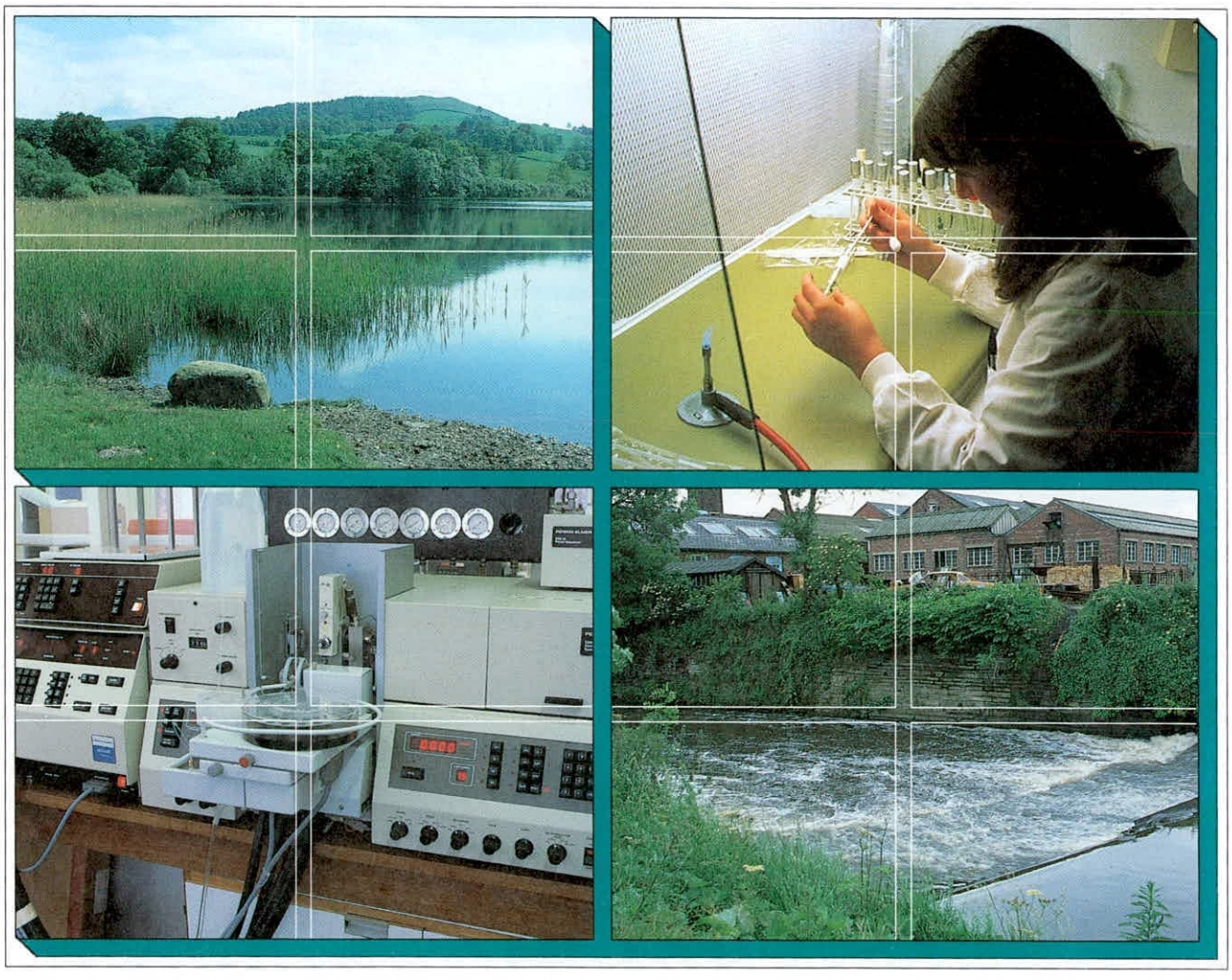
Institute of Freshwater Ecology

# Assessment of the potential for phosphorus reduction in river waters

**W.A. House**, PhD CChem FRSC
**F.H. Denison**, HNC
**S.M. Smith**
**R. Sadak**

Report To: Department of the Environment
Contract No: EPG/1/9/09
IFE Report Ref. No: RL/T11059J1/4



Natural Environment Research Council


Natural
Environment
Research
Council

Institute of Freshwater Ecology

River Laboratory
East Stoke
WAREHAM Dorset
BH20 6BB

Tel: 01929 462314
Fax: 01929 462180

# Assessment of the potential for phosphorus reduction in river waters

**W.A. House**, PhD CChem FRSC
**F.H. Denison**, HNC
**S.M. Smith**
**R. Sadak**

| | |
|---|---|
| Project Leader: | W A House |
| Report Start Date: | 1 September 1995 |
| Report End Date: | 1 March 1996 |
| Report To: | Department of the Environment<br>Romney House, 43 Marsham Street<br>London SW1P 3PY |
| Contract No: | EPG/1/9/09 |
| IFE Report Ref. No: | RL/T11059J1/4 |

## INTELLECTUAL PROPERTY RIGHTS

## CONFIDENTIALITY STATEMENT

*'In accordance with our normal practice, this report is for the use only of the party to whom it is addressed, and no responsibility is accepted to any third party for the whole or any part of its contents. Neither the whole nor any part of this report or any reference thereto may be included in any published document, circular or statement, nor published or referred to in any way without our written approval of the form and context in which it may appear.'*

CONTENTS

GLOSSARY OF SYMBOLS

| | |
|---|---|
| BAP | Bioavailable phosphorus measured here using iron oxide stripping. The concentration of phosphorus which is readily released over 24 h from unfiltered water, suspended sediment or sediment. |
| $C_e$ | Equivalent to EPC. Normally this is the equilibrium concentration of SRP but because of the slow kinetics involved in the release and uptake of SRP, this is defined here as the concentration after 24 h of contact with suspended solids in well-mixed conditions. |
| DO | Dissolved oxygen expressed as a % percentage of the aqueous saturation at the field temperature and atmospheric pressure. |
| EPC | Equilibrium phosphorus concentration. The concentration of SRP in contact with a suspended sediment after 24 h contact in well-mixed conditions. The $EPC_0$ is the EPC of a sediment containing only native phosphorus ie. when the sediment is in contact with a solution with SRP=$EPC_0$, there is no net flux of SRP. |
| $K_d$ | Distribution coefficient in units of $dm^3\ kg^{-1}$. The ratio of the concentration of adsorbed SRP to the concentration in the solution after 24 h contact. |
| Native P | Native phosphorus. That phosphorus in sediments prior to leaching or supplementation in laboratory experiments. |
| $n_i$ | Initial adsorption amount. The initial concentration of SRP associated with the sediment prior to sorption. $n_i$ is normally < BAP for sediments. |
| Non-M&R | Non Murphy and Riley phosphorus. Difference between TDP and SRP, ie that phosphorus in organic or polymeric form which is converted to SRP during digestion. |
| OM | Organic matter content expressed as a percentage of the dry weight measured by combustion at 550 $^0$C |
| PP | Particulate phosphorus. Difference between TP and TDP, ie that phosphorus associated with the particulate phase of size > 0.45 µm. |
| SRP | Soluble reactive phosphorus. Soluble phosphorus measured after filtration through a 0.45 µm membrane filter without acid digestion. |
| STW | Sewage treatment works. |
| TDP | Total dissolved phosphorus. Filtered through 0.45 µm membrane filter but subject to acid digestion prior to analysis. |

| | |
|---|---|
| TP | Total phosphorus. Unfiltered and subject to acid digestion prior to analysis. |
| $f_i$ | Flux in the ith river section; mmol $s^{-1}$ |
| $q_i$ | Discharge in the ith river section; $m^3$ $s^{-1}$ |
| $c_i$ | Concentration of SRP in the ith river section; µmol $dm^{-3}$ or mmol $m^{-3}$ |
| $pc_i$, $pq_i$ | Concentration and discharge of point-source in ith section |

## SUMMARY

Most of the effort over the last six months has been directed to the intensive field work, including completion of macrophyte surveys, and the ancillary fluvarium and laboratory work. This report covers the summer and winter sampling programme on the rivers Gt. Ouse, Blackwater and Wey, including the results from the field measurements, laboratory analysis, determination of the sorption isotherms of phosphorus on samples of the bed-sediments and calculation of the equilibrium phosphate concentrations, $EPC_0$, particle-size distributions of the bed-sediments, mineralogy of selected sediments and other relevant parameters. The results from the fluvarium channel experiments for sediments taken at the impacted sites downstream of the major STW inputs are also discussed.

An examination of the data collected on the characterisation of the sediments has also been started. Already some important links have been noted such as that between the silt content and the sorption affinity of the sediments. Modelling of the data from the NRA for the Gt. Ouse has also been continued with the analysis of summer data for 1992-94.

## 1. INTRODUCTION

Under the Urban Waste Water Treatment Directive (91/271/EEC), water bodies will be designated as sensitive areas if they fulfil certain criteria. Phosphorus removal will be required at sewage treatment works discharging into these phosphorus limited sensitive areas, the aim being to reduce phosphorus loading to the water body and therefore to reduce the biological symptoms of eutrophication. Member states also have to review and monitor eutrophication in their sensitive areas over the coming years.

There are uncertainties about how water bodies will respond to reductions in phosphorus loading and the time scale for the biological symptoms of eutrophication to be reduced. This project seeks to develop an understanding about how water bodies respond to reductions in phosphorus loading, and in particular how these reductions could be counteracted by phosphorus release from sediments.

The assessment of the effects of phosphorus removal from effluents must involve the development of criteria to establish the release of phosphorus from sediments after reducing phosphorus loading to a river. Sediments vary in their capacity for uptake and release of phosphorus depending on the nature of the binding and occurrence in the sediment. If the sediment has a high loading of exchangeable phosphorus caused by exposure to a diluted sewage effluent, a high release of phosphorus may be expected; this will largely negate the effects of tertiary treatment even in the longer-term. In other sediments, the phosphorus is likely to be fixed by heterogeneous reactions in the sediment. This phosphorus will not be easily released and will contribute a minor component of the phosphorus load in the river subsequent to tertiary treatment.

The objectives of the project are: (a) to develop criteria for predicting whether a sediment will remove/release a substantial flux of phosphorus following a reduction in the river water concentrations of phosphorus and (b) to validate a proposed procedure by prediction using criteria developed above and measured at selected sites.

## 2. LABORATORY METHODS

The following IFE (River Laboratory) Standard Operating Procedures (SOPs) were used in this work. When other methods are used they are explained or referenced in the text. The SOPs are available to the DoE on request.

| | |
|---|---|
| SOP: 26/20.7.94 Update none. | Particle size analysis of sediment samples. |
| SOP: 23/18.4.94 Update none. | The determination of the organic matter content of a sediment. |
| SOP: 22/14.3.94 Update none. | An ignition method for the determination of the total phosphorus in sediments. |
| SOP: 21/4.3.94 Update none. | Total phosphorus determination by persulphate digestion. |
| SOP: 20/7.3.94 Update none. | The determination of bioavailable phosphorus by iron oxide stripping. |
| SOP: 19/8.3.94 Update none. | The determination of the soluble reactive phosphorus in water by flow-injection analysis. |
| SOP: 15/12.8.93 Update 5.11.93 | Conductivity measurement using Ciba-Corning M90 field meter. |
| SOP: 14/12.8.93 Update 5.11.93 | Oxygen measurement using Ciba-Corning M90 meter |
| SOP: 13/12.8.93 Update 5.11.93 | pH measurement using Ciba-Corning field meter. |
| SOP: 36/16.5.95 Update none | Determination of total suspended solids in water. |

## 3.0 QUARTERLY SITE VISITS

The planned research included site visits to at least two of the rivers chosen from the information obtained in the pilot studies. It was decided after the last stage of the project to attempt intensive studies of three rivers: the Gt. Ouse, R. Wey and R. Blackwater with site visits organised on a seasonal basis. This report covers the work for the summer (1995) and winter (1995-96). The work includes measurements of flow related transfer fluxes (FRTF) in the fluvarium channel

### 3.1 Fluvarium Channel

The current version of the channel now incorporates the following features:

1. Control of the water velocity over the bed-sediment.
2. The channel is completely enclosed enabling the gas atmosphere to be controlled.
3. The concentration of oxygen in the water can now be controlled by air and nitrogen lines.
4. Measurements of pH, temperature and dissolved oxygen are logged using a Hunter portable computer. Because of electrical interference between conductivity and pH it is necessary to measure conductivity manually at suitable intervals.
5. The flow rate is continually measured using the flow transducer placed downstream of the recirculating pump. The flow rate may be altered by inserting appropriate restrictors in the downstream tank or adjusting the butterfly valve.
6. The filtration and sampling of the water is now fully automated. Samples can be taken at pre-defined intervals, filtered through a 0.45 μm membrane filter and placed in a collection

bottle. The system of tubes, filter and syringe are fully flushed prior to each sampling. In addition, the tube connected to the sample collector is flushed with air after each collection. This permits continuous operation over several days or however long is necessary. Normally the system is run for 24 or 48 h periods with sampling at 1 hour intervals.
7. The temperature of the channel is maintained close to the river Frome temperature by flowing water from the fluvarium.

Control experiments without sediment have been done and indicate no contamination of SRP from the equipment. Preliminary experiments have shown satisfactory performance including the ability to reach low oxygen (<2%) in the overlying water. The flow transducer has been calibrated by measuring the time of discharge at various heads of water. The calibration of the transducer was found to be linear with mA loop signal directly proportional to the discharge.

### 3.2 Field Work

On-site work involved the following:

(a) Sampling the water and on-site filtration for measurements of SRP, TDP, Si, $NO_3$ and Ca. Sampling the water for suspended solids measurements.
(b) Measurements of pH, T, conductivity and oxygen concentrations.
(c) Assessment of the riverine environment using macrophytes (NRA, 1994).
(d) Sampling the bed-sediment at selected sites for wet chemical analysis, sorption studies and particle size determinations.
(e) Sampling the surface (< 5 cm) bed-sediment at the site downstream of the main STW using stainless steel trays designed for direct insertion into the fluvarium channel.
(f) Measurement of the water velocity across a section of the river to enable the discharge at all the sites to be estimated.
(g) Sampling the water for major-ion and nutrient analysis at additional downstream sites to enable the calculation of discharge from NRA gauging stations. This was necessary for the Gt. Ouse and Blackwater rivers where the gauging station is situated downstream of the confluence with a major tributary.

Samples were filtered using a 0.45 μm cellulose nitrate membrane filter. Samples for total phosphorus measurement were taken on-site and placed in 60 ml HDPE Azlon bottles for direct measurement; this method avoids the loss of suspended solids caused by sub-sampling. All samples were stored in a cold box during transportation. The analyses were done as soon as possible after returning to the main laboratory with SRP, Si and $NO_3$ all analysed within 1 day of returning.

### 3.3 Laboratory Measurements

These include:

(a) Nutrient fractions including SRP, total dissolved phosphorus (TDP), total phosphorus (TP), nitrate, silicon as well as major ions such as calcium, magnesium, sodium, potassium and alkalinity.

(b) Measurements on the 2 mm sieved bed-sediment such as the organic matter content (OM), total phosphorus, calcium and iron concentrations after acid digestion.
(c) Measurements of the "biologically available phosphorus", BAP, by the method of iron-oxide stripping.
(d) Measurement of the sorption characteristics of the surface bed-sediment at 10 $^0$C and calculation of the equilibrium phosphate concentration, $EPC_0$, initial native phosphorus amount and adsorption affinity, $K_d$.

The fluvarium channel experiments were conducted as follows:

(a) River bed-sediments were collected from the sites downstream of the major STW input. Surface sediments (<5 cm depth) were collected using the four stainless steel sections. If possible these were forced into the sediment and a horizontal section taken by moving the tray through the sediment. Where this was difficult because of the depth of water, the sediment was taken in shorter sections and placed directly in the tray. No attempt was made to sieve the sediment; the prime purpose was to try and get a representative sediment from the site with a minimum disturbance to the sediment. At sites where the sediment surface was coarse and uneven, this structure was retained as much as possible.

(b) The sections were end-capped and placed in a tray containing about 2-3 cm depth of river water from the site. The tray was then covered with aluminium foil and transported immediately to the fluvarium. The transport time varies between sites from 1.5 to 3 h.

(c) On arrival at the fluvarium, the small amount of fines leached from the sediments were returned to the sections. The sections were then placed in the fluvarium channel in readiness for the phosphorus release experiment. Before adding the background electrolyte (2 mM $CaCl_2$), the pH and dissolved oxygen (DO) sensors were calibrated. The solution was then added and first phosphorus release experiment started. Manual sampling was done at time 0, 15 and 30 mins; thereafter the automatic sampler operated at 1 hour intervals for 24 h.

(d) SRP uptake was investigated by the augmentation of SRP above the expected $EPC_0$ of the sediment. The kinetics of uptake of SRP was measured over 24 or 48 h.

(e) The release of SRP under anaerobic conditions was evaluated by lowering the DO concentration in the fluvarium channel by the addition of $Na_2SO_3$ in sufficient amount to just remove all the DO. Subsequently, the solution was purged with high purity nitrogen gas to maintain a DO concentration in the water close to zero percent. The kinetics of the release of SRP was measured over 24 to 48 h.

### 3.4 Results

A summary of the site visits covered in this report is shown in Table 1. Only a brief discussion of the results is presented at this stage.

3.4.1 Gt. Ouse

Of the three rivers studied this has the greatest water hardness, with calcium concentrations greater than 3.5 mM; the sediments also contain the highest amounts of calcium (ca 5-18 % by mass). It also has the lowest concentrations of dissolved phosphorus, with all values for the different P fractions below 20 μM in the spring, autumn and winter surveys. However in the summer (1995) low flow, the highest concentration was 84.5 μM at site B downstream of the STW. The Gt. Ouse has the highest concentrations of nitrate of the order of 0.80 mM or greater compared with the other rivers which are generally less than 0.5 mM. In the winter and autumn surveys the silicon concentrations varied little along the study section in contrast to the spring survey when the concentration decreased from about 80 μM to 15 μM at the lower site, G, indicating uptake by diatoms. Changes in the silicon concentration can be used to estimate P-uptake by diatoms (Marker and Casey, 1982); this will be investigated when all the seasonal data are available.

The fluvarium channel results produced similar values of $K_p$ and the Elovich 'b' parameters for the sediments collected in the winter and spring surveys. The Elovich uptake parameters measured for the spring and summer bed-sediments are very similar (Table 2) and contrast with the results from the sediments collected in autumn. For this sediment the SRP released to the water reached a much higher concentration than expected from the $EPC_0$ value determined from the batch experiments. If both $K_p$ and $EPC_0$ are determined from the kinetic data, values of $k_p$=1.43 $10^{-7}$ $m^4$ $h^{-1}$ $\mu mol^{-1}$ and $EPC_0$=4.5 μM are obtained. This $EPC_0$ is higher than the measured value of 1.07 μM. The release experiments on the winter and spring sediments were very different with a substantial release of P in the winter but no net release in the spring.

**Table 1. Field site visits for the Summer and Autumn of 1995, and the Winter of 1996.**

| Name of river | Date of visit | Major STW |
|---|---|---|
| Gt. Ouse | 10 July 1995 | Brackley |
| Blackwater | 21 July 1995 | Aldershot (town and military) |
| Wey | 7 August 1995 | Alton |
| Gt. Ouse | 15 November 1995 | Brackley |
| Blackwater | 17 January 1996 | Aldershot (town and military) |

3.4.2 R. Wey

This is the only river for which an autumn survey has been reported (report RL/T11059J1/2; September 1994-March 1995). This is also a hardwater river with calcium concentrations in the range of 2.3 - 3.5 mM with a marked difference between the winter and spring concentrations. The silicon concentrations measured during the spring visit also showed a decrease in the downstream direction. It is interesting to note that the Ca, P and Fe concentrations in the sediment are in a similar range to the results from the Gt. Ouse. The

concentrations of phosphorus measured in the summer were particularly high reaching a TP value of 83 μM at site C which compares with the approximately 37 μM found in the spring site visit.

The fluvarium channel results gave similar values for the parabolic constant, $K_p$, and Elovich 'b' parameter for the summer, autumn and winter results for P release but lower values for each of the parameters derived from the spring data (Table 20). The uptake parameter, $K_p$, decreases from the winter to spring.

### 3.4.3 R. Blackwater

This river has lower concentrations of calcium in the water and sediments compared with the other two rivers. The total P concentration of the sediments are slightly higher at the downstream sites of the STW's compared with the other rivers but still < 0.1 % by dry mass of the sediment.

The results from the fluvarium channel experiments for the release of P produced almost linear release rates with little indication of a decrease in the rate as the $EPC_0$ is approached. In this situation, both the $EPC_0$ and the $K_p$ parameters were optimised to give best agreement with the experimental kinetic data. For both the winter and spring results, the optimised $EPC_0$ were greater than the value measured with the suspended sediment. The reason for this difference is as yet uncertain and will be examined in more detail later. The derived kinetic parameters, e.g. $K_p$, indicate a substantial decrease in the release rates for the spring sample compared with the winter sample but little change in the phosphorus uptake parameters. The recent results for the summer, autumn and winter (1996) show a consistency in the release experiments with similar values of the net uptake parameters for the models. The experiments for the release of SRP are less straight forward with high release in the summer but relatively low release in the autumn and winter (1996). No detectable release of SRP occurred for the bed-sediment collected in January 1996 until approximately 15 h from the start of the experiment.

**Table 2. Comparison of the results from the flow-related transfer flux (FRTF) measurements from the fluvarium channel. The parabolic parameter, $K_p$, is in units of $m^4\ h^{-1}\ \mu mol^{-1}$ and the Elovich parameters, a and b, are in units of $\mu mol\ m^{-2}\ h^{-1}$ and $m^2\ \mu mol^{-1}$, respectively.**

| river | season | parameter | net release of P | net uptake of P |
|---|---|---|---|---|
| Wey | autumn | $K_p/10^{-7}$ | 0.844(0.009) | 0.613(0.016) |
| | | a | 68.94(2.85) | 146(7.7) |
| | | $b/10^{-3}$ | 2.15(0.12) | 0.44(0.05) |
| Wey | winter | $K_p/10^{-7}$ | 0.811(0.008) | 0.218(0.017) |
| | | a | 29.44(1.20) | 568.9(157.7) |
| | | $b/10^{-3}$ | 2.70(0.02) | 1.80(0.22) |
| Wey | spring | $K_p/10^{-7}$ | 0.311(0.071) | 0.098(0.014) |
| | | a | 66.65(3.58) | 57.93(22.42) |
| | | $b/10^{-3}$ | 1.25(0.11) | 1.04(0.87) |
| Ouse | winter | $K_p/10^{-7}$ | 16.46(0.44) | 0.407(0.189) |
| | | a | 17.51(2.97) | 542.1(100.2) |
| | | $b/10^{-3}$ | 11.20(2.10) | 0.934(0.095) |
| Ouse | spring | $K_p/10^{-7}$ | no release | 0.626(0.026) |
| | | a | no release | 415(107) |
| | | $b/10^{-3}$ | no release | 0.80(0.13) |
| Blackwater | winter | $K_p/10^{-7}$ | 5.91(0.35) | 0.219(0.012) |
| | | a | 23.89(0.60) | 266.4(45.1) |
| | | $b/10^{-3}$ | 0.922(0.008) | 0.753(0.103) |
| Blackwater | spring | $K_p/10^{-7}$ | 0.231(0.198) | 0.211(0.005) |
| | | a | 27.09(2.31) | 276(24) |
| | | $b/10^{-3}$ | 1.57(0.29) | 0.771(0.005) |
| Wey | Summer | $K_p/10^{-7}$ | 11.7(1.38) | 0.18(0.0157) |
| | | a | 32.03(4.917) | 347.0(130.7) |
| | | $b/10^{-3}$ | 3.15(0.584) | 1.363(0.361) |

| river | season | parameter | net release of P | net uptake of P |
|---|---|---|---|---|
| Ouse | Summer | $K_p/10^{-7}$ | | 0.302(0.0128) |
| | | a | 1.92(0.143) | 493.3(74.5) |
| | | $b/10^{-3}$ | -10.2(1.02) | 0.869(0.0734) |
| Ouse | Autumn | $K_p/10^{-7}$ | | 0.14(0.0120) |
| | | a | 12.03(1.02) | 36.82(4.24) |
| | | $b/10^{-3}$ | 6.46(0.745) | -0.207(0.15) |
| Blackwater | Summer | $K_p/10^{-7}$ | | 0.391(0.021) |
| | | a | 23.2(1.08) | 642.5(139.6) |
| | | $b/10^{-3}$ | -0.367(0.0922) | 0.815(0.101) |
| Blackwater | Autumn | $K_p/10^{-7}$ | | 0.256(0.0076) |
| | | a | 0.368(0.0161) | 232.7(29.7) |
| | | $b/10^{-3}$ | -64.8(7.27) | 0.967(0.0951) |
| Blackwater | Winter | $K_p/10^{-7}$ | | 0.36(0.008) |
| | | a | 4.4(0.41) | 233.8(24.92) |
| | | $b/10^{-3}$ | -4.44(0.703) | 0.770(0.075) |

3.5 Regression analysis of the sediment properties and sorption characteristics

Multiple regression analysis was done of organic matter, total phosphorus, total calcium, BAP (by iron oxide stripping), $EPC_0$, $K_d$, $n_i$, sand, silt and clay for each river, both on a seasonal basis on each river and a seasonal basis including the data from all rivers. In addition the analysis was completed for all the rivers over all the seasons, i.e. 56 measurements of 11 determinands. Correlations between the kinetic parameters for the Elovich and parabolic equation with sediment properties were also examined. The results are summarised as follows:

3.5.1 Regressions for all the rivers and all seasons

Overall there was a general correlation between the percentage of the silt and clay fractions. The best correlation was found between the $K_d$ values and the percentage of silt in the bed-sediment (see Fig 1; R=0.80). Good correlations between the organic matter content and the silt fraction were also observed. The best positive correlation with the BAP (iron oxide stripping) was $n_i$ (native P from the isotherm measurements). The correlation between $K_d$ and percentage clay was relatively poor (R=0.44).

3.5.2 Regressions for each river.

(a) R. Wey

The best correlation is between $n_i$ and percentage clay (see Fig. 2) and may reflect the greater importance of the expandable clays in this sediment (Table 5). The R. Wey sediments also show the best relationship between the sorption affinities and clay content (see Table 3), whereas the other rivers show a better relationship between the $K_d$'s and the silt content. The R. Wey sediments also show the best correlation between the native P, $n_i$, and total P compared with the other rivers. This may reflect the importance of carbonate (or possibly calcium phosphate minerals), see Table 4.

(b) R. Blackwater

As shown in Table 3, the sediments show the highest correlations between the sorption affinity, $K_d$, and the organic matter content and silt content of these rivers (see Fig 3). The data also indicate a positive correlation between the $EPC_0$ and BAP.

(c) Gt. Ouse

The sediments show few good correlations when the seasonal data are combined although there are many good correlations ($R^2>0.9$) within the seasonal data. The best correlation is between the sorption affinity and silt content.

Figure 1

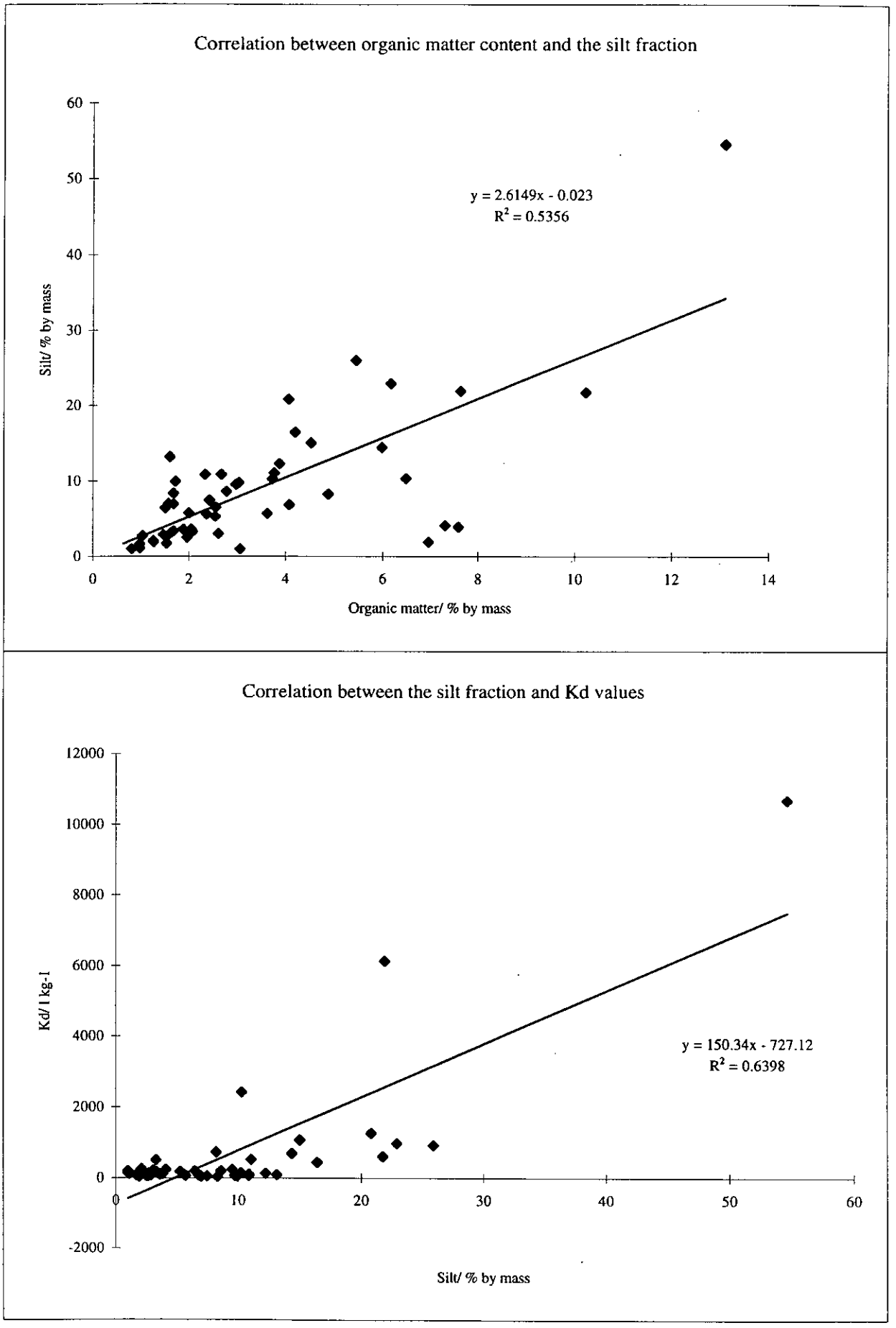

Correlation between organic matter content and the silt fraction
y = 2.6149x - 0.023
R² = 0.5356
Silt/ % by mass
Organic matter/ % by mass
0
10
20
30
40
50
60
0
2
4
6
8
10
12
14
Correlation between the silt fraction and Kd values
y = 150.34x - 727.12
R² = 0.6398
Kd/ l kg-1
Silt/ % by mass
12000
10000
8000
6000
4000
2000
0
-2000
0
10
20
30
40
50
60

Figure 2

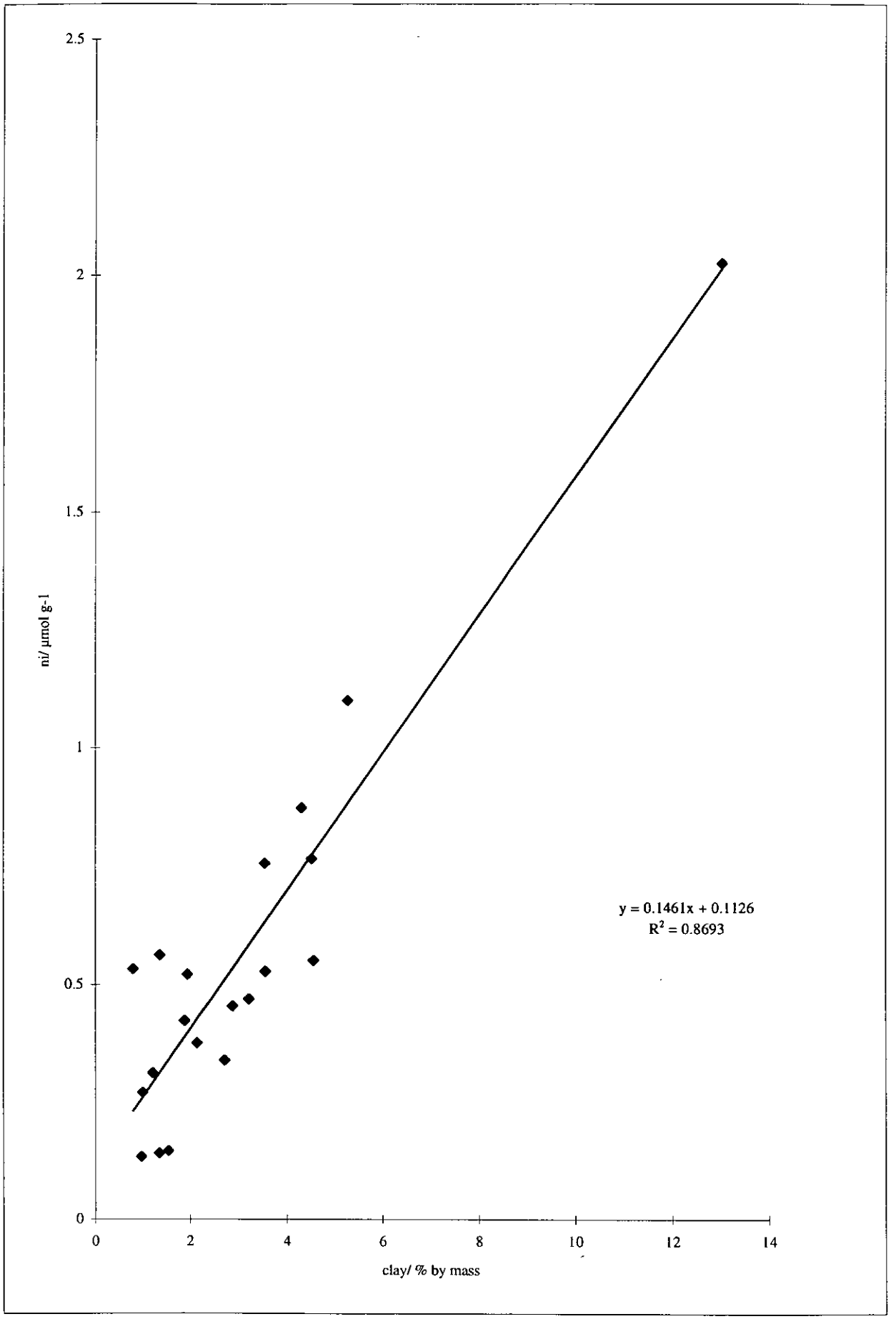
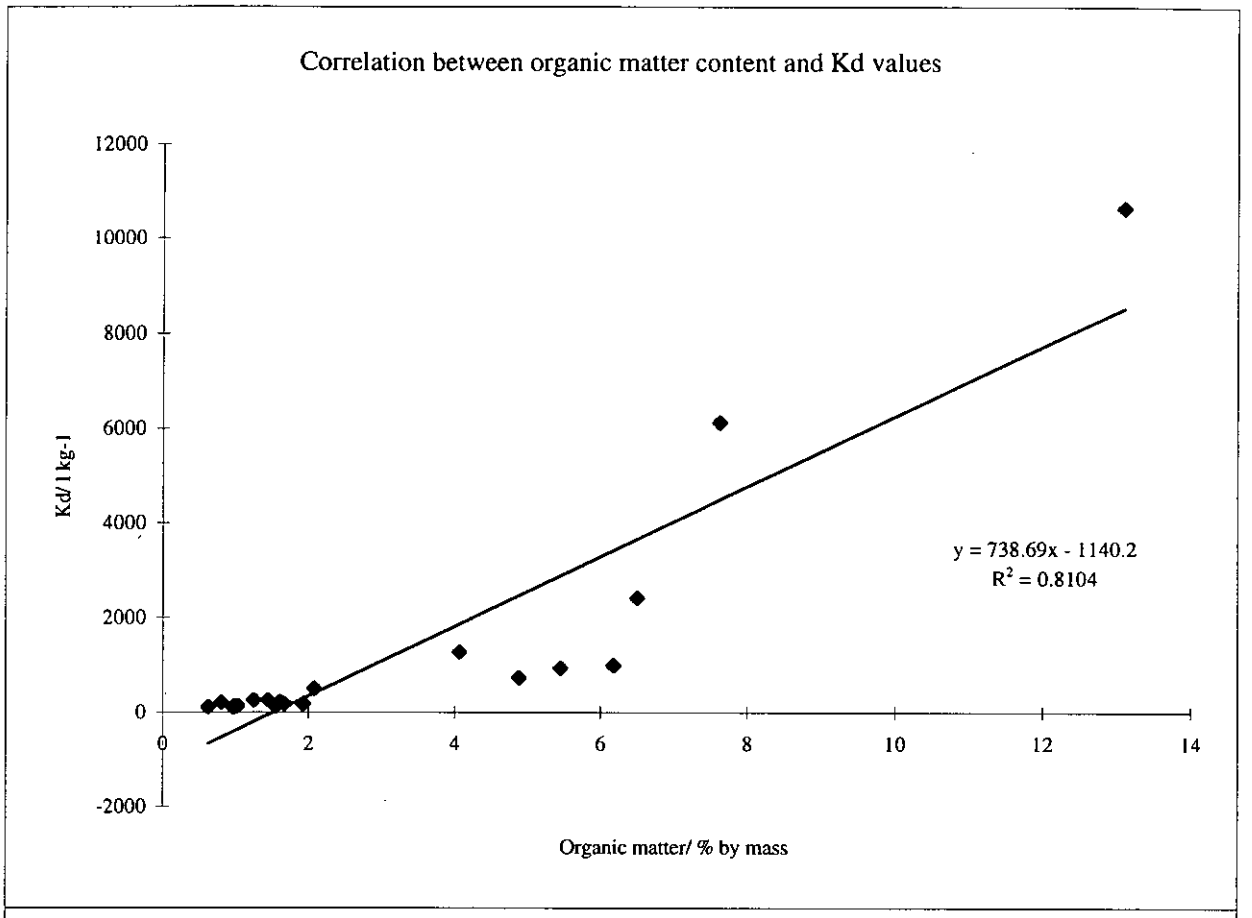

2.5
2
1.5
1
0.5
0
ni/ µmol g-1
0
2
4
6
8
10
12
14
clay/ % by mass
y = 0.1461x + 0.1126
R² = 0.8693

Figure 3


Correlation between organic matter content and Kd values
12000
10000
8000
6000
4000
2000
0
-2000
Kd/ l kg-1
0
2
4
6
8
10
12
14
y = 738.69x - 1140.2
R2 = 0.8104
Organic matter/ % by mass

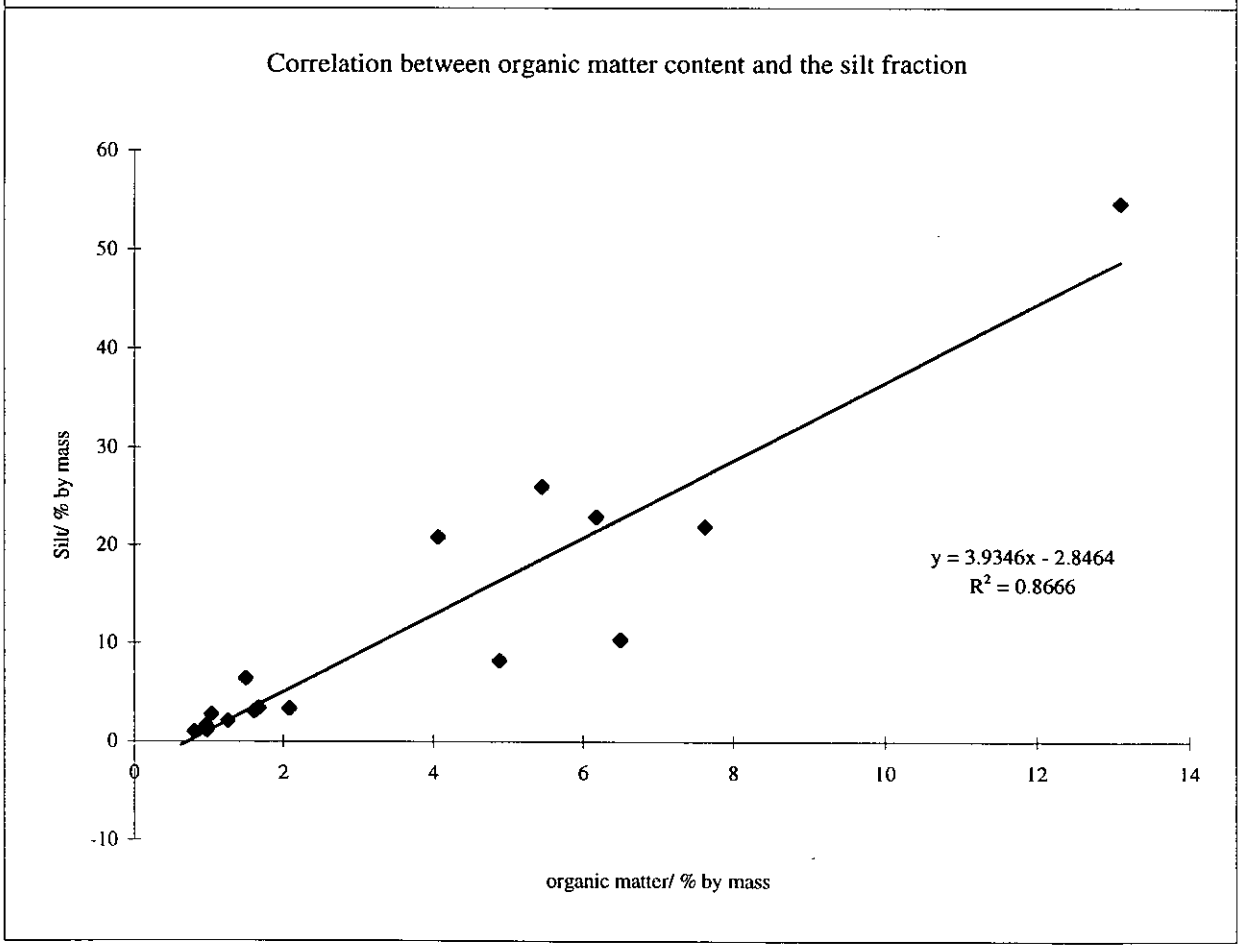

Correlation between organic matter content and the silt fraction
60
50
40
30
20
10
0
-10
Silt/ % by mass
0
2
4
6
8
10
12
14
y = 3.9346x - 2.8464
R2 = 0.8666
organic matter/ % by mass

**Table 3. Comparison of the correlation coefficients ($R^2$) for paired variables for each river over all seasons. Key: variables are defined in the glossary.**

| river | $EPC_0$-BAP | $EPC_0$-$n_i$ | $EPC_0$-$T_{Fe}$ | $K_d$-TP | $K_d$-OM |
|---|---|---|---|---|---|
| Wey | 0.32 | 0.03 | 0.15 | 0.78 | 0.79 |
| Blackwater | 0.63 | -0.11 | -0.41 | 0.01 | 0.90 |
| Gt. Ouse | 0.08 | 0.43 | 0.56 | 0.39 | 0.47 |
| | $K_d$-silt | $K_d$-clay | $n_i$-TP | $n_i$-OM | BAP-clay |
| Wey | 0.59 | 0.68 | 0.87 | 0.46 | 0.19 |
| Blackwater | 0.86 | 0.40 | 0.62 | 0.56 | -0.45 |
| Gt. Ouse | 0.85 | 0.66 | 0.25 | 0.55 | 0.36 |

3.6 Mineral Analysis

The X-ray diffraction analysis of 5 samples of bed-sediments are shown in Table 4. The samples of the R. Blackwater are dominated by quartz with only small (< 2 % by mass) amounts of clays and carbonate minerals. In contrast, although the rivers Ouse and Wey have high concentrations of quartz, they also contain appreciable amounts of calcite. The whole sample analysis is insensitive to small quantities of clay minerals. Separation of the < 2 μm size fraction for X-ray diffraction analysis showed the importance of the expandable clays such as montmorillonite, in most of these samples (Table 5). The R. Ouse sediment samples have a higher percentage of kaolinite compared with the other rivers. Neither dolomite or haematite were found to be abundant in these sediments.

