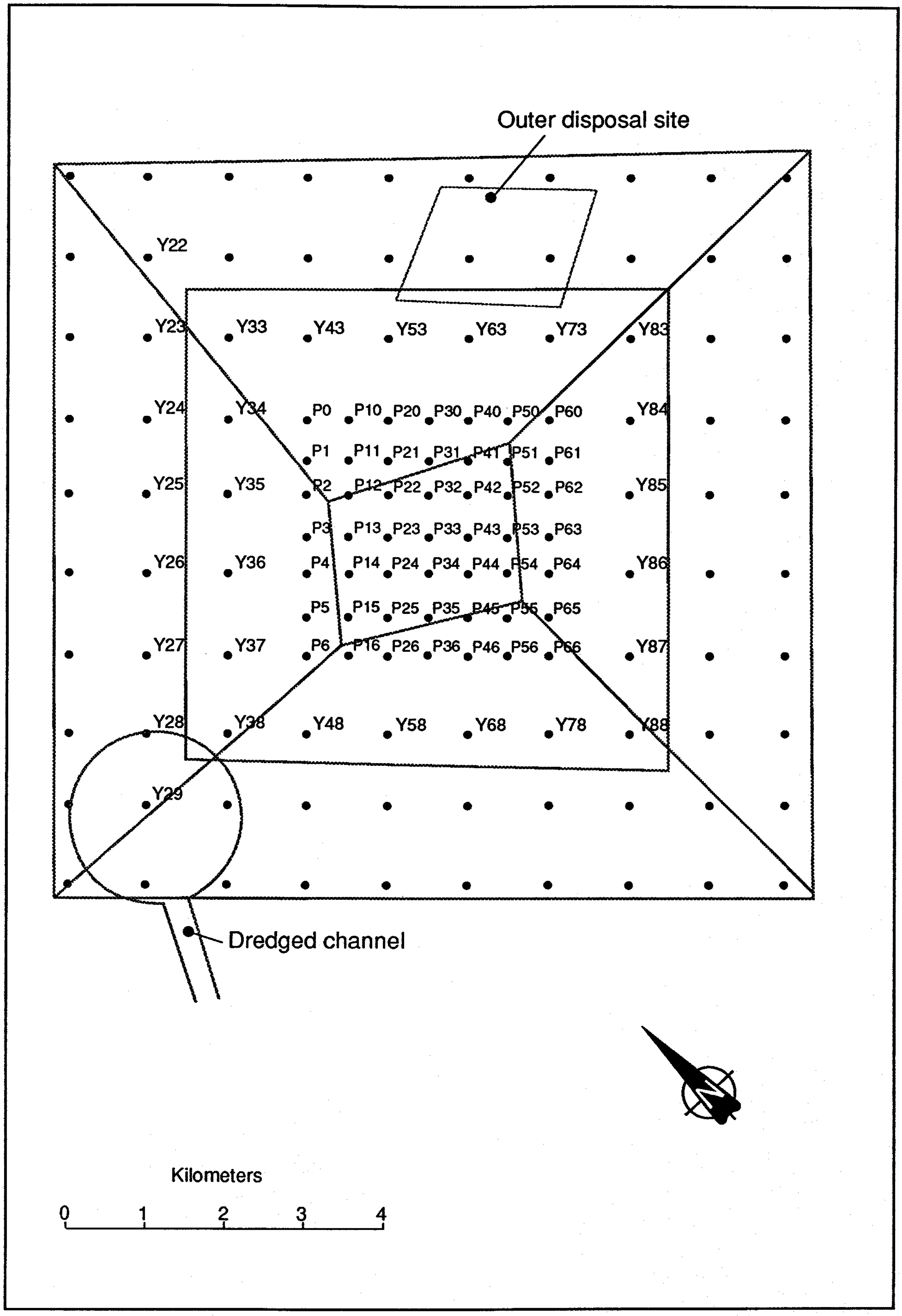


Fig 4. 1988 survey sampling positions

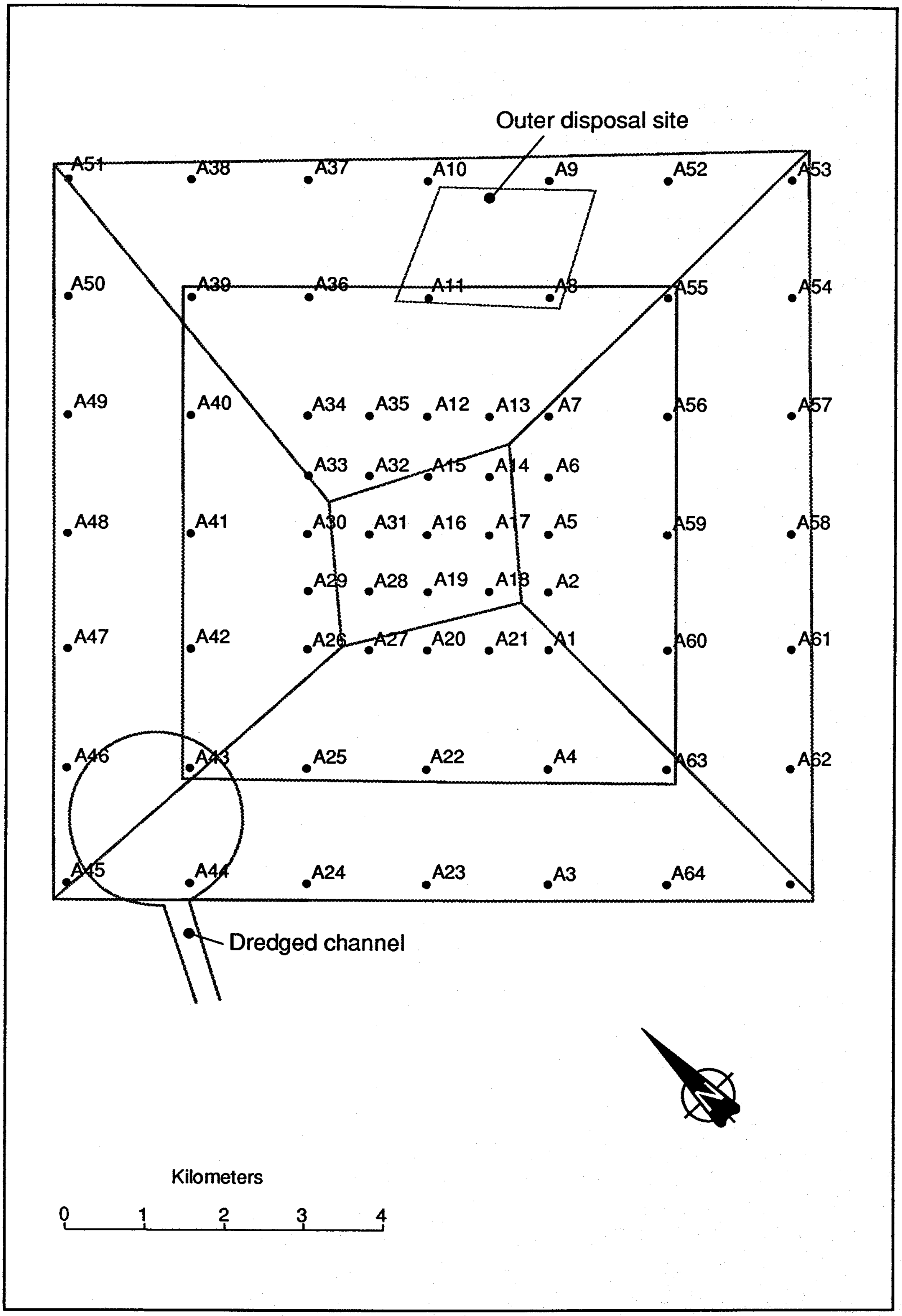


Fig 5. 1989 survey sampling positions

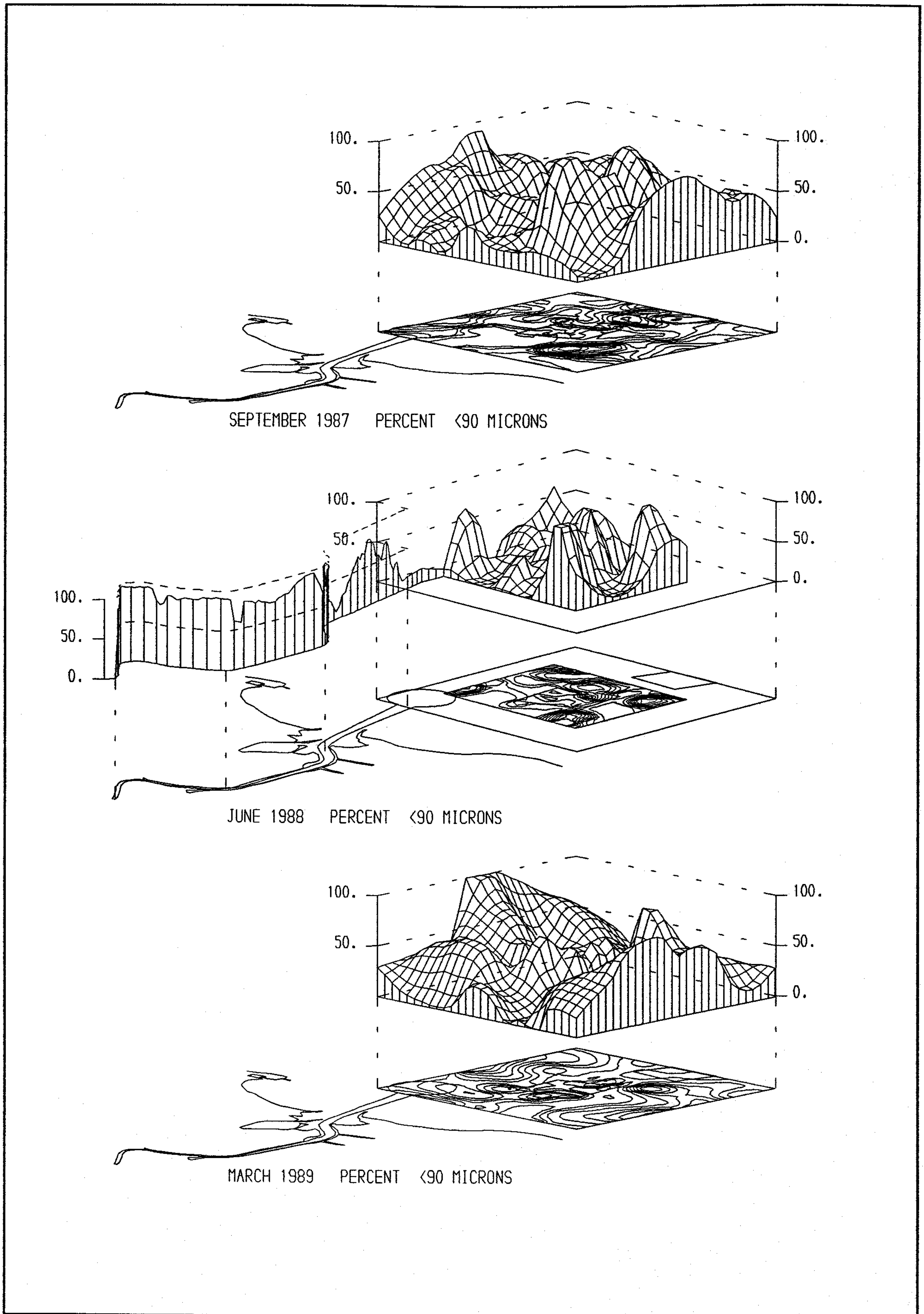


Fig 6 Isometric projections of %<90 microns (1987, 1988, 1989)

