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Aquatic Plant Diversity in Arable Ditches: Scoping Study

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Executive Summary

I. This report describes a scoping study conducted by the NERC Centre for Ecology and Hydrology on behalf of English Nature. The purpose of this study was to propose a series of characteristics for arable ditches that are associated with species rich plant communities and rare species (Section 1). Once identified, these characteristics were to be used to produce a decision-making protocol for identifying potentially valuable ditches for biodiversity. Although widely applicable to drainage channels on arable land within England and Wales, the study concentrated especially on Fenland.

II. The approach taken (Section 2) in the scoping study comprised three parts: a) a review of the literature on drainage channels (often present only as research reports); b) marshalling of data held by the CEH Biological Records Centre (BRC) on plants in drainage channels; and c) a survey of ecologists with long and wide experience on the flora of arable ditches. The paucity of work specifically on arable ditches necessitated the inclusion of some general information on ditches from grassland situations.

III. The results (Section 3) were reported separately for these three approaches and then compared to arrive at a general characterisation of a high quality arable ditch for flora (Section 4). The pre-eminence of water quality, and especially total available phosphorus, was underlined. However, the research showed that other factors had some predictive value for the occurrence of ditches with high aquatic plant diversity. These factors included geographical location and management status of the ditch, its dimensions, water-supply mechanisms and the soil/substrate present. Other factors such as crop type, freeboard and bank management were also discussed.

IV. The review of material was further summarised in a decision-making protocol that advanced a standard way of deciding where survey effort should be focused within Fenland. The protocol employed mapped information, data and expertise held by channel managers (notably Internal Drainage Boards) and the results of the reviews to provide a simple framework for survey and experimentation.

V. Finally the review material and protocol were used to advance 20 propositions on the factors governing high quality ditches for aquatic plants. These simple hypotheses are amenable to testing through surveys using the protocol or through experimentation.

VI. The text of the report is accompanied by a series of appendices presenting supporting material. The most important of these provides a summary of data held within BRC on high quality Fenland ditches. Other appendices provide i) a co-occurrence map of macrophyte richness in Fenland, ii) summaries of data on good arable ditches from particular surveys in Fenland, Romney Marsh and the Humberhead Levels, iii) a categorisation of species that might be used for quality assessment of drainage channels; iv) the text of a letter used to obtain expert input to the study; and v) a summary of environmental factors for a range of plant assemblages found in drainage channels (both arable and grassland).

Contents

1. Background

1.1 The need for surveys of arable ditches

The value of drainage channels (also known as ditches, dykes, sewers, fleets, eaus, rhynes, reens *etc*) for the conservation of macrophytes and aquatic invertebrates has become increasingly acknowledged over the past 30 years (Mountford in press). This habitat has been the subject of numerous surveys and reports commissioned by the conservation agencies and the Environment Agency. However, almost all this survey and research effort has been devoted to the channels of grazing marsh *i.e*. with stock-grazed grassland on one or both sides. Where surveys have included some arable land (*e.g.* Doarks 1984), the main conclusions have been to stress how crucial neighbouring land-use was as a factor in determining the biodiversity of the channel, and showing how generally species-poor the arable ditches were. Attention has mainly been devoted to those flatlands (*e.g*. the Broads and the Somerset Levels and Moors) where conservation interest resides not only in the channels, but also in the fields themselves (lowland wet grassland and breeding/wintering birds). In contrast, those areas such as Fenland and the Humberhead Levels, where arable farming is the overwhelming land-use, have seen negligible survey effort and what effort there has been is almost confined to the few grassland sites *e.g.* the washes of the Great Ouse (Cathcart 2002), Nene and Idle.

Despite this neglect, there have been indications that the open water-bodies of Fenland (and other arable flatlands) held important resources of biodiversity. From Fryer and Bennett's account of the pondweeds (1915) to surveys by Foster *et al.* (1990) on aquatic *Coleoptera*, it became clear that surprisingly rich communities might occur in the most unprepossessing areas. Limited investigation of arable ditch macrophytes did take place in Fenland during the 20th century, but largely as part of the compilation of county floras (Wells 2003) or as unstructured surveys whose results were contributed to local and national Biological Records Centres (Mountford 1968 onward – cited in Driscoll 1993).

It was not until the start of the 21st century that a partial systematic survey of ditches in arable Fenland was commissioned, and this study (Kirby and Lambert 2003) revealed how worthwhile attention to this habitat might prove. Taking three fairly representative areas of Fenland as case studies (Farcet Fen, Kingsland and Tick Fen), the authors found a Red Data Book stonewort (*Tolypella prolifera*), as well as numerous sites for the nationally scarce *Myriophyllum verticillatum*, seven county rarities and 23 plant species whose distribution in the UK is decidedly local. In addition their survey of the aquatic invertebrates revealed 37 Red Data Book or Nationally Scarce species (17% of the total inventory made during their fieldwork). Taken in the context of general impoverishment of biodiversity and drastic declines in many aquatic and wetland species (Mountford 1994; Preston *et al*. 2002b), the results of these surveys were enough to motivate renewed vigour in the study and survey of the arable ditch. Could important biodiversity resources have been overlooked, and might there be a pressing need to re-evaluate the arable flatlands?

English Nature (EN), supported by its associates in the Cambridgeshire Biodiversity Partnership, thus commissioned the NERC Centre for Ecology and Hydrology (CEH) at Monks Wood to conduct a scoping study as a means of reviewing what was known about this habitat, and proposing a way forward for survey, research and conservation effort. The present report describes the approaches taken within this scoping study together with the results of the review, and provides a decision-making protocol for evaluating drainage channels, with special regard to those in arable land. Several appendices marshal information from databases and reports to provide support for the conclusions of this study and to provide a background resource for future work by EN and its partners in Fenland.

1.2 Aims and Objectives

As outlined in the EN invitation to tender, CEH adopted three basic objectives for the scoping study on arable ditch biodiversity:

- *To propose a series of ditch characteristics associated with species rich plant communities or rare species***.**

- *To draft a decision-making protocol for determining potential biodiversity value of ditches.*

- *To propose an approach for further work, including locations for field survey in the Fenland, to investigate the potential of ditches within an arable landscape as reservoirs for rare aquatic plant species.*

To achieve these objectives, CEH undertook to deliver the following outputs:

I. The present project report, which should include:

a) Results of an analysis of arable ditch characteristics and their association with botanical biodiversity
b) A review of extant information on arable ditches, as present in published, manuscript and database sources.
c) A provisional protocol for the identification of "good" drainage channels in arable land.
d) A case study of how this protocol might be applied within one area of the Fenland basin.

II. A series of hypotheses on the relationship between arable ditch features and floristic diversity, that may be tested through survey and/or experiment and which could form the basis of a future research programme.

2. Methodology: Identifying Important Ditch Characteristics

In order to arrive at a body of channel characteristics associated with high-quality arable ditches, the study included a review of existing literature, marshalling of databases held by CEH and others and a limited survey of experts with direct knowledge of the assemblages of arable ditches. All these approaches had perforce to include some attention on grazing marsh ditches, since the vast bulk of information on the biodiversity of drainage channels referred to such ditches. However, such material is only included where there is evidence of its applicability to the arable situation.

2.1 Literature

The tremendous effort that was put into ditch survey in England between 1980 and 1995 is partially reflected in the references to this report (Section 5). There have been a number of attempts to draw this variety together and produce a consistent approach to the classification of ditch types, most notably by the Nature Conservancy Council (Anon 1989). Others (*e.g.* Mountford in press) have explored the correspondence of drainage channel assemblages to the *National Vegetation Classification* (Rodwell 1995) and other phytosociological systems. The habitat and its nature conservation value have been reviewed by Cadbury (1998) and Mountford and Sheail (1989), whilst others have focused on management of the ditch for drainage and nature conservation (McLaren *et al.* 2002; Newbold *et al.* 1989). Although all these works have relevance to the present study, the stress throughout is on the ditches of grazing marshes, a bias that is repeated as one turns to the regional surveys.

Compared with other areas with extensive networks of surface drainage channels, Fenland has had very little systematic attention, and almost all of this has concentrated on Cambridgeshire, with almost no consideration of the large area of Lincolnshire Fenland (see Driscoll 1993). Apart from Kirby and Lambert (2003) and their recent examination of "ordinary" arable Fenland, most research has covered the washlands (*e.g.* Cadbury *et al.* 1993, 2001; Cathcart 2002) or the major fen nature reserves (*e.g.* Friday 1997; Painter 1995 *et seq*.). It should be noted that the files of the Middle Level Commissioners include MS reports that deal with the biodiversity value of more important ditches in Fenland (Cave 2000). Those few areas of Fenland that did receive detailed study were amongst the last parts of the region to undergo intensive drainage and conversion to arable *e.g.* the ditches, ponds and grasslands of the Swavesey fens, where data from Cow and Overcote Fens include numerous arable water-bodies (Mountford *et al.* 1991, 1999).

Looking further afield for literature that addresses the arable ditch, there are a few examples in flatlands that underwent a major "arablisation" during the 20th century, especially in its latter half. Thus, the Humberhead levels have had surveys that include a high proportion of intensive arable land *e.g.* Page (1980) and Mountford and Sheail (1985). An interesting account of recent conversion to arable is given in Glading's (1986) account of the Pevensey Levels, and Driscoll (1982, 1983, 1984 and 1985) has made a number of surveys of parts of Broadland that have been subject to such land-use change. The Romney and Walland Marshes witnessed a huge change in the relative areas of arable and grassland during and following the Second World War (Sheail and Mountford 1984), and by the time of the ditch surveys (Latimer 1980; Mountford and Sheail 1982) *ca* 60% of these marshes were tilled.

There has been a remarkable focus on the ditches and rhynes of the Somerset Levels and Moors (*e.g.* Cox 1994; Hughes 1995; Walls 1996; Wolseley *et al.* 1984) and their extension north of the Mendips (Pollock *et al.* 1992). This intense activity, however, was almost confined to the grazing marshes, since there was a pressing need to inventory and monitor the new SSSIs and the Environmentally Sensitive Area (ESA) as they were declared during the 1980s. Standing somewhat outside this survey effort is the excellent analytical account of the ditches of North Moor, Higher and Lower Salt Moors and Southlake Moor made by Peter Raine (1980), which includes some arable ditches. Mountford and Sheail (1984) followed a stratified random approach to ditch survey, using soil types as their strata. This approach ensured that some arable ditches were included, but nonetheless >90% of the samples were in grazing marsh.

The full geographical extent of the drainage channel habitat in England and Wales was mapped by Marshall *et al*. (1978). Amongst those other areas indicated by this map and covered by surveys/accounts of the ditch flora, the concentration is once again almost solely on ditches in grassland. Thus within East Anglia, the main coverage of Broadland (Doarks and Leach 1990) hardly touches on arable land, and similarly the reports for North Norfolk (Reid *et al*. 1989), Suffolk and Essex (Wolfe-Murphy *et al*. 1991) address grazing marshes almost exclusively. In North Kent (Charman *et al.* 1985), Devon (Leach 1991) and Yorkshire (Birkinshaw 1991), the objective of the surveys was also to assess the value of the ditches in grassland. Studies in South Wales (*e.g.* Scotter *et al.* 1977) provide a more synoptic view of how the ditch habitat functions, but these investigations regard conversion to arable as the last stage in an impoverishment of the drainage channel habitat that begins with intensification of animal husbandry.

This refrain continues when the Dutch literature is consulted. Not surprisingly, the biodiversity value, ecology and management of the drainage channel have been addressed in greater detail in the Netherlands than anywhere else in Europe. For example, the classic account of the plant communities of ditches (de Lange 1972) has been complemented by excellent accounts of management impacts (Beltman 1984, 1987) and of the interaction between the channel itself, the ditch-bank and both environmental and management factors (Blomqvist 2005; van Strien *et al.* 1989).

Rather more useful for this scoping study were a series of more modern reports that looked at the drainage channel in terms of its role as a refuge for rare plants (notably *Charophyta e.g.* Stewart 2004; Williams and Stewart 2002) and invertebrate assemblages (Drake 2004). The changing valuation of the arable ditch is also reflected in the efforts to enhance their biodiversity (ADAS 2002) and to rigorously test the effectiveness of management practices on ditches within agri-environment schemes (McLaren *et al.* 2002).

Taken together with the original ground-breaking studies on the ecology of the drainage channel in Britain conducted in UWIST (Marshall 1981, 1984; Wade 1977), these works provide a detailed picture of the functioning of this habitat. These works were critically read and material relevant to this scoping study on arable ditches abstracted. Nonetheless, the presence of a "research-gap" identified by EN in commissioning the present project was confirmed. Although one can infer from these surveys and papers what might be the characteristics of arable drainage channels that can support diverse aquatic plant assemblages and sensitive species, this has to be done with real caution. There are so few published accounts that deal specifically and in detail with arable ditches that much of the characterisation of "good arable ditches" and the derivation of a decision-making protocol must depend on unpublished data (see Section 2.2).

2.2 CEH Databases

The primary means of assessing the distribution and composition of high quality arable ditches in Fenland was to consult the main botanical database in the Biological Records Centre (BRC) at *CEH* Monks Wood. The source material for this database includes.

- Data gathered for the *New Atlas of the British and Irish Flora* (Preston *et al.* 2002a).
- Databases used in *Aquatic Plants in Britain and Ireland* (Preston and Croft 1997), including the *Rivers Environmental Database* compiled for rivers, drains and ditches in the *NRA* (now *EA*) Anglian Region.
- Datasets on grazing marsh channels assembled over the past 30 years, with sites annotated where the channel lies within arable land. Much of this material reflects the work of CEH/ITE and EN/NCC (see reference list in Section 5).

The primary search of the database focussed on some 65 species (listed in the preamble to Appendix 1) whose presence in an arable ditch is believed to indicate a higher quality habitat. This core list of 65 was itself edited from a guidance note prepared by Chris Newbold (then EN freshwater expert) and one of the present authors (JOM), originally presented as part of a report to the Environment Agency and the RSPB (Mountford *et al*. 1998). The relevant part of this guidance note is included in the present report as Appendix 5. These records of individual species were indexed for Fenland, sorted by site and then presented as a catalogue (Appendix 1) including not only the information present within the *BRC* database but also information on soils, ditch-status and where within the Fenland landscape the ditch was located (Fenland margin, main body of the Fenland *etc*). Comparable listings were prepared for the Humberhead Levels and the Romney/Walland Marshes, but these are not included in the present report.

The material in the main *BRC* database tends to be fairly summary in nature, recording species, grid reference, date and locality (sometimes with an indication of habitat), which may alone be insufficient to formulate the determining features of a "good arable ditch". As mentioned above, the material from the central database for each ditch site was augmented with information derived from other sources, including soil maps (Anon 1983), land cover (Anon 2001) and local knowledge. Although less geographically comprehensive, it was therefore decided to also use databases derived from drainage channel surveys, where fuller information on the environmental features of ditches was included. The work of one of the present authors (JOM) was consulted for Fenland (1968 to the present), the Humberhead Levels (1983, 1984 and 1986), Broadland (1983 and 1994-1998), Somerset Levels and Moors (1982 to the present) and the Romney and Walland Marshes (1981-1990). Data derived from other surveys (see Section 2.1) were present in the main *BRC* database, but did not generally identify whether the ditch ran through grassland or arable land, hence requiring resort to the printed reports.

Such databases record specific instances of high quality arable ditches and their features. A further set of databases held by *BRC* were consulted on the ecological characteristics of those species in the British flora that occur within drainage channels *e.g*. Benstead *et al*. 1997; Fitter and Peat 1994; Grime *et al*. 1988; Hill *et al*. (1999, 2004), and Newbold and Mountford (1997). Amongst those characteristics that were deemed most relevant were the Ellenberg indicator values (Hill *et al.* 1999). Clearly, most ditch species would be expected to have an **F** (water/moisture) indicator value of 10 or above *i.e.*

10 Indicators of sites occasionally flooded but free from surface water for long periods

11 Plants rooting under water but at least for a time exposed above or floating on the surface

12 Submerged plants, permanently or almost constantly under water

Those ditch species with lower **F** values are likely to be confined to the banks, or transient with the channel proper. However, within drainage channel vegetation, there is much more variation in the indicator values for reaction (**R**), nitrogen/fertility (**N**) and, to some extent, salt/salinity (**S**). Revised indicator values for the UK are presented in Table 2.1 for those species that were used in the search for arable ditches of high quality (omitting the *Bryophyta* and stoneworts). Although there is an acknowledged risk of both subjectivity and tautology in using this selection of species to define the attributes of sites of high quality, some trends can be observed in the values. There are a few ditch species preferring weakly to moderately basic situations (**R** = 8) and others moderately acid situations (**R** = 4), but most of the discriminating ditch species occur in circumneutral situations. In terms of salinity, most species are absent from saline sites, though there is a small group that will tolerate some salt input (**S** ≥ 1). Most interestingly, there is a strong representation of species from less fertile and intermediately fertile sites (**N** ≤ 5), with relatively few species reflecting richly fertile waters and none at all from extremely rich situations. Such trends in **N** indicator value for ditch species correspond very well with the trophic classification developed by English Nature (Newbold and Palmer 1979).

Table 2.1 **Ellenberg indicator values for water (F), reaction (R), nitrogen (N) and salt (S) for less common macrophytes and marginal species** (after Hill *et al.* 2004)

	Ellenberg Indicator Values			
Species	**F**	**R**	**N**	**S**
Alisma lanceolatum	10	7	7	0
Alopecurus aequalis	9	4	7	0
Althaea officinalis	7	8	4	2
Apium inundatum	10	6	4	0
Baldellia ranunculoides	10	6	2	0
Butomus umbellatus	11	7	7	0
Callitriche hamulata	11	6	5	0
Callitriche obtusangula	11	7	6	1
Callitriche platycarpa	10	7	7	0
Carex pseudocyperus	9	6	6	0
Carex vesicaria	10	5	4	0
Catabrosa aquatica	9	7	7	1
Ceratophyllum submersum	12	8	8	2
Cladium mariscus	10	8	4	0
Eleocharis acicularis	10	7	5	1
Eleogiton fluitans	11	4	2	0
Galium palustre elongatum	9	5	4	0
Groenlandia densa	12	8	5	1
Hottonia palustris	11	7	5	0
Hydrocharis morsus-ranae	11	7	7	0
Hydrocotyle vulgaris	8	6	3	1
Juncus bulbosus s.l.	10	4	2	0
Juncus subnodulosus	9	8	4	0
Menyanthes trifoliata	10	4	3	0
Myosotis secunda	9	5	4	0
Myriophyllum alterniflorum	12	5	3	0
Myriophyllum verticillatum	12	7	7	0
Oenanthe aquatica	10	7	6	0
Oenanthe fistulosa	9	7	6	0
Oenanthe fluviatilis	10	8	6	0
Potamogeton alpinus	12	6	5	1
Potamogeton berchtoldii	12	6	5	0
Potamogeton coloratus	11	8	5	0
Potamogeton crispus	12	7	6	1
Potamogeton friesii	12	7	5	0
Potamogeton gramineus	12	6	3	0
Potamogeton lucens	12	6	6	0
Potamogeton natans	11	6	4	0
Potamogeton obtusifolius	12	6	5	0
Potamogeton perfoliatus	12	6	5	1
Potamogeton praelongus	12	7	5	1
Potamogeton pusillus	12	7	6	1
Potamogeton trichoides	12	7	6	0
Potamogeton x zizii	12	6	4	0
Ranunculus aquatilis s.s.	11	7	5	0
Ranunculus baudotii	11	7	6	4
Ranunculus circinatus	12	7	7	0
Ranunculus flammula	9	5	3	0
Ranunculus hederaceus	10	5	5	0
Ranunculus lingua	10	6	7	0
Sagittaria sagittifolia	11	7	6	0
Samolus valerandi	8	8	5	2
Schoenoplectus tabernaemontani	10	8	7	3
Senecio paludosus	9	7	6	0
Sium latifolium	10	7	7	0
Sparganium emersum	11	7	6	0
Stellaria palustris	8	6	4	0
Stratiotes aloides	11	7	6	1
Utricularia vulgaris s.l.	12	6	4	0

2.3 Survey of experts

A standard letter was sent to ten scientists who had studied or surveyed drainage channels for many years (text of letter included in Appendix 6), of which seven responded verbally or in writing (see acknowledgements). The purpose of this letter was, in effect, to convene an informal expert working group to pool ideas and experience, including not only the conclusions they had described in papers and reports, but also (possibly more importantly) to discuss their impressions of "good arable ditches". Such an approach was felt necessary since a) there exists so little written information on the arable ditch, and b) what information is present may be obscured within accounts that focus overwhelmingly on the drainage channels of grazing marshes and other grassland situations.

