Wetland Resource Evaluation and the NRA's Role in its Conservation

2. Classification of British Wetlands

Environmental Consultancy
University of Sheffield

R&D Note 378

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2. Classification of British Wetlands

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This document recommends a 'hydrotopographical' classification of British wetlands which should be adopted by the NRA and hopefully other organisations and individuals concerned with wetland resource assessment, management and conservation. It is one of a series of three reports with others covering, 'Wetland Resource Assessment' and, 'The NRA's Role in Wetland Conservation'.

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FOREWORD

Wetland ecologists have long wanted to distinguish particular 'types' of wetland. Out of a plethora of potential criteria that are available for classification (hydrology, hydrochemistry, land-use, vegetation *etc.*), one of the most widespread approaches has been to identify 'hydrotopographical' wetland types, based upon the 'shape' of the wetland and its situation with respect to apparent sources of water. The appeal of this approach is doubtless partly because the topography and water supply of a wetland may be regarded as one of its most 'fundamental' characteristics. It may also be because of the apparent simplicity of categorising sites by their 'shape and situation'. However, such supposed 'simplicity' is more apparent than real because the topographical variation of wetlands is not readily characterised and quantified, nor are hydrological mechanisms necessarily amenable to identification by casual inspection. Moreover, as this 'simplicity' has encouraged various workers to generate their own *ad hoc* 'hydrotopographical' classifications, a variety of rather different informal classifications exist, some of which are characterised by an inconsistent use of classificatory criteria and by poorly-defined categories.

Given these considerations, it might be most appropriate to abandon 'hydrotopography' as a basis for classifying wetlands. However, there is little doubt that many practitioners require to use a typology based broadly upon such features. Given that this is the case, in this document we explore the possibility of elaborating a classification of British wetlands in a way that may overcome some of the limitations of some existing 'hydrotopographical' classifications, primarily by attempting to be more comprehensive and more consistent. This R&D note develops a clear and coherent 'hydrotopographical' classification with a logical rationale, which, as far as possible, incorporates many of the existing ideas and classes of experienced wetland scientists.

Brief and preliminary consideration is given to some other approaches to classifying wetlands based on other attributes. These are not seen as 'competing' with hydrotopography as a basis for classification. Rather, it is recognised that the development of a comprehensive classification of wetlands may be approached using a series of features, which can be regarded as nominally-independent 'overlays' which can be superimposed upon one another.

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EXECUTIVE SUMMARY

This R&D note provides a clear classification for wetlands in England and Wales. The classification incorporates many of the existing ideas on the subject but avoids some of the problems associated with other classifications.

A two-layered 'hydrotopographical' classification is proposed. The first layer identifies *situation-types*, *i.e.* the position the wetland occupies in the landscape, with especial emphasis upon the principal sources of water. The second layer identifies *hydrotopographical elements*, *i.e.* units with distinctive water supply and, sometimes, distinctive topography in response to this.

This system is seen as an independent, basic, classification upon which it is possible to superimpose additional, independent classifications based on other features (*e.g.* base-status, fertility, vegetation, management *etc.*). Some proposals for such additional classifications are provided.

SUMMARY

In attempting to provide a working definition of 'wetland' and procedure for evaluating the wetland resource (R&D Note 377), it became clear that there is much confusion surrounding perceptions of wetlands, both in terms of what areas can be categorised as a 'wetland' and how these can be sub-divided appropriately into different categories. It was also recognised that the usefulness of the proposed major project to evaluate the extent of the wetland resource in England and Wales would be considerably enhanced if it included a basic classification into wetland types as these vary considerably in their response and susceptibility to internal and external influences. This document thus develops a clear classification for wetlands, which incorporates many of the existing ideas and classes of experienced wetland scientists, but which it is hoped avoids some of the problems associated with extant classifications.

Wetland ecologists have long wanted to use a simple and informal classification of wetlands, so that broad 'types' could be identified and recognised. Numerous features can be used to classify wetlands, but many workers have used 'hydrotopography' as a basis for an informal typology. 'Hydrotopography' essentially refers to the 'shape' and situation with respect to (usually presumed) water sources. Existing hydrotopographical classifications of wetlands in Britain have many limitations. These stem primarily from a failure to distinguish between (a) the topographical situation within which the wetland occurs; (b) the topography of the wetland itself; and (c) distinct 'hydrotopographical' elements *within* a wetland site.

To help overcome these limitations, a two-layered 'hydrotopographical' classification is proposed. The first layer identifies *situation-types*, *i.e.* the position the wetland occupies in the landscape, with especial emphasis upon principal apparent sources of water. Many, but not all, wetlands can be referred to a single *situation-type*. The second layer identifies *hydrotopographical elements*, *i.e.* units with distinctive water supply and, sometimes, distinctive topography in response to this. Many wetlands will contain a number of *hydrotopographical elements* and the same element may occur in wetlands belonging to different *situation-types*. The *hydrotopographical elements* may correspond in large measure with the concept of the *mesotope*.

The *situation-type* is a crude category which is as variable as the landscapes within which wetlands occur. It represents the first approximation for a wetland classification, but because of its variability it does not represent a very useful unit of wetland resource assessment, even in purely 'hydrotopographical' terms.

The *hydrotopographical element* is also variable, but is more readily categorised. The units adopted here broadly correspond to units recognised by other workers, with some amendment, addition and changes of rank in a manner consistent with the rationale of this classification. The *hydrotopographical element* is considered a more useful unit of wetland resource. Its main limitation is that some elements are not readily recognised without measurements. It is suggested that, as a first approximation, wetlands should be classified to the level of the *hydrotopographical element* when this is possible and to the level of the *situation-type* when it is not. Intuitive assessment of the hydrological properties of wetlands is discouraged.

A classification based upon *hydrotopographical elements* does not provide an adequate *environmental* or *biological* classification of wetlands, even at a first approximation. It is seen

as an independent, basic, classification upon which it is possible to superimpose independent classifications based on other features (*e.g.* base-status, fertility, vegetation, management *etc.*). Thus a given *hydrotopographical element* can (but does not necessarily) show much variation with respect to features such as base-status, fertility and vegetation. Some proposals for such additional classifications are provided.

In view of this, it is important that the potential value of 'hydrotopographical' units for assessing the wetland resource is clearly recognised. They are essentially 'rule-of-thumb' categories that can be used for describing wetland 'types', but they do not necessarily relate well to other specific features. For example, they do *not* provide a reliable guide to 'wildlife interest'. If an assessment of the wetland resource is primarily for establishing its importance for biological conservation then this should be done by direct assessment of the biological resource and classification of the wetland on this basis then superimposed on the basic hydrotopographical framework.

An outline of the proposed classification follows in Table S1.1. The main text provides the background to the structure and its use in the field while a rationale and justification for detail is presented in the Appendices.

KEYWORDS

Wetlands, Resource, Classification, Key, Hydrotopography, Survey

Table S1.1 Proposed classification of British wetlands

Wetland *situation-types* that have been recognised and the *hydrotopographical elements* that may occur within them. Elements that are particularly prominent are shown in bold type. Further detail is provided within the report.

A. Situation-types

BASIN WETLANDS
LAKESIDE WETLANDS
COASTAL PLAIN AND FLOOD-PLAIN WETLANDS
PLATEAU-PLAIN WETLANDS
VALLEYHEAD WETLANDS
HILLSLOPE WETLANDS

B. Hydrotopographical elements

(with sub-categories)

TOPOGENOUS WETLANDS (water level maintained by impeded drainage).

- **General topogenous wetland**
  - *General topogenous fen*
  - *General topogenous marsh*
- **Alluvial wetland**
  - *Alluvial fen*
  - *Alluvial marsh*
  - *Flood lands*
  - *Deltaic wetlands*
- **Waterfringe wetland**
  - *Littoral wetland*
  - *Floating wetland*
- **Sump wetland**
  - *Firm sump wetland*
  - *Floating sump wetland*
  - *Seasonal pool wetland*
- **Percolating wetland**
  - *Floating percolating wetland*
- **Maintained topogenous wetland**
- **Water track or soakway**

OMBROGENOUS WETLANDS (rain fed wetland)

- **Topogenous bog**
  - *(Sub-types have yet to be clearly defined)*
- **Hill bog**
  - *(Sub-types have yet to be clearly defined)*

SOLIGENOUS WETLANDS (fed by telluric water with little impedence of outflow)

- **Sloping wetland**
  - *Sloping fen*
  - *Wet slopes*
- **Spring-fed wetland**
  - *Spring mound*
  - *Spring flush*
  - *Seepage fen*
  - *Spring head*
  - *Supplemented spring wetland*
- **Run-off wetland**
  - *Run-off fen*
  - *Run-off flush*
  - *Ladder-fen*
  - *Seasonal wet slope*
- **Water track or soakway**

ARTIFICIAL WETLANDS

- **Root Zone beds**

C. Habitat Conditions

Base status
Broad substratum types
Site condition

1. INTRODUCTION

1.1 Wetland terminology

In the process of providing a working definition of 'wetland' and a procedure for evaluating the wetland resource (see R&D Note 377), it became clear that there is much confusion surrounding perceptions of wetlands, both in terms of what areas can be categorised as a 'wetland' and how these have been sub-divided into different categories and named. Wetland terminology is notoriously complex and inconsistent. This reflects the different perceptions and preferences of individual workers; the availability (and use) of a wide range of contrasting features to circumscribe and subdivide wetlands; and a comparatively limited vocabulary of appropriate descriptive nouns. In some instances the response of ecologists to this situation has been to coin a new terminology. More often, perhaps partly to avoid the generation of a plethora of new terms, they have given existing terms a specific (though sometimes not specified) meaning. One consequence of this is that there is a tendency for different ecologists to use the same wetland word with (sometimes strikingly) different nuances of meaning. As many of the terms (*e.g.* wetland, bog, marsh) are also vernacular words which, in ordinary usage, often lack the specificity of meaning conferred upon them by ecologists, it is scarcely surprising that the use of wetland terms often generates considerable (though not always recognised) confusion.