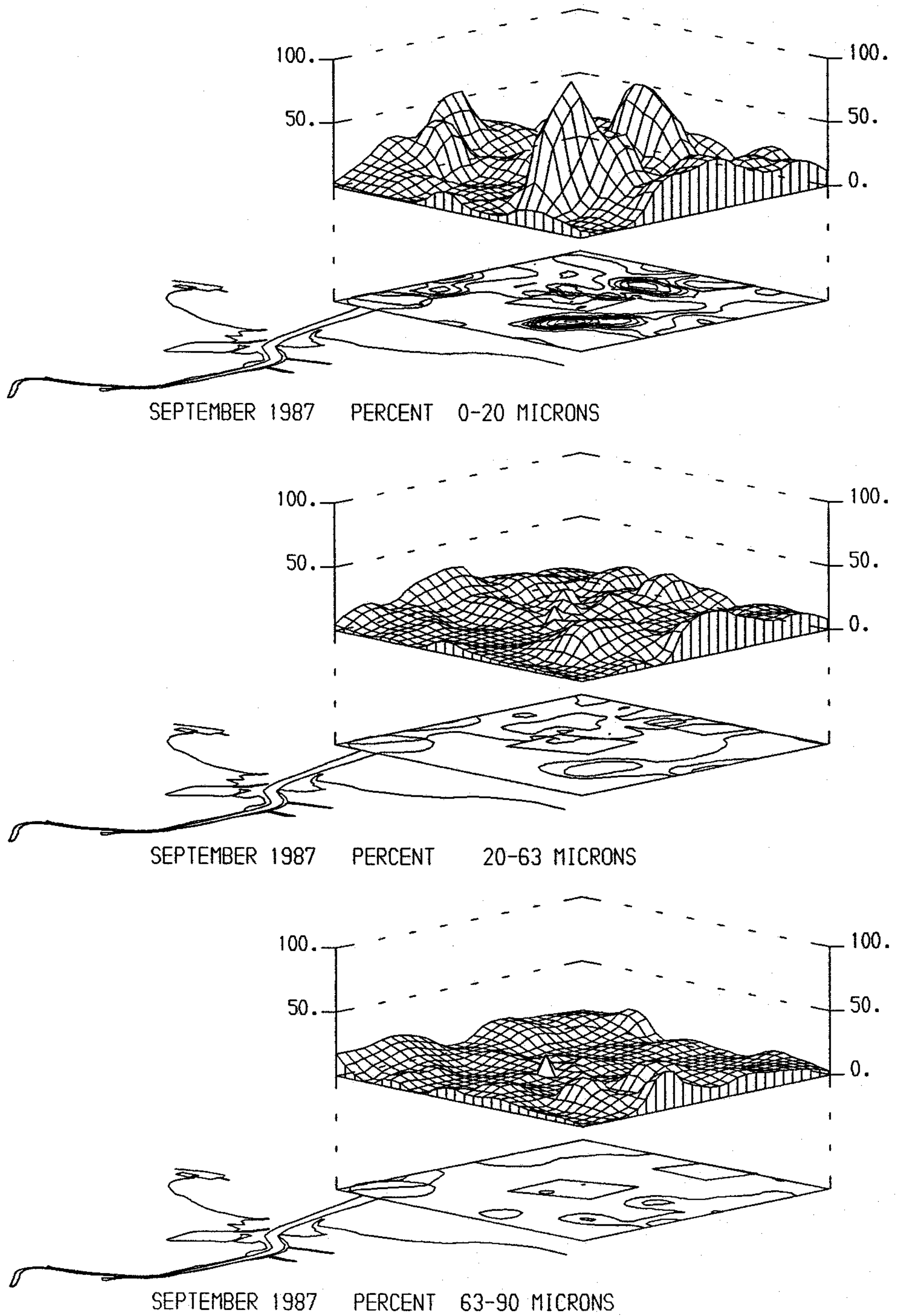


Fig 7 Isometric projections of particle size fractions

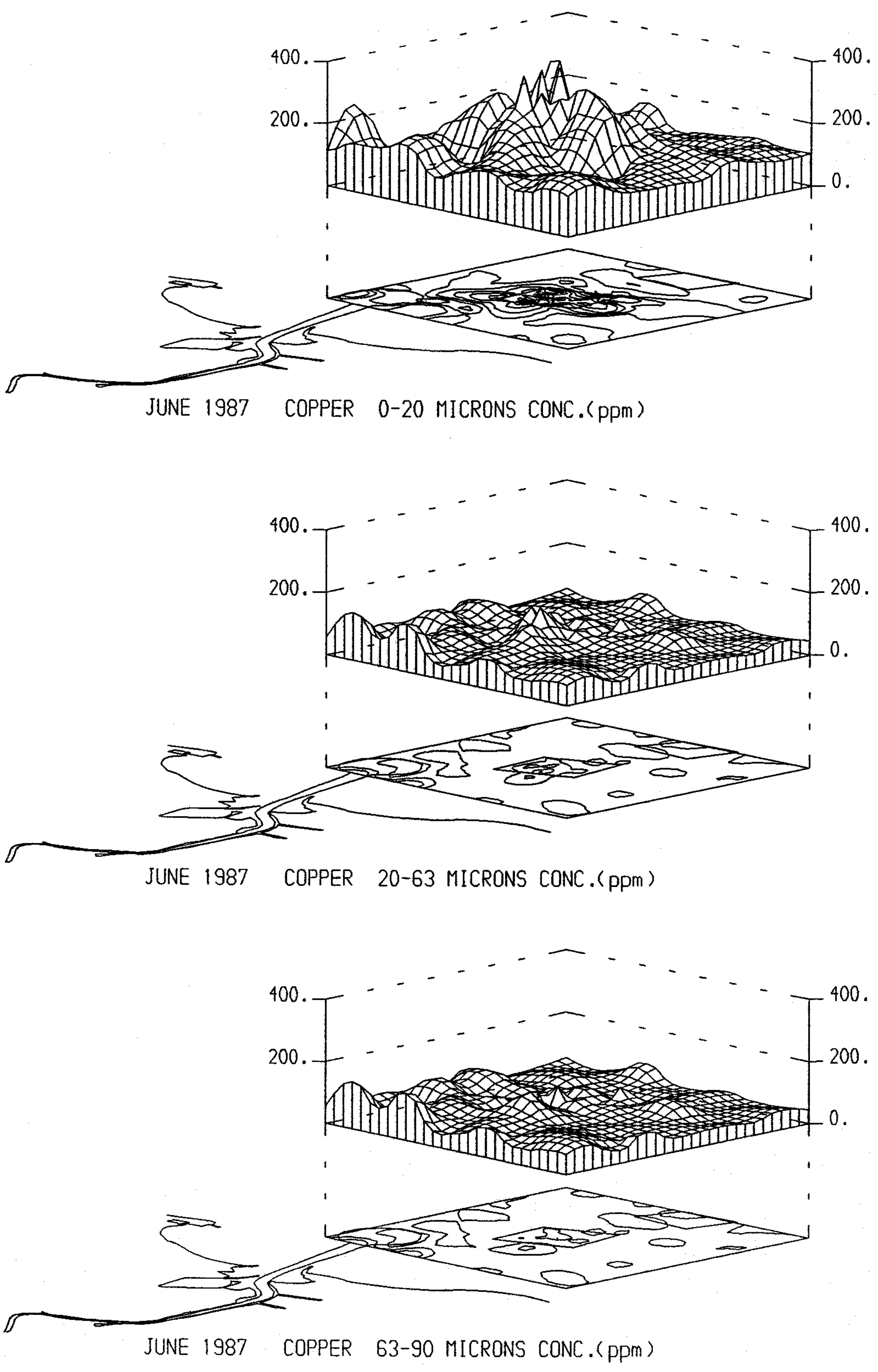


Fig 8 Isometric projections of copper on size fractions

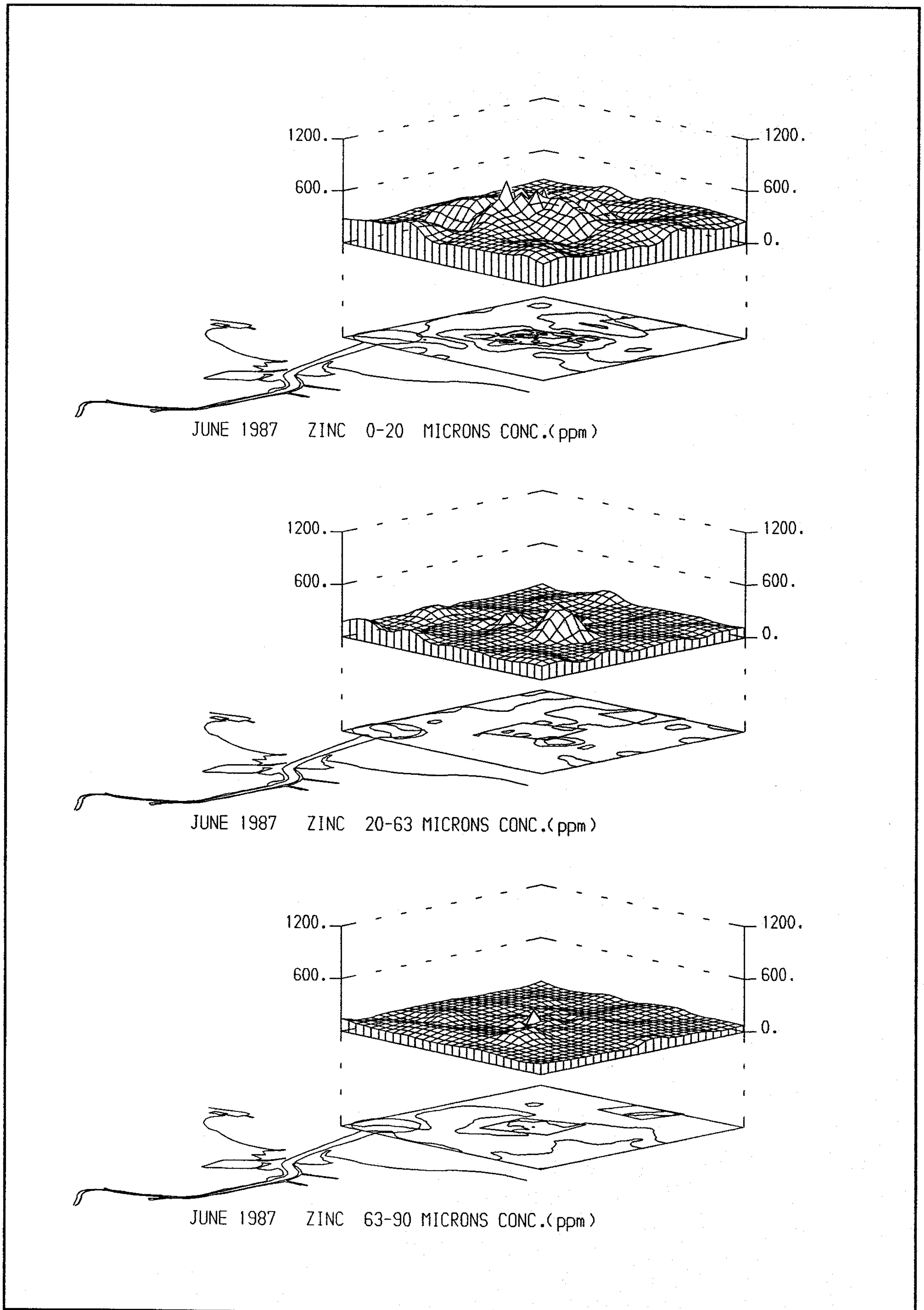


Fig 9 Isometric projections of zinc on size fractions

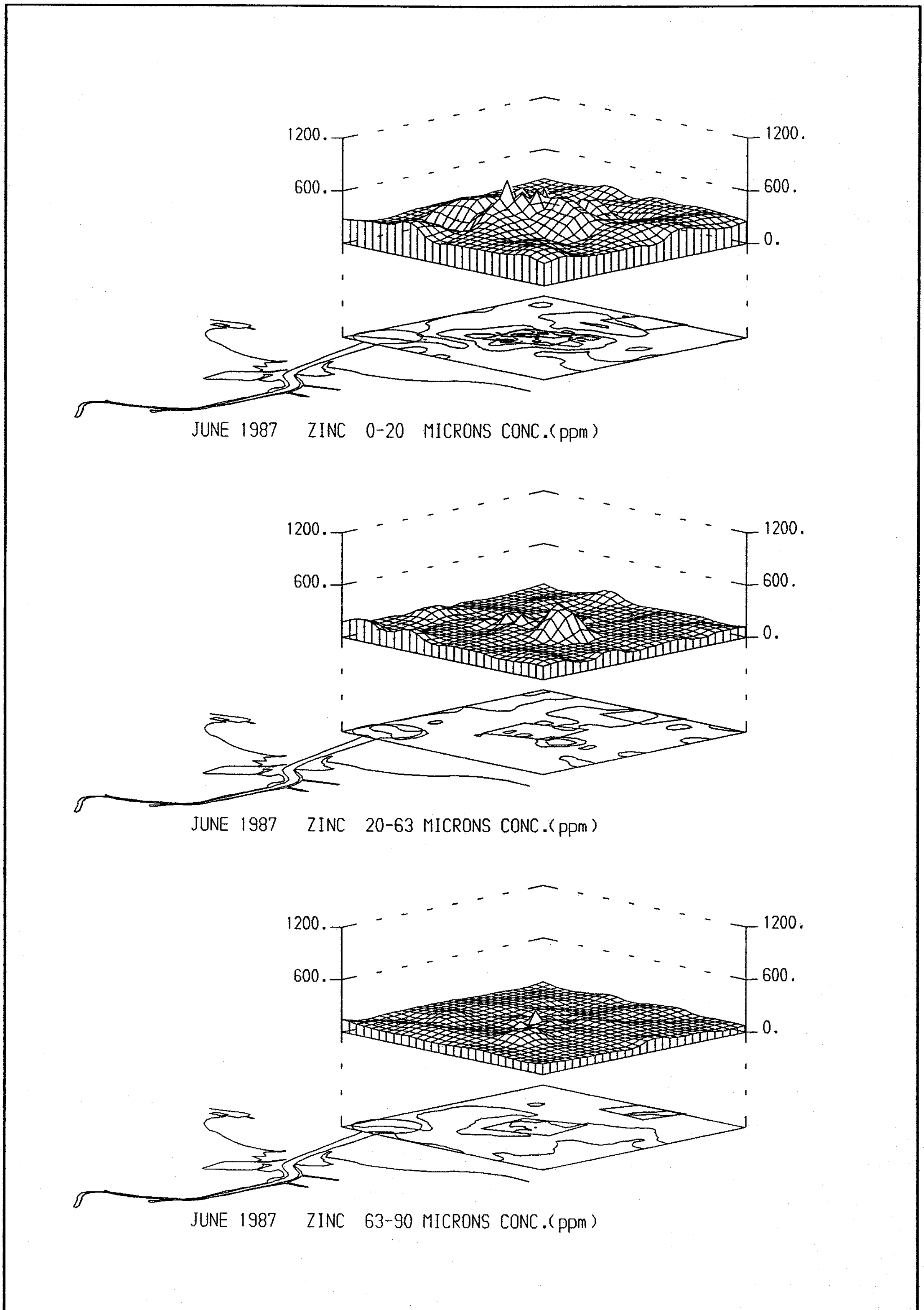


Fig 10 Isometric projections of lead on size fractions

