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REPORT ON THE CONTROL OF DISCHARGES OF TITANIUM DIOXIDE WASTE TO THE HUMBER ESTUARY.

- APPENDICES.

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NRA (Anglian Region) - TIO2 SURVEY REPORT, 1989.

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APPENDIX 1

MATHEMATICAL MODELLING.

1.1 Background.

The tidal system of the River Humber represents a complex regime for chemical monitoring. The principle of a mixing zone is a somewhat abstract idea which cannot be directly measured. It needs to be inferred from a range of supporting evidence.

The biological evidence obtained from a benthic survey of an estuary may be used to define areas of biological impact since the organisms involved are sedentary relative to the rapid bi-directional water flow. The sediments lend themselves to chemical analysis which can be interpreted to provide outlines of areas where chemical contamination of the sediments is enhanced or attenuated for a variety of reasons which may be inferred from a broader knowledge of the estuary; these might include deposition from the water column, accretion or scouring of the sediment by tidal action.

The analysis of the water column presents difficult challenges for interpretation. The water body changes in a tidal cycle in terms of its depth, width, velocity and direction of flow. Although tidal energy may be high thereby creating turbulence and the potential for rapid dispersion the total volume of the water body is not available for diluting an effluent immediately, since the effluent plume is very narrow in relation to the width of the estuary. Furthermore the plume may be vertically constrained by density differentials.

Effluent plumes in water behave like smoke does when discharged from a chimney into air. The plumes remain coherent for a period of time and for a distance down tide from the point of discharge with dilution of the plume occurring by migration from its edge. The plumes waver laterally and vertically thereby making their location and sampling difficult or impossible, unless they can be located by some means prior to or during sampling.

The measurement of the areas of the estuary affected over a period of time by specified concentrations in the water column requires the use of an inordinate quantity of data which would be impractical to obtain. Mathematical modelling offers a means to evaluate the sizes of such areas.

The Water Research Centre previously developed a depth averaged two dimensional bank side dispersion model to describe the long term impact of the discharges. The model evaluates the concentration distribution around an outfall of a contaminant discharged at given rates.

1.2 The Model.

The model works as follows. The estuary in the vicinity of the discharge in question is divided into boxes which move past the outfall according to the tide. The boxes change shape because the tide produces changes in depth.

In order to simplify the computation the model assumes that the contaminants are entirely conservative and that vertical mixing occurs through the water column.

The tidal cycle is broken down into 1,000 segments of time. In each time segment the discharge load is injected into the boxes which find themselves opposite the outfall. The boxes then move on with the tide and some of the pollution diffuses into neighbouring boxes.

Because the boxes move about and change shape, the model has to keep track of their positions with respect to a proper map. The output takes the form of contours of particular statistics of water quality or areas affected by particular statistics.

The model was validated using field observations of the pH values on transects at measured distances upstream and downstream of the discharges under known tidal conditions. The peak values predicted by the model were compared with the peak values measured using trailed pH probes. Within the limitations of the model an acceptable correlation was observed between the field data and the predicted values.

The objective of the model was to map the annual average concentration at specified values for a known input of iron to enable the mixing zone to be predicted. In the case of pH the input of a known concentration of acid was converted to 95 percentile pH values in the water column and the areas affected at specified values were calculated.

1.3 Model Predictions.

The model predictions were made assuming that the background value for iron in the estuary was 0.02 $mg.l^{-1}$.

The buffer capacity of Humber Estuary water and hence it's ability to neutralise an acidic discharge was measured in the laboratory.

a) SCM.

1989 loads were 25.719 $Ml.d^{-1}$ at 3,180 $mg.l^{-1}$ iron (as Fe) and 8,907 $mg.l^{-1}$ of H_2SO_4.
1984 loads were 21.000 $Ml.d^{-1}$ at 3,500 $mg.l^{-1}$ iron (as Fe) and 11,450 $mg.l^{-1}$ H_2SO_4.

Diffusion coefficients of 0.1 $m^2.s^{-1}$ laterally and 10$m^2.s^{-1}$ longitudinally have been used.

b) Tioxide.

1989 loads were 25.474 $Ml.d^{-1}$ at 7,538 $mg.l^{-1}$ iron (as Fe) and 19,373 $mg.l^{-1}$ of H_2SO_4.
1984 loads were 24.500 $Ml.d^{-1}$ at 6,500 $mg.l^{-1}$ iron (as Fe) and 19,850 $mg.l^{-1}$ H_2SO_4.

Diffusion coefficients of 1 $m^2.s^{-1}$ laterally and 10 $m^2.s^{-1}$ longitudinally have been used. The higher lateral coefficient reflects the additional scope for mixing because distance from the bank and the increased depth.

1.4 Predictions of Areas Affected.

The following tables compare the predicted areas of impact from the old outfalls and the new outfalls where the shorter outfall in each case is the old outfall.

TABLE 1.1 : Areas Affected (Ha) - Iron Concentrations.

Annual average conc $mg.l^{-1}$ Fe	SCM 50m outfall	300m outfall	% improve -ment	TIOXIDE 800m outfall	2200m outfall	% improv -ment
1.0	130	92	29%	550	44	92%
2.0	N/A	28	-	N/A	9.6	-
5.0	38	3.1	92%	240	0.8	99.7%
10.0	9	<0.1	100%	97	<0.1	100%

NB. In 1984 the area of moderate to severe biological damage was assessed as being that area impacted by an annual average iron concentration of 5 mg/l as predicted by the model.

The model predictions for iron show that the increased outfall length should reduce the area of impact at the EQS level by 29% in the case of the SCM outfall and by 92% in case of the Tioxide outfall. At the 5 mg/l level which in 1984 was equated with the area of moderate to severe biological damage the reductions in affected areas are predicted to be 92% in the case of the SCM outfall and 99.7% in the case of the Tioxide outfall.

TABLE 1.2 : Areas Affected (Ha) - Acid Concentrations.

pH 95%-ile value	SCM 50m outfall	300m outfall	% improve -ment	TIOXIDE 800m outfall	2200m outfall	% improve -ment
6.0	27	0.6	97%	160	<0.1	100%
6.5	55	6.0	89%	300	0.8	99.7%

The model predictions for pH show that the increased outfall length should reduce the area of impact at the pH 6.0 level by 97% in the case of the SCM outfall and by 100% in case of the Tioxide outfall.

APPENDIX 2

BIOLOGICAL MONITORING

2.1 Introduction.

The biological monitoring work essentially involves the deployment of classical techniques for examination of the estuarine benthos at different locations throughout the anticipated area of effect or impact. In its broadest context it also includes the collection of biological material for chemical analysis to investigate the levels of persistent contaminants associated with the discharges.

In the case of the old outfalls which discharged at approximately Mean Low Water Spring Tide (M.L.W.S.T.) the examination of the benthos was comprised of three components:

1. Survey of the shallow sub-tidal receiving area (mud/clay);

2. Survey of the adjacent inter-tidal mud-flats;

3. Survey of the rocky shore habitat at the top of the mud-flats.

For the first two of these components fixed grid patterns of survey stations were established to encompass the anticipated areas of impact. The geographical location of these grids is shown in Figure 2.1.1. Because the extent of the likely area of impact was not known the survey area extended longitudinally to 2.25 km in either direction from each discharge (equivalent to half the distance between the two outfalls) as described below. The off-shore extent of the grid was confined by a boundary approximately 300m off-shore from M.L.W.S.T. based on the narrow width of the effluent plume as ascertained from aerial reconnaissance. A detailed description of the survey design and sampling strategy for the old outfalls can be found in the 1984 report and is summarised below in Section 2.2.1.

In the case of the new outfalls, which discharge off-shore, only a sub-tidal survey programme has been deployed. The survey design, which is described in detail below, utilises a central line through the predicted axis of the effluent plume together with lines of sample points both off-shore and in-shore of the axial or "zero" line. The resulting grid pattern extends to only 1 km either side of the new discharge points. Based on the findings of the 1984 survey and the mathematical model predictions this arrangement was considered adequate and more likely to provide a detailed assessment of conditions within the new discharge zones. Prior to construction of the new outfalls a comprehensive baseline survey was conducted around each outfall. The proposed SCM discharge area was sampled in late summer/autumn of 1985, whilst the proposed Tioxide U.K. discharge area was surveyed in late summer/autumn of 1986, after a revised decision to extend the outfall pipe to the deep water channel.

For monitoring purposes two transects on both the upstream and downstream sides of each discharge were chosen for regular sampling. (It is not practicable to repeat sampling of the entire grid of stations on a regular basis). These surveys are consequently referred to as 'mini-grid' surveys. A detailed description of the mini-grid is given below.

For all surveys a number of remote "reference" or "control" sites were selected, from previous surveys of the entire estuary, to provide data from similar hydrographic and sedimentological areas within the estuary. Their positions within the estuary and in relation to the outfalls are shown in Figure 2.1.1.

2.2 Survey Design.

2.2.1 Old Outfalls.

Figures 2.2.1 (Tioxide) and 2.2.2 (SCM) show the axial or "zero" lines running through the discharge points with offshore grid-lines drawn at 100 and 300m from the zero line. Transect lines were established perpendicular to the zero line, spaced at 100, 300, 600, 1,000, 1,500 and 2,250 metres either side of the outfall,as illustrated in Figure 2.2.3. This provided an enhanced coverage of the area close to the outfall but at the same time allowed assessment of more remote areas. To achieve a greater resolution within the plume width, two intensive transects were established at 600m either side of the outfall by the addition of intermediate sample points at 50 and 200m offshore from the zero line, see Figure 2.2.3.

The transect lines are subsequently referred to as being West (upstream) or East (downstream) of the outfall and are numbered sequentially 1 (100m), 2 (300m), 3 (600m) etc. The offshore grid-lines are referred to as 100 and 300, each site may therefore be identified in terms of the appropriate combination of transect and grid line labelling codes. For example the station on the transect 1,000m downstream of an outfall on the 300m grid-line is identified as 4W.300. The numbering system is clearly evident in Figure 2.2.3.

Inshore of the outfalls, on the intertidal mud-flats, tidal height was used as a more ecologically appropriate means of determining the grid lines. Samples were taken at mid tide level,referred to as "mid-shore" (MS) and mean low water, referred to as "low-shore" (LS) as shown in Figure 2.2.3. Site coding follows the same principle as for sub-tidal sites, for example the low water sampling station on the transect 600m downstream of the outfall is referred to as 3W.LS.

The survey in 1984 was designed to assess the area of impact of the outfalls in use at that time. The entire grid of sampling stations was resampled in 1989, although for the purpose of this report, only sub-tidal sample points up to 1,000m either side of each outfall are considered; partly because of constraints on sample processing time, but also because this was maximum extent of the area deemed to be affected in 1984. This supposition will be confirmed by the analysis of all samples in due course. The surveys of the intertidal mud-flats and the rocky shore habitat have also been repeated in their entirety, and results for all sites are presented in this report, as the 1984 work demonstrated a greater extent of impact in the intertidal zone.

2.2.2 New Outfalls.

Assessment of the impact around the old outfalls indicated that any impact would be restricted to an area within one kilometre of the new outfalls. The baseline grids were drawn up accordingly.

2.2.2.1 Baseline Grids.

Figures 2.2.1 (Tioxide) and 2.2.2 (SCM) show the axial or zero lines running through the new discharge points. Grid-lines were established at 100m and 250m both in-shore and off-shore from the zero line. Transect lines were drawn perpendicular to the axial line in an arithmetic series at 100, 300, 500, 700 and 900m either side of the outfalls. The numbering of the transects on the new grids follows the system adopted for the old outfall grids and individual sites are identified by the same coding system. The transects are labelled sequentially i.e 1-(100m), 2-(300m), 3-(500m) etc.

2.2.2.2 Mini Grids.

For monitoring purposes a manageable number of sampling points in a suitable configuration were selected from the original baseline grids around the new outfalls. Only the transects at 100 and 500m either side (1E & 3E and 1W & 3W) were sampled and the most offshore lines, 250N, were excluded. These are subsequently referred to as 'partial' or 'mini' grids. The mini-grids are illustrated schematically in Figure 2.2.3.

The final position of the new Tioxide discharge point was found to be approximately 100m inshore of the estimated position.

To compensate four additional sample points were introduced on a line equivalent to 400S. Because the discharge was now effectively on the 100S line, the grid was re-labelled with the original 100S line becoming the zero line. Thus, in relation to the true position of the new outfall the grid lines are at 100N & 200N offshore and 150S and 300S inshore of the discharge, see Figure 2.2.4. The Tioxide grid is therefore different to the SCM grid although the enforced changes have resulted in the coverage of a larger area at a comparable intensity. The revised labelling system of the Tioxide grid, as shown in Figure 2.2.4, is used throughout the report.

The mini-grids were sampled in July 1988 (immediately prior to the commissioning of the new outfalls), September 1988, March 1989 and July 1989.

For the purpose of this report only the the July surveys are considered, mainly to eliminate the effects of seasonal changes in the benthos.

2.3 Ecological Sampling.

2.3.1 Sub-tidal Sampling.

Sample stations were arranged on the grid patterns illustrated in Figures 2.2.1 and 2.2.2 and the precise position of each site was located by a combined distance and angle measurement using shore-based laser range-finding equipment.

Three replicate samples were collected from each site using a 0.1m^2 Day grab. A subsample of sediment was taken from the second replicate for organic carbon determination and particle size analysis. Subsamples of surface sediment were removed from each replicate and bulked for heavy metals analysis. For each sample a visual description of the sediment was recorded.

Samples were sieved on board using a 0.5mm nylon mesh sieve and fixed and preserved in 10% formalin. The subsamples for physico-chemical analyses were stored deep frozen upon return to the laboratory.

2.3.2 Inter-tidal Sampling.

2.3.2.1 Mud Flats / Sedimentary Shores.

Figures 2.2.1 and 2.2.2 show the arrangement of intertidal sample stations. The precise position of each site was located by a combination of sextant angle and tidal height.

At each sample station four cores of sediment were collected using a rigid p.v.c. corer of 10cm diameter, inserted to a depth of 15cm, although some sites could not be sampled due to the presence of rocks on, or immediately below, the surface. A sample of surface sediment also was taken at each site for heavy metal analysis and samples for particle size analysis were collected by scooping the sediment to a depth of approximately 5 cm. Visual descriptions of the sediment were recorded at each sample station. The samples were returned to the laboratory, sieved through a 0.5mm mesh sieve and, fixed and stored in 5% formalin. Samples for physico-chemical analyses were stored deep frozen within 24 hours of collection.

2.3.2.2 Rocky shore.

Natural outcrops of rock do not occur in the lower Humber, but during the construction of flood defences large quantities of boulders (principally limestone) were tipped on the uppermost zone of the mud-flats or marsh. Depending on the topography and design criteria for these sea-walls an artificial boulder-type rocky shore exists at most locations throughout the survey area, but varies in extent from a few scattered rocks around Mean High Water (M.H.W.) to almost total boulder cover throughout the tidal range. An examination of the flora and fauna associated with this habitat was undertaken by means of a timed search. Two ecologists jointly recorded the organisms present both on the rock surface and those sheltering between or underneath the boulders during a standardised search period (10 minutes). Examination was confined to a band of approximately 30m width, but was extended down the shore according to the extent of the boulders present at each site. Sessile fauna and algae were recorded on arbitrary abundance scales according to the extent of 'cover', whilst individual specimens of mobile crustacea and mollusca were counted. Identification was carried out in the field except for some specimens of the genus Littorina, which were returned to the laboratory for examination.

2.4 Biota Collection.

Platichthys flessus (flounder), Solea Solea (Sole) and Crangon crangon (brown shrimp) were collected using a 5m beam trawl(with a main mesh size of 30 mm, and cod end of 15mm) and by deployment of fish traps. Fish of length 12-25 cm were retained for heavy metals analysis. Crangon from the trawls were bulked in batches of 50 individuals for each metals analysis sample. All samples were stored deep frozen prior to analysis.

Fig. 2.1.1 The Humber Estuary showing the Position of the Sampling Grids

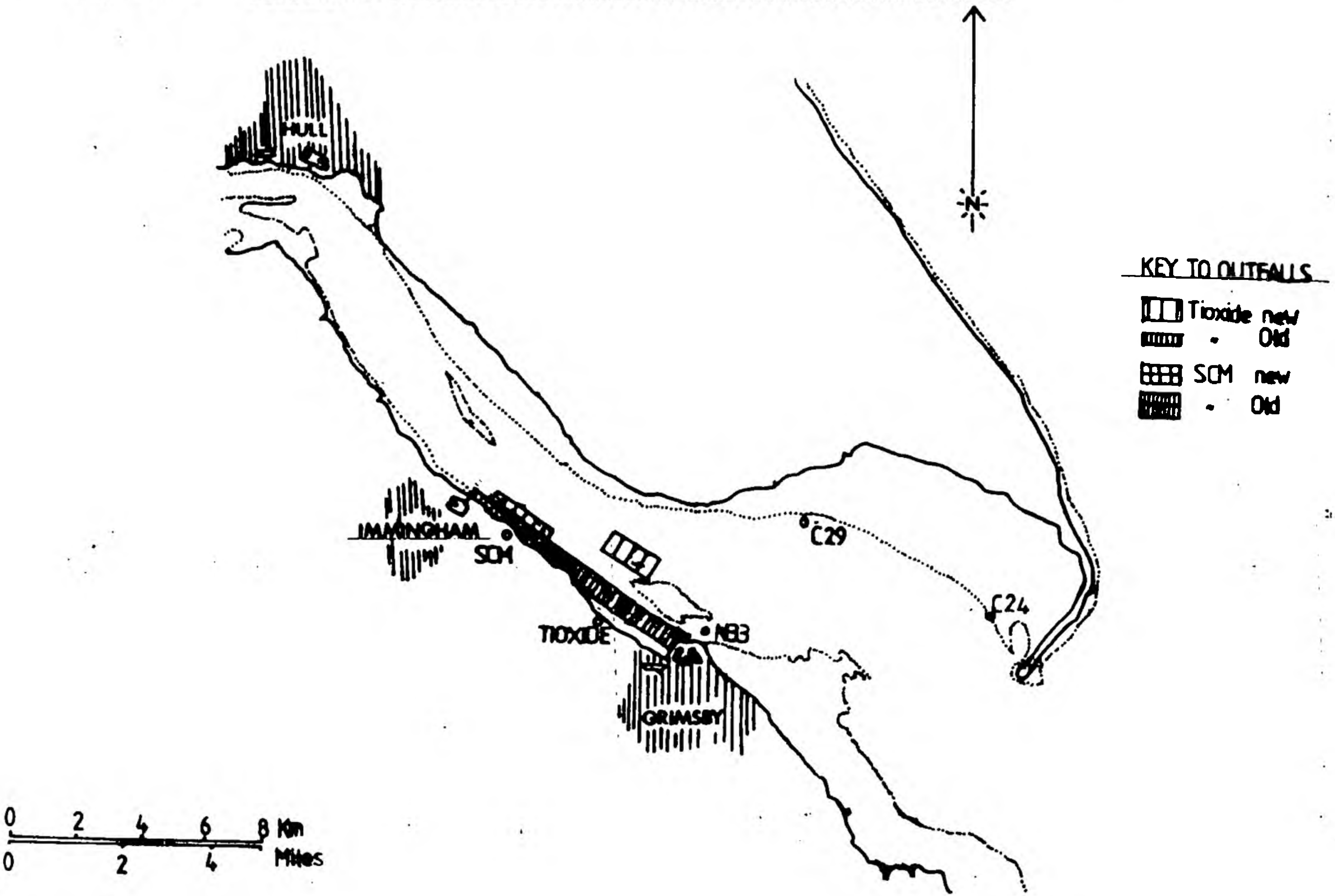


Fig. 2.2.1. Chart Section of the Humber showing locations of Tioxide UK Outfalls and sampling points

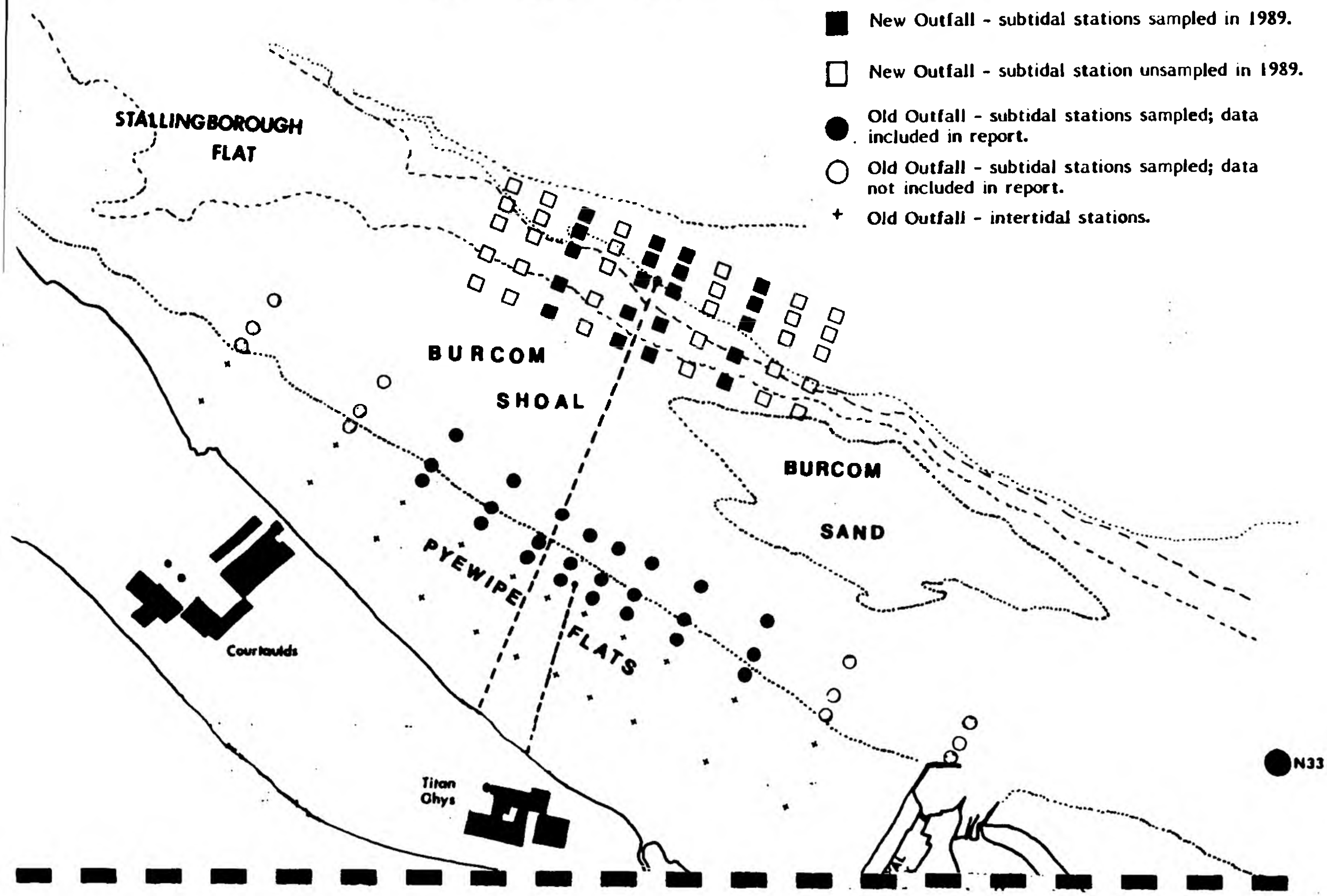


Fig. 2.2.2. Chart Section of the Humber showing locations of SCM Outfalls and sampling points

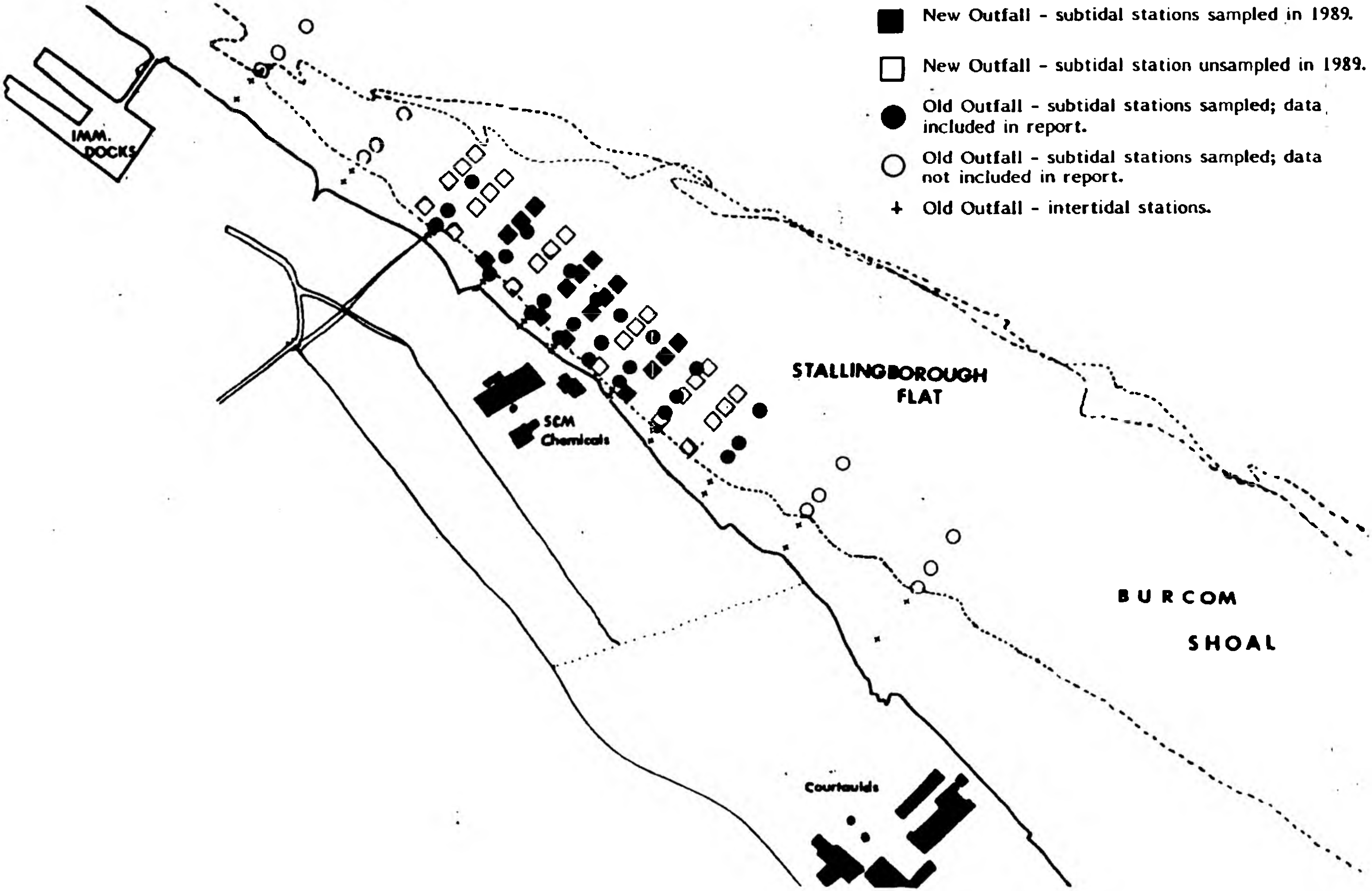


Fig. 2.2.3 A Schematic Representation of the Sampling Grid - SCM and Tioxide Old Outfalls

Key

- - - - - - - - Grid-lines

.... Transect Lines

● Sample Station

✱ Sample Stations not Utilised in 1989 Report

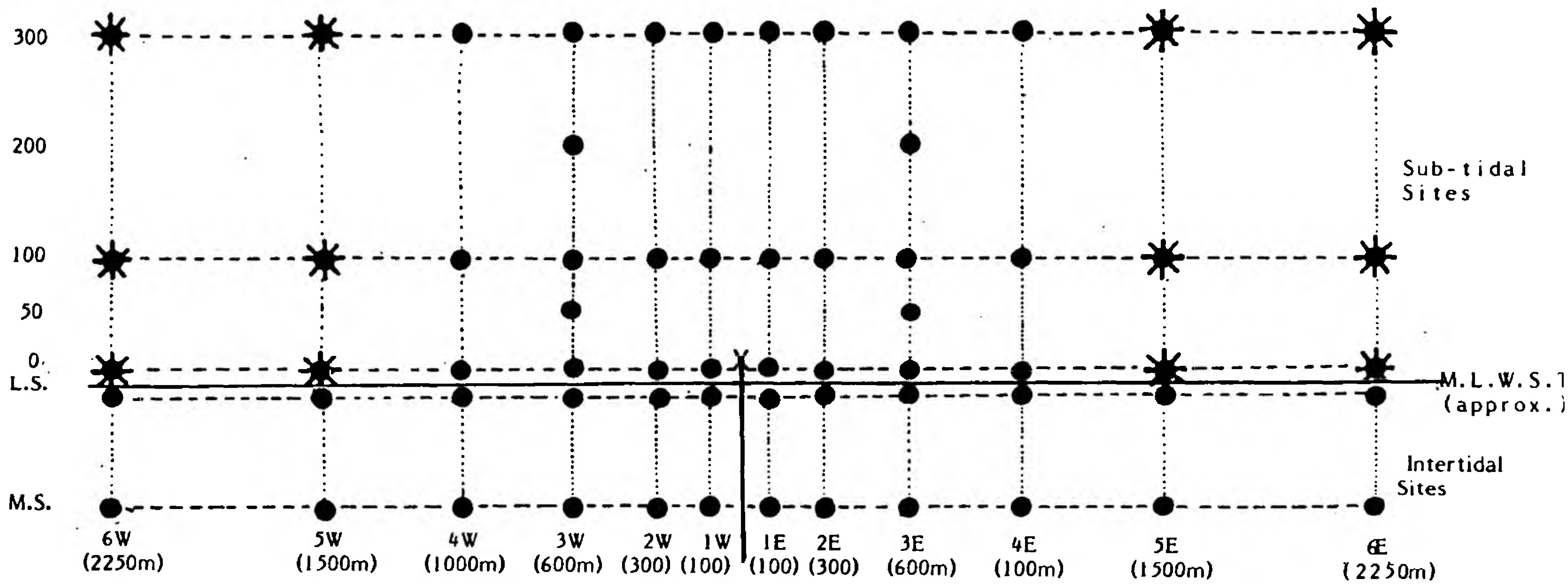


Fig. 2.2.4 A Schematic Representation of the "mini-grids" SCM and Tioxide UK New Outfalls

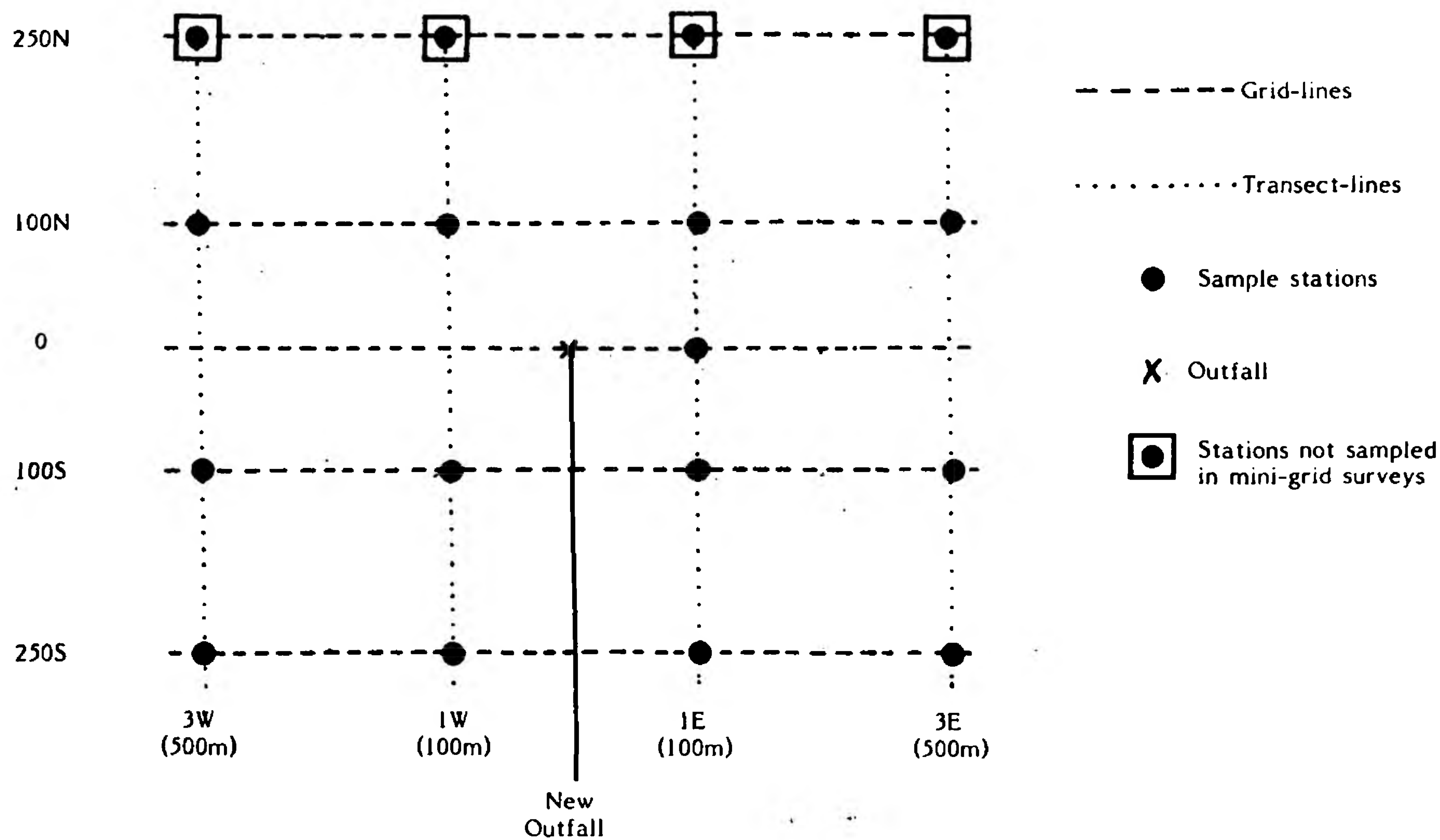
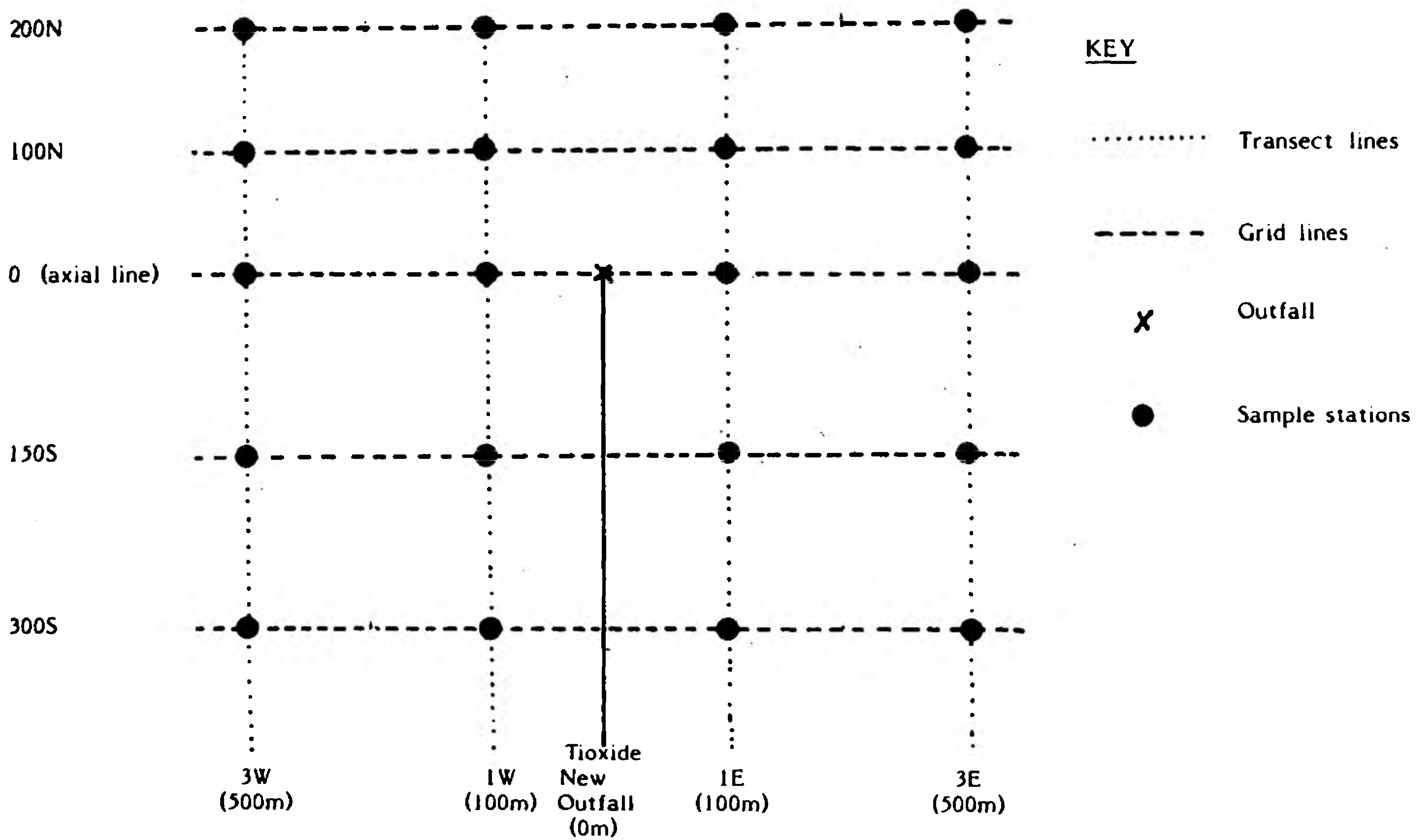


Fig. 2.2.5 A Schematic Representation of the Sampling Grid - Tioxide UK New Outfall



APPENDIX 3

BIOLOGICAL ANALYSIS.

3.1 Introduction.

Approximately 430 samples were generated during the July 1989 surveys conducted around the old and new TiO_2 industry outfalls. In view of the time-scales for analysis and reporting it was necessary to utilise reputable external contractors to conduct the biological analysis in order to meet the required deadline. Each contractor was supplied with comprehensive details of the techniques to be employed which are based on NRA. (Anglian Region) standard methods. These are described in the following sections.

3.2 Separation of Specimens from Residual Sediment.

Although samples are sieved at the time of collection, varying amounts of detritus and residual sediment remain in the preserved sample. Prior to analysis samples are washed thoroughly to remove formalin, and again sieved using a 0.5 mm mesh. (Washing is carried out in a fume cupboard to avoid exposure to formaldehyde fumes.) In the case of particularly cohesive and resistant sediments which would require excessive physical action to break down, material is processed using a freezing technique (Barnett, 1980).

3.3 Sample Sorting.

Wherever practicable the entire sample is sorted, but for some subtidal samples the number of specimens and in most cases the volume of detritus, dictated that a subsampling procedure be adopted. Intertidal samples are generally smaller in volume and contain fewer animals and were therefore not subsampled. Approximately 60% of all subtidal samples required some method of sub-sampling. Because of the varying quantity and nature of the detritus, two different techniques were employed.

3.3.1 Small Detrital Volume.

Although containing relatively small amounts of detritus, some samples yielded surprisingly high densities of animals. These samples were initially divided into four equal parts, only one of which was sorted completely. The remaining three-quarters were retained in case further analysis was required.

3.3.2 Large Detrital Volume.

Samples collected around the SCM outfalls were characteristically large in volume with the detritus mainly composed of woody/peaty fragments and resistant clay. This type of material requires a more elaborate method of subsampling than the smaller volume samples considered above. Samples are initially screened using a 2mm mesh sieve, and the material retained ('coarse fraction') is sorted completely. The finer detritus (<2mm) is thoroughly mixed with water to produce a known volume of slurry from which ten equal volume subsamples are siphoned off. Specimens are extracted and counted from one of these subsamples. Any material retained within the siphon tube and the residue from the base of the mixing vessel are also sorted. For samples of exceptionally large volume it was necessary to reduce the size of the subsample to 1/20th. This represented the smallest subsample taken from any sample during the surveys.

Subsampling procedures were especially rigorous for those sites closest to the outfalls. (No subsampling was required for any of the control sites).

3.4 Identification and Nomenclature.

Wherever practicable specimens are identified to species level using the most up to date keys and reference works available. (A full list of these keys is given in the reference list of section 3.6). In the case of particularly obscure or difficult groups, e.g. Nemerteans, enchytraeid oligochaetes and halacarid mites, specific identification is not generally attempted. Meiofaunal groups were not usually extracted or counted, although their presence was noted. For several groups of invertebrates, nomenclature is constantly being revised with the availability of more modern keys. The recent acquisition of one such key indicates that the polychaete species Anaitides maculata and Ampharete grubei may in fact be A. mucosa and A. acutifrons respectively. For consistency with earlier results both species have been listed under their previous names. The polychaete genus Tharyx is listed as Tharyx spp although it is likely that at least two species of Tharyx exist in the Humber (G. Christie, pers comm). Several species of crustacea of the orders Cirripedia and Decapoda were identified but excluded from the data analyses because they are not truly representative of the sediment dwelling benthos. Similarly epifaunal species belonging to the phyla Anthozoa, Hydrozoa and Bryozoa were excluded from the analyses.

3.5 Reliability of Techniques and Precision of Results.

Extraction efficiency is maximised by use of a low power stereo-microscope (Barnett, 1979) and initially sorting accuracy was assessed by a double-checking procedure.

The amount of time required for the processing of samples collected around both the old and new SCM outfalls in July 1989 proved to be excessive even when subsampling methods were employed. Consequently only two replicates were analysed in time for inclusion within this report. (Analysis of the third replicate is to be completed and data made available at a later date). Results for these two surveys will be less precise than those for other surveys.

3.5.1 Analytical Quality Control.

Sorting of all samples by external contractors was subject to a rigorous protocol to ensure that methods were comparable and conducted to a satisfactory standard. In order to assess the efficacy of these measures, 5% of all samples were cross-checked for extraction efficiency and the specimens removed were re-examined to ensure that they were correctly identified and counted. Results were acceptable only if it was demonstrated that all species had been recorded and that 95% of all the specimens had been extracted.

3.5.2 Sub-sampling.

The efficiency of subsampling for species acquisition was tested using data from samples collected during the 1985 baseline survey for the new SCM outfall. On average, 77% of the taxa present were recorded from the combined data of the coarse, residual and 1/10th subsample (Figure 3.4.1). Examination of the graph shows that relatively few additional species were recovered from the sorting of additional subsamples. It would therefore appear that within the imposed time constraints the sorting of these three fractions provided reasonably acceptable results. Inaccuracies resulting from subsampling may be reduced by examining replicate samples from the same site.

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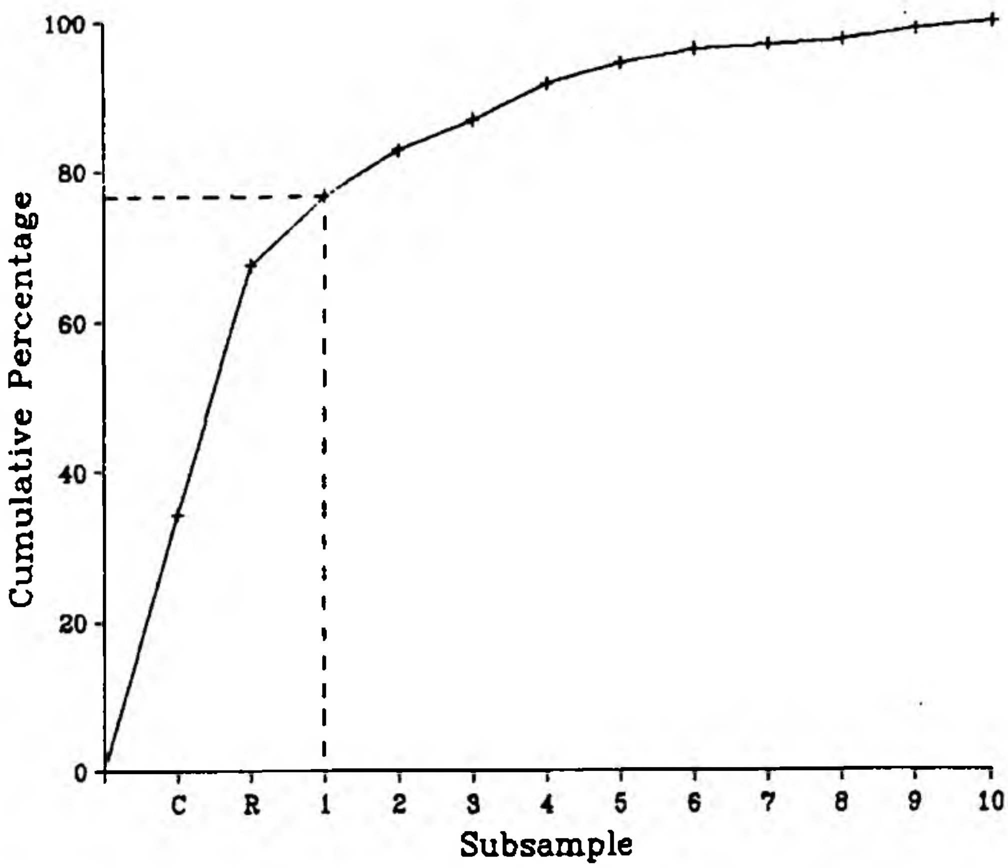
Fig. 3.4.1 Acquisition of Species by Subsamples



C = Coarse fraction
R = Residual fraction

Results based on 20 separate samples collected around the SCM new outfall during the baseline survey

APPENDIX 4

DATA ANALYSIS AND INTERPRETATION METHODS

FOR BIOLOGICAL RESULTS.

4.1 Introduction.

Environmental surveys of the type described in this report yield prodigious quantities of biological data. The presentation of large amounts of data by simple tabulation, mapping, histograms or graphs can display and summarise a sizeable data set quite conveniently, although such methods are not without their limitations. Even straight forward tabulation becomes unwieldy when more than one page is required to summarise the data. Difficulties are multiplied when attempting to simultaneously analyse or summarise a number of different results obtained at a number of different sampling points. All of these problems were encountered in the evaluation of data for the preparation of this report. The following paragraphs provide a summary of the principles and methods used in assessing and presenting the survey results.

4.2 Preliminary Treatment of Data.

The raw data for each sample is initially recorded on a standard sample record sheet. Subtidal results are collated by combining the data from all (3) grab samples at each site to produce species counts per site, after calculating appropriate sample totals from any sub-sampling procedures employed. This effectively provides subtidal data on the basis of a unit area of $0.3m^2$. The results from the subtidal surveys conducted around both of the SCM outfalls in 1989 however are based on the analysis of two replicates only. In the case of the new outfall, densities have been adjusted to represent numbers per $0.3m^2$ to allow a combined analysis of the pre- and post-discharge surveys. For the old outfall survey, densities are expressed per $0.2m^2$ and comparisons with 1984 results have been facilitated by recalculating the 1984 data on a compatible basis. The results from all 4 intertidal cores have also been pooled to produce species counts per site and numbers are equivalent to one sample of area $0.03m^2$.

Master tables were compiled to facilitate the input of data to the computer. Prior to multivariate analyses the data was screened to remove species present as single specimens at one site and animals that were not considered representative of the sediment dwelling benthos, i.e. decapod crustaceans, see Appendix 3, section 4.

4.3 Simple Methods of Data Evaluation and Presentation.

Much of the data produced in the course of the surveys described in this report are amenable to traditional methods of data analysis and representation. Hence the majority of the results are summarised by maps, even when more complex methods of data analysis have been used to produce the basic information for preparing these maps.

Most of the biological results are presented using mapping techniques. Data are represented by circles plotted at the location of the appropriate sampling point, see for example Figure 7.3.7A. The radius of the circle represents the magnitude of the feature under consideration and this facilitates visual assessment and interpretation of the data.

These "block diagrams" are used in preference to contour maps because the presentation of data in relation to discrete sample points is considered more appropriate than the notion of a continuum implicit in the contouring method. Considerations of scale require that this style of presentation is based on a schematic plan of sampling points.

4.4 Complex Numerical or 'Multivariate' Methods of Data Analysis.

4.4.1 Introduction.

Mapping or graphical presentations are ideal for presenting and examining individual data items such as the distribution of a particular biological species. However, in order to examine features of the distribution of several species together even composite mapping (displaying several data sets on the same map) soon becomes confusing. The problem is exemplified in the case of ecological data where any attempt to visually present and appraise the distributions and relative abundances of a large number of different species would be impossibly confused. Examination of large complex data sets requires the application of so-called 'multivariate' techniques.

A relatively wide variety of multivariate methods of data analysis have been developed in recent years. All of these require the use of a computer in order to carry out the vast number of calculations involved. The computer programs are often large and complicated so that substantial amounts of professional programming time are required to create the necessary 'packages' for conducting multivariate analyses. The two multivariate techniques available on the present computer system are cluster analysis and an ordination programme DECORANA. Cluster analysis was the primary method used in analysing the data sets produced from all the surveys. It was conducted on each individual survey and in the case of the new outfalls on the combined results from both the pre- and post-discharge surveys. DECORANA was only utilised in the analysis of the data collected around the old SCM discharge to help verify the interpretation of patterns produced from the results of cluster analysis.

4.4.2 Cluster Analysis.

The principal aim of cluster analysis is to group or cluster together sample points which have similar characteristics. This involves a two stage process. Firstly, it is necessary to compute a measure of similarity between all possible combinations of pairs of stations based on measurements made at these stations. For example two sites containing 10 and 20 individuals of an animal species could be considered to have a similarity of 50% since one value is half of the other value. In practice the calculation of the similarity value is slightly more complex and a number of different equations or so-called similarity coefficients are available. The estimate of similarity can be based on any number of observations at the sample points. From these calculations a matrix is constructed which contains the measures of similarity between any one sample point and each of the other sample points used.

The second stage of the process is to inspect the similarity matrix to find the pair of stations with the highest similarity which may then be linked or 'clustered' together. Further inspection of the matrix produces new pairs of stations. If a site is already linked to another site the new group will comprise three sample points. In this way any number of sample points may be clustered together at gradually declining levels of similarity. This process is termed 'sorting' and there are a variety of ways in which sites can be grouped together according to the 'sorting strategy' adopted.

A comprehensive account of the cluster analysis technique is available in an internally published report (Pearson and Barnett, 1982).

In the analysis of data used for this report clustering of biological results was performed using the Bray-Curtis similarity index (Field and McFarlane, 1968) and the group-average sorting strategy of Lance and Williams (1967). The single linkage clustering, known as 'nearest neighbour' sorting was also employed to help in the interpretation of patterns for the results from the old SCM discharge. Prior to analysis all data was log transformed using natural logarithms ($\log_e$).

The results of cluster analysis are initially plotted as trellis diagrams or dendrograms (see Figure 7.2.3 in Appendix 7). Sites are linked by horizontal lines or bars drawn at the observed level of similarity. Identifiable groups or clusters of stations are produced by selecting an arbitrary cut-off level above which the clusters are deemed meaningful. For ease of interpretation and presentation the groups are plotted out on a map of the survey area as in Figure 7.2.4A of Appendix 7.

4.4.2.1 Application of Cluster Analysis.

Selection of the cut-off level is necessarily subjective and in the case of the present surveys a relatively high level was chosen in order to achieve the necessary resolution. It may also be noted from Figure 5.4.2.1 that the demarcation is not rigid. The recognition of sub-groups at a higher similarity level may be somewhat unconventional, but the employment of cluster analysis to discriminate between samples taken over such a relatively small geographical area is unusual and this small departure from conventional procedure was deemed necessary in order to produce the clearest interpretation of the output. It is also unusual to assign so many sample points to an "unclassified" status, but this is also consistent with the need to achieve a high level of definition and the relatively unusual nature of the investigation.

4.4.3 Ordination - Detrended Correspondence Analysis (Decorana).

Decorana is an improved ordination technique that is effective in showing trends or gradients within the data set. Comparative tests with other ordination methods have shown that DECORANA is generally superior to other techniques (Gauch, 1982).

In ordination by DECORANA, sites are arranged into an objective order, those with similar taxonomic composition occurring most closely together. A number of options for manipulating the data set exist within the programme. In general the data were transformed prior to analysis using natural logarithms and if necessary the influence of rare species was minimised by invoking a 'down-weighting' option and any anomalous sites or species were excluded from the analysis.

4.4.3.1 Application of Decorana.

Results are usually displayed as two-dimensional graphs and sites are plotted on to these graphs using the axis scores. The strengths of Decorana axes are given by eigenvalues which broadly relate to the degree of variability accounted for by that axis. Cluster groups may be superimposed on to the Decorana plots to help identify and explain any patterns. The axis scores may be used in relating the ordination to environmental factors (e.g. sediment parameters).

4.4.4 Indices.

The employment of pollution indices has potential advantage for environmental management, but the production of a scientifically rigorous system for use in estuaries has not proved to be very practical. Of the few indices available for multi-disciplinary assessment of conditions in the marine or estuarine environment (see for example Tomlinson et al, 1980) none can be considered as proven and are certainly not applicable to the current investigation.

4.4.4.1 Biological Indices.

The complex nature of biological data has encouraged much more extensive efforts to produce indices for summarising ecological results than is the case with chemical information where mathematical modelling has proved useful. Thus a relatively wide variety of biological indices have been used in recent years. Their application has generally been confined to summarising data for non-specialists, and many such indices have now fallen into disrepute amongst environmental biologists. A wide range of biological indices have been reviewed by Washington (1984) who advises extreme caution in their application.

The most commonly used and the most generally accepted type of indices are diversity indices. Although they are regarded with some scepticism by many environmental biologists, they are frequently applied in impact assessment studies. In the 1984 impact assessment of the old discharges the application and usefulness of certain widely-used indices was examined. Shannon-Weaver, PIE and the evenness index (E) were selected for consideration based on the work of Read et al (1978). All three indices produced broadly similar patterns, none of which were helpful in describing the effects of the two effluents. It was therefore decided to avoid the use of indices in analysing and presenting data in this report.

4.5 Interpretation of Data.

There are two objectives of the present work;

1) To provide an assessment of conditions following cessation of the old discharges and to compare those with the impact assessment in 1984.

2) To provide an impact assessment of the new outfalls and compare those with an assessment of pre-discharge conditions.

There is a subtle but fundamental difference between a comparison of the assessments before and after a discharge ceases /commences and the broader, more generalised statement of comparing conditions before and after either the closure/commissioning of an outfall. This is best understood by considering the situation whereby conditions are shown to have improved as assessed for example in terms of a reduction in heavy metals in the sediments or an increase in species variety at sites near the outfall under investigation. The improvement has to be quantified, or at least qualified by reference to prevailing conditions elsewhere and it is quite conceivable that an improvement in conditions can take place and yet an impact still exist or be detected. An example of the latter case is demonstrated in Section 7.2.2 of Appendix 7, with reference to the the new SCM outfall. Cluster analysis identified a group of sites close to the discharge point which had a lower average number of species than the average for the majority of comparable sites, in the survey area and a lower number of individuals. On the basis of this anomaly and the observation of a change in pattern from that demonstrated 1988, these three sites were identified as being affected by the new discharge. In contrast, a comparison of the 'absolute changes' between the pre and post-discharge surveys would have contradicted this interpretation since marked increases in abundance were recorded at these three sites in 1989, and species variety had either increased or remained relatively unchanged. However the increases were small in comparison to those observed at most other stations in the survey area and at remote reference sites in the estuary. Therefore changes in pattern are more important in assessing changes in conditions than comparison of 'absolute changes'.

The experimental biologist can overcome such problems by the use of "controls". In the experimental situation the factor under test is varied, whilst the controls mimic all other conditions deployed, so that results pertaining to the variable under investigation can be isolated from any extraneous factors. Unfortunately, the environmental scientist can rarely (if ever) isolate the feature to be tested, because in the natural environment it is impossible to control all the factors which are not being tested. For example natural recruitment of major species may be poor in any given year, leading to universally low population densities. The recording of reduced abundance at a particular location compared to a previous occasion when conditions were more favourable would not signify a local deterioration, but merely reflect a general change. Hence, changes at any particular location must be evaluated in the context of overall changes in the system.

To a certain extent this approach has been adopted in the following sections by comparison with changes at 'control' or reference sites, but in the present context, the selection of realistic reference sites is almost impossible. This difficulty was recognised in the report on the 1984 surveys. Because of the presence of the two TiO_2 industry discharges on the south bank, it is difficult to find a comparable area remote from both without moving to a location which is not representative of either receiving area. The adoption of sites near the north bank in the estuary (control sites 24 and 29 as used in 1984) would initially seem to overcome this problem, but the estuary is so large that even such large scale factors as 'Coriolis effect' need to be taken into account in the lower estuary, so that sites on the northern shore with comparable hydrographic conditions and sediment type are not genuinely representative of the environment on the southern shore. This situation is exaggerated by large inputs of crude sewage on the south bank, which are not matched by conditions on the opposite shore. Enrichment from sewage discharged on the south bank probably accounts for the consistently higher populations at the south bank 'control' site (N33) compared to either of the north shore reference sites.

The problem is even greater around the SCM outfalls which discharge into an area which is predominantly a glacial clay with an admixture of peat-like plant material. Although this type of substratum covers a substantial area of the estuary bed around Immingham, it does not occur at locations which could reasonably be considered as isolated from the new SCM discharge. In 1984, when the old SCM outfall discharged close inshore, it was possible to utilise a more off-shore reference station (No.7707) as a "control" site. However, since the new discharge location is approximately 300m further off-shore than the old outfall, there was a reasonable possibility that the reference site used in 1984 would be subject to some effect of the effluent. It was therefore not possible to select a suitable reference site for the majority of the SCM receiving area.

In view of the unavoidable inadequacy of the 'control' stations which are repeatedly shown to have a low similarity with sites in the discharge areas, it is necessary to compare changes at sites near the outfalls with changes at more remote locations within the same survey area. Hence the analysis of changes in the ecological patterns around each of the various outfalls is of paramount importance. To achieve this cluster analysis is heavily utilised throughout the following appendices. A detailed explanation of this method is provided above (section 4.3.2). The general principles of the approach to data analysis/presentation therefore broadly follows the following sequence:

1. Analyses of patterns in 1989 - following the procedure adopted in 1984 - to identify inconsistencies in the pattern(s) which can be related to the discharge under assessment.

2. Comparison of these patterns with the patterns observed prior to the commencement/termination of the discharge in question.

3. Assessment of "absolute changes" in ecological characteristics (e.g. species variety) at sites identified from the above procedures as being of possible significance in relation to the outfall under investigation. These changes are then related to changes at sites identified by the above procedures as not having significance in relation to the outfall concerned.

This would appear to be the only way in which changes which may be connected with the outfalls under investigation can be realistically isolated from general changes throughout the survey area(s).

It is hoped that the basic principles of this underlying 'philosophy' will be evident from any of the examples in the examinations of individual outfalls which follow this section. On occasions, an outstandingly significant feature of the data will lead to modifications of the general principles and there are inevitably situations where cross-references to "absolute changes" are essential within the assessment of patterns, but the general procedure outlined above constitutes a framework for consistency of approach and logical assessment of what are often complex ecological patterns and changes.

4.6 References.

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APPENDIX 5

BIOLOGICAL RESULTS AROUND THE OLD OUTFALLS.

5.1 Introduction.

Data for the sub-tidal benthos around each outfall are summarised in two 'master' tables (Tables 5.1 II and 5.1 II) using combined results at each site as explained in Appendix 4. Results for intertidal benthos are summarised in one master table for both outfalls (Table 5.1 III). These tables formed the working basis for the data analysis.

Data for the rocky-shore survey is more conveniently summarised and is included as Table 5.1 IV.

Details of data analysis are provided in Appendix 4.

5.2 Data Presentation.

Results of cluster analyses and selected data are displayed by conventional mapping techniques using a schematic plan of the sampling stations. The schematic presentation is adopted to overcome the difficulties of representing a survey area which is much greater in length than in width. The sub-tidal sampling grid can be seen from Figure 2.2.3 (Appendix 2).

Because of the differences in sampling methodology (and season) and the obvious fundamental differences between the sub-tidal and intertidal habitats, examination of the results is divided into sub-tidal and intertidal data. The intertidal results are further divided into an appraisal of the mud-flat fauna and the rocky shore biota.

Following the approach adopted in 1984 the two outfalls are considered independently. The two sampling grids are linked at the "common point" or "centre point" (C.P.) as seen from Figures 2.2.1 & 2, but sub-tidal results are currently only available for sites up to 1km either side of each discharge point (Transect lines 4E to 4W). Consequently the data is both analysed and presented separately.

The complete results of the intertidal mud-flat survey are available and multivariate analyses have therefore been conducted on the entire data set, although for consistency with both the 1984 work and the sub-tidal presentation the results are presented and considered separately for each outfall.

Separate consideration of each outfall is also more appropriate in view of the physical differences between the survey areas as explained in the 1984 report and summarised below.

5.3 Physical Characteristics of the Survey Areas.

As can be seen from the chart section (Figures 2.2.1 & 2) there is a range of water depth throughout the general survey area. The old Tioxide outfall is situated in an area where the depth is consistently less than 2m above chart datum (L.A.T.), whilst depths greater than 2m are common throughout most of the survey area considered here in relation to the SCM outfall.

There is also a general difference in bed sediment types between the sub-tidal survey areas (Figures 5.3.1 and 5.3.2). Much of the sea-bed in the vicinity of SCM comprises firm clay type material whilst the sediment around the Tioxide outfall is a softer mud.

It can also be seen from the chart sections how the extent of the intertidal mud-flat increases on moving from Immingham to Grimsby. Thus the SCM outfall discharged to an area with relatively little mud-flat, whilst the Tioxide outfall is situated at the seaward edge of a very extensive mud-flat.

The potentially complicating effects of other discharge pipes, jetties and harbour approaches are self evident from the charts.

Sediment characteristics for the mud-flats are not illustrated. Although there is some variability, especially in the amount of soft mud overlying the more consolidated bed material, there is no obvious or consistent difference in the nature of the sediment around each outfalls, unlike the sub-tidal sediments.

The maps of sediment type at grab sample sites also show those sites at which visible evidence of the discharges was observed. These observations recorded the presence of a black "chemical" sand, believed to be unprocessed ilmenite ore, and areas where a thick "iron crust" resembling very heavy scale-rust was present. The latter is almost certainly the result of heavy precipitation of hydrated ferric oxide from the discharges, and neither phenomena have been observed elsewhere in the estuary.

5.4 Sub-tidal Benthos.

5.4.1 Introduction.

As explained above the distinct physical differences between the two discharge receiving zones, especially in terms of sediment type and width of the mud-flats make it both desirable and convenient to consider each outfall independently. Before doing so, a number of pertinent points concerning biological differences between the survey areas, and the suitability of the control sites should be considered. Compared to 1984, there has been a general influx of the spionid polychaetes Polydora spp and Pygospio elegans in both survey areas, but especially around the old Tioxide outfall. With the partial exception of one control site (N33) this phenomenon has not been detected at control stations.

Even so, the prevalence of softer mud around the Tioxide outfall encourages much greater populations of such species as Tharyx spp. and tubificid oligochaetes than in the majority of the SCM discharge area. These biological differences constitute an additional reason for examining the benthos in the two receiving areas independently.

The validity of the control sites has been discussed in Appendix 4 and as in 1984 it is considered that the results for these stations can only be used as an extremely general basis for comparison. As mentioned above only site N33, which is comparatively close to the old Tioxide outfall and similar in terms of sediment type, exhibits comparable characteristics with either of the survey areas. However, the relative proximity of this station to both the old and new Tioxide discharges must impose constraints on its ultimate suitability as a reference station. Because of the uncertainties regarding the validity of the control sites, emphasis is placed on ecological patterns. Throughout the following discussion changes in comparison to 1984 are assessed primarily in relation to changes elsewhere within the survey areas.

5.4.2 The Old SCM Outfall (sub-tidal).

5.4.2.1 Introduction.

Assessment of the old SCM discharge is particularly complicated and consequently difficult. These difficulties arise from:

1. The Nature of the Sea Bed.

The substratum in the receiving area comprises a complex variety of sediment types with at least two major categories of bed material: soft mud and hard clay, with various inter-grades between (Figure 5.3.1). The two extreme habitats exert a strong and distinctly different natural influence on the benthic communities. Difficulties in interpretation are exacerbated by the tendency for the substratum to change in composition according to a geographical pattern which is broadly similar to the estimated contours of the effluent plume. Any changes in patterns in the benthos relating to impact or recovery must be separated from this strong natural influence on the ecology of the receiving area. Furthermore, there is every likelihood that changes in the benthos relating to recovery (or impact) will take place at different rates according to the nature of the substratum so that not only the pattern, but the apparent changes at specific locations, may be influenced by natural processes related to sediment type rather than any influence of the discharge. It is against this complex background of variability in the physical environment that changes must be assessed.

2. Proximity of the New Outfall.

Unlike the situation with the Tioxide (UK) outfall the receiving areas (or at least the survey areas) of the old and new SCM outfalls overlap. In fact the most off-shore line (300m) of the original survey to assess the impact of the old discharge is now almost coincident with the axial ("zero") line for the new discharge. This is essentially equivalent to trying to repeat the 1984 impact assessment but with an identical*[1] discharge 100m west and 300m off-shore of the original outfall. (A new SCM pipeline was constructed following the 1984 Survey Report, with a relocated outfall extending a further 270m offshore.) Considered in the terms of trying to assess and separate the effects of two virtually identical* discharges in such close proximity the magnitude of the problem is immediately apparent.

3. Other Discharges.

Within, or near to the survey area around the SCM discharge as considered here, there are complicating influences of other discharges. These are the Harlow Chemicals and Doverstrand discharges at 5E and the Immingham sewage discharge at 4W. Future surveys are planned for these.

4. Physical Obstructions.

Also, within the survey area considered here, there is the physical obstruction of the old SCM jetty at approximately 2W. Consideration must also be given to the physical disturbance of the sea bed caused by construction of the new SCM outfall on the line of the 1W transect.

5. Previous Intensity of Impact.

Assessment of recovery around the old SCM outfall is also more difficult than for the old Tioxide outfall, since nothing more than a "moderate effect" of the discharge on the sub-tidal benthos was identified in 1984. Consequently, the scope for recovery would not be as great, and the smaller the expected recovery the more difficult it is to detect.

6. Adequacy of the 1989 Data.

The very high population densities found in the 1989 survey coupled with the large quantities of detritus at most sites (see Appendix 3) imposed such severe constraints on processing time that only 2 of the 3 replicate samples collected in 1989 were examined during the time available. Consequently, results for the current survey are likely to be less precise than the 1984 data. Insofar as is practicable comparisons are mediated by the recalculation of 1984 results on the same basis as those for 1989, but any interpretation based on 2, rather than 3 replicate samples is inevitably prone to a greater degree of uncertainty. To compensate for the reduced level of confidence in the data, "worst case" assumptions will be made throughout the following discussion.

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1. * Footnote: The new outfall, unlike the old one is fitted with a 50m diffuser section, so that the characteristics of the discharge are not completely identical with those of the 1984 discharge.

5.4.2.2 Results for the 'Old' SCM Discharge Area.

The cluster analysis of the data collected relating to the SCM discharge area is presented in dendrogram form in Figure 5.4.2.1. In view of the various complicating factors considered above, interpretation of the dendrogram has been stretched beyond normal limits for such analyses. For general consistency with the approach in 1984 and following close examination of the dendrogram and the similarity matrix, a cut-off level of approximately 66% is applied. For convenience of subsequent presentation site 3E.50 is considered to belong to Group 3.

Potential sub-divisions above the cut-off level are dealt with by the designation of sub-groups as previously but a still higher level of definition has been applied to create 'partial sub-groups'(p.s-groups). The validity of these 'partial sub-groups' is admittedly rather questionable since inspection of similarity values for individual pairs of stations shows some cross-over between them. However, when the robustness of these associations was tested by applying a procedure known as nearest neighbour sorting (Stephenson, 1972) to the similarity matrix, much the same pattern emerged. The data were further examined by detrended correspondence analysis, which also indicates that the assignment to 'partial sub-groups' is not entirely spurious. All three analyses suggested that there was a particular affinity between the fauna at different locations on the 300m line with the evident exception of site 4E.300, and the probable exception of site 1E.300. In view of the comments in Section 5.4.2.1 above concerning the new outfall, the possibility of any features associated with the 300m line necessitated very close scrutiny. The basic characteristics of individual sites and the cluster groups/sub-groups/p.s-groups to which they belong are summarised in Table 5.4.2.I. It is apparent that the p.s-group of sites on the 300m line (1B'') have a lower average species complement than the p.s-group (1B') comprising 100m and 200m line sites and there is almost no overlap in the species richness of individual sites within the two p.s-groups. The number of individuals at 300m sites is arguably higher than in the similar p.s-group of more inshore sites with the notable exception of site 2W.300, which is the closest upstream site to the new outfall. It may therefore be more than a strong coincidence that site 1E.300, which is equi-distant on the downstream side, has the same number of species and almost identical (comparatively low) number of individuals as 2W.300. The relatively low similarity of site 1E.300 to the remainder of this sub-group may also be of significance. The only other 300m site which failed to cluster with the majority was 4E.300, which is remote from the new discharge and yielded the highest species richness of any site in the survey. This site also had a lower similarity with other 300m sites in 1984. It is also pertinent to note that if the same elevated similarity cut-off is applied to the 1984 data, the tendency for the 300m sites to separate from others in the same general group does not occur. In fact there is as much tendency for sites to group according to the transect location (e.g. L.3W.200 with L.3W.300) as along any particular line and an equal mixture of "300" sites with those inshore is apparent from the 1984 dendrogram.

Changes in number of species and total number of individuals at "unaffected" sites on the 100m and 200m lines and changes on the 300m line in comparison to 1984 results are summarised in Table 5.4.2.IIA & IIB.

It is evident that the number of species at the inshore sites has remained similar, or even increased slightly, whilst the species variety at the 300m sites has declined (except at those sites furthest from the new discharge point). Furthermore, in 1984 the 300m line was on average slightly more diverse than the unaffected sites inshore, whilst in 1989 the pattern is reversed.

The observation of a slight increase in species richness at the inshore group of sites could be related to an improvement following closure of the old outfall, but the decrease on the 300m line and the associated reversal of the 1984 pattern can realistically only be accounted for by an impact from the new outfall or an unlikely level of coincidence. Relatively little significance can be ascribed to changes in abundance in areas which are so overwhelmingly dominated by spionid polychaetes. Even so, it is curious to note that only one of the five inshore sites displayed a lower abundance in 1989, whilst three of the seven "300" line sites were lower, and conspicuous amongst these was the site closest to the new outfall on the downstream side (1E.300). The possibility of an impact caused by the new outfall is dealt with specifically in Section 7.2 of Appendix 7 but is considered in some detail here because of the likely complicating influences of this eventuality on the assessment of recovery in the receiving area around the old outfall.

It should be recalled that this speculation on a possible effect from the new outfall began with a potentially dubious and hesitantly extravagant interpretation of the dendrogram for the 1989 results. However, the way in which the various facets examined tend to lead to the same tentative conclusion and the broadly similar conclusions reached in Appendix 7 may indicate that the original interpretation of the dendrogram was not entirely unjustified.*[2]

5.4.2.3 The Old SCM Outfall.

If the assessment and interpretation of the data discussed above can be considered to show some validity, then the following observations which rely on a generally lower level of resolution should hold true. The faunal associations derived from the rigorous interpretation of the dendrogram (Figure 5.4.2.1) are shown schematically in Figure 5.4.2.2. The grouping of stations around the new outfall is apparent. It is also apparent that the cluster pattern demonstrates some connection with the old outfall. Comparison of the arrangement of cluster groups with the map of sediment characteristics (Figure 5.3.1) suggests that the ecological pattern is by no means controlled by sediment type alone. There is also a distinct resemblance to the pattern observed in the 1984 survey. Group 4, which comprises sites on the zero line immediately adjacent to the old outfall, is comparatively low in species richness and faunal abundance (Table 5.4.2.I). This is especially true of the two sites closest to the outfall, see Figures 5.4.2.3 & 4. Group 5 sites at intermediate distances from the outfall location are little better. In spite of these findings the distinctly impoverished nature of the fauna within cluster group 3 is most surprising since it is arguably 'worse' than at sites closer to either outfall. The two sites within group 1B appear to be reasonably healthy in terms of species variety and faunal abundance, but the linking of these two sites is again reminiscent of the pattern seen in 1984.

Perhaps the most curious sites are those in the pair designated sub-group 1A. At first these two sites appear to be peculiar "mis-fits" but a detailed examination of the similarity matrix reveals some interesting associations. Site 2E.100 is actually most similar to site 2W.300, which is very close to the new outfall. The second highest paired similarity is with its partner 1W.100, and thereafter the highest similarity is with 4W.0 and 3W.100, both of which clustered in the same group as 2E.100 in 1984. Likewise 1W.100 is, after 2E.100, (next) most similar to 1E.300: The other site in closest proximity to the new discharge. Thereafter it has the highest paired similarity levels with sites 4W.0 and 3W.100 with which it constituted part of the same group, and sub-group in 1984. Thus there are strong indications that at least the "shadow" of the old impact zone remains. Both sites in sub-group 1A were classified as demonstrating a weak or peripheral effect in 1984, which may account for the difficulty in recognising their true affinity, and their association with sites most likely to be similarly designated with respect to the new outfall in 1989. Only the linking of site 2W.0 with other species rich and moderately abundant fauna in the north east corner of the survey area shows any clear evidence of an improvement in conditions near the old outfall.

The persistence of an impact from the old outfall indicated by the cluster patterns is also apparent from Figures 5.4.2.3 & 4. Sites with lower species variety are generally associated with the old discharge point (or in some cases the new outfall location) and clearly relate to the area of impact described in 1984, whilst higher species variety is generally found at sites remote from either discharge. There is an even more pronounced depression in faunal abundance at sites around the old outfall (Figure 5.4.2.4) but this must be mediated to a considerable extent by the nature of the bed sediments in this area. The overall impression from examination of these ecological patterns is that a recognisable influence of the old discharge still exists, although the pattern is less distinct than in 1984. A small number of sites (notably 2W.0 and 2W.100) exhibit reasonable species richness and faunal abundance and no longer conform to the 1984 pattern, suggesting that a patchy recovery has taken place.

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2. * Footnote: The interpretation and conclusions reached here were arrived at independently from those in Appendix 7 which was prepared simultaneously by another member of staff.

Changes at sites deemed affected in 1984 are summarised in Table 5.4.2 III. These are grouped according to their classification in 1984, i.e. moderate effect or weak/peripheral effect. In terms of species variety there are indications of an improvement in the moderately affected area with five out of seven sites showing an increase but this is only "significant" at two sites (2W.0 and 2E.0) and the average increase is quite small. At the sites deemed to show a weak effect there is no real evidence of improvement, except at 2W.100. Judged against changes at the reference sites where species numbers increased, the improvements would be negligible. However, as discussed elsewhere, the reference sites are not sufficiently compatible with the main part of the survey area to be realistically utilised in this context. A better basis for comparison is the changes at 'unaffected' inshore sites already presented in Table 5.4.2.II. These sites also demonstrate a slight improvement in terms of average species richness. Comparison with all sites deemed unaffected in 1984 would also include the 300m line sites where species variety was slightly lower in 1989. Such a comparison would suggest a greater degree of improvement at sites around the old outfall but since the decline in species variety at off-shore sites in 1989 may be attributable to the relocation of the effluent as previously discussed, such a comparison would be potentially spurious.

As stated in Section 5.4.2.2 changes in the numbers of individuals should be assessed with great caution, or even largely ignored when sizeable populations of spionid polychaetes are involved. However, the obvious increases in faunal abundance at sites previously deemed to show a 'moderate effect' (Table 5.4.2.III) may be indicative of at least some improvement in conditions. Certainly those sites which demonstrate at least a five-fold increase in abundance coupled with a 'significant' increase in species variety (2W.0 and 2E.0) must be considered to show an appreciable recovery. Similar large increases in abundance at two sites (4W.0 and 3W.100) in the area of weak effect may also be tentatively interpreted as evidence of improvement, although not accompanied by increases in species variety. However, on the same basis of comparison, sites 3E.100 and 4E.100 must be considered to show a marked deterioration. Other changes are clearly within the range observed at unaffected sites (Table 5.4.2.II) and consequently should be ascribed to natural variability rather than changes in environmental quality.

On the basis of the data available and in view of the considerable difficulties in interpretation, it is not possible to conclude that there has been more than a marginal overall improvement in conditions around the old SCM discharge. Alternatively, the findings may be viewed as evidence of a patchy improvement and recovery, with most previously affected areas exhibiting only very limited recovery and some sites apparently showing a deterioration. Undoubtedly the complications of different sediment types in the receiving area have some bearing on the results reported here but the persistence of several remnants of the 1984 pattern suggest that an impact still exists.

5.4.3 Old Tioxide Outfall (sub-tidal).

5.4.3.1 Ecological Patterns, and Comparison with the 1984 Pattern.

The results of the cluster analysis are presented in dendrogram form in Figure 5.4.3.1, and the groups of sites are illustrated in Figure 5.4.3.2. For consistency with the approach adopted in 1984, a similarity level of 69% was used, although this is actually approximately 2% higher than the 1984 criterion. Inspection of the raw data and an appraisal of the similarity values for pairs of adjacent stations suggests that a lower cut-off value may have been appropriate but this might have over-emphasised the impression of uniformity throughout the survey area. The construction of the dendrogram may suggest that a higher cut-off value could have been employed but, as explained above, this could not be justified from examination of the full similarity matrix. The potential for further sub-division is dealt with by the designation of sub-groups within the two largest groupings and this achieves an equivalent number of groups and sub-groups to those recognised in the same area for the 1984 survey. A summary of the principle characteristics for each group/sub-group is provided in Table 5.4.3.I.

The main impression from Figure 5.4.3.2 is the homogeneity of the area, particularly with regard to the location of the old outfall. An appraisal of each of the cluster groups enables clarification of this general observation. Probably the most interesting feature is the association of two sites (2E.0 and 1W.0) close to the outfall. Site 2E.0 with 20 species and over 9,000 individuals compares very favourably with sites nearby (Figures 5.4.3.3 & 4). It was in fact 76.6% similar to neighbouring site 1E.0 and its failure to group with other sites in the vicinity appears to be an artefact of the group averaging process. (The site was not deemed to be affected in 1984).

On the other hand, 1W.0 is unlike other nearby sites, having a somewhat lower species complement and lower total number of individuals (Figures 5.4.3.3 & 4). This site was deemed to be affected in 1984 and this may therefore represent a residual impact of the old discharge.

Alternatively, since the station was 75.1% similar to site 3E.100, and also 74.1% similar to 4W.0 it may be that 1W.0 (like 3E.100) is an unassociated easterly patch of cluster group 4, which in terms of number of species and total number of individuals it most closely resembles. The biological community recognised as cluster group 4 merits attention since it is characterised by relatively low species variety and faunal abundances (see Table 5.4.3.I). This latter feature relates to the comparative scarcity of spionid polychaetes (see below). The same general area to the west of the outfall was similarly occupied by a relatively impoverished fauna in 1984 but none of these sites were deemed to be affected by the discharge, although this could not be concluded with certainty. In view of the changes that have taken place at sites closer to the outfall the impoverished fauna at these more remote locations would appear to be a natural phenomenon, and the original interpretation may therefore be vindicated. It certainly seems unlikely that if substantial recovery has taken place in the immediate vicinity of the old discharge (as suggested below) that any residual impact would still be evident in comparatively remote areas. Cluster group 1 is the largest group and, with the exception of the two sites considered earlier, it encompasses most of the survey area adjacent to the old outfall and all but one of the sites (1W.0) deemed to be affected in 1984. The evident uniformity of the fauna throughout the area around the outfall strongly suggests that recovery has taken place, since the perturbations which were identified by the same techniques in 1984 are no longer evident.

Furthermore, examination of the general characteristics of cluster group 1, as shown in Table 5.4.3.I, demonstrates a relatively high species richness (comparable with control sites) and high or very high faunal abundance (see Figures 5.4.3.3 & 4) consistent with a reasonably 'healthy' and thriving benthic community. The high abundances are a consequence of large populations of spionid polychaetes which are widely recognised as 'opportunistic' species. Their presence in this area in such large numbers coupled with the virtual absence of the same phenomenon at control sites could be taken to indicate the preliminary stages of "classical" recovery of the benthos following pollution abatement. Similar observations from investigations conducted elsewhere are reported in the literature and have been summarised by Pearson & Rosenberg (1975). Whether or not the findings presented here should be interpreted in the same way is unclear, since the influx of these spionid polychaetes is more pronounced at sites remote from the outfall (particularly those in sub-group 1B) and less obvious at sites previously deemed affected. Furthermore, the fact that species richness within Group 1 sites is comparable with that at the control sites would indicate a more advanced state of recovery of the benthos. Enhanced natural recruitment as a consequence of the mild winter and unusually warm summer of 1989 could equally be invoked as an explanation for the evident success of the species concerned.

5.4.3.2 Changes in Abundance and Species Richness Compared to 1984.

In addition to the evidence of recovery provided by the analysis of patterns in the data the changes at individual sites previously considered to be affected illustrates the extent of the improvement. This is summarised in Table 5.4.3.II which compares the species complement and total number of individuals at each of the impacted sites in 1984 with the situation in 1989. On average the number of individuals has increased by an order of magnitude over the 1984 densities, whilst the opposite tendency is evident at control sites. This may tend to exaggerate the extent of the recovery, bearing in mind the large populations of spionid polychaetes as discussed above. However, such a significant increase in faunal abundance must be considered as a distinct improvement in comparison to the situation observed in 1984. The average number of species recorded at each site in 1989 is more than double the number found in 1984, suggesting a substantial improvement in conditions. With the exception of site 1W.0 the improvement is clearly evident at all stations and especially at 1E.0, which was the most severely impacted site in 1984. In spite of the four-fold increase in species variety at the latter site, the number of species is still marginally lower than at neighbouring sites and at other sites within the same cluster sub-group. It is therefore possible that a slight residual impact of the discharge is still evident at this location. The same inference may be made with respect to site 2W.0, although the less obvious improvement at this site may relate to its association with a naturally less diverse community as considered earlier. In view of the fact that two of the three 'control' sites exhibited a decrease in species variety compared to 1984, the increases at previously affected sites within the survey area must constitute sound evidence of a very substantial improvement in conditions and almost total recovery of the benthos. Even when compared with changes at unaffected sites within the survey area these improvements remain clearly substantial.

It may reasonably be concluded from the observations presented here that there are no longer any clear indications of an impact from the old discharge and that a major improvement has taken place resulting in almost total or possibly even complete recovery of the discharge area.

5.5 Intertidal Benthos.

5.5.1 Introduction.

For practical reasons considered earlier, multivariate analyses were conducted on the complete data set for all intertidal sites, thus effectively treating the two survey areas as one combined entity. Since both outfalls are considered, the general site coding system explained in Appendix 2 (Section 2.2.1) requires separation according to the outfall concerned. The labelling therefore follows the system employed in 1984, when Tioxide sites were pre--fixed by the letter 'T' and SCM sites by the letter 'L' (which relates to the previous owners of the factory: Laporte Industries Limited). The results of the cluster analysis are illustrated in dendrogram form in Figure 5.5.1. An arbitrary cut-off level of 63% is adopted which is comparable with, (although slightly higher than) the 1984 criterion. This establishes six groups and one additional sub-group with 5 sites unclassified, compared to five groups and one unclassified sample point in 1984. The characteristics of each group and the sub-groups are summarised in Table 5.5.I. Closer inspection of the distinction between the two sub-groups 5A and 5B shows a clearly justifiable difference with the latter being dominated by Hydrobia ulvae which accounts for the average abundance being approximately three times greater than in sub-group 5A. Such a clear separation of groups at a similarity level of almost 80% may argue for the adoption of a higher cut-off level but this would have led to the designation of too many unclassified sites. A cut-off slightly below the 63% similarity level would have incorporated the two control sites (routine monitoring points at Grimsby) into main groups, as was the case in 1984. However, changes at these stations following closure of a large sewer outfall in 1986 have resulted in what appears to be a transient faunal "community" which can not reasonably be considered as representative of any other area. It was therefore decided to adjust the cut-off level so as to exclude these particular sites from any cluster group. (As a consequence of this the problem of realistic control sites, as discussed with reference to the sub-tidal benthos, also applies to the intertidal fauna).

Examination of Table 5.5.I shows that the groups recognised do possess distinctly different characteristics and as can be seen from the arrangement of sites on the dendrogram (Figure 5.5.1) the majority are geographically coherent. Only sub-group 5A and group 1 comprise sites relating to both discharge areas. The former is consistent with regard to shore level and contains sites at appreciable distances from both outfalls. Group 1 contains sites from both shore levels, although only one (T.3W.LS) relates to the Tioxide outfall. All other groups are consistent with regard to shore level and outfall location. The tendency for neighbouring sites of the same tidal level to form part of the same faunal association in the Humber has been reported previously (Barnett, 1984). The similarity of site T.3W.LS with sites at comparable distances from the old SCM discharge and their subsequent linking with mid-shore sites relatively close to the SCM outfall suggests that some strong environmental factor is over-riding the natural pattern of zonation. The influence of polluting discharges is one possible cause (see Barnett, 1984). Otherwise, the separation of groups according to their respective outfall locations confirms that there is very little overlap between the two survey areas. It is therefore logical, as previously proposed, to consider the two receiving areas independently.

5.5.2 Old SCM Outfall (Intertidal).

The patterns deduced from cluster analysis are illustrated in schematic form in Figure 5.5.2.1. As considered in discussion of the sub-tidal habitat for this outfall, the situation is complicated by the presence of other discharges and physical obstructions which are also shown in Figure 5.5.2.1. In addition, four mid-shore sampling locations and the 1E low-shore site comprised boulders and stones (see section 5.7) which prevented samples being obtained.

Mid-shore sites at the eastern end of the area comprise part of cluster group 5A, which appears to be part of a typical mid-shore mud-flat 'community' as described in Section 5.5.3. Site 3W.MS also conforms to this description. The two mid-shore sites at the western extremity linked with the reference site at S. Killingholme in the small cluster group 6. The group is characterised by a relatively high species variety and reasonably large numbers of individuals and may therefore be considered as representative of the benthos associated with mid-shore sites at more upstream locations. Those mid-shore sites closer to the outfall from which samples could be collected form part of cluster group 1, which from the characteristics summarised in Table 5.5.I seems to comprise a reasonably 'healthy' fauna. The site immediately upstream of the outfall does contain an unusually high number of opportunist polychaetes but this is probably related to the sediment characteristics, or to disturbance of the ground during installation of the new outfall pipe. Site 2W.MS was unclassified. It is biologically different from other sites by virtue of an unusually high proportion of enchytraeid oligochaetes. The significance of this taxon in terms of pollution in the estuarine environment is uncertain, but the species variety and faunal abundance at 2W.MS is marginally better than at the neighbouring (mud) site 3W.MS.

In general, the pattern shown by cluster analysis for mid-shore sites is a patchwork of different 'communities', none of which have any characteristics which can reasonably be attributed to an impact of the effluent. A similar pattern was demonstrated in 1984, when five different cluster groups were represented at mid-shore sites in the survey area, compared to three groups and one unclassified sampling point in 1989. Interpretation of such complex patterns is not easy but the 1984 results were considered not to indicate any impact of the effluent at the mid-shore level. Four sites have clustered in noticeably different ways in 1989. In 1984 3E.MS was associated with all other mid-shore sites to the east of this location, and 6W.MS also belonged to this group of sites. Sites 3W.MS and 5W.MS formed a small group of their own. The changes at these sites are summarised in Table 5.5.2.II, 6W.MS and 3W.MS possess similar characteristics in both years regardless of their clustering. Site 3E.MS does demonstrate an apparent improvement in conditions but its grouping with so many other sites deemed unaffected in 1984 suggests that it was not incorrectly designated and the 'improvement' is therefore not connected with the closure of the SCM outfall. The improvement at 5W.MS however, may suggest that although it was recognised as an anomalous site in 1984, it was in fact also subject to some influence of the effluent. Whilst it is of some concern that one or possibly more sites were not correctly identified as 'affected' in 1989, this can not alter the general conclusion that there is no obvious residual impact at mid-shore sites subsequent to closure of the old outfall. Because none of these sites were considered to be affected in 1984, changes in 1989 can not be viewed as an improvement but if the 1984 pattern was misinterpreted it can be reasonably assumed that no persistent evidence of impact exists in 1989, (i.e. even if there was an unrecognised effect, it no longer exists).

The association of low shore sites shown in Figure 5.5.2.1 is also somewhat patchy, and three sites were unclassified by the cluster analysis. One of these sites (1W) is immediately adjacent to the outfall and the samples here yielded only a single specimen indicating that conditions were extremely unfavourable. The other two unclassified sites (4W and 6W, LS) are also particularly low in abundance and restricted in species variety (Figures 5.5.2.2 & 3) although neither site is appreciably different in these respects to sites in cluster Group 3, which comprises the majority of low shore sites. Cluster Group 3 is typically impoverished with an average of 4.7 species and only 35 individuals per site. The association of an extensive area of impoverished fauna with the location of the outfall is clearly evident from Figures 5.5.2.2 & 3. Similar observations in 1984 were ascribed to the impact of the effluent. In retrospect this may have been a somewhat harsh judgement, especially at more peripheral sites which are closer to other discharges. However, the persistence of a broadly similar pattern in 1989, in particular at those sites close to the old outfall suggests that distinct evidence of an impact still remains, and no recovery has taken place. The exceptions to this are the two low shore sites at 2E and 4E (cluster Group 1). As can be seen from Figures 5.5.2.2 & 3, both sites exhibit a relatively high species richness and abundance, inconsistent with continued impact, and indicating a recovery of the benthos. It may be significant that the only other low shore site in this cluster group was at a comparable distance to the west of the old Tioxide outfall, where a complete recovery of the benthos is inferred. In general, the patterns revealed by cluster analysis suggests that a substantial area of impact remains around the old outfall with only two patches of the low shore showing a recovery to the east of the discharge.

Details of the changes at sites deemed affected in 1984 are summarised in Table 5.5.2.III. The two sites identified above as exhibiting distinct evidence of recovery stand out clearly in terms of increased species variety and a dramatic increase in abundance compared to 1984. All other sites show much the same basic characteristics in both surveys, although the two remote sites to the west of the outfall both yielded a slightly increased number of species in 1989. This change is considered too small to be of any significance, as is the slight but consistent reduction in number of individuals. The pronounced decline in abundance at 4W.LS is surprising, since the proximity of this site to a sewage discharge would normally encourage large populations of those species which thrive on organic enrichment. There is no obvious explanation for the change observed at this site but it seems unlikely that it is associated with either the old or the new SCM outfall.

In conclusion, only two intertidal sites can be clearly said to demonstrate an improvement in conditions around the old SCM discharge. Much of the lower shore level retains the appearance of a substantial impact of the effluent, although the complicating influences of other discharges may be of significance. There is also a possibility that the steeply shelving nature of the intertidal area at sites closest to the outfall is associated with appreciable physical instability of low-shore muddy habitats and that this hostility of the physical environment is a limiting factor in re-colonisation and the resultant impression of recovery.