This document has been produced as a contribution towards this discussion. It attempts to clarify and rationalise some aspects of wetland terminology whilst avoiding excessive violation of long-standing or widespread usage.

1.2 The concept of 'wetland'

The term 'wetland' itself exemplifies many of the problems of terminology. At face value, it means 'land that is wet', but this generates the qualifying query: "How wet?". There is general agreement that wetland refers to a habitat occupying a position somewhere between 'dryland' and deep-water aquatic ecosystems and differences of definition refer mainly to the exact location of its upper and lower limits (Mitsch & Gosselink, 1993). Broadly, two main usages have been adopted (for details see R&D Note 377). In one, 'wetland' is restricted to refer to land that is (or once was) waterlogged, including swamp but excluding areas of open water. In the other, as exemplified by the 'Ramsar' convention, both waterlogged habitats and shallow bodies of open water are included within the concept of wetland. The 'Ramsar' definition[1] includes shallow water to 6 m depth.

There is undoubtedly a need for a generic term to refer to waterlogged habitats in their strict sense but there is an equal need for a collective name for waterlogged habitats plus associated bodies of shallow water. A strong case can be made for restricting the use of 'wetland' to refer just to waterlogged ground, but in practice this is not likely to receive widespread acceptance as it would exclude such complexes of open water and fen as the Norfolk Broadland which are widely, and popularly, referred to in aggregate as 'wetland'.

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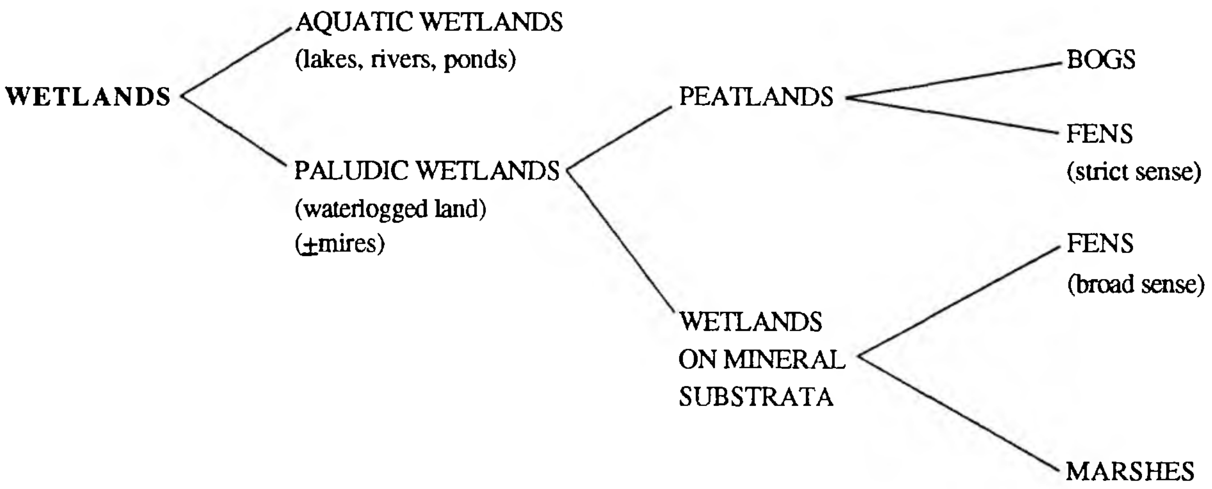
[1] The Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitats (1971)

One solution to this problem is to retain the general category of 'wetland' to refer to shallow water - wet land complexes, but to subdivide into two main types - AQUATIC and PALUDIC wetlands (Table 1.1). Aquatic wetlands include bodies of shallow open water (lakes, rivers, pools etc.), whilst the term paludic wetlands essentially includes sites that have (or once had) a water level close to the ground surface for much of the year, but which may experience some periodic inundation or drying. 'Paludic wetland' thus represents wet land in its strict sense and in its scope comes close to that of *mire* (Gore, 1983). **This document is exclusively concerned with paludic wetlands.**

TABLE 1.1 Broad wetland habitat classes based on (a) substratum type, (b) base status; (c) nutrient status; (d) main water source; (for detail see text & glossary).

A Substratum type



B Base status

BOG	POOR FEN	RICH FEN

C Nutrient status

OLIGOTROPHIC (nutrient poor)	MESOTROPHIC (moderate nutrient status)	EUTROPHIC (nutrient rich)

D Water source

OMBROTROPHIC (mire surface fed by precipitation only)	MINEROTROPHIC (mire surface fed by precipitation & groundwater)

Existing definitions and perceptions of wetlands are considered further in R&D Note 377. In this, a working definition of a 'wetland', appropriate to NRA responsibilities, has been developed, with a view to facilitating future evaluation of the geographical extent of the wetland resource in England and Wales. The following definition was suggested:

Wetland is land that has (or had until modified) a water level predominantly at, near, or up to 1.5 m above the ground surface for sufficient time during the year to allow hydrological processes to be a major influence on the soils and biota. These processes may be expressed in certain features, such as characteristic soils and vegetation.

This definition essentially corresponds with the category of paludic wetlands suggested above. It must, of course, be recognised that such a definition is rather broad and to some extent circular (for example when specifying or identifying 'characteristic wetland soils and vegetation types'). The definition refers only to the FRESHWATER WETLANDS and excludes brackish environments.

1.3 Some other wetland terms

A variety of terms exist as broad descriptors of more-or-less distinctive wetland types (*e.g.* bog, fen, marsh, mire, moor, peatland, swamp). Some of these are an almost endless source of confusion in wetland ecology. To help identify any inconsistencies, aspects of the use and derivation of some of the terms are discussed briefly below. The usage adopted in this Report (and definitions of some additional terms) is given in the Glossary. The relationship between some of the terms is shown in Table 1.1.

1.3.1 Bog

The vernacular word *bog* refers loosely to 'marshy ground', but wetland ecologists have come increasingly to restrict it to refer to *ombrotrophic* (*ombrogenous*) mire, *i.e.* wetlands fed directly and exclusively by rainfall. Such wetlands are invariably peat-based. 'Bog' is derived from the Irish and Gaelic word *bogach* (= soft) and has no close relative in other northern European languages. The German *hochmoor* is essentially equivalent to *bog*.

1.3.2 Carr

Most British ecologists follow Tansley (1939) and use *carr* to refer to fen woodland, reflecting its common usage in East Anglia. However, in parts of northern Britain *carr* is used as a general term for any wetland, irrespective of its vegetation-type, a usage which is similar to that of the Swedish *kärr* (± = *fen*). Interestingly, however, the East Anglian woodland connotations of *carr* are well reflected in Icelandic where *kjarr* means brushwood or copse (and marsh-woodland = *kjarr-myr*)!

1.3.3 Fen

As an ecological term, *fen* has received a variety of definitions, some idiosyncratic (see Wheeler, 1995). One of its most widespread (and earliest) usage has been as a synonym for *minerotrophic mire*. In this broadest sense, *fen* covers an enormous range of habitats as it effectively includes all examples of waterlogged ground irrigated by telluric water and is broader than the concept of peatland ((Mörnsjö, 1969). Nonetheless, some workers restrict *true* *fen* to refer to peat-based wetlands and adopt the term *marsh* for minerotrophic sites on mineral ground. Whilst this approach has the advantage of simplicity, limitations are that some important fen vegetation-types occur both on peat and on mineral soil and that in some sites mineral and peat-based systems are intimately juxtaposed.

Tansley (1939) restricted *fen* to refer not only to peat-based wetlands but also to base-rich examples. This may have reflected his familiarity with the vernacular use of *fen* in East Anglia, where the sites that are named 'Fen' are mostly (but not invariably) base-rich. Tansley's usage is more-or-less equivalent to the use of *rich fen* by Scandinavian workers. Ratcliffe (1964) adopted an idiosyncratic approach by restricting *fen* to refer to *topogenous* wetlands (and using *mire* to refer to *soligenous* examples). Although the distinction between topogenous and soligenous wetlands is an important one, and one which could conceivably benefit from the allocation of specific vernacular words, Ratcliffe's concept of both *fen* and *mire* runs counter to widely-established practise and has received little general support.