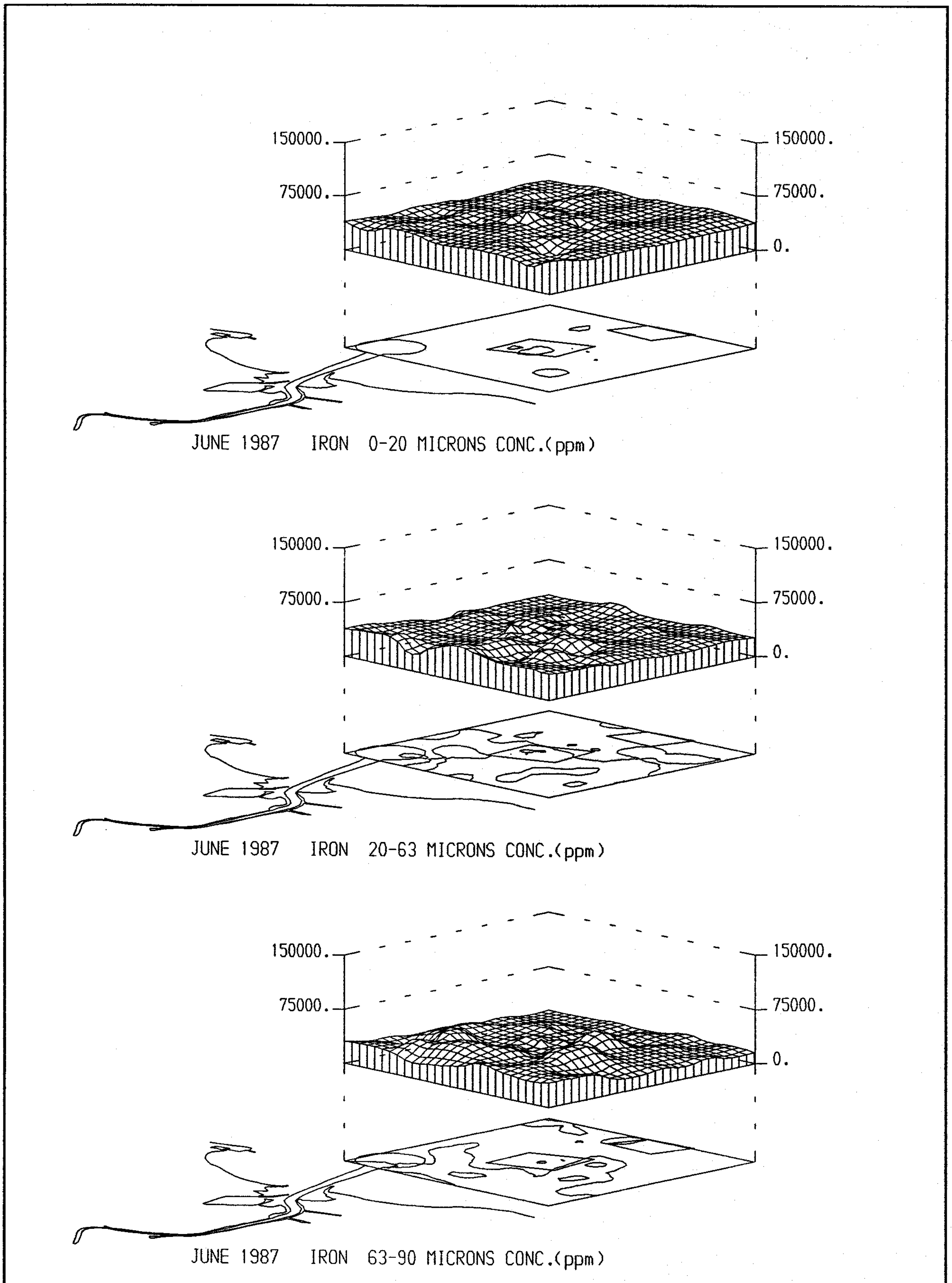


Fig 11 Isometric projections of iron on size fractions

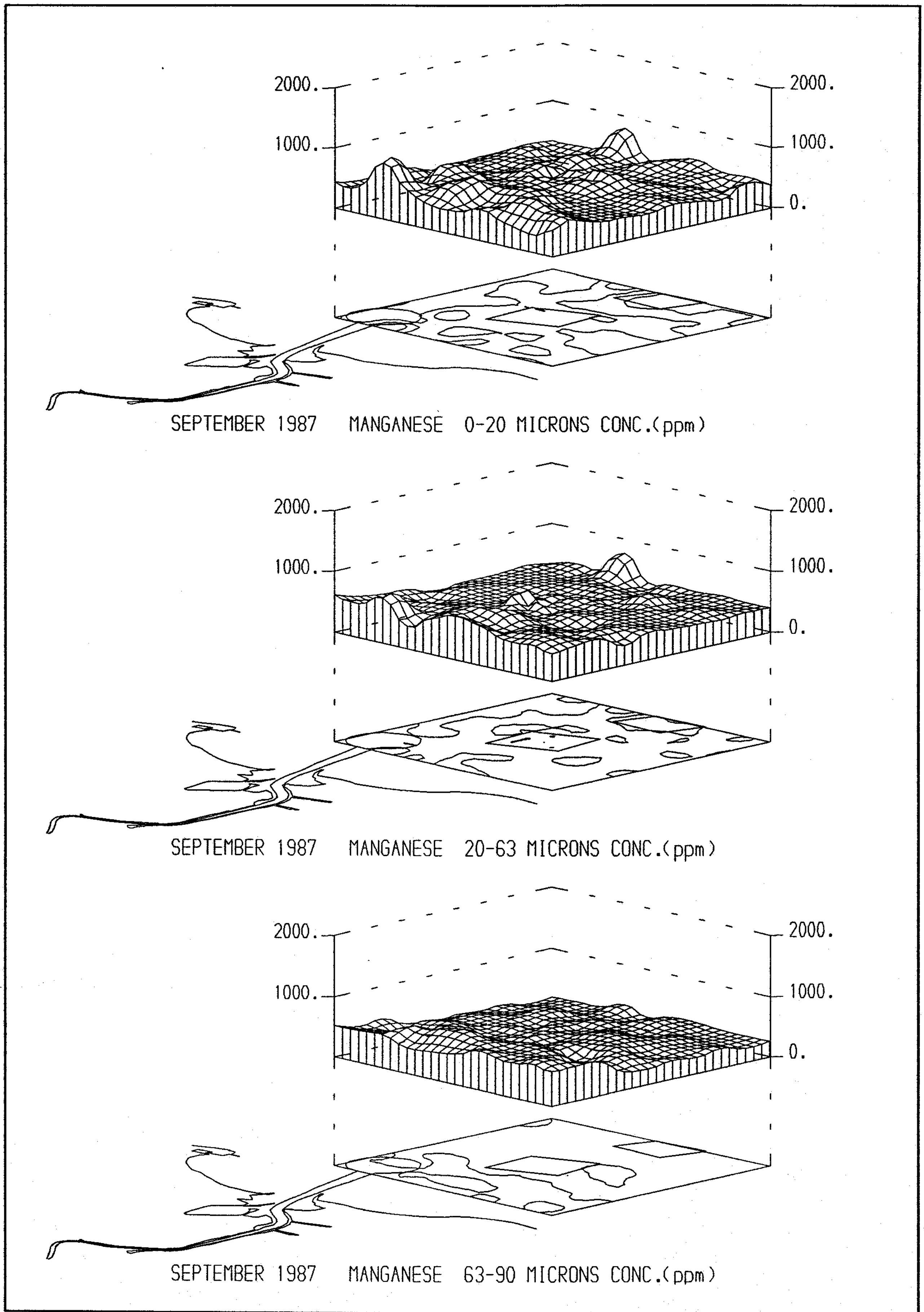


Fig 12 Isometric projections of manganese on size fractions

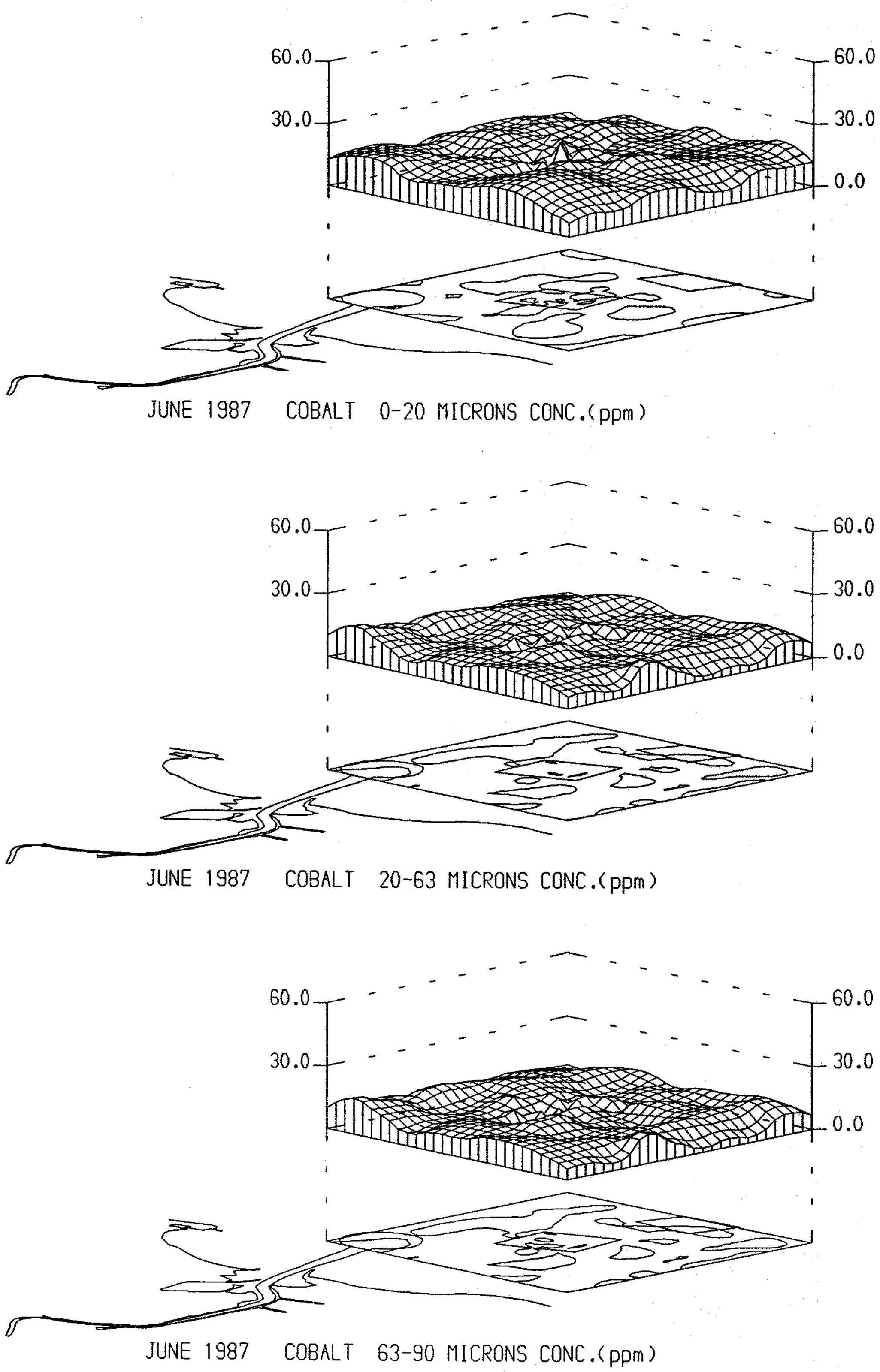


Fig 13 Isometric projections of cobalt on size fractions

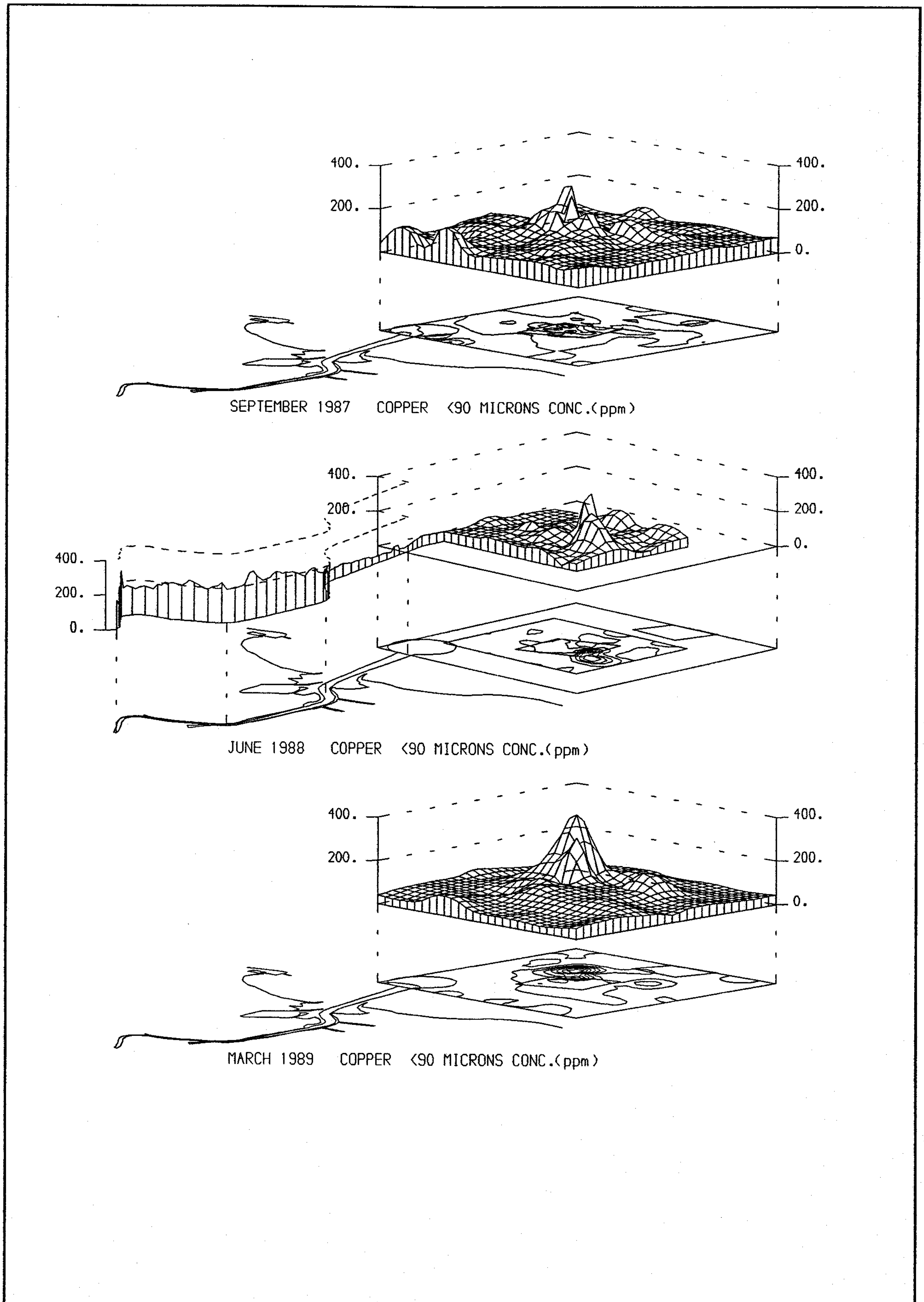


Fig 14 Isometric projections of copper on <90 micron fraction (1987, 1988, 1989)

