EA-NCEDS BOX 3

National Marine Baseline Survey 1995

Littoral Cell 1
St. Abb's Head to Flamborough Head

ENVIRONMENT AGENCY

Report NC/MAR/016 Part 3 of 17
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Foreword

In recent years we have carried out National Baseline Surveys of the coastal zone which have involved analysis of samples taken at specific locations in coastal waters around England and Wales for a wide range of determinants. These data have been supplemented by further continuous analysis from the Coastal Survey Vessels and by spatial data from airborne remote sensing operations.

The dissemination of information from these data in an easily digestible form has proved to be a difficult task. To try to overcome this problem the data for the 1995 surveys have been distilled into a summary for each littoral cell.

The information in these summaries is meant to reflect the main features of the littoral cell. More extensive data as well as data collected in previous surveys are held at the National Centre and can be made available on request.

DAVID PALMER
MANAGER, NATIONAL CENTRE

Introduction

The object of this report is to present an overview of the results of the four 1995 surveys in a compact form. The report is accompanied by the full laboratory analysis results and a catalogue of image data stored on CD-ROM and video. In total there are seventeen parts to the report, and those parts included in this pack are listed at the end of this section.

The coastline has been divided into coastal cells, known as littoral cells using the procedure developed by HR Wallingford (Motyka and Brampton, Report SR 328, January 1993). A map of the divisions between these cells is shown in Figure (i). The rationale of these cells means that any changes within a cell should not affect adjacent cells. In addition each cell has a significantly different character to adjacent cells, in terms of geology or biology. The divisions were defined principally for coastal defence construction, but the position of boundaries have implications on water quality variations. For example, effects from effluent outfalls should not be transferred across boundaries.

The water chemistry results for each cell have been reviewed for each season. In particular the nutrient results have been investigated for high concentrations in Summer which may be linked to anthropogenic sources, and which may result in eutrophic waters. In parallel with this the chlorophyll-*a* concentrations have been studied for any increases which are linked to high nutrient values, by two techniques. Firstly, the individual samples have been investigated, and secondly, maps of the entire coastal zone have been produced to allow spatial estimates of eutrophic waters to be made.

The absolute concentration of chlorophyll-*a* is compared with a concentration of 10 µg/l. This is the level suggested as representative of a bloom event by the Department of the Environment in their document "Criteria and Procedures for Identifying Sensitive Areas and Less Sensitive Areas" which was produced as a response to the EC Urban Waste Water Treatment Directive. Although this level signifies the presence of a phytoplankton bloom, it must be associated with other indicators to show that waters are effected by eutrophication.

Dissolved metals concentrations have been investigated in terms of their relation to the Environmental Quality Standard (EQS) levels. These levels are established in response to the EC Dangerous Substances Directive. The definition of the EQS level is as an annual mean. This has been calculated for any sites in which an individual sample exceeds the EQS. Organic contaminants have also been compared with EQS levels where they exist.

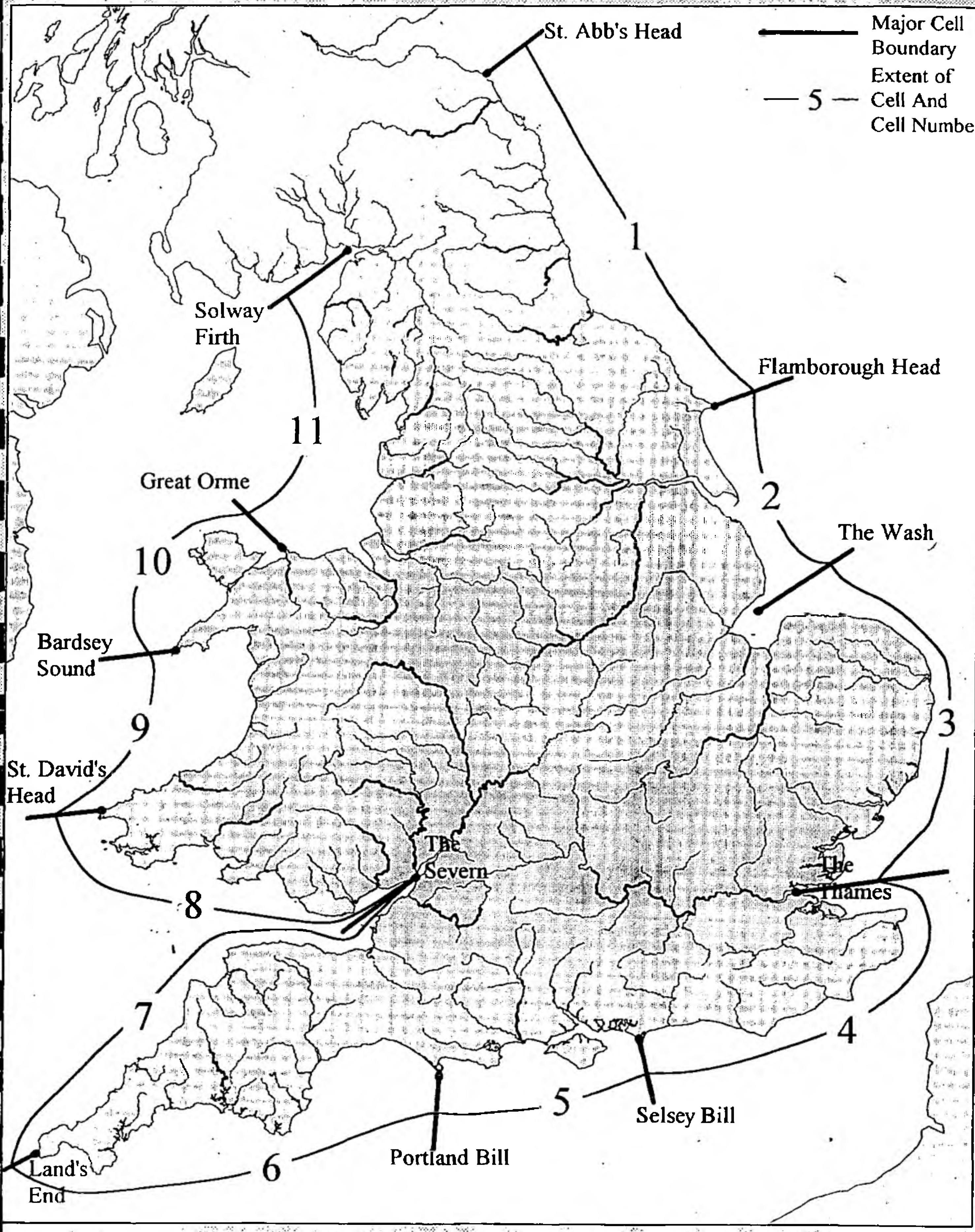
Consideration has been given to the position of the baseline sampling sites in relation to estuaries or major oceanographic features.

The image data and underway data have been investigated for major oceanographic features and changes in water quality. These may be manifested in the image data in two ways. Features are seen in the CASI imagery if they result in an alteration in the ocean colour signal. This usually requires a change in the amount of light scattered or absorbed by particles in the water column. Features such as estuarine plumes have higher particulate matter loading which increases the ocean colour signal. Phytoplankton blooms increase the absorption of light in selected wavebands and moreover result in fluorescence being detected in other wavebands. Some features do not record a CASI signal but have a difference in water temperature. The thermal video systems used in the baseline survey record only the surface temperature of the water, but clearly show features such as effluent discharges and outfalls from power station cooling systems, in addition to river plumes.

The underway data illustrates changes in temperature, salinity, dissolved oxygen, transmission and fluorescence. The longitudinal profiles from the underway systems have been investigated for major changes which may be associated with estuarine inputs or fronts between different water bodies. Data from the Skalar continuous monitoring nutrient analyser have been investigated to determine the geographical extent of elevated samples in the laboratory analyses.

Summaries have been produced for each littoral cell which provide a statement on the water quality of the region recorded by the baseline survey. The key local oceanographic features are also summarised.

Figure i. The Major Littoral Cells of England and Wales, After Motyka and Brampton, 1993.



* Motyka, J.M. and Brampton, A.H. (1993), "Coastal Management, Mapping of Littoral Cells", HR Wallingford.