Except in East Anglia, in modern vernacular English the word *fen* is much less commonly used than is *bog* or marsh. However, *fenn* appears to have been the main word used by the Anglo-Saxons to refer to wet areas of land, and had close equivalents elsewhere on the Northwest European mainland. *Veen* is a close relative of the word fen that is widely used in modern Dutch, but which encompasses both *fen* (*laagveen*) and *bog* (*hoogveen*). It may be observed that the Anglo-Saxon *fenn* appears to have had a similarly broad compass, being used in much the same broad and loose way that *marsh* and *bog* are in modern vernacular English. As paludologists widely use fen specifically for minerotrophic wetlands, it would be inappropriate now to return to the Anglo-Saxon concept of *fenn,* but nonetheless, such etymological considerations suggest that *fen* should be defined broadly rather than narrowly.

In modern German wetland terminology *niedermoor* seems to be the closest equivalent to *fen.*

1.3.4 Marsh

Marsh has been used loosely as a term for waterlogged mineral soils (*e.g.* Tansley, 1939), sometimes in contradistinction to peat-based *fen,* though it is sometimes practically difficult to make such a distinction, for example, in riverside wetlands, areas of mineral soil alongside the river may join with peats further away and sometimes peat and alluvium may be intercalated or mixed. As a vernacular word, *marsh* essentially just means a wet piece of land. Comparable words have similar usage in various other languages (*e.g. marsk* in Danish). *Marish* is a rare English alternative.

1.3.5 Mire

As a vernacular word this refers to any form of marshy ground. As an ecological term, it has had a variety of usage. Idiosyncratic definitions include that of Ratcliffe (1964) who narrowly restricted the term to refer to *soligenous* sites, but more usually, it has been used as a broad term to refer to waterlogged ground. It was Godwin (1956) rather than Tansley who championed *mire* in the British ecological literature, as an equivalent to the Swedish word *myr.* He seems to have regarded *mire* as a collective term for *fens* and *bogs* and effectively equivalent to *peatland.* Some other authors (*e.g.* Gore, 1983) have also restricted it to refer to peat-producing ecosystems, but others, including some Swedish authors, allocate some mineral-based wet land to its compass (*e.g.* ".. mire land is not always considered universally synonymous with peatland owing to the fact that all mirelands do not form peat but other types of humus or the strata may be of tufa" (Mörnsjö, 1971)). In this latter, broad sense *mire* is more-or-less equivalent to *paludic wetland.*

1.3.6 Ombrogenous, topogenous, soligenous

These terms constitute a tripartite classification of mires introduced by von Post & Granlund (1926) which is still widely used. *Ombrogenous* ('rain-made') mires are irrigated directly and exclusively by precipitation. *Topogenous* ('topography-made') mires are also irrigated by telluric water and occur in hollows *etc.* where the water surface is more-or-less horizontal. *Soligenous* ('soil-made') mires also receive telluric water, but occur on slopes where wetness is maintained by lateral water flow. Sjörs (1950a) introduced a fourth category of *limnogenous* mires to refer to wetlands kept waterlogged by adjoining rivers or lakes. Other workers, however, have regarded such situations to be topogenous.

1.3.7 Ombrotrophic

This is normally used to mean a wetland surface that is 'rain-nourished', *i.e.* directly and exclusively[1] fed by precipitation. Some workers make some distinction between *ombrotrophic* and *ombrogenous*, but for most practical purposes they are synonyms. This is because a mire surface that is exclusively 'rain-made' must also be exclusively 'rain-nourished'. Moreover, for the plants that form the living surface to be exclusively rain-nourished they must be growing not only on a surface which has precipitation as the sole water input but also upon a substratum that is ombrogenous. Note that, because *ombrotrophic* is usually defined as 'directly and *exclusively* rain-nourished', it is strictly-speaking an absolute term, *i.e.* there are no 'degrees of ombrotrophy' - a wetland *surface* is either ombrotrophic or it isn't and one that receives even only a very small amount of input of telluric water is strictly minerotrophic (*fen*). It is, however, possible for the upper horizons of a peat deposit to be strictly ombrotrophic and ombrogenous but for its vegetation to contain (fen) plants rooting in underlying minerotrophic strata, to produce a *mixed mire.*

1.3.8 Paludal, paludic, telmatic

Paludal and *paludic* are derived from the Latin *palus*, meaning a marsh or wet ground whereas *telmatic* is derived from the Greek τελμα, meaning 'pond, marsh, swamp'. It seems likely that both *palus* and τελμα may have once had a similar compass of meaning, but there now is a tendency for *telmatic* (and *telmatology*) to be used with specific reference to peat-based wetlands. Hence here *palus* has been adopted as the basis for a generic name for both peat-based and mineral-soil based non-aquatic wetlands.

1.3.9 Peatland

This term refers to peat-producing ecosystems. Peat may, of course, accumulate in various conditions and for a variety of reasons. Waterlogging, and its associated anaerobiosis, is an important, but not exclusive, cause of peat production. Peatlands formed in waterlogged conditions have sometimes been distinguished from other types by the title *mire peatlands* (*e.g.* Mörnsjö, 1969).

[1] this proviso is important, because all wetlands are partly rain-fed

1.3.10 Minerotrophic

Meaning 'rock-nourished', this refers to wetlands irrigated by water that has had some contact with the mineral ground (*i.e. telluric* water) as well as by rainfall. *Minerogenic* or *geogenous* are terms which are effectively synonyms for minerotrophic.

1.3.11 Rich fen, poor fen

These terms originate from a classification of Swedish mires elaborated by Du Rietz (1949). Both represent a form of *minerotrophic mire.* Du Rietz's definition was essentially floristic - *rich fen* contained species thought to indicate calcareous conditions whereas *poor fen* did not. This approach has been criticised because the precise base-status 'indicated' by particular wetland species is not rigorously known and because such species 'preferences' may vary between geographical regions or even between quite closely-adjoining sites. The terms have persisted, with quite widespread use, but they have generally been transmuted informally into terms representing base-status (*rich fen* = base-rich; *poor-fen* = base-poor), though it is difficult to specify a threshold value to separate the two categories. The terms have also received occasional usage by some workers to mean either 'species-rich' and 'species-poor' or 'nutrient-rich[1]' and 'nutrient-poor' (approaches which are, in fact, mutually exclusive as nutrient-rich sites are usually species-poor whilst nutrient-poor sites are often species-rich). Such idiosyncratic usage generates little other than confusion and if the terms rich-fen and poor-fen are to be retained then it would seem best to use them for base-status, which is still their most widespread use and the one which conforms closest to their original conception.

1.3.12 Swamp

British ecologists usually follow Tansley (1939) and use *swamp* to refer to emergent vegetation in shallow, standing water. However, in America, *swamp* is more often used to refer to forested wetlands.

1.4 The concept of the 'wetland site'

The concept of a 'wetland site' is determined by the compass of the definition of 'wetland'. In many lowland situations, individual wetland sites are clearly delimited and their extent may be measured readily. This is, for example, the case with many spring-fed sites, or wetlands in small, closed basins. However, where wetlands form extensive complexes, there is a tendency to subdivide them into smaller contiguous units rather than to regard the entire complex as a single site. This is usually done for purely practical reasons and various natural or artificial features (*e.g.* streams or ditches) can be used to subdivide them; or such subdivision can be largely arbitrary.

In many lowland areas, even in once-extensive wetland complexes, discrete 'wetland sites' are often readily distinguished because they occur as isolated units separated by agricultural land that has been claimed from former wetland. There is a tendency to regard such residual areas as 'wetlands' within a sea of agriculture. Thus it seems likely that, in popular opinion, Woodwalton Fen (Cambridgeshire) would be regarded as 'wetland' whilst the surrounding arable farmland would generally not be, even though it is based upon drained wetland soils.

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[1] nutrients here refering to the major growth-limiting nutrients of wetlands (NPK).

Whilst this may seem to be a quite logical distinction, it may be questioned for at least two reasons:

(a) A distinction between residual wetland and converted wetland is often not made consistently. For example, the Somerset Levels are frequently described, in aggregate, as 'wetland' though, like Fenland, they have also been substantially converted to agricultural use and, over large areas, their current plant cover bears little relationship to their original vegetation. The difference between the Somerset Levels and Fenland rests primarily in the *degree* of their agricultural modification.

(b) Although many parts of areas such as Fenland are probably somewhat better-drained than are the 'wetlands' of the Somerset Levels, in both cases the wetland 'habitat' has been modified. In one sense, however, it would be incorrect to suggest that in either case the 'wetland habitat' has been 'lost', because in both situations some form of wetland could be readily re-established by cessation of pump drainage.

Such considerations suggest that it is most logically consistent to regard all wetland areas (*i.e.* land with hydric soils) as 'wetland sites', but to distinguish between different states of wetland on the basis of their 'condition' (*i.e.* their degree of drainage and land use) and by vegetation and environmental characteristics.

The precise concept of a wetland site undoubtedly has profound repercussions upon the development and application of a classification, as in those 'sites' where a mosaic of contrasting, separate areas of wetland occurs. For example, Foulden Common in Norfolk consists of a series of small, discrete ground hollows, together with some larger wetland areas with axial water flow (in some cases probably formed by the coalescence of ground hollows). Within this complex the individual wetland units are mostly separated with dry grassland. If each small wetland is classed as an individual 'site', it can be classified unambiguously on various criteria, but if the complete area of Foulden Common is regarded as a single 'site' then it would include a heterogeneous range of wetland types. However, this latter situation would be little different from that in other wetland complexes which contain a range of *contiguous* contrasting wetland types. An effective classification needs to be sufficiently flexible to accommodate such different circumstances as well as the fact that the concept of a 'site' is likely to differ from place-to-place and between different observers.