5.5.3 Old Tioxide Outfall (Intertidal).

The patterns revealed by cluster analysis are shown in Figure 5.5.3.1. As in 1984 all the mid-shore sites clustered together, although in 1989 the peripheral sites belong to a different sub-group. Apart from this minor change the association of sites is almost identical with that observed in 1984, when the mid-shore was deemed to be unaffected by the effluent. This consistency of pattern would strongly suggest that the 1984 interpretation was correct and consequently no change in the grouping of mid-shore stations would have been expected.

Most of the low shore stations also comprise a single group (4) unlike the pattern reported for 1984, when all but one of the sites to the west of the outfall formed a separate cluster group, and were considered to show some effect of the effluent. The greater uniformity of low shore sites in 1989, as illustrated also in the sub-tidal environment, indicates that the impact of the effluent is no longer evident. However, in 1984 sites to the east of the outfall were believed to exhibit a residual impact of the old Pyewipe sewage discharge which had closed in 1983 and subsequent changes resulting from this may have also contributed to the impression of greater homogeneity of the low shore fauna. Even so, the association in 1989 of sites previously considered affected with those previously deemed unaffected must constitute evidence of an improvement in conditions. Sites closer to the outfall on the western side where any residual impact may be expected to be most apparent do not conform to the general pattern of uniformity, and therefore merit closer scrutiny. The two sites closest to the outfall are unlike most others. They are relatively rich in species variety (Figure 5.5.3.2) but of moderate to low abundance (Figure 5.5.3.3). The dominant species is the spionid polychate Pygospio, which, as discussed with reference to sub-tidal sites, is often considered to be an opportunist coloniser. These sites may therefore be showing the classic signs of preliminary recovery, although increased species variety was recorded at both sites in comparison to 1984 and the number of species present in 1989 was higher than at most other sites, which would suggest a more advanced stage of recovery. It may also be noted that site T.1W.LS was not recognised as being affected in 1984. Site T.3W.LS forms part of cluster group 1, which as already observed is characterised by relatively high species variety and abundance (Table 5.5.I.). The principal dominant within this group is Polydora spp the spionid which is so widespread and abundant at the nearby sub-tidal sites. Once again, the same remarks could be made with respect to opportunist colonisation, but in comparison to 1984 the site shows a three-fold increase in species richness suggesting a much more complete recovery of the fauna. Whilst failing to cluster with other sites in the old Tioxide discharge area, all three sites belong to cluster groups with relatively high species variety and moderate to high abundances.

The overall pattern suggests a much greater degree of uniformity within the old discharge area than was apparent in 1984, and the inconsistencies are essentially the result of a few (3) species-rich sites, rather than any areas of impoverishment of the fauna. It may therefore be suggested that the intertidal fauna in the receiving area demonstrates a recovery by virtue of the absence of any discernible area of impact, in contrast to the 1984 findings. As with the sub-tidal benthos a summary of changes at sites previously deemed impacted is presented in Table 5.5.3.I. Changes at site T.1W.LS. are also included in view of the change in faunal associations in this area and the average change at sites to the east of the outfall (previously deemed unaffected) are also presented for comparison.

Site T.1W.LS. shows an increase in both species variety and faunal abundance and yielded the highest species count for any intertidal site upstream of the outfall in either survey. It therefore seems unlikely that the changes at this site indicated by cluster analysis can be related to any residual damage from the effluent even if the 1984 data was somehow misinterpreted. Four of the five sites considered to be affected in 1984 also show a clear improvement in species richness . Only the C.P. site exhibits a decline in species compared to 1984. In view of the improvement at sites closer to the old outfall, the persistence of any residual impact at this distance from the discharge point seems most unlikely. On average the area shows an improvement of 2.2 species per site compared to 1984 results, so that the average species richness is now identical to the value for the eastern side of the outfall which was not considered to be affected in 1984. The equivalent decrease in species richness at sites to the east of the outfall which clearly contributes to the parity observed in 1989 can not be readily explained. (It does however serve to emphasise the point made in Appendix 4 that changes in areas deemed affected must be set in the context of changes elsewhere, since even a very small increase in species richness at affected sites would have constituted a significant improvement if the trend at unaffected sites was for a reduction in species).

In terms of total numbers of individuals per site, four of the five 'affected' sites showed a decrease. The average decrease is about 20%, which is well within the range of natural fluctuations. This decrease is however almost insignificant in comparison to the substantial (85%) decrease at 'unaffected' sites east of the old discharge point. The high numbers recorded at these sites in 1984 were attributed to nutrient enrichment from the then recently closed Pyewipe outfall, which discharged comminuted sewage on to the mud-flat in this area. Thus the decline in numbers to the east of the Tioxide discharge was largely predicted, and is almost certainly not associated with the latter outfall. It may therefore be concluded that changes on the western side of the Tioxide outfall demonstrate a recovery of the fauna following termination of the discharge, whilst changes to the east of the outfall relate to the cessation of sewage discharge in this area.

In the absence of suitable reference data the changes in numbers of species and individuals recorded from these low-shore sites can not be completely assessed, but compared to 1984 there is strong evidence of an improvement at sites previously deemed affected. Furthermore, the pattern revealed by cluster analysis suggests that no perturbations in the intertidal benthos remain, as a consequence of either discharge, and that recovery of the fauna is therefore substantially complete.

5.6 Comparison of Results for the Two Discharge Areas.

Assessment of conditions around the old Tioxide outfall and of changes following termination of the discharge are relatively straightforward because of the comparatively uniform nature of the receiving area, and the removal of the new outfall to a remote location. It is also considered that the old outfall was responsible for a 'severe' effect on the benthos on the receiving area, and consequently any improvements in conditions may be quite readily detected in view of the appreciable scope for recovery. In contrast, the old SCM outfall discharged into an area where the sea-bed is clearly not uniform in its physical characteristics and where other outfalls and man-made structures result in a somewhat complex background against which changes must be assessed. The relocation of the discharge to the off-shore edge of the survey area utilised to examine the impact of the old outfall is a particularly onerous complication. Furthermore, the discharge from the old outfall appeared to exhibit only a moderate or weak effect on the benthos throughout the majority of the receiving area. Consequently, the improvements which may be anticipated following abatement of the discharge are likely to be relatively small and difficult to detect. It is also pertinent to note that changes around both outfalls are assessed within one year of termination of the discharges, but complete recovery of the benthos may require several years.

It is clear from Sections 5.4.3 & 5.5.3 that there is no longer any pattern in the benthos around the old Tioxide outfall, which could be construed as indicating a residual impact of the effluent. Comparison with the pattern observed in 1984 suggests that a substantial, if not complete recovery has taken place. The improvement in conditions as demonstrated by considerable increases in species richness and faunal abundance at individual sites or groups of sites previously deemed affected, endorses the assessment of a complete recovery.

The results for the old SCM discharge area (Sections 5.4.2 and 5.5.2) show that the patterns recognised in both the sub-tidal and inter-tidal benthos still appear to have at least a superficial association with the location of the old outfall. The circumstantial evidence of a link between the old discharge point and areas of impoverished fauna suggests that some residual effect of the effluent still exists. Similarities with the pattern identified in 1984 also indicate the presence of a residual impact, although the influence of sediment type on ecological patterns almost certainly contributes to this apparent lack of change. Examination of changes in species richness and faunal abundance at individual sites and groups of sites (according to their designation in 1984) suggests only a relatively small overall improvement in conditions. Consideration of these changes in conjunction with changes in pattern indicates that recovery is patchy, with some sites showing a distinct improvement whilst others are broadly similar in basic composition. A few sites appear to demonstrate a deterioration in conditions and most low shore (inter-tidal) sites remain clearly impoverished.

The reasons for the incomplete recovery around the SCM outfall compared to the much more obvious and apparently total recovery of the Tioxide discharge area are not immediately apparent. The SCM discharge is situated further upstream where prevailing salinity is slightly lower, and the hydrographic conditions at Immingham are appreciably different from those on the Burcom shoal and Pyewipe mudflats. Greater sediment mobility at low shore sites around SCM where the bank shelves quite steeply may account for the apparent lack of recovery at some inter-tidal sites, although two sites do show signs of a quite pronounced improvement. The possibility that this physical 'stress' was previously mistaken for an effect of the effluent can not be discounted, and consequently no improvement could be expected as a result of the relocation of the discharge. Similar arguments could be proposed for the limited recovery of the sub-tidal fauna, and the designation of sub-tidal sites as only moderately or weakly affected also restricts the likely scope for improvement compared to the Tioxide discharge area, as considered above. However, two sites in the area of moderate effect identified in 1984, do show a very distinct improvement in both species variety and faunal abundance (Table 5.4.2.III). The magnitude of these changes is not quite as large as that observed at sub-tidal sites around the Tioxide outfall (Table 5.4.3.II) particularly with respect to abundance but the fact that some of these SCM sites show appreciable increases suggests that all sites should be able to do so. Even allowing for sampling error and natural variability, there are clear indications that recovery at the majority of sites is being suppressed by mechanisms other than those already considered. The persistence of contaminants or iron floc blanketing on the sea bed could be invoked as an explanation but such factors would be likely to apply equally to the Tioxide discharge area. The only other obvious factor which does not apply to the Tioxide situation is the proximity of the new discharge. Whilst it is not possible to offer any explanation as to how the new SCM discharge may be affecting the old receiving area, this is the only possible cause of the differences in recovery which can be identified in the light of current knowledge.

5.7 Rocky Shore Survey.

The results of this survey are shown in Table 5.1.IV, which also includes the numbers of species recorded in the 1984 survey. Whilst not recognised as a rocky shore species, the "mud-snail" Hydrobia is included in the results for consistency with the 1984 data and because specimens were actually found browsing on algae on the rock surfaces.

The overall pattern still suggests some depletion of species variety within the survey area, although abundances, especially for barnacles and shore crabs are comparable with or exceed those recorded at the control site, which represents an appreciable improvement in comparison to the 1984 situation.

Species variety shows an increase at the control site, which was largely anticipated in the 1984 report. If the control site is used as a 'bench-mark' the increased species variety at most sites between the two old outfalls can only be said to represent the preliminary stages of recovery. However, the increases in variety to the east of the old Tioxide outfall and to the west of the old SCM pipeline (especially evident at L.2W) indicate a substantial recovery of the biota. The less apparent recovery at sites between the two old outfalls may reflect the fact that this was obviously an area where both discharges had an overlapping effect as discussed in the 1984 report.

Although the results are essentially qualitative, there have been evident increases in abundance of those species present (especially barnacles) particularly at sites between the two old outfalls. Such observations are entirely consistent with the preliminary stages of environmental recovery.

5.8 References.

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Table 5.1.1 SCM Old Outfall, July 1989 - Biological Results

SITE	4W	4W	4W	3W	3W	3W	3W	3W	2W	2W	2W	1W	1W	1E	1E	1E	2E	2E	2E	3E	3E	3E	3E	3E	4E	4E	4E	C.24	C.29	N.33
SPECIES	300	100	0	300	200	100	50	0	300	100	0	100	0	300	100	0	300	100	0	300	200	100	50	0	300	100	0			
Nephtys hombergii	1	20				1	16	35		14	9		6			4	2		25		8			33	2		23	51	4	28
Nephtys sp juv			11	1		21	5	11	1		17		3		2			9	7		13		4		2	1	1	37	22	21
Nereis pelagica											3	1																		
Nereis longissima	319	372	344	301	156	294			149	206	49	40	2	238	249		267	11	2	223	140			1	20	1			82	9
Nereis virens	21	23	30	14	30	16			16	39	4	7		4	34		8	15							1				1	1
Procerea cornuta	2	127	163	1	214	141			10	65	204	143		103	146		50	76	19	2	179	1	6	3	27	8	1	1		1
Autolytus edwardsii		1			6	20				1	10			1							1				1					6
Harmothoe impar		2	2		21				1		33				5		3				7	1			2					
Harmothoe marphysae										4																				
Etone longa	343	385	311	533	318	315	12	10	254	410	118	80	38	9	360	66	478	83	53	170	154	6	4	4	123	44	10	7	4	25
Anaitides mucosa	621	364	215	516	261	161		2	224	192	65	32	10	84	180	6	261	67	20	173	111	9	2	1	18	16	3	15	149	45
Eumida sanguinea	56	40	55	75	79	20			40	64	22				57		87	8	1	67	23				1					
Sphaerodoridium minuta					8		2		7	6							22	8		24					8	1			1	1
Polydora sp	56038	35800	27808	37375	35530	20138	2	9	13790	11585	6660	8596	567	13490	34000	1276	37820	7660	2150	24990	4647	252	27	80	924	254	16		79	161
Pygospio elegans	677	788	845	2262	1937	1482	160	277	821	780	452	408	825	1010	3119	751	2035	1141	1759	1179	255	115	26	498	315	339	1108	96	7	1323
Streblospio shrubsoli	1				8				6				1		1			1	1		13				54		2	1		41
Spiophanes bombyx							3												10								6	153	1	2
Spiophanes kroyeri																								6						
Spio martinensis														2														1		
Scololepis squamata												1											1							
Aricidea minuta			9															7			77				346			13		28
Levensenia gracilis																												13		
Tharyx marioni							2						1						1		23			7	1		1	252	134	1152
Ampharete baltica	8						1																					2	3	11
Amphitrite johnstoni	19	113	20	77	185	1			25	31	42			13	59		96		2	96	61				2					
Capitella capitata			17		1	18				2		2				4							3		7	8		6	1	
Capitomastus minimus						20									38															
Mediomastus fragilis																									2			3		[illegible]
Scoloplos armiger										4					1	6					9			1	4			135	26	10
Arenicola marina	155	273	56	328	311	15		1	59	193	8	23		252	131	6	489	8	1	318	48	2				17				1
Tubificoides benedeni	7	10	14	8	1	10	120	103	6	2	84		23	13	3	46	1	1	66		44	1	5	20	131	1	44	1		16
Tubificoides swirencoides			1				551	39		5	117	1	21		1	17			264		19		1	580	55		3594	250	2	164
Tubificoides pseudogaster											8														16					1
Clitellio arenarius	33										11																			
Enchytraidae sp	87			42					1			1		2	19	6	139		9	97										
Golfingia sp																									7					
Atylus swammerdami																													1	[illegible]
Nemertea sp											2							1		1	10		1		2					1
Gammarus zaddachi																							2							
Corophium volutator		7																												
Callopidae sp																							1							
Cyathura carinata		37		9	31				15	3							9			11										
Gnathia sp																														
Heterocysis formosa																							2							
Leptomysis sp																									2	1				
Neomysis integer																											1			
Halcaridae sp	99	49			46									2							21		1		2					
Pychnogonidae sp			2		8					1	1	3		3	19				1											
Anoplodactylus sp														1	1				1									1		13
Abra alba																												13		
Macoma baltica							1	2								2								2			3	12	4	1
Mya arenaria	1	9								11				10	19														4	2
Mytilidae sp																												1	2	2
Retusa sp																												3		
Cerastoderma edule			8			20	3	2				2												1			2	1	27	1
Nudibranch indet																					7									
Number of species	18	18	18	14	19	16	12	10	17	21	20	15	10	17	21	11	16	15	18	13	21	8	15	14	26	12	14	23	19	29
Number of individuals	[illegible]	[illegible]	29911	[illegible]	39151	[illegible]	878	[illegible]	15438	13617	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 5.1.11. Biological results - Tioxide Old Outfall (subtidal July 1989)

Species		CONTROL C-24	C-29	C-N33	1E 0	1E 100	1E 300	2E 0	2E 100	2E 300	3E 0	3E 50	3E 100	3E 200	3E 300	4E 0	4E 100	4E 300
ud Nemertean A		-	-	1	-	-	-	-	4	-	-	-	-	-	-	-	-	4
Gattyana	cirrosa	-	-	-	-	5	-	-	48	-	-	-	-	-	-	-	-	8
Pholoe	inornata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anaitides	maculata/mucosa	15	149	45	61	68	557	25	302	236	130	80	4	76	136	-	47	48
Eumida	sanguinea	-	-	-	-	5	84	-	56	8	12	2	-	-	11	-	2	-
Eteone	longa	7	4	25	76	40	598	46	280	168	66	23	4	16	60	1	23	60
Autolytus	langerhansi	-	-	6	4	46	-	12	36	20	36	40	1	8	5	6	14	52
Proceraea spp.		1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nereis	diversicolor	-	-	-	-	5	16	-	-	12	4	1	-	16	1	-	5	8
Nereis	virens	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nereis	longissima	-	82	9	6	75	759	-	153	677	223	9	-	-	63	-	73	28
Nephtys	hombergii	51	4	28	15	34	8	48	24	-	48	55	30	20	4	67	10	4
ud Nephtys juv.		37	22	21	19	24	55	46	61	12	32	30	7	4	33	14	18	12
Sphaerodoropsis	minuta	-	1	1	2	1	8	2	60	20	4	1	-	-	7	-	4	4
Scoloplos	armiger	135	26	10	21	41	32	39	120	12	8	1	8	8	4	-	1	76
Aricidea	minuta	13	-	28	-	2	8	28	28	-	4	13	26	12	21	13	-	52
Levinsenia	gracilis	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spiophanes	bombyx	153	1	2	10	2	4	36	4	8	-	4	5	-	-	-	-	4
Spio	martinensis	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pygospio	elegans	96	7	1323	3220	1301	4337	4487	4055	4895	2768	3032	552	907	1166	12	1381	1628
Polydora	ligni	-	79	161	376	1403	22336	7	11076	11021	10879	409	5	309	7140	4	2251	633
Streblospio	shrubsolii	1	-	41	3	-	4	6	4	8	36	30	3	-	-	2	15	-
Tharyx	marioni	252	134	1152	159	400	4	430	9152	68	634	119	175	6924	1146	1444	65	3436
Capitella	capitata	6	1	-	-	-	12	1	57	8	4	-	-	4	-	-	-	12
Mediomastus	fragilis	3	-	9	-	-	-	-	752	12	-	2	1	176	90	-	-	108
Arenicola	marina	-	-	1	-	41	16	1	212	8	12	-	-	-	26	-	1	4
Pectinaria	koreni	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ampharete	acutifrons	2	3	11	6	5	1	4	17	8	4	3	-	4	5	-	2	12
Neoamphitrite	figulus	-	-	-	-	49	4	-	66	4	4	-	-	-	-	-	-	-
Manayunkia	aesturina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tubificoides	pseudogaster	230	2	164	-	-	-	-	-	-	-	-	-	108	-	-	-	32
Tubificoides	benedeni	1	-	16	16	17	16	87	8	4	28	54	7	16	5	8	6	16
Tubificoides	swirencoides	-	-	1	64	908	17	4162	345	60	998	2701	884	5	23	2242	1227	16
Atylus	swammerdami	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dyopedos	monacanthus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mesopodopsis	slabberi	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Neomysis	integer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crangon	crangon	-	-	-	1	-	-	-	-	4	-	-	-	4	1	1	2	-
Corystes	cassivelaunus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carcinus	maenas	-	-	-	-	-	12	-	5	-	4	3	-	-	-	-	2	-
Anoplodactylus	pygmaeus	1	-	13	-	-	-	4	-	8	-	38	-	-	17	-	11	4
Retusa sp.		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nucula sp.		1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mytilus	edulis	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
ud Mytilidae spat		1	2	2	1	-	-	-	-	-	-	1	2	-	5	-	-	-
Cerastoderma	edule	1	27	1	8	2	28	18	-	-	-	-	2	-	4	1	-	-
Petricola	pholadiformis	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Abra	alba	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Macoma	balthica	12	4	1	-	-	-	8	-	-	4	1	2	2	1	1	-	-
Ensis	ensis	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mya	sp.	-	4	2	-	-	16	-	-	24	-	4	-	-	8	-	-	8
TOTAL IND		1049	556	3082	4068	4476	28932	9497	26927	17307	15942	6656	1718	8619	9982	3816	5160	6269
TOTAL SPP		24	21	31	18	22	23	20	24	23	22	24	17	18	24	13	20	24

Abundance as number / 0.3 sq m

Table 5.1.II. Continued.

Species		CONTROL C-24	C-29	C-N33	1W 0	1W 100	1W 300	2W 0	2W 100	2W 300	3W 0	3W 50	3W 100	3W 200	3W 300	4W 0	4W 100	4W 300
ud Nemertean A		-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gattyana	cirrosa	-	-	-	-	-	28	-	-	12	4	-	-	-	-	-	-	-
Pholoe	inornata	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-
Anaitides	maculata/mucosa	15	149	45	1	93	572	65	-	120	149	6	123	213	2	-	6	2
Eumida	sanguinea	-	-	-	-	8	32	4	-	28	24	-	8	36	-	-	-	-
Eteone	longa	7	4	25	6	62	308	152	3	198	124	3	105	232	7	1	1	4
Autolytus	langerhansi	-	-	6	-	44	-	-	-	-	6	-	4	8	-	-	-	-
Proceraea spp.		1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nereis	diversicolor	-	-	-	-	12	20	4	-	8	12	-	-	8	-	-	-	-
Nereis	virens	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nereis	longissima	-	82	9	-	112	460	13	-	301	73	1	118	348	-	13	-	-
Nephtys	hombergii	51	4	28	25	14	28	35	29	16	76	50	36	8	60	34	57	29
ud Nephtys juv.		37	22	21	58	57	48	38	26	20	39	17	84	16	34	43	22	17
Sphaerodoropsis	minuta	-	1	1	1	-	40	4	-	-	17	-	8	8	-	3	-	-
Scoloplos	armiger	135	26	10	39	136	12	18	-	12	16	-	1	4	-	-	1	-
Aricidea	minuta	13	-	28	1	-	8	-	-	1	1	2	4	-	15	-	10	2
Levinsenia	gracilis	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spiophanes	bombyx	153	1	2	29	5	8	16	1	5	3	-	-	8	5	2	-	-
Spio	martinensis	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pygospio	elegans	96	7	1323	497	3377	2464	2366	12	2641	5996	140	3639	7192	132	46	124	13
Polydora	ligni	-	79	161	-	1075	15360	8227	-	11860	10188	596	17715	22446	18	6	94	3
Streblospio	shrubsolii	1	-	41	-	1	4	-	-	-	-	1	-	-	-	-	-	-
Tharyx	marioni	252	134	1152	1249	1169	280	1579	594	598	415	104	76	100	98	281	236	53
Capitella	capitata	6	1	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-
Mediomastus	fragilis	3	-	9	-	-	4	-	-	-	1	-	-	8	-	-	-	-
Arenicola	marina	-	-	1	-	26	140	-	-	-	8	-	-	36	-	-	-	-
Pectinaria	koreni	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ampharete	acutifrons	2	3	11	-	-	1	1	-	4	1	-	-	12	-	-	-	-
Neoamphitrite	figulus	-	-	-	-	12	24	-	-	4	8	-	-	4	-	-	-	-
Manayunkia	aesturina	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
Tubificoides	pseudogaster	230	2	164	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tubificoides	benedeni	1	-	16	97	18	4	277	4	6	24	5	24	-	1	22	6	7
Tubificoides	swirencoides	-	-	1	381	498	12	171	469	298	1565	1754	1177	196	1762	639	1223	1005
Atylus	swammerdami	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dyopedos	monacanthus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mesopodopsis	slabberi	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Neomysis	integer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Crangon	crangon	-	-	-	-	-	-	4	-	-	-	1	8	-	-	-	1	-
Corystes	cassivelaunus	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-
Carcinus	maenas	-	-	-	-	-	4	4	-	-	1	-	8	8	-	-	-	-
Anoplodactylus	pygmaeus	1	-	13	-	4	-	-	-	-	-	-	4	-	-	-	-	-
Retusa sp.		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nucula sp.		1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mytilus	edulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ud Mytilidae spat		1	2	2	-	-	-	-	-	-	4	-	4	-	-	-	-	-
Cerastoderma	edule	1	27	1	7	11	4	4	-	4	19	-	16	8	6	5	2	-
Petricola	pholadiformis	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Abra	alba	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Macoma	balthica	12	4	1	6	2	4	4	1	-	10	3	4	-	3	4	1	1
Ensis	ensis	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mya	sp.	-	4	2	-	-	16	4	-	8	20	-	12	24	-	-	-	-
TOTAL IND		1049	556	3082	2397	6736	19897	12990	1139	16144	18804	2683	23176	30927	2157	1100	1765	1136
TOTAL SPP		24	21	31	13	20	27	20	8	19	26	13	21	22	13	13	14	10

Abundance as number / 0.3 sq m

Table 5.1.II. Biological results - Tioxide Old Outfall (subtidal July 1989)

Species		CONTROL C-24	C-29	C-N33	1E 0	1E 100	1E 300	2E 0	2E 100	2E 300	3E 0	3E 50	3E 100	3E 200	3E 300	4E 0	4E 100	4E 300
ud Nemertean A		-	-	1	-	-	-	-	4	-	-	-	-	-	-	-	-	4
Gattyana	cirrosa	-	-	-	-	5	-	-	48	-	-	-	-	-	-	-	-	8
Pholoe	inornata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anaitides	maculata/mucosa	15	149	45	61	68	557	25	302	238	130	80	4	76	136	-	47	48
Eumida	sanguinea	-	-	-	-	5	84	-	56	8	12	2	-	-	11	-	2	-
Eteone	longa	7	4	25	76	40	598	46	280	168	66	23	4	16	60	1	23	60
Autolytus	langerhansi	-	-	6	4	46	-	12	36	20	36	40	1	8	5	6	14	52
Proceraea spp.		1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nereis	diversicolor	-	-	-	-	5	16	-	-	12	4	1	-	16	1	-	5	8
Nereis	virens	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nereis	longissima	-	82	9	6	75	759	-	153	677	223	9	-	-	63	-	73	28
Nephtys	hombergii	51	4	28	15	34	8	48	24	-	48	55	30	20	4	67	10	4
ud Nephtys juv.		37	22	21	19	24	55	46	61	12	32	30	7	4	33	14	18	12
Sphaerodoropsis	minuta	-	1	1	2	1	8	2	60	20	4	1	-	-	7	-	4	4
Scoloplos	armiger	135	26	10	21	41	32	39	120	12	8	1	8	8	4	-	1	76
Aricidea	minuta	13	-	28	-	2	8	28	28	-	4	13	26	12	21	13	-	52
Levinsenia	gracilis	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spiophanes	bombyx	153	1	2	10	2	4	36	4	8	-	4	5	-	-	-	-	4
Spio	martinensis	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pygospio	elegans	96	7	1323	3220	1301	4337	4487	4055	4895	2768	3032	552	907	1166	12	1381	1628
Polydora	ligni	-	79	161	376	1403	22336	7	11078	11021	10879	409	5	309	7140	4	2251	633
Streblospio	shrubsolii	1	-	41	3	-	4	6	4	8	36	30	3	-	-	2	15	-
Tharyx	marioni	252	134	1152	159	408	4	430	9152	68	634	119	175	6924	1146	1444	65	3436
Capitella	capitata	6	1	-	-	-	12	1	57	8	4	-	-	4	-	-	-	12
Mediomastus	fragilis	3	-	9	-	-	-	-	752	12	-	2	1	176	90	-	-	108
Arenicola	marina	-	-	1	-	41	16	1	212	8	12	-	-	-	26	-	1	4
Pectinaria	koreni	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ampharete	acutifrons	2	3	11	6	5	1	4	17	8	4	3	-	4	5	-	2	12
Neoamphitrite	figulus	-	-	-	-	49	4	-	66	4	4	-	-	-	-	-	-	-
Manayunkia	aesturina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tubificoides	pseudogaster	230	2	164	-	-	-	-	-	-	-	-	-	108	-	-	-	32
Tubificoides	benedeni	1	-	16	16	17	16	67	8	4	28	54	7	16	5	8	6	16
Tubificoides	amirencoides	-	-	1	64	908	17	4162	345	60	998	2701	884	5	23	2242	1227	16
Atylus	swammerdami	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dyopedos	monacanthus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mesopodopsis	slabberi	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Neomysis	integer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crangon	crangon	-	-	-	1	-	-	-	-	4	-	-	-	4	1	1	2	-
Corystes	cassivelaunus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carcinus	maenas	-	-	-	-	-	12	-	5	-	4	3	-	-	-	-	2	-
Anoplodactylus	pygmaeus	1	-	13	-	-	-	4	-	8	-	38	-	-	17	-	11	4
Retusa sp.		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nucula sp.		1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mytilus	edulis	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
ud Mytilidae spat		1	2	2	1	-	-	-	-	-	-	1	2	-	5	-	-	-
Cerastoderma	edule	1	27	1	8	2	28	18	-	-	-	-	2	-	4	1	-	-
Petricola	pholadiformis	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Abra	alba	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Macoma	balthica	12	4	1	-	-	-	8	-	-	4	1	2	2	1	1	-	-
Ensis	ensis	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mya	sp.	-	4	2	-	-	16	-	-	24	-	4	-	-	8	-	-	8
TOTAL IND		1049	556	3082	4068	4476	28932	9497	26927	17307	15942	6656	1718	8619	9982	3816	5160	6269
TOTAL SPP		24	21	31	18	22	23	20	24	23	22	24	17	18	24	13	20	24

Abundance as number / 0.3 sq m

Table 5.1.II. Continued.

Species		CONTROL C-24	C-29	C-N33	1W 0	1W 100	1W 300	2W 0	2W 100	2W 300	3W 0	3W 50	3W 100	3W 200	3W 300	4W 0	4W 100	4W 300
ud Nemertean A		-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gattyana	cirrosa	-	-	-	-	-	26	-	-	12	4	-	-	-	-	-	-	-
Pholoe	inornata	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-
Anaitides	maculata/mucosa	15	149	45	1	93	572	65	-	120	149	6	123	213	2	-	6	2
Eumida	sanguinea	-	-	-	-	6	32	4	-	28	24	-	8	36	-	-	-	-
Eteone	longa	7	4	25	6	62	308	152	3	198	124	3	105	232	7	1	1	4
Autolytus	langerhansi	-	-	6	-	44	-	-	-	-	6	-	4	8	-	-	-	-
Proceraea spp.		1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nereis	diversicolor	-	-	-	-	12	20	4	-	8	12	-	-	8	-	-	-	-
Nereis	virens	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nereis	longissima	-	82	9	-	112	460	13	-	301	73	1	118	348	-	13	-	-
Nephtys	hombergii	51	4	28	25	14	28	35	29	16	76	50	36	8	80	34	57	29
ud Nephtys juv.		37	22	21	58	57	48	38	26	20	39	17	84	16	34	43	22	17
Sphaerodoropsis	minuta	-	1	1	1	-	40	4	-	-	17	-	8	8	-	3	-	-
Scoloplos	armiger	135	26	10	39	136	12	16	-	12	16	-	1	4	-	-	1	-
Aricidea	minuta	13	-	28	1	-	8	-	-	1	1	2	4	-	15	-	10	2
Levinsenia	gracilis	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spiophanes	bombyx	153	1	2	29	5	8	16	1	5	3	-	-	8	5	2	-	-
Spio	martinensis	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pygospio	elegans	96	7	1323	497	3377	2464	2366	12	2641	5996	140	3639	7192	132	46	124	13
Polydora	ligni	-	79	161	-	1075	15360	8227	-	11860	10188	596	17715	22446	18	6	94	3
Streblospio	shrubsolii	1	-	41	-	1	4	-	-	-	-	1	-	-	-	-	-	-
Tharyx	marioni	252	134	1152	1249	1169	280	1579	594	598	415	104	76	100	90	281	236	53
Capitella	capitata	6	1	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-
Mediomastus	fragilis	3	-	9	-	-	4	-	-	-	1	-	-	8	-	-	-	-
Arenicola	marina	-	-	1	-	26	140	-	-	-	8	-	-	36	-	-	-	-
Pectinaria	koreni	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ampharete	acutifrons	2	3	11	-	-	1	1	-	4	1	-	-	12	-	-	-	-
Neoamphitrite	figulus	-	-	-	-	12	24	-	-	4	8	-	-	4	-	-	-	-
Manayunkia	aesturina	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
Tubificoides	pseudogaster	230	2	164	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tubificoides	benedeni	1	-	16	97	18	4	277	4	6	24	5	24	-	1	22	6	7
Tubificoides	swirencoides	-	-	1	381	498	12	171	469	298	1565	1754	1177	196	1762	639	1223	1005
Atylus	swammerdami	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dyopedos	monacanthus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mesopodopsis	slabberi	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Neomysis	integer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Crangon	crangon	-	-	-	-	-	-	4	-	-	-	1	8	-	-	-	1	-
Corystes	cassivelaunus	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-
Carcinus	maenas	-	-	-	-	-	4	4	-	-	1	-	8	8	-	-	-	-
Anoplodactylus	pygmaeus	1	-	13	-	4	-	-	-	-	-	-	4	-	-	-	-	-
Retusa sp.		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nucula sp.		1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mytilus	edulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ud Mytilidae spat		1	2	2	-	-	-	-	-	-	4	-	4	-	-	-	-	-
Cerastoderma	edule	1	27	1	7	11	4	4	-	4	19	-	16	8	6	5	2	-
Petricola	pholadiformis	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Abra	alba	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Macoma	balthica	12	4	1	6	2	4	4	1	-	10	3	4	-	3	4	1	1
Ensis	ensis	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mya	sp.	-	4	2	-	-	16	4	-	8	20	-	12	24	-	-	-	-
TOTAL IND		1049	556	3082	2397	6736	19897	12990	1139	16144	18804	2683	23178	30927	2157	1100	1765	1136
TOTAL SPP		24	21	31	13	20	27	20	8	19	26	13	21	22	13	13	14	10

Abundance as number / 0.3 sq m

TABLE 5.1.III Biological Results - Intertidal Surveys (Old Outfalls): 1989

SCM Outfall

SITE	6W	6W	5W	5W	4W	3W	3W	2W	2W	1W	1W	2E	3E	3E	4E	4E	5E	CP	CP	GY	GY	SK
SPECIES	LS	MS	LS	MS	LS	LS	MS	LS	MS	LS	MS	LS	LS	MS	LS	MS	LS	LS	MS	LS	MS	MS
HARMOTHOINAE spp. indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Eteone longa	2	77	1	40	0	0	25	1	0	0	47	14	1	156	6	11	0	0	13	0	6	17
Anaitides macul...	1	0	0	0	0	0	0	0	0	0	0	10	0	5	7	0	0	0	0	0	0	0
Sphaerodoridius ..uta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Autolytus spp. indet.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Nereis diversicolor	0	1	0	0	0	0	0	0	0	0	1	0	0	0	5	0	0	0	0	0	6	3
Nereis virens	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Nereis spp. juv.	0	1	0	0	0	0	1	0	1	0	0	1	0	0	2	0	0	0	0	0	0	0
Nephtys hombergi	3	2	1	0	1	1	6	1	1	0	0	1	1	1	0	8	1	15	8	7	11	1
Nephtys spp. juv.	0	0	3	1	1	4	3	2	0	0	0	0	2	1	0	14	3	2	10	4	1	0
SPIONIDAE sp. indet.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polydora ciliata	1	0	1	0	1	0	0	0	5	0	1194	710	0	136	195	0	0	0	0	0	0	0
Pygospio elegans	0	207	0	71	0	4	28	2	56	1	2020	50	10	359	84	69	3	1	137	1	38	58
Tharyx sp. indet.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7	0
Capitella capitata	0	21	0	1	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	25
Arenicola marina	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paranais littoralis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	452
Tubificoides benedeni	0	1048	29	651	12	8	98	11	6	0	3	1	6	56	7	149	5	31	361	7	3	500
Tubificoides swirencoides	0	0	1	0	0	2	0	0	0	0	0	0	29	0	0	0	52	61	0	2	1	0
ENCHYTRAEIDAE sp.	0	0	0	5	0	0	0	0	140	0	36	0	0	5	0	0	0	0	0	0	0	0
Anoplodactylus pygmaeus	0	0	0	0	0	0	0	0	0	0	2	0	0	0	40	0	0	0	1	0	0	0
Bathyporeia pilosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Corophium volutator	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0
Hydrobia ulvae	0	1	0	1	0	0	1	0	3	0	0	0	0	1	0	0	0	0	2	0	2	0
Cerastoderma sp. juv.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macoma balthica	0	39	0	15	1	0	49	0	0	0	0	2	0	4	0	64	0	3	105	0	1	58
Mya spp. juv.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Total number of species	4	10	5	8	5	4	7	4	8	1	9	9	5	10	8	5	4	5	7	6	11	8
Total number of individuals	7	1401	36	785	17	19	211	17	214	1	3305	790	49	729	347	315	64	113	637	24	78	1114

Abundance per $0.03m^2$

[ABLE 5.1.III (continued)

⁻.ɔxide Outfall

SITE	5W	5W	4W	4W	3W	3W	2W	2W	1W	1W	1E	1E	2E	2E	3E	3E	4E	4E	5E	5E	CP	CP	6Y	6Y	SK
ECIES	LS	MS	LS	MS	LS	MS	LS	MS	LS	MS	LS	MS	LS	MS	LS	MS	LS	MS	LS	MS	LS	MS	LS	MS	MS
EMERTINI sp. indet.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
naitides maculata	0	0	2	0	10	0	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
teone longa	1	4	0	4	4	0	1	0	4	1	0	0	0	1	0	2	0	5	1	7	0	13	0	6	17
ereis diversicolor	0	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	0	2	0	1	0	0	0	6	3
ereis virens	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ereis spp. juv.	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
ephtys cirrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
ephtys hombergii	4	20	5	10	4	7	7	12	8	21	10	23	12	21	10	22	3	14	9	7	15	8	7	11	1
ephtys spp. juv.	6	15	4	9	0	3	1	6	2	10	6	16	9	16	4	16	5	5	0	7	2	10	4	1	0
phaerodoridium minutum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
RBINIINAE sp. indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
olydora spp	0	0	0	0	531	1	23	0	36	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0
ygospio elegans	5	304	5	97	84	101	44	30	311	110	20	125	55	109	5	60	24	113	20	19	1	137	1	38	58
aulleriella killariensis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
haryx sp. indet.	33	0	4	0	0	0	0	0	4	0	55	0	73	0	40	0	4	0	1	1	0	0	2	7	0
apitella capitata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	25
aranais littoralis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	452
ubificoides benedeni	43	348	36	475	40	442	12	544	14	182	8	275	11	308	38	241	242	590	25	269	31	361	7	3	500
ubificoides heterochaetus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ubificoides swirencoides	134	3	8	0	8	0	2	0	1	0	75	0	36	0	46	0	3	0	23	0	61	0	2	1	0
nchytraeidae sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
oplodactylus pygmaeus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
athyporeia pilosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
YSIDACEA spp. indet.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ydrobia ulvae	0	16	0	252	0	595	17	52	0	788	1	923	0	604	2	174	2	30	0	6	0	2	0	2	0
erastoderma sp. juv.	0	0	0	0	0	0	0	0	0	4	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0
acoma balthica	3	82	0	85	0	100	1	54	1	104	0	116	1	93	1	50	1	69	1	34	3	105	0	1	58
ya spp. juv.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
otal number of species	7	8	7	6	9	8	9	5	10	8	6	6	6	7	8	6	8	7	9	9	5	7	6	11	8
otal number of individuals	229	793	65	932	687	1251	109	698	388	1221	175	1482	197	1153	149	565	285	828	84	353	113	637	24	78	1114

Abundance per $0.03m^2$

TABLE 5.1.IV OBSERVATIONS ON ROCKY SHORE HABITATS IN THE SURVEY AREA

FLORA/FAUNA	CONTROL	6W	5W	4W	3W	2W	1W	1E	2E	3E	4E	5E	CP	5W	4W	3W	2W	1W	1E	2E	3E	4E	5E
Eliminius modestus	+	+	+	++	++	++	++	++	++	+++	+++	+++	++	++	+++	+	+(+)	++	++	+++	++	++	
Carcinus maenas	22	20	37	33	34	26	16	44	40	40	40	40	40	31	13	-	-	-	20	1	6	38	
Littorina saxatilis (rudis)	20																2	2	7	20	50	50	
L.littorea																				1		50	
[Hydrobia ulvae]															P				P	P	P		
Enteromorpha/ filamentous green algae	√	√√√	√√	√	√√	√√√	√√	√√	√+	√√	√√√	√√√	√√√	√√√	√√	√√	√√	√√√	√√√	√√	√√√	√√	
Ulva sp.														(√)	√				√	√	√	√	
Fucus vesiculosus	√√	√	(√)	√	√	√	√+	√+	√	√+		√	√									(√)	
Gammarus	45	1			3	1		1															
Ligia	4																						
Mytilus (juv.)																					1		
Sea Anemone													1										
No of species recorded 1984 result in parentheses	7(5)	5(4)	4(2)	4(-)	5(2)	5(1)	4(2)	5(2)	4(2)	4(2)	3(2)	4(2)	5(3)	4(2)	5(3)	3(2)	3(2)	3(2)	6(4)	7(6)	7(5)	7(-)	

Key:

+ - Few	++ - Reasonable numbers	+++ - Abundant
√ - Sparse	√√ - Moderate Cover	√√√ - Heavy Cover
P - Present	(√) - Denotes very low abundance	- - No rocks present

TABLE 5.4.2.I

Principal Characteristics of Sites and Cluster Groups - 1989

Old SCM Discharge Area (Sub-tidal)

Group/ Sub-Group P.s-Group	Site	N_S	N_I	N_S Average	N_I Average	Dominant(s) [Sub-dominant(s)]
1A	1W 100	15	9,340	15	9,218	Polydora sp. [Pygospio
	2E 100	15	9,096			Procerea; Eteone]
(1B)	1E 300			17	15,237	Polydora sp. [Pygospio]
1B	4W 0	18	29,911		26,297	Polydora [Pygospio
	3W 100	16	22,683	17		Eteone, Nereis; Anaitides]
1B'	4W 100	18	38,420			Polydora sp. [Pygospio
	3W 200	19	39,151		32,407	Eteone; Nereis; Arenicola]
	2W 100	21	13,613	19.75		
	1E 100	21	38,444			
1B''	4W 300	18	58,488			Polydora [Pygospio
	2W 300	17	15,428			Anaitides; Eteone; Nereis]
	3W 300	14	41,542	15.6	36,915	
	2E 300	16	41,767			
	3E 300	13	27,351			
2	2W 0	20	7,919	22.3		Polydora [Pygospio
	3E 200	21	5,870		5,288	Eteone; Tubificoides sp.]
	4E 300	26	2,075			
3	3E 50	15	86	12.3		Polydora; Pygospio
	3E 100	8	387		388	
	4E 100	14	691			
4	1W 0	10	1,497	13.0		Polydora; Pygospio [Eteone]
	1E 0	11	2,190		2,693	
	2E 0	18	4,392			
5	3E 0	14	1,237	13.5		T.swirencoides; Pygospio
	3W 0	10	491			[T. benedeni]
	3W 50	12	878		1,855	
	4E 0	14	4,815			

Key: N_S = Total number of species N_I = Total number of individuals

Unclassified (control) sites not included: See Table 5.4.3.1 for details of these sites

TABLE 5.4.2.II

Comparison of 1984 and 1989 Summary Results for 'Unaffected' Off-shore Sites

Old SCM Outfall (Sub-tidal)

A. Unaffected "100" Sites and "200" Sites

	No. of Species		No. of Individuals	
Site	1984	1989	1984	1989
1E 100	18	21	18,502	38,444
(2E 100)	16	15	3,745	9,096
4W 100	18	18	35,925	38,420
3W 200	16	19	31,458	39,151
3E 200	23	21	32,569	5,870
Average	18.2	18.8	24,440	26,196

B. "300" Sites

	No. of Species		No. of Individuals	
Site	1984	1989	1984	1989
4W 300	18	18	44,505	58,488
3W 300	15	14	27,219	41,542
2W 300	19	17	15,261	15,428
1E 300	19	17	30,981	15,237
2E 300	30	16	16,420	41,767
3E 300	18	13	33,729	27,351
4E 300	22	26	7,415	2,075
Average	20.1	17.3	25,076	28,841

TABLE 5.4.2.III Comparison of 1984 and 1989 Summary Results for Stations Grouped by Level of Effect (1984)

Old SCM Outfall (Sub-tidal)

1. Moderate Effect

Site	No. of Species		No. of Individuals	
	1984	1989	1984	1989
3W 50	11	12	3,719	878
2W 0	13	20	1,783	7,919
1W 0	15	10	861	1,497
1E 0	13	11	251	2,190
2E 0	11	18	659	4,392
3E 0	12	14	614	1,237
4E 0	13	14	2,250	4,815
Average	12.6	14.1	1,448	3,275

2. Weak/Peripheral Effect

Site	No. of Species		No. of Individuals	
	1984	1989	1984	1989
4W 0	15	18	5,731	29,11
3W 100	18	16	3,821	22,683
2W 100	14	21	12,420	13,613
1W 100	17	15	6,520	9,340
(2E 100)	16	15	3,745	9,096
3E 50	10	15	288	86
3E 100	16	8	3,030	387
4E 100	16	14	5,101	691
	15.4	15.3	5,082	8,174

Unaffected, but near discharge

	No. of Species		No. of Individuals	
	1984	1989	1984	1989
1E100	18	21	18,502	38,444

TABLE 5.4.3.I

Principal Characteristics of Sites and Cluster Groups, 1989

Old Tioxide Discharge Area (Subtidal)

Group/ Sub-group	Site	N_S	N_I	Average N_S	Average N_I	Dominant(s) and [Sub-dominants]
	N33	31	3,082			Pygospio elegans;
	3E50	22	6,652			Tubificoides swirencoides
1A	4E100	18	5,156	21.75	4,739	[Tharyx sp.; Polydora sp.]
	1E0	16	4,066			
	3W200	21	30,919			Polydora sp.; Pygospio
	2E300	22	17,303			elegans.
1B	1W300	26	19,893	22.75	24,259	[Nereis longissima; Eteone
	1E300	22	28,920			longa; Anaitides maculata]
	3W100	18	23,158			
	3W0	24	18,799			
	2W300	19	16,144			Polydora sp;
1C	2W0	16	12,982			Pygospio elegans
	3E0	21	15,938	20.25	13,526	[Tubificoides swirencoides;
	1W100	20	6,736			Tharyx sp]
	1E100	22	4,476			
	3E300	22	9,976			
	2E100	23	26,922			
	4E300	24	6,269			Pygospio elegans;
2	3E200	17	8,615	20.25	7,442	Tharyx sp.
U	C29	21	556			
U	C24	24	1,049			
	2E0	20	9,497			Pygospio elegans; Tharyx sp.
3	W0	13	2,397	16.5	5,947	Tubificoides swirencoides
	4W300	10	1,136			Tubificoides swirencoides;
	2W100	8	1,139			Tharyx sp.
4A	4E0	12	3,815	10.75	1,798	
	4W0	13	1,100			
	4W100	12	1,783			Tubificoides swirencoides
	3W50	12	2,682			[Pygospio elegans]
4B	3W300	13	2,157	13.25	2,085	
	3E100	16	1,716			

Key: N_S = Total number of species N_I = Total number of individuals

U = Unclassified

TABLE 5.4.3.II

Summary of Changes in Benthos at Sites Recognised as Impacted in 1984

Old Tioxide Outfall (Sub-tidal)

Site	No. of Species		No. of Individuals	
	1984	1989	1984	1989
1E 0	4	16	10	4066
1W 0	9	13	221	2397
2W 0	10	18	720	12982
1W 100	10	20	279	6736
3W 0	10	24	510	18799
1E 100	9	22	1474	4476
Average	8.7	18.8	536	8243
Control 24	28	24	2590	1049
Control 29	28	21	9923	556
Control N33	26	31	14898	3082

TABLE 5.5.I

Summary of Characteristics for Intertidal Cluster Groups

Group/ Sub Group	N_S Average	N_I Average	No. of Sites	Dominant(s)/ Sub-dominant(s)	Comments
1	9.0	1,190	5	Polydora sp.; Pygospio/ Eteone; T. benedeni	Mixed tidal levels Mainly old SCM Species rich & high abundance
2	9.5	249	2	Pygopsio/ Polydora; T. benedeni	Low-shore. West of and adjacent to old Tioxide outfall
3	4.4	37	5	T. benedeni; T. swirencoides	Low-shore. Both sides of old SCM outfall. Impoverished.
4	7.0	162	8	T. swirencoides T. benedeni; Tharyx/Pygospio	Low-shore. Both sides of old Tioxide outfall
5A	6.8	379	4	T. benedeni; Pygospio/ Macoma	Mid-shore sites at intermediate or larger distances from either discharge
5B	6.7	991	9	T. benedeni; Hydrobia/ Pygospio; Macoma	Mid-shore sites around old Tioxide outfall
6	8.7	1100	3	T. benedeni/ Pygospio	Mid-shore sites to west of, and distant from old SCM outfall

Unclassified sites: Gy MS; Gy LS ("controls"); SCM 2W.MS; SCM 4W.LS

Key: N_S = No. of Species
N_I = Total number of Individuals

TABLE 5.5.2.II

Summary of Characteristics for Mid-shore Sites which Clustered Differently in 1989

Old SCM Outfall (Intertidal)

Site	No. of Species		No. of Individuals	
	1984	1989	1984	1989
3E	7	10	549	829
6W	10	10	997	1401
3W	9	7	286	211
5W	5	8	281	785

TABLE 5.5.2.III

Summary of Changes at Sites Deemed Affected in 1984

Old SCM Outfall (Intertidal)

Site	No. of Species		No. of Individuals	
	1984	1989	1984	1989
A. 'Severely Affected' Sites				
1W.LS	2	1	4	1
2W.LS	5	4	30	17
3W.LS	4	4	35	19
5W.LS	3	5	39	36
6W.LS	2	4	12	7
1E.LS	-	-	-	-
2E.LS	5	9	20	790
3E.LS	5	5	49	49
4E.LS	4	8	10	347
B. 'Moderately Affected' Site				
4W.LS	6	5	223	17
C. Sites showing 'Weak' effect				
5E.LS	5	4	88	64
(5E.MS)	6	-	334	-

TABLE 5.5.3.II

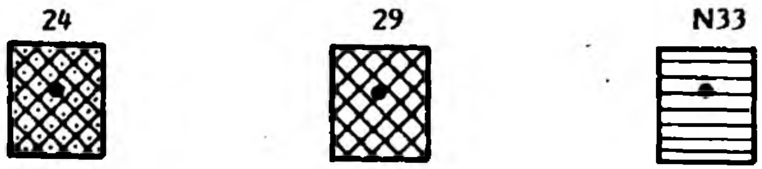
Summary of Changes at Low Shore Sites

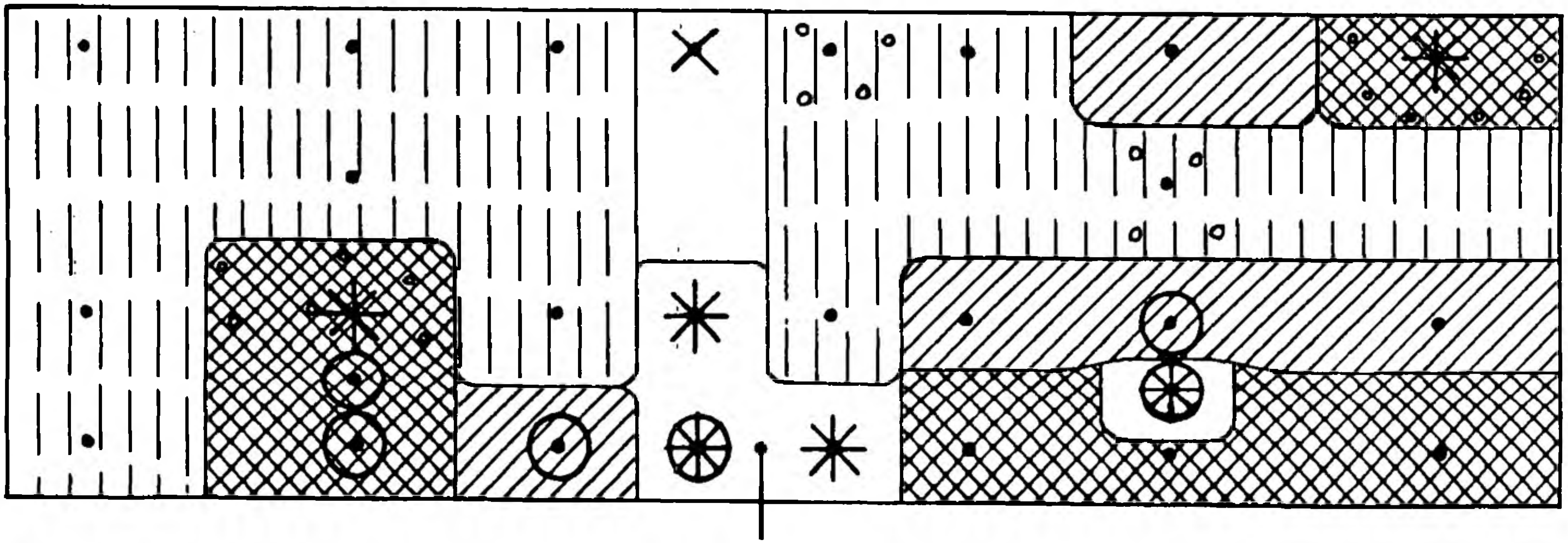
Old Tioxide Outfall (Intertidal)

Site	No. of Species		No. of Individuals	
	1984	1989	1984	1989
T1W.LS	8	10	312	388
T2W.LS	6	9	289	109
T3W.LS	3	9	49	683
T4W.LS	6	7	372	65
T5W.LS	4	7	335	229
C.P.LS	7	5	488	113
AVERAGE	5.2	7.4	306	240
T1E-T5E.LS AVERAGE	9.6	7.4	1183	178

Fig. 5.3.1 Sediment Types Around the old SCM Outfall (Sub-tidal): 1989 (Based on Visual Observations)

Reference Stations





Key as for Fig. 5.3.2

Fig. 5.3.2 Sediment Types Around Old Tioxide Outfall (Sub-tidal): 1989. (Based on Visual Observations

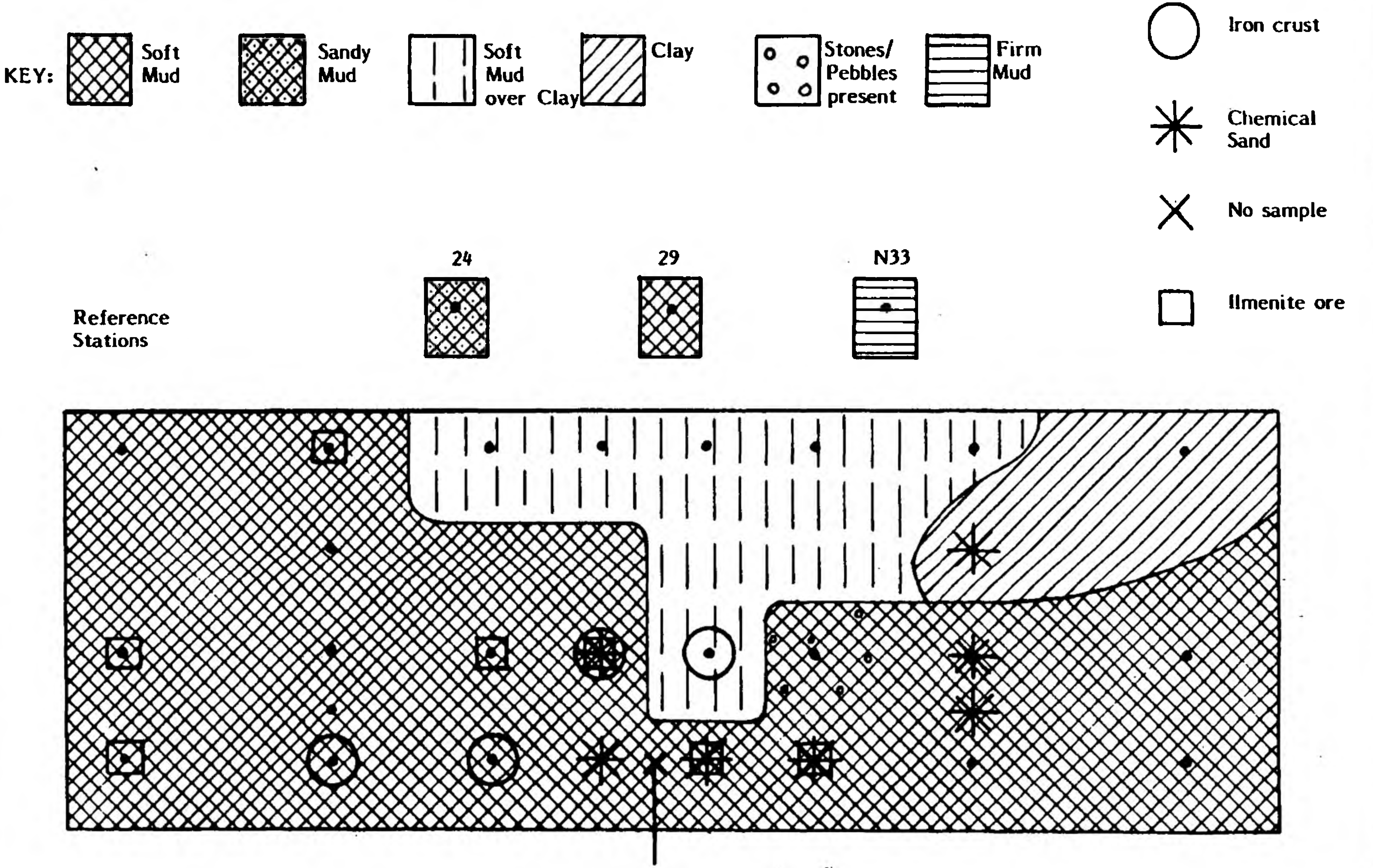


Fig. 5.4.2.1 Dendogram for Cluster Analysis of SCM Old Outfall Sub-tidal Survey (1989)

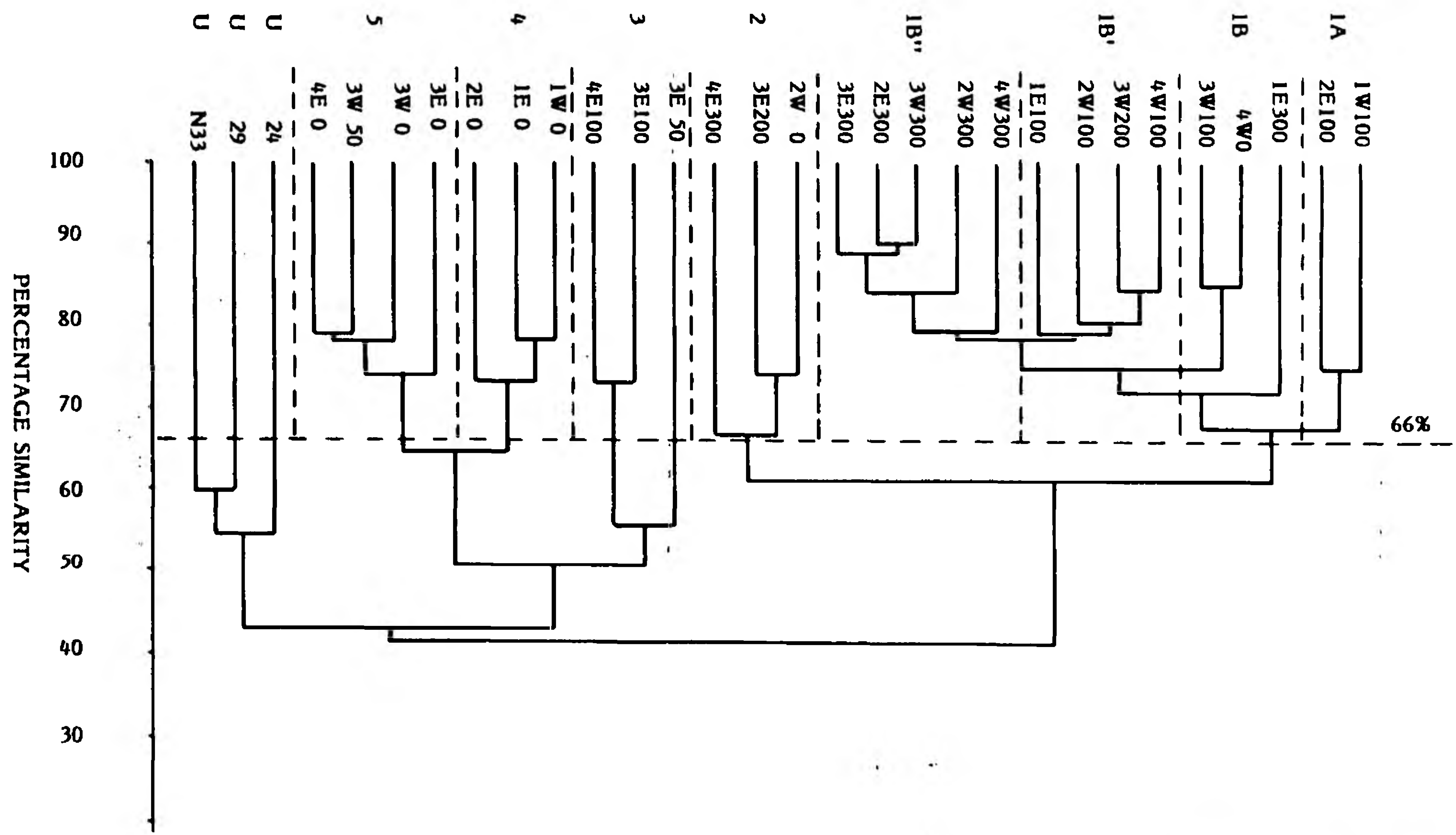


Fig. 5.4.2.2 <u>Cluster Patterns for the Old SCM Outfall (Sub-tidal): 1989</u>

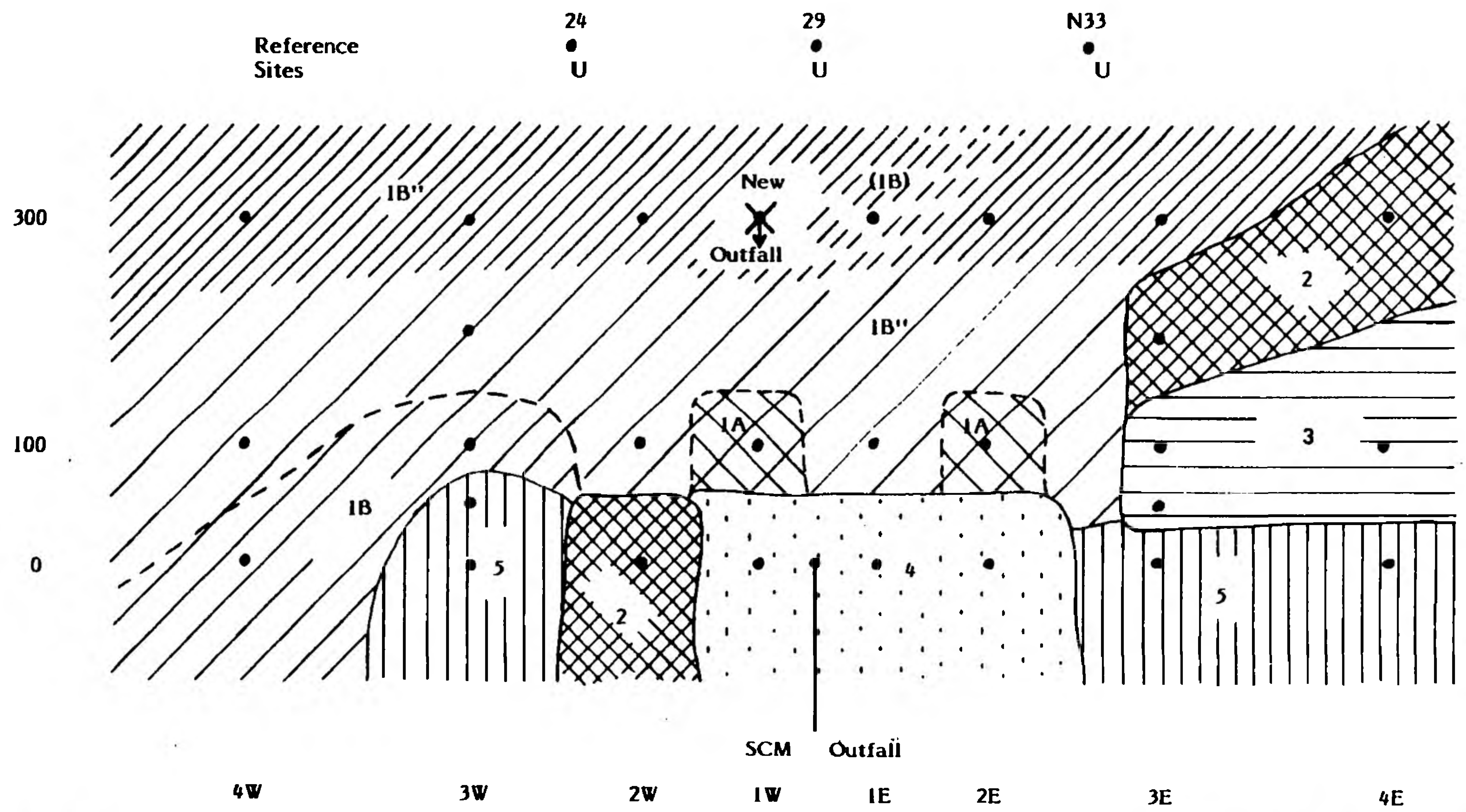


Fig. 5.4.2.3. Number of species for SCM OLD OUTFALL 1989 (sub-tidal)

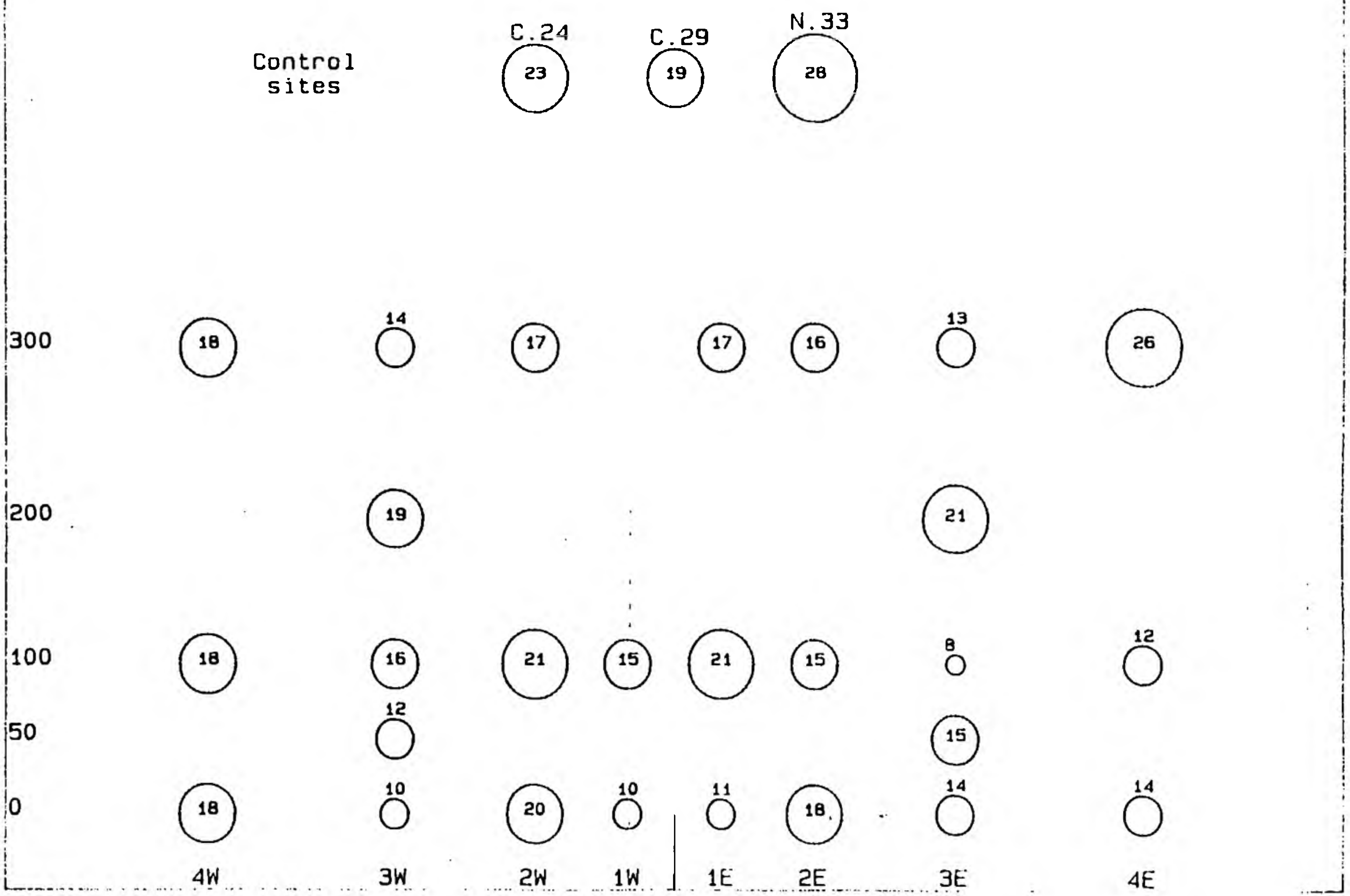


Fig. 5.4.2.4. Number of individuals for SCM OLD OUTFALL 1989 (sub-tidal)

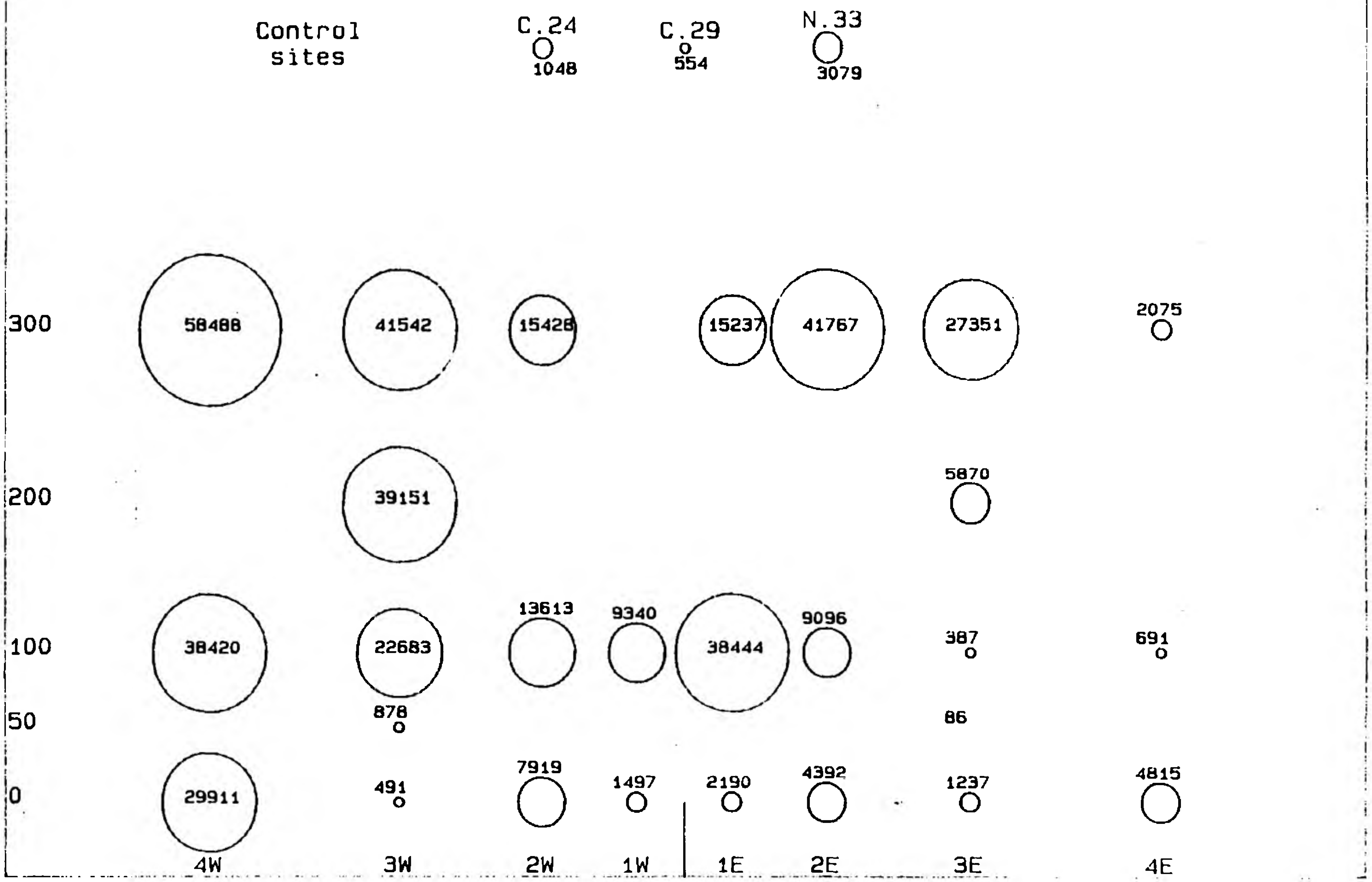


Fig. 5.4.3.1 Dendrogram for Cluster Analysis of Tioxide Old Outfall Sub-tidal Survey (1989)

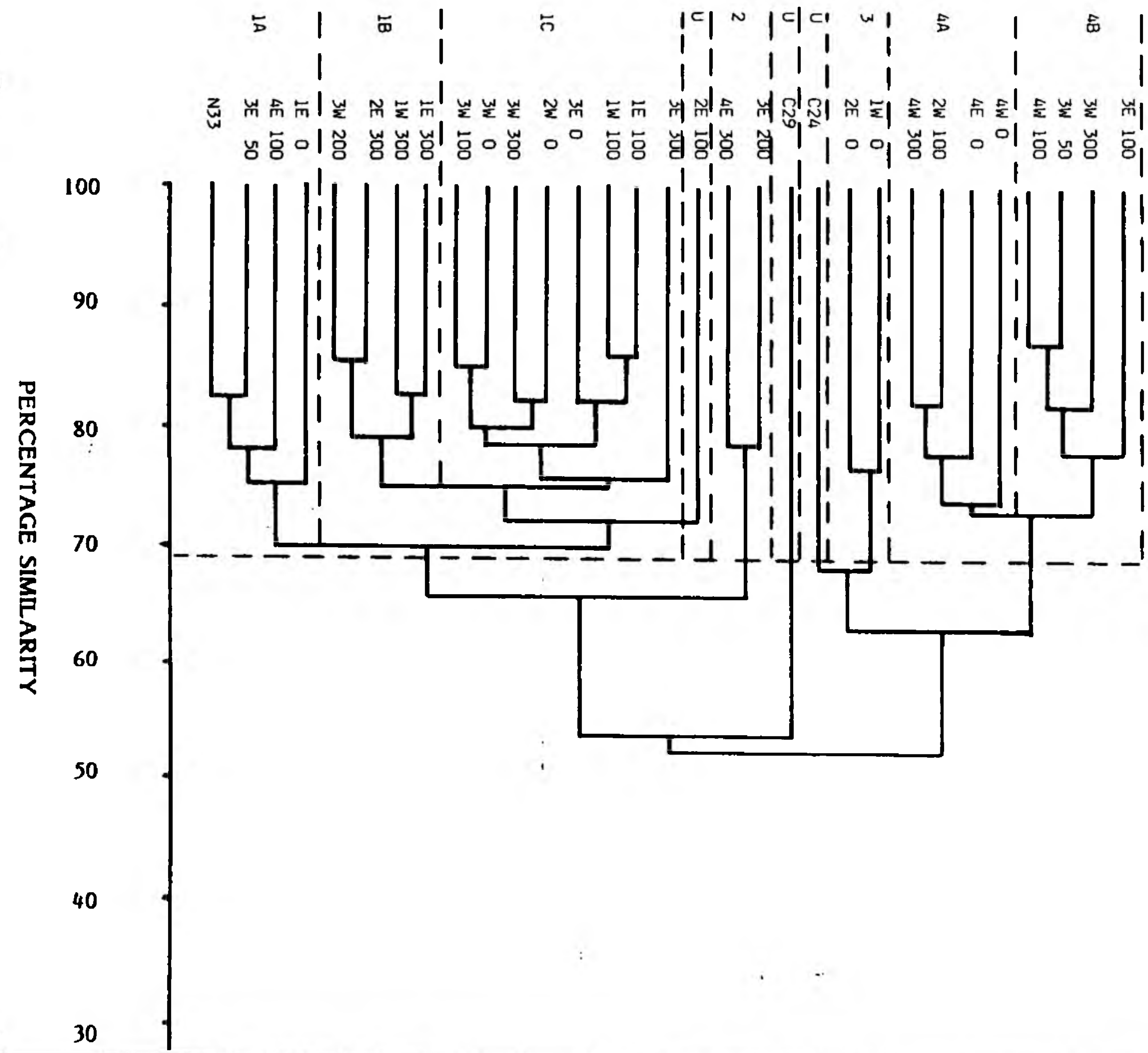


Fig. 5.4.3.2 Cluster Patterns for the Old Tioxide Outfall (Sub-tidal): 1989

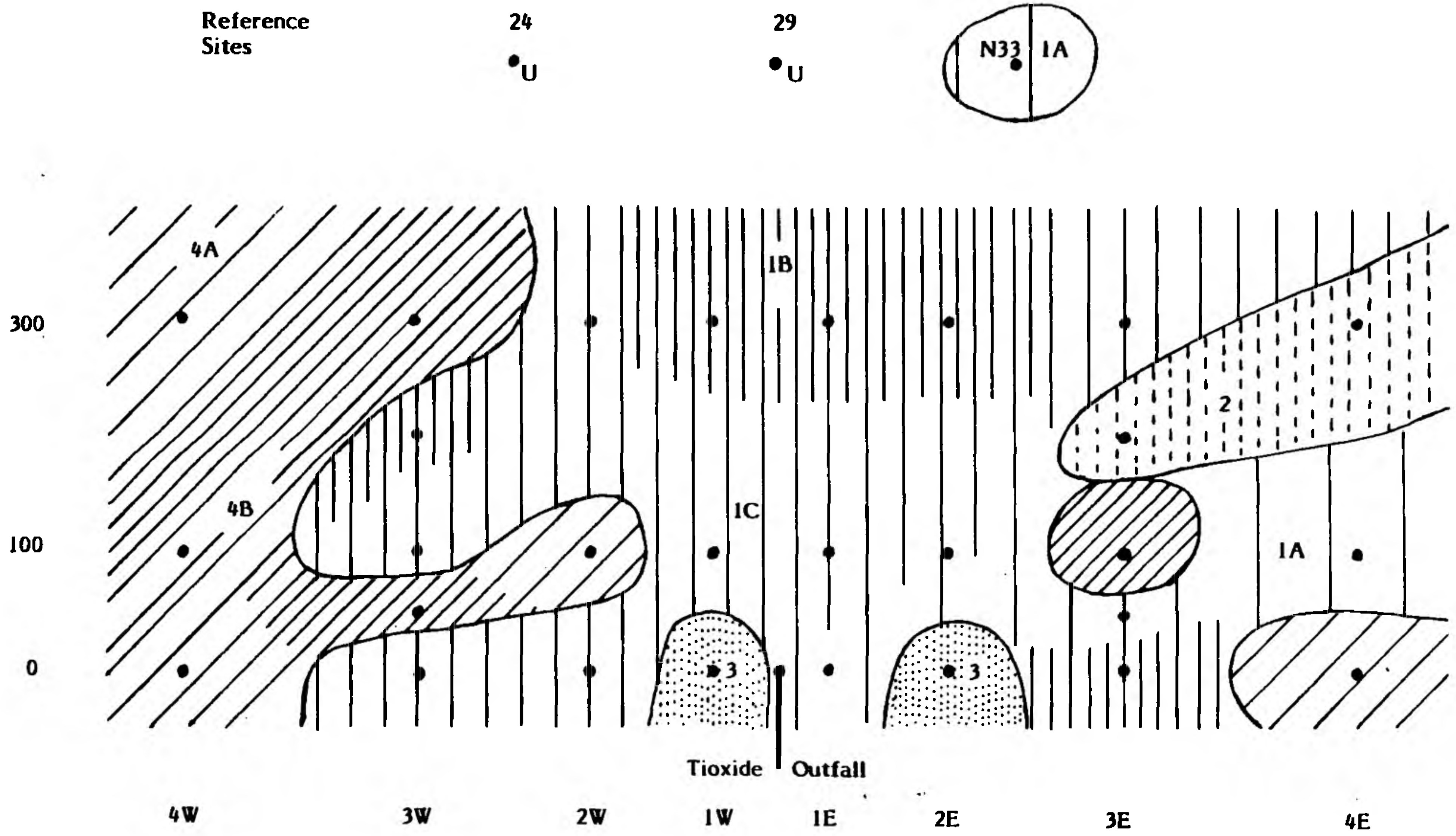
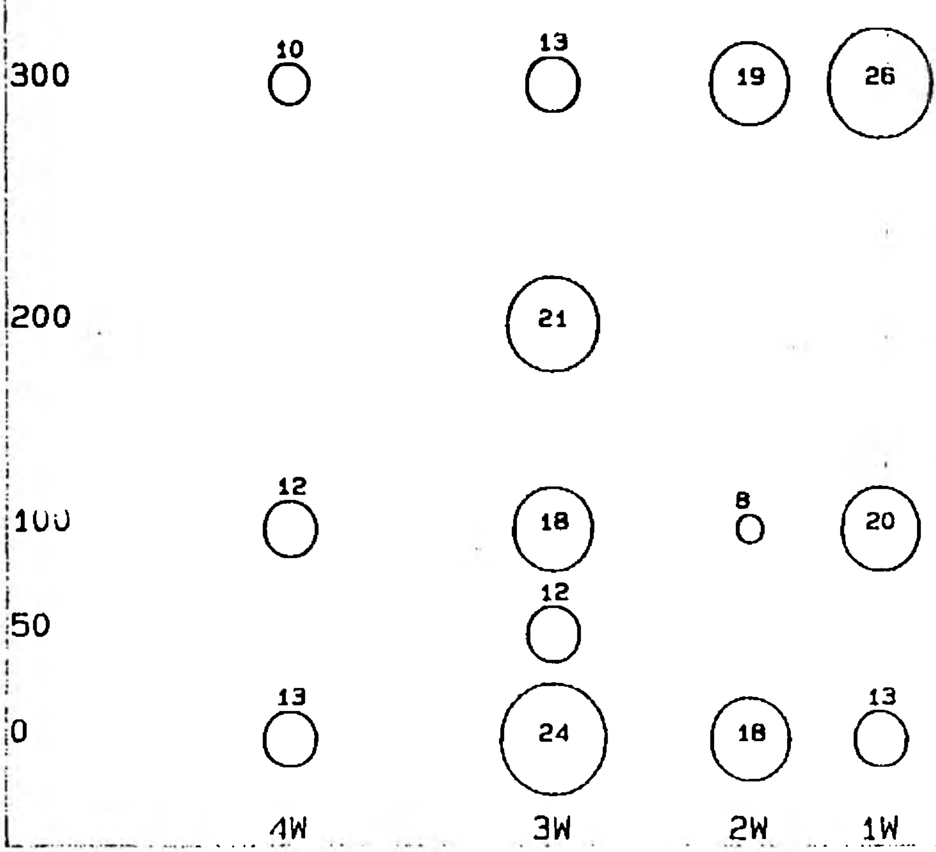


Fig. 5.4.3.3. Number of species for



TIOXIDE OLD OUTFALL 1989 (sub-tidal)

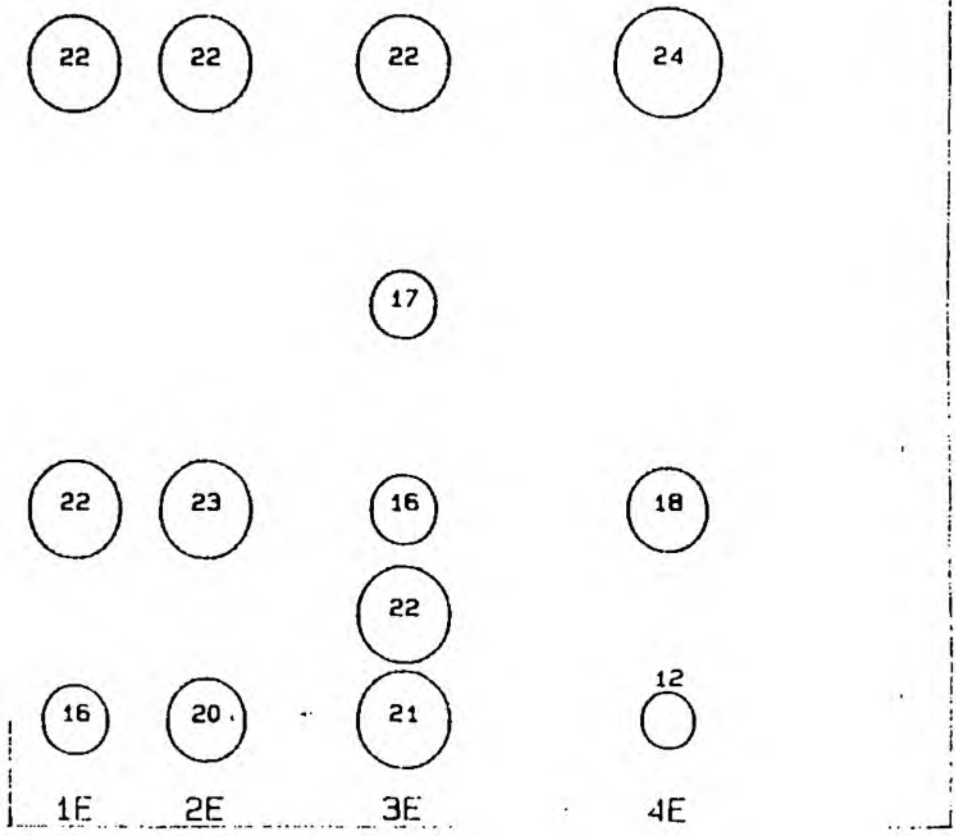
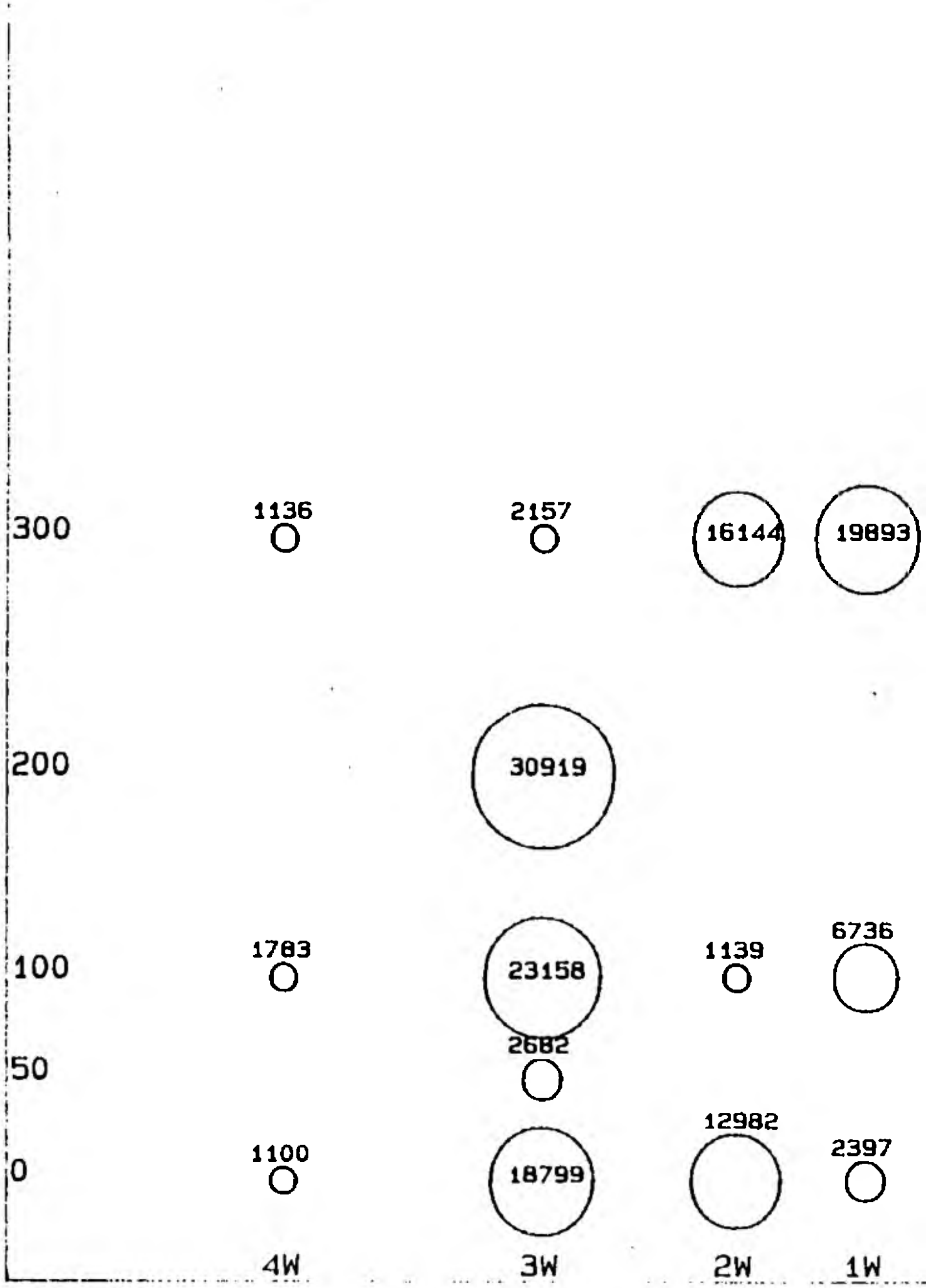
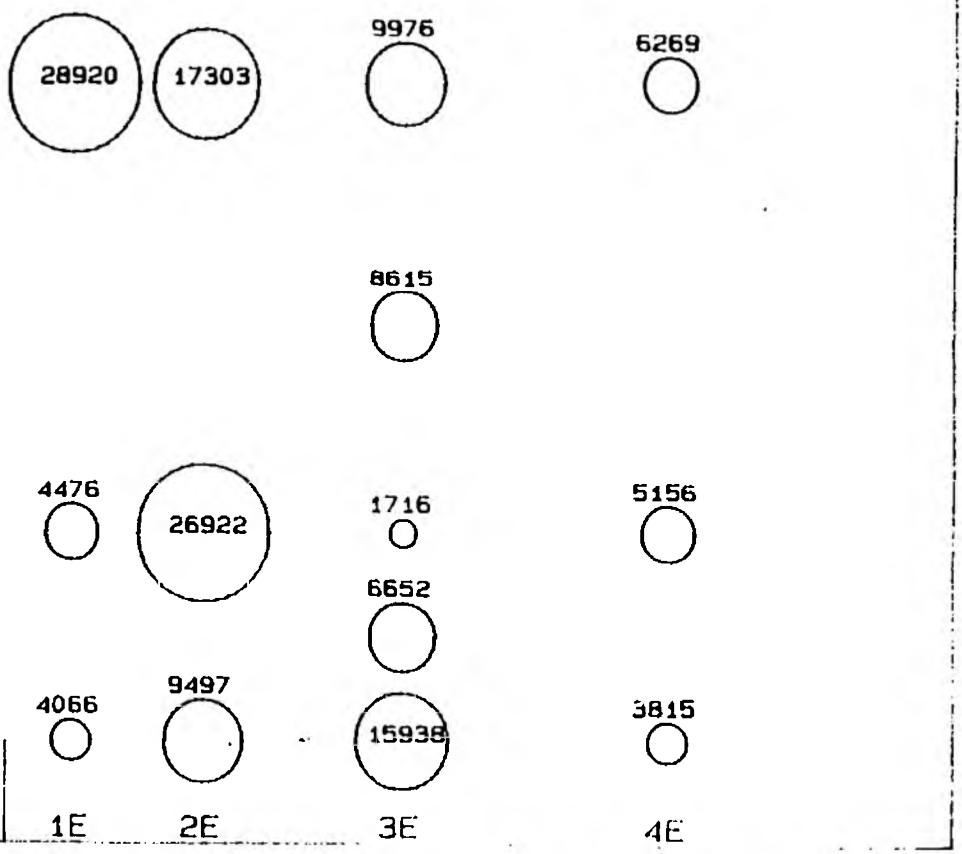


Fig. 5.4.3.4. Number of individuals



for TIOXIDE OLD OUTFALL 198.)