Littoral Cell 1: St Abbs Head to Flamborough Head

Executive Summary

This littoral cell extends from St Abbs Head to Flamborough Head on the North East coast of England. Water quality in this region varies in two key ways. Firstly a clear along coast variation is seen between rural and industrial regions, the industrial regions generally being associated with major estuarine locations, such as the Tyne and Tees. Secondly, the region is characterised by a coastal flow of sediment laden water, which results in a distinct variation in water quality perpendicular to the coastline. The opacity of this high sediment loading means that the majority of outfalls are not visible.

Highest concentrations of dissolved metals and nutrients are found in association with estuarine locations, such as the Tweed, Tyne and Tees. The Winter sample from Berwick exceeds the Environmental Quality Standard (EQS) of 5 μg/l for dissolved copper. The Tees sampling sites have concentrations of chlorophyll-*a* in excess of 10 μg/l in Summer with associated elevated levels of ammonia, which suggests that this region may be subject to eutrophication.

Spatial chlorophyll-*a* results support this suggestion, with a large percentage of the coast having concentrations greater than 10 μg/l at the time of this survey. Areas with highest concentrations are around the Tees Estuary, and from Newcastle-upon-Tyne northwards to Druridge Bay.

The remotely sensed data reveals that the major oceanographic features within this littoral cell are generally associated with major estuarine sources and sediment transport patterns. The River Tweed plume is seen to extend offshore at certain tidal states; facilitating the exchange of estuarine waters offshore. Similarly, sediment plumes are seen off Filey Brigg and northwards of Whitby, which again extend offshore. Between these major structures there is a coastal flow of sediment.

The thermal effects of power station and other industrial outfalls on the surface temperature of the surrounding waters is clearly seen, particularly the nuclear power station and steel works outfalls in Tees Bay.

1. Introduction

This littoral cell extends from St Abbs Head on the English / Scottish border to Flamborough Head on the Yorkshire coast. This represents approximately 1800 km^2 within the coastal zone for which the Envionment Agency has responsibility for controlled waters, as illustrated in Figure 1. Of this area, only 28 km^2 are estuarine waters. During 1995 data collection was carried out by Water Guardian. Three full vessel surveys were carried out in Winter (February), Summer (July), and Autumn (September), with a partial survey in Spring (May/June) due to instrument problems. Aircraft surveys were completed in July and September.

2. Water chemistry results

2.1 Background

This littoral cell extends from St Abbs Head to Flamborough Head, and is mainly affected by the presence of major estuarine inputs, in particular the Tweed, the Tyne, the Wear and the Tees. There are 25 sampling sites within the cell, with additional sites located at the major estuarine sources.

2.2 Nutrients and chlorophyll-a

2.2.1 Total Oxidised Nitrogen (TON)

TON concentrations recorded a winter maximum of 5655 µg/l N at Filey Brigg (24). In both Summer and Autumn the maximum value within this cell was found at Berwick (1), equal to 4250 µg/l N and 2385 µg/l N respectively.

2.2.2 Silicate

Silicate concentrations were highest at Berwick (1) in Winter, equal to 1049 µg/l Si. Spring and Summer levels were very low, with many samples below the laboratory minimum reporting value (MRV). The Berwick (1) sampling site showed the highest concentration in Autumn, equal to 847 µg/l Si. This was not high in comparison with the national results.

2.2.3 Orthophosphate

Orthophosphate concentrations exhibited a clear seasonal cycle, but show little geographical pattern. The sampling site at Tyne Middle (9) recorded the highest national figure in Winter, with a concentration of 438 µg/l P. Spring and Summer concentrations were low, with many sites less than the laboratory MRV of 0.5 µg/l P, rising once more in Autumn to a maximum of 45 µg/l P at Berwick (1).

2.2.4 Total Ammoniacal Nitrogen (Ammonia)

Ammonia results consistently showed elevated concentrations at the Tees sampling sites, with the highest results at Tees Middle (18) during the Winter survey, equal to 168 µg/l N and Tees North (17) in the Spring and Summer surveys, equal to 11 µg/l N and 19 µg/l N respectively. The tidal effects of the Tees river plume will be discussed in Section 4. In addition the ammonia result for Castlehead Rocks (2) in Autumn, equal to 245 µg/l N, was the highest recorded during the survey.

2.2.5 Nitrite

Nitrite concentrations above the laboratory MRV were only shown at the Tyne, Wear and Tees in Winter, and in the Spring only at Tees North (17). In Summer the maximum concentration was found once more at Tees North (17) equal to 12.7 µg/l N.

2.2.6 Chlorophyll-a

Concentrations of chlorophyll-*a* showed a seasonal cycle, with generally higher values in Spring, although the small number of samples carried out due to the incomplete Spring survey tend to mask this effect. During Winter concentrations were less than 2 µg/l throughout this region, and were low once more in Autumn. In Summer the Tees and the Tyne recorded concentrations above 10 µg/l, with the maximum of 17.72 µg/l at Tees North (17).

2.2.7 Nutrients/chlorophyll-a Summary
The seasonal nutrient cycling, with concentrations highest in Winter, and lowest during Spring, is consistent with the early development of the Spring phytoplankton bloom, and subsequent depletion of nutrient stocks prior to the Spring survey. Elevated nutrient concentrations in Spring and Summer were associated with major estuaries. In particular a clear link was seen between high chlorophyll-*a* concentrations, in excess of 10 μg/l, and high ammonia concentrations at the Tees North (17) site.

2.3 Suspended solids
Suspended solids concentrations were low for the entire section of coastline, with results only exceeding the MRV within estuarine plumes and headland eddies, for example at Filey Brigg (24) in Winter, equal to 49 mg/l and Tees Middle (18) in Summer, equal to 19 mg/l. This suggests that transport of sediment was constrained to a narrow coastal band.

2.4 Metals

2.4.1 Total Mercury
Concentrations of mercury were low during Winter, Summer and Autumn, with many results less than the MRV of 0.008 μg/l Hg. In Spring two sites recorded high concentrations: at Tees Middle the concentration was 0.217 μg/l Hg and at Flamborough Head the concentration was 0.301μg/l Hg, the latter of which exceeds the EQS level of 0.3 μg/l Hg, although this is defined for dissolved mercury.

2.4.2 Dissolved Cadmium
Dissolved cadmium concentrations were low throughout the region, with many sites below the laboratory MRV for all four surveys. The maximum cadmium concentration was recorded at Skinningrove (20) in Autumn equal to 0.146 μg/l Cd. This is less than one tenth of the EQS of 2.5 μg/l Cd.

2.4.3 Dissolved Copper
Dissolved copper concentrations recorded the national maximum value during the Spring survey, with a figure above the EQS of 5 μg/l Cu at Berwick (1) equal to 6.47 μg/l Cu. This site did not show elevated concentrations at other seasons.

2.4.4 Dissolved Lead
Dissolved lead concentrations showed two sites having survey maxima, at Tyne North (8) in Winter, equal to 6.41 μg/l Pb, and Berwick (1) in Summer, equal to 14.7 μg/l Pb. Neither of these exceeds the EQS level of 25 μg/l Pb.

2.4.5 Dissolved Arsenic
Dissolved arsenic concentrations were low, with only Castlehead Rocks (2) and Tees South (19) having concentrations above the laboratory MRV, both equal to 2.2 μg/l As, this being during the Winter survey,

2.4.6 Dissolved Zinc
Zinc concentrations were variable both seasonally and geographically. The Tyne North (8) site showed the highest concentration of dissolved zinc for this region during the Winter survey, equal to 28.2 μg/l Zn.

2.4.7 Dissolved Chromium
Dissolved chromium results were highest in Winter, with a concentration of 6.29 µg/l Cr at Marsden (11). In Autumn, Craster (4) recorded the national maximum of 2.44 µg/l Cr. Neither of these were in excess of the EQS level of 15 µg/l Cr.

2.4.8 Dissolved Nickel
Dissolved nickel results show highest concentrations in Spring and Summer, for example a concentration of 2.41 µg/l Ni at Berwick (1). The concentrations of dissolved nickel throughout this region are low in comparison with national averages.

2.4.9 Metals Summary
Metals concentrations were seasonally variable but showed a geographical pattern, with maximum concentrations associated with major estuaries. One sample recorded a dissolved copper concentration in excess of the EQS of 5 µg/l Cu at Berwick. This site also has other elevated metals concentrations, suggesting the sampling site to be within the influence of the Tweed estuarine plume.