Variations in the extent of continuous wetland area sometimes also influence perceptions of wetland type and characteristics. For example, the SSSI Guidelines (NCC, 1989) use wetland extent as a major part of the distinction between 'raised bog' and 'blanket bog' ('raised bog' occurring as discrete units, whilst 'blanket bog' forms peatland complexes). Apart from the fact that such a distinction ignores the evidence that 'raised bogs' in the lowlands of NW Europe once formed enormous complexes in excess of 1000 km^2 area, such an approach effectively serves to classify the wetland on the basis of its surroundings rather than on its own intrinsic characteristics. It also provides an artificial division which serves to separate, as different major wetland types, some sites which are otherwise extremely similar. An effective classification of wetlands needs to be sufficiently robust to identify distinctive wetland types for what they are, irrespective of their context. Nonetheless, it has to be recognised that, even with a robust classification, very small areas of wetland (< 1 ha) that are regarded as distinct wetland sites when isolated may be sometimes overlooked by ecologists and conservationists when they form a tiny component of a much larger peatland complex, despite whatever distinctive character they may have.

2. PROPOSALS FOR THE CLASSIFICATION OF BRITISH WETLANDS

2.1 Introduction

During the course of the current project it was recognised that the usefulness of the proposed project to evaluate the areal extent of the wetland resource in England and Wales (see R&D Note 377) would be greatly enhanced if it included a basic classification into wetland types as these vary considerably in their response and susceptibility to internal and external influences. However, existing classifications were considered to have many limitations (see Appendix 1 & 3). The remainder of this document presents a clear classification for wetlands, which incorporates many of the existing ideas and classes of experienced wetland scientists, but which it is hoped avoids some of the problems associated with existing classifications.

2.2 Approaches to the classification of wetlands

A variety of criteria have been used to classify wetlands. They include vegetation composition, soil characteristics, water supply, chemical conditions, topography and developmental history. It might be expected that a comprehensive classification of wetlands, which attempted to identify 'fundamental' units, would be based upon, or reflect, many, or all, of these features. However, in general such a multivariate approach has not been used, due primarily to lack of relevant site data. Rather, workers have tended to focus upon specific attributes to generate classifications and the fruits of their endeavours have sometimes been more a reflection of their particular interests and inclinations than 'fundamental' considerations. This is not unexpected, as the criteria used within classifications are largely a reflection of the purpose of the classification.

Recognising both the scarcity of data on some wetland attributes and the need to tailor classifications to specific user requirements, perhaps the most satisfactory way forward is to develop separate, but mutually-compatible, classification schemes for different major variables (hydrotopography, hydrology, hydrochemistry, vegetation, land use *etc.*) and to treat these as independent classificatory 'layers' which can be superimposed upon one another as required. Of course, such layers may not be strictly independent of one another - for example, vegetation composition is partly determined by hydrochemistry and hydrology, just as hydrochemistry is partly a function of hydrological mechanisms - but they can be treated as such for the purposes of developing a flexible classification scheme.

This philosophy is illustrated by the approach proposed here. Table 2.1 identifies some of the properties by which wetlands can (and have been) classified. Within each main heading there is a hierarchy of detail. The broader information (bold type) can often be obtained or deduced by more casual site inspection, or sometimes from published data. The finer detail (plain type) requires detailed investigation and measurement. Only some examples of fine detail information which are likely to be of particular value to wetland classification have been included. Items included below the horizontal dashed line may be of interest for the purposes of wetland inventory but may have more limited value in the development of a wetland typology.

Each main heading can be regarded as being independent of the others and classes based upon different main headings can be superimposed non-hierarchically. However, they can also form a hierarchical classification, as indicated here.

Table 2.1 Classification properties of wetlands

Situation in Landscape

Situation-types
Specific geomorphological features

Water Supply and Development

Hydrotopographical elements
Hydrodynamics and mechanisms of water supply

Habitat Conditions

Broad hydrochemical types
Hydrochemical classes
Hydrochemical dynamics etc.

Broad substratum types
Soil classification and description
Physicochemical properties of the substratum etc.
Peat stratigraphical analysis

Management Conditions

Drainage status

Land utilisation

Wetland Modification Classes

Biological Features

Physiognomic vegetation-types
Floristic vegetation-types
Species composition

- -

Published species records

Palaeoecological, archaeological and historical features

The main focus of the current document has been to extract meaningful categories of a hydrotopographical classification, *i.e.* the situation in the landscape and the water supply and development of the mire (see below). However, some proposals are also made for additional independent categories which can be superimposed on this basic classification.

2.3 Proposed classification

A classification of UK wetlands is proposed below. The extent to which it can be applied ultimately depends upon the level of information available for particular sites. It should be possible to allocate all sites, or parts of sites, to a 'situation-unit' with relative ease. Some of the 'hydrotopographical elements' are also very obvious, but others are not. It is inevitable that there will always be some overlap or transitional types.

In making a broad overview of the 'hydrotopographical' types of wetlands in Britain, emphasis is placed on features for which information is likely to be available - particularly features which can be readily seen (though not always easily quantified). Essentially this means the topographical situation of the site, its overall 'shape' and its proximity to potential sources and sinks of water. This can be seen as providing a broad framework classification which provides a context for, and can be overlain by, more elaborate classifications based on other types of information, such as detailed hydrology, hydrochemistry and vegetation composition or other ecological or biological information (when such data are available).

In doing this, existing units and terminology have been adopted where considered appropriate. An approach to classifying wetlands is suggested by their 'hydrotopography' which is clear, logical, consistent, comprehensive and capable of application at various levels of complexity. In particular, units are distinguished which reflect a) the topography of whole sites (or parts of sites) and b) units which are better seen as elements within sites. To a great extent, the proposals made here provide a rationalisation, clarification and synthesis of the suggestions of others.

It should be emphasised that it is preferable to implement a simple classification correctly than to apply a sophisticated classification inaccurately. It is important to avoid the temptation to base the allocation of sites upon an intuitive appraisal (a guess), even though it is recognised that the judgements of experienced practitioners (informed guesses) are often surprisingly accurate! This is particularly important, for example, in apparently 'flat' wetlands where seepage inputs from groundwater may not be apparent and in damaged sites where the nature of the dominant water supply may have changed.

2.3.1 Wetland 'situation-types'

Wetlands occur in various landscape situations, but all of them share the common feature that they permit the substratum to be waterlogged for either part or all of the year. Such saturation results essentially from an interaction between landscape topography and sources of water supply and occurs in two main situations:

(i) on flattish ground or in hollows, where water naturally collects, or where drainage is otherwise impeded, because of the topography of the landscape. Such wetlands are essentially maintained by *water detention*; and are often referred to as *topogenous* wetlands. These may be associated with:

- rivers (*flood-plain wetlands*),
- existing lakes and pools (*lakeside wetlands*),
- basins and ground hollows (*basin wetlands*),
- flat or undulating surfaces (*plateau plain wetlands*),

(ii) on sloping ground where surface-wet conditions are maintained by *water supply*, *i.e.* a frequent or continuous input of water. These wetlands are often referred to as *soligenous* wetlands.

The landscape situation in which wetlands typically occur has been categorised into a series of 'situation-types'. They are summarised in Table 2.2 and discussed in detail in Appendix 2. These units are essentially crude. They are difficult to define with precision and are as variable as the landscape topography upon which they are based. To some extent the units have been recognised with reference to the types of wetlands which occur within them and they do not attempt to represent specific landscape geomorphological features, except in a very broad sense. This is because, from the point of view of wetland development and character, it may make very little difference if, say, a waterlogged 'basin' originates from a kettle hole, a collapsed pingo, a moraine-blocked valleyhead, an ox-bow lake or an abandoned gravel pit.

Because of their plasticity, the number and identity of 'situation types' that can be recognised is arbitrary. Units are adopted that have been used already at this sort of level by other workers. The main reservation concerns the recognition of 'lakeside wetlands'. Lakes are obvious components of the landscape and have associated wetlands, but many can be regarded as secondary topographical features, as components of basins or river flood-plains (or both). However, for practical purposes it seems unrealistic to regard some large lakes (*e.g.* Lake Windermere, Lough Neagh) just as components of a basin or flood-plain system. 'Lakeside wetlands' have here been adopted as a situation-type appropriate for those landscapes in which a lake is the predominant landscape feature, but not for situations where the lake is obviously a component of a wider flood-plain or closed-basin 'site' (*e.g.* Norfolk Broads; Sweat Mere, Shropshire), though there is no absolute dividing-line between the two situations. Note, however, that in both cases any wetland vegetation encroaching upon the open water would be referable to the same main hydrotopographical element (water-fringe wetland).

Where wetland sites do not readily fit into one particular landscape category, this can be identified, and the site classified as a composite of two or more categories. For example, the 'situation-type' of the Insh Marshes (Inverness) would be a composite of flood-plain and lakeside wetlands.

Table 2.2. Main topographical situations in which British wetlands occur ('Situation Types').