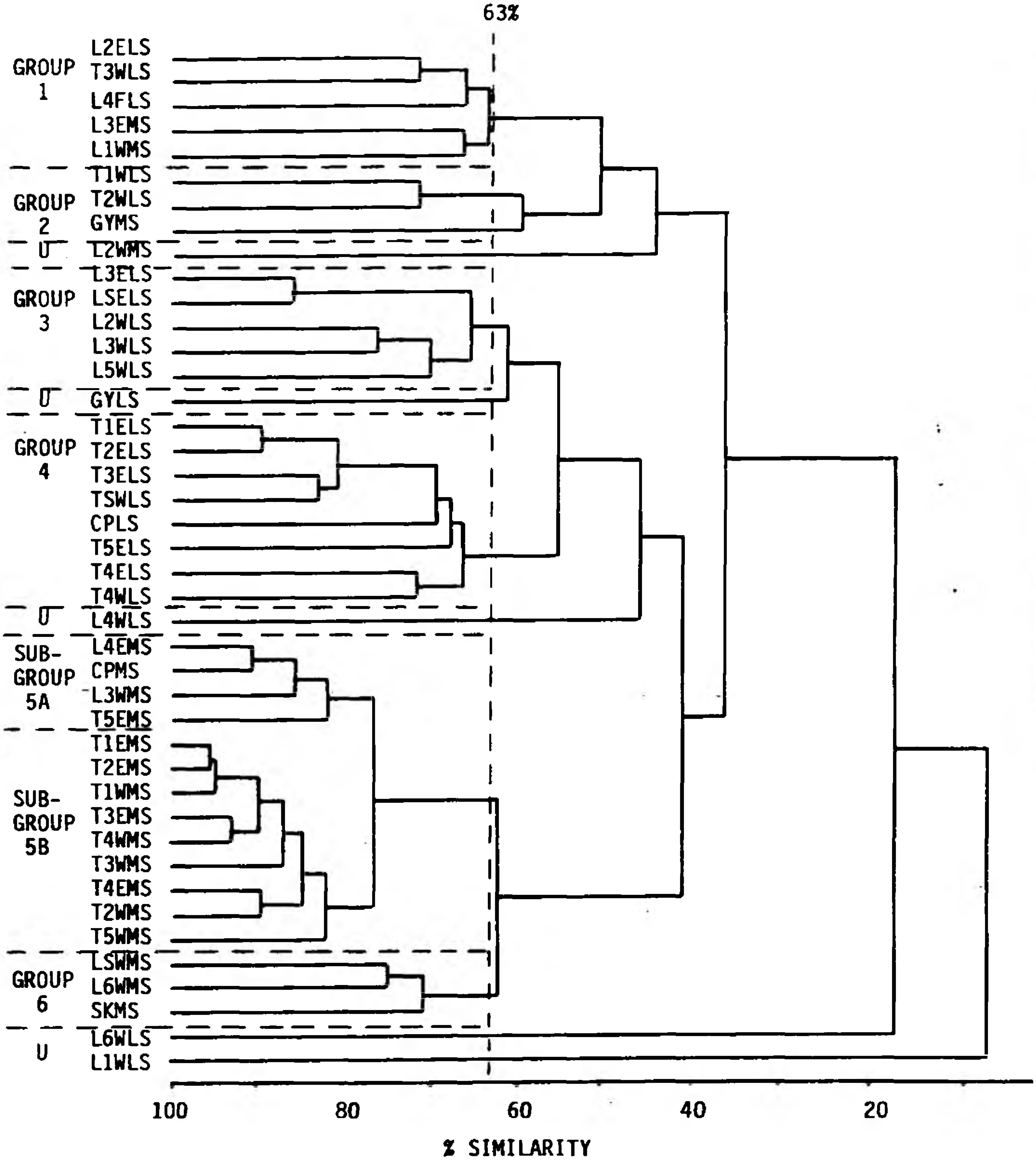


Fig. 5.5.1. Dendrogram for cluster analysis of intertidal survey

Fig. 5.5.2.1 Cluster Patterns for the Old SCM Outfall (Intertidal) 1989

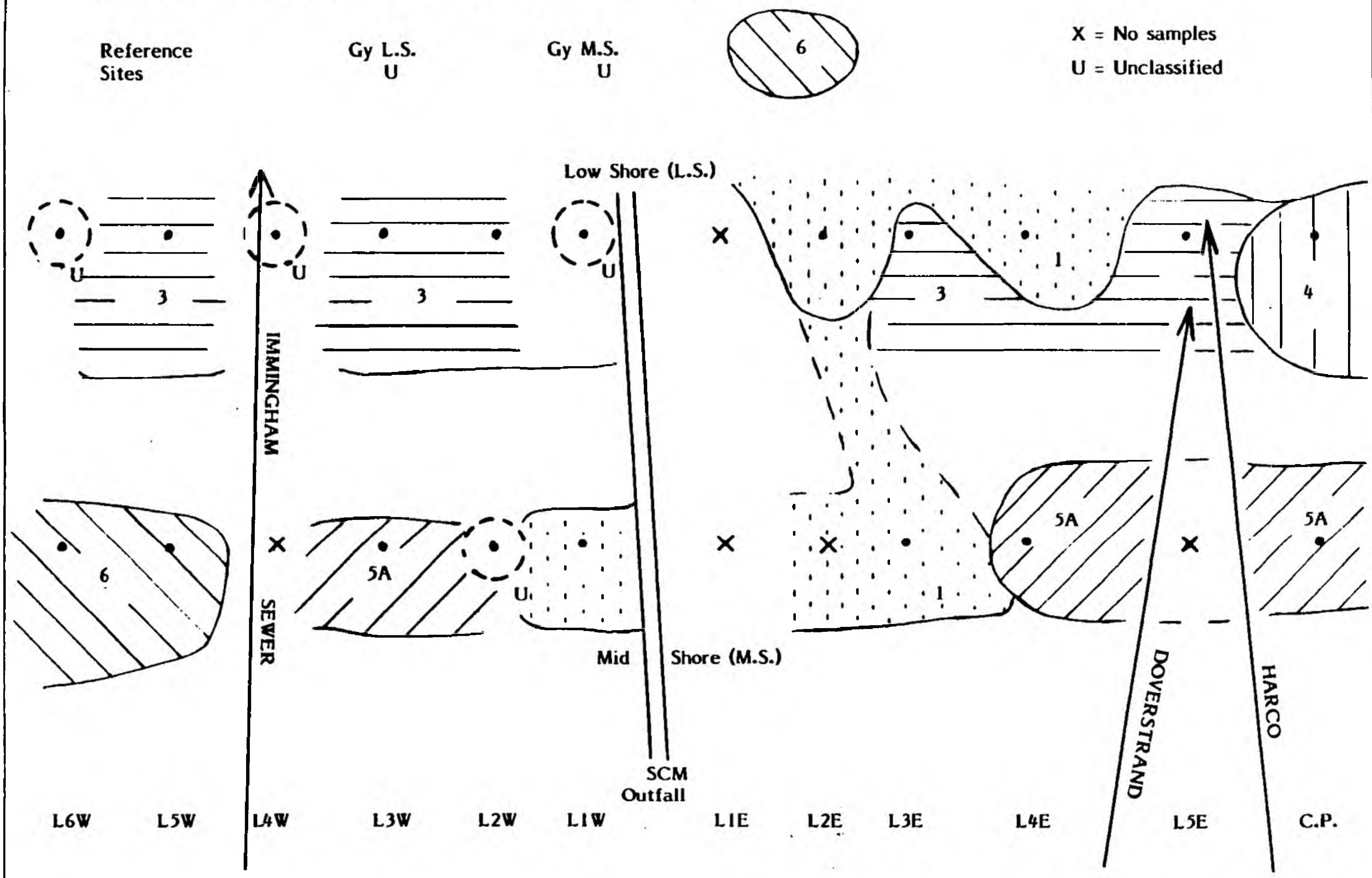
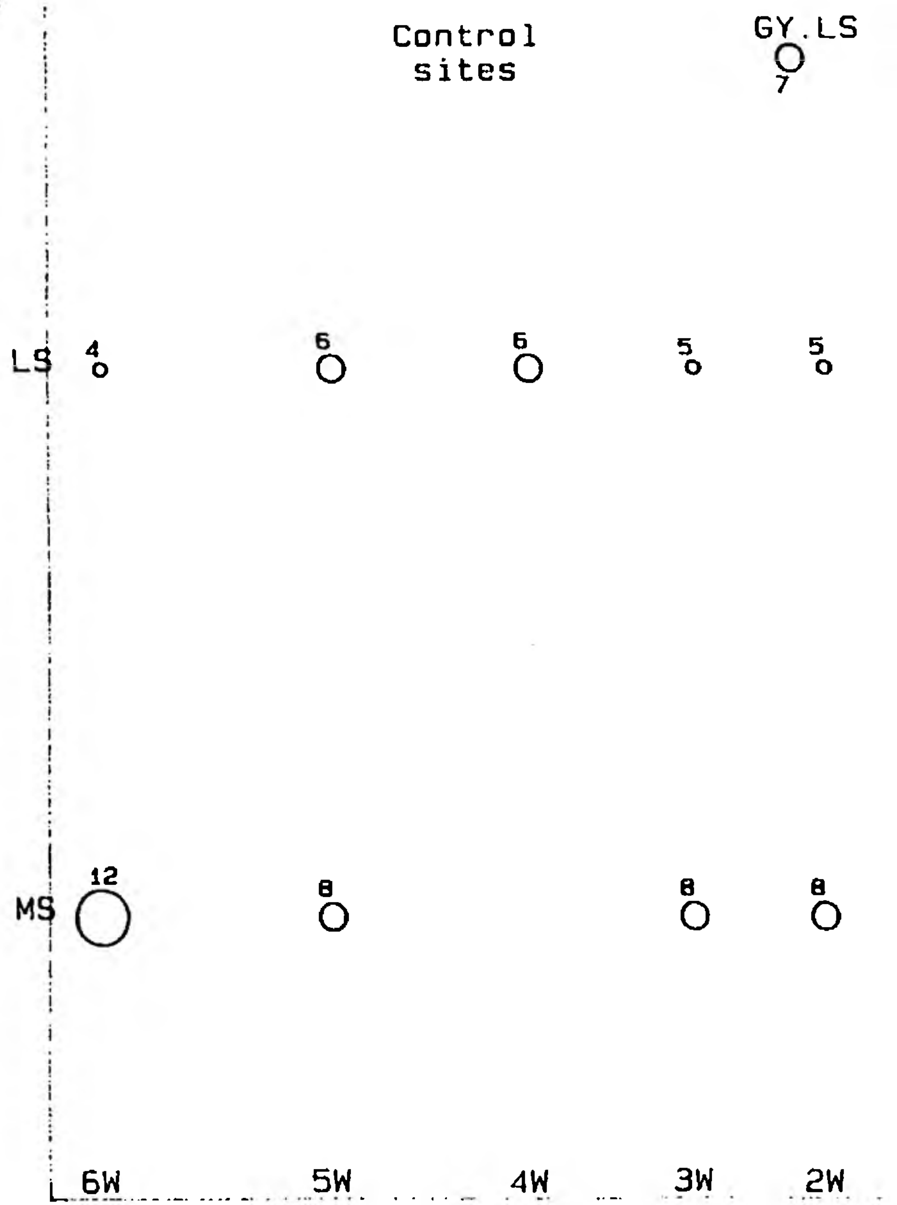


Fig. 5.5.2.2. Number of species



for SCM INTERTIDAL 1989

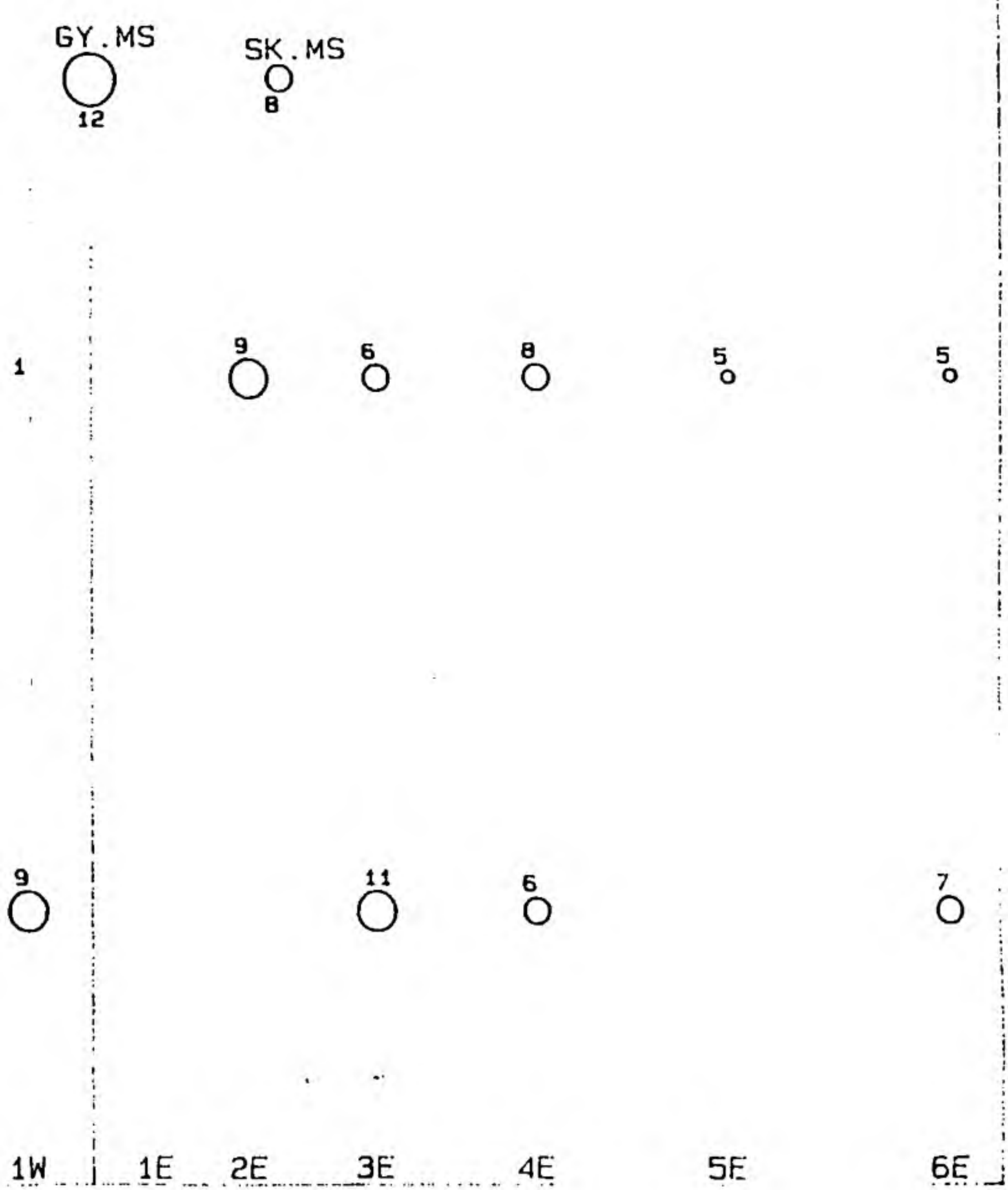


Fig. 5.5.2.3. Number of individuals for SCM INTERTIDAL 1989

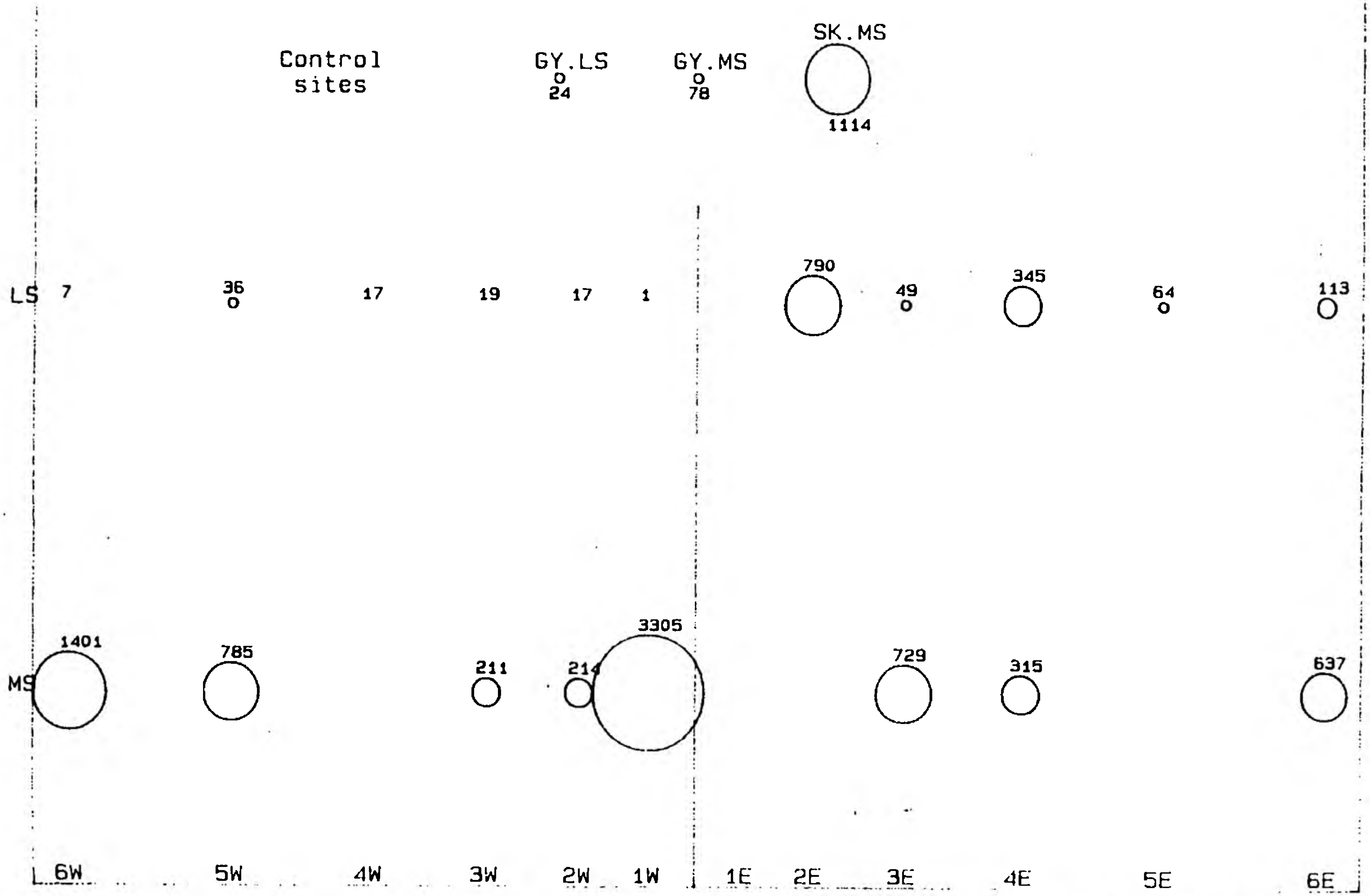


Fig. 5.5.3.1 Cluster Patterns for the Old Tioxide Outfall: Intertidal 1989

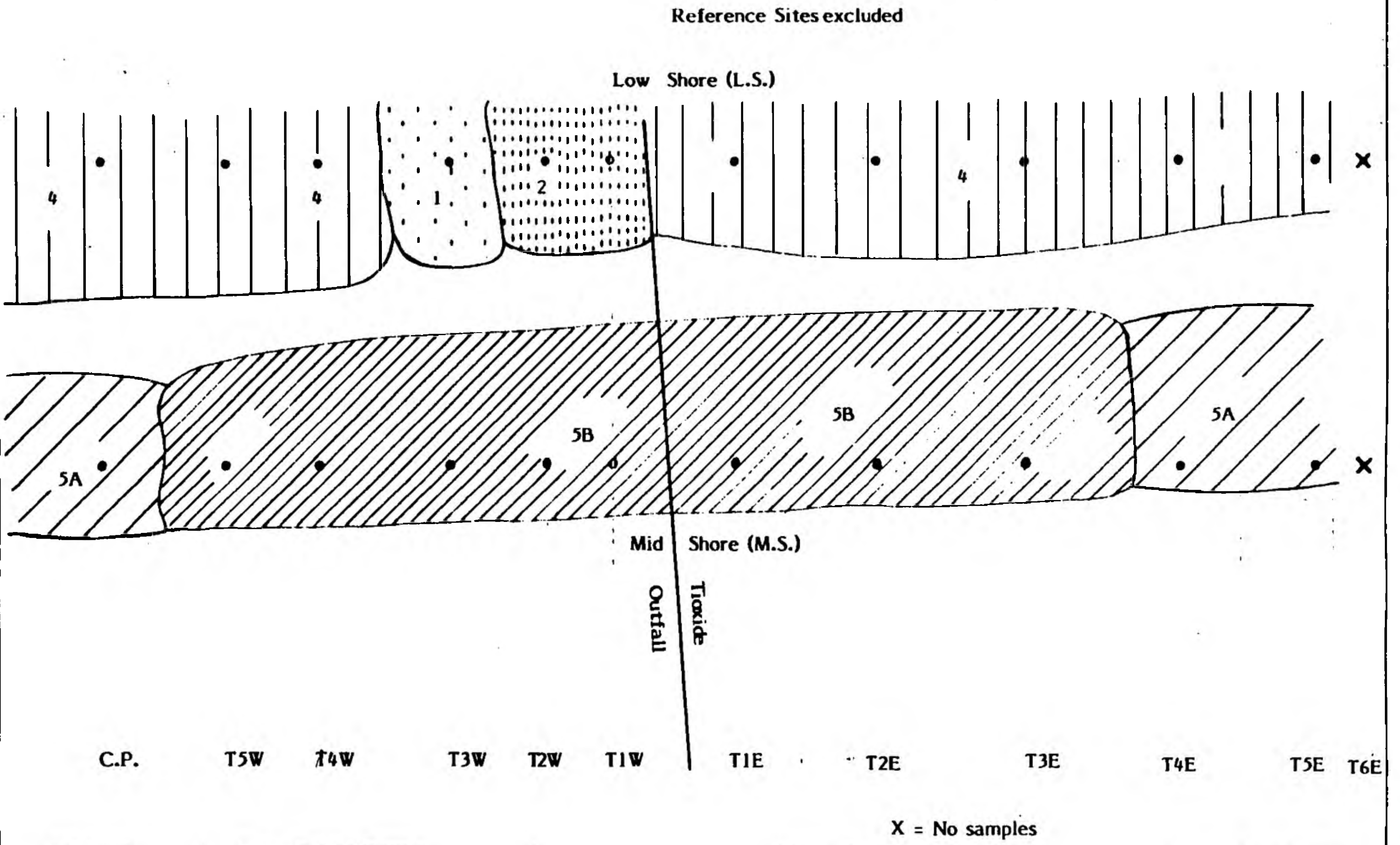


Fig. 5.5.3.2. Number of species for TIOXIDE INTERTIDAL 1989

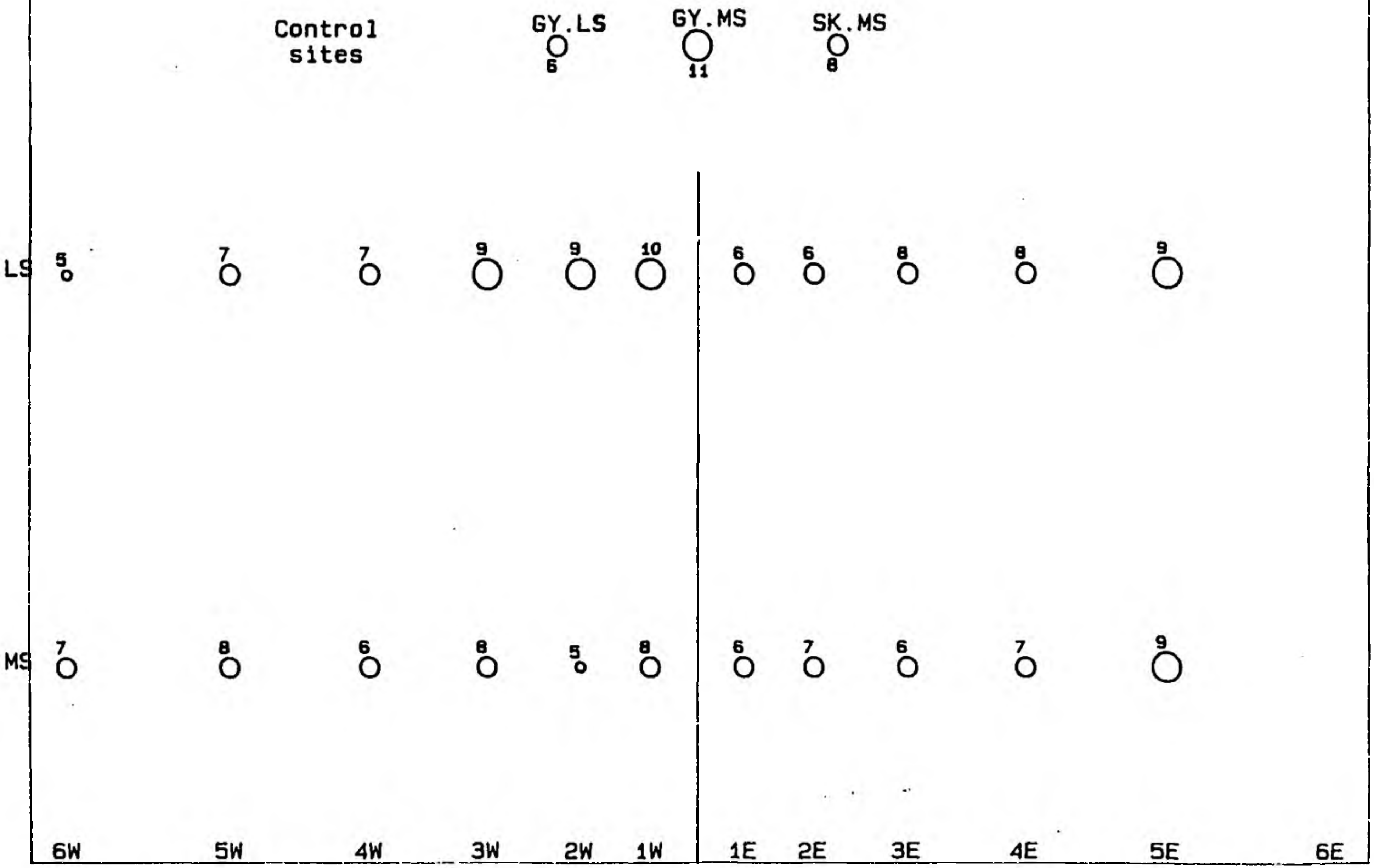
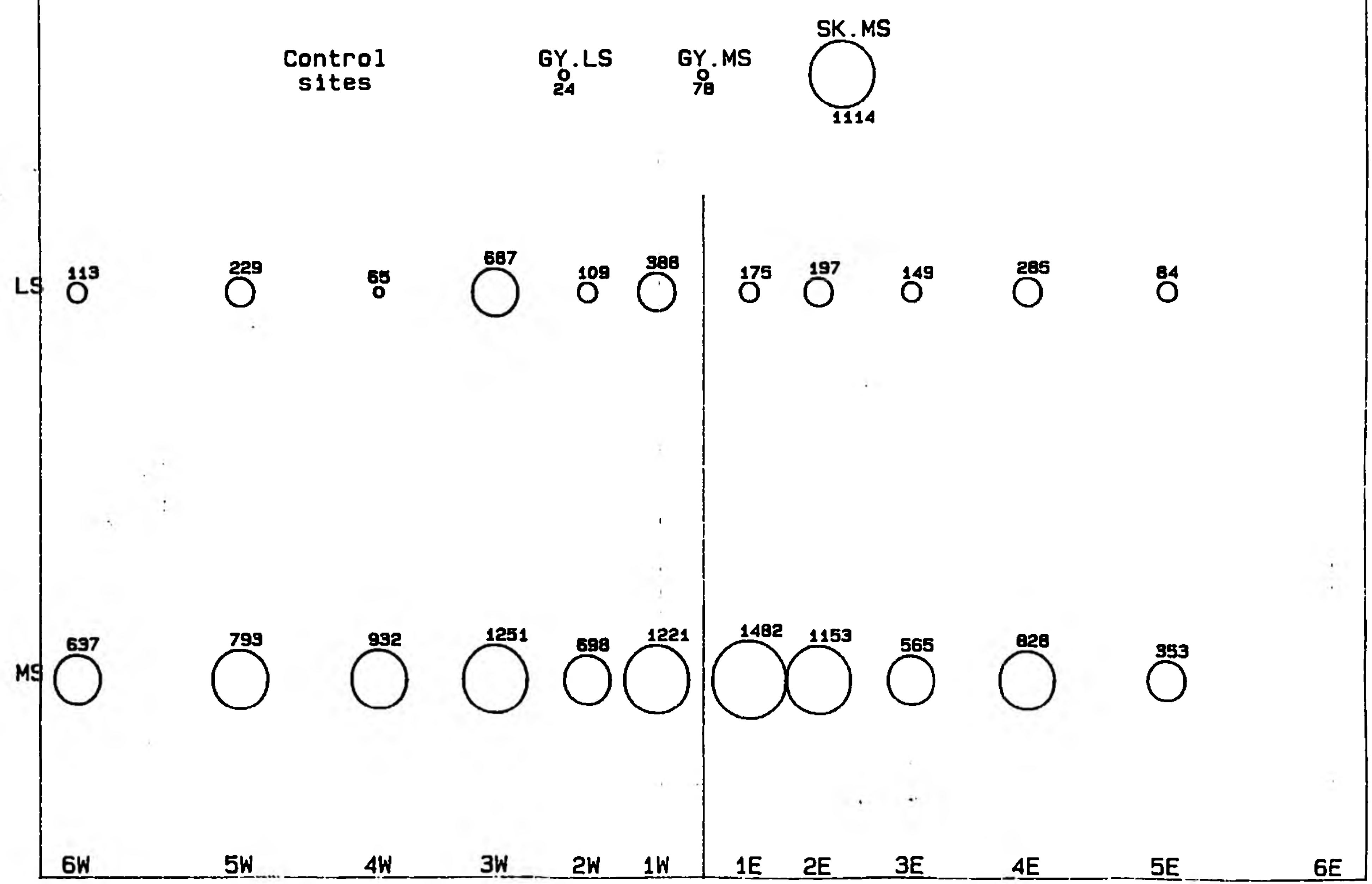


Fig. 5.5.3.3. Number of individuals for TIOXIDE INTERTIDAL 1989



APPENDIX 6

METALS RESULTS FOR SEDIMENTS NEAR THE OLD OUTFALLS.

6.1 Introduction.

The sediment sub-samples taken during benthic sampling were analysed for a range of metals. Distribution maps have been plotted for iron and titanium around each outfall and are shown in Figures 6.1 to 6.8. No meaningful contours could be easily plotted. The sub-tidal data are shown in Table 6.1 for SCM and Table 6.2 for Tioxide with the corresponding inter-tidal data shown in Tables 6.3 and 6.4 respectively.

Although there are significant discharges of metals to various parts of the Humber Estuary, the large body of moving water, the relatively high current velocities encountered and the naturally high level of suspended solids in the water column (predominantly fine silt) together have a tendency to hinder localised accumulation of metals in sediments.

Any significant trends in sediment enrichment were therefore likely to be the result of major sources of contamination. Furthermore, the old SCM and Tioxide outfalls discharged significant quantities of certain distinctive elements (viz. iron, titanium and vanadium) whereas other discharges in the vicinity are distinguishable by a different distinctive element, e.g. Courtaulds (located between SCM and Tioxide) discharges significant quantities of zinc (in predominantly soluble form).

If the pattern of enrichment of sediment by the discharges of specific elements was not matched by that of non-specific elements, then this would point to a specific source of the material.

The grid of sample sites around the old SCM outfall was largely overlapped by the sampling grid around the new SCM outfall. This created difficulties in relating some of the site data to an individual outfall.

The bathymetry around each outfall was a significant factor in the interpretation of the results, especially when taken in conjunction with the variable nature of the estuary bed. In particular, the old Tioxide outfall was very close to the low water line into a relatively shallow channel inshore of Burcom Shoal. At low tidal levels, therefore, there was little current motion to disperse the effluent. Although the old SCM outfall was always covered by the tide and there was less of a shoal hindering tidal flow, it only discharged about 50m from the shore which prevented good dispersion.

Three sub-tidal control sites from the Lower Humber Estuary were used for comparison purposes. They were selected as being unlikely to be contaminated by either effluent, past or present.

The elements of most interest were: iron, titanium and vanadium because they were distinctive to both SCM and Tioxide discharges; mercury and cadmium because they are subject to specific EEC legislation and zinc because it is distinctive to Courtaulds discharge. Copper was also of interest because deposits 20 times the average were found close to the old SCM discharge in 1984 and because previous work on metals in seaweed suggests there to be a significant copper input somewhere in the vicinity although no such input has been located.

From consideration of the data from the 1984 special surveys, some enrichment of iron and titanium would still be expected around the old outfalls, if to a lesser degree. A reduction in enrichment could be for a number of reasons:-

- the effect of the discharge is reduced, i.e. there has been little or no recent discharge of effluent in the area;

- there are strong localised currents which scour the estuary bed and have dispersed the surface sediment or solubilised some of metals in the sediment;

- the sampling program was deficient in some manner.

Unless otherwise stated, all references are to the old outfalls. Where zones of "depletion" have been identified they indicate areas of concentration less than the lowest control site.

6.2 Sub-tidal Results.

a) Iron in sediment.

There was no significantly obvious area of iron enrichment around either of the old outfalls.

At SCM there was a depleted zone about 300m offshore parallel to the shore. This fitted in with the data for the new outfall site and would appear merely to represent differences in the nature of the estuary bed. There was a single high point 2.2 km downstream and a second such point 2.1 km upstream and 350m offshore. The latter site, near the western edge of the oil terminal jetty was anomalously high for most metals.

At Tioxide, a depleted zone existed as a band, approximately 100-200m wide, running through the discharge point in an offshore direction. This probably reflected disturbance caused by construction of the new outfall.

There did not appear to be any significance in the fact that the mean iron value for the Tioxide sample grid was higher than that for the SCM grid by a factor of 1.07 since both mean figures were comparable to the range of values for the control sites.

These findings contrast very strongly with those of 1984, when one sample in particular, very close to the old Tioxide outfall, had an iron crust which was dramatically enriched in iron relative to all other sites. Iron enrichment was very evident around both the old outfalls and was generally coincident with the line of the effluent plumes.

b) Titanium in Sediments.

There was a significant titanium enrichment zone around the old SCM outfall, extending as a narrow band about 100m upstream and 100m downstream with values considerably in excess of the control sites. There was no titanium enrichment in the immediate vicinity of the old Tioxide outfall. Instead, there was a depleted zone, extending about 100m upstream and downstream with a band further offshore.

There was a small depleted zone approximately 200m offshore of the SCM outfall, with values considerably below those of the control sites.

There was one high point in the Tioxide sample grid, at 1000m upstream and 100m offshore with a value over twice that of the control sites and nearly twice that of the mean for the grid but there does not appear to be any significance in this.

The anomalously high point identified in the old SCM grid at 2.1 km upstream only had an average value for titanium. This would indicate that the enhanced values at this site for the majority of elements were not caused by deposition from the effluent.

The mean titanium value for the Tioxide grid was well above the mean of the control sites (by a factor of about 1.5) and also had an enrichment factor of 1.25 over the mean at SCM.

Around the old outfalls in 1984, there was evident titanium enrichment between Grimsby and Immingham closely matching the pathway of the soluble iron plume.

c) Vanadium in Sediments.

The patterns for vanadium are very similar to those for titanium. There was a narrow band of vanadium enriched sediment in line with the old SCM outfall extending about 100m upstream and 1100m downstream whereas there was a zone of vanadium depletion around the old Tioxide outfall extending about 300m upstream, 100m downstream and 400m offshore.

There was also a band of depletion about 200m offshore of the old SCM outfall.

The vanadium result at the anomalous site in the SCM grid was only slightly above average and was not the largest result.

The mean vanadium value for each sample grid exceeded that of the control sites with the figure for Tioxide showing a relative enrichment factor of 1.09 over that for SCM.

In 1984, vanadium enrichment was apparent in the intertidal sediments between the old Tioxide outfall and Immingham.

d) Mercury in Sediments.

There was a slight indication of mercury enrichment around the old SCM outfall (about 100m upstream and downstream) and a zone of mercury depletion around the old Tioxide outfall.

There was a large zone of mercury depletion about 200m offshore of the SCM outfall.

The largest mercury value in the SCM grid occurred at the anomalous point but it was not significantly high.

The largest value in the Tioxide grid was 1000m downstream and 100m offshore of the old outfall. It was approximately three times the average for the grid and over four times the control site values. Looked at in conjunction with the largest control site result (CL.N33 - a site about 1,700m downstream of Grimsby Docks) together with the relatively elevated levels of mercury within the Tioxide grid, there is the possibility that this enrichment is anthropogenic and not merely a function of the nature of the estuary bed. However, there is nothing to suggest that this is related to the old Tioxide discharge.

Whilst the mean mercury value for the SCM grid was comparable to that for the control sites, that for the Tioxide grid was much higher with an enrichment factor of 1.50 compared to SCM.

The complex pattern of mercury distribution in the 1984 results showed some enrichment of the intertidal sediments in the vicinity of each outfall. There was one site (L.300.E3 - 300m downstream of SCM discharge and about 300m offshore) which had a total mercury content over 30 times greater than the average value.

e) Cadmium in Sediment.

Since all cadmium results for sediment were below the limit of detection (0.5 $mg.kg^{-1}$, it was not possible to make any comparisons.

In 1984, the detection limit for cadmium was lower (about 0.24 $mg.kg^{-1}$) and two very distinctive areas of cadmium enrichment were apparent in the sub-tidal sediments, one of which was very symmetrical about the old SCM outfall.

f) Zinc in Sediments.

At SCM there was some zinc enrichment 100m downstream of the old outfall but at Tioxide there was only a sign of zinc depletion about 100m upstream and 400m downstream (100m offshore) of the old outfall.

There was a zone of zinc depleted sediment about 200m offshore of the SCM outfall, similar to that observed for other metals.

The highest point in the SCM grid was at the anomalous site, at a level about twice that of the control sites. There were other high points downstream and offshore but these did not appear to be linked to the old SCM outfall. It is highly probable that they were associated with the Courtaulds discharge downstream of SCM (upstream of Tioxide). The high points in the Tioxide grid are 1000m downstream and 2.25 km downstream of the old outfall and do not appear to have any significance.

The mean level for the Tioxide grid was a factor of 1.17 higher than that for SCM with the former being slightly higher than the control sites and the latter similar to two of them but higher than the third.

g) Other Metals in Sediments.

Aluminium, unlike previous surveys, was not determined, due to difficulties in both analysis and interpretation.

There was evidence of copper enrichment 100m upstream and downstream of the old SCM outfall with values approximately twice that of the mean for the grid. This suggested a copper hot-spot in the vicinity but measured values of copper in the SCM effluent do not appear to be large enough to account for this. Around the Tioxide outfall, there was a zone of copper depletion at a level about that of the lower control site.

There was a point of copper enrichment at 1000m downstream of the Tioxide outfall which did not appear to be significant.

There was a zone of copper depletion about 200m offshore of the SCM discharge which appeared to tie in with such a feature in the sample grid around the new outfall.

The highest value in the SCM grid, at approximately twice the mean, was at the anomalous site 2.1 km upstream (350m offshore) at the western end of the oil terminal jetty.

The mean copper value around the Tioxide outfall was higher than for the SCM outfall by a factor of 1.15. Only the SCM data was comparable to that for the control sites.

In 1984, the highest recorded copper values were around 1,300 $mg.kg^{-1}$ 50m upstream of the old SCM discharge whilst the figure at 50m downstream was about half this. The means (of 3 replicates) for each site were comparable at about 500 $mg.kg^{-1}$. This compares to values of 60 and 89 $mg.kg^{-1}$ at the same sites in this survey, a mean value of 41 $mg.kg^{-1}$ and a control site mean of 37 $mg.kg^{-1}$.

There was some chromium enrichment around the SCM outfall along the line of the old plume, 100m upstream and 1000m downstream with values about 1.5 times the control site figures. There was a chromium depleted zone around the Tioxide outfall offshore and approximately 500m downstream.

There was a chromium high point 1000m downstream of the Tioxide outfall with a second zone of enrichment about 700m downstream of SCM (250m offshore) neither of which has any apparent significance.

There was a zone of chromium depletion about 200m offshore of the SCM discharge which tied in with the sample grid around the new outfall.

There was a high chromium result at the identified anomalous site near the oil jetty with a value approximately twice that of both the mean of the grid and the control sites.

The mean chromium value around the Tioxide outfall was higher than the value for the SCM outfall by a factor of 1.13 as well as that for the control sites whilst the SCM data was comparable to the control site results.

There was lead enrichment extending 100m upstream and 1,100m downstream of the old SCM outfall with values approximately 50% higher than that of the grid mean and the control sites. Around the Tioxide outfall, there was a small zone of lead depletion where the values were less than that of the lowest control site.

There was a point of lead enrichment (approximately twice the level of the control sites) at 1,000m downstream of the Tioxide outfall which did not appear to be significant. There was a zone of lead depletion (lower than all the control sites) about 200m offshore of the SCM discharge which tied in with the sample grid around the new outfall.

The highest value in the SCM grid, at approximately twice the mean and the control sites, was at the anomalous site 2.1 km upstream (350m offshore) at the western end of the oil terminal jetty.

The mean lead value around the Tioxide outfall was higher than that for the SCM outfall by a factor of 1.22 as well as for the control sites, whilst the SCM data was comparable to the control results.

Data for nickel suggested the same picture as the other metals, although the nickel enriched zone around the SCM outfall was not clearly defined. There was a nickel depletion zone around the Tioxide outfall. The mean value for the Tioxide grid was the same as that for the SCM grid and both were comparable to the control site values. A high point was distinguishable at 1,000m downstream of the old Tioxide outfall. Similarly, the highest value in the SCM grid was at the anomalous point near the oil jetty 2.1 km upstream.

With the exception of a large manganese depletion zone around the old Tioxide discharge point (400m upstream and 500m downstream), manganese results did not follow the patterns of the other metals. There was a depletion zone around the old SCM outfall extending approximately 400m upstream and 600m downstream. This coincided with the high (enriched) zones for lead, chromium, titanium and vanadium.

However, the anomalous site in the SCM grid was identifiable, as for other metals, near the oil jetty, with almost the highest value in the grid.

Although both sample grids had some manganese results lower than the control site values (a significantly greater number for Tioxide) the mean values were greater than the mean for the control sites. The control site CL.24 did not provide the lowest result as was the case for the other metal results, although the site CL.29 did give the usual highest result as well as being higher than any result in either grid.

Also, the enrichment factor of the Tioxide sample grid over the SCM grid was reversed with a value of 0.82, partly because there was no identifiable depletion zone around the SCM outfall as there was for the other metals.

6.3 Overall Features of Metals in Sub-tidal Sediments.

There is no longer any evidence of enrichment of the sediments around either of the new outfalls, since the patterns of distribution for iron and titanium are generally matched by all other metals except manganese.

In general, the levels of iron measured in sediments were significantly lower than in 1984 when the highest levels were in excess of 60,000 $mg.kg^{-1}$, whereas all 1989 results were below 50,000 $mg.kg^{-1}$.

There was a significant difference between the surveyed areas around each outfall. The mean values for iron, titanium, vanadium, zinc, copper, chromium and lead were higher in the Tioxide grid than in the SCM grid with only manganese being lower in the Tioxide grid. One conclusion from this observation was that the nature of the estuary bed is distinctly different in the two areas. A second conclusion was that the concentration levels required to show an enrichment of the sediment would be different for the two outfall areas.

Control site 24 consistently provided lower results than did either control site 24 or control site N33 although all were chosen with the belief that they represented uncontaminated areas.

There was an anomalous site in the grid around the old SCM outfall at 2.1 km upstream of the outfall (site L.6W.300N). This has the highest results in the grid for all metals measured except manganese, although the significance of this observation is uncertain.

About 200m offshore of the old SCM outfall there is a band of metal depleted sediment which ties in with data collected around the new SCM outfall.

6.4 Inter-tidal Sediment Results.

Previous survey data have shown that results for inter-tidal sediments are not easily related to sub-tidal results and so different criteria need to be applied to their interpretation.

In 1984 the inter-tidal sediments in the vicinity of the old outfalls were found to have higher results for iron and titanium than did the sub-tidal sediments. In fact, some of the clearest evidence of the impact of these outfalls came from the inter-tidal data, notwithstanding the fact that sub-tidal results in general exhibited lower metal loadings than did locally related inter-tidal ones.

Conclusion :

The distribution of metals in inter-tidal sediments was essentially the same in 1989 as it was in 1984, although the levels are somewhat lower (see section above). In particular, the highest iron results were generally in a band along the mid-shore (MS) line for both surveys. Since there is no obvious relationship between this observation and the old outfalls, one must conclude that iron values in inter-tidal sediments are related to the nature of the estuary bed,as has been observed for sub-tidal sediments. Also, previous observations in the Humber Estuary suggest that 'banding' occurs in inter-tidal muds, i.e. metals frequently increase in concentration with distance up the shore from the low water mark.

Sample Number	Site	Code	NGR East	NGR North	V.M. %	Cd mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	Hg mg/kg	V mg/kg	Ti mg/kg
Outfall	0	0	522169	414958												
15,601	1W	0	522090	415026	8.6	<0.5	91	60	32,900	796	40	98	249	0.49	135	1,437
15,602	1W	100	522160	415100	7.2	<0.5	51	33	31,600	1,058	33	53	198	0.21	75	730
15,603	2W	0	521945	415175	6.6	<0.5	47	34	36,300	750	28	48	176	0.24	81	735
15,604	2W	100	522027	415230	6.9	<0.5	56	34	32,550	1,012	31	61	215	0.22	82	871
15,605	2W	300	522149	415378	7.3	<0.5	46	29	26,800	875	28	51	172	0.20	73	879
15,606	3W	0	521710	415327	9.9	<0.5	73	41	37,300	942	37	81	230	0.34	104	912
15,607	3W	50	521743	415365	10.4	<0.5	87	49	39,100	902	41	109	272	0.42	112	1,038
15,608	3W	100	521776	415402	7.9	<0.5	47	26	30,350	813	29	46	172	0.17	72	653
15,609	3W	200	521845	415482	7.5	<0.5	62	36	33,050	1,109	34	70	219	0.26	93	956
15,610	3W	300	521910	415554	6.7	<0.5	51	30	28,100	891	27	55	167	0.20	92	906
15,611	4W	0	521468	415636	7.7	<0.5	67	37	33,350	1,103	33	74	238	0.28	101	973
15,612	4W	100	521537	415718	6.6	<0.5	46	28	28,100	871	27	53	176	0.19	75	844
15,613	4W	300	521675	415864	7.0	<0.5	60	36	32,600	1,086	30	68	211	0.27	99	962
15,614	5W	0	521160	415760	8.5	<0.5	79	42	37,800	1,050	37	85	263	0.34	120	1,112
15,615	5W	100	521218	415824	7.8	<0.5	76	43	33,100	1,014	36	84	227	0.29	113	1,090
15,616	5W	300	521354	415981	7.7	<0.5	58	37	34,300	1,181	33	62	198	0.21	104	972
15,617	6W	0	520563	416329	7.4	<0.5	67	39	35,100	1,194	34	77	230	0.26	96	854
15,618	6W	100	520634	416403	9.4	<0.5	80	53	36,550	1,055	42	117	270	0.48	81	726
15,619	6W	300	520776	416564	10.5	<0.5	116	73	46,250	1,497	54	156	364	0.50	113	1,086
15,620	1E	0	522250	414907	9.7	<0.5	90	89	37,900	772	42	112	301	0.47	123	1,146
15,621	1E	100	522308	414989	5.4	<0.5	53	31	30,400	1,000	30	59	211	0.24	80	838
15,622	1E	300	522414	415158	4.8	<0.5	42	28	24,700	758	26	44	149	0.15	62	594

Table 6.1 : Sub-tidal Sediment Data for the Old SCM Outfall - Page 1 (of 2).

Sample Number	Site	Code	NGR East	NGR North	V.M. %	Cd mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	Hg mg/kg	V mg/kg	Ti mg/kg
15,623	2E	0	522435	414808	6.7	<0.5	95	50	34,550	680	40	107	259	0.32	140	1,260
15,624	2E	100	522470	414858	5.1	<0.5	34	21	27,500	882	34	28	138	0.07	44	193
15,625	2E	300	522598	415030	6.5	<0.5	72	38	35,400	1,033	33	76	229	0.23	111	1,053
15,626	3E	0	522623	414610	8.8	<0.5	98	52	42,300	838	43	110	247	0.41	157	1,274
15,627	3E	50	522651	414657	8.7	<0.5	68	46	37,500	830	38	180	237	0.29	96	798
15,628	3E	100	522676	414696	6.2	<0.5	42	25	33,450	527	45	24	107	0.05	44	37
15,629	3E	200	522731	414783	5.8	<0.5	57	30	35,000	821	42	44	187	0.16	83	428
15,630	3E	300	522784	414866	6.5	<0.5	50	34	30,950	1,119	31	52	174	0.27	92	774
15,631	4E	0	522957	414399	8.3	<0.5	93	52	38,850	808	41	109	278	0.49	133	1,276
15,632	4E	100	523022	414477	8.7	<0.5	42	39	31,300	1,552	52	37	194	0.28	62	399
15,633	4E	300	523128	414634	8.2	<0.5	90	51	44,750	1,097	39	97	303	0.33	147	1,438
15,634	5E	0	523380	414082	6.0	<0.5	58	32	32,200	846	31	58	237	0.18	83	647
15,635	5E	100	523427	414178	7.7	<0.5	85	51	43,400	822	39	100	300	0.35	118	1,024
15,636	5E	300	523555	414328	9.0	<0.5	97	53	45,000	1,155	45	120	307	0.34	135	1,205
MEAN :					7.6		67	41	34,732	965	36	78	225	0.28	98	892
15,735	CL	24	538010	411686	7.0	<0.5	49	31	33,200	757	30	61	184	0.26	71	710
15,736	CL	29	532148	416001	8.5	<0.5	67	38	43,300	1,624	36	80	241	0.31	88	729
15,737	CL	N33	529700	411400	8.2	<0.5	66	43	38,550	674	36	87	228	0.37	79	749
15,738	CP	0	523984	413743	9.1	<0.5	86	46	47,450	1,108	35	95	307	0.40	131	1,205
15,739	CP	100	524041	413824	7.1	<0.5	63	37	35,850	743	31	71	230	0.34	102	1,132
15,740	CP	300	524154	413985	7.6	<0.5	79	43	42,000	1,035	36	87	235	0.39	129	1,340

Table 6.1 : Sub-tidal Sediment Data for the Old SCM Outfall - Page 2 (of 2).

Sample Number	Site	Code	NGR East	NGR North	V.M. %	Cd mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	Hg mg/kg	V mg/kg	Ti mg/kg
Outfall	0	0	525881	412468												
15,663	1W	0	525788	412490	7.2	< 0.5	42	31	27,900	535	26	47	171	0.20	65	762
15,664	1W	100	525840	412576	7.1	< 0.5	53	32	31,250	528	28	60	193	0.29	85	1,055
15,665	1W	300	525953	412742	6.7	< 0.5	64	34	35,300	750	30	66	247	0.25	105	1,091
15,666	2W	0	525622	412593	6.5	< 0.5	65	41	34,250	562	31	84	226	0.37	92	1,221
15,667	2W	100	525674	412673	10.5	< 0.5	79	41	42,000	1,027	40	92	294	0.35	112	1,015
15,668	2W	300	525798	412844	9.7	< 0.5	89	46	41,750	938	39	102	268	0.39	127	1,160
15,669	3W	0	525397	412768	8.4	< 0.5	85	49	38,450	756	37	105	274	0.52	130	1,514
15,670	3W	50	525425	412810	8.6	< 0.5	77	49	38,950	696	40	105	268	0.44	96	1,190
15,671	3W	100	525451	412851	7.9	< 0.5	78	47	37,100	944	37	94	327	0.35	108	1,080
15,672	3W	200	525510	412943	7.1	< 0.5	63	40	32,450	878	31	75	259	0.30	87	942
15,673	3W	300	525561	413016	8.6	< 0.5	66	41	32,350	750	35	84	223	0.35	89	937
15,674	4W	0	525037	413052	9.0	< 0.5	78	42	34,700	618	36	90	259	0.45	119	1,215
15,675	4W	100	525093	413140	8.8	< 0.5	103	49	44,550	810	41	109	272	0.49	188	1,927
15,676	4W	300	525223	413308	10.0	< 0.5	91	48	42,300	1,072	41	105	266	0.42	138	1,256
15,677	5W	0	524608	413314	7.7	< 0.5	77	42	37,350	797	37	85	232	0.34	119	1,118
15,678	5W	100	524665	413400	7.7	< 0.5	79	43	38,400	1,053	38	89	249	0.34	100	833
15,679	5W	300	524774	413570	8.3	< 0.5	76	77	35,050	940	33	94	236	0.36	94	732
15,680	1E	0	525998	412433	5.3	< 0.5	63	34	38,600	452	29	71	191	0.67	103	1,490
15,681	1E	100	526029	412525	5.7	< 0.5	48	32	27,650	524	26	63	185	0.30	72	897
15,682	1E	300	526097	412721	5.8	< 0.5	63	35	32,500	810	29	68	235	0.27	96	882
15,683	2E	0	526230	412380	5.1	< 0.5	49	36	29,550	440	27	79	192	0.35	78	1,290
15,684	2E	100	526270	412471	6.8	< 0.5	72	40	35,850	876	32	85	286	0.41	108	1,084

Table 6.2 : Sub-tidal Sediment Data for Old Tioxide Outfall - Page 1 (of 2).

Sample Number	Site	Code	NGR East	NGR North	V.M. %	Cd mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	Hg mg/kg	V mg/kg	Ti mg/kg
15,685	2E	300	526342	412658	8.3	< 0.5	66	51	26,900	825	32	105	233	0.44	112	423
15,686	3E	0	526498	412206	7.1	< 0.5	80	51	42,000	764	41	110	291	0.49	102	1,396
15,687	3E	50	526511	412256	7.0	< 0.5	61	45	33,100	532	34	94	240	0.40	84	1,397
15,688	3E	100	526524	412306	9.8	< 0.5	95	50	41,450	738	38	105	291	0.43	146	1,509
15,689	3E	200	526555	412398	9.0	< 0.5	88	46	40,150	675	39	100	299	0.42	125	1,173
15,690	3E	300	526604	412490	9.3	< 0.5	82	60	35,000	947	39	129	267	0.51	72	477
15,691	4E	0	526834	412064	7.4	< 0.5	62	40	35,150	797	36	76	199	0.30	94	1,143
15,692	4E	100	526861	412166	8.4	< 0.5	104	90	38,550	687	48	163	361	1.23	88	1,225
15,693	4E	300	526945	412341	8.7	< 0.5	87	46	41,650	825	40	100	269	0.41	115	978
15,694	5E	0	527300	411920	9.0	< 0.5	73	44	38,150	852	38	91	214	0.37	102	1,125
15,695	5E	100	527340	412010	9.1	< 0.5	87	48	41,350	836	40	108	261	0.44	119	1,218
15,696	5E	300	527420	412190	9.8	< 0.5	85	46	43,050	830	40	101	275	0.38	115	1,045
15,697	6E	0	528038	411769	8.8	< 0.5	87	51	44,300	1,147	42	102	364	0.41	129	1,252
15,698	6E	100	528081	411863	8.7	< 0.5	77	64	39,900	993	41	104	292	0.44	93	832
15,699	6E	300	528160	412038	9.3	< 0.5	92	57	42,200	994	48	133	421	0.61	114	910
MEAN :					8.1	< 0.5	76	47	37,313	796	36	95	263	0.42	107	1,112
15,735	CL	24	538010	411686	7.0	< 0.5	49	31	33,200	757	30	61	184	0.26	71	710
15,736	CL	29	532148	416001	8.5	< 0.5	67	38	43,300	1,624	36	80	241	0.31	88	729
15,737	CL	N33	529700	411400	8.2	< 0.5	66	43	38,550	674	36	87	228	0.37	79	749
15,738	CP	0	523984	413743	9.1	< 0.5	86	46	47,450	1,108	35	95	307	0.40	131	1,205
15,739	CP	100	524041	413824	7.1	< 0.5	63	37	35,850	743	31	71	230	0.34	102	1,132
15,740	CP	300	524154	413985	7.6	< 0.5	79	43	42,000	1,035	36	87	235	0.39	129	1,340

Table 6.2 : Sub-tidal Sediment Data for Old Tioxide Outfall - Page 2 (of 2).

Sample Number	Site	Code	NGR East	NGR North	V.M. %	Cd mg/l	Cr mg/l	Cu mg/l	Fe mg/l	Mn mg/l	Ni mg/l	Pb mg/l	Zn mg/l	Hg mg/l	V mg/l	Tl mg/l
SCM	0	0	522169	414958												
15,762	CP	MS	523775	413450	9.3	< 0.5	68	46	34,400	1,173	30	85	275	0.32	105	937
15,763	CP	LS	523863	413538	10.6	< 0.5	68	39	36,350	926	35	85	234	0.32	95	816
15,764	1W	MS	522050	414975	8.3	< 0.5	77	42	40,050	939	32	77	333	0.31	145	1,388
15,765	1W	LS	522050	414950	10	< 0.5	84	44	37,750	1,054	35	88	327	0.33	139	1,304
15,766	2W	MS	521900	415125	8.1	< 0.5	40	19	25,250	256	37	19	134	0.06	54	98
15,767	2W	LS	521913	415113	8.3	< 0.5	83	49	38,400	851	35	85	308	0.42	143	1,465
15,768	3W	MS	521675	415288	8.4	< 0.5	83	47	38,800	1,001	32	79	370	0.33	152	1,590
15,769	3W	LS	521713	415325	10.6	< 0.5	89	43	38,900	970	39	103	280	0.34	127	960
15,770	4W	LS	521400	415550	6.3	< 0.5	43	26	28,850	493	34	38	175	0.15	64	482
15,771	5W	MS	521100	415688	9	< 0.5	95	45	35,500	759	39	84	240	0.41	175	1,561
15,772	5W	LS	521138	415725	9.1	< 0.5	67	50	31,800	826	39	80	226	0.36	83	1,186
15,773	6W	MS	520463	416175	10.6	< 0.5	76	45	38,100	1,195	36	82	316	0.3	113	1,013
15,774	6W	LS	520475	416238	8.1	< 0.5	62	37	31,450	829	31	59	228	0.25	94	961
15,775	2E	LS	522375	414725	8	< 0.5	67	37	30,900	616	33	68	210	0.26	74	806
15,776	3E	MS	522575	414475	8.7	< 0.5	79	46	41,100	1,045	34	87	303	0.29	140	1,452
15,777	3E	LS	522550	414500	8.1	< 0.5	67	35	29,050	548	32	67	173	0.26	115	1,131
15,778	4E	MS	522850	414238	8.8	< 0.5	72	41	36,250	910	33	81	283	0.28	120	1,070
15,779	4E	LS	522875	414288	6.9	< 0.5	34	20	28,250	533	30	27	131	0.07	47	224
15,780	5E	LS	523288	413988	10.4	< 0.5	68	40	35,700	829	34	848	222	0.28	95	903

TABLE 6.3 : Inter-tidal Sediment Data for the <90 um Fraction around the Old SCM Outfall. July - 1989.

Sample Number	Site	Code	NGR East	NGR North	V.M. %	Cd mg/l	Cr mg/l	Cu mg/l	Fe mg/l	Mn mg/l	Ni mg/l	Pb mg/l	Zn mg/l	Hg mg/l	V mg/l	Ti mg/l
Tioxide	0	0	525881	412468												
15,742	1W	MS	525625	412175	10.2	< 0.5	91	67	47,700	822	42	107	352	0.43	140	1,389
15,743	1W	LS	525763	412425	9.5	< 0.5	69	48	41,050	1,112	35	88	292	0.41	112	1,190
15,744	2W	MS	525425	412300	10.8	< 0.5	77	110	40,650	675	37	96	293	0.42	113	1,124
15,745	2W	LS	525588	412513	8.9	< 0.5	64	47	39,300	732	35	78	307	0.38	102	1,168
15,746	3W	MS	525175	412413	10.3	< 0.5	79	68	44,400	1,036	37	92	319	0.4	134	1,393
15,747	3W	LS	525350	412663	7.9	< 0.5	69	47	37,800	543	35	97	253	0.48	102	1,419
15,748	4W	MS	524788	412675	11.5	< 0.5	83	55	45,200	1,336	39	103	333	0.43	138	1,507
15,749	4W	LS	524913	412863	10.1	< 0.5	77	50	42,300	891	36	90	361	0.39	129	1,465
15,750	5W	MS	524400	412975	11	< 0.5	66	45	36,050	1,131	33	83	279	0.36	109	1,140
15,751	5W	LS	524513	413125	7.2	< 0.5	54	35	31,250	609	29	68	224	0.31	98	1,396
15,752	1E	MS	525800	412050	8.6	< 0.5	72	57	39,600	714	35	88	315	0.37	122	1,237
15,753	1E	LS	525938	412300	6.5	< 0.5	73	46	37,450	638	35	92	243	0.46	128	1,677
15,754	2E	MS	526038	411888	7.7	< 0.5	71	54	37,950	743	36	83	307	0.37	118	1,247
15,755	2E	LS	526175	412175	7.4	< 0.5	68	42	36,400	745	36	87	217	0.35	100	1,143
15,756	3E	MS	526350	411713	8.2	< 0.5	68	48	37,550	879	34	85	290	0.35	114	1,220
15,757	3E	LS	526450	412025	7.7	< 0.5	51	38	31,000	743	32	70	191	0.3	62	727
15,758	4E	MS	526663	411538	10.3	< 0.5	75	47	42,600	882	36	86	308	0.36	123	1,333
15,759	4E	LS	526775	411800	10.2	< 0.5	72	44	35,450	806	37	98	258	0.4	87	818
15,760	5E	MS	527050	411312	10.1	< 0.5	75	42	37,800	915	34	81	287	0.33	108	892
15,761	5E	LS	527200	411650	10.6	< 0.5	76	55	35,900	827	41	115	287	0.45	76	741
15,762	CP	MS	523775	413450	9.3	< 0.5	68	46	34,400	1,173	30	85	275	0.32	105	937
15,763	CP	LS	523863	413538	10.6	< 0.5	68	39	36,350	926	35	85	234	0.32	95	816

TABLE 6.4 : <u>Inter-tidal Sediment Data for the <90 um Fraction around the Old Tioxide Outfall.</u> <u>July - 1989.</u>

FIGURE 6.1 : Iron in Sub-tidal Sediments around the Old SCM Outfall.

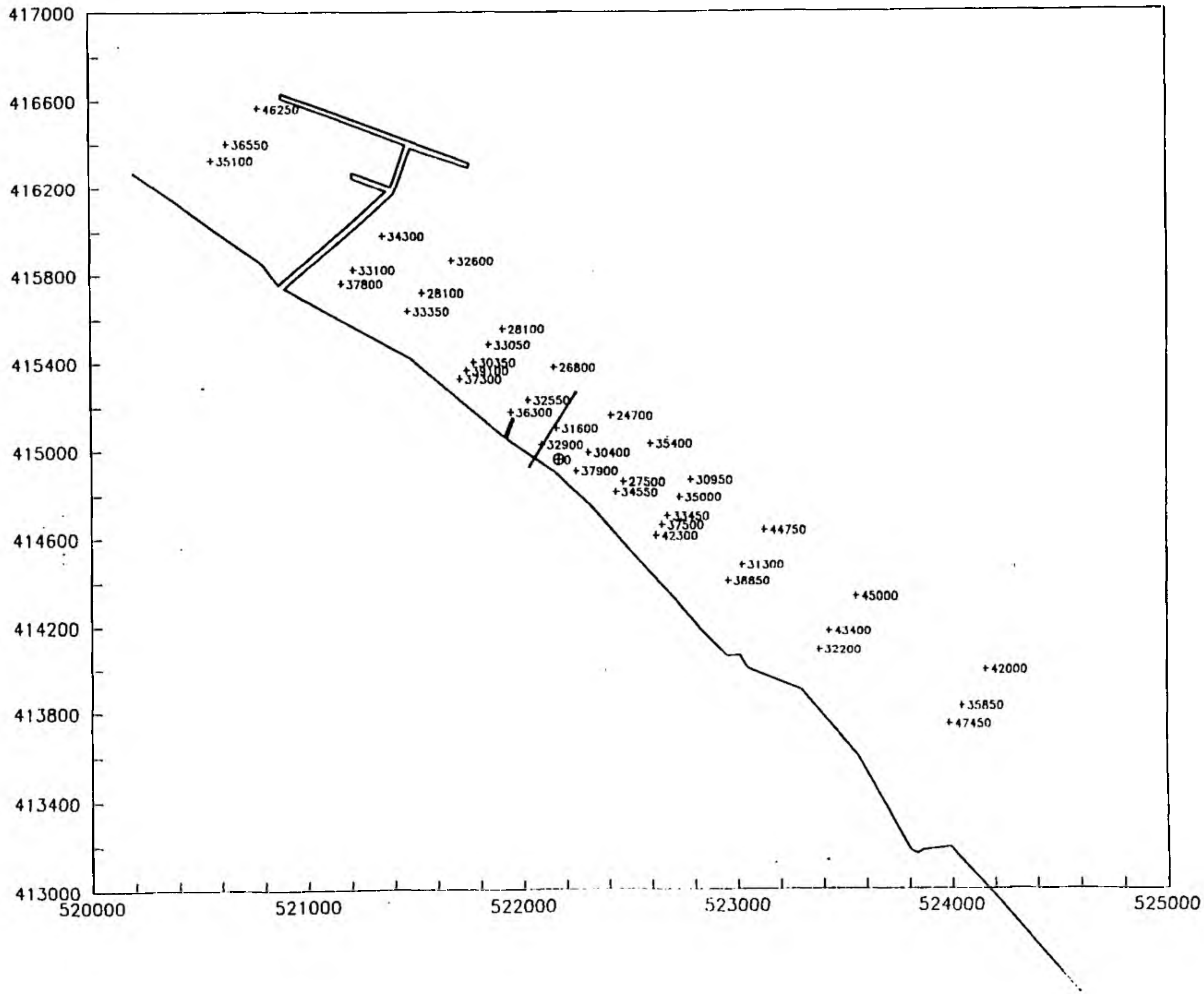


FIGURE 6.2 : Iron in Sub-tidal Sediments around the Old Tioxide Outfall.

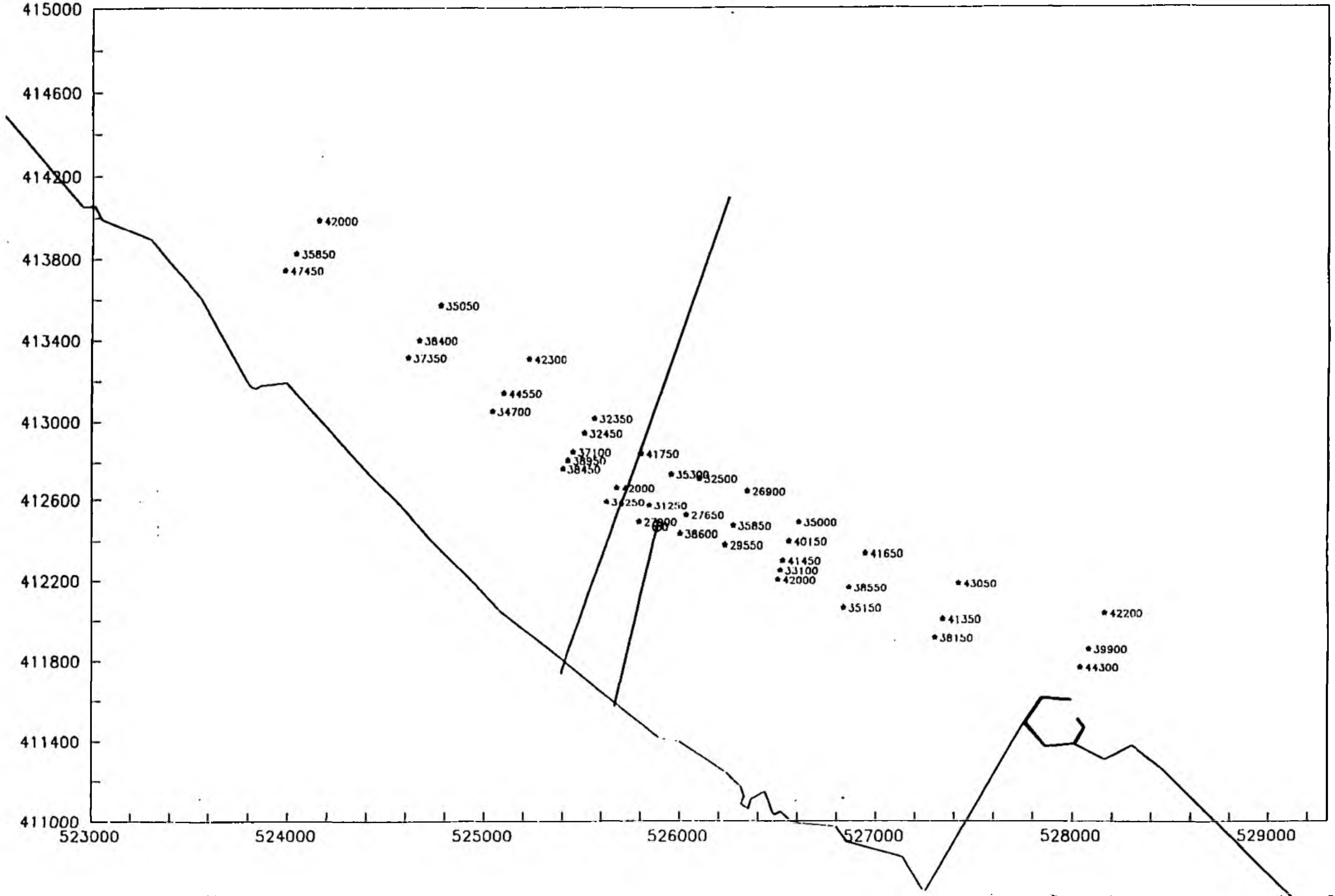


FIGURE 6.3 : Titanium in Sub-tidal Sediments around the Old SCM Outfall.

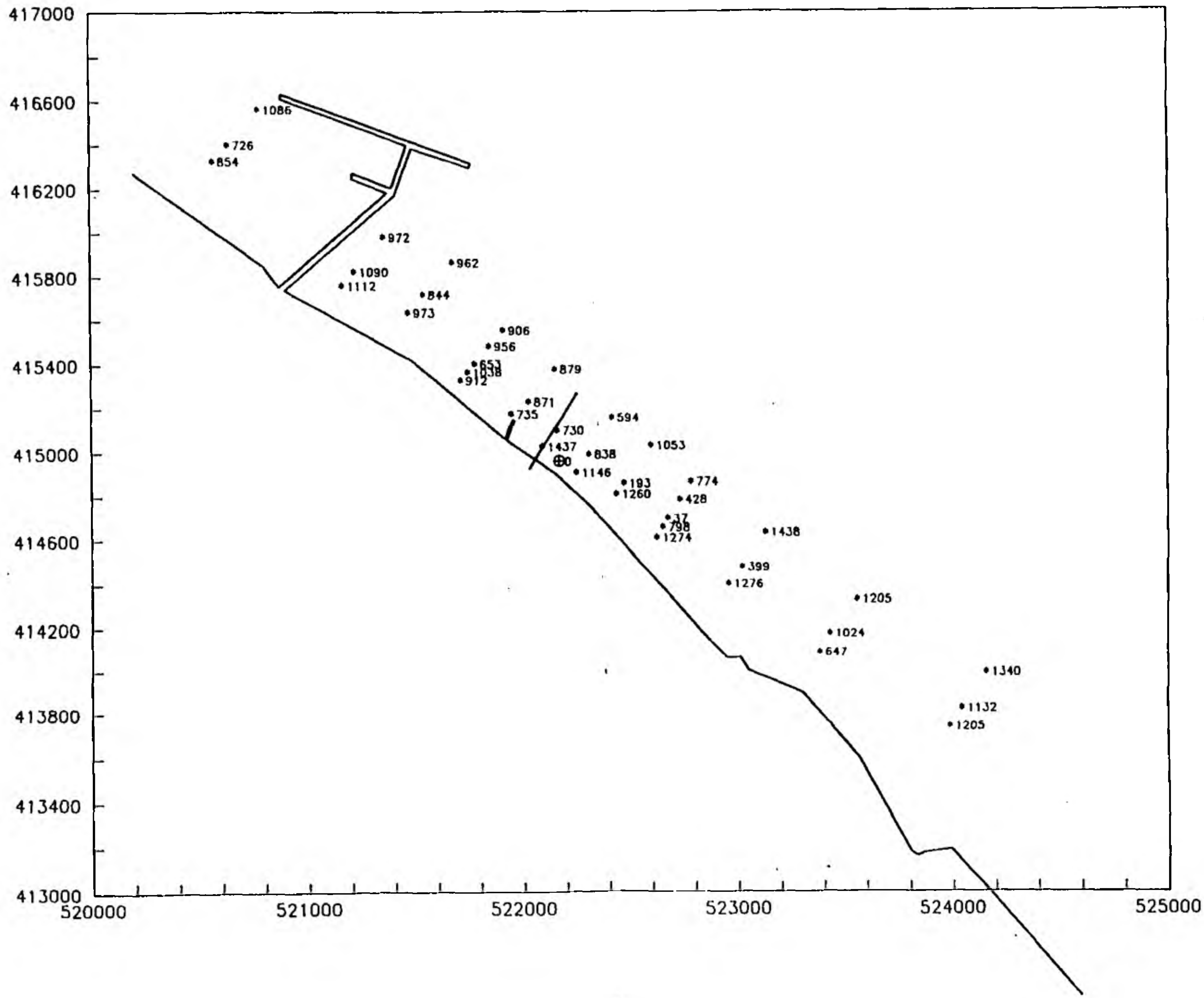


FIGURE 6.4 : Titanium in Sub-tidal Sediments around the Old Tioxide Outfall.

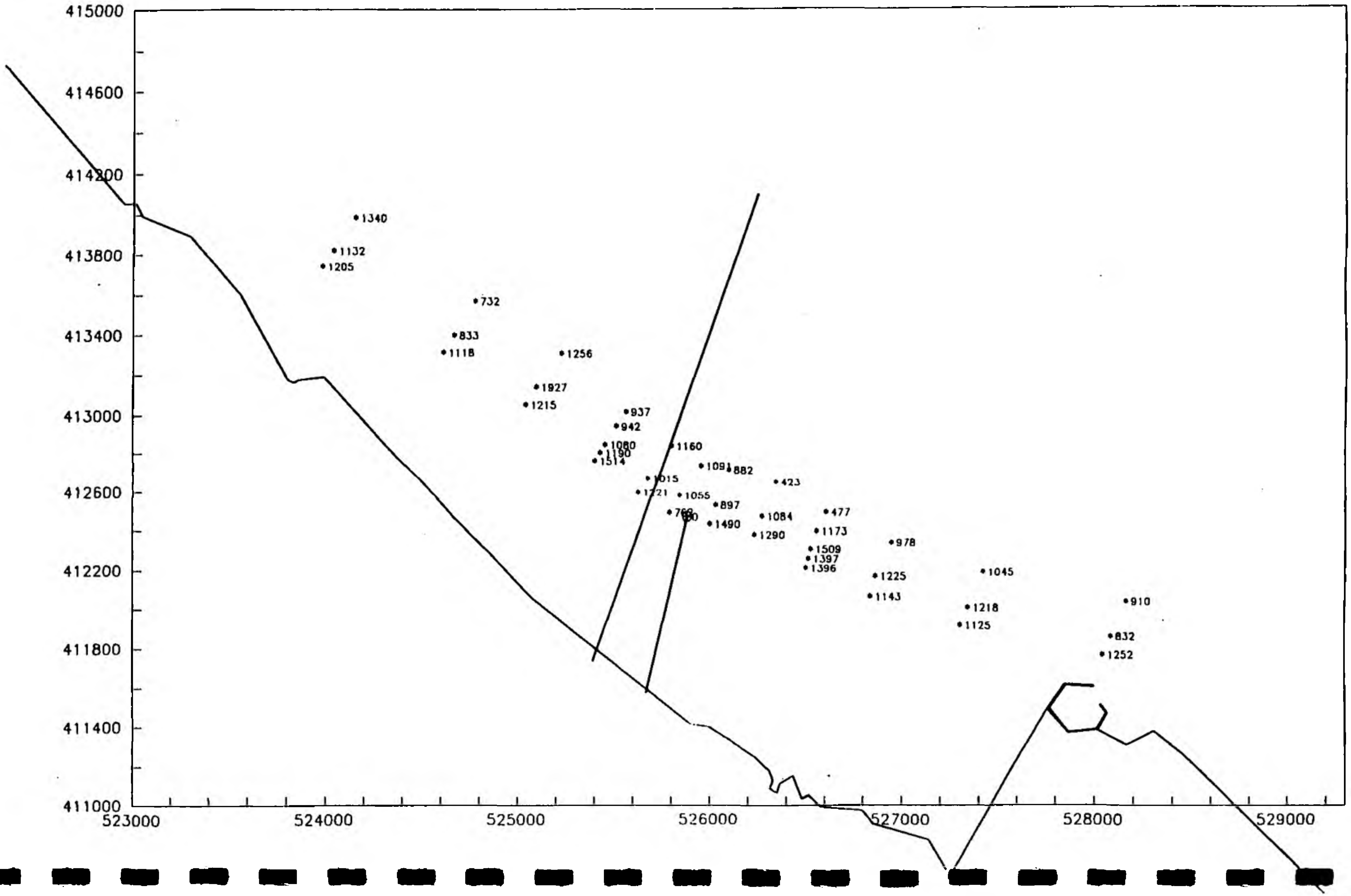


FIGURE 6.5 : Iron in Inter-tidal Sediments around the Old SCM Outfall.

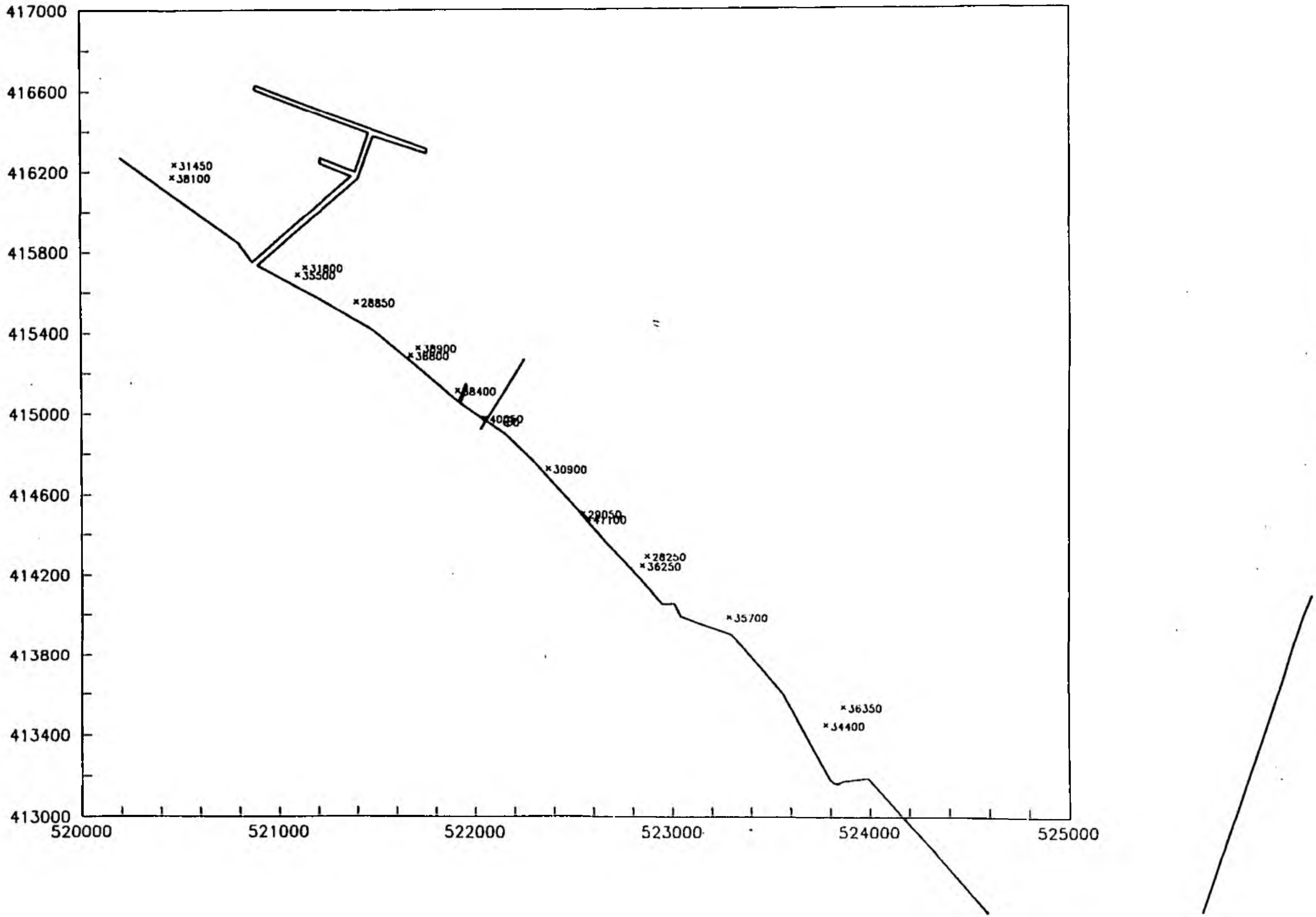


FIGURE 6.6 : Iron in Inter-tidal Sediments around the Old Tioxide Outfall.

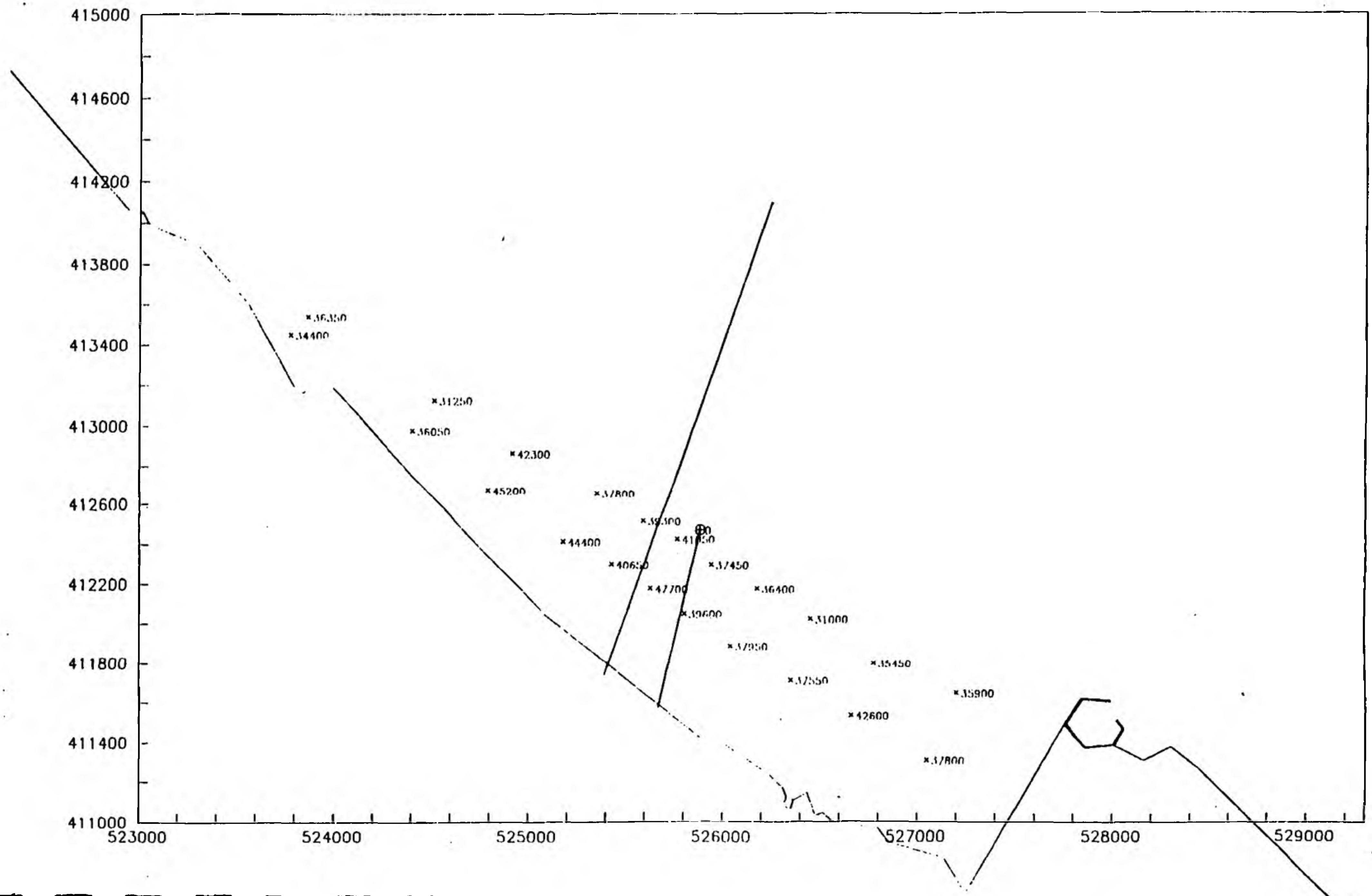


FIGURE 6.7 : Titanium in Inter-tidal Sediments around the Old SCM Outfall.

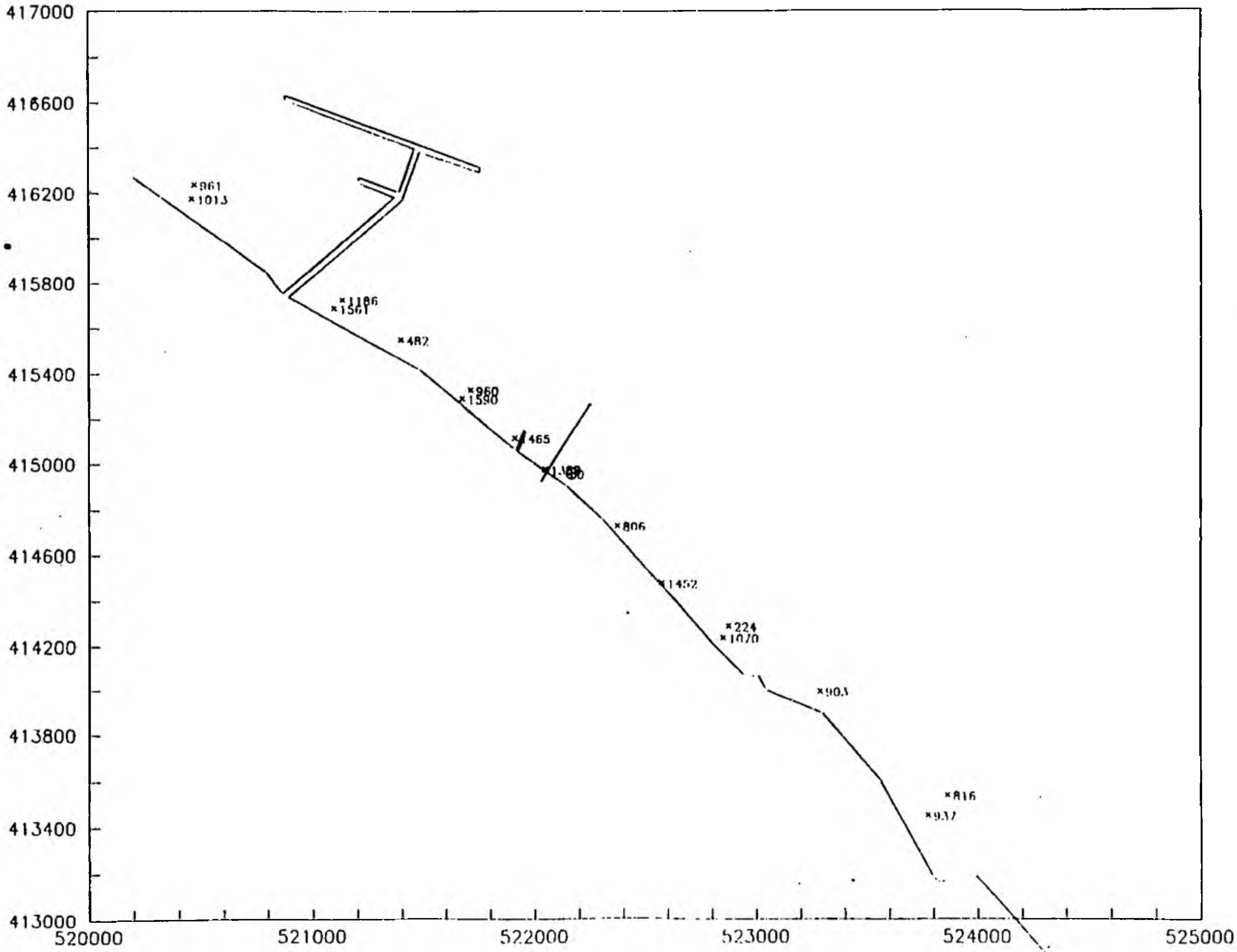
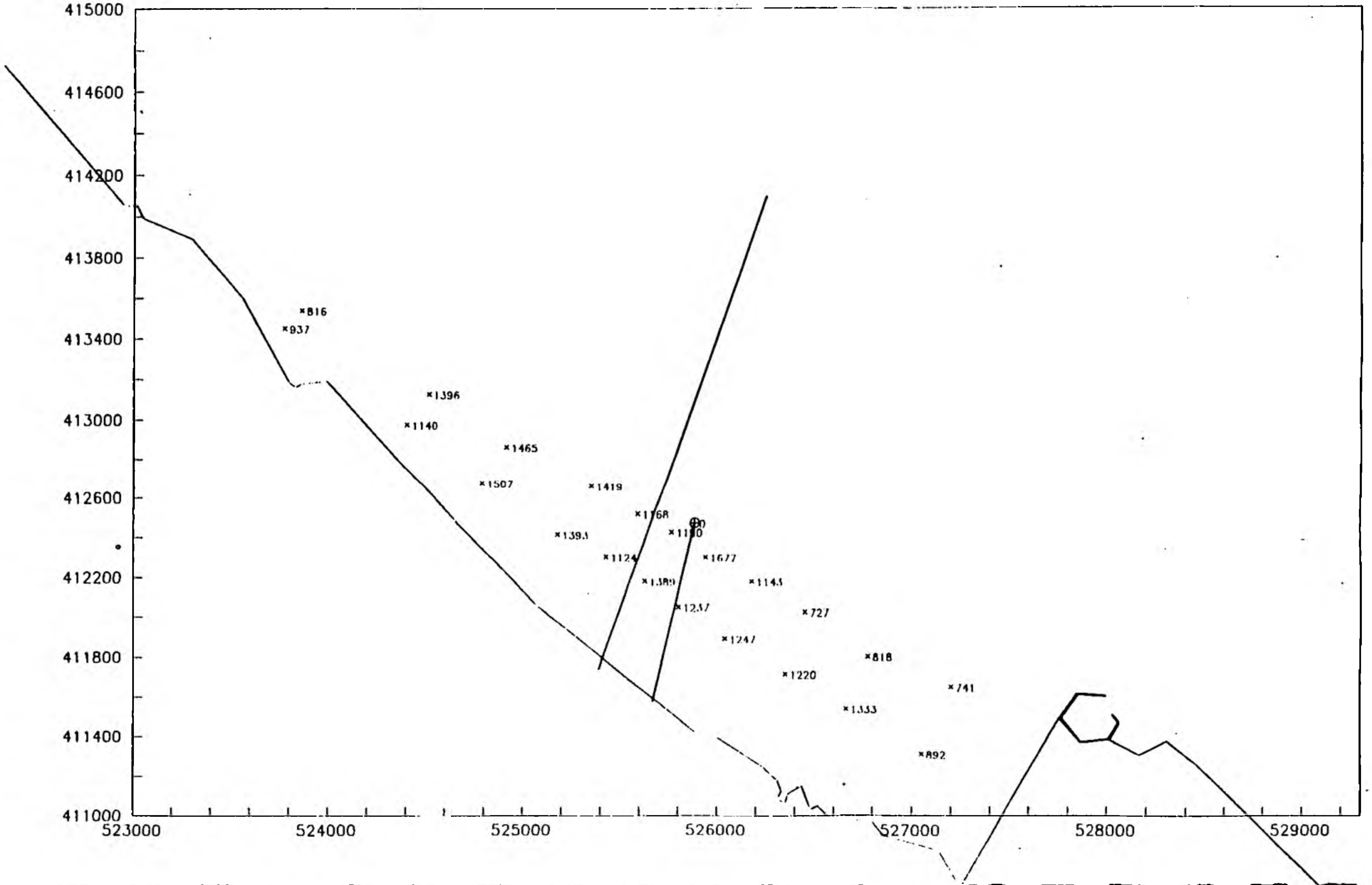


FIGURE 6.8 : Titanium in Inter-tidal Sediments around the Old Tioxide Outfall.