The interaction of SRP with montmorillonite (an expandable clay) is relatively low with reported Langmiur constant of 0.043 l $mg^{-1}$ at pH=7 and ionic strength, I, of 0.02 M. This corresponds to a $K_d$=17.9 l $kg^{-1}$ ( He et al, 1994). Other minerals have been shown to have a greater affinity with SRP at pH=7 and I=0.02 M, e.g. the calculated $K_d$'s for kaolinite goethite and aluminium oxide are 257, 21136 and 22414 l $kg^{-1}$ respectively ( He et al, 1994). The low affinity of montmorillonite with SRP has also been determined in laboratory experiments undertaken as part of the LOIS nutrient project. Experiments at pH= 6.4 and 2.0 mM $CaCl_2$ solution gave a $K_d$ of 81 l $kg^{-1}$ with relatively fast uptake kinetics (equilibrium established in < 30 mins). Further research as part of the LOIS project is in progress to find information about the interaction of phosphorus with these minerals and to assess whether any laboratory experiments are needed

**Table 4. Results of the X-ray diffraction analysis of selected whole samples of bed-sediments from the rivers Gt. Ouse, Wey and Blackwater. "T" indicates trace amounts of < 1 %. Key: kaol': kaolinite; gyp': gypsum; K feld': K feldspar; cal': calcite; dol': dolomite; haem': haematite**

| sample | mica | kaol' | gyp' | quartz | K feld' | cal' | dol' | haem' |
|---|---|---|---|---|---|---|---|---|
| Wey, site C 8.5.95 | T | 0 | 0 | 69 | 2 | 28 | 0 | 1 |
| Gt. Ouse, site B 27.8.95 | 0 | 2 | 0 | 45 | 1 | 51 | 0 | 1 |
| Blackwater, site B 30.1.95 | 0 | 0 | 0 | 98 | 2 | 0 | T | 0 |
| Blackwater, site B 10/4/95 | 1 | 1 | 1 | 94 | 1 | 1 | 0 | 1 |
| Blackwater, site D 10.4.95 | 0 | 0 | 0 | 99 | 1 | 0 | 0 | 0 |

**Table 5. Results of the X-ray diffraction analysis of the clay fraction (< 2 μm size fraction). The values are given as mass percent. The expandable mineral in the Wey sample is smectite. For the other sediments it is an illite-smectite mixed layer mineral of 60% smectite composition.**

| sample | illite | expandable | kaolinite |
|---|---|---|---|
| Wey, site C 8.5.95 | 25 | 71 | 4 |
| Gt. Ouse, site B 27.3.95 | 23 | 47 | 30 |
| Blackwater, site D 10.4.95 | 60 | 29 | 11 |
| Blackwater, site B 30.1.95 | 34 | 53 | 13 |
| Blackwater, site B 10.4.95 | 34 | 50 | 16 |

## 4. Modelling P transport

Work has continued on the analysis of the NRA data on the Gt. Ouse downstream of the Brackley STW. The computer program PNFILE has been developed and modified to enable the optimisation of the "b" and $K_p$ parameters of the P uptake model for a river section. The basic program was described in a previous report (RL/T11059J1/2). The program has been developed as follows:

1. The parameter "b" of the Elovich equation has been assigned a single value for each 1 km section. The parameter $K_p$ is also assigned a single value for the river section. These values are adjusted using the Levenberg-Marquardt method to minimise the differences between the field and generated data.
2. A contour map of the deviations between the field data and computed data may be generated for a specific range of "b" and $K_p$. This is used as a check of the occurrence of secondary minima in the deviations field.

The following information about the river sections was sought from the available data from the NRA and Anglian water:

1. Concentrations of SRP measured at as many sites as possible between Brackley and Thornborough downstream of the confluence of the Gt. Ouse and Padbury Brook between the beginning of 1991 until the end of 1994.

2. Concentrations of SRP, $Cl^-$, potassium and conductivity at Bourton Mill on the Gt. Ouse immediately upstream of the confluence with Padbury Brook, at Thornborough near the gauging station and at Padbury Brook near the confluence with the Gt. Ouse. The intention is to use these determinands to predict the discharge in the Gt. Ouse at Bourton Mill from the gauging information from Thornborough. Initial studies using samples collected on a previous field trip showed that conductivity, potassium and SRP should be good predictors for this purpose. The small differences in the chloride concentrations at the three sites shows this is likely to be a poor predictor. Data for SRP and potassium were not available for all the sites so conductivity was used as the predictor. Unfortunately the NRA data for Padbury Brook was for samples collected on different dates from that for the Gt. Ouse. Some of the sampling dates were close and these were used to calculate a mixing ratio of 0.71, i.e. the Gt. Ouse contributes 71 % of the volume of water to the flow gauged at Thornborough.

3. Discharge data from the Thornborough gauging station. This was provided by the NRA as mean daily values.

4. Discharge data from the main sewage inputs into the river section. We requested information from Anglian Water concerning three discharges. However the only data available was from the Brackley STW and this was limited to single values representing the mean daily value for each year together with the minimum and maximum values of the discharge.

5. Concentrations of SRP in the point-source inputs for Brackley STW and Westbury Grass Plot effluents were provided by the NRA. The data for Brackley were approximately bimonthly from January 1993 to August 1994. The information about the Westbury effluent was more limited with 23 values for the period from March 1991 to August 1994.

The calculation of the phosphorus profile downstream was computed by the following procedure using the mean seasonal concentration data:

1. The SRP concentrations for each season were calculated from the available NRA data. This amounted to 3-5 values each season. The $EPC_0$ values for the sediments at each sampling site were assumed the same as those measured at these sites in the summer 1995 sampling.

2. Given the SRP concentrations in the effluents, the upstream discharge and mixing ratio of the Brackley STW effluent were adjusted iteratively until the SRP concentration at Evenly Ft. Bridge (downstream of the STW input) and the discharge at Bourton Mill on the Gt. Ouse were in agreement with the field date. The mixing ratios for the Westbury and Water Stratford effluents were assumed to be 0.001. The Brackley STW effluent discharge calculated from the optimum mixing ratio and the river discharge was compared to the data provided by Anglian Water as an internal check.

3. The optimum values of the Elovich "b" parameter and parabolic parameter, $K_p$, were determined using PNFILE. The results were checked by: (i) comparing the computed SRP profile with the field data and (ii) calculating the contour map for the "b" and $K_p$ field. The phosphorus profile downstream was also computed by assuming phosphorus to be conservative.

The results of the computations completed to date are shown in Table 6. The profiles all show the decrease in SRP downstream as a result of in-stream processes such as interactions of SRP with the bed-sediments and uptake by macrophytes. The results of the intensive field work in 1994-95, of measurements of the stream flow discharge (Appendix 1), supports the assumption that other inputs of water to the river are not generally important in this section at low flow.

Further work is in progress to analyse the remaining NRA data and to apply the method to examine the data collected during the intensive sampling period. The $EPC_0$ values for the sediments at the time of sampling are available from the analysis of the fluvarium channel experiments described above. For this purpose further data as been requested from the NRA to cover the period of our intensive field work and from Anglian Water concerning the effluent discharges. The water discharges measured at each site as part of our field work will be compared with the values calculated from the Thornborough gauging information and appropriate mixing ratio. The kinetic parameters computed with PNFILE will be compared with the results from the fluvarium experiments and examined in the context of the macrophyte surveys.

**5. LOIS nutrient project**

The results of the first year of the LOIS CORE monitoring programme on nutrients (SRP, TDP, TP, nitrate, nitrite, ammonium and silicon) have been examined to estimate the loads of the individual Humber rivers into the estuary (House *et al*, 1995).The temporal changes and speciation of phosphorus in the load have been investigated. There are some important differences in the relative fractions of P transported to the estuary.

**Table 6. Results of the analysis of the NRA seasonal data using PNFILE. The parameters "a" and "b" are computed from the Elovich equation. "a" is in units of mmol $m^{-2}$ $s^{-1}$ and "b" in $m^2$ $mmol^{-1}$.**

| period | no. sampling dates | mixing ratio of Brackley STW | SRP concentration in the STW effluent/μM | a $/10^{-4}$ | b | parabolic $K_p$ / $10^{-7}$ $m^4$ $mmol^{-1}$ $s^{-1}$ |
|---|---|---|---|---|---|---|
| Summer 1992 | 3 | 0.22 | 189 | 1.62 | 0.7 | 2.6 |
| Summer 1993 | 4 | 0.22 | 89 | 0.83 | 1.5 | 3.96 |
| Summer 1994 | 3 | 0.32 | 189 | 1.85 | 0.3 | 1.8 |

All the fractions, i.e. SRP, particulate P and organic P, are important although some of the rivers transport more of one fraction than others. For example the R. Swale transports predominantly particulate P whereas the organic P or hydrolysable P is the main fraction transported in the R. Wharfe. In contrast the R. Trent transports mainly SRP. There are also noticeable differences between the exports of nutrients from the upland catchments compared with the more contaminated lowland industrial catchments such as the rivers Aire and Calder.

More intensive monitoring of the R. Swale catchment between Catterick and York has shown the importance of the major (Bedale Beck, R. Wiske and Cod Beck) and minor tributaries (15 streams) to the phosphorus exports to the Humber. The major tributaries are strongly influenced by STW inputs. Further work is evaluating the importance of in-stream processes for phosphorus and the other nutrients in the 54 km section of the R. Swale with intensive monitoring of main river sites, major tributaries and daily monitoring of the minor streams.

## 6. Future Research

Field work on the Gt. Ouse and R. Wey is now complete. The main effort on these rivers will be on the analysis of the field data and modelling both the field data and NRA data. Seasonal field work on the R. Blackwater will continue in the hope that the introduction of the tertiary treatment plant at Aldershot will fall within the lifetime of the project. Part of the funds for this project have been reallocated to 1997 so that completion is now scheduled for December 1997. Meanwhile if changes are made on the sewage treatment at Brackley or Alton, further field work will be continued to assess changes in the river sediments and nutrient chemistry at downstream sites.

The results from some of the sediments are unexpected, particularly from the fluvarium release of SRP experiments. It is hoped to do further research to understand the kinetics. It is clear that some sediments release SRP to water so that concentrations far in access of the $EPC_0$ are obtained. There is also some indication that mineralisation reaction are occurring

in the sediments of rivers Wey and Ouse. This possibility will also be examined with laboratory experiments using filtered river waters containing appropriate nucleating agents.

REFERENCES

Andersen, J.M. (1976) An ignition method for the determination of total phosphorus in lake sediments. Wat. Res. **10**, 329-331.

He, Z.L., Yang, K.N. and Zhu, Z.X. (1994) Desorption and plant availability of phosphate sorbed by some important minerals, Plant and Soil, **162**, 89-97.

House, W.A., Leach, D., Warwick, M., Whitton, B.A., Pattinson, S.N., Ryland, G., Pinder, A., Ingram, J., Lishman, J.P., Smith, S.M., Rigg, E. and Denison, F.H. (submitted), J. Tot. Environ.

House, W.A., Denison, F.H. and Armitage, P.D. (1995a) Comparison of the uptake of inorganic phosphorus to a suspended and stream bed-sediment. Wat. Res., **29**, 767-779.

House, W.A., Denison, F.H., Smith, J.T. and Armitage, P.D. (1995b) An investigation of the effects of water velocity on inorganic phosphorus influx to a sediment, Envir. Poll., **89**, 263-271.

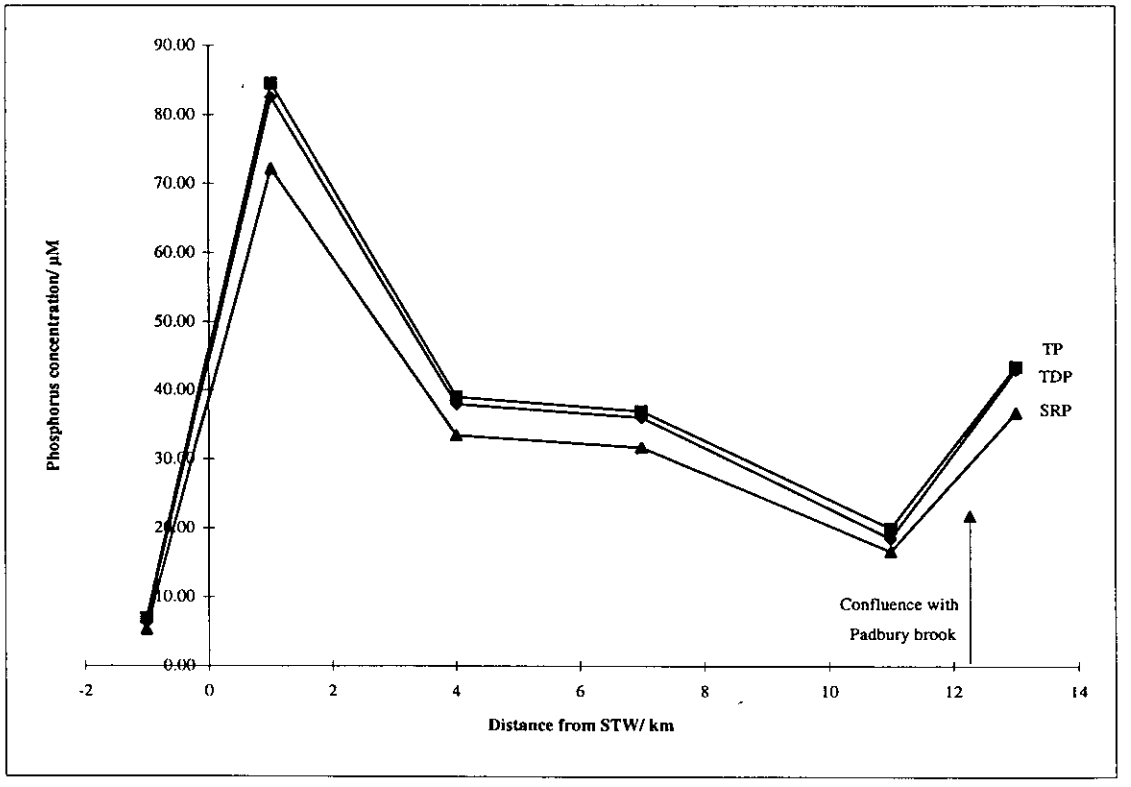
Sharpley, A.N. (1993) An innovative approach to estimate bioavailable phosphorus in agricultural runoff using iron oxide impregnated paper. J. Environ. Qual. **22**, 597-601.

Marker, A.F.H. and Casey, H. (1982) The population and production dynamics of benthic algae in an artificial recirculating hardwater stream. Phil. Trans. R. Soc. Lond., B298, 265-308.

# APPENDIX 1

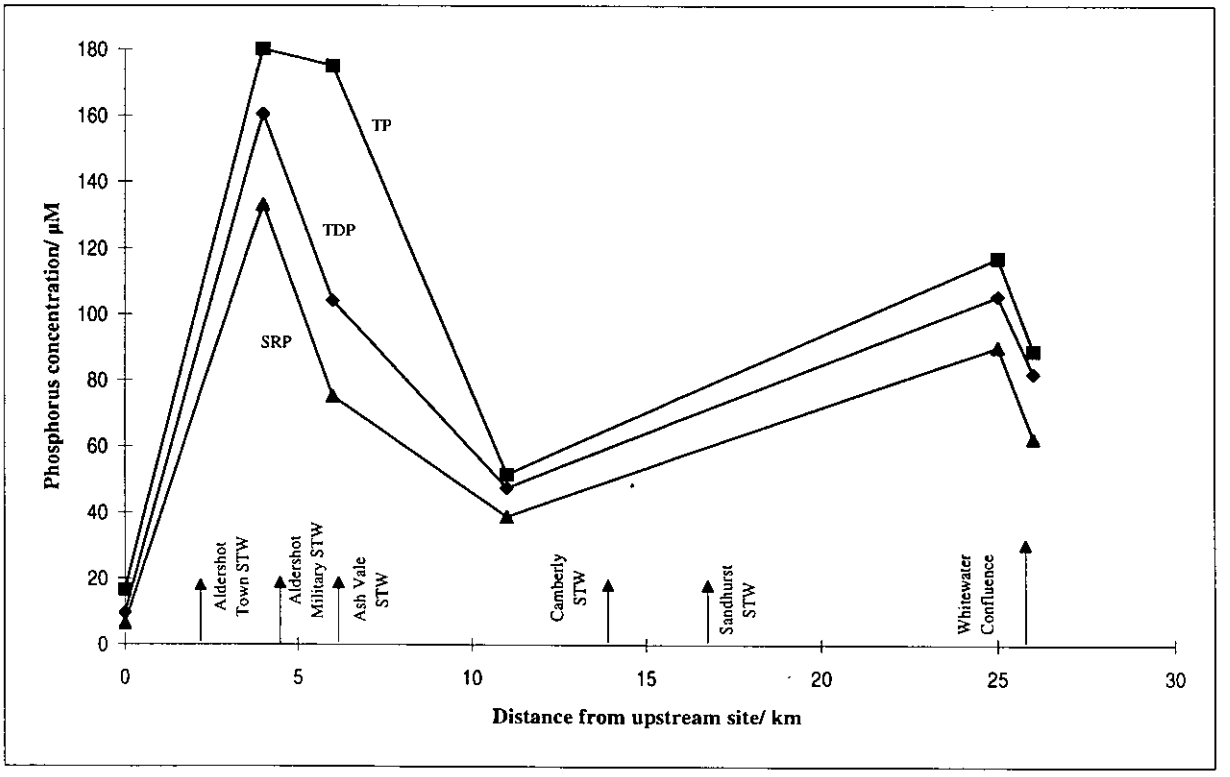
**SITE VISIT TO GT. OUSE**
**10/7/95**

| SITE | A | B | C | D | G | E (Padbury brook) | F |
|---|---|---|---|---|---|---|---|
| NGR of site | SP595 368 | SP 602 358 | SP 627 346 | SP 652 341 | SP 717 344 | SP 729 332 | SP 738 355 |
| Distance from STW/ km | -1 | 1 | 4 | 7 | 11 | | 13 |
| pH | 8.06 | 7.70 | 8.20 | 7.87 | 7.70 | 8.18 | 7.78 |
| Conductivity (µS/cm) | 811 | 981 | 871 | 882 | 874 | 810 | 865.00 |
| Dissolved Oxygen (%) | 106 | 93 | 138 | 101 | 99 | 87 | 93.00 |
| Temperature | 19.6 | 20.3 | 20.8 | 21.3 | 19.3 | 23.1 | 20.90 |
| Flow (m^3/s) | 0.05 | 0.16 | 0.14 | 0.15 | | | |
| Filtered water (0.45 µm) | | | | | | | |
| Ca++ (mM) | 3.75 | 3.71 | 3.61 | 3.71 | 3.58 | 3.49 | 3.53 |
| Mg++ (mM) | 0.23 | 0.28 | 0.22 | 0.22 | 0.26 | 0.33 | 0.29 |
| Na+ (mM) | 0.77 | 2.44 | 1.39 | 1.48 | 1.19 | 1.33 | 1.43 |
| K+ (mM) | 0.101 | 0.237 | 0.208 | 0.217 | 0.163 | 0.199 | 0.208 |
| Alkalinity (m Eq) | 5.43 | 4.07 | 4.62 | 4.57 | 4.87 | 4.44 | 4.75 |
| NO3- (mM) | 0.53 | 1.17 | 0.80 | 0.86 | 0.61 | 0.21 | 0.55 |
| Silicon (µM) | 147.8 | 206.2 | 167.7 | 170.2 | 144.2 | 91.9 | 135.7 |
| Soluble Reactive Phosphorus (µM) | 5.31 | 72.16 | 33.42 | 31.64 | 16.63 | 28.90 | 36.81 |
| Total Dissolved Phosphorus (µM) | 6.35 | 82.50 | 38.00 | 36.00 | 18.50 | 37.00 | 43.00 |
| Non - MR Reactive fraction (µM) | 1.04 | 10.34 | 4.58 | 4.36 | 1.87 | 8.10 | 6.19 |
| Unfiltered water | | | | | | | |
| Total Phosphorus (µM) | 7.00 | 84.50 | 39.00 | 37.00 | 20.00 | 39.00 | 43.50 |
| Particulate Phosphorus (µM) | 0.65 | 2.00 | 1.00 | 1.00 | 1.50 | 2.00 | 0.50 |
| Suspended Solids (mg/l) | 4.1 | 12.5 | 4.9 | 6.6 | 2.3 | 6.5 | 7.5 |
| Sediment sieved 2mm | | | | | | | |
| % water | 26.18 | 25.54 | 27.84 | 17.06 | | | |
| Organic Matter (% of dry wt) | 3.77 | 2.78 | 2.61 | 2.05 | | | |
| Total Phosphorus (µmol/g) | 43.50 | 26.91 | 22.45 | 25.87 | | | |
| Total Calcium (µmol/g) | 3014 | 4098 | 4580 | 4605 | | | |
| Total Iron (µmol/g) | 286.0 | 456.0 | 437.0 | 465.0 | | | |
| Bioavailable Phosphorus (µmol/g) | 0.65 | 1.25 | 1.85 | 1.11 | | | |
| Equilibrium Phosphorus Concentration (µM) | 0.33 | 1.92 | 5.67 | 3.40 | | | |
| Kd (dm^3/kg) | 524.6 | 203.0 | 103.2 | 90.6 | | | |
| ni (µmol/g) | 0.171 | 0.390 | 0.585 | 0.308 | | | |



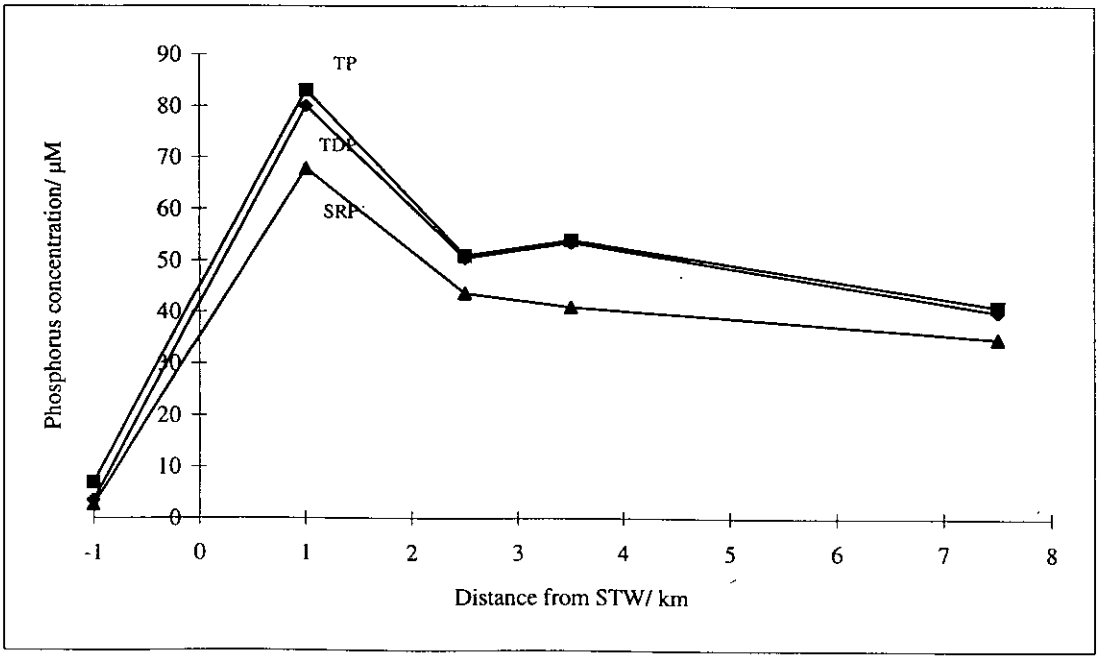
**SITE VISIT TO RIVER BLACKWATER**
**21/7/1995**

| SITE | A | B | C | D | E | G (Whitewater) | F |
|---|---|---|---|---|---|---|---|
| NGR of site | SU 882 499 | SU 885 538 | SU 880 559 | SU 859 594 | SU 742 634 | SU 742 635 | SU 740 638 |
| Distance from upstream site/ km | 0 | 4 | 6 | 11 | 25 | | 26 |
| pH | 7.27 | 7.21 | 7.88 | 7.92 | 7.84 | 8.00 | 8.01 |
| Conductivity (µS/cm) | 683 | 861 | 863 | 715 | 783 | 600 | 729 |
| Dissolved Oxygen (%) | 58 | 90 | 134 | 133 | | | |
| Temperature | 20.7 | 18.1 | 24.7 | 25.4 | | | |
| Flow (m^3/s) | ND | 0.11 | 0.15 | 0.25 | | | |
| Filtered water (0.45 µm) | | | | | | | |
| Ca++ (mM) | 2.24 | 2.44 | 2.45 | 1.98 | 2.44 | 2.38 | 2.49 |
| Mg++ (mM) | 0.26 | 0.30 | 0.27 | 0.25 | 0.29 | 0.13 | 0.23 |
| Na+ (mM) | 0.87 | 2.81 | 2.69 | 2.28 | 2.63 | 0.89 | 2.41 |
| K+ (mM) | 0.077 | 0.367 | 0.309 | 0.251 | 0.331 | 0.102 | 0.262 |
| Alkalinity (mEq) | 4.16 | 3.73 | 3.55 | 3.01 | 3.02 | 4.07 | 3.37 |
| NO3- (mM) | 0.14 | 0.84 | 0.57 | 0.31 | 0.47 | 0.36 | 0.43 |
| Silicon (µM) | 204 | 445 | 395 | 350 | 352 | 198 | 289 |
| Soluble Reactive Phosphorus (µM) | 6.49 | 133.01 | 75.22 | 38.74 | 90.08 | 25.34 | 62.31 |
| Total Dissolved Phosphorus (µM) | 9.50 | 160.50 | 104.00 | 47.50 | 105.50 | 30.00 | 82.00 |
| Non - MR Reactive fraction (µM) | 3.01 | 27.49 | 28.78 | 8.76 | 15.42 | 4.66 | 19.69 |
| Unfiltered water | | | | | | | |
| Total Phosphorus (µM) | 16.5 | 180 | 175 | 51.5 | 117 | 34.5 | 89 |
| Particulate Phosphorus (µM) | 7.00 | 19.50 | 71.00 | 4.00 | 11.50 | 4.50 | 7.00 |
| Suspended Solids (mg/l) | 11.0 | 7.2 | 3.6 | 2.9 | 5.0 | 7.2 | 5.6 |
| Sediment sieved 2mm | | | | | | | |
| % water | 38.54 | 25.34 | 23.99 | 23.50 | | | |
| Organic Matter (% of dry wt) | 4.06 | 1.51 | 1.68 | 1.62 | | | |
| Total Phosphorus (µmol/g) | 11.50 | 1.65 | 112.72 | 92.16 | | | |
| Total Calcium (µmol/g) | 4189.0 | 42.6 | 113.3 | 63.4 | | | |
| Total Iron (µmol/g) | 507.8 | 187.5 | 377.4 | 327.6 | | | |
| Bioavailable Phosphorus (µmol/g) | 0.77 | 0.55 | 6.39 | 7.01 | | | |
| Equilibrium Phosphorus Concentration (µM) | 0.34 | 0.17 | 7.12 | 3.81 | | | |
| Kd (dm^3/kg) | 1266.2 | | 176.2 | 219.6 | | | |
| ni (µmol/g) | 0.435 | | 1.254 | 0.837 | | | |



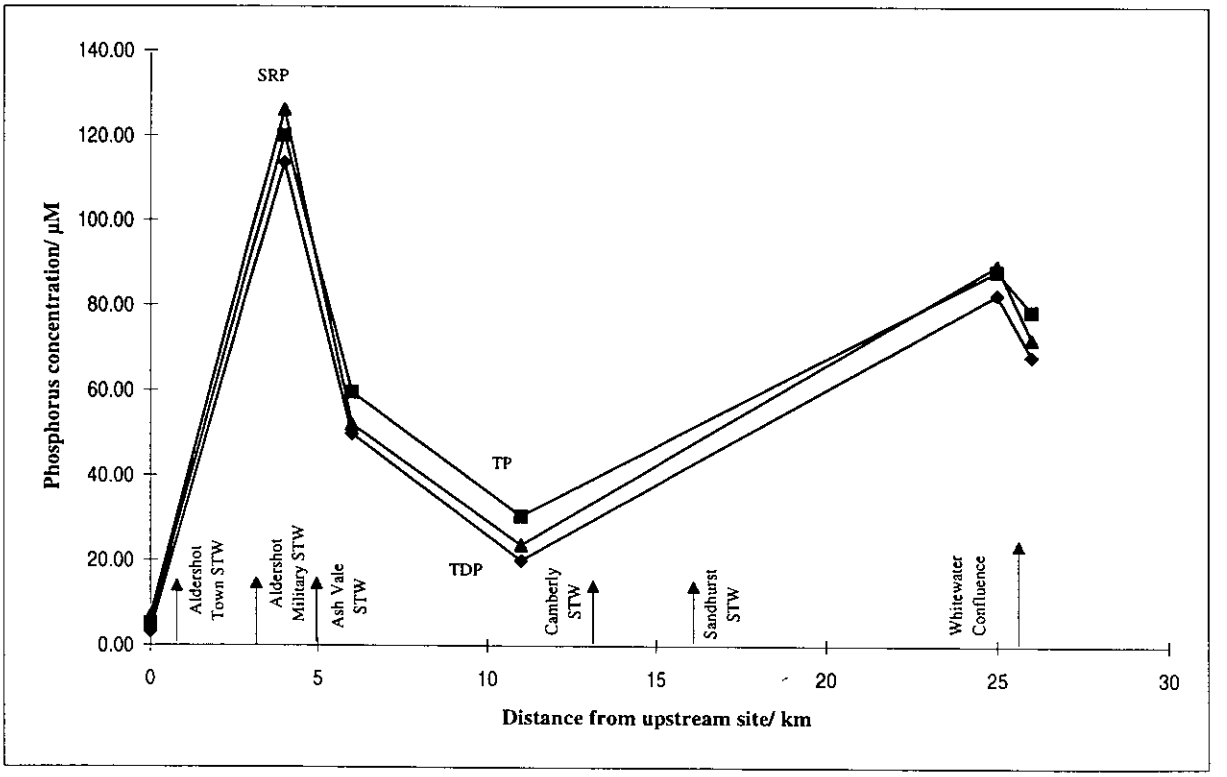
**SITE VISIT TO RIVER WEY**
**7/8/95**

| SITE | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| NGR of site | SU 724 396 | SU 730 387 | SU 733 403 | SU 745 412 | SU 756 417 | SU 786 432 |
| Distance from STW/ km | -1 | Tributary | 1 | 2.5 | 3.5 | 7.5 |
| pH | 7.30 | No Flow | 7.29 | 7.67 | 7.64 | 7.93 |
| Conductivity (µS/cm) | 681 | xxxx | 818 | 746 | 764 | 741 |
| Dissolved Oxygen (%) | 53 | xxxx | 60 | 67 | 73 | 72 |
| Temperature | 19.6 | xxxx | 19.5 | 19.2 | 17.9 | 17.9 |
| Flow (m^3/s) | 0.05 | xxxx | 0.15 | 0.19 | 0.19 | |
| Filtered water (0.45 µm) | | | | | | |
| Ca++ (mM) | 2.86 | xxxx | 3.01 | 3.03 | 3.02 | 3.12 |
| Mg++ (mM) | 0.09 | xxxx | 0.11 | 0.10 | 0.10 | 0.10 |
| Na+ (mM) | 0.87 | xxxx | 2.14 | 1.60 | 1.75 | 1.41 |
| K+ (mM) | 0.047 | xxxx | 0.171 | 0.132 | 0.138 | 0.126 |
| Alkalinity (mM) | 5.63 | xxxx | 6.04 | 6.08 | 6.06 | 6.25 |
| NO3- (mM) | 0.25 | xxxx | 0.68 | 0.50 | 0.49 | 0.32 |
| Silicon (µM) | 191 | xxxx | 304 | 256 | 299 | 308 |
| Soluble Reactive Phosphorus (µM) | 2.58 | xxxx | 67.80 | 43.58 | 41.00 | 34.87 |
| Total Dissolved Phosphorus (µM) | 3.50 | xxxx | 80.00 | 50.50 | 53.50 | 40.00 |
| Non - MR Reactive fraction (µM) | 0.92 | xxxx | 12.20 | 6.92 | 12.50 | 5.13 |
| Unfiltered water | | | | | | |
| Total Phosphorus (µM) | 7.00 | xxxx | 83.00 | 51.00 | 54.00 | 41.00 |
| Particulate Phosphorus (µM) | 3.50 | xxxx | 3.00 | 0.50 | 0.50 | 1.00 |
| Suspended Solids (mg/l) | 8.6 | xxxx | 4.5 | 5.6 | 4.1 | 3.1 |
| Sediment sieved 2mm | | | | | | |
| % water | 39.48 | xxxx | 25.91 | 36.12 | 29.39 | 28.91 |
| Organic Matter (% of dry wt) | 5.98 | xxxx | 2.67 | 4.19 | 3.87 | 2.34 |
| Total Phosphorus (µmol/g) | 2.73 | xxxx | 28.93 | 216.77 | 40.41 | 45.29 |
| Total Calcium (µmol/g) | 1204 | xxxx | 1692 | 1460 | 1138 | 1441 |
| Total Iron (µmol/g) | 348.0 | xxxx | 146.5 | 708.2 | 175.8 | 115.4 |
| Bioavailable Phosphorus (µmol/g) | 0.97 | xxxx | 1.71 | 2.51 | 1.78 | 1.14 |
| Equilibrium Phosphorus Concentration (µM) | 0.45 | xxxx | 5.33 | 2.47 | 3.97 | 4.09 |
| Kd (dm^3/kg) | 691.2 | xxxx | 70.3 | 444.9 | 131.1 | 103.3 |
| ni (µmol/g) | 0.311 | xxxx | 0.375 | 1.100 | 0.521 | 0.423 |



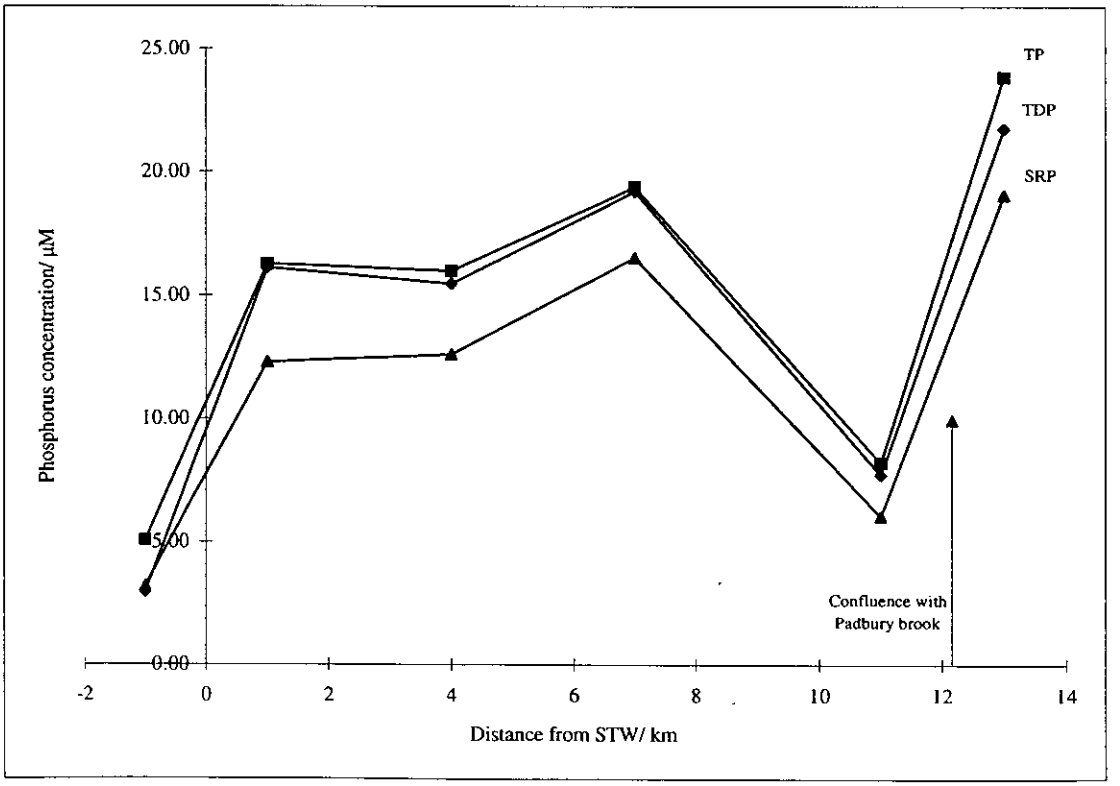
**SITE VISIT TO RIVER BLACKWATER**
**23/10/1995**

| SITE | A | B | C | D | E | G (Whitewater) | F |
|---|---|---|---|---|---|---|---|
| NGR of site | SU 882 499 | SU 885 538 | SU 880 559 | SU 859 594 | SU 742 634 | SU 742 635 | SU 740 638 |
| Distance from upstream site/ km | 0 | 4 | 6 | 11 | 25 | | 26 |
| pH | 7.89 | 7.36 | 7.58 | 7.64 | 7.71 | 7.78 | 7.78 |
| Conductivity (µS/cm) | 521 | 816 | 742 | 636 | 793 | 674 | 769 |
| Dissolved Oxygen (%) | 65 | 70 | 83 | 92 | | | |
| Temperature | 11.8 | 13.1 | 13.9 | 12.6 | | | |
| Flow (m^3/s) | ND | ND | ND | ND | | | |
| Filtered water (0.45 µm) | | | | | | | |
| Ca++ (mM) | 1.88 | 2.19 | 2.15 | 1.86 | 2.21 | 2.49 | 1.98 |
| Mg++ (mM) | 0.25 | 0.34 | 0.29 | 0.28 | 0.30 | 0.20 | 0.26 |
| Na+ (mM) | 1.50 | 2.57 | 1.99 | 1.59 | 2.00 | 1.52 | 1.74 |
| K+ (mM) | 0.243 | 0.365 | 0.598 | 0.261 | 0.326 | 0.404 | 0.280 |
| Alkalinity (mEq) | 3.38 | 3.47 | 3.35 | 2.62 | 2.67 | 3.68 | 2.19 |
| NO3- (mM) | 0.14 | 0.91 | 0.51 | 0.40 | 0.76 | 0.48 | 0.63 |
| Silicon (µM) | 159 | 393 | 370 | 265 | 422 | 272 | 397 |
| Soluble Reactive Phosphorus (µM) | 6.84 | 125.91 | 51.98 | 23.60 | 89.43 | 46.49 | 72.00 |
| Total Dissolved Phosphorus (µM) | 3.10 | 113.50 | 49.70 | 20.00 | 82.50 | 40.29 | 67.99 |
| Non - MR Reactive fraction (µM) | -3.74 | -12.41 | -2.28 | -3.60 | -6.93 | -6.20 | -4.00 |
| Unfiltered water | | | | | | | |
| Total Phosphorus (µM) | 5.10 | 120.00 | 59.50 | 30.50 | 88.00 | 46.20 | 78.50 |
| Particulate Phosphorus (µM) | 2.00 | 6.51 | 9.80 | 10.50 | 5.50 | 5.91 | 10.51 |
| Suspended Solids (mg/l) | 2.5 | 2.1 | 4.3 | 6.1 | 7.2 | 4.0 | 6.4 |
| Sediment sieved 2mm | | | | | | | |
| % water | 42.38 | 37.80 | 18.25 | 19.74 | | | |
| Organic Matter (% of dry wt) | 7.63 | 6.49 | 1.26 | 0.81 | | | |
| Total Phosphorus (µmol/g) | 22.29 | 90.83 | 41.66 | 38.81 | | | |
| Total Calcium (µmol/g) | 6833.0 | 3927.5 | 831.9 | 46.7 | | | |
| Total Iron (µmol/g) | 340.8 | 299.6 | 252.8 | 172.6 | | | |
| Bioavailable Phosphorus (µmol/g) | 0.91 | 3.07 | 3.75 | 4.85 | | | |
| Equilibrium Phosphorus Concentration (µM) | 0.27 | 1.88 | 6.09 | 7.85 | | | |
| Kd (dm^3/kg) | 6121.1 | 2418.2 | 256.9 | 197.8 | | | |
| ni (µmol/g) | 1.668 | 4.548 | 1.565 | 1.553 | | | |



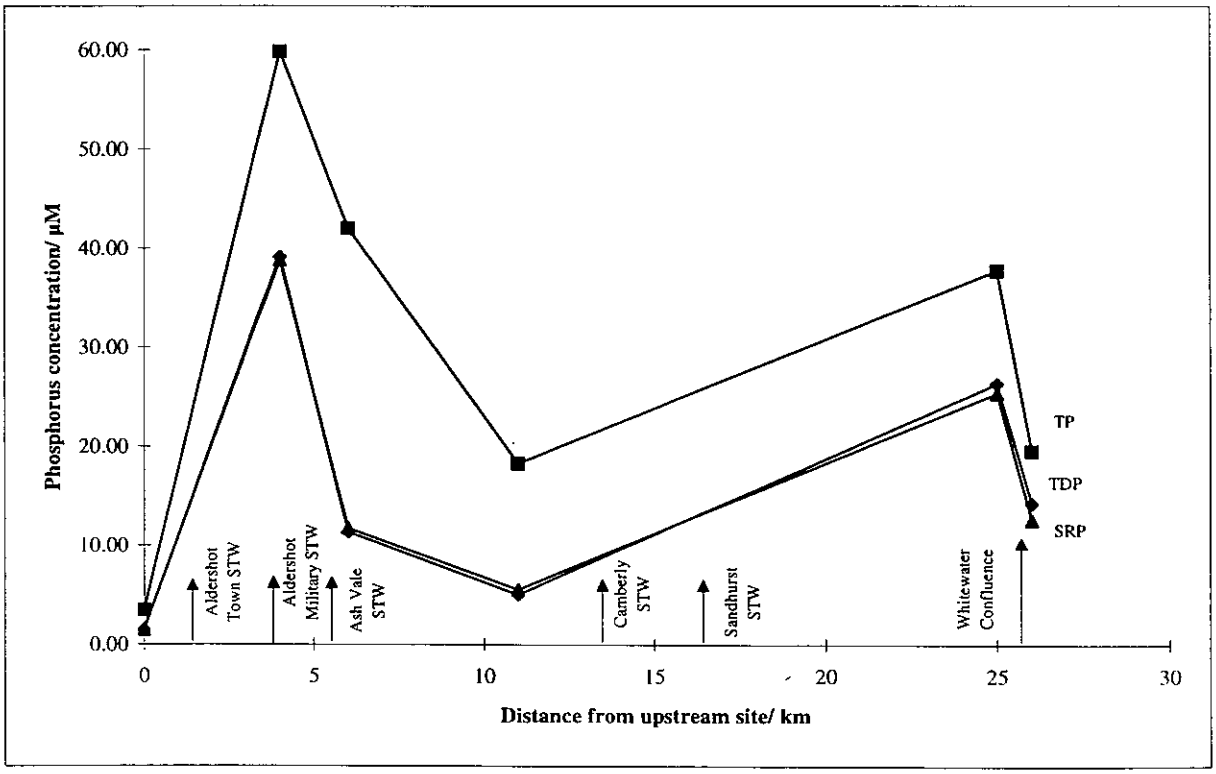
**SITE VISIT TO GT. OUSE**
**15/11/1995**

| SITE | A | B | C | D | G | E (Padbury brook) | F |
|---|---|---|---|---|---|---|---|
| NGR of site | SP595 368 | SP 602 358 | SP 627 346 | SP 652 341 | SP 717 344 | SP 713 315 | SP 738 355 |
| Distance from STW/ km | -1 | 1 | 4 | 7 | 11 | | 13 |
| pH | 8.09 | 8.19 | 8.26 | 8.19 | 7.93 | 7.99 | 7.97 |
| Conductivity (µS/cm) | 877 | 909 | 830 | 922 | 851 | 758 | 942.00 |
| Dissolved Oxygen (%) | 76 | 79 | 81 | 87 | 81 | 81 | 81.00 |
| Temperature | 11.0 | 11.9 | 11.1 | 11.1 | 10.8 | 11.2 | 10.9 |
| Flow (m^3/s) | 0.10 | 0.22 | 0.28 | 0.27 | | | |
| Filtered water (0.45 µm) | | | | | | | |
| Ca++ (mM) | 4.05 | 3.63 | 3.61 | 3.66 | 3.67 | 3.65 | 3.88 |
| Mg++ (mM) | 0.23 | 0.23 | 0.21 | 0.23 | 0.24 | 0.45 | 1.54 |
| Na+ (mM) | 0.82 | 2.05 | 1.36 | 2.58 | 0.99 | 1.41 | 1.31 |
| K+ (mM) | 0.674 | 1.335 | 1.097 | 1.408 | 0.802 | 1.404 | 1.413 |
| Alkalinity (mEq) | 5.13 | 4.51 | 4.99 | 4.49 | 4.50 | 3.94 | 4.12 |
| NO3- (mM) | 0.75 | 0.60 | 0.66 | 0.66 | 0.69 | 1.19 | 0.96 |
| Silicon (µM) | 154 | 140 | 141 | 140 | 128 | 149 | 141 |
| Soluble Reactive Phosphorus (µM) | 3.20 | 12.30 | 12.59 | 16.53 | 6.04 | 14.85 | 19.08 |
| Total Dissolved Phosphorus (µM) | 2.94 | 16.10 | 15.45 | 19.21 | 7.72 | 17.63 | 21.75 |
| Non - MR Reactive fraction (µM) | -0.26 | 3.80 | 2.86 | 2.68 | 1.68 | 2.78 | 2.67 |
| Unfiltered water | | | | | | | |
| Total Phosphorus (µM) | 5.04 | 16.27 | 15.99 | 19.37 | 8.21 | 18.03 | 23.87 |
| Particulate Phosphorus (µM) | 2.10 | 0.17 | 0.54 | 0.17 | 0.49 | 0.40 | 2.11 |
| Suspended Solids (mg/l) | 2.1 | 1.6 | 1.4 | 2.3 | 6.4 | 1.7 | 16.6 |
| Sediment sieved 2mm | | | | | | | |
| % water | 22.35 | 35.91 | 19.71 | 19.98 | | | |
| Organic Matter (% of dry wt) | 7.31 | 10.22 | 6.96 | 7.59 | | | |
| Total Phosphorus (µmol/g) | 15.37 | 33.75 | 29.27 | 49.33 | | | |
| Total Calcium (µmol/g) | 4123 | 2976 | 3883 | 3346 | | | |
| Total Iron (µmol/g) | 490.4 | 460.2 | 827.5 | 674.7 | | | |
| Bioavailable Phosphorus (µmol/g) | 0.76 | 1.83 | 1.17 | 1.15 | | | |
| Equilibrium Phosphorus Concentration (µM) | 1.65 | 1.07 | 9.88 | 3.79 | | | |
| Kd (dm^3/kg) | 241.8 | 610.6 | 60.5 | 122.2 | | | |
| ni (µmol/g) | 0.399 | 0.654 | 0.598 | 0.463 | | | |