Situation-type	Description	Examples
Basin wetlands	Associated with discrete basins and ground hollows (Fig 2.1).	Delamere Forest Mires, Border Mires (*e.g.* Beanrig Moss)
Lakeside wetlands	Associated with lakes (Fig 2.2).	Slapton Ley (Devon); Windermere (Cumbria)
Coastal- / Flood-plain wetlands	Associated with river flood-plains and coastal plains, including active examples and inactive ones (when their inactivity is largely a product of drainage and water management).(Fig 2.3).	Suffolk and Norfolk Broadland; Somerset Levels; Ouse Washes; Cors Fochno (Dyfed); Thorne Moors (S. Yorks.); Dersingham Bog (Norfolk); Woodwalton Fen (Cambs.); Wicken Fen (Cambs.)
Plateau-Plain wetlands	On flat or slightly undulating ground without close association with lakes, rivers; or discrete, shallow basins; kept wet by high rainfall, impermeable substratum, high groundwater level *etc.* (Fig 2.4).	Flanders West Moss (complex) (Stirling); Wedholme Flow (Cumbria); Haxey Grange Meadows (Lincs.); some Rhôs Meadows (Dyfed)
Valleyhead wetlands	Associated with the upper reaches of valleys; mainly soligenous (Fig 2.5)	New Forest valley mires; Redgrave and Lopham Fens (East Anglia); Roydon Common (Norfolk); Chippenham Fen (Cambs.)
Hillslope wetlands	On sloping ground and hillslopes (Fig 2.6).	Numerous soligenous fens; 'blanket bog'

Figures 2.1 to 2.6 diagrammatically show wetland development in these topographical situations. A key to the figures is provided below.

Key to Symbols

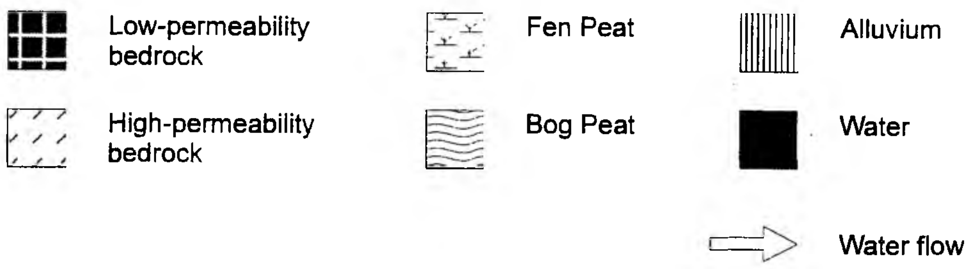
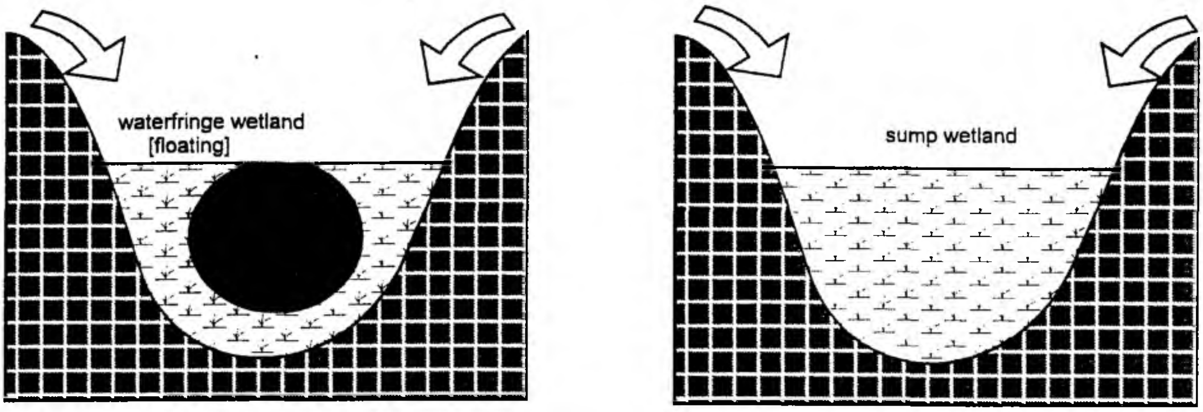
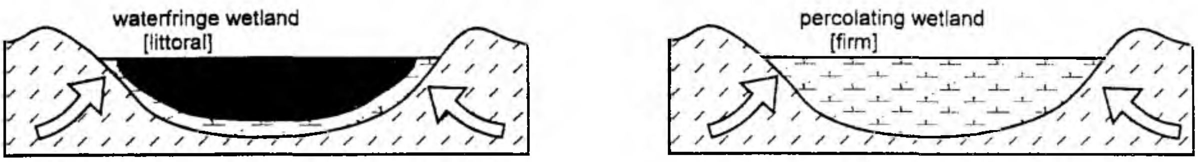


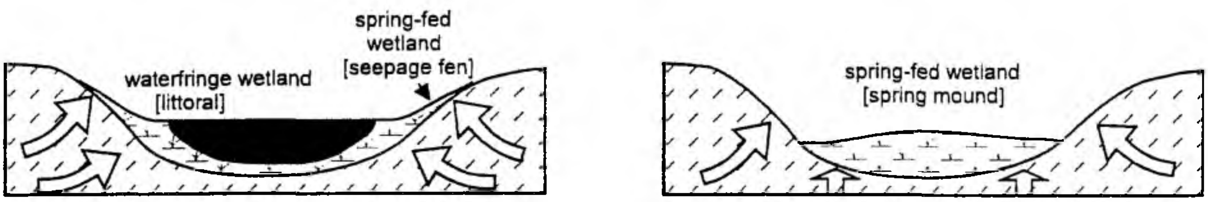
Figure 2.1. Some types of wetland development in basins



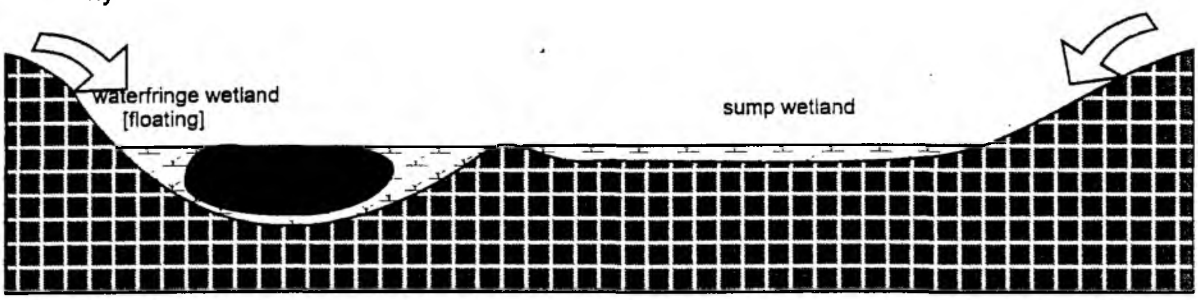
(a) wetland in steep-sided basin (kettle-hole) over impermeable substratum
(i) developed by encroachment of floating raft across open water
(ii) developed by paludification



(b) wetland in groundwater-fed shallow basin (collapsed pingo) upon permeable substratum
(i) developed by encroachment of littoral fringe into open water
(ii) developed by paludification

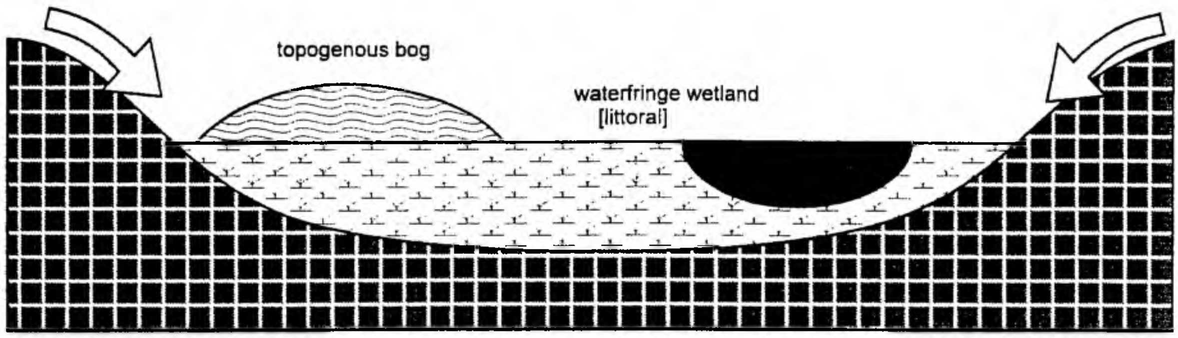


(c) wetland in spring-fed shallow basin upon permeable substratum
(i) soligenous fen formed on seepage slopes above basin; water discharge forms pool in basin which is subject to hydroseral enroachment
(ii) spring-fen formed in bottom of basin by water upwelling to form a shallow tufa-based dome

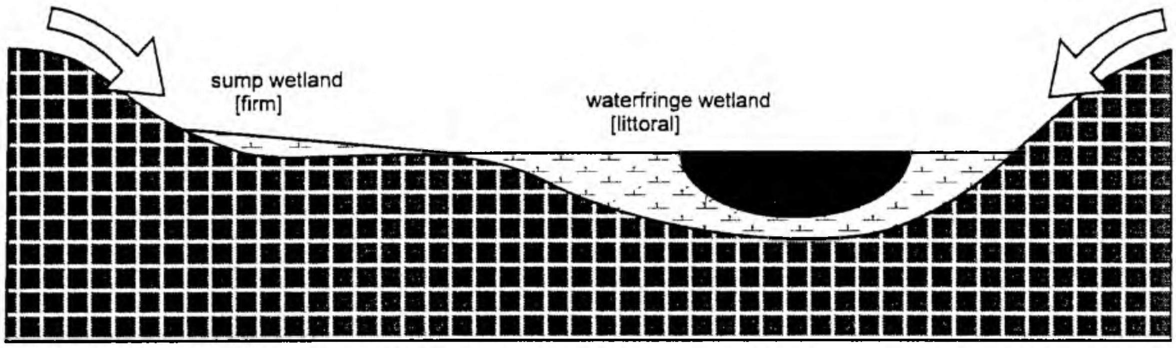


(d) complex basin wetland upon impermeable substratum; deep water-filled basin has partly terrestrialised by floating rafts; peripheral to this is a shallow basin which has developed by paludification, partly in response to water level change caused by impeded drainage induced by peat accumulation in the adjacent water-filled hollow.