APPENDIX 7

BIOLOGICAL RESULTS AROUND THE NEW OUTFALLS.

7.1 Introduction.

The results of the pre-discharge surveys in July 1988 and the main post-discharge surveys in July 1989 around both the new SCM and Tioxide outfalls are summarised in Tables 7.1.I & II and 7.1.V & VI respectively. Data is based on the combined results from three replicates with the exception of the results for the SCM outfall in July 1989 which are based only on two replicates; three grab samples were collected but results for the third replicate were not available at the time of preparing this report. The number of individuals has however been adjusted to represent the abundance/0.3m². Additional mini-grid surveys were also conducted in September 1988 (immediately after the commissioning of the discharges) and March 1989. Results from these surveys are presented (for information only) in Tables 7.1.III & IV and 7.1.VII & VIII.

The assessment of any impact of the new discharges is based on the results from the July surveys. Both the March and September surveys were excluded from the analysis to remove the complicating factor of seasonal variations and the associated problems of distinguishing these from changes related to the outfall. The September results were excluded for the additional reason that this survey was probably conducted too soon after the commissioning of the new outfall to detect any changes.

7.2 SCM Outfall.

7.2.1 Survey Area - Physical Characteristics.

The new SCM outfall extends approximately 250m further offshore than the old discharge point into an area with a water depth of 3m at lowest astronomical tide. In general, water depths vary little over the survey area.

The bed sediment type is uniform throughout most of the survey area and is characteristically a firm clay material with varying amounts of wood and peat fragments incorporated within the clay. The only exception to this are two sites located on the inshore line (3W.250S and 3E.250S) where sediments were a soft mud and a soft mud/chemical sand complex respectively (Figures 7.2.1 A & B). Superimposed on these diagrams are observations of iron-staining and the presence of unprocessed ilmenite ore. The occurrence of iron crusts at sites on the south eastern sector of the grid in 1988 (1W.250S, 1E.250S, 1E.100S and 3E.100S) was not unexpected as the discharge point of the old outfall corresponds approximately to the 1E.250S position. Comparison of Figure 7.2.1A with Figure 7.2.1B shows that the extent of iron deposition was considerably reduced in 1989, and was now confined to sites adjacent to the new outfall (1W.0, 3W.0). The percentage silt/clay values at each site (for the two surveys) are displayed in Figures 7.2.2 A & B. The silt/clay values were very high for both surveys, with a mean value of 76% for 1988 and 89% in 1989.

7.2.2 Results and Discussion.

Cluster analysis was conducted separately on the July 1988 and July 1989 results and also on the combined data set from both surveys. Only the results of the combined analysis are presented as there was little difference between the patterns produced by either approach. A graphical presentation (dendogram) of the results is shown in Figure 7.2.3. At a similarity value of 60.5% four distinct cluster groups can be identified. For ease of interpretation and presentation, the cluster groups are plotted on to schematic maps of the survey area (Figures 7.2.4 A & B). The characteristics of the main groups and sub-groups are summarised in Table 7.2.I.

All three control sites (24, 29 and N33) link only with the majority of sites at very low levels of similarity (29%) reflecting the fact that the species composition at these stations was very different from most of the sites in the survey area. In the past it has been difficult to select suitable control sites for this area since it is unique both in terms of sediment and faunal type within the estuary. The control stations are therefore included only for reference purposes as a measure of the general conditions and changes in 'clean' areas of the estuary.

The few remaining sites which also cluster independently (group 2) are located at the south east and south west corners of the survey area where sediments are a mixture of soft muds and chemical sand. The fauna in these areas was very different from the majority of sites in the survey area consisting mainly of tubificid oligochaetes. Of the two unclassified sites, 3E.250S (1989) had particularly low numbers of species and individuals, and 3W.100N (1988) contained a mixture of species common to both group 2 and groups 3 & 4.

The majority of sites are contained within groups 3 and 4 and are characterised by a fairly uniform and unique association of animals. In particular the spionid polychaete Polydora spp was found in considerable densities in the clay type sediments typical of the area. Sub-dominant species such as Pygospio elegans, Arenicola marina and enchytraeid oligochaetes were also found in high densities, although these were not comparable to those attained by Polydora.

Most of the July 1988 sites cluster together within group 3 whereas in 1989 the same stations clustered separately in group 4. This almost complete separation of the two surveys initially suggested that there may be an impact of the new discharge on a large part of the receiving area. However, closer inspection of the data shows that the differences between the two years are not consistent with this interpretation. The average number of species was noticeably higher in 1989 (group 4 :22) than in 1988 (group 3 :14) and the mean abundance was substantially elevated from 6,323 to 41,191 (Table 7.2.I). Comparison of the 1988 and 1989 plots of species variety and abundance (Figures 7.2.5 A & B, 7.2.6 A & B) further illustrates the differences between the two surveys by showing that these changes were evident throughout most of the survey area and not confined to a few individual sites. Abundances were higher in 1989 by a factor of ten at some sites, mainly due to increases in the abundance of the dominant species Polydora spp which accounted for 84% of the total number of specimens in 1989. The magnitude of the increase in density of this species is clearly shown by comparison of Figures 7.2.7 A & B. In communities dominated by relatively short-lived species such as Polydora, year to year variability, although predictable in its occurrence, is unpredictable in its nature and extent. The combination of a mild winter and exceptional summer (1989) probably contributed to the very successful recruitment of this species and the high numbers recorded in 1989.

Data from the reference stations does not show a similar increase in abundance but does reveal a rise in the average number of species from 16 to 25 (Table 7.2.II). This is consistent with that noted above and may indicate a general improvement in conditions throughout the estuary.

Examination of the 1989 cluster pattern in Figure 7.2.4B, reveals that three sites located along the zero line (1E.0, 1W.0 and 3W.0) were separated from the majority of stations into sub-group 4b. Both the average number of species and individuals were lower than at stations in sub-group 4a (Table 7.2.I). This depression in species variety and abundance may indicate an impact close to the new outfall.

Comparison of Figures 7.2.4 A & B illustrates a difference in cluster patterns between 1988 and 1989. In 1988 the three sites considered above, clustered with two offshore stations to form a sub-group (3c) which had a higher species complement and generally elevated abundances compared to inshore sites, sub-group 3a (Table 7.2.I). The species variety at the inshore sites in 1988 may well have been depressed, as these stations are located in the vicinity of the old discharge point. In 1989 these inshore stations grouped with the offshore stations in sub-group 4a (Figure 7.2.4B) as a result of a considerable increase in the number of species and individuals at the inshore sites. These changes may be related to a recovery of the inshore fauna following the closure of the old outfall and a subsequent improvement in conditions.

The three stations comprising sub-group 4b identified above as possibly impacted also exhibited changes between 1988 and 1989, although, with the exception of 1W.0, the general rise in abundance was not so pronounced as at other comparable sites on the grid (Table 7.2.II). Similarly, species variety did not increase as much at these sites (excluding 1W.0) as elsewhere on the grid and in the estuary as a whole. This coupled with the fact that the cluster patterns have changed quite noticeably between the two years would indicate that the discharge is affecting the benthos by suppressing species variety and densities at sites close to the outfall.

Whilst not included in the present analysis, a similar but smaller impact was also recognisable from the results of the March survey. Site 1E.0 was separated from the majority of stations using the same similarity value (60.5%) (Figure 7.2.8). Both the number of species and individuals were noticeably lower at this site than at other comparable stations in the survey area (Table 7.1.IV).

It may therefore be concluded that an impact exists around the new SCM outfall which extends along the zero line from at least 100m east of the discharge to 500m to the west. The affected area may extend beyond the western boundary of the grid, but this can not be determined from the present survey. Sampling of the full baseline grid (Appendix 2) would be necessary to accurately delimit the impact and to clarify the observations made here. Unlike the previous assessment of the old discharge there is no evidence of any serious damage to the benthos and only a weak or very weak effect is apparent in areas adjacent to the new outfall.

7.3 Tioxide Outfall.

7.3.1 The Survey Area-Physical Characteristics.

As can be seen from Figure 7.3.1 , there is a range of depths in the survey area. The most inshore sample stations are in shallow water of about 3m whilst the most offshore stations are in deeper water of about 9m and a "shelf" of intermediate depth runs in a roughly diagonal line from 3W.0 to 3E.150S. The new discharge is sited at a depth of approximately 7m.

The sediment throughout the survey area is predominantly soft mud with varying proportions of stones and gravel at some stations (Figures 7.3.2A and 7.3.2B). These figures also show an area on the 1E transect where the substratum comprises a mixture of chemical sand/soft mud. The presence of chemical sand can be regarded as visual evidence of the effluent. Inshore and upstream of the outfall the sediment was particularly stoney, with the percentage of silt/clay as low as 44.3% (Figures 7.3.3A and 7.3.3B).

7.3.2 Results and Discussion.

As for the SCM outfall, the combined data sets from July 1988 and July 1989 were analysed by cluster analysis and the outcome is presented in dendrogram form in Figure 7.3.4. Seven cluster groups were identified at a similarity level of 60.5%, leaving five sites unclassified. The cluster patterns are illustrated on schematic maps of the area (Figures 7.3.5A and 7.3.5B) and the characteristics of the cluster groups and unassigned stations are summarised in Table 7.3.I.

Control stations 24 and 29 did not cluster with the main groups (Figure 7.3.4). As concluded in the 1984 report this should not be taken to infer that the entire survey area is affected but merely reflects the different species composition at these distant sites. The difficulties in selecting suitable control sites are discussed in Appendix 4 and the data are primarily included for reference purposes as an indication of general conditions within the estuary.

In July 1989 there were two areas of impoverished fauna. One area comprised the four deeper water stations (recognised as cluster group 4 in Figure 7.3.5B) which supported an average of 152 individuals and 14 species per station. A more impoverished area is apparent on the 3E transect line at stations 100N, 0 and 150S, as can be seen from Figures 7.3.6B and 7.3.7B. These three stations supported an average of only 27 individuals and 8 species per site. In comparison, the other stations on the mini-grid in 1989 supported an average of 2,206 individuals and 20 species.

The existence of two impoverished areas in the vicinity of the outfall suggests the possibility of a sizeable impact of the effluent on the receiving area. However, examination of other data suggests that the sparse nature of the fauna was probably not related to the discharge. The 1988 cluster patterns (Figure 7.3.5A) do not identify any areas of impoverishment, although examination of Figures 7.3.6A and 7.3.7A show that in 1988 the corresponding stations already supported relatively low abundances and species variety. Results from the impoverished sites in 1989 are compared with results from the same sites in 1988 in Table 7.3.II. It can be seen that at both areas there was a reduction in the number of individuals in 1989, especially on the 3E transect, although species variety remained broadly constant.

The two impoverished areas were 'emphasised' in 1989 as all other stations showed an increased in abundance or species variety or both. The increases in abundance and species variety at the other sites in 1989 probably resulted from the expansion of the heterogeneous mud/stone/gravel bed as shown by comparing Figures 7.3.2A and 7.3.2B. This habitat is occupied by different species, often in greater abundances, to the more typically estuarine soft mud substratum.

The paucity of the fauna in offshore areas is almost certainly due to the mobile nature of the sediments in the deeper water channel, which represents a relatively hostile environment for benthic infauna. But since the same physical conditions can be assumed to have existed in 1988, tidal 'scour' can not explain the reduction in abundance in 1989. It is therefore possible that the changes relate to a weak impact of the effluent on the benthos. Species variety was not affected (Table 7.3.II) which may suggest that the impact is mediated by adverse effects on water-borne larvae, reducing the recruitment of juveniles into the receiving area but such considerations must be regarded as highly speculative.

The impoverishment on the 3E transect in 1989 was probably not related to the discharge. It is significant that the substratum at these stations comprised extremely fluid mud in 1989, which does not provide a stable habitat for the fauna. The substratum did not exhibit the same fluidity in 1988 but it was very soft, which may account for the lower than average abundances in 1988. An effect of the effluent on the 3E transect (500m from the discharge) also seems unlikely in view of the absence of any detectable impact at stations closer to the discharge. The station at 1E.0 in 1989 supported one of the highest recorded abundances (Figure 7.3.6B) although it was unclassified mainly because it contained a high proportion of the oligochaete Tubificoides swirencoides. It was in fact 58% similar to the same site in 1988 (Table 7.3.III). Furthermore, the highest recorded abundance in 1989 was at a site adjacent to the discharge, 1W.100N (Figure 7.3.6B). Although the site is slightly offshore from the predicted track of the effluent this observation may constitute further evidence that any effect of the discharge is extremely limited.

Evidently the survey area is comprised of relatively complex and variable habitats, with the offshore stations subject to physical disturbances associated with the channel systems. Observations on the nature of the estuary bed demonstrate appreciable changes in the physical environment from one year to the next and these have resulted in associated changes in the composition of the fauna.

Bearing in mind these complicating factors, it is difficult to assign any areas of impact to the new discharge, although the possibility of a very weak effect on sites north east of the outfall cannot be completely excluded.

7.4 Comparison of the effects of the new outfalls.

There is a considerable difference between the receiving areas of the new Tioxide and SCM discharges both in terms of the physical characteristics and resident fauna. The Tioxide outfall discharges much further offshore at the edge of the main channel, where the fauna is naturally impoverished due to the mobility of sediments caused by the strong tidal currents. As a consequence of the relatively low densities of animals present in this area, it was anticipated that difficulties would arise in determining any superimposed effect of the effluent on the benthos. In contrast, the new SCM outfall discharges much closer inshore into an area which typically supports extremely high numbers of organisms and where it is therefore more likely that any impact could be detected.

The results of both post-discharge surveys demonstrate that neither outfall was causing severe damage to the benthos. As expected there was no obvious area of effect around the Tioxide outfall, although compared to the pre-discharge survey a reduction in abundance was noted at more remote sites to the north east. Since no impact was evident at stations closer to the discharge, it is difficult to ascribe this decrease to an effect of the effluent. The fauna of this area is naturally very sparse and the decline in abundance is probably within scale of natural fluctuations for this type of environment. However, the fact than an increase in abundance was evident at other sites does not eliminate the possibility of a very weak effect at sites north east of the outfall.

Sites immediately adjacent to the SCM outfall did appear to show a weak or very weak effect. The average number of species and individuals was lower at these stations compared to similar sites elsewhere on the grid.

Unlike the 1984 assessment of the old TiO_2 industry outfalls, areas of severe effect were not apparent around either of the new outfalls. The results of the survey of the Tioxide discharge were inconclusive since it proved difficult to establish whether there were any affected areas, whereas a weak impact was identified close to the SCM discharge.

Table 7.1.1 SCM New Outfall, July 1988 - Biological Results

SPECIES / SITE	3W 100N	3W 0	3W 100S	3W 250S	1W 100N	1W 0	1W 100S	1W 250S	1E 100N	1E 0	1E 100S	1E 250S	3E 100N	3E 0	3E 100S	3E 250S	C.24	C.29	N.33
Turbellaria									6										
Nemertinea	4	62	12		31		226		80	21	56		147	8		38			
Pholoe inornata	4				14		36		29		7								
Anaitides maculata	49	70	89		205	147	185	19	338	79	153	128	270	203	99		5		
Eumida sanguinea									6										
Eteone longa	4	1	23	1	16	8	23	27	24	24	22	20	7	8	24	2	12		
Autolytus sp											7								
Proceraea cornuta	64	38			53	24	7		15	17	6								
Nereis diversicolor			7		8				6		6	36							
N. longissima					14				6	7	13						1		
Nephtys hombergii				39												5	53	66	20
Nephtys sp (juv)				3		7							7			1	56	21	130
Sphaerodoridium minutum	8				7	15		8	37	13			22	7	75		6	1	3
Scoloplos armiger									6								140	1	38
Aricidea minuta			13												24	2	36		23
Scolelepis squamata																	8		
Spiophanes bombyx																	49		
Spio martinensis																	3		
Pygospio elegans	24	68	143	19	227	363	310	698	277	1004	246	1060	114	118	75	24	169		97
Polydora spp	989	3141	2600	9	7549	4452	4659	2121	9786	4096	6884	6449	6917	6085	3042	3	3	5	1
Streblospio shrubsolii	8	18	28	1	6	7									51				66
Tharyx spp	4			1											75		2977	176	1271
Capitella capitata							14				7	89	8			77			6
Mediomastus fragilis																	4		9
Arenicola marina		235	92	2	177	178	260	286	257	306	551	580	133	96	273	7			
Ampharete grubei		6	11		6	16			23	7							2		1
Amphitrite johnstoni		6			14	43	66			30	122		14	8	75			1	
Tubificoides pseudogaster																	1		
T. benedeni	78	31	67	504	42	37	8	31	17			38		27	51	71			11
T. swirencoides	39	3	25	1815	6				6			6				198	6	40	337
Enchytraeidae	24	24	39		162	20	29	8	360	66	7	104	243	112	51	2			
Cyathura carinata		6	28		8				15	24				6					
Leptomysis gracilis				1															
Schistomysis sp				1															
Neomysis integer																2			
Mysidacea										7									
Halacaridae	8	2			50		23		22	13					24				
Anoplodactylus pygmaeus					6									7					
Retusa obtusa																	26		
Nucula sp																	3		
Mytilidae sp (juv)		6			6												13		1
Abra alba																	13		
Macoma balthica				3												4	6	4	3
Number of species	14	16	14	12	21	13	13	8	20	16	14	10	11	12	13	13	22	10	16
Number of individuals	1307	3717	3177	2399	8607	5317	5846	3398	11315	5714	8089	8510	7982	6685	3939	436	3592	316	2017

Abundance per $0.3m^2$

Table 7.1.II SCM New Outfall, July 1989 - Biological Results

SITE	3W	3W	3W	3W	1W	1W	1W	1W	1E	1E	1E	1E	3E	3E	3E	3E	C.24	C.29	N.32
ECIES	100N	0	100S	250S	100N	0	100S	250S	100N	0	100S	250S	100N	0	100S	250S			
ertinea	48	48	5	8	15	146	87	97	74	189	126	78	71	128	69				1
oice inornata			20		24	2	78	32	8		53	54	6		29				
itides maculata	300	128	198	2	660	264	389	234	662	191	294	375	194	195	137	2	15	149	45
uda sanguinea	15	17	48		83	38	234	17	170	5	275	122	105	11	75				
eone longa	411	341	587	12	459	101	602	1430	491	149	495	1296	503	822	270	2	7	4	25
usyllis sp											2								
tolytus sp								17			65								6
xceraea cornuta	93	2	50	2	513	59	639	201	431	3	1595	444	261		168		1		1
reis diversicolor	3	3	33		36	5	29	50	15	2	5	45	12	8	8			1	1
. longissima	2		11		72	2	89		3	3	6	6		6				82	9
reis sp (juv)	177	35	368		497	44	711	256	713	111	488	410	570	221	162				
phtys hombergii	2			27	3		2	56			2						51	4	28
phtys cirrosa							6												
ephtys sp (juv)	14		2	3	72		3	39	8		8	2		3	14	3	37	22	21
haerodoridium minutum	5		15		23		11	188	99		84	218	69	69	16			1	4
oloplos armiger																	135	26	10
icidea minuta																	13		28
evinsenia gracilis																	13		
iophanes bombyx																	153	1	2
io martinensis																	1		
gospio elegans	1029	996	1578	99	2183	4773	3327	3737	2435	5115	3171	9615	4289	6482	1023		96	7	1323
Polydora spp	24947	15429	34757	15	58818	37941	47874	16503	58365	17642	47591	43308	38096	34236	9707	3		79	161
Streblospio shrubsolii	23	14	26		2		3								30		1		41
aryx spp				3		2	2	104			35	50			33		252	134	1152
pitella capitata			5		2		15	23			2	4				45	6	1	
ediomastus fragilis																	3		9
renicola marina	50	327	228	2	182	683	266	1136	608	563	1017	1031	362	686	116				1
ctinaria koreni																			1
pharete grubei	2							3	8		2	5							
phitrite johnstoni	45	5	147		176	35	180	300	146	17	497	155	128	77	69		2	3	11
ubificoides pseudogaster																			1
benedeni	143	35	21	152	26	17	3	29	3		33	27		2	20		1		16
swirencoides	3			783		2		50		18		2			36		230	2	164
chytraeidae	260		3		233	288		2	671	293	227	123	401	407					
olfingiidae									2										
astylis bradyi						2													
yathura carinata			9		2	9	3		3	6	3			29	18				
ammarus zaddachi											4								
ylus swammerdami																		1	3
opedos monacanthus																		1	
aprella sp												2							
lacaridae	41	11	78		131	252	218	36	398	30	947	57	167	104	159				1
oplodactylus pygmaeus					2		2	2			2	2					1		13
etusa obtusa																	3		
isthobranchia							1				1				1				
cula sp																	1		
Mytilidae sp (juv)	2					17			3	3	5			2			1	2	2
Cerastoderma edule				5													1	27	1
etricola pholadiformis																			1
ra alba																	13		
bra sp (juv)																			
Macoma balthica	15	2	5		20		55	23	9	2	35	8	51	21	17		12	4	1
sis ensis																		1	
a truncata																		4	2
umber of species	21	14	20	12	22	20	24	23	21	17	28	24	15	18	21	5	24	21	31
umber of individuals	27630	17393	38194	1113	64234	44682	54829	24563	65725	24342	57068	57439	45285	43509	12179	55	1049	556	3062

Abundance per $0.3m^2$

Table 7.1.III SCM New Outfall, September 1988 - Biological Results

SITE SPECIES	3W 100N	3W 0	3W 100S	3W 250S	1W 100N	1W 0	1W 100S	1W 250S	1E 100N	1E 0	1E 100S	1E 250S	3E 100N	3E 0	3E 100S	3E 250S	24	29	N.33
Nemertinea		8		2		8				21				13	4				
Gattyana cirrosa						6													
Pholoe inornata						6									5		1		
Anaitides maculata	40	130	78		136	40	62	24	190	71	54	58	1136	130	24	1			9
Eumida sanguinea	24						10		23						2				
Eteone longa												6		7	4		2	1	9
Microphthalmus sp																			1
Proceraea cornuta						35			8					20	4				
Nereis diversicolor	8		8				17				22	6	7		1	1			
N. longissima	1	8	7			14		7	8		7			8	3				
Nephtys caeca															1				
Nephtys hombergii				28											1	1	50	47	8
Nephtys sp (juv)			7	11				8					22		4	3	40	56	14
Sphaerodoridium minutum	7	8	8	1	7	46		8	46	7			57	48	4		1		
Scoloplos armiger															16		238	1	103
Aricidea minuta	8														39		11		71
Levinsenia gracilis																	23		
Spiophanes bombyx																	21		
Pygospio elegans	102	326	108	1	114	1040	384	490	240	587	202	475	88	266	46		30		492
Polydora spp	1814	8525	3946	7	6951	4172	3521	5348	7430	5531	5654	6366	5612	4679	729	6		5	2
Streblospio shrubsolii	22		290			6		15							113				106
Tharyx spp															2		260	372	1798
Scalibregma inflatum																		1	
Capitella capitata	8					8		24			7	41	15		4	1			20
Mediomastus fragilis																			40
Arenicola marina	43	211	60		51	443	171	79	203	197	523	278	434	210	72	1			1
Ampharete grubei	2								8	7			7	7			2		3
Amphitrite johnstoni		34				83			39	49	171	6	15	22	38				
Tubificoides pseudogaster																	1		28
T. benedeni	52	8	42	856		14	7	95	8		16	89	53	21	56	90		2	15
T. swirencoides		16	37	995			10					9			62	92	282	60	54
Enchytraeidae	20	233	8		235	57		7	371	48		9	144	20	16				
Cyathura carinata		8	29		23	22	58		32	7	15				6				
Gammarus sp												9							
Caprella sp																	1		
Schistomysis spiritus																	1		
S. kervillei																		2	
Mesopodopsis slabberi																	6		
Halacaridae		115	5		8	97	10		23	28	15		7	7	7				1
Anoplodactylus pygmaeus					8		10				22		7		1				
Pycnogonum littorale															1				
Retusa obtusa																	6		
Hydrobia ulvae																	1		
Nucula turgida																	3		
Mytilidae sp (juv)		8	7		7	6			8								1		
Petricola pholadiformis																			2
Abra alba																	19		
Macoma balthica	8			2		8									1	3	7	4	1
Number of species	15	14	15	9	10	19	11	11	15	11	12	12	14	14	29	10	23	11	22
Number of individuals	2159	9648	4640	1905	7540	6111	4260	6105	8637	6553	6708	7352	7604	5458	1268	199	1007	532	2781

Abundance per $0.3m^2$

Table 7.1.IV SCM New Outfall, March 1989 - Biological Results

SITE	3W 100N	3W 0	3W 100S	3W 250S	1W 100N	1W 0	1W 100S	1W 250S	1E 100N	1E 0	1E 100S	1E 250S	3E 100N	3E 0	3E 100S	3E 250S	24	29	N.33
..CIES																			
..ertinea	11	73	7		39	42	6	93	79	23	20	20	44	113		38			
..loe inornata									8										1
..itides maculata	33	25	18		47	18	157	72	95		22	26	104	6	27	2			2
..ida sanguinea									8										
..one longa				1			9					14					4		1
..gone sp																		1	
..cerarea cornuta							6	8			20	6	7		1				
..eis diversicolor									8			13							
..longissima					39	6					7		23	7				3	
..htys caeca																			
..htys hombergii			4	6											2	3	153	10	59
..htys sp (juv)				19															
..haerodoridium minutum	17	24	7		125	6	66	351	72		126	125	275	37	60	1	4	3	5
..oloplos armiger								8							5		196		7
..cidea minuta				1											44		11		46
..insenia gracilis																	28		
..ophanes bombyx																	31		
..oospio elegans	71	424	29	8	289	701	289	2406	205	864	540	493	317	424	36	3	2		152
..ydora spp	737	1871	829	5	6583	1696	2851	4122	3782	327	4250	4263	2913	1764	492	3			
..eblospio shrubsolii	35	7	29			18	6	40			7		7		28	1			154
..ryx spp															3		79	611	646
..itella capitata												126				26			2
..iomastus fragilis																	1		6
..nicola marina	48	432	45	1	149	207	283	319	64	131	283	271	68	167	6	1	1		
..harete grubei															1				4
..phitrite johnstoni	28	89	7	2	79	24	180	559	63	8	573	391	298	98	72				
..bificoides benedeni	203	46	15	82	79	38-		128	103		7	154	37	28	34	14			13
..spirencoides	24		6	432		6		15				13			6	1	639	3	258
..hytraeidae					24				31		30		105	79	4	2			
..athura carinata		18					40			14	29		8		1				
..noria lignorum											7								
..marus sp		7	6			7	8								2				
..histomysis sp					8														
..omysis integer																	1		
..acaridae					8				8		13		7		1				1
..tusa obtusa																	22		
..ula sp																	3	1	
..ilidae sp (juv)					16				8								3		1
..a prismatica																	2		
.. alba																	?		
..coma balthica															1		34		
..valve juv													16				55		1
..ber of species	10	11	11	9	13	12	12	12	14	6	15	13	15	10	20	12	19	7	18
..ber of individuals	1207	3016	1002	557	7485	2765	3901	8121	4534	1367	5934	5915	4229	2723	826	95	1276	632	1359

Abundance per $0.3m^2$

Table 7.1.V Tioxide New Outfall

	3W 200N	3W 100N	3W 0	3W 150S	3W 300S	1W 200N	1W 100N	1W 0
Nemetean sp.								
Gattyana cirrosa				13	12			
Pholoe inornata		3		12	36			3
Anaitides maculata				27	42			
Eumida sanguinea	1			4				
Eteone longa				24	42			
Sphaerosyllis hystrix				2				
Autolytus spp				4				2
Proceraea spp		2		26	18			7
Nereis diversicolor				1	3			
Nereis longissima				2	3			
Nephtys caeca					6			2
Nephtys hombergii	2	2	5	5	9	3	6	6
Nephtys spp juv	5	7	2	16	36	16	50	2
Sphaerodorum gracilis				1				
Sphaerodoridium minutum	1	2	3	14	39		2	3
Scoloplos armiger	1	4	3	163	168	32	31	30
Aricidea minuta		4		11	9		3	13
Scolelepis squamata								
Spiophanes bombyx				1	3	1		
Spio martinensis						1		
Pygospio elegans	1	2	1	468	279	1		3
Polydora spp	1	4	1	163	351			7
Streblospio shrubsolii					15			1
Tharyx spp	2	4	11	19	69	33	25	4
Capitella capitata	1				12	2	1	6
Mediomastus fragilis		4		121	75			
Arenicola marina				3	33	1	1	1
Ampharete grubei		2		11	42			
Amphitrite johnstoni		2		86	57		1	1
Tubificoides pseudogaster								1
Tubificoides benedeni	4	15	8	7	6	7	10	5
Tubificoides swirencoides	6	319	131	10	39	11	2651	226
Gammarus sp.							1	
Corophium volutator								
Caprellidae								1
Neomysis integer			1					
Halcaridae sp.							1	
Anoplodactylus pygmaeus				4	3			1
Pycnogonum littorale				1			1	
Retusa obtusa								
Nucula turgida								
Mytilidae	3	8		5	9	4	4	7
Abra alba								
Macoma balthica					3	6	1	
Number of species	11	16	9	28	27	13	16	21
Number of individuals	29	385	164	1214	1419	119	2790	332

Abundance per $0.3m^2$

- July 1988 - Biological Results

1W 150S	1W 300S	1E 200N	1E 100N	1E 0	1E 150S	1E 300S	3E 200N	3E 100N	3E 0	3E 150S	3E 300S	C.24	C.29	N.33
1	1													
												5		
	2					1					1	12		
								1						
2	2		1						1					
												1		
	2													
4	12	3	2	5	5	10	5	1	3	3	12	53	66	20
18	185	113	16	18	25	70	230	22	10	11	86	56	21	130
8	15			5	2	5	1		2		3	6	1	3
45	293	78	16	28	48	261	161	21	31	14	59	140	1	38
11	47	4		4	6	4	1				4	36		23
												8		
	1						6					49		
1			2	1								3		
4	27	2	1	7	2	5	3	2			1	169		97
3	1			1	2	1	2	1	5		5	3	5	1
	5	1		2			2				30			66
39	405	84	19	81	11	69	139	20	37	13	176	2977	176	1271
3	8	4	5	2	3	8	2	1	1					6
	10											4		9
1		6	1		1	4			1					
	5					1						2		1
													1	
			1											
												1		
5	7	15	3	25	2	7	6	2	10	7	5			11
258	244	20	8	2671	15	53	103	10	187	99	502	6	40	337
							1							
											1			
			3						2	1	6			
			3											
1	6													
												26		
												3		
4	6	9	7	4	3	6	5	9	5	4	1	13		1
												13		
	3	3	3	3			4				1	6	4	3
16	21	12	16	14	13	15	15	10	12	7	15	22	10	16
408	1287	342	93	2859	126	507	671	90	294	152	893	3592	316	2017

[redacted]

	3W 200N	3W 100N	3W 0	3W 150S	3W 300S	1W 200N	1W 100N	1W 0	1W 150S	1W 300S	1E 200N	1E 100N	1E 0	1E 150S	1E 300S	3E 200N	3E 100N	3E 0	3E 150S	3E 300S	C.24	C.29	N.33
Nemetean sp.					2																		
Gattyana cirrosa				2	4																		
Pholoe inornata				7	23																1		
Anaitides maculata				35	38																		9
Eumida sanguinea				2	8																		
Eteone longa				25	18						1				2					1	2		9
Microphthalamus																							1
Sphaerosyllis hystrix																							
Autolytus spp				2	1														2				
Proceraea spp					1		1				1			1	1								
Nereis diversicolor				1																			
Nereis virens																							
Nereis longissima				6	4																		
Nephtys caeca				2	3																		
Nephtys hombergii	2	7	2		6	5	5	5	2	10	2	3	4	3	7	6	3	3	8	17	50	36	8
Nephtys cirrosa																							
Nephtys spp juv	19	40	3	11	53	28	26	1	63	114	26	17	24	71	138	31	25	19	85	228	40	62	14
Sphaerodorum gracilis																							
Sphaerodoridium minutum				1	4	1		1		3	1			1					1	1	1		2
Scoloplos armiger			1	444	529	23	8		39	53	52	8	31	58	75	51	21	10	21	82	238	1	103
Aricidea minuta				5	4		2		6	7			4	3	4					17	11		71
Levensenia gracilis																					23		
Scolelepis squamata	3																						
Spiophanes bombyx													1								21		
Spio martinensis																							
Pygospio elegans			1	311	288		1		5				4	1	1	2				1	30		492
Polydora spp				29	102			3	1	1		1		1		2						6	2
Streblospio shrubsoli		6		1	2				7	7		1	2	3	3			1		67			106
Tharyx spp	7	11	.1	30	87	35	13	4	26	147	46	8	14	26	158	19	34	11	41	462	260	300	1798
Capitella capitata				1	5			2	3			1	6	1				4					20
Mediomastus fragilis				42	90						1	1	2				2			1			40
Arenicola marina				2	3			1	1		1			2	3	1							1
Sabellaria spinulosa																							
Pectinaria koreni																							
Ampharete grubei				12	44																2		3
Amphitrite johnstoni				7	19																		
Tubificoides pseudogaster																					1		28
Tubificoides benedeni	11	61	26	8	8	22	17	3	45	24	24	10	18	5	11	22	27	22	6	16		6	15
Tubificoides swirencoides	14	1572	11	11	25	11	3214	117	1104	1098	49	43	2099	58	98	40	63	208	233	1247	282	01	54
Enchytraeidae				2																			
Caprellidae																					1		
Schistomysis sp			1														7	1			1	3	
Mesopodopsis slabberi										1	31	10	16	14	11	34				5	6		
Halcaridae sp.				2	4																		
Anoplodactylus pygmaeus				3	2																		1
Pycnogonum littorale				2	4						1												
Hydrobia																1		1			1		
Retusa obtusa																					6		
Nucula turgida																					3		
Mytilidae	1		4	2	2	5						2	1		.1	1·	15	1	2	3	1		
Petricola pholadiformis																							2
Abra alba			1		1																19		
Macoma balthica	4					3	1			1	8		1			3	1	2	1	1	7		1
Number of species	7	5	9	29	30	8	9	8	11	11	13	11	15	14	13	13	9	11	9	14	23	9	22
Number of individuals	61	1697	51	1008	1384	133	3789	137	1302	1466	244	105	2228	248	513	214	198	785	400	2167	1007	496	2781

Abundance per $0.3m^2$

Table 7.1.VII **Tioxide New Outfall - March 1989**

	3W 100N	3W 50S	3W 280S	3W 400S	1W 100N	1W 0	1W 100S	1W 250S	1W 400S
Turbellarian sp.							19	5	
Gattyana cirrosa				3					
Pholoe inornata		4	1	12				1	
Anaitides maculata		1	1						
Eumida sanguinea			6						
Eteone longa		4	4	6			2		
Exogone									
Autolytus spp								1	2
Proceraea spp		1	1						
Nereis longissima			1						
Nephtys caeca			2					1	
Nephtys hombergii	2	11			8	21	4	4	22
Nephtys spp juv	1	15	2		2	14	5	23	42
Sphaerodoridium minutum		1	10	10		1	1	2	1
Scoloplos armiger	1		40	57		1	1	60	36
Aricidea minuta				3		1		6	25
Levensenia gracilis									
Spiophanes bombyx									1
Spio martinensis									
Pygospio elegans		1	152	123		1	1	4	8
Polydora spp			8	3			2		1
Streblospio shrubsoli		1	1					3	38
Tharyx spp	1	4	10	30	1	22	5	40	134
Capitella capitata						1	4	1	
Mediomastus fragilis			30	10				1	5
Arenicola marina		5	9					3	
Ampharete grubei			13	42					6
Amphitrite johnstoni		100	166	231				2	29
Tubificoides benedeni		13				55	6	14	12
Tubificoides swirencoides	4	1127	4		7	10664	77	348	694
Halcaridae sp.				11					1
Retusa sp									
Nucula sp									
Mytilidae			13	9		2	1	1	5
Abra alba									
Macoma balthica	1	2							1
Bivalve spat									
Number of species	5	14	21	14	3	10	13	18	18
Number of individuals	10	1290	502	564	10	10783	129	520	1043

Abundance per $0.3m^2$

- Biological Results

1E 100N	1E 0	1E 100S	1E 250S	1E 400S	3E 100N	3E 0	3E 100S	3E 250S	3E 400S	C.24	C.29	N.33
												1
1					1			1				2
		1										
			1							4		1
											1	
		1								11		
											3	
5	1	8	4	8	7	6	7	16	16	27	5	23
		12	23	87	9	6	4	32	106	126	5	38
4		2	1	6			3	1	1	4	3	5
1		9	40	63		1		2	6	196		7
		1	2	5		1			7	1		46
										28		
										31		
			1	1			3	1	5	2		152
			6	19		1		3	64			154
1	1	15	23	67	2	8		36	548	79	611	646
		2		1								2
										1		6
1		2	3	1			1	2				
							1		2			4
1						1						
	2	10	6	10	1	6	2	5	9			13
1	5	200	40	88	23	25	55	221	1146	639	3	258
							1					1
										22		
										3	1	
	1	1	1				1		1	3		
										9		
1		1	1	1	4	4			1	34		
										55		1
8	5	13	13	13	6	12	9	11	12	20	7	19
15	10	265	152	358	47	62	77	321	1912	1306	632	1362

Table 7.1.VIII Tinside New Outfall - July 1989 - Biological Results

	200N	100N	0	150S	300S	200N	100N	0	150S	300S	200N	100N	0	150S	300S	200N	100N	0	150S	300S	L.29	L.29	H.33
Nemertean sp.				1			1																1
Gattyana cirrosa				43	71				2	2													
Pholoe inornata				6	8		2									1							
Anaitides maculata	1	3	1	227	180		763	1	31	10	5			1	1	1			5		15	149	45
Eumida sanguinea				178	229		26		9														
Eteone longa	1		1	206	209	3	88	6	19	8	2	1	3		4			1		1	7	4	25
Microphthalamus										1													
Autolytus spp			3	3	14		3		9	4		2	3	1			2		1	2			6
Proceraea spp				68	33			1	13	10											1		1
Nereis diversicolor		1		23	13		37				1		1									1	1
Nereis longissima	1			40	243		59			2			1									82	9
Nephtys caeca				2	1																		
Nephtys hombergii	1	2	1	12	1	6	14	1	1	10	38	21	13	8	26	9		3	3	11	51	4	20
Nephtys cirrosa	1		2						2														
Sphaerodorum gracilis							1																
Nephtys spp juv		10		42	40	5	1	1	1	81	8	13		36	59	20		3	8	45	37	22	21
Sphaerodoridium minutum				8	15		9	2	2													1	1
Scoloplos armiger		5	1	123	188	6	17		14	44	2	2		34	5	3		2			135	26	10
Aricidea minuta		3	1	3	10			7	18	9				15	6			2		1	13		20
Levensenia gracilis																					13		
Scolelepis squamata				12	8					1	2			1				1		18			
Spiophanes bombyx			1	2	3	1	5		3	2	5			2		7					153	1	2
Spio martinensis				2			1		1	2	1			2							1		
Pygospio elegans	35	7	24	920	957	21	1281	31	278	153	34	2	3	7	3	63	1		1	2	96	7	1323
Polydora spp	19	17	18	1654	5506	23	5498	29	68	199	19	18	5	2	3	15			6	1		79	161
Streblospio shrubsoli		3	3	6	65	1	1	1		3	32	6	1	41	15	2				65	1		41
Tharyx spp	1			31	91	8	4		3	146	19	23	4	12	41	48		1	2	35	252	134	1152
Capitella capitata	1	1		33	82	1	91	2	4	2			2			1					6	1	
Mediomastus fragilis		1		61	81	2	14		5	8	2	1		1	3						3		9
Arenicola marina				46	72		34		3	3					1					1			1
Sabellaria spinulosa				1																			
Pectinaria koreni																							1
Ampharete grubei				51	83				3	3					1						2	3	11
Amphitrite johnstoni			1	59	109	1	17		15														
Tubificoides pseudogaster																							1
Tubificoides benedeni	1	14	59	1	9	2	17	29	2	8	3	5	7	3	3	7	3	2	1	9	1		16
Tubificoides swirencoides	5	192	14	12	20	8	2258	321	20	419	19	5	2534	89	92	30	7	11	8	303	230	2	164
Atylus swammerdami																						1	3
Dyopedus monacanthus																						1	
Mesopodopsus slabberi																							1
Halcaridae sp.				1																			
Nymphon rubrum													1										
Anoplodactylus pygmaeus					2				1	1	1				1						1		13
Pycnogonum littorale				2	1				1								1						
Retusa obtusa																					3		
Nucula turgida																					1		
Mytilidae		4		13	7	5	1	12	3	5	3	3		1	5			1	3		1	2	2
Cerastoderma edule		1	1		1	1	2	9	1						1			1			1	27	1
Petricola pholadiformis																							1
Abra alba																					13		
Macoma balthica					2	1	7							2	2	2	1			3	12	4	1
Ensis ensis																						1	
Mya truncata				3	1				1	1												4	2
Number of species	11	14	15	34	33	16	27	14	29	20	17	11	13	17	18	13	6	10	9	13	24	21	11
Number of individuals	67	244	131	1911	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Abundance per 0.3m²

TABLE 7.2.I

Summary of the Main Characteristics of each Cluster Group

SCM New Outfall

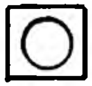
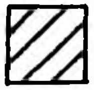
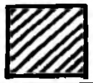
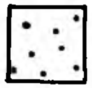
GROUP	CODE	NUMBER OF SITES	AVERAGE NUMBER OF SPECIES	AVERAGE ABUNDANCE	CHARACTERISTIC SPECIES	SEDIMENT TYPE
1		4	23	2,435	*Tharyx* spp *Pygospio elegans* *Tubificoides swirencoides*	Mud/ Sandy mud
2		3	12	1,316	*T. swirencoides* *T. benedeni*	Soft Mud
3		13	14	6,323	*Polydora* spp *P. elegans*	Clay
3a		4	11	4,756		
3b		4	13	7,126		
3c		5	17	6,934		
4		14	22	41,191	*Polydora* spp *P. elegans*	Clay
4a		11	22	44,569		
4b		3	17	28,806		

TABLE 7.2.II

Summary of Changes at Sites Around the New SCM Outfall

Site	Number of Species		Number of Individuals	
	1988	1989	1988	1989
Suspected impact sites				
1E 0	16	17	5,714	24,342
1W 0	13	20	5,317	44,682
3W 0	16	14	3,717	17,393
Average	15	17	4,916	28,806
Other Comparable Sites				
Average	14	22	6,745	44,569
Reference Sites	16	25	1,975	1,562

TABLE 7.3.1

Summary of Results and Group Characteristics

SITE	YEAR	N_I	N_S	CLUSTER GROUP	AVE. N_I	AVE. N_S	SUB-GROUP	S-G AVE. N_I	S-G AVE. N_S	DOMINANT SPECIES AND COMMENTS
N33	1989	3082	31							
1W300S	1989	1141	28							
1W150S	1989	534	29							
W100N	1989	10172	27	1	3732	30				Polydora, Pygospio, Tharyx,
3W300S	1989	8363	33	(n=8)						T. swirencoides.dominant
3W150S	1989	3931	34							Grouped on high species variety
3W300S	1988	1419	27							and large number of individuals
3W150S	1988	1214	28							
C24	1989	1049	24	2	2321	23				Tharyx dominated
C24	1988	3592	22	(n=2)						
C29	1989	556	21	U						Anaitides, Tharyx dominant.
3E300S	1989	497	13							
1E300S	1989	272	18							T. swirencoides, Tharyx, Nephtys,
1E150S	1989	278	17				3A	874	17	Scoloplos dominant. Relatively high
3E300S	1988	893	15				(n=6)			species variety
N33	1988	2017	16							
1W300S	1988	1287	21							
3E150S	1988	152	7							
3E 0	1988	294	12	3	729	14				
3W 0	1988	164	9	(n=19)						As above only single
3E100N	1988	90	10							species dominant
1E100N	1988	93	16				3B			
1W200N	1988	119	13				(n=13)	663	13	
3E200N	1988	671	15							
1E300S	1988	507	15							
1E200N	1988	342	12							
1E150S	1988	126	13							
1W150S	1988	408	16							
1E 0	1988	2859	14							
1W100N	1988	2790	16							
3E200N	1989	217	13							Pygospio, Nephtys, Polydora
1E100N	1989	100	11	4	150	14				dominated
1E200N	1989	196	17	(n=4)						
1W200N	1989	95	16							
1W 0	1989	453	14							
3W100N	1989	264	14	5	359	16				T. swirencoides dominant
1W 0	1988	332	21	(n=4)						
3W100N	1988	385	16							
C29	1988	316	10	U						Tharyx dominant
3E150S	1989	38	9	6						Very low abundance of all
3W200N	1988	29	11	(n=2)	34	10				species.
3E 0	1989	28	10	U						As above
1E 0	1989	2578	13	U						T. swirencoides dominant.
3W 0	1989	131	15	7	99	13				Pygospio, Polydora, dominated but
3W200N	1989	67	11	(n=2)						rel. low abundance
3E100N	1989	15	6	U						V. low abundance and species number

Key: U = Unclustered N_I = Number of Individuals N_S = Number of Species S-G = Sub-Group

TABLE 7.3.II

A Comparison of the Two "Impoverished Areas", Tioxide New Outfall
July 1988, July 1989

Stations	1988 Ave. N_I	1989 Ave. N_S	1988 Ave. N_I	1989 Ave. N_S
1W 200N 1E 200N 1E 100N 3E 200N	306	152	14	14
3E 100N 3E 0 3E 150	179	27	10	8
All Other Sites Combined	955	2,206	17	20

Key: N_I = Number of Individuals N_S = Number of Species

TABLE 7.3.III

Nearest Associates to Stations which were 'Unassigned' by Cluster Analysis

Station	Nearest Associate	
	Station	Similarity (%)
1E 0 89	3W 0 88	59
	3E 200N 89	59
	1E 0 88	58
3E 100N 89	3W 200N 88	41
	3E 1505 89	40
	3W 0 89	36
	3E 100N 88	36
3E 0 89	3W 200N 88	55
	3E 150S 88	50
	1E 150S 88	48
	3E 300S 89	46
	(3E 0 89)	(39)
C-29 88	3E 200N 89	63
	3E 300S 88	63
	3E 200N 88	62
	(C29 89)	(45)
C-29 89	1E 200N 89	58
	1W 200N 89	55
	3E 200N 88	54
	3E 200N 89	52
	(C29 88)	(45)

Fig 7.2.1A Sediment type based on Visual Observations - SCM New Outfall, July 1988

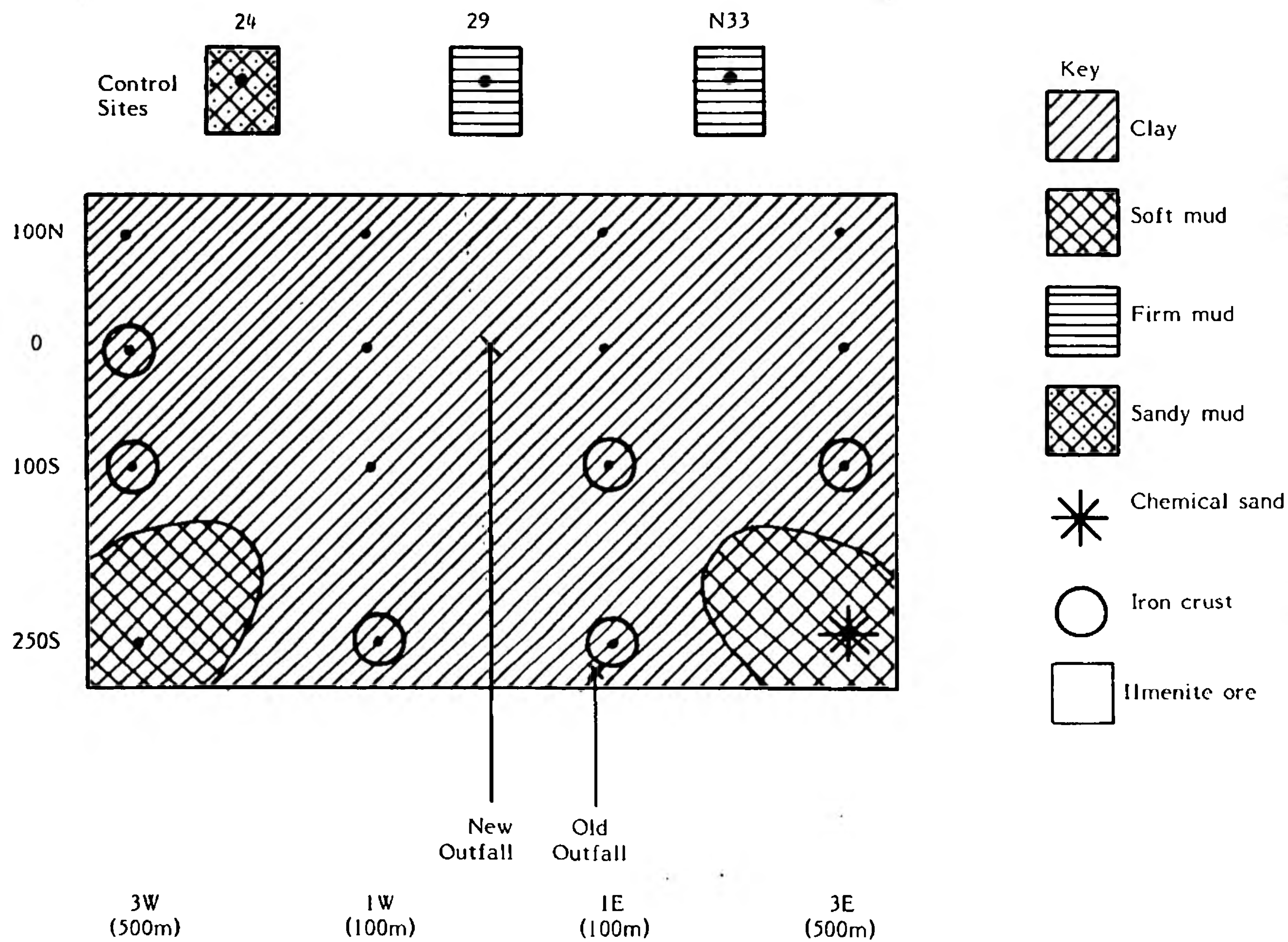
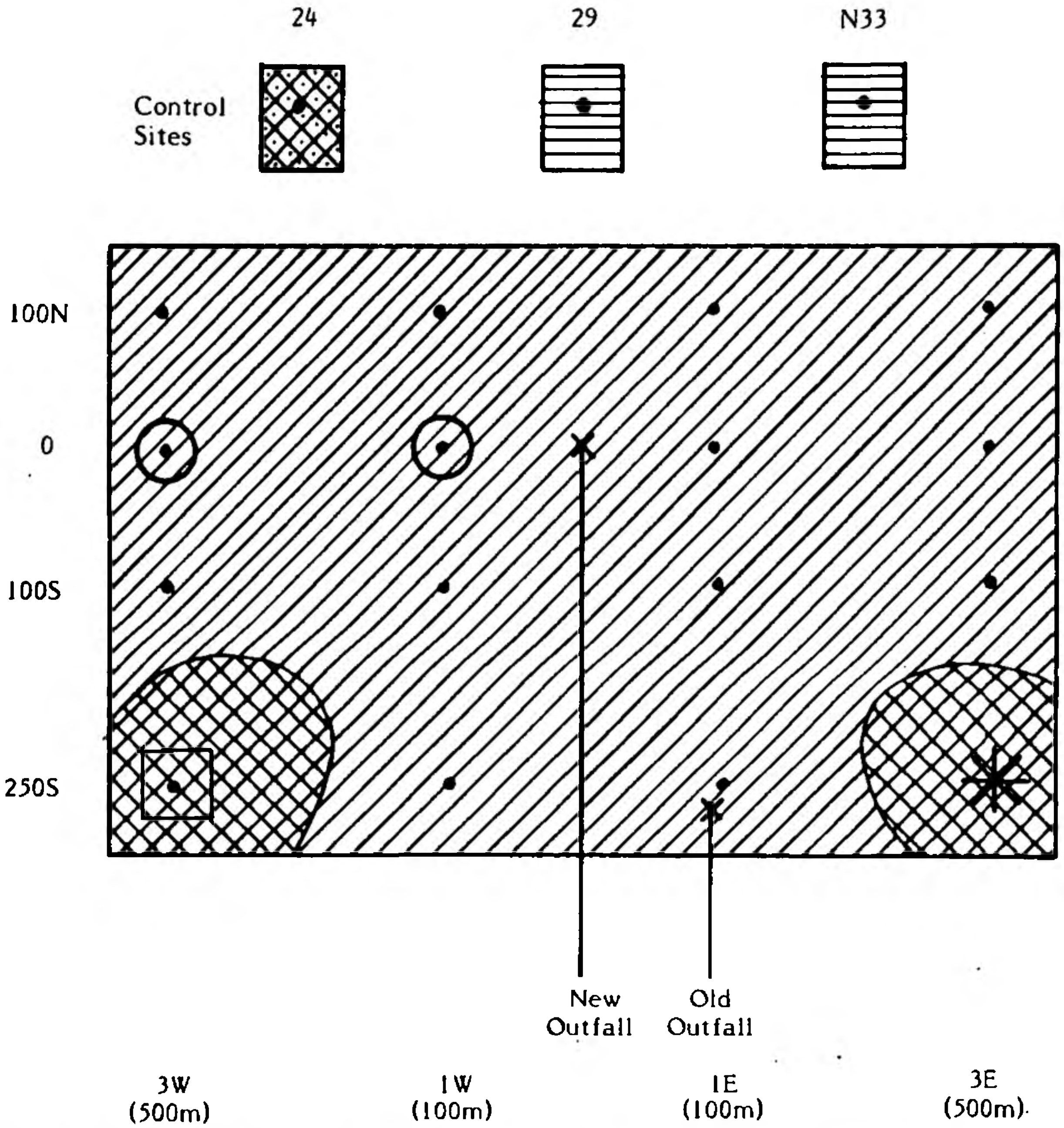


Fig. 7.2.1B Sediment type based on Visual Observations - SCM New Outfall, July 1989



Key as for Fig. 7.2.1A.

Fig. 7.2.2A Silt/Clay Content of Sediments - SCM New Outfall, July 1988

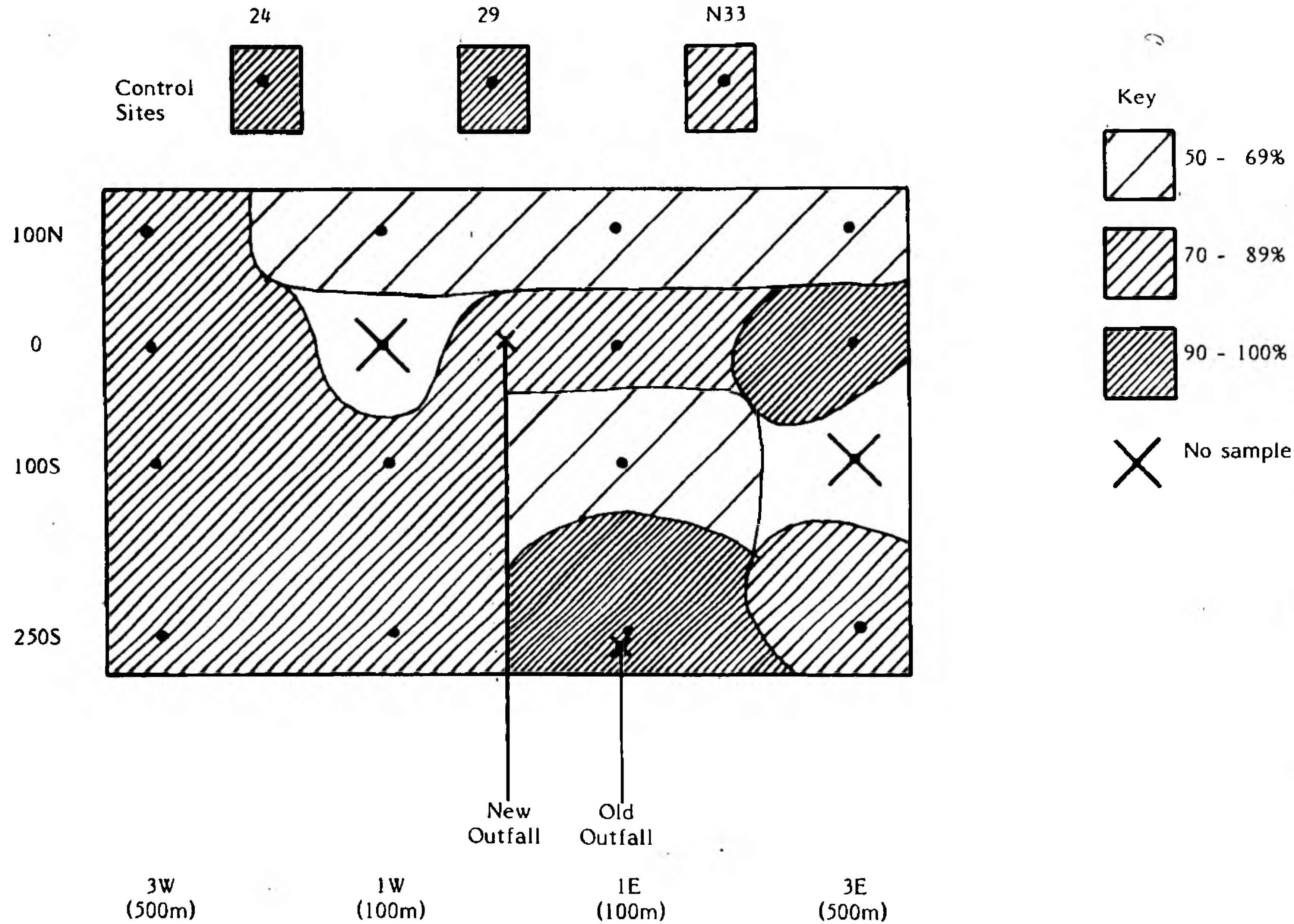
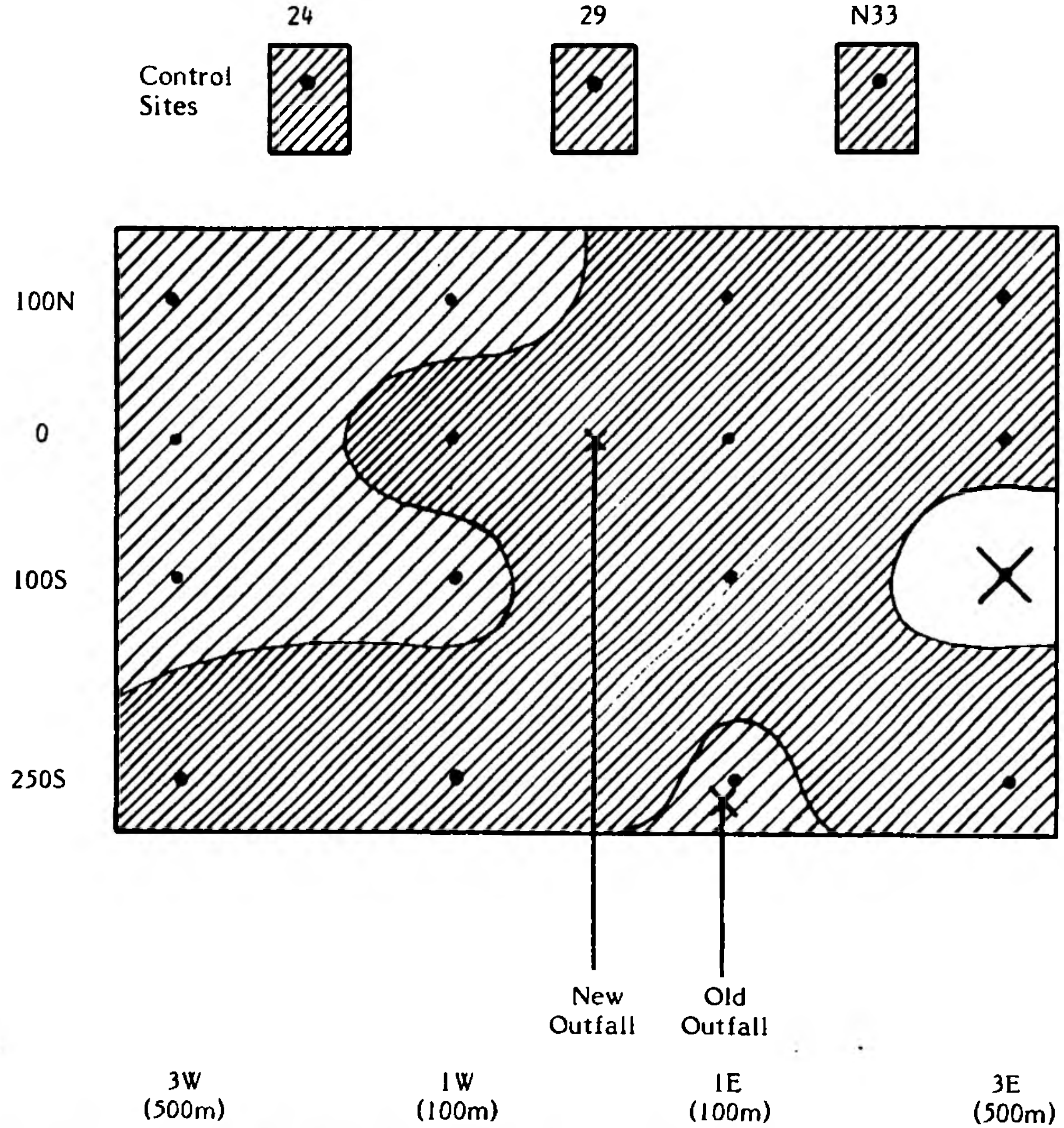
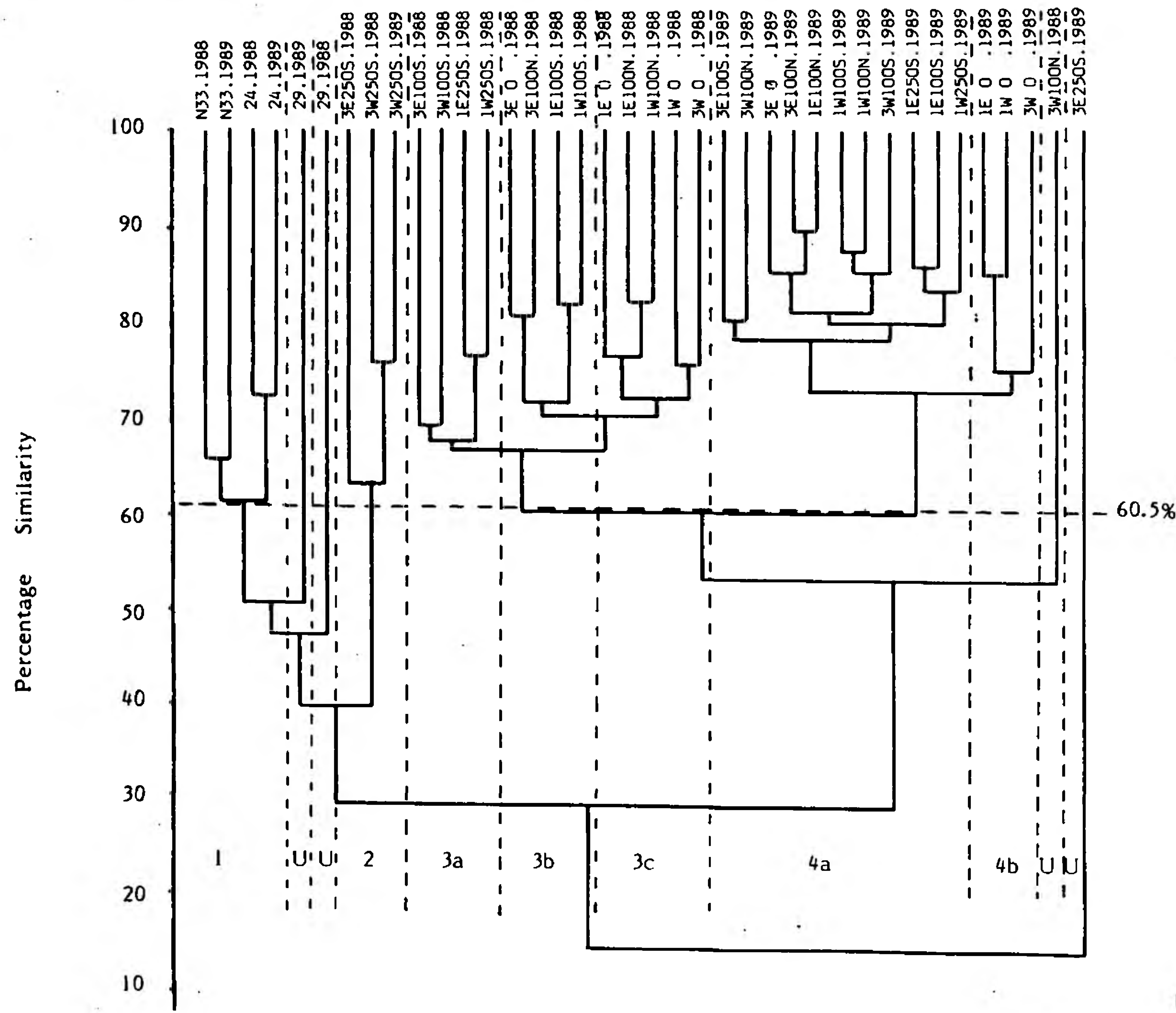


Fig. 7.2.2B Silt/Clay content of sediments - SCM New Outfall, July 1989



Key as for Fig. 7.2.2A.

Fig. 7.2.3 Cluster Analysis - July 1988 and 1989 sites, SCM New Outfall



U = Unclassified

Fig. 7.2.4A Faunal Associations identified by Cluster Analysis - SCM New Outfall, July 1988

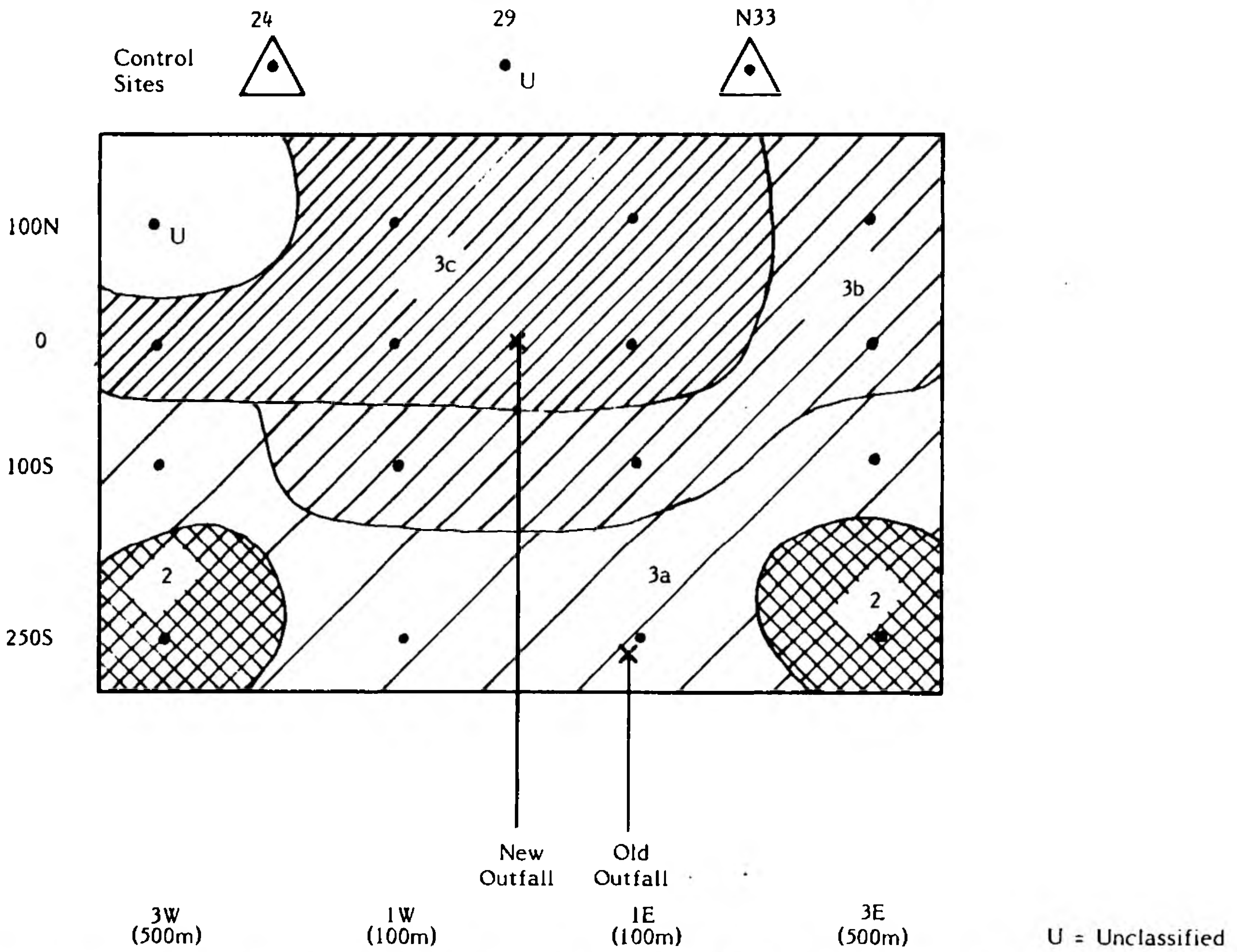


Fig. 7.2.4B Faunal Associations identified by Cluster Analysis - SCM New Outfall, July 1989

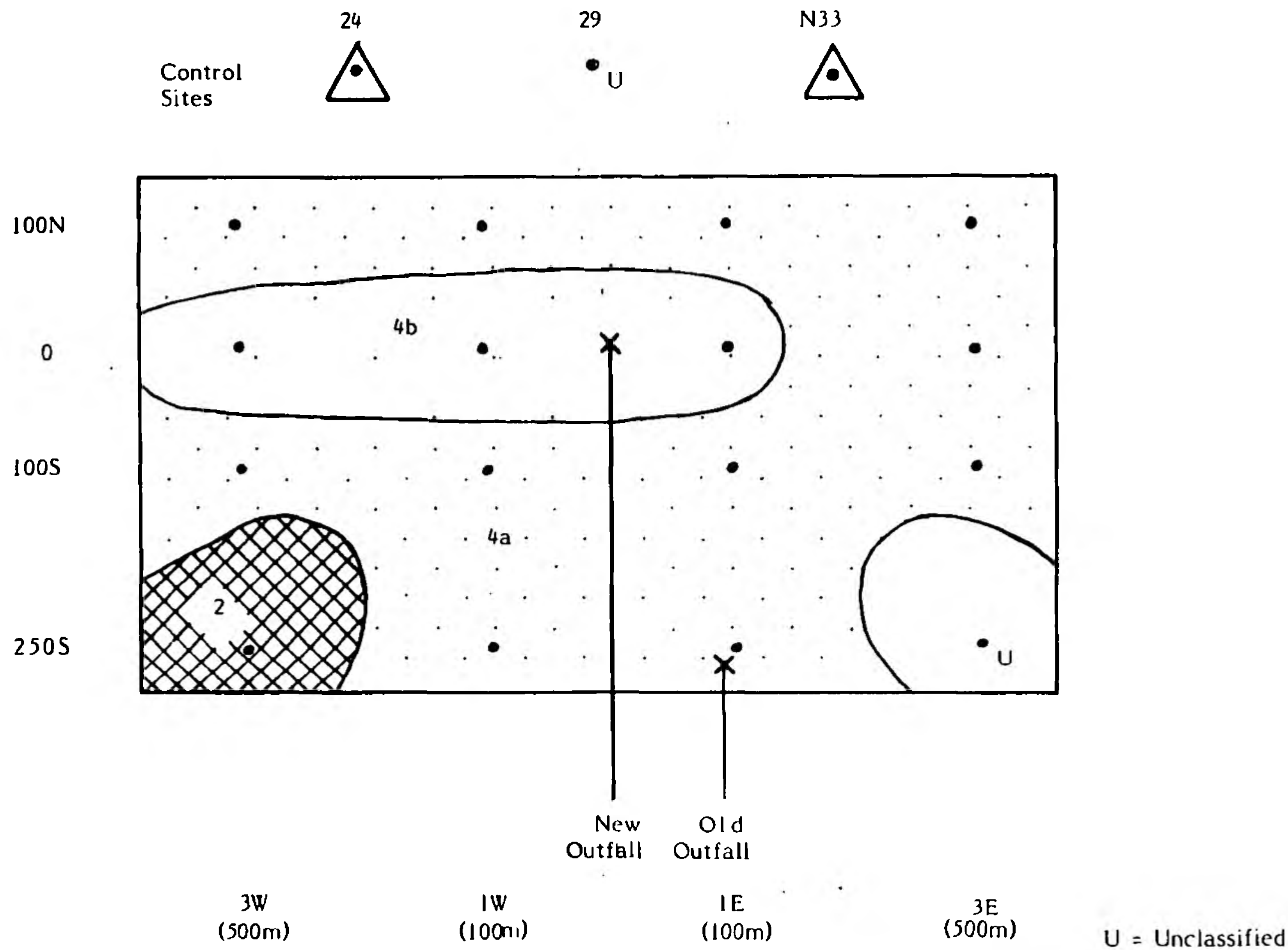


Fig. 7.2.5A Total Number of Species - SCM New Outfall, July 1988

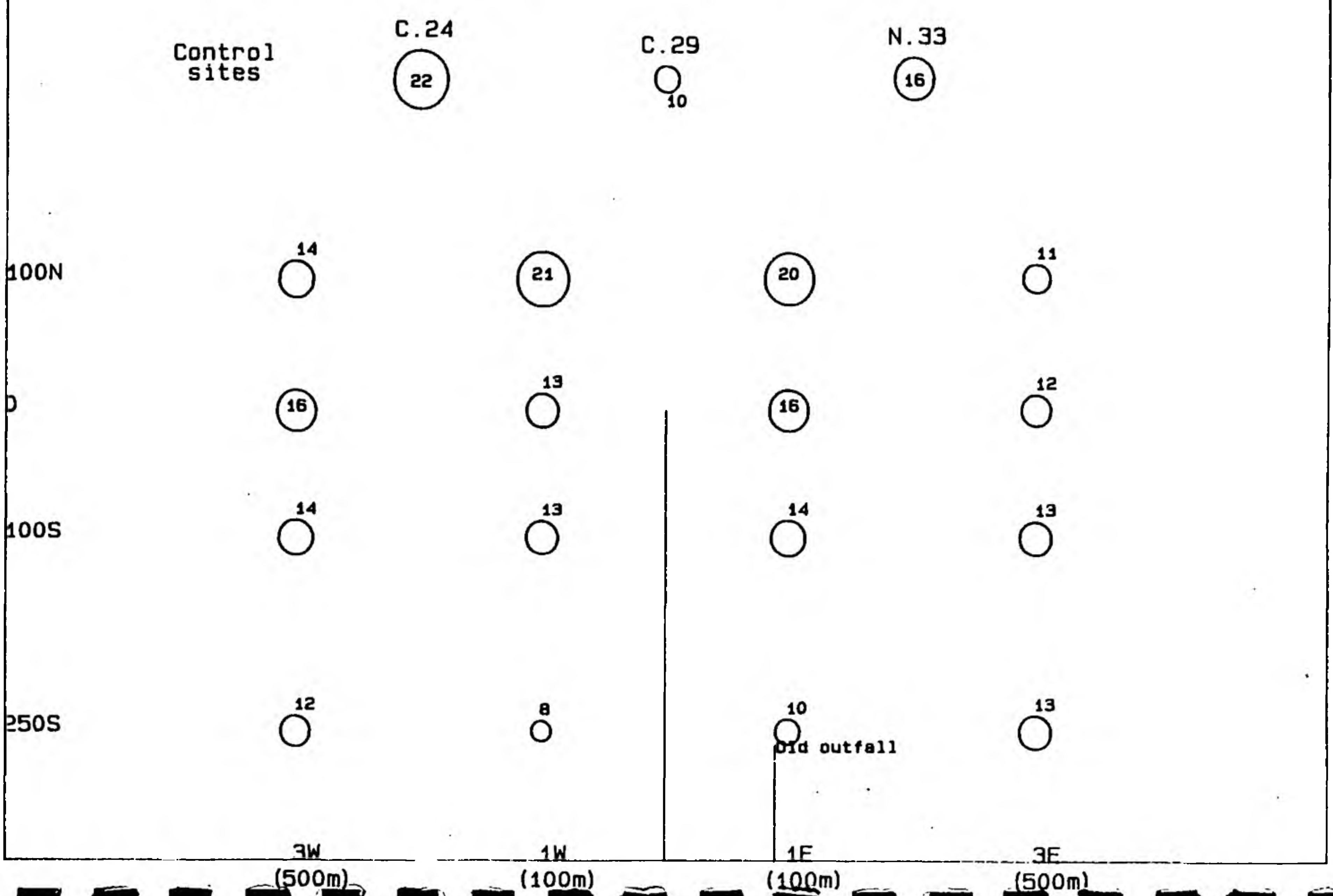


Fig. 7.2.5B **Total Number of Species - SCM New Outfall, July 1989**

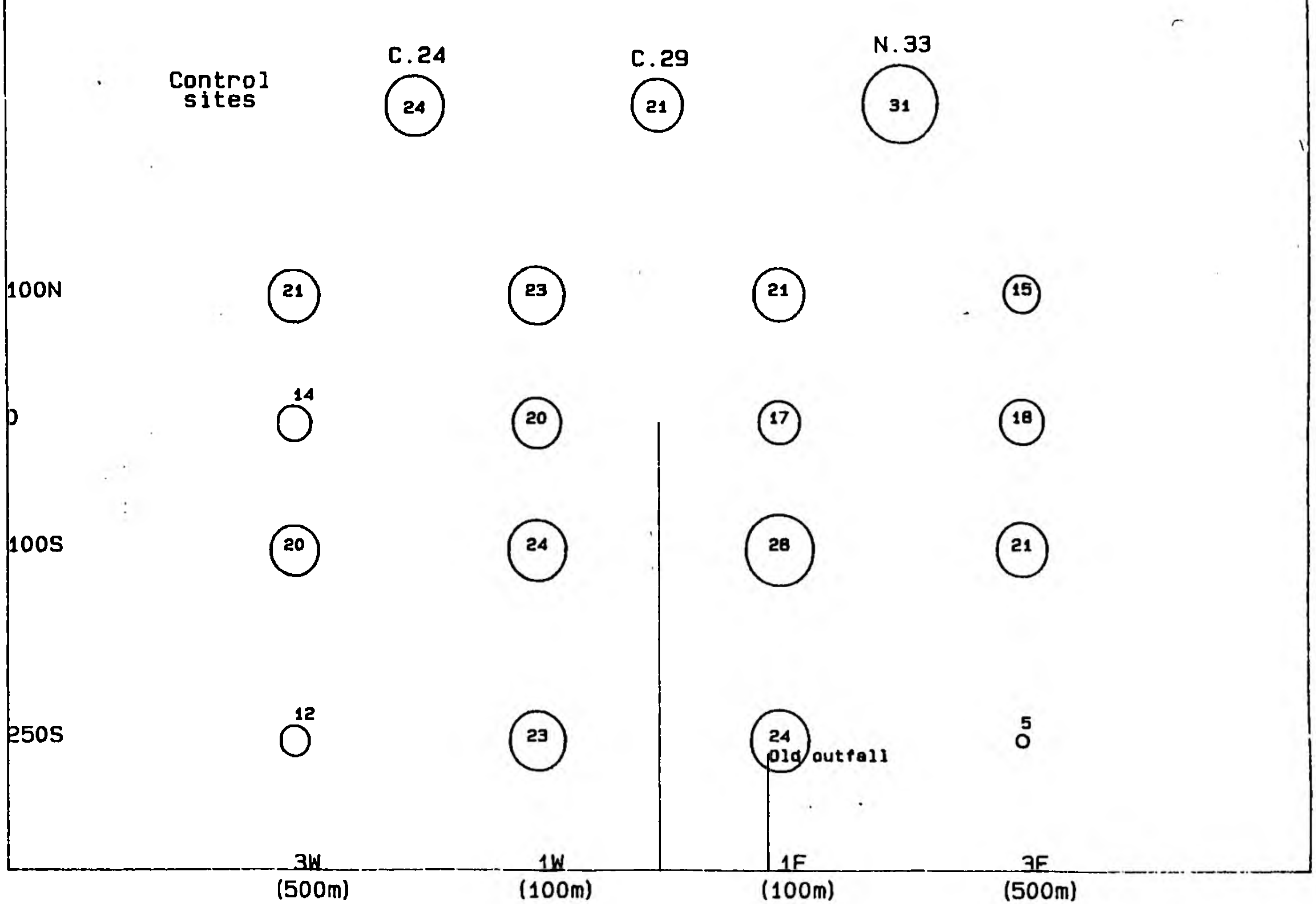


Fig. 7.2.6A Total Number of Individuals - SCM New Outfall, July 1988

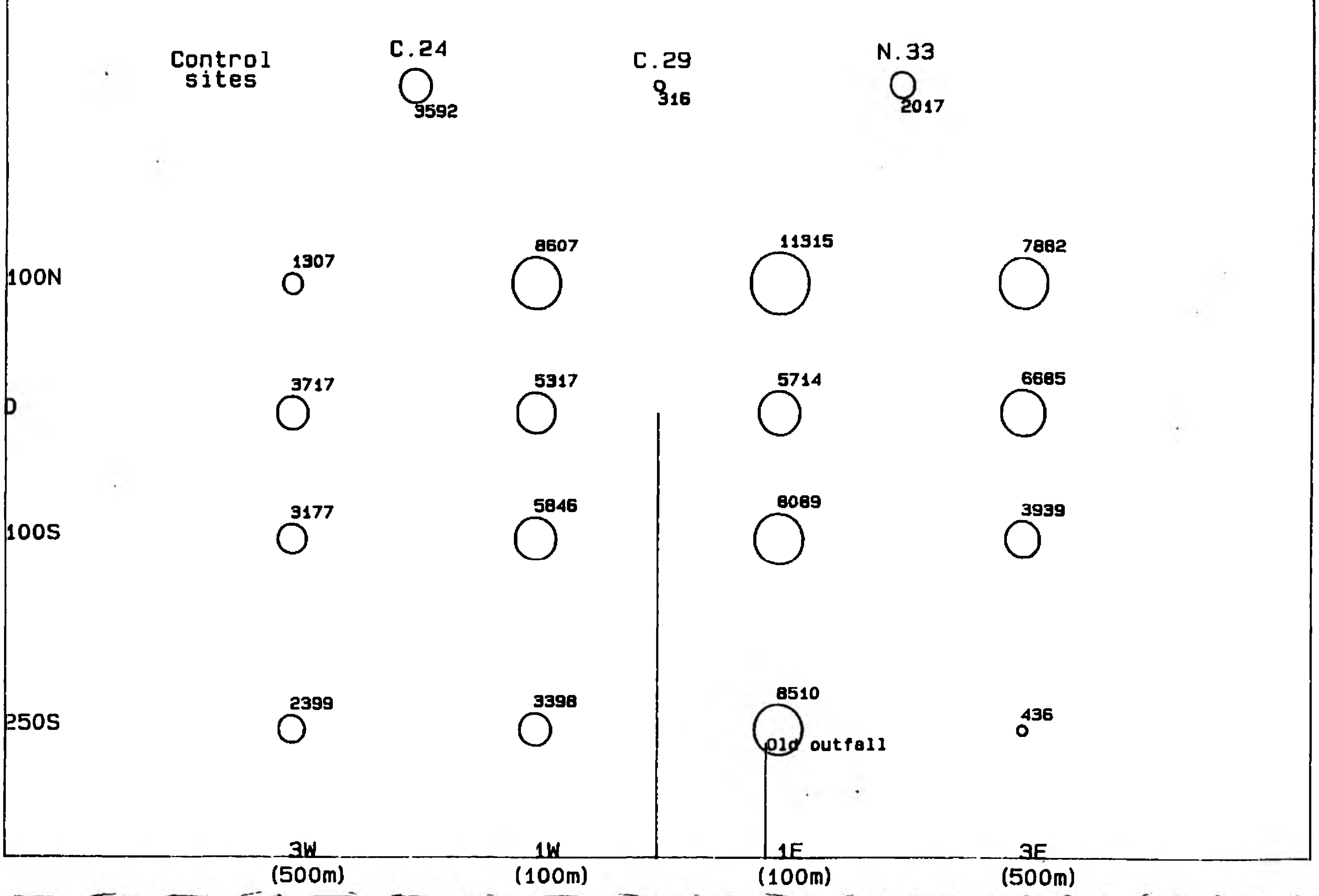


Fig. 7.2.6B Total Number of Individuals - SCM New Outfall, July 1989

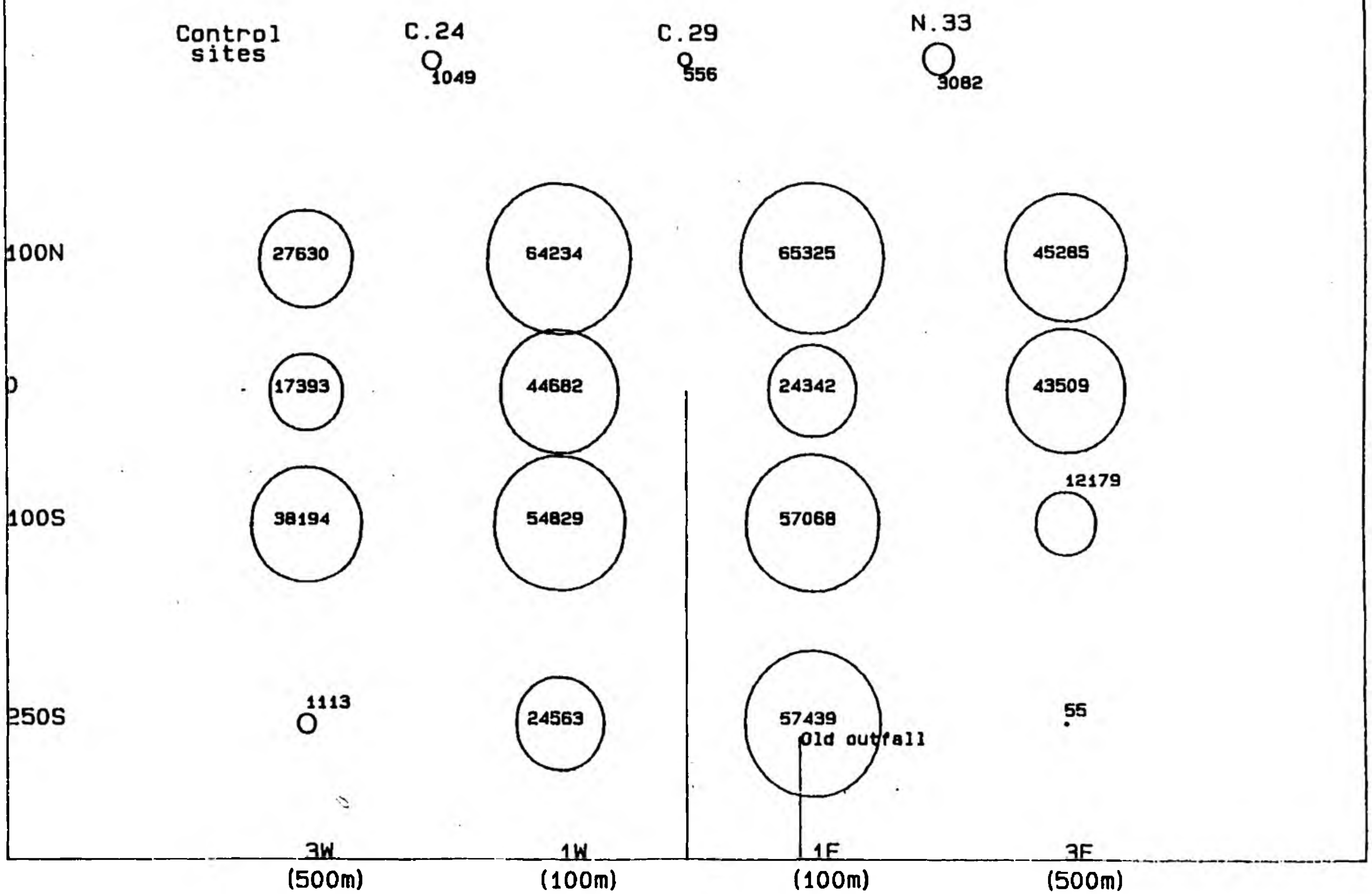
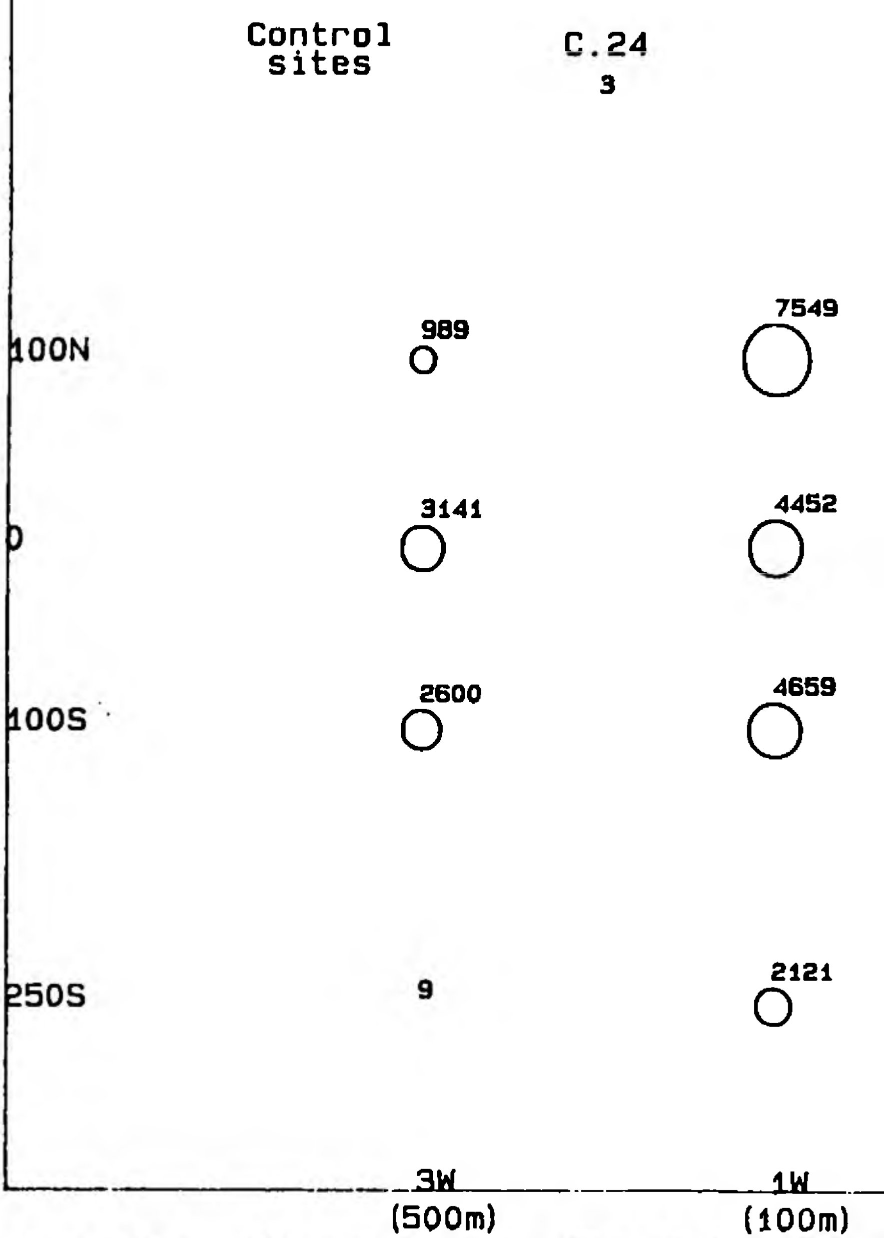