Although the survey was not structured as a questionnaire, the experts were invited to address 13 particular issues that had been identified by Kirby and Lambert (2003), the EN project advisory group and the CEH scientists as potentially important in determining where ditches might occur in arable land with less common macrophytes and marginal species. Their responses are thus reported, where possible, in terms of these 13 areas of interest.

2.4 Deriving a protocol to identify high quality ditches

The characteristics of a "good arable ditch" were thus derived from many disparate sources, some qualitative and others quantitative, some detailed and others relatively superficial. Consequently, a full formal analysis of all the material used in this study was not possible, and attention instead concentrated on deriving conclusions from each element of the review and then comparing these conclusions to seek out common themes and consistencies, as well as areas where information was clearly mixed and ambiguous.

The scoping study required that CEH produce a set of "decision rules" at a range of scales for determining the potential biodiversity value of drainage channels, and that this be presented a protocol (or decision tree) to guide EN *etc* in their assessment of ditches. These rules were based upon information derived from maps, from local and national floras, from databases of ecological attributes and from analysis of survey data.

3. Results

3.1 Literature

Study and survey of the vegetation and conservation value of drainage channels has been largely confined to grassland situations, with arable ditches covered only in passing and for comparative purposes. Those studies that do deal with arable land tend to focus on the general impoverishment of the ditch flora following arablisation (Driscoll 1982, 1985; Mountford and Sheail 1989). This marked bias in the literature is especially important in attempting to identify the characteristics of high-quality arable ditches, since attention is paid to the generality of arable ditches (species-poor) and not to those relatively few, but locally vital, cases that are refugia for uncommon macrophytes. In Broadland, Driscoll (1985) described the flora of arablised ditches as typified by narrow-leaved pondweeds *e.g. Potamogeton crispus, P. pusillus* and *Zannichellia palustris*. Amongst many similar studies within grazing marsh landscapes (see references – section 5), Mountford and Sheail (1982, 1984, 1985 and 1989) showed that in the Humberhead Levels, Romney and Walland Marshes and Somerset Levels and Moors, arable ditches were of three broad categories (Mountford in press):

- Eutrophic deep major ditches with *Potamogeton pectinatus*, *Lemnaceae* and filamentous algae.
- Field ditches and intermediate drains dominated by tall emergents with a very poor representation of floating and submerged species, except *Lemna minor* in shallow water.
- Field ditches that are at least summer-dry and dominated by *Urtica dioica, Galium aparine, Elytrigia repens, Holcus lanatus etc* in a community resembling a rough grass verge.

A detailed local investigation of recently arablised ditches was conducted by Glading (1986) as part of his survey of the Pevensey Levels. Here arable ditches were almost entirely allocated to a single end-group of the analysis, and there were no arable examples in any of the species-rich end-groups. Ditches in arable land that had recently converted from grassland were dominated by *Sparganium erectum* and *Alisma plantago-aquatica*, with associated species: *Agrostis stolonifera, Juncus articulatus, J. inflexus, Phragmites australis* and *Potamogeton natans*. Amongst more uncommon species, a few arable ditches continued to support small populations of *Butomus umbellatus, Potamogeton acutifolius* and *Ranunculus circinatus*, but *Hydrocharis morsus-ranae* was absent.

The well-structured account of McLaren *et al*. (2002) categorises ditches in terms of whether they are in arable or grassland situations, by depth (>60cm, <60cm or <10cm) and then by whether the vegetation cover is open, mixed or largely emergent-dominated. The seven arable types were discussed in terms of their distribution, ESA tiers, management regime and association with particular aspects of biodiversity, including flora (aquatic, emergent and marginal). Despite this rigorous and clear analysis, the connection between high botanical quality (presence of numerous uncommon plant species) and particular ditch characteristics cannot be made ambiguously from this study. Most of the arable ditch classes were unsurprisingly best represented in the lower tiers of ESAs.

The clearest determinant of a high-quality ditch, whether arable or grassland, is water of at most moderate (mesotrophic) fertility (Cadbury 1998). Species with Ellenberg **N** values of <6 are regularly cited in the literature as either declining in response to organic pollution or as species indicating the most important ditches for macrophytes. Working with grassland ditches, Cathcart (2002) demonstrated how, in high nutrient situations, the vegetation succession produced a dense cover of mat-forming *Lemnaceae*. Such high nutrient levels overload the buffering capacity of the habitat for phosphorus. Locally, certain factors may serve to buffer the background high nutrient levels, allowing earlier seral stages to persist. Such local factors included:

- binding of phosphorus by clay;
- reduction in nutrient concentrations with distance from source; and/or
- uptake by macrophytes or phytoplankton.

Very similar patterns are recorded for Stoneworts (Stewart 2004; Williams and Stewart 2002), stating that the richest assemblages and rarest species occur where there is low available phosphorus, where the levels of dissolved nitrogen are low and where the water has very low turbidity. Data for specific *NVC* types where less common macrophytes are important components reinforces this relationship. Thus the **A11** *Potamogeton pectinatus-Myriophyllum spicatum* community is said to occur under a pH range of 7.0-8.5, with 30-125 mg/l $CaCO_3$ and conductivities of 200-1000 µmho, whereas the more northern and western **A13** *Potamogeton perfoliatus-Myriophyllum alterniflorum* community is more typical of pH <7.0, <25 mg/l $CaCO_3$ and conductivities below100 µmho (Palmer 1992; Palmer *et al.* 1992). Data for Broadland vegetation with frogbit and water-soldier (referable to **A4**) reflects mesotrophic to locally eutrophic waters that are calcareous with relatively high values for both inorganic nitrogen concentration and Redox potential (Table 3.1).

Table 3.1 **Vegetation related to A4 *Hydrocharis morsus-ranae Stratiotes aloides* community**: pH, nutrient levels and Redox values for drainage channel water and sediments - measurements made in 1980 (after Wheeler and Giller 1982)

a) Water

Water chemistry variable	January	July
Soluble reactive phosphorus (mg l^{-1})	0.05	0.03
NH_4-N (mg l^{-1})	(no data)	0.15
NO_3-N (mg l^{-1})	2.41	1.32
pH (annual range 6.4-7.6)	6.4	7.5

b) Sediment

Sediment chemistry variable	January	July
Soluble reactive phosphorus (mg l^{-1})	1.44	1.08
NH_4-N (mg l^{-1})	16.2	11.52
NO_3-N (mg l^{-1})	7.68	15.52
Mean pH 10cm below surface (range)	6.5 (6.2-6.6)	6.8 (6.6-7.0)
Mean Redox value (mV) 10cm below surface corrected to pH 7 (range of uncorrected values)	61 (-30 to +100)	50 (-80 to +81)
Cations (mg l $sediment^{-1}$)		
Calcium	300	395
Magnesium	704	94
Sodium	180.4	293.2
Potassium	39.3	45.2

Probably the most relevant research to the problem of target levels for phosphorus and nitrogen in ditches has been conducted at the University of Wageningen (Netherlands), and this work has been used by British ecologists attempting to derive such targets for ditch systems that have a conservation designation (Mainstone 2005). Table 3.2 summarises the most detailed available information (for both nitrogen and phosphorus) on variation in a) critical load thresholds and b) presumed management targets. These thresholds relate to situations that differ in terms of substrate, depth and flow, but make no mention of whether the ditch might be in an arable or grassland situation. Thus for the purposes of these thresholds, the "average" ditch was defined as having a clay substrate, being 0.5m deep and with a flow rate of 30mm day^{-1}. Minimum values were related to sandy substrates, shallower ditches and lower flow rates, whilst maximum values relate to clay and peat substrates, deeper ditches and higher flow rates (Arts *et al*. 2002, van Liere *et al*. in press).

Table 3.2: An overview of critical thresholds in ditches, with tentative management targets. (From van Liere *et al.* in press – as quoted by Mainstone 2005)

Parameter	Value	Minimum		Average		Maximum	
		P	N	P	N	P	N
Load ($g\ m^{-2}\ yr^{-1}$)	Critical threshold	1.8	12.1	4.7	21.9	10.2	43.8
	Management target	0.9	6.0	2.3	10.9	5.1	21.9
Concentration ($mg\ l^{-1}$) [See note below]	Critical threshold	0.19	1.3	0.23	1.4	0.42	3.3
	Management target	0.09	0.6	0.11	0.7	0.21	1.6

Note: As summer mean, total nitrogen or phosphorus – these values were simulated for illustrative purposes but are not operationally applicable due to high variability of concentrations in the field.

In the great majority of cases, the literature does not distinguish trends in the nutrient regime of high quality ditches between arable situations and grassland. Hence, although the trophic level for "good arable ditches" may be inferred from these sources, the literature is not useful in indicating where such situations might exist in the Fenland landscape.

Alkalinity is a less sure determinant of species-rich ditches, with distinctive assemblages in both highly alkaline (*e.g.* including many stoneworts) and in markedly acidic situations, although most ditch species are preferential for mildly acidic to circumneutral waters. Again, the literature does not pay attention to high-quality arable ditches in its discussion of alkalinity.

Many of the less common macrophyte species are relatively light-demanding, competing poorly where tall emergent species dominate, and are thus excluded from such situations (Mountford 1994). In some instances, such as Charophyta, early seral stages are preferred where recent management has suppressed competition (Stewart 2004). McLaren *et al.* (2002) stress the importance of regular, even if infrequent, management in order to prevent impoverishment of the flora through dominance by reed or succession to terrestrial vegetation. Working in grazing marshes, Mountford (in press) distinguished twenty ditch vegetation assemblages whose occurrence was principally determined by the management regime and water-depth, with the richest types occurring in field ditches with grazed margins and which were liable to slubbing-out at infrequent intervals (See Appendix 7).

Several workers on ditch vegetation have suggested that the location of the ditch within the landscape and relative to the drainage hierarchy may be crucial. Thus, Stewart (2004) states that the best ditches for stoneworts in Fenland tend to be close to the edge of the basin or adjacent to fen islands, presumably where more calcareous water feeds these areas. He further states that within a ditch network, good stonewort ditches are very often "somehow isolated" from the main drainage system, particularly where such ditches are groundwater-fed from underlying gravels.

The survey of Kirby and Lambert (2002) provides much more specific information on the features of high quality arable ditches. Appendix 2 provides a summary of the characteristics (substrate, depth, width and water quality) for three areas of arable Fenland: Farcet Fen (Table A), Kingsland (Table B) and Tick Fen (Table C). Amongst those arable ditches where uncommon macrophytes or marginal species occur, the authors distinguish the highest quality ditches from those with moderate quality. The typical water depth for the highest quality ditches was just less than 1m, and (eliminating one exceptional drain) the typical width was *ca* 3.5m. The water quality, in terms of clarity/turbidity, was good to excellent, with only 16% of samples poor or turbid. In about half the cases, the substrate was organic, with the remaining samples equally divided between mineral and marl. Rather less rich (though still with value for biodiversity) ditches were slightly shallower but broader, and with poorer water-quality (nearly half moderate or poor) and where mineral substrates were commoner but marl less frequent. Both categories were clearly separated from the poorer ditches, which were shallow and narrow (or more rarely very wide and deep) and of poor water quality with very few marl situations. From this survey, there is also evidence that the best ditches are near the edges of the fenland (or close to fen islands) and that they tend to be removed from the areas receiving nutrient-rich water.

3.2 CEH Databases and Field Survey results

Appendix 1 contains a catalogue of those ditches where uncommon macrophytes have been recorded in Fenland, with trends in the data summarised in the table of Appendix 1A. Some 200 ditches were included on this catalogue, varying from discrete field ditches to main drains (*e.g.* Moreton's Leam or the Counter Drain to the Ouse Washes) that run through several 10km squares.

Certain soil types seem to have greater densities of high-quality ditches, though distribution of soil type is also related to position in the Fenland landscape, such that some confounding of soil and location cannot be avoided. Appendix 2 provides a map showing the co-occurrence of less common macrophytes in Fenland. There is a clear association between high co-occurrence of macrophytes and sites that are either near the upland margin or associated with the main rivers entering the Fenland basin *e.g.* Witham, Welland, Great Ouse and Nene. The main washlands (Great Ouse and Nene) and fen relicts (Wicken and Wood Walton) are clearly indicated, though many of the ditches in these locations are in grassland or rich fen situations.

From this database, the best soils for uncommon macrophytes and marginal species are apparently humic-alluvial gley soils (Downholland 1 association), alluvial gley soils (Midelney and Wallasea 2 soil associations) and earthy eutro-amorphous peats (Adventurers' 1 and 2 associations). Also important are argillic humic gleys (Ireton association) and calcareous humic gleys (Peacock and Clayhithe soil associations). Those types of groundwater gley that are commonest near the sea (*e.g.* calcareous alluvial gley soils – Wisbech association) have markedly few high quality ditches.

In terms of location within the Fenland basin, most of the best ditch sites are shown to be at or near the Fenland margin (or close to a fen island), except the ditches on humic-alluvial gley soils, which are commonest in the main body of the Fenland.

The clearest pattern in the ditches from the catalogue is related to status within the drainage hierarchy, with intermediate and roadside drains (not arterial drains and managed by IDBs rather than EA) having far better representation of uncommon macrophytes. Field ditches and main arterial drains appear less rich. However, certain caveats need to me made. Roadside ditches are more liable to be surveyed than those remote from public access in arable fenland. Intermediate and major ditches (as opposed to field ditches) are also easier to identify and name on a map, as well as being more likely to be surveyed, than are field ditches with little importance to drainage managers *etc*.

The definition of location, ditch status and dimensions *etc* can be refined by comparison with ditch surveys, such as those by Kirby and Lambert (2002 – see section 3.1) and Mountford and Sheail (1982 and 1985). Many arable ditches were included in the latter surveys of the Romney and Walland Marshes and the Humberhead Levels, though of these only 19 arable ditches (Appendix 4) could be defined as higher quality, two of which are samples from the Royal Military Canals and thus unrepresentative of arable levels. The mean ditch width (2.66m) for these samples is rather narrower than those from the Kirby and Lambert survey, but the mean water depth is almost identical (0.94m). These ditches were relatively unshaded and unfenced. The soil types were varied, but with markedly few peaty sites and a good representation of pelo-alluvial gleys (Romney – similar to some Fenland sites) and humic-sandy gley soils (Humberhead – a type poorly represented in the Fenland catalogue). Water pH was circumneutral to mildly acidic or mildly alkaline (mean pH 6.94). In terms of management, these arable ditches are (not surprisingly) ungrazed, but usually either clearly managed in the past 1-5 years or, as the responsibility of IDBs, on a regular management schedule, even if there was no apparent evidence of recent ditch cleaning. In contrast to the Kirby and Lambert survey (and the Fenland catalogue derived from BRC data), there is a relatively equal balance between field ditches and more important ditches, reflecting a more intensive management regime of field ditches in the Humberhead Levels. High quality field ditches and major drains in these surveys were principally close to the upland margin.

3.3 Expert Opinion

The survey of experts cannot be considered as comprehensive and entirely objective nor, given the limited number of consultees, sufficiently robust to allow generalisations to be made with absolute confidence. However, not only was there consistency in the responses to the 13 questions (Appendix 6) but these opinions also largely agreed with the trends revealed from the literature and databases. Admittedly, there is a degree of confounding in that the experts consulted included many of the authors of the literature and the contributors to the databases! Nonetheless this survey produced very useful insights into the salient features of a high quality arable ditches.

Water quality was identified by all respondents as much the most important determinant of the better arable ditches. The most species-rich examples are mesotrophic (rarely mesotrophic-eutrophic) with low levels of dissolved nitrogen and phosphorus, associated with relatively low conductivity and low turbidity. Those respondents who provided quantitative definitions suggested that "good" ditches had <0.05 mg/l of total available phosphorus whilst "bad" ditches had >0.15 mg/l – intermediate levels might have high or low quality assemblages of macrophytes depending upon other interacting factors. For example, water quality might interact with location such that situations where inputs from arable drainage or rivers are somehow diluted by less polluted water may support richer ditch assemblages than would otherwise be expected. In coastal levels inputs of saline water, *e.g.* through "leaky" flood-defences along tidal rivers, reduce overall diversity of the macrophyte assemblage, though providing suitable conditions for a limited flora of specialist plants. Respondents agreed that pH strongly affected the composition of the ditch flora, but was not linked to species richness or assemblage quality *per se*. Some flow in the ditch may help prevent eutrophication.

The water-supply mechanism (Wheeler *et al.* 2004) is also a key factor, with general agreement that input from upwelling groundwater is associated with the best arable ditches. Sites nearer the fenland margin might also benefit from upland runoff especially where this hinterland to the ditches is not under intensive arable. Indeed very locally, sites receiving such surface water input appear higher in macrophyte quality than those with groundwater supply. There is a clear association between water-supply mechanism and substrate – high quality sites were frequently said to be commonest on firm gravelly or sandy substrates. Many good arable ditches also exist in clayey situations. Some respondents described peat substrates as less favourable, though a distinctive flora is associated with mesotrophic (or oligotrophic) water on organic soils.

Though mentioned by only a few respondents, location within the basin was seen as important, with the best arable ditches being found along the upland margin of the flatlands or close to the islands within the basin. Again there is interaction between the varying factors influencing the occurrence of good arable ditches. The source of the water in ditches is important, both in the fenland margin and within the main body of the basin. Thus many main drains carry upland water directly through the reclaimed marsh to the rivers, separating them from the fenland proper. The water quality of these drains may be enriched by upland inputs or may be buffered from eutrophic water draining from the intensive arable fenland.

The relationship between site quality and status or size of the ditch (field ditch, IDB or main drain) is complex. Some high quality ditches are important within the drainage hierarchy, whereas other rich ditch assemblages appear to survive because the ditch is minor or subsidiary and thus receives lower levels of nutrient inputs. Still others are intermediate status ditches where regular maintenance reduces competition and where macrophytes are then able to recolonise from field ditches that feed into such intermediate drains. Better arable ditches thus occur over a range of statuses with variation in precise community composition in relation to the status of the site *i.e.* "good big ditches" may have a flora distinct from "good little ditches". Most experts stated that drainage channels with a diversity of macrophytes are usually relatively wide, though including shallow and deep examples. Freeboard also appears important, since deep dug ditches (high freeboard) tend to suffer shade from the banks and some authorities felt a freeboard of as little as *ca* 30cm was preferable.