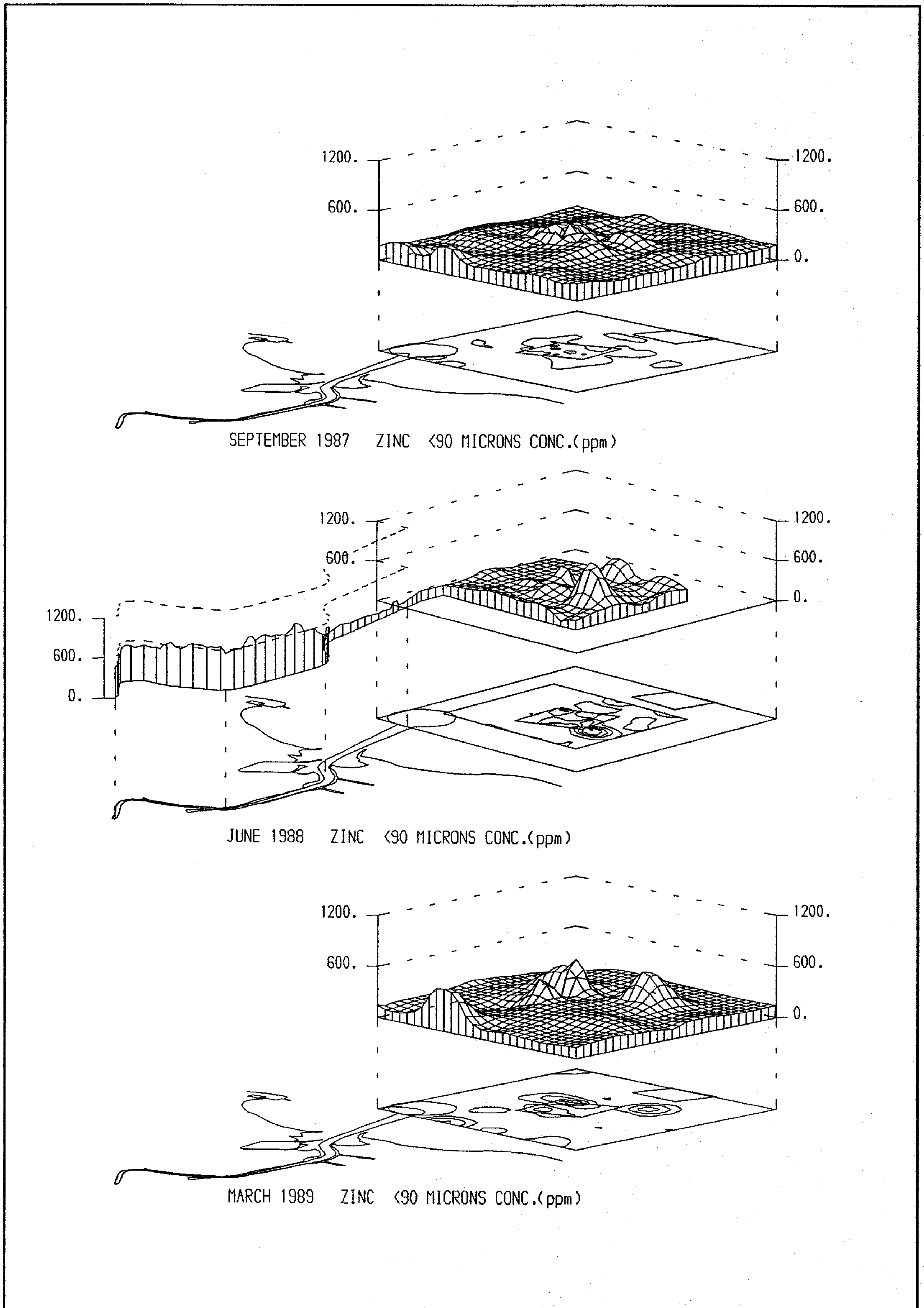


Fig 15 Isometric projections of zinc on <90 micron fraction (1987, 1988, 1989)

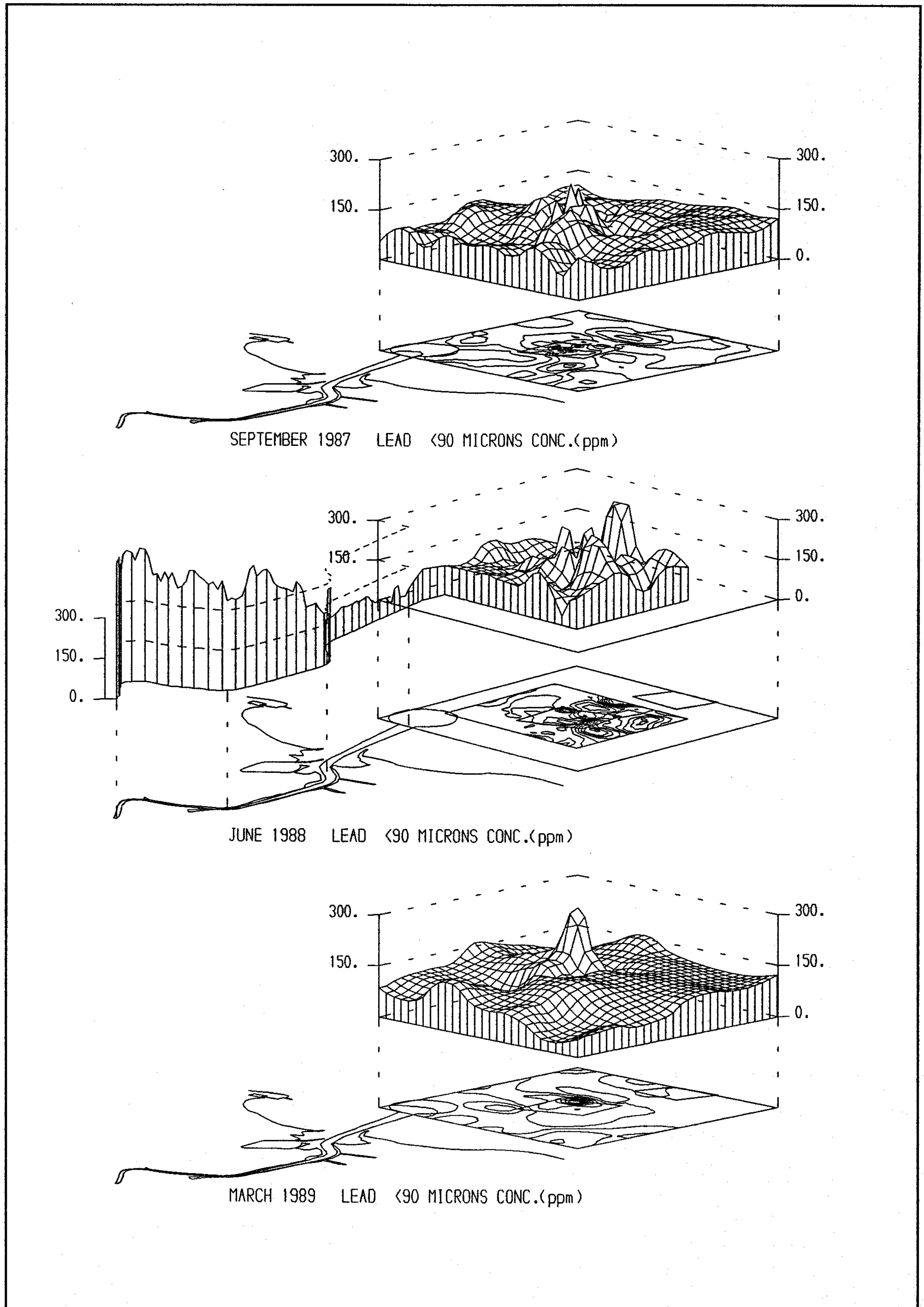


Fig 16 Isometric projections of lead on <90 micron fraction (1987, 1988, 1989)

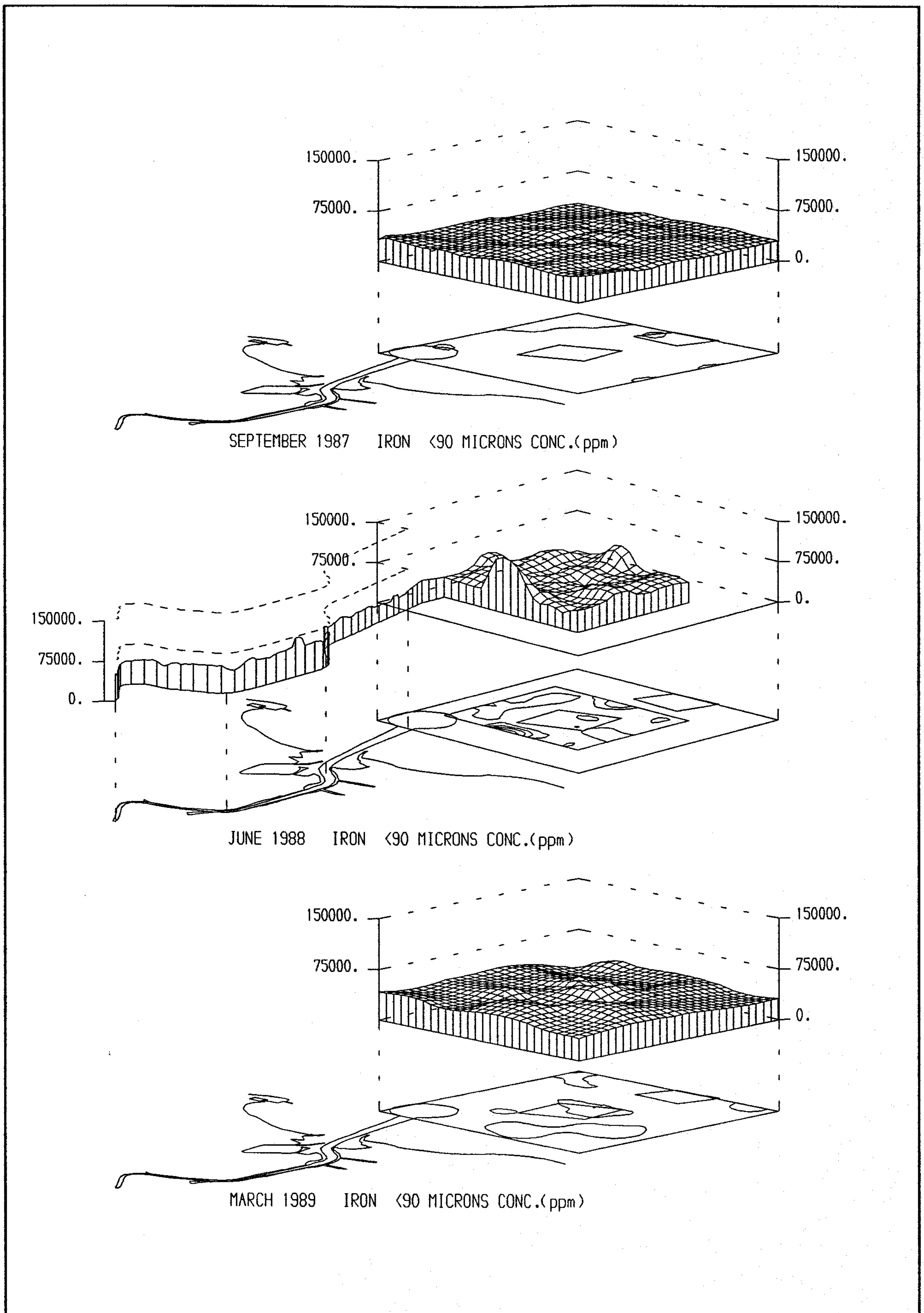


Fig 17 Isometric projections of iron on <90 micron fraction (1987, 1988, 1989)

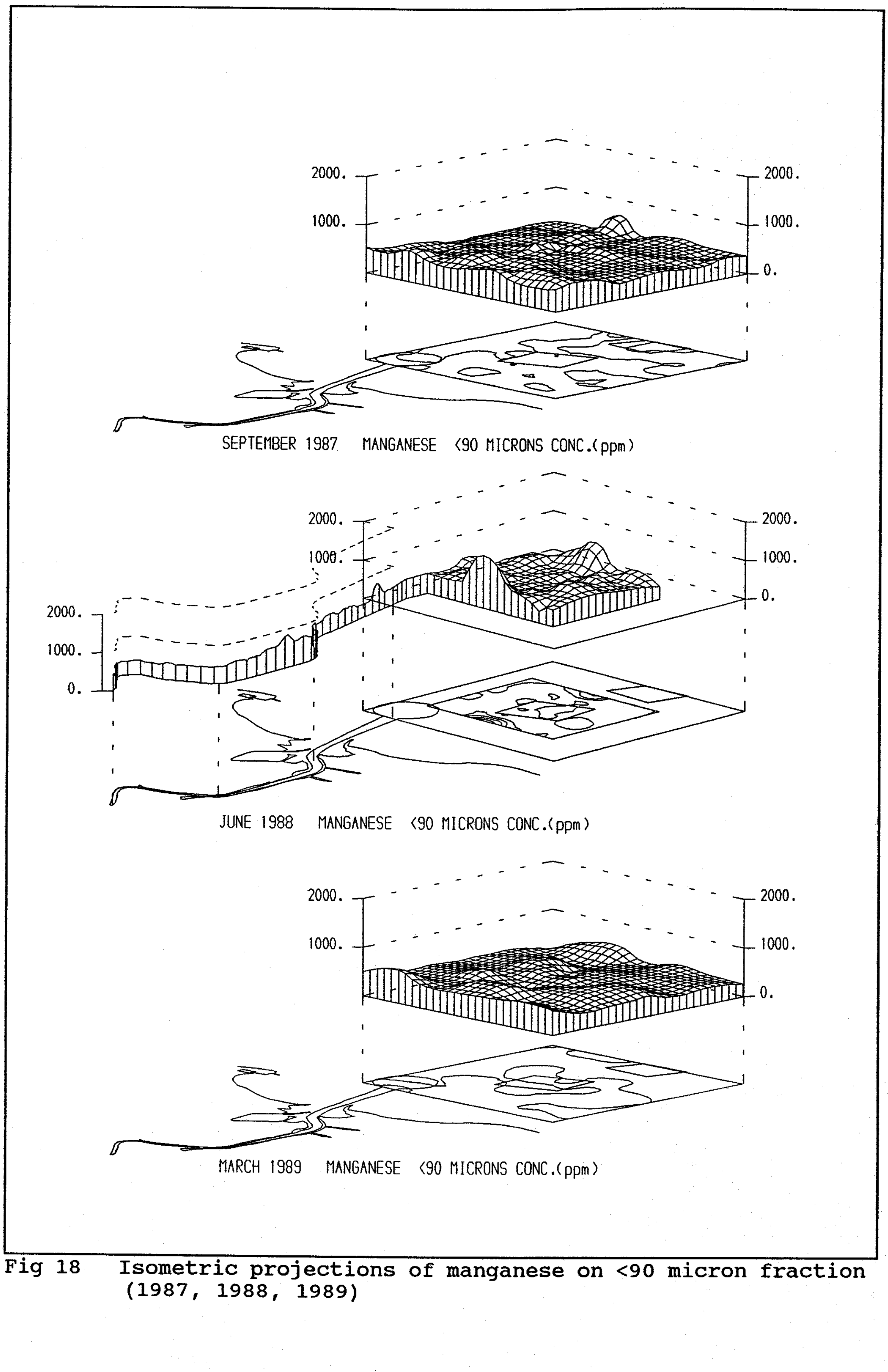


Fig 18 Isometric projections of manganese on <90 micron fraction (1987, 1988, 1989)

