ENVIRONMENT AGENCY

ANGLIAN REGION

EVALUATING THE IMPACT OF GROUNDWATER ABSTRACTION ON KEY CONSERVATION SITES

REPORTS FOR AMP3

Project No: KA 100128

FINAL REPORT

YARE BROADS AND MARSHES (STRUMPSHAW FEN)

hsi

Hydrogeological Services International Ltd
6 Millmead
Guildford
Surrey
GU2 5BE

in association with

ECUS

Environmental Consultancy
University of Sheffield
Endcliffe Holt
343 Fulwood Road
Sheffield S10 3BQ

August 1998

ENVIRONMENT AGENCY

EA-Anglian Water Resources

TABLE OF CONTENTS

FIGURES (at thc back of the report)

1. DESCRIPTION OF SITE

1.1 PHYSICAL ASPECTS

Strumpshaw Fen and Common are part of the Yare Broads & Marshes SSSI. The site is located at TG 330 063 over the northern floodplain area of the River Yare, to the southeast of Brundall and to the south of Strumpshaw, about 10 km east of Norwich (Figures 1 and 2). An aerial photograph of the Fen taken in 1993 (shown in Figure 2a) illustrates the main features of the site at the time.

The site is very flat lying, located within the floodplain of the River Yare at elevations of between -1 and 1 m OD. The extent of the floodplain is generally about 500 - 1000 m wide on each side of the river. To the northeast the ground rises relatively steeply to a maximum elevation (Strumpshaw Hill) of 42 maOD within 2 km of the site. Apart from Strumpshaw Hill, more typical elevations on the higher ground away from the floodplain to the northeast are 25 - 30 maOD.

Strumpshaw SSSI comprises 197 ha (488.7 acres) of open water, reedbed/fen, carr, woodland and grazing marsh on the floodplain of the River Yare. Most of the site is now covered by relatively species-poor vegetation, dominated by reed and greater pond sedge, although a few more species-rich areas do occur. Some parts of the site were probably once better drained than at present, and management has included grazing and mowing in various areas.

1.2 SITE HISTORY AND MANAGEMENT

The early history of the site is well documented by M Martin (1987). In summary, the area is thought to have been subjected to peat digging from 879 AD onwards. As the sea level continued to rise, the diggings became flooded to become what are known as the broads; the flood of 1287 probably brought deep peat diggings to an end. Subsequently, Strumpshaw Broads silted up gradually and marginal vegetation encroached into the centre, eventually forming a reed swamp. Peat which formed as a result of the decay of reeds and other vegetation led to the surface level to progressively rise, and conditions to become drier. Colonisation by fen vegetation such as rush and carr followed, giving way gradually to alder carr with sallow and birch. As a result, the areas of open water became progressively smaller, as indicated by topographic maps dating back to 1846, 1881 and 1946, when "open water was almost obliterated" (Ellis, 1965).

Whilst this natural progression has been taking place, the area has been subject to considerable artificial influences. Embankments were built along the River Yare and Lackford Run, and the area between Strumpshaw Broad and the River was drained by a windmill in the 19th Century and probably used to grow hay or for grazing. It is not known when this ceased, although when a summer flood in 1916 breached the banks, they fell into disrepair and the drained area of marsh reverted to rough fen (Ellis, 1965). A central embankment known as the "sandy wall" was also constructed, prior to 1881, which now separates the wetland area in the west from the drained grazing

marsh area in the east, as shown in Figure 2. It appears that these two areas have been managed separately for many years; the area to the east is still being managed as a grazing marsh.

In 1975, the Royal Society for the Protection of Birds (RSPB) took control of the management of the site, buying some of the land and leasing the remainder from a local landowner. The area is currently divided into three parts on the basis of the management strategy as follows; the latter two collectively are known as Strumpshaw Fen:

- The area known as Strumpshaw Common to the east of the sandy wall, as far east as the embankment separating Strumpshaw and Buckenham Marshes. This area is managed as a drained grazing marsh with water levels controlled by a drainage pump discharging to the River Yare.

- The area to the east of Lackford Run and to the west of sandy wall. This area comprises mixed fen carr, reedbeds and broad. Originally the water level was controlled by levels in Lackford Run and the River Yare. However, the RSPB have adopted a management policy aimed at restoring the area to reedswamp, in order to meet the conservation objectives of the site with regard to certain rare birds and flora. The RSPB decided to isolate the area from tidal influence, due to enrichment in nutrients of waters in Lackford Run and the River, resulting from discharge from the Sewage Treatment Works at Strumpshaw and Whitlingham, respectively. The work on embankments was instigated in 1978 and completed in 1980. In 1983 Strumpshaw Broad was mud-pumped and the open water area greatly increased, although it was not restored to its original size.

  In order to meet the conservation objectives of this area, high water levels are required. As a result, the yearly cycle of water level management normally involves capture of high flooded river water in winter and spring, followed by a gradual fall in water levels through the summer and early autumn. Water levels are topped up using a compensation borehole, drilled by Anglian Water Services in 1986 following a report by Martin (1987), assessing the effect of abstractions on the SSSI caused by the nearby Strumpshaw Anglian Water public supply source. The borehole is generally referred to as the marsh support or RSPB borehole.

- The area to the west of Lackford Run (Bradeston Marsh). The area is currently fen carr with some reedbeds; work is currently in progress to clear remaining areas of alder carr and encourage the area to return to reed swamp. The area was originally open to Lackford Run and to the River Yare, but it is now isolated from surface water inflows (as of 1987), for the same reasons as those described above, except possibly for some minor inflows from a drain to the northwest of the area.

2. ECOLOGY

2.1 CONSERVATION STATUS AND MAIN INTEREST

2.1.1 Status

Strumpshaw Fen is part of the Yare Broads and Marshes SSSI. The site lies within The Broads candidate SAC and Broadland Ramsar Site and Broadland SPA. The fen also forms an important part of the Royal Society for the Protection of Birds Mid-Yare Nature Reserve, a site recently designated a National Nature Reserve.

2.1.2 Vegetation

Much of the fen vegetation present is version of NVC type *Phragmites australis–Peucedanum palustre* fen (S24). Nationally-scarce plants include water soldier *(Stratiotes aloides)*, marsh pea *(Lathyrus palustris)*, cowbane *(Cicuta virosa)* and marsh sow-thistle *(Sonchus palustris)*.

2.1.3 Invertebrates

The table in Appendix 1 provides a summary of scarce invertebrates associated with wetland conditions at Strumpshaw. The site is important for invertebrates, including the 'endangered' swallowtail butterfly *(Papilio machaon)*, plus a number of RDB and nationally-notable species. There is a good assemblage of scarce wetland Diptera, which includes members of many families, but snail-killing flies (Sciomyzidae) are especially well represented. The water beetles show some interest, but appear from available ISR records to be poorly and erratically recorded. Though they include two nationally scarce species, there is a good assemblage of local wetland Auchenorhyncha, chiefly associated with tall/dense vegetation such as reed and sedge beds. The dragonflies include Norfolk hawker *Aeshna isosceles*, as well as other scarce species. The Lepidoptera include a number of nationally scarce species, and are especially rich in species associated with reed beds. The Lepidoptera include the swallowtail butterfly and a number of nationally scarce species, and are especially rich in species associated with reed beds. The wetland spiders show significant interest, and include nationally scarce species characteristic of East Anglian wetlands. The recorded interest is primarily of species associated with more or less open wetlands, especially tall fen vegetation, and water margins.

2.1.4 Birds

The SSSI citation for the Yare & Broads Marshes SSSI describes this as an area of "great ornithological interest". Much of this interest is now focused upon Strumpshaw Fen, which is clearly a nationally important bird site. Particularly important breeding birds include bittern (*Botaurus stellaris*), marsh harrier (*Circus aeroginosus*), bearded tit (*Panurus biarmicus*), Cetti's warbler (*Cettia cetti*), Savi's warbler (*Locustella luscinioides*); all of which are afforded legal protection under Schedule I of the 1981 Wildlife & Countryside Act. These, and a number of other birds occuring at Strumpshaw, have also been selected as UK red data species (Batten et al, 1990). In

addition, bittern and marsh harrier have been selected for special conservation measures under Annex I of the EC 'Wild Birds' Directive (79/409/EEC).

Other 'red data' wetland breeding birds at Strumpshaw include shelduck (*Tadorna tadorna*), teal (*Anas crecca*), gadwall (*Anas strepera*), shoveler (*Anas clypeata*) and pochard (*Aythya ferina*). In addition, little grebe (*Tachybaptus ruficollis*), great crested grebe (*Podiceps cristatus*), mute swan (*Cygnus olor*), greylag goose (*Anser anser*), mallard (*Anas platyrhynchos*), tufted duck (*Aythya fuligula*), coot (*Fulica atra*), moorhen (*Gallinula chloropus*), water rail (*Rallus aquaticus*), lapwing (*Vanellus vanellus*), snipe (*Gallinago gallinago*), reed warbler (*Acrocephalus scirpaceus*), sedge warbler (*Acrocephalus schoenobaenus*) and reed bunting (*Emberiza schoeniclus*) also breed at Strumpshaw.

The Yare Valley SSSI also supports nationally important numbers of passage and wintering birds, including wigeon (*Anas penelope*) (red data species) and hen harrier (*Circus cyaneus*) (red data, Schedule 1 and Annex I species). In addition, this stretch of the Yare Valley supports England's only remaining wintering flock of bean geese (*Anas fabalis*) (red data species).

2.2 ENGLISH NATURE CONSERVATION OBJECTIVES

The following objectives relate to Strumpshaw Fen and Common.

National Objectives:

The national objectives are subsumed by the international objectives.

International Objectives:

SAC objectives

- Increase the extent of, and enhance the condition of the internationally important chalk-rich fen dominated by saw sedge (great fen sedge).

This objective refers to the S2 and S24 vegetation types. These vegetation types are situated within the northern part of the fen, in areas that have been extensively peat cut in the past (Parmenter pers. comm.).

- Enhance the condition of the internationally important 'naturally nutrient rich lakes and dykes which are often dominated by pondweeds'.

This objective refers to water bodies both within the Strumpshaw Fen and Common sections, and includes invertebrate interest. Improvements in water quality on the site and the reduction of the river supply are required to achieve the objective.

- Maintain the internationally important 'alder woodland on floodplains'.

[Note that English Nature believe that the additional SAC objective "Maintain internationally important populations of Desmoulins snail" is not relevant to the

present case at this site, as this snail is not considered to be particularly sensitive to variations in water level and nutrients.]

SPA objective

- Increase the internationally important populations of breeding bittern and marsh harrier.

reeding bittern will only return to the Yare valley following improvements to the habitat and water quality. The RSPB are currently undertaking a programme of habitat improvement on the fen.

Ramsar features

- Criterion 1a; many good and representative examples of wetland habitats characteristic of the biogeographic region.

English Nature contend that this project would improve the quality of the wetland.

- Criterion 2a; supports an outstanding assemblages of rare plants and invertebrates.

Within the Broads site, this objective includes nine RDB plants including the rare moss *Cinclidium stygium*, a species formerly present at Strumpshaw (last recorded 1975), and 136 RDB invertebrates. Improvements to water quality on the site would be of benefit to this feature.

- Criterion 3c; recognises a number of bird species which include the bittern and marsh harrier, as the SPA feature/objective.

2.3 RELATIONSHIP OF FLORA AND FAUNA TO WATER SUPPLY

2.3.1 Flora

Groundwater Dependency Categories: 2

There is no reason to suppose that any of the vegetation present on this site, or that which used to occur (including the former *Cinclidium stygium* vegetation) requires groundwater input, though it is possible that this site naturally received some marginal groundwater discharge. It is not known how important this may once have been in maintaining the water balance of the river transgression fen.

Inputs of groundwater (including the pumped supply) may be/have been important in providing water of better quality than that of river water, and hence of importance to the objectives of pondweed dykes and bitterns.

The general water level regime of flooded in winter and drier in summer is appropriate for the fen vegetation types of international importance (S2 and S24), but it is not conducive to the maintenance or creation of wet reedbed (for bittern) (SPA objectives), for which a high water table throughout the year is required. However, it

should be possible to undertake extra measures on site to allow achievement of both objectives, for example by increasing the amount of open water in some areas by lowering the peat surface. This work is currently receiving English Nature funding.

Ecologically, there is no doubt that, as with most Broadland fens, Strumpshaw Fen is naturally a system where water tables are strongly influenced by river water levels. [Note that this does not apply to Strumpshaw Common, which is more isolated.] This almost certainly means that parts of the fen show a natural tendency to dry out considerably in drought years. However, even without such extreme events, the natural character of the vegetation of the Yare Fens is almost certainly partly a product of a greater degree of seasonal water level fluctuation than is found in the northern valleys of Broadland. The richness of the distinctive 'Yare Valley Fen', described by Pallis (1911), in dicotyledons (including uncommon species such as *Lathyrus palustris*) is almost certainly because these fens naturally have relatively low summer water levels and are slightly more nutrient rich than many other fens in Broadland. It thus seems likely that attempts to exclude river water from the systems will shift these systems away from their 'natural' ecological status and water supply mechanism. Likewise, attempts to make good the water deficit induced by exclusion of river water by the introduction of a supplementary supply will also shift the system from its natural state. Nor is such an approach addressing the real cause of the problem. It is fully recognised that the desire to exclude river water from parts of Strumpshaw Fen stems mainly from the nutrient richness of this water, but we would suggest that as this fen is naturally fed primarily by the river, the only real solution to reinstating its former character is to reduce the nutrient loadings in the river. Moreover, it is important to recognise that Strumpshaw is not the only fen in the Yare Valley, nor is it necessarily any 'better' than some of the other examples (Wheatfen has long displayed some of the 'best' vegetation gradients, and greatest floristic diversity and remains a particularly good example of Pallis' 'Yare Valley Fen'). Many, if not all, of these sites would benefit substantially from improvement in river water quality.

2.3.2 Fauna

The rarer dragonflies recorded require more or less permanent clean water; drainage ditches are likely to be the key habitat for them. Most of the other recorded scarce invertebrates require herbaceous fen vegetation or water margin vegetation, including reed beds, which are wet for a large proportion of the year (and preferably at least damp for the whole year). However, receding water in the summer, and the mud and stranded snails which result, may be of significant benefit to a number of species.

The open water, dyke network, wet grassland / fen meadow and reedbeds, together with their associated flora and fauna, provide feeding and breeding opportunities for many birds, which are dependent on these habitats to varying extents. The amount of open water, vegetation structure and availability of food (including vertebrates and invertebrates) are often primary considerations in determining the suitability of a particular area for breeding, foraging or roosting, and can be affected both by water regime and water quality. Alterations to the soil physical characteristics, which may also occur as a result of changes in hydrological regime, can also be important, for example by affecting the ease with which birds such as snipe can probe the ground for prey (earthworms and tipulid larvae).

2.4 SUMMARY OF MANAGEMENT

Different areas of the site have been managed for marsh crops such as reed and litter or grazed, and parts may once have been better drained than at present (particularly the northern section). There was little management after the Second World War, until RSPB took the lease in 1976. The Strumpshaw Common section of the site is managed by grazing. The management history of the site is summarised by Parmenter (1995).

In 1978, the RSPB instigated a work programme to protect the broad and surrounding fen from the polluted river water, as described in section 2.2, including building dams and embankments (see Tickner *et al* (1991). The compensation water borehole was also installed. Additional work included 'mud-pumping' the broad, clearance of scrub/carr, re-instatement of reed cutting, clearance of dykes and excavation of 4 ha of shallow turf ponds.

In the last few years, a specific programme of work has been implemented under a project to attract bitterns to the site. This has involved clearing out dykes, and creation of shallow excavations, particularly in the section closest to the river. There has been some scrub/bush removal from areas closer to the upland margin.

Strumpshaw Common is managed as fen meadow / wet grassland under the ESA Tier 2 and 3 ESA, mainly by sheep grazing, supplemented by mowing on some of the botanically rich areas. Dykes are cleared out on a rotational basis, approximately once every ten years.

At present the management prescriptions for the site are based on making the best of the current situation, and not necessarily aimed at a 'natural' state. Clearly these prescriptions could be reviewed if water quality and quantity problems were to be addressed satisfactorily.

2.5 SUMMARY OF ECOLOGICAL CHANGES

2.5.1 Vegetation

Considerable changes have occurred on this site over a long period of time, in particular as a result of deterioration of water quality in the River Yare. Much of the vegetation is now highly degraded, although probably in response to various influences. It is important to recognise that the present degraded communities were not always present, though equally lack of good documentary evidence makes it difficult to trace the processes of vegetation change.

In the early 1970s (visit by B.D. Wheeler) much of Strumpshaw Fen was broadly similar to Wheatfen (on the opposite side of the river) – typical, colourful forb-rich 'Yare Valley Fen' (*sensu* Pallis, 1911), though more derelict than at Wheatfen. The former communities with *Cinclidium stygium* (referred to in the English Nature Objectives) had long since disappeared. The land margin edge was slightly more

diverse than the more riverward areas, with a greater abundance of such species as *Carex appropinquata* (in this respect also showing the same pattern as at Wheatfen). Since the 1970's there has been a further loss of diversity (see below).

There is no doubt that substantial changes have occurred, probably related to both drying and nutrient enrichment, though it can be difficult to separate the two as in these systems considerable nutrient release can be induced by drying (this was evident at Wheatfen: one drought year resulted in a switch from a relatively diverse, *Phragmites*-dominated community to a very impoverished community with much willowherb *Epilobium hirsutum*, meadowsweet *Filipendula ulmaria* and stinging nettle (*Urtica dioica*).

Given the character of the vegetation, and the existence of some comparable floristic changes at Wheatfen, where groundwater abstraction is not thought to have much influence on the water balance, there is little reason to suppose that groundwater abstraction at Strumpshaw is the proximate cause of the observed changes. It seems more likely that the changes relate partly to natural water deficits and to reduction of river inflows as part of a water management strategy. It is, of course, possible that higher rates of groundwater flow may once have reduced the extent of penetration of river water into the fens but, without knowledge of the magnitude of the presumed flow, no comment can be made on this.

A report by Tickner et al (1991) describes the management work undertaken since 1975, and subsequent progress towards recovery, including improvements in water quality, and increase in aquatic macrophytes in the broad and dykes. Changes in the fen vegetation were slow, but there was some indication of an increase in common reed (*Phragmites australis*), and a decline in such species as reed sweet-grass (*Glyceria maxima*) and great hairy willow herb (*Epilobium hirsutum*), possibly in response to improvements in water quality. Invertebrates and birds also responded positively to the improvements in habitat conditions, in species numbers and breeding populations. Scrub encroachment is an ongoing problem; higher water levels could help to alleviate the problem, but would not solve it.

Records have been examined from surveys of the dyke flora in 16 stretches of dyke on the Strumpshaw Common section of the site, carried out in 1988/9 and 1997. A few observations can be made, although only limited significance can be attached to them, particularly as aquatics are notoriously labile, and the general trend was for water levels to be higher at the time of the second survey, which was carried out earlier in the season (July) than the first (August/September). The water soldier *Stratiotes aloides* was recorded from three stretches of dyke in both surveys, two of which coincided. In 1997, *Myriophyllum verticillatum* was absent from 5 of the 6 dykes in which it had been found in the first survey. Similarly, there was a reduction from 5 to 1 locations for *Potamogeton* species. *Elodea canadensis* was recorded from four dykes in 1988/9, but not at all in 1997. The stonewort *Chara vulgaris* was recorded from two 'new' stretches of dyke, but absent from its single 1989 location. The bladderwort *Utricularia vulgaris* was recorded in one dyke in 1988, but not found at all in 1997.

2.5.2 Invertebrates

The Red Data Book mollusc *Pseudamnicola confusa* has apparently been lost from the site as a result of destruction of its habitat through site management (Invertebrate Site Register). The swallowtail butterfly (*Papilio machaon*) has been continuously present on the site for many years, and recent monitoring results give no reason to suspect long-term change. Otherwise, the invertebrate records do not permit detection of change; though there is some spread of records through time, those for any one group tend to be concentrated over a short period. Persistence over a short period of years is indicated for some species, but these are too few to permit overall conclusions.

2.5.3 Birds

Increases in the numbers of wetland breeding species were reported by Tickner (1991), including marsh harrier, Cetti's warbler, and first breeding of Savi's warbler on the site. Increases in breeding populations of many other wetland species were also reported, including great crested grebe, little grebe, gadwall, mallard, shoveler, pochard, tufted duck, coot, lapwing, snipe and redshank. In addition, dramatic increases in the numbers of passage/wintering wigeon, gadwall and tufted duck were also reported at that time. These changes were largely attributed to the RSPB's remediation works and habitat management at Strumpshaw.

Since 1981, bittern have been recorded booming in three years, and are thought to have bred in 1987. Breeding populations of marsh harrier and bearded tit have also increased during this period, reaching 4 pairs and 12 pairs respectively in 1997. Breeding populations of a number of other wetland species have also increased; with those of little grebe, great crested grebe, coot, greylag goose, shoveler, mallard, pochard and tufted duck showing the largest increases over this period. By contrast, breeding populations of Cetti's and Savi's warblers have remained unchanged overall, and there is some indication that breeding numbers of teal may have declined recently.

In summary, a number of wildfowl numbers have increased, and this is likely to be due to an increase in open surface water and marginal wetland habitats. The changes in numbers of other wetland species are perhaps less likely to be directly linked with water level changes, given the other factors at this site.

Unfortunately, there are no data for other wetland bird species, for example, breeding populations of reed warbler, sedge warbler and water rail, due to the difficulties in censusing these species in extensive reedbeds. There are also no recent data on changes in numbers of passage/wintering wetland birds at the site.

3. WATER RESOURCES

3.1 RAINFALL AND EVAPOTRANSPIRATION

3.1.1 Rainfall

The site lies with MORECS square 131. Figure 3a shows, in bar chart form, annual rainfall in the period 1973 - 1995. The mean annual rainfall for the periods 1961 - 1990 and 1973 - 1995 was 600 mm and 598 mm, respectively. As can be seen from the figure, during the years 1989 - 1992, annual rainfall was approximately 17% less than the long term mean.

Figure 3b shows the Cumulative Deviation of Rainfall form the mean for the period 1973 - 1995. The plot clearly demonstrates that 1989 - 1992 was a relatively long period of persistently low rainfall, contrary to 1976 drought, the duration of which was short, though lower rainfall was also experienced in 1977 and 1978.

3.1.2 Evapotranspiration

Figure 4a shows a bar chart of annual evapotranspiration for the period 1973 - 1995 for MORECS square 131. Figure 4b shows the mean daily evapotranspiration for the period 1961 - 1990. Mean values are:

	1961 - 1990	1973 - 1995
Annual Mean Potential Evapotranspiration	527	534
Annual Mean Actual Evapotranspiration	437	435
Daily Mean Potential Evapotranspiration	1.45	-
Daily Mean Actual Evapotranspiration	1.20	-

As would be expected, highest evapotranspiration occurs in June-July (2.3 mm/day actual: 2.9 mm/day potential), and the lowest in December to January (0.5 mm/day actual and potential).

3.1.3 Effective Rainfall

Figure 5a shows in bar chart form annual effective rainfall for the period 1973 - 1995. Mean annual effective rainfall for 1961 - 1990 was 173 mm and for 1973 - 1995, 174 mm. During the years of low rainfall of 1989 - 1992, annual effective rainfall was about 42% less than mean effective rainfall.

Figure 5b shows the Cumulative Deviation of Effective Rainfall from the Mean for the period 1973 - 1995. The plot illustrates the decreasing trend in effective rainfall beginning in 1989 and persisting to 1993.

3.2 SITE HYDROLOGY AND DRAINAGE

Figure 2 shows the site drainage. The aerial photograph, Figure 2.a, taken in 1993, shows some of the surface water features, although management of the site since has brought about significant changes.

Western area (Bradeston Marsh)

The area is characterised by interconnecting dykes, and more recently includes larger scrape and broad areas. The scrape areas are linked to the dykes. Drainage from the area is via a sluice gate, which separates the marsh from the River Yare; the sluice gate can be opened to allow inflows from the River. Surge tides breaching the embankments also provide inflows to the site. Minor surface water inflows are also thought to be occurring into the northwestern part of the area via a drain.

Central Strumpshaw Broad and Marshes area

The area is characterised by interconnecting dykes, broads and scrape areas. The largest and most permanent of the broads is Strumpshaw Old Broad, located near the northeast corner of the area. The area is hydraulically isolated from both inflows and outflows, although a sluice gate can be opened to allow water to enter from the River Yare. Water is generally only allowed to enter when the water is of reasonable quality. Breaching of the embankments also occurs at times of surge tides, which tend to take place every year in December or January. Water levels are topped up by using the compensation RSPB borehole.