Arable land is by no means uniform and different crops have different schedules of cultivation and varying requirements for nutrients and water. All respondents who referred to crop-type agreed that cultivation of beet or potatoes was associated with poor ditch vegetation, and that almost all the best sites were found adjacent to wheat or other cereal fields.

Other than water quality, ditch management is repeatedly mentioned as the chief influence on quality of the macrophyte assemblage. The preferred regime is light ditch cleaning at regular but infrequent intervals, keeping the assemblage at an early seral stage. Vegetation cutting and skimming of the sediment surface at the same time of year for each management event seems best, but this should not be annual. Water levels may vary but certainly should not be allowed to dry out and preferably should be as close as possible to bank-full (consistent with the requirements of the crop). Management of the banks is also relevant – where retaining a fringe of coarse herbaceous vegetation may aid aquatic diversity by intercepting spray drift and producing sufficient shade of the water margin to suppress aggressive emergent species to the advantage of the submerged and floating species. However, heavy shade, especially of woody plants, is uniformly associated with poor sites for aquatic macrophytes.

Although the experts focussed most of their responses on the thirteen areas of interest listed in the original letter, several added points that were not covered in the "survey of opinion". Two particular comments were made by more than one respondent. Berms have been advocated as useful tolls for diversifying ditch plant communities by providing a range of depths and an intermittently flooded zone. However, in the arable situation berms may be not be advantageous for ditch macrophytes since they provide a "bridgehead" for emergents that may invade and dominant the channel. Such berms may need to be engineered or managed to prevent such encroachment.

Possibly the key general point made by the consultees was that arable ditches (and indeed all drainage channels) vary greatly in their flora from year to year. Thus sites that have supported important populations of uncommon macrophytes or rich assemblages over a long period may have occasional (or even frequent) years when the special plants are rare or apparently absent and the site appears of low quality with abundant filamentous algae *etc*. The causes for this variation are uncertain and rather intriguing, and make it essential that the biodiversity value of a ditch be assessed over a number of years and not on the basis of a single visit.

4. Discussion – What makes a "good arable ditch"?

4.1 Review and protocol for identifying high quality ditches

Three types of source have contributed to attempting a characterisation of what enables a ditch in arable land to support a rich macrophyte flora *i.e*. literature (both published and as science reports), databases and the experience and judgement of other scientists. From this material we might summarise the situation of a "good arable ditch" in Fenland as:

<u>WATER QUALITY</u>

- ❑ *Phosphorus*: Total available phosphorus ideally <0.05 mg/l, though values up to 0.1 mg/l are permissible and on the clay and peat ditches of Fenland, levels might reach 0.2 mg/l for short periods.
- ❑ *Nitrogen*: Total nitrogen should if possible be <0.7mg/l, though levels to 1.6 (rarely) 2.4 mg/l may be tolerable.
- ❑ *pH*: Variable, though most macrophytes occur over the range 6.5-7.5, higher or lower values may be required for obligate calcicole and calcifuge macrophytes.
- ❑ *Calcium carbonate*: As with pH, values may vary depending upon the target macrophytes. Typically 25-125 mg/l, but for more mesotrophic assemblages, values of <25 mg/l are preferable.
- ❑ *Conductivity*: Similarly, for the majority of macrophyte species, the range should be 200-1000 μmho, but certain assemblages will only occur where conductivity is <100 μmho.
- ❑ *Turbidity*: clarity of the water should be good to excellent.

<u>SOILS and SUBSTRATES</u>

- ❑ *Soil*: the majority of high quality arable ditches in Fenland occur on groundwater gley soils, including humic-alluvial gleys, humic-sandy gleys and more rarely alluvial gleys. However, there is a distinct grouping of macrophytes that occur preferentially on organic soils (earthy eutro-amorphous peats).
- ❑ *Substrate*: The pattern for substrates corresponds to the soils, with more "good ditches" on gravel/sand or clay, but a significant minority having an organic substrate. The special situation of a marl substrate is markedly rarer, but often supports a rich ditch flora.

<u>LOCATION and WATER-SUPPLY MECHANISM</u>

- ❑ *General location*: At the edge of the Fenland basin or closely adjacent to a major fen island – not close to the coast.
- ❑ *Specific location*: the ditch should be somehow isolated from both main rivers and from blocks of intensive arable. These situations might be in the ultimate branches of the drainage hierarchy or where eutrophic water bypasses the site in arterial drains. There is some evidence that "older ditches" (*i.e.* whose origin might be as streams or as early attempts at drainage) have a richer macrophyte flora.
- ❑ *Water-supply mechanism*: A significant proportion of high-quality ditches are groundwater-fed with nutrient-poor (and often calcareous) water. Such situations are overwhelmingly close to the Fenland margin.

<u>DIMENSIONS and MANAGEMENT</u>

- ❑ *Width*: moderately wide ditches appear best (*i.e.* 2.5-3.5m wide), though some excellent ditches occur in the range 4.0->8.0m wide. Narrower ditches are generally poor, probably due to shade from the bank and their low status in the drainage hierarchy often resulting in their drying out in mid-late summer.
- ❑ *Depth*: moderately deep ditches (mean maximum depth *ca* 1.0m) are preferred – shallower are prone to drying out, whilst deeper situations are associated with eutrophic main drains.

- *Freeboard etc*: As low as possible (*i.e.* 0.3-1.0m), though the demands of arable agriculture make lower freeboards very uncommon. Low freeboards are especially important in narrower field ditches.
- *Drain status*: generally neither EA main drains nor field ditches, many "good ditches" are secondary (or intermediate status) ditches managed by an IDB or adjacent to a road or drove.
- *Channel management*: light slubbing out at intervals of *ca* 2-6 years is much to be preferred, without use of aquatic herbicides *etc*. Slubbing out should produce an early seral stage but must not remove the entire accumulated sediment with its propagules *etc.*
- *Bank management*: eliminate scrub, but retain a fringe of tall herbaceous vegetation on the bank top to screen against spray drift and create light shade on the channel margin (suppressing competitive tall emergent species).
- *Crop type*: preferably cereal (especially wheat) and not root crops with a heavy demand for water and nutrients.

This review of the state of knowledge on arable ditches may be reformulated into a decision-making protocol, as required by the present project. A first attempt at such a protocol is presented in Figure 4.1. The protocol takes the criteria outlined in the above review of ditch characteristics, and attempts to order them in such a way as they might be employed to decide on where field surveys might be targeted.

I. Thus, the protocol begins with a desk exercise whereby information that might be readily gained from maps (Ordnance Survey, CEH Land Cover Map, Soil Survey *etc*) is marshalled to delineate areas of Fenland or individual ditches that should repay survey. Where the questions listed in the desk exercise cannot be answered unequivocally (**Yes**/**No**), the protocol assumes that a short consultation (signified "**?**") with local IDBs or landowners may be required.

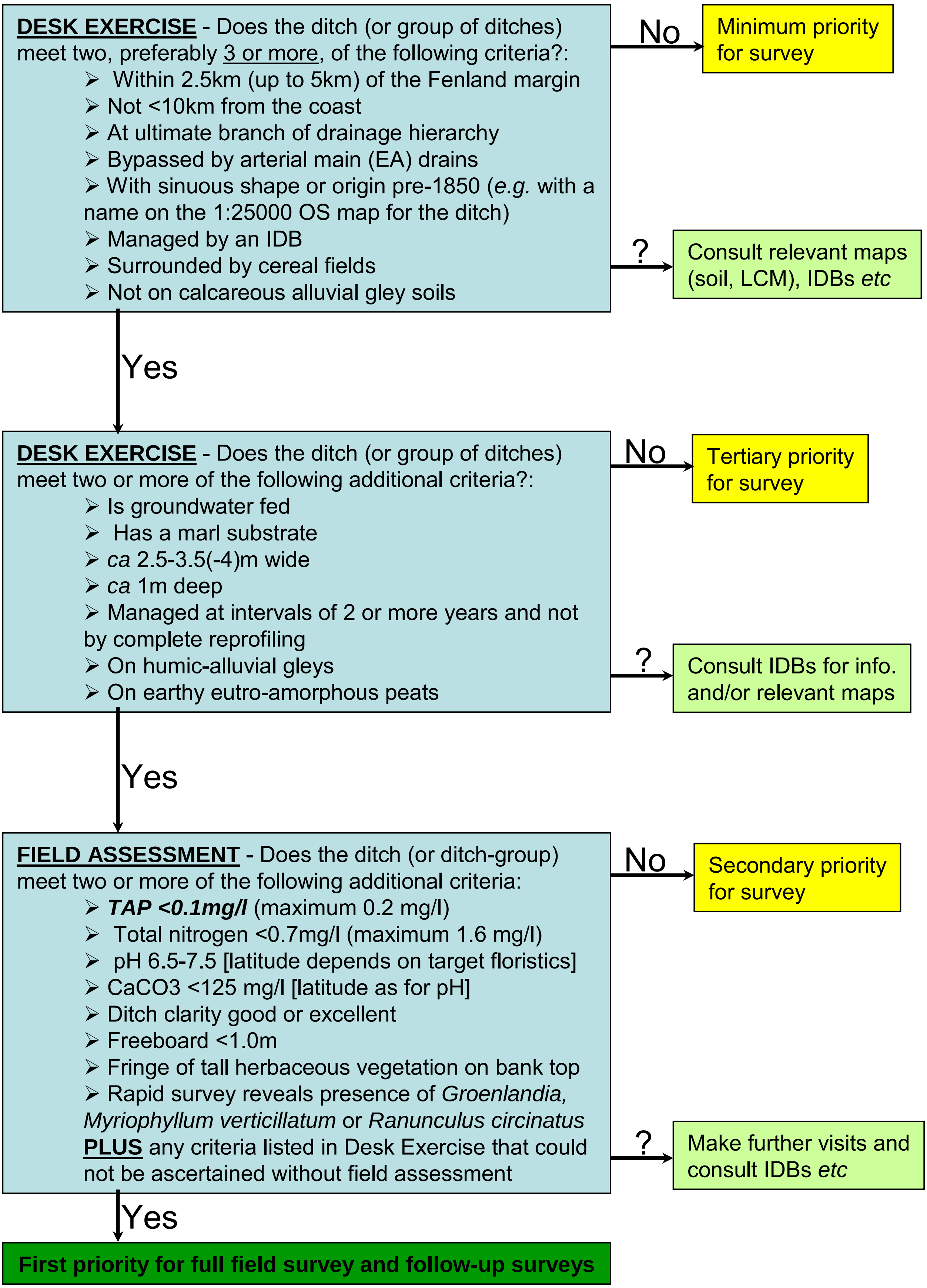
II. The second stage should also be a desk exercise, but involves not only mapped characteristics but information that might require more lengthy consultation with the relevant IDBs, landowners or others with local knowledge.

III. The third stage would require rapid reconnaissance field assessment, including the taking of water samples for analysis and some brief survey of the macrophyte flora. Some further consultation with the managers of the channel would be required to check whether the situation observed during the reconnaissance was typical over several years.

The protocol could be used to prioritise areas for detailed field survey. Thus ditches (or groups of ditches) passing all stages of the protocol would be given maximum priority for field survey of both vegetation (macrophytes and emergent marginal) and environmental variables. Those ditches meeting the conditions of the desk exercises but not the reconnaissance assessment would be given secondary priority for survey. Similarly, ditches meeting the first group of mapped criteria would be surveyed only when ditches of first and secondary priority had been surveyed, whilst those ditches failing to meet even the basic "desk criteria" would only be surveyed where time and resources allowed.

Although this protocol appears to assumes that each of the criteria listed be weighed equally, any reference to section 3 of this report shows that some ditch characteristics are recognised as more fundamental in determining the occurrence of a flora rich in uncommon macrophytes and marginal emergent species. The overwhelming influence of water quality, and especially total available phosphorus (TAP), should be taken as the most important criterion for determining which channels have the greatest potential for biodiversity importance. Hence the protocol could be revised to take account of any available water quality information, with sites known to have low TAP given top priority for survey.

Figure 4.1: Decision-making protocol to determine potential biodiversity of an arable ditch



4.2 A Fenland Case Study

A full testing of this protocol is not possible without some element of fieldwork and discussion with Internal Drainage Boards. However, some indication of how the mapped criteria might be used may be outlined through a very approximate case study based in one 10km square of the National Grid. So as not to bias the example by taking an area where many drainage channels are known to have rich macrophyte assemblages, the present discussion focuses on a 10km square where few such species are known *i.e.* **TL59** – the area around Welney and Hilgay, but excluding the Ouse Washes as a grassland area of known high value for its ditch flora.

Application of the protocol would identify the following areas and individual ditches as worthy of some attention:

- **a)** None of **TL59** is close to the Fenland margin, although the southern fringe around Hale Drove is quite close to the Littleport "island" and areas within 1km of Welney village or between Christchurch and Lakesend might be provisionally earmarked for survey.
- **b)** All areas are >10km from the coast.
- **c)** Cul-de-sac ditches such as that at TL566964 would be included.
- **d)** Drains bypassed by the Main Engine Drain and Glover's Drain in Hilgay Fen would be included following consultation with the relevant IDB as to water flows and management.
- **e)** Sinuous ditches such as the Old Crooked Dike (TL575925) and that south of Hill Farm, Upwell Fen (TL544990 *etc*) would be included, together with apparently ancient channels like the Old Mail Lode (TL582990) and the Old Croft River (TL562906 *etc*).
- **f)** IDB drains and other drains of intermediate importance would be included *e.g.* the droveside ditch between Middle Farm (Hilgay) and Venney Farm (TL575977).
- **g)** Much of **TL59** is on apparently suitable soils *i.e.* humic-alluvial gleys of the Downholland 1 association. Most of the remaining peat is within the Ouse Washes, but in the northeast of **TL59** toward Ten Mile Bank are areas of the Adventurers' 1 soil association that could be included as a criterion in site selection for survey. The presence of fragments of the Dowels association (a pelo-alluvial gley soil) may be of interest, though this soil type if uncommon in Fenland, with no the sites identified in the catalogue (Appendix 1).

Other contributory criteria would need consultation with ditch managers and especially identification of the most detailed and long-term accounts of water quality. As discussed in Section 3.3, it is unwise to make conclusions about a drainage channel based upon a single visit. Equally, in assessing where ditch survey might be targeted, it is much preferable to have evidence that a particular channel has met selection criteria over long period.

The presence of particular plant species has often been taken to provide a convenient shortcut to deciding that a ditch is of high quality for biodiversity. Examination of Appendix 2 shows that within **TL59** only the Ouse Washes have apparent high value for macrophytes. Hence a co-occurrence approach would not suggest other areas outwith the Washes that ought to be surveyed. However, the categorisation of species to guide quality assessment of arable ditches (Appendix 5 - after Mountford *et al.* 1998) could be used during reconnaissance visits to earmark ditches for thorough survey. The presence of any one of the species indicative of ***Excellent*** conditions or several species from the list reflecting ***Good*** conditions would be sufficient to give a ditch more than cursory attention.

Assuming that this preliminary protocol is used to arrive at a temporal and spatial strategy for campaign, the results of a single reconnaissance visit should not be taken as the definitive account of a ditch's value, especially if the channel concerned meets the more exacting water-quality criteria. Admittedly, resources may preclude multiple surveys of remote ditches, but wherever possible repeat surveys should occur in drainage channels that have scored well in the three-stage assessment of potential for high biodiversity.

4.3 Suggested hypotheses to be tested

To a great extent the review and preliminary decision-making protocol can be immediately adapted into a number of hypotheses on the association between botanical diversity and channel characteristics that lend themselves to testing by survey and, where necessary, experimentation. However, as one of the experts consulted during this scoping exercise commented – "*(the situation of arable ditches) is so multi-factorial that it impossible to come up with a (single) satisfactory answer*". Hence the best approach is to render the review as a series of propositions that are amenable to testing <u>one by one</u> through survey and experiment. The 15 different propositions/hypotheses for testing would state that "*high quality arable ditches will occur where the:*

- ❑ *Total available phosphorus of <0.1 mg/l*
- ❑ *Nitrogen concentration of <0.7 mg/l*
- ❑ *Water clarity good or excellent*
- ❑ *Soil was humic-alluvial gley, humic-sandy gley or earthy peat but not calcareous alluvial gley.*
- ❑ *Site is within 2.5km of the Fenland margin or a fen island, but not within 10km of the coast.*
- ❑ *Ditch is isolated from the main arterial network.*
- ❑ *Ditch is of relatively ancient origin*
- ❑ *The site is groundwater-fed*
- ❑ *Channel is 2.5-3.5m wide*
- ❑ *Maximum water depth is 1.0m ±0.25m*
- ❑ *Freeboard is <1.0m*
- ❑ *Ditch is of intermediate importance (IDB, roadside etc)*
- ❑ *Ditch receives regular though infrequent management (2-6 years) that does not remove propagules*
- ❑ *Ditch bank-top has a fringe of tall herbaceous vegetation*
- ❑ *Crop type in surrounding fields is wheat (or other cereal except maize) but not a root crop*".

To these propositions for species-rich ditches, one could add five further propositions related to particular floristic compositions. Thus: "*Characteristic species assemblages would occur where the criteria for high quality ditches were met,* ***<u>AND</u>****:*

- ❑ *Water pH is >7.5*
- ❑ *Water pH is <5.5*
- ❑ *Concentration of CaCO3 is <25mg/l*
- ❑ *Concentration of CaCO3 is >125mg/l*
- ❑ *Conductivity of the water is >1000 µmho*".

These hypotheses should form the basis of a programme of further work that will inform the targeting of channel surveys and derive protocols for the conservation of drainage channels within an intensively farmed arable landscape.

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Appendix 1: Provisional catalogue and characteristics of Fenland ditches holding populations of less common macrophytes and marginal species

APPROACH

- Data held in Biological Records Centre at NERC *Centre for Ecology and Hydrology*, Monks Wood.
- 10km squares searched were: TF06-07, TF10-16, TF20-25, TF30-35, TF40-46, TF50-52, TF55-56 and TF61; TL28-29, TL37-39, TL47-49, TL56-59 and TL 67-69.
- Marginal 10km squares holding fragments of Fenland and omitted from the search were: SK97; TF00, TF05, TF17, TF26, TF36 and TF60; TL18-19, TL36, TL46 and TL77-79.
- All records since *ca* 1970, and most from 1987 onward
- Species included within the search:

Alisma lanceolatum
Alopecurus aequalis
Althaea officinalis
Apium inundatum
Baldellia ranunculoides
Butomus umbellatus
Callitriche hamulata
Callitriche obtusangula
Callitriche platycarpa
Carex pseudocyperus
Carex vesicaria
Catabrosa aquatica
Ceratophyllum submersum
Cladium mariscus
Eleocharis acicularis
Eleogiton fluitans
Fontinalis antipyretica
Galium palustre elongatum
Groenlandia densa
Hottonia palustris
Hydrocharis morsus-ranae
Hydrocotyle vulgaris
Juncus bulbosus s.l.
Juncus subnodulosus
Menyanthes trifoliata
Myosotis secunda
Myriophyllum alterniflorum
Myriophyllum verticillatum
Oenanthe aquatica
Oenanthe fistulosa
Oenanthe fluviatilis
Potamogeton alpinus
Potamogeton berchtoldii
Potamogeton coloratus
Potamogeton crispus
Potamogeton friesii
Potamogeton gramineus
Potamogeton lucens
Potamogeton natans
Potamogeton obtusifolius
Potamogeton perfoliatus
Potamogeton praelongus
Potamogeton pusillus
Potamogeton trichoides
Potamogeton x fluitans
Potamogeton x salicifolius
Potamogeton x zizii
Ranunculus aquatilis s.s.
Ranunculus baudotii
Ranunculus circinatus
Ranunculus flammula
Ranunculus hederaceus
Ranunculus lingua
Sagittaria sagittifolia
Samolus valerandi
Schoenoplectus tabernaemontani
Senecio paludosus
Sium latifolium
Sparganium emersum
Stellaria palustris
Stratiotes aloides
Tolypella intricata
Tolypella prolifera
Utricularia vulgaris s.l.