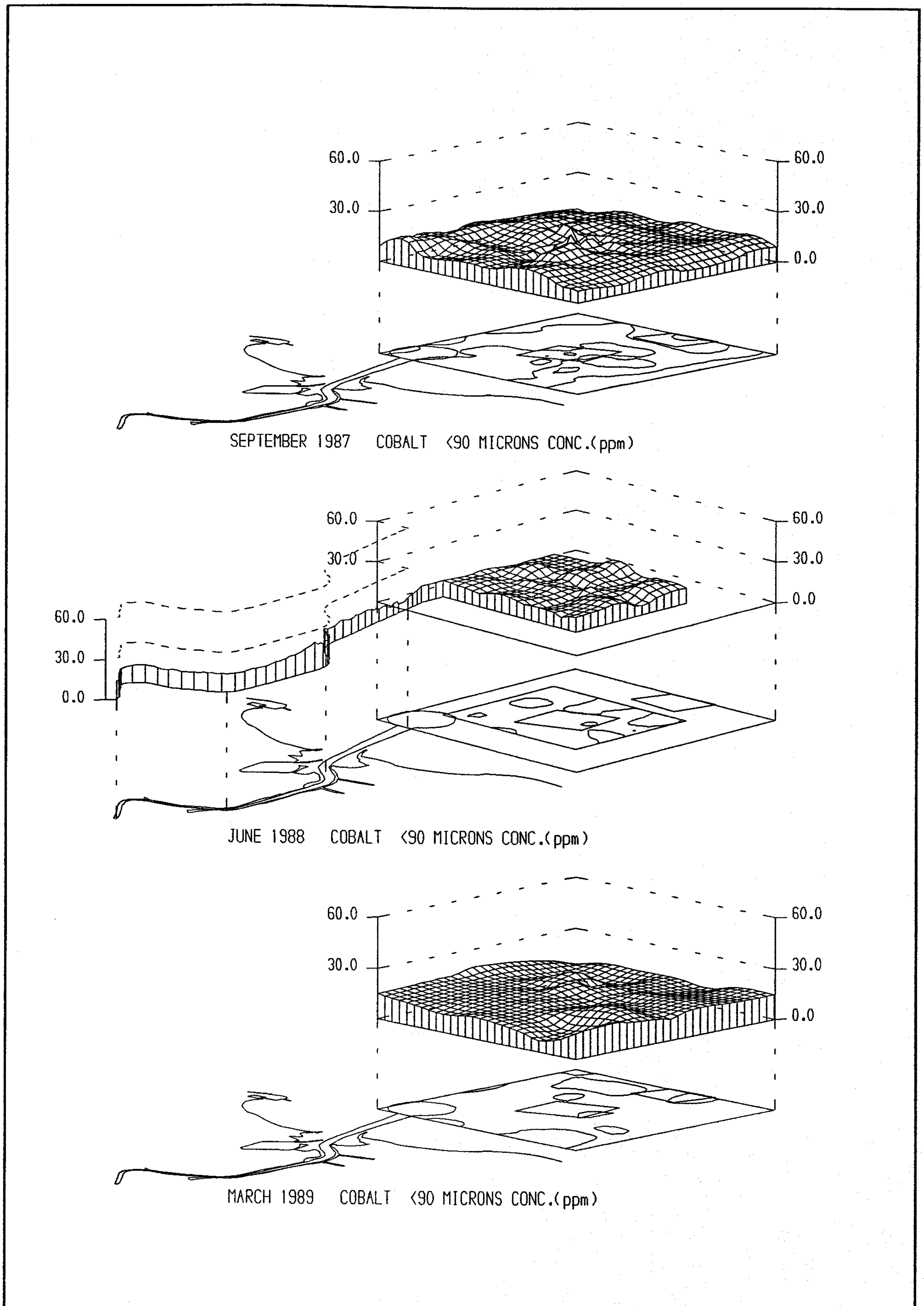


Fig 19 Isometric projections of cobalt on <90 micron fraction (1987, 1988, 1989)

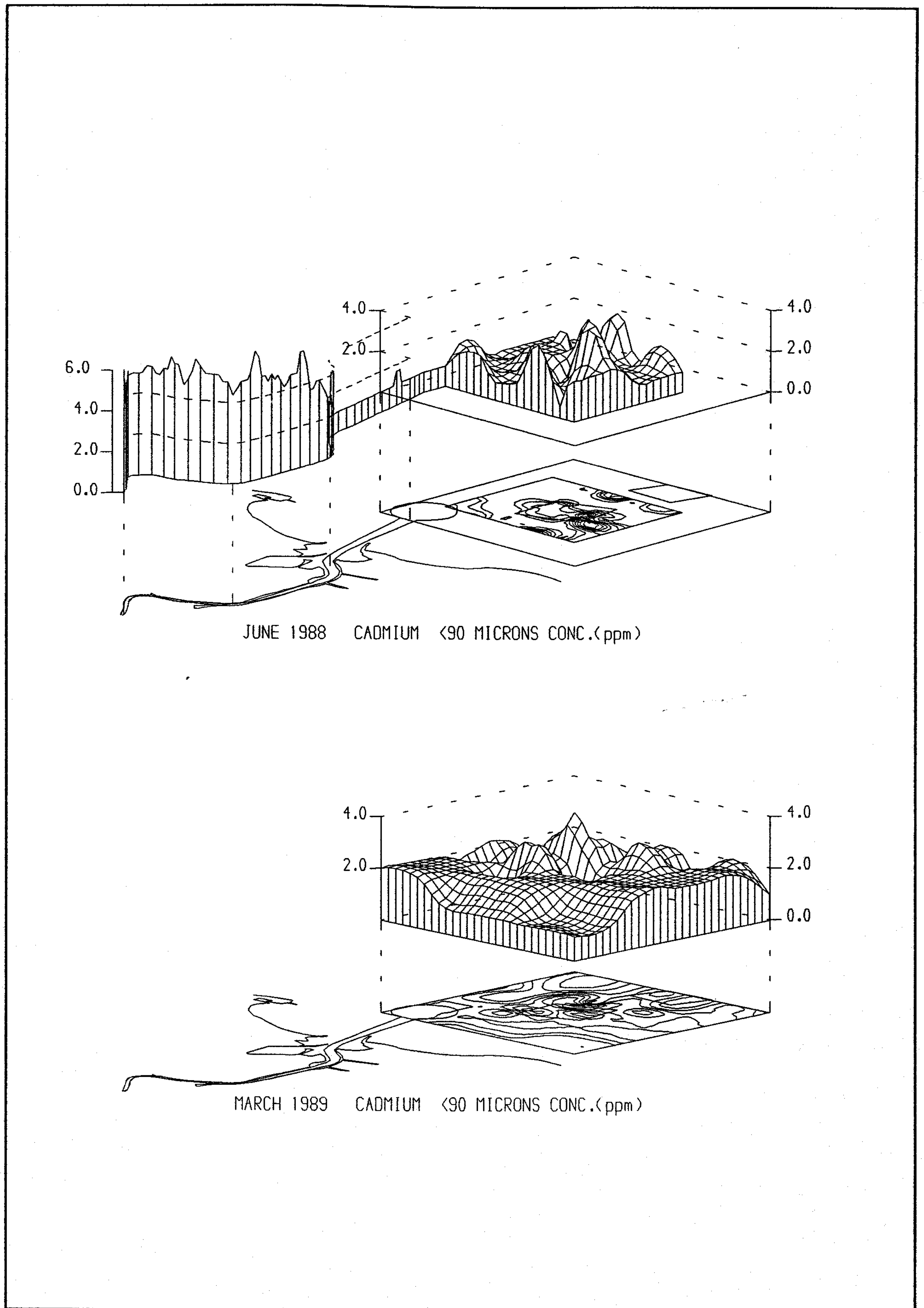


Fig 20 Isometric projections of cadmium on <90 micron fraction (1988, 1989)

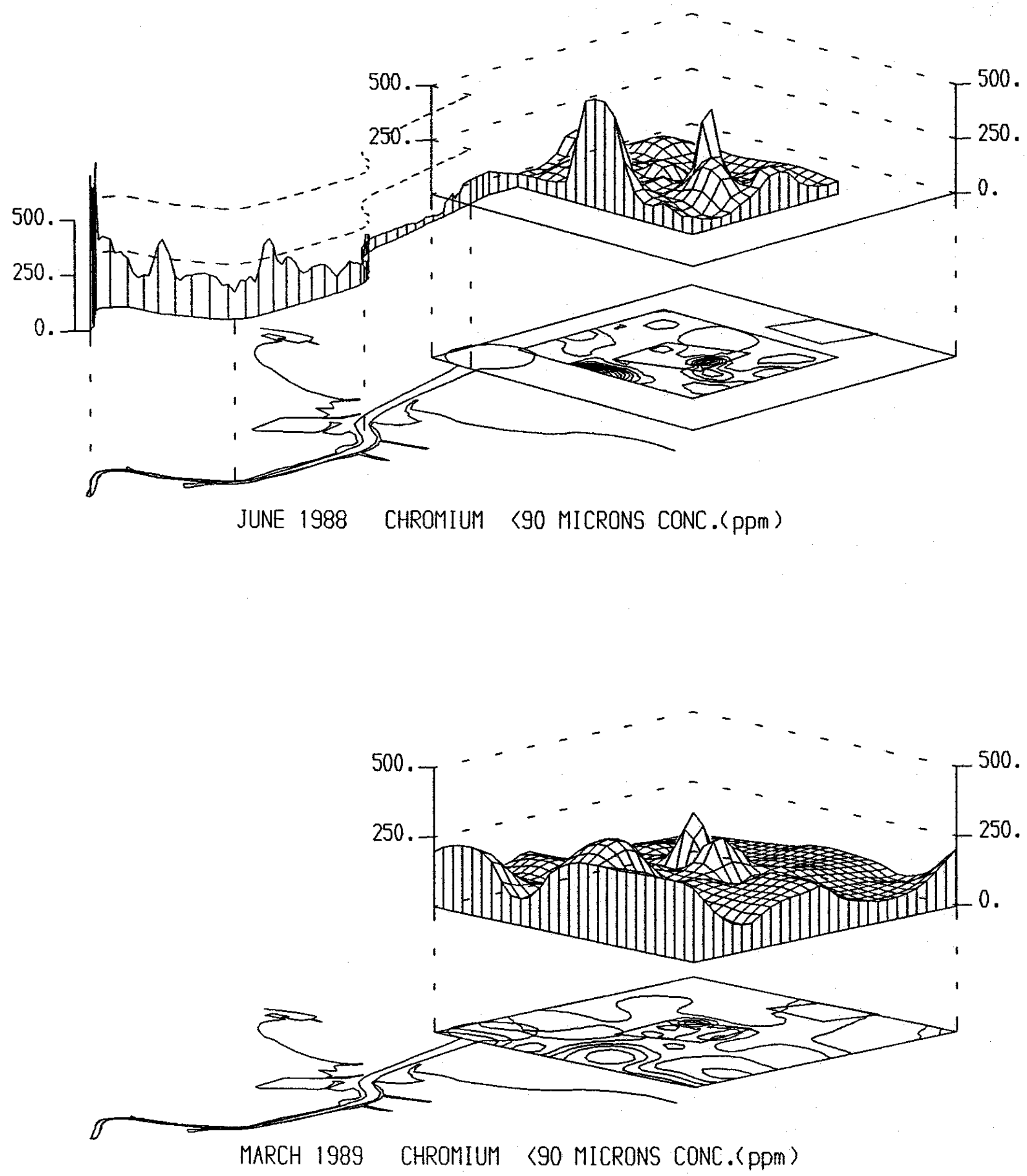


Fig 21 Isometric projections of chromium on <90 micron fraction (1988, 1989)

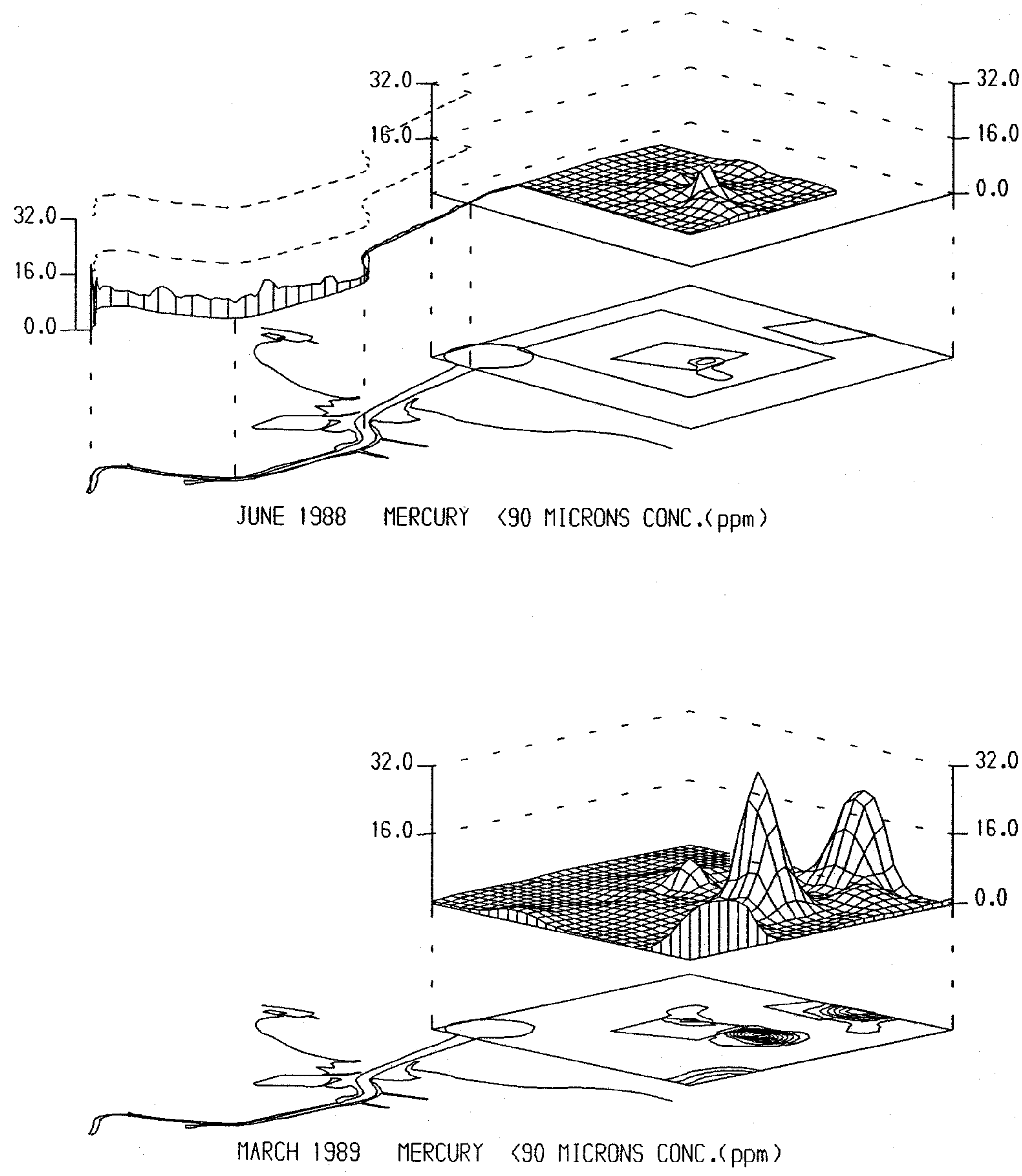


Fig 22 Isometric projections of mercury on <90 micron fraction (1988, 1989)