Eastern Area including Strumpshaw Common

The area is also characterised by an interconnecting network of dykes which are drained by pumps which discharge to the River Yare at TG 341 057. Surface water inflows to the site are from a watercourse, which drains the 'uplands' to the north. There are not thought to be any other inflows to the area.

3.3 HYDROGEOLOGY

3.3.1 Geology

The regional geology of the area is shown in Figure 6 (which has been reproduced from Sheet 162, Geology of Great Yarmouth, 1:50,000), and is further illustrated by a geological section, Figure 7. The lithostratigraphy of the area is shown in Table 1.

The entire area is underlain by the Upper Chalk, which slopes gently to the east. Within the vicinity of the SSSI, the Chalk surface is at approximately -25 maOD, 25 - 30 m below ground level, recorded at the sites of the Anglian Water public water supply borehole and the RSPB borehole. The top of the Chalk is very hard comprising a 1 - 2 m band of hard chalk and flint, encountered in all boreholes drilled in the area.

To the east and south of the area, the Chalk is overlain by Eocene deposits, including London Clay, although there is some uncertainty as to the position and extent of the Eocene boundary. The Upper Chalk and Eocene deposits, where present, are overlain successively by the Norwich Crag and glacial deposits. Beneath the site the Crag directly overlies the Chalk.

TABLE 1 LITHOSTRATIGRAPHY OF THE STUDY AREA

Period	Formation	Lithology	Thickness (m)
Holocene		Peat, Clay and Alluvium	Up to 8 m
Pleistocene	Lowestoft Till Formation Corton Formation	Sand & Gravel Undivided; mainly sand; some sand clay.	20 - 30
	Kesgrave Formation	Sand & Gravel	5 - 15
	Crag Group	Sand, some silt clay	15 – 30
Eocene	London Clay	Clay	0 – 90
Cretaceous	Upper Chalk	Chalk with flints	>250

Below -15 mOD, the Crag consists mainly of sand with shell fragments and some silt, as well as clay lenses which tend to be thin, mostly less than 3 m, but variable in both extent and thickness. Above -15 mOD, the Crag consists of coarse sand & gravel. The total thickness of the Crag can be variable, generally between 15 and 30 m.

Within the Yare Valley, where the SSSI is situated, there are extensive alluvial and fen deposits overlying the Crag. The geology and stratigraphy of these deposits has been complicated by the history of peat digging and subsequent flooding over the last few hundred years. The near surface stratigraphy has been described by Lambert and Jennings (1960) who drew two north-south geological sections through Strumpshaw, one of which has been adapted by Martin (1987) and is reproduced for reference in Appendix 2. The section shows that the sequence thickens to about 10 m close to the river channel but thins out northeastward towards the railway embankment. The deposits consist mainly of brushwood and mixed fen peat overlain by organic clay layers. In the lower part of the fen close to the River Yare the clays are thicker and of estuarine origin. In the upper part, they consist of Nekron mud (an organic mud rich in mineral nutrients) which is thought to have been deposited within steep-sided basins excavated for peat in the past. At the surface there is 1 - 2 m of reed and sweet grass peat.

Out of the valley, to the north and east, where the land rises steeply, the Norwich Crag is overlain by Pleistocene deposits, comprising mainly Boulder Clay and glacial sands & gravels. The lower glacial deposits, more recently referred to as the Kesgrave Formation, are very similar to the Crag in composition, and in places can be difficult to distinguish. Together they have a thickness of up to 30 - 40 m. At the site of the RSPB borehole (TG 336 074) near the edge of the floodplain, the lithological log indicates that there are approximately 12 m of Crag overlain by 8 m of sand & gravels; at the surface there are approximately 3 m of peat.

Above the Lower Pleistocene deposits there are 20 - 30 m of clay-rich deposits, including Till of the Corton Formation, which are in turn overlain by glacial sands & gravels on the high ground. These sands & gravels have in the past been extracted from the Buckenham Wood sand pit, about 1 km to the northeast of the SSSI. It is now utilised as a waste disposal site.

3.3.2 Groundwater Conditions

The hydrogeology beneath the site comprises three main identifiable units:

- The multi-layered peat aquitard/aquifer, which is approximately 10 m thick close to the River Yare, thinning to about 2 m near the railway line. The peat can be divided into two parts comprising a lower mixed fen/brushwood semi-confined peat (up to 5 m) and an upper more recent (1 - 2 m thick) unconfined peat layer. The two aquifer layers are separated over much of the SSSI by a 2 - 3 m thick confining clay/mud aquitard. Close to the River Yare, the lower peat is not present, and is replaced by estuarine clay.

  The lower peat is in hydraulic continuity with the underlying Crag aquifer and semi-confined by the clay/mud aquitard. The upper peat is generally unconfined, although superficial estuarine clays lining the dykes and broad areas may restrict hydraulic continuity with surface water features.

- The semi-confined Crag sand aquifer (15 m thick) occurs below the peat, except near and to the north of the railway where it outcrops at the surface. Beneath the site, it is in hydraulic continuity with the lower peat. Further north it is in hydraulic continuity within the compositionally similar sands & gravel of the Kesgrave Formation, and together these units are potentially confined by the clay-rich Boulder Clay deposits.

- The semi-confined Upper Chalk aquifer which occurs at a depth of 20 - 25 mbgl. It is in hydraulic continuity with the overlying Crag aquifer.

3.3.3 Piezometry and Groundwater Movement

Chalk/Crag Aquifer System

The regional piezometry of the Chalk is shown in Figure 6. Groundwater movement is away from the groundwater divides, located both to the northeast and southwest of the floodplain, towards the valley axis of the River Yare. The hydraulic gradient to the northeast of the site is approximately 3×10^{-3}. The average water level measured at the Waste Disposal Site borehole (TG30/572, TG 3528 0724) is about 3.3 maOD; the rest water level recorded at the Anglian Water Services No 3 borehole was 5.05 mbgl (approximately -3 mOD) on 11/06/98; within the SSSI Chalk water levels are close to 0 mOD. The rest water level at the Anglian Water Services Strumpshaw No 1 borehole (TG 3414 0670) in 1951 prior to source development was recorded as -0.3 mOD, although the accuracy of this measurement is not known.

It is expected that abstractions by Anglian Water Services, from Strumpshaw, have resulted in a cone of depression in the vicinity of pumping boreholes. Under natural conditions, that is, prior to abstractions, chalk water levels were probably close to or above ground level within the floodplain of the River, and therefore artesian. Whether artesian conditions were experienced over all the area now designated as the SSSI is not known, although spring discharges probably occurred in the vicinity of woodland

carr areas (Ward's Carr and Farm Carr) which are located along the floodplain margins.

A comparison of chalk water levels with those in the Crag (deep piezometer) and overlying sands & gravels (shallow piezometer) can be seen from data from the RSPB borehole pumping-test in November 1986, as shown in Table 2. The RSPB borehole and Chalk OBH are the only chalk boreholes located within the SSSI. The rest water level data indicates that the vertical hydraulic gradient was downard suggesting flow from the sands & gravels to the Chalk via the Crag. A water level measurement of the RSPB borehole was not possible during the field visit of 15 - 16 June 1998, due to the absence of a dip tube.

Peat Aquifer/Aquitard

Water level data are available from a number of piezometers and boreholes, both shallow, up to 2.10 m, and deep, up to 5.93 m, constructed in 1986, located within the SSSI. Information regarding their locations and general construction, including datum elevations and water levels, is presented in tables in Appendix 3. In general, water levels in both sets of piezometers were between -0.2 maOD and 0.4 maOD. Piezometries drawn for different dates included in the report by Martin (1987) indicated that there was a shallow hydraulic gradient from the northwest of the SSSI (near Lackford Run) towards the centre of the marsh (southeast). Water levels in the shallow piezometers were generally higher than that in the deeper piezometers, suggesting a potential for downward leakage.

Water levels were again measured in March 1992, during 14-day testing of the Anglian Water Services Strumpshaw No 3 borehole. Over the period 2 - 16 March 1992, levels in both shallow and deep piezometers were between 0.34 maOD and 1.06 maOD. The data indicated that at some locations shallow piezometer water levels were higher than those in deep piezometers; at other locations, the reverse was the case.

3.3.4 Water Level Fluctuations

Long term water level fluctuations have only been recorded by the agency at a single Chalk observation borehole in the area, TG30/572, located at the Waste Disposal site about 1.5 km northeast of Strumpshaw Broad.

The hydrograph, presented in Figure 8, shows the period of record 1977 - 1997. Seasonal fluctuations appear to be small, between 0.2 and 0.3 m. Water levels were relatively constant between 1977 and 1987, in the range 3.0 - 3.5 maOD, although the data shows a gradual decline from 3.5 to 3.0 maOD between 1982 and 1987, probably in response to the increase in pumpage of the Strumpshaw source, followed by a recovery to 3.6 maOD in 1988. Between 1989 and 1992, coincident with the extended period of low rainfall, water levels fell quite sharply to a minimum of about 2.4 maOD in January 1992. They subsequently recovered by the end of 1994 to pre-1988 levels of 3.0 - 3.5 maOD; the data since 1994 has been somewhat erratic.

Water levels in the drift piezometers on the site were reported by Martin (1987) who presented hydrographs of all monitored piezometers for the period of observations between June 1986 and January 1987. Fluctuations were approximately 0.5 - 0.6 m in both deep and shallow boreholes. Depending on location minimum water levels were generally in the range -0.2 maOD and 0.85 maOD, and maximum water levels 0.45 to 1.6 maOD.

For comparison with site water levels, the highest level recorded in the River Yare for the period 1969 - 1971 was 1.39 maOD at Rockland Broad, about 1 km to the south. Flood water levels recorded in 1986 at Rockland Broad were about 1.13 maOD; and the highest water level in Lackford Run recorded in 1986 was 1.03 maOD.

3.3.5 Pumping Test Results and Hydraulic Parameters

Results of Tests

A yield test was undertaken on the Anglian Water Services Public Supply source at Strumpshaw (Boreholes No 1 and No 2) in 1971, although the nature of the test prevented detailed analysis. The two boreholes were constructed in 1951 and are 6.3 m apart, located at TG 3414 0680. Borehole No 1 was pumped at increasing rates of discharge of up to 85 l/s over a period of 10 days, whilst No 2 was maintained at a constant discharge of 19 l/s throughout. The drawdown recorded at 85 l/s was 26.4 m (No 1) from a rest water level of 5.72 mbdat, and the interference drawdown in No 2, 7.1 m, from an initial pumping water level of 10.7 mbdat. The resulting specific capacity of Borehole No 1 was about 3.2 l/s/m; that of No 2 is thought to be comparable. Stabilisation of water levels was observed after a few hours of pumping, probably indicative of leakage occurring from overlying strata.

The marsh support (RSPB) borehole, drilled in 1986 by Anglian Water Services, was pump-tested subsequent to construction. Pump-testing consisted of a step-test (4/11/86) comprising five incremental rates of discharge up to a maximum of 30 l/s followed by a 7-day constant rate test (6 - 14/11/86) at 29.8 l/s. During the testing, water levels were measured at a number of observation boreholes, shown in Table 2, some of which were drilled as part of the 1986 study to assess the effects of abstraction on the SSSI. The data shows a stabilisation of water levels in the pumped chalk borehole after about 4 hours of pumping, probably as a result of leakage from the overlying strata.

A longer duration test lasting approximately 4 months of intermittent pumping, was undertaken on the RSPB borehole between 15/7/1988 and 3/11/1988. Water levels were again measured at on site drift piezometers and the shallow and deep piezometer adjacent to the RSPB borehole. The data records appear to be incomplete and do not lend themselves to rigorous assessment and interpretation.

TABLE 2 RESULTS OF RSPB BOREHOLE PUMP TEST (6-14/11/1986)

Borehole	NGR (TG)	Datum (maOD)	Depth (m)	Distance from Tested BH (m)	Rest Water Level		Pumping Water Level		Drawdown (m)
					(mbdat)	(maOD)	(mbdat)	(m OD)	
RSPB Borehole	3361 0740	1.552	70		1.33	0.22	13.65	-12.10	12.32
Chalk OBH	3361 0732	0.829	50	14	0.48	0.35	4.60	-3.77	4.12
Deep Piezometer	3360 0730	0.974	18.5	5.35	0.53	0.44	0.56	-0.41	0.03
Shallow Piezometer	3360 0730	0.906	9	6.66	0.40	0.51	0.64	-0.27	0.24
Well No 11, Stone	3355 0648	-	-	330	4.15	-	4.35	-	0.20
Well No 4, Tacon	3358 0770	-	-	360	7.18	-	7.285	-	0.105

In 1992, the Anglian Water Services Public Supply Borehole No 3, located about 500 m to the northwest of the two pumping station boreholes and 400 m east of the RSPB borehole was pump-tested, shortly after its construction. Pump-testing comprised a step-test on 29/2/92 up to a maximum discharge rate of 107 l/s, followed by a 14-day constant rate test at a discharge of 85 l/s. Throughout the test, abstraction from Anglian Water Services Public Supply boreholes and the RSPB borehole were maintained at 40 - 48 l/s and 30 l/s, respectively. The water level changes observed are detailed in Table 3.

TABLE 3 AWS BOREHOLE No 3 PUMPING TEST RESULTS (2 - 16/03/1992)

Borehole	Location NGR (TG)	Borehole Depth (mbgl)	Distance from Test BH (m)	Pumping Water Level		Drawdown (m)
				(mbdat)	(m OD)	
Test Borehole (AWS BH3)	3397 0732	81		2.15	15.90	13.75
RSPB Borehole	3359 0730	70	380	5.01	6.08	1.07
Deep Piezometer	3360 0730	18.5	380	0.44	042	-0.02
Shallow Piezometer	3360 0730	9	370	0.38	0.77	0.39
Well 4 Common Close	3357 0769	7.9		7.41	7.73	0.32
Well 5 High Noon Farm	3405 0822	10.15	920	8.75	8.78	0.03
Well 6 High Noon Farm	3398 0821	8.45	920	7.98	8.08	0.10
Well 19 Robin Hill	3387 0752	4.2	225	2.49	2.54	0.05
Pond at Everglades	Not known	-	80	0.25	0.20	0.05
Lake at Rosebank	Not known	-	70	0.54	0.48	0.06

Note: The figures make allowance for natural fluctuations in level during the pumping test.

The drawdown observed in the RSPB borehole was 0.97m in less than 24 hours and 1.07m at the end of the test. In the adjacent shallow piezometer into sands & gravels the drawdown was 0.39 m. The deep piezometer in Crag was reported to be completed in a clay band and hence this may be the reason for the lack of water level response. Water level falls were also observed in the other drift boreholes (4, 5, 6, and 19) and in the surface water features.

Hydraulic Parameters

The hydraulic parameters of the Chalk have been determined from the various pumping tests undertaken on boreholes in the area. The values are shown in Table 4. Chalk transmissivity values derived from pumped well data or data from observation boreholes close to the pumped well vary, from about 200 - 260 m^2/d for the No 1 and RSPB boreholes, to much higher values of more than 600 m^2/d for Borehole No 3. Analysis of the drawdown data from the RSPB borehole which was used for observation during the AWS No 3 pumping test, indicated a much higher transmissivity (1,332 m^3/d) for this borehole compared to that from the analysis of pumped well data. It is possible that due to its distance (approximatly 400 m) from the tested well and leaky behaviour, this value may not be representative of the Chalk aquifer at this borehole site. Storativity values ranged from about 6.5×10^{-4} to 1.4×10^{-3}, indicating confined to semi-confined conditions. The tests indicate a leaky response to pumping. Leakage factors (L) of 130 m to approximatley 1,000 m, indicate moderate to high rates of downward leakage.

TABLE 4 SUMMARY OF AQUIFER PARAMETERS

Test	Method of Analysis	Pumped Borehole	Observation Borehole		
		T (m^2 /d)	T(m^2/d)	S	r/L
RSPB Constant Rate Test (11/1996)	Jacob	255	245	1.48×10^{-3}	-
	Theis Recovery	251	263	-	-
	Theis	-	244	1.38×10^{-3}	-
	Walton	-	228	1.45×10^{-3}	0.11
	Hantush	-	217	1.82×10^{-3}	0.12
AWS BH No.3 Constant Rate Test (3/1992)	Cooper-Jacob	634	-	-	-
	Walton		1,332	6.5×10^{-4}	0.4

Aquifer parameters of the Crag and the peat are less well known. However, the Crag is thought to comprise relatively permeable sands, interbedded with low permeability layers of clay and silt and reasonable storage. The hydraulic parameters of the peat are highly variable (10^2 to 10^{-5} m/d). Peat permeabilities quoted in the Agency's files from various authors are as follows:

	m/d
Highly humified blanket peat	5×10^{-5}
Slightly humified fen peat	4×10^{2}
Shagham peat	5×10^{-3} - 1
Brushwood peat	1
Sphagnum, cotton sedge and heather peat	9×10^{3} - 9×10^{2}

The ratio of horizontal to vertical permeability is also reported to up to about 7.

3.3.6 Springs and Seepages

Under present conditions there appear to be no springs or seepages occurring within the SSSI site. However, on the basis of piezometric elevations of the Chalk, it is probable that in the past under non-pumping conditions, groundwater could have naturally discharged to the SSSI. Whether this was by upward leakage or by lateral discharge from springs along the northeastern margins of the Fen and Common where the Crag aquifer and overlying Kesgrave sands are at outcrop or overlain by only a small thickness of superficial deposits, is not known.

3.3.7 Hydraulic Relationships

Between Hydrogeological Units

Beneath the site, the absence of London Clay maintains hydraulic continuity between the Chalk and the Crag, although this may not be the case further to the southeast. The Chalk/Crag aquifer system is, in turn, considered to be in hydraulic continuity with overlying Kesgrave sands & gravels where they are present. The natural hydraulic relationship between this larger aquifer system and the peat multi-layered aquifer /aquitard is a little uncertain. However, it is considered, on the basis of water level responses from piezometers on the site, and pumping test results, that the peat layers are hydraulically connected to the underlying aquifer system, albeit perhaps somewhat imperfectly. Thus, the lowering of water levels in the Chalk due to abstraction, probably induced downward leakage from the peat. Martin (1987) estimated that groundwater loss from the marshes to be approximately 27% of the total abstraction by Anglian Water from the Strumpshaw Chalk boreholes for June - September 1986. Although, the estimate is only approximate, it illustrates that there maybe a significant component of loss from the marshes to the underlying aquifer system.

Between Aquifers and Surface Water Features

The shallow peat aquifers are considered to be in hydraulic continuity with many of the surface water features within the site, including dykes, broads and other areas of standing water. In places, the degree of continuity may be limited, especially within some of the deeper broads which lie directly on clay strata and also in areas open to tidal inflows, where deposition of clays and silts may occur.

3.3.8 Conceptual Groundwater Model

The main aquifer is the Chalk which is semi-confined and in hydraulic continuity with the overlying Crag sands. The near surface multi-layered hydrogeological unit, which lies immediately beneath the site, comprises peat aquifers and a clay aquitard, which are considered to be in hydraulic continuity with the underlying Crag and indirectly with the Chalk. Relative piezometries of the peat, Crag and Chalk indicate that there is potential for downward movement of groundwater. Chalk/Crag groundwater converges into the Yare valley area. Under natural conditions in the historic past, groundwater may have discharged as seepages along the wetland margin.

3.4 WATER SUPPLY TO THE WETLAND

3.4.1 Inflows and Outflows

Surface water inflows comprise rainfall and flood waters from the adjacent River Yare. In historic times, the latter were probably the main source of water to the wetland. The building of embankments, drainage works and management practices have over the years modified river water inputs. Groundwater inputs comprise the artificial discharge from the Chalk marsh compensation borehole of up to a licence limit of 285,000 m^3/year, (licence no 7/34/15/202), though actual pumped quantities are much less, 185,000 m^3 in 1989, 1548 m^3 in 1994 and 143,085 m^3 in 1996. Pumping is normally from June to September. As far as can be ascertained there are no natural groundwater inflows in the form of seepages or springs. Outflows are via the drainage dyke systems into the River Yare, evaporation from the many open water surfaces and evapotranspiration. The last two components can be substantial.

3.4.2 Water Balance

Martin (1987) in her report on the impact of Anglian Water's proposal to increase abstraction from their Strumpshaw Chalk source from 745,000 m^3/year to 2,000,000 m^3/year, presented water budgets for the central Strumpshaw Fen part of the SSSI, which indicated that for most of the year the average rainfall was sufficient to meet the evapotranspiration demand. However, during May to August inclusive, the growing season of the reedbeds, evapotranspiration exceeded rainfall by 122 mm, on average. A detailed water balance using water level data from piezometers and published rainfall/ evapotranspiration data was outlined for the summer months (June-September 1986) as follows:

Inputs:		Outputs:	
Rainfall	178 mm	Evapotranspiration	318 mm
Change in Water Storage in the Peat	328 mm	Groundwater Leakage	188 mm (estimated)

The estimated groundwater leakage during the period over the SSSI (84 ha) was 152,000 m^3, representing 27 % of the total groundwater abstraction of 570,000 m^3. The figure of 27% was subsequently used to quantify the required compensation quantity, as a result of the proposed increase in abstraction. The water balance

equation used is fairly simple and probably not especially representative of the complex hydrological regime at Strumpshaw. However, it is considered sufficient for the purpose for which it was intended.

Water balance calculations have not been carried out for the site as a whole. Calculations would be complicated by the occurrence of flooding due to breaching of the embankment walls following surge tides, and surface water inflows only occurring to certain parts of the SSSI.

3.5 HYDROCHEMISTRY

3.5.1 Surface Waters

The poor quality of the water within the River Yare and Lackford Run in terms of high nutrient concentrations was the original reason for restoration of the embankments and isolation of parts of the site from them in the late 1970s and 1980s. Hydrochemical data for the River Yare sampled at Strumpshaw Common (TG 3410 0530) and for Lackford Run at Long Lane Bridge (TF 3370 0750) has been obtained for the period 1992 - 1998, and 1985 - 1998, respectively.

The data for the River Yare is presented in Table 5. Most of the parameters recorded show no discernible trends over the period 1992 - 1998, except perhaps for chloride and conductivity which show a slight increase: chloride from 60 - 70 mg/l to 70 - 80 mg/l; conductivity (field) from 800 - 900 to 900 - 950 (µS/cm at 25°C assumed). Phosphates are relatively constant between 500 and 1,000 µg/l P, ammonia variable between <0.3 and 1.3 mg/l N and TON 3.4 - 7.7 mg/l N.

A study undertaken by the Agency on the River Yare in connection with EC Urban Waste Water Treatment and Nitrate Directives (1997) reported that the mean annual average phosphorus concentrations at Buckenham Ferry (TG 350 044, R04BFYAR230) were well over the criteria of 100 µg/l. Samples are taken monthly; the lowest annual average between 1991 and 1996 was 500 µg/l in 1994, falling from 1320 µg/l (1991) over the preceding years and rising to 860 µg/l in 1996. The report concluded that phosphorus control at the Whitlingham Sewage Treatment Works is required if there is to be any improvement in the eutrophic status of the river.

A sample of River Yare water was also taken as part of this study, and submitted for full chemical analysis. The results are shown in Table 9 and presented on a Durov diagram, Figure 11. The conductivity was 722 µS/cm, phosphorus 620 µg/l P, ammonia 0.177 mg/l N, TON 5.95 mg/l N, and chloride 61/mg/l.

The Environment Agency, (and their predecessor, the National Rivers Authority) have carried out water quality monitoring of main paramenters twice weekly since 1989 at Strumpshaw Broad and since 1985 at Lackford Run. Table 6 summarises the concentration of three parameters of significance, chloride, phosphorus and ammonia. The table also shows a summary of the quality data of the effluent at the Anglian Strumpshaw Sewage Treatment Works, which was closed in 1997.

At Strumpshaw Broad, chloride concentrations vary from about 100mg/l to 700mg/l, but highest values can reach 1,500 - 2,300mg/l, as occurred in June 1989 and March - July 1993. In general, chlorides are low in the winter and higher in the summer. Phosphorus concentrations range from 0.1 to 1.3 mg/l P and ammonia between 0.03 to a maximum of 0.7 mg/l N.