- The records were then manually examined and certain categories of record were eliminated:
  - Sites not in Fenland *i.e.* located within the upland fringe
  - All records known unequivocally to be in non-arable situations *i.e*. within grassland or fenland blocks (thus removing most Ouse and Nene Washes records, as well as those from Holme, Wicken and Woodwalton Fens *etc*) or from gravel/sand pits.
  - All records from rivers (Nar, Wissey, Lark, Little Ouse, Cam, Great Ouse, Nene, Welland, Glen, Witham *etc*), as well as certain canalised rivers and main drains within grassland blocks *e.g.* Old and New Bedford Rivers, River Delph *etc*. Records for ponds were also omitted.

- Certain categories of site remain within the catalogue that might best be omitted on the above criteria, most importantly counter drains *etc* at the boundary of washland and some more minor drains whose origins are as canalised rivers. These ambiguous cases are indicated within the catalogue.

- It has as yet not been possible to check the neighbouring land use of <u>all</u> the ditches and drains listed.

- The sites are catalogued by 10km square, and wherever possible a series of records for adjacent lengths of the same ditch/drain are merged. Where such a ditch straddles more than one 10km square, reference is made to the site under all relevant squares.

- As a rule of thumb, the "fen margin" is said to extend to 2.5km from the upland, with "near fen margin" up to 5km from the upland.

KEY to SOIL CODE NUMBERS & ASSOCIATIONS (After Soil Survey of England & Wales 1983):

Man- made soils:		
92a:	Disturbed Soils	
Lithomorphic soils – rendzinas:		
346:	Humic gleyic rendzinas	*Reach soil association*
Brown calcareous earths:		
511i:	Typical brown calcareous earths	*Badsey 2 soil association*
Surface-water gley soils - stagnogleys:		
711r:	Typical stagnogley soils	*Beccles 1 soil association*
711s:	Typical stagnogley soils	*Beccles 2 soil association*
Groundwater gley soils – alluvial gley soils:		
812b:	Calcareous alluvial gley soils	*Wisbech soil association*
813a:	Pelo-alluvial gley soils	*Midelney soil association*
813b:	Pelo-alluvial gley soils	*Fladbury 1 soil association*
813g:	Pelo-alluvial gley soils	*Wallasea 2 soil association*
815:	Sulphuric alluvial gley soils	*Normoor soil association*
Groundwater gley soils – argillic gley soils:		
841d:	Typical argillic gley soils	*Shabbington soil association*
Groundwater gley soils – humic-alluvial gley soils:		
851a:	Typical humic-alluvial gley soils	*Downholland 1 soil association*
851b:	Typical humic-alluvial gley soils	*Downholland 2 soil association*
Groundwater gley soils – humic-sandy gley soils:		
861b:	Typical humic-sandy gley soils	*Isleham 2 soil association*
Groundwater gley soils – humic gley soils:		
872a:	Calcareous humic gley soils	*Peacock soil association*
872b:	Calcareous humic gley soils	*Clayhithe soil association*
873:	Argillic humic gley soils	*Ireton soil association*
Peat soils – earthy peat soils:		
1022a:	Earthy eu-fibrous peat soils	*Altcar 1 soil association*
1024a:	Earthy eutro-amorphous peat soils	*Adventurers' 1 soil association*
1024b:	Earthy eutro-amorphous peat soils	*Adventurers' 2 soil association*

TF06: Metheringham, Nocton and Potterhanworth Fens

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Branston Delph	061691-070697	*Baldellia ranunculoides* *Ranunculus circinatus* (2 sites) *Schoenoplectus tabernaemontani* *Sparganium emersum*	Fen margin	Cul-de-sac major drain linking upland and R. Witham	Earthy eutro-amorphous peat (**1024a**)	See also **TF07**
Car Dyke	062689-066686	*Ranunculus hederaceus* (2 sites)	Defining margin of fens	Ancient ditch, now of lesser importance	As latter (**1024a**)	Parts of Car Dyke in **TF10-12**, **TF15** & **TF20**
Nocton Delph	089645-099649	*Callitriche hamulata* *Potamogeton natans* (2 sites) *Ranunculus circinatus* *Sparganium emersum*	Fen margin	Cul-de-sac major drain linking upland and R. Witham	Typical humic-alluvial gley (**851b**)	See also **TF16**

TF07: Floodplain of R. Witham downstream of Lincoln as far as Bardney Lock

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Branston Delph	075700-084706	*Ranunculus circinatus* (2 sites)	Fen margin	Cul-de-sac major drain linking upland and R. Witham	Earthy eutro-amorphous peat (**1024b**)	See also TF06
Sandhillbeck	043708	*Catabrosa aquatica* *Groenlandia densa* *Potamogeton natans*	Fen margin	Field ditch?	Earthy eutro-amorphous peat (**1024b**)	
Sincil Dyke	003708-099702	*Butomus umbellatus* (2 sites) *Catabrosa aquatica* (10 sites) *Groenlandia densa* (2 sites) *Hydrocotyle vulgaris* (3 sites) *Juncus bulbosus* (2 sites) *Juncus subnodulosus* *Potamogeton crispus* (2 sites) *Potamogeton lucens* (2 sites) *Potamogeton natans* (5 sites) *Potamogeton perfoliatus* (3 sites) *Sagittaria sagittifolia* (16 sites) *Sparganium emersum* (19 sites) *Utricularia vulgaris*	Parallel with R. Witham in narrow floodplain	Major drain – counter drain to river.	Earthy eutro-amorphous peat (**1024b**)	To be confirmed – assume narrow bank between Dyke and Witham entirely grass-covered
South Delph Drain	016708	*Potamogeton perfoliatus*	Fen margin - parallel to river & Sincil Dyke	Intermediate drain	As latter (**1024b**)	

n.b. In **TF07**, two adjacent lengths of embanked and canalised river also have numerous records of the commoner macrophytes (*Potamogeton crispus, P. lucens, P. natans, Sagittaria* and *Sparganium emersum*, as well as some *Groenlandia* and *Hottonia*. These are Barlings Eau (059773-093716) and Stainfield Beck (099702 *etc*). Ditch with single record of local macrophytes: Fiskerton Drain (085720 – *Groenlandia*).

TF10: Maxey, Peakirk and the Deepings

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Brook Drain	164025-145057	*Groenlandia densa* (6 sites) *Sparganium emersum* (2 sites)	Fen margin, tributary of Maxey Cut (Welland)	Sinuous drain derived from stream	**511i** & **813b** (see below)	
Car Dyke & Folly River	193033-172066 (esp. at latter)	*Groenlandia densa* *Potamogeton crispus* *Potamogeton lucens* *Potamogeton perfoliatus* *Sparganium emersum* (3 sites)	Fen margin	Ancient ditch, partly upgraded to main drain	Pelo-alluvial gley (**813b**) & Typical argillic gley (**841d**)	Other parts of Car Dyke in **TF06, TF11-12, TF15** & **TF20**
Catchwater Drain, New-borough Fen	191057	*Groenlandia densa* *Myriophyllum verticillatum* *Potamogeton crispus*	Near fen margin	Roadside drain of intermediate status	Typical humic-alluvial gley (**851a**)	
Deeping Gate	149092, 150091 & 152091	*Alopecurus aequalis* *Groenlandia densa* (2 sites) *Hottonia palustris*	Fen margin – floodplain of R. Welland	Sites include field ditches (& ?gravel pit)	Pelo-alluvial gley (**813b**)	
Northborough	163088, 164089 & 165075	*Groenlandia densa* (2 sites) *Hottonia palustris*	Fen margin	One certainly a field ditch, other 2 may be R. Welland or associated	Pelo-alluvial gley (**813b**) & Typical brown calcareous earth (**511i**)	
Peakirk	166073, 173074 & 175074	*Alisma lanceolatum* *Apium inundatum* *Groenlandia densa* (2 sites) *Sparganium emersum*	Fen margin – floodplain of R. Welland	Field ditches – one may be R. Welland	Pelo-alluvial gley (**813b**)	
Slip Bridge, Newborough Fen	195064 (and 195063)	*Alisma lanceolatum* *Apium inundatum* *Baldellia ranunculoides* *Groenlandia densa* (2 sites) *Myriophyllum verticillatum*	Near fen margin	Probably roadside drain of intermediate status	Pelo-alluvial gley (**813b**)	See note on ISA below. See also **TF20**.

n.b. Also within **TF10** is a) the Maxey Cut (canalised river Welland) with *Catabrosa aquatica* and *Groenlandia densa*, and b) a site at 182087 (*Potamogeton crispus, P. friesii, P. pusillus* and *Ranunculus circinatus*) that is probably entirely a gravel pit, but may include the drain along Station Road as well as c) minor ditches with *Groenlandia densa* by Crowland Road (187082) and Deeping St James (198088), and *Potamogeton crispus* along King Street (111064-111066). The nationally important stonewort site (ISA) of Peakirk Moor is at 189072-190068 (Stewart 2004)

TF11: Baston, Langtoft and Thurlby Fens

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Bourne Eau	124198-151188	*Myriophyllum alterniflorum* (2 sites) *Potamogeton natans* *Potamogeton perfoliatus* (2 sites) *Ranunculus flammula* *Sparganium emersum* (3 sites)	Fen margin	Main drain connecting urban area and River Glen	Earthy eutro-amorphous peat (**1024b**)	(Records from western part excluded as in urban area)
Car Dyke North	108152-103194	*Potamogeton crispus* (3 sites) *Sparganium emersum* (3 sites)	Defining margin of fens	Ancient ditch, now of lesser importance	Typical brown calcareous earth (**511i**)	Parts of Car Dyke in **TF06, TF10, TF12, TF15** & **TF20**
Cross Drain (SSSI)	150150-187104	*Groenlandia densa* (3 sites) *Myriophyllum verticillatum* *Potamogeton coloratus* *Potamogeton natans* (4 sites) *Sparganium emersum*	Near fen margin	Intermediate-major drain	Calcareous humic gley (**872b**)	
Hop Pole Fm	194133	*Eleocharis acicularis* *Potamogeton pusillus*	Near fen margin	Probably field ditch	Typical humic-alluvial gley (**851a**)	
King Street Drain	108104-107130	*Groenlandia densa* (10 sites) *Sagittaria sagittifolia* (2 sites) *Sparganium emersum* (4 sites)	Outwith the fenland under a strict definition?	Roadside drain of intermediate status	Typical brown calcareous earth (**511i**)	
Langtoft Fen	148129	*Groenlandia densa* *Potamogeton natans*	Near fen margin	Roadside drain of intermediate status	Typical brown calcareous earth (**511i**)	
Long Drove Drain	118193	*Potamogeton crispus* *Potamogeton pusillus*	Fen margin	Roadside drain of intermediate status	Earthy eutro-amorphous peat (**1024b**)	

n.b. Ditches within/around the Baston Fen, Thurlby Slipe and Chasm nature reserve complex have a rich flora, including the following in the Counter Drain *etc* on the margin between the semi-natural vegetation and the arable fenland: *Hottonia palustris* (3 sites), *Potamogeton perfoliatus* (3 sites), *P. x zizii, Sagittaria sagittifolia, Samolus valerandi, Sium latifolium* and *Utricularia vulgaris*. The Baston Fen area is an important local area for Stoneworts (Stewart 2004). Also in **TF11** are individual drains with *Groenlandia* at Langtoft (118120) and north of Frognall (158111), as well as *Potamogeton natans* at Tongue End (159190) and *P. perfoliatus* in North Drove Drain (151152).

TF12: Bourne, Dyke, Morton, Haconby, Dunsby, Rippingale and Dowsby Fens

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Car Dyke (North)	103207-112249	*Groenlandia densa* (4 sites) *Potamogeton natans* (2 sites)	Defining margin of fens	Ancient ditch, now of lesser importance	Pelo-alluvial gley (**813g**) & Typical brown calcareous earth (**511i**)	Parts of Car Dyke in **TF06, TF10-11, TF15** & **TF20**
Counter Drain (near Guthram)	178209	*Hottonia palustris* *Potamogeton perfoliatus* *Sagittaria sagittifolia*	In main body of fenland	Major roadside drain	Pelo-alluvial gley (**813g**)	
Rippingale Running Dyke	139273-160275	*Potamogeton crispus* (2 sites) *Potamogeton lucens* (5 sites)	From fen margin into main body of fenland	Probably flowing ditch continuing "Old Beck"	Pelo-alluvial gley (**813g**)	

TF13: Aslackby, Pointon, Billingborough, Horbling, Swaton, Helpringham, Surfleet, Quadring and Donington Fens

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Billingborough Lode	125331-156329	*Groenlandia densa* (3 sites) *Potamogeton lucens* *Potamogeton natans* (2 sites)	Fen margin	Probably flowing ditch linking upland and South Forty Foot	Pelo-alluvial gley (**813g**) [Some typical brown calcareous earth - **511i**]	
Pointon Lode	124312-152310	*Groenlandia densa* (4 sites)	Fen margin	Probably flowing ditch linking upland and South Forty Foot	Pelo-alluvial gley (**813g**) [Some typical brown calcareous earth - **511i**]	

n.b. Ditches with single records include: *Groenlandia* in the Billingborough Ouse (117345), *Potamogeton crispus* in a Pointon Fen field ditch (137309), *P. lucens* in a Horbling Fen field ditch (145350), *P. natans* in an Aslackby Fen field ditch (158304),), *P. gramineus* in a field ditch by Billingborough Drove (162334) and *Alisma lanceolatum* by South Drove, Quadring fen (187324).

TF14: Great Hale, Heckington and South Kyme Fens

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Five Willow Wath Farm	185468	*Menyanthes trifoliata* *Ranunculus lingua*	Near fen margin	Major drain or field ditch	Pelo-alluvial gley (**813g**)	Very close to next
South of Head Dike	186467	*Callitriche obtusangula* *Eleocharis acicularis* *Hottonia palustris* *Myriophyllum verticillatum* *Potamogeton perfoliatus* *Sagittaria sagittifolia*	Near fen margin	Intermediate drain parallel to Head Dike	Pelo-alluvial gley (**813g**)	Very close to latter
South Kyme Fen	182486 & 184479	*Callitriche obtusangula* (2 sites) *Potamogeton natans*	Near fen margin	Field ditches	Pelo-alluvial gley (**813g**)	

n.b. A site at Cobbler's Lock (128495-129497) with *Hottonia* and *Myosotis secunda* is almost certainly not in arable land. A trackside ditch near Ewerby Thorpe (135483) has *Alisma lanceolatum*, and *Potamogeton crispus* occurs in the Kyme Eau at 178498.

TF15: Damford Grounds, Anwick, Ruskington, North Kyme, Digby, Billinghay and Thorpe Tilney Fen

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
West of Allens Farm	114550	*Callitriche obtusangula* *Groenlandia densa* *Potamogeton pusillus*	Fen margin	Field ditch	Typical humic-alluvial gley (**851a**)	
Billinghay Skirth	146532-174554	*Butomus umbellatus* (3 sites) *Oenanthe fistulosa* (3 sites) *Sagittaria sagittifolia* (3 sites)	Fen margin and adjacent	Main drain (modified river?) from upland edge to R. Witham	Pelo-alluvial gley (**813g**)	
Car Dyke	152553-124589	*Lysimachia vulgaris* *Potamogeton crispus*	Defining edge of fens	Ancient ditch, now of lesser importance	Pelo-alluvial gley (**813g**) [Some **711r**]	Parts of Car Dyke in **TF06, 10-12, 16** & **20**
Digby Fen	107543, 110550 & 137540	*Baldellia ranunculoides* (2 sites) *Callitriche obtusangula* *Eleocharis acicularis* *Potamogeton natans* *Samolus valerandi*	Fen margin	Roadside and field ditches	Typical humic-alluvial gley (**851a**)	A locally important area for stoneworts at 1354 (Stewart 2004)
Kyme Eau	194516-195511	*Sparganium emersum* (2 sites)	Near fen margin	Modified river	**813g** – as above	
North Kyme (New Cut?)	144539	*Myriophyllum verticillatum* *Potamogeton natans*	Fen margin	Intermediate drain	Typical humic-alluvial gley (**851a**)	

n.b. In **TF15**, *Baldellia* occurs in a roadside ditch on Dorrington Fen (129534), but the Tattershall site (196562) for *Myriophyllum verticillatum* is probably in the River Witham.

TF16: Blankney Fen, Metheringham Washway and Martin Dales

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Bucknall Catchwater Drain	160881-163658	*Groenlandia densa* (3 sites) *Potamogeton natans* (2 sites) *Sagittaria sagittifolia* (2 sites)	In upland fringe – not strictly a Fenland site	Canalised stream or main drain	Pelo-alluvial gley (**813g**)	
Car Dyke	118617	*Ranunculus flammula*	Defining edge of fens	Ancient ditch, now of lesser importance	Typical humic-alluvial gley (**851b**)	Parts of Car Dyke in **TF06, 10-12, 15** & **20**
Metheringham Delph	132633-149648	*Eleocharis acicularis* *Oenanthe fistulosa* *Potamogeton friesii* *Potamogeton lucens* *Sparganium emersum*	Fen margin	Cul-de-sac major drain linking upland and R. Witham	Typical humic-alluvial gley (**851b**)	A locally important area for stoneworts at 1263 (Stewart 2004)
Nocton Delph	104652	*Potamogeton natans*	Fen margin	Cul-de-sac major drain linking upland and R. Witham	Typical humic-alluvial gley (**851b**)	See also **TF06**

TF20: Eye, Thorney, Newborough and Nene Terrace

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Baxters Bridge	218060	*Myriophyllum verticillatum* *Potamogeton natans*	Near fen margin	Roadside drain	Typical humic-alluvial gley (**851a**)	
Highland Drain	207062-230058	*Groenlandia densa* (2 sites) *Myriophyllum verticillatum*	Near fen margin	Intermediate roadside drain	Typical humic-alluvial gley (**851a**)	
Nene Terrace (Hundreds Rd)	244077 & 245075	*Myriophyllum verticillatum* *Potamogeton perfoliatus* (2 sites)	In main body of fens	Intermediate drain	Argillic humic gley (**873**)	
Newborough (Borough Fen)	207090	*Groenlandia densa* *Hottonia palustris*	Near fen margin	Field ditch	Pelo-alluvial gley (**813a**)	See also **TF10**
Newborough (Guntons Rd)	201038 & 202051 ISA at 200038	*Alisma lanceolatum* *Baldellia ranunculoides* *Potamogeton natans*	Fen margin	Roadside drain & intermediate drain	Typical humic-alluvial gley (**851a**)	Nationally important stonewort area (ISA) (Stewart 2004)

TF20: (continued)

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Newborough Pumping Stn.	215091-215093	*Myriophyllum verticillatum* *Potamogeton natans* (2 sites) *Sagittaria sagittifolia* (2 sites) *Sparganium emersum*	In main body of fens	Intermediate drain (and pool)	Pelo-alluvial gley (**813a**)	Check – is northern part in grassland?
Teakettle Hall Farm	273001 & 273003	*Callitriche obtusangula* (2 sites) *Myriophyllum verticillatum* (2 sites) *Potamogeton crispus* (2 sites) *Potamogeton natans* (2 sites) *Ranunculus circinatus* (2 sites)	In main body of fens	Field ditches	Typical humic-alluvial gley (**851a**)	Close to next 2 sites
Thorney (Prior's Fen)	265003 & 265004	*Potamogeton natans* (2 sites) *Ranunculus aquatilis* *Sparganium emersum*	In main body of fens	Field ditches	Typical humic-alluvial gley (**851a**)	
Thorney River & North Side Drain	275002-276009 (and 277006)	*Callitriche obtusangula* *Eleocharis acicularis* *Eleogiton fluitans* (2 sites) *Potamogeton crispus* *Potamogeton natans* *Potamogeton pusillus* *Ranunculus circinatus* *Sparganium emersum*	In main body of fens (but close to a clay island)	Major drain	Typical humic-alluvial gley (**851a**)	
Thorney (north)	281049	*Potamogeton perfoliatus* *Potamogeton pusillus*	In main body of fens (but close to a clay island)	Intermediate drain	Sulphuric alluvial gley (**815**)	Linking Old Wryde & Highland Drains

n.b. Other sites in **TF20** include *Groenlandia* in Car Dyke (213017) and Cat's Water (sinuous ditch at 256077); *Eleocharis acicularis* by Black Drove (276065); *Potamogeton pusillus* at Chicell's Hurst (270030); and *Ranunculus circinatus* in North Fen, Thorney (290085). Records for *Potamogeton perfoliatus, P. berchtoldii, Groenlandia* and *Schoenoplectus tabernaemontani* near Eye, including America Farm *etc* seem to be all for gravel pits.