2.5 Organic determinands

Water samples were analysed for twenty three trace organic determinands at eight baseline sites within this littoral cell, at Berwick (1), Craster (4), Blyth (7), Tyne Middle (9), Wear Middle (13), Pincushion Rock (15), Tees Middle (18) and Scarborough outfall (23). Only γ-HCH gave positive analyses. The other 22 determinands were not detected at their laboratory MRVs of 0.001 µg/l for the entire survey.

During Winter and Autumn no samples were above the MRV for any of the determinands. In Spring samples from Tees Middle (18) and Scarborough Outfall (23) recorded values above the MRV of 0.001 µg/l for γ-HCH, but at concentrations clearly below the EQS value for total HCH. In Summer γ-HCH results were found at Tyne Middle (9)and Tees Middle (18), which were again less than the EQS level for total HCH.

3. Spatial chlorophyll-*a* results

The CASI imagery has been used in combination with the laboratory baseline samples and the underway fluorimeter to produce maps of chlorophyll-*a* concentration of the coastal zone. The technique used involves calculation of the Fluorescence Line Height (FLH) of the imagery and correlation of the three measuring techniques. The objective of the production of these maps is to gain information on those regions which have high chlorophyll-*a* concentration, and may be subject to eutrophication.

Figure 2 shows the chlorophyll-*a* concentration during Summer 1995 for this littoral cell, as derived from the FLH technique. The chlorophyll-*a* concentration was above 2 µg/l for all parts of the coastline, with the region between Druridge Bay and the Tees having concentrations as high as 8 µg/l. This area is shown in greater detail in the inset. This inset shows that the chlorophyll-*a* concentration does not vary away from the coast. A clear indication is given of the position of the change in chlorophyll-*a* concentration to the north of the Tees Estuary.

Figure 3 shows the continuous track boat fluorimeter data for this cell, which has been calibrated using the laboratory samples. This map shows the same overall pattern as the FLH map, but with greater detail. This is because the FLH technique results in some smoothing, particularly of higher concentrations. This fluorimeter technique is, however, not truly spatial, as an interpolation must be applied to extend the results to the full three nautical mile zone.

The highest concentrations are again seen at Tees Bay and from Newcastle-upon-Tyne northwards to Druridge Bay. This map shows that the chlorophyll-*a* concentration for a large section of this littoral cell at this time are in excess of 10 µg/l. This is the concentration which signifies the presence of a phytoplankton bloom according to the Department of the Environment Identification of Sensitive Areas. These areas are therefore potentially subject to the effects of eutrophication, and may require further investigation.

4. Local oceanographic descriptions

Underway measurements have been investigated in order to show which areas within this littoral cell show most variability in the underway parameters measured, namely temperature, salinity, fluorescence, transmission and dissolved oxygen. In addition the imagery has been studied for variation in ocean colour signal and temperature signal, or where discrete bathymetric and oceanographic features are visible during either July or September. These areas will be discussed in more detail below, in terms of results from remote sensing imagery, laboratory sampling and underway measurements. This will provide an overview of the results for this section of coastline.

Flamborough Head marks the divide between littoral cells 1 and 2. This headland is, however, a one way drift divide, and as such the residual littoral flow is to the south on both sides of the headland. The description of activities around this headland will therefore be included in the results for littoral cell 2. The following areas have been selected for further description.

1. River Tweed plume
2. Mudflats around Lindisfarne
3. Southerly flow of sediment
4. Tees Bay
5. Filey Brigg

4.1 River Tweed plume

CASI imagery from September shows a large plume of water with a differing ocean colour signal emanating from the harbour at Berwick-upon-Tweed (see Plate 1(ii)). This plume is higher in suspended sediment loading and as such is increasing the magnitude of the CASI signal due to particulate scattering. Imagery from July shows some evidence of a plume structure but not of the magnitude shown in September (see Plate(i))..

The magnitude and position of this plume may be explained with reference to the varying tidal states and weather conditions between the two data collection dates. In July, the image was collected 3 hours after High Water at Berwick, which means there would be some water flow from the harbour. This is shown in the imagery, with a small plume being visible. The tidal stream is weak at this time, with a slight southerly flow. The flow apparent from the imagery is weakly to the north, which means that additional effects are in operation.

In September, the image was collected 1 hour before Low Water at Berwick, when the outflow of water from the harbour would have been continuing for six hours. In addition, the tidal stream is directed strongly northwards, which is clearly seen in the position of the plume in the imagery.

The magnitude of the plume is also dependent on rainfall. In September there was high rainfall run off due to heavy rain in the week previous to the survey. July, in contrast, had very low rainfall, with little appreciable rainfall for three months previous to the image date.

The position of this river plume may have implications on the collection of laboratory samples from the Berwick baseline sampling point, the position of which is marked on Plate 1(ii). For example, the sample taken in Winter was in excess of the Environmental Quality Standard for dissolved copper of 5 μg/l Cu. This is potentially due to the samples having been taken within the plume of water from Berwick Harbour. The use of annual mean measurements for the determination of EQS breaches may remove this problem. However, it is possible that results would appear unreasonably high for a coastal location, if they were always occurring in this body of estuarine water.

In future it may be appropriate to position two baseline sampling sites in this region, with one offshore from the plume position. Further investigation of the plume dynamics would be required in order to establish the optimum position for this site.

4.2 Mudflats around Lindisfarne

Algal growth on the expanse of mud and sand around Lindisfarne is potentially being affected by an increase in nutrients leading to eutrophic conditions. As part of the baseline survey a sample is taken off Castlehead Rocks to the east of the island. Investigation of the 1995 laboratory data shows that levels of Total Oxidised Nitrogen (TON) are enhanced here in Winter and Summer relative to the rest of this littoral cell. Concentrations of chlorophyll-*a* are however low.

The baseline sampling does not therefore answer the question of whether or not eutrophication is occurring, with more intensive local surveys required. These should consist of a combination of water sampling for nutrient and chlorophyll-*a* concentration and a ground based survey of algal species. The CASI data is capable of producing classification of broad algal species within the intertidal zone, and this area could be worked up in future if it were thought to be of use.

4.3 Southerly flow of sediment

This littoral cell is characterised along its length by a residual south easterly flow of sediment. However, the flow is low and intermittent, with some variation in direction caused by tidal influences. To the north of the Tyne estuary, the flow is interrupted by headlands, meaning that the flow within individual bays is only weakly dependent. Further south, the beaches have been extended by the accretion of colliery waste such that the flow between bays is more connected.

CASI images illustrate this feature. Plate 2 shows an area higher in suspended sediment concentrations close to the coast at Boulmer. Circulation within individual embayments is clearly seen. In comparison the flow of sediment further south at Crimdon; north of Hartlepool, is more linear, with less interruption by headlands.

This flow of sediment along the coast is evident in all imagery from this littoral cell. The band of sediment extends approximately 0.5 km offshore, where there is a distinct boundary between this higher suspended sediment and the clearer open ocean waters. It is only at points such as estuarine outflows, for example the River Tweed plume, that the higher sediment region extends further into the coastal waters. Thus the water quality of this littoral cell varies most markedly perpendicular to the coastline.

The transfer of contaminants across this boundary into the offshore waters has implications on the discharge of effluent into the near coastal zone. It is imperative that this be understood, else effluent may be held within the coastal zone, limiting dilution and dispersion to offshore waters. Similarly, to the north there is a potential for entrapment of effluent where little exchange takes place between bays.

4.4 Tees Bay

The Tees is one of the most heavily industrialised areas within this littoral cell, and in addition has a nuclear power station at its mouth at Hartlepool. Laboratory samples are collected at three sampling stations around the mouth, which reflects the complexity of the riverine input at this point. An inland flight line is included in the baseline survey which traverses down the River Tees to cover the major industrial inputs.

Laboratory samples from the baseline sampling sites within Tees Bay (sites 17, 18 and 19) show elevated concentrations of dissolved metals and nutrients during each of the surveys. In particular concentrations of ammonia are high at all seasons. Figure 4 shows the continuous monitoring Skalar nutrient analyser data for Winter 1995. This is the season at which the background nutrient levels are at their highest. This figure illustrates that the Tees Estuary acts as a further nutrient source to the coastal zone, with the ammonia concentrations in the mouth of the estuary being extremely high, in excess of 100 µg/l N. Concentrations of TON, phosphate and silicate are also elevated from the Tees southwards towards Saltburn. Waters to the north of Hartlepool are not affected.