**SITE VISIT TO RIVER BLACKWATER**
**17/1/1996**

| SITE | A | B | C | D | E | G (Whitewater) | F |
|---|---|---|---|---|---|---|---|
| NGR of site | SU 882 499 | SU 885 538 | SU 880 559 | SU 859 594 | SU 742 634 | SU 742 635 | SU 740 638 |
| Distance from upstream site/ km | 0 | 4 | 6 | 11 | 25 | | 26 |
| pH | 6.20 | 7.45 | 6.53 | 7.45 | 7.42 | 7.37 | 7.43 |
| Conductivity (µS/cm) | 563 | 771 | 738 | 631 | 637 | 557 | 623 |
| Dissolved Oxygen (%) | 76 | 67 | 68 | 79 | | | |
| Temperature | 9.0 | 9.2 | 9.4 | 10.2 | | | |
| Flow (m^3/s) | 0.05 | 0.34 | 0.56 | 0.67 | | | |
| Filtered water (0.45 µm) | | | | | | | |
| Ca++ (mM) | 2.00 | 2.25 | 2.10 | 1.89 | 1.87 | 1.81 | 2.01 |
| Mg++ (mM) | 0.31 | 0.37 | 0.35 | 0.31 | 0.29 | 0.28 | 0.24 |
| Na+ (mM) | 0.57 | 1.48 | 1.68 | 1.29 | 1.73 | 1.38 | 0.91 |
| K+ (mM) | 0.098 | 0.239 | 0.181 | 0.137 | 0.177 | 0.150 | 0.070 |
| Alkalinity (mEq) | 2.90 | 3.31 | 2.98 | 2.44 | 2.12 | 2.34 | 2.96 |
| NO3- (mM) | 0.32 | 0.48 | 0.46 | 0.37 | 0.49 | 0.50 | 0.53 |
| Silicon (µM) | 178 | 239 | 256 | 269 | 276 | 267 | 221 |
| Soluble Reactive Phosphorus (µM) | 1.48 | 38.74 | 11.72 | 5.57 | 25.34 | 22.28 | 12.56 |
| Total Dissolved Phosphorus (µM) | 1.50 | 39.09 | 11.34 | 5.02 | 26.30 | 23.76 | 14.28 |
| Non - MR Reactive fraction (µM) | 0.02 | 0.34 | -0.38 | -0.55 | 0.95 | 1.49 | 1.72 |
| Unfiltered water | | | | | | | |
| Total Phosphorus (µM) | 3.47 | 59.83 | 41.98 | 18.24 | 37.76 | 33.78 | 19.54 |
| Particulate Phosphorus (µM) | 1.98 | 20.75 | 30.64 | 13.22 | 11.46 | 10.01 | 5.26 |
| Suspended Solids (mg/l) | 14.4 | 20.4 | 22.3 | 10.8 | 11.8 | 12.0 | 6.9 |
| Sediment sieved 2mm | | | | | | | |
| % water | 63.03 | 34.24 | 52.07 | 18.27 | | | |
| Organic Matter (% of dry wt) | 13.10 | 4.88 | 6.17 | 0.98 | | | |
| Total Phosphorus (µmol/g) | 55.11 | 85.73 | 300.52 | 52.37 | | | |
| Total Calcium (µmol/g) | 712.3 | 219.8 | 284.9 | 40.5 | | | |
| Total Iron (µmol/g) | 529.8 | 253.8 | 864.6 | 229.2 | | | |
| Bioavailable Phosphorus (µmol/g) | 1.38 | 3.48 | 9.69 | 4.33 | | | |
| Equilibrium Phosphorus Concentration (µM) | 0.18 | 3.00 | 3.95 | 7.33 | | | |
| Kd (dm^3/kg) | 10668.0 | 724.3 | 980.9 | 116.7 | | | |
| ni (µmol/g) | 1.931 | 2.170 | 3.877 | 0.855 | | | |



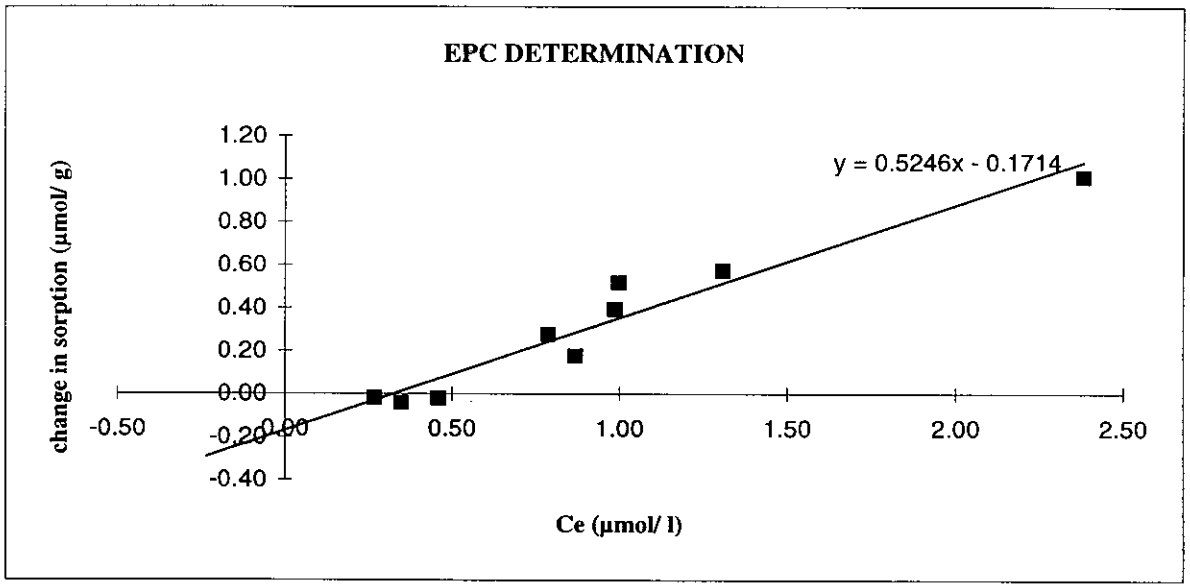
# APPENDIX 2

**SITE A GREAT OUSE. SEDIMENT & WATER COLLECTED 10-11/7/95**

| EPCo DETERMINATION: ANALYSIS 18/7/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 2.26 | 1.67 | 0 | 0.35 | -0.04 |
| 2.10 | 1.55 | 5 | 1.00 | 0.52 |
| 2.04 | 1.51 | 10 | 2.38 | 1.01 |
| 4.20 | 3.10 | 0 | 0.27 | -0.02 |
| 4.10 | 3.03 | 5 | 0.79 | 0.28 |
| 4.11 | 3.03 | 10 | 1.31 | 0.57 |
| 6.17 | 4.55 | 0 | 0.46 | -0.02 |
| 6.32 | 4.66 | 5 | 0.87 | 0.18 |
| 6.22 | 4.59 | 10 | 0.99 | 0.39 |

% WATER OF SEDIMENT = 26.18
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 3.77
TOTAL PHOSPHORUS OF SEDIMENT = 43.5 µmol/ g

SRP OF WATER = 5.31 µM
TDP OF WATER = 6.35 µM
TP OF WATER = 7.00 µM
EPCo = 0.33 µM
Kd = 524.6 l/kg
ni = 0.17 µmol/g

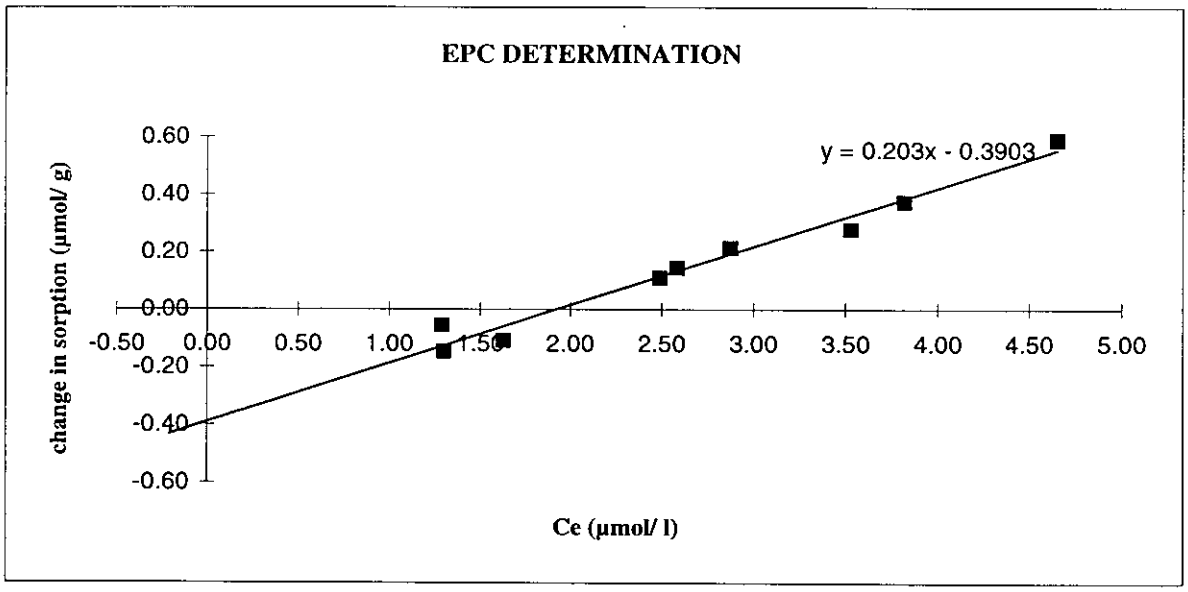


**SITE B GREAT OUSE. SEDIMENT & WATER COLLECTED 10-11/7/95**

| EPCo DETERMINATION: ANALYSIS 18/7/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 2.39 | 1.78 | 0 | 1.30 | -0.15 |
| 2.68 | 2.00 | 5 | 2.87 | 0.21 |
| 2.44 | 1.82 | 10 | 4.65 | 0.59 |
| 4.02 | 2.99 | 0 | 1.63 | -0.11 |
| 4.50 | 3.35 | 5 | 2.59 | 0.14 |
| 4.44 | 3.31 | 10 | 3.82 | 0.37 |
| 6.11 | 4.55 | 0 | 1.29 | -0.06 |
| 6.25 | 4.65 | 5 | 2.49 | 0.11 |
| 6.24 | 4.65 | 10 | 3.53 | 0.28 |

% WATER OF SEDIMENT = 25.54
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 2.78
TOTAL PHOSPHORUS OF SEDIMENT = 26.91 µmol/ g

SRP OF WATER = 72.16 µM
TDP OF WATER = 82.50 µM
TP OF WATER = 84.50 µM
EPCo = 1.92 µM
Kd = 203.0 l/kg
ni = 0.39 µmol/g

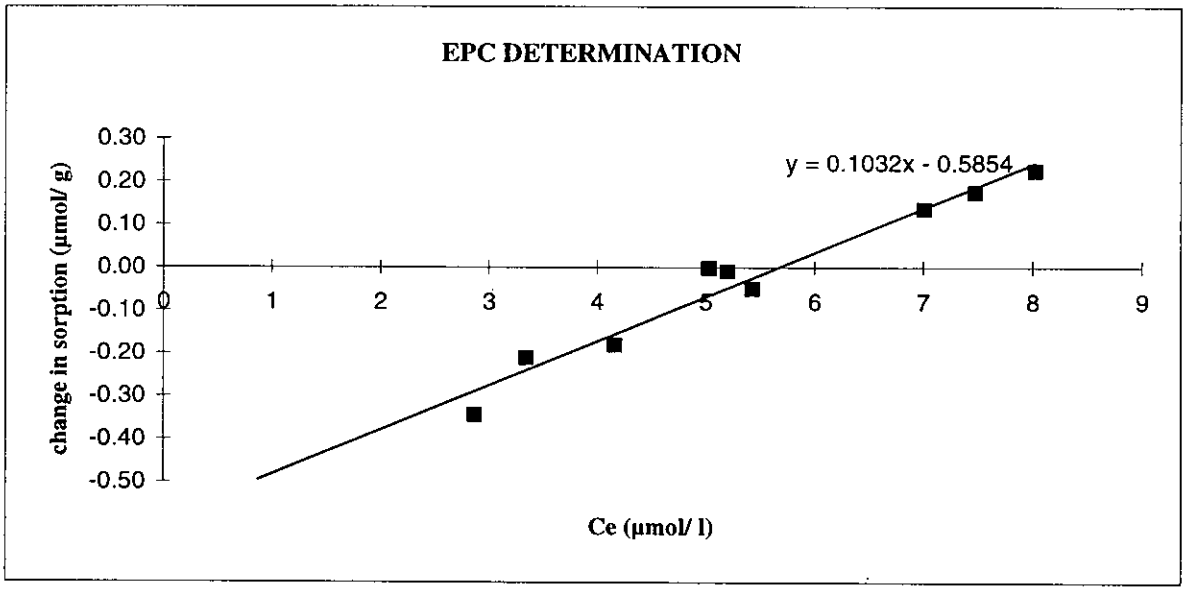


**SITE C GREAT OUSE. SEDIMENT & WATER COLLECTED 10-11/7/95**

| EPCo DETERMINATION: ANALYSIS 18/7/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 2.32 | 1.67 | 0 | 2.87 | -0.34 |
| 2.44 | 1.76 | 5 | 5.43 | -0.05 |
| 2.43 | 1.75 | 10 | 8.03 | 0.23 |
| 4.40 | 3.18 | 0 | 3.34 | -0.21 |
| 4.19 | 3.03 | 5 | 5.03 | 0.00 |
| 4.00 | 2.89 | 10 | 7.47 | 0.18 |
| 6.36 | 4.59 | 0 | 4.16 | -0.18 |
| 6.14 | 4.43 | 5 | 5.20 | -0.01 |
| 6.13 | 4.42 | 10 | 7.01 | 0.14 |

% WATER OF SEDIMENT = 27.84
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 2.61 %
TOTAL PHOSPHORUS OF SEDIMENT = 22.45 µmol/ g

SRP OF WATER = 33.42 µM
TDP OF WATER = 38.0 µM
TP OF WATER = 39.0 µM
EPCo = 5.67 µM
Kd = 103.2 l/kg
ni = 0.59 µmol/g

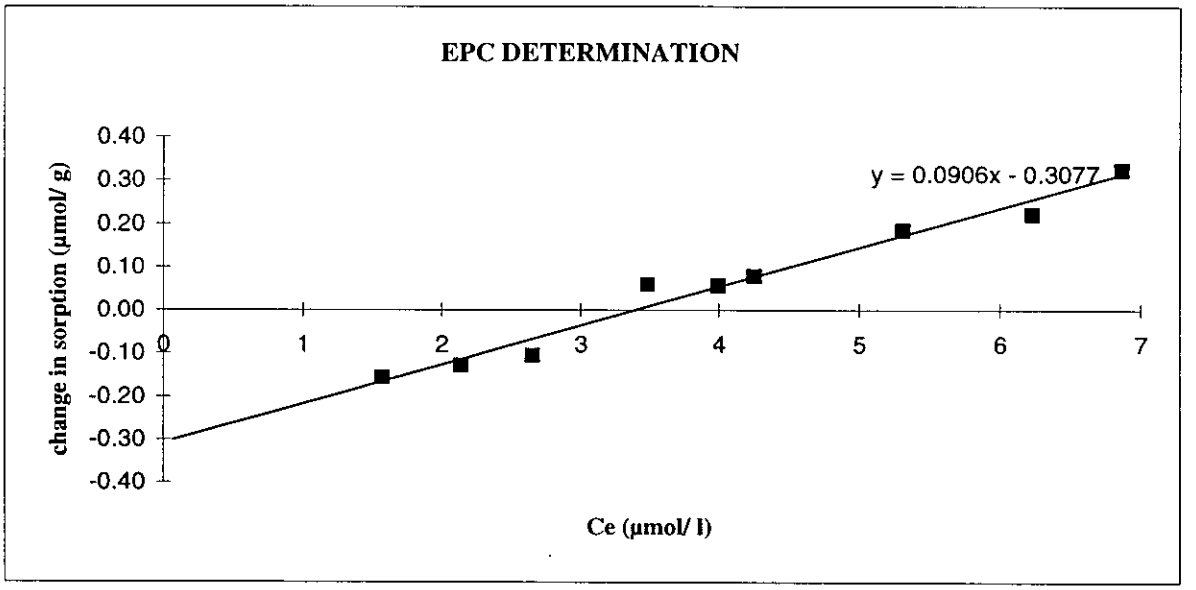


SITE D GREAT OUSE. SEDIMENT & WATER COLLECTED 10-11/7/95

| EPCo DETERMINATION: ANALYSIS 18/7/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 2.43 | 2.01 | 0 | 1.57 | -0.16 |
| 2.29 | 1.90 | 5 | 4.25 | 0.08 |
| 2.33 | 1.93 | 10 | 6.87 | 0.32 |
| 4.01 | 3.33 | 0 | 2.14 | -0.13 |
| 4.26 | 3.54 | 5 | 3.99 | 0.06 |
| 4.09 | 3.40 | 10 | 6.23 | 0.22 |
| 6.02 | 5.00 | 0 | 2.66 | -0.11 |
| 6.12 | 5.08 | 5 | 3.49 | 0.06 |
| 6.13 | 5.08 | 10 | 5.31 | 0.18 |

% WATER OF SEDIMENT = 17.06
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 2.05 %
TOTAL PHOSPHORUS OF SEDIMENT = 25.87 µmol/ g

SRP OF WATER = 31.64 µM
TDP OF WATER = 36.0 µM
TP OF WATER = 37.0 µM
EPCo = 3.40 µM
Kd = 90.6 l/kg
ni = 0.31 µmol/g

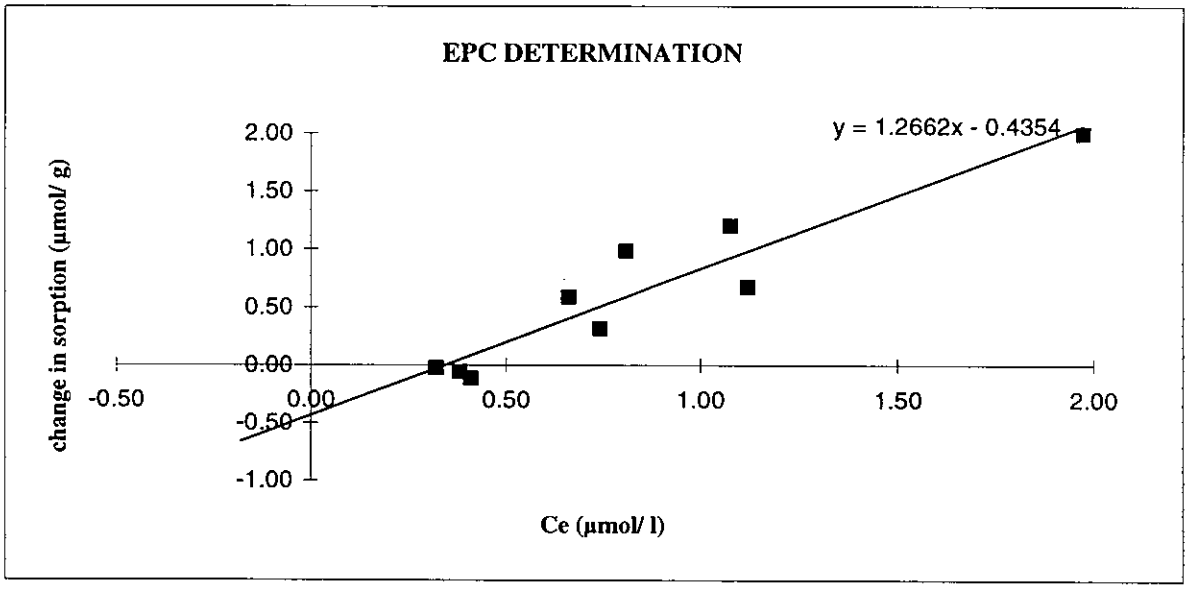


**SITE A BLACKWATER. SEDIMENT & WATER COLLECTED 21/7/95**

| EPCo DETERMINATION: ANALYSIS 1/8/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.19 | 0.73 | 0 | 0.41 | -0.11 |
| 1.39 | 0.85 | 5 | 0.81 | 0.98 |
| 1.31 | 0.81 | 10 | 1.97 | 1.99 |
| 2.24 | 1.38 | 0 | 0.38 | -0.06 |
| 2.41 | 1.48 | 5 | 0.66 | 0.59 |
| 2.41 | 1.48 | 10 | 1.08 | 1.20 |
| 4.31 | 2.65 | 0 | 0.32 | -0.02 |
| 4.42 | 2.71 | 5 | 0.74 | 0.31 |
| 4.29 | 2.63 | 10 | 1.12 | 0.67 |

% WATER OF SEDIMENT = 38.54
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 4.06
TOTAL PHOSPHORUS OF SEDIMENT = 11.50 µmol/ g

SRP OF WATER = 6.49 µM
TDP OF WATER = 9.50 µM
TP OF WATER = 16.5 µM
EPCo = 0.34 µM
Kd = 1266.2 l/kg
ni = 0.44 µmol/g

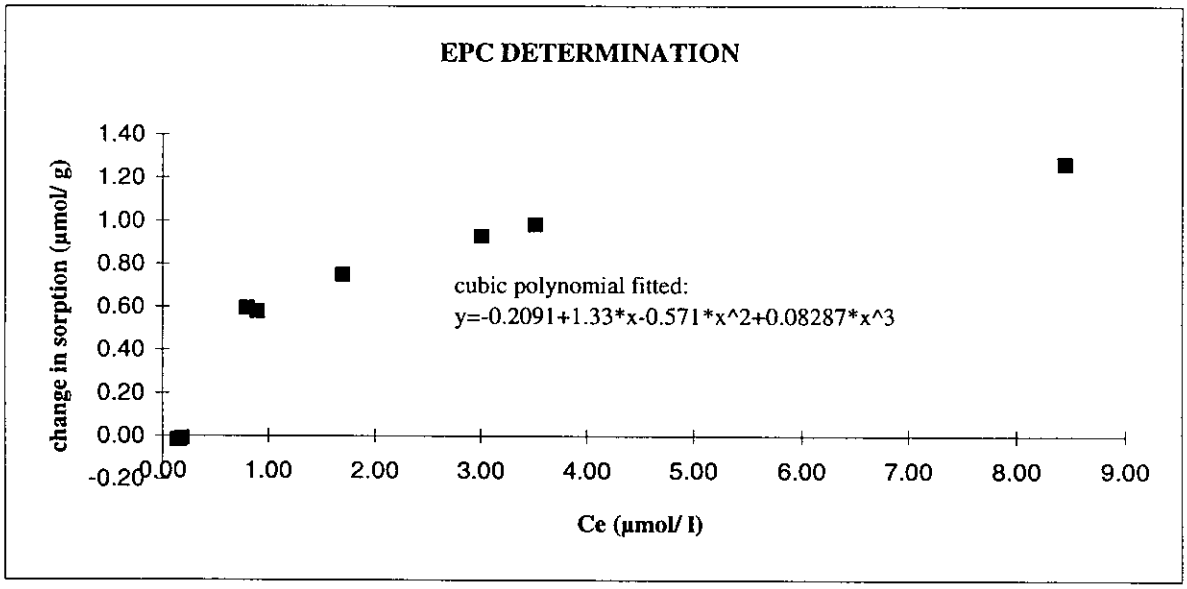


**SITE B BLACKWATER. SEDIMENT & WATER COLLECTED 21/7/95**

| EPCo DETERMINATION: ANALYSIS 1/8/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.90 | 1.42 | 0 | 0.14 | -0.02 |
| 1.89 | 1.41 | 5 | 0.80 | 0.59 |
| 1.77 | 1.32 | 10 | 3.51 | 0.98 |
| 2.94 | 2.20 | 0 | 0.17 | -0.02 |
| 2.97 | 2.22 | 10 | 1.70 | 0.75 |
| 2.45 | 1.83 | 20 | 8.45 | 1.26 |
| 4.37 | 3.26 | 0 | 0.18 | -0.01 |
| 4.22 | 3.15 | 10 | 0.90 | 0.58 |
| 4.91 | 3.67 | 20 | 3.01 | 0.93 |

% WATER OF SEDIMENT = 25.34
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 1.51
TOTAL PHOSPHORUS OF SEDIMENT = 1.65 µmol/ g

SRP OF WATER = 133.01 µM
TDP OF WATER = 160.5 µM
TP OF WATER = 180 µM
EPCo = 0.17 µM

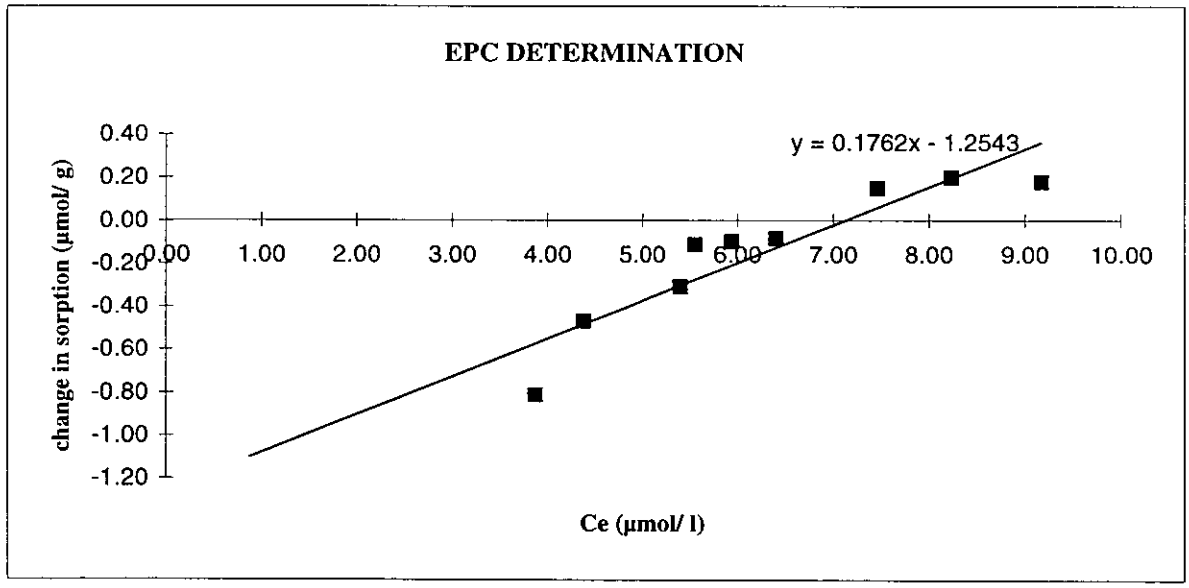


**SITE C BLACKWATER. SEDIMENT & WATER COLLECTED 21/7/95**

| EPCo DETERMINATION: ANALYSIS 1/8/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.25 | 0.95 | 0 | 3.87 | -0.81 |
| 1.31 | 1.00 | 5 | 5.56 | -0.11 |
| 1.21 | 0.92 | 10 | 9.17 | 0.18 |
| 2.45 | 1.87 | 0 | 4.38 | -0.47 |
| 2.52 | 1.92 | 5 | 5.94 | -0.10 |
| 2.33 | 1.77 | 10 | 8.23 | 0.20 |
| 4.62 | 3.51 | 0 | 5.40 | -0.31 |
| 4.57 | 3.47 | 5 | 6.40 | -0.08 |
| 4.43 | 3.37 | 10 | 7.46 | 0.15 |

% WATER OF SEDIMENT = 23.99
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 1.68
TOTAL PHOSPHORUS OF SEDIMENT = 112.7 µmol/ g

SRP OF WATER = 75.22 µM
TDP OF WATER = 104.0 µM
TP OF WATER = 175.0 µM
EPCo = 7.12 µM
Kd = 176.2 l/kg
ni = 1.25 µmol/g

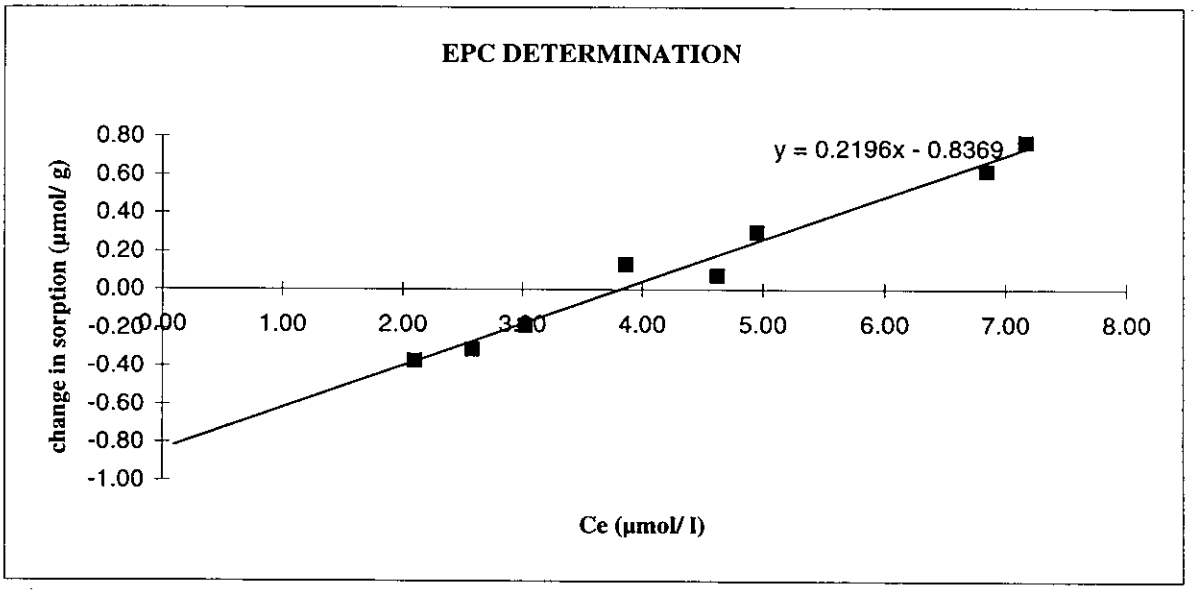


**SITE D BLACKWATER. SEDIMENT & WATER COLLECTED 21/7/95**

| EPCo DETERMINATION: ANALYSIS 1/8/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.48 | 1.13 | 0 | 2.10 | -0.37 |
| 1.32 | 1.01 | 5 | 4.63 | 0.07 |
| 1.34 | 1.02 | 10 | 6.84 | 0.62 |
| 2.17 | 1.66 | 0 | 2.58 | -0.31 |
| 2.24 | 1.72 | 5 | 3.86 | 0.13 |
| 2.62 | 2.01 | 10 | 2.32 | 0.77 |
| 4.22 | 3.23 | 0 | 3.02 | -0.19 |
| 4.43 | 3.39 | 10 | 4.95 | 0.30 |
| 4.35 | 3.33 | 20 | 7.17 | 0.77 |

% WATER OF SEDIMENT = 23.50
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 1.62
TOTAL PHOSPHORUS OF SEDIMENT = 92.16 µmol/ g

SRP OF WATER = 38.74 µM
TDP OF WATER = 47.5 µM
TP OF WATER = 51.5 µM
EPCo = 3.81 µM
Kd = 219.6 l/kg
ni = 0.84 µmol/g

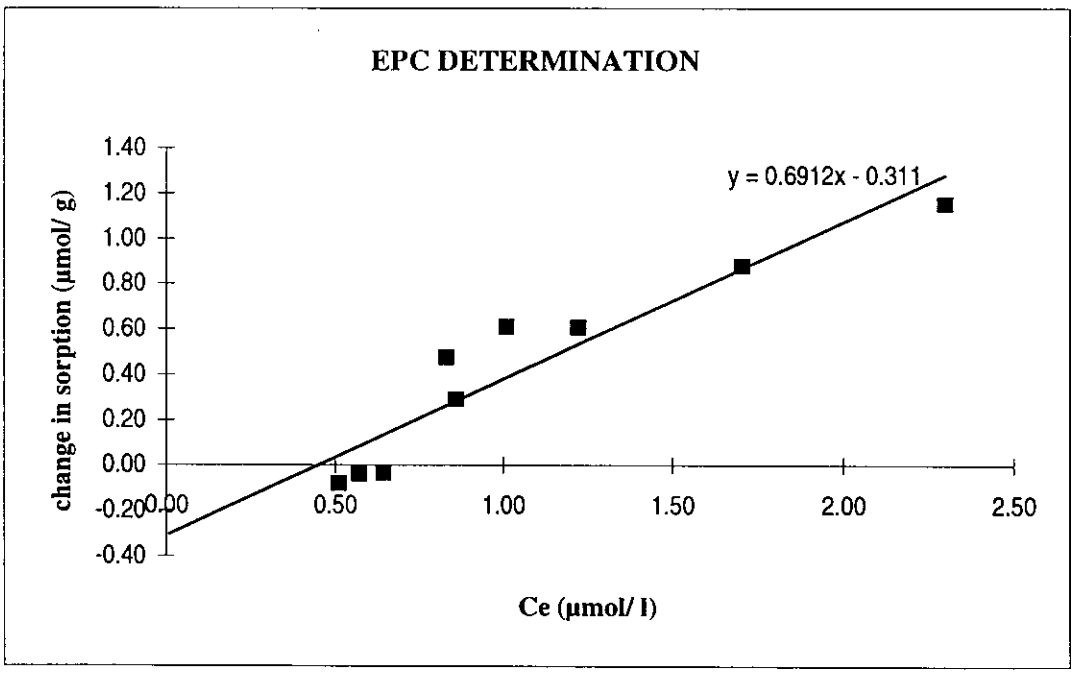


**SITE A RIVER WEY. SEDIMENT & WATER COLLECTED 7/8/95**

| EPCo DETERMINATION: ANALYSIS 15/8/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (μM) | [P] at 24 h (μM) | dN (μmol/ g dry wt) |
| 2.11 | 1.28 | 0 | 0.51 | -0.08 |
| 2.16 | 1.30 | 5 | 1.01 | 0.61 |
| 2.21 | 1.34 | 10 | 2.30 | 1.15 |
| 4.82 | 2.92 | 0 | 0.57 | -0.04 |
| 4.67 | 2.82 | 5 | 0.86 | 0.29 |
| 4.77 | 2.89 | 10 | 1.22 | 0.61 |
| 6.32 | 3.83 | 0 | 0.64 | -0.03 |
| 6.35 | 3.84 | 10 | 0.83 | 0.48 |
| 6.87 | 4.16 | 20 | 1.70 | 0.88 |

% WATER OF SEDIMENT = 39.48
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 5.98
TOTAL PHOSPHORUS OF SEDIMENT = 2.73 μmol/ g

SRP OF WATER = 2.58 μM
TDP OF WATER = 3.5 μM
TP OF WATER = 7.0 μM
EPCo = 0.45 μM
Kd = 691.2 l/kg
ni = 0.31 μmol/g

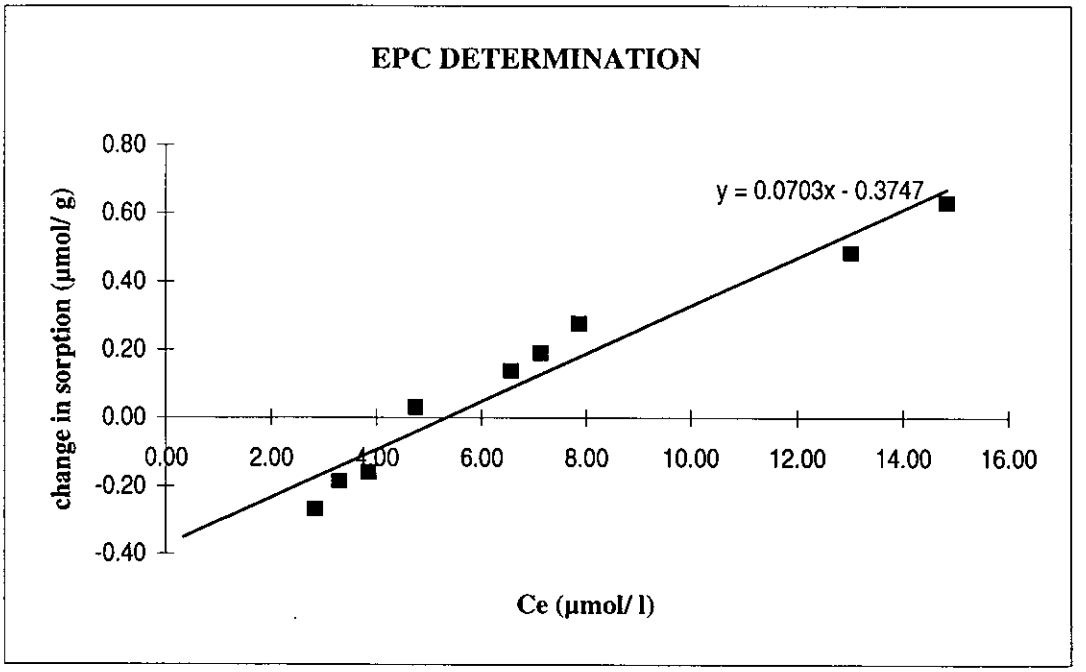


**SITE C RIVER WEY. SEDIMENT & WATER COLLECTED 7/8/95**

| EPCo DETERMINATION: ANALYSIS 15/8/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 2.85 | 2.11 | 0 | 2.84 | -0.27 |
| 2.35 | 1.74 | 5 | 4.73 | 0.03 |
| 2.08 | 1.54 | 10 | 7.87 | 0.28 |
| 4.76 | 3.53 | 0 | 3.29 | -0.19 |
| 4.07 | 3.01 | 10 | 7.14 | 0.19 |
| 4.36 | 3.23 | 25 | 14.83 | 0.63 |
| 6.57 | 4.87 | 0 | 3.86 | -0.16 |
| 6.67 | 4.95 | 10 | 6.57 | 0.14 |
| 6.69 | 4.95 | 25 | 13.01 | 0.48 |

% WATER OF SEDIMENT = 25.91
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 2.67
TOTAL PHOSPHORUS OF SEDIMENT = 28.93 µmol/ g

SRP OF WATER = 67.80 µM
TDP OF WATER = 80.0 µM
TP OF WATER = 83.0 µM
EPCo = 5.33 µM
Kd = 70.3 l/kg
ni = 0.38 µmol/g

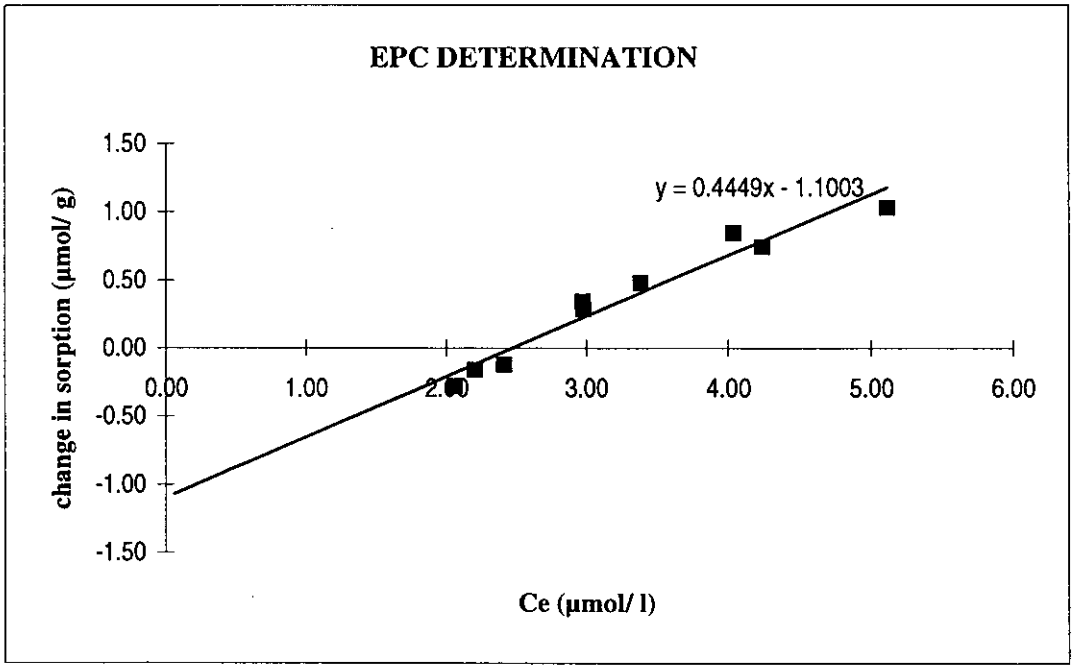


**SITE D RIVER WEY. SEDIMENT & WATER COLLECTED 7/8/95**

| EPCo DETERMINATION: ANALYSIS 15/8/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (μM) | [P] at 24 h (μM) | dN (μmol/ g dry wt) |
| 2.33 | 1.49 | 0 | 2.06 | -0.28 |
| 2.20 | 1.40 | 5 | 2.98 | 0.29 |
| 2.20 | 1.41 | 10 | 4.04 | 0.85 |
| 4.35 | 2.78 | 0 | 2.20 | -0.16 |
| 4.33 | 2.77 | 10 | 3.38 | 0.48 |
| 4.52 | 2.89 | 20 | 5.11 | 1.03 |
| 6.13 | 3.91 | 0 | 2.41 | -0.12 |
| 6.45 | 4.12 | 10 | 2.97 | 0.34 |
| 6.63 | 4.24 | 20 | 4.24 | 0.74 |