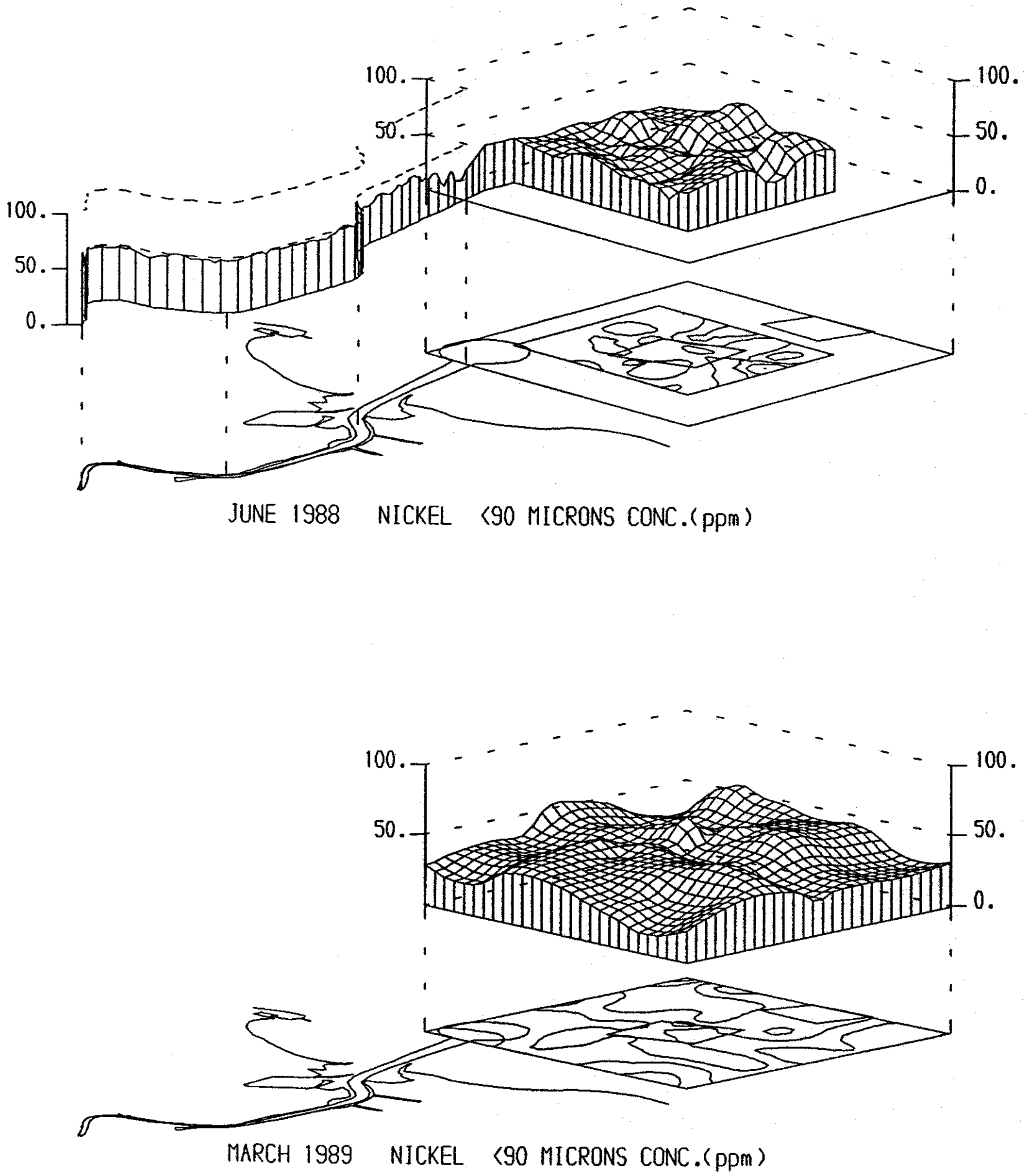
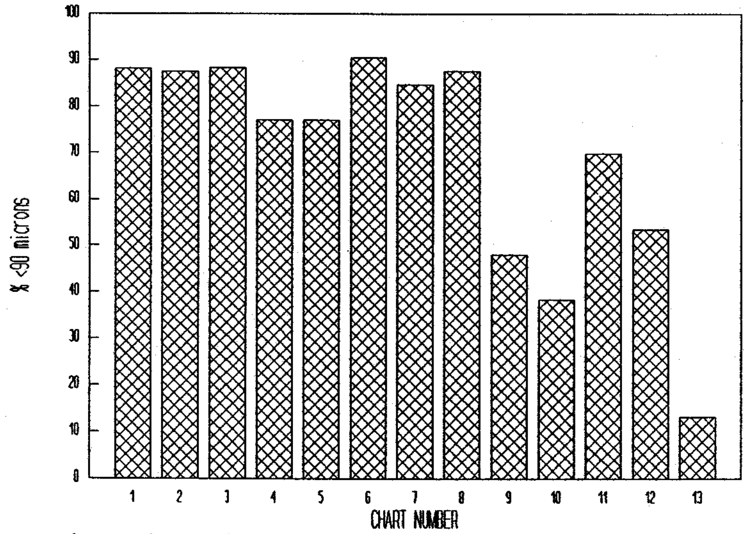
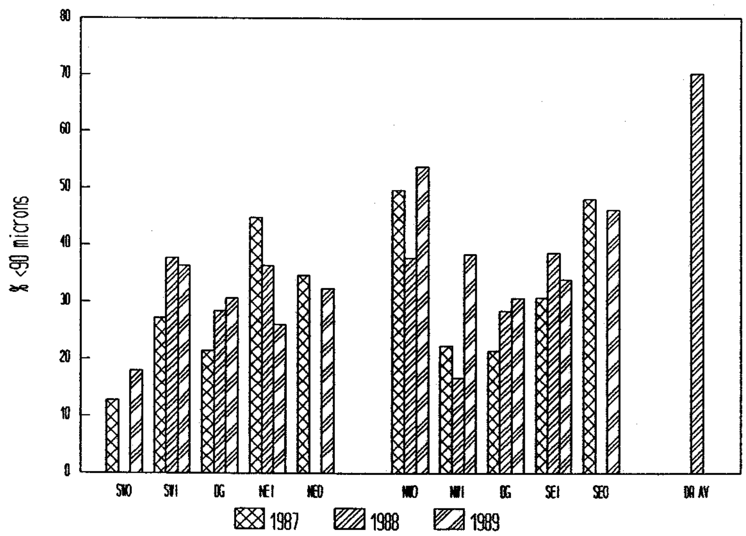


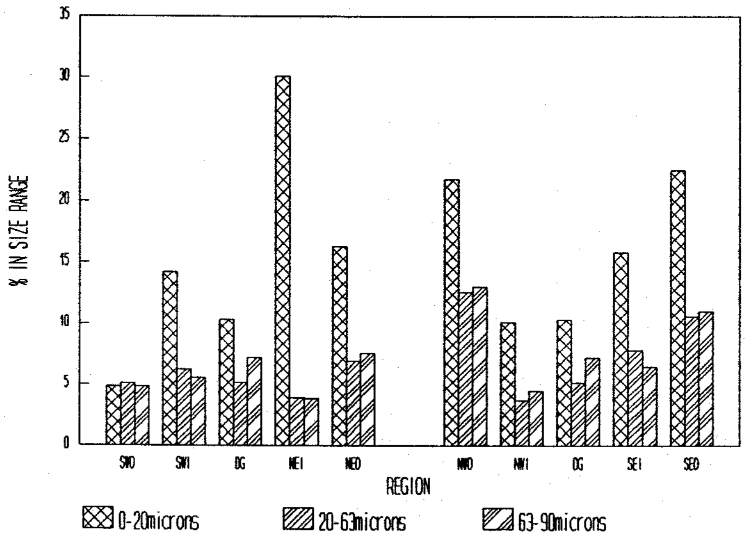
Fig 23 Isometric projections of nickel on <90 micron fraction (1988, 1989)



Distribution in dredged river 1988

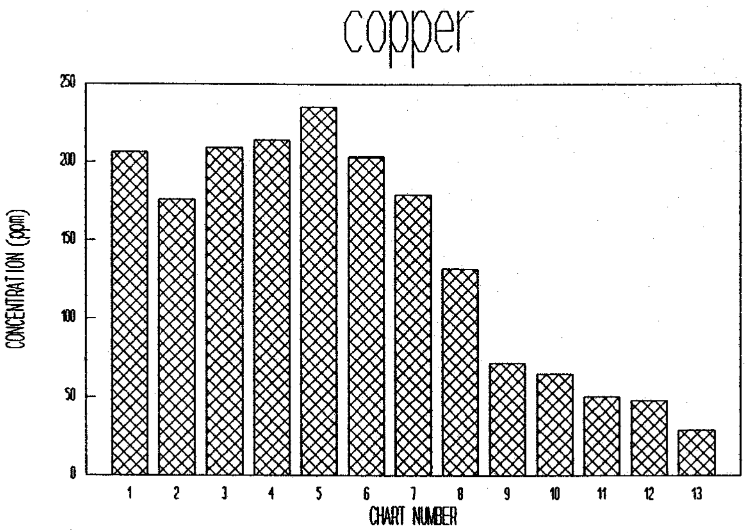


Distribution in disposal ground and surrounding areas

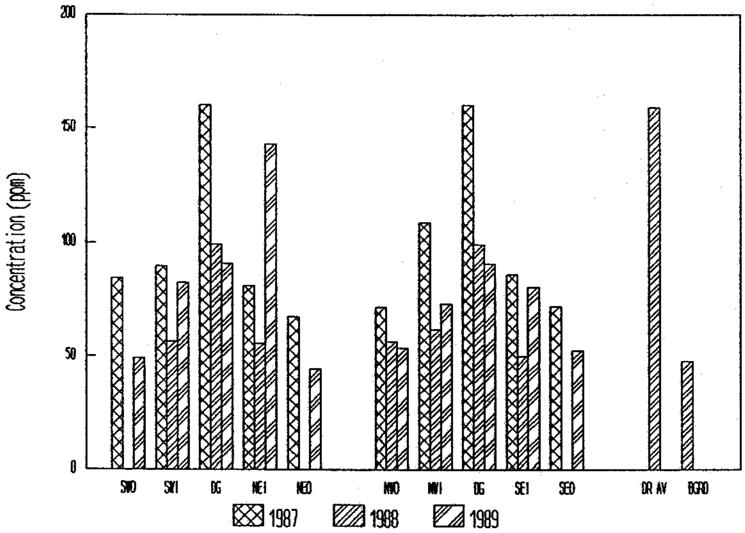


Distribution of metal on each size fraction

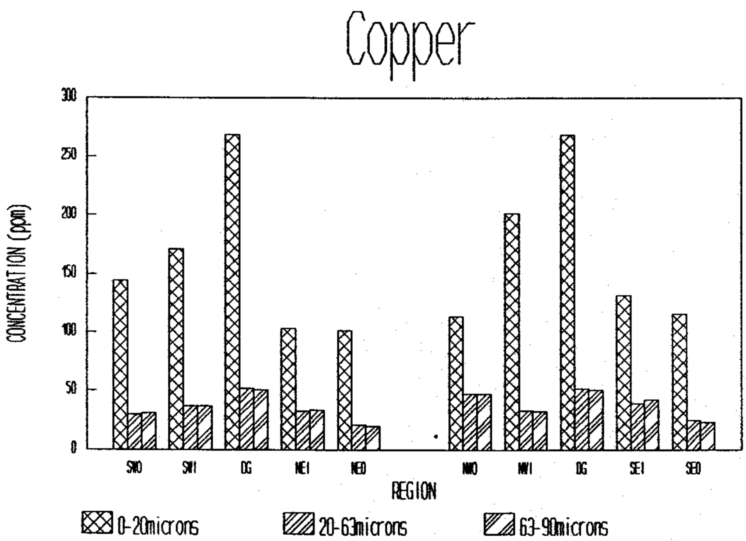
Fig 24 Averaged area histograms of particle size