Of more significance is the continuation of high ammonia concentrations throughout the year. Figure 5 shows that in Summer the other nutrients have decreased to background levels, whereas ammonia still records concentrations in excess of 100 µg/l N in the mouth of the Tees. Elevated concentrations up to 50 µg/l N are found northwards to Hartlepool.

In Autumn (Figure 6) when nutrients are beginning to increase once again, the ammonia concentrations are extremely high, with concentrations above 100 µg/l N being recorded from North of Hartlepool to South of Redcar.

The complex series of inputs is clearly visible in both CASI and thermal video imagery taken in July and September. The two CASI images were taken at differing tidal states, with the image from 26th July taken at High Water and the image from 23rd September at Low Water. Both images are close to Spring tide conditions, such that the tidal range is highest. Thus in September, there is maximum outflow of water as shown in Plate 3 (i). In July the flow of water is into the river mouth and forms part of the continual flow of sediment flow this coastline.

Thermal imagery shows in particular the outfall of warmer than ambient temperature from Hartlepool power station. In September this forms a large plume, as illustrated in Plate 4. In July the feature is less well marked, with thermal features within the river mouth more clearly seen. This is due to the warmer ambient temperature at this time of year. The imagery from 21st September clearly illustrates that at this tidal state, three hours before High water, the warmer than ambient temperature water is passing southwards and as such may form a stratified thermal barrier across the river mouth. This may have detrimental effects on the ecology of the region, although this is a matter that would need *in-situ* sampling to establish.

The thermal video system records the surface temperature of the water, and this feature may simply be a surface effect. Further investigation should involve the use of vertical temperature profilers which would assess the depth of thermal influence of the plume. The image also shows a further thermal outfall, which although has a lower temperature than that from the power station is still causing significant warming of the neighbouring shoreline. This outfall is most probably from the steel works, although no source is visible from the imagery.

4.5 Filey Brigg

A second baseline flight line is flown parallel to the first between Filey and Scarborough to allow the inclusion of Filey Brigg. CASI images from this flight line are shown in Plate 5 for both July and September 1995. Thermal video imagery for this region is shown in Plate 6 collected in July.

In July sediment movement is seen off the south of the brigg, which may be investigated more clearly in the thermal imagery. An eddy has developed off the headland, with warmer, more sediment laden water circulating clockwise. In addition a frontal feature is seen in both the CASI and the thermal imagery further offshore. The tidal stream when this image was taken was strongly to the south and explains the position of the eddy feature to the south of the headland. The frontal structure probably represents the seaward extent of coastal sediment transport, with generally warmer, more sediment laden water towards the coast.

In September, the CASI imagery shows a more defined plume structure to the north of the brigg, which appears to diverge in direction, with the main flow to the West forming an eddy structure, but a secondary flow to the east. It is probable that the plume is encountering some boundary in water type, but it is not possible to explain the cause with the available data.

Underway data for September does not show the presence of this structure in terms of variation in transmission or fluorescence. In July, higher levels of suspended solids are found to the south of Filey Brigg, represented by lower transmission. A slightly higher temperature is also recorded. This would suggest a southerly flow of sediment off the headland. The tidal state during sampling is close to slack water which results in high sediment laden water being trapped within the coastal embayment between Filey Brigg and Flamborough Head.

The laboratory sampling site is located off the headland, as shown in Plate 5. Samples collected from this site are therefore sometimes representative of nearshore water, with higher suspended solids loadings and potential higher dissolved metals and nutrient concentrations. In future it may be appropriate to position a further baseline sampling site in more offshore waters which would clearly be representative of broader coastal water quality.

In Winter 1995, high concentrations of dissolved mercury and copper were found at this site. Additionally, a concentration of total oxidised nitrogen equal to 5655 µg/l was recorded. The results clearly suggest that the site is within the influence of the coastal plume at this time. The tidal state at the time of sampling was the same as in the September imagery with a northerly tidal state, which supports this assumption.

Similar plume structures are seen further up the coastline at Robin Hoods Bay and Whitby, as shown in Plate 7 from the same day. These features cause a break in the linear coastal flow of sediment and facilitate the exchange of dissolved and particulate matter to offshore waters. The position of features such as these should be considered when selecting suitable sites for effluent and industrial discharges.

5. Conclusions

This littoral cell is characterised by the presence of major estuaries which have detrimental effects on coastal water quality due to heavy industrial activity. Thus the water quality results from these sections of coastline are very different to those from the rural sections. The sample from Berwick in Winter is in excess of the dissolved copper EQS of 5 µg/l, but upon calculation of an annual mean measurement from the four samples, this site does not breach the EQS. The Tees shows elevated concentrations of chlorophyll-*a* in Summer, with associated high ammonia results. This area is therefore potentially subject to eutrophication.

The spatial chlorophyll-*a* results support this suggestion, with elevated chlorophyll-*a* concentrations greater than 10 µg/l not only at the Tees but from the Tyne northwards to Druridge Bay. The Lindisfarne area, is not, however, subject to eutrophication at the time of this survey.

The major local oceanographic features seen within this area are either due to sediment transport patterns or estuarine inputs. The Tweed river plume is shown to extend offshore at some tidal states, facilitating mixing with offshore waters. Plume structures off Filey Brigg and north of Whitby also extend offshore.

Additionally, warming of coastal waters by outfalls from power stations and other industrial sources may have a detrimental effect on the ecology and water quality of the cell. Further investigation, including vertical temperature profiles would allow the full extent of the influence of these outfalls to be assessed.

Figure 1.

Littoral Cell 1*, From St Abb's Head to Flamborough Head

*After Motyka, J.M. and Brampton, A.H. (1993), "Coastal Management, Mapping of Littoral Cells", HR Wallingford.