% WATER OF SEDIMENT = 36.12
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 4.19
TOTAL PHOSPHORUS OF SEDIMENT = 216.8 μmol/ g

SRP OF WATER = 43.58 μM
TDP OF WATER = 50.5 μM
TP OF WATER = 51.0 μM
EPCo = 2.47 μM
Kd = 444.9 l/kg
ni = 1.10 μmol/g

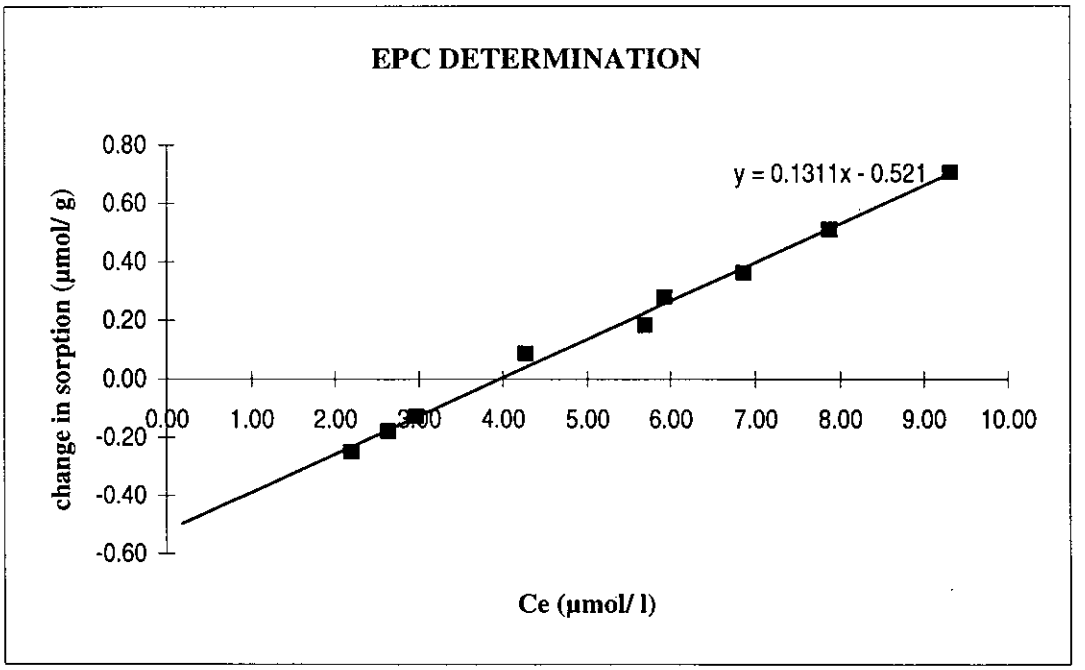


## SITE E RIVER WEY. SEDIMENT & WATER COLLECTED 7/8/95

| EPCo DETERMINATION: ANALYSIS 15/8/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 2.46 | 1.74 | 0 | 2.19 | -0.25 |
| 2.37 | 1.68 | 5 | 4.27 | 0.09 |
| 2.45 | 1.73 | 10 | 6.86 | 0.36 |
| 4.16 | 2.94 | 0 | 2.64 | -0.18 |
| 4.12 | 2.91 | 10 | 5.93 | 0.28 |
| 4.29 | 3.03 | 20 | 9.32 | 0.71 |
| 6.60 | 4.66 | 0 | 2.97 | -0.13 |
| 6.70 | 4.73 | 10 | 5.69 | 0.18 |
| 6.72 | 4.74 | 20 | 7.88 | 0.51 |

% WATER OF SEDIMENT = 29.39
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 3.87
TOTAL PHOSPHORUS OF SEDIMENT = 40.41 µmol/ g

SRP OF WATER = 41.00 µM
TDP OF WATER = 53.5 µM
TP OF WATER = 54.0 µM
EPCo = 3.97 µM
Kd = 131.1 l/kg
ni = 0.52 µmol/g

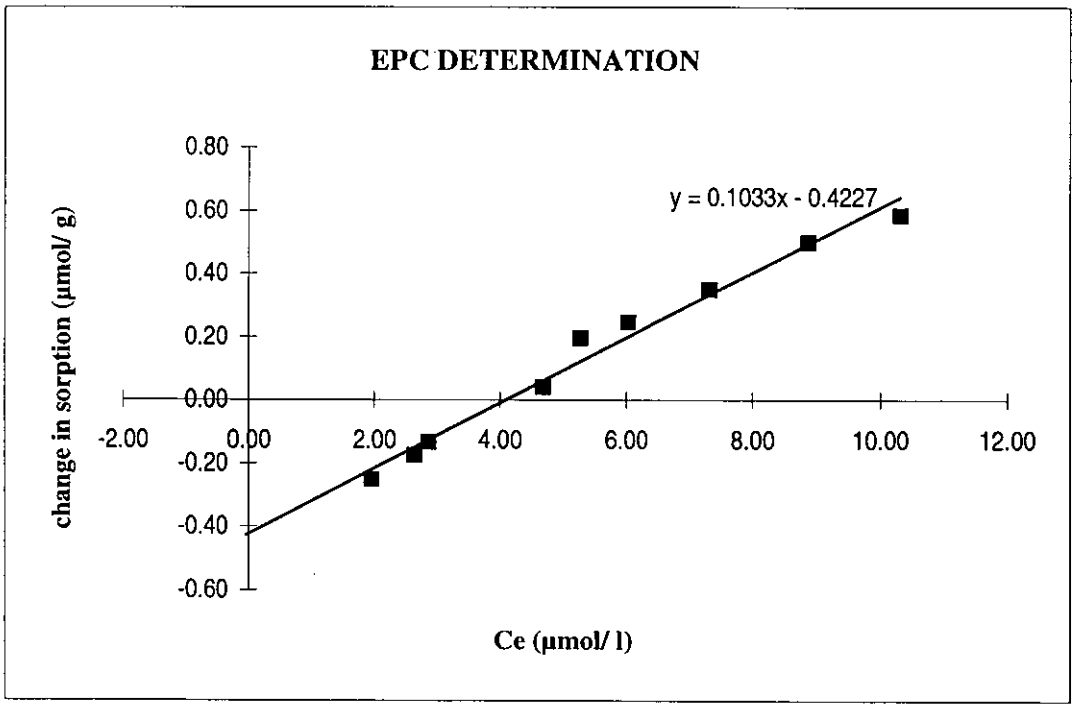


## SITE F RIVER WEY. SEDIMENT & WATER COLLECTED 7/8/95

| EPCo DETERMINATION: ANALYSIS 15/8/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 2.20 | 1.56 | 0 | 1.96 | -0.25 |
| 2.20 | 1.56 | 5 | 4.68 | 0.04 |
| 2.15 | 1.53 | 10 | 7.32 | 0.35 |
| 4.27 | 3.03 | 0 | 2.65 | -0.17 |
| 4.54 | 3.23 | 10 | 6.03 | 0.25 |
| 4.66 | 3.31 | 20 | 10.31 | 0.59 |
| 6.07 | 4.31 | 0 | 2.87 | -0.13 |
| 6.80 | 4.83 | 10 | 5.28 | 0.20 |
| 6.27 | 4.45 | 20 | 8.88 | 0.50 |

% WATER OF SEDIMENT = 28.91
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 2.34

SRP OF WATER = 34.87 µM
TDP OF WATER = 40.0 µM
TP OF WATER = 41.0 µM
EPCo = 4.09 µM
Kd = 103.3 l/kg
ni = 0.42 µmol/g

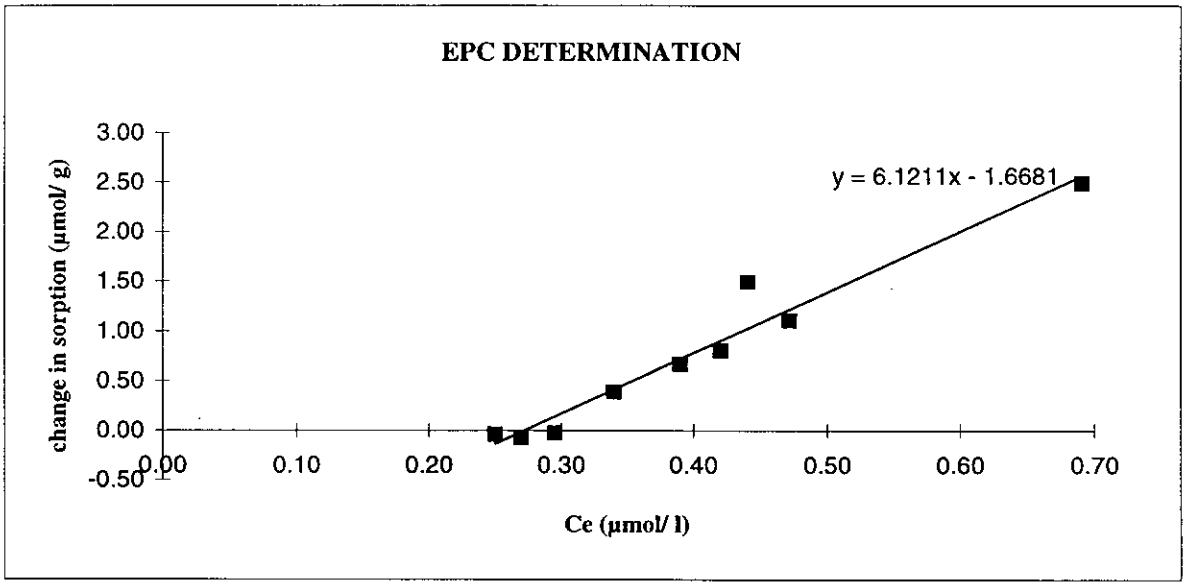


**SITE A BLACKWATER. SEDIMENT & WATER COLLECTED 23/10/95**

| EPCo DETERMINATION: ANALYSIS 31/10/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.27 | 0.73 | 0 | 0.27 | -0.07 |
| 1.42 | 0.82 | 5 | 0.47 | 1.11 |
| 1.30 | 0.75 | 10 | 0.69 | 2.49 |
| 2.36 | 1.36 | 0 | 0.25 | -0.04 |
| 2.40 | 1.38 | 5 | 0.39 | 0.67 |
| 2.22 | 1.28 | 10 | 0.44 | 1.50 |
| 4.10 | 2.36 | 0 | 0.30 | -0.03 |
| 4.17 | 2.41 | 5 | 0.34 | 0.39 |
| 4.13 | 2.38 | 10 | 0.42 | 0.81 |

% WATER OF SEDIMENT = 42.38
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 7.63
TOTAL PHOSPHORUS OF SEDIMENT = 22.29 µmol/ g

SRP OF WATER = 6.84 µM
TDP OF WATER = 3.1 µM
TP OF WATER = 5.1 µM
EPCo = 0.27 µM
Kd = 6121.1 l/kg
ni = 1.67 µmol/g

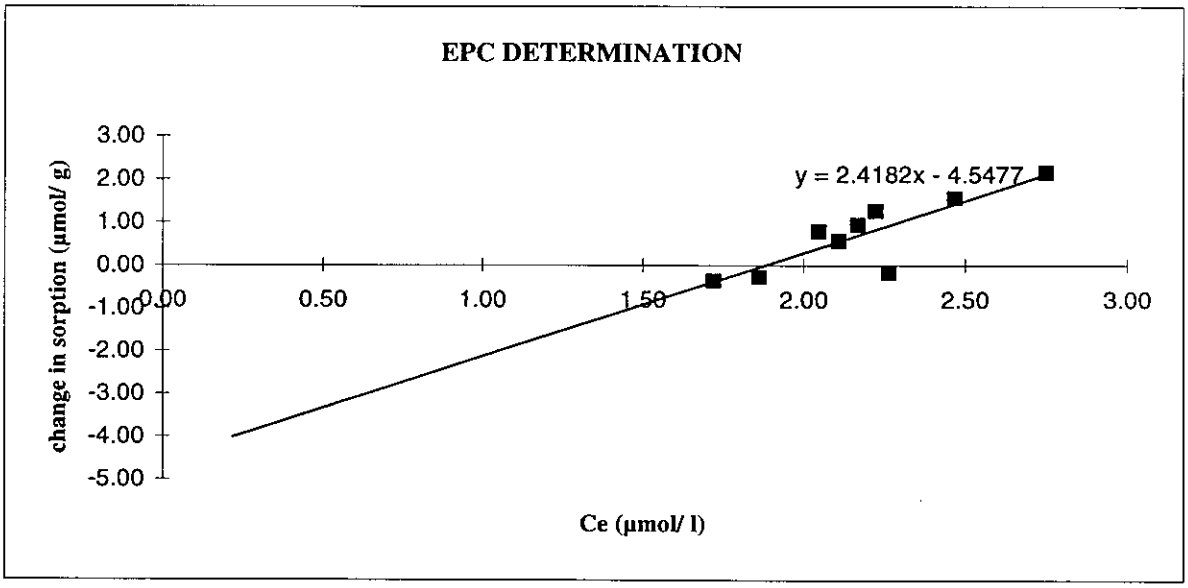


**SITE B BLACKWATER. SEDIMENT & WATER COLLECTED 23/10/95**

| EPCo DETERMINATION: ANALYSIS 31/10/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.51 | 0.94 | 0 | 1.72 | -0.37 |
| 1.20 | 0.75 | 5 | 2.05 | 0.79 |
| 1.55 | 0.96 | 10 | 2.47 | 1.57 |
| 2.24 | 1.39 | 0 | 1.86 | -0.27 |
| 2.66 | 1.65 | 10 | 2.17 | 0.95 |
| 2.58 | 1.60 | 20 | 2.75 | 2.15 |
| 4.31 | 2.68 | 0 | 2.26 | -0.17 |
| 4.47 | 2.78 | 10 | 2.11 | 0.57 |
| 4.52 | 2.81 | 20 | 2.22 | 1.27 |

% WATER OF SEDIMENT = 37.80
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 6.49
TOTAL PHOSPHORUS OF SEDIMENT = 90.83 µmol/ g

SRP OF WATER = 125.91 µM
TDP OF WATER = 113.5 µM
TP OF WATER = 120.0 µM
EPCo = 1.88 µM
Kd = 2418.2 l/kg
ni = 4.55 µmol/g

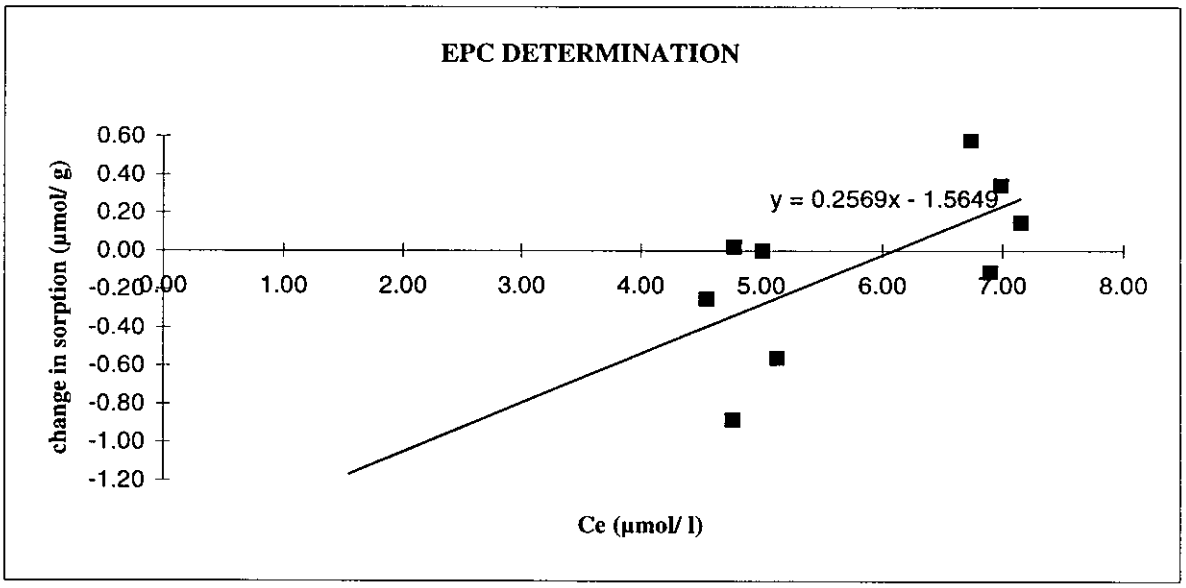


**SITE C BLACKWATER. SEDIMENT & WATER COLLECTED 23/10/95**

| EPCo DETERMINATION: ANALYSIS 31/10/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.33 | 1.08 | 0 | 4.77 | -0.88 |
| 1.30 | 1.06 | 5 | 5.01 | 0.00 |
| 1.39 | 1.13 | 10 | 6.74 | 0.58 |
| 2.25 | 1.84 | 0 | 5.13 | -0.56 |
| 2.63 | 2.15 | 5 | 4.78 | 0.02 |
| 2.15 | 1.76 | 10 | 6.99 | 0.34 |
| 4.38 | 3.58 | 0 | 4.55 | -0.25 |
| 4.20 | 3.44 | 5 | 6.90 | -0.11 |
| 4.79 | 3.92 | 10 | 7.15 | 0.15 |

% WATER OF SEDIMENT = 18.25
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 1.26
TOTAL PHOSPHORUS OF SEDIMENT = 41.66 µmol/ g

SRP OF WATER = 51.98 µM
TDP OF WATER = 49.7 µM
TP OF WATER = 59.5 µM
EPCo = 6.09 µM
Kd = 256.9 l/kg
ni = 1.57 µmol/g

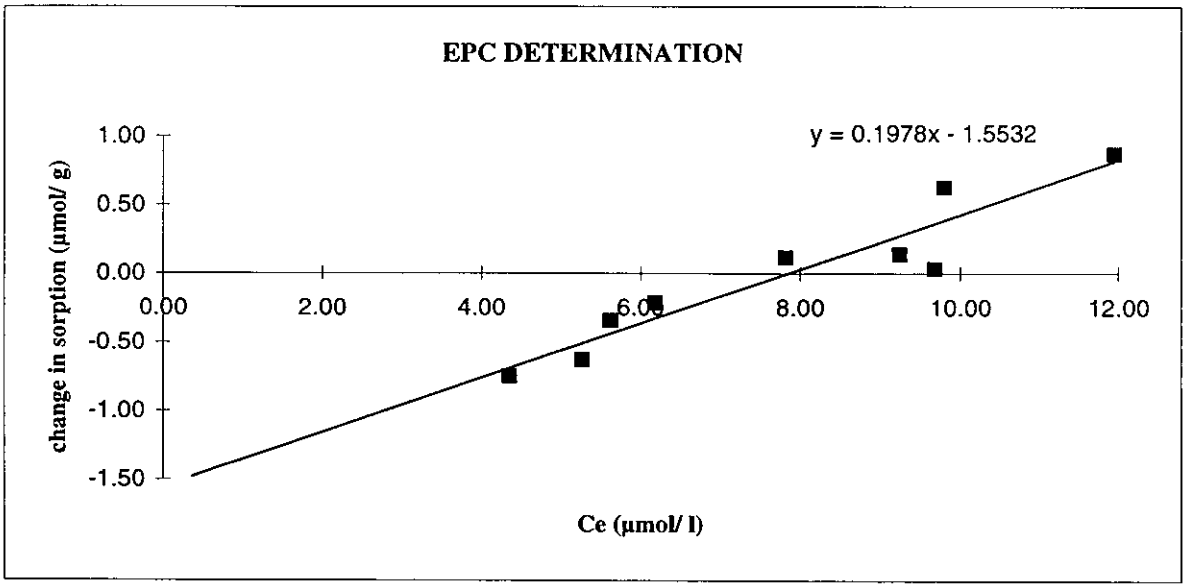


SITE D BLACKWATER. SEDIMENT & WATER COLLECTED 23/10/95

| EPCo DETERMINATION: ANALYSIS 31/10/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.45 | 1.16 | 0 | 4.36 | -0.75 |
| 1.37 | 1.10 | 5 | 6.18 | -0.21 |
| 1.35 | 1.08 | 10 | 9.24 | 0.14 |
| 2.09 | 1.68 | 0 | 5.27 | -0.63 |
| 2.25 | 1.81 | 10 | 9.69 | 0.03 |
| 2.31 | 1.85 | 20 | 11.95 | 0.87 |
| 4.11 | 3.30 | 0 | 5.62 | -0.34 |
| 4.58 | 3.67 | 10 | 7.81 | 0.12 |
| 4.07 | 3.27 | 20 | 9.79 | 0.62 |

% WATER OF SEDIMENT = 19.74
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 0.81
TOTAL PHOSPHORUS OF SEDIMENT = 38.81 µmol/ g

SRP OF WATER = 23.60 µM
TDP OF WATER = 20.0 µM
TP OF WATER = 30.5 µM
EPCo = 7.85 µM
Kd = 197.8 l/kg
ni = 1.55 µmol/g

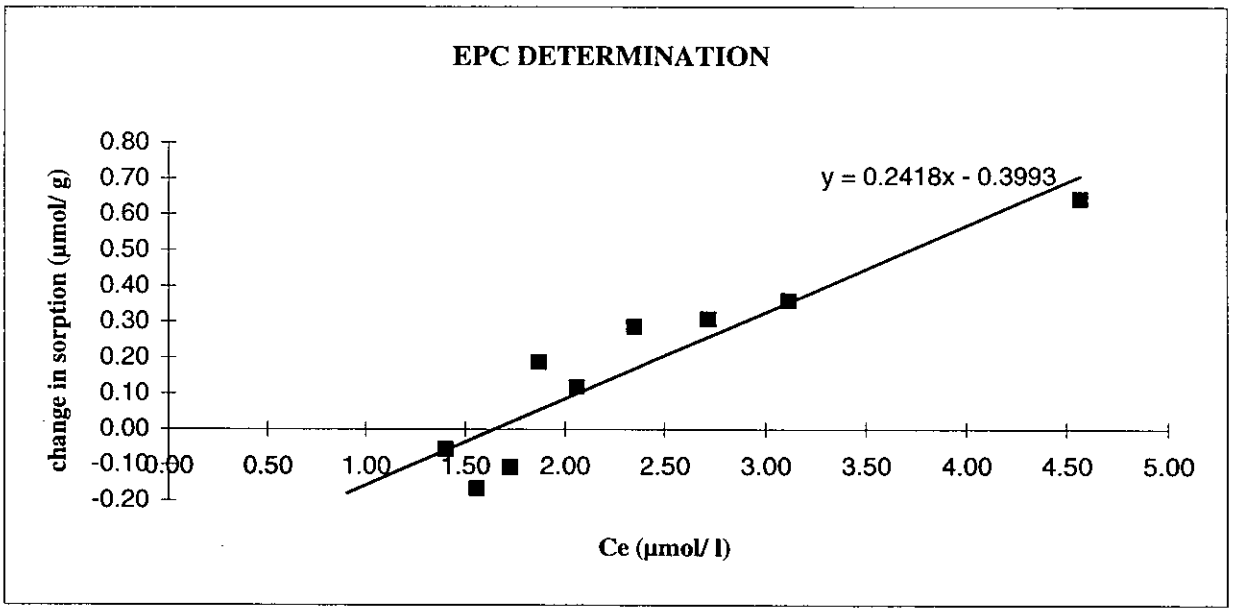


**SITE A GREAT OUSE. SEDIMENT & WATER COLLECTED 15/11/95**

| EPCo DETERMINATION: ANALYSIS 18/11/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 2.41 | 1.87 | 0 | 1.56 | -0.17 |
| 2.38 | 1.85 | 5 | 2.35 | 0.29 |
| 2.18 | 1.69 | 10 | 4.57 | 0.64 |
| 4.20 | 3.26 | 0 | 1.73 | -0.11 |
| 4.31 | 3.35 | 5 | 1.87 | 0.19 |
| 4.93 | 3.83 | 10 | 3.11 | 0.36 |
| 6.37 | 4.94 | 0 | 1.40 | -0.06 |
| 6.42 | 4.98 | 5 | 2.06 | 0.12 |
| 6.07 | 4.72 | 10 | 2.72 | 0.31 |

% WATER OF SEDIMENT = 22.35
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 7.31
TOTAL PHOSPHORUS OF SEDIMENT = 15.37 µmol/ g

SRP OF WATER = 3.20 µM
TDP OF WATER = 2.94 µM
TP OF WATER = 5.04 µM
EPCo = 1.65 µM
Kd = 241.8 l/kg
ni = 0.40 µmol/g

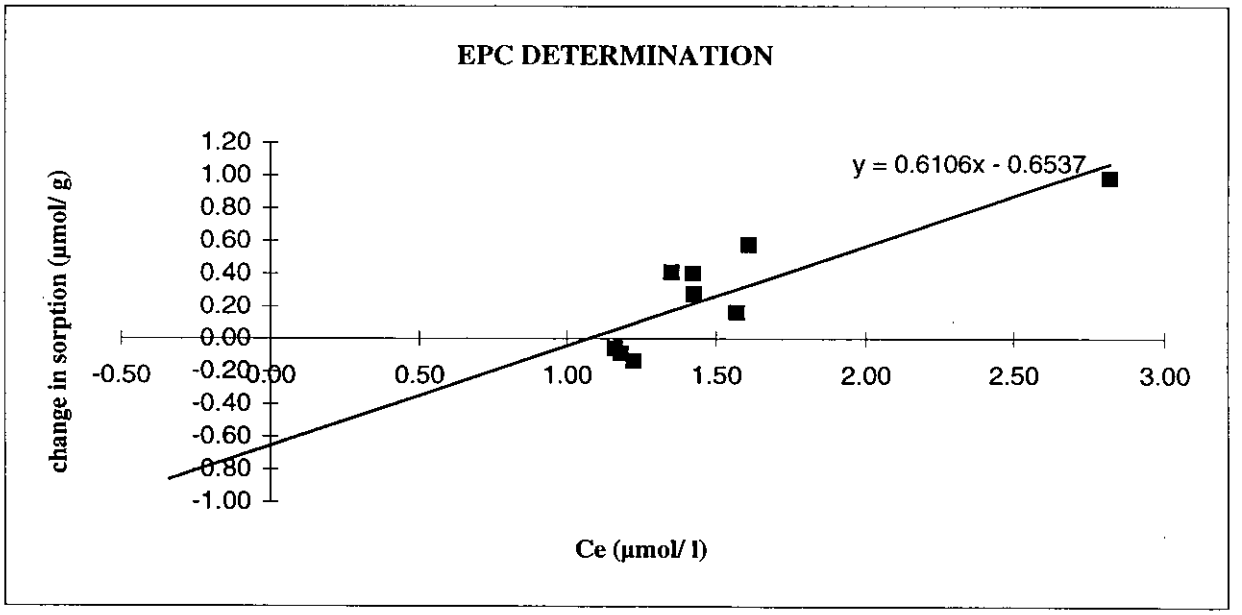


**SITE B GREAT OUSE. SEDIMENT & WATER COLLECTED 15/11/95**

| EPCo DETERMINATION: ANALYSIS 18/11/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 2.84 | 1.82 | 0 | 1.22 | -0.13 |
| 2.79 | 1.79 | 5 | 1.35 | 0.41 |
| 2.28 | 1.46 | 10 | 2.82 | 0.98 |
| 4.13 | 2.65 | 0 | 1.18 | -0.09 |
| 4.09 | 2.62 | 5 | 1.43 | 0.27 |
| 4.56 | 2.92 | 10 | 1.61 | 0.57 |
| 6.38 | 4.09 | 0 | 1.16 | -0.06 |
| 6.60 | 4.23 | 5 | 1.57 | 0.16 |
| 6.70 | 4.30 | 10 | 1.42 | 0.40 |

% WATER OF SEDIMENT = 35.91
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 10.22
TOTAL PHOSPHORUS OF SEDIMENT = 33.75 µmol/ g

SRP OF WATER = 12.30 µM
TDP OF WATER = 16.10 µM
TP OF WATER = 16.27 µM
EPCo = 1.07 µM
Kd = 610.6 l/kg
ni = 0.65 µmol/g

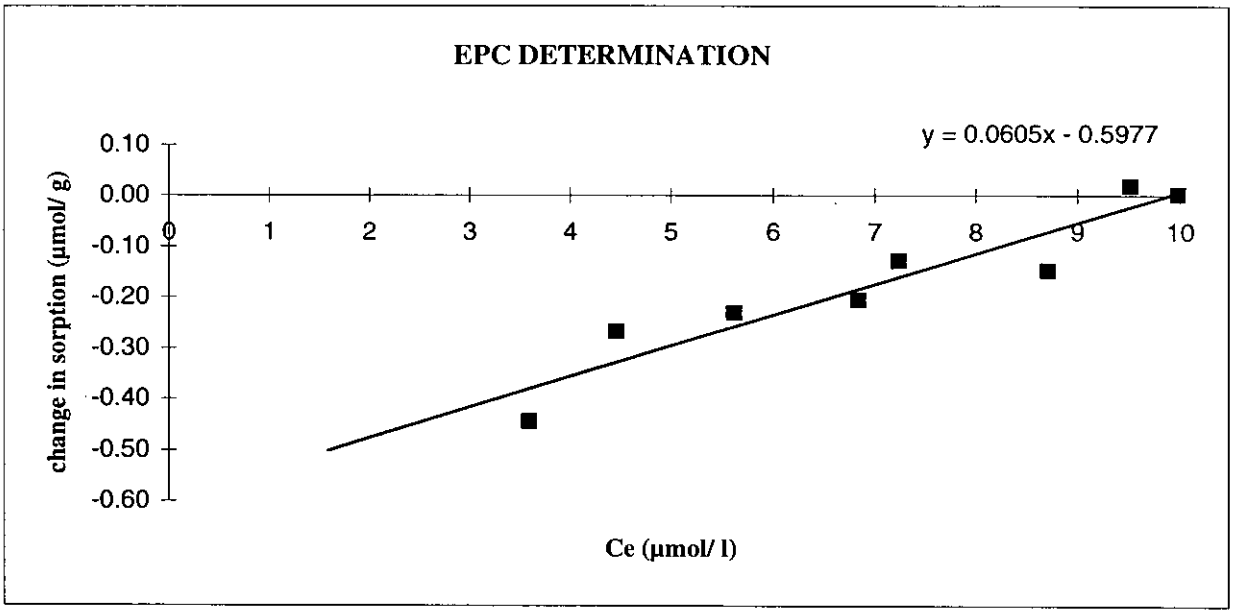


## SITE C GREAT OUSE. SEDIMENT & WATER COLLECTED 15/11/95

| EPCo DETERMINATION: ANALYSIS 18/11/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g_dry wt) |
| 2.02 | 1.62 | 0 | 3.59 | -0.44 |
| 2.24 | 1.80 | 5 | 6.84 | -0.20 |
| 2.07 | 1.66 | 10 | 9.98 | 0.00 |
| 4.15 | 3.33 | 0 | 4.46 | -0.27 |
| 4.35 | 3.49 | 5 | 7.23 | -0.13 |
| 4.10 | 3.29 | 10 | 14.71 | -0.29 |
| 6.10 | 4.90 | 0 | 5.62 | -0.23 |
| 6.30 | 5.06 | 5 | 8.71 | -0.15 |
| 6.23 | 5.00 | 10 | 9.51 | 0.02 |

% WATER OF SEDIMENT =19.71
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 6.96
TOTAL PHOSPHORUS OF SEDIMENT = 29.27 µmol/ g

SRP OF WATER = 12.59 µM
TDP OF WATER = 15.45 µM
TP OF WATER = 15.99 µM
EPCo = 9.88 µM
Kd = 60.5 l/kg
ni = 0.60 µmol/g

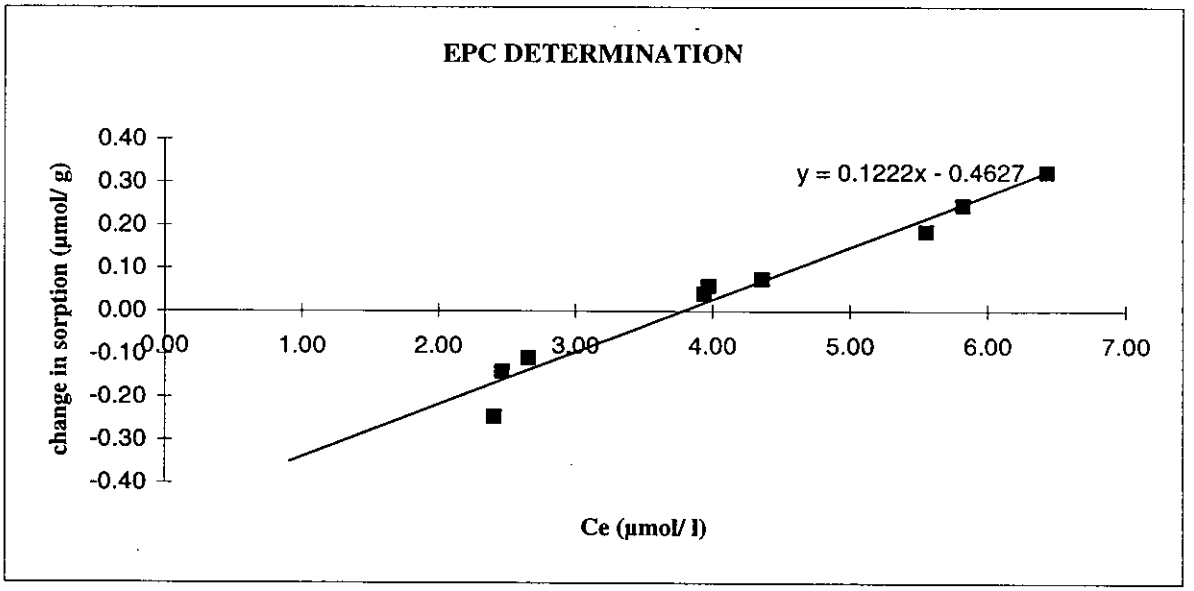


**SITE D GREAT OUSE. SEDIMENT & WATER COLLECTED 15/11/95**

| EPCo DETERMINATION: ANALYSIS 18/11/95 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 2.45 | 1.96 | 0 | 2.41 | -0.25 |
| 2.14 | 1.71 | 5 | 4.36 | 0.07 |
| 2.77 | 2.21 | 10 | 6.43 | 0.32 |
| 4.39 | 3.52 | 0 | 2.47 | -0.14 |
| 4.40 | 3.52 | 5 | 3.97 | 0.06 |
| 4.24 | 3.39 | 10 | 5.82 | 0.25 |
| 6.08 | 4.86 | 0 | 2.66 | -0.11 |
| 6.62 | 5.30 | 5 | 3.94 | 0.04 |
| 6.02 | 4.82 | 10 | 5.55 | 0.18 |

% WATER OF SEDIMENT = 19.98
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 7.59
TOTAL PHOSPHORUS OF SEDIMENT = 49.33 µmol/ g

SRP OF WATER = 16.53 µM
TDP OF WATER = 19.21 µM
TP OF WATER = 19.37 µM
EPCo = 3.79 µM
Kd = 122.2 l/kg
ni = 0.46 µmol/g

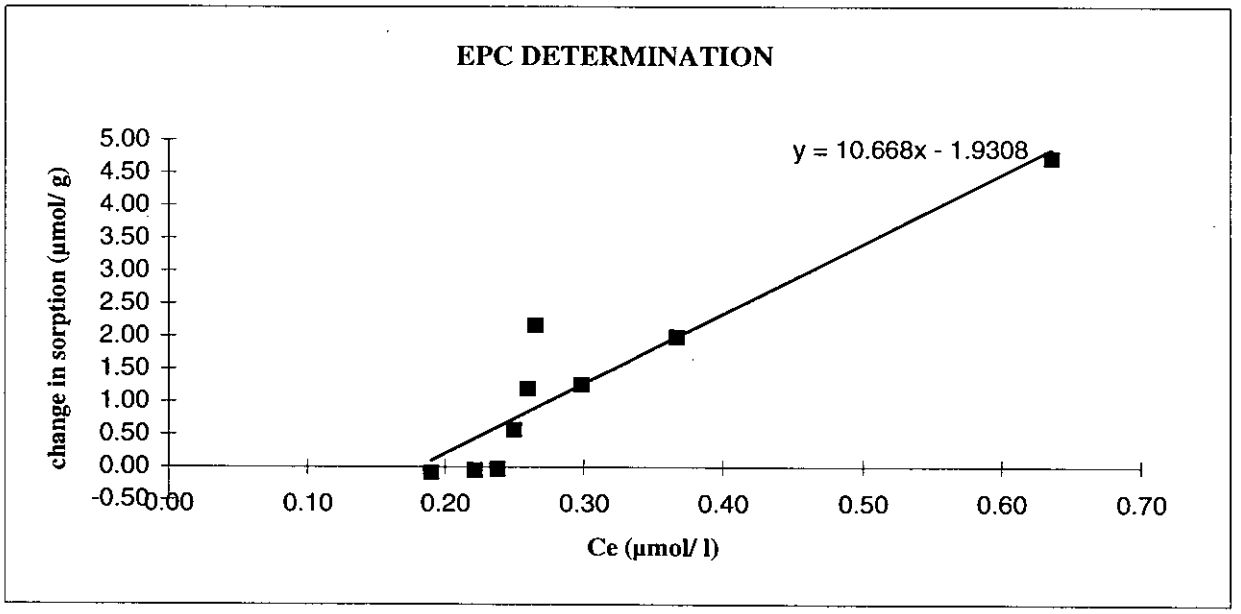


## SITE A BLACKWATER. SEDIMENT & WATER COLLECTED 17/1/96

| EPCo DETERMINATION: ANALYSIS 27/1/96 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.18 | 0.43 | 0 | 0.19 | -0.09 |
| 1.26 | 0.47 | 5 | 0.37 | 1.99 |
| 1.07 | 0.40 | 10 | 0.64 | 4.71 |
| 2.29 | 0.85 | 0 | 0.22 | -0.05 |
| 2.15 | 0.79 | 5 | 0.26 | 1.19 |
| 2.43 | 0.90 | 10 | 0.27 | 2.16 |
| 4.79 | 1.77 | 0 | 0.24 | -0.03 |
| 4.50 | 1.66 | 5 | 0.25 | 0.57 |
| 4.20 | 1.55 | 10 | 0.30 | 1.25 |

% WATER OF SEDIMENT = 63.03
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 13.10
TOTAL PHOSPHORUS OF SEDIMENT = 55.11 µmol/ g

SRP OF WATER = 1.48 µM
TDP OF WATER = 1.50 µM
TP OF WATER = 3.47 µM
EPCo = 0.18 µM
Kd = 10668 l/kg
ni = 1.93 µmol/g

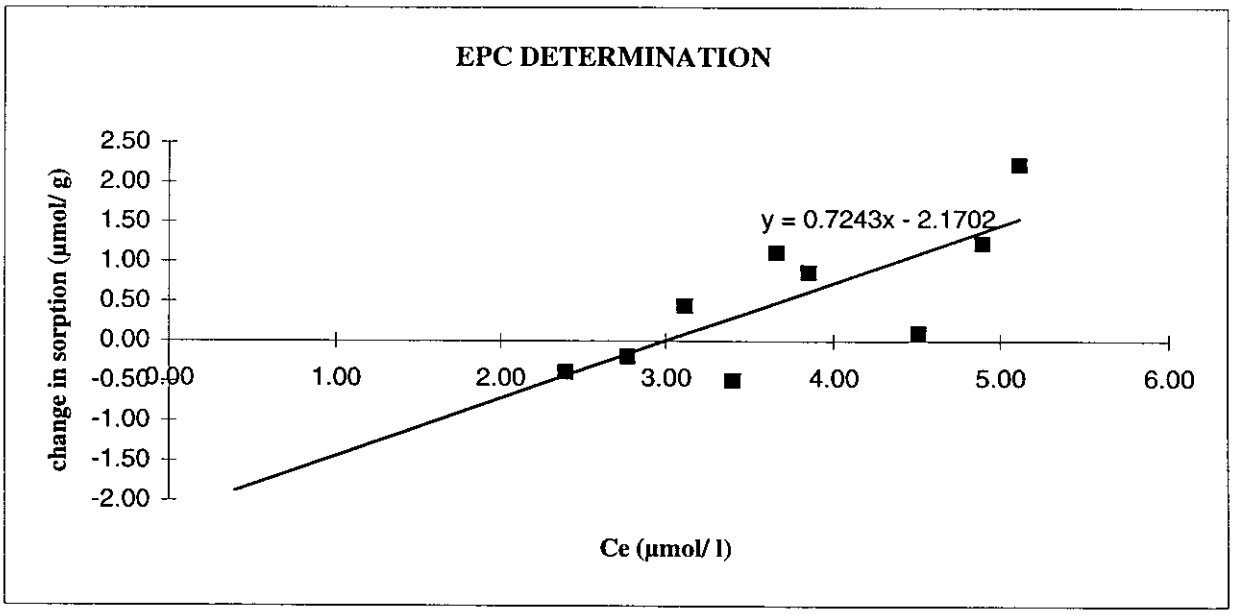


## SITE B BLACKWATER. SEDIMENT & WATER COLLECTED 17/1/96

| EPCo DETERMINATION: ANALYSIS 27/1/96 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.87 | 1.23 | 0 | 2.40 | -0.39 |
| 1.39 | 0.91 | 5 | 4.51 | 0.11 |
| 1.27 | 0.84 | 10 | 4.89 | 1.22 |
| 2.10 | 1.38 | 0 | 3.40 | -0.49 |
| 2.17 | 1.42 | 10 | 3.85 | 0.86 |
| 2.04 | 1.34 | 20 | 5.12 | 2.22 |
| 4.27 | 2.81 | 0 | 2.77 | -0.20 |
| 4.75 | 3.13 | 10 | 3.12 | 0.44 |
| 4.45 | 2.93 | 20 | 3.66 | 1.12 |

% WATER OF SEDIMENT = 34.24
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 4.88
TOTAL PHOSPHORUS OF SEDIMENT = 85.73 µmol/ g

SRP OF WATER = 38.74 µM
TDP OF WATER = 39.09 µM
TP OF WATER = 59.83 µM
EPCo = 3.00 µM
Kd = 724.3 l/kg
ni = 2.17 µmol/g