TABLE 5 WATER QUALITY RESULTS FOR THE RIVER YARE (1992 - 1998) – SAMPLE POINT CODE R04BFYAR227

Parameter/Date	23/7/92	20/4/93	17/8/93	04/5/94	14/9/94	04/5/95	27/9/95
pH	8.01	8.20	8.35	8.30	7.90	8.70	7.90
Turbidity	15.3	5.61	>19.0	8.9	4.1	7.3	6.8
EC (µS/cm at 25°C)	798	890	837	810	830	840	870
Bod + Atu T (mg/l)	2.62	2.1	2.6	<6	1.3	4.2	<1
Ammonia (mg/l N)	<0.023	<0.023	0.031	<0.05	1.3	<0.03	0.08
TON (mg/l N)	3.56	7.68	4.46	7.1	0.12	6.6	5.9
Chloride (mg/l Cl)	64.7	67.6	66.2	57	62	67	69
Soluble Phosphate (mg/l P)	0.979	0.552	0.859	0.18	0.71	0.51	1
E Coli (No/100 ml)	7500	82	455	160	3900	-	-
Conductivity Field	800	860	777	808	912	846	864
Salinity (g/l)	<1.0	0.122	0.12	0.103	0.11	0.121	0.124
pH Field	7.7					8.63	7.74
DO Field (%)	69	115	100	135	74.4	196	67

TABLE 5 WATER QUALITY RESULTS (continued)

Parameter/Date	12/4/96	02/9/96	16/4/97	11/9/97	03/4/98	Minimum	Maximum
pH	8.20	7.88	8.19	8.04	8.18	7.88	8.70
Turbidity	5	11.8	4.8	7	8.4	4.1	>19.0
EC (µS/cm at 25°C)	910	710	930	960	910	710	960
Bod + Atu T (mg/l)	3.8	1.4	1.9	1.2	1.9	<1	4.2
Ammonia (mg/l N)	0.08	0.14	0.03	0.03	0.04	<0.03	1.3
TON (mg/l N)	6.8	3.4	6	4.1	7.1	0.12	7.68
Chloride (mg/l Cl)	84	61	80	94	76	57	94
Soluble Phosphate (mg/l P)	0.62	0.71	0.49	1	0.49	0.18	1
E Coli (No/100 ml)	330	1800	150	370	-	82	7500
Conductivity Field	924	700	922	964	900	700	964
Salinity (g/l)	0.151	0.11	0.145	0.17	0.137	0.10	0.17
pH Field	8.13	7.52	8.02	7.66	7.94	7.52	8.63
DO Field (%)	125	50.4	90.1	81.3	96.6	50.4	196

At Lackford Run, chloride concentrations in 1985 - 1988 were 50 - 80 mg/l, increasing to 70 - 170 mg/l in 1989 - 1990 and again decreasing to 60 - 90 mg/l in 1997, probably coincident with the closure of the sewage works in 1997. Phosphorus ranged from 1 - 7 mg/l P and ammonia from 0.2 to 6.2 mg/l N.

At Strumpshaw Sewage Treatment Works chloride concentrations varied from 80 - 400 mg/l, phosphorus from 6 - 19 mg/l P and ammonia from 0.5 to 6.0 mg/l N.

TABLE 6 SUMMARY OF WATER QUALITY AT STUMPSHAW BROAD, LACKFORD RUN AND STRUMPSHAW STW

Sample Location	NGR (TG)	Period	Chloride (mg/l Cl)	Phosphorus (mg/l P)	Ammonia (mg/l N)
Strumpshaw Broad	3380 0680	1989 – 1996	100 – 700 (2,330 max)	0.1 - 1.3	<0.03 – 0.7 (0.03 – 0.1)
Lackford Run	3370 0750	1985 – 1988	50 – 80	1 - 7	0.2 – 1.9
		1989 – 1996	70 – 170	(1985 - 97)	0.2 – 6.2
		1997	60 – 90		<0.03 - 0.7
Strumpshaw STW, Final Sediment Tank	3400 0780	1985 – 1988	80 – 200		0.5 – 6.0
		1989	110 – 180	6 - 19	4 – 13
		1993	160 – 270	(1985 - 96)	0.8 – 3.0
		1996	140 – 400		2 - 20

3.5.2 Groundwaters

Anglian Water Services Boreholes

Hydrochemical data (chloride and total hardness) has been provided by Anglian Water Services for raw waters from the three Strumpshaw boreholes for the period 1992 - 1998, in addition to longer-term plots (1987 - 1997) of chloride and ammonia. The plots are presented in Figure 9, as are additional plots of chloride and total hardness for the period 1992 - 1998 in Figure 10. Minimum and maximum values (1992 - 1996) for the parameters recorded are shown in Table 7. The overall picture is one of a steady deterioration of water quality within Boreholes No 1 and No 2, compared to a relatively stable water quality within Borehole No 3.

The most dramatic rise has been observed for chloride concentrations, which have shown an increase from 70 - 80 mg/l in 1986 to 1987, to 220 mg/l in 1997, and two values in excess of 350 mg/l in 1998. Total hardness has shown a steady increase from already high values of about 400 mg/l $CaCO_3$ in 1992 to 450 mg/l in 1995, to approximately 540 mg/l in 1998. Ammonia concentrations have risen from approximately 0.03 mg/l N in 1990 to over 0.15 mg/l N in 1995. Other parameters, such as sodium, calcium and manganese, have also shown a steady increase. By comparison, Borehole No 3 has lower concentrations for most parameters and since 1992 when the borehole was first utilised concentrations have remained relatively constant. Common to all boreholes are the high iron concentrations.

Although the chloride concentrations of Borehole No 1 and No 2 are below the PCV of 400 mg/l Cl, Borehole No 3 is now used in preference to No 1/No 2 due to its lower total hardness and chloride concentrations. The rise in concentrations is being monitored by Anglian Water Services and is providing some cause for concern in terms of future utilisation of the No 1/No 2 Boreholes.

TABLE 7 SUMMARY OF HYDROCHEMISTRY FOR AWS BOREHOLES (1992-1998)

Parameter	Units	Borehole No 1		Borehole No 2		Borehole No 3		RSPB Borehole
		Min	Max	Min	Max	Min	Max	(13/03/92)
Alkalinity	mg/l $CaCO_3$	262	321	280	312	219	286	263
Aluminium	mg/l Al	0.02	6	-	-	0.01	0.03	-
Ammonia	mg/l NH_4	0.06	0.19	0.09	0.29	0.03	0.25	0.09
Barium	µg/l Ba	110	123	-	-	0.06	70	-
Boron	mg/l B	0.02	50	-	-	0.01	50	-
Cadmium	µg/l Cd	0.1	0.4	-	-	0.1	0.4	-
Calcium	mg/l Ca	3	173	162	162	114	131	99*
Chloride	mg/l Cl	82	229	164	396	35	51	122
Chromium	µg/l Cr	1	1.1	-	-	0	1.1	-
Conductivity	µs/cm @ 25°C	894	1277	-	-	50	702	907
Copper	mg/l Cu	0.01	0.1	-	-	0.01	0.1	-
Fluoride	mg/l F	0.28	0.38	0.34	0.34	0.26	0.35	-
Total Hardness	mg/l $CaCO_3$	357	538	425	610	310	344	308
Iron	mg/l Fe	0.07	6.49	0.52	2.46	0.45	1.57	0.97
Lead	µg/l Pb	1.01	2.9	-	-	1	9.5	-
Magnesium	mg/l Mg	9.9	12.0	12.2	12.2	6.4	8.3	19*
Manganese	µg/l Mn	0.1	113	0.1	99.1	0.1	67.5	0.03
Nitrate	mg/l NO_3	<0.1	1	<0.1	0.7	<0.1	0.7	<0.1
Nitrite	mg/l N	<0.003	0.10	<0.003	0.55	<0.003	0.01	<0.1
pH	pH Units	6.7	7.7	7.0	7.4	7.0	7.3	7.3
Potassium	mg/l K	2.1	3.6	3.3	3.3	1.6	2.1	3.6
Sodium	mg/l Na	52.8	88.5	96.0	96.0	18.6	29.4	86.5
Sulphate	mg/l SO_4	57	85	65	65	37	57	51
TDS 105°C	mg/l	625	762	-	-	317	451	-
TOC	mg/l C	1.1	3.7	1.6	1.9	0.7	1.7	-
TON	mg/l NO_3	0.1	1	0.1	0.347	0.1	0.52	-
Turbidity	FTU	0.8	19.6	0.5	30	3.0	15	-
Zinc	mg/l Zn	0.04	0.05	-	-	0.002	0.05	-

Note: *1988 value

RSPB Borehole

Some hydrochemical data has been obtained for the RSPB borehole for the period 1986 – 1992. Most of the data is from periods of pump-testing of the borehole itself or of other boreholes. A fairly representative analysis taken on 13/03/92 is shown in Table 7. The water quality is less good in terms of hardness and chloride (308 mg/l $CaCO_3$) and chloride (122 mg/l Cl) than Borehole No 3, but better than No 1/No 2. The chloride concentration measured during the recent field investigation after a short time of pumping was 193 mg/l. The difference in water quality between the borehole and surface waters has been noted by the RSPB, particularly with regard to high chloride concentrations. In addition, a bacterium harmful to fish, called *Primnesium*, has been observed, and monitored by Anglian Water Services. Although the borehole is utilised especially in summer months, these water quality considerations have placed some constraints on its use.

Strumpshaw Waste Disposal Site

The waste disposal site is presently managed by Norfolk County Council / WRA and currently used as a civic amenity tip. Historically it has been used since 1947 for disposal of various types of waste including: cesspool liquid, dry non-notifiable waste, and Grade 2 radioactive waste. Hydrochemical data from the various Chalk boreholes located around the waste disposal site for the period 1988 - 1994 are presented in Table 8. The data shows a large variation in the range of chloride values, from 30 - 40 mg/l, in one borehole No 3, to as high as 100 - 870 mg/l, in another, No 8. Moreover, there appears to be no clear spatial distribution of higher chloride values, for example, indicating higher concentrations on one side of the site.

TABLE 8 SUMMARY OF HYDROCHEMISTRY OF SELECTED PARAMETERS AT THE STRUMPSHAW WASTE DISPOSAL SITE

Sample Location	NGR (TG)	Period	Chloride (mg/l Cl)	Fe Total (mg/l Fe)	Ammonia (mg/l N)
Centre BH		1989 – 1994	30 – 35	-	-
No 1		1989 – 1990	230 – 370	-	-
No 2	3503 0707	1988 – 1994	50 – 490	7 – 70	<0.05 – 0.2
No 3	3503 0701	1988 – 1994	30 – 40	0.2 – 1.0	<0.02 – 0.1
No 4	3533 0708	1988 – 1994	50 – 270	0.8 – 21	<0.02 – 0.3
No 5A	3523 0705	1989 – 1991	80 – 380	0.8 – 11	<0.05 – 0.4
No 6	3527 0732	1989 – 1994	100 – 310	0.4 – 21	0.1
No 8		1990 – 1994	100 – 870	-	-
No 9	3524 0728	1990 – 1994	30 – 330	0.9 – 2.1	<0.04

3.5.3 Field Investigation

A detailed field survey of the water quality of the SSSI site was undertaken on 15 and 16 June 1998. The survey involved measurement of the physicochemical parameters, pH, temperature and electrical conductivity (EC). In addition, samples were taken and

submitted for analysis at the AWS Whitlingham Laboratory: four underwent a full chemical analysis of major ions; a further six were analysed only for chloride.

Physicochemical Results

Selective physicochemical measurements were undertaken at the site; only a few were carried out to the south of the sandy wall embankment. In addition, access to the central area of Strumpshaw Fen was not possible due to the presence of marsh harrier nests. The results of the investigation are presented in tabular form and on a map in Appendix 4.

The results are summarised in Table 9 below. The Table shows that within each of the three areas of the SSSI, there is a considerable range in the hydrochemistry of surface waters. Surface waters in the area to the north of Lackford Run are most similar to river waters. The waters within dykes in the grazing marsh area appear to have the highest ECs of those sampled.

TABLE 9 SUMMARY OF ELECTRICAL CONDUCTIVITY AND pH VALUES

Area/Location	Electrical Conductivity (µS/cm)	pH
Surface waters to the west of Lackford Run	639 – 800	7.39 - 9.07
Surface waters east of Lackford Run and west of sandy wall	830 - 1041	7.16 - 8.97
Grazing marsh area to the east of sandy wall	1223 - 2160	7.50 - 7.84
River Yare (mean)	805	8.02
Lackford Run (mean)	728	7.65
Piezometers 4A, 4B	511, 698	6.31, 7.26
6A, 6B	2030, 781	6.97, 7.04
Marsh Support Borehole (RSPB)	1235	7.47
AWS Borehole No 3	802	7.38

Physicochemical measurements for piezometers and the RSPB and AWS No 3 boreholes are also shown. Piezometers generally appear to have more acidic waters than surface waters; the RSPB borehole has a higher EC than those of surface waters within the central marsh area to which the borehole is providing compensation discharge. The Chalk boreholes have alkaline waters (pH 7.4 - 7.5) compared with the waters of the shallow piezometers.

Water Quality Analyses

The results of water quality analyses carried out during the study are presented in Table 10 and the chemical analysis certificates in Appendix 4. The Durov diagram, Figure 11 shows plots of there analyses and of selected historical analyses. Waters vary from being of calcium bicarbonate type (Borehole No 3) to being richer in

sodium or with no dominant anion or cation (SSSI waters and RSPB Borehole). The River Yare water is seen to be more similar to the water in Borehole No 3, but compared to SSSI surface waters it has lower concentrations of chloride, sodium, magnesium, and manganese. The nitrate concentration of the River Yare (5.87 mg/l N) is much higher than that in any of the surface waters sampled in the SSSI (<0.5 mg/l N), although the phosphorus concentration of the River is comparable.

Chloride concentrations measured during this study (shown in Tables 10 and 11) vary considerably for both surface waters and groundwaters. For surface waters, chloride concentrations range from 61 mg/l (River Yare) and 71 mg/l (scrape area to the north of Lackford Run) to as high as 154.0 mg/l. Groundwaters also vary, with 55.8 mg/l recorded in the AWS No 3 borehole and 193.0 mg/l recorded in the RSPB borehole located along 400 m to the west. The chloride concentration in piezometer 4A, which has a depth of about 5 m, was the lowest recorded, 48.1 mg/l.

TABLE 10 HYDROCHEMICAL PARAMETERS OF THE SAMPLED WATERS (16/06/98)

Parameter / Sample Location	Hidden Broad	Old Broad Dyke (South End)	River Yare	South End of Dyke between 6 & 8
NGR (TG)	3384 0681	3353 0623	3352 0618	3333 0646
Alkalinity (mg/l $CaCO_3$)	206.0	215.0	234.0	272.0
Total Hardness (mg/l $CaCO_3$)	248	255	305	245
Chloride (mg/l Cl)	124.0	129.0	60.7	154.0
Sulphate (mg/l SO_4)	38	37	68	15
Sodium (mg/l Na)	84.2	84.4	39.1	116.0
Potassium (mg/l K)	2.6	12.9	1.1	17.3
Magnesium (mg/l Mg)	11.0	10.3	6.7	19.2
Calcium (mg/l Ca)	84.9	82.1	132.0	102.0
Ammonia (mg/l N)	<0.03	<0.030	0.177	<0.030
Nitrate (mg/l N)	<0.5	<0.5	5.87	<0.5
Nitrite (mg/l N)	<0.04	<0.04	0.082	<0.04
TON (mg/l N)	<0.40	<0.40	5.95	<0.40
Total Manganese (mg/l Mn)	0.072	0.073	0.037	1.050
Filtered Manganese (mg/l Mn)	0.061	0.066	0.034	0.981
Total Iron (mg/l Fe)	0.094	0.112	0.238	0.651
Filtered Iron (mg/l Fe)	<0.01	0.02	0.02	0.09
Phosphorus (mg/l P)	0.19	0.40	0.62	1.04
EC µS/cm @ 25°C (lab)	810	806	722	935
pH (Lab)	7.83	8.02	7.83	7.41
Turbidity (FTU)	1.90	2.20	1.20	3.70

TABLE 11 CHLORIDE CONCENTRATIONS OF THE SAMPLED WATERS (16/06/98)

Sample Location	NGR (TG)	Chloride Concentration (mg/l Cl)
AWS Strumpshaw Borehole No 3	3397 0732	55.8
North End of Canal Dyke near Dr Martin George's	3384 0697	128.0
Old Broad	3396 0662	127.0
Piezometer 4A	3379 0705	48.1
Marsh Support (RSPB) Borehole	3359 0730	193.0
North End of Hide Scrape Area	3312 0701	71.3

3.5.4 Hydrochemical Interpretation

The main water inflow to the parts of the site to the north of sandy wall is from flooding of the River Yare during surge tides. As a result, in these parts the hydrochemistry is heavily influenced by the water quality of the River. Isolation of the system from water inflows subsequent to flooding, except for rainfall, leads to a general increase in salinity as water is lost by open water evaporation and by evapotranspiration. Inflows are also provided by discharge from the RSPB compensation borehole, which also has relatively high chloride, into the central part of the SSSI, and possibly from a minor surface watercourse entering the northernmost part of the SSSI. The occurrence of the minor inflows has not been established.

The part of the SSSI south of sandy wall is isolated from the River Yare and from flooding, and relies upon surface water inflows, which drain the uplands, and upon rainfall. During the June 1998 survey this area had electrical conductivities in dykes which are higher than those in other parts of the SSSI.

The origin of the higher concentrations, of chloride especially, in the groundwaters is subject to discussion. Hiscock et al. (1988) reported on the basis of tritium and Carbon-14 measurements, that the groundwaters from Boreholes No 1/No 2 were of mixed origin, comprising both modern and old water. The ratio of modern to old water was estimated to be 1.4:1, and the age of the older water, 2300 ± 600 years. The older more saline water was thought to be derived from beneath the Yare valley where Eocene deposits confine the Chalk. The overlying Eocene deposits there, which include London Clay, prevent recharge to the aquifer system and thus dilution of the saline water. Suggestions have also been made that the Chalk water quality might also be affected by leachate from the waste disposal site (1.5 km) to the northeast, which is up hydraulic gradient from the source. The hydrochemistry of the Chalk groundwaters from the waste disposal site (Table 8) indicates high chlorides. Therefore the possibility that landfill leachate may be contributing to the increased chloride concentrations at the Anglian Water Boreholes 1 & 2 and the RSPB borehole cannot be ruled out, although the fact that there has been no increase in chlorides at the nearby AWS No 3 borehole is difficult to account for. A third explanation is that of downward leakage of chloride rich marsh and sub-surface waters into the Chalk aquifer via the Crag. The hydraulic evidence from differential piezometries and pumping tests strongly indicate downward leakage, whilst observed increases in

ammonia, are consistent with relatively high concentrations of ammonia in the surface waters and near surface groundwaters. Boreholes 1 and 2 and RSPB borehole are located at the edge of the marshland, and therefore most likely to induce downward movement of marsh waters, especially as their transmissivity appears to be low. Borehole No 3, which is situated in the upland area at some distance from the marshland and has a higher transmissivity than the other three boreholes, probably derives most of its water from the Chalk aquifer, with relatively small amouts from peat groundwater and marsh waters. As a result, its chloride and ammonia concentrations are low.

In conclusion, it could be suggested that the isolation of the fen from the River Yare in the 1970s has led to increases in the salinity of the surface waters and shallow groundwaters of the fen. Downward leakage of these waters induced by pumping of the Anglian Water boreholes has probably resulted in the observed progressive increase in chlorides (and other constituents) of the Chalk groundwaters close to the fen. If the proposed hypothesis is valid, free access of the Fen to the River Yare may in the future assist in reducing the salinity of the fen waters and in turn of the Chalk groundwaters.

4. ABSTRACTIONS AND THEIR IMPACT ON THE WETLAND

4.1 WATER ABSTRACTIONS

4.1.1 Licensed Abstractions

Within 5 km from the SSSI (TG 330 063) there are 41 licensed abstractions, comprising;

Surface Water:	10 nr
Groundwater:	24 nr
Mixed:	7 nr

Figure 12 shows the location of all licensed abstractions within 3 km of the site and Appendix 5 a listing of all licensed sources within a radius of 5 km. Within 3 km from the site (TG 330 063) abstractions are as follows:

Surface Water

0 - 1 km : 1nr; from dykes joining the River Yare from the south, for spray irrigation licensed at 27,300 m^3/year (licence No 7/34/15/ 180 part licence).

1 - 2 km : 2nr; one from the River Yare at Strumpshaw Common for spray irrigation licensed at 55,000 m^3/year (licence No 7/34/15/197). A second, part licence 7/34/15/147 for spray irrigation.

2 - 3 km : 5nr; one part licence 7/34/15/147 for spray irrigation. Licensed at 54,500 m^3/ year; a second, part licence 7/34/15/180 from a

reservoir at Surlingham, licenced for spray irrigation at 18,300 m^3/year; the third (licence No 7/34/15/122) for spray irrigation from the River Yare at 18,300 m^3/year; the fourth (licence No 7/34/15/173) from a dyke joining the River Yare, for spray irrigation licensed at 136,300 m^3/year (part licence); the fifth from Lackford Run, part licence No 7/34/15/88 for spray irrigation licensed at 97,700 m^3/year.

Groundwater

0 - 1 km : 2nr; small abstractions : 1 from the Chalk at 100 m^3/year, 900 m northwest from TG 330 063, and a second from drift at 4,900m^3/year, 800 m southwest.

1 - 2 km : 5nr; the largest is by Anglian Water Services for public supply from the Chalk part of linked licence No 7/34/15/177, licensed 2,000,000 m^3/year (7,500 m^3/d) from three boreholes, 2 (BH1/2) at 100 m northwest of the northern boundary of Strumpshaw Fen, and 1 (BH3) at 500 m northwest of BH1/2.

Licence No 7/34/15/702 is for amenity and is held by RSPB; it comprises a Chalk borehole (RSPB or compensation borehole) licensed at 285,000 m^3/year (2,000 m^3/d) to provide compensation water to Strumpshaw Fen the borehole is situated within the northern part of the Fen; adjacent to Lackford Run. The other three licensed abstractions are very small from Chalk/drift and are situated south of the River Yare.

2 - 3 km : There are seven very small borehole abstractions, all except for one from the Chalk, and 5 situated south of the River Yare.

4.1.2 Actual Abstraction (Groundwater)

Non-public Supply

0 - 1 km: Negligible

1 - 2 km: Licensed: 285,000 m^3/year
Abstracted: 143,000 m^3/year, 1996 (50% of licence)

2 - 3 km: Negligible

"Abstracted" qualities are based on returns received by the Environment Agency and might not be entirely representative of all abstracted water. Nevertheless, it appears that non-public supply abstraction in 1996 close to the site was less than the licensed amount.

Public Supply

Figure 13 shows annual and monthly abstractions by Anglian Water from their Strumpshaw source. During 1973 - 1980, abstractions were on average 805,000 m^3/year, and between 1981 and 1996 remained more or less the same, at an average of 1,400,000 m^3/year. In the last 5 years (1992 - 1996) abstractions were on average 1,452,800 m^3/year or approximately 73% of the licensed quantity of 2,000,000 m^3/year. In the last three years or so, abstraction from boreholes 1 & 2 which are very close to the northern boundary of the wetland have been very small, (due to recent increases in hardness) and borehole No 3, situated in the upland, 200 m form the boundary is being used instead.

4.2 IMPACT OF ABSTRACTIONS

Surface water abstractions are not considered to have any impact on the wetland. However, the construction of embankments adjacent to the Yare and Lackford Run, and the sandy wall embankment have reduced the surface water component to the site, particularly in the two parts of the wetland to the west of sandy wall, which now rely on rainfall. In addition there are surface water inflows when the River Yare overtops its banks during surge tides, usually in December - January, which are augmented by flows via the sluice on the River Yare.

Any historic groundwater contributions to the site, either by lateral flow along the upland margin or from upward leakage from the Chalk, have decreased or ceased as a result of abstraction from the Anglian Water Public Supply at Strumpshaw.

Though there is little doubt that groundwater abstraction has lowered water levels in the Chalk, the natural hydraulic relationship of this aquifer with the near surface peat and marsh waters remains uncertain, especially in the light of historic natural changes in the fen topography and modifications of the surface water regime in the last two centuries, and more recently in 1978-1980, and in 1987. It is possible that groundwater contributions in the historic past have been small and that the wetland was primarily sustained by surface water incursions during flooding, and that the sealing off of part of the site by the RSPB in 1978-1980, and another part in 1987, deprived the wetland of its main source of water supply. The impact of the Anglian Water abstractions, by comparison, has been probably minor. The ecological assessment, (section 2.3.1 of this report) indicates that there is no reason to suppose that any of the vegetation on the site, or that which used to occur, requires groundwater input. It is recognised, however, that groundwater inflows could have had a diluting effect on the eutrophic river water but the degree of dilution provided is uncertain, though judged to have been minor. It seems more likely that ecological changes have been the result of natural water deficits and reductions of river inflows as part of water management strategy rather than groundwater abstraction. Hence, a restoration of groundwater input may not assist in meeting the conservation objectives, as long as river water quality remains eutrophic and the present water management continues. In the last 3 years or so Anglian Water have been mainly using borehole No3, which probably has a reduced the impact on the wetland in comparison with boreholes 1 and 2. The net result is probably that downward leakage is likely to be less.