Fig. 7.2.7A Distribution of Polydora spp –



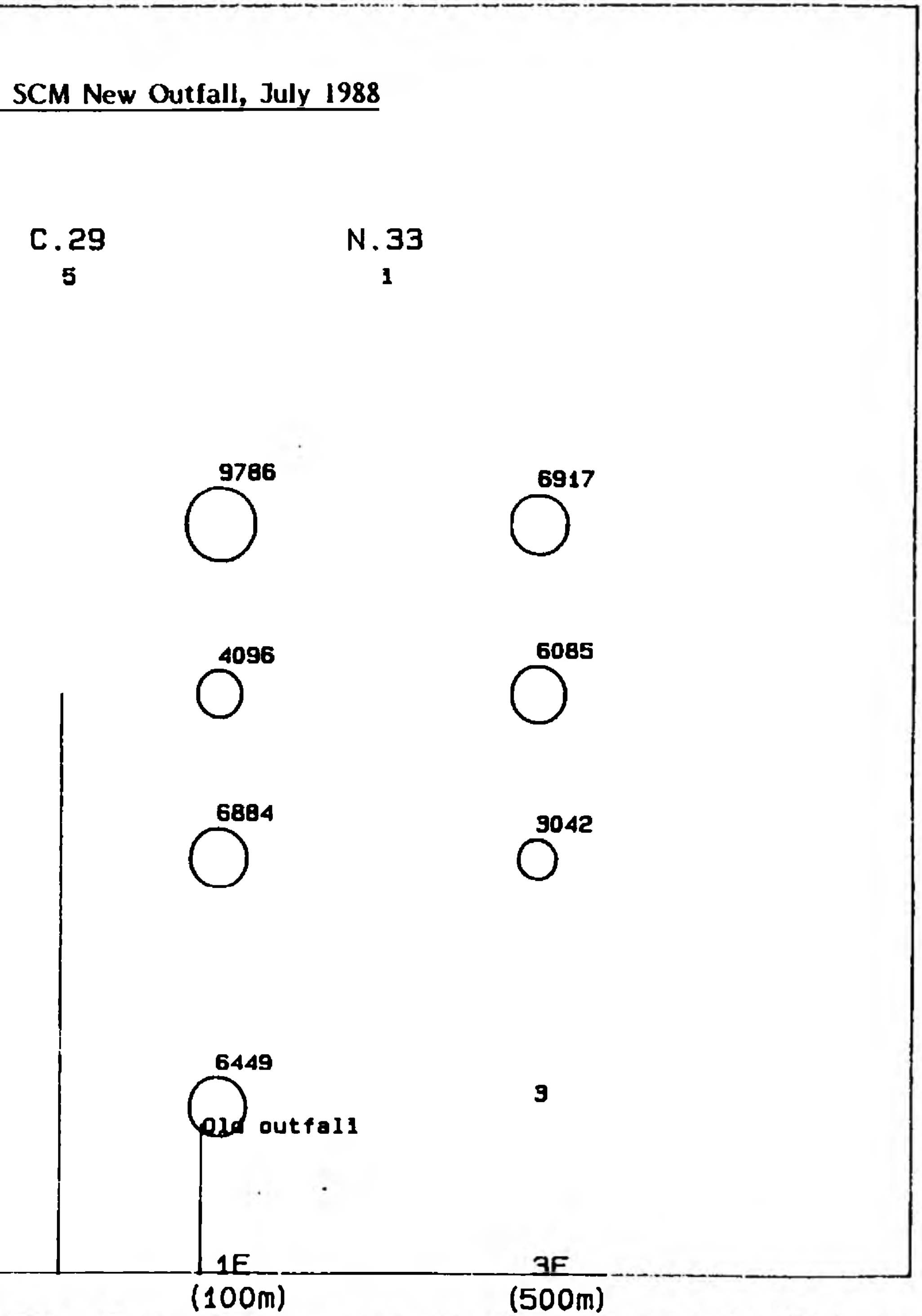

SCM New Outfall, July 1988
C.29
5
N.33
1
9786
6917
4096
6085
6884
3042
6449
9
Old outfall
1E
(100m)
3F
(500m)

Fig. 7.2.7B Distribution of Polydora spp - SCM New Outfall, July 1989

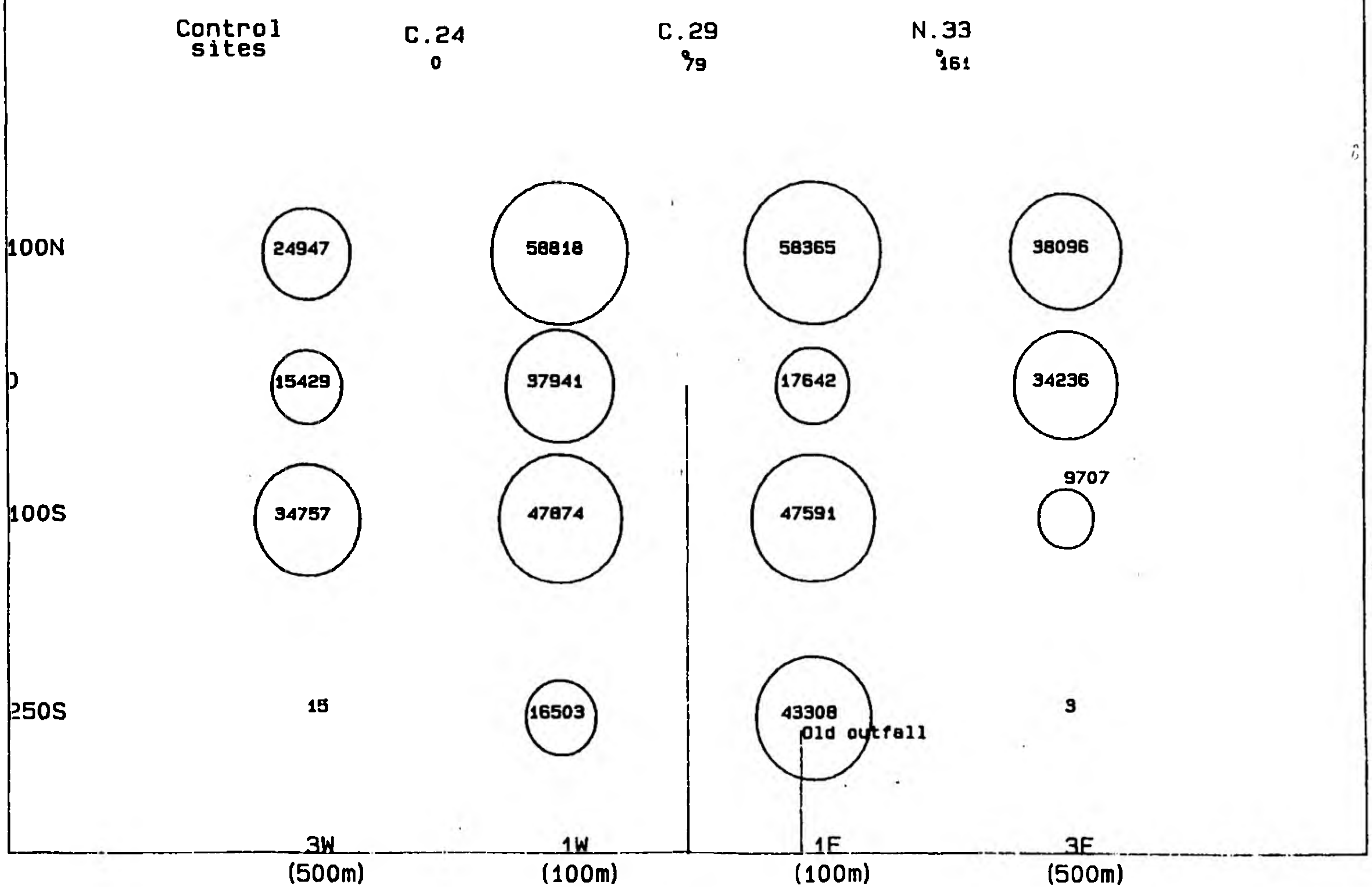


Fig. 7.2.8 Cluster Analysis, March 1989 - SCM New Outfall

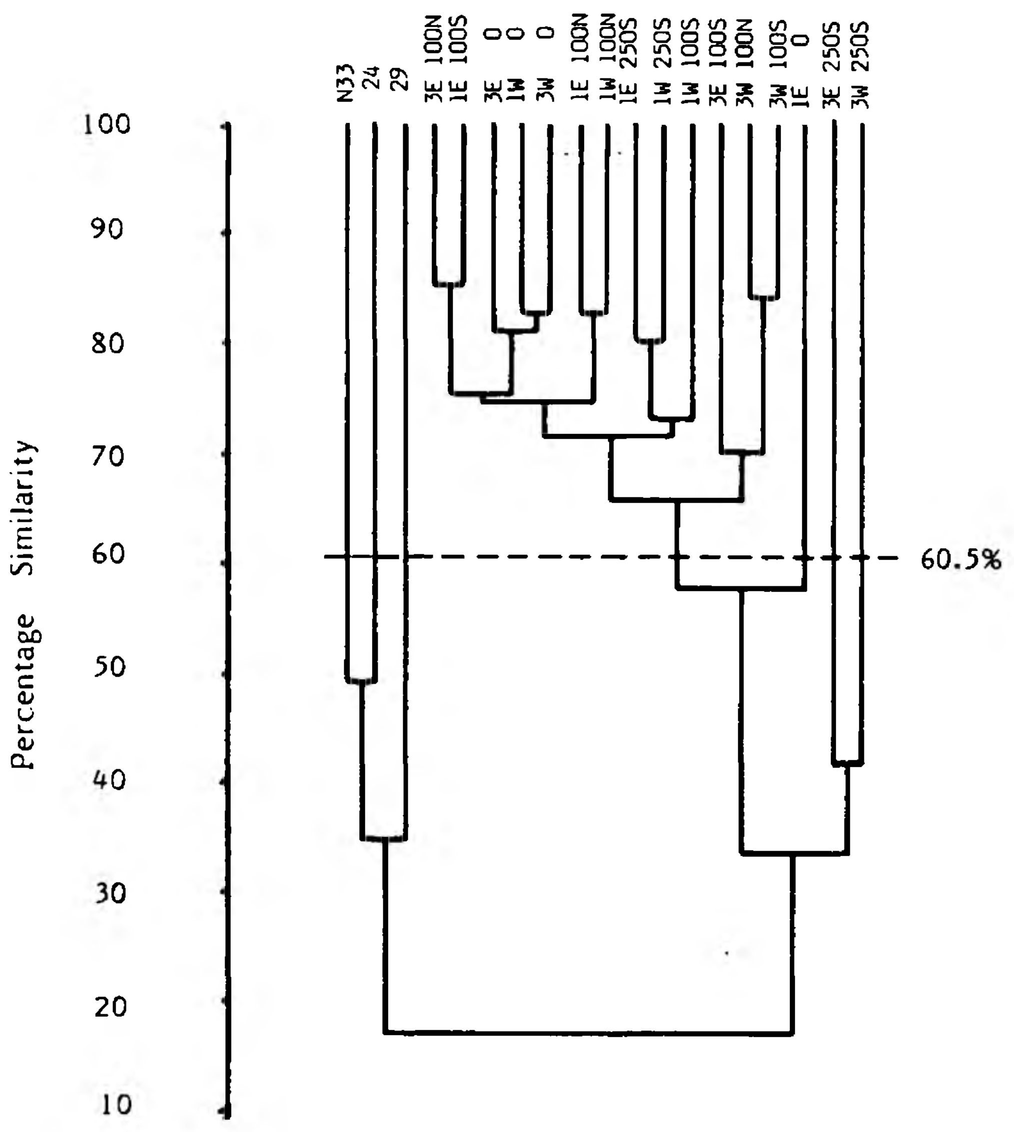


Fig. 7.3.1. Chart Section of the Humber showing the range of depth in the survey area , Tioxide New Outfall

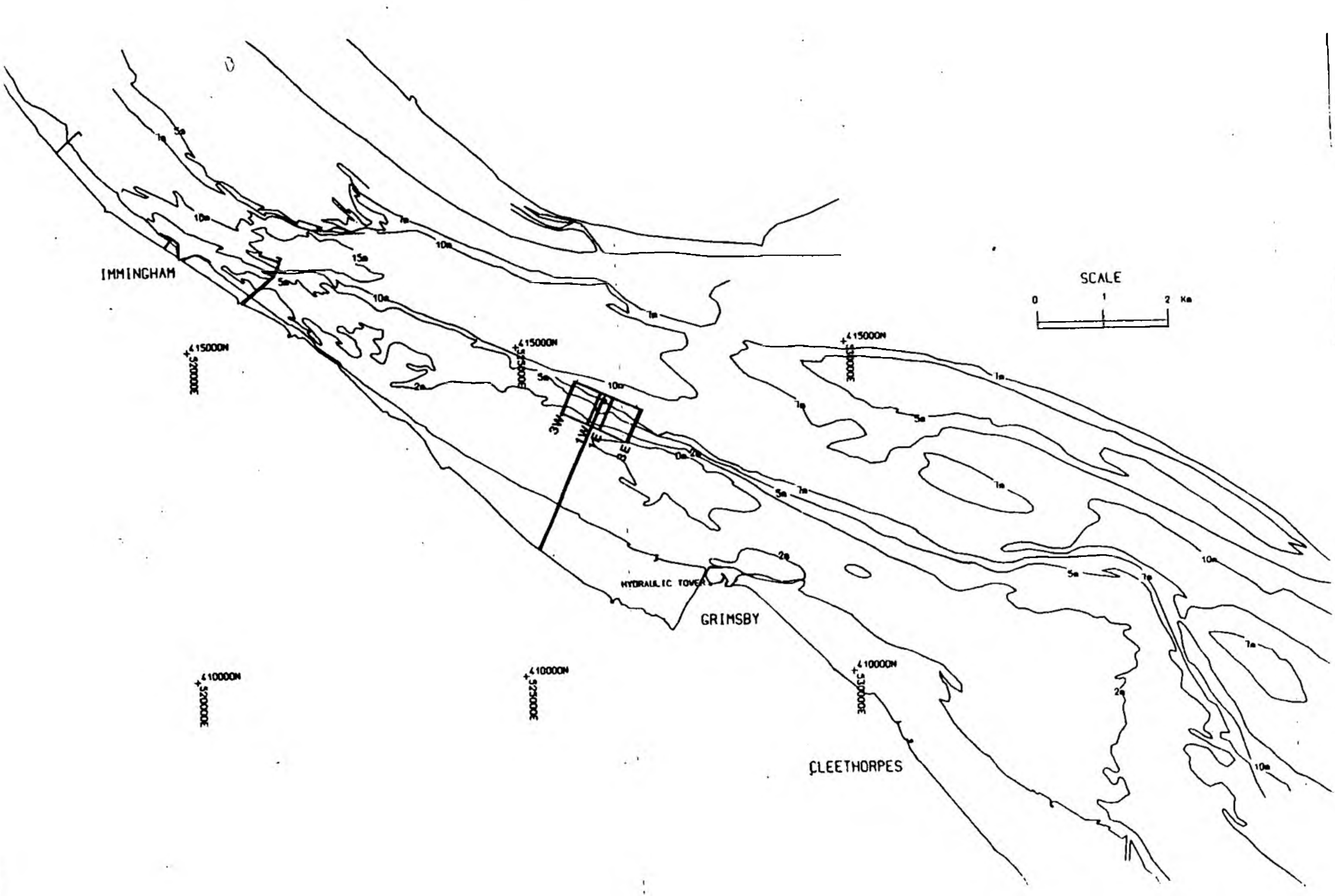


Fig. 7.3.2A Sediment type based on Visual Observations - Tioxide New Outfall 1989

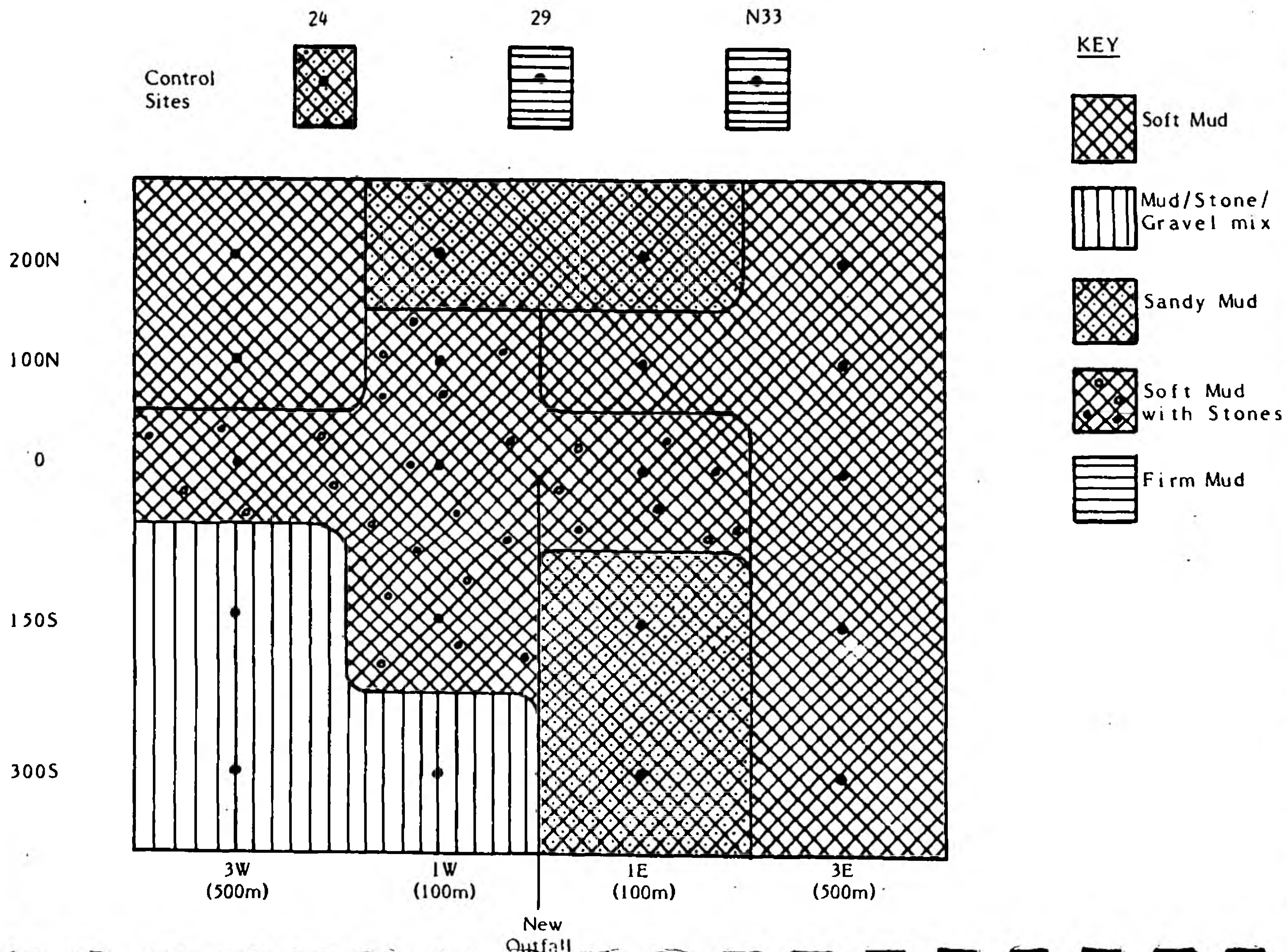
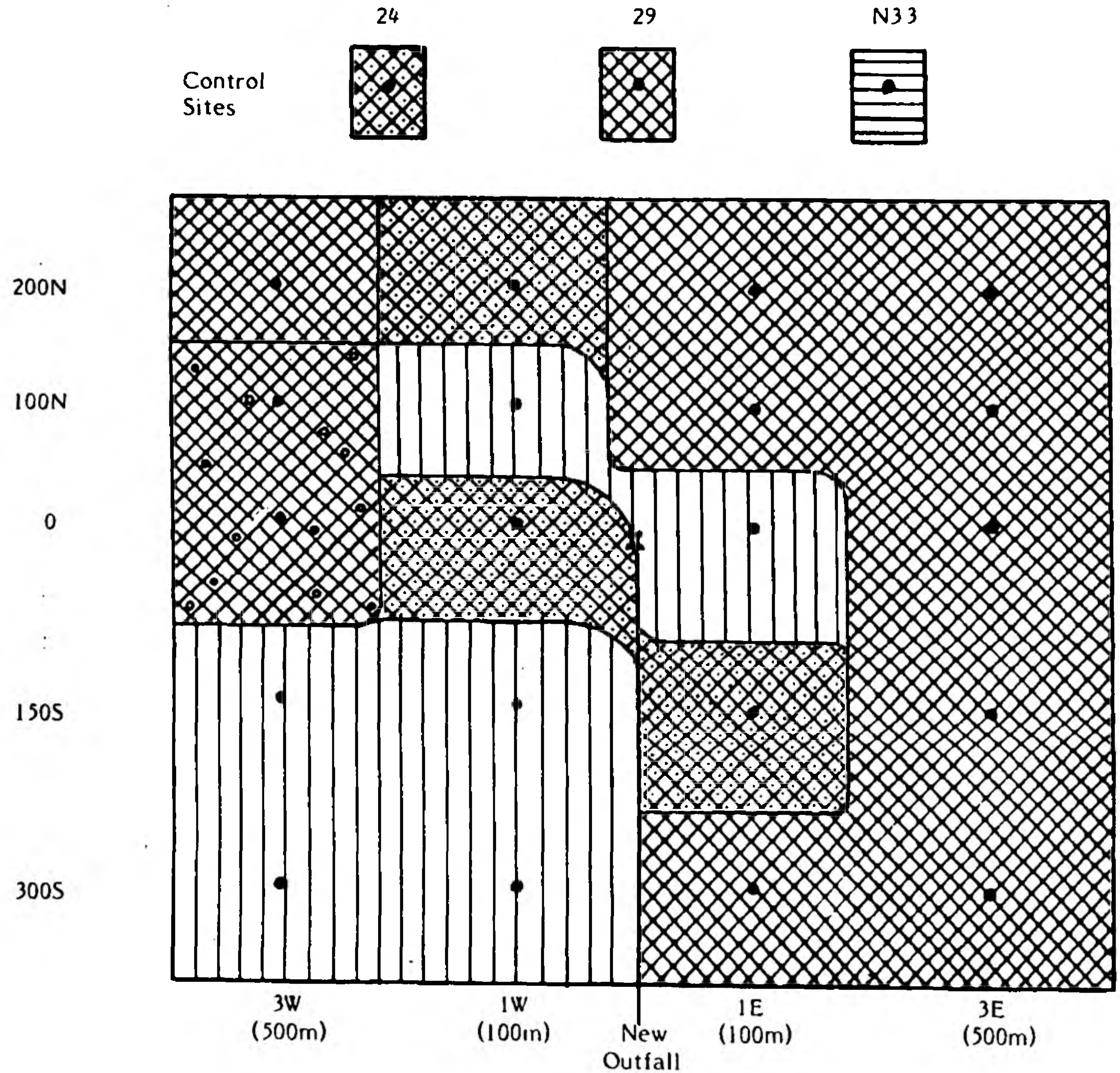


Fig. 7.3.2B Sediment type based on Visual Observations - Tioxide New Outfall, July 1989



Key as Fig. 7.3.2A

Fig. 7.3.3A Silt/Clay Content of Sediments Tioxide New Outfall, July 1988

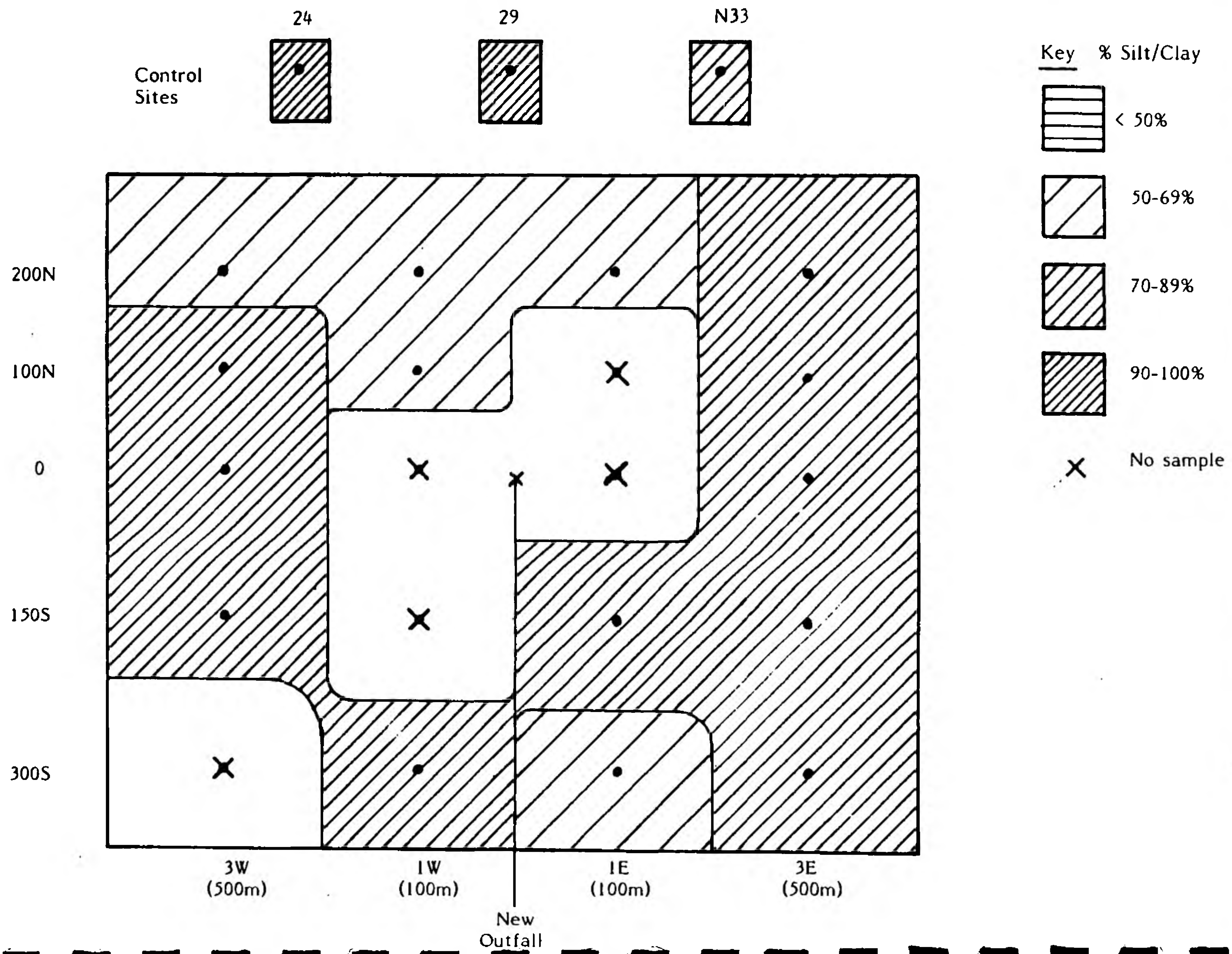
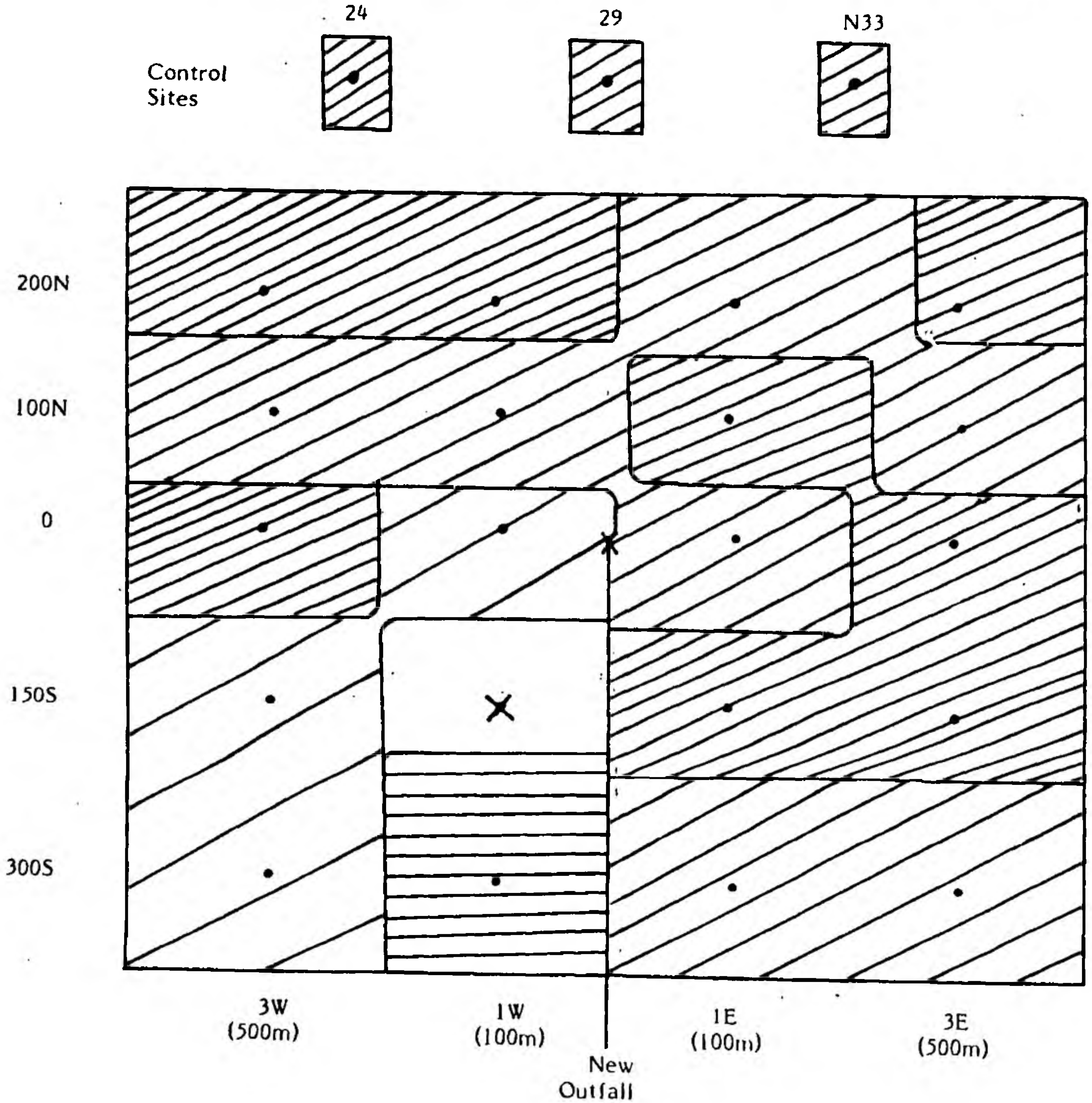


Fig. 7.3.3B Silt/Clay Content of Sediments Tioxide New Outfall, July 1989



Key as Fig. 7.3.3A

Fig. 7.3.4 Cluster Analysis - July 1988 and 1989, Tioxide New Outfall

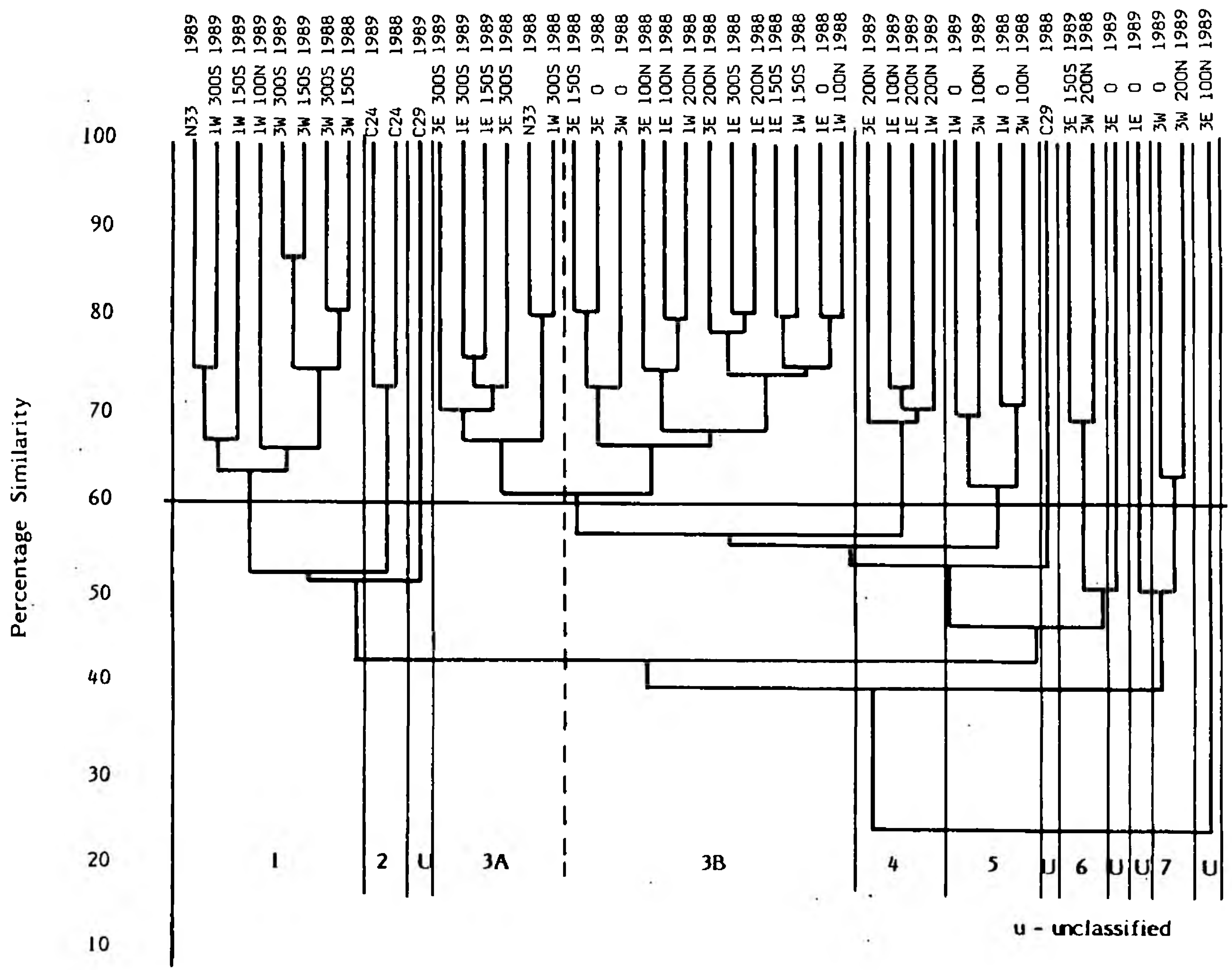


Fig. 7.3.5A Faunal Associations Identified by Cluster Analysis - Tioxide New Outfall, July 1988

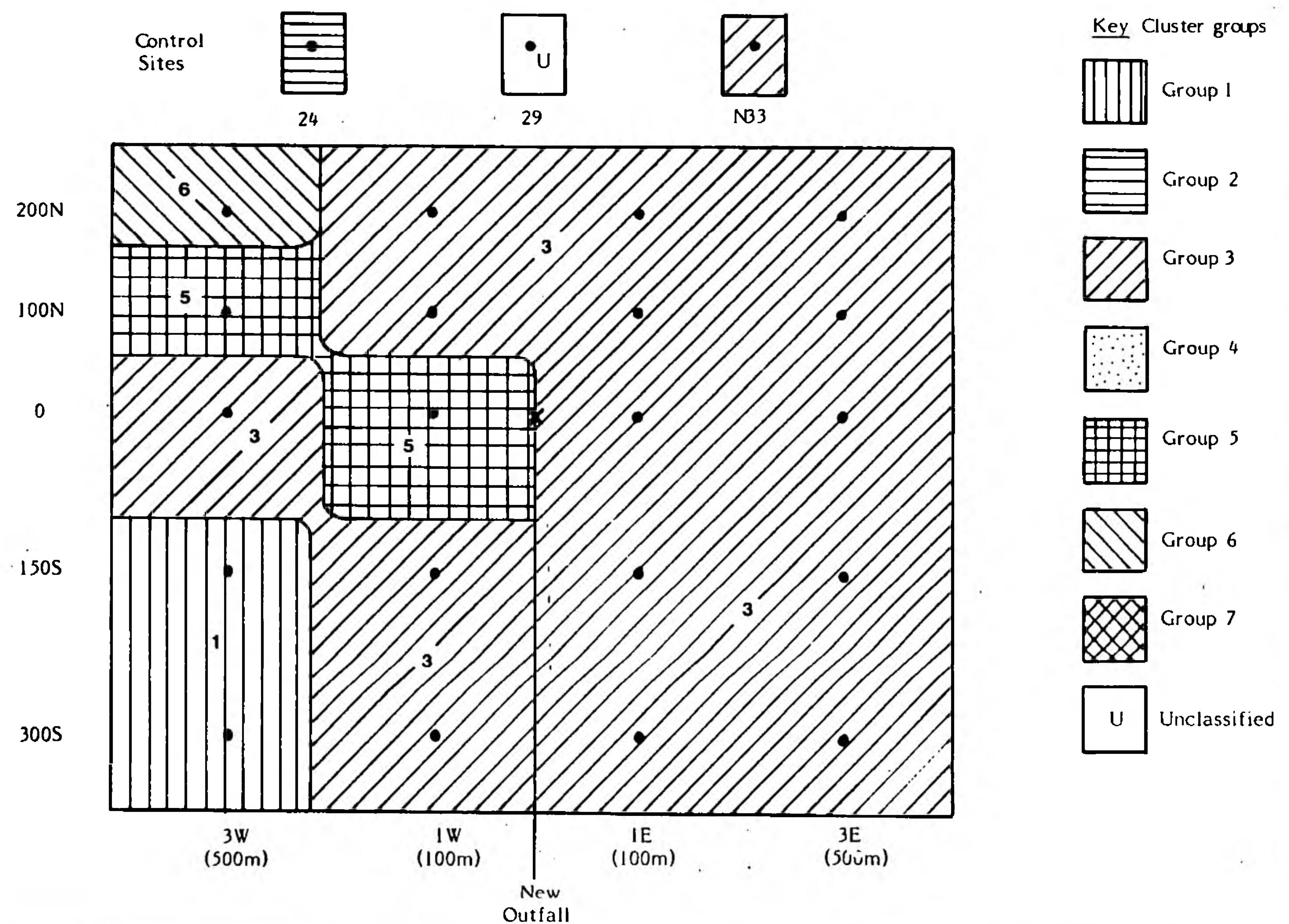
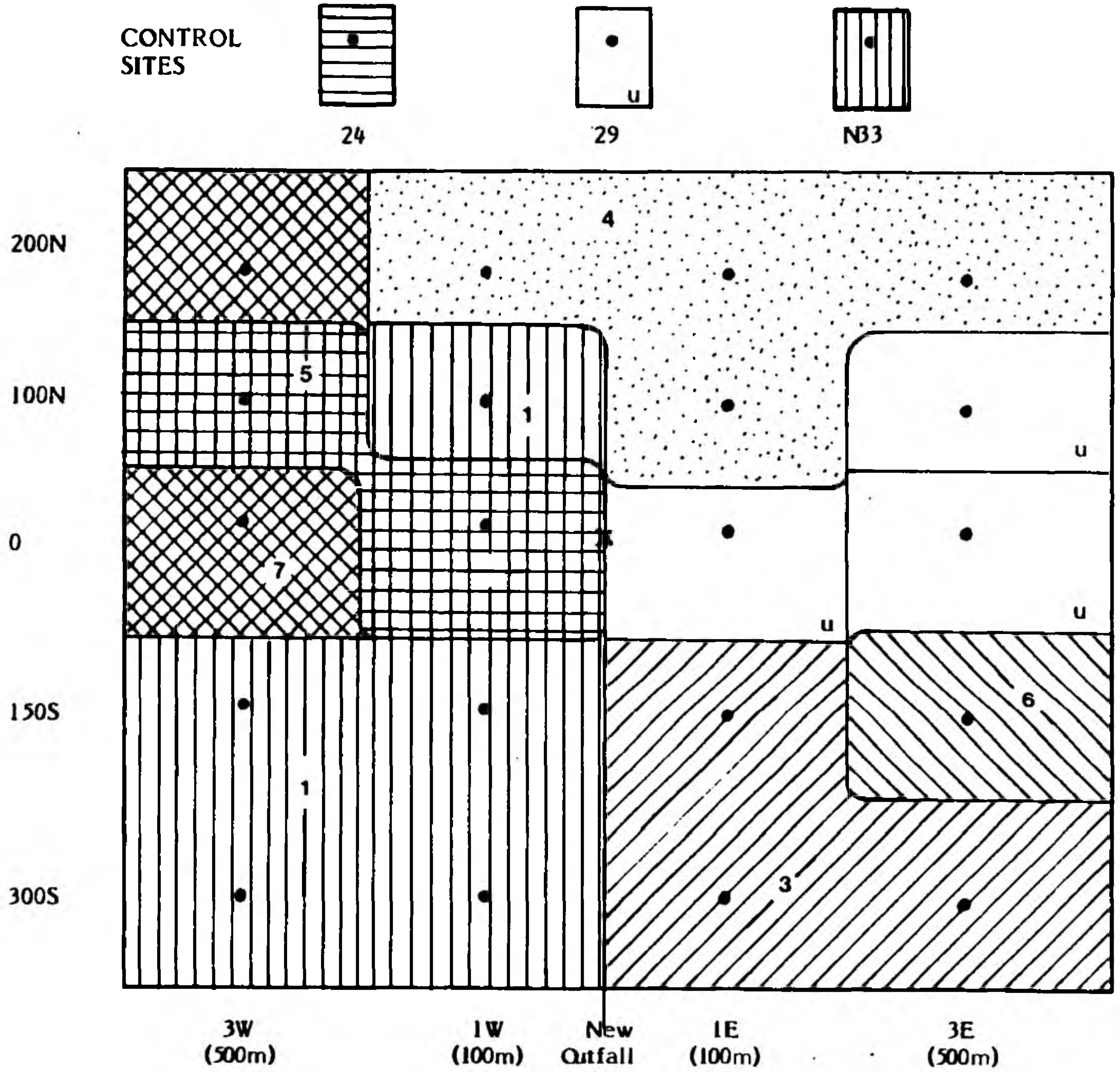


Fig. 7.3.5B. Faunal Associations identified by cluster analysis - Tioxide New Outfall July 1989



Key as Fig. 7.3.5A

Fig. 7.3.6A Number of Individuals for Tioxide New Outfall, July 1988

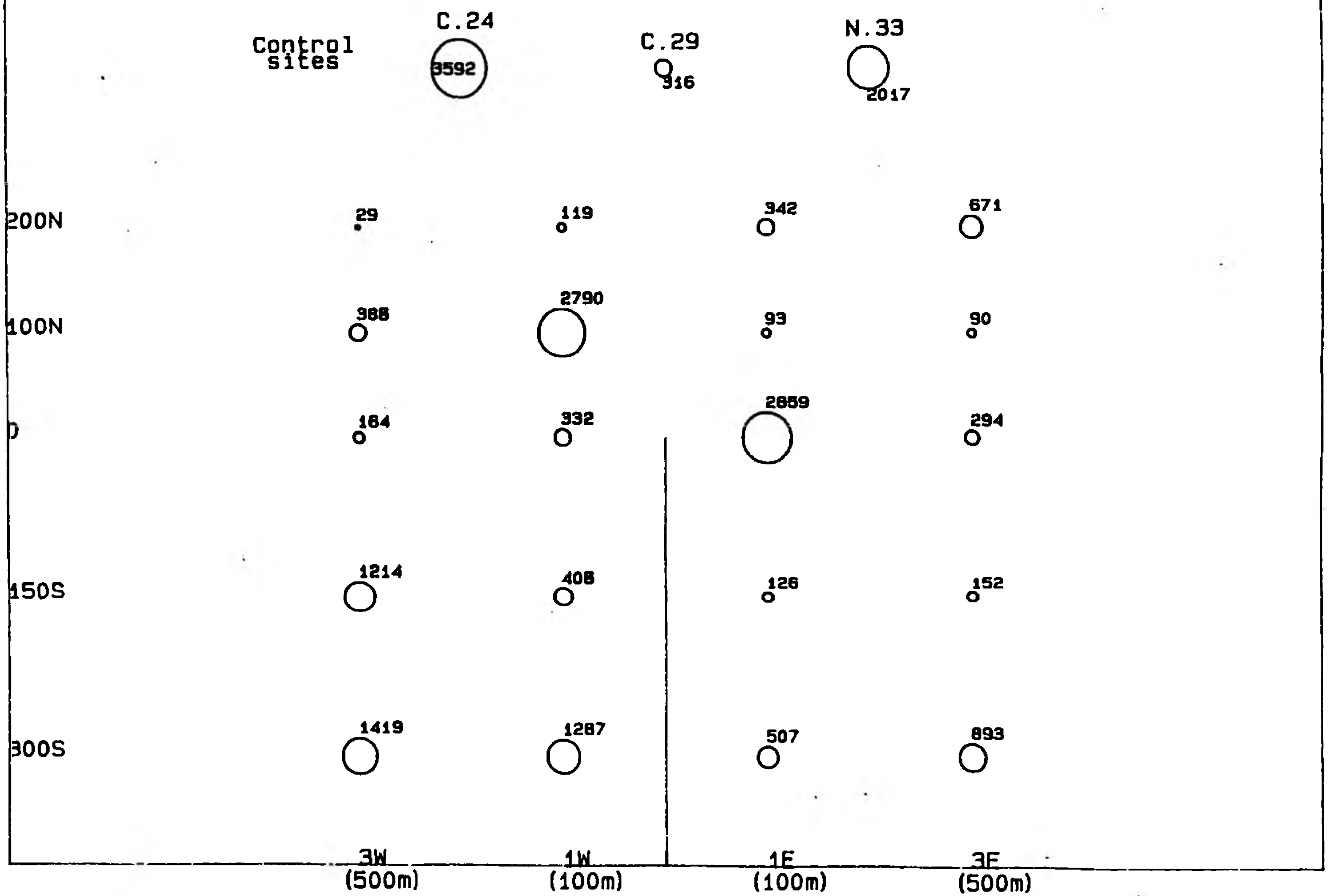


Fig. 7.3.6B Number of Individuals for Tioxide New Outfall, July 1989

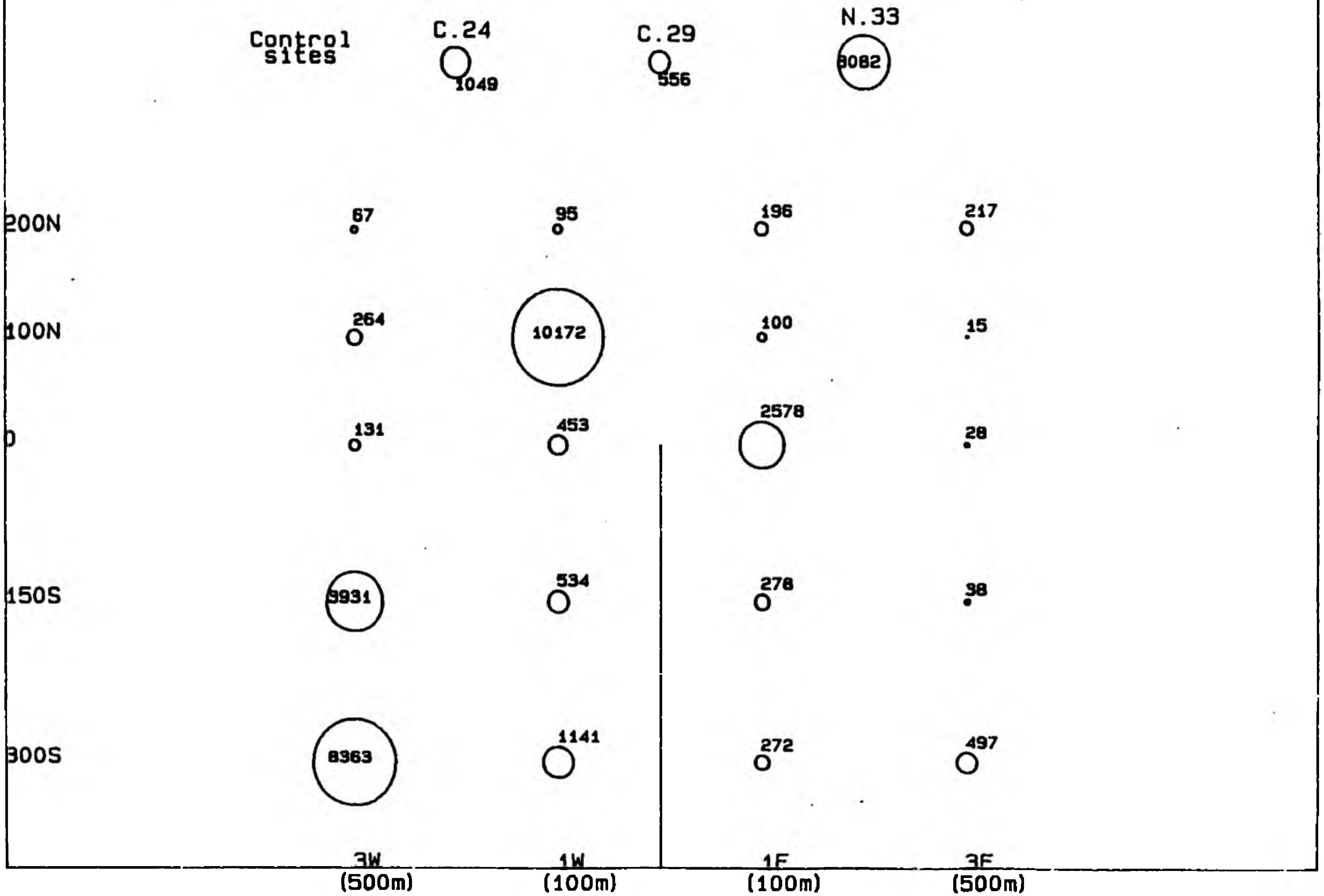


Fig. 7.3.7A Number of Species for Tioxide New Outfall, July 1988

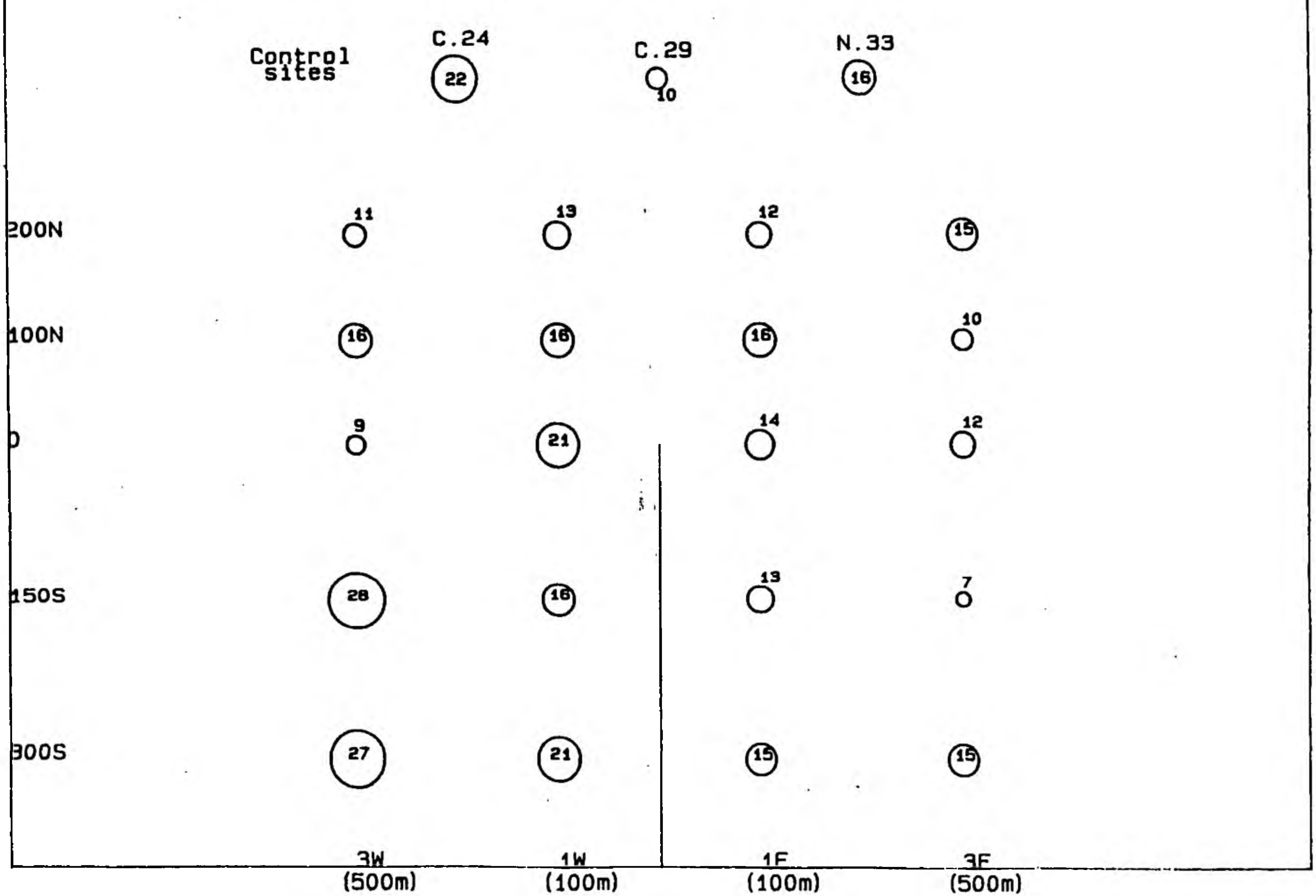
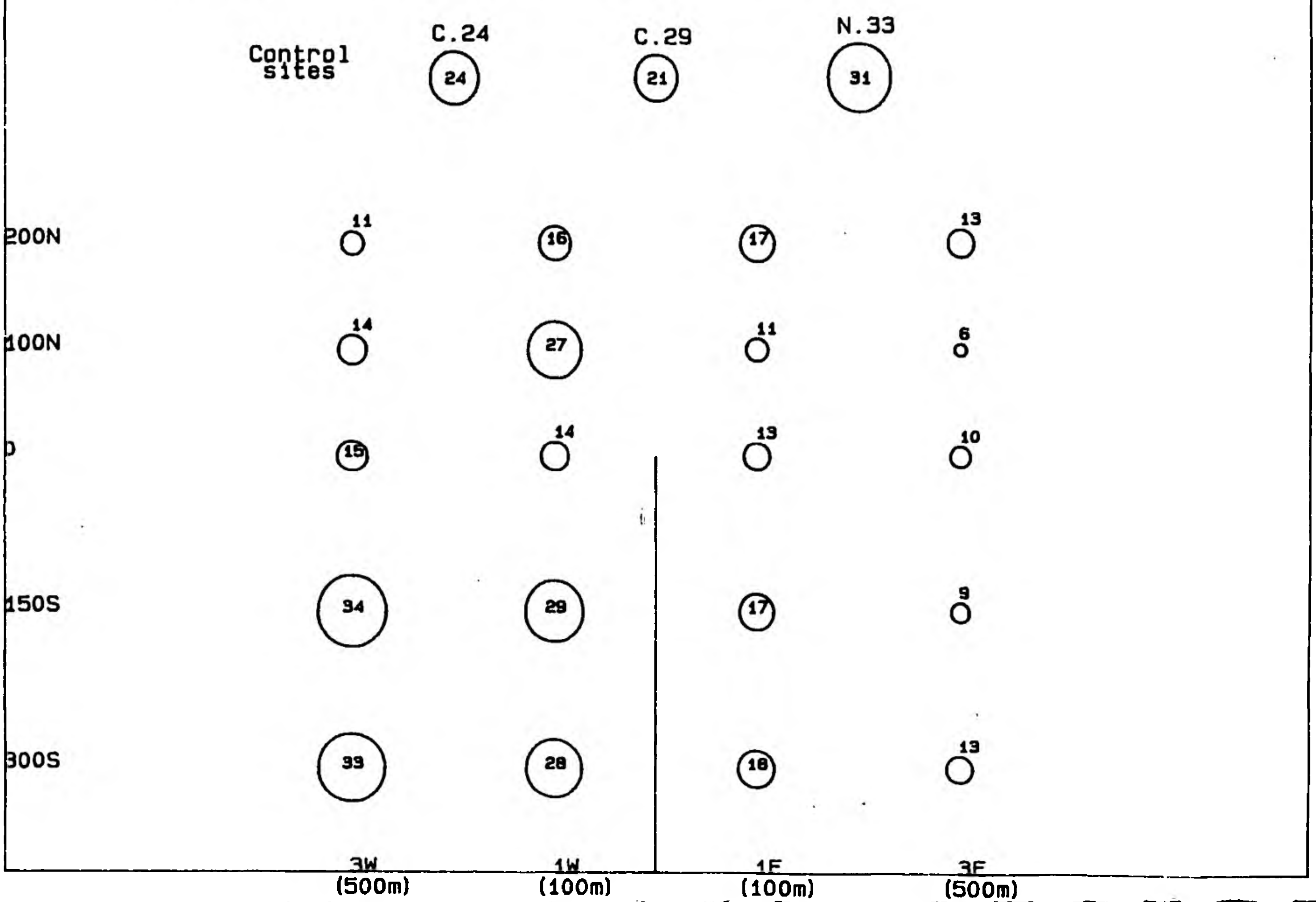


Fig. 7.3.7B Number of Species for Tioxide New Outfall, July 1989



APPENDIX 8

CHEMICAL RESULTS AROUND THE NEW OUTFALLS.

8.1 Introduction.

The previous major surveys of 1984 demonstrated the problems of working in the estuarine environment, viz:

i) The Humber is a very turbid estuary which means that there is usually negligible visibility in the water column;

ii) The topography of the estuary bed is variable giving rise to local variations in current velocity;

iii) It is difficult to define control sites which are representative of the study area yet are themselves unaffected by the effluent plume;

iv) The dilution of each factory effluent varies due to differing tidal and discharge characteristics;

v) The discharge plumes stratify in the water although this is less significant under low water conditions;

vi) The extent of the soluble iron plume cannot be assessed in the field making it difficult to determine representative sample points along the transect;

vii) Plume shape varies continuously with time from slack water, i.e. with current velocity and direction;

viii) Wind speed and direction are variable and the plumes may well be affected by wind;

ix) Pools of concentrated effluent are formed around slack water which distort the plume shape immediately afterwards.

In October 1988, some preliminary surveys were carried out as a first attempt at sampling around the new outfalls. Some of the conclusions were:

- Total iron values of >10 $mg.l^{-1}$ were found within 200m of the new SCM outfall, although the dissolved iron was usually < 5 $mg.l^{-1}$. There were some dissolved iron values in excess of 10 $mg.l^{-1}$ within 150m of this outfall. This suggested that the measurable plume of dissolved iron would be considerably smaller than the one measured in 1984 and that the 1 $mg.l^{-1}$ EQS contour might be within 500m of the SCM discharge.

- The peak of dissolved iron around the new SCM outfall was clearly sub-surface (c. 2-5m). Although the plume was occasionally visible during the survey, it was anticipated that future surveys would encounter difficulties in locating the plume whilst it was sub-surface in waters of up to 11m depth.

- Negligible dissolved iron was measured around the new Tioxide outfall (maximum value 2.52 $mg.l^{-1}$, 90m down-tide). It was sometimes possible to see the plume immediately above the outfall but not away from it. This difficulty was obviously reflected by the low results. However, the effluent plume was expected to be narrower and better dispersed from the new outfall (which discharged into deeper water and stronger currents).

- The full scale special surveys were going to be more difficult than previous surveys.

These new special surveys have confirmed this information. Although a large amount of data has been obtained, there is clearly further scope for further interpretation.

8.2 pH Data.

As well as carrying out fieldwork to locate the areas of the estuary affected by acid, some laboratory studies were performed to assess the effect on pH of diluting the factory discharges with estuary water. Comparisons have also been made with the discharges from the old outfalls, monitored in 1984.

a) Laboratory Dilution Studies.

Figures 8.1 and 8.2 show the effect of mixing SCM and Tioxide effluent with estuary water from South Killingholme. The results show that SCM effluent required about 225 times dilution to reach pH 6.0 and Tioxide effluent required about 405 times dilution. The data used to prepare the figures were taken from Tables 8.1 and 8.2.

Results from the 1984 special surveys showed that Tioxide effluent required about 270 times dilution to reach pH 6.0 and SCM effluent required about 175 times dilution.

The differences are attributable to changes in the respective effluent quality (see next section).

b) Location of Acid in the Estuary.

Both SCM and Tioxide effluent plumes were monitored on neap tides only, since these tides produce the lowest tidal velocities and therefore the slowest (worst) mixing conditions. It was anticipated that there would be considerable practical difficulties in locating the plume under spring tide conditions due to the new location of the outfalls in relatively deep water.

A summary of all significant pH measurements around the new SCM and Tioxide outfalls are summarised in Tables 8.3 and 8.4. The depth of maximum effect is indicated where possible. Figures 8.3 and 8.4 show those points affected by the effluents at the time of measurement although no account has been taken of the depth of the plume.

Data for the factory effluents on all survey days are shown in Tables 8.7 and 8.8. These show that the acid content of Tioxide effluent increased by 35% between 1984 and 1989 compared to a decrease of 20% for the SCM effluent. During the same period, the effluent flow from Tioxide has remained similar (an increase of 2%) but there has been a significant 46% increase in flow for the SCM effluent.

Both effluent plumes were expected to be sub-surface at an indeterminate depth whereas this was only the case around high water when the effluent was discharged from the old outfalls.

Under the neap tide conditions at the time of survey, the detectable plumes were narrow and of consistent width (100-200m). The plume was measured for at least 1,200m in either direction from the SCM discharge and for at least 900m upstream and 1,200m downstream from the Tioxide discharge.

Unlike the surveys of 1984, no offshore acidic "patches" of <pH 7.0 were detected. These were considered to be bodies of water apparently not continuous with the main plume and were assumed to be remnants from the previous tidal cycle not having been fully dispersed. The lack of detection of such patches during these studies around the new outfalls may well be

indicative of improved mixing of the effluent. Neither was there any evidence of the exaggerated bulges in the pH 6-7 areas previously detected near the SCM outfall.

c) **SCM Results.**

Acidic water of pH > 6.5 was detectable for an estimated 650m upstream and 500m downstream from the SCM discharge.

Acidic water of pH > 6.0 was detectable for up to 100m upstream and about 250m downstream from the SCM discharge.

The minimum pH detectable at the extremities of the plume was 6.7 upstream and 6.6 downstream of the SCM discharge.

Unlike the surveys around Tioxide, the plume was often visible in the surface layer where a pH depression was frequently measured (less than 3m depth) and the probes did not need lowering further than 5m to complete the monitoring work.

The path of the measured SCM plume appeared to follow the expected tidal pattern. However, about 1,300m upstream of the outfall, there was a major oil terminal jetty extending 900m offshore. The various pilings had some influence on the plume, mostly by further increasing the dispersion. Whilst it was just possible to detect the plume upstream of this jetty, there was no significant pH depression.

d) **Tioxide Results.**

Acidic water of pH > 6.5 was detectable for at least 900m upstream and about 650m downstream from the Tioxide discharge.

Acidic water of pH > 6.0 was detectable for at least 900m upstream and about 400m downstream from the Tioxide discharge.

The minimum pH detectable at the extremities of the plume was 5.8 upstream and 6.7 downstream of the Tioxide discharge.

Around the new Tioxide outfall it was rarely possible to measure a pH depression in the surface layer (< 1m depth) whilst the plume was virtually never visible. Consequently, because the water was usually more than 10m deep, it was necessary to expend a considerable amount of effort trying to locate the plume. There was a danger of prematurely concluding that the effluent was being so well dispersed in the deep water channel that it was undetectable. Eventually it was discovered that the probes needed to be suspended to depths of around 7 or 8m or more, in order to be certain of detecting the plume. Unfortunately, 8m depth was the limit of the analytical techniques employed. In these circumstances, therefore, the deep pH measurements probably represented the top surface of the plume.

The higher current velocities encountered during Spring tides would have reduced the practical depth limit to something like 4m. Further consideration will need to be given to overcoming this problem if further monitoring is required. The problem was not fully anticipated, because work around the old outfalls had nearly always detected the plumes in the top 3m of the water column.

There were some spurious points of pH depression evident inshore of the Tioxide discharge (Figure 8.4). There was good reason to believe that this was due to remnants of the pool formed at low slack water (see a similar observation under the dissolved iron section) but the project was not designed to provide the intensive sampling necessary to characterise this pool area.

The acid plume from the new Tioxide outfall appeared to be significantly influenced by the bottom topography. On a flood tide the plume was distorted by being pushed inshore as the tidal stream was able to fill deeper water closer inshore. Conversely, on an ebb tide the plume was pushed offshore as it followed the edge of the deep water channel around the offshore side of Burcom Shoal and was probably also influenced by the pressure of water escaping from the Pyewipe mudflats around the Grimsby Docks. The effect was more pronounced around the old outfalls in 1984 and was supported by the mathematical model. This offshore movement can only benefit the dispersion of the plume, since it is moved into yet deeper water, where the currents and potential for mixing are greater.

e) Discussion and Comparison with 1984 Results.

The acid plumes from the new outfalls were far less detectable than those from the old outfalls. During the 1984 surveys, acidic water was readily detectable (under both neap and spring tide conditions) for at least 6 km in either direction from each discharge. Overall, water of pH < 7.0 was measured approximately 6.4 km upstream of SCM and 12.1 km downstream of Tioxide, there being an overlap of the two effluent plumes.

In this recent work, it was not possible to detect any difference between the ebb and flood acid plumes. The 1984 data suggested that the areas of high acidity were greater on the flood tide than on the ebb tide. This observation was partly a reflection of the sampling pattern and partly the fact that the water was at its shallowest at the beginning of the flood tide when the effluent was forced into a depth of less than 3m. At this stage there was far less dilution than the corresponding situation at high water and the start of the ebb tide. The observed change is a consequence of the repositioning of the outfalls into deeper water which has reduced this disparity between high and low water dilution.

Lack of data around the new outfalls for a Spring tide may not be important. Results from 1984 suggested that a plume for a spring tide would be longer but narrower than that measured for a neap tide, although the latter would produce a more extensive area of pH < 6.5 covering a greater proportion of plume area. Since the new plumes were substantially smaller than the old ones of 1984, it is unlikely that any plume would have been detectable around the Tioxide outfall during a Spring tide although it is not possible to assess how much of a reduction might occur around the SCM outfall.

The repositioning of the outfalls might be expected to modify the following observations made 1984 but no evidence is presented for the current situation around the new outfalls because the plumes were not detected at comparable distances.

Firstly, the old Tioxide plume was clearly influenced by the presence of Grimsby docks, especially during a neap ebb whilst the plume pathway downstream of Grimsby was observed to alter between neap and spring tides, being further offshore during a spring ebb and which was merely a reflection of the lower water levels during such tides.

Secondly, the shape of the old plume upstream of SCM and South Killingholme also varied between spring and neap tide, being further offshore during a neap flood, again merely reflecting the lower water levels during such a tide as well as the slower upstream motion, since there are no significant fresh water inputs in the vicinity.

In conclusion, therefore, it is fair to say that the overriding factor in the observed path fluctuations was the location of the discharges close inshore, so that with dilution effectively from only one side, the plumes were forced to follow the estuary boundary.

8.3 Soluble Iron Data.

The SCM and Tioxide effluent plumes were monitored on spring and neap tides. All the data is collated together for each outfall in Tables 8.5 and 8.6 where distances from the appropriate outfall have been calculated. The mean soluble iron figure for the discharge on the day of the survey was used.

The soluble iron data are shown diagrammatically in figures 8.5 and 8.6. The higher value of a surface and sub-surface pair has been taken in order to plot the points which therefore represent a maximum concentration at a particular point.

The 1.0 mg.l⁻¹ Fe contour represents the EQS for the Humber Estuary, whilst the other contours were chosen arbitrarily. Some concentrations in excess of 20 mg.l⁻¹ Fe were measured. The highest result, only 59 m from the SCM outfall, was 98.5 mg.l⁻¹ (approximately 24-fold dilution), unlike the previous surveys of 1984 when there were a number of results greater than 100 mg.l⁻¹ Fe. Then, values of 387, 231 and 173 mg.l⁻¹ were measured 512 m upstream, 1,004 m upstream and 1,522 m upstream of the old Tioxide outfall, respectively.

Data for the factory effluents on all survey days are shown in Tables 8.7 and 8.8. These show that the iron content of Tioxide effluent increased by 59% between 1984 and 1989 compared to an increase of 44% for the SCM effluent. During the same period, the effluent flow from Tioxide has little changed (an increase of 2%) but there has been a significant flow increase of 46% for the SCM effluent.

Unlike the previous surveys of 1984, no specific site was chosen as a "control" since many results around the outfalls were as low as the limit of detection of 0.007 mg.l⁻¹. With there being an EQS of 1.0 mg.l⁻¹ for soluble iron in the Humber, this suggests that there is a significant amount of uncontaminated water passing through the vicinity of the outfalls. Previously, uncontaminated water in the Humber was thought to contain less than 0.2 mg.l⁻¹ iron in solution.

a) General Observations.

The data frequently showed a significant difference between the corresponding surface and sub-surface sample. This was attributed to stratification of the discharge, a factor which was clearly visible from the behaviour of the plume and has been observed before.

The preliminary surveys around the new outfalls in October 1988 measured 46.7 mg.l⁻¹ at 51m upstream, 8.9 mg.l⁻¹ at 248m upstream and 4.65 mg.l⁻¹ at 252m downstream of SCM whilst only a figure of 2.3 mg.l⁻¹ at 246m downstream was significant at Tioxide and clearly reflected the inadequacies of the sampling.

From a combination of all the survey data, the soluble iron plume was not as narrow or as consistent in width as that for pH. Iron values exceeding the EQS were measured for at least 1,175m upstream (2.43 mg.l⁻¹; 979-fold dilution) and at least 1,648m downstream (27.1 mg.l⁻¹; 88-fold dilution) from the SCM discharge and for at least 983m upstream (5.2 mg.l⁻¹; 1,188-fold dilution) and 1,253m downstream (1.66 mg.l⁻¹; 3,723-fold dilution) from the Tioxide discharge.

b) SCM Results.

Iron rich water of > 5.0 mg.l⁻¹ was detectable for at least 515m upstream (14.4 mg.l⁻¹; 165-fold dilution) and 1,648m downstream (27.1 mg.l⁻¹; 88-fold dilution) from the SCM outfall.

Iron rich water of > 10.0 mg.l⁻¹ was detectable for at least 515m upstream (14.4 mg.l⁻¹; 165-fold dilution) and 1,648m downstream (27.1 mg.l⁻¹; 88-fold dilution) from the SCM outfall.

Iron rich water of > 20.0 mg.l⁻¹ was detectable for at least 68m upstream (71.4 mg.l⁻¹; 33-fold dilution) and 1,648m downstream (27.1 mg.l⁻¹; 88-fold dilution) from the SCM outfall.

c) Tioxide Results.

Iron rich water of > 5.0 mg.l⁻¹ was detectable for at least 983m upstream (5.2 mg.l⁻¹; 1,188-fold dilution) and nearly 1,069m downstream (4.45 mg.l⁻¹; 1,389-fold dilution) from the Tioxide outfall.

Iron rich water of > 10.0 mg.l⁻¹ was detectable for at least 506m upstream (10.2 mg.l⁻¹; 606-fold dilution) and nearly 349m downstream (10.2 mg.l⁻¹; 606-fold dilution) from the Tioxide outfall.

Iron rich water of > 20.0 $mg.l^{-1}$ was detectable for at least 337m upstream (23.2 $mg.l^{-1}$; 266-fold dilution) and none was measured downstream of the Tioxide outfall.

During the 1984 surveys around the old Tioxide outfall an area of iron rich water was detected inshore of the outfall, discontinuous from the main plume.

An area of iron rich water, similar to one observed during the 1984 surveys, was visually observed and tracked during this work shortly after one low water. This "patch" (1.29 and 1.86 $mg.l^{-1}$) was almost certainly the remnants of a small pool of effluent discharged just prior to slack water that was then pushed inshore by the flood tide.

In 1984, it was originally thought that this "patch" represented a secondary source of soluble iron, but a more realistic explanation was that iron rich water from the flood tide was trapped against the shore where dilution occurred only slowly.

With the movement of the Tioxide outfall to deeper water, entrapment of the plume is most unlikely to occur, since there is always a substantial body of mobile water on the inshore side of the outfall.

d) Discussion and Comparison with 1984 Results.

The soluble iron plumes from the new outfalls were far less detectable than those from the old outfalls. In 1984, the maximum measured ranges of the > 20 $mg.l^{-1}$ areas were 2.1 km upstream and 1.5 km downstream of SCM and 4.13 km upstream and 2.38 km downstream of Tioxide.

In 1984, for a given distance, higher figures were observed around the old Tioxide outfall than around the old SCM outfall. This reflected the higher concentrations and flows discharged by Tioxide.

By contrast, the 1989 data have shown that higher values were detected around the new SCM outfall than the new Tioxide outfall. Also, many more low dilution factors were detected around SCM than around Tioxide. There were 92 factors < 1000 and 23 factors < 100 for SCM whilst there were only 7 factors < 1000 for Tioxide and none < 100.

Two explanations are possible. Firstly, the samples collected around the Tioxide outfall were not representative of the prevailing conditions. This would only be the case if the plume was at a significantly lower depth than measured in these surveys. This is not thought to be the case, since one survey day was designed to sample at depths only a few metres above the estuary bed, which would have been sufficient to locate the plume if it was there. Secondly, the discharged effluent may be dispersed so well that the plume is too narrow to be readily located with a "random" sampling scheme, such as was employed here.

For the old plumes in 1984, these "random" samples and their results were confirmed by the numerical model which should determine the overall shape of the plume more accurately. The field observations merely indicated that particular concentrations were observable at some time during the tidal cycle. It would not be feasible to devise a survey programme able to determine exposure times to various concentrations of iron; only modelling can achieve this.

The soluble iron data from these 1989 surveys do not readily demonstrate any effects of bottom topography, since the path of both iron plumes would appear to follow the expected tidal pattern. However, the 1984 survey results indicated that the shapes of the > 20 $mg.l^{-1}$ Fe plumes differed between the two discharges. The bottom topography obviously had a significant influence on the relative plume shapes. SCM's was longer and narrower than that of Tioxide's, due no doubt to faster current velocities and deeper water around the SCM outfall, since the area around the old Tioxide outfall was largely mudflats, producing shallower and slower moving water. Now that the Tioxide outfall is in deeper water than the SCM outfall, the observed reversal in relative plume sizes can be explained.

It was thought that the "patches" may have been a common occurrence, especially since they were detected on the two spring tide surveys of 1984, where evidence suggested that the higher mass movement and current velocities created greater mixing and dispersion. It was also thought that moderate on-shore winds would cause a greater degree of mixing than usual, leading to an absence of such patches. However, the effect of wind speed on mixing characteristics has not been assessed.

A major observation was that around each old outfall the plumes were constrained inshore and therefore dilution and dispersion could only occur on the offshore side. The plumes around the new outfalls have substantial amounts of uncontaminated water on both sides, indicating much greater potential for dispersion.

8.4 Comparison Between the pH and Soluble Iron Plumes.

The SCM pH and soluble iron plumes coincide, although the pH plume is more constrained but clearly defined. This is partly explained by the fact that neutralised water will still carry some soluble iron before it eventually precipitates out onto the particulate material.

The Tioxide pH and soluble iron plumes do not coincide so effectively. This could be due to either a sparsity of data leading to poorly defined plumes, or else that dispersion is so effective that the plumes are too small to define clearly.

Patches of affected water were noted inshore of Tioxide, for both iron and acidity.

These comparisons match those of 1984, when the characteristics of the pH plume and the soluble iron plume for a given discharge on a given tide (either spring or neap) were found to be similar, the pathways generally matching.

8.5 Other Soluble Metal Results.

Although the analytical methods for trace metals in sea water require further development due to both the low levels involved and the saline matrix, some interpretation has been attempted.

If it is assumed that neither the iron nor the trace metals have precipitated out within the first hour after discharge, it is possible to predict the expected concentration of trace metals in the water column from the analysis of the appropriate factory effluent together with the iron result for the water column sample. Any background levels need to be taken into account. Some of the filtered estuary samples from around both the new outfalls were analysed for a range of metals and the results compared to the derived data.

For the selected samples, concentrations were calculated for cadmium, chromium, copper, lead, nickel, zinc and manganese. These values are shown in Table 8.9 for the new SCM outfall and Table 8.10 for the new Tioxide outfall. The daily average (composite) result for the factory has been used, so there is some leeway in the results to allow for normal fluctuations. Where real results exceed the derived values, then the difference represents a minimum value for the background level.

No cadmium was detected in either the SCM or Tioxide effluents (<20 $ug.l^{-1}$ for factory samples) and therefore this metal is not included in the derived tables. With a limit of detection in the estuarine samples of <0.25 $ug.l^{-1}$, some cadmium was detected in those samples containing larger values of soluble iron. This was almost certainly erroneous, since the effluent cadmium values were already at the EQS level and the background was insignificant. The results were obviously affected by the matrix problems of an industrial effluent and seawater.

8.6 Discussion of Predicted and Observed Results.

Below are shown the relevant EQS and LOD soluble metal values required for the Humber Estuary ($ug.l^{-1}$).

	EQS	Required LOD	Actual LOD	Levels in Estuary
Cadmium	5	0.5	0.5	0.28
Chromium	15	1.5	1.5	<1
Copper	5	0.5	2.8	5
Lead	25	2.5	2.5	0.8
Nickel	30	3	3.0	6
Zinc	40	4	4.0	15

With one exception, no real chromium results exceeded derived values, suggesting that the background level was negligible, which agrees with past monitoring data. Assuming a zero background level, with only one exception, the derived values were greater than the analytical results. It was clear that the chromium was being quickly lost from solution, either by precipitation or adsorption.

For lead, without using a background figure, all real results were below the derived values, which was as expected. All results and derived values were below the EQS with past monitoring data suggesting that soluble lead in the Humber is normally below the limit of detection (<0.7 $ug.l^{-1}$). Lead results would only exceed the EQS if the iron result near SCM was >126 $mg.l^{-1}$ or >177 $mg.l^{-1}$ near Tioxide, assuming a zero background level. Again, it is clear that lead was being rapidly lost from solution, as would be expected.

Derived values for copper predicted that the concentration of copper would be in excess of the EQS (5 $ug.l^{-1}$) in the vicinity of the SCM discharge when the soluble iron content exceeded about 12.5 $mg.l^{-1}$ in the water column. Ten samples exceeded the EQS while nine exceeded the derived value but they were not all the same in each case. For the Tioxide discharge, the soluble iron content would need to exceed about about 61 $mg.l^{-1}$. No values were measured at this level around the Tioxide outfall. Calculations with this data suggest that there was a background copper level of about 3 $ug.l^{-1}$, which compared well with known results.

Although the copper LOD is a little high, no copper was measured in some samples that would be expected to contain soluble copper. Some of the higher results tied in with the derived values (allowing for a background figure of about 5 $ug.l^{-1}$) but there were several results with peculiarly high copper but with low iron results. This suggested a saline matrix analytical problem rather than an iron matrix one.

Very poor agreement was noted between the nickel results and the derived values. All the high values were associated with high iron results and were considerably greater than the derived results. These figures also exceeded the EQS of 30 $mg.l^{-1}$, suggesting a major matrix problem in the analysis. Where positive results have been recorded, they significantly exceeded the derived values with only the lower results being accountable as background. On the basis of the factory effluent data, soluble nickel would only exceed the EQS if the iron result near SCM was >64 $mg.l^{-1}$ or >634 $mg.l^{-1}$ near Tioxide, assuming a zero background level.

Reasonable agreement existed between the zinc results and derived values, if allowance was made for a background of between 5 and 20 $ug.l^{-1}$. Although only two exceeded the zinc EQS value of 40 $ug.l^{-1}$, the highest results were associated with the highest iron values and could not be accounted for from the derived values and background levels. This suggested a matrix problem in the analysis. Soluble zinc would only exceed the EQS if the iron result near SCM was >129 $mg.l^{-1}$ or >64 $mg.l^{-1}$ near Tioxide, assuming a zero background level.

The results for manganese suggested a background value of between 150 and 250 $ug.l^{-1}$, although a figure of about 40 would be anticipated. The large over estimation of soluble manganese compared to the derived results appeared to be related to a high iron content. This suggested a matrix problem in the determination of soluble manganese.

Conclusion: Where soluble iron was less than about 12 $mg.l^{-1}$ near the SCM outfall or less than about 61 $mg.l^{-1}$ near the Tioxide outfall, no other metal EQS would be exceeded. Consequently, the iron EQS of 1 $mg.l^{-1}$ will, if met, mean that the levels of other metals in the discharge will automatically satisfy their own EQS, assuming the discharge figures remain similar to those used here.

8.7 Results for Metals in Sediments (<90 um fraction).

The sediment sub-samples taken during benthic sampling were analysed for a range of metals. Distribution maps have been plotted for iron and titanium around each outfall and are shown in Figures 8.7 to 8.10. No meaningful contours could be easily plotted. The basic data are shown in Table 8.11 for SCM and Table 8.12 for Tioxide.

Although there are significant discharges of metals to various parts of the Humber Estuary, the large body of moving water, the relatively high current velocities encountered and the naturally high level of suspended solids in the water column (predominantly a fine silt) tend to hinder localised accumulation of metals in sediments.

Therefore any significant trends in sediment enrichment were likely to be the result of major sources of contamination. Furthermore, the Tioxide and SCM outfalls discharge significant quantities of certain distinctive elements, whereas other discharges in the vicinity can be distinguished by a different distinctive element, e.g. Courtaulds, located between SCM and Tioxide, discharges significant quantities of zinc (in predominantly soluble form).

If the pattern of enrichment of sediment by the discharges of specific elements was not matched by that of non-specific elements, then this would point to a specific source of the metal.

The grid of sample sites around the new SCM outfall was largely overlapped by the sampling grid around the old SCM outfall leading to difficulties in interpretation at some sites.

The bathymetry around each outfall was a significant factor in the interpretation of the results, especially when taken in conjunction with the variable nature of the estuary bed. In particular, there is a tongue of deeper water running inshore on the downstream side of the new SCM outfall. The new Tioxide outfall is right on the outer edge of a shoal and the estuary bed steepens significantly in an offshore direction at this point.

Three sub-tidal control sites from the lower Humber Estuary were used for comparison purposes. They were selected as being unlikely to be contaminated by these particular effluents (past or present).

The elements of most interest were: Fe, Ti and V because they were distinctive to both SCM and Tioxide discharges; mercury and cadmium because they are subject to specific EEC legislation and Zn because it is distinctive to Courtaulds discharge. Cu was also of interest because deposits 20 times the average were found close to the old SCM discharge in 1984 and because previous work on metals in seaweed suggested there to be a significant copper input somewhere in the vicinity although no such input has been located.

From consideration of the data from the 1984 special surveys, some enrichment of iron and titanium would be expected around the new outfalls, if to a lesser degree. Lack of evidence for enrichment could be for a number of reasons:-

- the outfalls have not been in operation long enough for the full effect to become apparent;

- the estuary bed material is not readily affected by the contents of the discharge;
- there are strong localised currents which scour the estuary bed;
- the sampling program was deficient in some manner, e.g. too sparse;
- the effect of the discharge is reduced, i.e. spread over a wider area.

Unless otherwise stated, all references are to the new outfalls with all 1984 data referring to the old outfall. Where zones of "depletion" have been identified, they indicate areas of concentration less than the lowest control site.

a) Iron in sediment.

From the 1989 data, no iron enrichment was apparent around either of the new outfalls. Consequently, no comparison can be made with the effluent plumes. In fact, for SCM, there was an iron depleted zone running through the discharge point, along the line of the plume. Similarly for Tioxide, there were iron depleted zones running through the discharge point, both along the line of the plume and at right angles. The former line coincided with the steepening gradient of the estuary bed where significant current scour can be expected, whilst the latter followed the line of the pipeline where the recent disturbance of the sediments during construction is probably a factor.

The highest value in the grid for Tioxide did not appear to have any significance. However, the highest value for SCM (most easterly inshore site, 500m downstream) was significantly higher than all other values around this discharge but was still lower than one of the 3 control sites (CL.29). This anomalous site was physically different to the others in the grid consisting of loose, unconsolidated mud, whereas the remaining sites were hard, consolidated mud (as evidenced from the grab sample collection).

The mean iron value around Tioxide was significantly higher (by a factor of 1.27) than that around SCM, with the former matching the highest value at SCM as well as the result for the highest control site (CL.29). The mean iron value for SCM matched the lowest control site (CL.24) whilst the third control site had a value mid way between the other two.

In 1984, one sample in particular found very close to the old Tioxide outfall had an iron crust which was dramatically enriched in iron relative to all other sites. Iron enrichment was evident around both the old outfalls and was generally coincident with the line of the effluent plumes.

b) Titanium in Sediments.

There was no obvious titanium enrichment in the immediate vicinity of either new outfall. However, in both cases there were high points a little distance from the discharge, 500m downstream and inshore of SCM and offshore of the Tioxide plume. In fact, there appeared to be a zone of titanium depletion around the Tioxide outfall, the most likely explanation being that the currents were strong enough to disperse the effluent before the titanium had time to either settle out (from the ore waste) or precipitate (from solution) close to the outfall.

Similar to the iron results, there was the same "anomalous" site near the SCM outfall (500m downstream and 250m inshore of outfall). This site was also enriched in comparison to the average values around the Tioxide outfall.

The mean titanium value around the new Tioxide outfall was higher than that around the SCM outfall by a factor of 1.39, the latter results being comparable to the values at the three control sites.

Around the old outfalls in 1984, there was titanium enrichment between Grimsby and Immingham closely matching the pathway of the soluble iron plume.

c) Vanadium in Sediments.

There was a small area of slight vanadium enrichment around the SCM outfall (about 100m upstream and downstream), with a depleted zone on the inshore side. There was no enrichment around the Tioxide outfall with there being a suggestion of vanadium depletion along the path of the effluent plume.

There was the same "anomalous" site at SCM as for iron and titanium. The value was over twice the value of the control sites and also exceeded all the Tioxide sites.

The mean value around the Tioxide outfall was higher than that around the SCM outfall by a factor of 1.19 (if excluding the anomalous site, 1.27). Both areas were enriched in comparison to the three control sites.

In 1984, vanadium enrichment was apparent in the intertidal sediments between the old Tioxide outfall and Immingham.

d) Mercury in Sediments.

There was no trend apparent in the mercury distribution for either outfall. At SCM the lowest concentrations were around the outfall, rising towards the shore. The values around the Tioxide outfall were also below average with mercury distribution being somewhat random.

Again there was an anomalous site (500m downstream and 250m inshore) with a mercury value nearly three times the mean.

There was no significant difference between the mean values around both outfalls (the ratio was 1.00) although these values were enriched in comparison to two of the control sites.

The complex pattern of mercury distribution in the 1984 results showed some enrichment of the intertidal sediments in the vicinity of each outfall with there also being areas exhibiting low levels although with some 96% of the mercury in the SCM discharge being associated with the particulate matter it had been expected that the deposition would be localised around the outfall. The site 300m downstream of SCM and about 300m offshore (L.300.E3) had a total mercury content over 30 times greater than the average value.

e) Cadmium in Sediment.

Whilst cadmium is subject to a specific EEC directive, there were no detectable amounts present in either the SCM or the Tioxide effluents. Since all cadmium results for sediment were below the limit of detection (0.5 $mg.kg^{-1}$), it was not possible to make any comparisons.