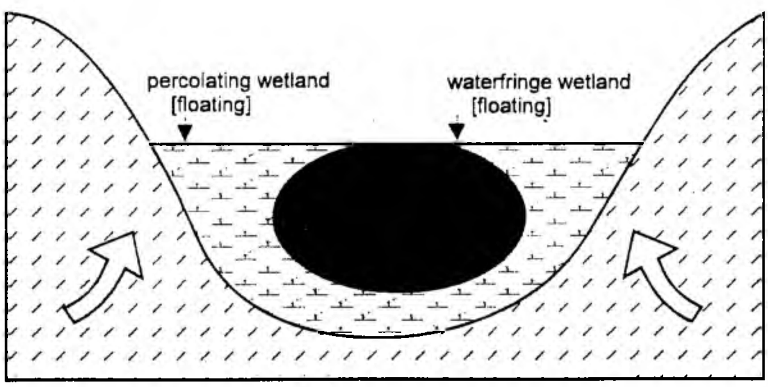
Figure 2.2. Some types of wetland development around lakes



(a) Shallow lake basin that has largely terrestrialised (littoral mechanism) to form an extensive area of fen. Dome of bog has developed over part of this.

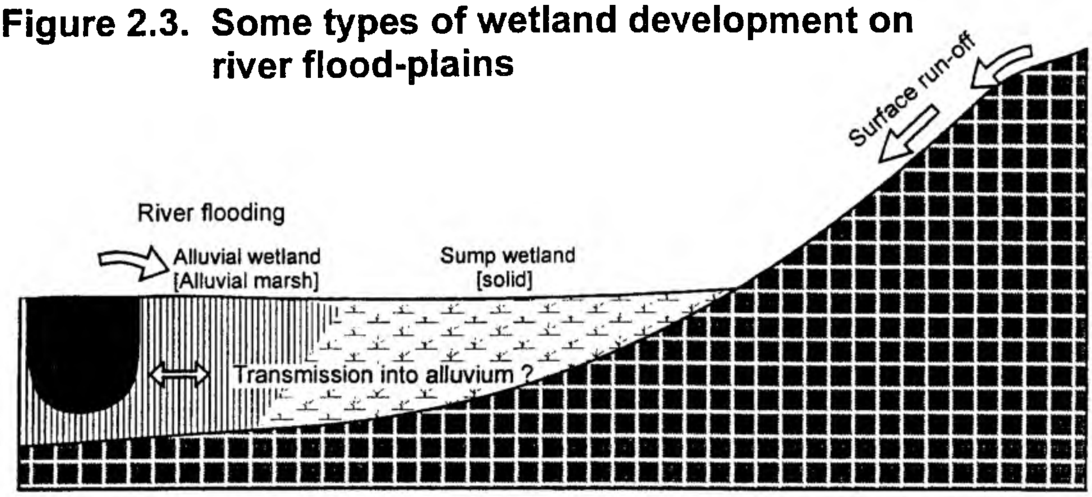


(b) Shallow lake basin that has largely terrestrialised (littoral mechanism) to form fen. To the left of the residual lake is a peripheral wetland that is not directly fed with lake water.

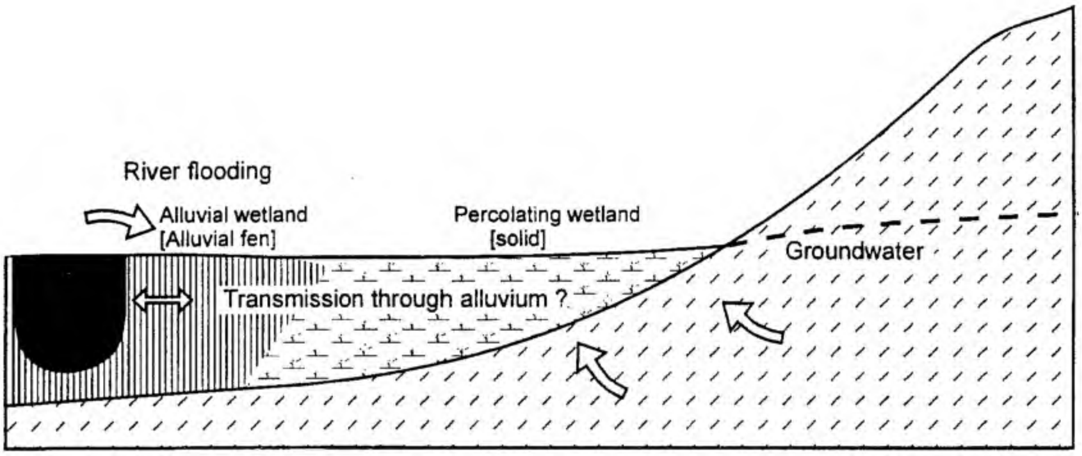


(c) Steep lake basin that has partly terrestrialised (by floating rafts). Basin is fed by groundwater from aquifer in surrounding permeable bedrock.

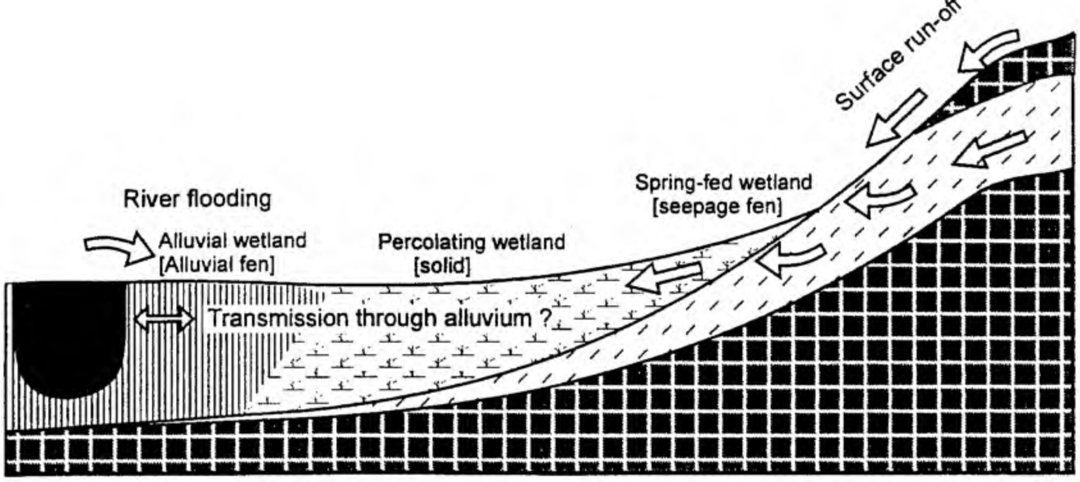
Figure 2.3. Some types of wetland development on river flood-plains



(a) river flood-plain upon impermeable substratum; water table maintained by overbank flooding, surface run-off and precipitation

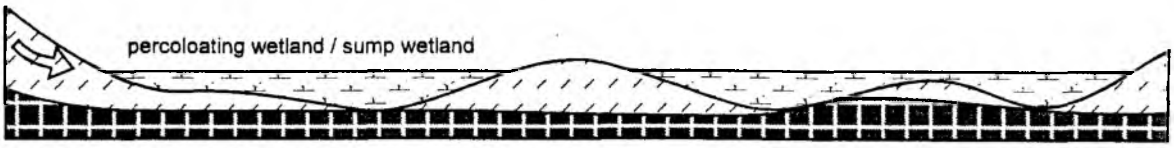


(b) river flood-plain upon permeable substratum; water table maintained by overbank flooding, precipitation and high groundwater table

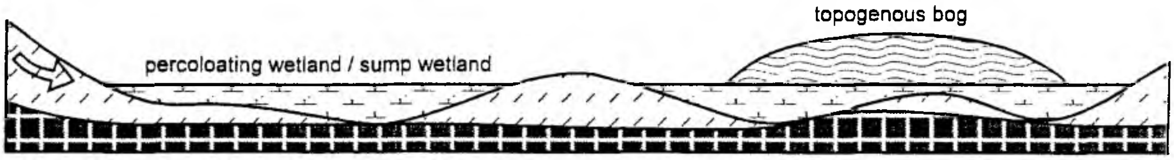


(c) river floodplain upon variable substratum; water table maintained by overbank flooding, precipitation, run-off and groundwater input; groundwater discharge from confined aquifer forms soligenous slopes above main peat deposit; water from these percolates through upper peats to river.