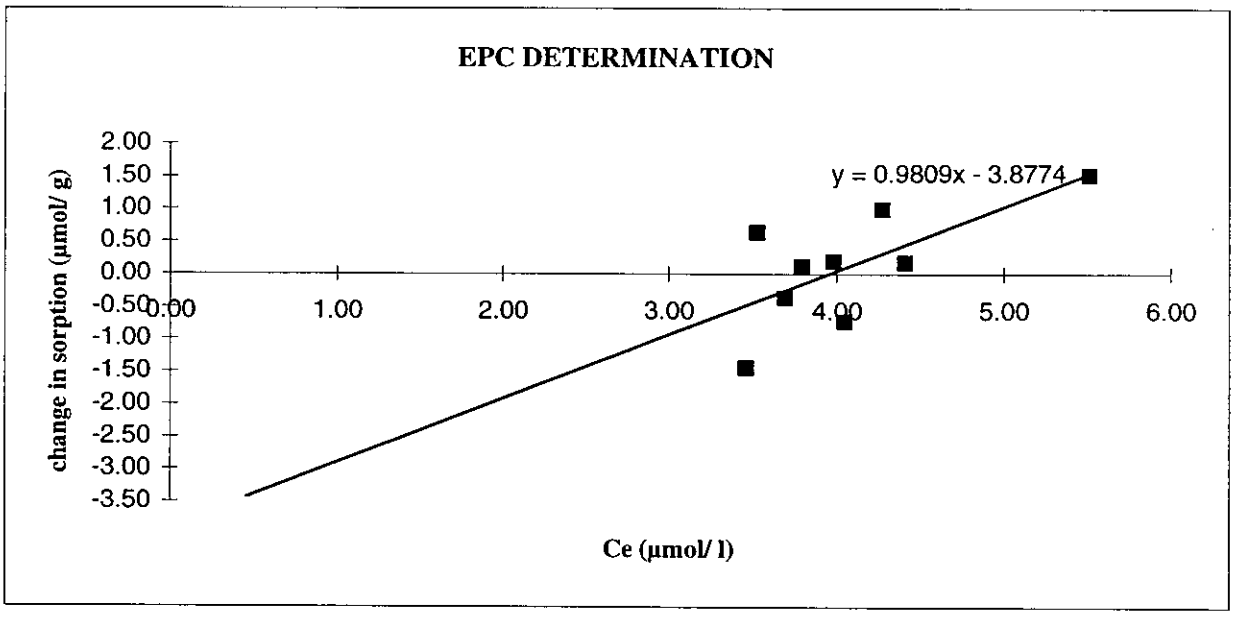


**SITE C BLACKWATER. SEDIMENT & WATER COLLECTED 17/1/96**

| EPCo DETERMINATION: ANALYSIS 27/1/96 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.00 | 0.48 | 0 | 3.46 | -1.44 |
| 1.38 | 0.66 | 5 | 4.41 | 0.18 |
| 1.23 | 0.59 | 10 | 5.52 | 1.52 |
| 2.32 | 1.11 | 0 | 4.05 | -0.73 |
| 2.19 | 1.05 | 5 | 3.98 | 0.19 |
| 2.41 | 1.15 | 10 | 4.27 | 0.99 |
| 4.21 | 2.02 | 0 | 3.70 | -0.37 |
| 4.18 | 2.00 | 5 | 3.79 | 0.12 |
| 4.24 | 2.03 | 10 | 3.53 | 0.64 |

% WATER OF SEDIMENT = 52.07
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 6.17
TOTAL PHOSPHORUS OF SEDIMENT = 300.52 µmol/ g

SRP OF WATER = 11.72 µM
TDP OF WATER = 11.34 µM
TP OF WATER = 41.98 µM
EPCo = 3.95 µM
Kd = 980.9 l/kg
ni = 3.88 µmol/g

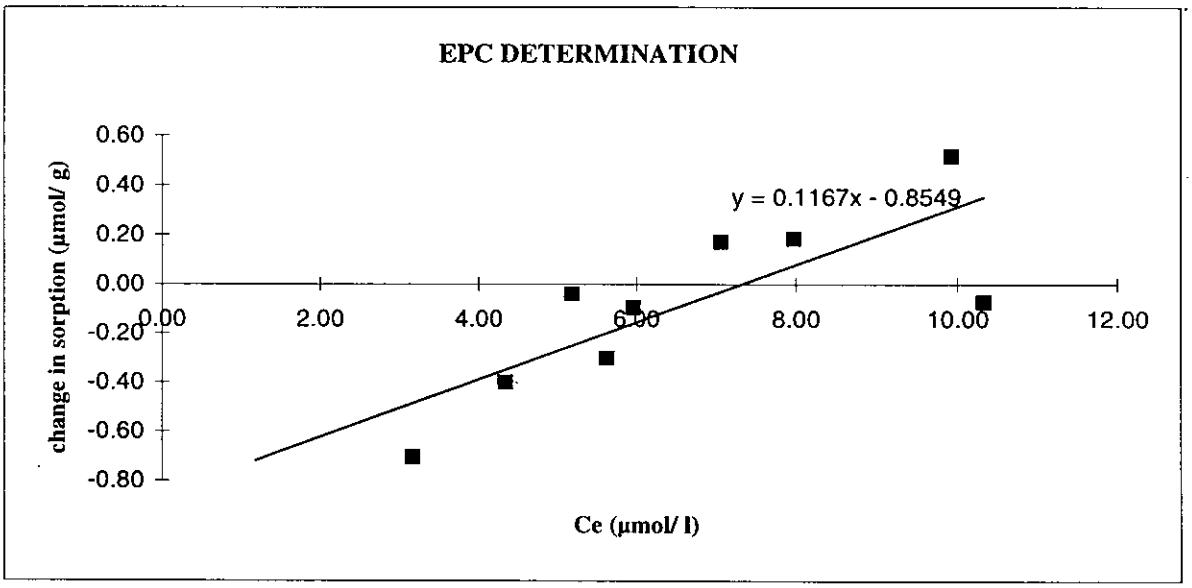


**SITE D BLACKWATER. SEDIMENT & WATER COLLECTED 17/1/96**

| EPCo DETERMINATION: ANALYSIS 27/1/96 | | | | |
|---|---|---|---|---|
| weight of wet sediment/ g | weight of dry sediment/ g | initial [P] (µM) | [P] at 24 h (µM) | dN (µmol/ g dry wt) |
| 1.10 | 0.90 | 0 | 3.17 | -0.70 |
| 1.09 | 0.89 | 5 | 5.18 | -0.04 |
| 1.12 | 0.91 | 10 | 10.33 | -0.07 |
| 2.65 | 2.17 | 0 | 4.34 | -0.40 |
| 2.49 | 2.03 | 5 | 5.96 | -0.09 |
| 2.69 | 2.20 | 10 | 7.97 | 0.18 |
| 4.58 | 3.74 | 0 | 5.62 | -0.30 |
| 4.19 | 3.43 | 10 | 7.06 | 0.17 |
| 4.77 | 3.90 | 20 | 9.93 | 0.52 |

% WATER OF SEDIMENT = 18.27
ORGANIC MATTER OF SEDIMENT AS % OF DRY MASS = 0.98
TOTAL PHOSPHORUS OF SEDIMENT = 52.37 µmol/ g

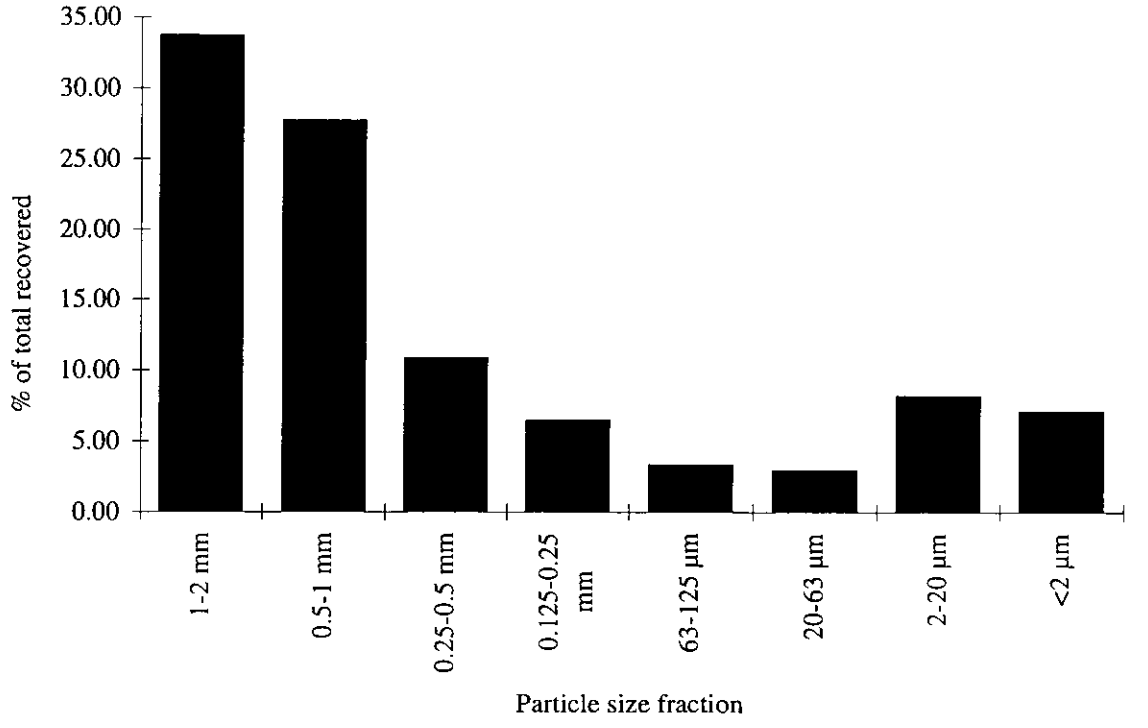
SRP OF WATER = 5.57 µM
TDP OF WATER = 5.02 µM
TP OF WATER = 18.24 µM
EPCo = 7.33 µM
Kd = 116.7 l/kg
ni = 0.86 µmol/g



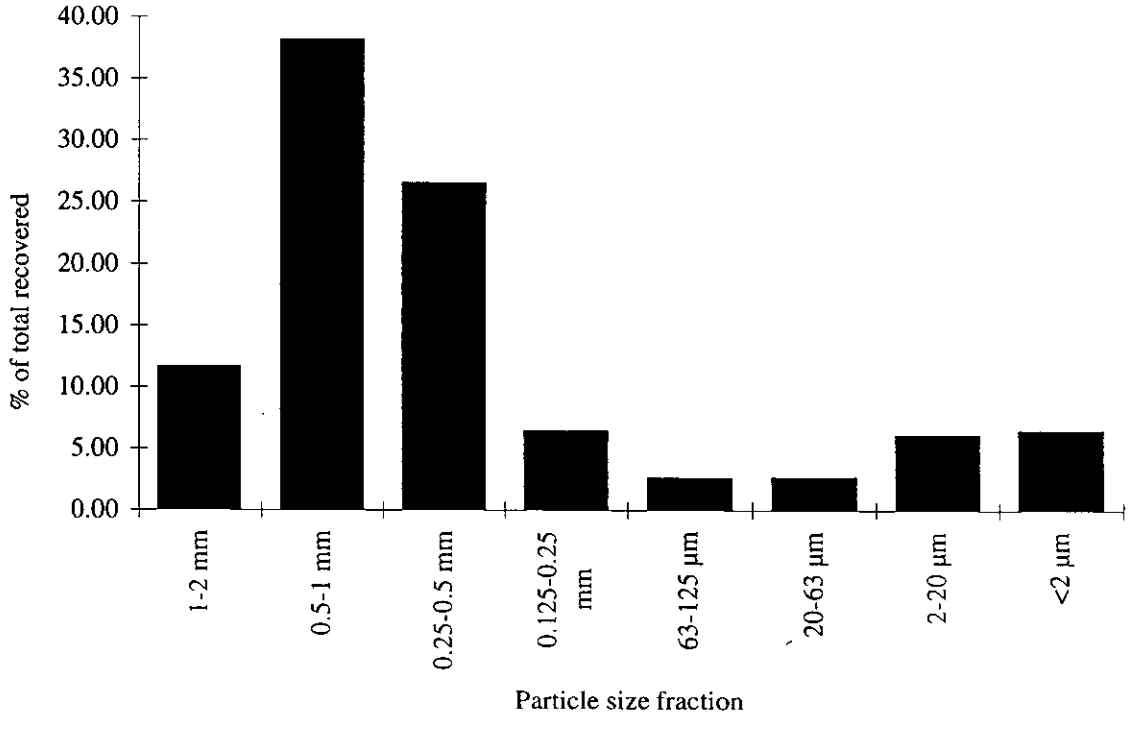
# APPENDIX 3

## PARTICLE SIZE DISTRIBUTION OF Gt. OUSE SEDIMENTS
## SAMPLE DATE 10-11/7/95

### Ouse site A

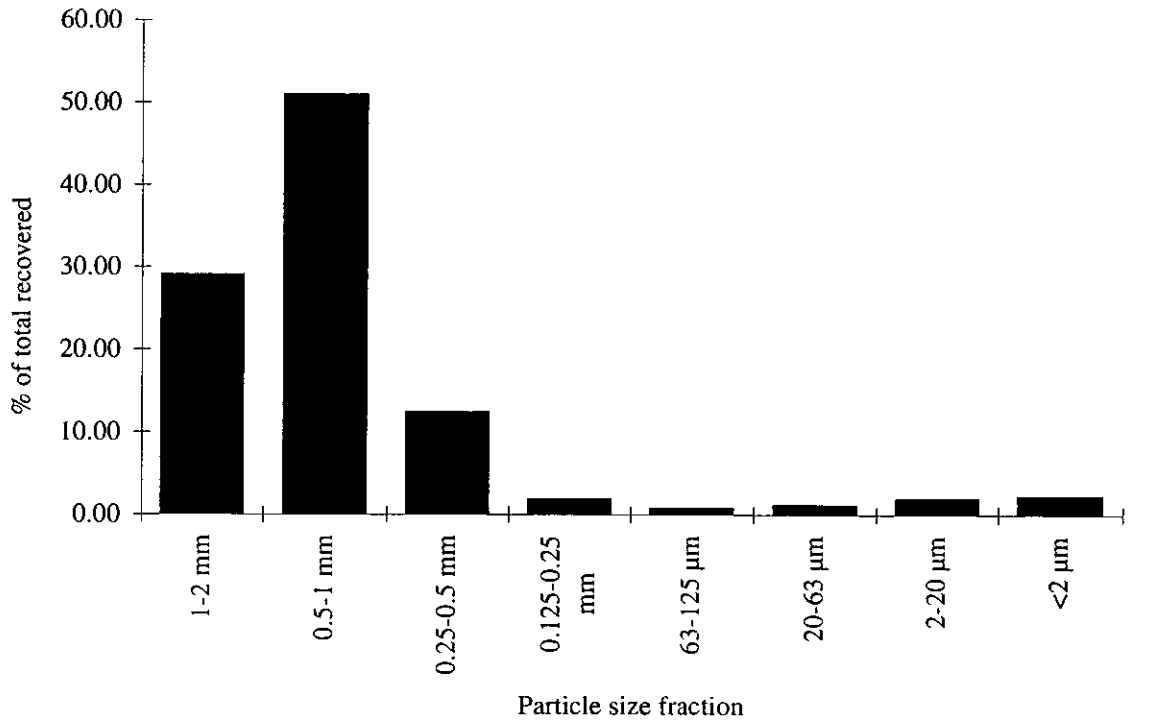



### Ouse site B

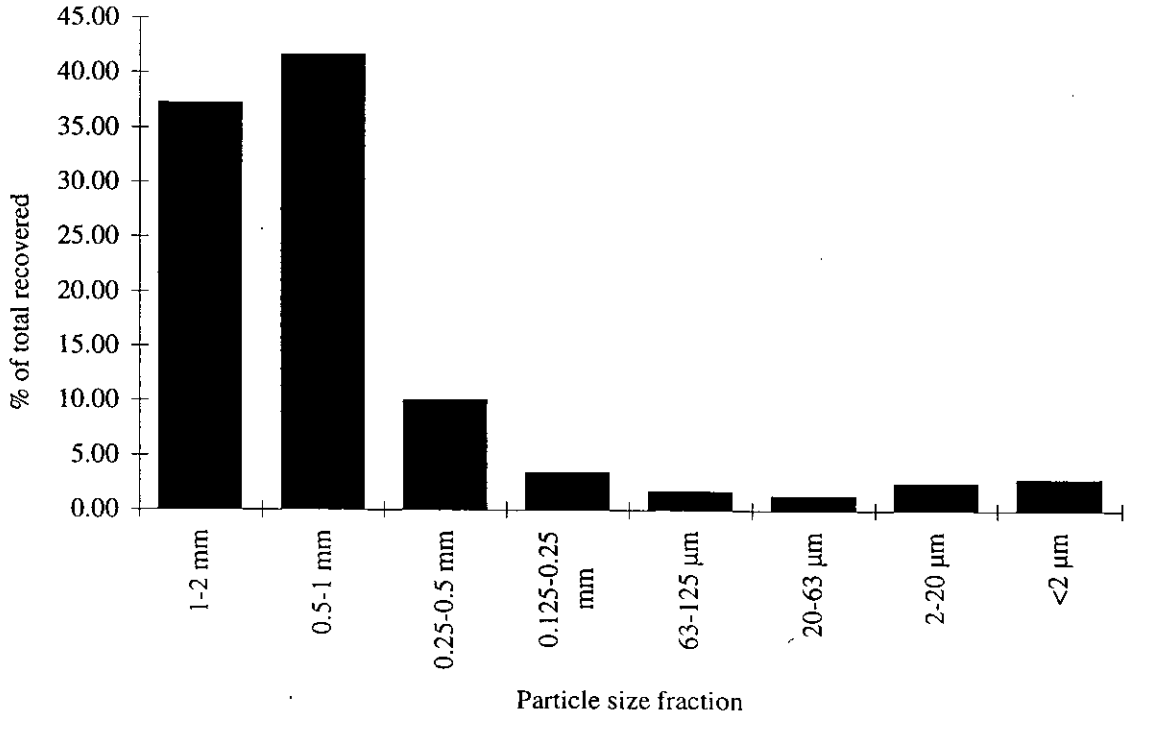


## PARTICLE SIZE DISTRIBUTION OF Gt. OUSE SEDIMENTS
## SAMPLE DATE 10-11/7/95

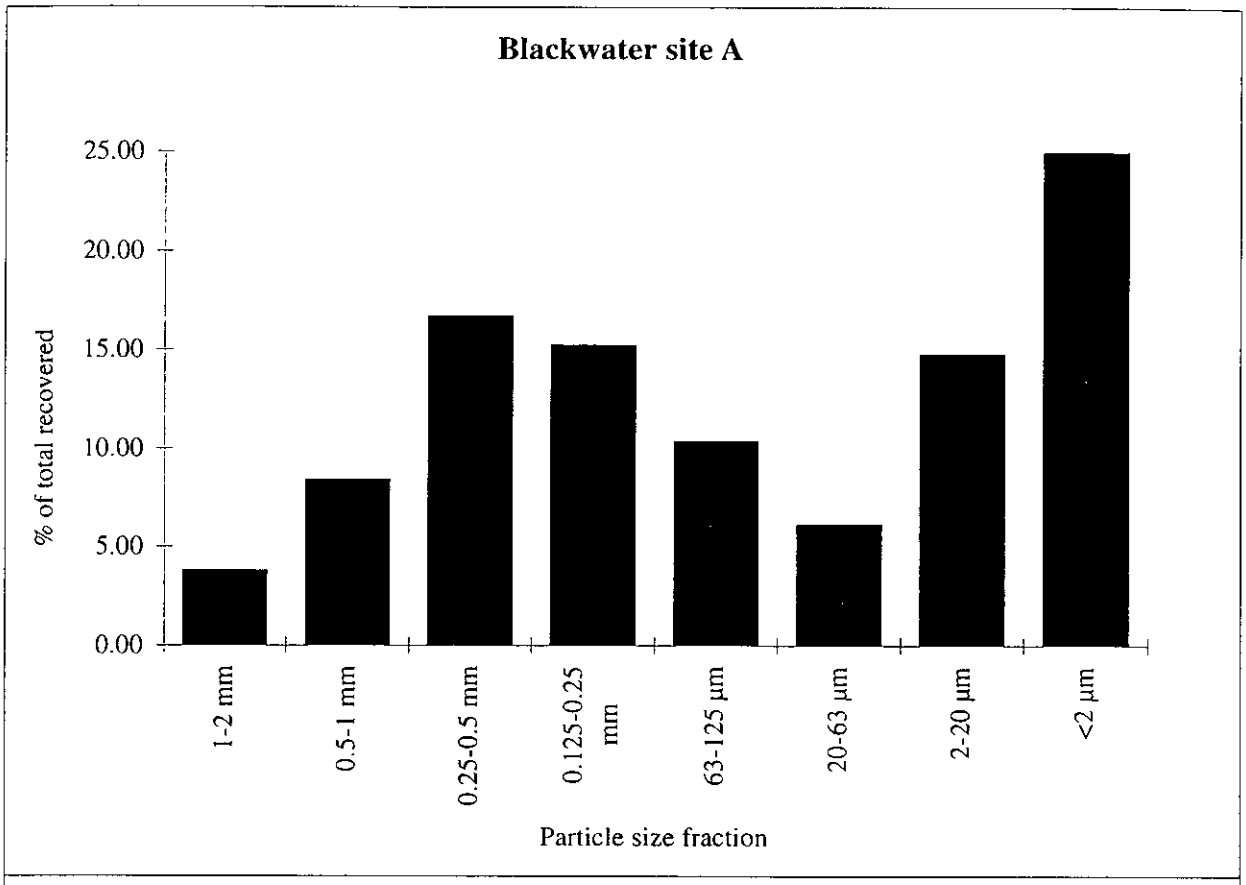
### Ouse site C

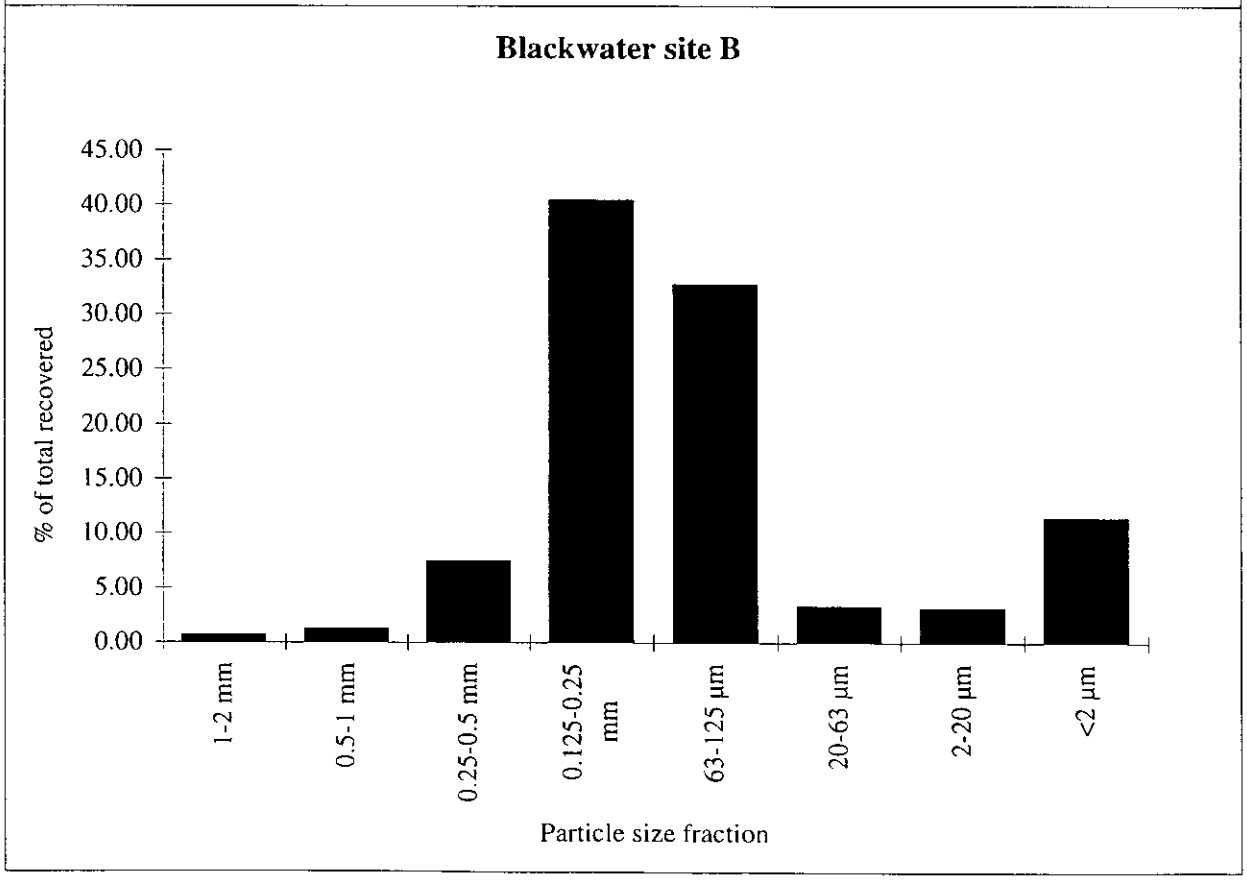



### Ouse site D

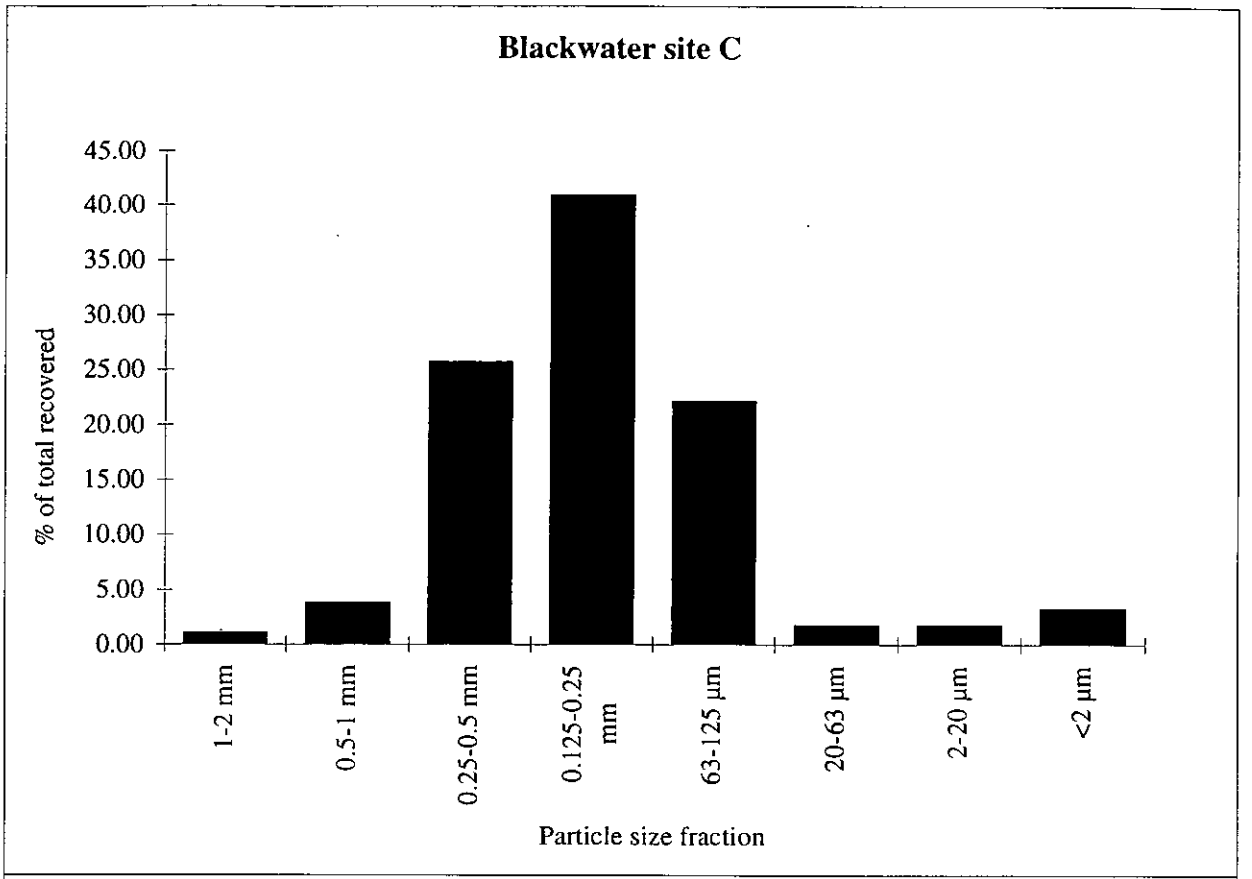


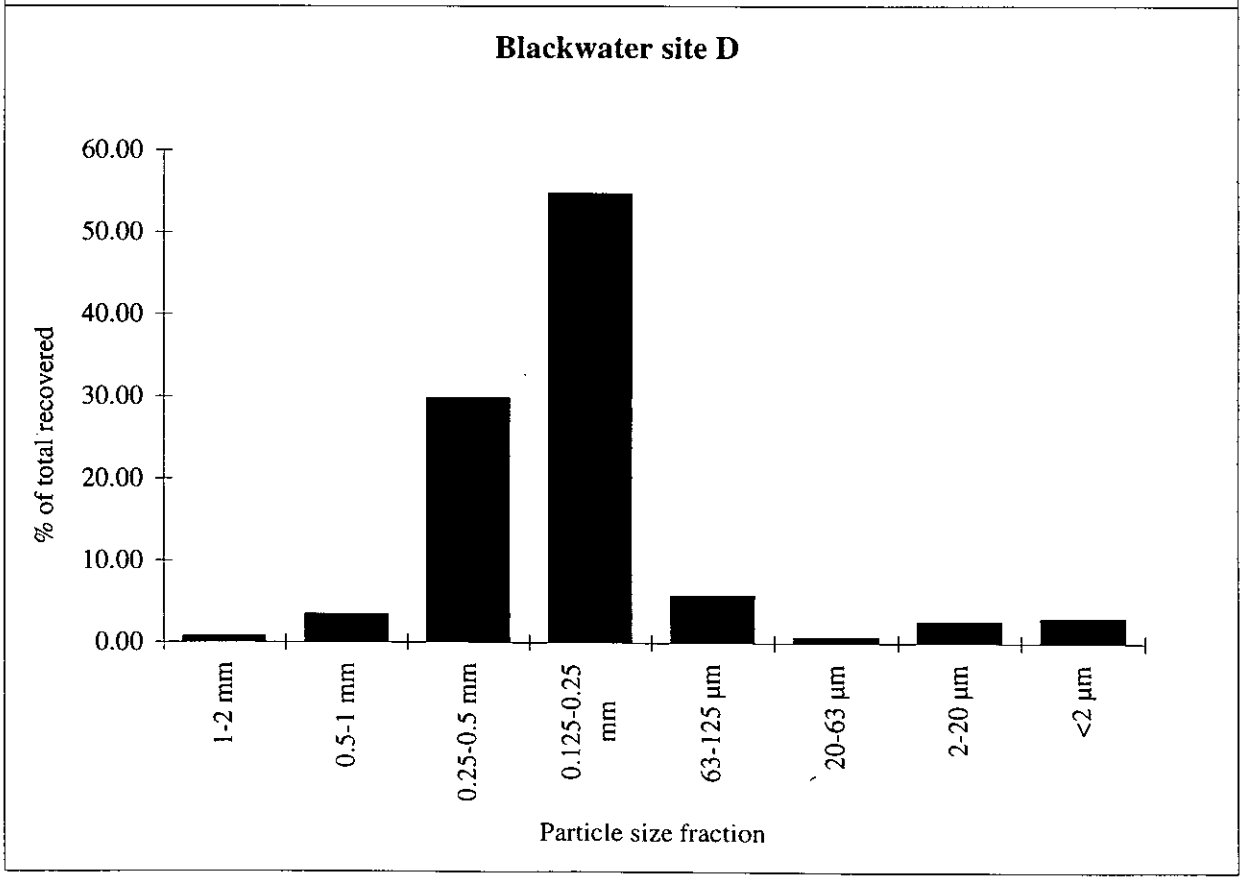
## PARTICLE SIZE DISTRIBUTION OF RIVER BLACKWATER SEDIMENTS SAMPLE DATE 21/7/95



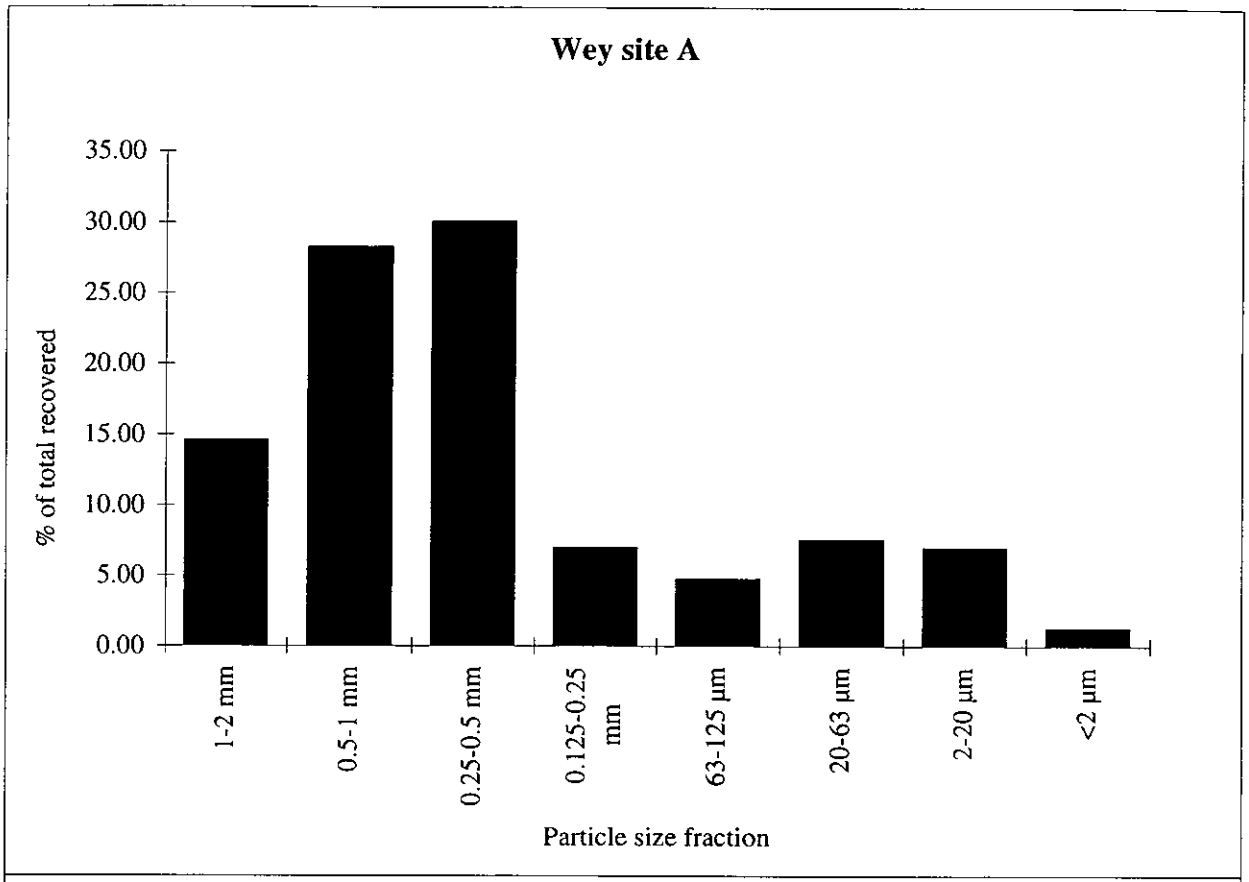



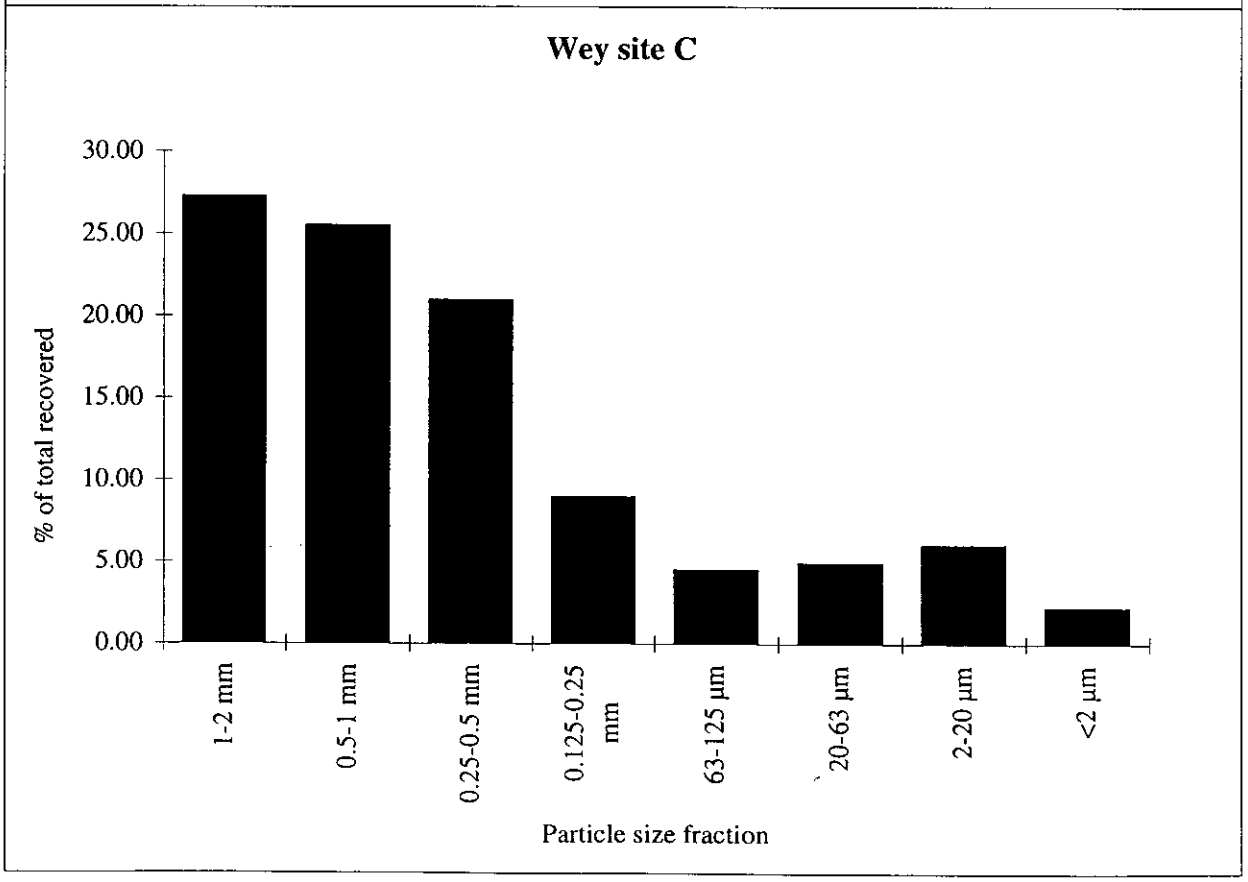
**PARTICLE SIZE DISTRIBUTION OF RIVER BLACKWATER SEDIMENTS**
**SAMPLE DATE 21/7/95**