In 1984, the detection limit for cadmium was lower (about 0.24 $mg.kg^{-1}$) and two very distinctive areas of cadmium enrichment were apparent in the sub-tidal sediments, one of which was very symmetrical about the old SCM outfall.

f) Zinc in Sediments.

There was no sign of enrichment around either outfall. At SCM there was a line of low zinc levels along the line of the plume. At Tioxide there was a zone of enriched zinc one side of the pipeline with a zone of depleted zinc on the other side (both inshore of the outfall) which was possibly a consequence of the pipeline construction.

The highest result within the Tioxide grid was well away from the discharge point and any other known sources of zinc.

For the SCM grid there was the same anomalous point (500m downstream and 250m inshore) which was nearly twice the level of the lowest control site (CL.24) and higher than all values around Tioxide.

The mean level for the Tioxide grid was a factor of 1.20 higher than that for SCM with the former being slightly higher than the control sites and the latter slightly lower. However, there was not good agreement between the values at the three control sites.

g) Other Metals in Sediments.

Aluminium, being a basic component of the clay mineral sediments might reasonably be expected to show a negative correlation with metals in otherwise enriched sediments. However, unlike previous surveys this element was not determined, due to difficulties in both analysis and interpretation.

There was evidence of copper enrichment 50m downstream of the SCM outfall with a value that was approximately twice that of the remaining sites and which matched the value at the previously identified anomalous site. This suggested a copper input in the vicinity. Around the Tioxide outfall, copper values were spread relatively evenly throughout the grid although there was a small peak 100m upstream of the outfall.

The mean copper value around the Tioxide outfall was slightly higher than for the SCM outfall by a factor of 1.07, although the latter was enhanced by two particularly large values. Both sets of data were higher than the mean control site figure (which did not share a consistent value).

In 1984, the highest recorded copper values were around 1,300 $mg.kg^{-1}$ 50m upstream of the old SCM discharge whilst the figure at 50m downstream was about half this, although the means for each site were comparable at about 500 $mg.kg^{-1}$. This compares to values of 31 to 43 $mg.kg^{-1}$ at the current control sites.

There was no indication of chromium enrichment around either outfall. In both areas, values were evenly distributed, with there being a slightly depleted zone around the SCM outfall and a significantly depleted zone 100m upstream of the Tioxide outfall.

There was a high chromium value at the identified anomalous site near SCM (500m downstream and 250m offshore), approximately twice that of the mean of the grid.

The mean chromium value for the Tioxide grid was again higher than that for SCM (by a factor of 1.21). Both values were significantly higher than the lowest control site (CL.24) with the other two control sites having values between those of the two outfall grids.

There was no evidence of lead enrichment around either outfall. Instead, there was a zone of lead depletion around both of them.

There was a high lead value at the identified anomalous site near SCM (500m downstream and 250m offshore), approximately twice that of the mean of the grid.

The mean lead value for the Tioxide grid was again higher than that for SCM (by a factor of 1.37). The value for SCM was comparable to that of control site 24 which was significantly lower than the other two control sites whereas the mean value for Tioxide was slightly higher than all three control sites.

There was no indication of nickel enrichment around either outfall. The usually "anomalous" site near SCM was not as apparent as for other metals and the mean nickel values were very similar around the two outfalls (the factor was 1.03). These mean values were comparable to two of the control sites with the third (CL.24) being somewhat lower.

There was a definite manganese enrichment zone around the new SCM outfall where the contours appeared symmetrical about the line of the plume with the values decreasing away from the outfall in all directions. This was not the case around Tioxide where the lowest result in the grid was 50m upstream of the outfall.

The site 500m downstream and 100m inshore from SCM was particularly unusual. For nearly every other metal, this site had a considerably larger result than the rest of the grid but for manganese it had the lowest result. This could be evidence that uptake of manganese was dependent on the uptake of other metals. It had been observed at many sites in the Humber Estuary in the past that Mn could show an inverse trend with other metals and especially with iron.

The mean manganese value around the Tioxide outfall was slightly higher than that for SCM (by a factor of 1.06). Both outfall grids were enriched in manganese by comparison with two of the control sites (CL.24 and CL.N33) but all values were lower than the third control site (CL.29).

h) Overall Features of Metals in Sediments.

There was no evidence of enrichment of the sediments surrounding either of the new outfalls by the factory effluents, since the patterns of distribution for iron and titanium were matched by all other metals except manganese.

There was a significant difference between the surveyed areas around each outfall. The mean values for iron, titanium, vanadium, zinc, chromium and lead were considerably higher in the Tioxide grid than in the SCM grid with copper, nickel and manganese being slightly enhanced. One conclusion from this observation was that the nature of the estuary bed was distinctly different between the two areas. A second conclusion was that the levels required to show an enrichment of the sediment would be different for the two outfall areas.

It was possible that the mini-grid was too small to show the full range of effect, either by there being too great a distance between sample points or else by not being large enough to distinguish the area affected from surrounding areas, especially if the effects of the plume are being more widely dispersed than previously.

Control site 24 consistently provided lower results than did either control site 24 or control site N33 although all were chosen with the belief that they represented uncontaminated areas.

There was an anomalous site in the grid around the old SCM outfall at 500m downstream and 100m inshore of the track of the plume (site SCM.3E.250S). For all metals measured except manganese, this had much higher results than the remaining sites in the grid. The sampling grid used around the old outfall largely overlapped that around the new outfall. Examination of results from the old grid showed a depleted zone offshore of the old outfall for all metals except manganese. The anomalous site in the new outfall grid corresponded with an area outside the depleted zone in the old outfall grid, thus confirming the legitimacy of the conclusion.

Finally, the effect of the current titanium dioxide discharges on the sediments around the new outfalls is much less than that previously measured around the old outfalls in 1984.

8.8 Comparison of the Chemical Plumes with the Biota/Sediment Sample Grid.

With there being no apparent enrichment of the sediments surrounding either of the new outfalls, it was not possible to make any direct comparison with the chemical plumes. However, it was possible to make some observations. Firstly, due to the relatively deep water and fast currents, the plume was probably not touching the estuary bed close to an outfall for any significant length of time (slack water might well be an exception). Secondly, current velocities were quite probably carrying the effluent an appreciable distance before any settling or precipitation could take place.

In 1984, the overall length of the sampling grid around the old outfalls was much greater (2.25 km upstream and downstream) and proved to cover the area which was most severely affected by the discharge plumes. It was felt that such an area was inappropriate for these surveys, with the grids extending only 500m up and downstream.

SCM TITRATION RESULTS

400 ml of Estuary water, Alkalinity of 130 mg/l (as $CaCO_3$).

Strength of Effluent 12,985 mg/l (as sulphuric acid).

Strength of Effluent 19,610 mg/l (as $CaCO_3$).

Volume of Effluent Added (ml)	Total Volume (ml)	Resulting pH	Dilution Factor
0.0	400.0	7.40	
0.1	400.1	7.21	4,001
0.2	400.2	7.08	2,001
0.3	400.3	6.93	1,334
0.4	400.4	6.83	1,001
0.5	400.5	6.72	801
0.6	400.6	6.64	668
0.7	400.7	6.58	572
0.8	400.8	6.49	501
0.9	400.9	6.39	445
1.0	401.0	6.36	401
1.1	401.1	6.31	365
1.2	401.2	6.25	334
1.3	401.3	6.19	309
1.4	401.4	6.14	287
1.5	401.5	6.11	268
1.6	401.6	6.03	251
1.7	401.7	6.00	236
1.8	401.8	5.95	223
1.9	401.9	5.89	212
2.0	402.0	5.83	201
2.1	402.1	5.75	191
2.2	402.2	5.70	183
2.3	402.3	5.63	175
2.4	402.4	5.54	168
2.5	402.5	5.43	161
2.6	402.6	5.30	155
2.7	402.7	5.14	149
2.8	402.8	4.92	144
2.9	402.9	4.64	139
3.0	403.0	4.33	134
3.1	403.1	4.08	130
3.2	403.2	3.91	126

TABLE 8.1 : pH Values for the Addition of SCM Effluent to Estuary Water - page 1 (of 2).

Volume of Effluent Added (ml)	Total Volume (ml)	Resulting pH	Dilution Factor
3.3	403.3	3.78	122
3.4	403.4	3.67	119
3.5	403.5	3.58	115
3.6	403.6	3.51	112
3.7	403.7	3.44	109
3.8	403.8	3.34	106
3.9	403.9	3.29	104
4.0	404.0	3.20	101
4.1	404.1	3.16	99
4.2	404.2	3.13	96
4.3	404.3	3.10	94
4.4	404.4	3.05	92
4.5	404.5	3.01	90
4.6	404.6	2.99	88
4.7	404.7	2.96	86
4.8	404.8	2.94	84
4.9	404.9	2.92	83
5.0	405.0	2.90	81
5.1	405.1	2.89	79
5.2	405.2	2.87	78
5.3	405.3	2.85	76
5.4	405.4	2.84	75
5.5	405.5	2.83	74

TABLE 8.1 : pH Values for the Addition of SCM Effluent to Estuary Water - page 2 (of 2).

TIOXIDE TITRATION RESULTS

400 ml of Estuary water, Alkalinity of 130 mg/l (as $CaCO_3$).

Strength of Effluent 18,530 mg/l (as sulphuric acid).

Strength of Effluent 30,330 mg/l (as $CaCO_3$).

Volume of Effluent Added (ml)	Total Volume (ml)	Resulting pH	Dilution Factor
0.0	400.0	7.36	
0.2	400.2	6.90	2,001
0.4	400.4	6.60	1,001
0.6	400.6	6.39	668
0.8	400.8	6.16	501
1.0	401.0	5.99	401
1.2	401.2	5.87	334
1.4	401.4	5.75	287
1.6	401.6	5.42	251
1.8	401.8	5.22	223
2.0	402.0	4.95	201
2.2	402.2	4.46	183
2.4	402.4	3.86	168
2.6	402.6	3.53	155
2.8	402.8	3.33	144
3.0	403.0	3.19	134
3.2	403.2	3.00	126
3.4	403.4	2.93	119
3.6	403.6	3.00	112
3.8	403.8	2.93	106
4.0	404.0	2.97	101
4.2	404.2	2.81	96
4.4	404.4	2.76	92
4.6	404.6	2.71	88
4.8	404.8	2.68	84
5.0	405.0	2.64	81
5.2	405.2	2.60	78
5.4	405.4	2.57	75
5.6	405.6	2.54	72

TABLE 8.2 : pH Values for the Addition of Tioxide Effluent to Estuary Water.

Table 8.3 : **Summary of pH Data around the New SCM Outfall.**

Date	Time BST	NGR East	NGR North	Range (m)	pH	Plume Depth (m)	Time after HSW (hrs)	(mins)
Outfall		522252	415262	0				
13-Jul-89	01:43:00						HSW	103
13-Jul-89	10:44:56	522060	415459	275	6.6	4.2	9.0	645
13-Jul-89	11:00:28	522076	415379	211	6.6	3.8	9.3	660
13-Jul-89	11:08:00	522124	415411	196	6.7	3.7	9.4	668
13-Jul-89	11:32:16	522147	415317	119	6.8	3.7	9.8	692
13-Jul-89	11:41:02	522194	415349	105	6.8	3.8	10.0	701
13-Jul-89	11:52:08	521951	415486	375	6.8	3.7	10.2	712
13-Jul-89	12:03:38	521872	415678	563	6.9	4.3	10.3	723
13-Jul-89	12:21:18	521817	415631	570	6.8	4.1	10.6	741
13-Jul-89	12:33:44	521748	415802	739	6.8	4.2	10.8	753
13-Jul-89	12:44:02	521687	415765	756	7.0	4.2	11.0	764
13-Jul-89	14:06:00						HSW	846
13-Jul-89	14:44:28	522331	415157	131	4.7	4.2	0.6	884
13-Jul-89	15:15:46	522383	415134	183	6.3	4.0	1.2	915
13-Jul-89	15:22:10	522439	415041	289	6.2	3.8	1.3	922
13-Jul-89	15:58:10	522539	414959	417	6.2	4.7	1.9	958
13-Jul-89	16:30:10	522552	415008	393	6.4	4.8	2.4	990
13-Jul-89	16:40:16	522606	414909	500	6.5	4.9	2.6	1000
13-Jul-89	17:13:03	522639	414884	541	6.8	3.8	3.1	1033
13-Jul-89	17:13:06	522640	414879	545	6.8	0.2	3.1	1033
13-Jul-89	17:22:44	522699	414906	571	6.8	4.2	3.3	1042
13-Jul-89	17:22:44	522699	414906	571	6.8	0.2	3.3	1042
13-Jul-89	17:53:23	522753	414855	645	6.9	3.6	3.8	1073
13-Jul-89	17:53:23	522753	414855	645	6.8	3.5	3.8	1073
13-Jul-89	17:53:53	522754	414793	687	6.8	0.2	3.8	1074
14-Jul-89	02:54:00						HSW	174
14-Jul-89	15:22:00						HSW	922
14-Jul-89	19:23:31	522239	415216	48	5.8	3.4	4.0	1163
14-Jul-89	19:30:28	522302	415264	50	4.5	3.6	4.1	1170
14-Jul-89	19:37:06	522306	415136	137	6.1	3.5	4.3	1177
14-Jul-89	19:42:38	522398	415184	166	6.2	3.5	4.3	1182
14-Jul-89	19:50:04	522382	415068	234	6.2	3.5	4.5	1190
14-Jul-89	19:50:10	522378	415062	236	6.5	0.2	4.5	1190
14-Jul-89	19:54:24	522469	415123	258	6.5	0.2	4.5	1194
14-Jul-89	19:54:28	522472	415127	258	6.0	3.2	4.5	1194
29-Jul-89	03:40:00						HSW	220
29-Jul-89	14:04:03	522175	415338	108	6.5	3.0	10.4	844
29-Jul-89	14:11:15	522115	415351	163	6.4	4.2	10.5	851
29-Jul-89	14:20:33	522071	415420	240	6.4	4.8	10.7	860
29-Jul-89	14:40:37	522005	415442	306	6.6	3.8	11.0	880
29-Jul-89	14:47:03	522023	415439	289	6.6	3.6	11.1	887

Table 8.3 : Summary of pH Data around the New SCM Outfall - Page 1 (of 2).

Date	Time BST	NGR East	NGR North	Range (m)	pH	Plume Depth (m)	Time after HSW (hrs)	(mins)
29-Jul-89	15:02:17	521943	415527	407	6.8	3.8	11.4	902
29-Jul-89	15:13:11	521917	415518	422	6.7	3.7	11.6	913
29-Jul-89	15:30:33	521816	415671	598	6.7	4.0	11.8	930
29-Jul-89	15:44:31	521826	415674	593	6.6	4.7	12.1	944
29-Jul-89	15:52:13	521679	415778	771	6.6	4.0	12.2	952
30-Jul-89	04:30:00						HSW	270
30-Jul-89	07:24:29	522257	415227	35	6.5	4.9	2.9	444
30-Jul-89	07:31:57	522352	415174	133	6.3	5.8	3.0	452
30-Jul-89	07:42:49	522505	415014	354	6.7	5.7	3.2	462
30-Jul-89	07:50:37	522519	415028	355	6.6	5.6	3.3	470
30-Jul-89	07:58:23	522626	414916	510	6.6	4.5	3.5	478
30-Jul-89	08:08:17	522684	414919	552	6.6	4.2	3.6	488
30-Jul-89	08:14:29	522748	414840	651	6.6	3.8	3.7	494
30-Jul-89	08:25:01	522801	414834	696	6.6	3.7	3.9	505
30-Jul-89	08:34:55	522866	414757	795	6.6	4.3	4.1	515
30-Jul-89	08:42:53	522880	414788	787	6.7	4.8	4.2	523
30-Jul-89	08:54:23	522996	414679	945	6.7	4.3	4.4	534
30-Jul-89	09:05:41	523064	414669	1,005	6.6	4.1	4.6	545
30-Jul-89	09:13:39	523312	414937	1,109	6.9	4.5	4.7	553
30-Jul-89	09:22:45	523152	414546	1,150	6.6	3.0	4.9	562
30-Jul-89	09:29:27	523219	414579	1,184	6.6	1.5	5.0	569
30-Jul-89	13:51:26	522211	415253	42	5.8	3.6	9.4	831
30-Jul-89	13:57:14	522176	415325	99	6.4	5.0	9.5	837
30-Jul-89	14:10:24	522100	415370	186	6.3	3.3	9.7	850
30-Jul-89	14:17:36	522046	415454	282	6.8	4.5	9.8	857
30-Jul-89	14:27:04	521920	415536	430	6.6	3.2	10.0	867
30-Jul-89	14:35:16	521865	415619	527	6.6	4.3	10.1	875
30-Jul-89	14:41:26	521754	415681	651	6.8	3.3	10.2	881
30-Jul-89	14:53:02	521608	415867	884	6.7	4.1	10.4	893
30-Jul-89	15:02:14	521626	415845	855	6.9	3.3	10.5	902
30-Jul-89	15:02:56	521633	415817	831	6.9	3.3	10.5	903
30-Jul-89	15:03:38	521634	415780	806	6.9	3.3	10.6	903
30-Jul-89	15:18:36	521593	415864	893	6.7	4.7	10.8	918
30-Jul-89	15:26:20	521492	415893	988	6.9	3.7	10.9	926
30-Jul-89	15:33:14	521514	415862	951	6.8	4.7	11.1	933
30-Jul-89	15:41:40	521397	415929	1,084	6.6	3.5	11.2	941
30-Jul-89	15:42:20	521368	415891	1,085	6.6	3.5	11.2	942
30-Jul-89	15:50:20	521324	415946	1,153	6.7	4.7	11.3	950
30-Jul-89	15:50:56	521339	415979	1,161	6.7	4.7	11.3	951

Table 8.3 : Summary of pH Data around the New SCM Outfall - Page 2 (of 2).

Table 8.4 : **Summary of pH Data around the New Tioxide Outfall.**

Date	Time BST	NGR East	NGR North	Range (m)	pH	Plume Depth (m)	Time after HSW (hrs)
Outfall		526245	414091	0			
13-Jul-89	14:06:00						HSW
13-Jul-89	20:25:00	526384	414076	140	7.1	3.7	6.3
14-Jul-89	02:54:00						HSW
14-Jul-89	07:46:19	526308	414093	63	2.8	7.6	4.9
14-Jul-89	11:59:49	525426	414456	897	5.8	4.7	9.1
14-Jul-89	12:38:21	524808	414495	1,493	5.9	4.4	9.7
14-Jul-89	13:57:16	525557	414231	702	5.7	4.1	11.1
14-Jul-89	14:20:29	525642	414189	611	5.6	3.6	11.4
14-Jul-89	14:40:21	525706	414204	551	5.8	4.1	11.8
14-Jul-89	15:20:32	525944	414059	303	6.0	3.7	12.4
14-Jul-89	15:22:00						HSW
14-Jul-89	16:30:16	526143	413765	342	5.3	3.7	1.1
29-Jul-89	03:40:00						HSW
29-Jul-89	11:12:04	526049	413945	244	6.8	3.5	7.5
29-Jul-89	12:34:02	525573	414362	725	6.8	4.0	8.9
29-Jul-89	16:17:00						HSW
29-Jul-89	16:51:10	525963	414158	290	6.8	4.9	0.6
29-Jul-89	16:59:38	526037	414043	213	6.1	6.2	0.7
29-Jul-89	17:05:38	526083	414036	171	5.9	6.7	0.8
29-Jul-89	17:18:00	526160	413946	168	6.6	6.5	1.0
29-Jul-89	17:33:52	526508	413999	279	7.0	6.7	1.3
29-Jul-89	17:49:10	526607	413827	448	6.3	6.3	1.5
29-Jul-89	19:19:02	526477	414036	238	6.3	4.2	3.0
29-Jul-89	19:34:36	526807	413926	586	6.5	4.1	3.3
29-Jul-89	19:45:00	526508	414030	270	6.4	4.8	3.5
29-Jul-89	19:55:28	526594	413983	365	5.8	7.0	3.6
29-Jul-89	20:10:28	526645	413990	413	6.1	7.9	3.9
29-Jul-89	20:16:56	526822	413930	599	6.2	8.8	4.0
29-Jul-89	20:31:02	526833	413898	619	6.5	0.2	4.2
29-Jul-89	20:32:40	526888	413960	656	6.6	7.5	4.3
30-Jul-89	17:27:00						HSW
30-Jul-89	19:18:16	527259	413546	1,151	6.7	5.7	1.9
30-Jul-89	19:48:56	526260	414077	21	3.6	8.0	2.4

Table 8.5: Soluble Iron Data from around the New SCM Outfall.

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
26-Aug-89	01:59	522252	415262						2965.000	0	0.0
26-Aug-89	08:04	522207	414993	16,644	0.2		27.1	6.6	0.006	273	6.1
26-Aug-89	08:04	522207	414993	16,645	3.0		27.5	6.9	0.006	273	6.1
26-Aug-89	08:07	522282	415086	16,646	0.2		27.1	6.8	0.006	179	6.1
26-Aug-89	08:07	522282	415086	16,647	3.0		27.1	6.3	0.006	179	6.1
26-Aug-89	08:10	522344	415166	16,648	0.2		26.6	5.0	18.500	133	6.2
26-Aug-89	08:10	522344	415166	16,649	2.0		26.6	5.5	0.752	133	6.2
26-Aug-89	08:11	522357	415192	16,650	0.2		27.1	5.6	0.152	126	6.2
26-Aug-89	08:11	522357	415192	16,651	3.0		27.1	7.4	0.006	126	6.2
26-Aug-89	08:13	522368	415215	16,652	0.2		27.1	6.6	0.101	125	6.2
26-Aug-89	08:13	522368	415215	16,653	3.0		27.3	7.2	0.006	125	6.2
26-Aug-89	08:42	522400	414906	16,654	0.2		27.3	6.8	0.032	386	6.7
26-Aug-89	08:42	522400	414906	16,655	2.0		27.5	6.8	0.006	386	6.7
26-Aug-89	08:44	522444	414967	16,656	0.2		27.3	6.5	11.800	352	6.8
26-Aug-89	08:44	522444	414967	16,657	2.0		27.1	6.4	0.050	352	6.8
26-Aug-89	08:50	522465	414994	16,658	0.2		26.9	6.2	16.600	342	6.9
26-Aug-89	08:50	522465	414994	16,659	3.0		27.5	6.5	0.246	342	6.9
26-Aug-89	08:52	522477	414990	16,660	0.2		27.1	6.3	10.800	353	6.9
26-Aug-89	08:52	522477	414990	16,661	3.0		27.3	6.4	0.502	353	6.9
26-Aug-89	08:54	522482	415091	16,662	0.2		27.1	6.5	1.140	287	6.9
26-Aug-89	08:54	522482	415091	16,663	3.0		27.5	6.6	1.870	287	6.9
26-Aug-89	09:20	522134	415157	16,664	0.2		26.9	4.4	0.006	158	7.4
26-Aug-89	09:20	522134	415157	16,665	3.0		27.6	5.8	0.009	158	7.4
26-Aug-89	09:23	522194	415262	16,666	0.2		26.7	2.6	58.000	58	7.4
26-Aug-89	09:23	522194	415262	16,667	3.0		26.7	3.4	40.700	58	7.4
26-Aug-89	09:25	522218	415310	16,668	0.2		26.4	2.3	98.500	59	7.4
26-Aug-89	09:25	522218	415310	16,669	3.0		27.3	5.0	20.000	59	7.4
26-Aug-89	09:28	522256	415330	16,670	0.2		26.6	2.5	68.400	68	7.5
26-Aug-89	09:28	522256	415330	16,671	3.0		26.6	2.5	71.400	68	7.5
26-Aug-89	09:31	522319	415391	16,672	0.2		26.4	7.4	0.029	145	7.5
26-Aug-89	09:31	522319	415391	16,673	3.0		26.0	6.4	0.026	145	7.5

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 1 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
26-Aug-89	10:02	521972	415181	16,674	0.2		26.7	7.3	9.210	291	8.1
26-Aug-89	10:02	521972	415181	16,675	3.0		27.1	7.3	2.800	291	8.1
26-Aug-89	10:04	522018	415283	16,676	0.2		27.1	7.4	1.350	235	8.1
26-Aug-89	10:04	522018	415283	16,677	3.0		27.1	7.4	0.580	235	8.1
26-Aug-89	10:07	522034	415335	16,678	0.2		26.6	7.6	0.024	230	8.1
26-Aug-89	10:07	522034	415335	16,679	3.0		26.9	7.5	0.230	230	8.1
26-Aug-89	10:09	522113	415411	16,680	0.2		26.7	7.5	0.039	204	8.2
26-Aug-89	10:09	522113	415411	16,681	3.0		26.7	7.5	0.009	204	8.2
26-Aug-89	10:10	522142	415474	16,682	0.2		26.6	7.4	0.056	239	8.2
26-Aug-89	10:10	522142	415474	16,683	3.0		27.1	7.5	0.010	239	8.2
26-Aug-89	10:21	521761	415369	16,684	0.2		26.7	7.2	2.580	503	8.4
26-Aug-89	10:21	521761	415369	16,685	3.0		26.9	7.3	0.976	503	8.4
26-Aug-89	10:25	521783	415477	16,686	0.2		26.9	7.3	3.100	516	8.4
26-Aug-89	10:25	521783	415477	16,687	3.0		26.9	7.2	2.190	516	8.4
26-Aug-89	10:27	521847	415535	16,688	0.2		26.4	7.2	0.430	488	8.5
26-Aug-89	10:27	521847	415535	16,689	3.0		26.7	7.3	0.598	488	8.5
26-Aug-89	10:29	521867	415604	16,690	0.2		26.9	7.2	7.200	515	8.5
26-Aug-89	10:29	521867	415604	16,691	3.0		27.1	7.0	14.400	515	8.5
26-Aug-89	10:31	521929	415616	16,692	0.2		26.6	7.6	0.007	479	8.5
26-Aug-89	10:31	521929	415616	16,693	3.0		27.1	7.6	0.041	479	8.5
26-Aug-89	11:18	521428	415686	16,694	0.2		27.3	7.3	0.841	927	9.3
26-Aug-89	11:18	521428	415686	16,695	3.0		27.6	7.2	1.230	927	9.3
26-Aug-89	11:20	521515	415788	16,696	0.2		27.6	7.3	0.930	905	9.4
26-Aug-89	11:20	521515	415788	16,697	3.0		28.4	7.2	1.450	905	9.4
26-Aug-89	11:22	521562	415878	16,698	0.2		28.4	7.4	0.787	925	9.4
26-Aug-89	11:22	521562	415878	16,699	3.0		28.4	7.3	0.046	925	9.4
26-Aug-89	11:23	521617	415959	16,700	0.2		28.2	7.4	0.099	943	9.4
26-Aug-89	11:23	521617	415959	16,701	3.0		28.5	7.4	0.076	943	9.4
26-Aug-89	11:26	521669	416071	16,702	0.2		27.5	7.2	0.011	997	9.5
26-Aug-89	11:26	521669	416071	16,703	3.0		28.2	7.4	0.222	997	9.5
26-Aug-89	11:42	521975	415185	16,704	0.2	6.8	29.1	7.3	0.046	288	9.7
26-Aug-89	11:42	521975	415185	16,705	3.0	6.8	29.6	7.4	0.028	288	9.7
26-Aug-89	11:44	522008	415274	16,706	0.2		27.8	7.5	0.039	244	9.8
26-Aug-89	11:44	522008	415274	16,707	3.0		28.8	7.5	0.061	244	9.8

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 2 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
26-Aug-89	11:46	522063	415383	16,708	0.2	6.8	27.5	7.6	0.015	224	9.8
26-Aug-89	11:46	522063	415383	16,709	3.0	6.8	29.1	7.4	0.890	224	9.8
26-Aug-89	11:48	522098	415424	16,710	0.2	8.5	27.6	7.5	0.113	224	9.8
26-Aug-89	11:48	522098	415424	16,711	3.0	8.5	29.1	7.4	0.080	224	9.8
26-Aug-89	11:50	522120	415463	16,712	0.2		27.6	7.3	0.037	240	9.9
26-Aug-89	11:50	522120	415463	16,713	3.0		28.9	7.4	0.082	240	9.9
26-Aug-89	12:14	521766	415378	16,714	0.2		28.4	7.4	0.020	500	10.3
26-Aug-89	12:14	521766	415378	16,715	3.0		28.5	7.4	0.028	500	10.3
26-Aug-89	12:16	521847	415471	16,716	0.2		28.4	7.3	0.028	456	10.3
26-Aug-89	12:16	521847	415471	16,717	3.0		28.5	7.4	0.037	456	10.3
26-Aug-89	12:17	521906	415519	16,718	0.2		31.8	7.2	0.540	431	10.3
26-Aug-89	12:17	521906	415519	16,719	3.0		28.4	7.1	1.750	431	10.3
26-Aug-89	12:19	521988	415578	16,720	0.2		28.4	7.4	0.057	412	10.3
26-Aug-89	12:19	521988	415578	16,721	3.0		28.9	7.4	0.099	412	10.3
26-Aug-89	12:20	522027	415623	16,722	0.2		28.0	7.4	0.044	425	10.4
26-Aug-89	12:20	522027	415623	16,723	3.0		28.4	7.4	0.501	425	10.4
26-Aug-89	13:28	521969	415187	16,724	0.2	6.3	28.9	7.4	0.011	293	11.5
26-Aug-89	13:28	521969	415187	16,725	3.0	6.3	29.3	7.4	0.026	293	11.5
26-Aug-89	13:29	522025	415256	16,726	0.2	8.5	28.5	7.4	0.009	227	11.5
26-Aug-89	13:29	522025	415256	16,727	3.0	8.5	29.3	7.4	0.043	227	11.5
26-Aug-89	13:31	522110	415336	16,728	0.2		28.9	7.4	0.013	160	11.5
26-Aug-89	13:31	522110	415336	16,729	3.0		29.1	7.1	2.960	160	11.5
26-Aug-89	13:33	522136	415375	16,730	0.2		28.9	7.4	0.054	162	11.6
26-Aug-89	13:33	522136	415375	16,731	3.0		28.9	7.4	0.043	162	11.6
26-Aug-89	13:35	522184	415425	16,732	0.2	8.0	28.9	7.5	0.043	177	11.6
26-Aug-89	13:35	522184	415425	16,733	3.0	8.0	28.9	7.4	0.087	177	11.6
26-Aug-89	13:49	521726	415367	16,734	0.2		28.9	7.4	0.006	536	11.8
26-Aug-89	13:49	521726	415367	16,735	3.0		28.7	7.4	0.037	536	11.8
26-Aug-89	13:51	521816	415424	16,736	0.2		28.4	7.4	0.015	465	11.9
26-Aug-89	13:51	521816	415424	16,737	3.0		28.7	7.3	0.022	465	11.9
26-Aug-89	13:53	521901	415509	16,738	0.2		28.2	7.4	0.006	429	11.9
26-Aug-89	13:53	521901	415509	16,739	3.0		28.7	7.1	0.568	429	11.9
26-Aug-89	13:54	521928	415529	16,740	0.2		28.4	7.4	0.065	420	11.9
26-Aug-89	13:54	521928	415529	16,741	3.0		24.7	6.8	6.420	420	11.9

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 3 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
26-Aug-89	13:56	521978	415580	16,742	0.2		28.2	7.3	0.425	420	12.0
26-Aug-89	13:56	521978	415580	16,743	3.0		28.7	7.3	0.072	420	12.0
26-Aug-89	14:22	521440	415684	16,744	0.2		28.7	7.4	0.006	915	12.4
26-Aug-89	14:22	521440	415684	16,745	3.0		28.7	7.4	0.015	915	12.4
26-Aug-89	14:24	521469	415772	16,746	0.2		28.5	7.4	0.035	934	12.4
26-Aug-89	14:24	521469	415772	16,747	3.0		29.1	7.4	0.048	934	12.4
26-Aug-89	14:26	521493	415841	16,748	0.2		30.0	7.4	0.096	955	12.5
26-Aug-89	14:26	521493	415841	16,749	3.0		29.1	7.3	0.185	955	12.5
26-Aug-89	14:29	521553	415964	16,750	0.2		28.9	7.4	0.096	991	12.5
26-Aug-89	14:29	521553	415964	16,751	3.0		29.1	7.2	1.940	991	12.5
26-Aug-89	14:30	521619	416079	16,752	0.2		28.9	7.2	3.250	1,034	12.5
26-Aug-89	14:30	521619	416079	16,753	3.0		28.9	7.2	0.285	1,034	12.5
26-Aug-89	14:45	521978	415169	16,754	0.2		28.2	7.6	0.041	289	12.8
26-Aug-89	14:45	521978	415169	16,755	3.0		29.1	7.5	0.040	289	12.8
26-Aug-89	14:47	522031	415257	16,756	0.2		28.9	7.6	0.014	221	12.8
26-Aug-89	14:47	522031	415257	16,757	3.0		29.3	7.5	0.007	221	12.8
26-Aug-89	14:49	522177	415349	16,758	0.2		29.4	7.1	6.640	115	12.8
26-Aug-89	14:49	522177	415349	16,759	3.0		29.4	7.4	0.044	115	12.8
26-Aug-89	14:51	522189	415396	16,760	0.2		29.3	7.5	0.222	148	12.9
26-Aug-89	14:51	522189	415396	16,761	3.0		29.8	7.0	5.380	148	12.9
26-Aug-89	14:52	522195	415429	16,762	0.2		28.9	7.4	0.022	176	12.9
26-Aug-89	14:52	522195	415429	16,763	3.0		29.8	7.4	0.018	176	12.9
26-Aug-89	14:54	522252	415262						2965.000	0	0.0
26-Aug-89	15:14	521728	415303	16,764	0.2		28.9	7.4	0.014	526	0.3
26-Aug-89	15:14	521728	415303	16,765	3.0		29.4	7.4	0.009	526	0.3
26-Aug-89	15:16	521755	415429	16,766	0.2		28.4	7.3	0.006	524	0.4
26-Aug-89	15:16	521755	415429	16,767	4.0		29.3	7.4	0.009	524	0.4
26-Aug-89	15:19	521835	415555	16,768	0.2		28.2	7.1	0.009	510	0.4
26-Aug-89	15:19	521835	415555	16,769	4.0		28.7	7.3	0.244	510	0.4
26-Aug-89	15:21	521917	415684	16,770	0.2		28.4	7.3	0.660	539	0.5
26-Aug-89	15:21	521917	415684	16,771	4.0		29.6	7.4	8.380	539	0.5
26-Aug-89	15:23	521961	415754	16,772	0.2		27.8	7.4	0.353	572	0.5
26-Aug-89	15:23	521961	415754	16,773	4.0		30.2	7.4	3.000	572	0.5
26-Aug-89	15:48	522223	415063	16,774	0.2		28.4	6.8	0.017	201	0.9

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 4 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
26-Aug-89	15:48	522223	415063	16,775	4.0		29.4	7.1	0.004	201	0.9
26-Aug-89	15:53	522347	415165	16,776	0.2		28.7	6.8	0.615	136	1.0
26-Aug-89	15:53	522347	415165	16,777	4.0		29.3	6.9	22.700	136	1.0
26-Aug-89	15:55	522370	415186	16,778	0.2		28.9	7.3	1.750	140	1.0
26-Aug-89	15:55	522370	415186	16,779	4.0		29.3	6.9	19.900	140	1.0
26-Aug-89	15:57	522433	415178	16,780	0.2		28.9	7.4	0.237	200	1.1
26-Aug-89	15:57	522433	415178	16,781	4.0		29.4	7.3	0.880	200	1.1
26-Aug-89	16:01	522465	415223	16,782	0.2		28.9	7.4	0.224	217	1.1
26-Aug-89	16:01	522465	415223	16,783	4.0		29.3	7.4	0.318	217	1.1
26-Aug-89	16:12	522546	414965	16,784	0.2		28.4	7.4	0.008	418	1.3
26-Aug-89	16:12	522546	414965	16,785	4.0		29.1	7.4	0.070	418	1.3
26-Aug-89	16:15	522705	414973	16,786	0.2		28.7	7.0	3.860	537	1.4
26-Aug-89	16:15	522705	414973	16,787	4.0		29.6	7.1	1.310	537	1.4
26-Aug-89	16:17	522756	415081	16,788	0.2		28.7	7.3	0.088	536	1.4
26-Aug-89	16:17	522756	415081	16,789	4.0		29.3	7.2	0.970	536	1.4
26-Aug-89	16:19	522822	415138	16,790	0.2		28.7	7.4	0.099	583	1.4
26-Aug-89	16:19	522822	415138	16,791	4.0		29.6	7.2	0.481	583	1.4
26-Aug-89	16:22	522695	414934	16,792	0.2		29.1	7.4	0.041	551	1.5
26-Aug-89	16:22	522695	414934	16,793	4.0		29.3	6.6	0.492	551	1.5
17-Sep-89	07:41	522252	415262						2194.000	0	0.0
17-Sep-89	07:17	522168	415813	19006	0.2	11.0	30.2	7.2	0.006	557	-0.4
17-Sep-89	07:17	522168	415813	19007	8.0	11.0	32.5	7.4	0.006	557	-0.4
17-Sep-89	07:19	522108	415583	19008	0.2	11.0	30.3	7.2	0.023	352	-0.4
17-Sep-89	07:19	522108	415583	19009	8.0	11.0	32.3	7.5	0.033	352	-0.4
17-Sep-89	07:22	522030	415426	19010	0.2	11.0	30.7	7.3	0.016	276	-0.3
17-Sep-89	07:22	522030	415426	19011	7.0	11.0	32.3	7.4	0.084	276	-0.3
17-Sep-89	07:24	522028	415279	19012	0.2	10.0	30.7	7.3	0.016	225	-0.3
17-Sep-89	07:24	522028	415279	19013	7.0	10.0	32.3	7.4	0.006	225	-0.3
17-Sep-89	07:26	522000	415221	19014	0.2	10.0	31.3	7.2	0.006	255	-0.3
17-Sep-89	07:26	522000	415221	19015	6.0	10.0	32.0	7.3	0.006	255	-0.3
17-Sep-89	07:30	522010	415856	19016	0.2	12.0	31.1	7.2	0.006	641	-0.2
17-Sep-89	07:30	522010	415856	19017	8.0	12.0	32.3	7.4	0.006	641	-0.2
17-Sep-89	07:33	521915	415715	19018	0.2	15.0	30.7	7.2	0.006	565	-0.1
17-Sep-89	07:33	521915	415715	19019	8.0	15.0	32.2	7.4	0.011	565	-0.1

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 5 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
17-Sep-89	07:36	521830	415565	19020	0.2	12.0	30.9	7.2	0.015	520	-0.1
17-Sep-89	07:36	521830	415565	19021	8.0	12.0	32.2	7.2	0.599	520	-0.1
17-Sep-89	07:38	521753	415439	19022	0.2	10.5	30.9	7.2	0.017	529	-0.1
17-Sep-89	07:38	521753	415439	19023	7.0	10.5	32.0	7.2	0.007	529	-0.1
17-Sep-89	07:40	521707	415335	19024	0.2	6.7	29.8	7.4	0.006	550	0.0
17-Sep-89	07:40	521707	415335	19025	3.0	6.7	31.3	7.3	0.006	550	0.0
17-Sep-89	08:17	522690	415359	19026	0.2	10.0	30.7	7.4	0.024	449	0.6
17-Sep-89	08:17	522690	415359	19027	7.0	10.0	32.0	7.5	0.007	449	0.6
17-Sep-89	08:20	522668	415212	19028	0.2	9.3	30.9	7.3	0.210	419	0.7
17-Sep-89	08:20	522668	415212	19029	6.0	9.3	32.0	7.5	0.013	419	0.7
17-Sep-89	08:22	522615	415140	19030	0.2	10.0	30.7	7.3	0.006	383	0.7
17-Sep-89	08:22	522615	415140	19031	6.0	10.0	31.8	6.7	12.200	383	0.7
17-Sep-89	08:27	522524	415039	19032	0.2	10.5	30.7	7.2	0.006	352	0.8
17-Sep-89	08:27	522524	415039	19033	6.0	10.5	32.2	7.5	0.073	352	0.8
17-Sep-89	08:29	522430	415024	19034	0.2	10.5	30.7	7.3	0.006	297	0.8
17-Sep-89	08:29	522430	415024	19035	6.0	10.5	32.0	7.3	0.455	297	0.8
17-Sep-89	08:34	522839	415042	19036	0.2	9.0	30.3	7.3	0.035	627	0.9
17-Sep-89	08:34	522839	415042	19037	6.0	9.0	32.0	7.4	0.389	627	0.9
17-Sep-89	08:36	522777	414982	19038	0.2	9.5	29.8	7.3	0.010	595	0.9
17-Sep-89	08:36	522777	414982	19039	6.0	9.5	31.0	7.3	0.602	595	0.9
17-Sep-89	08:39	522656	414919	19040	0.2	9.0	29.9	7.2	0.032	530	1.0
17-Sep-89	08:39	522656	414919	19041	6.0	9.0	31.8	7.4	0.170	530	1.0
17-Sep-89	08:42	522578	414833	19042	0.2	9.0	29.6	7.2	0.020	539	1.0
17-Sep-89	08:42	522578	414833	19043	6.0	9.0	32.0	7.4	0.096	539	1.0
17-Sep-89	08:44	522550	414784	19044	0.2	9.0	29.6	7.2	0.028	563	1.1
17-Sep-89	08:44	522550	414784	19045	6.0	9.0	31.9	7.4	0.170	563	1.1
17-Sep-89	09:17	522810	415360	19046	0.2	9.0	31.2	7.4	0.066	567	1.6
17-Sep-89	09:17	522810	415360	19047	6.0	9.0	32.1	7.5	0.028	567	1.6
17-Sep-89	09:21	522749	415267	19048	0.2	8.7	31.5	7.4	0.011	497	1.7
17-Sep-89	09:21	522749	415267	19049	6.0	8.7	32.0	7.5	0.006	497	1.7
17-Sep-89	09:23	522581	415174	19050	0.2	8.4	31.7	7.4	0.028	341	1.7
17-Sep-89	09:23	522581	415174	19051	5.0	8.4	31.8	7.4	0.013	341	1.7
17-Sep-89	09:25	522506	415090	19052	0.2	9.5	31.2	7.4	0.006	307	1.7
17-Sep-89	09:25	522506	415090	19053	6.0	9.5	31.7	7.4	0.020	307	1.7

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 6 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
17-Sep-89	09:28	522416	415002	19054	0.2	8.8	31.2	7.4	0.071	307	1.8
17-Sep-89	09:28	522416	415002	19055	6.0	8.8	31.7	7.4	0.009	307	1.8
17-Sep-89	09:31	522834	415155	19056	0.2	8.0	31.9	7.4	0.119	592	1.8
17-Sep-89	09:31	522834	415155	19057	5.0	8.0	31.9	7.4	0.015	592	1.8
17-Sep-89	09:33	522793	415095	19058	0.2	8.0	31.8	7.4	0.005	566	1.9
17-Sep-89	09:33	522793	415095	19059	5.0	8.0	31.5	7.4	0.011	566	1.9
17-Sep-89	09:35	522684	415028	19060	0.2	8.0	31.5	7.4	0.006	491	1.9
17-Sep-89	09:35	522684	415028	19061	5.0	8.0	31.5	7.4	0.011	491	1.9
17-Sep-89	09:38	522607	414935	19062	0.2	8.0	31.3	6.8	0.092	483	2.0
17-Sep-89	09:38	522607	414935	19063	5.0	8.0	31.0	6.8	2.360	483	2.0
17-Sep-89	09:40	522521	414862	19064	0.2	9.0	30.7	7.3	0.006	482	2.0
17-Sep-89	09:40	522521	414862	19065	5.0	9.0	31.0	7.3	0.009	482	2.0
17-Sep-89	10:23	523898	414926	19066	0.2	8.0	30.5	7.4	0.006	1,680	2.7
17-Sep-89	10:23	523898	414926	19067	5.0	8.0	30.5	7.4	0.006	1,680	2.7
17-Sep-89	10:28	523342	414904	19068	0.2	7.5	30.1	7.4	0.015	1,147	2.8
17-Sep-89	10:28	523342	414904	19069	5.0	7.5	30.1	7.4	0.009	1,147	2.8
17-Sep-89	10:30	523244	414824	19070	0.2	7.0	29.8	7.3	0.006	1,084	[illegible]
17-Sep-89	10:30	523244	414824	19071	4.0	7.0	29.8	7.3	0.006	1,084	2.8
17-Sep-89	10:32	523122	414767	19072	0.2	7.0	29.5	7.3	0.006	1,001	2.9
17-Sep-89	10:32	523122	414767	19073	4.0	7.0	29.6	7.3	0.054	1,001	2.9
17-Sep-89	10:36	523162	414618	19074	0.2	6.6	29.1	7.2	0.033	1,115	2.9
17-Sep-89	10:36	523162	414618	19075	4.0	6.6	29.7	7.2	0.011	1,115	2.9
17-Sep-89	10:41	522800	415393	19076	0.2	7.5	29.3	7.3	0.042	563	3.0
17-Sep-89	10:41	522800	415393	19077	5.0	7.5	29.3	7.3	0.018	563	3.0
17-Sep-89	10:44	522806	415340	19078	0.2	6.6	29.1	7.3	0.011	559	3.1
17-Sep-89	10:44	522806	415340	19079	4.0	6.6	29.1	7.3	0.009	559	3.1
17-Sep-89	10:47	522693	415193	19080	0.2	6.0	29.0	7.2	0.007	446	3.1
17-Sep-89	10:47	522693	415193	19081	3.0	6.0	28.9	7.2	0.015	446	3.1
17-Sep-89	10:50	522560	415069	19082	0.2	6.0	28.3	7.2	0.006	363	3.2
17-Sep-89	10:50	522560	415069	19083	3.0	6.0	28.8	7.2	0.007	363	3.2
17-Sep-89	10:52	522431	414993	19084	0.2	7.0	28.1	7.2	0.006	323	3.2
17-Sep-89	10:52	522431	414993	19085	4.0	7.0	28.4	7.2	0.037	323	3.2
17-Sep-89	11:38	523278	415404	19086	0.2	6.5	27.6	7.2	0.110	1,036	4.0
17-Sep-89	11:38	523278	415404	19087	3.0	6.5	28.4	7.2	0.177	1,036	4.0

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 7 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
17-Sep-89	11:40	523183	415334	19088	0.2	6.0	28.7	7.2	0.044	934	4.0
17-Sep-89	11:40	523183	415334	19089	3.0	6.0	27.6	7.2	0.007	934	4.0
17-Sep-89	11:43	522998	415224	19090	0.2	5.2	28.7	7.2	0.195	747	4.0
17-Sep-89	11:43	522998	415224	19091	2.5	5.2	28.7	7.2	0.006	747	4.0
17-Sep-89	11:47	522705	414967	19092	0.2	4.5	28.4	8.7	0.017	541	4.1
17-Sep-89	11:47	522705	414967	19093	2.0	4.5	28.7	7.2	0.025	541	4.1
17-Sep-89	11:50	522568	414927	19094	0.2	5.0	28.7	7.2	0.273	461	4.2
17-Sep-89	11:50	522568	414927	19095	2.5	5.0	28.7	7.2	0.017	461	4.2
17-Sep-89	12:35	522384	415096	19096	0.2	4.5	28.4	7.2	1.970	212	4.9
17-Sep-89	12:35	522384	415096	19097	2.0	4.5	28.0	7.1	0.258	212	4.9
17-Sep-89	12:37	522390	415063	19098	0.2	4.5	27.8	7.2	0.006	242	4.9
17-Sep-89	12:37	522390	415063	19099	2.0	4.5	27.8	7.2	0.009	242	4.9
17-Sep-89	12:40	522385	415132	19100	0.2	4.0	27.8	6.7	3.160	186	5.0
17-Sep-89	12:40	522385	415132	19101	2.0	4.0	27.8	6.6	3.680	186	5.0
17-Sep-89	12:42	522403	415132	19102	0.2	4.0	27.6	6.8	0.940	199	5.0
17-Sep-89	12:42	522403	415132	19103	2.0	4.0	28.0	7.0	0.577	199	5.0
17-Sep-89	12:44	522406	415122	19104	0.2	4.0	27.8	6.7	2.500	208	5.1
17-Sep-89	12:44	522406	415122	19105	2.0	4.0	27.6	0.0	1.490	208	5.1
17-Sep-89	15:53	522135	415559	19126	0.2	4.6	25.7	7.2	0.664	319	8.2
17-Sep-89	15:53	522135	415559	19127	3.0	4.6	25.7	7.1	0.025	319	8.2
17-Sep-89	15:56	522048	415535	19128	0.2	3.7	25.8	7.0	0.216	341	8.3
17-Sep-89	15:56	522048	415535	19129	2.0	3.7	26.0	7.0	0.140	341	8.3
17-Sep-89	15:58	522036	415411	19130	0.2	5.4	25.8	6.5	6.150	262	8.3
17-Sep-89	15:58	522036	415411	19131	3.0	5.4	26.4	6.3	9.450	262	8.3
17-Sep-89	16:00	521992	415316	19132	0.2	3.4	26.6	7.0	0.204	266	8.3
17-Sep-89	16:00	521992	415316	19133	2.0	3.4	26.6	7.0	0.266	266	8.3
17-Sep-89	16:02	522036	415413	19134	0.2	5.2	26.6	6.3	6.440	264	8.4
17-Sep-89	16:02	522036	415413	19135	3.0	5.2	26.4	6.2	8.000	264	8.4
17-Sep-89	16:40	521962	415780	19136	0.2	6.9	25.1	7.0	0.008	594	9.0
17-Sep-89	16:40	521962	415780	19137	4.0	6.9	25.2	7.1	0.006	594	9.0
17-Sep-89	16:43	521924	415594	19138	0.2	6.0	25.6	7.1	0.006	467	9.0
17-Sep-89	16:43	521924	415594	19139	3.0	6.0	26.3	7.1	0.006	467	9.0
17-Sep-89	16:45	521823	415535	19140	0.2	7.0	25.5	7.1	0.389	508	9.1
17-Sep-89	16:45	521823	415535	19141	4.0	7.0	25.8	7.2	0.075	508	9.1

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 8 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
17-Sep-89	16:47	521781	415443	19142	0.2	6.2	26.5	7.2	0.010	505	9.1
17-Sep-89	16:47	521781	415443	19143	4.0	6.2	26.8	7.2	0.089	505	9.1
17-Sep-89	16:50	521741	415651	19144	0.2	8.0	25.2	7.1	0.235	642	9.2
17-Sep-89	16:50	521741	415651	19145	4.0	8.0	26.1	7.0	0.408	642	9.2
17-Sep-89	16:54	521576	416168	19146	0.2	9.0	24.8	7.2	0.046	1,130	9.2
17-Sep-89	16:54	521576	416168	19147	6.0	9.0	23.9	7.2	0.014	1,130	9.2
17-Sep-89	16:56	521483	416122	19148	0.2	8.0	24.2	7.2	0.035	1,154	9.3
17-Sep-89	16:56	521483	416122	19149	4.0	8.0	24.8	7.2	0.019	1,154	9.3
17-Sep-89	17:01	521403	416008	19152	0.2	7.0	25.6	7.1	0.044	1,130	9.3
17-Sep-89	17:01	521403	416008	19153	4.0	7.0	26.0	7.1	0.137	1,130	9.3
7-Oct-89	10:36	522252	415262						2380.000	0	0.0
7-Oct-89	08:12	522209	415467	21210	0.2	7.0	28.7	7.2	0.172	209	-2.4
7-Oct-89	08:12	522209	415457	21211	4.0	7.0	29.6	7.2	0.147	200	-2.4
7-Oct-89	08:14	522131	415344	21212	0.2	8.0	28.5	7.2	0.089	146	-2.4
7-Oct-89	08:14	522131	415344	21213	4.0	8.0	29.1	7.0	2.050	146	-2.4
7-Oct-89	08:16	522082	415253	21214	0.2	6.0	28.4	7.2	0.201	170	-2.3
7-Oct-89	08:16	522082	415253	21215	3.0	6.0	28.9	7.2	0.195	170	-2.3
7-Oct-89	08:21	521961	415684	21216	0.2	10.0	28.7	7.2	0.108	513	-2.3
7-Oct-89	08:21	521961	415684	21217	6.0	10.0	29.3	7.2	0.243	513	-2.3
7-Oct-89	08:23	521941	415586	21218	0.2	8.0	28.9	7.2	0.029	449	-2.2
7-Oct-89	08:23	521941	415586	21219	4.0	8.0	29.4	7.2	0.087	449	-2.2
7-Oct-89	08:25	521894	415480	21220	0.2	8.0	28.5	7.2	0.063	419	-2.2
7-Oct-89	08:25	521894	415480	21221	4.0	8.0	28.7	7.2	0.166	419	-2.2
7-Oct-89	08:29	521686	416121	21222	0.2	11.0	28.4	7.2	0.006	1,029	-2.1
7-Oct-89	08:29	521686	416121	21223	6.0	11.0	28.5	7.2	0.009	1,029	-2.1
7-Oct-89	08:35	521538	415807	21226	0.2	8.0	28.5	7.2	0.286	898	-2.0
7-Oct-89	08:35	521538	415807	21227	5.0	8.0	29.1	7.0	1.400	898	-2.0
7-Oct-89	08:38	521465	416058	21228	0.2	9.0	28.7	7.2	0.164	1,119	-2.0
7-Oct-89	08:38	521465	416058	21229	5.0	9.0	29.3	7.1	0.270	1,119	-2.0
7-Oct-89	09:08	522237	415519	21230	0.2	8.0	29.8	7.2	0.207	257	-1.5
7-Oct-89	09:08	522237	415519	21231	4.0	8.0	29.8	7.2	0.040	257	-1.5
7-Oct-89	09:10	522145	415355	21232	0.2	10.0	29.1	7.2	0.034	142	-1.4
7-Oct-89	09:10	522145	415355	21233	5.0	10.0	29.1	6.4	13.050	142	-1.4
7-Oct-89	09:12	522069	415232	21234	0.2	10.0	28.9	7.2	0.034	185	-1.4

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 9 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
7-Oct-89	09:12	522069	415232	21235	4.0	10.0	29.6	7.2	0.016	185	-1.4
7-Oct-89	09:16	521956	415657	21236	0.2	9.0	29.4	7.2	0.162	494	-1.3
7-Oct-89	09:16	521956	415657	21237	5.0	9.0	30.0	7.2	0.047	494	-1.3
7-Oct-89	09:18	521903	415558	21238	0.2	9.0	29.6	7.2	0.050	458	-1.3
7-Oct-89	09:18	521903	415558	21239	5.0	9.0	29.8	6.8	2.900	458	-1.3
7-Oct-89	09:20	521854	415455	21240	0.2	7.0	29.4	7.2	0.041	442	-1.3
7-Oct-89	09:20	521854	415455	21241	3.5	7.0	29.1	7.2	0.062	442	-1.3
7-Oct-89	09:24	521686	416077	21242	0.2	12.0	29.6	7.2	0.269	992	-1.2
7-Oct-89	09:24	521686	416077	21243	6.0	12.0	30.3	7.1	0.495	992	-1.2
7-Oct-89	09:26	521627	415960	21244	0.2	9.5	29.6	6.9	2.950	937	-1.2
7-Oct-89	09:26	521627	415960	21245	5.0	9.5	30.0	7.2	0.089	937	-1.2
7-Oct-89	09:28	521543	415842	21246	0.2	8.5	29.6	7.1	0.414	916	-1.1
7-Oct-89	09:28	521543	415842	21247	5.0	8.5	29.8	7.0	0.169	916	-1.1
7-Oct-89	09:31	521432	416104	21248	0.2	8.0	29.6	6.9	2.430	1,175	-1.1
7-Oct-89	09:31	521432	416104	21249	4.0	8.0	30.0	6.8	2.260	1,175	-1.1
7-Oct-89	09:59	522252	415415	21250	0.2	8.0	30.3	7.2	0.372	153	-0.6
7-Oct-89	09:59	522252	415415	21251	4.0	8.0	30.5	7.2	0.016	153	-0.6
7-Oct-89	10:02	522152	415304	21252	0.2	8.0	30.5	6.8	4.640	108	-0.6
7-Oct-89	10:02	522152	415304	21253	4.0	8.0	30.3	6.6	5.000	108	-0.6
7-Oct-89	10:05	522096	415270	21254	0.2	7.0	30.3	7.2	0.006	156	-0.5
7-Oct-89	10:05	522096	415270	21255	3.5	7.0	30.5	7.2	0.006	156	-0.5
7-Oct-89	10:08	521943	415656	21256	0.2	10.0	30.5	7.2	0.206	501	-0.5
7-Oct-89	10:08	521943	415656	21257	5.0	10.0	30.7	7.2	0.006	501	-0.5
7-Oct-89	10:10	521923	415571	21258	0.2	9.0	29.8	7.2	0.010	451	-0.4
7-Oct-89	10:10	521923	415571	21259	4.0	9.0	30.0	6.6	5.350	451	-0.4
7-Oct-89	10:11	521892	415480	21260	0.2	9.0	29.6	7.2	0.201	421	-0.4
7-Oct-89	10:11	521892	415480	21261	4.0	9.0	30.0	7.2	0.290	421	-0.4
7-Oct-89	10:16	521653	416008	21262	0.2	10.0	29.6	7.0	1.890	957	-0.3
7-Oct-89	10:16	521653	416008	21263	5.0	10.0	30.2	7.2	0.133	957	-0.3
7-Oct-89	10:18	521608	415897	21264	0.2	10.0	29.6	7.2	0.053	904	-0.3
7-Oct-89	10:18	521608	415897	21265	5.0	10.0	29.6	7.2	0.068	904	-0.3
7-Oct-89	10:21	521521	415802	21266	0.2	9.0	29.6	7.2	0.010	909	-0.3
7-Oct-89	10:21	521521	415802	21267	5.0	9.0	29.8	7.2	0.010	909	-0.3
7-Oct-89	10:23	521450	416074	21268	0.2	10.0	29.4	7.2	0.030	1,141	-0.2

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 10 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
7-Oct-89	10:23	521450	416074	21269	5.0	10.0	29.6	7.1	0.786	1,141	-0.2
7-Oct-89	10:59	522328	415213	21270	0.2	9.0	29.6	3.3	38.900	90	0.4
7-Oct-89	10:59	522328	415213	21271	5.0	9.0	30.2	6.6	0.493	90	0.4
7-Oct-89	11:02	522345	415214	21272	0.2	8.0	29.6	3.1	39.200	105	0.4
7-Oct-89	11:02	522345	415214	21273	4.0	8.0	29.8	6.5	1.690	105	0.4
7-Oct-89	11:08	522442	415281	21274	0.2	8.0	29.6	4.6	32.700	191	0.5
7-Oct-89	11:08	522442	415281	21275	3.0	8.0	30.0	6.1	6.910	191	0.5
7-Oct-89	11:12	522346	415182	21276	0.2	8.6	29.6	6.0	11.100	123	0.6
7-Oct-89	11:12	522346	415182	21277	4.0	8.6	29.8	5.6	21.000	123	0.6
7-Oct-89	11:15	522491	415288	21278	0.2	8.0	29.8	6.0	7.150	240	0.7
7-Oct-89	11:15	522491	415288	21279	4.0	8.0	30.0	6.4	1.480	240	0.7
7-Oct-89	11:17	522494	415131	21280	0.2	8.0	29.6	5.8	17.300	275	0.7
7-Oct-89	11:17	522494	415131	21281	4.0	8.0	30.0	5.0	27.300	275	0.7
7-Oct-89	11:20	522343	415042	21282	0.2	8.0	28.7	6.8	0.062	238	0.7
7-Oct-89	11:25	522835	415216	21284	0.2	8.0	29.4	7.0	0.151	585	0.8
7-Oct-89	11:25	522835	415216	21285	4.0	8.0	29.8	7.0	0.205	585	0.8
7-Oct-89	11:27	522787	415052	21286	0.2	8.0	29.3	6.0	19.200	575	0.9
7-Oct-89	11:27	522787	415052	21287	4.0	8.0	29.4	6.6	0.363	575	0.9
7-Oct-89	11:29	522602	414941	21288	0.2	7.4	29.3	7.0	0.033	475	0.9
7-Oct-89	11:29	522602	414941	21289	4.0	7.4	29.3	7.0	0.900	475	0.9
7-Oct-89	11:58	522886	414821	21290	0.2	7.0	29.1	7.2	0.221	772	1.4
7-Oct-89	11:58	522886	414821	21291	3.5	7.0	29.4	7.2	0.449	772	1.4
7-Oct-89	12:00	522993	414732	21292	0.2	7.8	28.7	6.9	2.710	911	1.4
7-Oct-89	12:00	522993	414732	21293	3.5	7.8	29.4	7.0	0.573	911	1.4
7-Oct-89	12:02	522946	414670	21294	0.2	7.8	29.3	7.1	0.751	912	1.4
7-Oct-89	12:02	522946	414670	21295	0.2	7.8	29.4	6.9	1.520	912	1.4
7-Oct-89	12:11	522552	415232	21296	0.2	7.5	29.3	7.0	0.488	301	1.6
7-Oct-89	12:11	522552	415232	21297	3.0	7.5	29.8	7.0	0.550	301	1.6
7-Oct-89	12:13	522431	415145	21298	0.2	8.0	29.4	7.1	0.469	214	1.6
7-Oct-89	12:13	522431	415145	21299	4.0	8.0	29.4	7.2	0.147	214	1.6
7-Oct-89	12:15	522352	415116	21300	0.2	7.0	29.1	7.2	0.062	177	1.7
7-Oct-89	12:15	522352	415116	21301	3.5	7.0	29.4	7.0	1.810	177	1.7
7-Oct-89	12:18	522767	415120	21302	0.2	7.5	29.1	7.2	0.474	534	1.7
7-Oct-89	12:18	522767	415120	21303	4.0	7.5	29.4	7.2	0.383	534	1.7

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 11 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
7-Oct-89	12:20	522714	415018	21304	0.2	7.0	29.4	7.1	0.480	522	1.7
7-Oct-89	12:20	522714	415018	21305	4.0	7.0	30.0	7.2	0.242	522	1.7
7-Oct-89	12:22	522627	414906	21306	0.2	7.0	30.3	7.0	2.540	517	1.8
7-Oct-89	12:22	522627	414906	21307	3.5	7.0	30.5	7.0	1.430	517	1.8
7-Oct-89	12:25	523033	414844	21308	0.2	7.0	30.5	7.2	0.426	886	1.8
7-Oct-89	12:25	523033	414844	21309	3.5	7.0	30.5	7.2	0.169	886	1.8
7-Oct-89	13:51	522489	415200	21310	0.2	7.0	30.5	7.2	0.037	245	3.3
7-Oct-89	13:51	522489	415200	21311	4.0	7.0	30.5	7.2	0.033	245	3.3
7-Oct-89	13:53	522397	415133	21312	0.2	7.0	31.1	6.9	4.500	194	3.3
7-Oct-89	13:53	522397	415133	21313	3.0	7.0	30.5	7.2	0.151	194	3.3
7-Oct-89	13:55	522304	415091	21314	0.2	6.0	30.5	7.2	0.149	179	3.3
7-Oct-89	13:55	522304	415091	21315	3.0	6.0	30.5	7.2	0.010	179	3.3
7-Oct-89	13:58	522775	415114	21316	0.2	6.0	30.3	7.2	0.090	544	3.4
7-Oct-89	13:58	522775	415114	21317	3.0	6.0	30.5	7.2	0.012	544	3.4
7-Oct-89	14:00	522672	415051	21318	0.2	6.0	30.3	7.2	0.010	470	3.4
7-Oct-89	14:00	522672	415051	21319	3.0	6.0	30.5	7.2	0.052	470	3.4
7-Oct-89	14:02	522608	414966	21320	0.2	6.0	30.5	7.2	0.079	463	3.4
7-Oct-89	14:02	522608	414966	21321	3.0	6.0	29.8	7.2	0.025	463	3.4
7-Oct-89	14:05	523079	414952	21322	0.2	8.0	30.3	7.3	0.008	883	3.5
7-Oct-89	14:05	523079	414952	21323	3.0	8.0	30.3	7.3	0.006	883	3.5
7-Oct-89	14:07	523056	414852	21324	0.2	5.8	30.3	7.3	0.006	903	3.5
7-Oct-89	14:07	523056	414852	21325	3.0	5.8	30.3	7.3	0.025	903	3.5
7-Oct-89	14:09	522962	414766	21326	0.2	7.0	30.5	7.3	0.006	866	3.6
7-Oct-89	14:09	522962	414766	21327	3.0	7.0	30.3	7.3	0.010	866	3.6
7-Oct-89	14:12	522893	414715	21328	0.2	6.5	30.3	6.8	5.270	843	3.6
7-Oct-89	14:12	522893	414715	21329	3.0	6.5	30.5	6.6	5.650	843	3.6
7-Oct-89	14:40	522478	415216	21330	0.2	6.5	28.5	7.2	0.128	231	4.1
7-Oct-89	14:40	522478	415216	21331	3.0	6.5	29.1	7.2	0.033	231	4.1
7-Oct-89	14:42	522436	415134	21332	0.2	6.5	29.1	7.2	0.039	224	4.1
7-Oct-89	14:42	522436	415134	21333	3.0	6.5	28.9	7.2	0.014	224	4.1
7-Oct-89	14:44	522357	415096	21334	0.2	6.0	28.4	7.2	0.021	196	4.1
7-Oct-89	14:44	522357	415096	21335	3.0	6.0	29.1	7.2	0.012	196	4.1
7-Oct-89	14:46	522754	415053	21336	0.2	5.2	29.1	7.2	0.016	544	4.2
7-Oct-89	14:46	522754	415053	21337	2.5	5.2	29.1	7.2	0.018	544	4.2

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 12 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
7-Oct-89	14:49	522627	415013	21338	0.2	4.8	29.1	7.2	0.016	450	4.2
7-Oct-89	14:49	522627	415013	21339	2.0	4.8	29.1	7.2	0.021	450	4.2
7-Oct-89	14:51	522553	414948	21340	0.2	6.0	28.7	6.9	2.700	435	4.3
7-Oct-89	14:51	522553	414948	21341	3.0	6.0	29.1	6.8	2.420	435	4.3
7-Oct-89	14:54	522991	414868	21342	0.2	5.5	28.9	7.2	0.063	837	4.3
7-Oct-89	14:54	522991	414868	21343	2.5	5.5	29.3	7.2	0.023	837	4.3
7-Oct-89	14:56	522949	414779	21344	0.2	5.8	29.3	7.2	0.021	848	4.3
7-Oct-89	14:56	522949	414779	21345	2.5	5.8	29.1	7.2	0.113	848	4.3
7-Oct-89	14:58	522862	414726	21346	0.2	5.8	28.7	6.8	3.470	812	4.4
7-Oct-89	14:58	522862	414726	21347	3.0	5.8	29.3	6.8	3.710	812	4.4
7-Oct-89	15:01	522809	414695	21348	0.2	6.0	29.3	7.2	0.048	795	4.4
7-Oct-89	15:01	522809	414695	21349	3.0	6.0	28.9	7.2	0.113	795	4.4
7-Oct-89	15:29	522408	415220	21350	0.2	5.7	28.7	7.2	0.056	162	4.9
7-Oct-89	15:29	522408	415220	21351	2.5	5.7	28.7	7.2	0.830	162	4.9
7-Oct-89	15:31	522324	415149	21352	0.2	5.6	28.7	6.9	2.920	134	4.9
7-Oct-89	15:31	522324	415149	21353	2.5	5.6	28.9	6.8	2.920	134	4.9
7-Oct-89	15:33	522279	415041	21354	0.2	4.2	27.8	7.2	0.006	223	5.0
7-Oct-89	15:33	522279	415041	21355	2.0	4.2	26.7	7.2	0.035	223	5.0
7-Oct-89	15:37	522761	415081	21356	0.2	5.0	28.0	7.2	0.006	540	5.0
7-Oct-89	15:37	522761	415081	21357	2.5	5.0	27.6	7.2	0.044	540	5.0
7-Oct-89	15:39	522626	415007	21358	0.2	4.4	27.8	7.2	0.006	453	5.1
7-Oct-89	15:39	522626	415007	21359	2.0	4.4	27.8	7.2	0.006	453	5.1
7-Oct-89	15:41	522532	414952	21360	0.2	5.5	27.1	6.8	2.640	418	5.1
7-Oct-89	15:41	522532	414952	21361	2.5	5.5	27.5	6.8	1.680	418	5.1
7-Oct-89	15:45	522968	414860	21362	0.2	5.5	27.6	7.2	0.006	821	5.2
7-Oct-89	15:45	522968	414860	21363	2.5	5.5	29.4	7.2	0.960	821	5.2
7-Oct-89	15:47	522909	414824	21364	0.2	5.5	27.5	7.2	0.006	790	5.2
7-Oct-89	15:47	522909	414824	21365	2.5	5.5	27.3	7.2	0.088	790	5.2
7-Oct-89	15:49	522826	414762	21366	0.2	4.4	27.6	6.7	5.470	761	5.2
7-Oct-89	15:49	522826	414762	21367	2.0	4.4	27.6	6.8	2.230	761	5.2
7-Oct-89	15:52	523041	414624	21368	0.2	5.0	27.6	6.6	3.860	1,015	5.3
7-Oct-89	15:52	523041	414624	21369	2.5	5.0	27.8	6.6	4.030	1,015	5.3
7-Oct-89	16:23	522507	415190	21370	0.2	6.0	26.9	7.2	0.115	265	5.8
7-Oct-89	16:23	522507	415190	21371	3.0	6.0	26.9	7.2	0.012	265	5.8

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 13 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
7-Oct-89	16:25	522391	415134	21372	0.2	6.0	26.9	6.4	8.870	189	5.8
7-Oct-89	16:25	522391	415134	21373	3.0	6.0	26.7	6.4	8.110	189	5.8
7-Oct-89	16:27	522345	415088	21374	0.2	5.6	26.9	7.2	0.044	197	5.9
7-Oct-89	16:27	522345	415088	21375	3.0	5.6	27.1	7.2	0.012	197	5.9
7-Oct-89	16:30	522723	415037	21376	0.2	4.6	26.9	7.2	0.006	522	5.9
7-Oct-89	16:30	522723	415037	21377	2.0	4.6	27.1	7.2	0.046	522	5.9
7-Oct-89	16:32	522678	414965	21378	0.2	4.5	27.6	7.2	0.006	519	5.9
7-Oct-89	16:32	522678	414965	21379	2.0	4.5	28.2	7.2	0.045	519	5.9
7-Oct-89	16:34	522586	414939	21380	0.2	4.6	28.2	6.6	9.100	465	6.0
7-Oct-89	16:34	522586	414939	21381	2.0	4.6	28.4	6.7	3.330	465	6.0
7-Oct-89	16:37	522989	414879	21382	0.2	5.0	28.2	7.2	0.026	831	6.0
7-Oct-89	16:37	522989	414879	21383	2.5	5.0	27.8	7.2	0.012	831	6.0
7-Oct-89	16:38	522931	414801	21384	0.2	5.6	27.8	7.1	0.782	821	6.0
7-Oct-89	16:38	522931	414801	21385	3.0	5.6	28.2	7.0	0.815	821	6.0
7-Oct-89	16:41	522822	414743	21386	0.2	4.4	27.8	6.8	3.450	771	6.1
7-Oct-89	16:41	522822	414743	21387	2.0	4.4	28.5	6.9	1.600	771	6.1
7-Oct-89	16:44	523031	414563	21388	0.2	4.6	28.4	6.8	3.070	1,047	6.1
7-Oct-89	16:44	523031	414563	21389	2.0	4.6	28.4	6.8	1.980	1,047	6.1
7-Oct-89	17:26	522249	415236	21390	0.2	5.3	27.1	3.1	53.700	26	6.8
7-Oct-89	17:26	522249	415236	21391	2.0	5.3	27.3	4.5	37.500	26	6.8
7-Oct-89	17:28	522255	415198	21392	0.2	5.2	27.3	5.2	25.600	64	6.9
7-Oct-89	17:28	522255	415189	21393	2.8	5.2	27.8	6.0	10.300	73	6.9
7-Oct-89	17:33	522429	415227	21394	0.2	6.0	27.5	7.0	0.160	180	7.0
7-Oct-89	17:33	522429	415227	21395	3.0	6.0	27.6	7.0	1.220	180	7.0
7-Oct-89	17:34	522388	415162	21396	0.2	6.0	27.5	7.0	1.070	169	7.0
7-Oct-89	17:34	522388	415162	21397	3.0	6.0	27.6	6.8	2.190	169	7.0
7-Oct-89	17:36	522297	415051	21398	0.2	5.5	27.5	6.8	0.485	216	7.0
7-Oct-89	17:36	522297	415051	21399	2.5	5.5	28.0	7.0	0.410	216	7.0
8-Oct-89	11:44	522252	415262						2817.000	0	0.0
8-Oct-89	12:42	522631	415044	21470	0.2	7.0	29.3	5.3	29.300	437	1.0
8-Oct-89	12:42	522631	415044	21471	3.0	7.0	29.3	5.1	25.500	437	1.0
8-Oct-89	12:45	522677	414935	21472	0.2	7.0	29.1	2.9	43.800	536	1.0
8-Oct-89	12:45	522677	414935	21473	3.0	7.0	29.1	3.2	34.600	536	1.0
8-Oct-89	12:47	522595	414869	21474	0.2	7.0	28.7	6.6	0.242	522	1.1

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 14 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
8-Oct-89	12:47	522595	414869	21475	3.0	7.0	28.9	7.0	0.176	522	1.1
8-Oct-89	12:52	522908	414684	21476	0.2	8.0	29.1	6.3	9.180	874	1.1
8-Oct-89	12:52	522908	414684	21477	3.0	8.0	29.4	6.7	2.069	874	1.1
8-Oct-89	12:59	522972	414611	21478	0.2	7.3	29.3	6.5	6.900	971	1.3
8-Oct-89	12:59	522972	414611	21479	5.0	7.3	29.1	6.6	3.190	971	1.3
8-Oct-89	13:03	523126	414508	21480	0.2	7.0	29.1	6.0	14.400	1,154	1.3
8-Oct-89	13:03	523126	414508	21481	6.0	7.0	28.7	6.5	2.050	1,154	1.3
8-Oct-89	13:08	523150	414520	21482	0.2	6.4	29.3	5.2	26.200	1,165	1.4
8-Oct-89	13:08	523150	414520	21483	2.5	6.4	29.3	4.9	26.900	1,165	1.4
8-Oct-89	13:12	523255	414458	21484	0.2	7.0	28.5	5.0	25.100	1,285	1.5
8-Oct-89	13:12	523255	414458	21485	3.0	7.0	29.3	5.2	25.400	1,285	1.5
8-Oct-89	13:17	523424	414343	21486	0.2	7.0	29.1	4.2	29.000	1,489	1.6
8-Oct-89	13:17	523424	414343	21487	2.0	7.0	28.9	4.0	30.000	1,489	1.6
8-Oct-89	13:22	523546	414241	21488	0.2	6.5	28.9	4.8	27.100	1,648	1.6
8-Oct-89	13:22	523546	414241	21489	2.5	6.5	28.9	6.0	11.900	1,648	1.6

Table 8.5 : Soluble Iron Data from around the New SCM Outfall - Page 15 (of 15).

Table 8.6: **Soluble Iron Data from around the New Tioxide Outfall.**

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
28-Aug-89	04:45	526245	414091						11,200.000	0	0.0
28-Aug-89	07:22	526421	414019	16,794	0.2		30.2	7.4	0.027	190	2.6
28-Aug-89	07:22	526421	414019	16,795	4.0		30.3	7.3	1.750	190	2.6
28-Aug-89	07:29	526425	414033	16,796	0.2		30.3	7.3	0.019	189	2.7
28-Aug-89	07:29	526425	414033	16,797	4.0		29.8	7.2	1.020	189	2.7
28-Aug-89	07:31	526476	413996	16,798	0.2		30.3	7.3	0.016	250	2.8
28-Aug-89	07:31	526476	413996	16,799	4.0		30.2	7.4	0.010	250	2.8
28-Aug-89	07:35	526406	414004	16,800	0.2		30.3	7.4	0.105	183	2.8
28-Aug-89	07:35	526406	414004	16,801	4.0		30.3	7.4	0.010	183	2.8
28-Aug-89	07:37	526402	413957	16,802	0.2		30.3	7.4	0.012	206	2.9
28-Aug-89	07:37	526402	413957	16,803	5.0		30.5	7.4	0.034	206	2.9
28-Aug-89	08:04	526504	414048	16,804	0.2		30.2	7.3	0.071	263	3.3
28-Aug-89	08:04	526504	414048	16,805	5.0		30.3	7.3	0.280	263	3.3
28-Aug-89	08:06	526504	413987	16,806	0.2	9.5	30.2	7.3	0.038	279	3.4
28-Aug-89	08:06	526504	413987	16,807	5.0	9.5	30.3	7.3	0.006	279	3.4
28-Aug-89	08:08	526494	413936	16,808	0.2	9.2	30.5	7.3	0.006	293	3.4
28-Aug-89	08:08	526494	413936	16,809	5.0	9.2	30.3	7.3	0.049	293	3.4
28-Aug-89	08:10	526469	413936	16,810	0.2	8.6	30.5	7.3	0.116	272	3.4
28-Aug-89	08:10	526469	413936	16,811	5.0	8.6	30.3	7.4	0.018	272	3.4
28-Aug-89	08:13	526421	413878	16,812	0.2	7.6	30.0	7.3	0.028	276	3.5
28-Aug-89	08:13	526421	413878	16,813	5.0	7.6	30.8	7.3	0.019	276	3.5
28-Aug-89	08:36	526629	413905	16,814	0.2	9.0	30.7	7.1	0.006	427	3.9
28-Aug-89	08:36	526629	413905	16,815	5.0	9.0	30.9	7.2	0.006	427	3.9
28-Aug-89	08:38	526612	413893	16,816	0.2	8.8	31.1	7.2	0.014	417	3.9
28-Aug-89	08:38	526612	413893	16,817	5.0	8.8	31.1	7.2	0.006	417	3.9
28-Aug-89	08:42	526552	413815	16,818	0.2	6.8	30.9	7.2	0.006	413	4.0
28-Aug-89	08:42	526552	413815	16,819	5.0	6.8	30.2	0.0	0.006	413	4.0
28-Aug-89	09:13	526803	413777	16,824	0.2	7.8	29.6	7.2	0.044	640	4.5

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
28-Aug-89	09:13	526803	413777	16,825	5.0	7.8	30.2	7.2	0.035	640	4.5
28-Aug-89	09:15	526836	413741	16,826	0.2		30.2	7.2	0.016	687	4.5
28-Aug-89	09:15	526836	413741	16,827	5.0		30.2	7.2	0.012	687	4.5
28-Aug-89	09:18	526837	413687	16,828	0.2		29.3	7.2	0.006	717	4.6
28-Aug-89	09:18	526837	413687	16,829	5.0		29.4	7.2	0.046	717	4.6
28-Aug-89	09:20	526837	413654	16,830	0.2	5.1	29.4	7.2	0.046	736	4.6
28-Aug-89	09:20	526837	413654	16,831	5.0	5.1	29.4	7.2	0.034	736	4.6
28-Aug-89	09:22	526856	413613	16,832	0.2		29.4	7.2	0.014	776	4.6
28-Aug-89	09:22	526856	413613	16,833	3.0		29.6	7.2	0.018	776	4.6
28-Aug-89	09:49	526658	413879	16,834	0.2	8.3	29.6	7.1	0.006	464	5.1
28-Aug-89	09:49	526658	413879	16,835	5.0	8.3	28.9	7.0	0.016	464	5.1
28-Aug-89	09:52	526679	413832	16,836	0.2	7.8	28.7	7.1	0.042	505	5.1
28-Aug-89	09:52	526679	413832	16,837	5.0	7.8	29.3	7.1	0.006	505	5.1
28-Aug-89	09:54	526694	413791	16,838	0.2	7.3	28.9	7.1	0.010	540	5.2
28-Aug-89	09:54	526694	413791	16,839	5.0	7.3	29.3	7.1	0.006	540	5.2
28-Aug-89	09:58	526742	413707	16,840	0.2	5.2	29.4	7.2	0.010	628	5.2
28-Aug-89	09:58	526742	413707	16,841	5.0	5.2	31.8	7.1	0.030	628	5.2
28-Aug-89	10:02	526736	413650	16,842	0.2	3.5	29.0	7.1	0.056	660	5.3
28-Aug-89	10:02	526736	413650	16,843	3.0	3.5	28.7	7.2	0.008	660	5.3
28-Aug-89	11:20	526526	413916	16,844	0.2	7.4	26.9	7.4	0.108	331	6.6
28-Aug-89	11:20	526526	413916	16,845	5.0	7.4	29.1	7.3	0.008	331	6.6
28-Aug-89	11:21	526552	413929	16,846	0.2	7.8	26.9	7.4	0.034	347	6.6
28-Aug-89	11:21	526552	413929	16,847	5.0	7.8	28.0	7.4	0.040	347	6.6
28-Aug-89	11:23	526507	413848	16,848	0.2	6.0	27.3	7.4	0.015	357	6.6
28-Aug-89	11:23	526507	413848	16,849	5.0	6.0	28.5	7.3	0.006	357	6.6
28-Aug-89	11:25	526480	413775	16,850	0.2	5.4	28.7	7.3	0.006	394	6.7
28-Aug-89	11:25	526480	413775	16,851	3.0	5.4	29.1	7.3	0.007	394	6.7
28-Aug-89	11:26	526442	413739	16,852	0.2	3.2	29.1	7.1	0.340	403	6.7
28-Aug-89	11:26	526442	413739	16,853	3.0	3.2	29.3	7.1	0.415	403	6.7
28-Aug-89	11:54	526245	414056	16,854	0.2		26.7	7.2	0.045	35	7.2
28-Aug-89	11:54	526245	414056	16,855	5.0		27.6	7.2	0.015	35	7.2

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 2 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
28-Aug-89	11:57	526205	413952	16,856	0.2		26.7	7.2	0.007	145	7.2
28-Aug-89	11:57	526205	413952	16,857	5.0		28.0	7.2	0.013	145	7.2
28-Aug-89	11:58	526175	413865	16,858	0.2		27.3	7.2	0.006	237	7.2
28-Aug-89	11:58	526175	413865	16,859	5.0		27.8	7.0	0.650	237	7.2
28-Aug-89	12:00	526127	413766	16,860	0.2		27.3	6.9	0.850	346	7.3
28-Aug-89	12:00	526127	413766	16,861	5.0		28.2	6.9	1.860	346	7.3
28-Aug-89	12:02	526074	413724	16,862	0.2		28.4	6.9	1.290	405	7.3
28-Aug-89	12:02	526074	413724	16,863	5.0		28.4	6.9	0.770	405	7.3
28-Aug-89	12:23	526131	414283	16,864	0.2		27.8	7.4	0.149	223	7.6
28-Aug-89	12:23	526131	414283	16,865	5.0		26.7	7.4	0.026	223	7.6
28-Aug-89	12:26	526052	414191	16,866	0.2		27.3	7.4	0.034	217	7.7
28-Aug-89	12:26	526052	414191	16,867	5.0		26.9	7.2	1.780	217	7.7
28-Aug-89	12:28	525982	414079	16,868	0.2		26.7	7.3	0.019	263	7.7
28-Aug-89	12:28	525982	414079	16,869	5.0		29.6	7.2	0.190	263	7.7
28-Aug-89	12:31	525964	413928	16,870	0.2		26.7	7.3	0.052	325	7.8
28-Aug-89	12:31	525964	413928	16,871	5.0		28.0	7.2	0.243	325	7.8
28-Aug-89	12:32	525959	413841	16,872	0.2		25.5	7.2	0.009	380	7.8
28-Aug-89	12:32	525959	413841	16,873	5.0		28.4	7.2	0.317	380	7.8
28-Aug-89	12:54	525783	414297	16,874	0.2	8.1	26.9	7.4	0.006	506	8.2
28-Aug-89	12:54	525783	414297	16,875	6.0	8.1	27.8	7.3	0.273	506	8.2
28-Aug-89	12:56	525672	414211	16,876	0.2	5.8	26.9	7.4	0.021	585	8.2
28-Aug-89	12:56	525672	414211	16,877	5.0	5.8	27.5	7.3	0.006	585	8.2
28-Aug-89	12:58	525583	414154	16,878	0.2	4.5	25.3	7.4	0.009	665	8.2
28-Aug-89	12:58	525583	414154	16,879	4.0	4.5	26.9	7.4	0.027	665	8.2
28-Aug-89	13:00	525466	414042	16,880	0.2	8.2	26.6	7.4	0.025	781	8.3
28-Aug-89	13:00	525466	414042	16,881	3.0	8.2	27.3	7.3	0.079	781	8.3
28-Aug-89	13:01	525380	413955	16,882	0.2	3.4	26.7	7.3	0.006	876	8.3
28-Aug-89	13:01	525380	413955	16,883	2.0	3.4	27.3	7.2	0.079	876	8.3
28-Aug-89	13:20	525944	414243	16,884	0.2	8.1	27.5	7.4	0.061	337	8.6
28-Aug-89	13:20	525944	414243	16,885	5.0	8.1	26.7	6.4	23.200	337	8.6
28-Aug-89	13:22	525843	414188	16,886	0.2	8.4	27.5	7.2	0.130	414	8.6

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 3 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
28-Aug-89	13:22	525843	414188	16,887	4.0	8.4	27.8	7.2	0.050	414	8.6
28-Aug-89	13:24	525718	414088	16,888	0.2		27.5	7.2	0.014	527	8.7
28-Aug-89	13:24	525718	414088	16,889	3.0		27.3	7.3	0.049	527	8.7
28-Aug-89	13:27	525600	414001	16,890	0.2	4.6	27.3	7.3	0.100	651	8.7
28-Aug-89	13:27	525600	414001	16,891	3.0	4.6	27.3	7.3	0.040	651	8.7
28-Aug-89	13:29	525521	413900	16,892	0.2	3.8	27.3	7.3	0.010	749	8.7
28-Aug-89	13:29	525521	413900	16,893	2.0	3.8	27.5	7.3	0.022	749	8.7
28-Aug-89	13:56	526064	414187	16,894	0.2	9.3	28.5	7.3	0.006	205	9.2
28-Aug-89	13:56	526064	414187	16,895	8.0	9.3	28.5	7.3	0.353	205	9.2
28-Aug-89	13:58	526007	414135	16,896	0.2	7.8	28.5	7.3	0.133	242	9.2
28-Aug-89	13:58	526007	414135	16,897	7.0	7.8	28.5	7.4	0.037	242	9.2
28-Aug-89	13:59	525966	414060	16,898	0.2	7.3	28.9	7.3	0.018	281	9.2
28-Aug-89	13:59	525966	414060	16,899	5.0	7.3	28.7	7.3	0.070	281	9.2
28-Aug-89	14:01	525916	413964	16,900	0.2	5.5	28.7	7.3	0.051	353	9.3
28-Aug-89	14:01	525916	413964	16,901	4.0	5.5	27.8	7.3	0.626	353	9.3
28-Aug-89	14:02	525869	413801	16,902	0.2	5.1	28.2	7.3	0.178	475	9.3
28-Aug-89	14:02	525869	413801	16,903	5.0	5.1	29.8	7.2	0.060	475	9.3
28-Aug-89	14:28	525792	414326	16,904	0.2	12.6	29.4	7.3	0.092	510	9.7
28-Aug-89	14:28	525792	414326	16,905	8.0	12.6	29.3	7.2	0.122	510	9.7
28-Aug-89	14:30	525603	414266	16,906	0.2	7.9	29.4	7.3	0.272	665	9.8
28-Aug-89	14:30	525603	414266	16,907	6.0	7.9	29.3	7.2	0.006	665	9.8
28-Aug-89	14:32	525498	414173	16,908	0.2	6.4	29.4	7.3	0.010	751	9.8
28-Aug-89	14:32	525498	414173	16,909	5.0	6.4	29.4	7.3	0.145	751	9.8
28-Aug-89	14:34	525463	414052	16,910	0.2	11.5	29.1	7.3	0.092	783	9.8
28-Aug-89	14:34	525463	414052	16,911	9.0	11.5	29.3	7.3	0.006	783	9.8
28-Aug-89	14:36	525436	413877	16,912	0.2		28.7	7.2	0.021	837	9.9
28-Aug-89	14:36	525436	413877	16,913	6.0		28.9	7.2	0.044	837	9.9
28-Aug-89	15:06	525468	414392	16,914	0.2	8.4	28.9	7.4	3.030	833	10.4
28-Aug-89	15:06	525468	414392	16,915	7.0	8.4	29.1	7.2	4.860	833	10.4
28-Aug-89	15:09	525321	414306	16,916	0.2	7.4	29.6	7.2	0.034	949	10.4
28-Aug-89	15:09	525321	414306	16,917	7.0	7.4	29.6	7.2	0.119	949	10.4

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 4 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
28-Aug-89	15:11	525230	414204	16,918	0.2	7.1	29.6	7.2	0.006	1,021	10.4
28-Aug-89	15:11	525230	414204	16,919	6.0	7.1	29.6	7.2	0.006	1,021	10.4
28-Aug-89	15:13	525178	414064	16,920	0.2	6.7	28.9	7.2	0.006	1,067	10.5
28-Aug-89	15:13	525178	414064	16,921	6.0	6.7	29.3	7.2	0.014	1,067	10.5
28-Aug-89	15:15	525149	413961	16,922	0.2	5.9	28.9	7.1	0.036	1,104	10.5
28-Aug-89	15:15	525149	413961	16,923	5.0	5.9	28.9	7.1	0.006	1,104	10.5
28-Aug-89	15:33	526034	414189	16,924	0.2	10.4	30.0	7.6	0.361	233	10.8
28-Aug-89	15:33	526034	414189	16,925	7.0	10.4	30.3	7.4	0.299	233	10.8
28-Aug-89	15:35	526025	414255	16,926	0.2	10.9	30.0	7.4	0.027	274	10.8
28-Aug-89	15:35	526025	414255	16,927	9.0	10.9	30.5	7.3	0.021	274	10.8
28-Aug-89	15:37	525978	414085	16,928	0.2	9.3	30.0	7.4	0.012	267	10.9
28-Aug-89	15:37	525978	414085	16,929	8.0	9.3	30.5	7.4	0.062	267	10.9
28-Aug-89	15:39	525947	413993	16,930	0.2	7.6	30.0	7.3	0.133	314	10.9
28-Aug-89	15:39	525947	413993	16,931	6.0	7.6	30.3	7.3	0.096	314	10.9
28-Aug-89	15:41	525927	413893	16,932	0.2	7.1	30.3	7.3	0.006	375	10.9
28-Aug-89	15:41	525927	413893	16,933	6.0	7.1	30.5	7.3	0.021	375	10.9
28-Aug-89	16:00	525986	414172	16,934	0.2	10.5	29.4	7.4	0.023	271	11.3
28-Aug-89	16:00	525986	414172	16,935	7.0	10.5	29.8	6.4	30.300	271	11.3
28-Aug-89	16:02	525975	414109	16,936	0.2	9.1	30.7	7.4	0.053	271	11.3
28-Aug-89	16:02	525975	414109	16,937	9.0	9.1	30.9	7.4	0.092	271	11.3
28-Aug-89	16:04	525948	414050	16,938	0.2	9.1	30.0	7.4	0.025	300	11.3
28-Aug-89	16:04	525948	414050	16,939	9.0	9.1	30.5	7.4	0.055	300	11.3
28-Aug-89	16:06	525939	413976	16,940	0.2	7.9	30.3	7.4	0.050	327	11.4
28-Aug-89	16:06	525939	413976	16,941	7.0	7.9	30.5	7.3	0.036	327	11.4
28-Aug-89	16:09	526177	414107	16,942	0.2	11.3	30.5	7.4	0.019	70	11.4
28-Aug-89	16:09	526177	414107	16,943	0.2	11.3	31.4	7.0	3.310	70	11.4
16-Sep-89	07:00	526245	414091						7,806.000	0	0.0
16-Sep-89	07:34	526351	414100	18,826	0.2	14.2	31.6	7.4	0.629	106	0.6
16-Sep-89	07:34	526351	414100	18,827	8.0	14.2	32.4	7.5	0.009	106	0.6
16-Sep-89	07:40	526345	414000	18,828	0.2	13.0	31.5	7.5	0.009	135	0.7
16-Sep-89	07:40	526345	414000	18,829	8.0	13.0	32.4	6.6	6.650	135	0.7