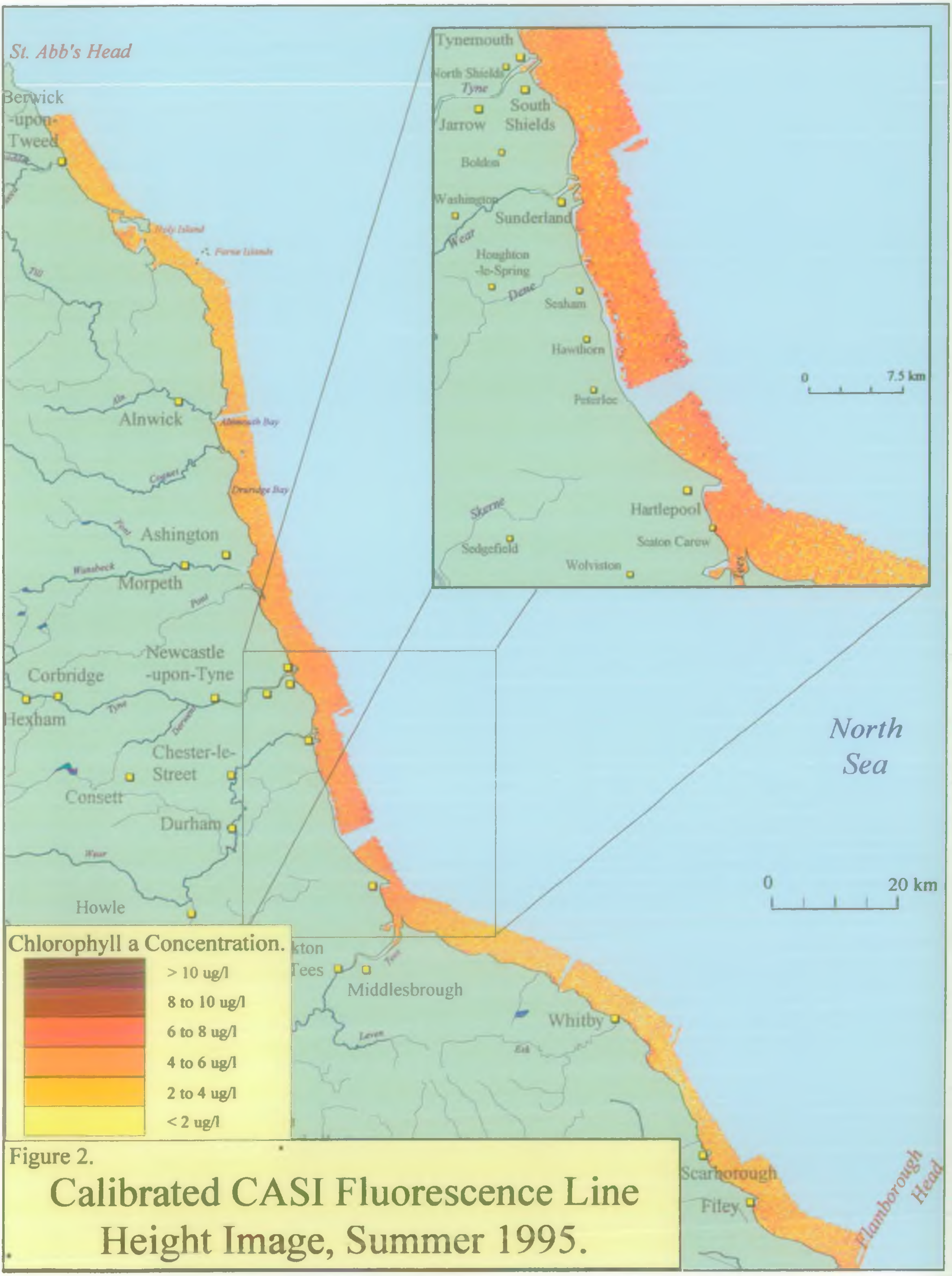


Figure 2.

Calibrated CASI Fluorescence Line Height Image, Summer 1995.

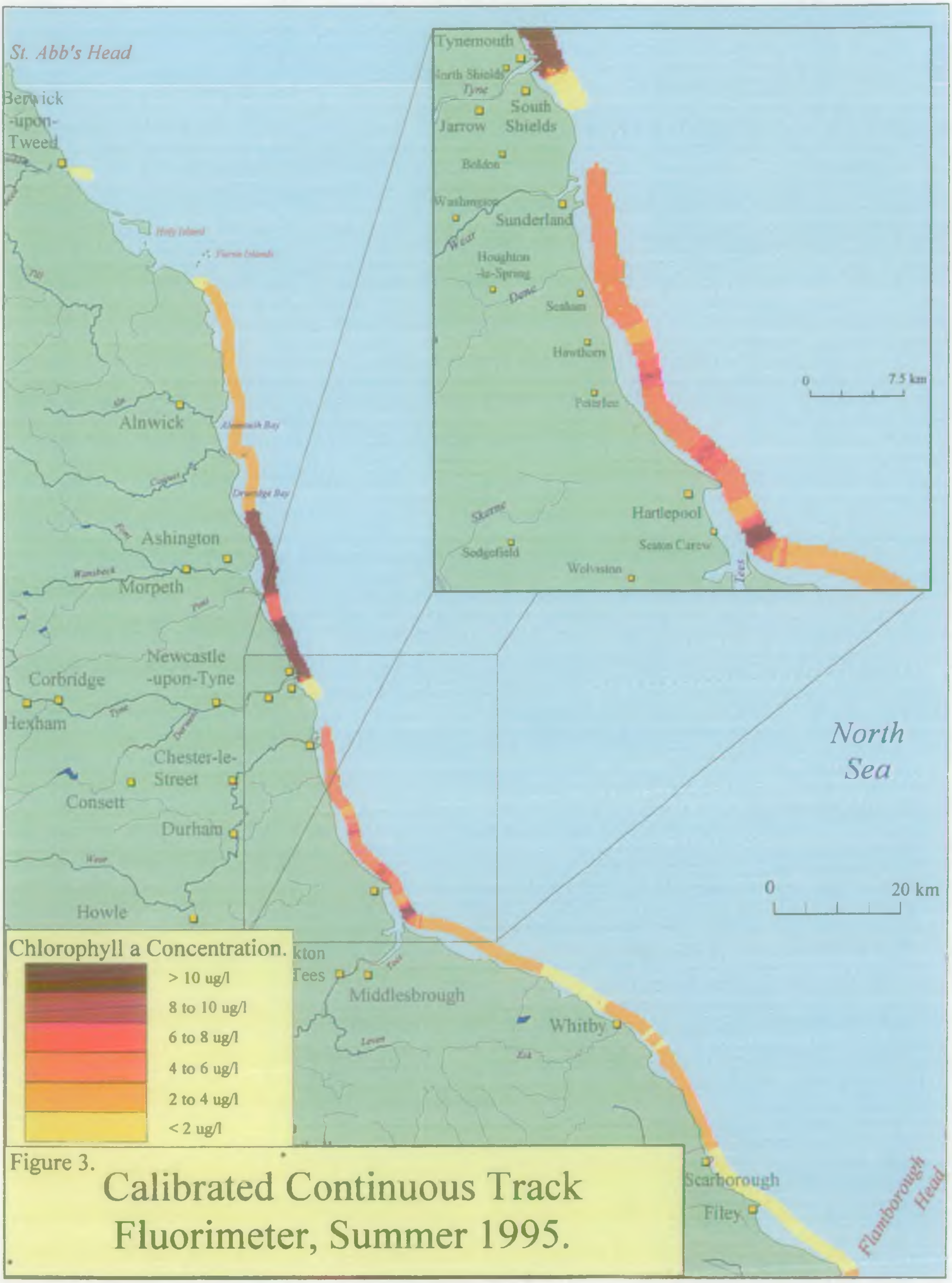


Figure 3.
Calibrated Continuous Track Fluorimeter, Summer 1995.

Figure 4.

Skalar Nutrient Data from the Tees Estuary Area, Winter 1995.