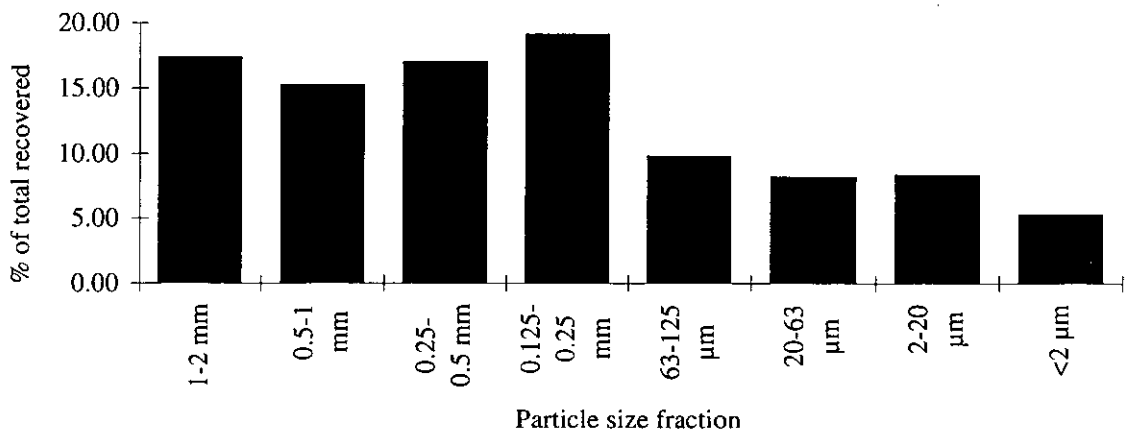
**PARTICLE SIZE DISTRIBUTION OF RIVER WEY SEDIMENTS**
**SAMPLE DATE 7/8/95**



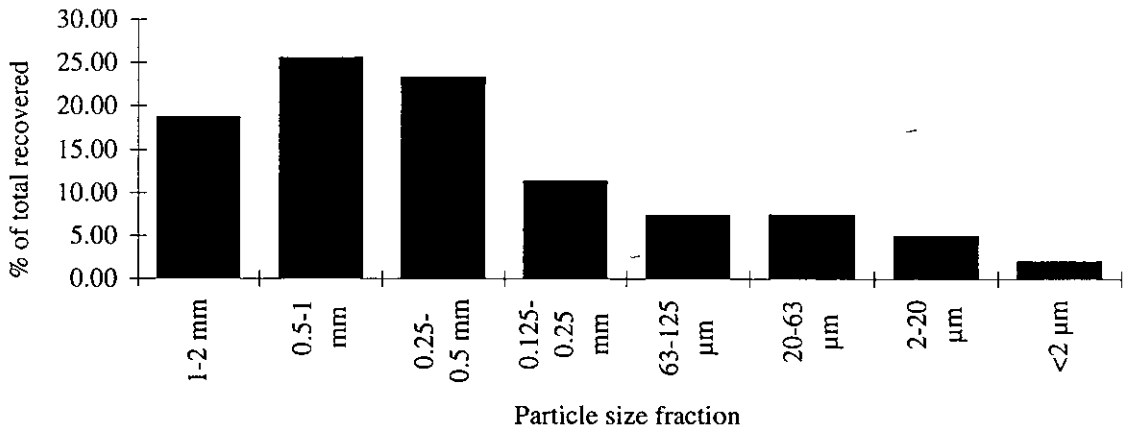



## PARTICLE SIZE DISTRIBUTION OF RIVER WEY SEDIMENTS
## SAMPLE DATE 7/8/95

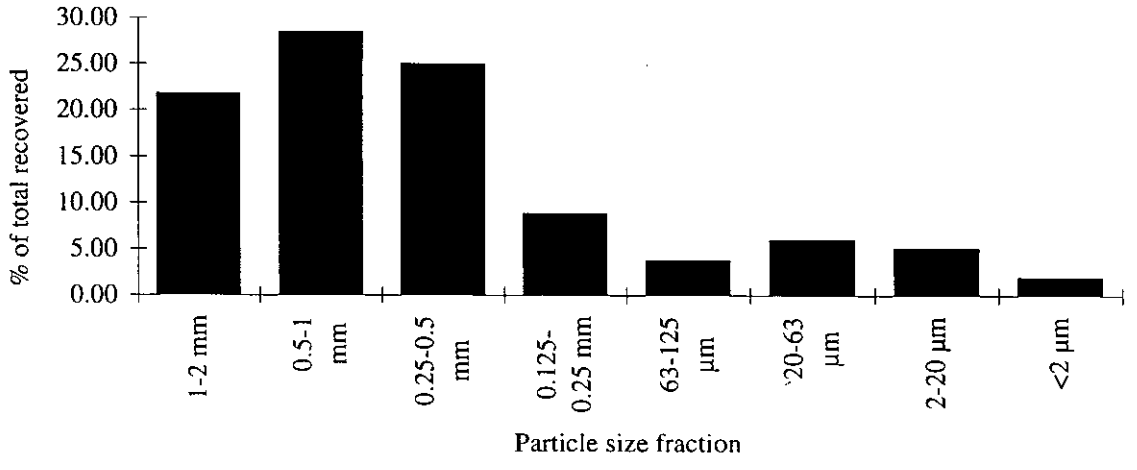
### Wey site D




### Wey site E

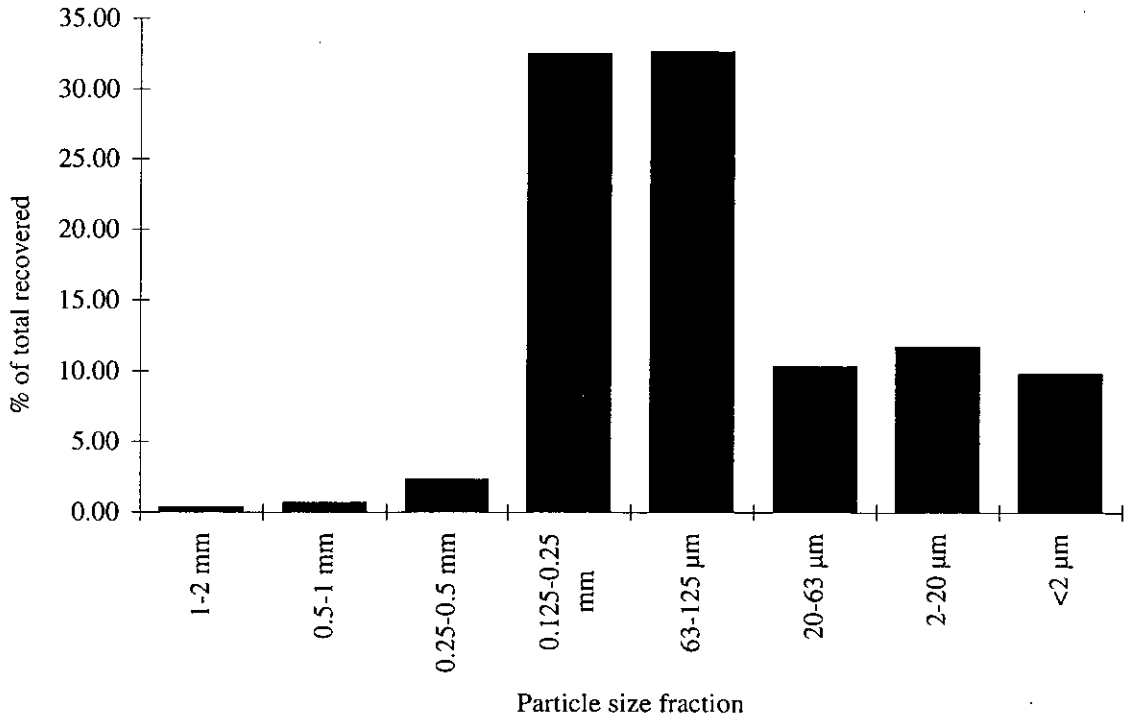



### Wey site F

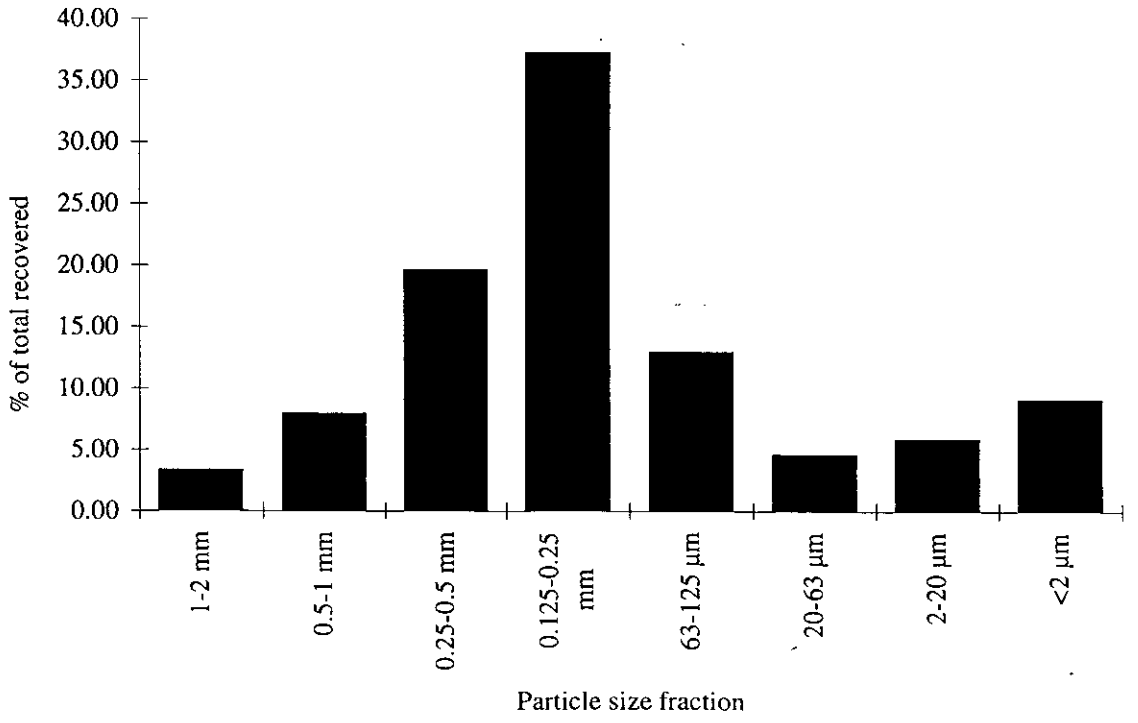


## PARTICLE SIZE DISTRIBUTION OF RIVER BLACKWATER SEDIMENTS SAMPLE DATE 23/10/95

### Blackwater site A

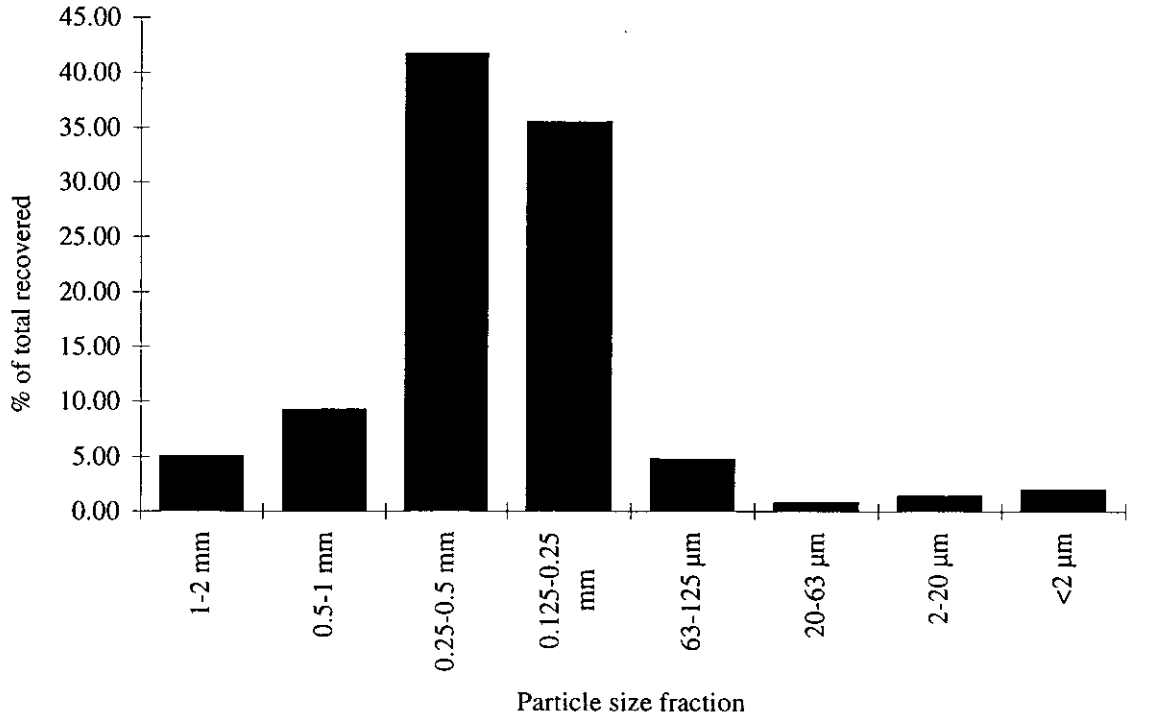



### Blackwater site B

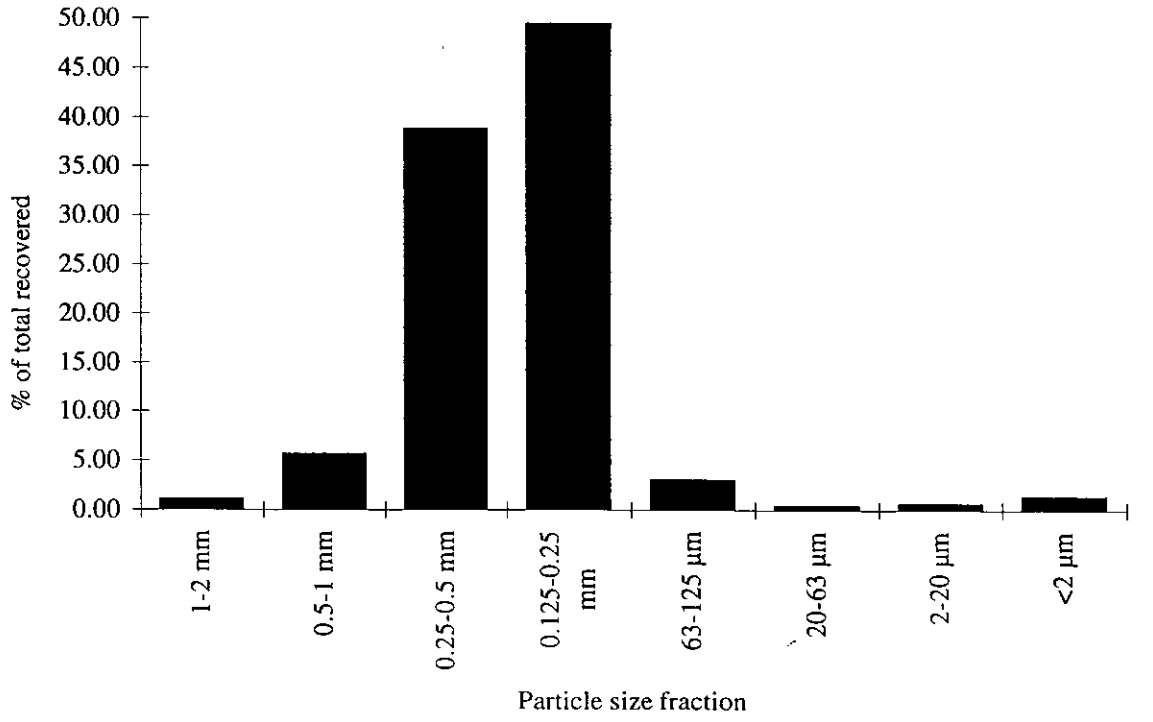


## PARTICLE SIZE DISTRIBUTION OF RIVER BLACKWATER SEDIMENTS SAMPLE DATE 23/10/95

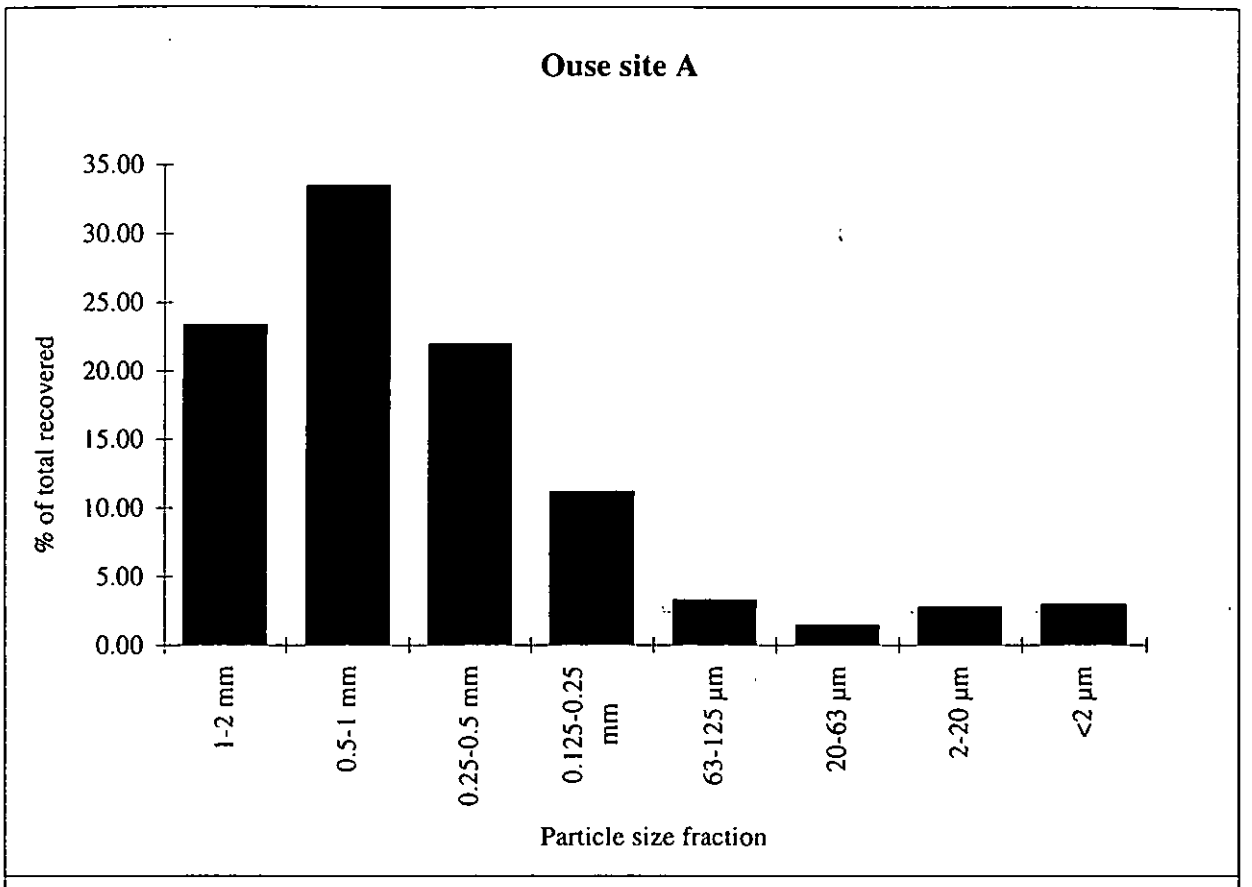
### Blackwater site C

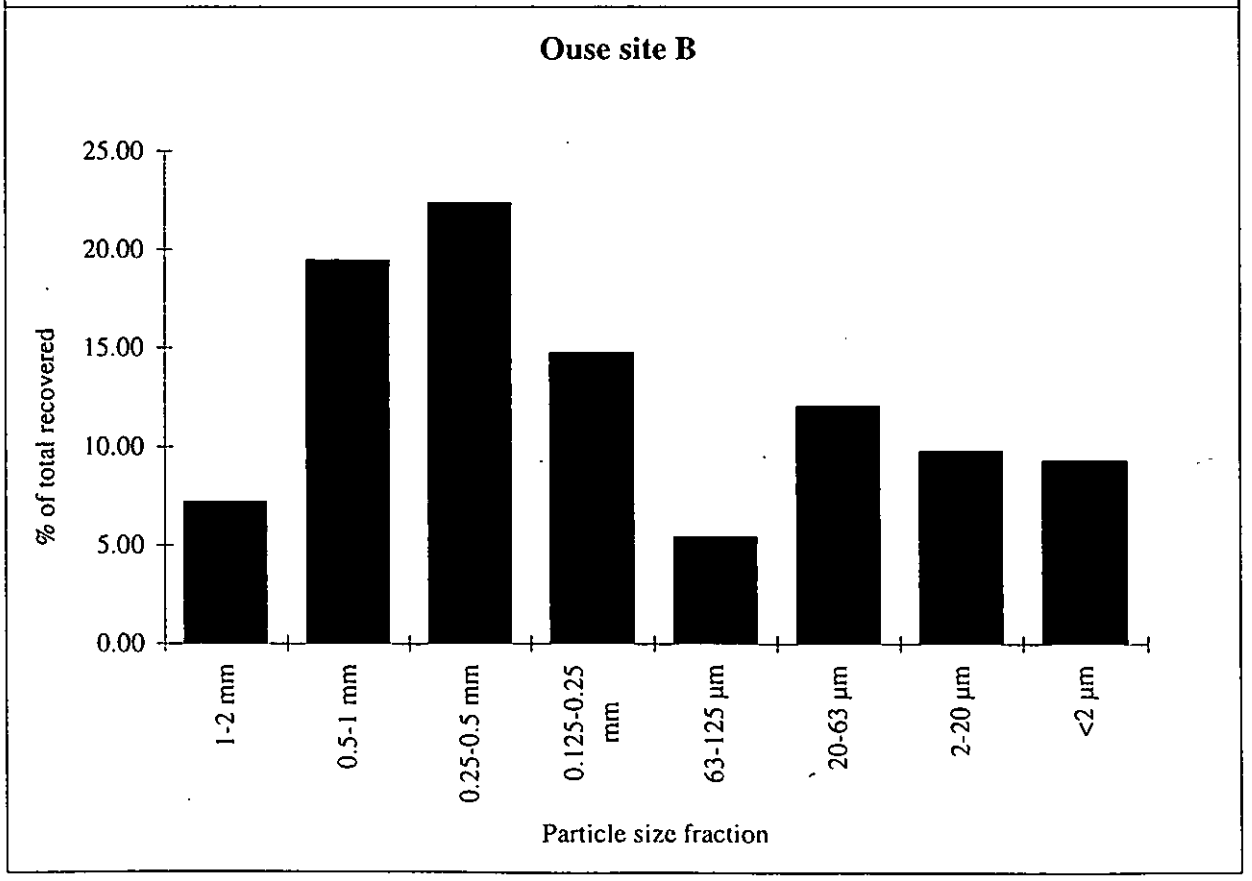



### Blackwater site D

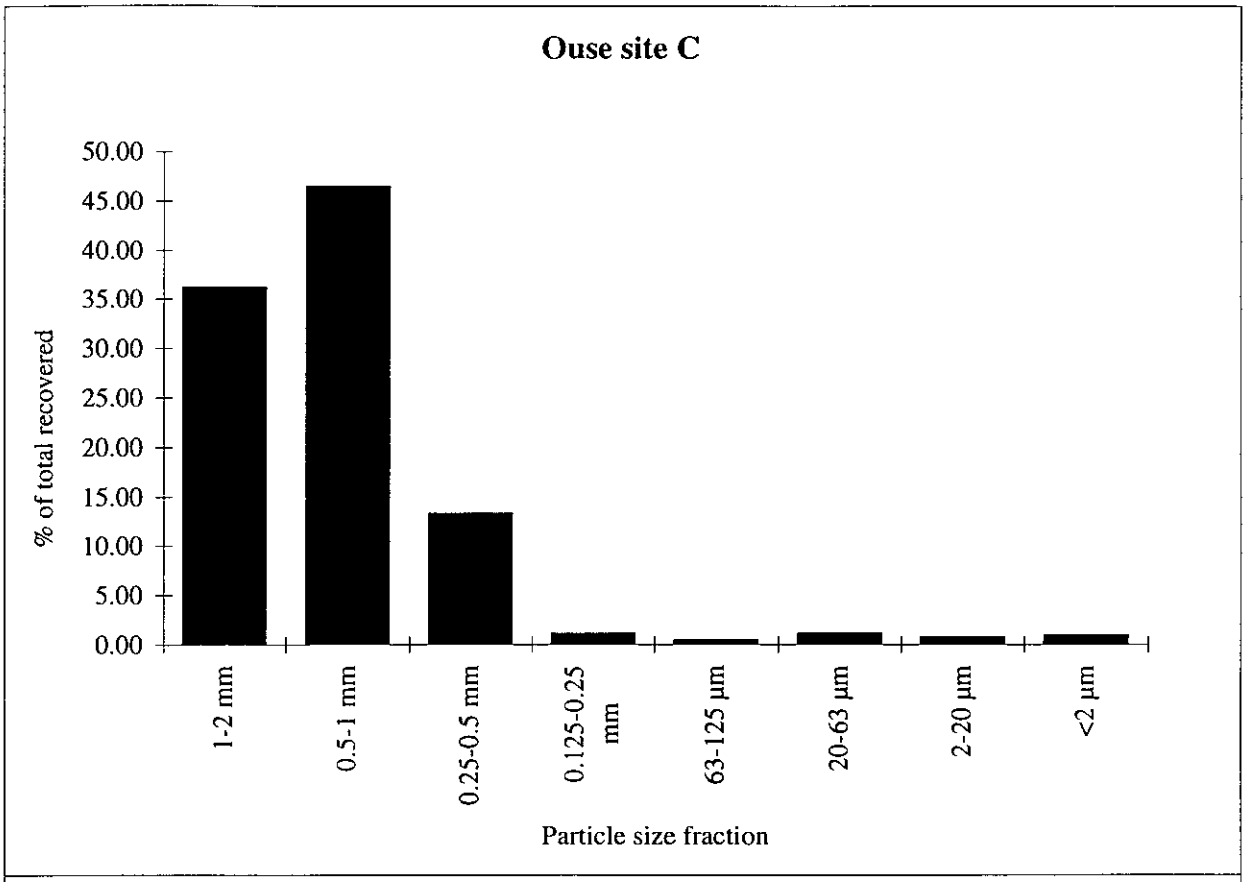


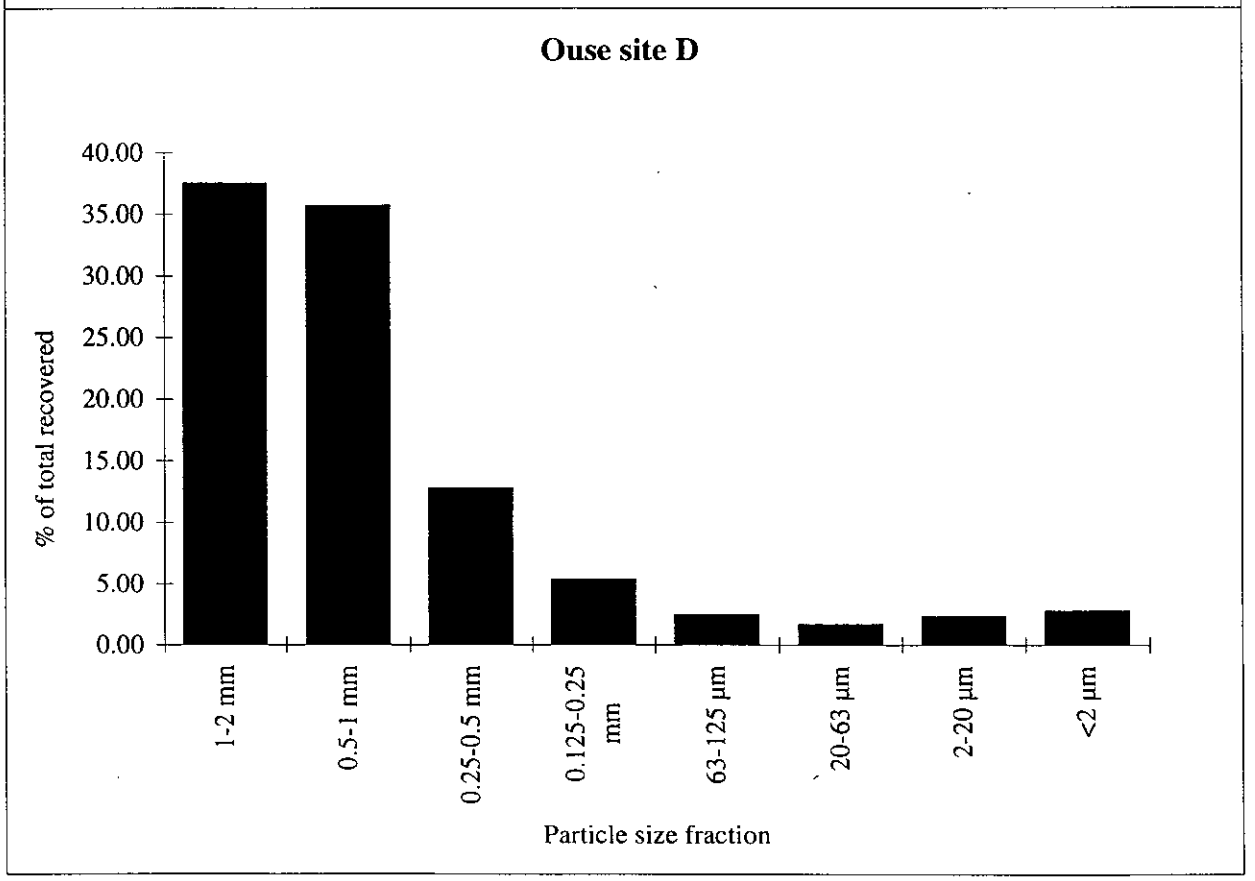
## PARTICLE SIZE DISTRIBUTION OF Gt. OUSE SEDIMENTS
## SAMPLE DATE 15/11/95



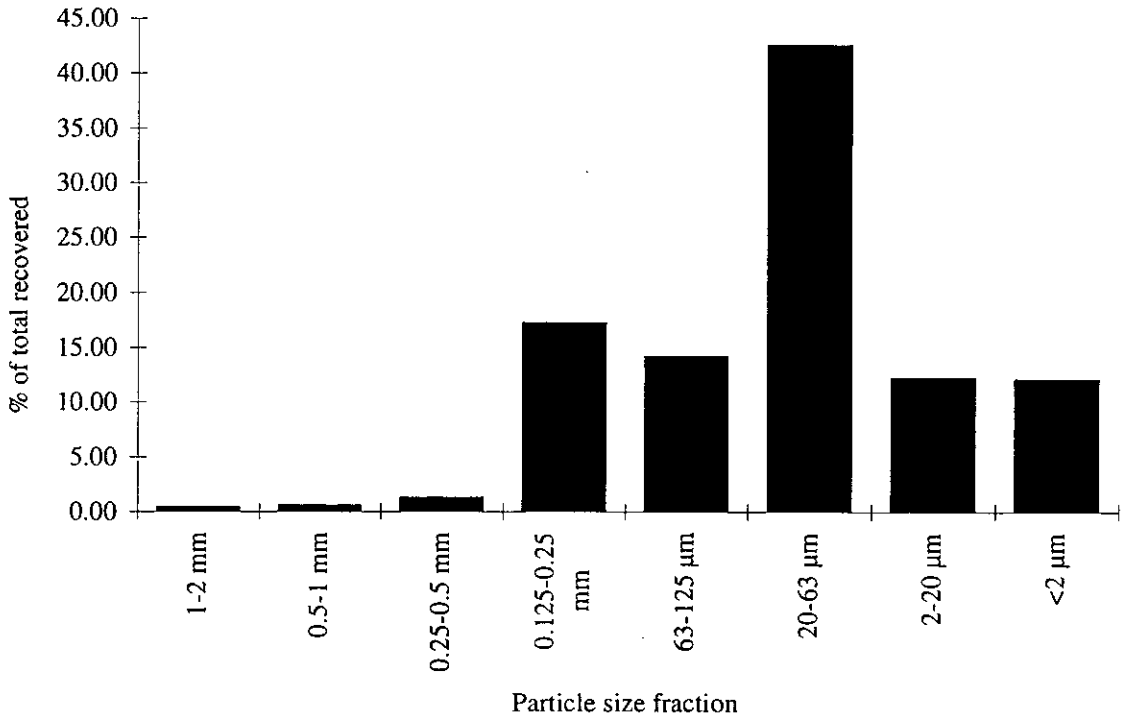
## PARTICLE SIZE DISTRIBUTION OF Gt. OUSE SEDIMENTS SAMPLE DATE 15/11/95



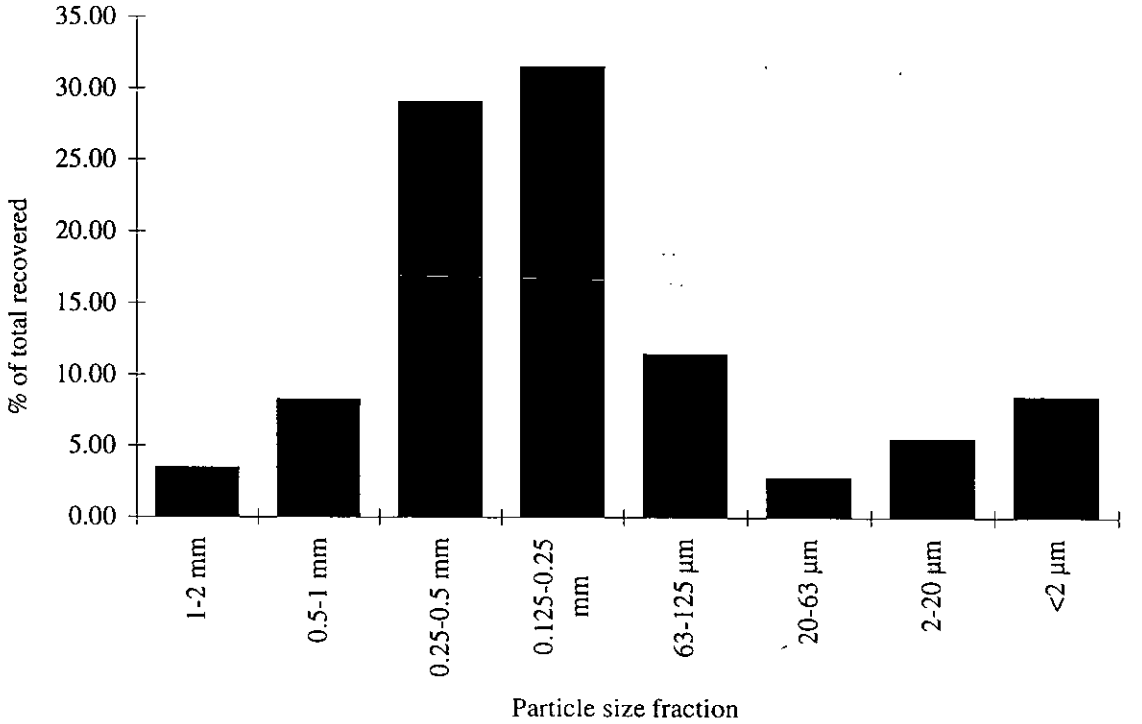



**PARTICLE SIZE DISTRIBUTION OF RIVER BLACKWATER SEDIMENTS**
**SAMPLE DATE 17/1/96**

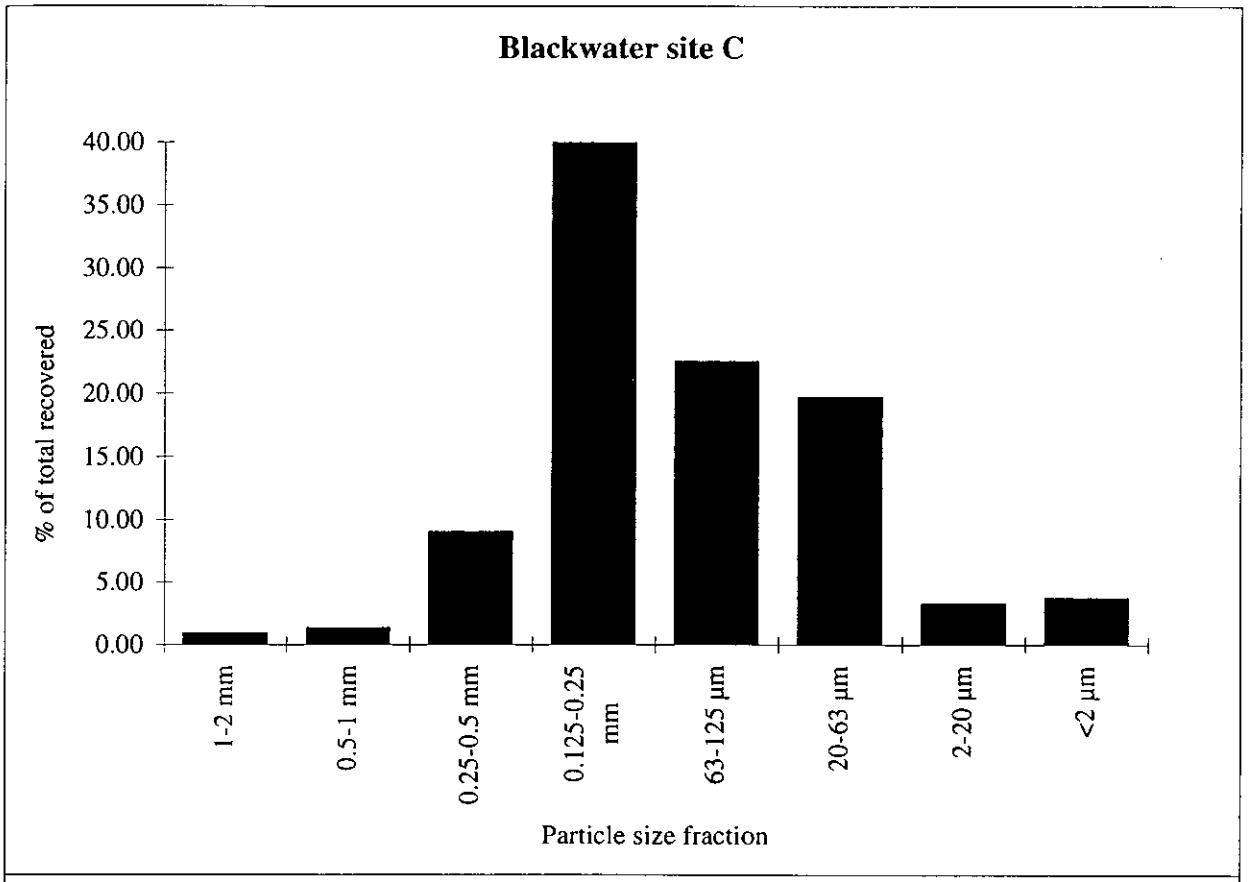
**Blackwater site A**

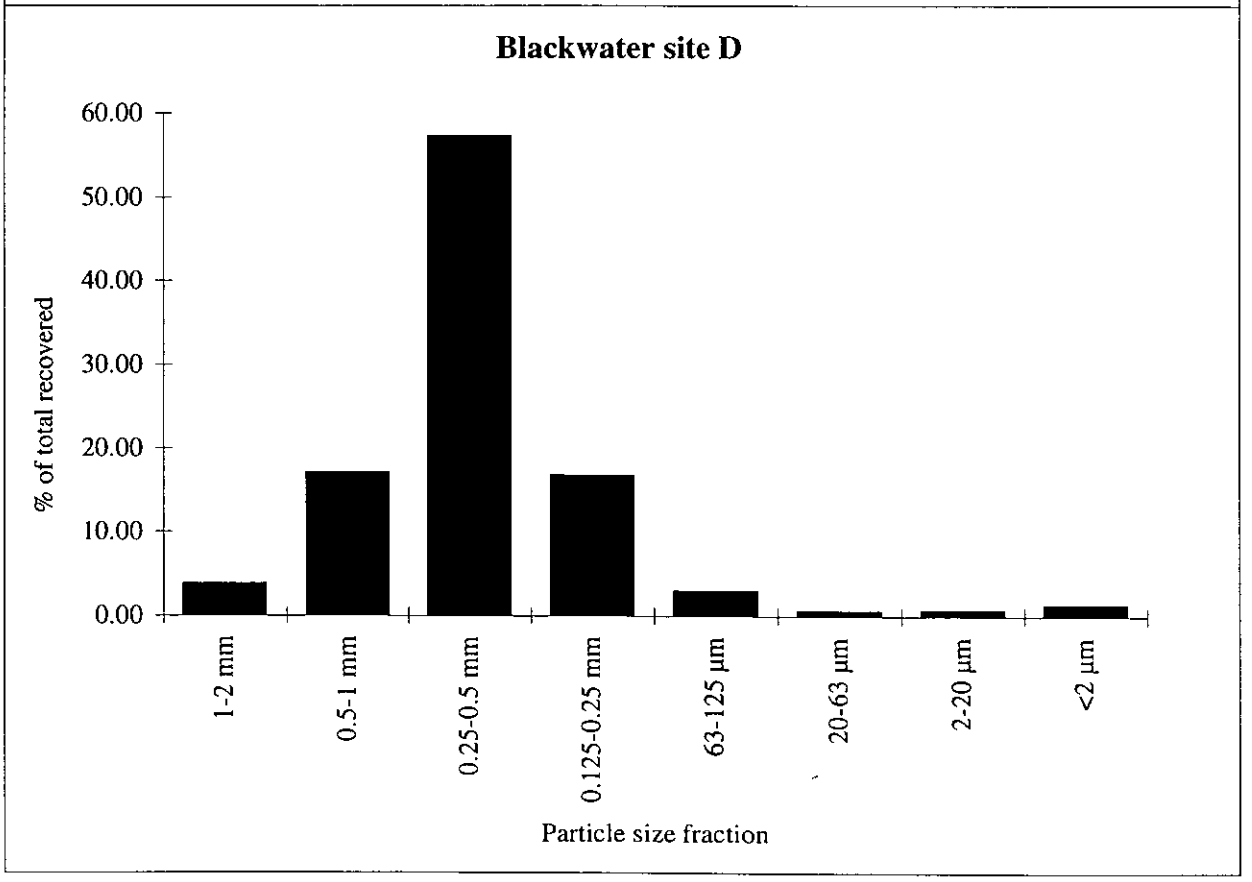



**Blackwater site B**



**PARTICLE SIZE DISTRIBUTION OF RIVER BLACKWATER SEDIMENTS**
**SAMPLE DATE 17/1/96**



# APPENDIX 4

## Fluvarium experiments with Gt. Ouse sediment summer 1995

Sediment collected 11/7/95

River water chemistry at time of sampling:

| | |
|---|---|
| Ca++ = 3.71 mM | NO3- = 1.17 mM |
| Mg++ = 0.28 mM | Silicon = 206.2 µM |
| Na+ = 2.44 mM | SRP = 72.16 µM |
| K+ = 0.24 mM | TDP = 82.50 µM |
| Alkalinity = 4.07 mEq | TP = 84.50 µM |

Channel experiment conditions:
Volume of solution = 21 litres
Flow rate = 28.3 litres/min
Velocity over sediment = 14.3 cm/s

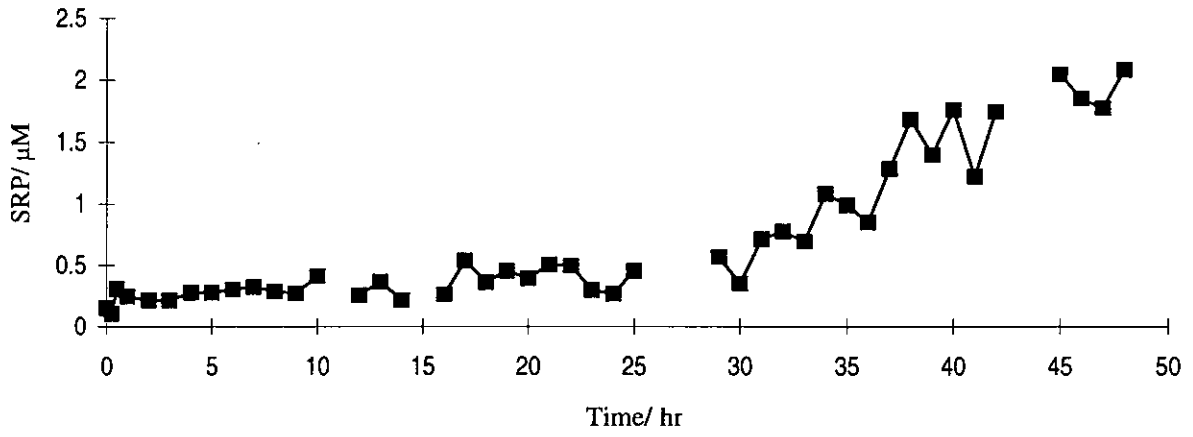
Experiment 1 - release experiment. 2 mM CaCl2 solution put into channel and sampling started 5 minutes after circulation started.

Experiment 2 - uptake experiment. 23.3 ml of 36 mM KH2PO4 added and sampling started after 5 minutes.

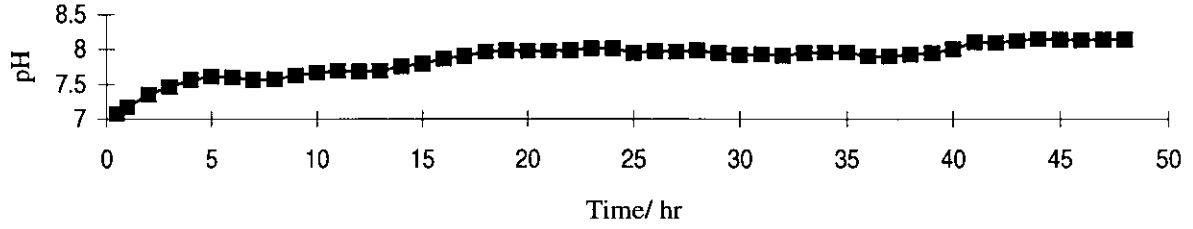
Experiment 3 - Anaerobic experiment. 6.7 g sodium sulphite added, and Nitrogen supply switched on. 1st sample after 5 minutes.