TF21: Crowland, Cowbit, Deeping Fen and Great Postland:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Crowland Gravel Causeway	230106-235105	*Potamogeton crispus* (2 sites) *Potamogeton pusillus* (3 sites) *Ranunculus circinatus*	In main body of fens (but close to a clay island)	Probably all in intermediate drain	Pelo-alluvial gley (**813a**)	

n.b. Other sites in **TF21** include *Myriophyllum verticillatum* in South Drove Drain (209133); *Sagittaria* in Common Drain (219120-220118); *Callitriche hamulata* on Crowland Common (230118); *Butomus* south of Cowbit House (256154); and *Sium* North of Cowbit (258195).

TF22: Spalding, Surfleet, Pinchbeck and Weston:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Blue Gowt Drain	275288-276290	*Alisma gramineum* *Potamogeton perfoliatus*	In main body of fens	Old major drain	Calcareous alluvial gley (**812b**)	
Moulton-Weston	298250 &299250	*Althaea officinalis* (2 sites)	In main body of fens	Roadside ditch	Calcareous alluvial gley (**812b**)	
Vernatt's Drain	222227-281291	*Alisma gramineum* *Butomus umbellatus* *Fontinalis antipyretica* *Juncus subnodulosus* *Myriophyllum verticillatum* (4 sites) *Oenanthe fistulosa* (2 sites) *Ranunculus baudotii*	In main body of fens (but close to a clay island)	Main drain	Calcareous alluvial gley (**812b**)	

n.b. Also in **TF21** is a site for *Ranunculus lingua* probably in Westlode Drain (228219).

TF23: Donington, Bicker, Wigtoft, Sutterton, Drayton, Gosberton and Quadring: NO sites for less common macrophytes

TF24: Swineshead, Langrick and Holland Fen:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Boston Road, Swineshead	249416	*Butomus umbellatus*	In main body of fens	Roadside drain	Calcareous alluvial gley (812b)	

TF25: Tattershall and West Fen:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
West Fen (Catchwater Drain)	222554-280599	*Butomus umbellatus* *Groenlandia densa* (4 sites) *Potamogeton crispus* (6 sites) *Ranunculus circinatus*	Fen margin	Intermediate drain	Typical stagnogley (**711s**)	

n.b. Other sites within **TF21** include: *Sium latifolium* at Tattershall (207561 – possibly a gravel pit) and *Stratiotes* in the Ings, Coningsby (217574) in what is probably a grassland site.

TF30: Guyhirn, Parson Drove and Thorney Toll:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Counter Drain	345004-384019	*Butomus umbellatus* (11 sites) *Oenanthe fistulosa* (4 sites) *Potamogeton lucens* *Potamogeton perfoliatus* *Sagittaria sagittifolia* (6 sites) *Sparganium emersum* (2 sites) *Utricularia vulgaris s.l.* (5 sites)	In main body of fens	Intermediate drain	Typical humic-alluvial gley (**851a**)	Continued in **TL29** and **TL39**
Moreton's Leam	337001-397027	*Hottonia palustris* (2 sites) *Hydrocharis morsus-ranae* *Myriophyllum verticillatum* *Potamogeton natans* *Samolus valerandi* (3 sites) *Sagittaria sagittifolia* *Schoenoplectus tabernaemontani* (4 sites) *Sium latifolium* *Utricularia vulgaris s.l.*	In main body of fens	Main drain (on edge of washes grassland) – probably not strictly relevant	Boundary between typical humic-alluvial gley (**851a**) & Earthy eutroamorphous peat (**1024a**)	Continued in **TL29** and **TL39** (*q.v.*)

n.b. Also in **TF30** is a site for *Potamogeton coloratus* in a field ditch near Thorney Toll (344034) and another for *Sium latifolium* in a branch of the Counter Drain (398019), and *Callitriche obtusangula* in the New South Eau (308086).

TF31: Gedney Hill, Sutton St James and Holbeach St John:

n.b. Single site for *Potamogeton crispus* in the North Level Main Drain (386113)

TF32: Holbeach, Moulton, Whaplode and Fleet Hargate:

n.b. Single sites for *Althaea officinalis* in field and roadside ditches near Fleet Hargate (392258 and 393257)

TF33: Kirton, Frampton, Fosdyke and Holbeach St Marks: NO sites for less common macrophytes

TF34: Boston, Wyberton, Freiston, Butterwick and Leverton:

n.b. Sites: for *Althaea officinalis* in roadside ditch near Freiston (385440); and *Potamogeton crispus* in the South Forty Foot Drain at Boston (315432).

TF35: Sibsey, Stickney, Leake Commonside and West Fen:

n.b. Sites: *Butomus umbellatus* in the Hagnaby Beck (347589); *Potamogeton perfoliatus* in West Fen Catchwater Drain (343548); and *Ranunculus hederaceus* in the East Fen Catchwater Drain (348555) – see also **TF46.**

TF40: Coldham, Friday Bridge and Wisbech St Mary:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Waldersey Main Drain	413007	*Potamogeton crispus* *Potamogeton natans*	In main body of fens	Intermediate drain	Typical humic-alluvial gley (**851a**)	

n.b. Another record of *Potamogeton natans* in **TF40** is at 408005, but this is a borrow pit by the old Whitemoor railway yard.

TF41: Gorefield, Newton, Tydd Gote and Walpole Marsh:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
North Level Main Drain	453177-4558178	*Potamogeton crispus* *Potamogeton perfoliatus*	In main body of fens	Main drain	Calcareous alluvial gley (**812b**)	

n.b. Three other sites in **TF41:** *Althaea officinalis* in 2 field ditches near Newton (443137 and 457148); and *Oenanthe aquatica* in a roadside ditch near White Cross Farm (420184).

TF42: Long Sutton, Sutton Bridge and Gedney Drove End:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Crosskeys Bridge Bank	492206	*Juncus bulbosus* *Juncus subnodulosus*	In main body of fens	Field ditch?	Calcareous alluvial gley (**812b**)	

TF43: Holbeach St Matthew and Dawsmere:

n.b. Site for *Althaea officinalis* in droveside ditch at Sot's Hole (435326).

TF44: Benington Sea End and Leverton Highgate:

n.b. Sites for *Althaea officinalis* by old sea bank (418467) and in roadside ditch (418498) – both "Old Leake".

TF45: Wrangle, Friskney, New Leake and Wainfleet All Saints:

n.b. Site for *Potamogeton lucens* in Wainfleet Relief Channel (495599) – main drain (see also **TF46**).

TF46: Thorpe St Peter and Little Steeping:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Cowcroft Drain	483642-495626	*Butomus umbellatus* (2 sites) *Potamogeton crispus* *Potamogeton friesii* *Potamogeton lucens* (8 sites) *Potamogeton natans* (7 sites) *Potamogeton perfoliatus* *Sagittaria sagittifolia*	Fen margin	Old intermediate drain (sinuous)	Pelo-alluvial gley (**813g**)	
East Fen Catchwater	423629-428630	*Potamogeton crispus* (2 sites)	Fen margin	Intermediate to major drain	Typical humic-alluvial gley (**851a**)	**See also** TF35
Steeping River	440630-462615	*Potamogeton crispus* (2 sites) *Potamogeton perfoliatus* (4 sites)	Fen margin	Main drain, taking R. Lymm water to Wainfleet Haven	Typical humic-alluvial gley (**851b**) & Pelo-alluvial gley (**813g**)	**See also** TF55
Wainfleet Relief Channel	472603-489601	*Potamogeton lucens* (4 sites)	Near fen margin	Main drain	Pelo-alluvial gley (813g)	See also TF45

n.b. Also in **TF46** is a site for *Stratiotes aloides* at Thorpe Culvert (468609) in what is apparently a pit.

TF50: Outwell, Nordelph and Marshland St James:

n.b. Site for *Sagittaria sagittifolia* in Popham's Eau (main drain at 500001).

TF51: Marshland (Tilneys, Walpoles and Wiggenhalls):

n.b. Sites for *Althaea officinalis* by roadside ditches at Small Drove (503103) and Gravel Bank (551112); and *Ranunculus baudotii*, also roadside ditch, near Antioch (551154).

TF52: Clenchwarton and Terrington St Clement:

n.b. Site for *Ranunculus baudotii* in a field ditch at Ongar Hill (581248).

TF55: Wainfleet St Mary and Gibraltar Point:

n.b. Site for *Sagittaria sagittifolia* in the Steeping River (503588) – see also **TF46**.

TF56: Skegness and Croft:

n.b. Sites in the Croft area in field and roadside ditches: *Carex pseudocyperus* (506611); *Potamogeton natans* (501616); and *P. pusillus* (504606).

TF61: Setchey and Wormegay:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Blackborough Straight Drain	669138	*Potamogeton lucens* *Potamogeton natans*	Fen margin	Intermediate drain	Earthy eutro-amorphous peat (**1024b**)	
Petticoat Lane Drain	673114	*Callitriche obtusangula* *Groenlandia densa* *Myriophyllum verticillatum* *Potamogeton berchtoldii* *Potamogeton crispus* *Potamogeton lucens* *Potamogeton natans* *Sagittaria sagittifolia*	Fen margin	Intermediate to major drain	Earthy eutro-amorphous peat (**1024b**)	See notes below
Wormegay	670117	*Ceratophyllum submersum* *Potamogeton pusillus*	Fen margin	Field ditch	As last two - **1024b**	

n.b. The Grid Reference listed for "Petticoat Lane Drain, Wormegay" seems to actually refer to Black Drain (on the edge of forest at Shouldham Warren) – *Potamogeton alpinus* and *P. berchtoldii* are actually noted for Black Drain at the same Grid Reference, and *P. alpinus* and *P. crispus* are noted for other forest edge ditches here at 686107 and 686109. Other potential/probable arable ditches include *Baldellia ranunculoides* in a field ditch near Blackborough End (649146); *Potamogeton crispus* near the Sugar Beet factory (611172); and *P. lucens* at 680128 (Dunstall's Drain, R. Nar or a pit). The interesting sites around Tottenhill Row and Watlington all appear to be in gravel pits in the upland margin.

TL28: Ramsey Mereside, Woodwalton and Holme Fens:

n.b. Most macrophyte records in **TL28** are within the NNRs, especially Woodwalton, with a few in the upland Broughton Brook. Others actually relevant to the present study include: *Oenanthe aquatica* by Ugg Mere Court Road (254871); *Potamogeton coloratus* in a ditch by Middle Drove (241856); *P. x fluitans* (*P. lucens x P. natans*) in a field ditch on Conington Fen (209858); and *Ranunculus circinatus* by Jack's Corner Drove (295830).

TL29: Whittlesey, Pondersbridge and Stanground:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Bevill's Leam	240910-263922	*Butomus umbellatus* (3 sites) *Potamogeton lucens* *Potamogeton perfoliatus* (2 sites)	In main body of fens	Main drain	Typical humic-alluvial gley (**851a**)	Continued in **TL39**
Blackbush Drove	257944-263962	*Myriophyllum verticillatum* *Potamogeton crispus* (2 sites) *Potamogeton lucens* *Potamogeton natans* (2 sites)	In main body of fens	Intermediate to major drain	Typical humic-alluvial gley (**851a**) [Some argillic humic gley – **873**]	
Counter Drain	259982-264982	*Hydrocharis morsus-ranae* (2 sites)	In main body of fens	Intermediate drain – probably with grassland on one side	Typical humic-alluvial gley (**851a**)	Continued in **TL39** and **TF30**
Drysides	220975 & 221975	*Potamogeton coloratus* (2 sites) *Potamogeton natans*	Near fen margin	Field ditch (or clay pit)	Pelo-alluvial gley (**813a**)	
Feldale Drove	299981	*Potamogeton berchtoldii* *Potamogeton crispus* *Potamogeton x zizii*	Edge of fen island	Droveside ditch	Typical humic-alluvial gley (**851a**)	
Flag Fen	224994, 224995, 227989 & 229984	*Alopecurus aequalis* *Eleocharis acicularis* *Groenlandia densa* (2 sites) *Potamogeton natans*	Fen margin	Intermediate drain (Adderley Drain) & field ditch	Pelo-alluvial gley (**813a**)	
Moreton's Leam	208973-295990	*Butomus umbellatus* (11 sites) *Hydrocharis morsus-ranae* (2 sites) *Juncus subnodulosus* *Oenanthe fistulosa* *Potamogeton crispus* (2 sites) *Potamogeton friesii* *Potamogeton lucens* (9 sites) *Potamogeton perfoliatus* (9 sites) *Potamogeton pusillus* *Potamogeton trichoides* *Ranunculus circinatus* (9 sites) *Sagittaria sagittifolia* (7sites) *Samolus valerandi* *Sparganium emersum* *Utricularia vulgaris s.l.*	From fen margin into the main body of fenland	Main drain (on edge of washes grassland) – probably not strictly relevant	Pelo-alluvial (**813a**) & typical humic-alluvial gleys (**851a**) – on boundary with earthy eutro-amorphous peat (**1024a**)	Continued in **TL39** and **TF30**
Stanground Lode	201965-201967	*Butomus umbellatus* *Potamogeton lucens* *Potamogeton natans*	Fen margin	Intermediate drain in urban area	Pelo-alluvial gley (**813a**)	

n.b. Also in **TL29** are many ditches within the grassland of the Nene Washes, as well as pit areas and grassland ditches on the island of Whittlesey (where *Groenlandia* is locally frequent). More definitely relevant are: *Apium graveolens* by Green Drove (277999); and *Potamogeton pusillus* near Bird's Hundred (266963).

TL37: Swavesey, Over and Chatteris Fens:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Counter Drain	396760-398762	*Butomus umbellatus* (2 sites) *Potamogeton crispus* *Potamogeton lucens* *Potamogeton natans* (3 sites) *Ranunculus circinatus* *Sagittaria sagittifolia* (2 sites) *Sparganium emersum*	From fen margin into the main body of fenland	Main drain (on edge of washes grassland) – probably not strictly relevant	Pelo-alluvial gley (**813a**)	Continued into **TL47** and **TL48** (*q.v.*)
Ouse Fen	372733, 373724 & 375725	*Potamogeton crispus* *Ranunculus baudotii* *Sium latifolium*	Fen margin	Field ditches	Pelo-alluvial gley (**813a**)	

n.b. Several areas with good macrophyte records occur in the grassland ditches (and ponds) of Middle Fen, as well as locally in pits. Probably arable ditches occur in: Bare Fen (390715) with *Alopecurus aequalis*; *Potamogeton natans* in the Cranbrooke Drain (395763); and near Earith (394758) with *Ranunculus circinatus*.

TL38: Chatteris, Tick Fen and Benwick Mere:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Brown Butts	378880	*Butomus umbellatus* *Hydrocharis morsus-ranae*	By fen island	Intermediate drain	Calcareous humic gley (**872a**)	
Ferry Burrows	388824 & 390826	*Potamogeton lucens* *Potamogeton natans* (2 sites) *Sagittaria sagittifolia*	Near fen island	Field ditch	Typical humic-alluvial gley (**851a**)	
Hammond's Eau	391813	*Hottonia palustris* *Potamogeton lucens* (2 sites) *Ranunculus circinatus* *Sagittaria sagittifolia* (2 sites)	In main body of fens	Old intermediate drain (sinuous)	Typical humic-alluvial gley (**851a**)	Continued in **TL48** *q.v.*)

TL38: (continued)

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Horseley	394829	*Potamogeton lucens* *Potamogeton natans*	In main body of fens	Roadside ditch?	Argillic humic gley (**873**)	
Long North Fen	390817	*Potamogeton lucens* *Potamogeton natans*	In main body of fens	Old intermediate drain (sinuous)	Typical humic-alluvial gley (**851a**)	Near latter
Long North Fen drove	399811	*Potamogeton lucens* *Potamogeton natans* *Potamogeton perfoliatus* *Sagittaria sagittifolia*	In main body of fens	Droveside ditch	Typical humic-alluvial gley (**851a**)	Near last two sites
Pickle Fen	388828	*Potamogeton crispus* *Potamogeton natans*	Near fen island	Field ditch	Typical humic-alluvial gley (**851a**)	
Somersham High N. Fen	376808	*Groenlandia densa* *Potamogeton crispus*	Fen margin	Field ditch	Typical humic-alluvial gley (**851a**)	
Warboys High Fen Drain	347821-351824	*Potamogeton coloratus* (2 sites) *Potamogeton lucens*	Fen margin	Intermediate drain	Typical humic-alluvial gley (**851a**)	
Warboys New Barn Drove	329835	*Potamogeton friesii* *Potamogeton lucens* *Potamogeton perfoliatus* *Ranunculus circinatus*	Fen margin	Droveside ditch	Typical humic-alluvial gley (**851a**)	

n.b. Several individual records, mostly for field ditches: *Hydrocharis morsus-ranae* in the Forty Foot Drain (376884); *Potamogeton perfoliatus* near Dawson's Farm (345870); *Potamogeton praelongus* near Howmoor Farm (385995); *Ranunculus aquatilis* s.s. in Colne Fen (376825); and *Samolus valerandi* near Megg's Drove (315876)

TL39: Coates, Benwick, Turves and Floods Ferry:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Benwick Road	311930	*Potamogeton berchtoldii* *Potamogeton praelongus*	In main body of fens	Roadside drain	Typical humic-alluvial gley (**851a**)	
Counter Drain	326994	*Juncus subnodulosus* *Samolus valerandi* *Schoenoplectus tabernaemontani* *Sparganium emersum*	In main body of fens	Intermediate drain	Typical humic-alluvial gley (**851a**)	Continued in **TL29** and **TF30**

TL39: (continued)

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Moreton's Leam	337001-397027	*Alisma lanceolatum* *Butomus umbellatus* (4 sites) *Hydrocharis morsus-ranae* *Myriophyllum verticillatum* *Potamogeton lucens* (2 sites) *Potamogeton perfoliatus* (4 sites) *Ranunculus circinatus* (2 sites) *Sparganium emersum* *Utricularia vulgaris s.l.* (3 sites)	In main body of fens	Main drain (on edge of washes grassland) – probably not strictly relevant	Typical humic-alluvial gley (**851a**) [On boundary with earthy eutro-amorphous peat - **1024a**]	Continued in **TL29** and **TL39** (*q.v.*)
Wype Doles	304959	*Potamogeton lucens* *Potamogeton perfoliatus* *Potamogeton pusillus*	In main body of fens	Roadside drain	Typical humic-alluvial gley (**851a**)	

n.b. Also in **TL39** are: *Oenanthe aquatica* in Benwick (340907 – in the river?); *Potamogeton crispus* at both Doddington (385903 – fen island) and in a roadside drain near Flood's Ferry (397949); *P. lucens* in Bevill's Leam (see also **TL29** - 306956); and *P. pusillus* in a White Fen field ditch 339913).