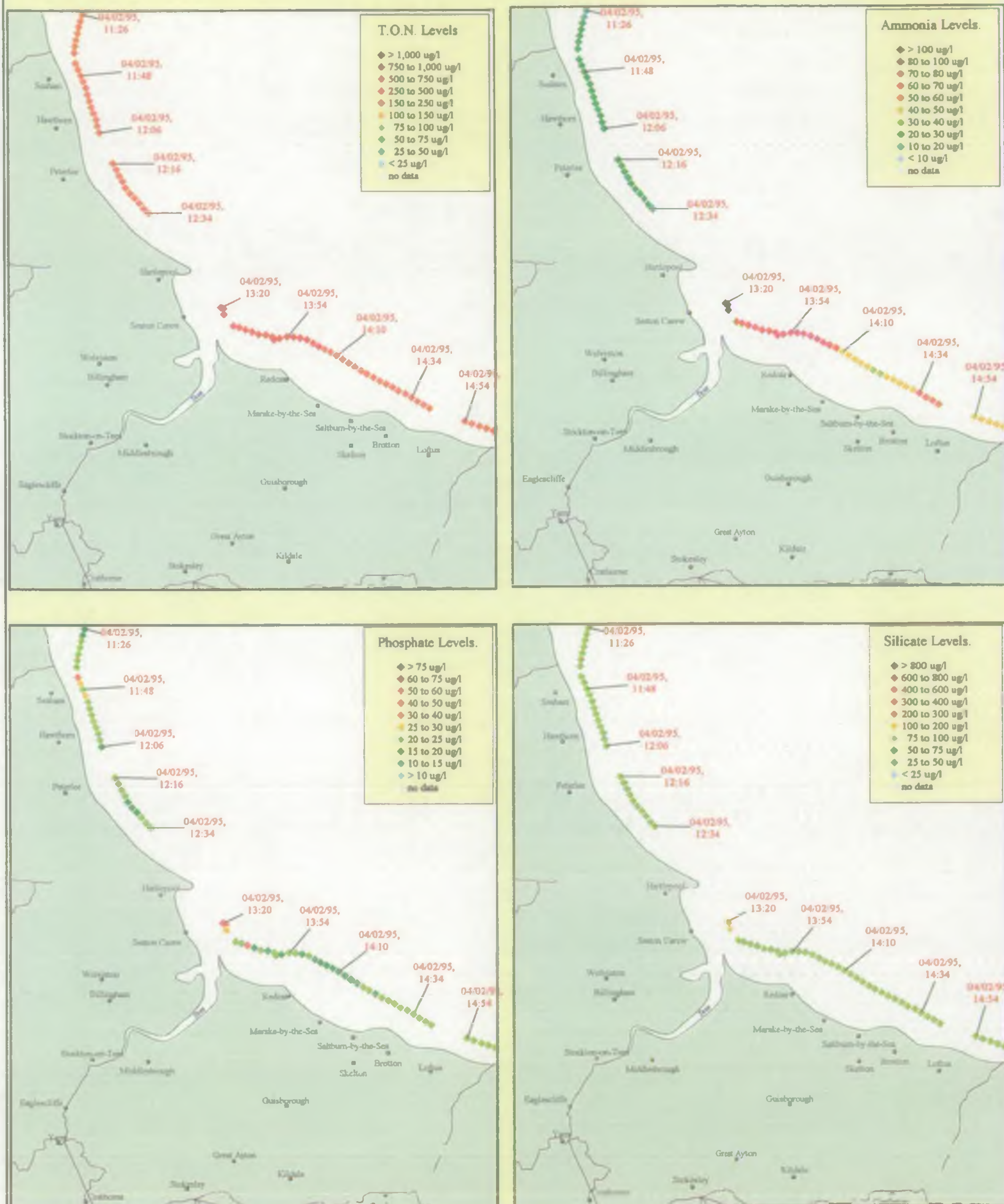


Figure 5.

Skalar Nutrient Data from the Tees Estuary Area, Summer 1995.

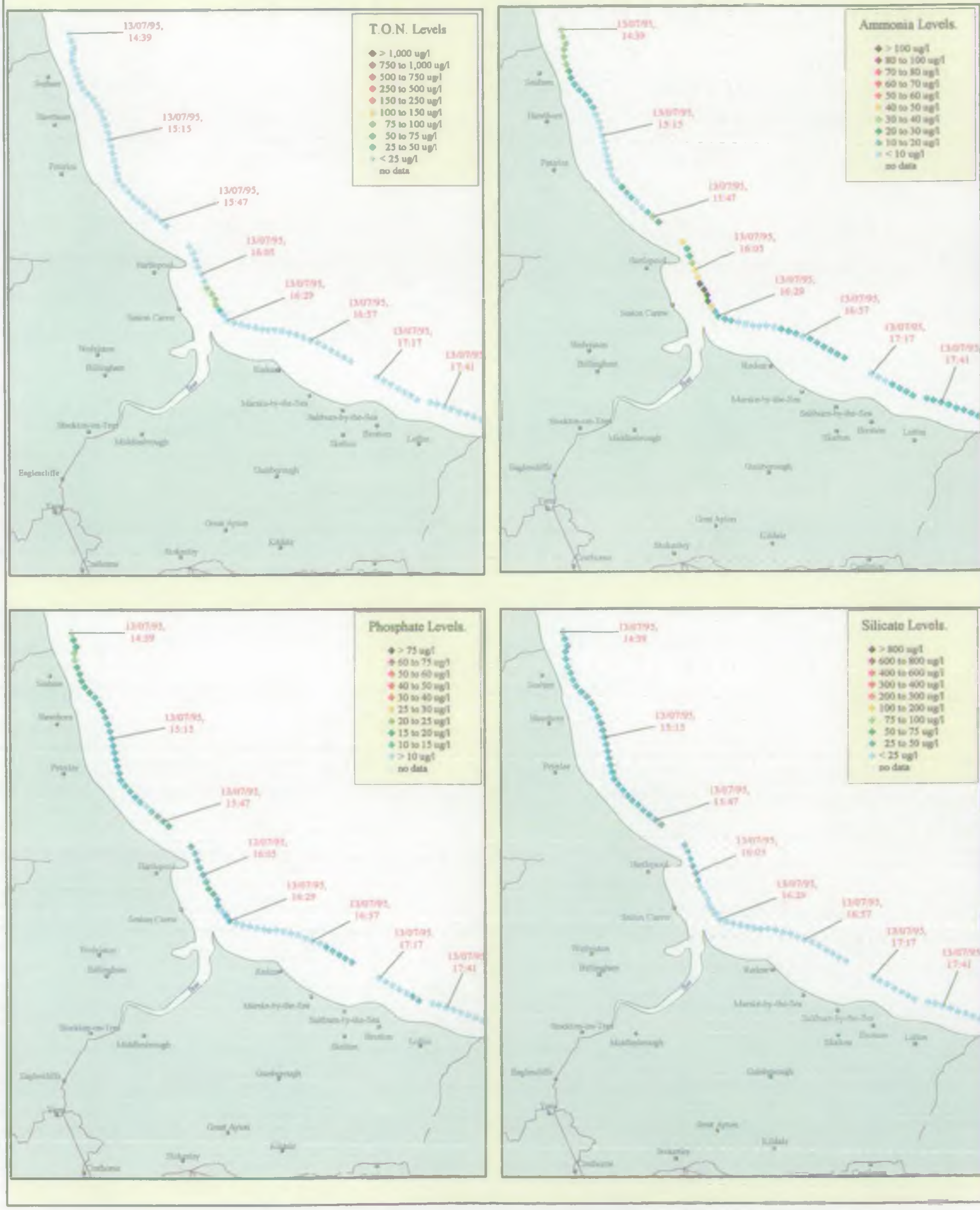
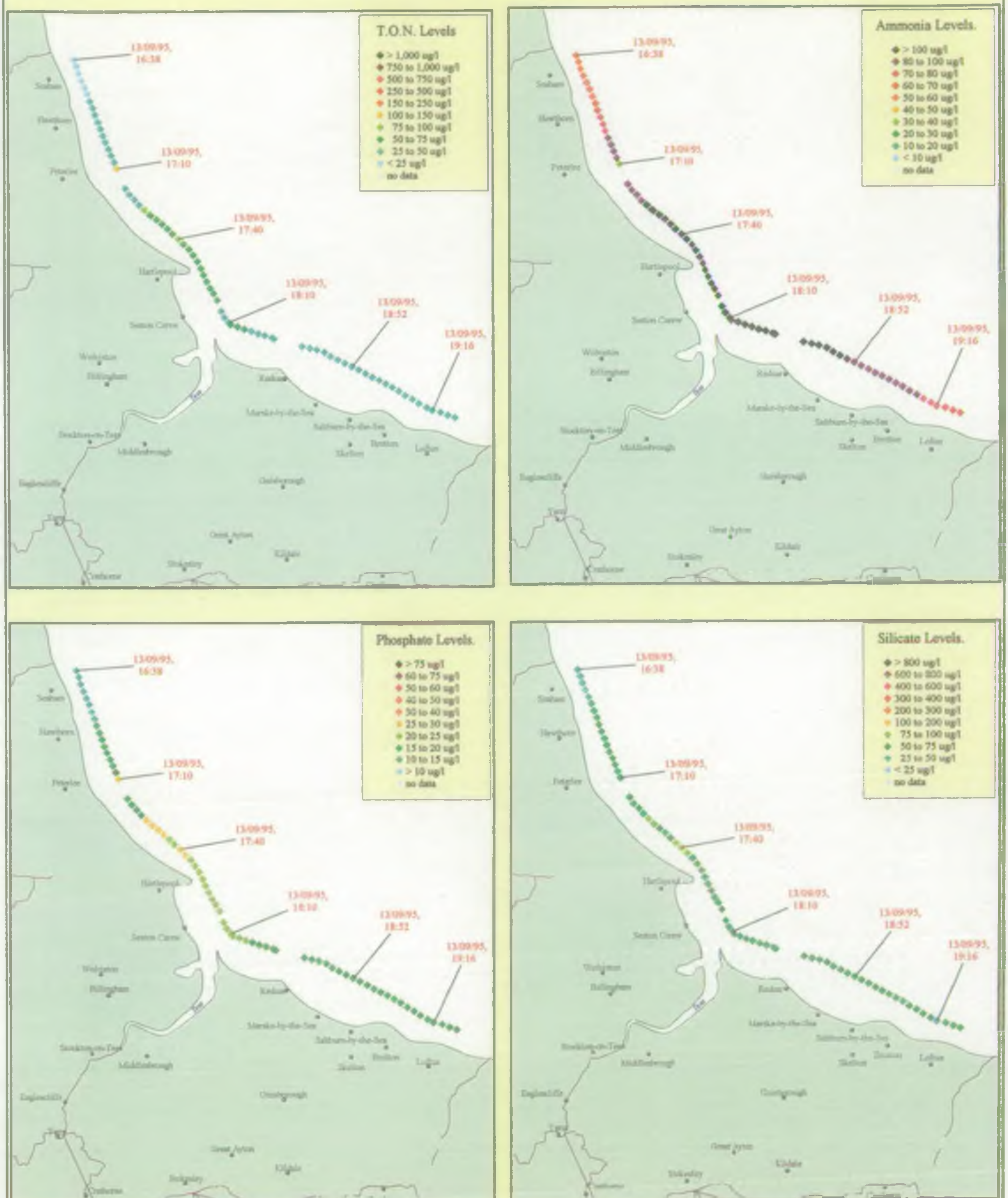


Figure 6.