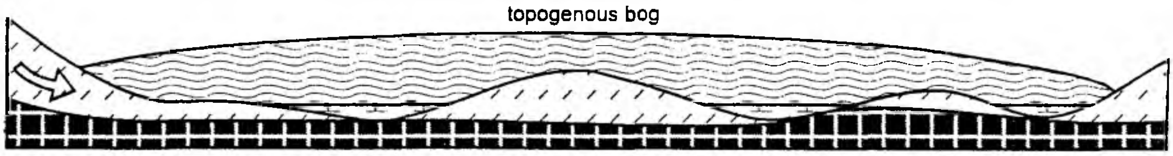
Figure 2.4. Some types of wetland development on undulating plains and plateaux



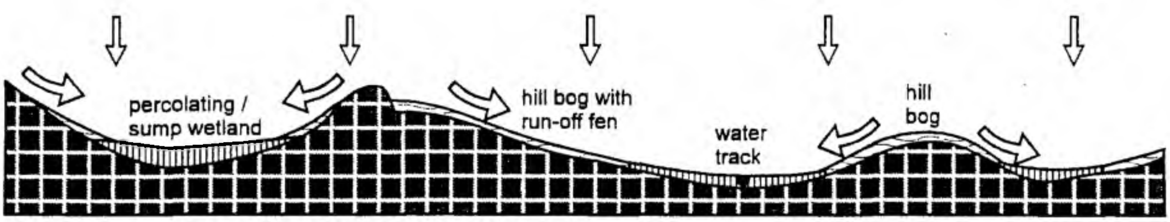
(a) Paludification fen developed over clay platform capped with undulating deposits of sand and gravel, watered by precipitation, groundwater and surface run-off



(b) Paludification fen, developed as in (a), but with localised successional development of rain-fed bog (raised bog) over fen deposits



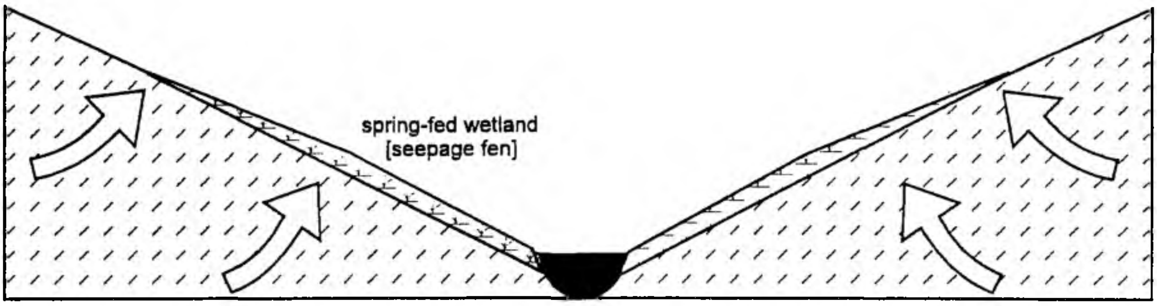
(c) Raised bog, developed over undulating clay / sand platform. Was initiated in hollows after a short-lived phase of fen and has since spread across separating ridges to coalesce into a single dome of ombrogenous peat



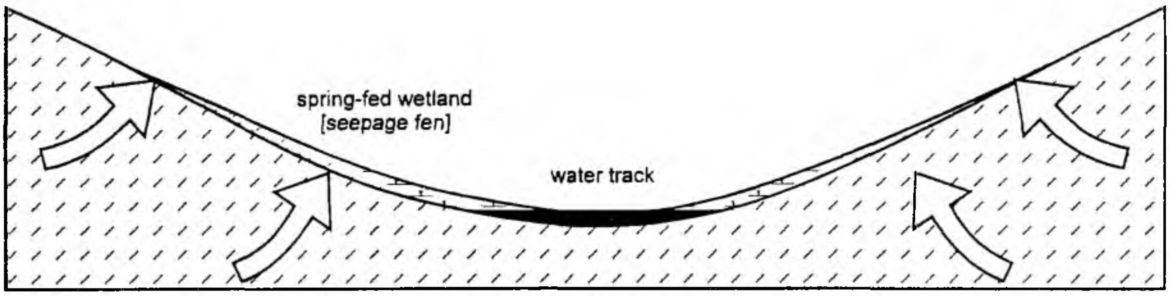
(d) Mire complex developed upon an undulating, rocky plateau. Hollows are occupied by deposits of fen peat of variable depth whilst all but the steepest slopes and knolls have become covered by ombrogenous hill bog. This has also extended partially across former areas of fen.

Figure 2.5. Some types of wetland development in valley heads

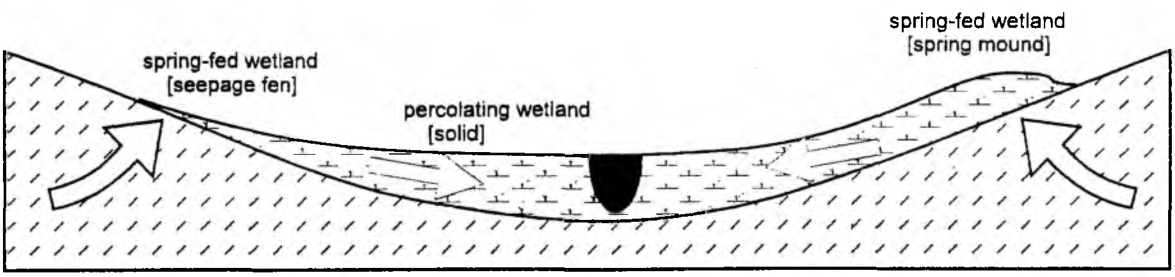
Note that all of the examples below are shown as being fed by groundwater discharge. A comparable sequence of types occurs upon impermeable substrata, fed by surface run-off.



(a) Fen developed upon quite steep soligenous slopes. Water moves downslope by seepage and runnels, discharging into a small axial stream that runs through the mire

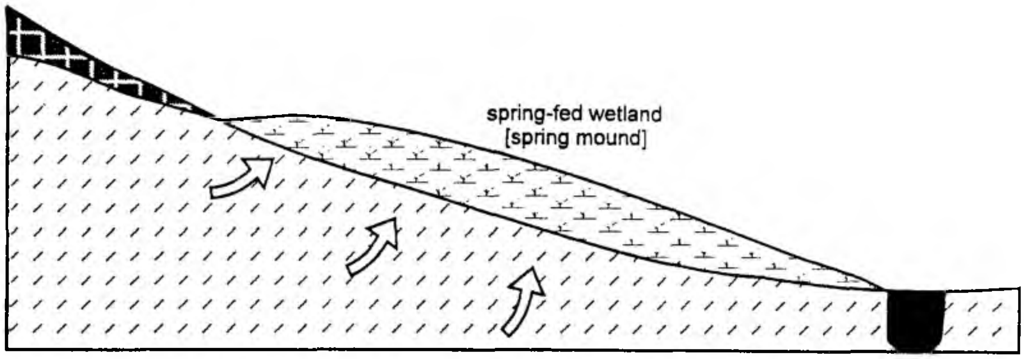


(b) Fen developed over shallow soligenous slopes with small axial gradient. Water collects at bottom of valley to form a sluggish water-track.

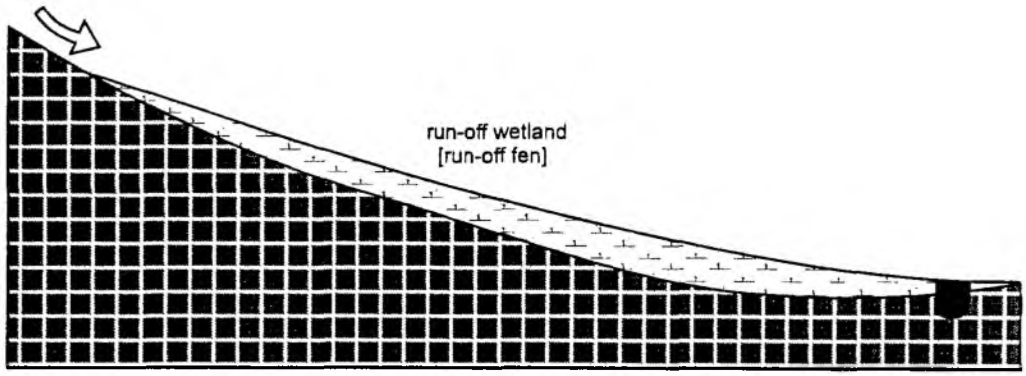


(c) Fen developed over quite deep peat in broad, shallow valley. Water enters from a marginal spring line and then percolates through the peat mass to reach the river