4.3 AMP3 WATER ABSTRACTION CATEGORY

Following a process of consultation between English Nature and the Environment Agency, the site has been assigned an AMP3 Abstraction Category 1, meaning that there are evident problems as a result of water company abstraction which would require costings for the revision of the abstraction licence.

The present evaluation has found no evidence of ecological damage that is definitely attributable to company groundwater abstractions. The ecological evidence suggests that in addition to natural causes, management changes and eutrophic river water are most probably the main causes for the degradation of vegetation. Hydrogeological considerations indicate that a proportion of the water company abstraction is derived from fen surface waters and groundwaters. The amount has probably decreased since the operation of borehole No 3 in the last 3 years. The fen is, however, primarily surface water fed, and under natural conditions of open access to the River Yare, induced water into the Chalk aquifer would have been replenished by river water, which would have also probably ensured reasonably low chloride waters. As there are no evident problems attributable to water company abstraction, AMP3 Category 1, but also Category 2, are inappropriate. In view of the existing uncertainties, an AMP3 Category 3 may be the most appropriate. Under this category further investigations will need to be undertaken in order to determine whether groundwater abstraction has a significant impact on the wetland conservation objectives.

5. MONITORING

5.1 ECOLOGICAL MONITORING

5.1.1 Existing monitoring

RSPB monitor the main key species of birds (bittern, marsh harrier and bearded tit), marsh pea and swallowtail butterfly.

5.1.2 Proposed monitoring

It is considered that additional invertebrate monitoring could be valuable at this site, but if undertaken should be concentrated either on particular methods or particular groups. The latter may be the most cost-effective option. Water beetles are an obvious candidate for monitoring, but baseline survey to establish the extent of the interest of this group is needed before this can be decided. Snail-killing flies are another obvious candidate group, which might perhaps be monitored by a combination of active sampling and water traps (or by either method alone); other families of Diptera could be added, and water traps might also catch spiders in sufficient quantity for monitoring; pitfall traps could also be used, but might be superfluous. The large and varied character of the site, however, mean that any fixed monitoring points, areas or transects would need to be very carefully chosen.

5.2 HYDROGEOLOGICAL MONITORING

5.2.1 Existing Monitoring

Surface water: At present, a staff gauge is installed on Strumpshaw Broad and the water level recorded weekly.

Groundwater: Within the site; there is no existing monitoring being undertaken. During 1986, eight shallow (2 - 3 m) and eight deep (5 m) piezometers were installed in the wetland and, as part of the borehole compensation Chalk borehole scheme (M Martin, 1987). During the field investigation only some of the piezometers were located. In addition, close to the RSPB borehole there should be three observation boreholes: one in the Chalk OBH, a second in the Crag, and a third in shallow gravels.

Outside the site; There is a Chalk observation borehole located about 1.5 km to the northeast of the site (TG 3528 0724), which has been monitored by the Agency since 1977.

PROPOSED MONITORING

Surface water: Staff gauges should be installed in the drains/dykes within the three management parts of the site. It is recommended that, including the Strumpshaw Broad gaugeboard, there should be two within each of the compartments (assume 6 no).

Groundwater: If insufficient numbers exist, piezometers should be installed in clusters in the following approximate numbers at locations within the site, to be decided at a later date.

Organic Clay	:	10 no (1 - 2 m deep)
Peat	:	10 no (2 - 6 m deep)
Crag	:	10 no (3 - 12 m deep)
Chalk	:	1 no (35 m deep) adjacent to one of the clusters

The clusters should be situated at easily accessible locations and should include all parts of the site, including Strumpshaw Common, to the east of sandy wall. In addition, 3 more Chalk boreholes (35 - 50 m deep) should be installed at the following approximate locations:

- 1 no halfway between the fen and the waste disposal site
- 1 no approximately 500 SE of the Anglian Water 2 PS boreholes
- 1 no approximately 800 SW of the Anglian Water 2 PS boreholes, close to the River Yare.

6. PROPOSED ACTIONS

6.1 MONITORING AND MONITORING INSTALLATIONS

As proposed in paragraphs 6.1.2 and 6.2.2.

6.2 INVESTIGATION

6.2.1 Ecology

The vegetation was surveyed as part of the Broadland Fen Resource Survey (Parmenter, 1995). Baseline ecological survey information is considered adequate for present purposes, however, a water beetle survey would be of value, not only to establish the interest of this site, but also because this group would provide a potentially valuable one for monitoring purposes.

It would also be of value for Common Bird Census (CBC) and Wetland Bird Survey (WeBS) counts to be made at the site to establish a baseline against which future changes can be monitored. Territory/nest-mapping of all wetland species could also be attempted, to enable future correlation of population changes with changing surface water patterns (depths/quality/geographical .extent of surface waters) and habitat management activities throughout the site.

6.2.2 Hydrogeology

The following are proposed:

a) Monitoring of the water quality of Lackford Run should be continued and a study should be made in order to assess whether it might be of a suitable quality for use in the short term for maintaining water levels in Strumpshaw Fen. In addition, monitoring of the River Yare and Strumpshaw Broad should continue.

b) More comprehensive chemical analysis and monitoring of the RSPB compensation borehole to assess whether it remains of suitable quality for its present usage.

c) Installation of piezometers as proposed in 5.2.2 above including groundwater sampling and chemical analysis.

d) A controlled long duration pumping test for approximately 90 days over the summer/Autumn period using AWS No 3. The proposed and existing boreholes (both AWS No 1/2 and compensation borehole) should be used for the monitoring of water levels and hydrochemistry. If possible, prior to the test, the 3 AWS PS boreholes should be shut down for a minimum of 10 days, in order to establish near non-pumping conditions. All data should be analysed and reported on with the objective of establishing as accurately as possible the leakage rates and thus the impact of abstractions on groundwater levels and the wetland.

6.3 ALLEVIATION MEASURES

It is considered important that the issues surrounding the poor water quality of the River Yare in relation to nutrients and phosphorus in particualr, are addressed under AMP3 water quality so that re-instatement of a more natural floodplain system, with re-connection of the dykes to the river may become possible. Added benefits would probably be less salinity of the fen waters and groundwaters, and in the long term an improvement in Chalk groundwater quality.

6.4 SITE MANAGEMENT

There is an on-going requirement for vegetation management to prevent/control scrub invasion and for hydroglogical controls to facilitage manipulations of water levels across the site.

7. HABITATS DIRECTIVE INITIAL ASSESSMENT

The Conservation Objectives for the site, given in section 2.2 of this report, give details of the qualifying features for which the site has been given international designation, and include the following 'interest groups' (as defined in Annex 1, by EC Directive, Review of Consents Stage 2: Guidance Note for Abstraction Licences, Environment Agency, May 1998, DRAFT).

1. SAC habitat interest groups:

1.1 Fens and wet habitats (not vulnerable to acidification)

1.5 Standing waters (not vulnerable to acidification)

2. SPA bird species

3.6 Birds of lowland freshwaters and their margins.

All of the features listed above can be considered as 'vulnerable' to changes in water regime. However, there are insufficient records available to allow a specific assessment of changes in the relevant plant, bird and invertebrate populations over the last 5 years which could be attributed to inadequate groundwater supply to the site, caused by company or non-company abstraction.

Because present information is on balance insufficient to make a definite judgement as to whether the site is in a "favourable" or in an "unfavourable" condition as defined by the EC directive, a precautionary approach is advised which requires that abstraction consents should be initially assessed as likely to have a significant impact.

The monitoring and investigations as recommended in sections 5 and 6 of this report combined with existing knowledge should be adequate to fulfil the needs of the Review of Consents under the Requirements of the Habitats Directive. However, additional ecological monitoring will be required if it is necessary to show that each of the interest features are maintained in favourable condition.

It must be emphasised that, as well as addressing the potential impacts of water abstraction on the groundwater supply to the site, it is important that the issues surrounding the water quality of the River Yare are addressed, which appear to be, indirectly, the reason for the recent RSPB management strategy with its attendant problems on the water supply to the Fen.

8. REFERENCES

ANGLIAN WATER AUTHORITY, 1988, The Reliable Yield of the Strumpshaw PWS Source. Internal Report .

BATTEN, L. A., BIBBY, C. J., CLEMENT, P., ELLIOTT, G. D. & PORTER, R. F. (1990), Red Data Birds in Britain, T. & A. D. Poyser, London.

ELLIS, E. A. (1965), The Broads, Collins, London.

ENVIRONMENT AGENCY, EC Urban Waste Water Treatment & Nitrate Directives. River Yare (Tidal), Norfolk.

HISCOCK, K. M. & BISHOP, P. K., 1987, Report on Borehole Logging at Strumpshaw P.S., Norfolk. Alta Geophysics, University of Birmingham.

HISCOCK, K. M. & BISHOP, P. K., 1987, Report on Groundwater Dating at Strumpshaw P.S., Norfolk. Alta Geophysics, University of Birmingham.

LAMBERT, J. M., JENNINGS, J. N., SMITH, C. T., GREEN, C. & HUTCHINSON, J. N. (1960), The makings of the Broads: a reconsideration of their origin in the light of new evidence, Royal Geographical Society, Memoir No3.

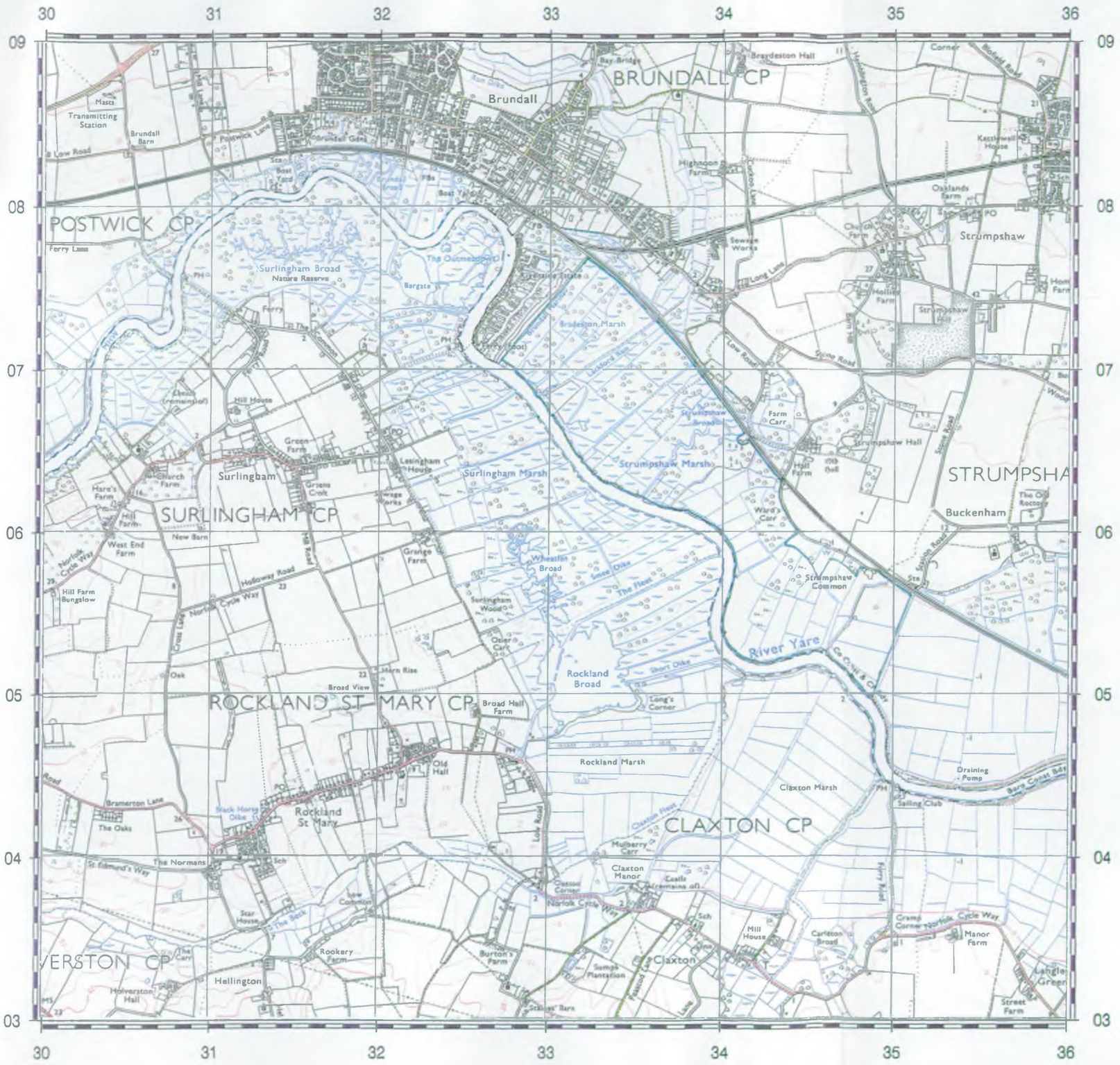
MARTIN, M., 1987, Strumpshaw PWS Source and Strumpshaw Marshes SSSI. Investigations into dewatering of the Marshes by the PWS source and the construction and testing of a marsh support borehole. Anglian Water Authority Internal Report.

PALLIS, M. A. (1911), The River Valleys of East Norfolk: Their Aquatic and Fen Formations, In: Types of British Vegetation, Ed. A. G. Tansley. Cambridge University Press, Cambridge.

PARMENTER, J. (1995). The Broadland Fen Resource Survey. English Nature/Broads Authority.

TICKNER ET AL (1991). The Rehabilitation of a Norfolk Broad at Strumpshaw RSPB Reserve. RSPB Management Case Study. RSPB, Sandy.

STRUMPSHAW MARSH



SSSI Boundary
(marked in green)

Scale 1:25,000

0 1km

National Grid Square: TG

Evaluating the Impact of Groundwater Abstractions on Key Regional Conservation Sites -
Stage 1 Reports for AMP3

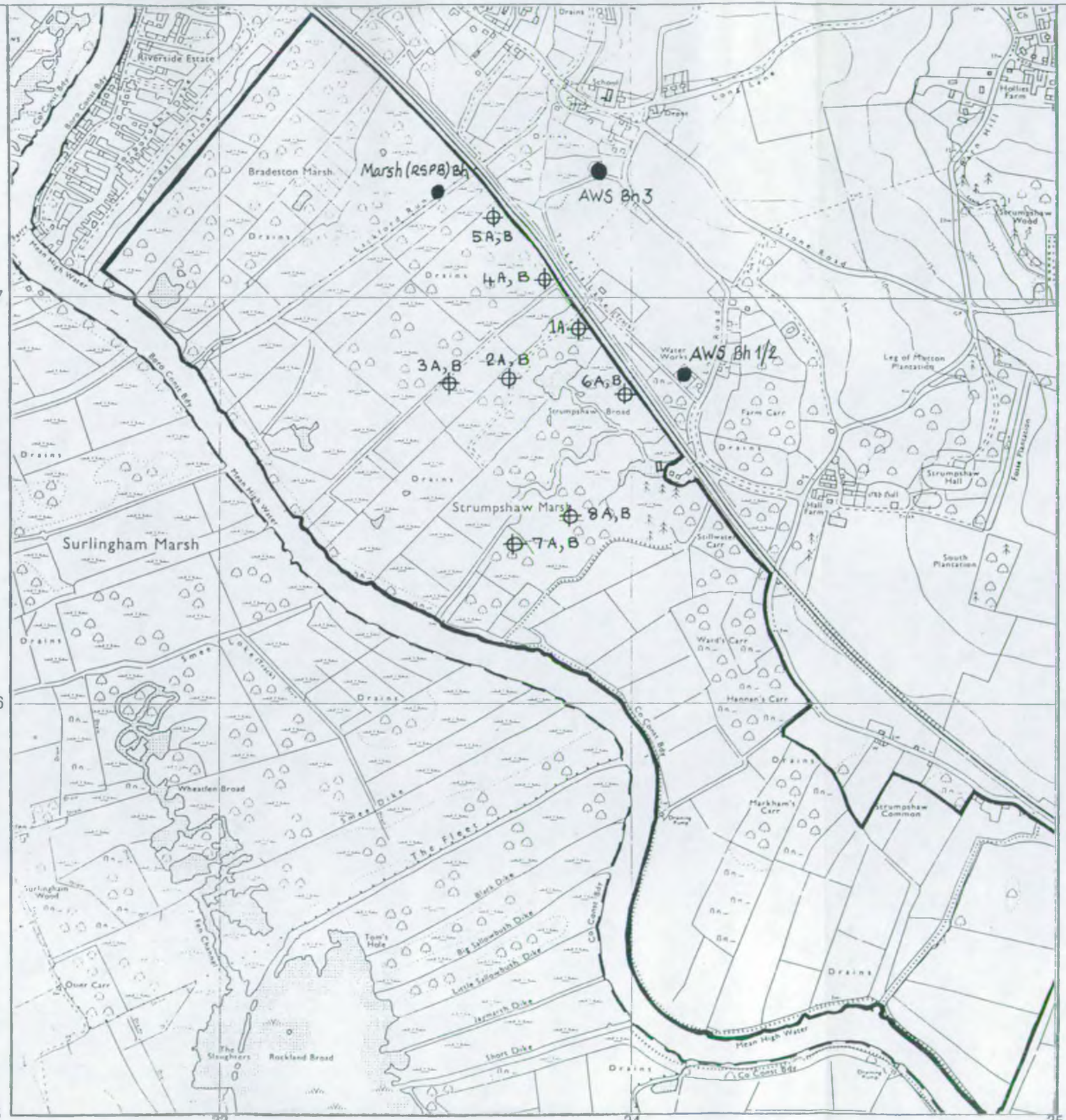
Topographic Map
STRUMPSHAW MARSH

Date: July 1998

Figure Number 1

ENVIRONMENT AGENCY

bsi Hydrogeological Services International Limited
6 Millmead, Guildford, Surrey. GU2 5BE
01483 504221 mail@hsiltd.co.uk



07

Piezometers used in 1986

LEGEND	
SSSI Boundary	
Currently Monitored Borehole	
Gaugeboard	
Scale 1:10,000	Grid Square: TG

Evaluating the Impact of Groundwater Abstractions on Key Regional Conservation Sites - Stage 1 Reports for AMP3

Site Map
STRUMPSHAW MARSH

Date: July 1998

Figure Number 2

bsi Hydrogeological Services International Limited
6 Millmead, Guildford, Surrey. GU2 5BE

Figure 2a Site Aerial Photograph (1993)