Distribution in dredged river 1988

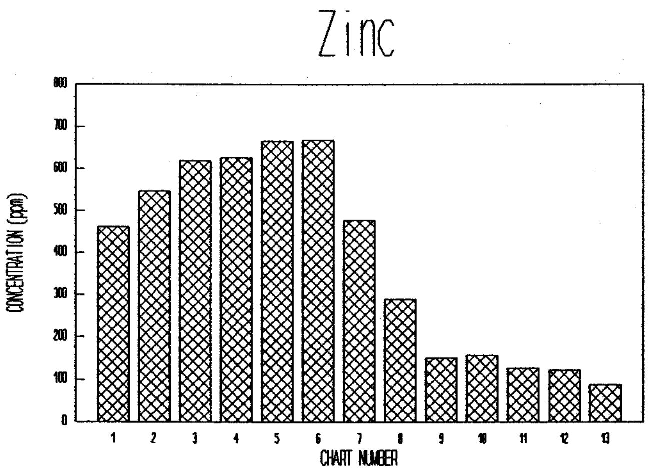


Distribution in disposal ground and surrounding areas

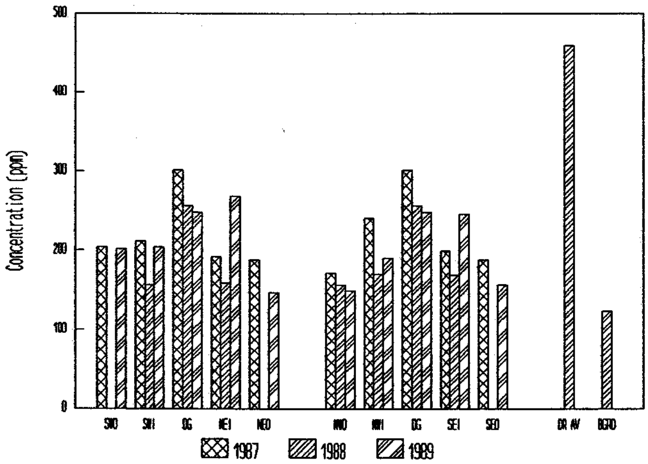


Distribution of metal on each size fraction

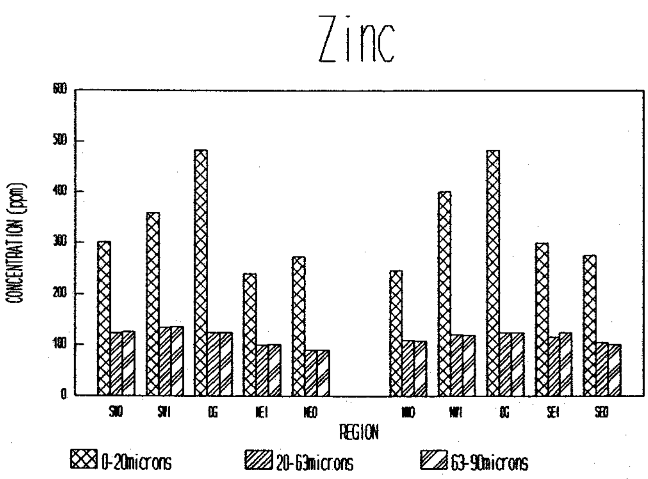
Fig 25 Averaged area histograms of copper distribution.



Distribution in dredged river 1988

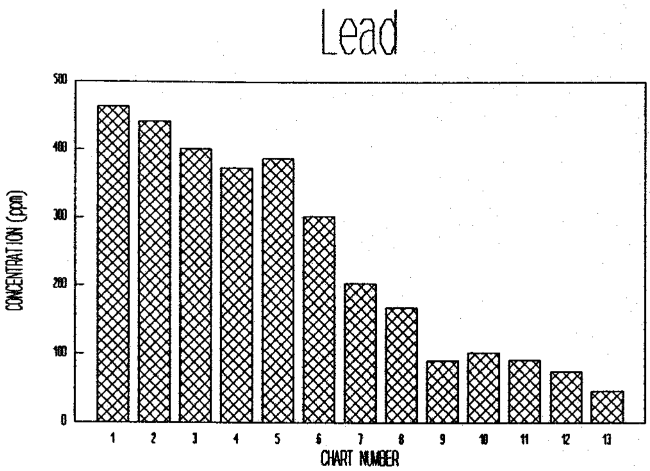


Distribution in disposal ground and surrounding areas

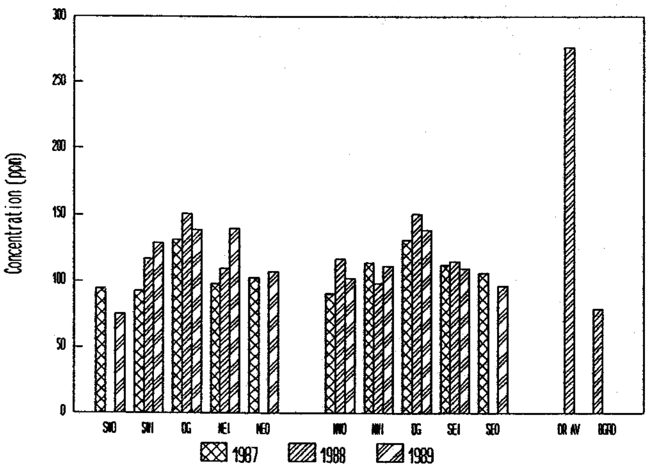


Distribution of metal on each size fraction

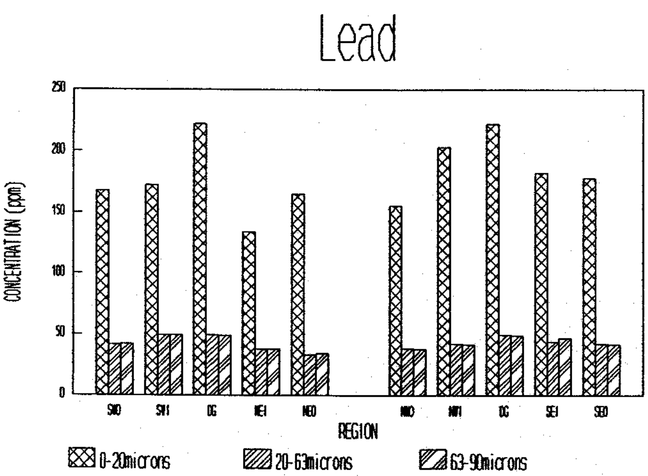
Fig 26 Averaged area histograms of Zinc distribution.



Distribution in dredged river 1988

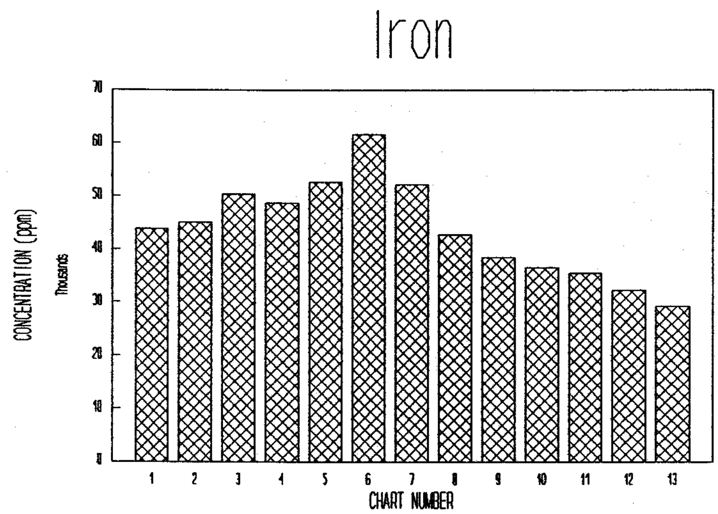


Distribution in disposal ground and surrounding areas

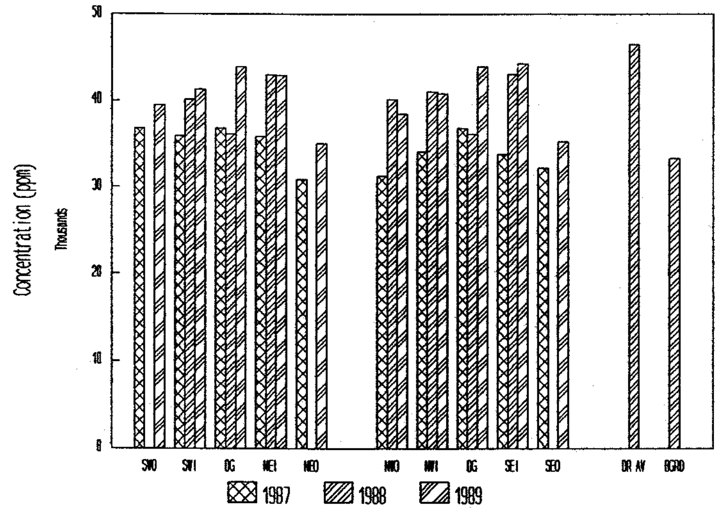


Distribution of metal on each size fraction

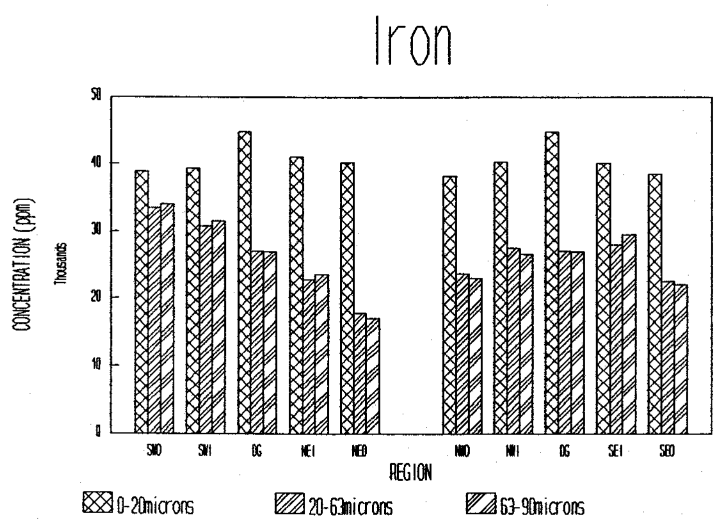
Fig 27 Averaged area histograms of lead distribution.