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 5 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
16-Sep-89	07:42	526319	413936	18,830	0.2	11.7	31.3	7.2	0.009	172	0.7
16-Sep-89	07:42	526319	413936	18,831	8.0	11.7	31.5	7.2	0.433	172	0.7
16-Sep-89	07:45	526278	413878	18,832	0.2	10.0	31.6	7.4	0.006	216	0.8
16-Sep-89	07:45	526278	413878	18,833	8.0	10.0	31.9	7.4	0.007	216	0.8
16-Sep-89	07:47	526333	413793	18,834	0.2	9.0	31.5	7.4	0.006	311	0.8
16-Sep-89	07:47	526333	413793	18,835	8.0	9.0	31.6	7.4	0.007	311	0.8
16-Sep-89	07:54	526932	414173	18,836	0.2	16.3	31.7	7.4	0.034	692	0.9
16-Sep-89	07:54	526932	414173	18,837	8.0	16.3	32.3	7.5	0.040	692	0.9
16-Sep-89	07:57	526957	414067	18,838	0.2	15.8	31.6	7.4	0.013	712	1.0
16-Sep-89	07:57	526957	414067	18,839	8.0	15.8	32.0	7.5	0.006	712	1.0
16-Sep-89	08:00	526917	413963	18,840	0.2	15.3	31.7	7.3	0.491	684	1.0
16-Sep-89	08:00	526917	413963	18,841	8.0	15.3	32.6	7.5	0.019	684	1.0
16-Sep-89	08:04	526790	413940	18,842	0.2	14.9	31.6	7.5	0.043	566	1.1
16-Sep-89	08:04	526790	413940	18,843	8.0	14.9	32.8	7.6	0.007	566	1.1
16-Sep-89	08:06	526730	413837	18,844	0.2	13.0	31.8	7.5	0.006	547	1.1
16-Sep-89	08:06	526730	413837	18,845	8.0	13.0	32.5	7.6	0.006	547	1.1
16-Sep-89	08:54	526920	413982	18,846	0.2	14.5	31.4	7.4	0.017	684	1.9
16-Sep-89	08:54	526920	413982	18,847	8.0	14.5	32.7	7.6	0.013	684	1.9
16-Sep-89	08:59	526958	413865	18,848	0.2	10.8	31.2	7.4	0.022	748	2.0
16-Sep-89	08:59	526958	413865	18,849	8.0	10.8	32.6	7.6	0.011	748	2.0
16-Sep-89	09:05	526947	413839	18,850	0.2	14.0	31.2	7.5	0.012	746	2.1
16-Sep-89	09:05	526947	413839	18,851	8.0	14.0	31.5	7.6	0.008	746	2.1
16-Sep-89	09:08	526808	413821	18,852	0.2	13.2	31.5	7.6	0.006	624	2.1
16-Sep-89	09:08	526808	413821	18,853	8.0	13.2	31.3	7.5	0.010	624	2.1
16-Sep-89	09:10	526765	413780	18,854	0.2	11.2	31.1	7.5	0.023	606	2.2
16-Sep-89	09:10	526765	413780	18,855	8.0	11.2	31.4	7.5	0.010	606	2.2
16-Sep-89	09:18	527281	413683	18,856	0.2	14.5	31.3	7.4	0.088	1,113	2.3
16-Sep-89	09:18	527281	413683	18,857	8.0	14.5	31.3	7.4	0.064	1,113	2.3
16-Sep-89	09:22	527258	413567	18,858	0.2	10.5	31.2	7.4	0.013	1,141	2.4
16-Sep-89	09:22	527258	413567	18,859	8.0	10.5	31.2	7.4	0.017	1,141	2.4
16-Sep-89	09:25	527008	413399	18,860	0.2	5.2	31.2	7.4	0.012	1,030	2.4

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 6 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
16-Sep-89	09:25	527008	413399	18,861	5.0	5.2	31.0	7.4	0.043	1,030	2.4
16-Sep-89	09:29	526938	413277	18,862	0.2	5.2	31.0	7.4	0.006	1,069	2.5
16-Sep-89	09:29	526938	413277	18,863	4.0	5.2	30.8	7.4	0.027	1,069	2.5
16-Sep-89	09:32	526840	413129	18,864	0.2	5.5	30.9	7.3	0.006	1,131	2.5
16-Sep-89	09:32	526840	413129	18,865	4.0	5.5	30.9	7.3	0.015	1,131	2.5
16-Sep-89	10:18	526636	414098	18,866	0.2	12.3	30.4	7.4	0.099	391	3.3
16-Sep-89	10:18	526636	414098	18,867	8.0	12.3	30.7	7.3	0.603	391	3.3
16-Sep-89	10:21	526581	413998	18,868	0.2	11.0	30.5	7.0	1.480	349	3.4
16-Sep-89	10:21	526581	413998	18,869	8.0	11.0	30.4	6.4	10.200	349	3.4
16-Sep-89	10:23	526496	413930	18,870	0.2	9.0	30.3	7.2	0.028	298	3.4
16-Sep-89	10:23	526496	413930	18,871	7.0	9.0	30.2	7.2	0.013	298	3.4
16-Sep-89	10:26	526476	413781	18,872	0.2	6.0	30.5	7.3	0.036	387	3.4
16-Sep-89	10:26	526476	413781	18,873	5.0	6.0	30.6	7.3	0.099	387	3.4
16-Sep-89	10:29	526380	413685	18,874	0.2	4.5	30.9	7.3	0.023	428	3.5
16-Sep-89	10:29	526380	413685	18,875	3.0	4.5	31.1	7.3	0.054	428	3.5
16-Sep-89	10:35	526851	414068	18,876	0.2	12.0	31.1	7.3	0.083	606	3.6
16-Sep-89	10:35	526851	414068	18,877	8.0	12.0	31.2	7.3	0.236	606	3.6
16-Sep-89	10:38	526822	413914	18,878	0.2	12.0	31.0	7.2	0.046	604	3.6
16-Sep-89	10:38	526822	413914	18,879	8.0	12.0	31.0	7.0	0.618	604	3.6
16-Sep-89	10:40	526746	413817	18,880	0.2	9.0	30.9	7.2	0.035	571	3.7
16-Sep-89	10:40	526746	413817	18,881	7.0	9.0	31.0	7.2	0.035	571	3.7
16-Sep-89	10:43	526596	413652	18,882	0.2	4.3	30.9	7.2	0.010	562	3.7
16-Sep-89	10:43	526596	413652	18,883	3.0	4.3	30.7	7.2	0.094	562	3.7
16-Sep-89	10:46	526568	413616	18,884	0.2	4.0	30.8	7.2	0.010	574	3.8
16-Sep-89	10:46	526568	413616	18,885	3.0	4.0	30.6	7.2	0.014	574	3.8
16-Sep-89	11:19	527433	413727	18,886	0.2	11.0	30.1	6.8	0.113	1,243	4.3
16-Sep-89	11:19	527433	413727	18,887	8.0	11.0	30.3	7.2	0.276	1,243	4.3
16-Sep-89	11:23	527233	413607	18,888	0.2	8.7	29.6	7.2	0.572	1,100	4.4
16-Sep-89	11:23	527233	413607	18,889	7.0	8.7	30.8	7.2	0.091	1,100	4.4
16-Sep-89	11:26	527076	413599	18,890	0.2	5.5	29.9	7.2	0.098	966	4.4
16-Sep-89	11:26	527076	413599	18,891	4.0	5.5	30.0	7.3	0.048	[illegible]	4.4

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 7 (of 15)

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
16-Sep-89	11:29	527103	413549	18,892	0.2	3.5	30.0	7.2	0.345	1,015	4.5
16-Sep-89	11:29	527103	413549	18,893	3.0	3.5	29.8	7.2	0.027	1,015	4.5
16-Sep-89	11:31	527202	413649	18,894	0.2	8.5	29.5	7.2	0.042	1,054	4.5
16-Sep-89	11:31	527202	413649	18,895	7.0	8.5	30.2	7.2	0.033	1,054	4.5
16-Sep-89	11:36	526689	414177	18,896	0.2	11.0	29.5	7.2	0.575	452	4.6
16-Sep-89	11:36	526689	414177	18,897	8.0	11.0	30.0	7.2	0.220	452	4.6
16-Sep-89	11:39	526555	414046	18,898	0.2	10.0	29.4	7.2	0.006	313	4.7
16-Sep-89	11:39	526555	414046	18,899	8.0	10.0	29.5	7.2	0.079	313	4.7
16-Sep-89	11:41	526478	413969	18,900	0.2	8.0	29.4	7.2	0.019	263	4.7
16-Sep-89	11:41	526478	413969	18,901	6.0	8.0	29.4	7.2	0.058	263	4.7
16-Sep-89	11:44	526400	413901	18,902	0.2	6.5	29.3	7.2	0.025	245	4.7
16-Sep-89	11:44	526400	413901	18,903	5.0	6.5	28.9	7.2	0.064	245	4.7
16-Sep-89	11:46	526355	413857	18,904	0.2	4.9	29.2	7.2	0.006	259	4.8
16-Sep-89	11:46	526355	413857	18,905	3.0	4.9	29.8	7.2	0.016	259	4.8
16-Sep-89	12:24	526833	414059	18,906	0.2	9.7	28.5	7.3	0.527	589	5.4
16-Sep-89	12:24	526833	414060	18,907	7.0	9.7	28.5	7.2	0.076	589	5.4
16-Sep-89	12:27	526745	413903	18,908	0.2	8.5	28.6	7.2	0.175	534	5.5
16-Sep-89	12:27	526745	413903	18,909	6.0	8.5	28.8	7.2	0.014	534	5.5
16-Sep-89	12:29	526621	413759	18,910	0.2	4.5	29.0	7.2	0.058	502	5.5
16-Sep-89	12:29	526621	413759	18,911	3.0	4.5	29.0	7.2	0.034	502	5.5
16-Sep-89	12:31	526580	413762	18,912	0.2	3.5	29.0	7.2	0.432	470	5.5
16-Sep-89	12:31	526580	413762	18,913	2.0	3.5	29.2	7.2	0.081	470	5.5
16-Sep-89	12:34	526703	413912	18,914	0.2	7.5	28.7	7.2	0.029	492	5.6
16-Sep-89	12:34	526703	413912	18,915	5.0	7.5	28.7	7.2	0.058	492	5.6
16-Sep-89	12:36	527235	413868	18,916	0.2	9.0	28.6	7.2	0.150	1,015	5.6
16-Sep-89	12:36	527235	413868	18,917	7.0	9.0	28.8	6.9	0.948	1,015	5.6
16-Sep-89	12:41	527191	413694	18,918	0.2	9.5	28.8	7.2	0.013	1,026	5.7
16-Sep-89	12:41	527191	413694	18,919	6.0	9.5	29.2	7.2	0.034	1,026	5.7
16-Sep-89	12:44	527115	413631	18,920	0.2	5.5	29.7	6.9	0.560	984	5.7
16-Sep-89	12:44	527115	413631	18,921	3.0	5.5	29.9	6.8	0.825	984	5.7
16-Sep-89	12:46	527171	413726	18,922	0.2	9.3	29.2	7.1	0.080	995	5.8

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 8 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
16-Sep-89	12:46	527171	413726	18,923	6.0	9.3	29.2	7.1	0.009	995	5.8
16-Sep-89	12:48	527279	413819	18,924	0.2	10.3	29.1	7.2	0.132	1,069	5.8
16-Sep-89	12:48	527279	413819	18,925	6.0	10.3	29.4	6.8	4.450	1,069	5.8
16-Sep-89	14:11	526200	414390	18,926	0.2	10.5	26.7	7.2	0.039	302	7.2
16-Sep-89	14:11	526200	414390	18,927	0.2	10.5	28.6	7.2	0.613	302	7.2
16-Sep-89	14:14	526100	414270	18,928	0.2	9.8	26.2	7.2	0.104	230	7.2
16-Sep-89	14:14	526100	414270	18,929	0.2	9.8	27.5	7.2	0.026	230	7.2
16-Sep-89	14:16	525990	414231	18,930	0.2	6.6	25.5	7.2	0.123	291	7.3
16-Sep-89	14:16	525990	414231	18,931	4.0	6.6	27.3	6.8	3.900	291	7.3
16-Sep-89	14:19	525964	414152	18,932	0.2	6.0	25.8	7.2	0.257	288	7.3
16-Sep-89	14:19	525964	414152	18,933	4.0	6.0	27.3	6.8	2.600	288	7.3
16-Sep-89	14:21	526013	414010	18,934	0.2	4.5	25.9	7.2	0.044	246	7.4
16-Sep-89	14:21	526013	414010	18,935	2.0	4.5	26.8	7.1	0.058	246	7.4
16-Sep-89	14:26	526033	414567	18,936	0.2	12.0	25.1	7.2	0.543	521	7.4
16-Sep-89	14:26	526033	414567	18,937	8.0	12.0	26.6	7.2	0.028	521	7.4
16-Sep-89	14:29	525912	414288	18,938	0.2	7.2	25.0	7.1	0.006	387	7.5
16-Sep-89	14:29	525912	414288	18,939	5.0	7.2	27.4	6.6	5.825	387	7.5
16-Sep-89	14:32	525693	414165	18,940	0.2	4.5	25.8	7.1	0.016	557	7.5
16-Sep-89	14:32	525693	414165	18,941	2.5	4.5	27.1	7.0	0.193	557	7.5
16-Sep-89	14:36	525734	414301	18,942	0.2	7.5	24.8	7.1	0.052	552	7.6
16-Sep-89	14:36	525734	414301	18,943	5.0	7.5	27.8	7.0	1.025	552	7.6
16-Sep-89	14:38	525797	414350	18,944	7.1	9.5	24.5	7.1	0.019	517	7.6
16-Sep-89	14:38	525797	414350	18,945	6.0	9.5	25.9	7.1	0.073	517	7.6
16-Sep-89	15:15	525975	414566	18,946	0.2	13.0	25.8	7.2	0.023	546	8.3
16-Sep-89	15:15	525975	414566	18,947	8.0	13.0	26.8	7.2	0.004	546	8.3
16-Sep-89	15:18	525889	414414	18,948	0.2	11.6	26.0	7.2	0.028	481	8.3
16-Sep-89	15:18	525889	414414	18,949	8.0	11.6	27.2	7.1	0.002	481	8.3
16-Sep-89	15:19	525831	414299	18,950	0.2	7.8	26.0	7.2	0.019	463	8.3
16-Sep-89	15:19	525831	414299	18,951	5.0	7.8	26.7	7.2	0.006	463	8.3
16-Sep-89	15:22	525768	414144	18,952	0.2	6.6	26.7	7.2	0.004	480	8.4
16-Sep-89	15:22	525768	414144	18,953	3.5	6.6	26.9	7.2	0.004	480	8.4

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 9 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
16-Sep-89	15:25	525622	414006	18,954	0.2	4.5	26.7	7.2	0.012	629	8.4
16-Sep-89	15:25	525622	414006	18,955	2.5	4.5	27.3	7.1	0.006	629	8.4
16-Sep-89	15:30	525446	414770	18,956	0.2	15.0	26.2	7.2	0.199	1,049	8.5
16-Sep-89	15:30	525446	414770	18,957	8.0	15.0	27.3	7.1	0.036	1,049	8.5
16-Sep-89	15:32	525345	414592	18,958	0.2	8.6	26.2	7.1	0.006	1,030	8.5
16-Sep-89	15:32	525345	414592	18,959	6.0	8.6	26.9	7.1	0.012	1,030	8.5
16-Sep-89	15:34	525324	414435	18,960	0.2	7.0	26.4	7.1	0.012	983	8.6
16-Sep-89	15:34	525324	414435	18,961	5.0	7.0	26.4	6.6	5.200	983	8.6
16-Sep-89	15:37	525212	414186	18,962	0.2	5.0	26.9	7.1	0.006	1,037	8.6
16-Sep-89	15:37	525212	414186	18,963	3.0	5.0	27.3	7.0	0.045	1,037	8.6
16-Sep-89	15:39	525178	413953	18,964	0.2	4.0	27.3	7.1	0.038	1,076	8.7
16-Sep-89	15:39	525178	413953	18,965	2.0	4.0	27.3	7.1	0.047	1,076	8.7
16-Sep-89	16:10	526010	414427	18,966	0.2	13.0	29.1	7.1	0.091	410	9.2
16-Sep-89	16:10	526010	414427	18,967	8.0	13.0	29.6	7.1	0.054	410	9.2
16-Sep-89	16:12	526024	414203	18,968	0.2	12.0	29.1	7.1	0.045	248	9.2
16-Sep-89	16:12	526024	414203	18,969	8.0	12.0	29.8	7.1	0.012	248	9.2
16-Sep-89	16:15	525954	414016	18,970	0.2	7.0	29.6	7.0	0.019	301	9.3
16-Sep-89	16:15	525954	414016	18,971	5.0	7.0	29.8	7.0	0.010	301	9.3
16-Sep-89	16:18	525868	413801	18,972	0.2	6.0	29.1	7.1	0.007	476	9.3
16-Sep-89	16:18	525868	413801	18,973	3.0	6.0	29.1	7.0	0.038	476	9.3
16-Sep-89	16:21	525809	413998	18,974	0.2	6.0	29.1	7.1	0.007	446	9.4
16-Sep-89	16:21	525809	413998	18,975	3.0	6.0	29.8	0.0	0.026	446	9.4
16-Sep-89	16:25	525832	414407	18,976	0.2	11.0	29.8	7.0	0.010	520	9.4
16-Sep-89	16:25	525832	414407	18,977	0.2	11.0	30.3	7.0	0.019	520	9.4
16-Sep-89	16:27	525759	414311	18,978	0.2	11.0	30.2	7.0	2.980	533	9.5
16-Sep-89	16:27	525759	414311	18,979	7.0	11.0	29.6	7.0	0.216	533	9.5
16-Sep-89	16:29	525707	414161	18,980	0.2	7.0	29.4	7.1	0.006	543	9.5
16-Sep-89	16:29	525707	414161	18,981	5.0	7.0	30.2	7.2	0.072	543	9.5
16-Sep-89	16:32	525642	413989	18,982	0.2	6.3	30.2	7.2	0.006	612	9.5
16-Sep-89	16:32	525642	413989	18,983	3.0	6.3	30.5	7.2	0.075	612	9.5
16-Sep-89	16:34	525505	413884	18,984	0.2	5.5	28.7	7.0	0.006	768	9.6

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 10 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
16-Sep-89	16:34	525505	413884	18,985	3.0	5.5	30.3	7.1	0.012	768	9.6
16-Sep-89	17:13	525467	414847	18,986	0.2	16.5	31.1	7.2	0.006	1,085	10.2
16-Sep-89	17:13	525467	414847	18,987	9.0	16.5	30.9	7.2	0.010	1,085	10.2
16-Sep-89	17:16	525405	414705	18,988	0.2	16.0	30.3	7.2	0.024	1,040	10.3
16-Sep-89	17:16	525405	414705	18,989	9.0	16.0	31.3	7.3	0.006	1,040	10.3
16-Sep-89	17:18	525386	414520	18,990	0.2	11.0	31.8	7.3	0.010	960	10.3
16-Sep-89	17:18	525386	414520	18,991	7.5	11.0	32.0	7.4	0.006	960	10.3
16-Sep-89	17:21	525261	414357	18,992	0.2	9.0	32.3	7.4	0.006	1,019	10.4
16-Sep-89	17:21	525261	414357	18,993	6.0	9.0	32.3	7.4	0.034	1,019	10.4
16-Sep-89	17:23	525103	414203	18,994	0.2	8.0	32.5	7.4	0.012	1,147	10.4
16-Sep-89	17:23	525103	414203	18,995	5.0	8.0	32.3	7.4	0.058	1,147	10.4
16-Sep-89	17:29	526091	414371	18,996	0.2	15.5	31.8	7.3	0.006	320	10.5
16-Sep-89	17:29	526091	414371	18,997	9.0	15.5	31.8	7.3	0.154	320	10.5
16-Sep-89	17:31	526012	414221	18,998	0.2	12.0	32.0	7.3	0.010	267	10.5
16-Sep-89	17:31	526012	414221	18,999	8.0	12.0	31.8	7.3	0.140	267	10.5
16-Sep-89	17:33	525885	414091	19,000	0.2	10.0	32.3	7.3	0.008	360	10.6
16-Sep-89	17:33	525885	414091	19,001	7.0	10.0	32.0	7.3	0.027	360	10.6
16-Sep-89	17:35	525843	413967	19,002	0.2	8.5	32.3	7.4	0.025	421	10.6
16-Sep-89	17:35	525843	413967	19,003	5.0	8.5	32.0	7.4	0.157	421	10.6
16-Sep-89	17:37	525792	413806	19,004	0.2	8.0	32.3	7.4	0.006	535	10.6
16-Sep-89	17:37	525792	413806	19,005	5.0	8.0	32.5	7.4	0.006	535	10.6
17-Sep-89	07:41	526245	414091						7,884.000	0	0.0
17-Sep-89	14:22	527493	413502	19,106	0.2	6.0	27.3	7.1	0.840	1,380	6.7
17-Sep-89	14:22	527493	413502	19,107	3.0	6.0	27.6	7.2	0.480	1,380	6.7
17-Sep-89	14:27	527413	413513	19,108	0.2	6.8	28.0	7.2	0.501	1,303	6.8
17-Sep-89	14:27	527413	413513	19,109	3.0	6.8	27.8	7.2	0.028	1,303	6.8
17-Sep-89	14:36	526296	414017	19,110	0.2	6.0	26.9	7.2	0.093	90	6.9
17-Sep-89	14:36	526296	414017	19,111	3.0	6.0	27.3	7.1	0.012	90	6.9
17-Sep-89	14:39	526312	413992	19,112	0.2	5.9	26.6	7.1	0.156	120	7.0
17-Sep-89	14:39	526312	413992	19,113	3.0	5.9	27.5	7.1	0.100	120	7.0
17-Sep-89	14:42	526286	413911	19,114	0.2	4.5	25.5	7.2	0.061	185	7.0

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 11 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
17-Sep-89	14:42	526286	413911	19,115	2.5	4.5	27.8	7.2	0.044	185	7.0
17-Sep-89	15:05	525886	414297	19,116	0.2	6.0	24.7	7.2	0.083	414	7.4
17-Sep-89	15:05	525886	414297	19,117	3.0	6.0	25.8	7.2	0.007	414	7.4
17-Sep-89	15:07	525902	414294	19,118	0.2	5.0	24.4	7.2	0.006	399	7.4
17-Sep-89	15:07	525902	414294	19,119	2.5	5.0	24.6	7.2	0.006	399	7.4
17-Sep-89	15:10	525901	414247	19,120	0.2	5.4	24.9	7.1	0.006	378	7.5
17-Sep-89	15:10	525901	414247	19,121	3.0	5.4	25.8	7.1	0.125	378	7.5
17-Sep-89	15:24	526108	414047	19,122	0.2	5.4	24.6	7.1	0.118	144	7.7
17-Sep-89	15:24	526108	414047	19,123	4.0	5.4	25.1	7.1	0.100	144	7.7
17-Sep-89	15:28	526056	414073	19,124	0.2	5.3	24.0	7.2	0.006	190	7.8
17-Sep-89	15:28	526056	414073	19,125	3.0	5.3	25.3	7.2	0.008	190	7.8
17-Sep-89	17:35	525878	414563	19,156	0.2	14.4	31.2	7.2	0.007	598	9.9
17-Sep-89	17:35	525878	414563	19,157	8.0	14.4	30.7	7.2	0.029	598	9.9
17-Sep-89	17:37	525864	414452	19,158	0.2	13.5	30.7	7.2	0.007	525	9.9
17-Sep-89	17:37	525864	414452	19,159	8.0	13.5	31.4	7.2	0.071	525	9.9
17-Sep-89	17:40	525722	414381	19,161	7.0	13.0	31.1	7.2	0.087	598	10.0
17-Sep-89	17:42	525658	414331	19,163	6.0	9.0	31.6	6.6	6.000	634	10.0
17-Sep-89	17:44	525575	414147	19,165	4.0	7.0	31.3	7.2	0.017	672	10.1
7-Oct-89	10:36	526245	414091						7,884.000	0	0.0
7-Oct-89	17:54	525997	413814	21,400	0.2	4.9	29.3	6.5	0.338	372	7.3
7-Oct-89	17:54	525997	413814	21,401	2.0	4.9	30.0	6.8	0.410	372	7.3
7-Oct-89	18:04	526071	414190	21,402	0.2	8.8	28.7	7.2	0.010	200	7.5
7-Oct-89	18:04	526071	414190	21,403	6.0	8.8	29.1	7.1	0.904	200	7.5
7-Oct-89	18:05	526048	414136	21,404	0.2	8.4	28.5	7.2	0.006	202	7.5
7-Oct-89	18:05	526048	414136	21,405	5.0	8.4	28.9	7.2	0.549	202	7.5
7-Oct-89	18:07	526070	414142	21,406	0.2	8.4	28.5	7.3	0.006	182	7.5
7-Oct-89	18:07	526070	414142	21,407	5.0	8.4	28.7	7.2	0.488	182	7.5
7-Oct-89	18:09	526170	414121	21,408	0.2	8.9	28.5	7.2	0.006	81	7.6
7-Oct-89	18:09	526170	414121	21,409	5.0	8.9	28.7	7.2	0.904	81	7.6
8-Oct-89	11:44	526245	414091						6,180.000	0	0.0
8-Oct-89	09:06	526022	414224	21,410	0.2	9.7	30.0	7.2	0.067	260	-2.6

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 12 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
8-Oct-89	09:06	526022	414224	21,411	5.0	9.7	30.0	7.1	0.024	260	-2.6
8-Oct-89	09:08	525962	414194	21,412	0.2	9.3	29.8	6.6	3.130	301	-2.6
8-Oct-89	09:08	525962	414194	21,413	5.0	9.3	29.6	6.6	4.210	301	-2.6
8-Oct-89	09:10	525902	414126	21,414	0.2	8.4	30.0	7.0	0.045	345	-2.6
8-Oct-89	09:10	525902	414126	21,415	4.0	8.4	30.0	7.0	0.014	345	-2.6
8-Oct-89	09:13	525775	414278	21,416	0.2	10.3	30.2	6.6	3.490	506	-2.5
8-Oct-89	09:13	525775	414278	21,417	5.0	10.3	29.8	6.2	10.200	506	-2.5
8-Oct-89	09:16	525756	414274	21,418	0.2	9.5	30.2	6.6	0.113	522	-2.5
8-Oct-89	09:16	525756	414274	21,419	5.0	9.5	30.0	6.8	0.603	522	-2.5
8-Oct-89	09:20	525727	414281	21,420	0.2	8.4	30.0	7.0	0.271	552	-2.4
8-Oct-89	09:20	525727	414281	21,421	4.0	8.4	29.8	7.0	0.031	552	-2.4
8-Oct-89	09:23	525390	414430	21,422	0.2	8.4	29.8	6.6	5.060	920	-2.4
8-Oct-89	09:23	525390	414430	21,423	4.0	8.4	30.0	6.4	5.250	920	-2.4
8-Oct-89	09:27	525355	414416	21,424	0.2	8.2	30.0	6.6	1.830	947	-2.3
8-Oct-89	09:27	525355	414416	21,425	4.0	8.2	30.0	6.6	2.080	947	-2.3
8-Oct-89	09:30	525336	414409	21,426	0.2	8.4	28.5	6.9	0.540	963	-2.2
8-Oct-89	09:30	525336	414409	21,427	5.0	8.4	29.3	6.9	0.563	963	-2.2
8-Oct-89	09:34	525142	414607	21,428	0.2	9.4	29.3	7.1	0.032	1,218	-2.2
8-Oct-89	09:34	525142	414607	21,429	5.0	9.4	29.3	7.1	0.034	1,218	-2.2
8-Oct-89	10:01	526003	414238	21,430	0.2	10.2	29.8	6.6	0.077	283	-1.7
8-Oct-89	10:01	526003	414238	21,431	5.0	10.2	29.8	7.2	0.011	283	-1.7
8-Oct-89	10:10	525920	414129	21,432	0.2	9.0	29.8	7.2	0.084	327	-1.6
8-Oct-89	10:10	525920	414129	21,433	5.0	9.0	29.8	7.2	0.011	327	-1.6
8-Oct-89	10:12	525964	414132	21,434	0.2	8.7	29.8	7.2	0.006	284	-1.5
8-Oct-89	10:12	525964	414132	21,435	4.0	8.7	29.8	7.2	0.006	284	-1.5
8-Oct-89	10:16	525720	414327	21,436	0.2	10.0	30.0	7.0	1.510	576	-1.5
8-Oct-89	10:16	525720	414327	21,437	5.0	10.0	29.6	6.5	9.250	576	-1.5
8-Oct-89	10:19	525728	414265	21,438	0.2	8.7	29.6	7.0	0.557	545	-1.4
8-Oct-89	10:19	525728	414265	21,439	4.0	8.7	29.6	7.2	0.580	545	-1.4
8-Oct-89	10:21	525704	414212	21,440	0.2	8.2	29.4	7.2	0.009	554	-1.4
8-Oct-89	10:21	525704	414212	21,441	4.0	8.2	29.6	7.2	0.008	554	-1.4

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 13 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
8-Oct-89	10:25	525401	414439	21,442	0.2	8.8	29.4	7.3	0.135	913	-1.3
8-Oct-89	10:25	525401	414439	21,443	4.0	8.8	29.8	7.3	0.148	913	-1.3
8-Oct-89	10:27	525390	414392	21,444	0.2	8.6	29.4	7.0	2.250	906	-1.3
8-Oct-89	10:27	525390	414392	21,445	4.0	8.6	29.8	6.9	4.400	906	-1.3
8-Oct-89	10:29	525395	414343	21,446	0.2	8.3	29.8	7.2	0.013	887	-1.3
8-Oct-89	10:29	525395	414343	21,447	4.0	8.3	29.4	7.2	0.017	887	-1.3
8-Oct-89	10:33	525108	414588	21,448	0.2	9.1	29.4	7.2	0.231	1,241	-1.2
8-Oct-89	10:33	525108	414588	21,449	5.0	9.1	27.8	7.2	0.090	1,241	-1.2
8-Oct-89	11:22	526009	414258	21,450	0.2	10.8	30.2	7.2	0.019	289	-0.4
8-Oct-89	11:22	526009	414258	21,451	5.0	10.8	30.9	7.2	0.019	289	-0.4
8-Oct-89	11:24	526024	414211	21,452	0.2	10.4	30.5	7.2	0.037	251	-0.3
8-Oct-89	11:24	526024	414211	21,453	6.0	10.4	31.6	7.1	0.299	251	-0.3
8-Oct-89	11:26	526047	414119	21,454	0.2	10.0	30.7	7.2	0.006	200	-0.3
8-Oct-89	11:26	526047	414119	21,455	5.0	10.0	30.9	7.2	0.011	200	-0.3
8-Oct-89	11:31	525726	414331	21,456	0.2	10.0	30.7	7.2	0.066	572	-0.2
8-Oct-89	11:31	525726	414331	21,457	5.0	10.0	31.1	7.2	0.104	572	-0.2
8-Oct-89	11:34	525727	414241	21,458	0.2	9.5	30.5	7.2	0.007	539	-0.2
8-Oct-89	11:34	525727	414241	21,459	4.5	9.5	30.9	6.5	8.580	539	-0.2
8-Oct-89	11:36	525736	414112	21,460	0.2	10.9	30.5	7.2	0.007	509	-0.1
8-Oct-89	11:36	525736	414112	21,461	5.0	10.9	30.9	7.2	0.017	509	-0.1
8-Oct-89	11:43	525417	414489	21,462	0.2	10.0	30.5	7.2	0.017	919	0.0
8-Oct-89	11:43	525417	414489	21,463	5.0	10.0	30.9	7.2	0.007	919	0.0
8-Oct-89	11:45	525439	414411	21,464	0.2	9.0	30.9	7.1	0.645	867	0.0
8-Oct-89	11:45	525439	414411	21,465	4.5	9.0	30.3	6.8	3.980	867	0.0
8-Oct-89	11:47	525455	414300	21,466	0.2	8.5	30.7	7.2	0.015	817	0.1
8-Oct-89	11:47	525455	414300	21,467	4.0	8.5	30.5	7.2	0.260	817	0.1
8-Oct-89	11:53	525084	414665	21,468	0.2	10.3	30.5	7.2	0.009	1,295	0.2
8-Oct-89	11:53	525084	414665	21,469	5.0	10.3	30.5	7.2	0.009	1,295	0.2
8-Oct-89	13:43	526503	414039	21,490	0.2	12.0	30.7	6.8	0.058	263	2.0
8-Oct-89	13:43	526503	414039	21,491	8.0	12.0	30.5	7.0	0.064	263	2.0
8-Oct-89	13:45	526497	413975	21,492	0.2	11.0	30.2	7.0	0.070	277	2.0

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 14 (of 15).

Date	Time (BST)	NGR East	NGR North	Sample Number	Sample Depth (m)	Water Depth (m)	Salinity (p.p.t.)	pH	Soluble Iron (mg/l)	Range (m)	Time after HW (hrs)
8-Oct-89	13:45	526497	413975	21,493	7.0	11.0	30.5	6.5	6.050	277	2.0
8-Oct-89	13:47	526480	413919	21,494	0.2	10.3	30.2	7.0	0.006	291	2.1
8-Oct-89	13:47	526480	413919	21,495	7.0	10.3	30.7	7.0	1.460	291	2.1
8-Oct-89	13:49	526783	413934	21,496	0.2	12.5	30.3	7.0	0.068	560	2.1
8-Oct-89	13:49	526783	413934	21,497	8.0	12.5	30.7	7.1	0.068	560	2.1
8-Oct-89	13:50	526786	413882	21,498	0.2	12.2	29.8	7.2	0.025	580	2.1
8-Oct-89	13:50	526786	413882	21,499	7.0	12.2	30.0	7.2	0.032	580	2.1
8-Oct-89	13:53	526774	413834	21,500	0.2	11.2	30.0	7.2	0.017	588	2.2
8-Oct-89	13:53	526774	413834	21,501	7.0	11.2	30.3	7.1	0.681	588	2.2
8-Oct-89	13:55	527125	413893	21,502	0.2	13.2	30.2	7.2	0.038	902	2.2
8-Oct-89	13:55	527125	413893	21,503	8.0	13.2	30.5	7.2	0.028	902	2.2
8-Oct-89	13:57	527097	413856	21,504	0.2	13.0	30.3	7.2	0.040	884	2.2
8-Oct-89	13:57	527097	413856	21,505	8.0	13.0	30.3	7.2	0.079	884	2.2
8-Oct-89	13:59	527082	413813	21,506	0.2	13.0	30.2	7.2	0.082	882	2.3
8-Oct-89	13:59	527082	413813	21,507	8.0	13.0	30.2	7.2	0.105	882	2.3
8-Oct-89	14:02	527452	413755	21,508	0.2	13.8	29.6	7.1	1.660	1,253	2.3
8-Oct-89	14:02	527452	413755	21,509	8.0	13.8	30.2	7.0	0.487	1,253	2.3
8-Oct-89	14:08	526518	414051	21,510	0.2	12.4	29.8	7.2	0.006	276	2.4
8-Oct-89	14:08	526518	414051	21,511	8.0	12.4	29.8	7.2	0.472	276	2.4
8-Oct-89	14:09	526520	413992	21,512	0.2	11.0	29.6	7.3	0.008	292	2.4
8-Oct-89	14:09	526520	413992	21,513	7.0	11.0	29.6	7.3	0.010	292	2.4
8-Oct-89	14:11	526530	413919	21,514	0.2		29.4	7.4	0.006	333	2.5
8-Oct-89	14:13	526750	413905	21,515	0.2		29.4	7.3	0.006	538	2.5
8-Oct-89	14:13	526787	413920	21,516	0.2		29.6	7.4	0.006	568	2.5
8-Oct-89	14:14	526832	413883	21,517	0.2		29.6	7.4	0.010	623	2.5
8-Oct-89	14:14	526812	413858	21,518	0.2		29.4	7.4	0.006	613	2.5

Table 8.6 : Soluble Iron Data from around the New Tioxide Outfall - Page 15 (of 15).

Date	Survey Period mean Acid mg/l H2SO4	Survey Period mean Total Fe mg/l Fe	Mean Flow cu.m/day	Factory 24-hour mean Acid mg/l H2SO4	Factory 24-hour mean Total Fe mg/l Fe
1987-1988.	8,907	3,180	25,719		
1984	11,600	2,150	19,703		
11 July, 1989			29,971	7,557	3,606
12 July, 1989			29,876	7,184	2,822
13 July, 1989	9,106	4,760	28,579	7,277	2,307
14 July, 1989			28,851	8,490	4,010
15 July, 1989			29,707	8,677	2,800
16 July, 1989			29,192	8,117	3,270
17 July, 1989			28,010	10,169	2,957
18 July, 1989			29,166	8,770	3,382
30 July, 1989	8,534	2,089	29,750		
26 August, 1989	10,135	2,965	29,121		
17 September, 1989	9,200	2,194	30,079		
7 October, 1989		2,380	26,796		
SURVEY MEAN :	**9,580**	**2,817**	**28,180**	**8,280**	**3,144**

TABLE 8.7 : Factory Effluent Discharge Data for SCM.

Date	Survey Period mean Acid mg/l H2SO4	Survey Period mean Total Fe mg/l Fe	Mean Flow cu.m/day	Factory 24-hour mean Acid mg/l H2SO4	Factory 24-hour mean Total Fe mg/l Fe
1987-1988	19,373	7,538	25,474		
1984	18,500	5,460	24,869		
11 July, 1989			23,366	20,300	7,770
12 July, 1989			23,648	22,600	8,290
13 July, 1989			25,341	21,620	7,700
14 July, 1989	25,537	11,600	25,358	20,000	7,420
15 July, 1989			25,508	21,300	9,460
16 July, 1989			24,304	17,400	7,600
17 July, 1989			25,513	20,400	8,010
18 July, 1989				20,500	7,730
29 July, 1989	26,614	5,405	23,651		
28 August, 1989	23,673	11,200	24,898		
16 September, 1989	24,000	7,806	22,283		
8 October, 1989		6,180	23,640		
SURVEY MEAN :	**22,950**	**7,884**	**24,450**	**20,515**	**7,998**

TABLE 8.8 : <u>Factory Effluent Discharge Data for Tioxide.</u>

TABLE 8.9 : <u>Soluble Metals in Selected Samples from around the New SCM Outfall - 26th August, 1989.</u>

Sample Number	NGR East	NGR North	Cr ug/l	Zn ug/l	Ni ug/l	Mn ug/l	Pb ug/l	Cu ug/l	Soluble Fe mg/l	DERIVED VALUES Cr ug/l	Zn ug/l	Ni ug/l	Mn ug/l	Pb ug/l	Cu ug/l
Factory	522252	415262	19,000	920	1,390	43,000	590	1,190	2,965	19,000	920	1,390	43,000	590	1,190
16,644	522207	414993	<1.5	7.5	4.5	47	<2.5	<0.5	0.006	0.0	0.0	0.0	0.1	0.0	0.0
16,645	522207	414993	<1.5	5.9	<3.0	51	<2.5	<0.5	0.006	0.0	0.0	0.0	0.1	0.0	0.0
16,646	522282	415086	<1.5	<4.0	<3.0	41	<2.5	<0.5	0.006	0.0	0.0	0.0	0.1	0.0	0.0
16,647	522282	415086	<1.5	5.9	<3.0	41	<2.5	<0.5	0.006	0.0	0.0	0.0	0.1	0.0	0.0
16,648	522344	415166	<1.5	36.0	130.0	630	<2.5	21.0	18.500	118.5	5.7	8.7	268.3	3.7	7.4
16,649	522344	415166	<1.5	22.0	76.0	470	<2.5	3.4	0.752	4.8	0.2	0.4	10.9	0.1	0.3
16,650	522357	415192	<1.5	11.0	7.9	45	<2.5	1.7	0.152	1.0	0.0	0.1	2.2	0.0	0.1
16,651	522357	415192	<1.5	8.9	5.2	41	<2.5	<0.5	0.006	0.0	0.0	0.0	0.1	0.0	0.0
16,652	522368	415215	<1.5	12.0	5.2	43	<2.5	28.0	0.101	0.6	0.0	0.0	1.5	0.0	0.0
16,655	522400	414906	<1.5	7.0	<3.0	40	<2.5	<0.5	0.006	0.0	0.0	0.0	0.1	0.0	0.0
16,656	522444	414967	<1.5	18.0	81.0	390	<2.5	<0.5	11.800	75.6	3.7	5.5	171.1	2.3	4.7
16,657	522444	414967	<1.5	4.7	<3.0	47	<2.5	<0.5	0.050	0.3	0.0	0.0	0.7	0.0	0.0
16,658	522465	414994	<1.5	17.0	110.0	490	<2.5	<0.5	16.600	106.4	5.2	7.8	240.7	3.3	6.7
16,659	522465	414994	<1.5	9.1	<3.0	57	3.6	13.0	0.246	1.6	0.1	0.1	3.6	0.0	0.1
16,660	522477	414990	<1.5	14.0	73.0	350	<2.5	<0.5	10.800	69.2	3.4	5.1	156.6	2.1	4.3
16,661	522477	414990	<1.5	8.3	<3.0	77	<2.5	<0.5	0.502	3.2	0.2	0.2	7.3	0.1	0.2
16,662	522482	415091	<1.5	12.0	6.6	99	<2.5	<0.5	1.140	7.3	0.4	0.5	16.5	0.2	0.5
16,663	522482	415091	<1.5	11.0	11.0	150	<2.5	<0.5	1.870	12.0	0.6	0.9	27.1	0.4	0.8
16,664	522134	415157	<1.5	8.9	<3.0	38	<2.5	1.3	0.006	0.0	0.0	0.0	0.1	0.0	0.0
16,665	522134	415157	<1.5	9.1	<3.0	48	<2.5	<0.5	0.009	0.1	0.0	0.0	0.1	0.0	0.0
16,666	522194	415262	200.0	31.0	460.0	1450	8.9	5.5	58.000	371.7	18.0	27.2	841.1	11.5	23.3
16,667	522194	415262	100.0	31.0	330.0	1090	6.8	1.9	40.700	260.8	12.6	19.1	590.3	8.1	16.3
16,668	522218	415310	490.0	59.0	830.0	2070	1.8	40.0	98.500	631.2	30.6	46.2	1428.5	19.6	39.5

Sample Number	NGR East	NGR North	Cr ug/l	Zn ug/l	Ni ug/l	Mn ug/l	Pb ug/l	Cu ug/l	Soluble Fe mg/l	DERIVED VALUES Cr ug/l	Zn ug/l	Ni ug/l	Mn ug/l	Pb ug/l	Cu ug/l
16,669	522218	415310	<1.5	19.0	160.0	510	<2.5	1.3	20.000	128.2	6.2	9.4	290.1	4.0	8.0
16,670	522256	415330	310.0	38.0	580.0	1940	1.2	13.0	68.400	438.3	21.2	32.1	992.0	13.6	27.5
16,671	522256	415330	360.0	46.0	630.0	2130	1.2	17.0	71.400	457.5	22.2	33.5	1035.5	14.2	28.7
16,672	522319	415391	<1.5	22.0	10.0	39	<2.5	23.0	0.029	0.2	0.0	0.0	0.4	0.0	0.0
16,673	522319	415391	<1.5	14.0	5.5	49	<2.5	3.1	0.026	0.2	0.0	0.0	0.4	0.0	0.0
16,674	521972	415181	<1.5	24.0	85.0	370	<2.5	17.0	9.210	59.0	2.9	4.3	133.6	1.8	3.7
16,675	521972	415181	<1.5	15.0	23.0	180	<2.5	1.2	2.800	17.9	0.9	1.3	40.6	0.6	1.1
16,676	522018	415283	<1.5	11.0	9.1	150	<2.5	<0.5	1.350	8.7	0.4	0.6	19.6	0.3	0.5
16,677	522018	415283	<1.5	10.0	<3.0	107	<2.5	<0.5	0.580	3.7	0.2	0.3	8.4	0.1	0.2
16,684	521761	415369	6.6	10.0	22.0	150	<2.5	<2.1	2.580	16.5	0.8	1.2	37.4	0.5	1.0
16,684	521761	415369	<1.5	9.0	5.6	110	<2.5	<2.1	0.976	6.3	0.3	0.5	14.2	0.2	0.4
16,686	521783	415477	<1.5	12.0	31.0	190	<2.5	<2.1	3.100	19.9	1.0	1.5	45.0	0.6	1.2
16,687	521783	415477	3.1	14.0	33.0	170	<2.5	<2.1	2.190	14.0	0.7	1.0	31.8	0.4	0.9
16,690	521867	415604	4.2	17.0	67.0	200	<2.5	<2.1	7.200	46.1	2.2	3.4	104.4	1.4	2.9
16,691	521867	415604	5.7	17.0	120.0	370	<2.5	<2.1	14.400	92.3	4.5	6.8	208.8	2.9	5.8
16,694	521428	415686	<1.5	13.0	14.0	130	<2.5	<2.1	0.841	5.4	0.3	0.4	12.2	0.2	0.3
16,695	521428	415686	1.6	14.0	19.0	160	<2.5	<2.1	1.230	7.9	0.4	0.6	17.8	0.2	0.5
16,696	521515	415788	<1.5	28.0	14.0	130	<2.5	15.0	0.930	6.0	0.3	0.4	13.5	0.2	0.4
16,697	521515	415788	<1.5	21.0	16.0	130	<2.5	<2.1	1.450	9.3	0.4	0.7	21.0	0.3	0.6
16,698	521562	415878	<1.5	10.0	8.2	120	<2.5	<2.1	0.787	5.0	0.2	0.4	11.4	0.2	0.3
16,709	522063	415383	<1.5	40.0	5.8	100	<2.5	<2.1	0.890	5.7	0.3	0.4	12.9	0.2	0.4
16,719	521906	415519	<1.5	21.0	26.0	110	<2.5	<2.1	1.750	11.2	0.5	0.8	25.4	0.3	0.7
16,729	522110	415336	<1.5	24.0	27.0	110	2.9	<2.1	2.960	19.0	0.9	1.4	42.9	0.6	1.2
16,739	521901	415509	<1.5	28.0	8.5	97	<2.5	<2.8	0.568	3.6	0.2	0.3	8.2	0.1	0.2
16,741	521928	415529	<1.5	33.0	47.0	150	<2.5	<2.8	6.420	41.1	2.0	3.0	93.1	1.3	2.6
16,742	521978	415580	<1.5	13.0	<3.0	87	<2.5	<2.8	0.425	2.7	0.1	0.2	6.2	0.1	0.2
16,751	521553	415964	<1.5	21.0	19.0	150	<2.5	<2.8	1.940	12.4	0.6	0.9	28.1	0.4	0.8
16,752	521619	416079	<1.5	19.0	26.0	190	<2.5	<2.8	3.250	20.8	1.0	1.5	47.1	0.6	1.3

Table 8.9 : Soluble Metals in Selected Samples from around the New SCM Outfall - 26th August, 1989.

Sample Number	NGR East	NGR North	Cr ug/l	Zn ug/l	Ni ug/l	Mn ug/l	Pb ug/l	Cu ug/l	Soluble Fe mg/l	DERIVED VALUES Cr ug/l	Zn ug/l	Ni ug/l	Mn ug/l	Pb ug/l	Cu ug/l
16,758	522177	415349	<1.5	20.0	32.0	110	<2.5	<2.8	6.640	42.5	2.1	3.1	96.3	1.3	2.7
16,761	522189	415396	<1.5	24.0	43.0	140	<2.5	<2.8	5.380	34.5	1.7	2.5	78.0	1.1	2.2
16,771	521917	415684	<1.5	38.0	62.0	170	<2.5	<2.8	8.380	53.7	2.6	3.9	121.5	1.7	3.4
16,776	522347	415165	<1.5	53.0	4.6	81	<2.5	<2.8	0.615	3.9	0.2	0.3	8.9	0.1	0.2
16,777	522347	415165	3.8	67.0	160.0	290	<2.5	<2.8	22.700	145.5	7.0	10.6	329.2	4.5	9.1
16,778	522370	415186	<1.5	53.0	14.0	95	<2.5	<2.8	1.750	11.2	0.5	0.8	25.4	0.3	0.7
16,779	522370	415186	6.7	73.0	150.0	270	<2.5	<2.8	19.900	127.5	6.2	9.3	288.6	4.0	8.0
16,781	522433	415178	<1.5	63.0	<3.0	84	<2.5	<2.8	0.880	5.6	0.3	0.4	12.8	0.2	0.4
16,786	522705	414973	<1.5	57.0	16.0	120	<2.5	<2.8	3.860	24.7	1.2	1.8	56.0	0.8	1.5
16,787	522705	414973	<1.5	49.0	<3.0	96	<2.5	<1.6	1.310	8.4	0.4	0.6	19.0	0.3	0.5
16,789	522756	415081	<1.5	40.0	<3.0	88	<2.5	<1.6	0.970	6.2	0.3	0.5	14.1	0.2	0.4
16,791	522822	415138	<1.5	29.0	<3.0	92	<2.5	<1.6	0.480	3.1	0.1	0.2	7.0	0.1	0.2
16,793	522695	414934	6.3	46.0	96.0	220	<2.5	<1.6	0.492	3.2	0.2	0.2	7.1	0.1	0.2

Table 8.9 : Soluble Metals in Selected Samples from around the New SCM Outfall - 26th August, 1989.

TABLE 8.10 : **Soluble Metals in Selected Samples from around the New Tioxide Outfall - 28th August, 1989.**

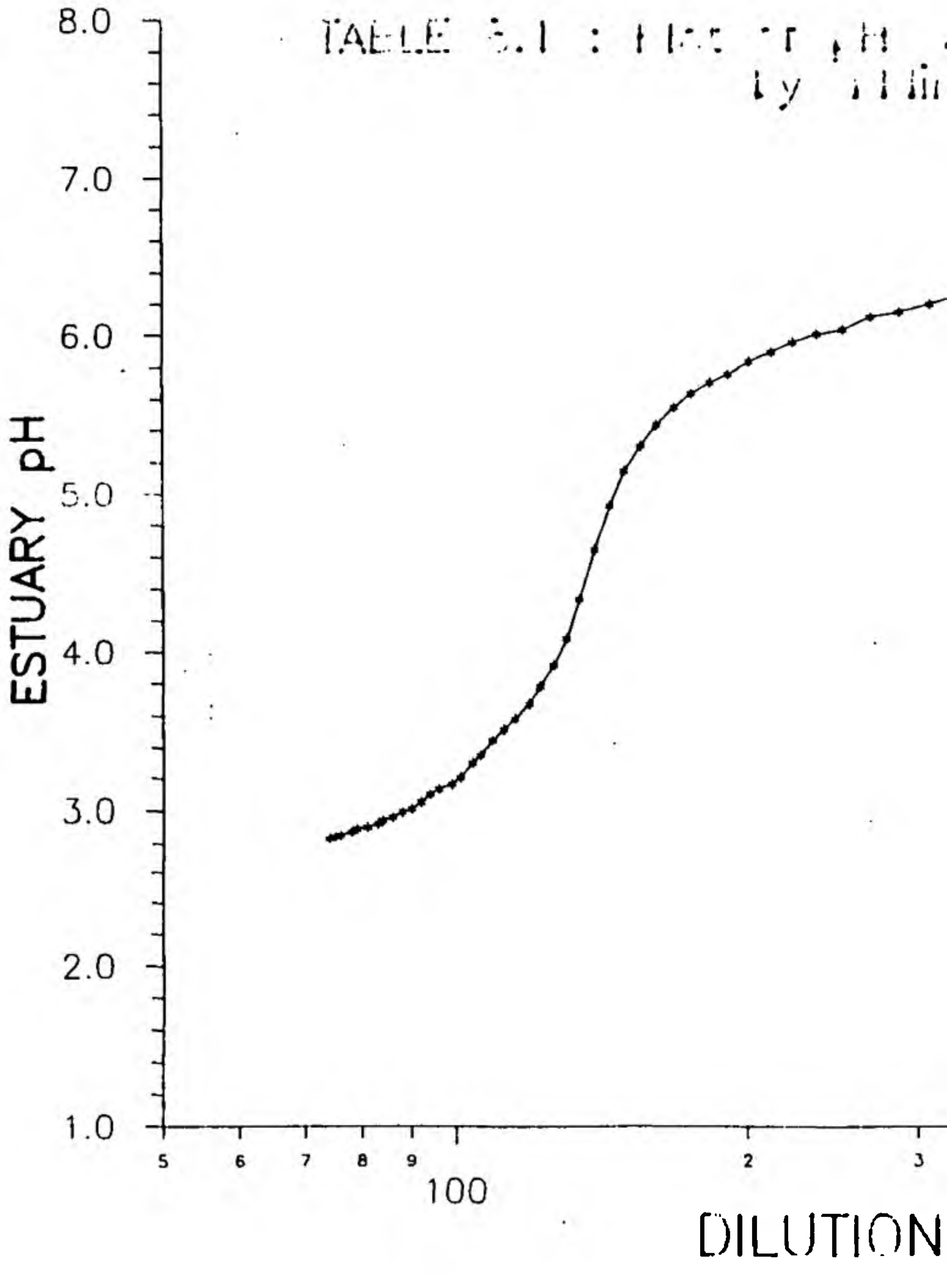
Sample Number	NGR East	NGR North	Cr ug/l	Zn ug/l	Ni ug/l	Mn ug/l	Pb ug/l	Cu ug/l	Soluble Fe mg/l	DERIVED VALUES Cr ug/l	Zn ug/l	Ni ug/l	Mn ug/l	Pb ug/l	Cu ug/l
Factory	522252	415262	6,080	7,000	530	260	1,580	920	11,200	6,080	7,000	530	260	1,580	920
16,795	526421	414019	<1.5	18.0	6.9	190	<2.5	<1.6	1.750	1.0	1.1	0.1	0.0	0.2	0.1
16,797	526425	414033	<1.5	12.0	<3.0	140	<2.5	<1.6	1.020	0.6	0.6	0.0	0.0	0.1	0.1
16,859	526175	413865	<1.5	14.0	<3.0	140	<2.5	<1.6	0.650	0.4	0.4	0.0	0.0	0.1	0.1
16,860	526127	413766	<1.5	12.0	<3.0	140	<2.5	<1.6	0.850	0.5	0.5	0.0	0.0	0.1	0.1
16,861	526127	413766	<1.5	14.0	<3.0	260	<2.5	<1.6	1.860	1.0	1.2	0.1	0.0	0.3	0.2
16,862	526074	413724	<1.5	13.0	<3.0	200	<2.5	<1.6	1.290	0.7	0.8	0.1	0.0	0.2	0.1
16,863	526074	413724	<1.5	13.0	<3.0	200	<2.5	<1.6	0.770	0.4	0.5	0.0	0.0	0.1	0.1
16,867	526052	414191	<1.5	11.0	6.2	110	<2.5	<1.6	1.780	1.0	1.1	0.1	0.0	0.3	0.1
16,885	525944	414243	0.0	0.0	0.0	0	0.0	0.0	23.200	12.6	14.5	1.1	0.5	3.3	1.9
16,914	525468	414392	0.0	0.0	0.0	0	0.0	0.0	3.030	1.6	1.9	0.1	0.1	0.4	0.2
16,915	525468	414392	0.0	0.0	0.0	0	0.0	0.0	4.860	2.6	3.0	0.2	0.1	0.7	0.4
16,935	525986	414172	0.0	0.0	0.0	0	0.0	0.0	30.300	16.4	18.9	1.4	0.7	4.3	2.5
16,936	525975	414109	0.0	0.0	0.0	0	0.0	0.0	0.053	0.0	0.0	0.0	0.0	0.0	0.0
16,937	525975	414109	0.0	0.0	0.0	0	0.0	0.0	0.092	0.0	0.1	0.0	0.0	0.0	0.0
16,938	525948	414050	0.0	0.0	0.0	0	0.0	0.0	0.025	0.0	0.0	0.0	0.0	0.0	0.0
16,939	525948	414050	0.0	0.0	0.0	0	0.0	0.0	0.055	0.0	0.0	0.0	0.0	0.0	0.0
16,940	525939	413976	0.0	0.0	0.0	0	0.0	0.0	0.050	0.0	0.0	0.0	0.0	0.0	0.0
16,941	525939	413976	0.0	0.0	0.0	0	0.0	0.0	0.036	0.0	0.0	0.0	0.0	0.0	0.0
16,942	526177	414107	0.0	0.0	0.0	0	0.0	0.0	0.019	0.0	0.0	0.0	0.0	0.0	0.0
16,943	526177	414107	0.0	0.0	0.0	0	0.0	0.0	3.310	1.8	2.1	0.2	0.1	0.5	0.3

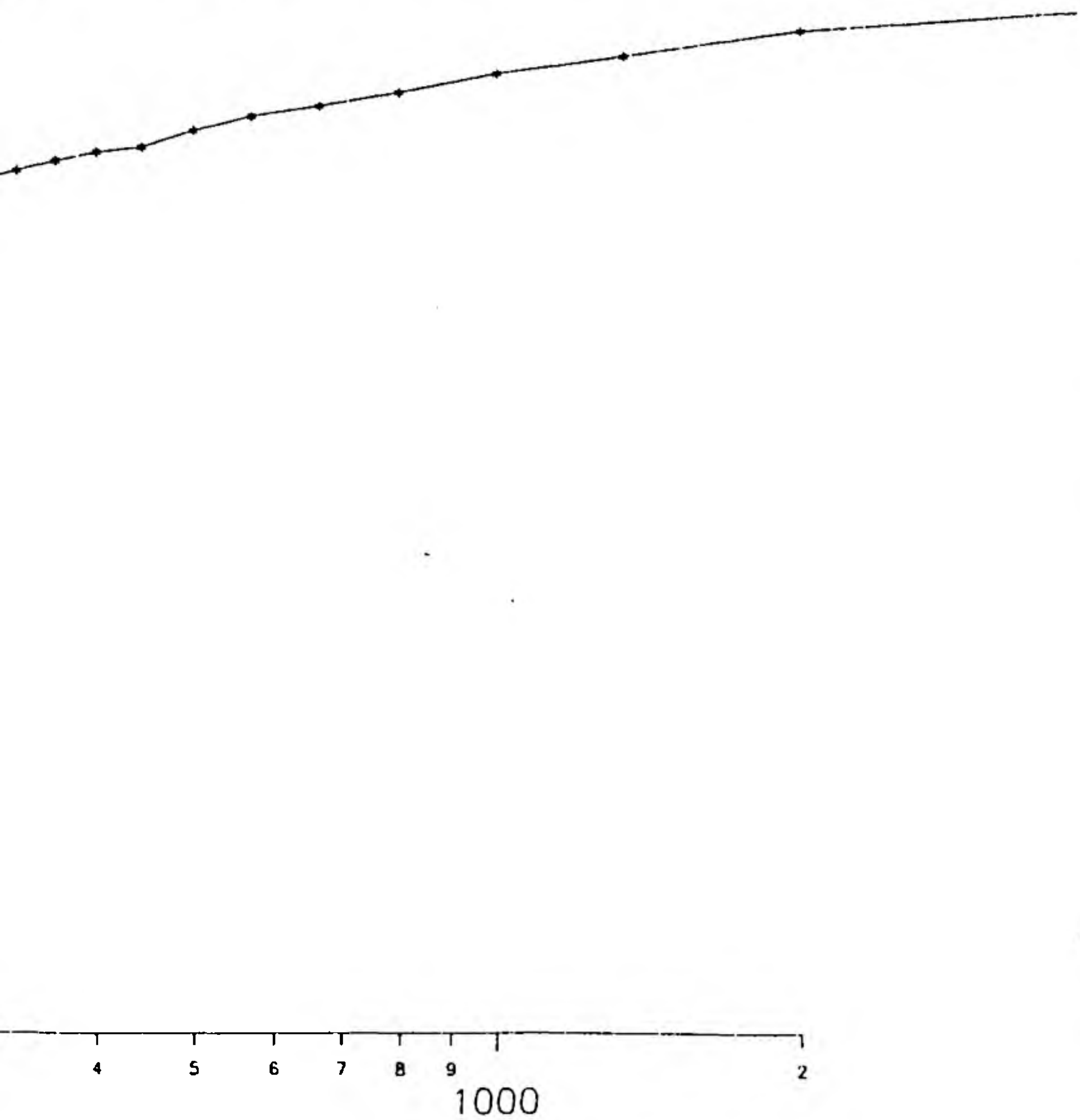
Sample Number	Site	Code	NGR East	NGR North	V.M. %	Cd mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	Hg mg/kg	V mg/kg	Ti mg/kg
Outfall	0	0	522252	415262												
15,700	1W	100N	522236	415405	6.6	< 0.5	63	37	33,850	1,047	37	68	219	0.25	92	833
15,701	1W	0	522174	415327	8.1	< 0.5	54	38	32,350	1,137	40	43	164	0.22	105	763
15,702	1W	100S	522112	415248	7.1	< 0.5	56	36	29,550	922	31	63	218	0.36	80	747
15,703	1W	250S	522019	415132	8.1	< 0.5	59	37	30,250	1,061	32	69	233	0.48	87	813
15,704	3W	100N	521929	415663	7.6	< 0.5	54	32	29,950	871	30	60	191	0.25	82	818
15,705	3W	0	521871	415581	7.2	< 0.5	46	28	31,600	1,042	33	44	164	0.18	80	499
15,706	3W	100S	521815	415500	7.7	< 0.5	55	34	30,950	977	30	59	208	0.28	83	784
15,707	3W	250S	521731	415379	9.8	< 0.5	71	43	35,500	903	37	86	247	0.44	94	850
15,708	1E	100N	522394	415279	8.1	< 0.5	65	37	34,050	999	33	73	227	0.28	97	957
15,709	1E	0	522336	415198	7.9	< 0.5	54	68	32,550	1,274	39	66	183	0.23	102	654
15,710	1E	100S	522278	415117	6.9	< 0.5	49	32	28,900	948	32	51	196	0.22	69	613
15,711	1E	250S	522191	414997	7.2	< 0.5	58	39	31,150	939	34	63	228	0.27	83	736
15,712	3E	100N	522709	415036	7.0	< 0.5	59	34	30,750	964	32	66	212	0.27	85	742
15,713	3E	0	522650	414955	6.2	< 0.5	57	44	30,150	985	32	62	192	0.29	105	1,015
15,714	3E	100S	522591	414874	7.0	< 0.5	66	38	35,050	1,071	37	74	241	0.27	101	939
15,715	3E	250S	522504	414753	9.8	< 0.5	116	72	41,750	824	49	123	325	0.91	187	1,924
MEAN :					7.6	< 0.5	61	41	32,397	998	35	67	216	0.33	96	855
15,735	CL	24	538010	411686	7.0	<0.5	49	31	33,200	757	30	61	184	0.26	71	710
15,736	CL	29	532148	416001	8.5	<0.5	67	38	43,300	1,624	36	80	241	0.31	88	729
15,737	CL	N33	529700	411400	8.2	<0.5	66	43	38,550	674	36	87	228	0.37	79	749

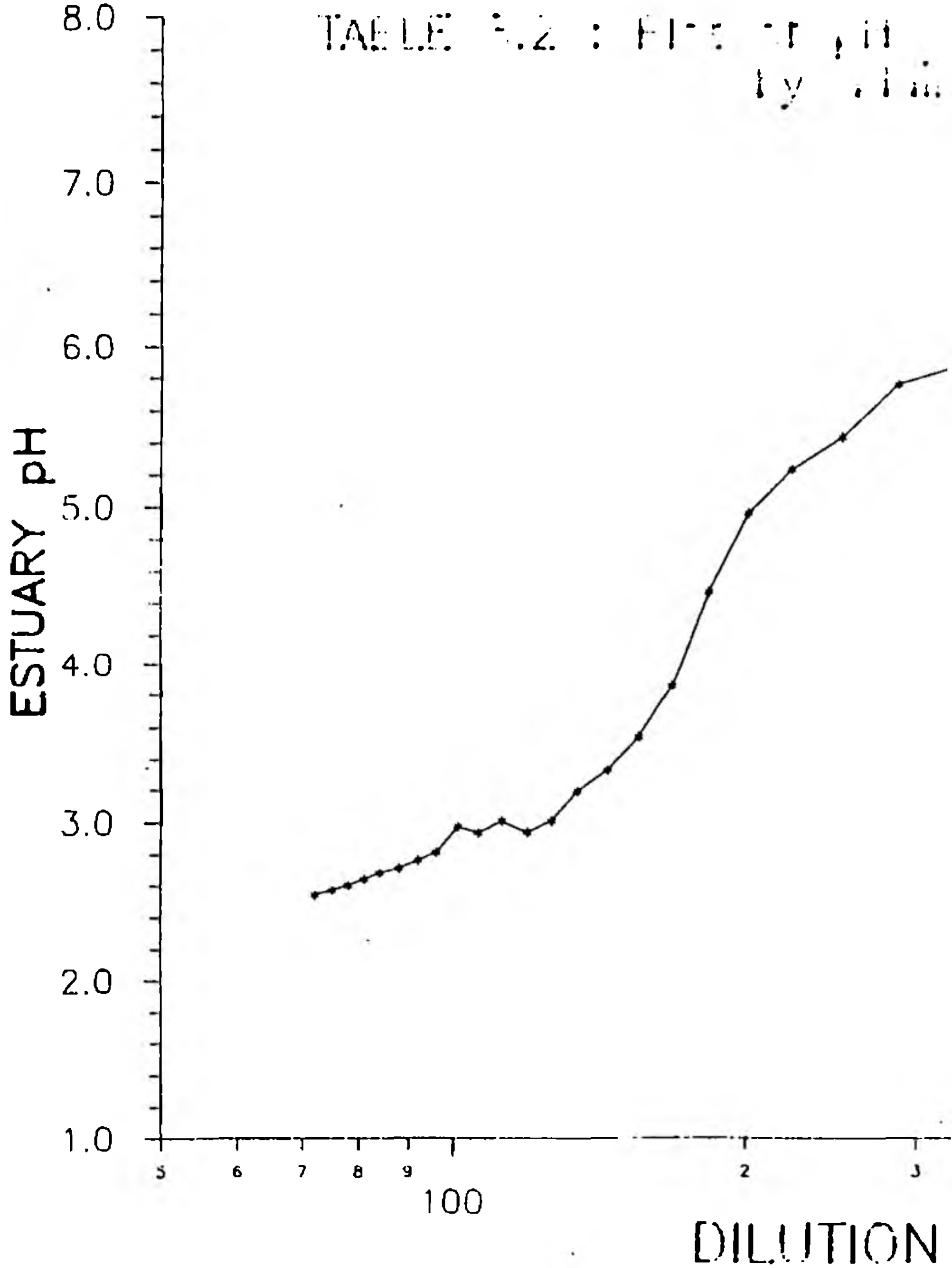
TABLE 8.11 : <u>Sediment Data for the <90 um Fraction around the New SCM Outfall.</u> <u>July - 1989.</u>

Sample Number	Site	Code	NGR East	NGR North	V.M. %	Cd mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Ni mg/kg	Pb mg/kg	Zn mg/kg	Hg mg/kg	V mg/kg	Ti mg/kg
Outfall	0	0	526245	414091												
15,716	1W	100N	526041	414547	8.4	< 0.5	79	46	42,050	1,016	39	94	278	0.36	137	1,552
15,717	1W	0	525996	414458	6.7	< 0.5	58	56	33,100	867	32	73	202	0.25	90	1,094
15,718	1W	100S	525951	414369	6.2	< 0.5	50	37	33,250	586	29	75	186	0.30	89	1,708
15,719	1W	400S	525815	414101	6.6	< 0.5	78	46	39,950	883	38	95	268	0.33	120	1,212
15,720	3W	100N	525691	414657	6.8	< 0.5	79	47	37,750	1,100	39	100	246	0.35	108	1,062
15,721	3W	0	525648	414567	6.4	< 0.5	77	44	42,300	1,020	36	88	264	0.29	127	1,457
15,722	3W	100S	525604	414477	9.6	< 0.5	84	52	40,400	1,167	42	111	283	0.41	101	868
15,723	3W	250S	525538	414342	9.2	< 0.5	79	51	44,100	1,640	45	100	298	0.32	132	1,390
15,724	3W	400S	525472	414207	7.9	< 0.5	79	46	40,100	1,048	37	90	273	0.32	127	1,198
15,725	1E	100N	526213	414447	7.3	< 0.5	67	41	36,000	1,012	34	81	249	0.29	99	951
15,726	1E	0	526169	414358	9.4	< 0.5	73	42	43,900	1,167	36	89	268	0.31	110	1,029
15,727	1E	100S	526124	414268	9.4	< 0.5	77	42	44,800	1,153	36	95	272	0.31	120	1,272
15,728	1E	250S	526056	414134	9.8	< 0.5	85	47	47,550	1,083	39	102	290	0.34	132	1,210
15,729	1E	400S	525989	414000	9.1	< 0.5	67	36	39,650	893	31	80	234	0.28	104	1,052
15,730	3E	100N	526625	414259	9.5	< 0.5	70	42	40,900	1,081	36	97	253	0.32	98	903
15,731	3E	0	526578	414170	10.0	< 0.5	75	41	46,350	1,200	35	98	273	0.38	117	1,198
15,732	3E	100S	526531	414082	10.2	< 0.5	78	42	45,200	1,240	38	101	281	0.35	119	1,089
15,733	3E	250S	526461	413949	9.9	< 0.5	75	39	43,350	1,000	33	87	250	0.28	119	1,220
15,734	3E	400S	526391	413817	9.4	< 0.5	74	40	39,800	998	34	88	247	0.36	118	1,104
MEAN :					8.5	< 0.5	74	44	41,079	1,061	36	92	259	0.32	114	1,188
15,735	CL	24	538010	411686	7.0	< 0.5	49	31	33,200	757	30	61	184	0.26	71	710
15,736	CL	29	532148	416001	8.5	< 0.5	67	38	43,300	1,624	36	80	241	0.31	88	729
15,737	CL	N33	529700	411400	8.2	< 0.5	66	43	38,550	674	36	87	228	0.37	79	749

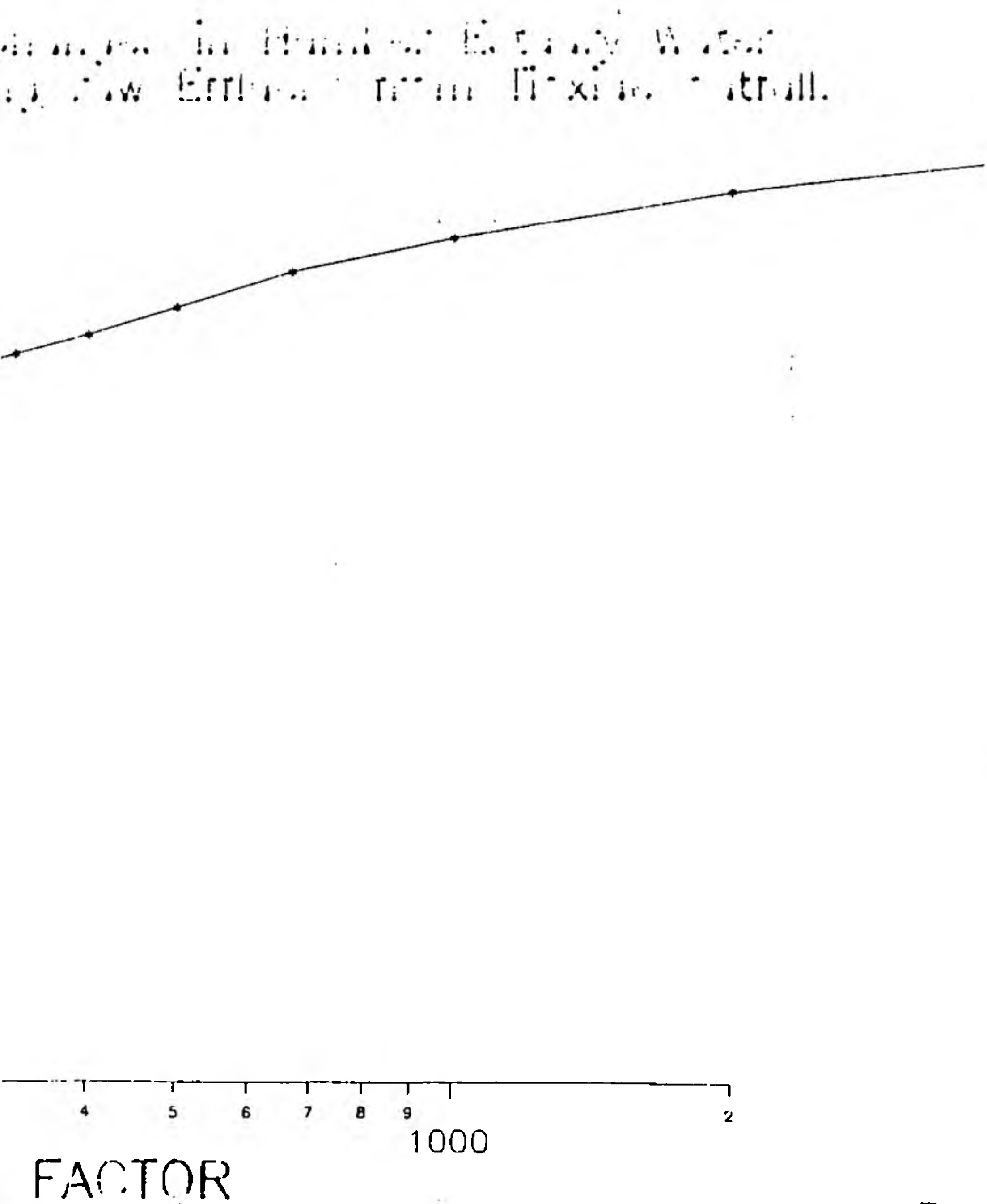
TABLE 8.12 : Sediment Data for the <90 um Fraction around the New Tioxide Outfall. July - 1989.


ESTUARY pH
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
5
6
7
8
9
100
2
3
DILUTION


4
5
6
7
8
9
1000
2
FACTOR



ESTUARY pH
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
5
6
7
8
9
100
2
3
DILUTION



4
5
6
7
8
9
2
1000
FACTOR

FIGURE 8.3 : Summary of pH Peaks around the New SCM Outfall.

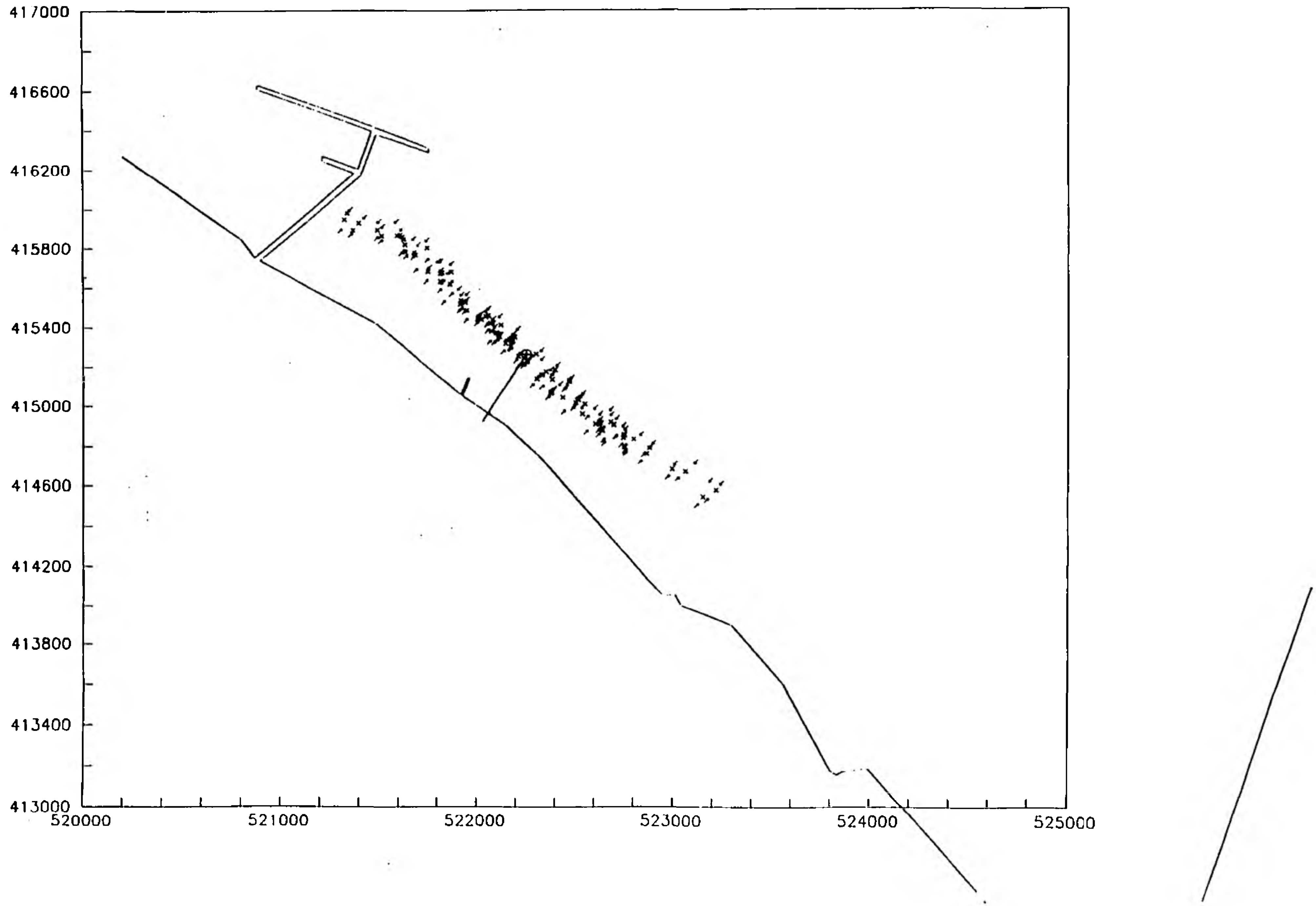


FIGURE 8.4 : Summary of pH Peaks around the New Tioxide Outfall.

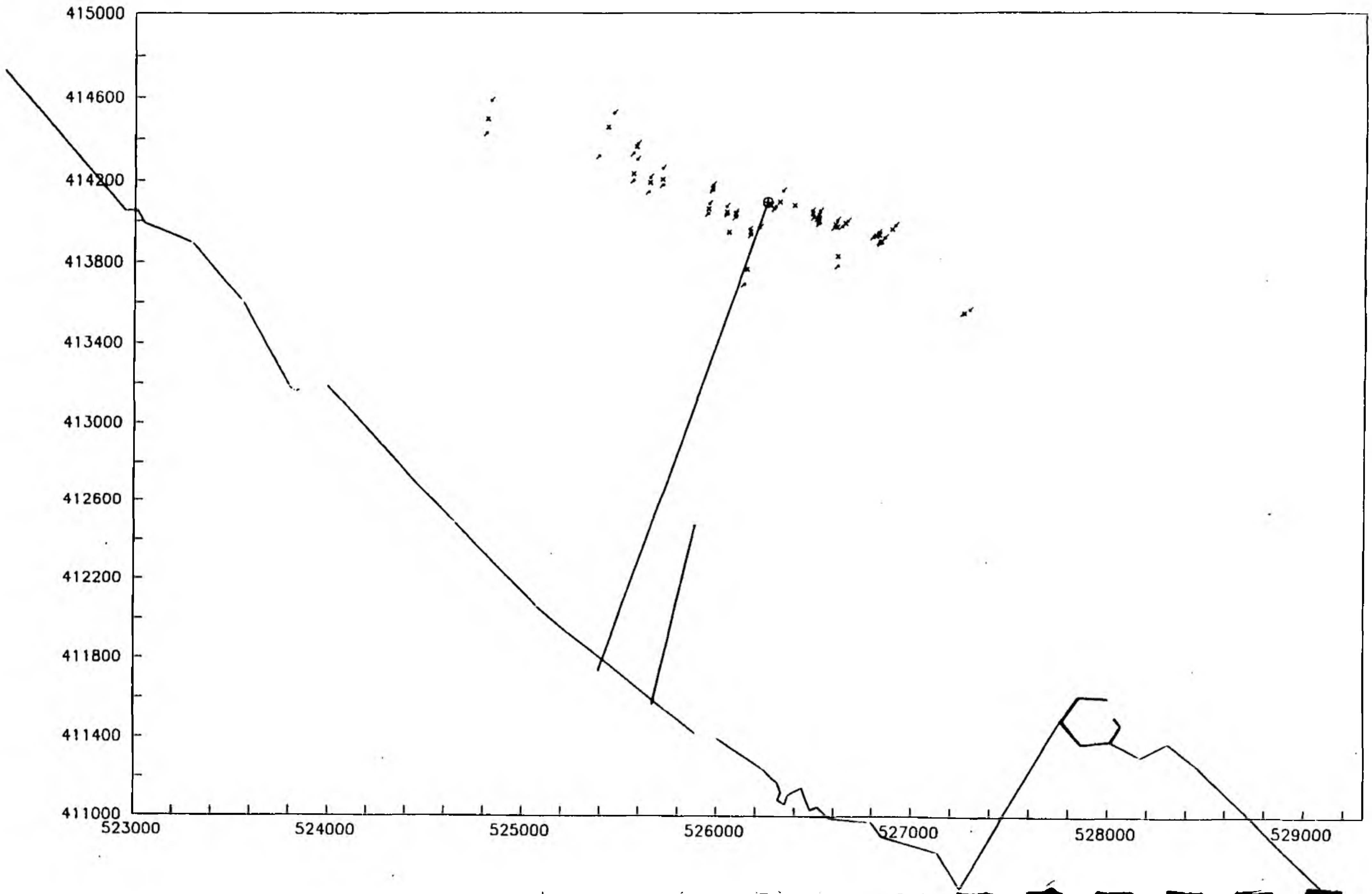


FIGURE 8.5 : Summary of Soluble Iron Data around the New SCM Outfall.

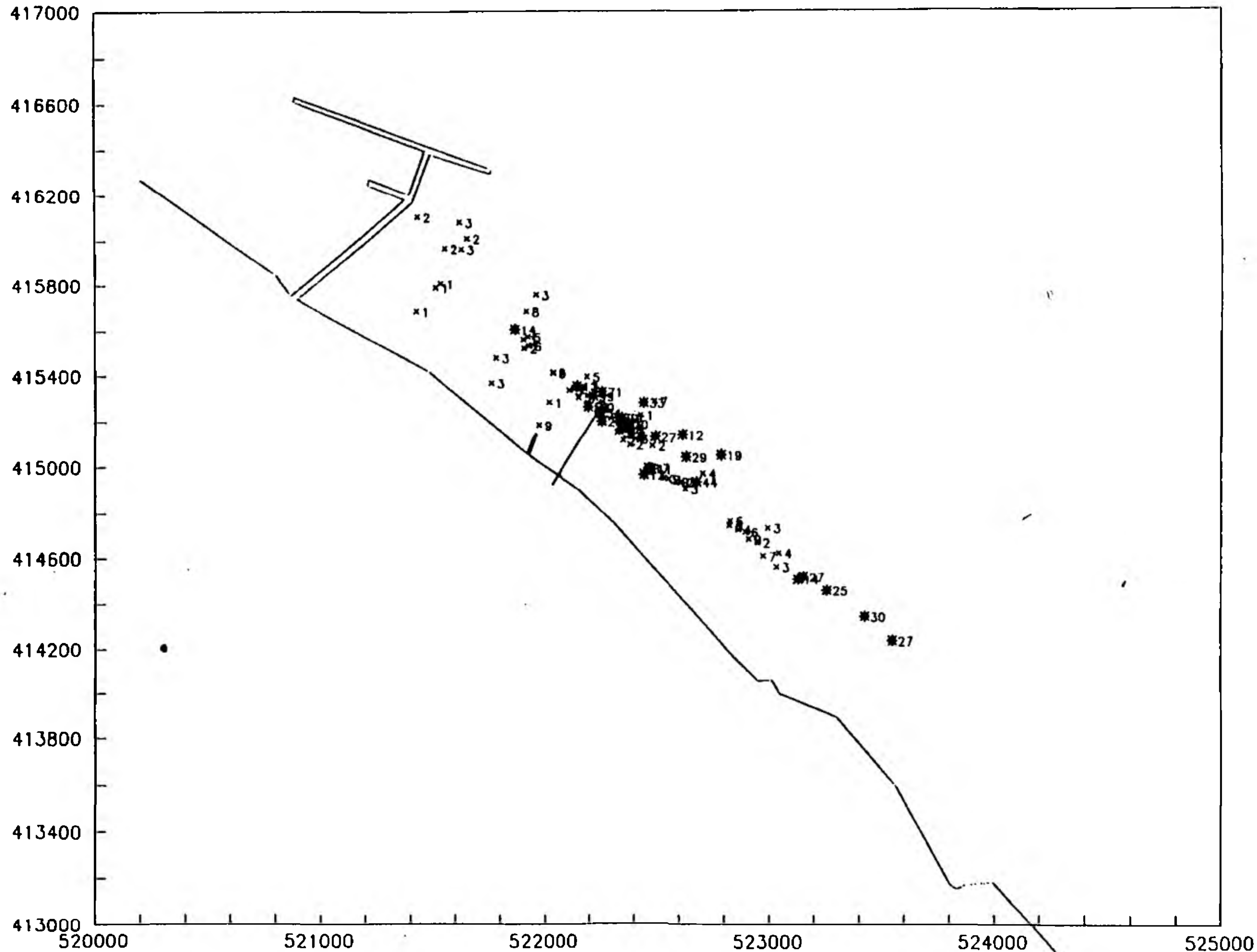


FIGURE 8.6 : Summary of Soluble Iron Data around the New Tioxide Outfall.

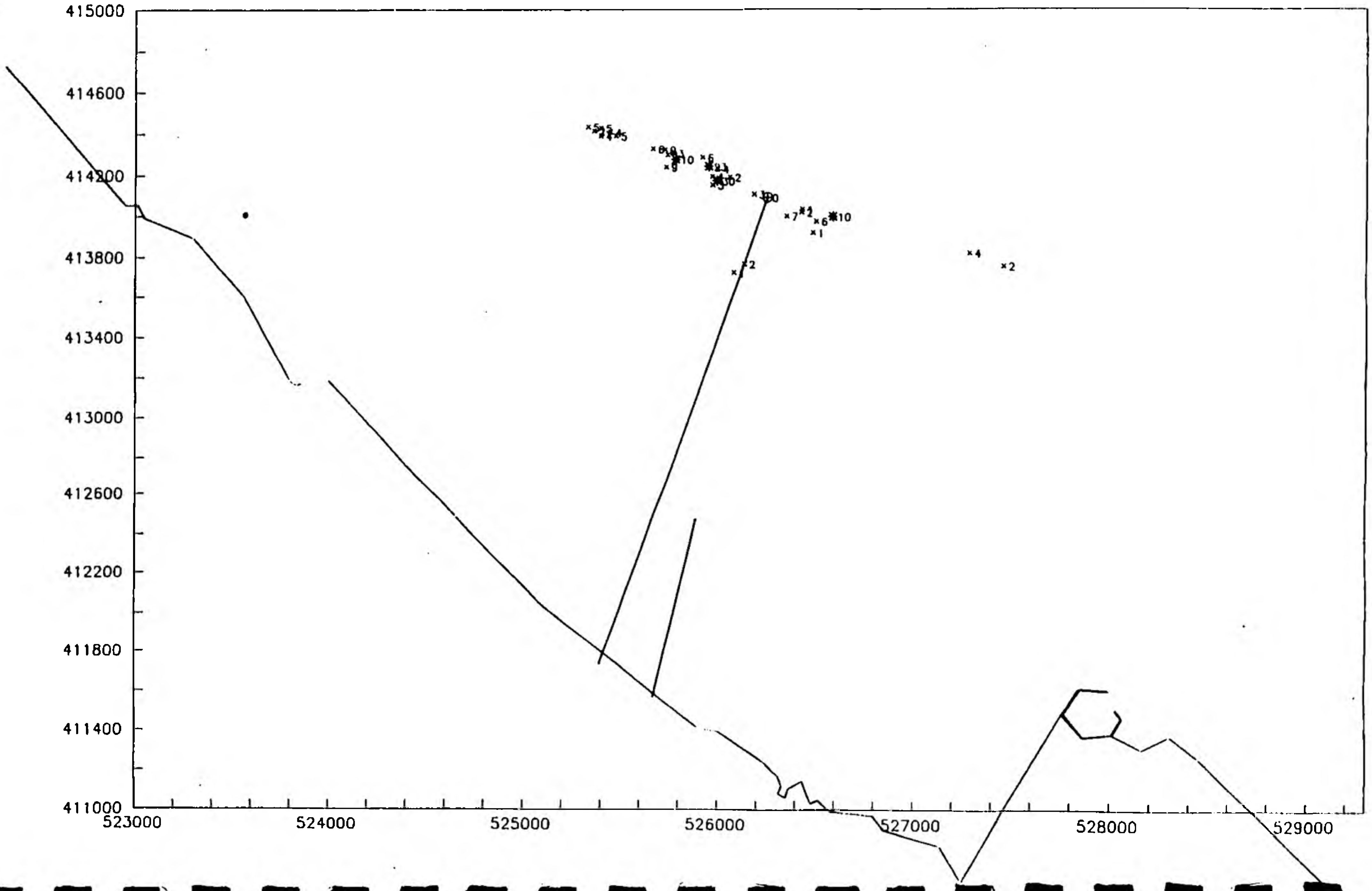


FIGURE 8.7 : Iron in Sediments around the New SCM Outfall.