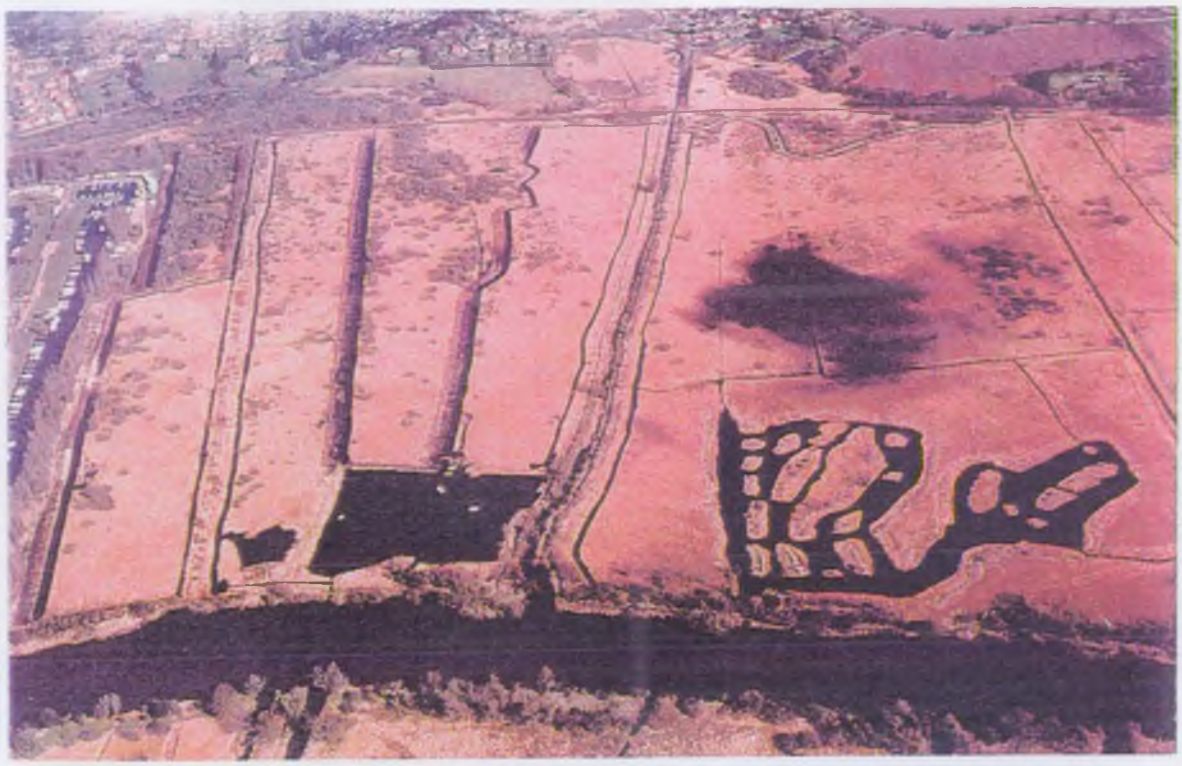


Figure 3a

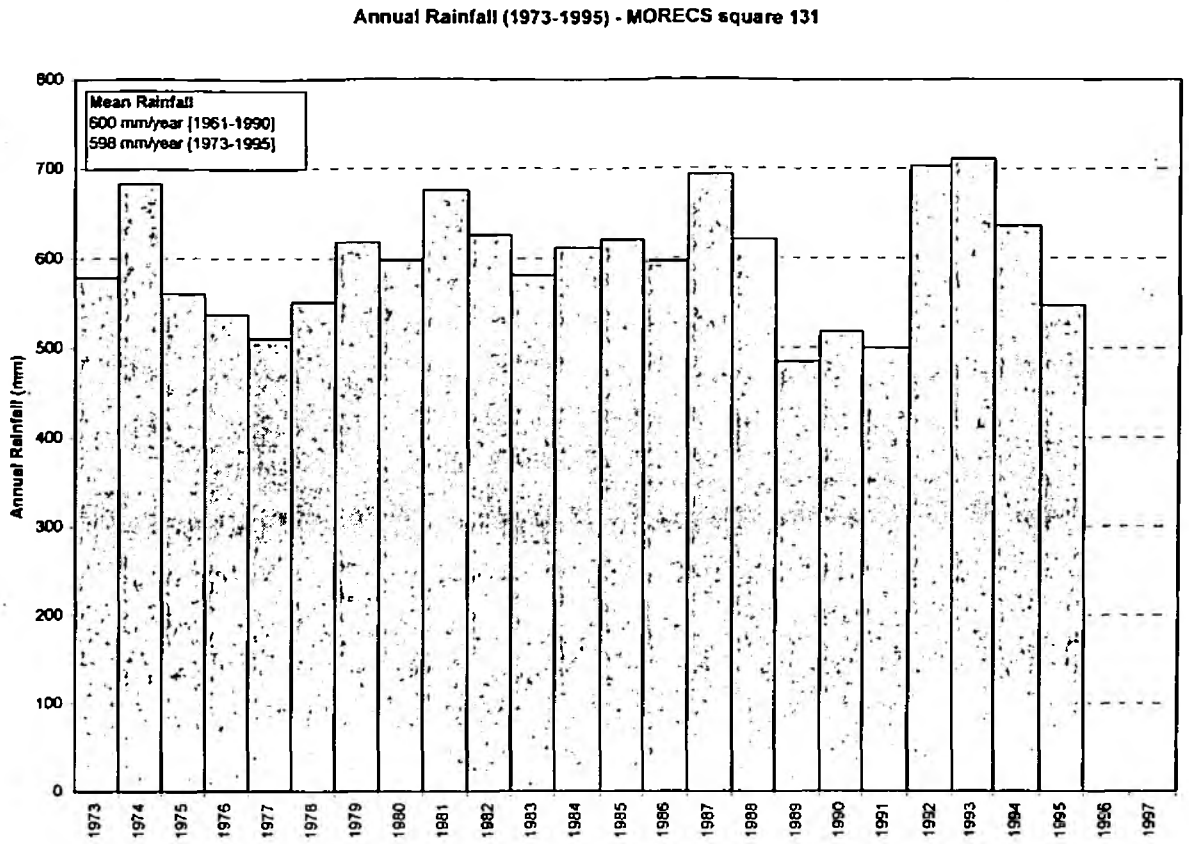


Figure 3b

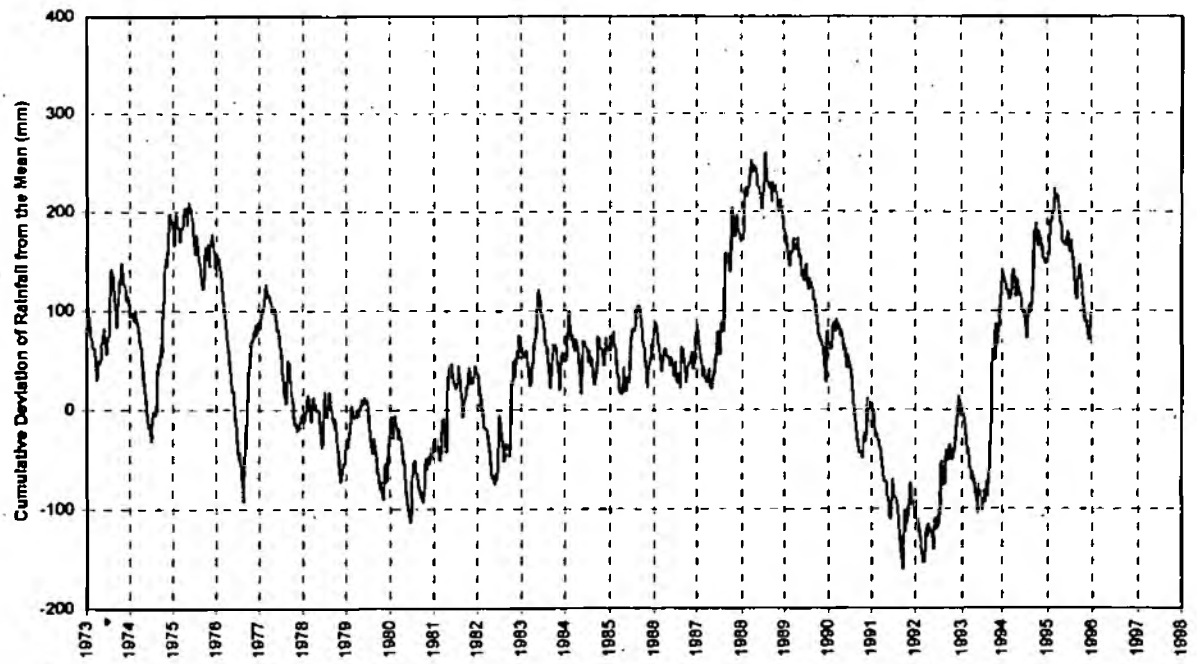


Figure 4a

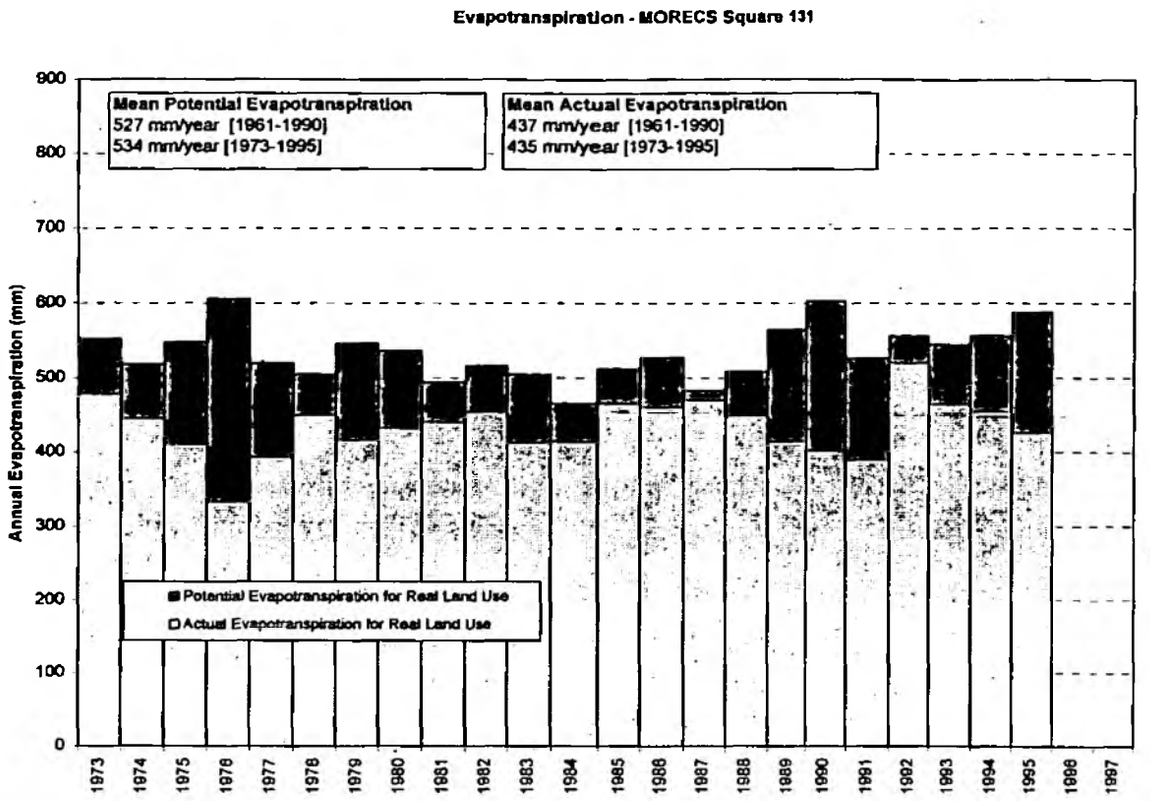


Figure 4b

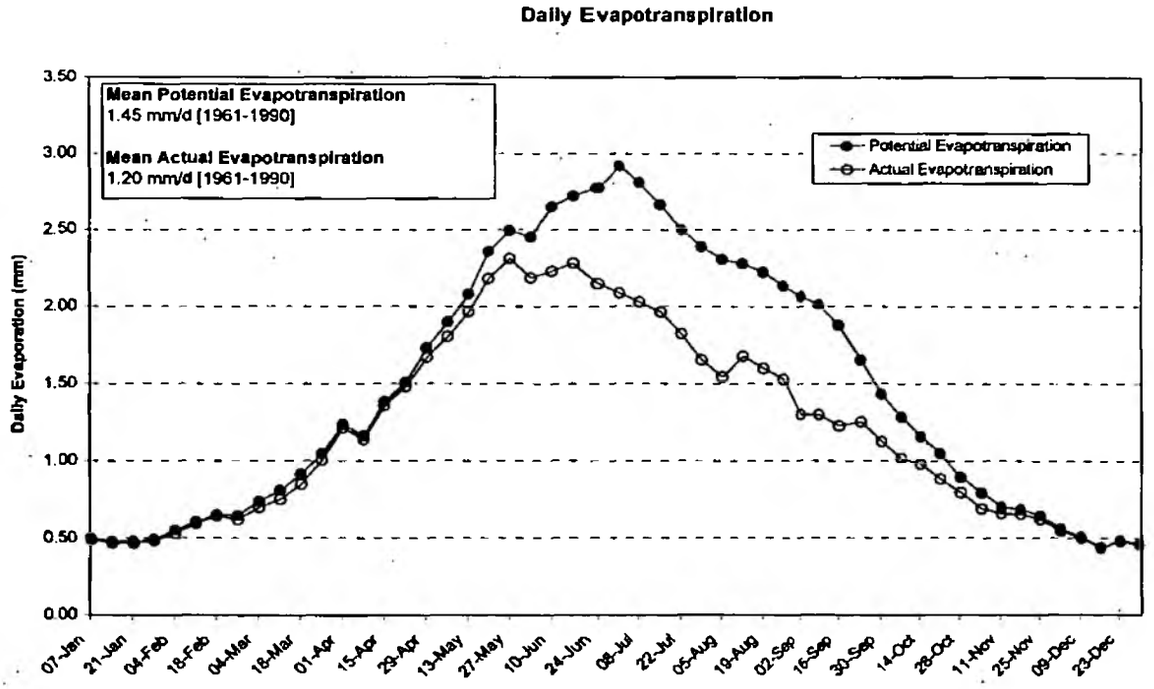


Figure 5a

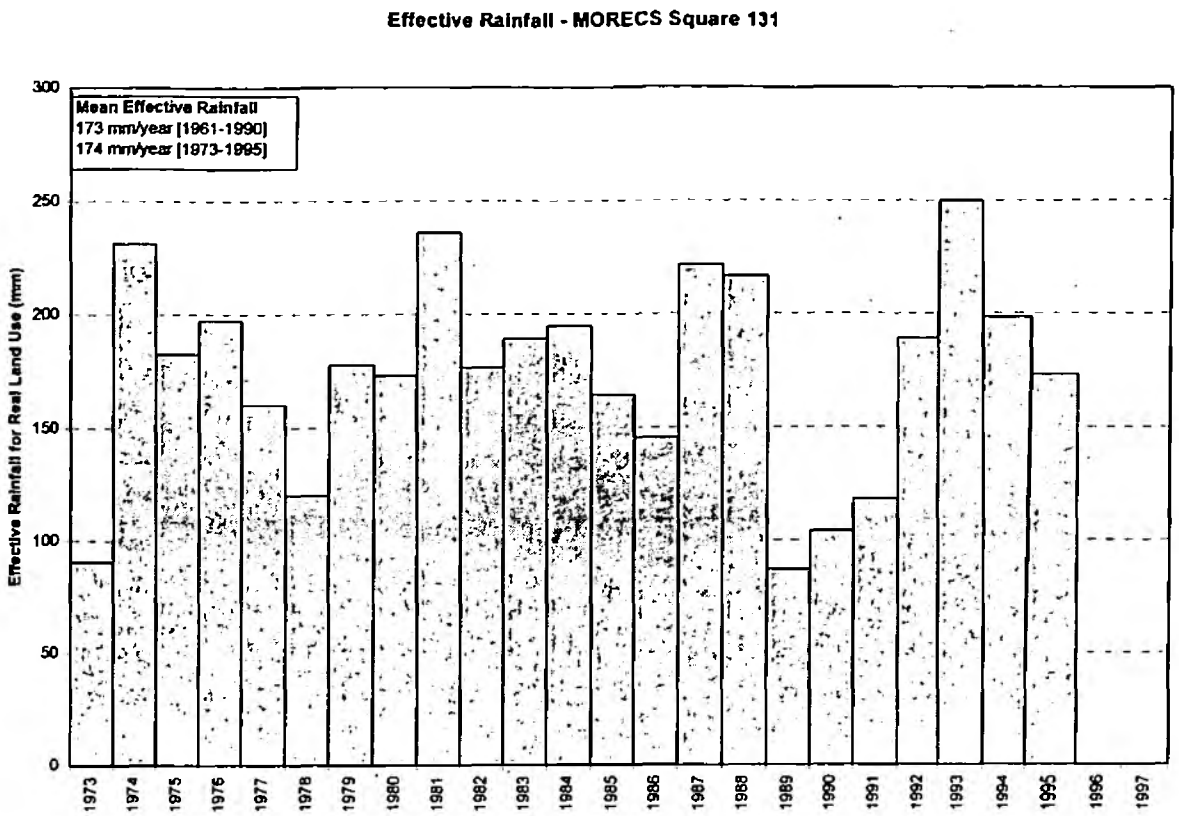
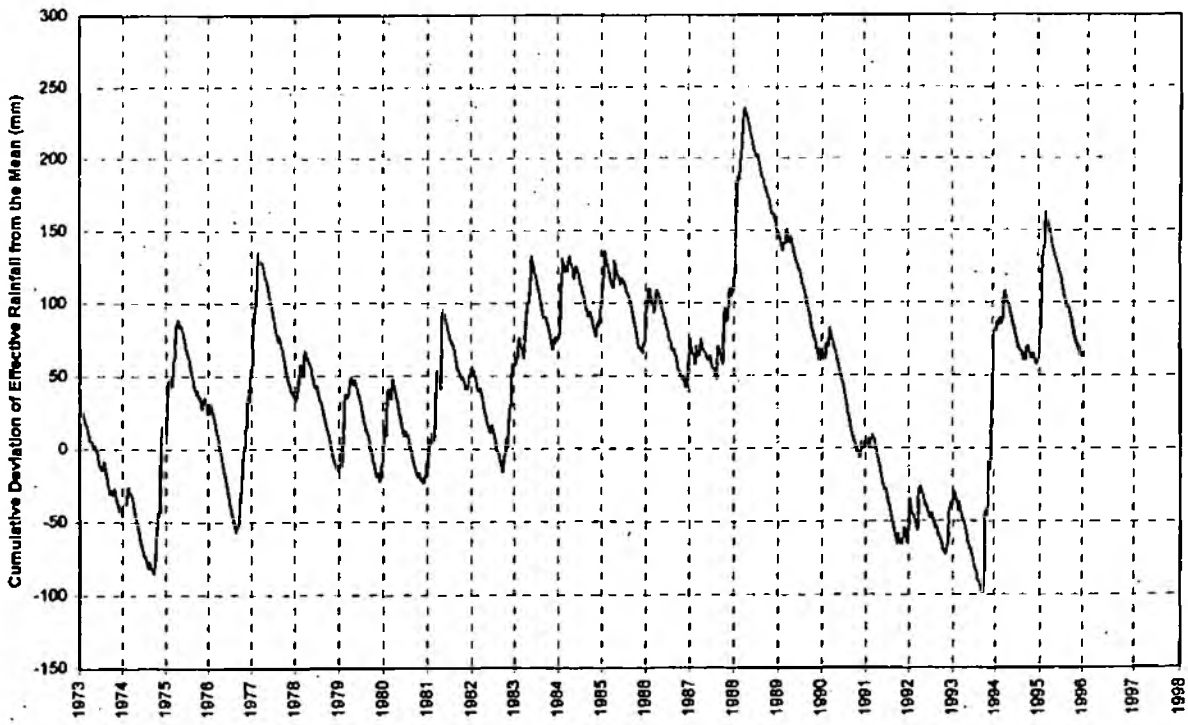
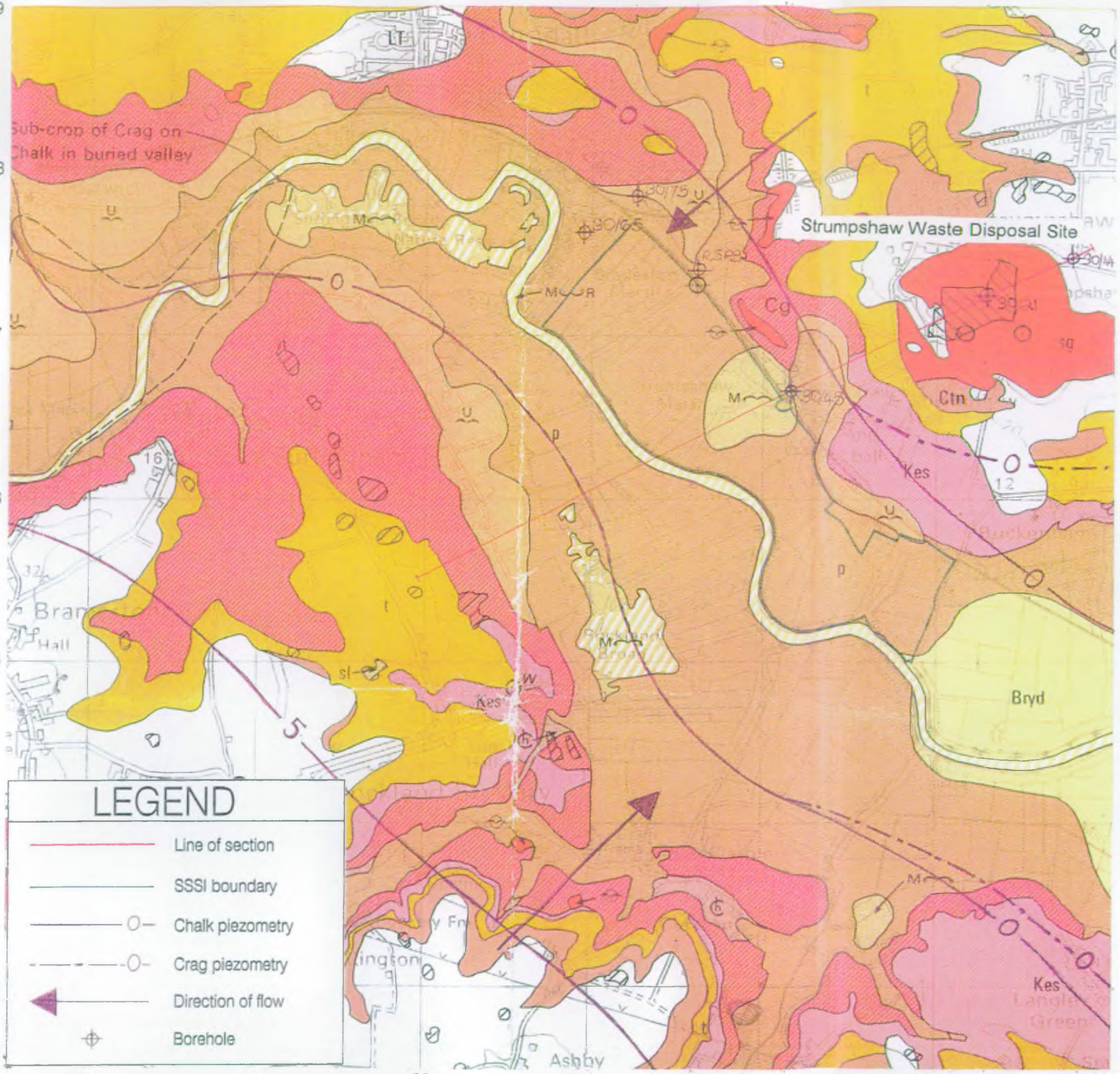


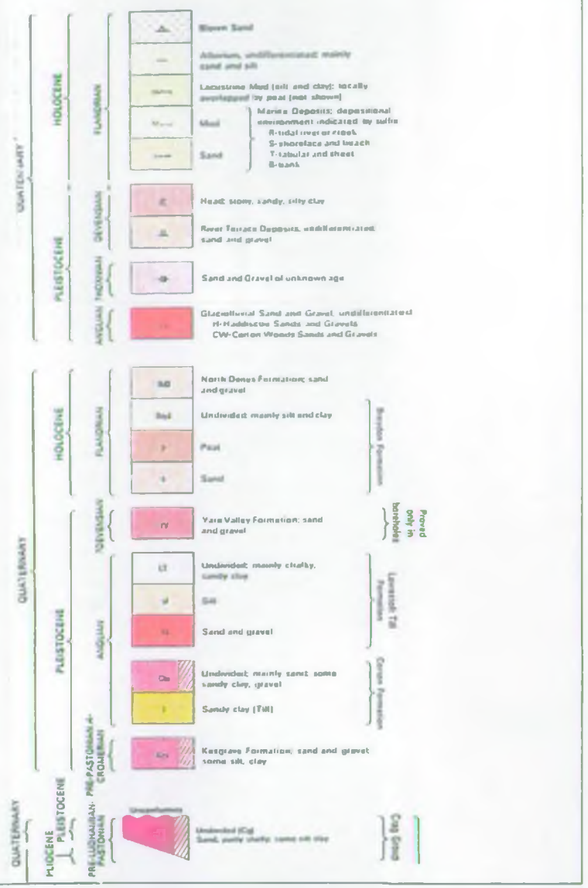
Figure 5b



STRUMPSHAW MARSH



LEGEND



Scale 1:25,000 (enlarged from 1:50,000)

0 1km

National Grid Square: TG

Evaluating the Impact of Groundwater Abstractions on Key Regional Conservation Sites - Stage 1 Reports for AMP3

Geological Map
STRUMPSHAW MARSH

Date: July 1998

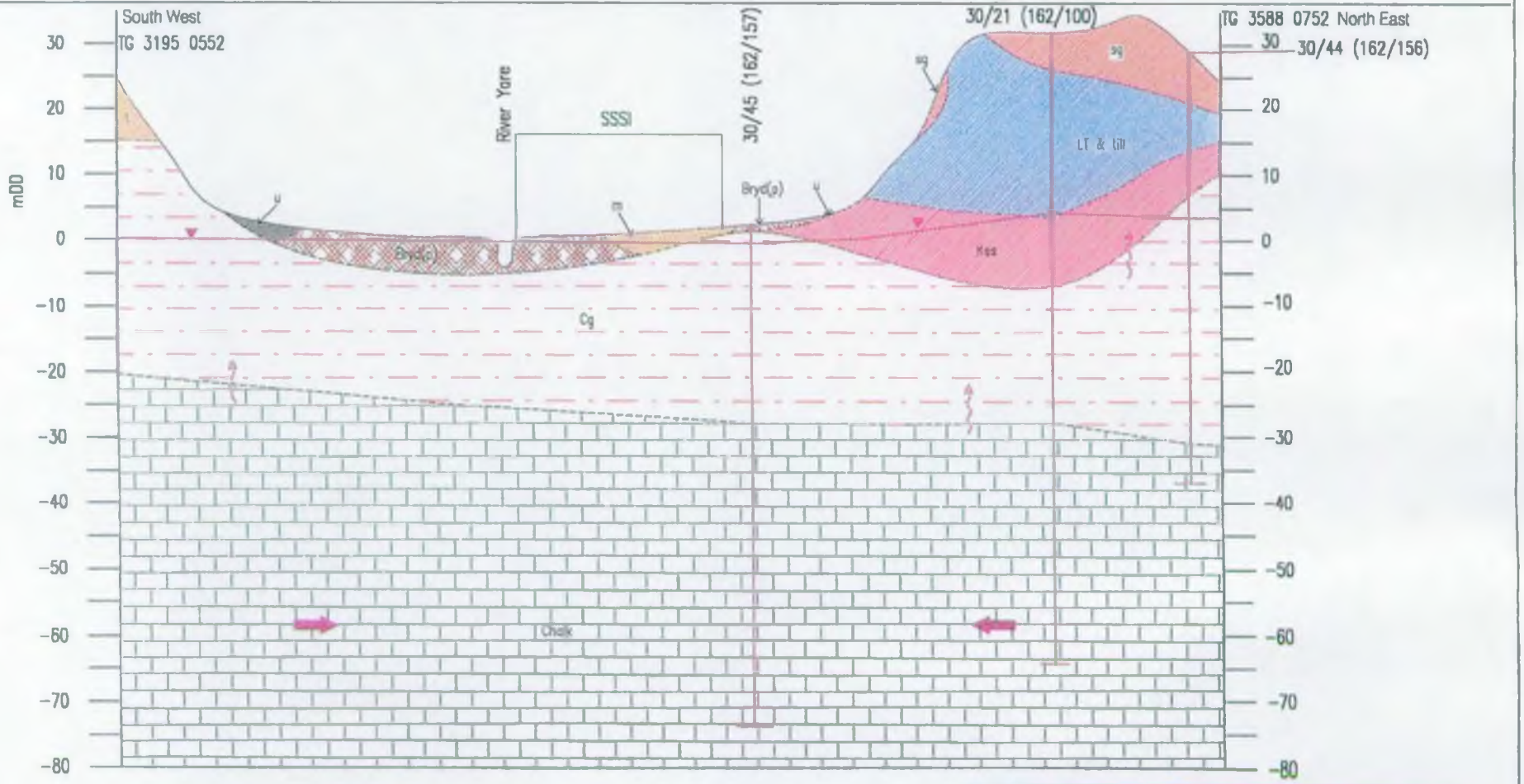
Figure Number 6

ENVIRONMENT AGENCY

bsi Hydrogeological Services International Limited
6 Millmead, Guildford, Surrey. GU2 5BE
01483 504221 mail@hsiltd.co.uk

HYDROGEOLOGICAL CROSS SECTION THROUGH

STRUMPSHAW MARSH



NOTE: Line of section, see Hydrogeological Map

Water levels shown are for Nov 1997.