Distribution in dredged river 1988

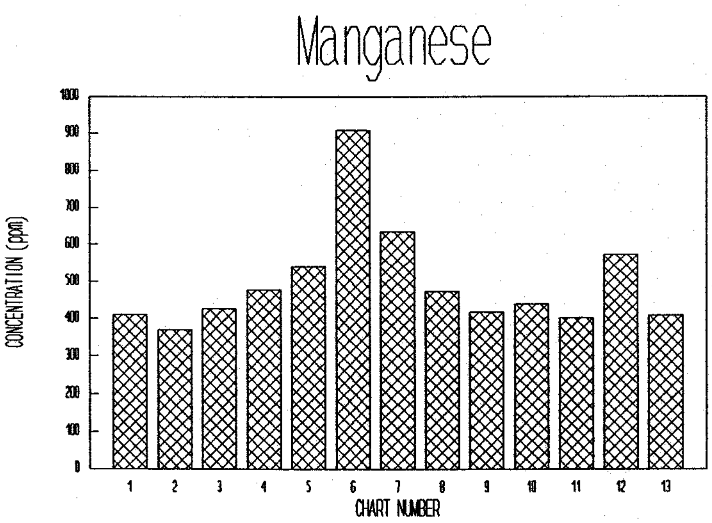


Distribution in disposal ground and surrounding areas

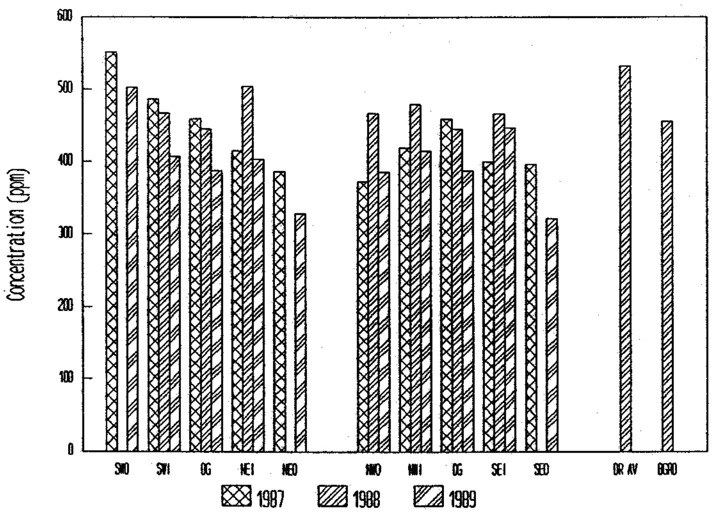


Distribution of metal on each size fraction

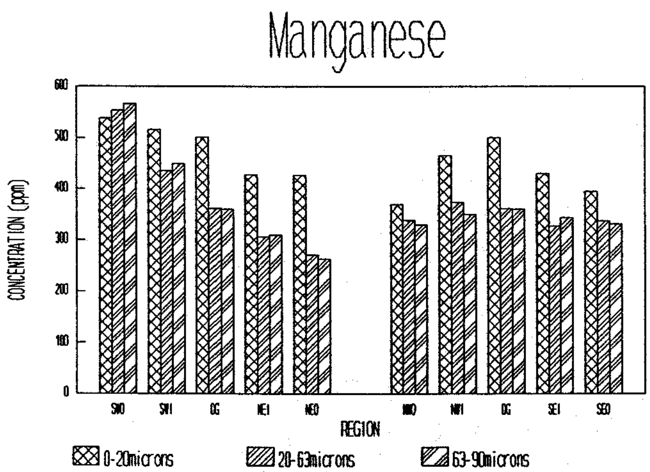
Fig 28 Averaged area histograms of iron



Distribution in dredged river 1988

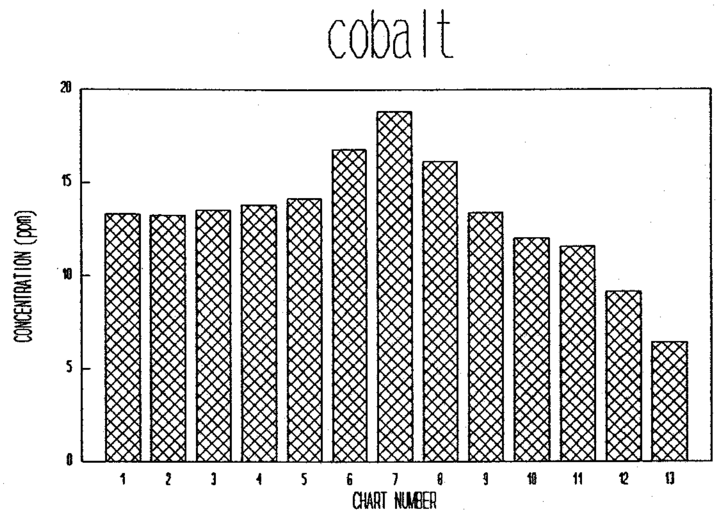


Distribution in disposal ground and surrounding areas

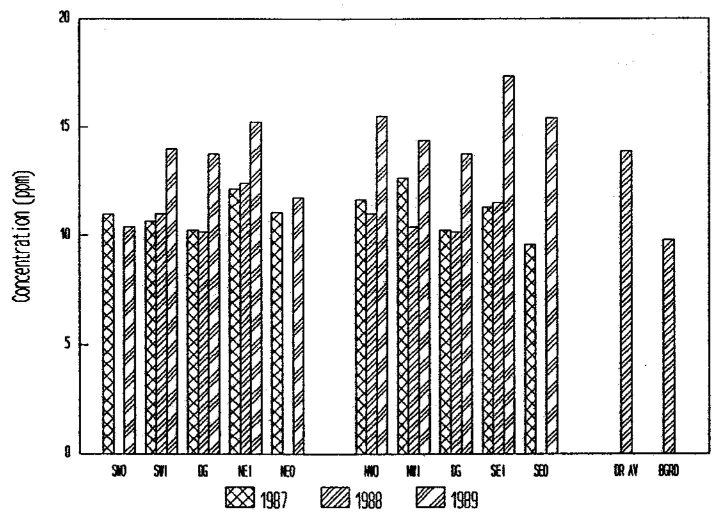


Distribution of metal on each size fraction

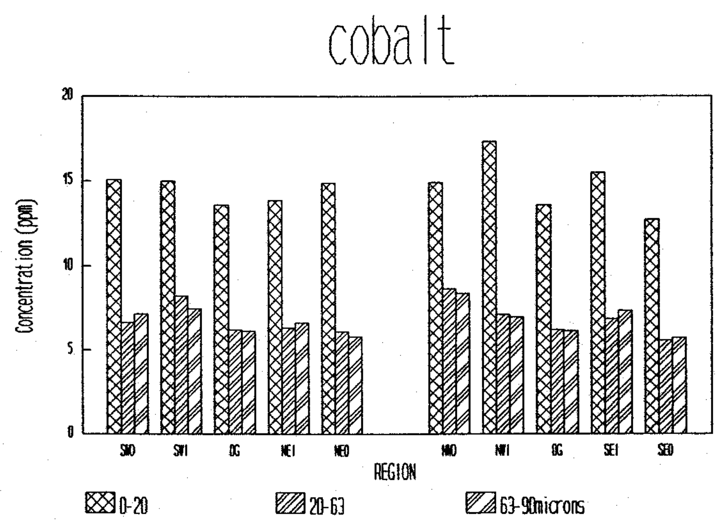
Fig 29 Averaged area histograms of manganese



Distribution in dredged river 1988

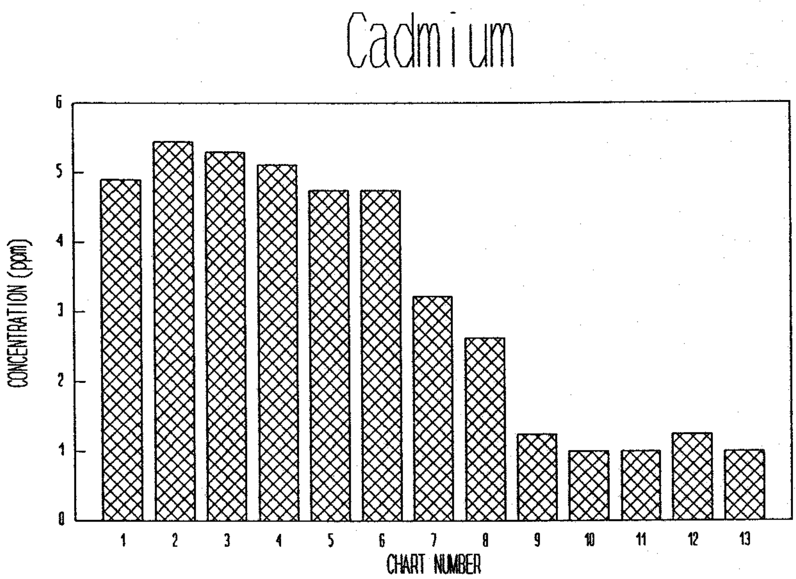


Distribution in disposal ground and surrounding areas

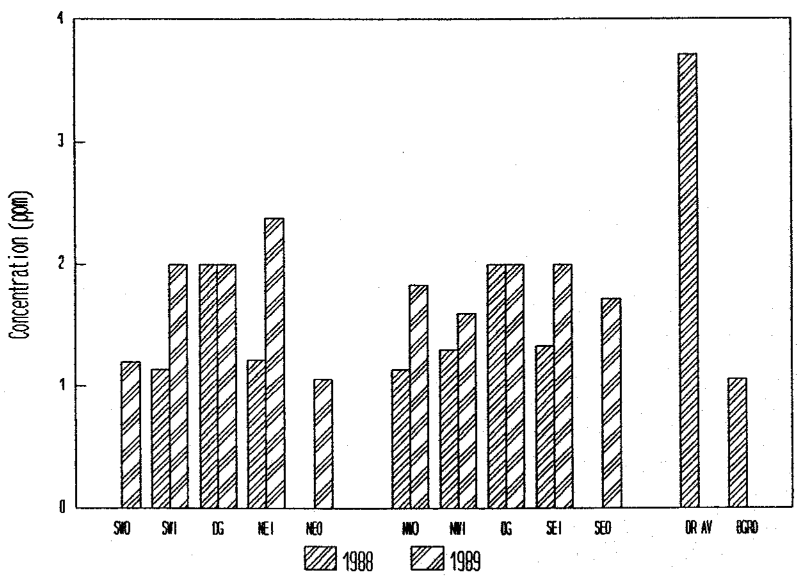


Distribution of metal on each size fraction

Fig 30 Averaged area histograms of cobalt



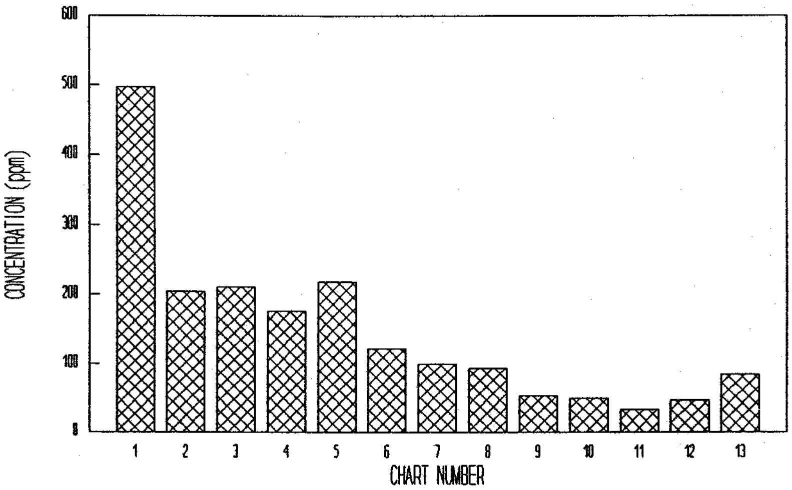
Distribution in dredged river 1988
on <90 micron fraction



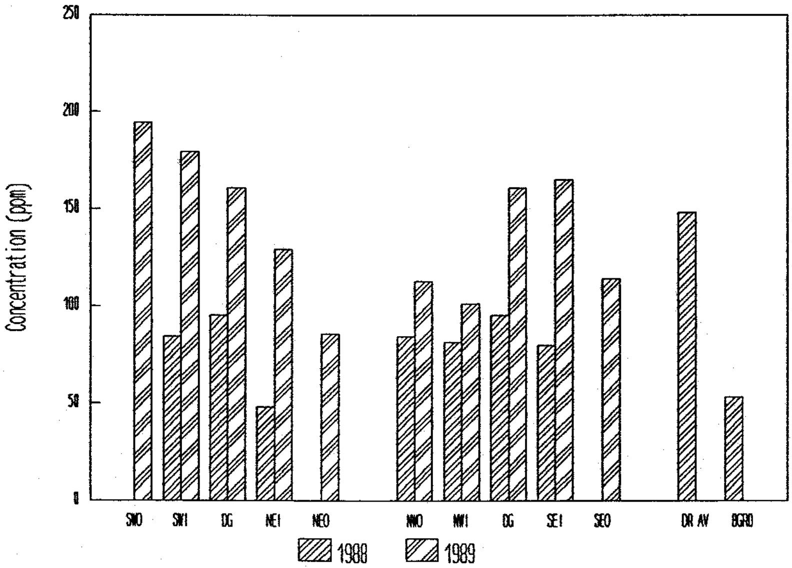
Distribution in disposal ground and
surrounding area on <90 micron fraction

Fig 31 Averaged area histograms of cadmium

Chromium



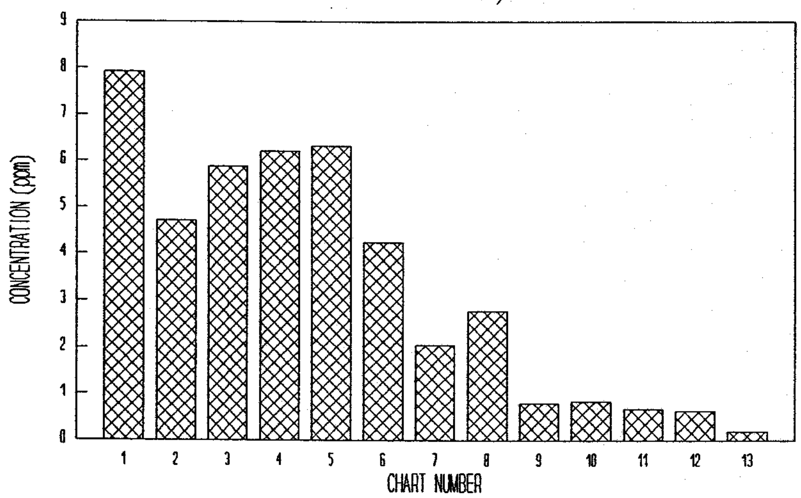
Distribution in dredged river 1988 on <90 micron fraction



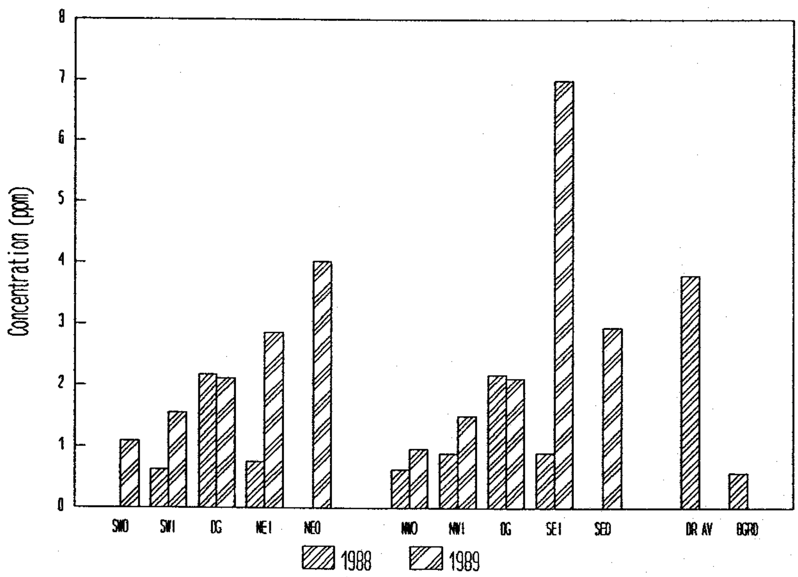
Distribution in disposal ground and surrounding areas <90 micron fraction

Fig 32 Averaged area histograms of chromium

Mercury



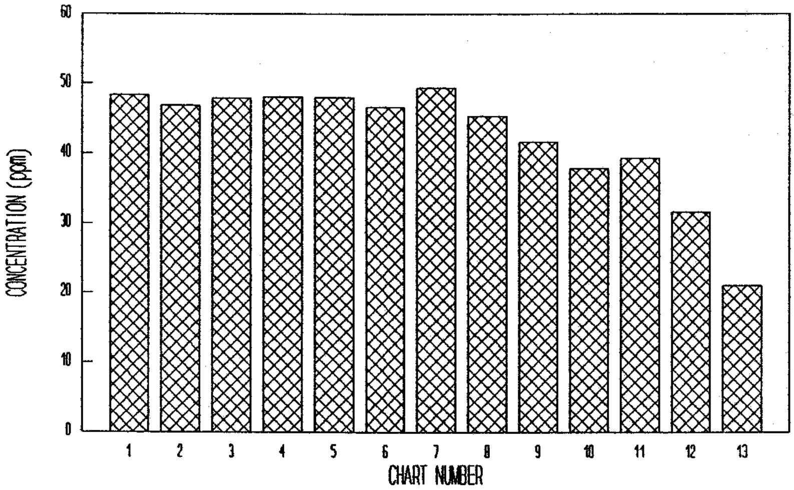
Distribution in dredged river 1988
on <90 micron fraction



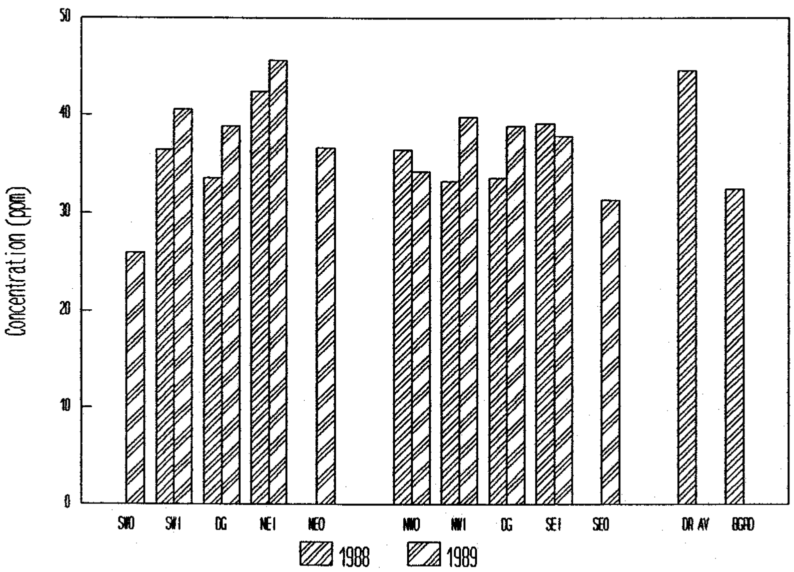
Distrubution in disposal ground and
surrounding areas on <90 micron fraction

Fig 33 Averaged area histograms of mercury

Nickel



Distribution in dredged river 1988
on <90 micron fraction



Distrubution in disposal ground and
surrounding areas on <90 micron fraction

Fig 34 Averaged area histograms of nickel