Skalar Nutrient Data from the Tees Estuary Area, Autumn 1995.

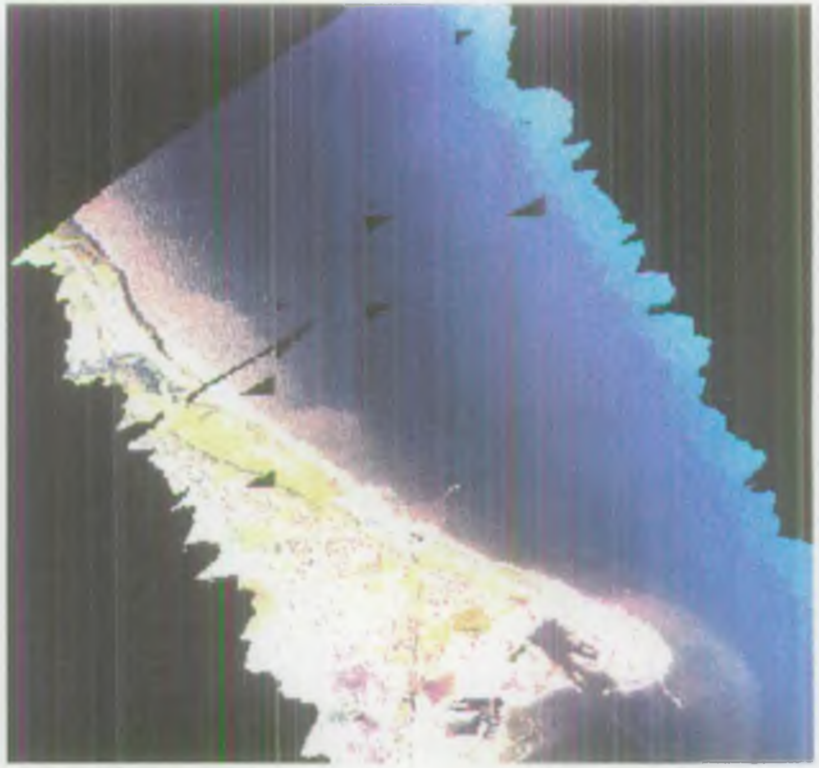


26th July 1995
16:54 GMT

13th September 1995
10:13 GMT

Plate 1: River Tweed plume
CASI enhanced true colour composite images
The baseline sampling site at Berwick is marked as the red cross

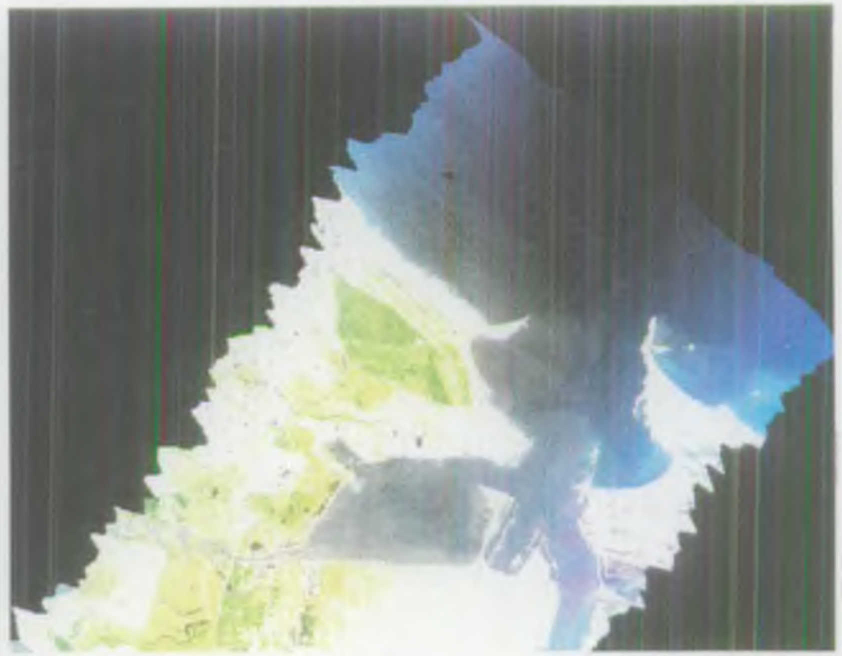
Boulmer, Northumberland
Sediment transport is constrained by headlands within individual bays



Hartlepool Bay, Cleveland
Sediment transport is linear due to the regularity of the coast

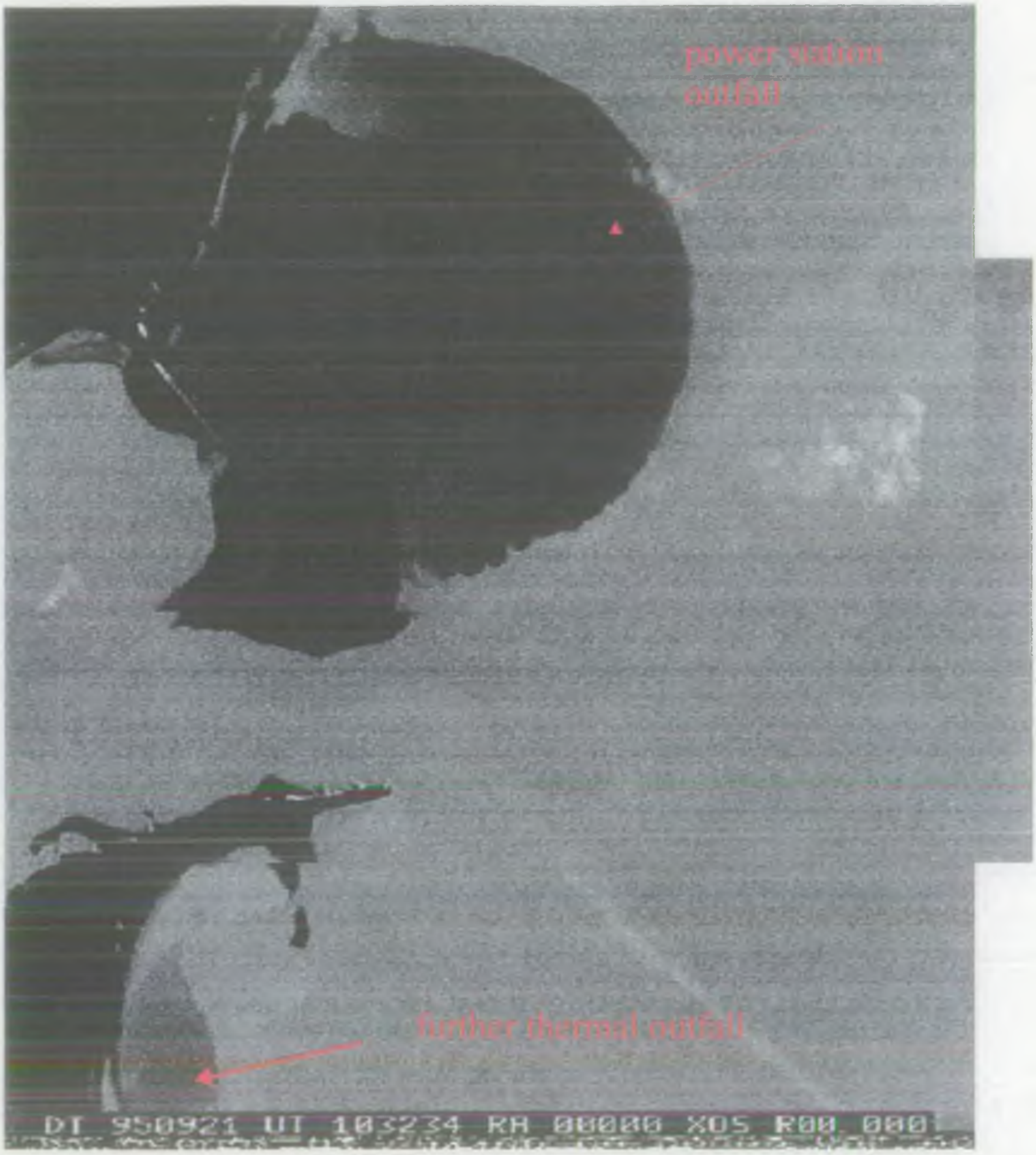
Plate 2: Sediment transport
CASI enhanced true colour composite images