Regional direction of groundwater flow

Groundwater movement between units

VERTICAL SCALE 1:1000
HORIZONTAL SCALE 1:25,000
0 1 km

Vertical Exaggeration x25

Evaluating the Impact of Groundwater Abstractions on Key Regional Conservation Sites - Stage 1 Reports for AMP3

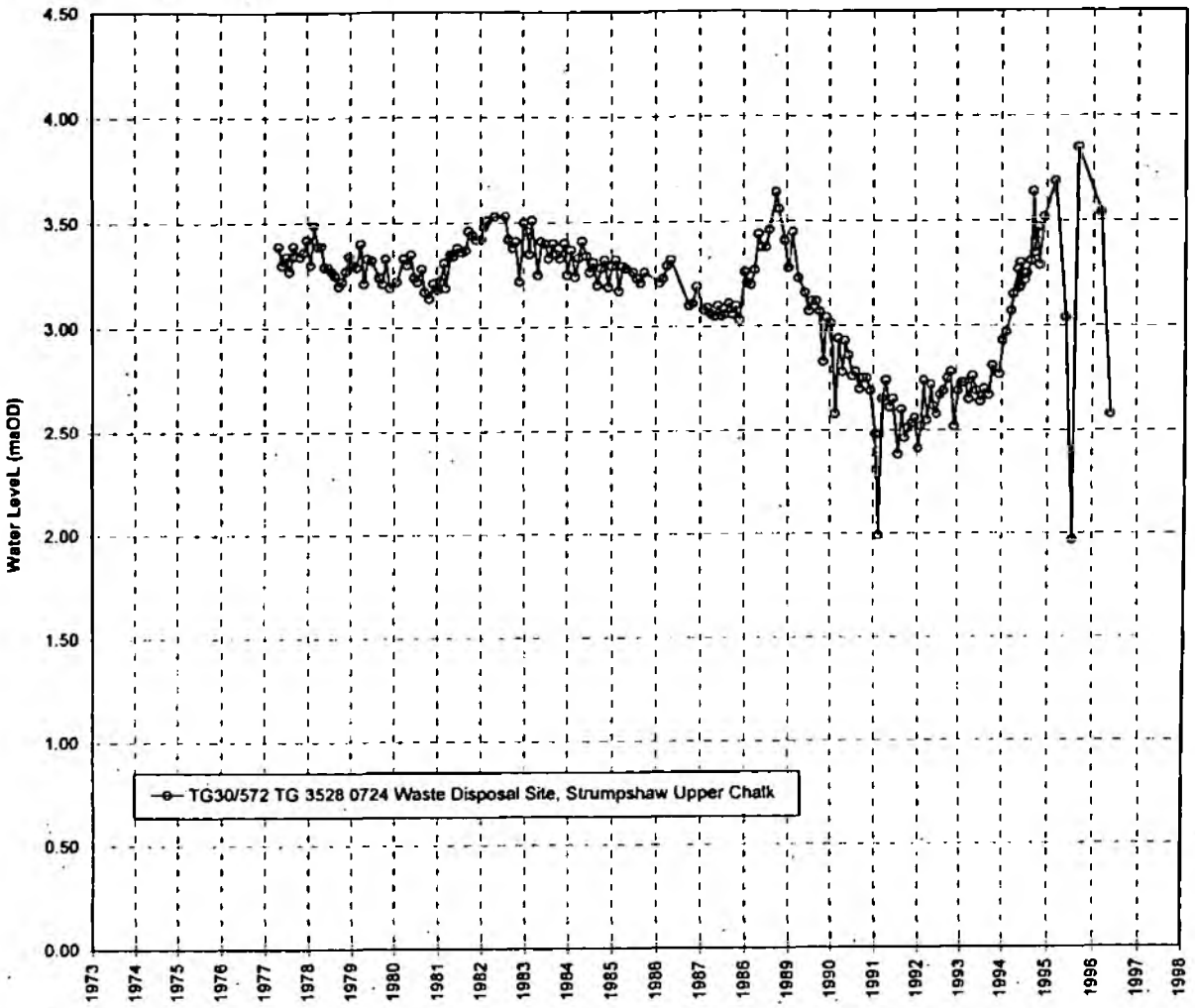
STRUMPSHAW MARSH

FIGURE: 7 | Date: July 1998

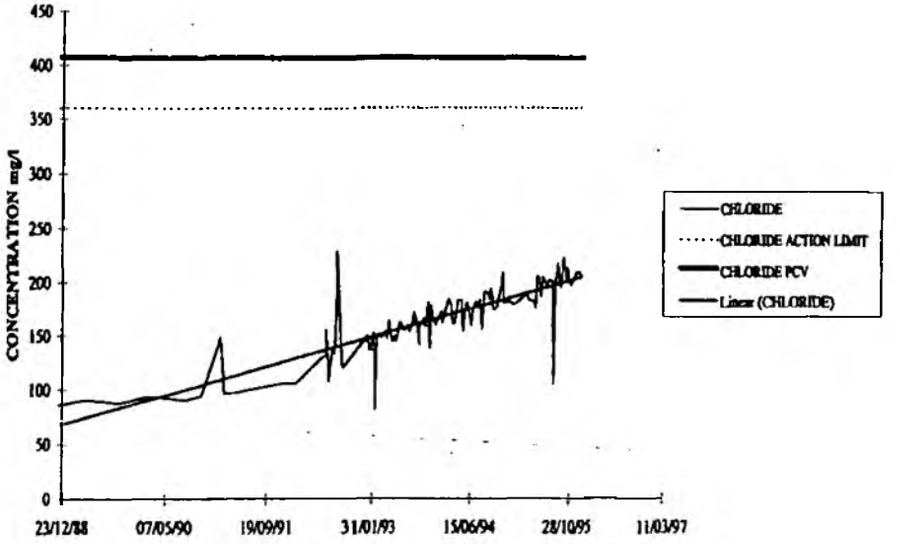
bsi Hydrogeological Services International Limited
6 Millmead, Guildford, Surrey, GU2 5BE. Tel 01483 504221

Figure 7

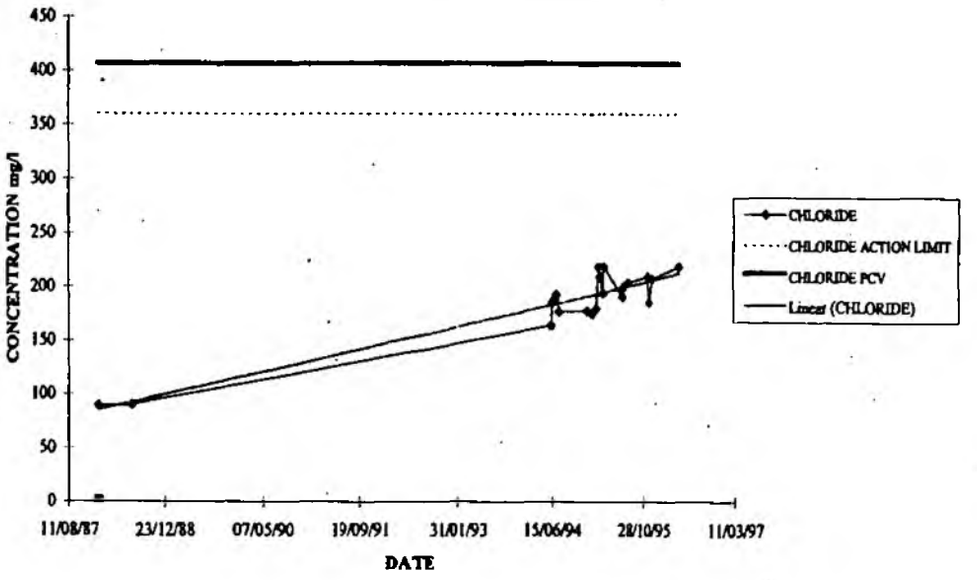
Figure 8


Water Level (msOD)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
TG30/572 TG 3528 0724 Waste Disposal Site, Strumpshaw Upper Chalk

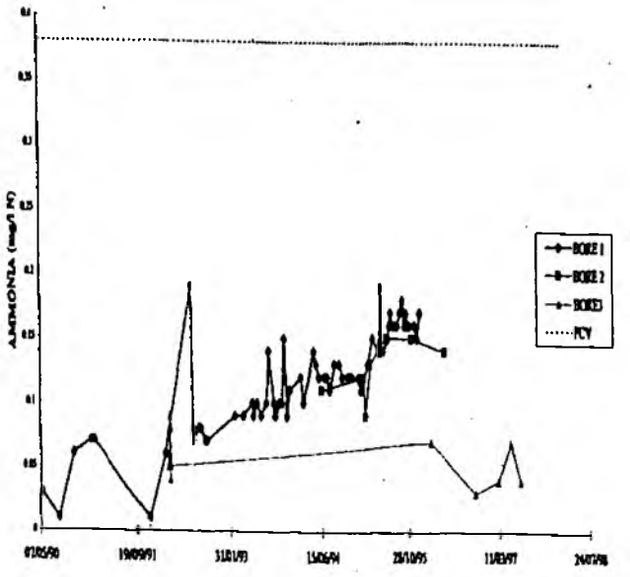
STRUMPSHAW NO.1 BORE
CHLORIDE TREND



STRUMPSHAW NO.2 BORE
CHLORIDE TREND



STRUMPSHAW WTW - RAW WATER AMMONIA CONCENTRATIONS



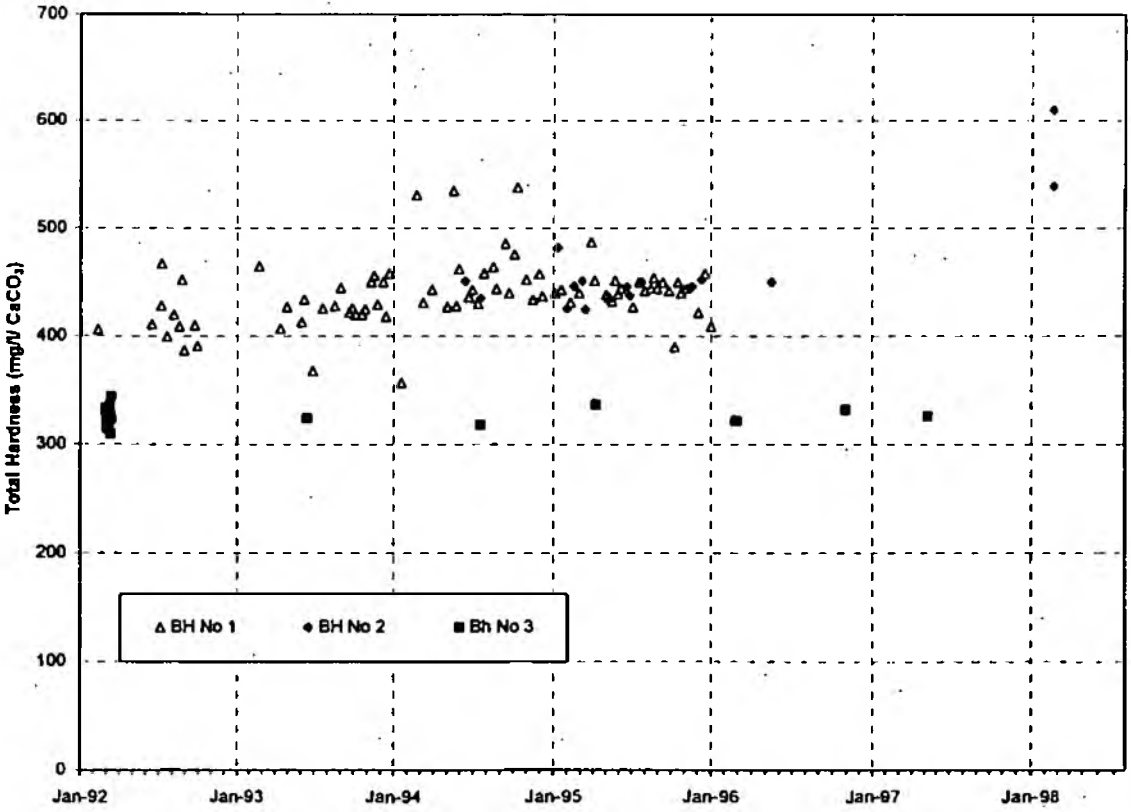
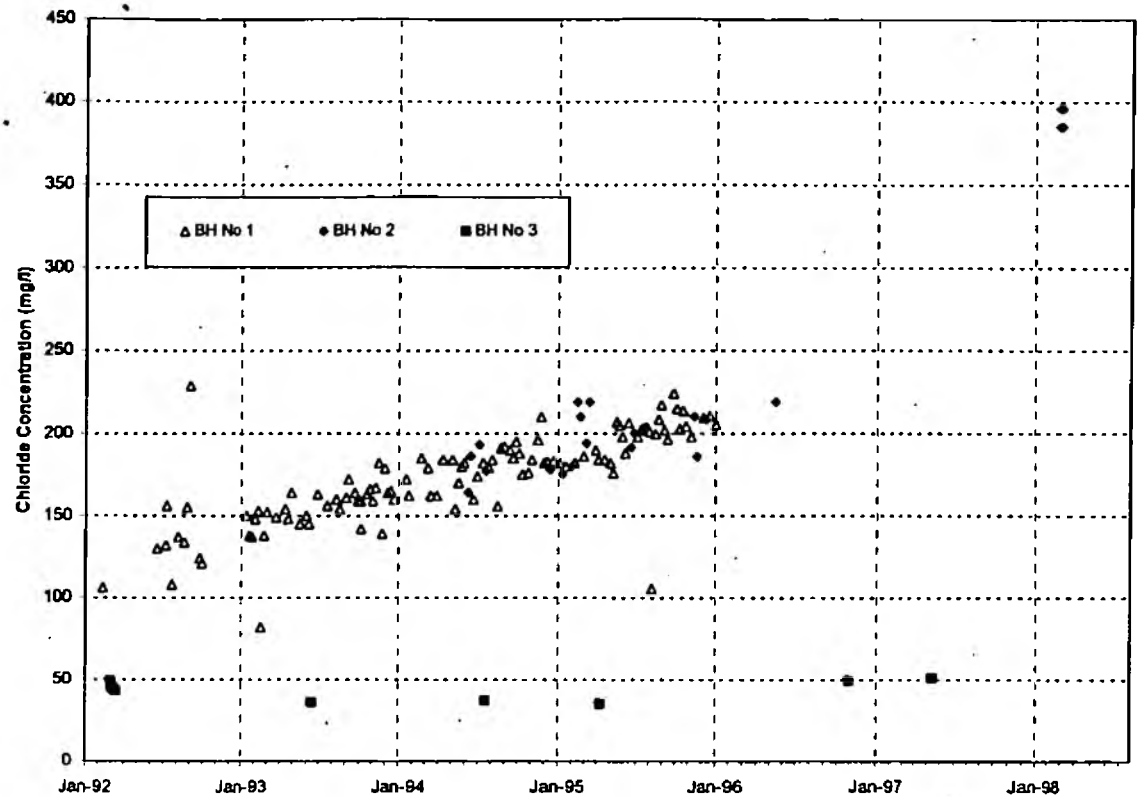
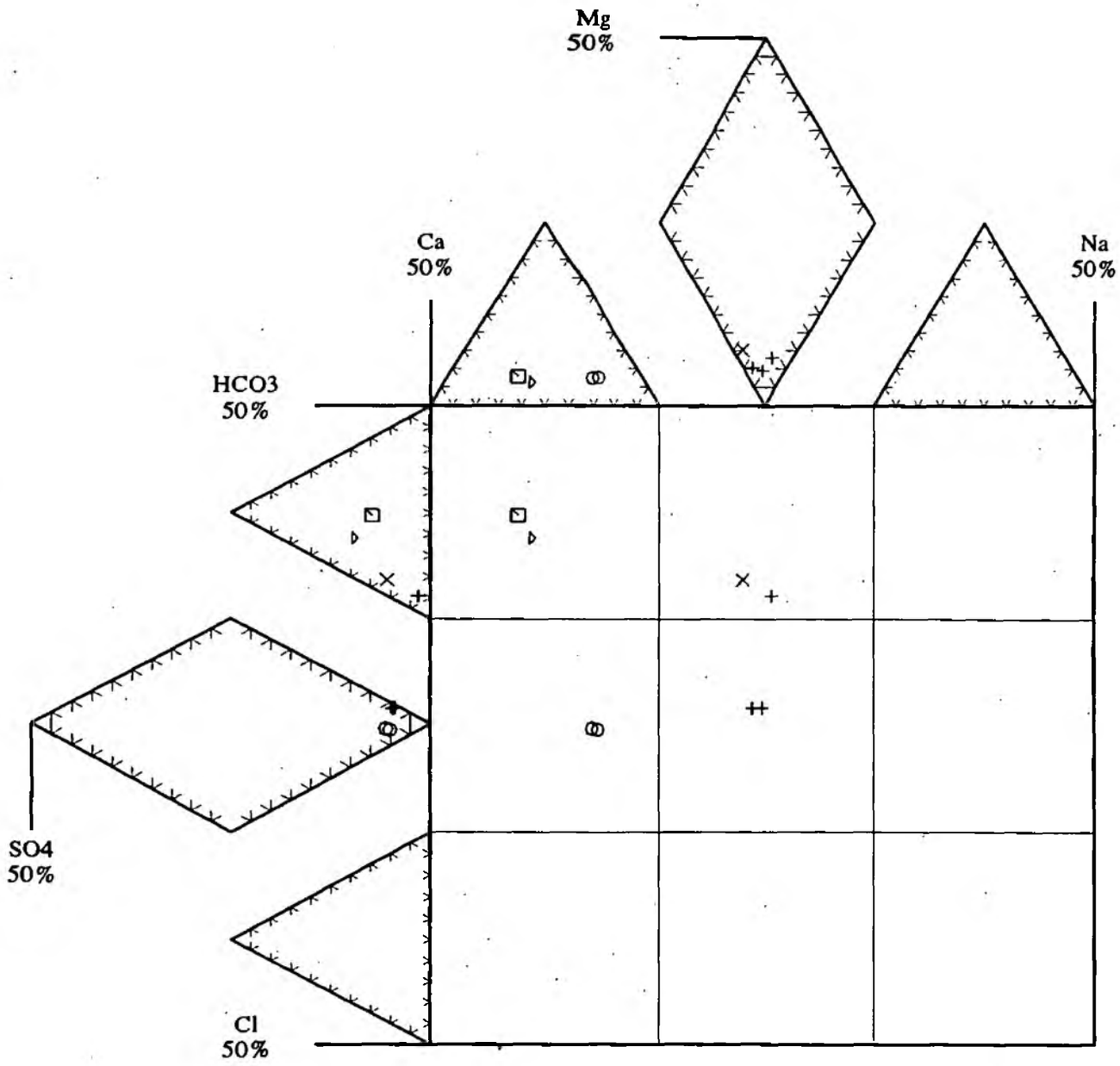

Total Hardness (mg/l/ $CaCO_3$)
700
600
500
400
300
200
100
0
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
BH No 1
BH No 2
Bh No 3

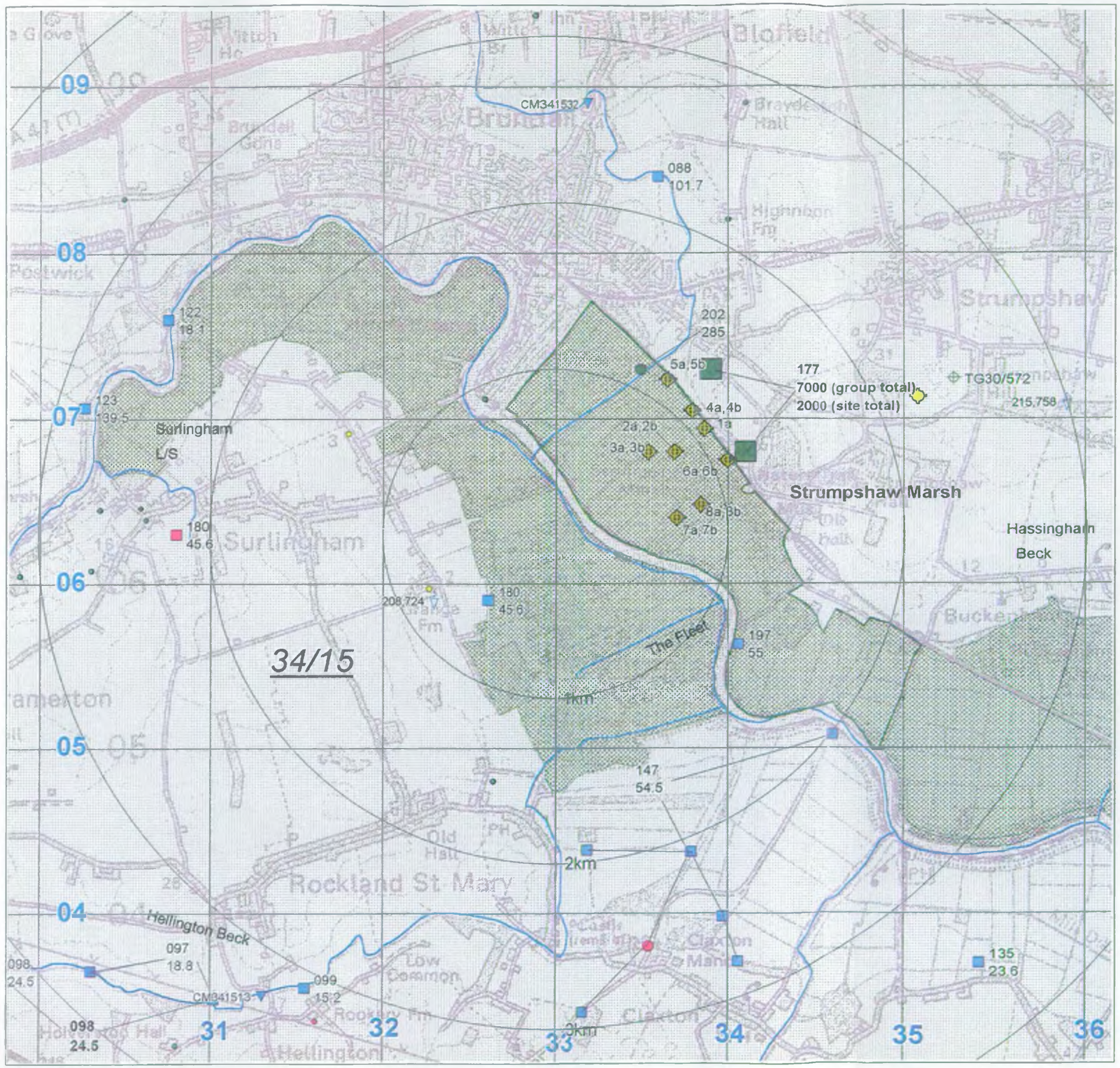
Figure 10


Chloride Concentration (mg/l)
450
400
350
300
250
200
150
100
50
0
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
BH No 1
BH No 2
BH No 3

DUROV Hydrochemical Plots

+ SSSI Waters
○ Strumpshaw No1/No2
□ Strumpshaw No3
× RSPB Bh
▷ River Yare





STRUMPSHAW MARSH

LEGEND

Abstraction Licences

Surface Water | Chalk | Crag | Drift | Other

Source Use

- Public Water Supply
- Spray Irrigation
- Industrial
- Other Uses

large symbol > 7.3Ml/a
small symbol < 7.3Ml/a

Symbol annotated with Serial Number above Licence Quantity (Ml/a)

Monitoring & Other Boreholes

Borehole Status

- Currently Monitored Borehole
- Previously Monitored Borehole
- Other Borehole

Symbol annotated with Site Reference

Surface water flow station, Raingauge

Site of Special Scientific Interest (SSSI) not all are annotated

34/11 Subcatchment Number

Subcatchment Boundary

Main River

04 OS Grid lines with number

1km Circles centred on the SSSI at 1km increments

Scale 1:25,000 (0 – 1km)

National Grid Square: TG

Evaluating the Impact of Groundwater Abstractions on Key Regional Conservation Sites - Stage 1 Reports for AMP3