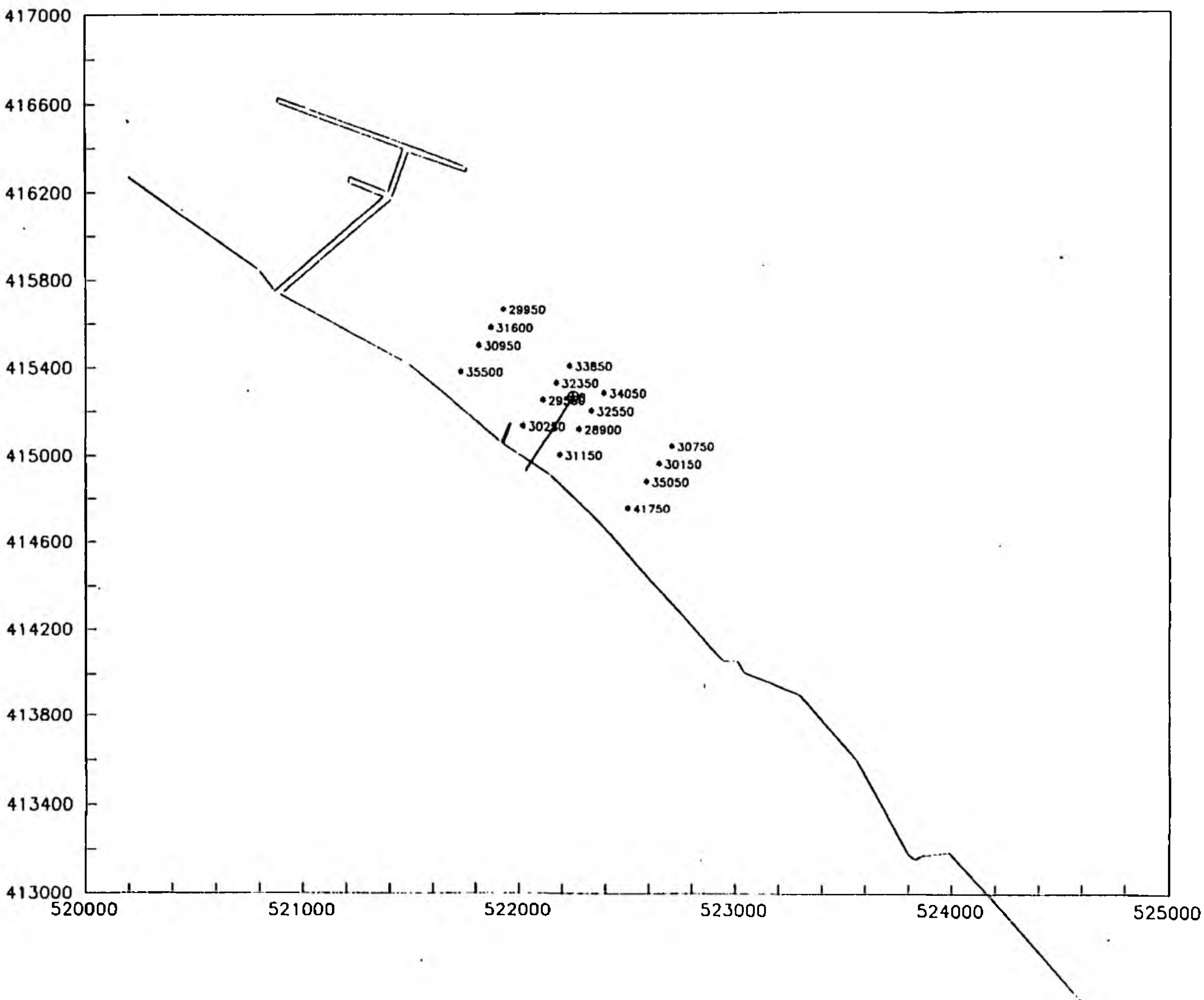


FIGURE 8.8 : Iron in Sediments around the New Tioxide Outfall.

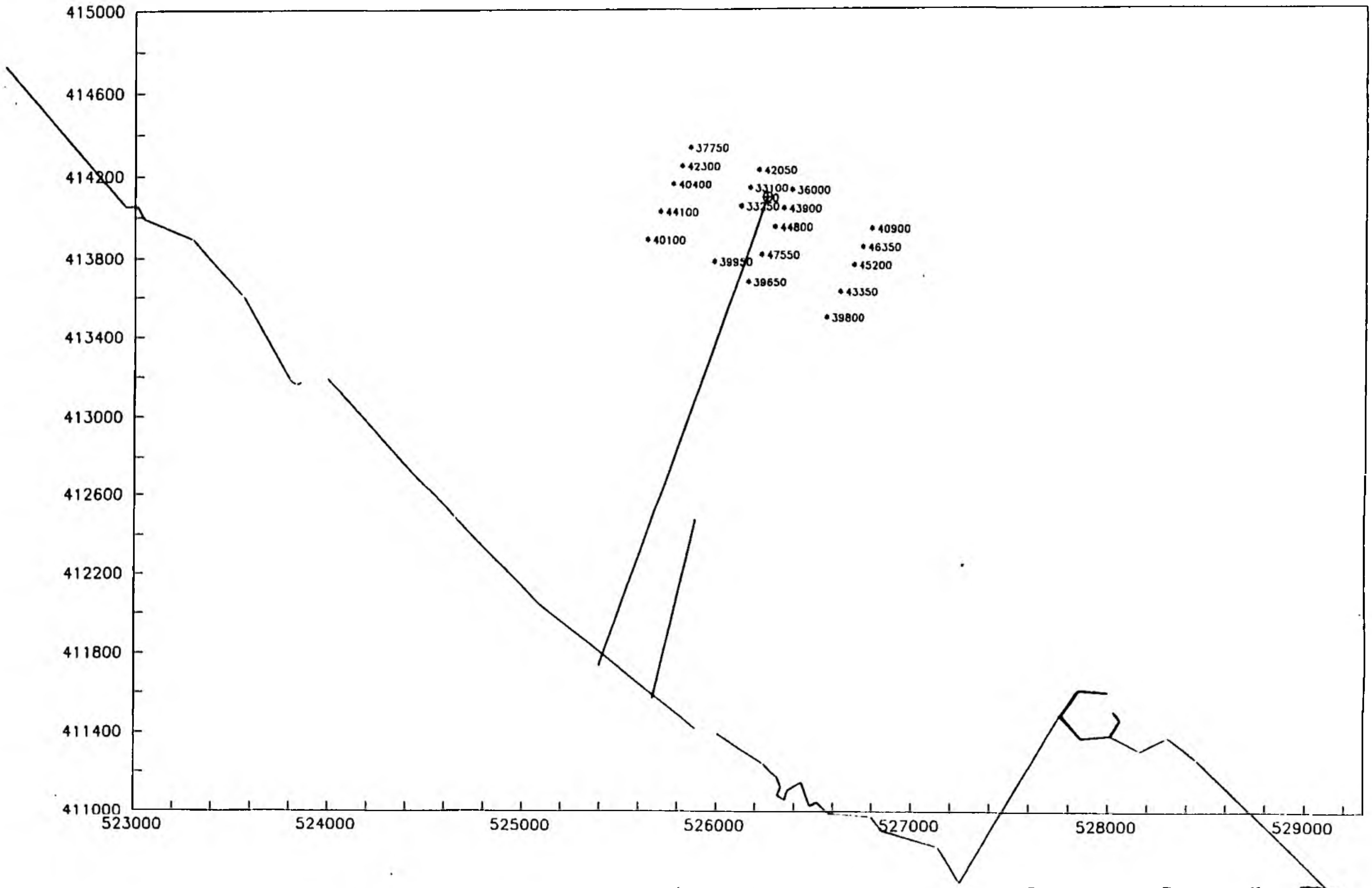


FIGURE 8.9 : Titanium in Sediments around the New SCM Outfall.

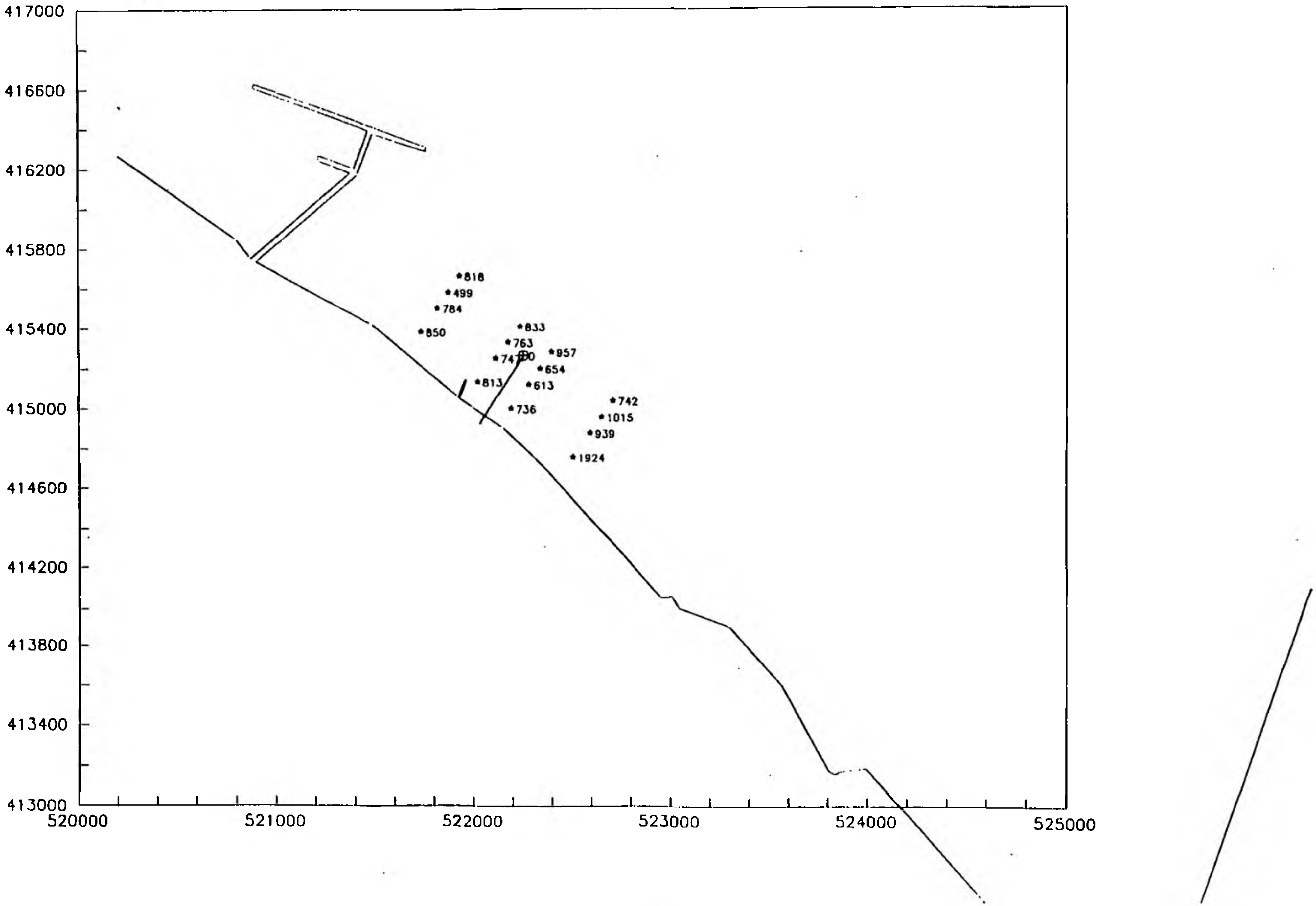
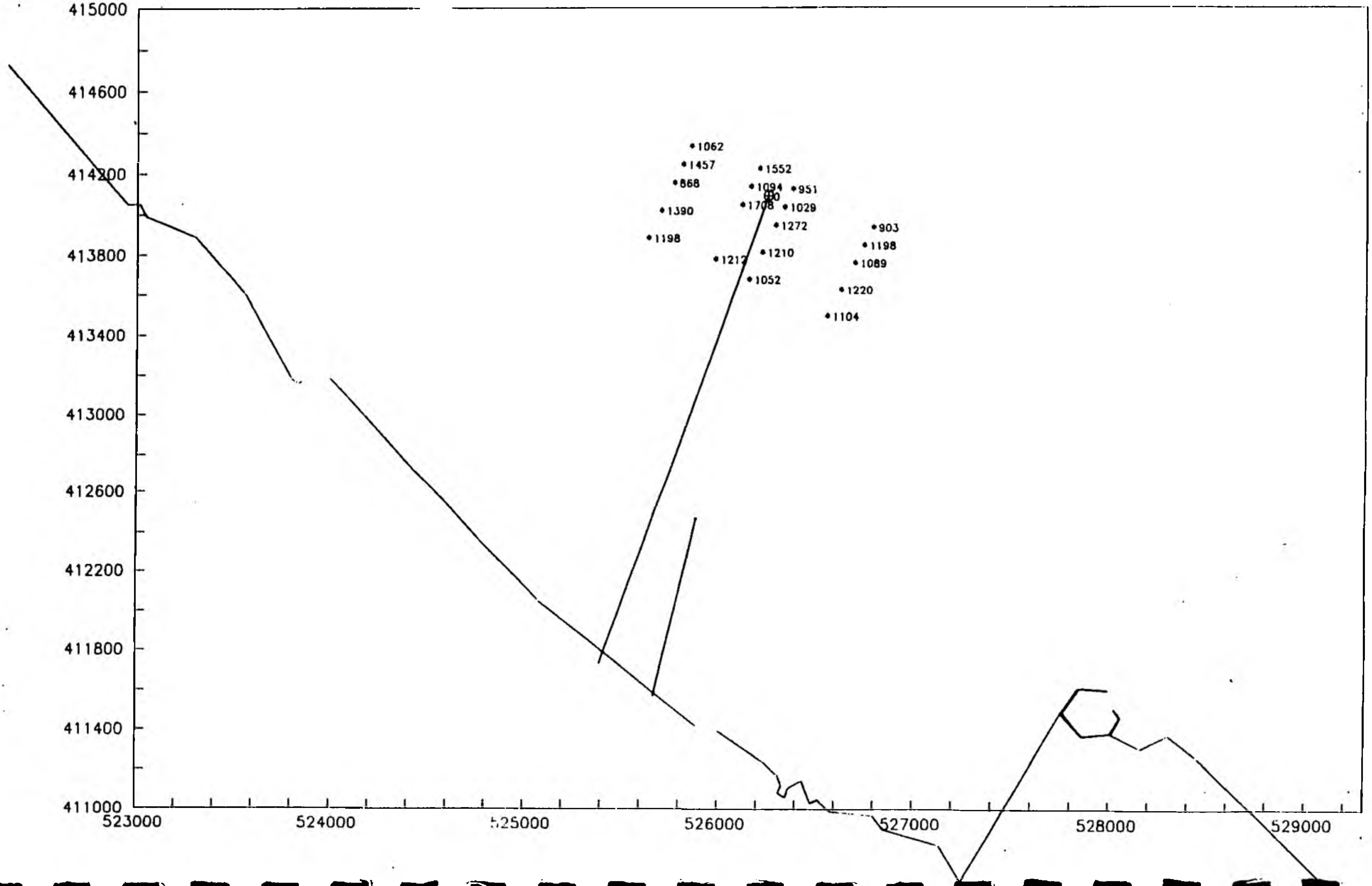


FIGURE 8.10 : Titanium in Sediments around the New Tioxide Outfall.



APPENDIX 9

CHEMICAL MONITORING AND COLLECTION TECHNIQUES.

9.1 Introduction.

This appendix summarises the techniques used for data and sample collection.

The SCM and Tioxide outfalls were monitored separately, although there was obviously the possibility of their plumes overlapping.

There were three purposes to the fieldwork:

- to collect data to allow the effluent plume from each factory to be accurately identified;
- to use some of the collected data to validate the mathematical model;
- to calculate a mixing zone within the Estuary for each factory discharge and to assess compliance with the appropriate EQS's.

Two factors were of greater significance in planning these surveys than they were during the special 1984 surveys:

- neap tides produce the lowest tidal velocities and therefore the slowest (worst) mixing conditions. Consequently, they should provide the best chance of locating the effluent plume. Conversely, it may not be possible to locate the plume during spring tides;
- the outfalls have been relocated further off-shore, into deeper water. This has 3 consequences:
    - there should be improved vertical and horizontal dispersion of the effluent (especially at SCM where diffusers are used) and a consequent reduction in size of the detectable plume;
    - there is the advantage of allowing sampling at all states of the tide;
    - there is the disadvantage that where stratification occurs (most of the time) there is a greater depth of water to be searched in order to detect the plume.

The two companies have not moved their outfalls equally offshore. A new Tioxide pipeline was built to extend a further 1600m offshore, past Burcom Shoal, to the edge of the deep water channel whilst the new SCM pipeline only extends a further 290m offshore, part way to the deep water channel. Since this could lead to different dispersion characteristics around the two outfalls, the sampling strategy might vary between the outfalls. Except for the Anglian Water Pyewipe sewer outfall, these are the two outfalls furthest offshore. No other outfalls were expected to interfere with the results.

It was therefore anticipated that monitoring the water column in 1989 for the acid and iron plumes would be considerably more difficult than during the 1984 special surveys.

In preparation for the major surveys of 1989, preliminary surveys were conducted around each outfall in October 1988. The conclusions included:

- Around the new SCM outfall, the peak dissolved iron concentration was clearly sub-surface (c. 2-5m). Although the plume was sometimes actually visible during the survey, there were likely to be difficulties (in future surveys) finding the plume whilst it was sub-surface in waters up to 11m deep.

- Negligible dissolved iron was measured around the new Tioxide outfall (maximum value 2.52 $mg.l^{-1}$, 90m down-tide). During sampling, it was sometimes possible to see the plume immediately above the outfall but not away from it. This difficulty was reflected in the low results. However, the effluent plume was expected to be better dispersed from this new outfall (into deeper water and stronger currents). Finding and measuring the Tioxide plume in future surveys would require new techniques.

- The special water column surveys of 1989 were going to be more difficult than previous surveys.

9.2 pH Data Collection and Measurement.

This project aimed to produce a continuous record of pH so as to "track" the discharge plumes. By using a line weighted with a heavy (14 kg) streamlined brass "fish", it was possible to suspend pH probes over the side of the boat and draw them through the water at low speed on transects roughly perpendicular to the shore. pH profiles at up to three separate depths for each transect were obtained. Depth was measured with a pressure transducer attached to the lowest probe. However, the weighted fish proved unable to keep the pH probe at the depth required when the vessel was under way, even on neap tides. Also, the hydrostatic pressure on each sub-surface electrode forced seawater through the porous membrane, thus causing gradual degradation of the electrode.

Data from the pH meter was collected using solid state data loggers at two second intervals. (The loggers were Squirrel SQ-12 20KB models from Grant Instruments Ltd). Using 5 channels, 4000 readings per channel were possible, thus providing just over two hours of continuous data. When full, the loggers were downloaded to a portable MS-DOS computer (Compaq SLT/286 with 20MB HD). Proprietary software (from Grant's) was then used to view and plot the pH data (on the computer's LCD screen). It was thus possible to quickly assess the success of the previous sampling run. To provide an instantaneous check on progress through the plume, a portable chart recorder was also attached to one of the probes. As a backup, manual readings of the pH meter were logged at each position fix together with all major events.

Sample position was measured once per minute using the ship's high resolution Micro-Fix system. This gave an immediate position in National Grid Reference co-ordinates (to within one metre) together with the time to the nearest second. Since the update time was of the order of 1 second, readings could be tied in very accurately with position.

The vessel used for these surveys was the 'Humber Surveyor' from Grimsby, on hire from Associated British Ports. It was a 70 foot sea-going ship which was completely self contained and was quite capable of working in the Estuary in winds in excess of Force 5, which, for our work, was a realistic limit. These surveys employed 4 sampling staff plus the hired vessel and its crew, including a surveyor to operate the Micro-Fix system and it was possible to work continuously throughout the day.

9.3 Water Column Sample Collection.

Water column samples were collected along transects at roughly pre-defined distances on each side of the outfall in question. The samples were taken at locations selected whilst sampling each transect, with a view to "straddling" the location of the plume. The objective was to take one surface and one sub-surface sample at five points per transect. An echo sounder was used to ascertain the depth at which to collect the sample. Water depth varied from as little as 2.5m to as much as 16m. Since the plume appeared to be well below the surface, the sub-surface sample was generally taken from between 2 and 4 metres above the estuary bed, resulting in samples being between 2 and 8 metres from the surface (with 8m being the maximum practical limit).

When samples were collected from a fast manoeuvrable craft (semi-rigid inflatable) the position of each sample was accurately fixed by a shore-based survey team. The 10 samples per transect were collected within 10 minutes of one another. At other times, the samples were collected from on board a ship carrying its own high resolution Micro-Fix system (the 'Humber Surveyor'), thus providing instantaneous National Grid Reference co-ordinates.

From each sample collected, 250 ml water were filtered through a 0.45 um cellulose acetate membrane filter (a proportion of which we-definedre pre-weighed). The filtrate was collected in a clean screw topped polypropylene bottle and was later acidified to 0.2% V/V nitric acid in the laboratory. No special storage arrangements were made.

At a proportion of the sampling points, a separate sample was collected for mercury analysis. In each case, 250 ml of water was filtered through a pre-defined-cleaned glass-fibre filter (Whatman GF/F). The filtrate was transferred to a glass-stoppered pyrex bottle and was preserved on receipt by the laboratory.

No separate sample collection was needed for other soluble metals, since analysis could be performed on a sub-sample of the one collected for soluble iron.

All filter papers were retained for the analysis of particulate metals and thus the calculation of the total metal content.

For information, the semi-rigid inflatable was 5m long with a remote steering, centre console. It was fitted with twin 30 hp Evinrude engines with electric start and independent batteries, electrical circuits and fuel lines. It was extremely manoeuvrable and responsive, with a top speed of about 30 knots. It was seaworthy to Force 8 or 9. However, a realistic working level was Force 4. An additional vessel was necessary when using the inflatable, to act as a moored base. This was a sea-going boat, the 'Alkelda', (frequently used in previous surveys). It was an ex-naval pinnace, providing a very stable working platform as well as being easily accessible from the inflatable. Whilst the inflatable collected all samples, the moored vessel was exclusively used to process all the samples and store equipment. This method of working employed 6 sampling staff together with 2 shore-based surveyors plus the vessels' crew. Work could proceed uninterrupted throughout the day and it was possible to collect and process 20 samples in about an hour.

The surveys using the 'Humber Surveyor' only required 4 sampling staff plus the crew (including a surveyor to operate the Micro-Fix system). All sample collection and processing was done on board and it was possible to work continuously throughout the day. Whilst the ship was less manoeuvrable than the inflatable, it could work in winds greater than Force 5 which was our realistic limit, although this necessarily biased the monitoring towards good weather. It was possible to collect and process 20 samples in about an hour.

9.4 Sediment and Biota Sample Collection.

All these samples were collected by the marine biologists during the benthic sampling programme. The sediments requiring metals analysis were bulked sub-samples from the replicated benthic grab samples and were representative of the top 2cm layer. Each sample was collected directly into a 125 ml screw-topped polypropylene jar. The samples were frozen within 24 hours of collection and kept that way until analysis could commence.

No separate surveys were used to collect samples for metals analysis because the labour involved was only a tiny proportion of the total effort required to collect the benthic samples. Further surveys would have incurred considerable extra expense, in both boat hire and staff time.

APPENDIX 10

THE CHEMICAL ANALYTICAL TECHNIQUES.

This appendix summarises the analytical techniques. More complete details of some of the methods can be made available to any interested party.

Although the SCM and Tioxide Outfalls were monitored separately, the resulting data were processed in a similar manner.

10.1 pH Data Processing.

Data for temperature, depth and pH were recorded at 2 second intervals on Squirrel SQ-12 data loggers. Each run contained up to 20,000 data points and represented about two and a half hours worth of recording with 4 channels and about two hours when using 5 channels. Each data run was a single file on 3.5 inch MS-DOS diskettes. The logger automatically recorded the date and time of each data point.

The proprietary software supplied for the data loggers was used to plot out each complete data run (all channels together) for a visual record. These records were used to identify the "peaks" of pH depression measured during the surveys.

The same software was used to convert each data file to Lotus 1-2-3 readable files which were then read into Dbase IV where the files were edited. Finally they were imported directly into an Excel spreadsheet.

Further processing was done on a Honeywell-SP 80386 MS-DOS computer with 4MB RAM using Microsoft Excel which was capable of handling the very large data spreadsheets produced.

Each peak was identified as a 5-minute portion and custom plotted. This allowed the time of each pH peak to be accurately identified along with the times corresponding to the start and end of each such peak (i.e. equivalent to the overall plume width).

It was then possible to insert the necessary Micro-Fix data into the spreadsheet and calculate the position of each peak. The time of each fix was recorded to the nearest second.

Finally, the position and pH details for each peak were extracted and stored in a Dbase IV file for each outfall. Excel was then used to create a special text data file for each outfall which could then be read by the SURFER package for plotting the position data.

10.2 Water Column Samples.

Samples with recognisably high iron content (brown precipitation on storage) were marked as an aid to dilution requirements. The samples were then acidified to 0.2% V/V nitric acid in the laboratory, shaken and left to stand for a few days prior to analysis (to allow the iron to re-solubilize). No special storage arrangements were made.

Analysis for soluble iron was carried out using a specially developed auto-analyser technique which simultaneously determined the chloride content (and hence salinity).

The method of analysis used to determine total dissolved iron (Fe^{2+} and Fe^{3+}) was based on the reaction between ferrous ion and TPTZ (2,4,6-tri-(2'-pyridyl)-1,3,5-triazine) to form a blue-violet coloured complex. The extinction of the complex was measured spectrophotometrically using a matrix photometer at 590 nm. Background correction was measured at 700 nm. The ferric iron was reduced in-situ using hydroxylamine hydrochloride prior to the addition of the TPTZ. The range of application was 0 to 0.8 $mg.l^{-1}$ Fe but the analytical range was extended by making dilutions for samples exceeding 0.8 $mg.l^{-1}$ Fe. The laboratory limit of detection for this technique was 0.007 $mg.l^{-1}$ Fe.

Two iron quality control standards were used. A 0.72 $mg.l^{-1}$ standard gave a mean result of 0.72225 $mg.l^{-1}$ with a mean RSD of 1.02%. A 0.08 $mg.l^{-1}$ standard gave a mean result of 0.07903 $mg.l^{-1}$ with a mean RSD of 2.67%. The mean spiked recovery was 102.5% with an RSD of 1.56% and the mean field blank value was 0.00067 $mg.l^{-1}$, giving a limit of detection of 0.0099 $mg.l^{-1}$ Fe.

The chloride determination method was based on the ability of the chloride ion to quantitatively release thiocyanate ions from mercuric thiocyanate. After reaction of thiocyanate with ferric ions, the extinction of the ferrithiocyanate was measured at 470 nm. Because of the sensitivity of the method, on-line dilution was used to give a range of application of 0 to 20,000 $mg.l^{-1}$ Cl.

A small proportion (about 8%) of these samples were analysed for Cd, Cr, Cu, Mn, Ni, Pb and Zn using an ICP-MS system. Since high chloride levels cause suppression of the analytical signal, the samples were grouped according to their chloride content. The chloride content of the blank and standard solutions were matched with that of the sample. No performance or recovery data are currently available for this technique. However, the previously used technique of solvent micro-extraction with APDC and trichloroethane has shown good performance and recovery. Further development is required for these analyses.

The samples specially collected for dissolved mercury were analysed by an atomic absorption/cold vapour technique using stannous chloride as the reductant. Preservation and subsequent digestion of samples was carried out using 1% nitric acid and potassium persulphate.

Particulate samples (material collected on filter papers) were analysed as for sediments.

10.3 Sediment and Biota Samples.

The analysis of these samples was contracted out to a laboratory using techniques routinely used in that laboratory. The determination of Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Hg and % volatile matter have been NAMAS accredited. Only Ti and V have yet to be tested in inter-laboratory exercises.

Sediment samples were wet sieved to produce a < 90um fraction. Appropriate quantities of sample (< 1g for sediments, ca. 3g for biota) were digested with nitric acid and hydrogen peroxide and finally made up in 10% hydrochloric acid. All metals except Hg were analysed by flame AAS with nitrous oxide being used for titanium, vanadium and chromium. Mercury was analysed as for the water column samples. Results were calculated as $mg.kg^{-1}$ dry weight for the sediment and biota and additionally as $mg.kg^{-1}$ wet weight for the biota, in order to facilitate comparison with other data.

Whilst the total sediment fraction should reflect the presence of all types of deposit (e.g. crusts, sand, waste ore etc.) results from the large number of samples analysed in 1984 showed that only 1 or 2 samples gave distinctly different results by this technique when compared to the < 90um fraction results. Consequently only the latter was prepared for analysis since this is widely used and the one which has been historically analysed on the Humber samples.

APPENDIX 11

METALS IN BIOTA.

11.1 Introduction.

The sessile seaweed Fucus vesiculosus and the relatively sedentary polychaete Nereis diversicolor are both collected as part of a routine programme to monitor heavy metals throughout the Humber. A small number of sampling points within this programme relate to the region of the estuary considered in this investigation, and results for these sites are reported below. Both of the species utilised are confined to the upper intertidal zone and may therefore be expected to reflect reductions in metal load resulting from the closure of the old outfalls. It must, however, be recognised that other significant discharges of heavy metals are present in the nearshore zone within this region.

Juvenile flatfish and brown shrimp are also collected as part of the routine Humber Estuary monitoring programme. However, these organisms are very much more mobile than the species referred to above and are only utilised on the basis that their migration routes and life histories will confine them to a broad sector of the estuary for an extended but uncertain period. Results for this latter group of organisms can therefore only be used to make general statements about levels of heavy metals in the estuary, and cannot be related to point source discharges. The proviso stated above, concerning other discharges, is of even greater significance in the context of these mobile organisms. It is also recognised that both flat-fish and shrimps are by no means ideal 'sentinel' organisms for monitoring heavy metals (see Bryan et al, 1985), but in the absence of any more suitable sub-tidal species the results are presented here as the only available general indication of biologically assessed heavy metal contamination in the sub-tidal habitat.

11.2 Metals in Fucus Vesiculosus.

The nearest Fucus collection points in the routine monitoring programme are at the eastern edge of the sampling grid for the old Tioxide outfall (Grimsby Docks) and at S.Killingholme, approximately 3 km west of the SCM discharge. (The species was previously absent from the area between these locations). Both sites, but especially the former, have persistently yielded very high levels of iron in the Fucus tissue, which has been ascribed to the inputs from the titanium dioxide factories (Barnett et al, 1989; Barnett & Ashcroft, 1985). This can be seen by reference to the example of the August 1984 survey as shown in Fig. 11.2.1.A where sites 8 and 9 are S. Killingholme and Grimsby respectively. Summer 1984 is chosen as an example since most of the work reported here is compared with conditions assessed at that time. Overall values for 1984 are lower than in most other years, but the distribution pattern is representative of the situation prior to the closure of the old outfalls, as explained in the papers previously referred to. The pattern for iron levels in Fucus subsequent to the closure of the old TiO_2 outfalls is shown in Fig. 11.2.1.B, which depicts the results of the August 1989 survey. For the purposes of direct comparison this is plotted on the same scale as Fig. 11.2.1.A. Whilst a small peak in Fe concentrations is still apparent at sites 8 and 9, it is scarcely discernible in comparison to the very distinct peak observed in surveys conducted before the closure of the old outfalls. (No material was available at site 10 in 1984.)

The reduction in iron levels at the two contaminated sites is clearly shown by inspection of the historical time series data for each site. Sampling is undertaken in February and August of each year, but for simplicity the results are presented here as annual averages, since there are indications that seasonal factors associated with the growth cycle of the seaweed may obscure long-term trends (Barnett et al, 1989). Concentrations of iron in Fucus from 1982 to 1989 are shown for each of the two sites in Figures 11.2.2.A and 11.2.2.B. These clearly demonstrate a pronounced reduction in iron levels following the closure of the old outfalls, and at the Grimsby site this change is most remarkable.

Dissolved iron may be considered as the natural 'label' for TiO_2 effluents and the above observations therefore constitute strong evidence for a large reduction in metal contamination from these discharges, at least in the intertidal zone. Only two other explanations for these findings are possible. Firstly, it is possible, although unlikely, that Fucus at the two monitoring sites did not accumulate metals effectively in 1989. However, inspection of the long-term trends for zinc, which is discharged in substantial quantities from another industrial outfall in the survey area, effectively refute this idea. As can be seen from Figures 11.2.3.A and 11.2.3.B zinc levels were higher in 1989 than in a number of previous years, which would be most unlikely if the algae were not accumulating metals efficiently. Since the same observation also applies to copper levels (Figures 11.2.4.A and B) the possibility of some failure in the normal uptake mechanism can be discounted. It is interesting to speculate on the hypothesis that the increases in concentrations of metals other than iron are a result of reduced competition between metal ions for binding sites in the plant tissues, as a consequence of the huge reduction in available iron, rather than increased environmental concentrations. However, such considerations are beyond the scope of this report.

The second possible alternative explanation for the findings discussed above is a general reduction in the "background" levels of iron throughout the estuary. The changes in the distribution pattern for iron revealed from Fig. 11.2.1 contradicts such an explanation, and examination of the long-term trends at a site remote from the discharges (site 4: New Holland) suggests that 'background' levels in 1989 were entirely comparable with previous years (Fig. 11.2.5). (This site was chosen as it is the only other site where substantially elevated levels of iron have previously been recorded).

These observations also preclude the likelihood of inconsistencies in sampling procedure, or inadequacies of chemical digestion as explanations for the lower iron values found in 1989. It may therefore be concluded with some certainty that levels of iron at the two most appropriate monitoring points have been substantially reduced by the closure of the old TiO_2 outfalls. By inference, the levels of other heavy metals discharged through these outfalls has also been reduced, although this is clearly masked by much larger inputs of these metals from other sources.

The magnitude of the reduction of iron concentrations in Fucus can be seen from the data reported to the Humber Estuary Joint Monitoring Group. This is presented as the "whole Estuary" average concentration (i.e. the average of all ten monitoring points shown in Fig. 11.2.1.B) for each survey. These summary results are plotted in Fig. 11.2.6, which clearly shows that in the two surveys conducted subsequent to the closure of the old TiO_2 outfalls iron levels were appreciably lower than in any preceding surveys. Thus the reduction in iron concentrations may be judged to be significant in the context of the estuary as a whole.

Unfortunately, brown seaweeds do not occur sub-tidally, and it is therefore not possible to use the same approach to determine the present fate of metals from the new outfalls.

11.3 Metals in Nereis Diversicolor.

Ragworms are collected from seven sites along the estuary, three of which relate to the TiO_2 survey area. Two of these sites (at Grimsby and South Killingholme) are virtually coincident with the two Fucus sampling points referred to above, whilst the third is approximately mid-way between the two TiO_2 discharges ("Doverstrand"). Unfortunately, unlike the seaweed monitoring programme, Nereis collections on the south bank of the estuary only commenced in August 1988, although a more comprehensive long-term data base exists for sites on the North shore. The results of metal analyses for 1988 and 1989 at the three relevant sites on the southern shore are presented in Table 11.3.I, and the distribution of iron along the estuary as indicated by concentrations in Nereis is illustrated in Fig. 11.3.1. It can be seen from these distribution plots that the peak value in each survey occurred at the point between the two TiO_2 discharges, and that generally higher levels were found in the TiO_2 survey area (sites 5, 6, and 7), than further up the estuary. (Ragworms are absent from the sandy beaches seawards of

Grimsby.) This pattern was largely predictable for the 1988 survey, but the persistence of peak concentrations in the lower estuary following closure of the old outfalls is at first sight contradictory to the evidence presented in Section 11.2.). However, unlike Fucus which absorbs metals from solution in the overlying water, Nereis is believed to accumulate metals principally from the sediment in which it lives and feeds. Since the deposition of iron in sediments over many years is still evident at some sites (see Appendix 6) and given the likely residence time for iron in the intertidal muds, it is quite plausible to suggest that the persistence of the pattern reflects historical sources of iron rather than the present nature of inputs. The working of old, contaminated sediments by these relatively deep burrowing worms is by no means unlikely, and diagenesis of metals following cessation of the discharges may conceivably result in enhanced availability. It is however, also possible that sediment transport mechanisms and the tendency for fine material to be deposited on mud-flats may still result in the build-up of metals in this compartment of the estuarine environment.

Perhaps more surprising in its implications is the evidence that levels of iron in the survey area were higher in 1989 than in 1988. There is no obvious explanation for such a finding, but it is perhaps significant that an increase was recorded at six of the seven sampling points. Furthermore, with the exception of Nickel , an increase in concentrations of all metals was apparent at the majority of sites as illustrated in the last column of Table 11.3.I. This suggests some kind of general biological environmental or analytical difference, rather than a genuine trend. It is however interesting to note that for those metals which displayed a reasonable balance of increases and decreases between the two years (cadmium and nickel) a decline in concentrations was recorded in five out of six results obtained within the TiO_2 survey area. Nickel decreased in concentration at all three TiO_2 related sampling points, whilst Cadmium concentrations were lower in 1989 at two of the three locations . In each case, only one other site (a different one for each metal) produced a lower value in 1989 suggesting that decreases in concentrations of nickel and cadmium may in some way be related to the TiO_2 discharge area. However, the natural fluctuations and ambient levels of these metals are not known. The apparently universal increase in mercury levels may relate to analytical procedures as considered in Section 11.4.

Data for iron levels at two sites on the north bank of the estuary are presented in Table 11.3.II. Results for 1989 are not yet available, so that direct comparison with some of the above observations on the south bank data can not be made. These figures do however serve to demonstrate that relatively high iron concentrations have been recorded at sites remote from the TiO_2 discharges, and that year on year increases in concentrations of the order of 45% (Stone Creek 1986-87) can occur for no obvious reason.

Some doubt remains therefore over the correct interpretation of the results from analyses of ragworm samples, and further data is evidently required to assess whether or not conditions are worse following the relocation of the TiO_2 discharges as partly suggested by the iron results, or better - as indicated by the levels of nickel and cadmium.

11.4 Metals in Flat-Fish.

The results of metals analyses conducted on individual specimens of Dover sole (Solea solea) and flounder (Platicthys flessus) captured within the survey area are shown in Table 11.4.IA and 11.4.IB together with the mean values and standard deviations. Mean values from the above are compared with those from the 1984 investigation in Table 11.4.II. It may be noted in passing that fewer fish were captured in 1989. However, quantitative collection techniques are not employed, and this observation may simply relate to the deployment of different gear (from a different vessel) in 1989. Even if the observation could be construed as genuine, it is probably related to the unusually dry summer of 1989, or some other variable associated with the natural environment. Whatever the reason for this finding, if indeed it can be said to be 'real', it is unlikely in the extreme that it is in any way associated with the discharges under consideration here. The collection area was initially designated because of the availability of suitable species in this part of the estuary, and proximity to the old outfalls. The area is geographically and, in particular, hydrographically, comparatively remote from the new outfalls. Any decline in fish populations would therefore be associated with the termination of the original discharges: an association which appears intuitively and scientifically unlikely on any logical basis.

Only those metals for which quantifiable results were obtained have been included in Table 11.4.II, since no meaningful comparisons can be made on the basis of "less than" results. A small number of cadmium results for both species in the 1984 survey were above the limit of detection, but it would be unwise to ascribe any significance to the absence of such results in 1989. Concentrations of copper in both species are almost identical with those recorded in 1984. Mean levels of iron in flounder were somewhat lower in 1989 than in 1984, but the 1984 data comprised a wide spread of values, such that the standard deviations around the two means do overlap. (Mean value for 1989 is actually slightly below the minimum value reported for 1984.) The same observation can be made for the 1989 results for sole if comparison is made with data for the smaller specimens collected in 1984, although the reverse is true if the comparison is made with the results for the larger fish collected in 1984. Very little is known about the accumulation of iron by flat-fish, and it is therefore difficult to draw firm conclusions, although it may be tentatively noted that a reduction in available iron would be consistent with the findings from the Fucus work as discussed in Section 11.2. The results for zinc are somewhat contradictory. Concentrations in Dover sole in 1989 are similar to those reported for 1984, regardless of size, whilst the levels in flounder tissue for 1989 are clearly lower than in 1984. Since flounder is regarded as a reasonable 'indicator' of zinc contamination (Bryan et al, 1985) the data could be considered to demonstrate a reduction in available zinc. However, such a finding can realistically not be related to the termination of the 'old' discharges, since these were essentially insignificant as inputs of zinc in the survey area, and furthermore, this interpretation is opposite to the indications from the Fucus data (Section 11.2). Mercury is the only metal which appears to be present in higher levels in both species of fish in 1989, although the differences in mean concentrations do not exceed the ranges indicated by the standard deviations. The 1989 levels may in fact be genuinely higher than those recorded in 1984, but the most likely explanation is in terms of analytical factors rather than a change in environmental levels. The report on the work carried out in 1984 specifically recognised the existence of a potential problem with regard to the analyses of mercury in biota (Section 2.8.6, 1984), and probably underestimates the mercury concentrations in fish tissue. The data presented here are derived from analyses conducted by a different laboratory, using different equipment, and it is therefore suggested that the earlier conjecture is now substantiated. It should also be noted that there is no evident mechanism by which the relocation of the outfalls could result in an increase in the levels of available mercury (assuming no change in effluent total load) although a change in ore could account for such a change.

In an attempt to clarify the situation, data for flounder from the three years preceding the present survey has been examined, and these results are compared with those presented in Table 11.4.II in Table 11.4.III. It is apparent that no appreciable changes in metal levels have taken place over the period 1986-89. Data for mercury is somewhat variable, but mean concentrations recorded subsequent to the 1984 survey endorse the comments made above with respect to this metal. The average values derived from the data for the three years preceding closure of the old outfalls is compared with the mean data for 1989 in Table 11.4.IV. It would not be appropriate to present average standard deviations, but given the magnitude of the standard deviations for individual years, it may be concluded that there is no difference in metal concentrations in Flounder following closure of the old discharges. A similar examination of the data for Sole could not be justified in view of the low number of specimens for 1989.

11.5 Metals in Brown Shrimp.

The concentrations of heavy metals in brown shrimp (Crangon crangon) collected in the survey area in the summer of 1989 are presented in Table 11.5.I. The mean values and standard deviations for each metal where quantifiable results were obtained are compared with the same data for the 1984 survey in Table 11.5.II. Levels of cadmium, copper, nickel and zinc in 1989 are essentially similar to those for 1984. (Copper, of course, is regulated since it is the metalloid constituent of the respiratory pigment.) The zinc result is interesting (although the difference in concentrations is well within the range indicated by the standard deviations) because it shows an increase rather than a decrease, in contrast to the flat-fish data. The results for iron suggests that lower concentrations were present in 1989, but the large standard deviations (especially for the 1984 data) undermine the confidence in this comparison. Re-examination of the 1984 results reveals that the apparent variability was caused by a single value which was one order of magnitude lower than the other five, and this was the smallest sample used. The highest concentration in the 1989 data set (634 mg/kg) was in fact less than the mean value for 1984 (675 mg/kg) and it is therefore not entirely unreasonable to infer that lower levels of iron were present in Crangon in 1989 than in the 1984 survey.

However, as in the case of the Flounder results, when the comparison is extended to include data for other years a different pattern emerges. Results for iron in shrimps collected from the same area at the same time of year for the period 1985-1988 are shown in Table 11.5.III, together with the data from Table 11.5.II. It is immediately apparent that the 1989 values are no lower than those recorded in 1985 or 1986, although they must be considered as substantially lower than results for material collected shortly before the closure of the old outfalls. Data for individual batches indicates appreciable variability, as discussed above, although combined results for each year seem to fall in to higher or lower concentration categories. This may indicate that the levels observed are related to the duration and intensity of contact with the effluent, as well as the proportion of shrimps in any given batch which have been exposed. Evidently, these factors vary from year to year, although it may be assumed that the higher levels are in some way related to the inputs of iron. If this supposition is correct, the repeated recording of lower values for some years following closure of the old outfalls will be required to demonstrate any reduction.

11.6 Summary and Conclusions.

Iron concentration in Fucus have fallen dramatically since the closure of the old outfalls, indicating a very large improvement in terms of reduced levels of dissolved iron at least for inshore areas. However, results for Nereis suggest elevated levels of residual iron in sediments.

Results from flat-fish and shrimp are included although they are recognised as being limited in their suitability as sentinel-organisms and no clear conclusions can be drawn from the data.

11.7 References.

Barnett, B.E. and Ashcroft, C.R. (1985). Heavy metals in Fucus vesiculosus in the Humber Estuary. Environ. Pollut, B, 9, pp.193-213.

Barnett, B.E., Forbes, S.K. and Ashcroft, C.R. (1989). Heavy metals on the South bank of the Humber Estuary. Mar. Pollut. Bull. 20, No.1, pp.17-21.

Bryan, G.W., Langston, W.J., Hummerstone, L.G. and Burt, G.R. (1985). A guide to the assessment of heavy metal contamination in estuaries using biological indicators. Mar. Biol. Assoc. U.K. Occasional Publications, No. 4.

TABLE 11.3.I

Heavy Metals in Nereis: Humber Estuary (South Bank) August 1988 and 1989

Sites in TiO_2 Survey Area

Site	South Killingholme		Doverstrand		Grimsby (N. Wall)	
	*1988	1989	*1988	*1989	*1988	*1989
No.	275		247		170	
Wt. (mg)	28020		27490		51140	
Mean Wt.	101.9		110.1		300.5	
Cu	70.5	68	51	98	36	50
Zn	213.5	268	167.5	162	210	223
Cd	0.45	0.6	0.3	0.5	0.3	0.5
Hg	0.157	0.33	0.023	0.1	0.006	0.09
Pb	1.65	2	1.25	2	0.7	2
Cr	0.6	2	0.65	2	0.4	2
Mn	11.7	12	9.5	14	9.6	13
Fe	277	340	409	560	263	331
Ni	7.15	5	5.35	4.8	5.85	4.95

Figures expressed as mg/Kg * Average values from 2 replicates

TABLE 11.3.II

Levels of Iron in N. Diversicolor from North Bank 1982 - 1988

Site	1982	1983	1984	1985	1986	1987	1988
Hessle	371	375	349	428	261	359	338
Stone Creek	281	318	415	324	305	447	325

TABLE 11.4.IA <u>RESULTS OF METALS ANALYSIS FOR FLOUNDER</u> (P. flessus)

SAMPLE	LENGTH (mm)	%DS	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg	V	Ti
1	280	20.0	0.5	2	1.9	19	2	2	2	35	0.09	10	50
2	275	22.9	0.5	2	2.2	22	2	2	2	52	0.07	10	50
3	290	23.7	0.5	2	1.7	21	2	2	2	35	0.13	10	50
4	255	19.0	0.5	2	1.8	22	2	2	2	35	0.37	10	50
5	230	22.6	0.5	2	1.7	21	2	2	2	44	0.06	10	50
6	230	22.4	0.5	2	1.3	13	2	2	2	45	0.32	10	50
7	240	22.1	0.5	2	2.3	14	2	2	2	35	0.12	10	50
8	235	21.0	0.5	2	1.9	18	2	2	2	35	0.05	10	50
9	230	21.1	0.5	2	1.9	11	2	2	2	33	0.10	10	50
Mean	252	-	0.5	2	1.86	17.9	2	2	2	38.8	0.15	10	50
± S.D					± 0.29	± 4.2				± 6.6	± 0.12	10	.50

TABLE 11.4.IB <u>RESULTS OF METALS ANALYSIS FOR DOVER SOLE (Solea solea)</u>

SAMPLE	LENGTH (mm)	%DS	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg	V	Ti
1	137*	23.2	0.5	2	2.7	28	2	2	2	26	0.14	10	50
2	160	21.0	0.5	2	2.5	24	2	2	2	26	0.25	10	50
3	180	22.5	0.5	2	2.0	16	2	2	2	20	0.25	10	50
Mean	[159]		0.5	2	2.4	22.7	2	2	2	24.0	0.21		
± S.D.					± 0.36	± 6.1				± 3.5	± 0.06		

*Mean length of 5 bulked fish

TABLE 11.4.II

Comparison of Results from Analyses of Flatfish Tissue: 1984-1989

Species	Year	Cu	Fe	Zn	Hg	N	MEAN SIZE
Flounder	1989	1.86 +/- 0.29	17.9 +/- 4.2	38.8 +/- 6.6	0.15 +/- 0.12	9	252
	1984	1.96 +/- 0.64	94 +/- 78	80.4 +/- 21.4	0.06 +/- 0.03	18	141
D Sole	1989	2.40 +/- 0.36	22.7 +/- 6.1	24.0 +/- 3.5	0.21 +/- 0.06	3	[159]
(Lge)	1984	1.01 +/- 0.31	15 +/- 14	30.4 +/- 4.5	0.07 +/- 0.05	15	245
(Sm)	1984	3.04 +/- 1.11	128 +/- 107	32.5 +/- 3.9	0.03 +/- 0.01	16	123

Results expressed as mg/kg (dry wt.)

Mean +/- Standard deviation

TABLE 11.4.III SUMMARY METALS RESULTS FOR FLOUNDER 1984 - 1989 (but excluding 1985)

Year	Mean ± S.D. Size	No.	Fe	Zn	Hg	Cu
1984	141 ± 28	18	94 ± 78	80.4 ± 21.4	0. 06 ± 0.03	1.96 ± 0.64
1986	196 ± 36	12	10.6 ± 3.3	41.4 ± 6.9	0.168 ± 0.064	1.74 ± 0.29
1987	212 ± 36	37	13.1 ± 5.0	40.0 ± 11.3	0. 09 ± 0.056	1.52 ± 0.04*
1988	235 ± 34	36	18.9 ± 35.6	42.5 ± 13.2	0.142 ± 0.224	1.33 ± 0.21
1989	252 ± 24	9	17.9 ± 4.2	38.8 ± 6.6	0.15 ± 0.12	1.86 ± 0.29

Results expressed as mg/kg (dry weight)

TABLE 11.4.IV AVERAGE RESULTS FOR THE THREE YEARS PRECEDING CLOSURE OF THE OLD OUTFALLS COMPARED WITH THE 1989 VALUES

	No.	Fe	Zn	Hg	Cu
Average 1986-1988	(28.3)	14.2	41.3	0.134	1.53
1989	9	17.9	38.8	0.15	1.86

(Results expressed as mg/kg (dry weight)

TABLE 11.5.I RESULTS OF HEAVY METALS ANALYSIS FOR BROWN SHRIMP (*Crangon crangon*)

BATCH NO	WET WEIGHT	%DS	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg	V	Ti
1		26.4	2.6	2	85	426	36	2.3	2	114	0.19	10	50
2		26.8	2.2	2	62	397	36	2.3	2	103	0.10	10	50
3		26.4	1.9	2	61	634	36	2.4	2	96	0.15	10	50
4		26.9	1.0	2	56	446	36	2.2	2	97	0.10	10	50

All results expressed as mg/kg (dry weight)

TABLE 11.5.II

Comparison of Results from Analyses of Brown Shrimp (1984 & 1989)

Year	No. of Batches	Cd	Cu	Fe	Ni	Zn	Hg	MEAN WET BATCH Wt.
1989	4	1.93 +/- 0.68	66 +/- 13	476 +/- 107	2.30 +/- 0.08	103 +/- 8.3	0.14 +/- 0.04	54.8
1984	6	2.77 +/- 2.45	97 +/- 15	675 +/- 303	1.63 +/- 0.30	94.5 +/- 11.1	0.09 +/- 0.06	(16.7)

All Results mg/kg (dry wt.)

TABLE 11.5.III

Levels of Iron in Crangon for July of each Year 1984-89

Year	No. of Batches	Mean Batch Wt.	Results for Each Batch	Mean Value +/- S.D.
1984	6	[16.7]	746; 770; 727; 862; 69; 878	675 +/- 303
1985	2	38.5	388; 531	460 +/- 101
1986	2	128.2	359.4; 443.7	402 +/- 60
1987	0	--	- No Data -	--
1988	3	92.1	1063; 1116; 582	920 +/- 294
1989	4	54.8	426; 397; 634; 446	476 +/- 107

(Results in mg/kg Dry Weight)

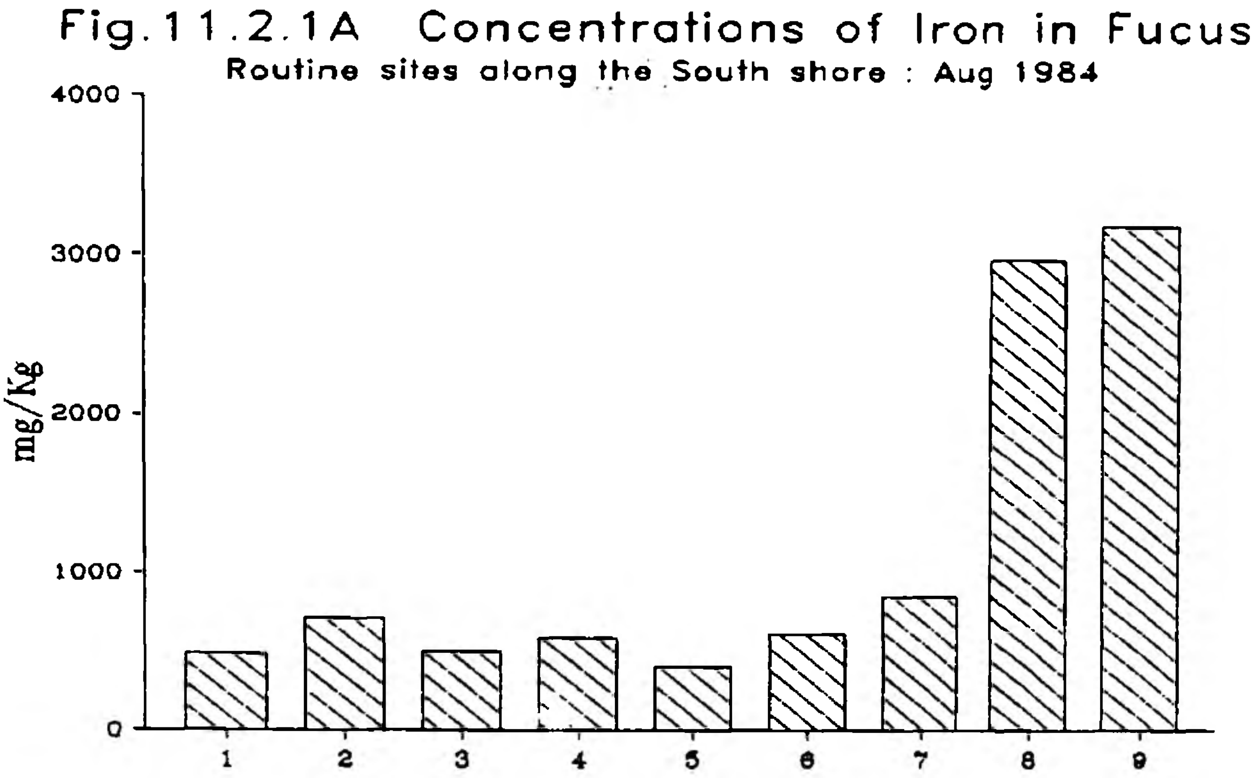


Fig.11.2.1A Concentrations of Iron in Fucus
Routine sites along the South shore : Aug 1984
mg/Kg
4000
3000
2000
1000
0
1
2
3
4
5
6
7
8
9

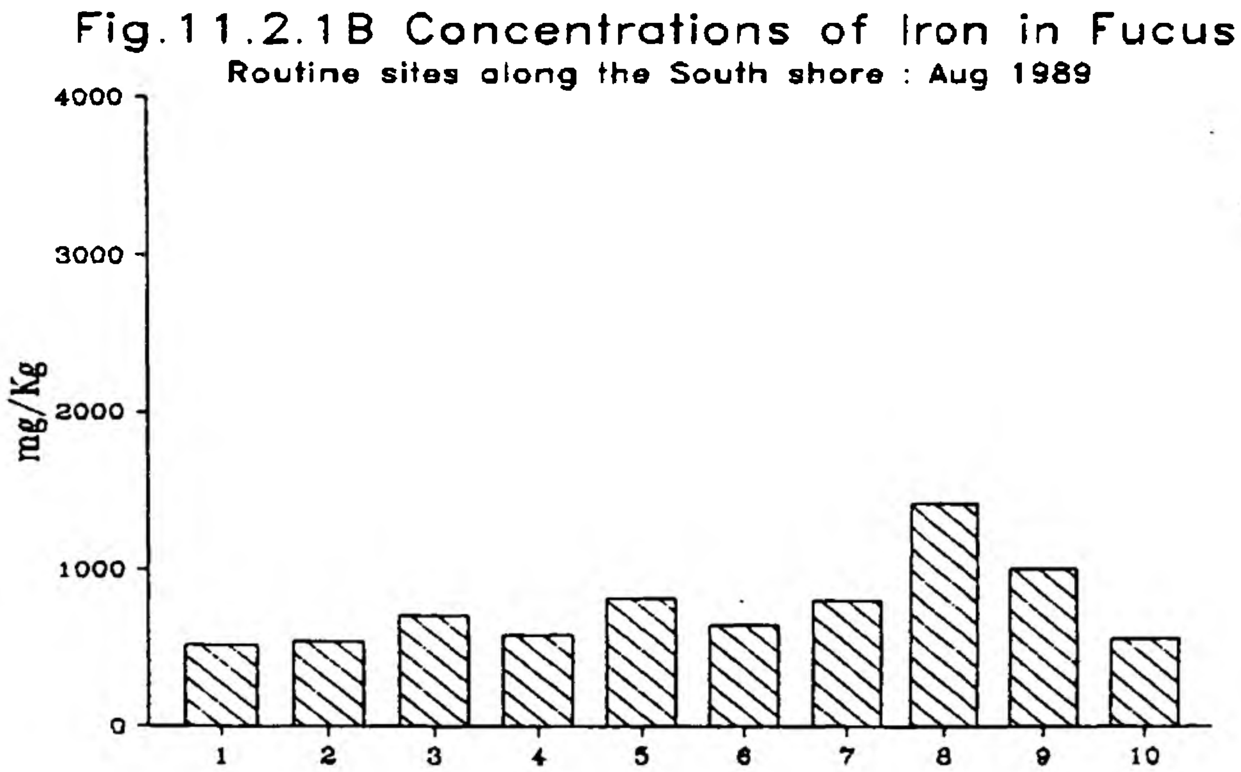


Fig.11.2.1B Concentrations of Iron in Fucus
Routine sites along the South shore : Aug 1989
mg/Kg
4000
3000
2000
1000
0
1
2
3
4
5
6
7
8
9
10

Fig.11.2.2A Concentrations of Iron in Fucus
South Killingholme 1982–1989

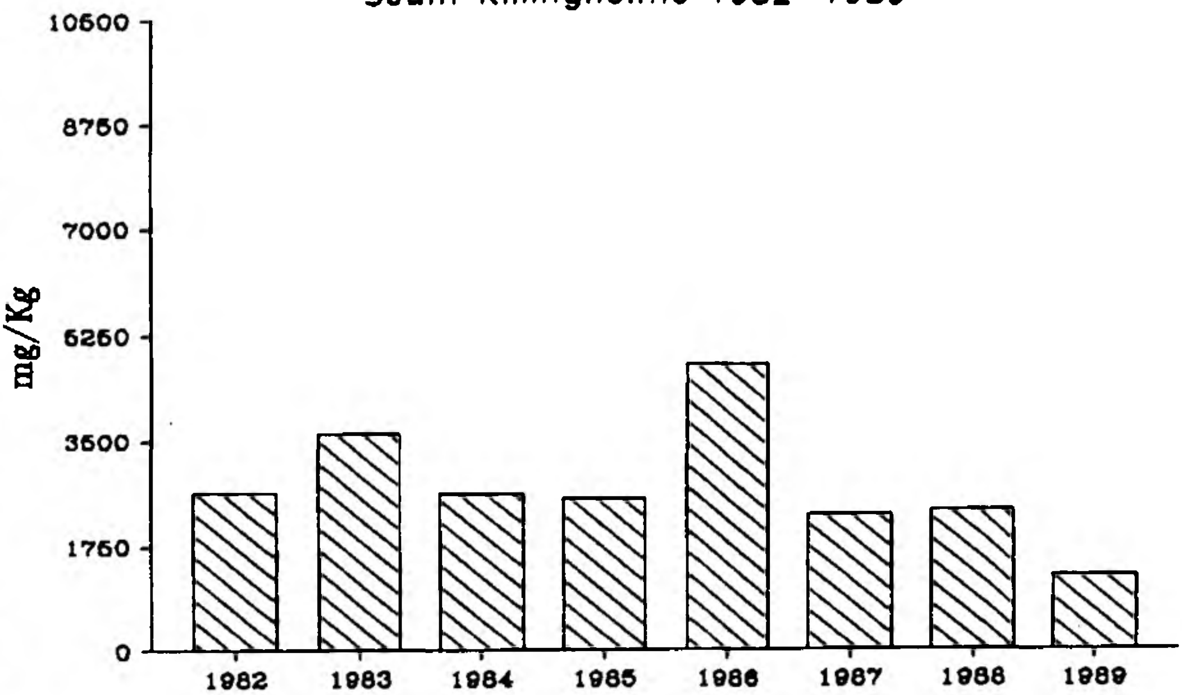


Fig.11.2.2B Concentrations of Iron in Fucus
Grimsby Docks 1982–1989

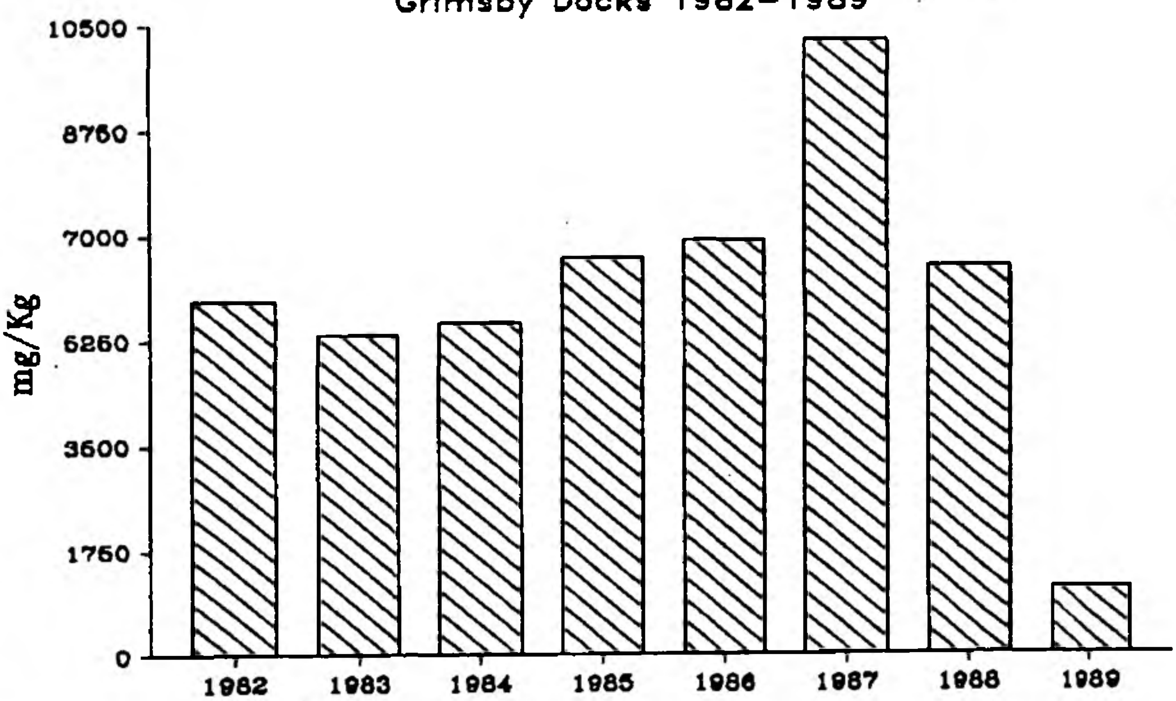


Fig.11.2.3A Concentrations of Zinc in Fucus

South Killingholme 1982–1989

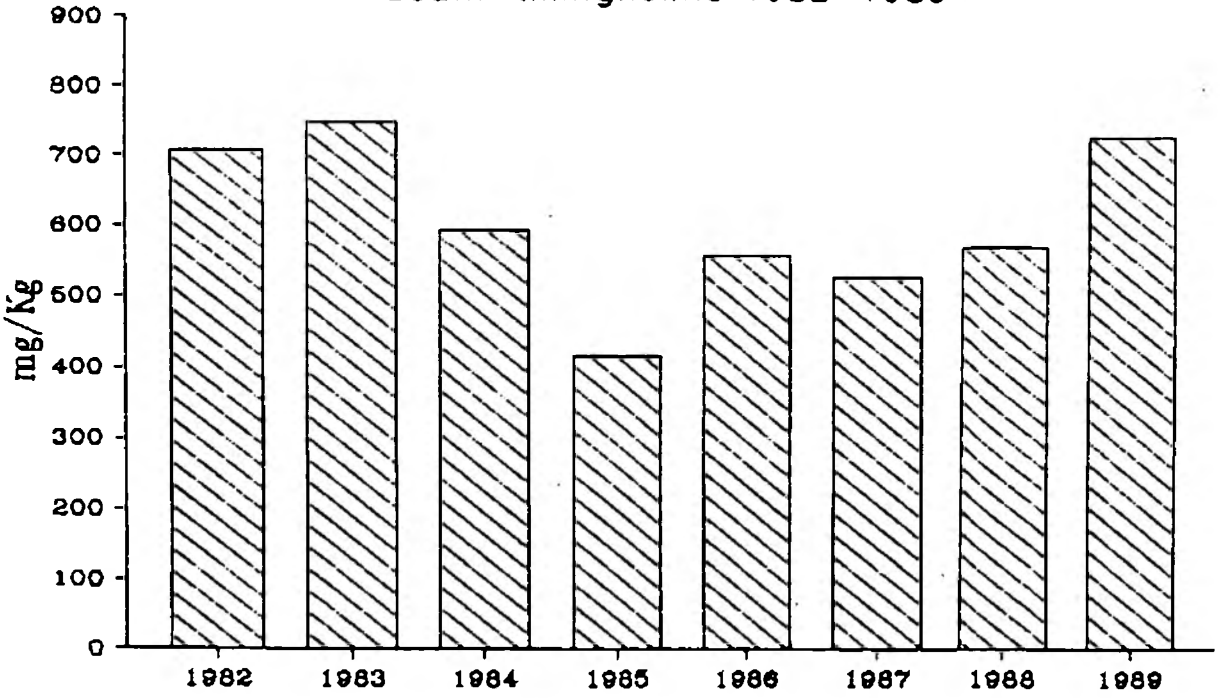


Fig.11.2.3B Concentrations of Zinc in Fucus

Grimsby Docks 1982–1989

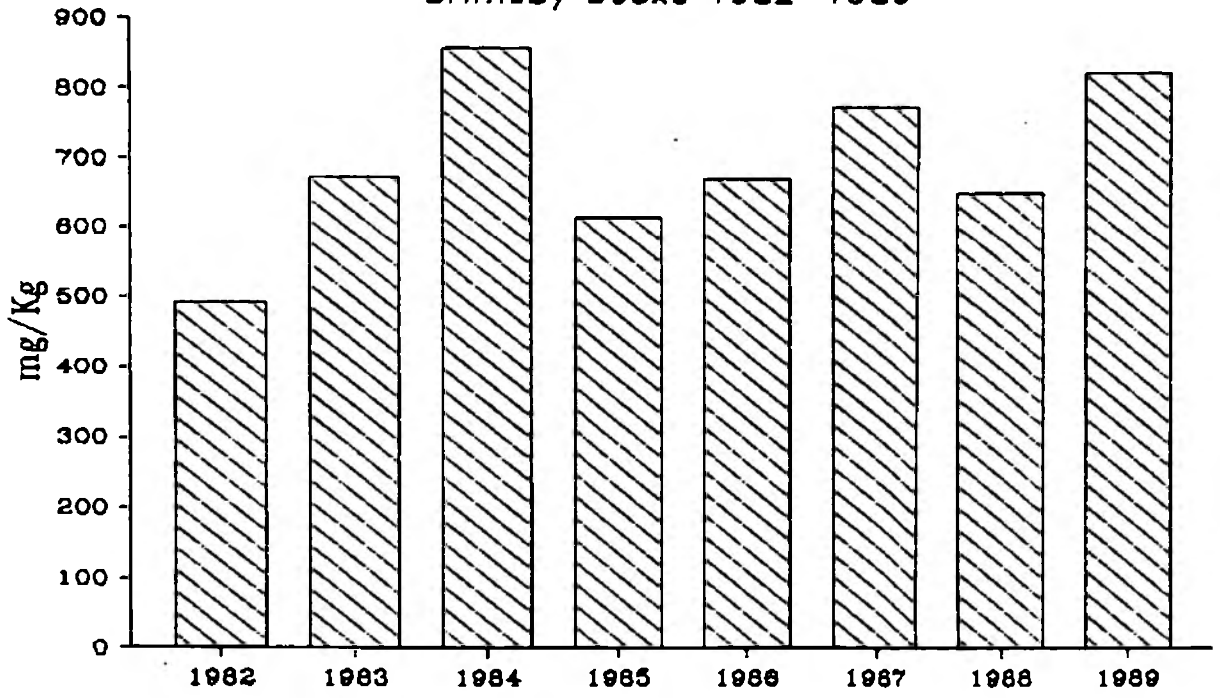


Fig.11.2.4A Concentrations of Copper in Fucus

South Killingholme 1982–1989

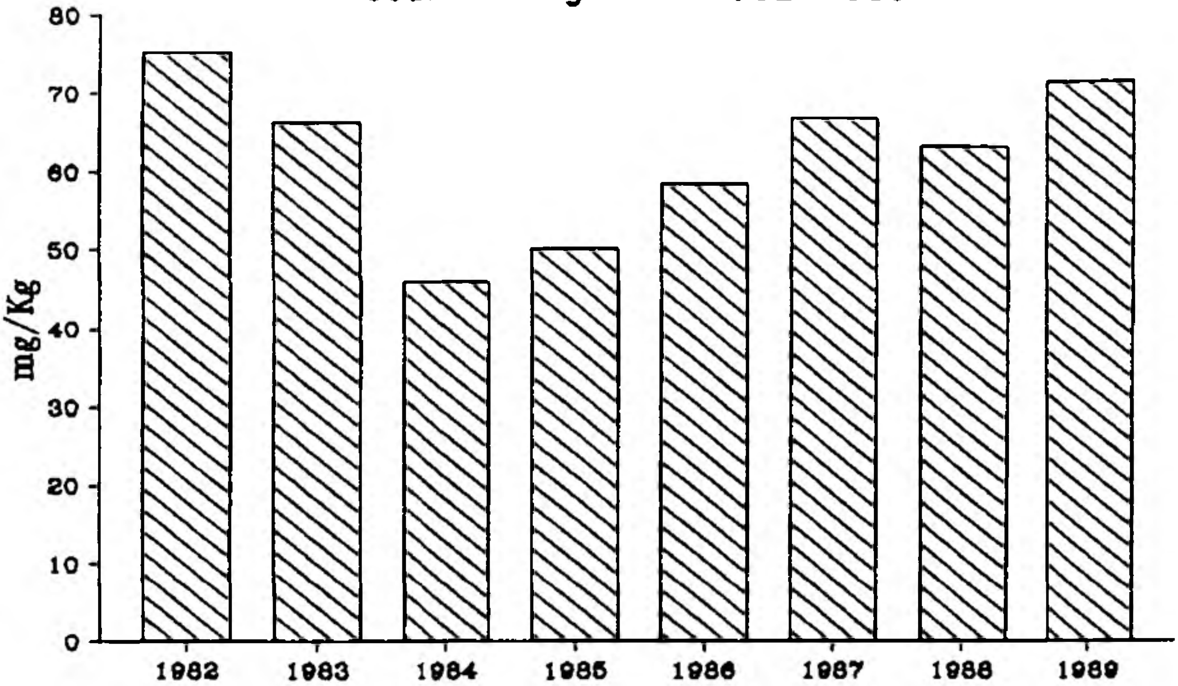


Fig.11.2.4B Concentrations of Copper in Fucus

Grimsby Docks 1982–1989

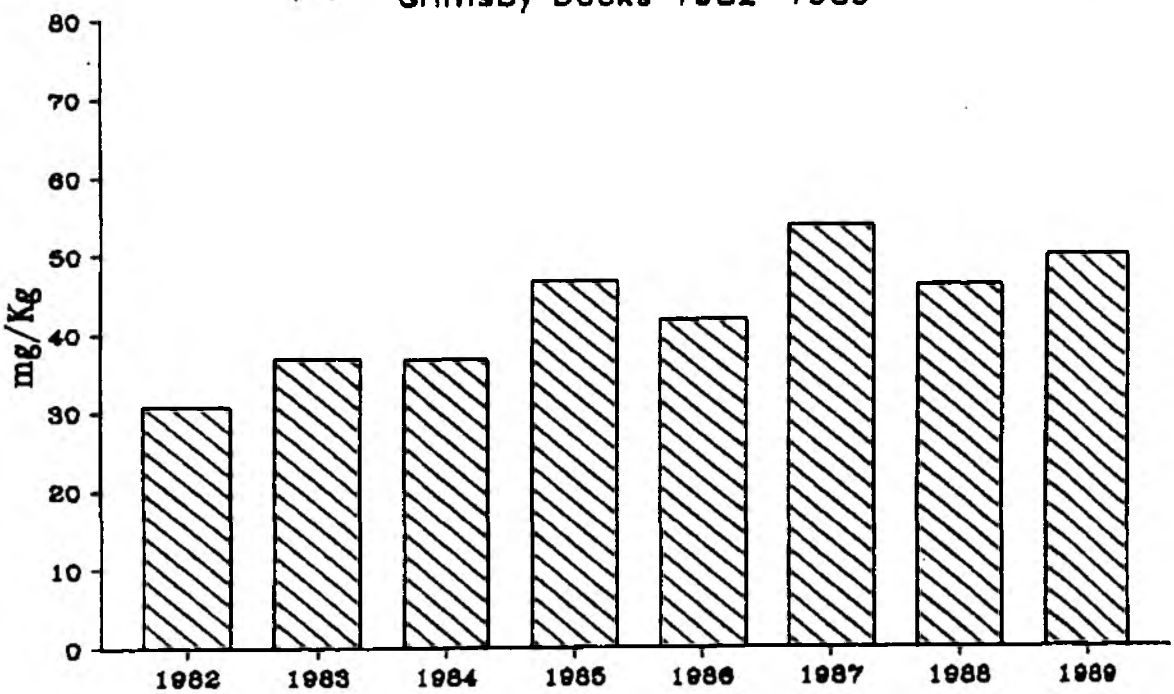


Fig. 11.2.5 Concentrations of Iron in Fucus

New Holland 1982–1989

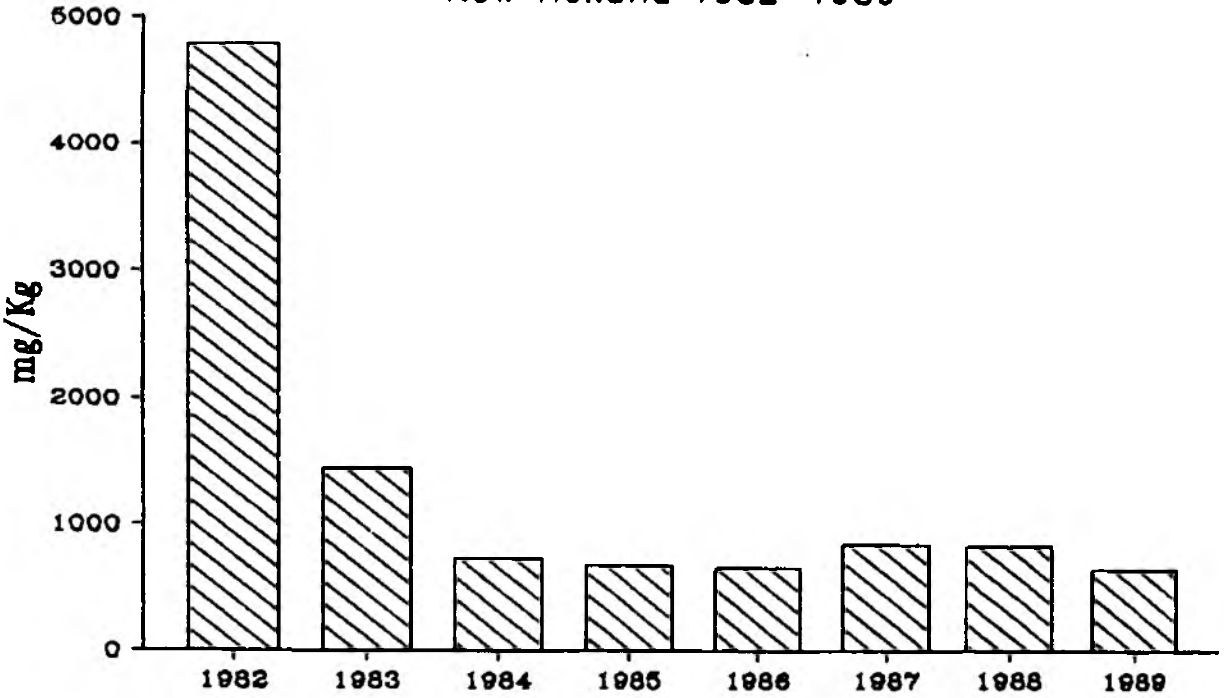


Fig.11.2.6 Concentrations of Iron in Fucus

Mean concentrations by season (All sites combined)

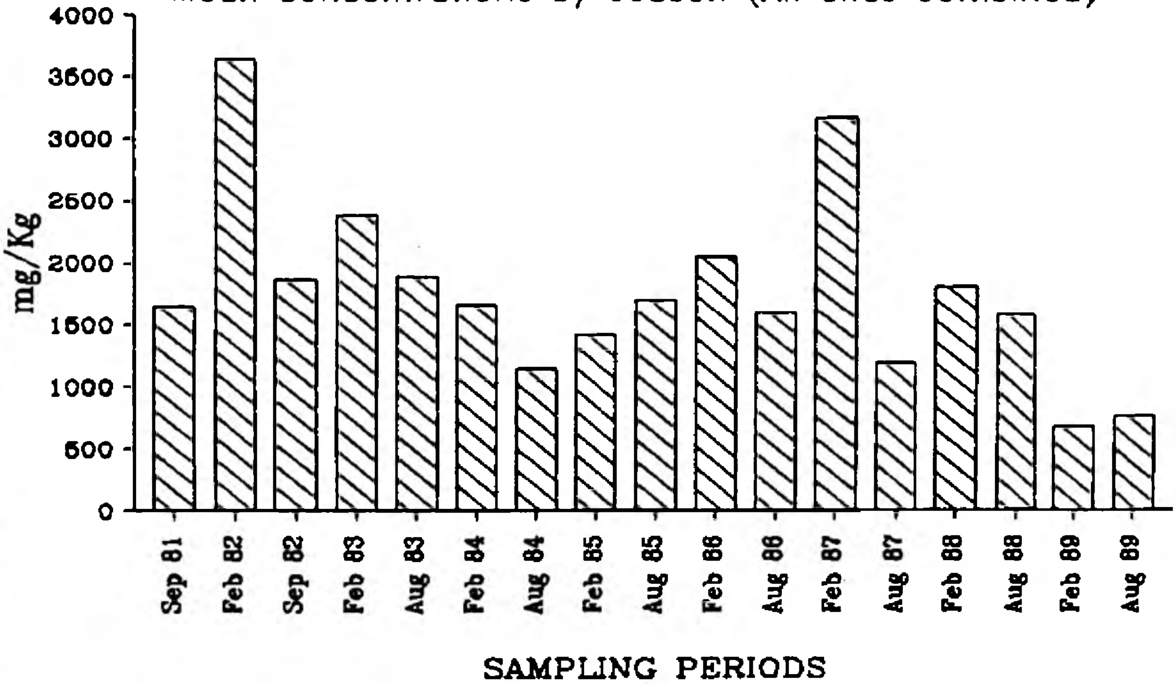


Fig.11.2.6 Concentrations of Iron in Fucus

Mean concentrations by season (All sites combined)

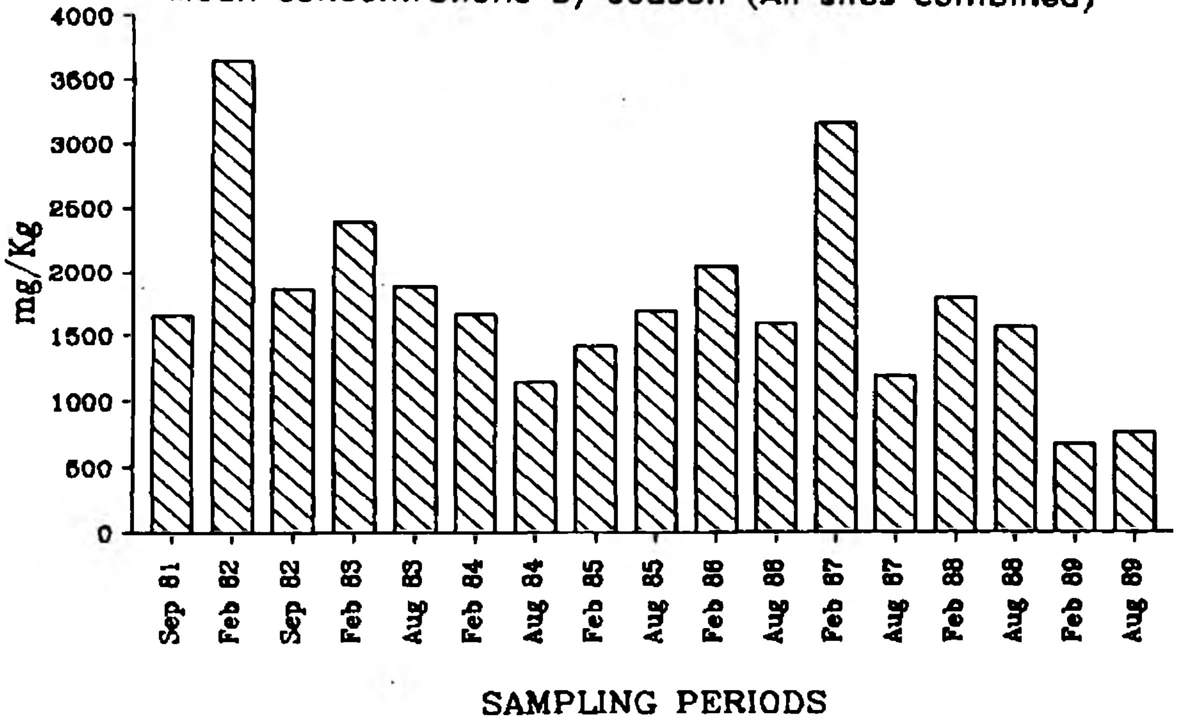
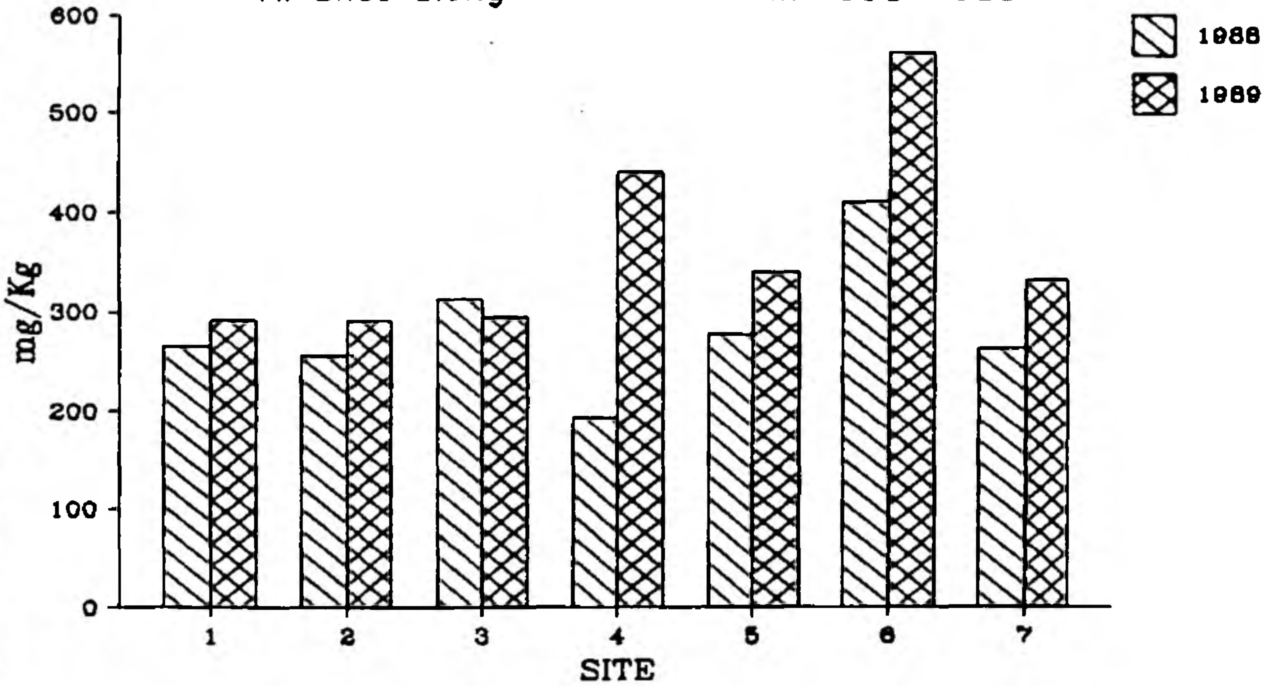


Fig.11.3.1 Concentrations of Iron in Nereis

At Sites along the South Bank 1988-1989



APPENDIX 12

RECOVERY AROUND THE OLD OUTFALLS.

Based on the patterns of the benthic 'communities' around the old Tioxide outfall in 1989, there is no identifiable effect of the discharge, which suggests a substantial or complete recovery of the receiving environment. Comparison of the pattern in 1989 with that observed in 1984 also indicates that the old discharge is not exerting a residual impact on the benthos, thus endorsing the impression of a recovery. This is also clearly evident from distribution patterns derived from species variety and abundances in 1989, and comparison of these patterns to those observed in 1984. Whilst species richness and faunal abundance has increased at most sites in the survey area, a much greater increase is evident at sites previously considered to be affected by the effluent. These increases constitute evidence of a distinct improvement in conditions in the old discharge receiving area and also confirm the above conclusion that there has been a substantial or complete recovery of the environment around the old Tioxide outfall.

These findings are not matched by observations around the old SCM outfall. For a variety of reasons, not least of which is the possibility of an impact associated with the close proximity of the new SCM outfall, interpretation of the results for the old outfall is extremely difficult. However, the ecological patterns derived from cluster analysis indicate a relationship between the location of the old outfall and the faunal associations in the immediate vicinity. Close inspection of these patterns reveals some similarity with the grouping of sites identified in 1984. Whilst both of these two observations must to some extent be mediated by the sediment distribution patterns they are also considered to suggest a residual impact of the old discharge. Some sites in the old receiving area are conspicuous in containing relatively low numbers of species and abundances in comparison to the majority of the survey area, and only a few sites show significant increases in these two parameters compared to the 1984 results. These observations are particularly apparent at low-shore intertidal sites, although influences of the physical environment in controlling the ecological communities here can not be excluded. Since remnants of the affected area identified in 1984 can still be recognised and only small increases in species variety and abundance have been recorded at most sites, the recovery of the environment around the old SCM outfall must be considered marginal. The designation of much of the impacted area in 1984 as only 'moderately' affected may suggest that the scope for improvement was relatively small, especially in comparison to the old Tioxide discharge receiving area, and therefore more obvious evidence of improvement could not be expected. However, a minority of sites have demonstrated quite appreciable improvement, and it may therefore be more precise to conclude that recovery around the old SCM outfall is patchy but clearly incomplete.

APPENDIX 13

DAMAGE TO ENVIRONMENT AROUND THE NEW OUTFALLS.

The assessment of any impact(s) related to the new outfalls is limited by the nature of the mini-grids. These were designed essentially for monitoring purposes and not to provide comprehensive impact assessments which can only be made from a repetition of the complete basline grids. This has not been possible in the time available.

To compensate for the limitations of the mini-grid data, worst case assumptions are generally made but the potential inadequacies of the data should be borne in mind throughout the following discussion.

The new Tioxide outfall discharges at the edge of a deep water channel so that the areas in-shore and off-shore of the discharge are physically different in terms of depth and sediment stability. These features of the natural environment exert strong influences on the benthos of the receiving area. In particular, the highly mobile sediments of the channel periphery present a naturally inhospitable habitat for benthic organisms. Against this physical background it has not been possible to determine any recognisable impact of the effluent.

Areas of impoverished fauna do exist, but these are almost certainly due to the natural rigours of the habitat and were apparent before the commissioning of the new outfall. Comparable areas supported somewhat lower abundances in the post-discharge survey, but did not show any appreciable decline in species variety which probably suggests that these changes were not related to effects of the effluent. Furthermore, sites closest to the outfall continued to support substantial populations of certain species and also failed to exhibit any consistent decline in species variety.

Whilst the decline in abundances at more remote sites may be considered suspicious, there are no indications from the ecological patterns, or the overall changes in the benthos after commissioning of the new outfall, which can reasonably be associated with any impact of the effluent. The results of investigations around the new Tioxide outfall should therefore be viewed as inconclusive with no clear evidence of any identifiable effects which can be attributed to the discharge.

The new SCM outfall discharges into a much more homogeneous environment and perturbations should therefore be more readily detected. However, the proximity of the old outfall and its associated discharge receiving area presents complications in the interpretaiton of changes related to the new outfall.

The pattern observed in the post-discharge survey around the new outfall indicates an area of some effect along the predicted axial line of the effluent plume, especially to the west of the discharge. Comparison of this pattern with the pattern derived from the pre-discharge survey is undoubtedly complicated by changes which relate to closure of the old outfall, but lends support to the recognition of an impact associated with the new outfall. Furthermore, widespread and substantial increases in species variety were conspicuously absent at two of the three sites in the suspected area of impact. The same two sites also demonstrated distinctly smaller increases in faunal abundance than was recorded at other comparable sites. Whilst the ecological changes at the third site were generally more consistent with those observed at sites elsewhere in the survey area, the presence of an iron 'crust' provides irrefutable evidence of the influence of the discharge. It was therefore concluded that an area of impact exists around the new SCM outfall, although the effect can only be regarded as weak or very weak.

Considering the clearly limited data on which this conclusion is based it would normally be necessary to qualify these statments. However, although not designed to provide information pertaining to the new outfall, the off-shore line of stations sampled for assessment of the old discharge is almost coincident with the axial line of the new outfall survey. Because any effects of the new outfall could interfere with interpretaiton of results relating to the old outfall, the results for the off-shore sites were subjected to very close scrutiny. A similar conclusion was reached, with a possible effect of the new outfall being identified further to the west than to the east. Whilst the data analysis techniques employed are the same for both assessments they were prepared from completely independent data sets by different workers. The corroboration of one assessment by the other does not constitute proof of an effect, but only an unlikely degree of coincidence can otherwise explain the similarity of the findings. Neither survey can accurately define the width of the impact zone, or delimit the western extent of the effect, although it seems unlikely that this extends beyond 1 Km. The most reasonable assumption for the width estimate is to take the mid-point between sites identified as affected in the new outfall survey and the unaffected sites off-shore, and in-shore of these lines. This equates to a width of 100m. The upstream and downstream extent of the effect based on 'worst case' estimates from the old outfall survey would suggest the impact extended to 900m east of the new discharge point and 1,000m to the west. Thus the total area of effect would be $190,000m^2$ (19 hectares). It must however be emphasised that the intensity of the effect is only weak, or very weak on the same subjective basis as used in 1984.

Conclusion

There is no clear evidence of any impact associated with the new Tioxide outfall. Suspicions remain over the presence of some areas where the fauna is clearly impoverished, but even these would only be responding to a very weak effect.

There is well supported evidence of a very weak effect associated with the new SCM outfall, over an area up to 19 hectares, but this designation is less certain than was the case in 1984. The area and intensity of effect are appreciably less than those identified around the old outfall in 1984.