TL47: Willingham, Haddenham and Sutton:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Adventurers' Head Drain	426767-428749	*Myriophyllum verticillatum* (3 sites) *Potamogeton natans* *Sagittaria sagittifolia* (2 sites)	Near fen island	Intermediate to major drain	Pelo-alluvial gley (**813a**) & earthy eutro-amorph. peat (**1024a**)	Near Little Adventurers' Drain (*q.v.*)
Aldreth Causeway (east side)	439723	*Hottonia palustris* *Myriophyllum verticillatum* *Potamogeton berchtoldii* *Potamogeton crispus*	Near fen island	Droveside drain	Earthy eutro-amorphous peat – (**1024a**) & calcareous humic gley (**872a**)	
Aldreth (South of High Bridge)	438718	*Alopecurus aequalis* *Potamogeton x salicifolius*	Near fen island	Intermediate drain	As next – **1024a**	
Back Drove (Haddenham)	432767 & 421766	*Hottonia palustris* (2 sites) *Juncus subnodulosus* *Oenanthe fluviatilis* *Sium latifolium*	Near fen island	Droveside ditch	Earthy eutro-amorphous peat – (**1024a**)	Close to Adventurers' Head Drain (*q.v.*)

TL47: (Continued)

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Cottenham Lode	470701-477707	*Butomus umbellatus* *Potamogeton natans* *Sagittaria sagittifolia* (2 sites) *Sparganium emersum*	Fen margin	Intermediate drove-side drain linking upland and R. Great Ouse	Calcareous humic gley (**872b**)	
Counter Drain	402767-425798	*Butomus umbellatus* *Hottonia palustris* *Myriophyllum verticillatum* *Oenanthe aquatica* (2 sites) *Oenanthe fistulosa* (7 sites) *Potamogeton crispus* (4 sites) *Potamogeton lucens* (6 sites) *Potamogeton natans* (7sites) *Potamogeton perfoliatus* *Potamogeton x salicifolius* (2 sites) *Ranunculus circinatus* *Sagittaria sagittifolia* (2 sites) *Samolus valerandi*	From fen margin into the main body of fenland	Main drain (on edge of washes grassland) – probably not strictly relevant	Pelo-alluvial gley (**813a**)	Continued into **TL37** and **TL48** (*q.v.*)
Engine Drain (Chear Fen)	480709-494712	*Apium inundatum* (2 sites) *Butomus umbellatus* (2 sites) *Callitriche obtusangula* (2 sites) *Eleocharis acicularis* *Fontinalis antipyretica* *Groenlandia densa* (3 sites) *Hottonia palustris* (2 sites) *Potamogeton crispus* *Potamogeton friesii* *Potamogeton gramineus* *Potamogeton lucens* (6 sites) *Potamogeton natans* (2 sites) *Potamogeton perfoliatus* (4 sites) *Potamogeton pusillus* *Potamogeton trichoides* (2 sites) *Potamogeton x fluitans* (2 sites) *Potamogeton x salicifolius* (2 sites) *Potamogeton x zizii* (2 sites) *Ranunculus circinatus* (2 sites) *Sagittaria sagittifolia* (2 sites) *Sparganium emersum*	Near fen margin	Intermediate to major drain	Calcareous humic gley (**872b**)	Close to Fourth Sock Drain (*q.v.*). One grid reference ambiguous – might indicate branch drain to Chear Lode.

TL47: (Continued)

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Fourth Sock Drain (Chear Fen)	483712-488714	*Callitriche obtusangula* *Groenlandia densa (2 sites)* *Myriophyllum verticillatum* *Potamogeton natans* *Potamogeton pusillus* (2 sites)	In main body of fen	Intermediate drain (counter to Gt Ouse)	Calcareous humic gley (**872b**)	Close to Engine Drain (*q.v.*)
Galls Drain (Haddenham)	434759	*Callitriche obtusangula* *Myriophyllum verticillatum* *Potamogeton crispus* *Potamogeton lucens* *Potamogeton natans* *Ranunculus circinatus* *Sagittaria sagittifolia* *Sium latifolium*	Near fen island	Intermediate drain	Calcareous humic gley (**872a**)	Close to Second Bridge Drove (*q.v.*)
Haddenham (Dam Bank)	423734	*Hottonia palustris* *Myriophyllum verticillatum*	Near fen island	Roadside drain	Earthy eutro-amorph. peat (**1024a**)	Near next drain (*q.v.*)
Little Adventurers' Drain (Back Drove)	425734 & 430742	*Butomus umbellatus* *Hottonia palustris* *Myriophyllum verticillatum* *Potamogeton crispus* *Potamogeton natans* (2 sites) *Potamogeton trichoides* *Sagittaria sagittifolia*	Near fen island	Intermediate drain	Earthy eutro-amorphous peat (**1024a**) & calcareous humic gley (**872a**)	Close to Adventurers' Head Drain (*q.v.*)
Second Bridge Drove	433762-434761 (& 433760)	*Fontinalis antipyretica* (2 sites) *Hottonia palustris* (2 sites) *Oenanthe fluviatilis* *Sagittaria sagittifolia* *Sium latifolium* (2 sites)	Near fen island	Droveside ditch (intermediate)	Earthy eutro-amorphous peat (**1024a**) & calcareous humic gley (**872a**)	Close to Galls Drain (*q.v.*)
Small Fen (Haddenham)	419773	*Hottonia palustris* *Myriophyllum verticillatum* *Potamogeton natans*	In main body of fen (but not far from fen island)	Intermediate drain	Earthy eutro-amorphous peat (**1024a**)	
Third Sock Drain (Setchel)	468717-470717	*Baldellia ranunculoides* *Sparganium emersum*	In main body of fen	Intermediate drain (counter to Gt Ouse)	Calcareous humic gley (**872b**)	
Willingham (north)	400715	*Alisma lanceolatum* *Potamogeton natans*	Fen margin	Field ditch	Pelo-alluvial gley (**813a**)	

n.b. Other sites in **TL47** include: *Alisma lanceolatum* at Sutton Gault (424798 – grassland?); *Potamogeton lucens* in New Cut (479729); *P. natans* near North Fen Drove (459768); and *P. pusillus* in Mitchell Hill Common (474704) & North Fen Drove (461767; a stonewort area at 4676 - Stewart 2004)

TL48: Manea, Mepal and Horseway:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Block Fen	431840-434844	*Potamogeton berchtoldii* *Potamogeton crispus* *Potamogeton gramineus* (3 sites) *Potamogeton lucens* *Potamogeton perfoliatus* (2 sites) *Potamogeton pusillus* (2 sites) *Potamogeton trichoides* (2 sites) *Ranunculus circinatus* *Samolus valerandi*	In main body of fen	Droveside ditch (or northern shallows of gravel pit!)	Argillic humic gley (**873**)	
Blockmoor Fen	419808-419809	*Callitriche obtusangula* (2 sites) *Hottonia palustris* (2 sites) *Myriophyllum verticillatum* (2 sites) *Potamogeton crispus* (2 sites) *Potamogeton lucens* *Potamogeton natans* (2 sites) *Potamogeton perfoliatus* (2 sites) *Potamogeton x salicifolius* (2 sites) *Ranunculus circinatus* (2 sites) *Sagittaria sagittifolia*	In main body of fen	Intermediate or roadside drain	Typical humic-alluvial gley (**851a**)	
Bottom Farm (near Counter Drain)	454839	*Hottonia palustris* *Myriophyllum verticillatum* *Oenanthe fluviatilis* *Potamogeton lucens* *Potamogeton natans* *Potamogeton perfoliatus* *Ranunculus circinatus* *Sagittaria sagittifolia*	In main body of fen	Intermediate drain	Argillic humic gley (**873**)	Close to Counter Drain (*q.v.*)
Chatteris - Poplar Hall	401811	*Hottonia palustris* *Potamogeton berchtoldii*	In main body of fens	Roadside drain	Typical humic-alluvial gley (**851a**)	Near Horseley Fen Middle Drove (*q.v.*)
Cooper's Farm (Chatteris)	449848	*Potamogeton lucens* *Potamogeton natans*	In main body of fen	Field ditch	Argillic humic gley (**873**)	
Counter Drain	(see next page)					
Crooked Drain	420825	*Potamogeton lucens* *Potamogeton natans* *Sagittaria sagittifolia*	In main body of fen	Old intermediate drain	Argillic humic gley (**873**)	
Downham Main Drain	482858	*Potamogeton trichoides* *Ranunculus circinatus*	In main body of fens	Major drain	Typical humic-alluvial gley (**851a**)	See also **TL58**

TL48: Continued

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Counter Drain	4288802-477868	*Alisma lanceolatum* (3 sites) *Butomus umbellatus* (2 sites) *Callitriche obtusangula* *Hottonia palustris* (5 sites) *Myriophyllum verticillatum* (4 sites) *Oenanthe aquatica* *Oenanthe fistulosa* (9 sites) *Oenanthe fluviatilis* (2 sites) *Potamogeton berchtoldii* *Potamogeton coloratus* *Potamogeton crispus* (13 sites) *Potamogeton lucens* (23 sites) *Potamogeton natans* (18 sites) *Potamogeton perfoliatus* (8 sites) *Potamogeton praelongus* *Potamogeton pusillus* (2 sites) *Potamogeton trichoides* (2 sites) *Potamogeton x salicifolius* (6 sites) *Ranunculus circinatus* (5 sites) *Sagittaria sagittifolia* (14 sites) *Sparganium emersum* *Tolypella prolifera*	From fen margin into the main body of fenland	Main drain (on edge of washes grassland) – probably not strictly relevant	Combination of typical humic-alluvial gley (**851a**), argillic humic gley (**873**) and earthy eutro-amorphous peat (**1024a**)	Continued into **TL37** and **TL47** (*q.v.*) A nationally important stonewort area (ISA) is at TL435812. See Stewart (2004)
Fortrey's Hall	441824, 442730, 443823 & 445833	*Callitriche obtusangula* *Hottonia palustris* *Lysimachia vulgaris* *Potamogeton lucens* (2 sites) *Potamogeton natans* *Potamogeton perfoliatus* *Potamogeton trichoides* *Ranunculus aquatilis s.s.* *Sium latifolium*	In main body of fen	Intermediate drains	Earthy eutro-amorphous peat (**1024a**)	
Hammond's Eau	418807	*Callitriche obtusangula* *Hottonia palustris* *Myriophyllum verticillatum* *Potamogeton crispus* *Potamogeton natans* *Potamogeton x salicifolius* *Ranunculus circinatus*	In main body of fen	Old intermediate drain	Typical humic-alluvial gley (**851a**)	See also **TL38**

TL48: Continued

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Horseley Fen Middle Drove	400816	*Eleocharis acicularis* *Fontinalis antipyretica* *Hottonia palustris* *Potamogeton lucens* *Potamogeton natans* *Potamogeton perfoliatus* *Potamogeton pusillus* *Sagittaria sagittifolia*	In main body of fen	Intermediate drain (either roadside or sinuous)	Typical humic-alluvial gley (**851a**)	Close to Hammond's Eau and Poplar Hall (*q.v.* & see **TL38**)
Mepal Engine Drain	437827-441821	*Callitriche obtusangula* *Groenlandia densa* *Hottonia palustris* *Myriophyllum verticillatum* *Potamogeton crispus* *Potamogeton lucens* (2 sites) *Potamogeton natans* (2 sites) *Potamogeton perfoliatus* (3 sites) *Potamogeton x salicifolius* (3 sites) *Ranunculus circinatus* *Sagittaria sagittifolia* (3 sites)	Near fen island	Major drain	Typical humic-alluvial gley (**851a**)	Near Fortrey's Hall & Witcham Meadlands (*q.v.*)
Mepal Long Highway	426815-427825 & 427832	*Groenlandia densa* (TL427832) *Myriophyllum verticillatum* *Potamogeton crispus* *Potamogeton friesii* *Potamogeton lucens* (2 sites) *Potamogeton natans* (2 sites) *Potamogeton perfoliatus* *Ranunculus circinatus* *Sagittaria sagittifolia*	Near fen island	Droveside drain	Calcareous humic gley (**872b**)	
Mepal Toll Farm	436815	*Myriophyllum verticillatum* *Utricularia vulgaris s.l.*	Near fen island	Field ditch	Calcareous humic gley (**872b**)	
Old Mill Drove	472863	*Potamogeton crispus* *Potamogeton natans*	In main body of fen	Droveside ditch	Typical humic-alluvial gley (**851a**)	
Purls Bridge (southwest)	474866 & 475866	*Hottonia palustris* (2 sites)	In main body of fen	Field ditch	Typical humic-alluvial gley (**851a**)	
Purls Bridge Drove	476881	*Potamogeton perfoliatus* *Ranunculus circinatus*	In main body of fen	Field ditch	Typical humic-alluvial gley (**851a**)	

TL48: Continued

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Sutton Gault Hole area	432802, 433802, 435804 & 435806	*Callitriche obtusangula* *Hottonia palustris* *Potamogeton crispus* *Potamogeton lucens* *Potamogeton natans* *Ranunculus aquatilis s.s.* *Tolypella intricata*	Edge of fen island	Field ditches – possibly in grassland	Calcareous humic gley (**872a**)	
Vermuden's (or Forty foot) Drain	425872-469859	*Alisma gramineum* * *Butomus umbellatus* *Callitriche obtusangula* *Myriophyllum verticillatum* *Potamogeton lucens* (6 sites) *Potamogeton natans* (2 sites) *Potamogeton perfoliatus* (4 sites) *Potamogeton trichoides* *Potamogeton x salicifolius* *Ranunculus lingua* * *Sagittaria sagittifolia* (2 sites)	In main body of fen	Main drain	Combination of calcareous humic gley (**872b**), argillic humic gley (**873**) and earthy eutro-amorphous peat (**1024a**)	* See Welches Dam A Stonewort area of local importance (see Stewart 2004)
Vicarage Farm	453885	*Callitriche obtusangula* *Myriophyllum verticillatum* *Potamogeton crispus* *Potamogeton pusillus*	In main body of fen	Field ditch	Argillic humic gley (**873**)	
Welches Dam (including triangle)	467857, 467858, 468857, 468858, 469857 & 469858	*Carex vesicaria* *Groenlandia densa* (2 sites) *Juncus subnodulosus* *Lysimachia vulgaris* *Myriophyllum verticillatum* *Oenanthe fistulosa* *Potamogeton crispus* *Potamogeton lucens* *Potamogeton natans* (2 sites) *Potamogeton perfoliatus* *Ranunculus circinatus* (3 sites) *Ranunculus lingua* (2 sites) *Schoenoplectus tabernaemontani* *Sparganium emersum* *Stellaria palustris* *Utricularia vulgaris s.l.*	In main body of fen	Probably grassland or tall-herb fen sites – to be checked	Earthy eutro-amorphous peat (**1024a**)	Near Counter Drain (*q.v.*)

TL48: Continued

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
West of Welches Dam	466856	*Hottonia palustris* *Potamogeton lucens* *Sparganium emersum*	In main body of fen	Field ditch	Argillic humic gley (**873**) & earthy eutro-amorph. peat (**1024a**)	Near Counter Drain (q.v.)
Witcham Meadlands (East)	446835, 448837 & 449834	*Hottonia palustris* (3 sites) *Potamogeton crispus* *Potamogeton lucens*	Near fen island	Field ditch	Argillic humic gley (**873**) & earthy eutro-amorph. peat (**1024a**)	Near Fortrey's Hall & Mepal Engine Drain (q.v.)
Witcham Meadlands (West)	436831, 438831, 440837 & 440835	*Potamogeton natans* (4 sites) *Potamogeton perfoliatus* *Ranunculus circinatus* (2 sites) *Sagittaria sagittifolia* (4 sites)	Near fen island	Sinuous ditch	Argillic humic gley (**873**) & earthy eutro-amorph. peat (**1024a**)	Near Fortrey's Hall & Mepal Engine Drain (q.v.)

TL49: March, Wimblington and Christchurch:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Brown's Hill	435907	*Juncus subnodulosus* *Potamogeton berchtoldii* *Potamogeton natans*	In main body of fen	Field ditch? May be part of Wimblington Common pits.	Argillic humic gley (**873**)	
Latchesfen Farm	427918-427820	*Hottonia palustris* *Myriophyllum verticillatum* *Potamogeton berchtoldii* *Potamogeton coloratus* *Potamogeton natans*	In main body of fen	Field ditch	Earthy eutro-amorphous peat (**1024a**)	
Stonea Camp (Harding's Drain)	447934-447936	*Potamogeton crispus* (2 sites) *Potamogeton friesii* *Potamogeton perfoliatus* *Potamogeton pusillus* (2 sites)	In main body of fen	Intermediate drain (sinuous)	Argillic humic gley (**873**)	A Stonewort area of local importance (see Stewart 2004) is located to 4593
Upwell Road Drain	431961	*Potamogeton friesii* *Potamogeton pusillus* *Sagittaria sagittifolia*	In main body of fen	Roadside drain	Typical humic-alluvial gley (**851a**)	

n.b. In **TL49** are: *Potamogeton crispus* in field ditches at Villa Florida (405962) Manor Farm (407907) and Three Corner Cut (426985); *P. lucens* in Binnimoor Drain (434935); and *P. pusillus* in Cranmoor Lots (491922). Gravel pits at Wimblington Common *etc* are more macrophyte-rich.

TL56: Waterbeach, Lode and Reach:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Bottisham Lode	527639-510658	*Fontinalis antipyretica* *Groenlandia densa* *Sagittaria sagittifolia*	Fen margin	Cul-de-sac major drain linking upland & R. Cam	Disturbed soil (**92a**) with **872b** & **1024a** [see below]	
Burwell Lode	541696-537698	*Butomus umbellatus* *Eleocharis acicularis* *Potamogeton crispus* *Potamogeton friesii* (3 sites) *Potamogeton lucens* *Potamogeton perfoliatus*	Fen margin	Cul-de-sac major drain linking upland & R. Cam	Earthy eutro-amorphous peat (**1024a**)	
Swaffham Bulbeck Lode	540650-522671	*Myriophyllum verticillatum* *Potamogeton crispus* *Ranunculus circinatus*	Fen margin	Cul-de-sac major drain linking upland & R. Cam	Calcareous humic gley (**872a/b**) and earthy eutro-amorph. peat (**1024a**)	
Waterbeach Fen (E. of rd)	525699	*Potamogeton praelongus* *Sagittaria sagittifolia*	Main body of fen	Roadside drain	Earthy eutro-amorph. peat (**1024a**)	
The Weirs (Burwell)	583673	*Sagittaria sagittifolia* *Sparganium emersum*	Marking fen margin	Intermediate drain in urban area	Humic gleyic rendzina (**346**)	

n.b. Also in **TL56** are: *Ceratophyllum submersum* near Harcamlow Way (520627); *Cladium mariscus* in Burwell Fen – now NT (558678); and *Samolus valerandi* in White Fen (540651). Monk's Lode and Wicken Lode are excellent, but omitted from this catalogue as non-arable. Local areas of stonewort importance exist at Burwell Fen (5768) and Bottisham Fen (5364) – Stewart 2004.