Licence & Monitoring Location Map STRUMPSHAW MARSH

Date: July 1998

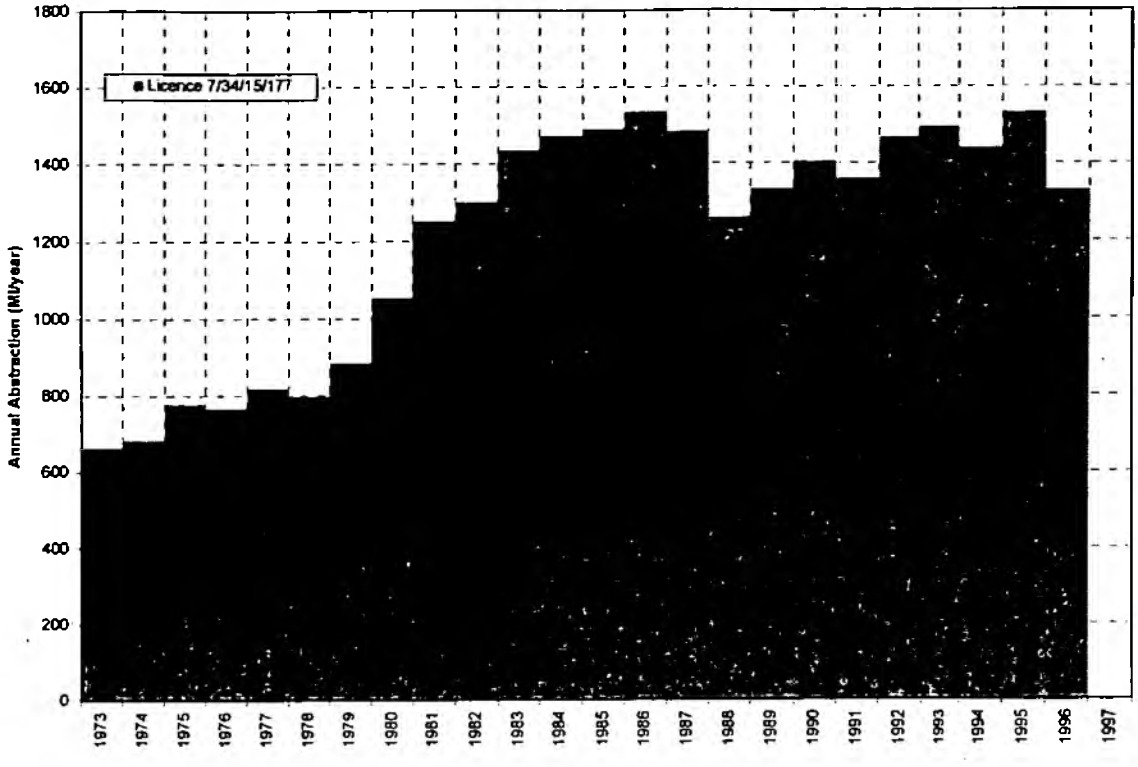
Figure Number: 12

ENVIRONMENT AGENCY

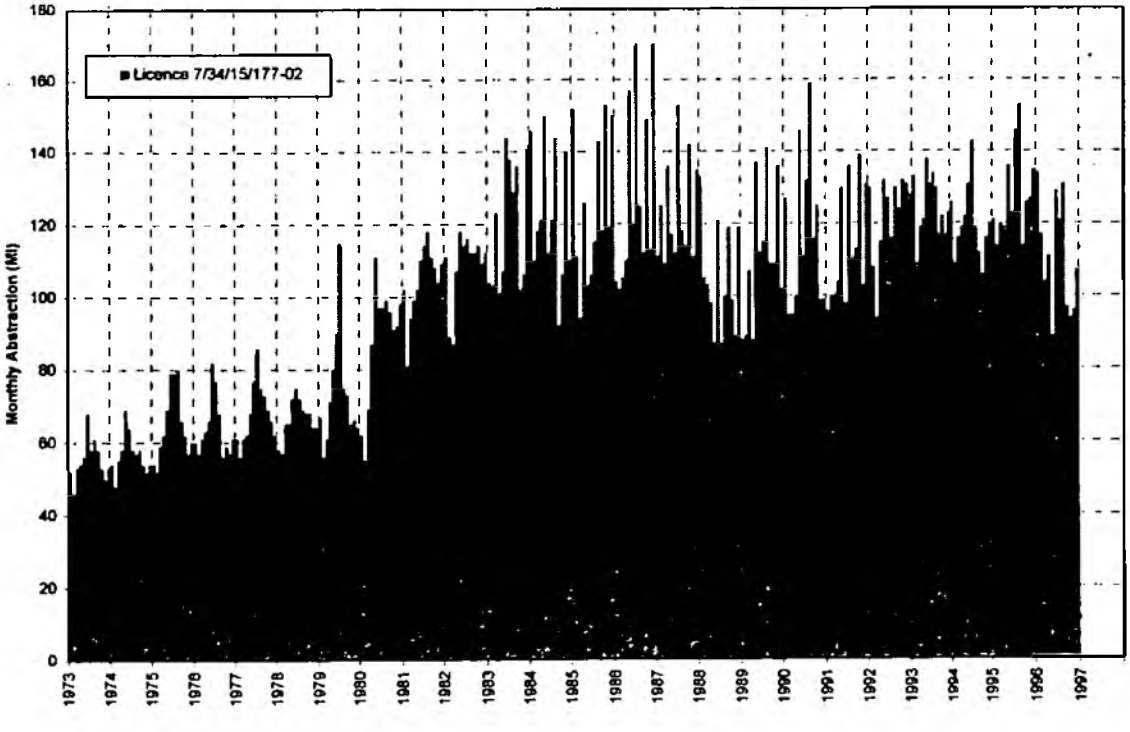
bsi Hydrogeological Services International Limited
6 Millmead, Guildford, Surrey. GU2 5BE
01483 504221 mail@hsiltd.co.uk

Figure 13

Anglian Water - Low Town (Strumpshaw) PWS - Annual Abstraction



Anglian Water - Nr Low Town, Strumpshaw PWS, Monthly Abstractions



APPENDIX 1

Summary of records for scarce invertebrates associated with wetland conditions

Appendix 1: Summary of Scarce Invertebrates Associated with Wetland Conditions

Species	Status	Dates	Requirements
Mollusca			
Pseudamnicola confusa	R1	1977	soft mud with emergent vegetation in barely saline sheltered tidal conditions
Vertigo moulinsiana	R3	?	old calcareous wetlands, usually with large Carex
Coleoptera			
- water beetles			
Dryops anglicanus	R3	1989	shallows of standing water
Hydraena testacea	Nb	1981	streams and old fens, in shallows
Noterus crassicornis	Nb	1972-4	fens and grazing levels, in well-vegetated clean water
Scarodytes halensis	Nb	1972-4	still and slow-flowing base-rich water, esp. with *Chara*
- terrestrial beetles			
Silis ruficollis	Nb	1983	tall fen vegetation and *Phragmites* beds
Diptera			
Achalcus melanotrichus	N	1988	tall vegetation in swamps and water margins
Anasimyia interpuncta	R3	1988	tall emergent vegetation by nutrient-rich winter-flooded sites
Antichaeta brevipennis	R2	1988	damp shady places with lush vegetation
		1989	
Cephalops perspicuus	R2	1988	apparently wetland
		1989	
Colobaea bifasciella	N	1988	base-rich marshlands
		1989	
Colobaea distincta	N	1989	temporary pools?
Cordilura aemula	pR3	1989	larvae in leaf bases of sedges?
Dixella serotina	N	1988	fens: larvae in meniscus at edge of stems of emergent vegetation
		1989	
Epicypta limnophila	N	1989	fungal growth on waterside plants?
Hercostomus chalybeus	N	1988	*Phragmites* beds and other tall swamp vegetation
Limonia danica	pR3	1988	bare mud and sparse vegetation, usually
		1989	brackish
		1990	
Nephrotoma lunulicornis	N	1989	sandy river banks with woodland or trees
Ochthera manicata	pR3	1988	bare water margins, often peaty: E Anglia
		1993	
Pherbellia nana	N	1988	wide range of wetlands
Psacadina verbeckei	N	1988	fens and mesotrophic wetlands
Pseudexechia parallela	X	1988	apparently wetland
		1989	
Rhaphium nasutum	N	1970+	river banks

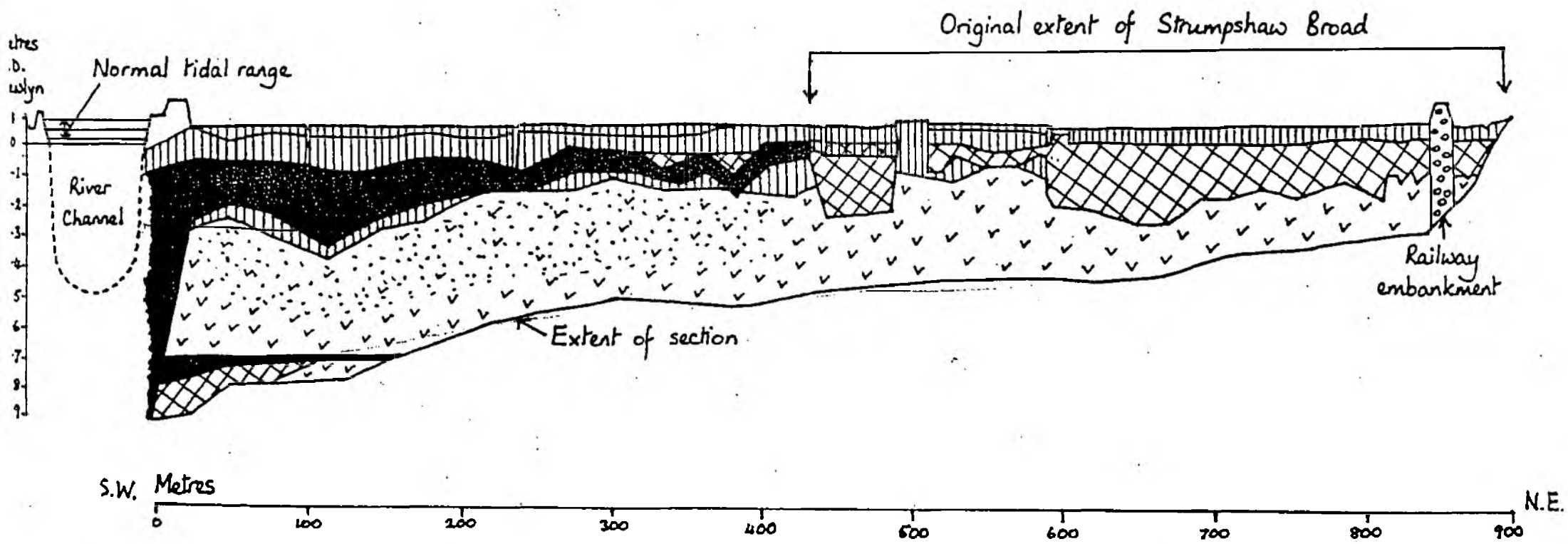
Species	Status	Dates	Requirements
Scathophaga tinctinervis	R2	1988	East Anglian fens
Sciomyza dryomyzina	R2	1988	fens, marshes and water margins
Sciomyza simplex	N	1988	marshy depressions with fluctuating water table
		1989	
Stratiomys singularior	N	1988	shallow water, often temporary and often brackish
Tetanocera freyi	R3	1988	wide range of wetlands, probably all base-rich
Hemiptera-Auchenorhyncha			
Paralimnus phragmitis	Nb	1989	*Phragmites* beds
Stroggylocephalus livens	Nb	1989	fens, bogs, acid mires
Hemiptera-Heteroptera			
Saldula opacula	Nb	1988	water margins, especially old peatland and estuarine
Hymenoptera-Aculeata			
Passaloecus clypealis	R3	1980	*Phragmites* beds
Lepidoptera			
Anticollix sparsata	Na	1986	*Lysimachia vulgaris*
Archanara algae	R3	1985	*Scirpus, Typha, Iris*
	(unconfirmed)		
Archanara dissoluta	Nb	1986	*Phragmites*
Archanara geminipunctata	Nb	1984	*Phragmites*
	(unconfirmed)		
Archanara sparganii	Nb	1986	*Typha, Iris, Scirpus, Sparganium*
Chilodes maritimus	Nb	1986	*Phragmites*
Earias clorana	N	1986	*Salix*
Eustrotia uncula	Nb	1986	fens, wet heath, etc: grasses
Hydraecia petasitis	Nb	1984-5	*Petasites*
Idaea muricata	Na	1986	*Potentilla palustris*
Macrochilo cribrumalis	Na	1973	fens and marshes: *Carex* etc.?
Mythimna obsoleta	Nb	1983	*Phragmites*
	(unconfirmed)		
Nascia cilialis	Na	1986	fens: *Cladium: Carex*
Papilio machaon britannicus	R2	1986	E Anglian fens; *Peucedanum palustre*
		1989	
Perizoma sagittata	R2	1986	*Thalictrum flavum*
		1987	
Photedes brevilinea	R3	1984	*Phragmites*
Senta flammea	R3	1973	*Phragmites* beds
		1986	
Simyra albovenosa	Na	1986	*Phragmites*, fens and marshes
Odonata			
Aeshna isosceles	Nb	1986	unpolluted grazing ditches with a permanent high water table containing *Stratiotes aloides*

Species	Status	Dates	Requirements
Brachytron pratense	Nb	1982 1983-6	mesotrophic ponds, lakes, ditches etc with abundant emergent vegetation
Coenagrion pulchellum	Nb	1982	fens, mesotrophic ponds, ditches etc with permanent high water tables and rich vegetation
Plecoptera			
Nemoura dubitans	N	1990	seepages and trickles with dense vegetation
Araneae			
Donachara speciosa	Na	1988 1989	fens and marshes, often *Phragmites* beds
Entelecara omissa	Na	1988	sedge tussocks and litter in fens and marshes
Hypomma fulvum	Na	1988 1989	*Phragmites* beds
Theridiosoma gemmosum	N	1988	low herbage in fens, bogs, ditch margins, etc

APPENDIX 2

Geological Section (after Lambert & Jennings 1960, adapted by Martin 1987)

Figure 1. Section through Strumpshaw Broad (see Map No. 2 for line of section)



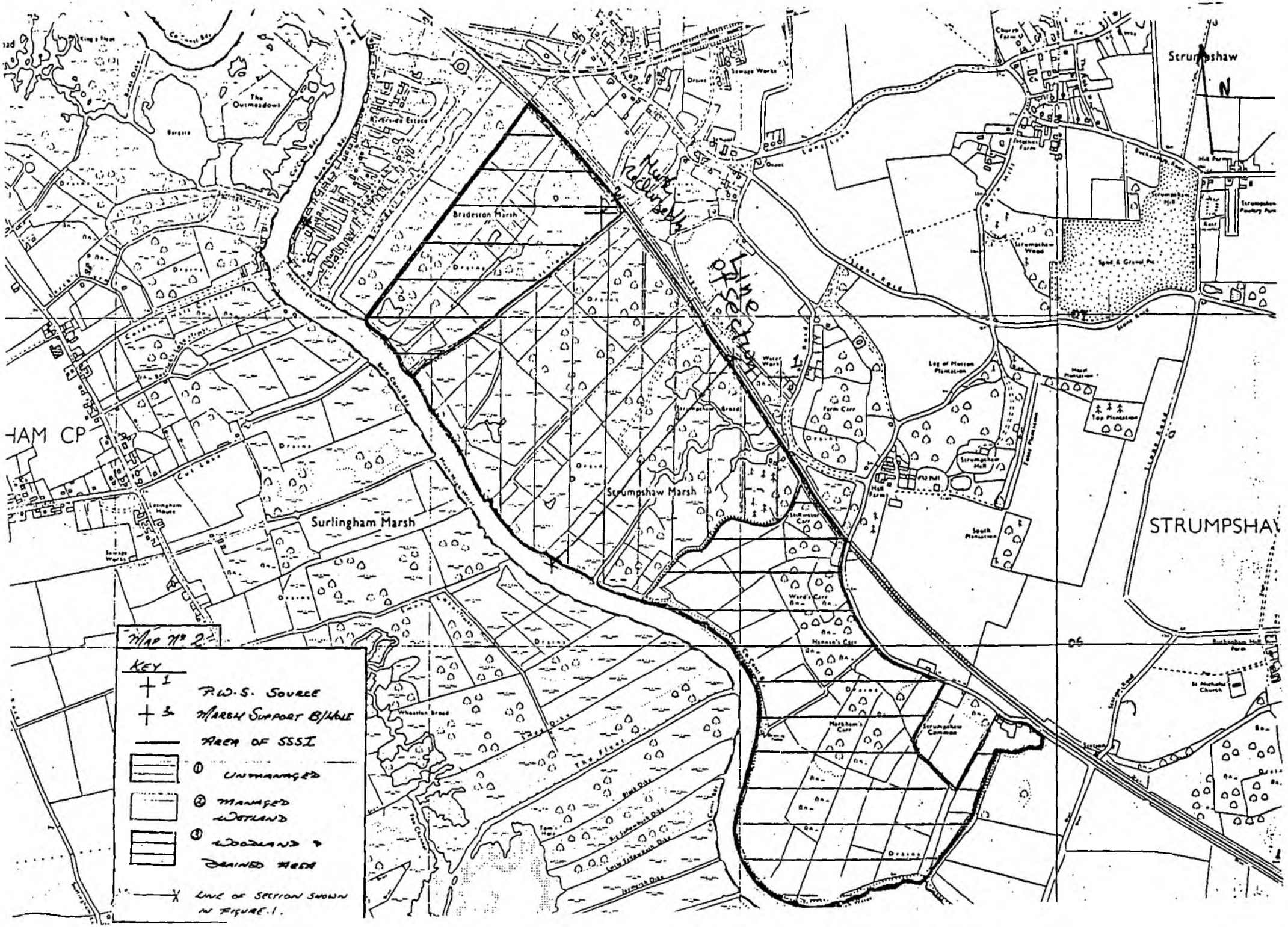
Scale

Horizontally 1: 3600
Vertically 1: 185
Vertical exaggeration x 19·5

Key

- Reed and sweet-grass peat
- Organic and calcareous mud
- Estuarine clay
- Mixed fen peat
- Brushwood peat

(After Lambert, Jennings et al., 1960)


Strumpshaw
N
Bradeston Marsh
River Yare
Surlingham Marsh
Strumpshaw Marsh
STRUMPSHAW
MAP No 2.
KEY
1 R.W.S. Source
2 Marsh Support B/Hole
Area of SSSI
① Unmanaged
② Managed Wetland
③ Woodland & Drained Area
Line of Section shown in Figure 1.

APPENDIX 3

Data on the 1986 Piezometers within Strumpshaw Fen

DETAILS OF PIEZOMETERS

Piezometer	Measured depth (m)	Total tube depth (m)	Height of tube above ground (m)	Piezometer depth below ground (m)	Datum Elevation (maOD)	NGR (TG)
1A	2.53	2.91	0.28	2.63	1.058	3388 0694
2A	4.95	5.33	0.55	4.78	1.324	3370 0679
2B	1.16	1.54	0.16	1.38	0.820	
3A	4.00	4.38	0.46	3.92	1.291	3355 0678
3B	1.86	2.24	0.44	1.80	1.250	
4A	4.27	4.65	0.54	4.11	1.278	3379 0705
4B	1.85	2.23	0.45	1.78	1.167	
5A	5.84	6.22	0.38	5.84	1.099	3367 0719
5B	1.87	2.25	0.51	1.74	1.302	
6A	4.46	4.84	0.36	4.48	1.046	3401 3675
6B	1.35	1.73	0.17	1.56	0.788	
7A	4.20	4.58	0.50	4.08	1.186	3372 0639
7B	1.60	1.98	0.45	1.53	1.141	
8A	5.93	6.31	1.10	5.21	1.811	3385 0646
8B	2.10	2.48	0.57	1.91	1.271	

WATER LEVEL DATA FOR ON-SITE PIEZOMETERS

Piezometer	Water Level (maOD)		Fall (m)	Water Level 2/3/92 (No 3 Test)		Water Level 26/3/92		Fall (m)
	20/6/86	1/8/86		(mbdat)	(maOD)	(mbdat)	(maOD)	
1A	0.278	0.018	0.26	0.495	0.563	0.317	0.741	- 0.178
1B ?				0.635	-	0.498	-	- 0.137
2A				0.635	0.689	0.530	0.794	- 0.105
2B				0.550	0.270	0.370	0.450	- 0.180
3A				0.700	0.591	0.590	0.701	- 0.110
3B				0.605	0.645	0.510	0.740	- 0.095
4A	0.368	0.158	0.21	0.770	0.508	0.615	0.663	- 0.155
4B	0.307	0.097	0.21	0.265	0.902	0.110	1.057	- 0.155
5A	0.359	0.139	0.22					
5B	0.372	0.182	0.19					
6A	0.266	0.026	0.24	0.530	0.516	0.380	0.666	- 0.150
6B	0.308	0.108	0.20	0.450	0.338	0.388	0.40	- 0.062
7A	0.266	0.076	0.19	0.545	0.641	0.399	0.787	- 0.146
7B	0.291	0.081	0.21	0.635	0.506	0.496	0.645	- 0.139
8A	0.201	-0.039	0.24	1.40	0.411	1.253	0.558	- 0.147
8B	0.301	0.071	0.23	0.48	0.791	0.310	0.961	- 0.170

APPENDIX 4

Results of Physiochemical Survey

Chemical Analysis Certificates

Location Sampling Map

FIELD PHYSICOCHEMICAL MEASUREMENTS (15 – 16 June 1998)

Sample Point	Description	pH (pH Units)	Electrical Conductivity (µS/cm @25C)	Temperature (°C)
1	Dyke near start of fen trail	7.16	945	16.1
2	Dyke near footbridge, north side of fen trail	7.39	1005	15.6
3	Further up dyke, west of 2 above	7.58	1025	15.9
4	Dyke other side of fen trail to 3 above	7.66	959	16.4
5	Dyke further west from 4, near end adjacent to Lackford Run	7.47	933	16.8
6	Dyke other side of fen trail to 5 above	7.62	1020	16.4
7	Top end of Lackford Run, south of Railway line	7.63	729	15.3
8	Top end of dyke to west of Lackford Run	7.39	666	16.3
9	Top end of dyke, further west from 8	7.42	800	17.3
10	Lackford Run, near willow tree	7.67	727	15.3
11	Lackford Run, further south from 10	7.68	733	15.5
12	Dyke to east of Lackford Run, opposite 11	7.51	852	17.0
13	Scrape area to north of hide	7.84	661	18.8
14	Near sluice gate, south side of scrape area	8.98	639	19.4
15	River Yare, south of sluice gate	8.01	808	16.5
16	South end of dyke to west of scrape area	9.07	670	18.7
17	Dyke to west of 16 above	7.97	705	18.6
18	River Yare, near south end of Lackford Run	8.10	804	16.5
19	South end of dyke, to east of Lackford Run	7.70	905	18.1
20	Broad area in front of hide	8.17	893	18.6
21	Middle section of broad, as 20 above	8.32	892	18.6
22	Dyke/broad, east of 21 above	8.01	943	20.0
23	Dyke to east of dyke in 22 above	7.51	1041	18.0
24	South part of scrape area	8.57	944	20.8
25	North part of scrape area	8.97	852	19.3
26	Hidden Broad. Sample No 1	7.91	891	15.8
27	Channel between Hidden Broad and Canal Dyke.	7.86	879	15.9
28	North end of canal Dyke, near Dr Martin George's house. Chloride sample	8.04	866	15.9
29	Canal Dyke, half way down	8.09	858	16.0
30	Dyke running south from Old Broad	7.85	868	15.8
31	Dyke, running east to north of rustic hide	7.57	830	15.8
32	South end of Old Broad dyke. Sample No 2	8.17	882	15.8
33	River Yare, to south of Old Broad dyke. Sample No 3	7.95	802	14.8
34	As 23 above. Sample No 4			
35	Old Broad. Chloride sample	8.11	890	16.1
36	Piezometer 4A, 4.95 m deep. Chloride sample	6.31	511	11.2
	Piezometer 4B, 1.97 m deep	7.26	698	13.5
	Surface Water at location of piezometer	7.35	952	12.9

FIELD PHYSICOCHEMICAL MEASUREMENTS Continued

37	Marsh Support Borehole. Chloride sample	7.47	1235	11.3
38	As 13 above. Chloride sample			
39	Dyke in fen area to east of sandy embankment	7.50	1223	14.8
40	South end of dyke to west of 39 above	7.63	2160	14.5
41	North end of dyke to west of 39 above. Chloride sample	7.84	2060	15.0
42	Piezometer 6A, 4.57 m deep	6.97	2030	11.7
	Piezometer 6B, 1.44 m deep	7.04	781	13.1
	Also recorded: AWS Borhole No 3	7.38	802	12.1

Anglian Water

Anglian Scientific

Anglian Water
Services Limited

The Laboratory
Cambridge Sewage Treatment Works
Cowley Road
Cambridge CB4 4DL

Telephone 01223 372811
Facsimile 01223 372810

Sample Point : HSI Ltd
AWS Reference : S01HSILTD BZ

Our ref

Your ref

Sample Number.....98302509
Sampled Date/Time.....16/06/98 10:00
Comments .....HIDDEN BROAD STUMPSHAW