Sediment: EPCo = 1.92 µM; Kd = 203.0 dm^3/kg; ni = 0.39 µmol/g

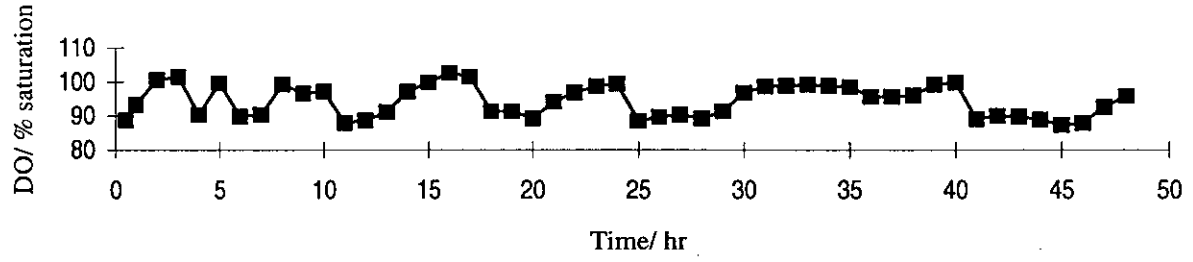
**Release of SRP from Gt. Ouse sediment**



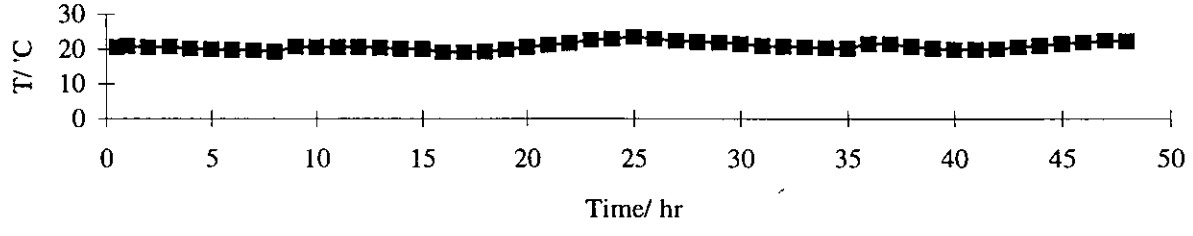

**pH during release experiment with Gt. Ouse sediment**



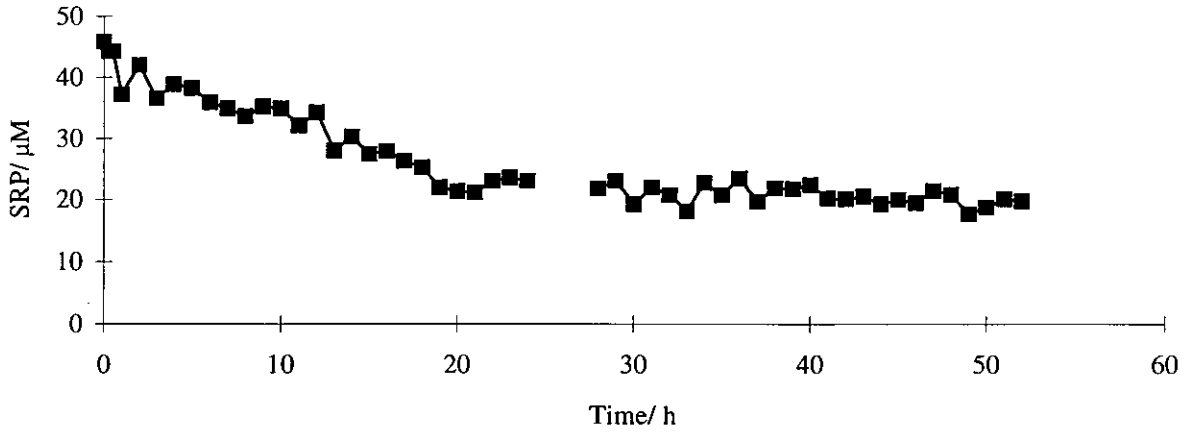

**Dissolved oxygen concentration during release experiment with Gt. Ouse sediment**



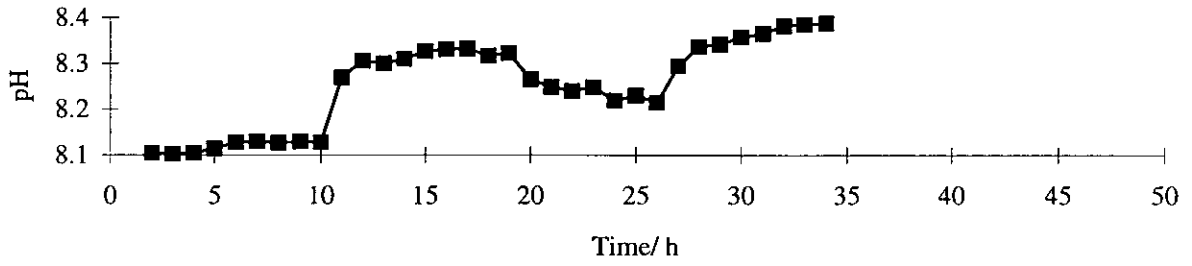

**Temperature during release experiment with Gt. Ouse sediment**



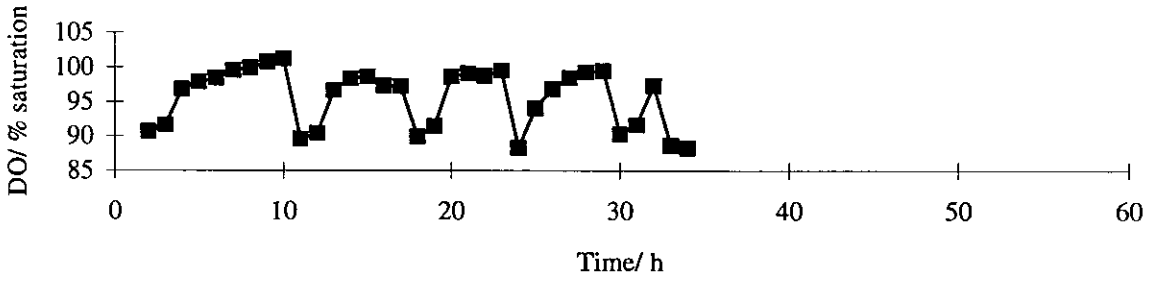
**Uptake of SRP by Gt. Ouse sediment**



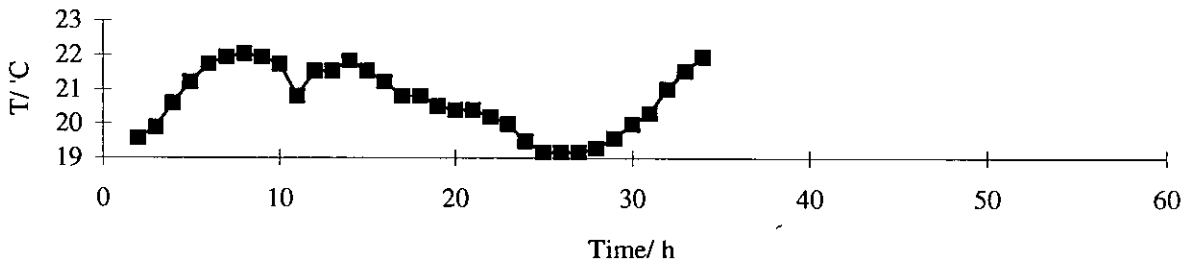

**pH during uptake experiment with Gt. Ouse sediment**



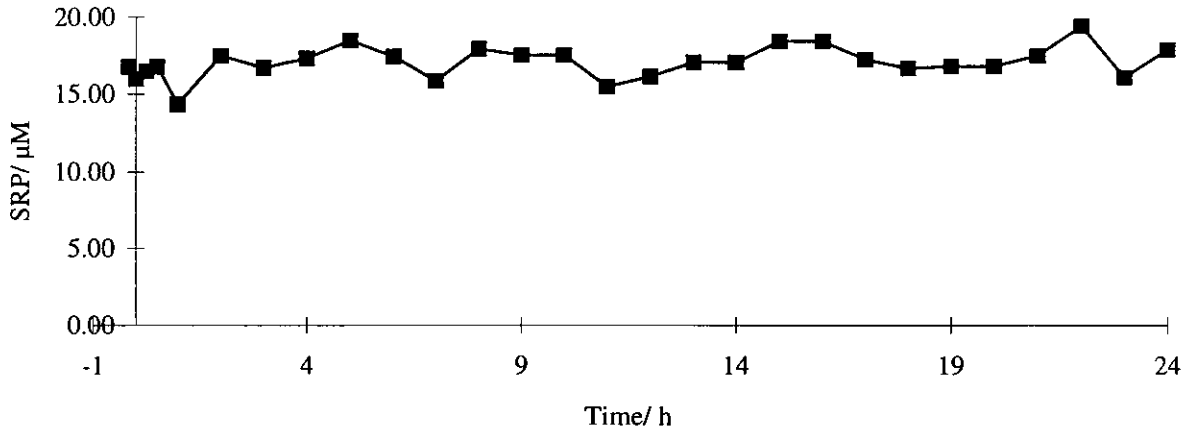

**Dissolved oxygen concentration during uptake experiment with Gt. Ouse sediment**



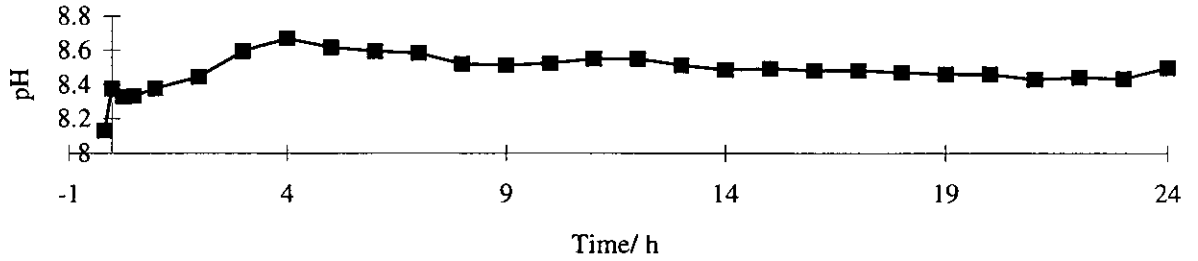

**Temperature during uptake experiment with Gt. Ouse sediment**



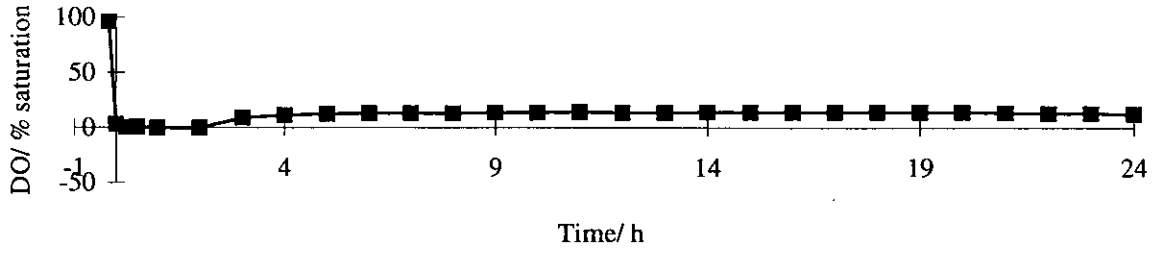
**SRP Concentration during anaerobic experiment with Gt. Ouse sediment**



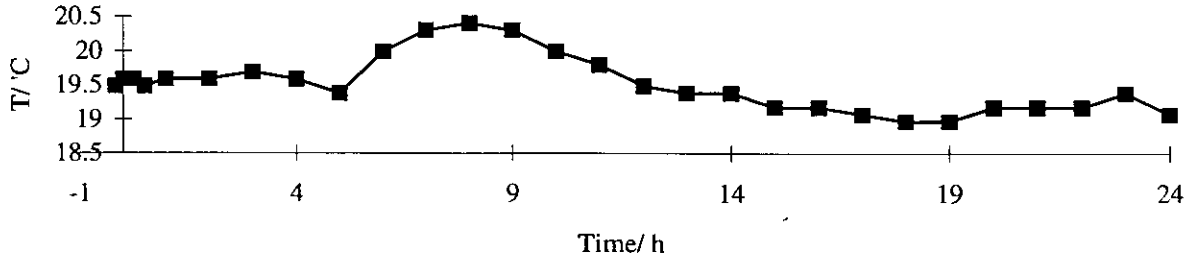

**pH during anaerobic experiment with Gt. Ouse sediment**




**Dissolved oxygen concentration during anaerobic experiment with Gt. Ouse sediment**




**Temperature during anaerobic experiment with Gt. Ouse sediment**



**Fluvarium experiments with River Blackwater sediment summer 1995**

Sediment collected 21/7/95

River water chemistry at time of sampling:

| | |
|---|---|
| Ca++ = 2.44 mM | NO3- = 0.84 mM |
| Mg++ = 0.30 mM | Silicon = 445 µM |
| Na+ = 2.81 mM | SRP = 133.01 µM |
| K+ = 0.37 mM | TDP = 160.5 µM |
| Alkalinity = 3.73 mEq | TP = 180 µM |

Channel experiment conditions:
Volume of solution = 21 litres
Flow rate = 14.27 litres/min
Velocity over sediment = 9.23 cm/s

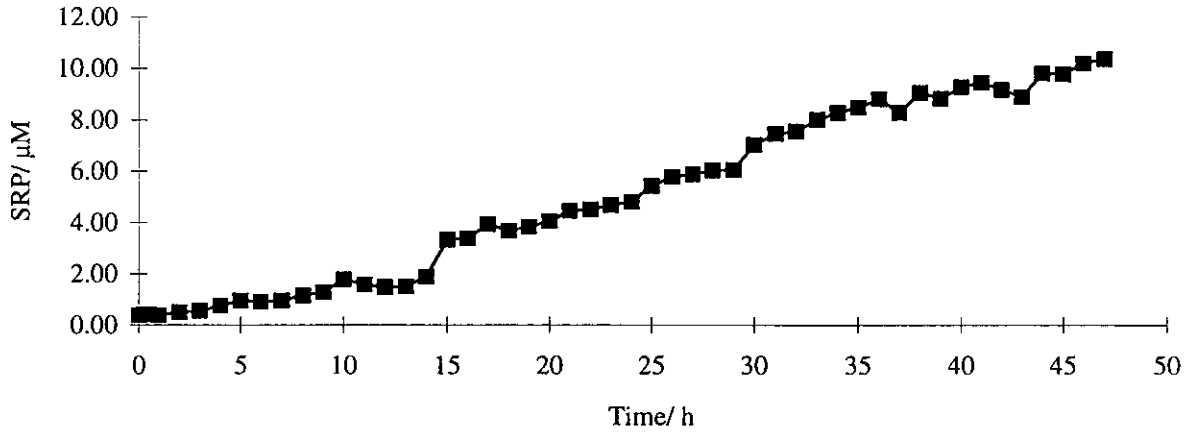
Experiment 1 - release experiment. 2 mM CaCl2 solution put into channel and sampling started 5 minutes after circulation started.

Experiment 2 - uptake experiment. 23.3 ml of 36 mM KH2PO4 added and sampling started after 5 minutes.

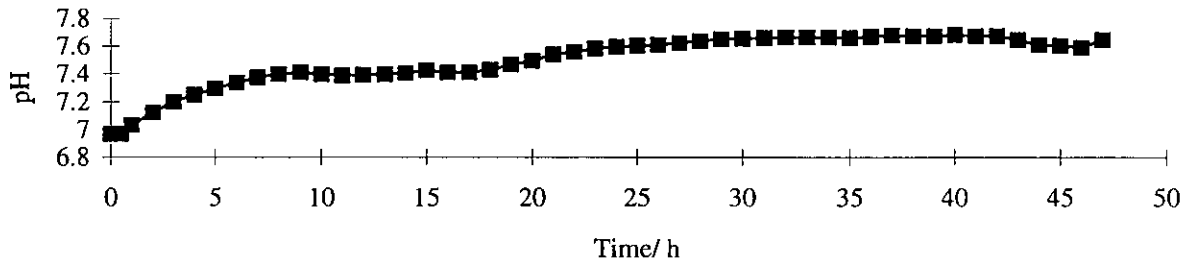
Experiment 3 - Anaerobic experiment. System allowed to equilibriate over weekend, then 6.7 g sodium sulphite added, and Nitrogen supply switched on. 1st sample after 5 minutes.

Sediment: EPCo = 0.17 µM

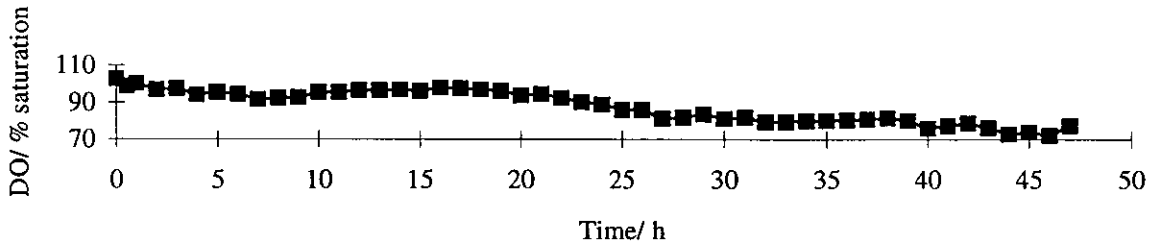
**Release of SRP from R. Blackwater bed sediment**



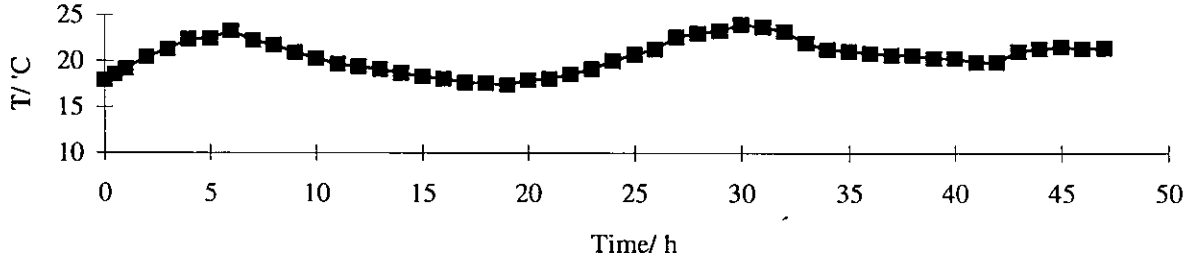

**pH during release experiment with R. Blackwater bed sediment**



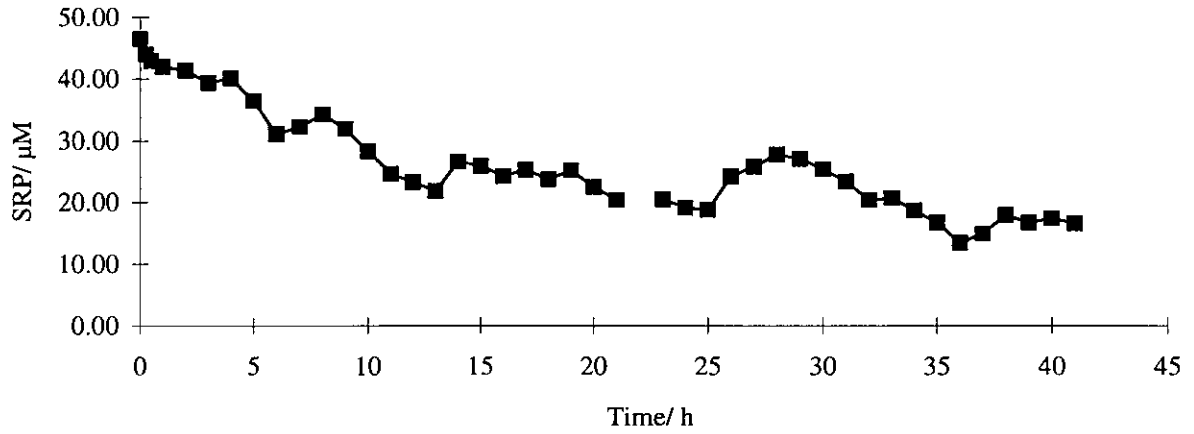

**Dissolved oxygen concentration during release experiment with R. Blackwater bed sediment**



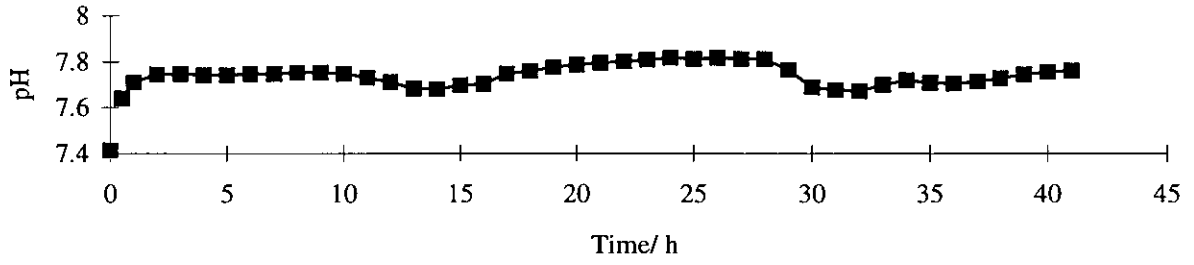

**Temperature during release experiment with R. Blackwater bed sediment**



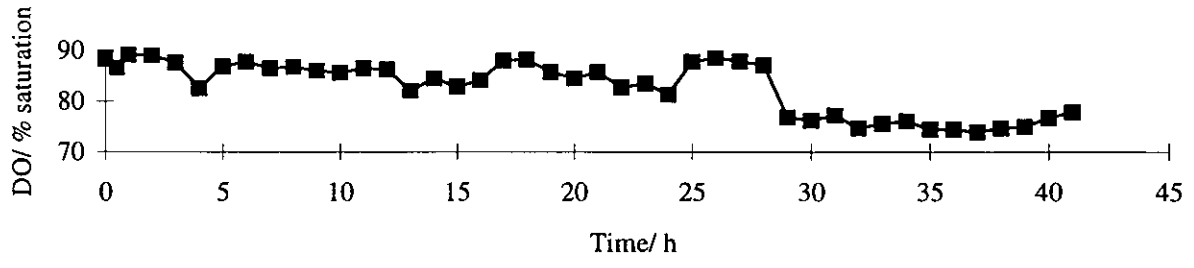
**Uptake of SRP by R. Blackwater bed sediment**



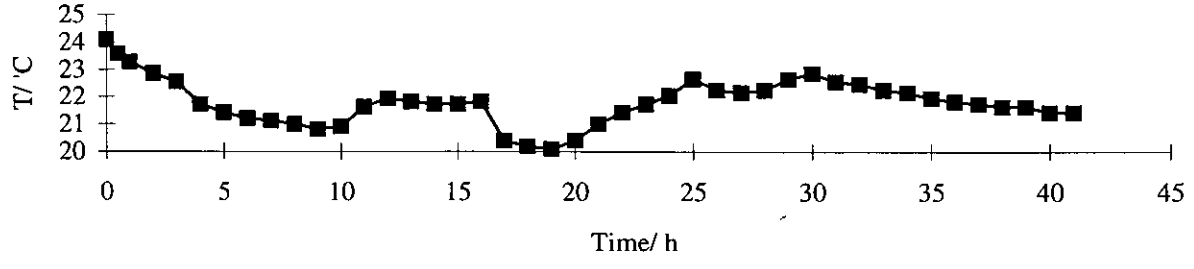

**pH during uptake experiment with R. Blackwater bed sediment**



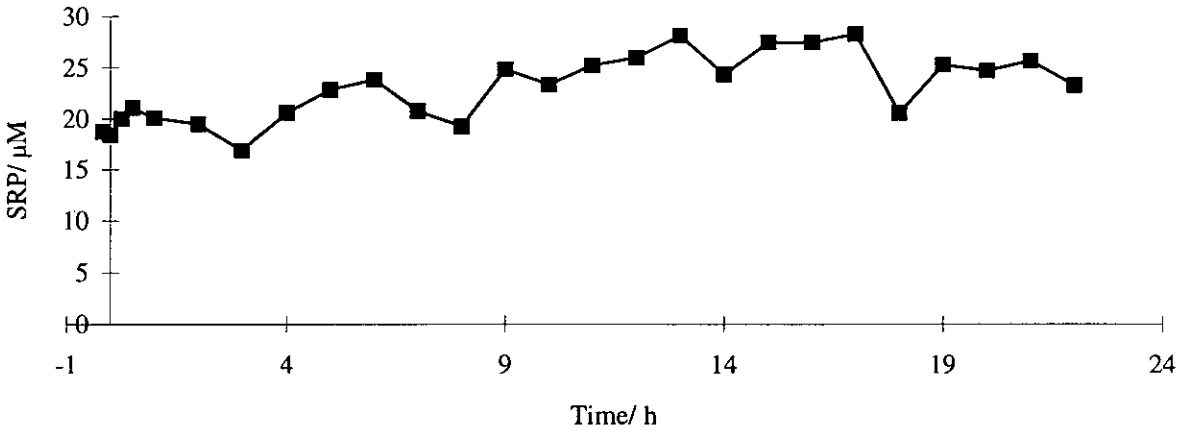

**Dissolved oxygen concentration during uptake experiment with R. Blackwater bed sediment**



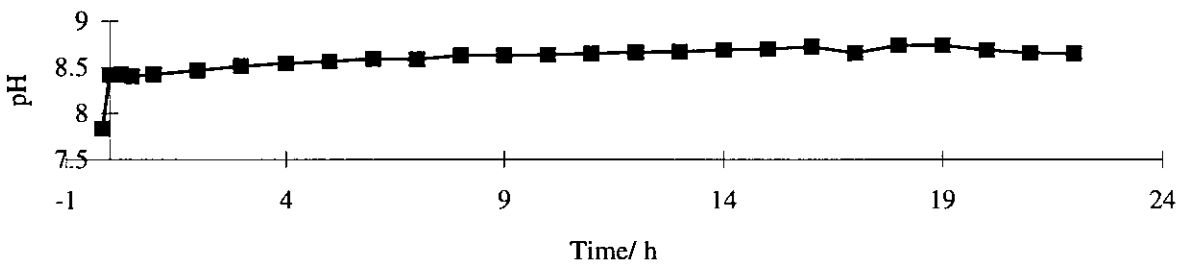

**Temperature during uptake experiment with R. Blackwater bed sediment**



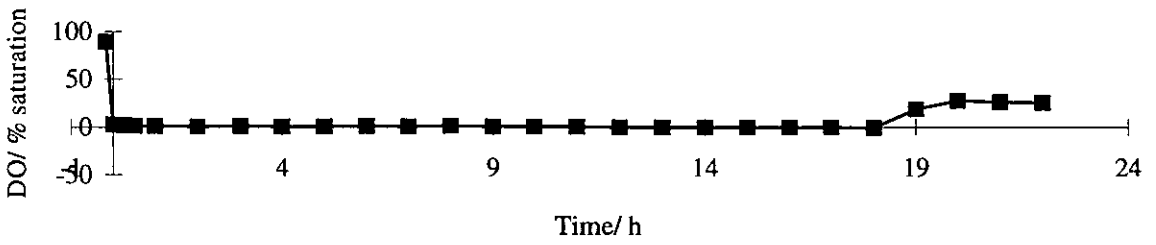
**SRP Concentration during anaerobic experiment with R. Blackwater sediment**



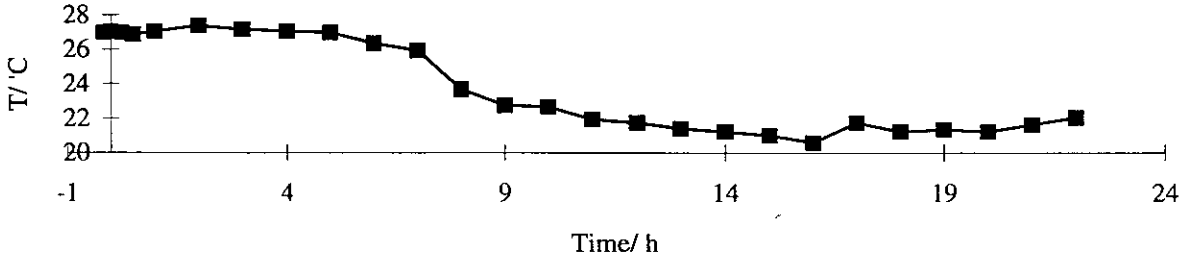

**pH during anaerobic experiment with R. Blackwater sediment**




**Dissolved oxygen concentration during anaerobic experiment with R. Blackwater sediment**




**Temperature during anaerobic experiment with R. Blackwater sediment**



**Fluvarium experiments with River Wey sediment summer 1995**

Sediment collected 7/8/95

River water chemistry at time of sampling:

| | |
|---|---|
| Ca++ = 3.01 mM | NO3- = 0.68 mM |
| Mg++ = 0.11 mM | Silicon = 304 µM |
| Na+ = 2.14 mM | SRP = 67.8 µM |
| K+ = 0.171 mM | TDP = 80 µM |
| Alkalinity = 6.04 mEq | TP = 83 µM |

Channel experiment conditions:
Volume of solution = 21 litres
Flow rate = 28.2 litres/min
Velocity over sediment = 15.5 cm/s

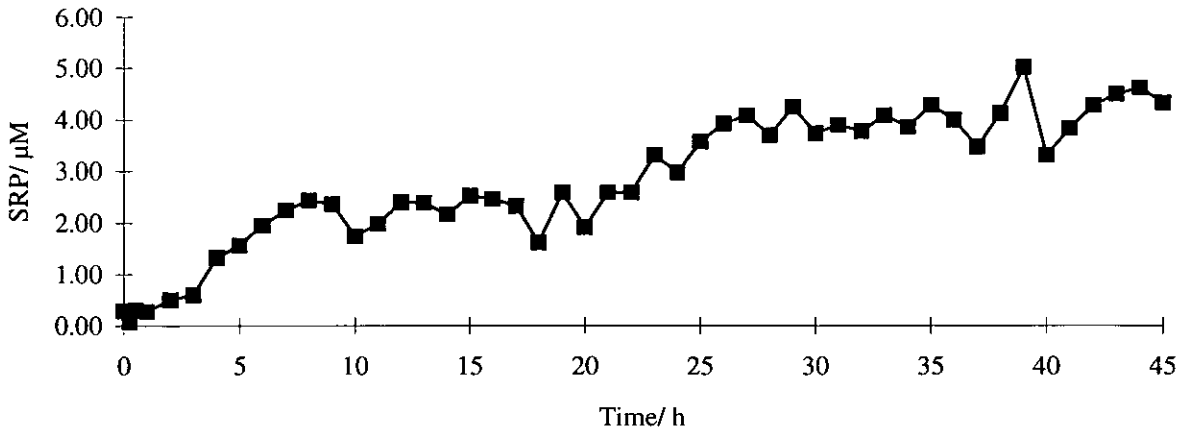
Experiment 1 - release experiment. 2 mM CaCl2 solution put into channel and sampling started 5 minutes after circulation started.

Experiment 2 - uptake experiment. 23.3 ml of 36 mM KH2PO4 added and sampling started after 5 minutes.

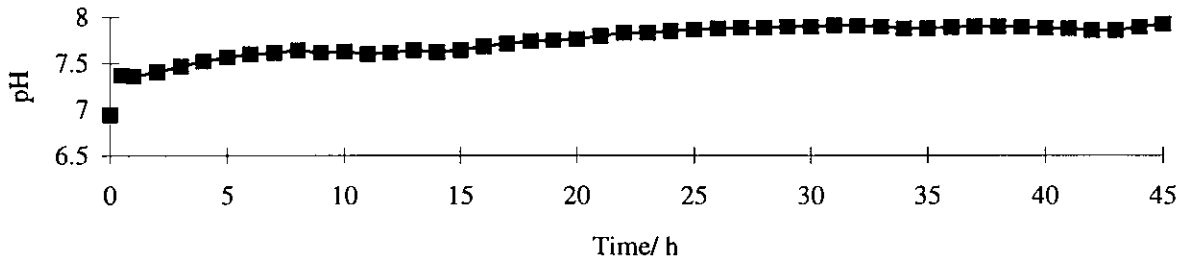
Experiment 3 - Anaerobic experiment. System allowed to equilibriate over weekend, then 6.7 g sodium sulphite added, and Nitrogen supply switched on. 1st sample after 5 minutes.

Sediment: EPCo = 5.33 µM; Kd = 70.3 dm^3/kg; ni = 0.375 µmol/g

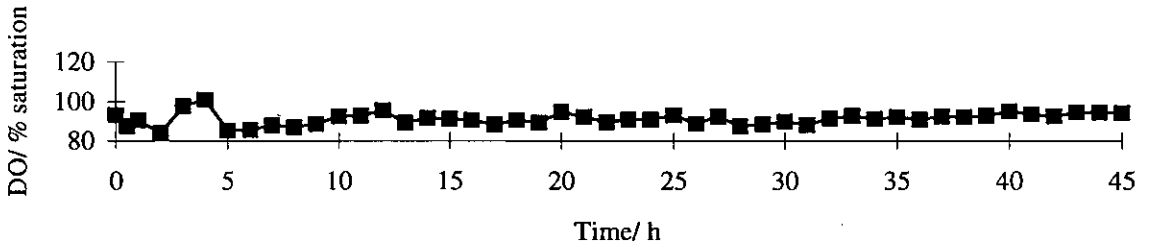
**Release of SRP from R. Wey bed sediment**



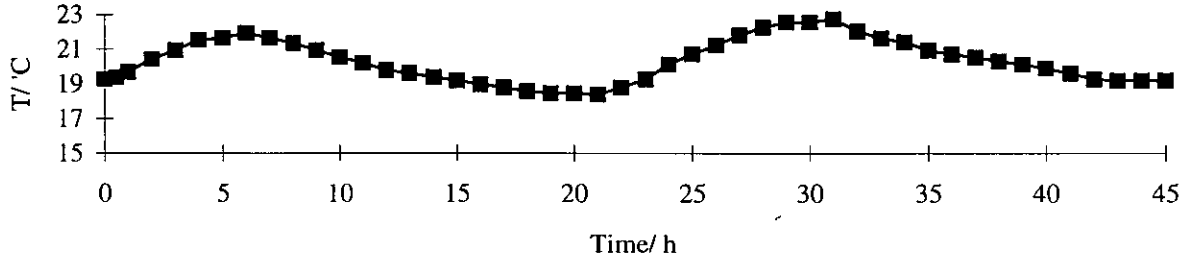

**pH during release experiment with R. Wey bed sediment**



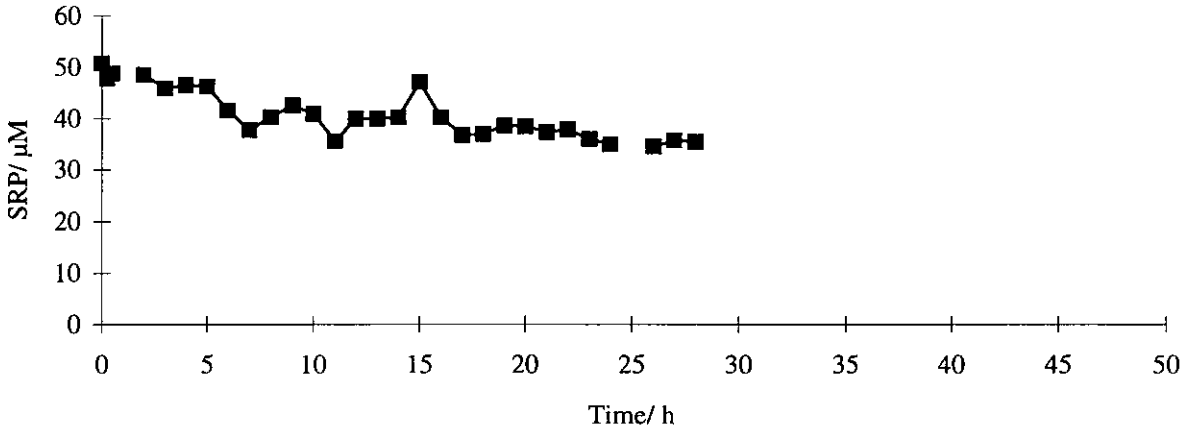

**Dissolved oxygen concentration during release experiment with R. Wey bed sediment**



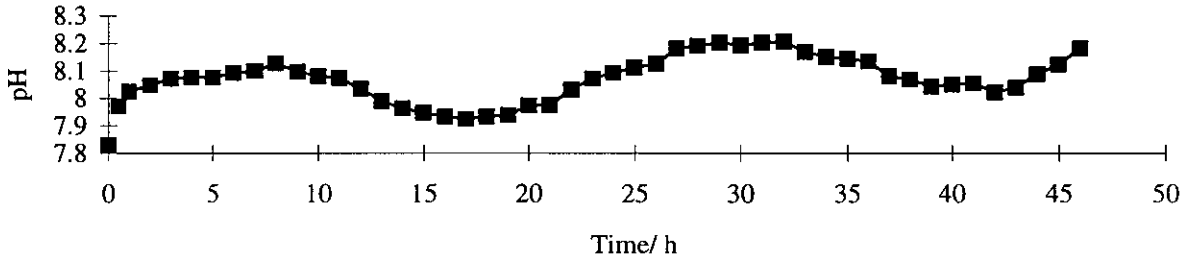

**Temperature during release experiment with R. Wey bed sediment**



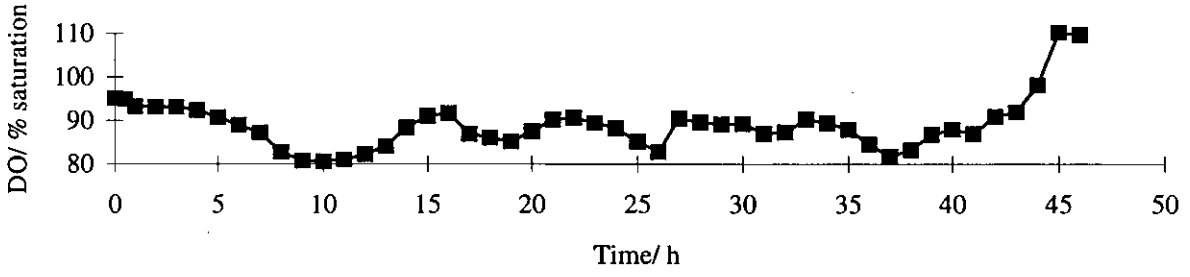
**Uptake of SRP by R. Wey bed sediment**



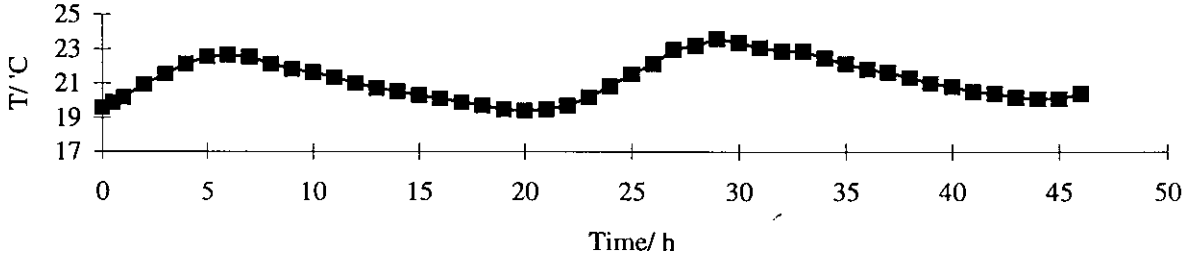

**pH during uptake experiment with R. Wey bed sediment**



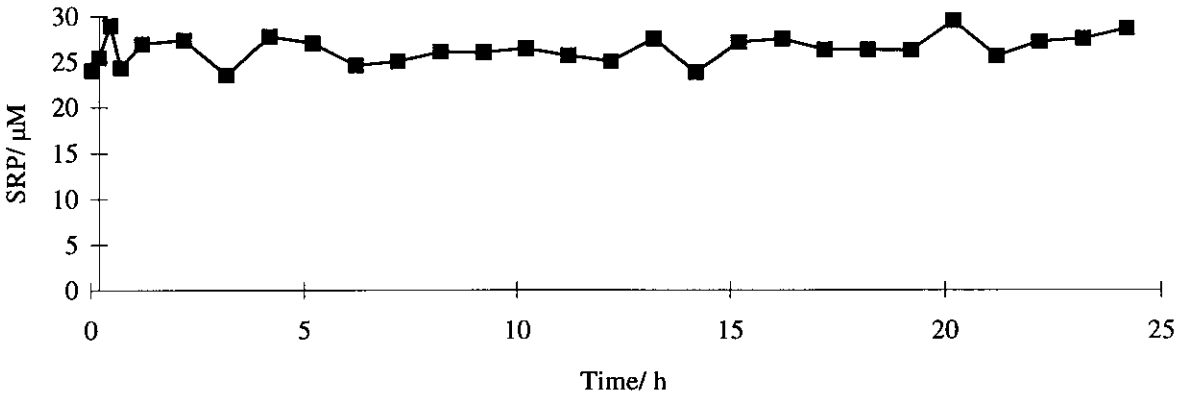

**Dissolved oxygen concentration during uptake experiment with R. Wey bed sediment**



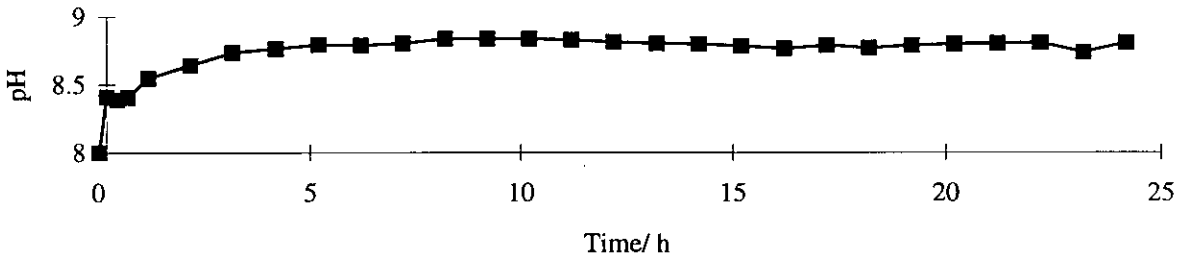

**Temperature during uptake experiment with R. Wey bed sediment**



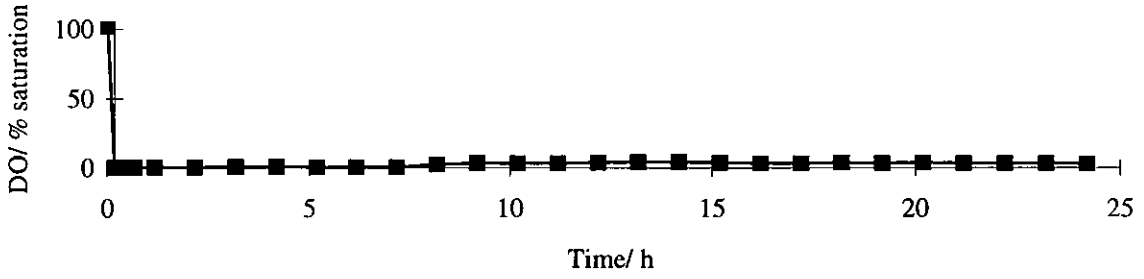
**SRP Concentration during anaerobic experiment with R. Wey sediment**



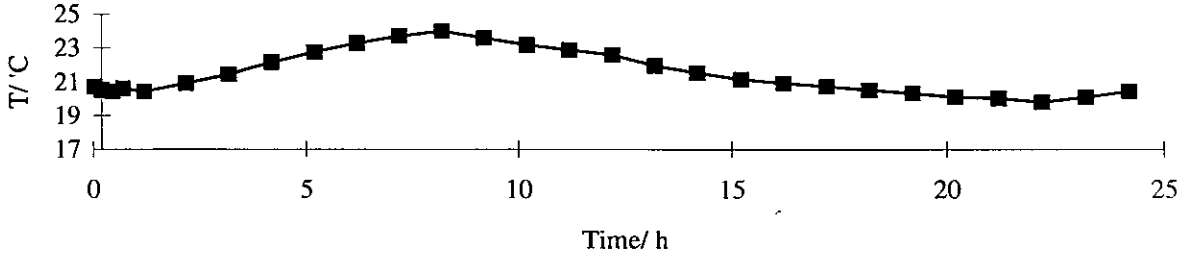

**pH during anaerobic experiment with R. Wey sediment**




**Dissolved oxygen concentration during anaerobic experiment with R. Wey sediment**




**Temperature during anaerobic experiment with R. Wey sediment**



**Fluvarium experiments with River Blackwater sediment autumn 1995**

Sediment collected 23/10/95

River water chemistry at time of sampling:

| | |
|---|---|
| Ca++ = 2.19 mM | NO3- = 0.91 mM |
| Mg++ = 0.34 mM | Silicon = 393 µM |
| Na+ = 2.57 mM | SRP = 125.9 µM |
| K+ = 0.37 mM | TDP = 113.5 µM |
| Alkalinity = 3.47 mEq | TP = 120 µM |

Channel experiment conditions:
Volume of solution = 21 litres
Flow rate = 13.9 litres/min
Velocity over sediment = 9.4 cm/s

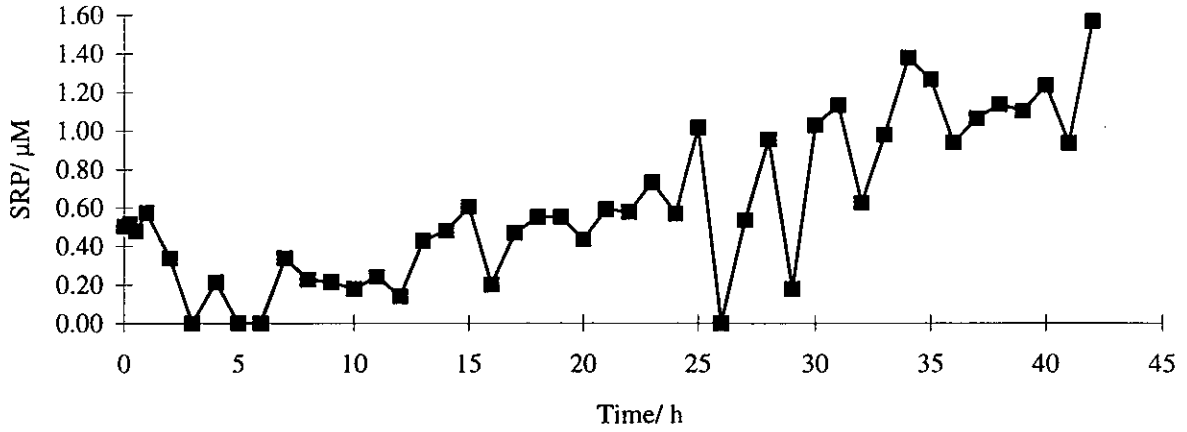
Experiment 1 - release experiment. 2 mM CaCl2 solution put into channel and sampling started 5 minutes after circulation started.

Experiment 2 - uptake experiment. 23.3 ml of 36 mM KH2PO4 added and sampling started after 5 minutes.

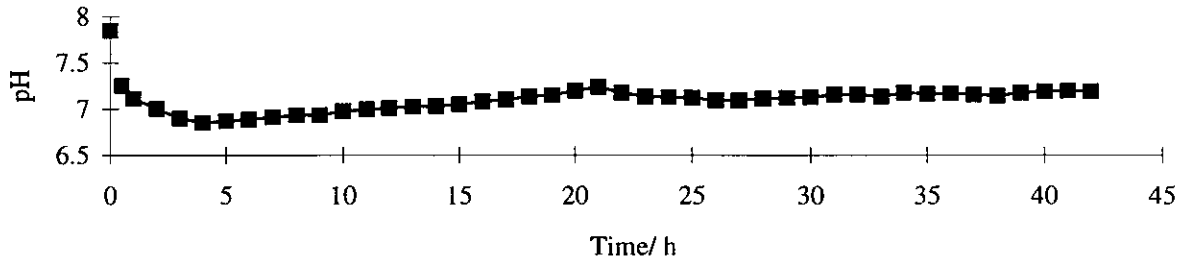
Experiment 3 - Anaerobic experiment. System allowed to equilibriate over weekend, then 6.7 g sodium sulphite added, and Nitrogen supply switched on. 1st sample after 5 minutes.