TL57: Soham, Stretham and Stuntney:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Stretham Engine Drain	517729	*Hottonia palustris* *Myriophyllum verticillatum* *Potamogeton crispus* *Potamogeton natans*	In main body of fens	Main drain	Calcareous humic gley (**872a**)	Stonewort area of local importance at 5072 (see Stewart 2004)
Stuntney-Ely Road	552787	*Potamogeton lucens* *Senecio paludosus*	Near fen island	Roadside ditch	Earthy eutro-amorph. peat (**1024a**)	

n.b. Also in **TL57** are: *Alopecurus aequalis* near Stuntney-Ely road (553788); *Hottonia palustris* in rail-side ditch at Little Thetford (536767); *Potamogeton perfoliatus* by Newmarket Road, Stretham (522735 and 527729). The *Sium latifolium* site at Soham Qua Fen (597743) is presumably in grassland. All the Wicken Fen and Kingfishers Bridge ditches are omitted from this catalogue.

TL58: Ely, Littleport and Little Downham:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Chettisham (by railway)	543840-544840	*Hottonia palustris* (2 sites)	Edge of fen island	Rail-side ditch	Calcareous humic gley (**872a**)	
Downham Main Drain	500854-518860	*Potamogeton perfoliatus* *Potamogeton pusillus* (2 sites) *Potamogeton trichoides* (2 sites) *Ranunculus circinatus* (3 sites)	Near fen island	Major drain	Typical humic-alluvial gley (**851a**)	See also **TL48**
Ely Black Wing Drain	595820-597818	*Potamogeton perfoliatus* *Potamogeton pusillus* (2 sites) *Sagittaria sagittifolia*	In main body of fen	Major drain	Typical humic-alluvial gley (**851a**)	

n.b. Also in **TL58** are: *Butomus umbellatus* at edge of Littleport island (560849) *Potamogeton coloratus* by Ely bypass (554847); and *Samolus valerandi* in roadside ditches at West Fen Road (508819) and Ten Mile Bank (583887).

TL59: Welney, Hilgay Fen and the Ouse Washes:

n.b. Within the Ouse Washes, the grassland ditches and adjacent main drains (River Delph and both Old and New Bedford Rivers) have good assemblages of less common macrophytes. However, there are no unequivocal records in **TL59** for such plants in arable ditches.

TL67: Fordham, Isleham and Beck Row:

n.b. Several river records but only two relevant to the present study: *Potamogeton natans* by Skelton's Drove Mildenhall (681792); and *Sium latifolium* in the Soham Lode (613727) – both are fen edge.

TL68: Burnt Fen, Feltwell Anchor, Hockwold Fens and Shippea Hill:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Littleport White House	610878-610879	*Myriophyllum verticillatum* (2 sites) *Sagittaria sagittifolia*	In main body of fen	Intermediate roadside drain	Typical humic-alluvial gley (**851a**)	
Soham Black Wing Drain	610802	*Potamogeton perfoliatus* *Potamogeton pusillus*	In main body of fen	Intermediate roadside drain	Typical humic-alluvial gley (**851a**)	

n.b. Also in **TL68** is *Sagittaria sagittifolia* near Holywell Drove (681804).

TL69: Southery, Methwold and Hilgay:

Site Name	Grid References	Notable species	Characteristics of location	Status of ditch or drain	Soil type	Other characteristics
Flood Relief Cut-off Channel	612994-616993	*Butomus umbellatus* *Potamogeton natans* *Sagittaria sagittifolia*	Fen margin	Main drain	Earthy eutro-amorphous peat (**1024b**)	
Hilgay (S. of R. Wissey)	615983, 616984 & 617985	*Fontinalis antipyretica* *Myriophyllum verticillatum* *Oenanthe fistulosa*	Fen margin	Field ditches	Calcareous humic gley (**872a**)	
Hilgay (East)	642978, 643978 & 645977	*Potamogeton friesii* *Potamogeton x salicifolius*	Fen margin	Counter drain to R. Wissey	Typical humic-sandy gley (**861b**)	Probably continuous with Methwold Lode
Methwold Decoy by B1160	650953-652957	*Carex pseudocyperus* *Potamogeton crispus* *Potamogeton friesii* *Potamogeton trichoides*	Near fen margin	Roadside ditch	Earthy eu-fibrous peat (**1022a**)	
Methwold Lode	695971-699968	*Lysimachia vulgaris* (2 sites)	Near fen margin	Counter drain to R. Wissey	Humic gleyic rendzina (**346**)	See Hilgay (east)
Methwold Severals	668959	*Myriophyllum verticillatum* *Potamogeton crispus* *Potamogeton natans* *Potamogeton pusillus* *Potamogeton trichoides*	Near fen margin	Field ditch	Earthy eu-fibrous peat (**1022a**)	
Ten Foot Drain (Southery)	632948	*Potamogeton crispus* *Potamogeton lucens* *Potamogeton pusillus* *Potamogeton trichoides* *Ranunculus circinatus*	By fen island	Intermediate to major drain	Typical humic-alluvial gley (**851a**)	

Appendix 1A: Tabular summary of trends in Fenland Ditches (as listed in **Appendix 1**)

- Tabulated by soil type
- Listing how many ditches with less common macrophytes are known for that soil type
- Classifying the quality of these ditches as:
    - "Average" *i.e*. ≤ 2 less common macrophytes recorded
    - "Moderate" *i.e.* 3-5 less common macrophytes recorded
    - "High" *i.e.* > 5 less common macrophytes recorded
- Further categorising these ditches in terms of their status:
    - Canalised river
    - Main drain
    - Major drain (IDB or EA)
    - Intermediate of roadside drain (often IDB)
    - Field ditch
- And also categorising them in terms of their location within Fenland:
    - At the fen margin *i.e*. within 2.5km of the upland edge.
    - Near the fen margin *i.e.* 2.5-5.0km from the upland edge.
    - By a fen island *i.e.* within 2.5km of a clay outcrop/island in the Fenland
    - Main fen body *i.e.* >5km from the upland edge and >2.5km from the nearest fen island.
- Sub-totals for each combination of 1) status and quality and 2) location and quality are given, expressed as a percentage of the total number of ditches included within the catalogue.

Appendix 1A (continued): Disturbed soils, rendzinas, brown soils and surface-water gleys

	Average	Moderate	High	Sub-total %		Average	Moderate	High	Sub-total %
92a: Disturbed Soils			1 ditch (0.5%)						
Canalised					**Margin**		1		**0.5%**
Main					**Near margin**				
Major		1		**0.5%**	**By fen island**				
Inter/RSV					**Main fen body**				
Field									
Sub-total %		**0.5%**			**Sub-total %**		**0.5%**		
346: Humic gleyic rendzinas			2 ditches (1%)						
Canalised					**Margin**	1			**0.5%**
Main					**Near margin**	1			**0.5%**
Major					**By fen island**				
Inter/RSV	2			**1%**	**Main fen body**				
Field									
Sub-total %	**1%**				**Sub-total %**	**1%**			
511i: Typical brown calcareous earths			8 ditches (4.4%)						
Canalised	2	1		**1.6%**	**Margin**	5	2		**3.5%**
Main					**Near margin**	1			**0.5%**
Major					**By fen island**				
Inter/RSV	3	1		**2.2%**	**Main fen body**				
Field	1			**0.5%**					
Sub-total %	**3.3%**	**1%**			**Sub-total %**	**3%**	**1%**		
711r: Typical stagnogley soils			1 ditch (0.5%)						
Canalised					**Margin**	1			**0.5%**
Main					**Near margin**				
Major					**By fen island**				
Inter/RSV	1			**0.5%**	**Main fen body**				
Field									
Sub-total %	**0.5%**				**Sub-total %**	**0.5%**			
711s: Typical stagnogley soils			1 ditch (0.5%)						
Canalised					**Margin**		1		**0.5%**
Main					**Near margin**				
Major					**By fen island**				
Inter/RSV		1		**0.5%**	**Main fen body**				
Field									
Sub-total %		**0.5%**			**Sub-total %**		**0.5%**		

Appendix 1A (continued): Alluvial gley soils (groundwater gleys)

	Average	Moderate	High	Sub-total %		Average	Moderate	High	Sub-total %
812b: Calcareous alluvial gley soils			6 ditches (3.3%)						
Canalised					**Margin**				
Main	1		1	**1%**	**Near margin**				
Major	1			**0.5%**	**By fen island**				
Inter/RSV	2			**1%**	**Main fen body**	5		1	**3%**
Field	1			**0.5%**					
Sub-total %	**2.7%**		**0.5%**		**Sub-total %**	**2.5%**		**0.5%**	
813a: Pelo-alluvial gley soils			13 ditches (7.1%)						
Canalised					**Margin**	1	3	3	**3.5%**
Main			3	**1.6%**	**Near margin**	2	1	3	**3%**
Major		1		**0.5%**	**By fen island**		1		**0.5%**
Inter/RSV		4		**2.2%**	**Main fen body**		2	3	**2.5%**
Field	3	2		**2.7%**					
Sub-total %	**1.6%**	**3.8%**	**1.6%**		**Sub-total %**	**1.5%**	**3.5%**	**4.5%**	
813b: Pelo-alluvial gley soils			6 ditches (3.3%)						
Canalised	1			**0.5%**	**Margin**	2	2	1	**2.5%**
Main					**Near margin**			1	**0.5%**
Major			1	**0.5%**	**By fen island**				
Inter/RSV			1	**0.5%**	**Main fen body**				
Field	1	2		**1.6%**					
Sub-total %	**1%**	**1%**	**1%**		**Sub-total %**	**1%**	**1%**	**1%**	
813g: Pelo-alluvial gley soils			15 ditches (8.2%)						
Canalised	3	2		**2.7%**	**Margin**	5	2	1	**4%**
Main	2	1		**1.6%**	**Near margin**	5	1	1	**3.5%**
Major		1		**0.5%**	**By fen island**				
Inter/RSV	1		3	**2.2%**	**Main fen body**	1	1		**1%**
Field	1		1	**1%**					
Sub-total %	**3.8%**	**2.2%**	**2.2%**		**Sub-total %**	**5.5%**	**2%**	**1%**	
815: Sulphuric alluvial gley soils			1 ditch (0.5%)						
Canalised					**Margin**				
Main					**Near margin**				
Major					**By fen island**	1			**0.5%**
Inter/RSV		1		**0.5%**	**Main fen body**	1			**0.5%**
Field									
Sub-total %		**0.5%**			**Sub-total %**	**1%**			

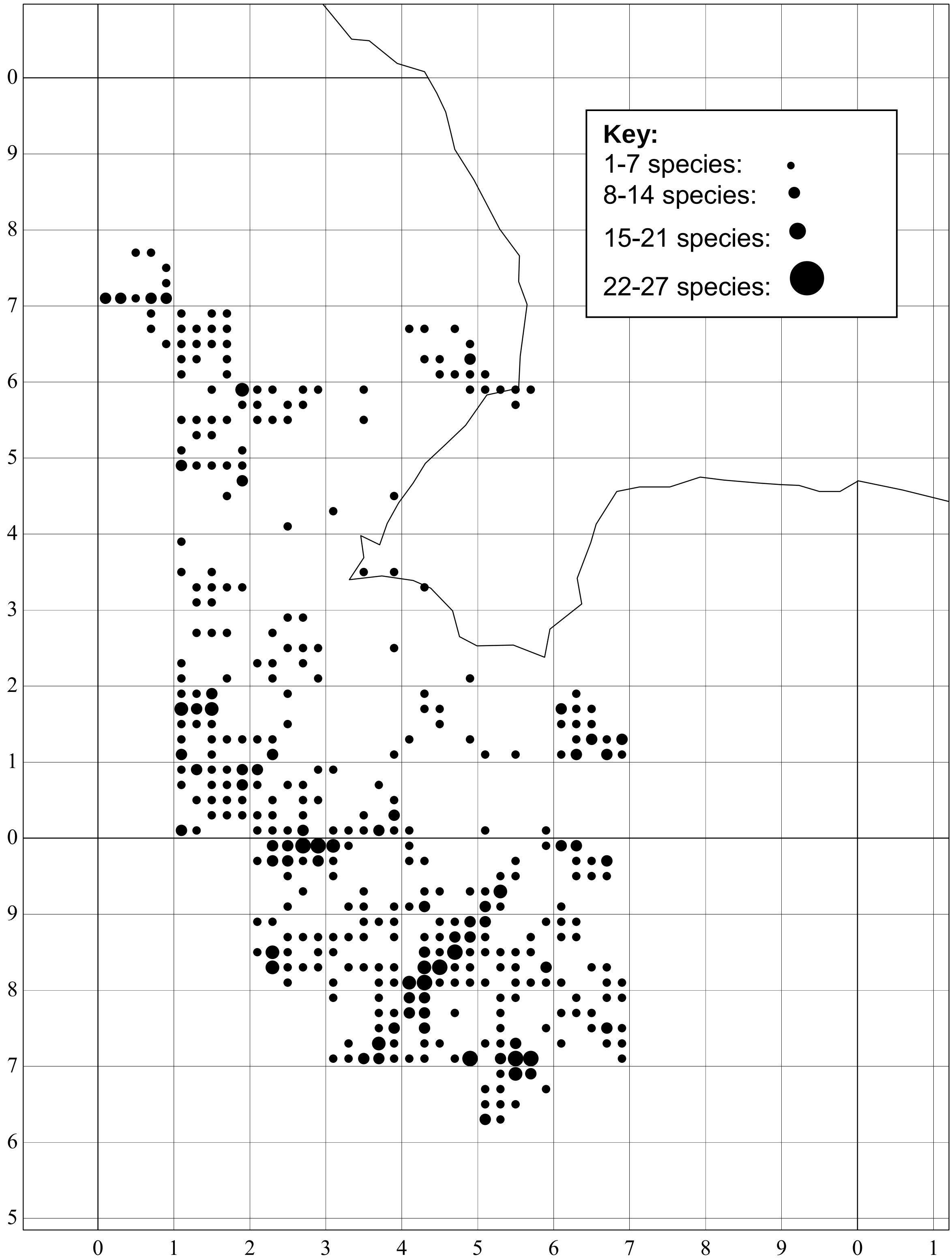
Appendix 1A (continued): Other groundwater gley soils *i.e.* Argillic, humic-alluvial, humic-sandy and some humic gley soils

	Average	Moderate	High	Sub-total %		Average	Moderate	High	Sub-total %
841d: Typical argillic gley soils			1 ditch (0.5%)						
Canalised					**Margin**			1	**0.5%**
Main					**Near margin**				
Major					**By fen island**				
Inter/RSV			1	**0.5%**	**Main fen body**				
Field									
Sub-total %			**0.5%**		**Sub-total %**			**0.5%**	
851a: Typical humic-alluvial gley soils			49 ditches (27%)						
Canalised					**Margin**	4	3	3	**5%**
Main		1	4	**2.7%**	**Near margin**	3	1	2	**3%**
Major	1	2	2	**2.7%**	**By fen island**	1	3	3	**3.5%**
Inter/RSV	14	10	5	**16%**	**Main fen body**	13	9	10	**16%**
Field	5	3	2	**5.5%**					
Sub-total %	**11%**	**8.8%**	**7.1%**		**Sub-total %**	**10.5%**	**8%**	**9%**	
851b: Typical humic-alluvial gley soils			5 ditches (2.7%)						
Canalised					**Margin**	3	1	1	**2.5%**
Main	1			**0.5%**	**Near margin**				
Major	1	1	1	**1.6%**	**By fen island**				
Inter/RSV	1			**0.5%**	**Main fen body**				
Field									
Sub-total %	**1.6%**	**0.5%**	**0.5%**		**Sub-total %**	**1.5%**	**0.5%**	**0.5%**	
861b: Typical humic-sandy gley soils			1 ditch (0.5%)						
Canalised					**Margin**	1			**0.5%**
Main					**Near margin**				
Major					**By fen island**				
Inter/RSV	1			**0.5%**	**Main fen body**				
Field									
Sub-total %	**0.5%**				**Sub-total %**	**0.5%**			
872a: Calcareous humic gley soils			9 ditches (4.9%)						
Canalised					**Margin**		2		**1%**
Main		1		**0.5%**	**Near margin**				
Major		1		**0.5%**	**By fen island**	2	1	3	**3%**
Inter/RSV	1	1	3	**2.7%**	**Main fen body**		2		**1%**
Field	1	1		**1%**					
Sub-total %	**1%**	**2.2%**	**1.6%**		**Sub-total %**	**1%**	**2.5%**	**1.5%**	

Appendix 1A (continued): Humic gley soils and Earthy peat soils

	Average	Moderate	High	Sub-total %		Average	Moderate	High	Sub-total %
872b: Calcareous humic gley soils			10 ditches (5.5%)						
Canalised					**Margin**		3		**1.5%**
Main			1	**0.5%**	**Near margin**			3	**1.5%**
Major		2		**1%**	**By fen island**	1		1	**1%**
Inter/RSV		1	4	**2.7%**	**Main fen body**			2	**1%**
Field	1		1	**1%**					
Sub-total %	**0.5%**	**1.6%**	**3.3%**		**Sub-total %**	**0.5%**	**1.5%**	**3%**	
873: Argillic humic gley soils			17 ditches (9.3%)						
Canalised					**Margin**			1	**0.5%**
Main			2	**1%**	**Near margin**			1	**0.5%**
Major					**By fen island**		2		**1%**
Inter/RSV	3	4	2	**4.9%**	**Main fen body**	4	6	4	**7%**
Field	1	4	1	**3.3%**					
Sub-total %	**2.2%**	**4.4%**	**2.7%**		**Sub-total %**	**2%**	**4%**	**3%**	
1022a: Earthy eu-fibrous peat soils			2 ditches (1%)						
Canalised					**Margin**			1	**0.5%**
Main					**Near margin**		1		**0.5%**
Major					**By fen island**				
Inter/RSV		1		**0.5%**	**Main fen body**				
Field			1	**0.5%**					
Sub-total %		**0.5%**	**0.5%**		**Sub-total %**		**0.5%**	**0.5%**	
1024a: Earthy eutro-amorphous peat soils			24 ditches (13.2%)						
Canalised					**Margin**	2	3	2	**3.5%**
Main			3	**1.6%**	**Near margin**			1	**0.5%**
Major		3	1	**2.2%**	**By fen island**	1	7	2	**5%**
Inter/RSV	5	7	3	**8.2%**	**Main fen body**	1	2	5	**4%**
Field		1	1	**1%**					
Sub-total %	**2.7%**	**6%**	**4.4%**		**Sub-total %**	**2%**	**6%**	**5%**	
1024b: Earthy eutro-amorphous peat soils			10 ditches (5.5%)						
Canalised					**Margin**	6	2	2	**5%**
Main		1	1	**1%**	**Near margin**				
Major	1		1	**1%**	**By fen island**				
Inter/RSV	4			**2.2%**	**Main fen body**				
Field	1	1		**1%**					
Sub-total %	**3.3%**	**1%**	**1%**		**Sub-total %**	**3%**	**1%**	**1%**	

Appendix 2: Macrophyte-richness in Fenland – co-occurrence of species mapped by tetrad.