Det Code	Det Name	Result	Units
00614x	pH - Non Potable and Wastewater	7.83	pH Units
00682	Turbidity (FTU)	1.90	FTU
00771x	Conductivity at 25 C	810	uSie/cm
01119x	Ammonia	<.030	mg/l N
01165x	Total Oxidised Nitrogen	<.40	mg/l N
01171x	Nitrate	<0.5	mg/l N
01183x	Nitrite	<.04	mg/l N
01351x	Suspended Particulate Solids at 105C	13.0	mg/l
01582	Hardness Total As CaCO3	248	MG/L CACO3
01622	Alkalinity Total	206.0	mg/l CaCO3
01728x	Chloride	124.00	mg/l Cl
01835x	Sulphate	38	mg/l SO4
02075x	Sodium	84.2	mg/l Na
02115x	Potassium	2.6	mg/l K
02375x	Magnesium	11.0	mg/l Mg
02415x	Calcium	84.9	mg/l Ca
04014	Manganese, 0.45um membrane filtered	0.061	mg/l Mn
04035	Manganese total	0.072	mg/l Mn
04195	Iron, 0.45um membrane filtered	<0.01	mg/l Fe
04215x	Iron	0.094	mg/l Fe
73601x	Phosphorus As P Total Settled	0.19	mg/l P

Signed: _____
Dr C Gilfoyle
Senior Scientist

Note : Determinand Code Qualifiers as follows
X : issuing AWS Lab, UKAS accredited x : other AWS Lab, UKAS accredited
+ : external Lab, UKAS accredited - : external Lab, NOT UKAS accredited

NAMAS
TESTING
1223

Anglian Water

■ *Anglian Scientific*

Anglian Water
Services Limited

The Laboratory
Cambridge Sewage Treatment Works
Cowley Road
Cambridge CB4 4DL

Telephone 01223 372811
Facsimile 01223 372810

Sample Point : HSI Ltd
AWS Reference : S01HSILTD BZ

Sample Number.....98302510
Sampled Date/Time.....16/06/98 11:15
Comments .....OLD BROAD DYKE SOUTH END

Our ref

Your ref

Det Code	Det Name	Result	Units
00614x	pH - Non Potable and Wastewater	8.02	pH Units
00682	Turbidity (FTU)	2.20	FTU
00771x	Conductivity at 25 C	806	uSie/cm
01119x	Ammonia	<.030	mg/l N
01165x	Total Oxidised Nitrogen	<.40	mg/l N
01171x	Nitrate	<0.5	mg/l N
01183x	Nitrite	<.04	mg/l N
01351x	Suspended Particulate Solids at 105C	4.0	mg/l
01582	Hardness Total As CaCO3	255	MG/L CACO3
01622	Alkalinity Total	215.0	mg/l CaCO3
01728x	Chloride	129.00	mg/l Cl
01835x	Sulphate	37	mg/l SO4
02075x	Sodium	84.4	mg/l Na
02115x	Potassium	12.9	mg/l K
02375x	Magnesium	10.3	mg/l Mg
02415x	Calcium	82.1	mg/l Ca
04014	Manganese, 0.45um membrane filtered	0.066	mg/l Mn
04035	Manganese total	0.073	mg/l Mn
04195	Iron, 0.45um membrane filtered	0.02	mg/l Fe
04215x	Iron	0.112	mg/l Fe
73601x	Phosphorus As P Total Settled	0.40	mg/l P

Signed: _____
Dr C Gilfoyle
Senior Scientist

Note : Determinand Code Qualifiers as follows
X : issuing AWS Lab, UKAS accredited x : other AWS Lab, UKAS accredited
+ : external Lab, UKAS accredited - : external Lab, NOT UKAS accredited

NAMAS
TESTING
1223

Anglian Water

■ *Anglian Scientific*

Anglian Water
Services Limited

The Laboratory
Cambridge Sewage Treatment Works
Cowley Road
Cambridge CB4 4DL

Telephone 01223 372811
Facsimile 01223 372810

Sample Point : HSI Ltd
AWS Reference : S01HSILTD BZ

Our ref

Your ref

Sample Number.....98302511
Sampled Date/Time.....16/06/98 11:30
Comments.....RIVER YARE

Det Code	Det Name	Result	Units
00614x	pH - Non Potable and Wastewater	7.83	pH Units
00682	Turbidity (FTU)	1.20	FTU
00771x	Conductivity at 25 C	722	uSie/cm
01119x	Ammonia	0.177	mg/l N
01165x	Total Oxidised Nitrogen	5.95	mg/l N
01171x	Nitrate	5.87	mg/l N
01183x	Nitrite	0.082	mg/l N
01351x	Suspended Particulate Solids at 105C	8.0	mg/l
01582	Hardness Total As CaCO3	305	MG/L CACO3
01622	Alkalinity Total	234.0	mg/l CaCO3
01728x	Chloride	60.70	mg/l Cl
01835x	Sulphate	68	mg/l SO4
02075x	Sodium	39.1	mg/l Na
02115x	Potassium	1.1	mg/l K
02375x	Magnesium	6.7	mg/l Mg
02415x	Calcium	132.0	mg/l Ca
04014x	Manganese, 0.45um membrane filtered	0.034	mg/l Mn
04035x	Manganese total	0.037	mg/l Mn
04195	Iron, 0.45um membrane filtered	0.02	mg/l Fe
04215x	Iron	0.238	mg/l Fe
73601x	Phosphorus As P Total Settled	0.62	mg/l P

Signed: _____
Dr C Gilfoyle
Senior Scientist

Note : Determinand Code Qualifiers as follows
X : issuing AWS Lab, UKAS accredited x : other AWS Lab, UKAS accredited
+ : external Lab, UKAS accredited - : external Lab, NOT UKAS accredited

NAMAS
TESTING
1223

Anglian Water

Anglian Scientific

Anglian Water
Services Limited

The Laboratory
Cambridge Sewage Treatment Works
Cowley Road
Cambridge CB4 4DL

Telephone 01223 372811
Facsimile 01223 372810

Sample Point : HSI Ltd
AWS Reference : S01HSILTD BZ

Sample Number.....98302530
Sampled Date/Time.....16/06/98 11:40
Comments .....SOUTH END OF DYKE BETWEEN 6&8

Our ref

Your ref

Det Code	Det Name	Result	Units
00614x	pH - Non Potable and Wastewater	7.41	pH Units
00682	Turbidity (FTU)	3.70	FTU
00771x	Conductivity at 25 C	935	uSie/cm
01119x	Ammonia	<.030	mg/l N
01165x	Total Oxidised Nitrogen	<.40	mg/l N
01171x	Nitrate	<0.5	mg/l N
01183x	Nitrite	<.04	mg/l N
01351x	Suspended Particulate Solids at 105C	14.0	mg/l
01582	Hardness Total As CaCO3	245	MG/L CACO3
01622	Alkalinity Total	272.0	mg/l CaCO3
01728x	Chloride	154.00	mg/l Cl
01835x	Sulphate	15	mg/l SO4
02075x	Sodium	116.0	mg/l Na
02115x	Potassium	17.3	mg/l K
02375x	Magnesium	19.2	mg/l Mg
02415x	Calcium	102.0	mg/l Ca
04014x	Manganese, 0.45um membrane filtered	0.981	mg/l Mn
04035x	Manganese total	1.050	mg/l Mn
04195	Iron, 0.45um membrane filtered	0.09	mg/l Fe
04215x	Iron	0.651	mg/l Fe
73601x	Phosphorus As P Total Settled	1.04	mg/l P

Signed: *Dr C Gilfoyle*
Senior Scientist

Note : Determinand Code Qualifiers as follows
X : issuing AWS Lab, UKAS accredited x : other AWS Lab, UKAS accredited
+ : external Lab, UKAS accredited - : external Lab, NOT UKAS accredited

NAMAS TESTING 1223

Anglian Water

■ *Anglian Scientific*

Anglian Water
Services Limited

The Laboratory
Cambridge Sewage Treatment Works
Cowley Road
Cambridge CB4 4DL

Telephone 01223 372811
Facsimile 01223 372810

Sample Point : HSI Ltd
AWS Reference : S01HSILTD BZ

Our ref

Your ref

Sample Number.....98302531
Sampled Date/Time.....15/06/98 13:30
Comments .....AW STUMPSHAW NO 3

Det Code	Det Name	Result	Units
01728x	Chloride	55.80	mg/l Cl

Signed: _____
Dr C Gilfoyle
Senior Scientist

Note : Determinand Code Qualifiers as follows
X : issuing AWS Lab, UKAS accredited x : other AWS Lab, UKAS accredited
+ : external Lab, UKAS accredited - : external Lab, NOT UKAS accredited

NAMAS TESTING 1223

Anglian Water

■ *Anglian Scientific*

Anglian Water
Services Limited

The Laboratory
Cambridge Sewage Treatment Works
Cowley Road
Cambridge CB4 4DL

Telephone 01223 372811
Facsimile 01223 372810

Sample Point : HSI Ltd
AWS Reference : S01HSILTD BZ

Our ref

Sample Number.....98302534
Sampled Date/Time.....16/06/98 10:10
Comments.....NORTH END OF CANAL DYKE NEAR DR MARTIN GEORGES HOUSE

Your ref

Det Code	Det Name	Result	Units
01728x	Chloride	128.00	mg/l Cl

Signed: _____
Dr C Gilfoyle
Senior Scientist

Note : Determinand Code Qualifiers as follows
X : issuing AWS Lab, UKAS accredited
x : other AWS Lab, UKAS accredited
+ : external Lab, UKAS accredited
- : external Lab, NOT UKAS accredited

NAMAS
TESTING
1223

Anglian Water

■ *Anglian Scientific*

Anglian Water
Services Limited

The Laboratory
Cambridge Sewage Treatment Works
Cowley Road
Cambridge CB4 4DL

Telephone 01223 372811
Facsimile 01223 372810

Our ref

Your ref

Sample Point : HSI Ltd
AWS Reference : S01HSILTD BZ

Sample Number.....98302535
Sampled Date/Time.....16/06/98 12:30
Comments .....OLD BROAD

Det Code	Det Name	Result	Units
01728x	Chloride	127.00	mg/l Cl

Signed: _____
Dr C Gilfoyle
Senior Scientist

Note : Determinand Code Qualifiers as follows
X : issuing AWS Lab, UKAS accredited x : other AWS Lab, UKAS accredited
+ : external Lab, UKAS accredited - : external Lab, NOT UKAS accredited

NAMAS
TESTING
1223

Registered in England No 2366656
Registered Office:
Anglian House Ambury Road
Huntingdon Cambridgeshire PE18 6NZ

Anglian Water

■ *Anglian Scientific*

Anglian Water
Services Limited

The Laboratory
Cambridge Sewage Treatment Works
Cowley Road
Cambridge CB4 4DL

Telephone 01223 372811
Facsimile 01223 372810

Our ref

Your ref

Sample Point : HSI Ltd
AWS Reference : S01HSILTD BZ

Sample Number.....98302545
Sampled Date/Time.....16/06/98 14:30
Comments.....PIEZOMETER 4A

Det Code	Det Name	Result	Units
01728x	Chloride	48.10	mg/l Cl

Signed: _____

Dr C Gilfoyle
Senior Scientist

Note : Determinand Code Qualifiers as follows
X : issuing AWS Lab, UKAS accredited
x : other AWS Lab, UKAS accredited
+ : external Lab, UKAS accredited
- : external Lab, NOT UKAS accredited

NAMAS
TESTING
1223

Anglian Water

■ *Anglian Scientific*

Anglian Water
Services Limited

The Laboratory
Cambridge Sewage Treatment Works
Cowley Road
Cambridge CB4 4DL

Telephone 01223 372811
Facsimile 01223 372810

Sample Point : HSI Ltd
AWS Reference : S01HSILTD BZ

Sample Number.....98302536
Sampled Date/Time.....16/06/98 15:00
Comments .....MARSH SUPPORT BOREHOLE

Our ref

Your ref

Det Code	Det Name	Result	Units
01728x	Chloride	193.00	mg/l Cl

Signed: _____
Dr C Gilfoyle
Senior Scientist

Note : Determinand Code Qualifiers as follows
X : issuing AWS Lab, UKAS accredited
x : other AWS Lab, UKAS accredited
+ : external Lab, UKAS accredited
- : external Lab, NOT UKAS accredited

NAMAS
TESTING
1223

Anglian Water

■ *Anglian Scientific*

Anglian Water
Services Limited

The Laboratory
Cambridge Sewage Treatment Works
Cowley Road
Cambridge CB4 4DL

Telephone 01223 372811
Facsimile 01223 372810

Our ref

Your ref

Sample Point : HSI Ltd
AWS Reference : S01HSILTD BZ

Sample Number.....98302537
Sampled Date/Time.....16/06/98 15:30
Comments .....NORTH OF HIDE SCRAPE AREA

Det Code	Det Name	Result	Units
01728x	Chloride	71.30	mg/l Cl

Signed: _____
Dr C Gilfoyle
Senior Scientist

Note : Determinand Code Qualifiers as follows
X : issuing AWS Lab, UKAS accredited
x : other AWS Lab, UKAS accredited
+ : external Lab, UKAS accredited
- : external Lab, NOT UKAS accredited

NAMAS
TESTING
1223

Evaluating the Impact of Groundwater Abstractions on Key Regional Conservation Sites - Stage 1 Reports for AMP3

Map showing Field Physicochemical Measurements (17-18 June 1998)

FIGURE: | Date: July 1998

bsi Hydrogeological Services International Limited
6 Millmead, Guildford, Surrey, GU2 5BE. Tel 01483 504221

LEGEND

- • 10 — Sample Location & Number
- 750 — pH (pH units)
- 1223 — Electrical Conductivity (µS/cm)

Highdon Farm
Sewage Works
Drains
School
Depot
Long Lane
Stone Road
Leg of Mutton Plantation
Fosse Plantation
Strumpshaw Hall
South Plantation
Mob Hall
Hall Farm
Farm Carr
Water Works
Tinker's Lane (Track)
Broad Row
Strumpshaw Broad
Stillwater Carr
Ward's Carr
Hannan's Carr
Markham's Carr
Strumpshaw Common
Bradeston Marsh
Strumpshaw Marsh
Lackford Run
Co Const Bdy
Boro Const Bdy
Mean High Water
Ferry
Marina
The Fleet
Black Dike
Sallowbush Dike
Flowbush Dike
Dike
Drains
Drawing Pump
15m
10m
5m

APPENDIX 5

Abstraction Licences Listing, 1998

LICENCE NO	LICENCE HOLDER	SITE NAME	USE	TCHA	CM/DAY	G.W.U	GRID REF
7/34/15/*G/007	W W YANN AND SONS	BORE AT HEATH FM,POSTWICK	GENAG/DOM	3.8	10.5	E CHALK	TG29050886
7/34/15/*G/011	MR C MACK	BORE AT WITTON HALL,POSTWICK	GENAG/DOM	1.6	5.0	E CHALK	TG31350965
7/34/15/*G/022	A J KING AND SON	BORE AT SHEE FM,GT PLUMSTEAD	GEN. AGRIC	0.4	5.0	E CHALK	TG29650965
7/34/15/*G/035	C E D H D BLAKE	WELL AT HALL FM,BRAMERTON	GEN. AGRIC	3.4	18.0	E CHALK	TG29600520
7/34/15/*G/044	MR R J CLOUGH	WELL NR PUB,SURLINGHAM	GEN. AGRIC	0.4	2.0	GLAC. S/G	TG31800691
7/34/15/*G/061	L J EASTWOOD LTD	BORE NR COLDHAM HALL INN FERRY	P.W.U.	0.1	5.0	E CHALK	TG32590712
7/34/15/*G/074	A.R.H. GLOVER	WELL W OF ROCKLAND DYKE	GEN. AGRIC	0.4	14.0	E CHALK	TG32640480
7/34/15/*G/081	G HORLEY-CLARKE	BORE AT THE FERRY HSE,SURL'HAM	P.W.U.	0.3	1.0	E CHALK	TG30840755
7/34/15/*S/086	G J BUTLER	WITTON RUN AT BLOFIELD	SPRAY IRR	6.3	518.0		TG31991011 TG32350965
7/34/15/**/087	G E & G H POINTER	BORE AT MANOR FARM,BLOFIELD	GEN. AGRIC	1.4	4.0	E CHALK	TG37890943
7/34/15/**/088	BRAYDESTONE FARMS LTD	WHOLE LICENCE (LN)		101.7	1641.0		
		BORE AT BRAYDESTONE HALL	GEN. AGRIC	4.0	11.0	E CHALK	TG34100890
		LACKFORD RUN AT BLOFIELD	SPRAY IRR	97.7	1630.0		TG33600846
7/34/15/*S/097	E & E J ANDREWS LTD	HELLINGTON BECK,ROCKLAND ST M	SPRAY IRR	18.800	873.00		TG30300365 TG31020348
7/34/15/*S/098	BIXLEY FARMS	THE BECK HOLVERSTON	SPRAY IRR	24.500	546.00		TG29760365 TG31020348
7/34/15/**/099	E H MACK	WHOLE LICENCE (LN)		15.2	550.0		
		WELL AT ROOKERY FM,HELLINGTON	GEN. AGRIC	1.6	5.0	CRAG	TG31610335
		THE BECK,HELLINGTON	SPRAY IRR	13.600	546.00		TG31550355
7/34/15/**/102	E H MACK	WELL AT GRANGE FM,SURLINGHAM	GEN. AGRIC	4.9	14.0	GLAC. S/G	TG32270597
7/34/15/*S/104	MR T P S CANE	WHOLE LICENCE (SI)	SPRAY IRR	13.600	682.00		
		DYKE AT WHITLINGHAM LANE	SPRAY IRR	13.600	682.00		TG25790795
		DYKE NR KIRBY MARSH,K.BEDON	SPRAY IRR	13.600	682.00		TG28290717
7/34/15/*S/105	D LANGRIDGE	R YARE AT POSTWICK	SPRAY IRR	114.5	1538.0		TG28810696
7/34/15/*S/122	MR RUSSELL MAURICE BLAKE	R YARE AT BRUNDALL	SPRAY IRR	18.1	682.0		TG30750760

LICENCE NO.	LICENCE HOLDER	SITE NAME	USE	TCHA	CM/DAY	G.W.U	GRID REF
7/34/15/**/123	P P & E D WALKER	WHOLE LICENCE (LN)		139.5	1810.0		
		WELL AT THE GRANGE,POSTWICK	GEN. AGRIC	2.4	7.0	GLAC. S/G	TG29650869
		BORE AT BRUNDALL BARN,POSTWICK	GEN. AGRIC	0.8	3.0	E CHALK	TG30490833
		MARSH DYKE JOINED TO R.YARE;P	SPRAY IRR	136.300	1800.00		TG30260707
7/34/15/**/135	R R BABEY-FISHER & SON	WHOLE LICENCE (LN)		25.6	1094.0		
		ALL SITES (USAGE - 2)	SPRAY IRR				
		WELL AT HALL FM,CARLETON ST P	GEN. AGRIC	0.4	1.0	CRAG	TG34190248
		WELL AT LOWER FM,CARLETON ST P	GEN. AGRIC	0.4	1.0	CRAG	TG34300263
		LANGLEY MARSH DYKE,CARLETON ST	SPRAY IRR	9.000	546.00		TG35420370
		CARLETON BECK,CARLETON ST P.	SPRAY IRR	13.600	546.00		TG33910250
7/34/15/**/147	MAJOR D S ALLHUSEN	WHOLE LICENCE (LN)		54.500	3273.00		
	LINKED B	ALL SITES (USAGE - 2)	SPRAY IRR				
		WELL AT CLAXTON MANOR	GEN. AGRIC	8.200	23.00	CRAG	TG33550380
		SPR FED POND,SUMPS PLTN,CL'TON	SPRAY IRR	38.700	1250.00		TG33170340
	LINKED B	MARSH DYKE,ROCKLAND ST MARY	SPRAY IRR	7.600	750.00		TG33200438
							TG33790437
	LINKED B	MARSH DYKE,CLAXTON MARSH	SPRAY IRR	7.600	1250.00		TG33970398
							TG34600508
	LINKED B	MARSH DYKE NR CLAXTON MANOR	SPRAY IRR	7.600	1250.00		TG34060371
7/34/15/*G/149	THE EXORS OF H G CUSHION DEC'D	BORE AT HALL FM,SURLINGHAM	GEN. AGRIC	5.4	12.0	E CHALK	TG30300608
7/34/15/*S/159	T P S CANE	R YARE AT KIRBY BEDON	SPRAY IRR	31.800	691.00		TG28950640
7/34/15/*S/163	D N CATCHPOLE & SON	WHOLE LICENCE (SI)	SPRAY IRR	25.000	582.00		
		CARLETON BECK AT CARLETON ST P	SPRAY IRR				TG33790176
		CARLETON BECK AT CARLETON ST P	SPRAY IRR				TG33800235
7/34/15/**/167	JOHN MACK & SONS	WHOLE LICENCE (LN)		36.3	701.0		
		BORE AT HOME FM,BLOFIELD	GEN. AGRIC	4.5	14.0	E CHALK	TG31841096
		WITTON LAKE AT BLOFIELD	SPRAY IRR	31.800	687.00		TG31701049
7/34/15/*G/175	MR M J ELLERBROOK	BORE AT BLOFIELD NURSERIES	SPRAY IRR	21.0	91.0	E CHALK	TG32681092
7/34/15/*G/177	ANGLIAN WATER SERVICES LTD	WHOLE LICENCE (LN)		7000.000	30230.00		
	LINKED A	2 BORES AT THORPE RD,THORPE	P.W.S.	5000.000	22730.00	E CHALK	TG253 084
	LINKED B	2 BORES NR LOW TOWN,STRUMPSHAW	P.W.S.	2000.000	7500.00	E CHALK	TG341 068
	LINKED B	BORE AT STRUMPSHAW	P.W.S.	2000.000	7500.00	E CHALK	TG339 073
7/34/15/**/180	MESSRS E H MACK & SON	WHOLE LICENCE (LN)		45.6	1091.0		
		MARSH DYKES JOINING R YARE	SPRAY IRR	27.300	409.00		TG32610590
		RES S OF SURLINGHAM	SPRAY IRR	18.300	682.00	CRAG	TG308 063

LICENCE-NO	LICENCE HOLDER	SITE NAME	USE	TCMA	CH/DAY	G.W.U.	GRID REF
7/34/15/*G/185	JOHN BARCLAY & CO.	BORE OFF A47 E OF BLOFIELD	SPRAY IRR	17.000	450.00	E CHALK	TG34040984
7/34/15/*G/188	MR J H HARRIS	BORE AT HILL FM,SURLINGHAM	GEN. AGRIC	2.7	12.0	E CHALK	TG29880605
7/34/15/*G/189	P J,E R AND D J DRIVER	BORE NR ST MARY'S CH,SURLING'M	INDUSTRIAL	0.2	7.0	E CHALK	TG30590646
7/34/15/*G/190	T E MACK,ESQ	BORE AT CHURCH FM,SURLINGHAM	GEN. AGRIC	3.6	12.0	E CHALK	TG30620639
7/34/15/*G/196	R D HUTTON AND PARTNERS	20 WELLPOINTS NR LOW COMMON	SPRAY IRR	195.2	1652.0	GLAC. S/G	TG33500140
LINKED-6			W.T. (G-R)	8.000	500.00	GLAC. S/G	TG33500140
7/34/15/*S/197	J W H KEY,ESQ	R YARE AT STRUMPSHAW COMMON	SPRAY IRR	55.0	1500.0		TG34060563
7/34/15/*G/200	YARE FARM PARTNERSHIP	BORE AT SURLINGHAM	GEN. AGRIC	2.270	9.10	E CHALK	TG30350645
7/34/15/*G/202	ROYAL SOCIETY FOR THE	BOREHOLE AT STRUMPSHAW	AMENITY	285.000	2600.00	E CHALK	TG335-073
7/34/15/*G/204	C + A CARVER	BOREHOLE AT YELVERTON	SPRAY IRR	4.090	49.10	E CHALK	TG30420222
7/34/15/*S/205	T.S. & M.D. BAVORY,	WET CARR DYKE BUCKINGHAM	SPRAY IRR	9.092	100.00		TG364-058
7/34/15/*G/211	N F HEWITT	BOREHOLE - STRUMPSHAW	GEN. AGRIC	3.285	9.00	E CHALK	TG340 082
7/34/15/*G/214	A W STANSBY	BOREHOLE - HOLVERSTON	P.W.U.	0.766	2.10	E CHALK	TG308-032
7/34/15/*G/219	NORWICH UNITED FOOTBALL CLUB	BOREHOLE AT BLOFIELD	INDUSTRIAL	2.985	10.00	E CHALK	TG339 101

TOTAL NUMBER OF LICENCES ON INDEX = 41