Sediment: EPCo = 1.88 µM; Kd = 2418.2 dm^3/kg; ni = 4.55 µmol/g

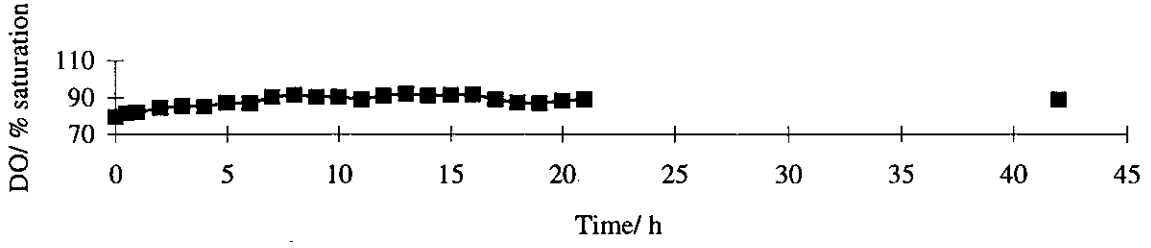
**Release of SRP from R. Blackwater bed sediment**



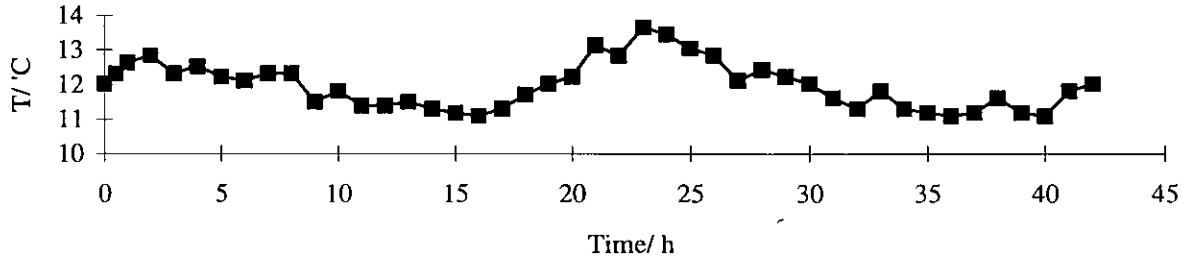

**pH during release experiment with R. Blackwater bed sediment**



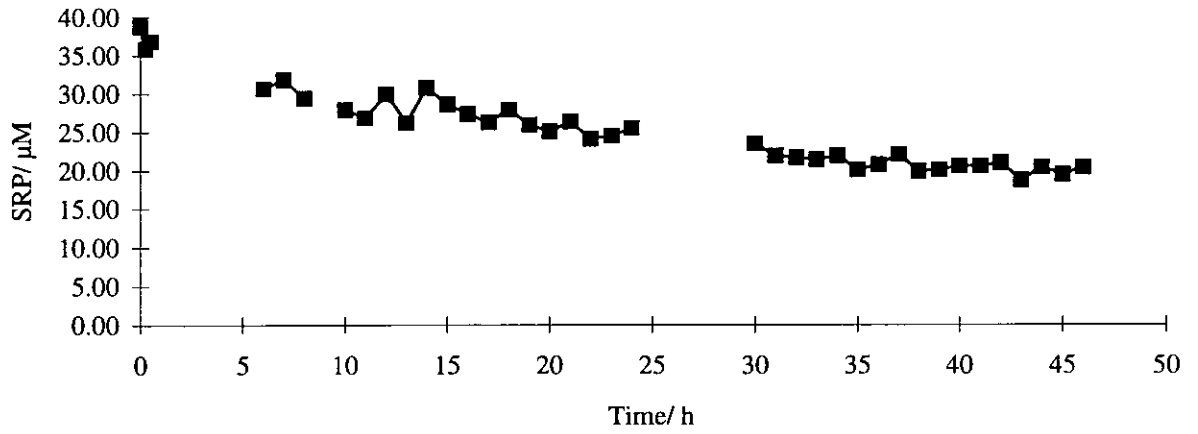

**Dissolved oxygen concentration during release experiment with R. Blackwater bed sediment**



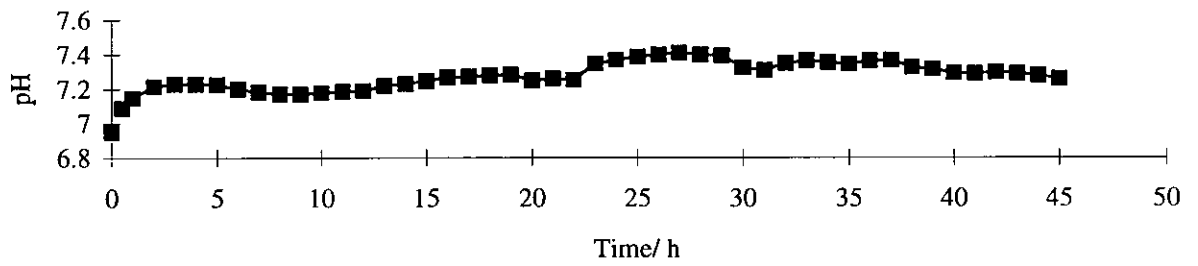

**Temperature during release experiment with R. Blackwater bed sediment**



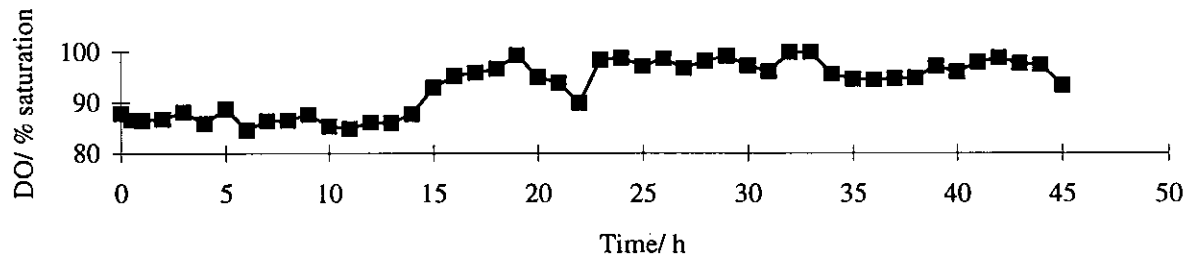
**Uptake of SRP by R. Blackwater bed sediment**



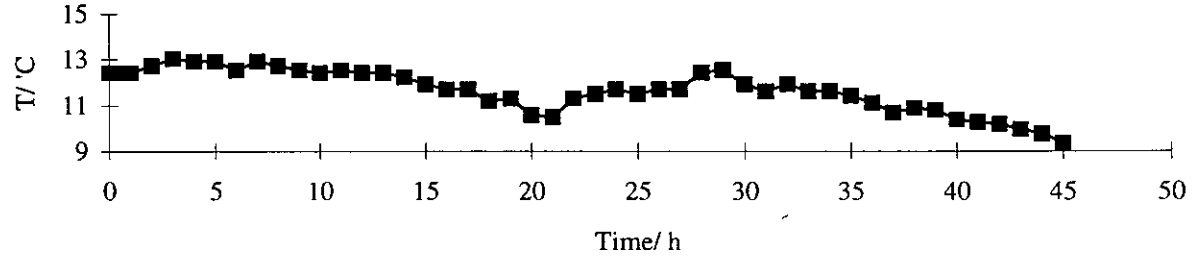

**pH during uptake experiment with R. Blackwater bed sediment**



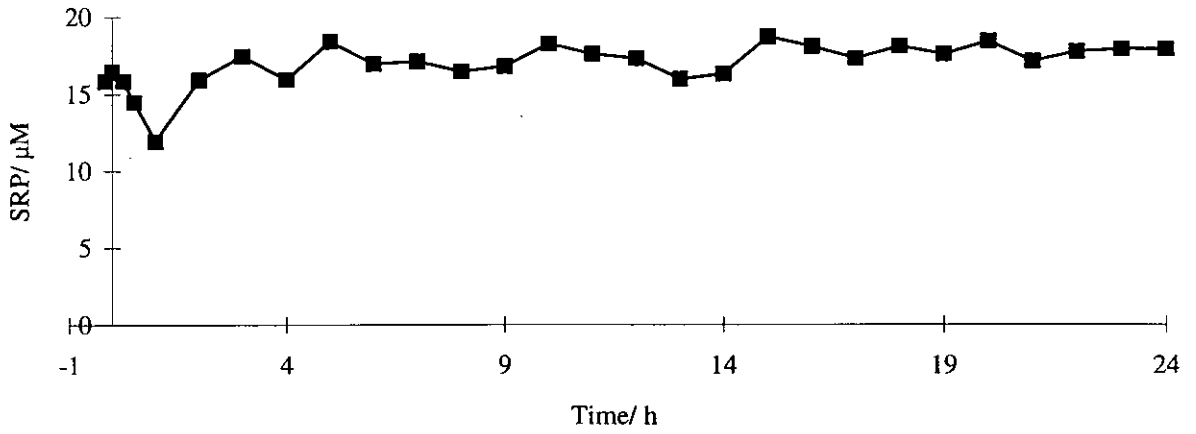

**Dissolved oxygen concentration during uptake experiment with R. Blackwater bed sediment**



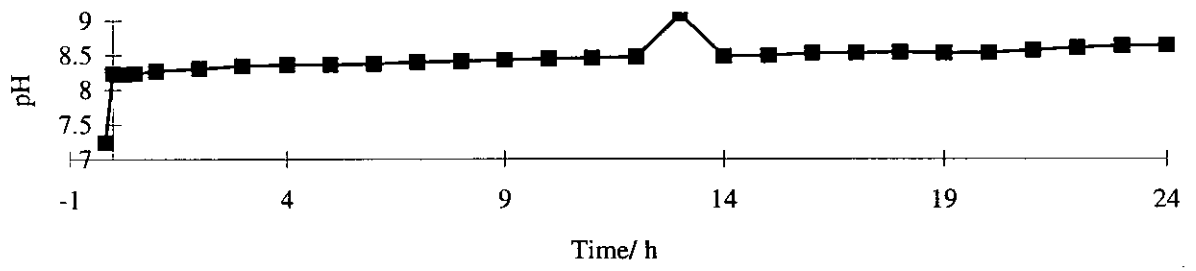

**Temperature during uptake experiment with R. Blackwater bed sediment**



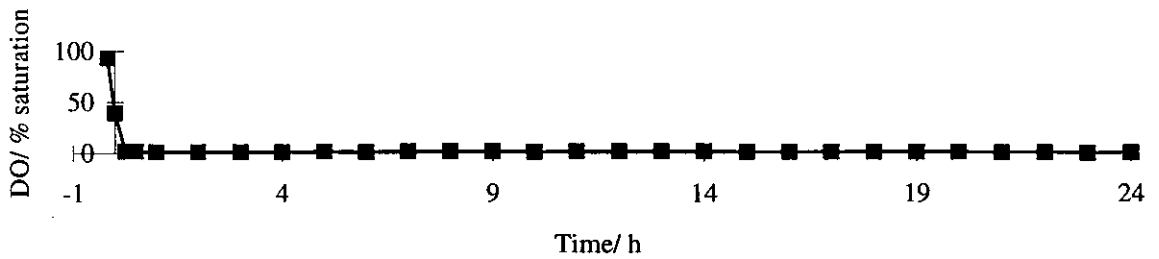
**SRP Concentration during anaerobic experiment with R. Blackwater sediment**



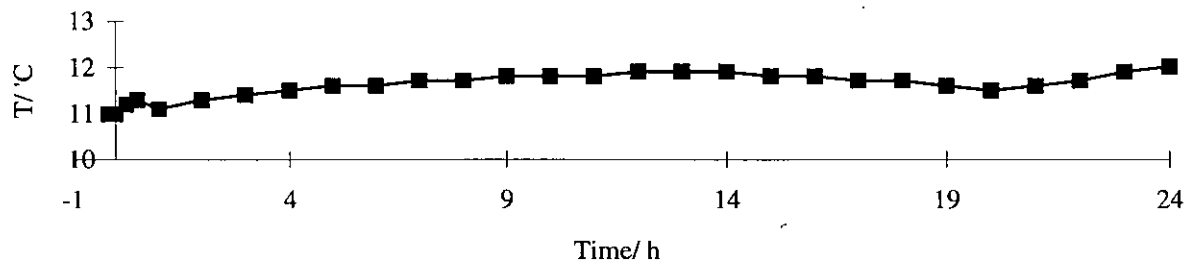

**pH during anaerobic experiment with R. Blackwater sediment**




**Dissolved oxygen concentration during anaerobic experiment with R. Blackwater sediment**




**Temperature during anaerobic experiment with R. Blackwater sediment**



**Fluvarium experiments with Gt. Ouse sediment autumn 1995**

Sediment collected 15/11/95

River water chemistry at time of sampling:

| | |
|---|---|
| Ca++ = 3.63 mM | NO3- = 0.60 mM |
| Mg++ = 0.23 mM | Silicon = 140 µM |
| Na+ = 2.05 mM | SRP = 12.30 µM |
| K+ = 1.34 mM | TDP = 16.10 µM |
| Alkalinity = 4.51 mEq | TP = 16.27 µM |

Channel experiment conditions:
Volume of solution = 21 litres
Flow rate = 28.2 litres/min
Velocity over sediment = 17.4 cm/s

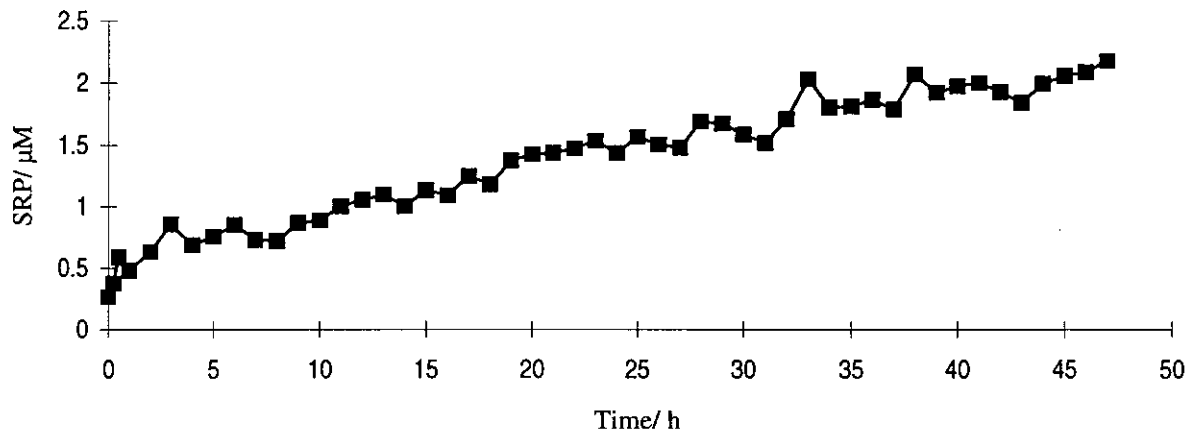
Experiment 1 - release experiment. 2 mM CaCl2 solution put into channel and sampling started 5 minutes after circulation started.

Experiment 2 - uptake experiment. 23.3 ml of 36 mM KH2PO4 added and sampling started after 5 minutes.

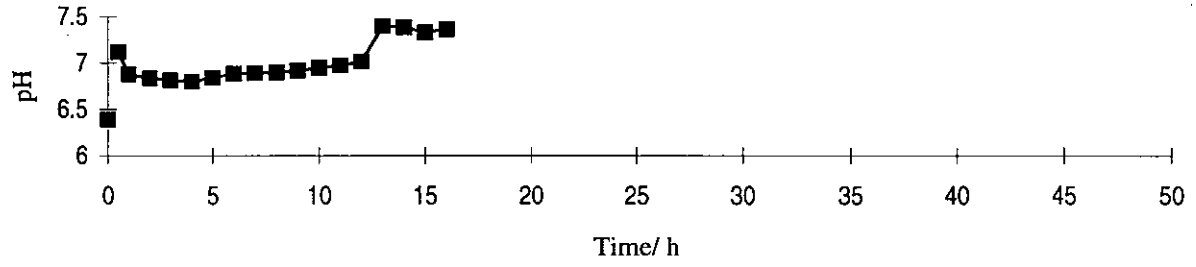
Experiment 3 - Anaerobic experiment. System allowed to equilibriate over weekend, then 6.7 g sodium sulphite added, and Nitrogen supply switched on. 1st sample after 5 minutes.

Sediment: EPCo = 1.07 µM; Kd = 610.6 dm^3/kg; ni = 0.654 µmol/g

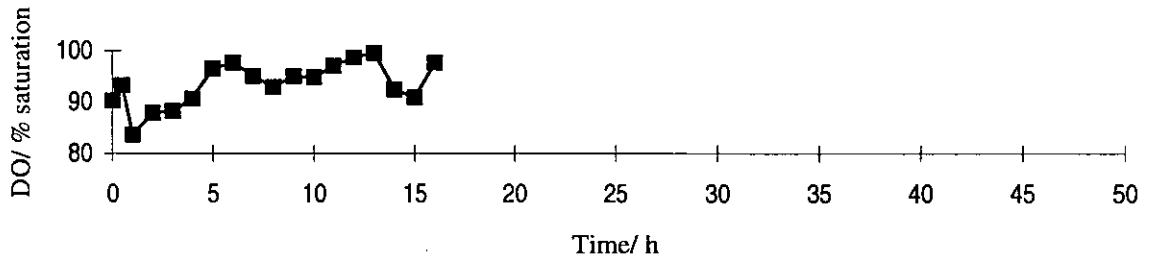
**Release of SRP from Gt. Ouse sediment**



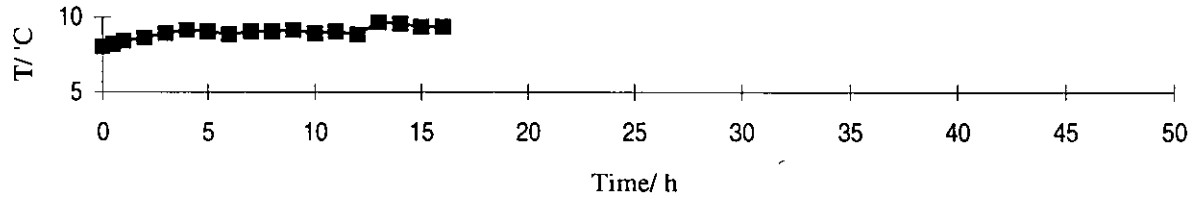

**pH during release experiment with Gt. Ouse sediment**



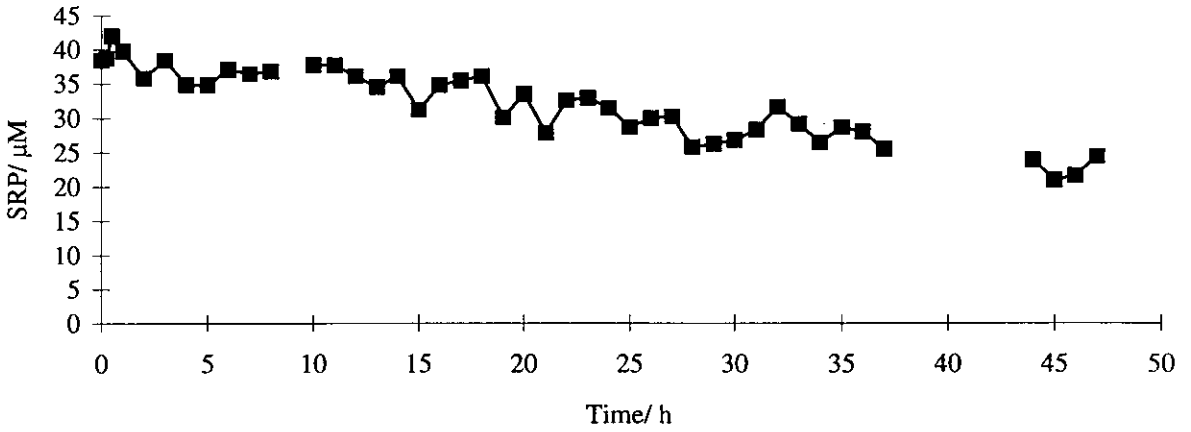

**Dissolved oxygen concentration during release experiment with Gt. Ouse sediment**



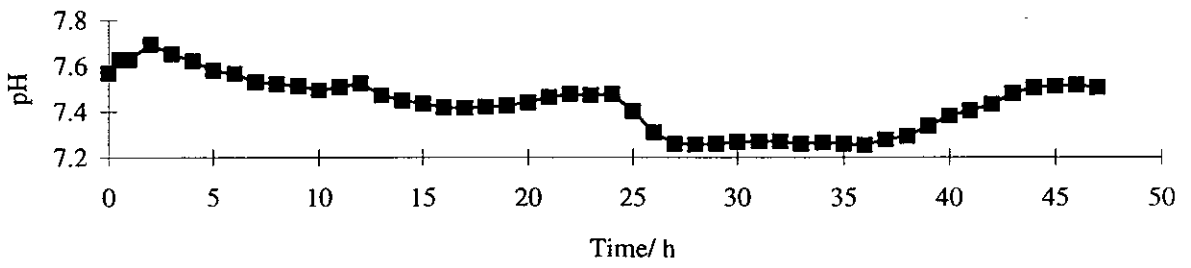

**Temperature during release experiment with Gt. Ouse sediment**



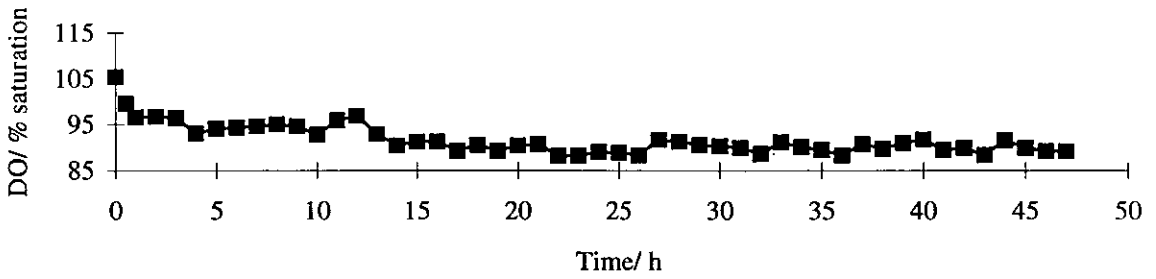
**Uptake of SRP by Gt. Ouse sediment**



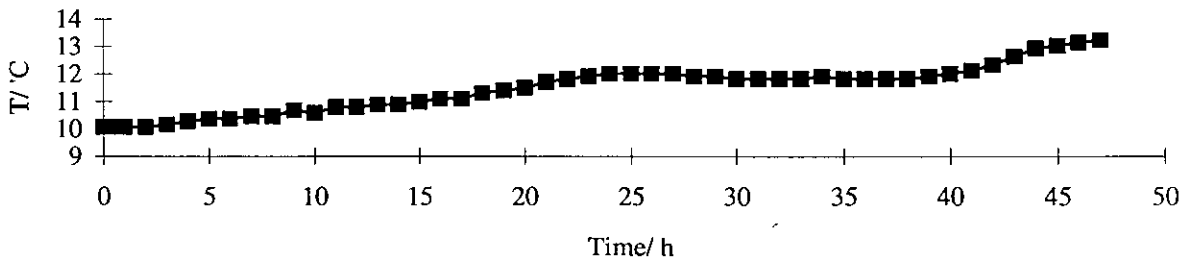

**pH during uptake experiment with Gt. Ouse sediment**



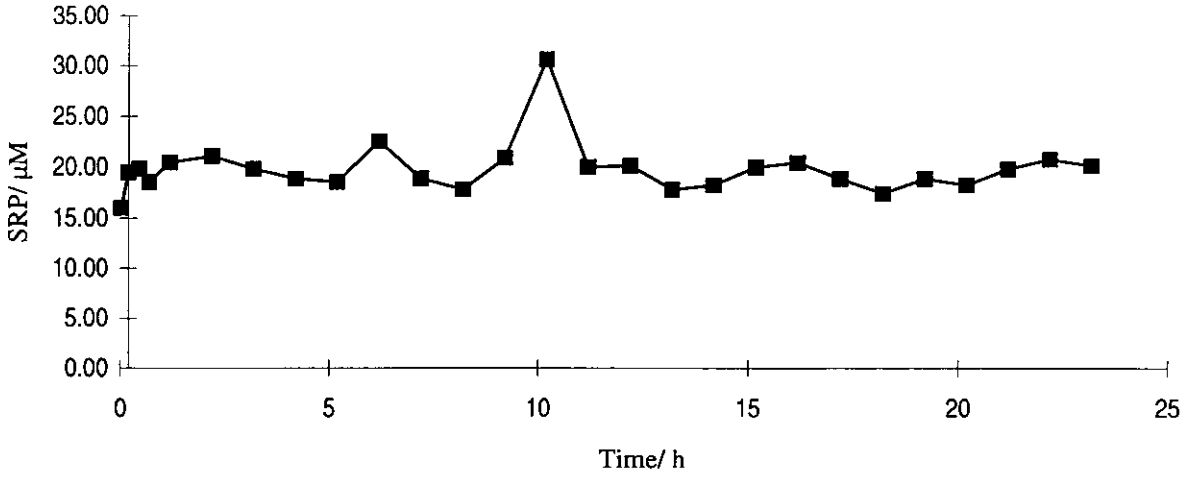

**Dissolved oxygen concentration during uptake experiment with Gt. Ouse sediment**



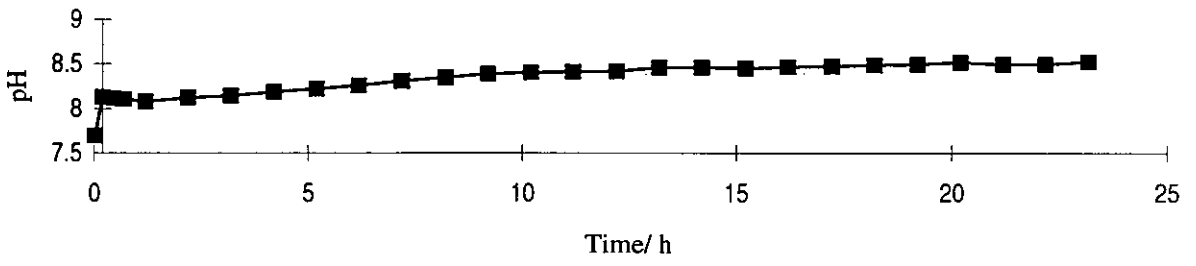

**Temperature during uptake experiment with Gt. Ouse sediment**



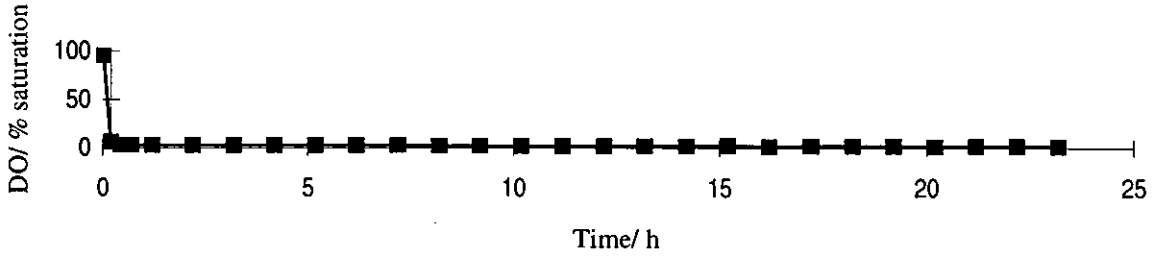
**SRP Concentration during anaerobic experiment with Gt. Ouse sediment**



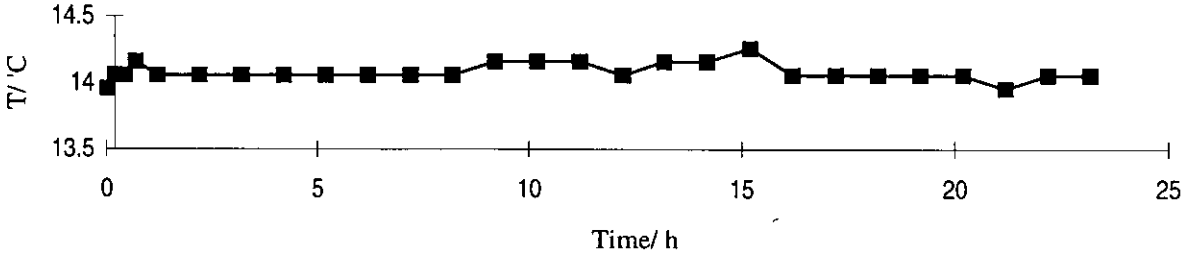

**pH during anaerobic experiment with Gt. Ouse sediment**




**Dissolved oxygen concentration during anaerobic experiment with Gt. Ouse sediment**




**Temperature during anaerobic experiment with Gt. Ouse sediment**



**Fluvarium experiments with River Blackwater sediment Winter 1996**

Sediment collected 17/1/96

River water chemistry at time of sampling:

| | |
|---|---|
| Ca++ = 2.25 mM | NO3- = 0.48 mM |
| Mg++ = 0.37 mM | Silicon = 239 µM |
| Na+ = 1.48 mM | SRP = 38.74 µM |
| K+ = 0.24 mM | TDP = 39.09 µM |
| Alkalinity = 3.31 mEq | TP = 59.83 µM |

Channel experiment conditions:
Volume of solution = 21 litres
Flow rate = 13.3 litres/min
Velocity over sediment = 9.64 cm/s

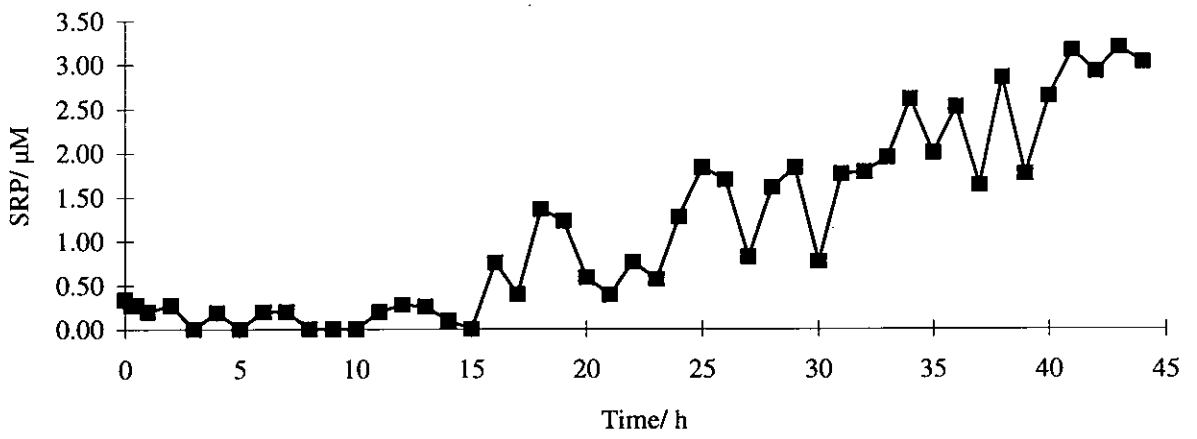
Experiment 1 - release experiment. 2 mM CaCl2 solution put into channel and sampling started 5 minutes after circulation started.

Experiment 2 - uptake experiment. 42 ml of 20 mM KH2PO4 added and sampling started after 5 minutes.

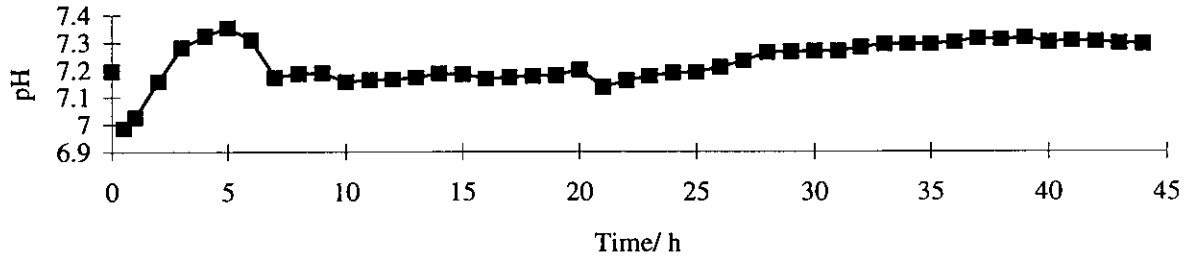
Experiment 3 - Anaerobic experiment. System allowed to equilibriate over weekend, then 6.7 g sodium sulphite added, and Nitrogen supply switched on. 1st sample after 5 minutes.

Sediment: EPCo = 3.00 µM; Kd = 724.3 dm^3/kg; ni = 2.17 µmol/g

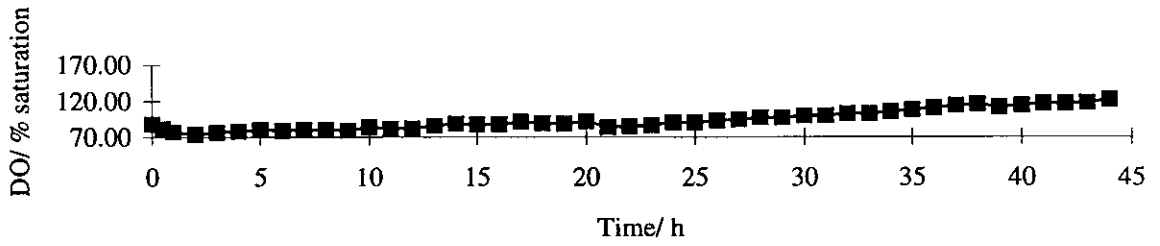
**Release of SRP from R. Blackwater bed sediment**



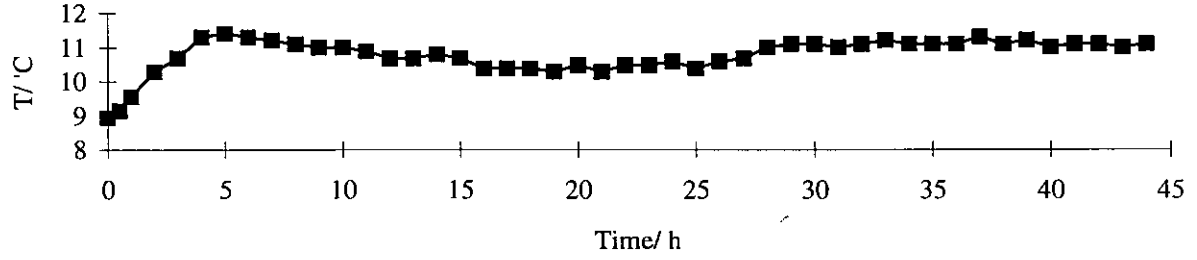

**pH during release experiment with R. Blackwater bed sediment**



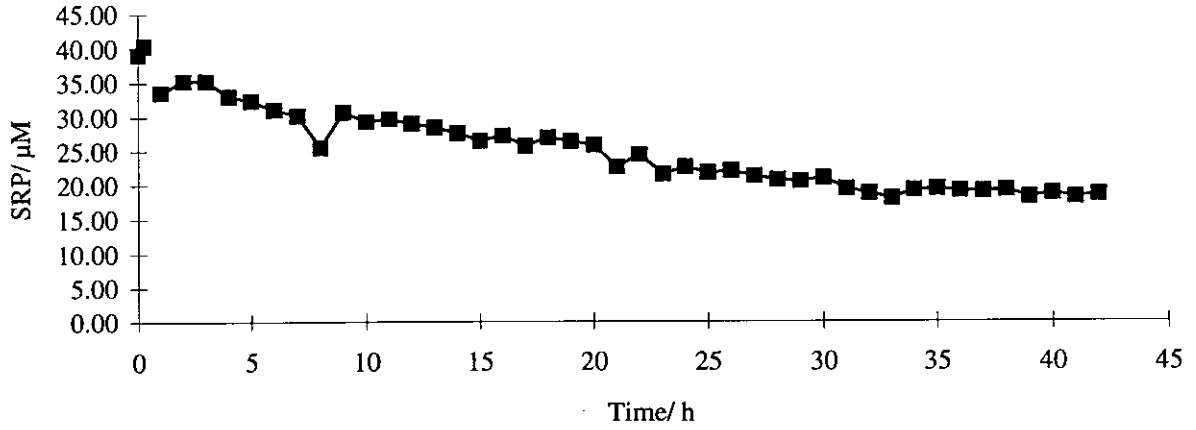

**Dissolved oxygen concentration during release experiment with R. Blackwater bed sediment**



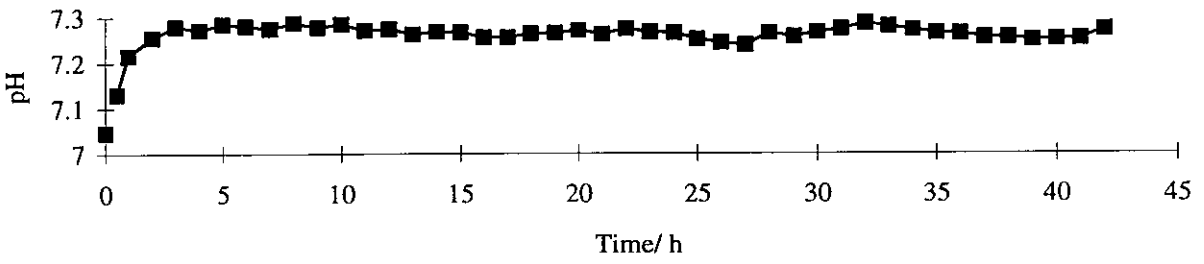

**Temperature during release experiment with R. Blackwater bed sediment**



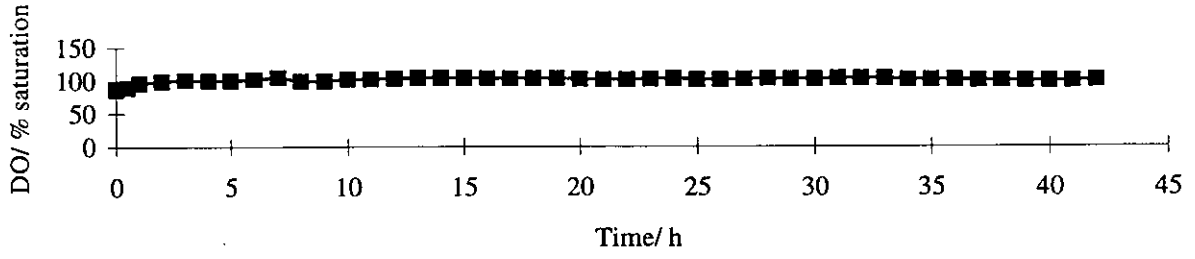
**Uptake of SRP by R. Blackwater bed sediment**



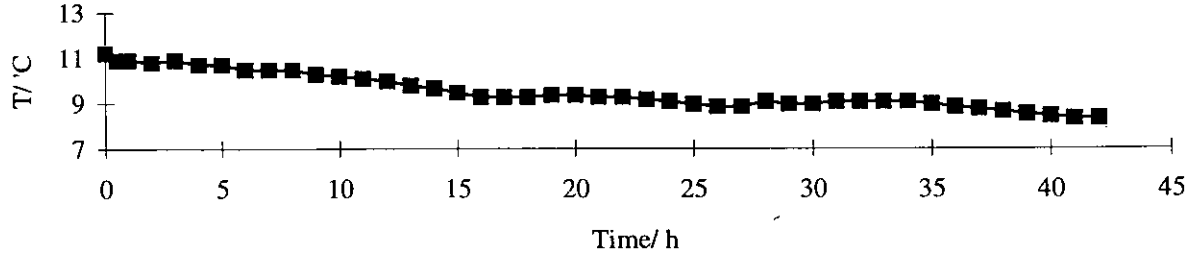

**pH during uptake experiment with R. Blackwater bed sediment**



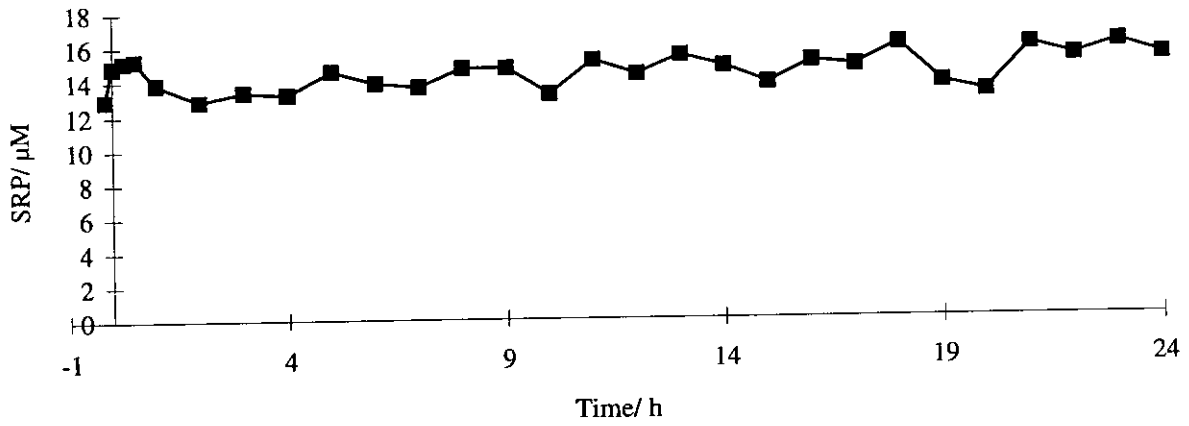

**Dissolved oxygen concentration during uptake experiment with R. Blackwater bed sediment**



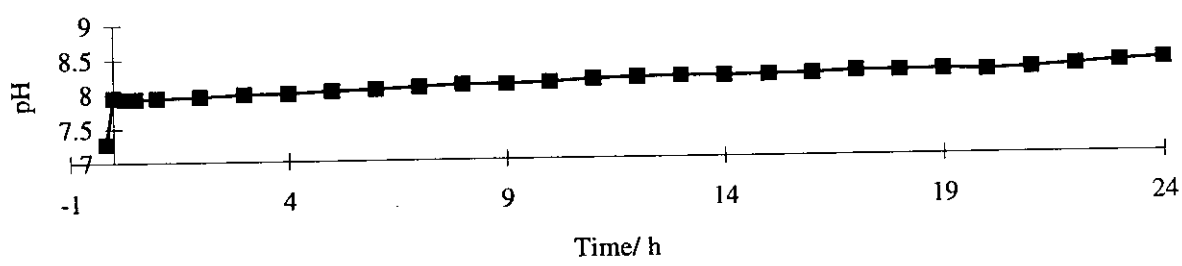

**Temperature during uptake experiment with R. Blackwater bed sediment**



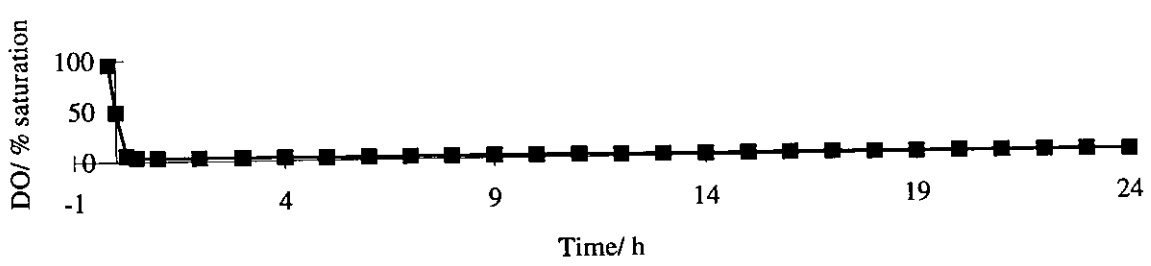
**SRP Concentration during anaerobic experiment with R. Blackwater sediment**




**pH during anaerobic experiment with R. Blackwater sediment**




**Dissolved oxygen concentration during anaerobic experiment with R. Blackwater sediment**




**Temperature during anaerobic experiment with R. Blackwater sediment**