Appendix 3: Kirby and Lambert (2003) – summary of Good Arable ditches

Those in **blue bold-face** are clearly high quality, whilst those in ordinary type (black) are of intermediate quality

Table A: Farcet Fen

Grid Reference	Sample Number	Ditch Substrate	Water Depth (m.)	Ditch width (m.)	Water quality
TL225934	**F1**	**Mud & Silt**	**0.35**	**2.0**	**Clear**
TL233937	F2A	Gravel & silt	0.8-1.0	3.0	Clear
TL218836	**F5**	**Peat**	**0.7**	**2.0-2.5**	**Turbid & peaty**
TL209941	**F6**	**Peaty organic**	**>1.0**	**4.0**	**Moderate**
TL230918	**F8A**	**Marl**	**>1.0**	**3.0-5.0**	**Very good**
TL215926	F8B	Mineral	0.6	Fairly narrow	Good
TL206930	**F10A**	**Mineral**	**0-0.5**	**Wide**	**Good**
TL215921	F10B	Peat/marl	>1.0	4.0-5.0	Clear, peat-stained

Table B: Kingsland

Grid Reference	Sample Number	Ditch Substrate	Water Depth (m.)	Ditch width (m.)	Water quality
TL323969	K1	Mineral	1.0	4.0	Turbid, algal growth
TL323970	K2	Mineral	>2.0	8.0	Turbid, algal growth
TL323974	K3A	Mineral & organic	>1.5	8.0	Turbid
TL325978	**K4**	**Organic**	**>1.0**	**4.0-5.0**	**Moderate**
TL346993	K9	Organic	0.8	3.0	Poor
TF357009	**K11A**	**Organic/silt**	**>2.0**	**20.0**	**Good, peat-stained**
TF385019	**K11B**	**Organic**	**>1.0**	**6.0**	**Turbid, flocculent, iron-stained**
TF353004	**K12A**	**Organic**	**1.5**	**4.0**	**Turbid**
TF355005	**K12B**	**Organic**	**1.0**	**4.0**	**Good**
TL357998	K14B	Organic	0.85	4.0	Good, very clear

Table C: Tick Fen

Grid Reference	Sample Number	Ditch Substrate	Water Depth (m.)	Ditch width (m.)	Water quality
TL350877	T3A	Mineral	>2.0	10.00	Moderate
TL353874	T4A	Organic	0.7	2.5-3.0	Moderate
TL370872	**T5A**	**Organic**	**1.5**	**3.0**	**Good**
TL370865	T5B	Mineral	0.5	2.5	Good
TL360840	T7B	Mineral	1.0	3.0	Good
TL370872	**T9**	**Mineral**	**0.5**	**1.5**	**Good**
TL368845	T10B	Mineral	0-0.4	1.0	Moderate
TL361838	**T11**	**Mineral**	**0.15**	**1.2**	**Good**
TL361844	T12	Mineral	0.5	3.0	Moderate
TL345817	T13	Organic	0.15	2.0	Poor
TL354820	T14B	Organic/ mineral	>1.0	6.0	Good
TL346811	**T15A**	**Marl**	**>1.0**	**3.0**	**Excellent**
TL353810	**T16**	**Marl**	**1.0**	**3.0**	**Excellent**
TL356820	T17A	Mineral	1.5	5.0	Good (clear peat-stained)
TL358318	T19A	Mineral	0.75	3.0	Moderate
TL367813	**T19B**	**Mineral, marl**	**0.7**	**3.0**	**Good**
TL360819	**T20A**	**Mineral, marl**	**>1.0**	**3.5**	**Good**
Tl363821	T20B	Mineral, marl	>1.0	3.5	Good
TL363823	T21A	Mineral	0.7	3.0	Moderate
TL370817	T21B	Mineral, marl	0.1	1.0-1.5	Good
TL332835	T22	Organic	0.15	2.0-2.5	Poor
TL316843	**T23B**	**Mineral, marl**	**>1.5**	**5.0**	**Excellent**
TL315845	T24A	Mineral, large stones	>1.5	10.0	Good
TL318850	T24B	Mineral	>1.0	8.0	Good to moderate
TL346857	**T30A**	**Organic**	**0.4**	**4.0**	**Moderate**
TL357851	T30B	Organic	0.4	5.0	Moderate
TL346866	T31A	Organic	0.5	6.0	Moderate
TL331872	T33	Mineral?	>2.0	10.0	Moderate

Table D: Summary

Data	Ditch Substrate	Mean water depth (m.)	Mean ditch width (m.)	Water quality
High quality ditches only	47% organic 26% mineral 21% marl 5% mud/silt	0.97	4.33 3.41 (excluding K11A)	68% good-excellent 16% moderate 16% poor or turbid
All intermediate and high quality	43% organic 37% mineral 13% marl 7% other (silt with mud or gravel)	0.91	4.54 4.19 (excluding K11A)	54% good-excellent 26% moderate 20% poor or turbid

Appendix 4: Summary of environmental factors for Romney and Humberhead arable ditches with high quality (after Mountford & Sheail 1982, 1985).

Ditch No.	Width	Depth	pH	Wood Shade	Herb	Soil	NLU	Grazed?	Fenced?	Status	Management?
1033	1.75	0.40	6.91	0	5	PeloGley	I/A	Ungrazed	Unfenced	Field ditch	Unmanaged
1042	2.00	0.50	7.63	0	20	PeloGley	A/A	Ungrazed	Unfenced	Field ditch	Unmanaged
1061	2.00	0.45	7.70	2	5	PeCaGley	A/Rd	Ungrazed	Unfenced	IDB	Unmanaged
1062	2.00	0.70	7.40	1	5	PeCaGley	A/A	Ungrazed	Unfenced	IDB	Unmanaged
1086	18.00	2.50	6.84	0	1	PeloGley	A/A	Ungrazed	Unfenced	WA	New Mgmt
1087	18.00	2.50	6.84	0	1	PeloGley	A/A	Grazed	Unfenced	WA	New Mgmt
1113	2.00	1.00	7.63	0	5	PeloGley	A/A	Ungrazed	Unfenced	IDB	Unmanaged
1127	2.50	1.50	7.63	0	2	PeCaGley	A/A	Ungrazed	Unfenced	IDB	New Mgmt
3002	1.30	0.50	6.70	0	35	SandHumG	A/A	Ungrazed	Unfenced	Field ditch	Old Mgmt
3010	4.00	0.80	6.80	0	2	EufiPeat	A/Rd	Ungrazed	Unfenced	WA	New Mgmt
3023	1.30	0.40	6.70	0	8	SandHumG	A/A	Ungrazed	Unfenced	Field ditch	Unmanaged
3109	1.30	0.15	7.00	0	15	SandHumG	A/Rd	Ungrazed	Unfenced	Field ditch	Old Mgmt
3123	1.50	0.75	6.20	0	15	SandHumG	A/Rd	Ungrazed	Fenced	Field ditch	New Mgmt
3136	1.20	0.15	6.20	3	8	SandHumG	A/A	Ungrazed	Unfenced	Field ditch	Old Mgmt
3168	7.00	1.80	6.40	0	3	SandHumG	A/Rd	Ungrazed	Unfenced	IDB	Unmanaged
3170	2.40	0.75	6.30	0	25	SandHumG	A/A	Ungrazed	Unfenced	Field ditch	New Mgmt
3172	2.30	0.65	6.23	0	15	EufiPeat	A/A	Ungrazed	Unfenced	Field ditch	Unmanaged
3183	7.50	1.20	8.40	0	2	SandHumG	A/Rd	Ungrazed	Unfenced	IDB	Unmanaged
3197	3.20	0.90	6.30	0	2	SandHumG	A/Rd	Ungrazed	Unfenced	IDB	Unmanaged
Mean:	4.28 (2.66*)	0.94 (0.76*)	6.94	0.3	9.1	Not peat	[As defined by the group]			Varied	Most "unmanaged" are IDB, so really "occ. Managed"

Notes: Ditch numbers **1086** and **1087** are EA main rivers (Royal Military Canal) and amended mean values (*) exclude these rather extreme examples. NLU signifies neighbouring land-use, and broad soil types are as tabulated in the preamble to Appendix 1.

The important stonewort area (ISA) at North Idle Drain is at **SE**74.09. – just outside the CEH study area on the Humberhead levels, and as well as *Tolypella prolifera*, has *Pilularia globulifera*.

Appendix 5: Species to guide quality assessment of arable ditches: categories advanced by Chris Newbold & Owen Mountford (Mountford *et al.* 1998)

Notes: *** Grazing marsh represents the major part of their distribution; and
* Markedly commoner in grazing marsh than other wetland habitats.

Excellent - when found in arable ditches, species indicating the highest quality habitat.

Alisma gramineum
Alisma lanceolatum ***
Apium inundatum
Baldellia ranunculoides ***
Butomus umbellatus ***
Carex rostrata
Carex vesicaria
Chara spp[2]
Cladium mariscus *
Eleocharis acicularis ***
Eleogiton fluitans *
Groenlandia densa *
Hydrocotyle vulgaris
Juncus subnodulosus ***
Leersia oryzoides ***
Luronium natans
Menyanthes trifoliata
Myriophyllum alterniflorum
Oenanthe fistulosa *
Pilularia globulifera
Potamogeton acutifolius ***
Potamogeton alpinus
Potamogeton coloratus ***
Potamogeton compressus ***
Potamogeton friesii ***
Potamogeton gramineus
Potamogeton obtusifolius *
Potamogeton polygonifolius
Potamogeton praelongus
Potamogeton hybrids[1]
Potentilla palustris
Ranunculus baudotii ***
Ranunculus hederaceus
Ranunculus lingua *
Ruppia cirrhosa
Ruppia maritima *
Sium latifolium ***
Sonchus palustris *** (if native)
Sparganium natans
Stellaria palustris ***
Utricularia intermedia s.l.
Utricularia minor

Good - when found in arable ditches, species indicating high quality habitat

Alisma lanceolatum ***
Alopecurus aequalis
Alopecurus bulbosus *
Alopecurus geniculatus
Althaea officinalis *
Apium graveolens *
Bidens cernua
Bidens tripartita
Callitriche obtusangula ***
Callitriche truncata ***
Caltha palustris
Carex acuta
Carex elata ***
Carex pseudocyperus *
Ceratophyllum submersum *
Cicuta virosa
Galium uliginosum
Hottonia palustris ***
Hydrocharis morsus-ranae ***
Hypericum elodes
Juncus bulbosus s.l.
Lysimachia vulgaris
Myosotis secunda
Myriophyllum verticillatum ***
Nitella spp.[3]
Nymphaea alba (if native)
Nymphoides peltata * (if native)
Oenanthe aquatica *
Oenanthe fluviatilis
Potamogeton crispus
Potamogeton lucens ***
Potamogeton perfoliatus
Potamogeton trichoides ***
Ranunculus circinatus ***
Ranunculus flammula
Ranunculus peltatus
Riccia fluitans
Rorippa amphibia
Rorippa microphylla
Rumex hydrolapathum *
Rumex maritimus ***
Rumex palustris ***
Sagittaria sagittifolia *
Sparganium emersum *
Stratiotes aloides *** (if native)
Tolypella spp.[4]
Utricularia vulgaris s.l. *
Veronica catenata ***
Wolffia arrhiza

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[1] *e.g. P. x lintonii, P. x zizii, P. x billupsii, P. x fluitans, P. x sparganifolius, P. x nitens, P. x lanceolatus, P. x salicifolius, P. x cognatus, P. x cooperi, P. x grovesii, P. pseudofriesii*
[2] *e.g. C. vulgaris, C. hispida, C. pedunculata, C. globularis, C. aspera*
[3] *e.g. N. flexilis, N. mucronata, N. tenuissima, N. capillaris*
[4] *e.g. T. prolifera, T. intricaqta, T. nidifica*

Moderate - when found in arable ditches, species indicating average quality habitat

Alisma plantago-aquatica *
Alopecurus geniculatus
Berula erecta *
Bolboschoenus maritimus
Callitriche hamulata
Callitriche platycarpa *
Callitriche stagnalis
Catabrosa aquatica *
Eleocharis palustris *
Elodea canadensis (*?)
Equisetum fluviatile
Equisetum palustre
Fontinalis antipyretica
Galium palustre elongatum *
Glyceria declinata
Hippuris vulgaris *[5]
Iris pseudacorus
Juncus articulatus
Lemna trisulca *
Lotus pedunculatus
Mentha aquatica
Myriophyllum spicatum *
Nuphar lutea
Oenanthe aquatica *
Potamogeton berchtoldii *
Potamogeton natans
Potamogeton pectinatus *[6]
Potamogeton pusillus *
Ranunculus aquatilis s.s. *
Ranunculus sceleratus *
Ranunculus trichophyllus *
Rorippa nasturtium-aquaticum s.s.
Samolus valerandi
Schoenoplectus lacustris s.s.
Schoenoplectus tabernaemontani *
Sparganium erectum
Typha angustifolia *
Veronica anagallis-aquatica s.s.
Veronica beccabunga
Zannichellia palustris *

Poor - when found in arable ditches, species indicating "ordinary" or degraded habitat, especially when present in large quantities

Apium nodiflorum
Azolla filiculoides
Carex acutiformis (*?)
Carex riparia *
Ceratophyllum demersum *
Crassula helmsii
Elodea nuttallii
Glyceria fluitans
Glyceria maxima *
Glyceria notata
Lemna gibba *
Lemna minor
Lemna minuta
Persicaria amphibia *
Phalaris arundinacea
Phragmites australis *
Spirodela polyrhiza *
Typha latifolia

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[5] If emergent and not abundant.

[6] Provided only an associated species, not dominant (also true for *Zannichellia*)

Appendix 6: Text of form letter sent to selected experts, asking their opinion of the criteria that determine the presence of a "good arable ditch".

What makes a "good" arable ditch for aquatic macrophytes?

I am presently working on a short scoping study for English Nature with the following objectives:

- *To propose a series of ditch characteristics associated with species rich plant communities or rare species***.**
- *To draft a decision-making protocol for determining potential biodiversity value of ditches.*
- *To propose an approach for further work, including locations for field survey in the Fenland, to investigate the potential of ditches within an arable landscape as reservoirs for rare aquatic plant species.*

The focus of the work is the Fenland basin, and specifically on ditches in arable land. In effect, one could summarise my job as trying to answer the question: "*What is it about some ditches in the arable Fenland that has allowed species-rich assemblages of macrophytes to survive, often with a good representation of (nationally/regionally) scarce and local species*?"

I'm partly addressing this question through examination of huge reams of data in BRC and elsewhere, as well as the numerous ditch surveys that have taken place over the past 25 years or so. However, much of these data and surveys either don't refer to the neighbouring land-use, or if they do, the focus is clearly grazing marsh – and hence not really apposite to the current project.

Hence, I'm conducting a limited "opinion poll" of those folk who I know have enough relevant experience in ditches to make a well-informed stab at outlining the features of a "good" arable ditch. Of course the more thoughts that you have, and the more detail, the merrier, but to guide you in your response, below are some of the questions that occurred to me (in no particular order). Are species-rich ditches in arable land especially associated with:

1) Specific arable crops?
2) A range of freeboard and bank width?
3) Ditches of certain widths and depths?
4) A limited range of pH and conductivity?
5) Particular trophic status?
6) Ditches of a certain status in the drainage network (*i.e.* field ditch, IDB or main drain *etc*)?
7) Definite locations in the landscape – close to the upland fringe, fen islands etc*?*
8) Certain water supply mechanisms (*e.g.* from upland runoff, groundwater-fed, *etc*)?
9) A fairly precise regime of ditch management?
10) Situations that have flow or frequent pumping?
11) Ditches with or without woody/herbaceous shade?
12) Certain soil types and substrates?
13) Accompanying terrestrial species and community types?

Some of these questions have reasonably obvious answers, but I wanted to allow for all sorts of thoughts and inputs at this stage, so I threw the net pretty wide. I'm sure you could add governing factors of your own to the mix, and would be delighted if you did.

With best wishes

Yours sincerely,

(J. Owen Mountford)

APPENDIX 7 ENVIRONMENTAL FACTORS DETERMINING OCCURRENCE OF DITCH VEGETATION TYPES (AFTER MOUNTFORD IN PRESS)

Summary data for 20 assemblages. The units for each environmental variable are given, but note that "percentage" is used in two ways: a) for shade (woody and herbaceous), the value is the mean percentage of the ditch surface that is shaded; whereas b) all other percentage values (gleys *etc*) reflects the proportion of channels within the assemblage that are in a particular category *i.e.* 67% of channels in assemblage **B** are on gley soils, and 17% are on peat soils.

	Drainage channel assemblage																			
Environmental variable (mean for assemblage)	**B**	**C**	**D**	**N**	**M**	**L**	K	**O**	**H**	**E**	**F**	**I/J**	**P**	**Q**	**T**	**S**	**R**	**W**	**V**	**X**
Channel width (m)	5.62	3.92	1.79	4.50	2.04	1.74	1.26	1.82	2.02	2.28	2.42	1.8 (1.1)	1.79	1.02	1.64	1.53	1.25	0.99	1.29	0.89
Maximum depth (m)	1.25	1.25	0.51	0.96	0.77	0.48	0.20	0.47	0.58	0.77	0.78	0.52 (0.21)	0.39	0.23	0.34	0.17	0.09	0.003	0.08	0
Freeboard (m)	1.41	1.19	1.25	1.11	0.63	0.98	1.31	1.26	1.22	1.26	1.32	1.25 (1.27)	0.89	2.09	1.50	0.92	1.05	1.14	1.15	0.66
Woody shade (%)	0	0.8	3.9	4.2	1.0	10.8	18.6	13.9	11.6	6.5	12.1	17.6 (15.9)	16.1	2.0	6.9	28.1	3.8	7.6	67.0	30.5
Herbaceous shade (%)	3.8	3.8	8.4	6.7	11.1	11.1	12.7	16.7	14.4	11.6	14.2	13.7 (28.6)	12.8	29.4	26.7	24.7	20.9	45	26.5	36.9
Water pH	7.31	7.64	7.20	6.84	6.76	6.93	6.78	6.89	7.03	6.67	6.91	6.87 (6.23)	6.57	6.70	6.54	6.60	6.75	6.34	6.76	n/a
Channels on gleys (%)	67	88	77	73	69	73	73	87	100	86	90	94 (71)	66	60	61	78	54	29	75	79
Channels on peats (%)	17	0	18	26	28	27	9	7	0	0	0	0 (24)	24	0	26	18.5	27	14	0	8
Land-use arable or road (%)	54	35	56	15	9	40	36	60	37	53	75	75 (69)	40	90	82	28	59	75	35	88
Channel and banks unmanaged (%)	0	7	12	5	9	31	55	27	35	36	20	67 (76)	55	40	25	33	33	79	92	100
Channel margins and banks grazed (%)	42	69	6	46	62	42	18	27	42	36	0	3 (0)	18	0	14	44	31	7	0	0
Channel cleaned or dredged in previous year (%)	92	60	65	81	12	0	0	30	4	50	30	0 (0)	18	20	50	4	18	7	0	0
Channel managed by EA or IDB (%)	58	55	24	45	21	8	9	33	23	29	30	13 (0)	18	0	14	4	8	7	0	0
Channel subject to ditching grant (%)	0	33	12	28	56	54	46	40	54	36	40	70 (48)	45	60	27	44	41	43	21	39
Adjacent land subject to grant for under-drainage (%)	21	33	38	12	10	27	9	32	33	46	55	42 (43)	10	50	43	13	26	25	21	27