(i) 23rd September 1995, 08:27 GMT



(ii) 26th July 1995, 15:40 GMT

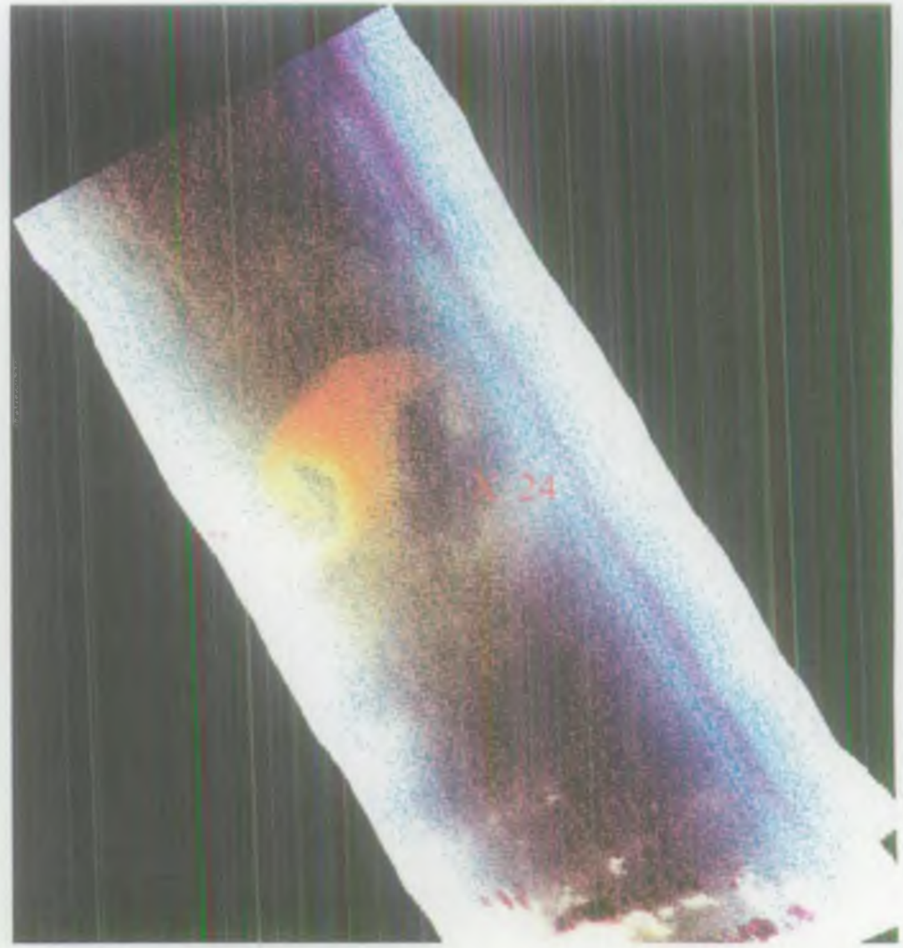
Plate 3:Teesmouth
CASI enhanced true colour composite images



21st September 1995, 10:32 GMT

Plate 4: Hartlepool Power Station, Cleveland
Thermal video composite image

26th July 1995, 14:54 GMT



14th September 1995, 10:45 GMT

Plate 5: Filey Brigg
CASI enhanced true colour composite image
The baseline sampling site is marked by the red cross

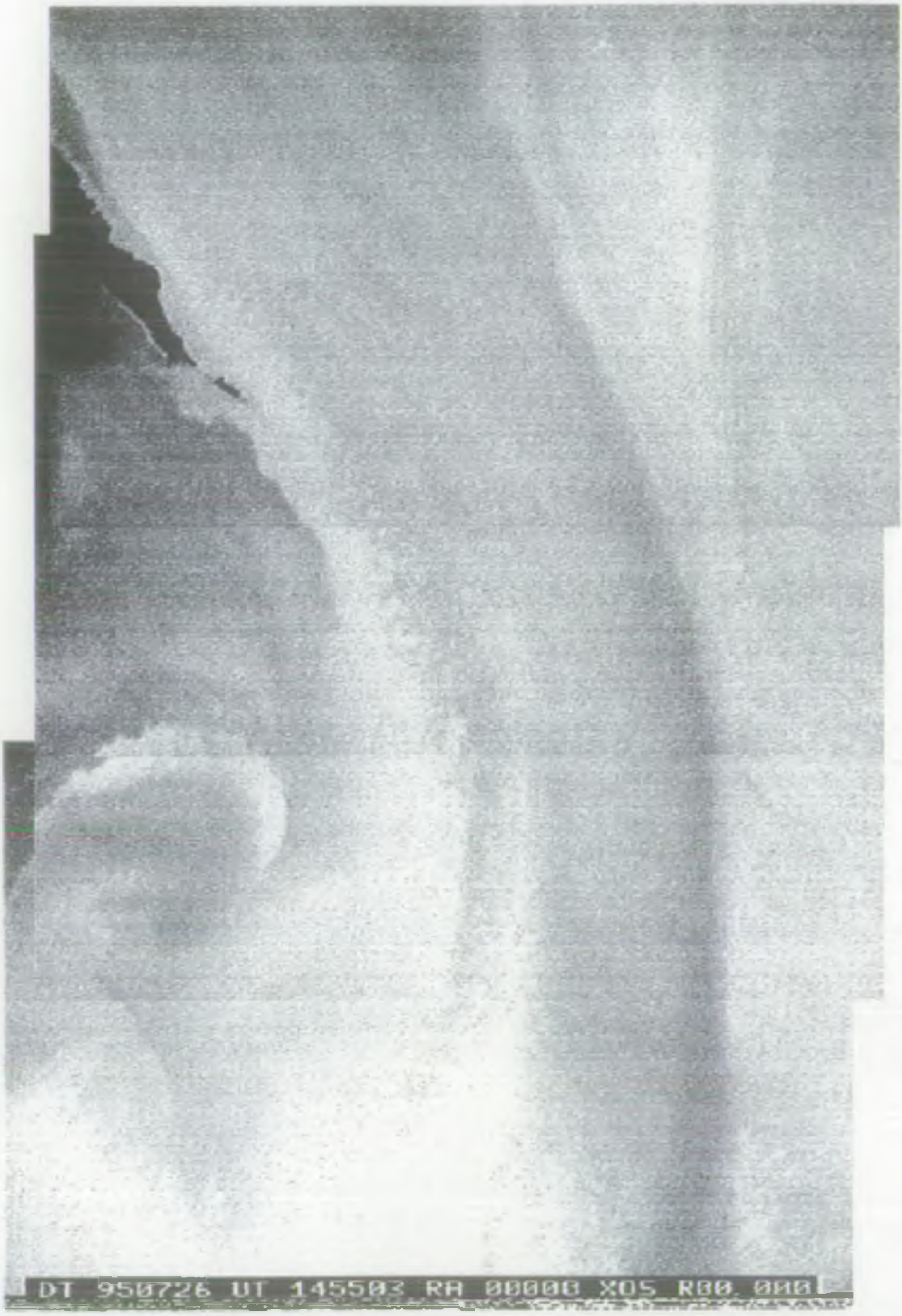


Plate 6: Filey Brigg
Thermal video image composite
26th July 1995, 14:55 GMT

Robin Hood's Bay

Whitby

Plate 7: Yorkshire coast
CASI enhanced true colour composite images
14th September 1995