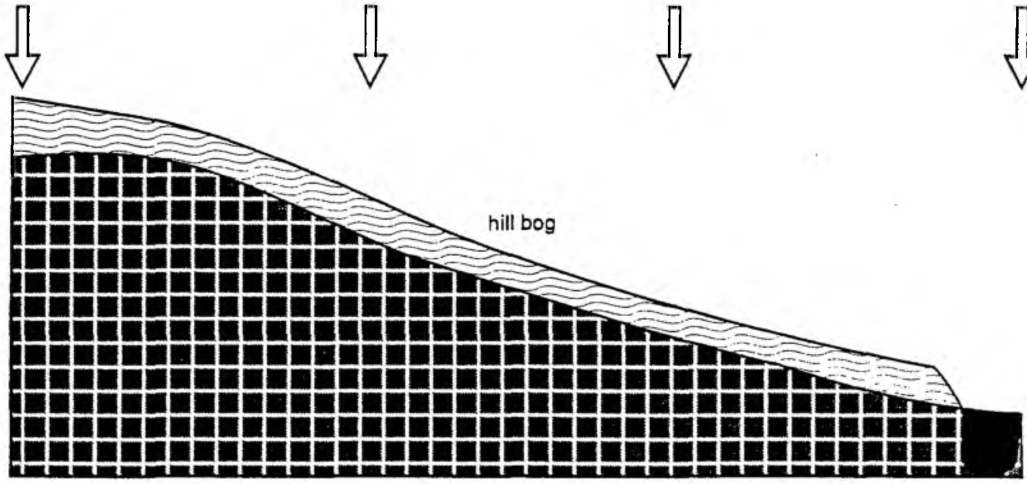
Figure 2.6. Some types of wetland development on hill slopes



(a) Spring fen: sloping site with development of a small mound of peat and mineral material under influence of groundwater discharge from a confined aquifer



(b) Run-off fen: Sloping site covered by shallow peat irrigated by surface run-off



(c) Hill bog (blanket bog): Sloping hillside covered with ombrotrophic peat irrigated by precipitation

2.3.2 Wetland 'hydrotopographical elements'

'Hydrotopographical elements' can refer to entire wetlands or to parts of wetlands. They represent areas with a distinctive water supply that is, in some cases, clearly related to aspects of the topography of the wetland. The precise mechanisms of water supply to wetland sites, or parts of them, are, of course, potentially complex and can involve several water sources, the contribution of which is sometimes difficult to assess, even when detailed studies have been carried out (for example, it is extremely difficult to quantify directly the volume of groundwater discharge into wetlands). As it is impractical for water balance studies to be performed on a large number of wetlands for the purposes of developing a typology, in proposing 'hydrotopographical elements' we have tried to identify robust units that can be assessed by observation, simple measurement or deduction. However, to avoid the proliferation of 'yet another wetland classification', units that have been tried-and-tested by other workers have been adopted, where these are appropriate, though in some cases with some modification of their compass to fit the character of British wetlands. Some of the existing units are well defined and readily-identifiable, but others may require some measurement for their accurate detection. These latter units may have sometimes present some practical problems, but it is appropriate to incorporate them into the classification when they are regarded by experienced practitioners as an important and distinctive type of wetland. To accommodate difficulties which may arise with the identification of certain elements, we provide some guidelines for their detection. The classification category of 'not certain' should also be included as it is preferable not to classify objects rather than to misclassify them.

The proposed 'hydrotopographical elements' are summarised below in Table 2.3 and discussed in detail in Appendix 2.

Table 2.3 Basic hydrotopographical elements (with sub-categories)

i. TOPOGENOUS WETLANDS - wetlands in which high water level is maintained by impeded drainage (detention) of water inputs. Water inputs may include precipitation, land-drainage, river flooding, run-off and groundwater. Impeded drainage is typically a product of landscape configuration, but it may also be induced by river water levels or the topography of the wetland itself.

- **General topogenous wetland** - topogenous wetland where source of water is not known, not obvious or in which no particular water source is dominant [default category for topogenous wetlands]

General topogenous fen	*sites with ± permanently high water levels*
General topogenous marsh	*seasonally wet sites*

- **Alluvial wetland** - irrigated by overbank flooding of watercourses; can be quite extensive, but more usually forms a quite narrow ribbon alongside rivers *etc.* substratum usually with a considerable fraction of mineral material (silts *etc.*)

Alluvial fen	*sites with ± permanently high water levels*
Alluvial marsh	*sites with strongly fluctuating water levels*
Flood lands	*land liable to occasional or controlled flooding*
Deltaic wetlands	*wetlands forming in a deltaic environment, e.g. resulting from a stream flowing into a lake*

- **Waterfringe wetland** - wetland fringing open water of lakes and pools, typically of rather small extent. [In principle, waterfringe wetlands can also occur alongside rivers, but examples in the UK are usually extremely narrow and fragmentary.]

Littoral wetland	*encroachment by rooting*
Hover wetland	*encroachment by rafting*

- **Sump wetland** - ± flat-surfaced wetland, usually in depressions, where precipitation, drainage or run-off water collects or where water level is maintained by a high groundwater level, but with little net through-flow of water. Often characterised by substantial water level flux, the ecological effects of which depend *inter alia* upon base-line water levels and the vertical mobility (if any) of the vegetation / substratum.

Firm sump wetland	*sump wetland with solid peat infill with little vertical mobility.*
Floating sump wetland	*sump wetland with loose or floating peat infill with vertical mobility.*
Seasonal pool wetland	*wetlands around temporary pools or other sites which periodically flood and dry.*

- **Percolating wetland** - gently sloping wetland irrigated by groundwater percolating from marginal soligenous slopes, or by groundwater discharge into the peat mass; often situated between land margins and rivers or pools; sites range from being small to very large; probably very widespread, but recognition may require hydrological/ topographical/stratigraphical studies though it can sometimes be deduced by the position of the mire in the landscape.

Firm percolating wetland	*wetland with ± solid peat infill; water movement mostly confined to upper horizons.*
Floating percolating wetland	*wetland with loose or floating peat infill; water movement throughout much of peat infill, or sometimes beneath it.*

- **Maintained topogenous wetland** - topogenous wetlands of varying character in which much or all of the water supply is artificially contrived.
- **Water track or soakway** - trackways of preferential water movement through topogenous wetlands.

ii. SOLIGENOUS WETLANDS - wetlands primarily kept wet by supply of telluric water with little impedance to outflow. Most typical of relatively steep slopes where groundwater or run-off input produces surface-wet conditions. Spring-fed wetlands on flat surfaces would often *not* be classified here unless characterised by rates of water through-flow comparable to that on the steeper slopes. Often have thin deposits of peat and water movement is often more by surface flow than percolation through the peat.

- **Sloping wetland** - soligenous wetland where the main source of water is not known, or in which no particular water source is dominant or where there is an evident and complex mosaic of areas fed by springs and by surface run-off [default category for soligenous wetlands].

Sloping fen	*± permanently wet.*
Wet slopes	*seasonally wet slope.*

- **Spring-fed wetland** - irrigated primarily by groundwater discharge; often sloping and frequently small.

Spring mound	*cupolas of peat and mineral material (especially calcite) developed upon the sites of strong springs; much size variation; sometimes large.*
Spring flush	*open vegetation upon skeletal substratum, with much water movement, developed around and below point sources of groundwater discharge lacking obvious cupolation.*
Seepage fen	*peat-based wetland developed below springs and groundwater seepage, lacking obvious cupolation.*
Spring head	*very small, discreet point-source of water discharge into spring-fed wetlands.*
Supplemented spring wetland	*Spring-fed sites in which much, or all, of the summer water supply originates from artificial supplementation.*

- **Run-off wetland** - hillslope wetland irrigated primarily by surface run-off; principally found in the wetter regions of Britain where low-permeability bed-rock coupled with high precipitation permits the development of, sometimes extensive, wetlands fed primarily by run-off and rainfall.

Run-off fen	*relatively slow water-movement; peat-based.*
Run-off flush	*relatively rapid water-movement; skeletal substratum.*
Ladder-fen	*scalariform (ladder-like) sloping mires.*
Seasonal wet slope	*slopes which are not permanently wet.*

- **Water track or soakway** - tracks of preferential water-movement through sloping wetlands

iii. OMBROGENOUS WETLANDS - wetlands, or parts of wetlands, with surfaces kept wet primarily because of high rates of supply of precipitation input with part-autogenic impeded drainage of this.

- **Topogenous bog** - rain-fed peatlands in hollows, flats and gentle slopes; peat surface raised slightly above the level of any groundwater level, fen peat or mineral soil, often to produce a (slight) dome of peat that is sometimes independent of subsurface topography.

  (Sub-types have yet to be clearly defined)

- **Hill bog** - rain-fed peatlands on sloping ground; peat surface raised slightly above the level of underlying fen peat or mineral soil, usually conforming quite closely to subsurface topography.

  (Sub-types have yet to be clearly defined)

iv. ARTIFICIAL WETLANDS - wetlands created by human activity and maintained specifically by this. This category does *not* include many of the wetlands that have been produced deliberately or incidentally by human activity, as many of these (*e.g.* clay pits, reservoirs) occur in, or mimic, various natural 'situation-types' and support similar 'hydrotopographical elements and they are most appropriately classified as man-made examples of the appropriate natural types. However, there are other wetlands which have not only been deliberately engineered but are also maintained by an artificial supply of water and these seem best allocated to a separate category.

- **Root Zone beds** - wetlands constructed to treat domestic and industrial effluent.

2.3.3 Occurrence of wetland types

Table 2.4 summarises the potential occurrence of the various hydrotopographical elements within each wetland situation type.

Table 2.4 Potential occurrence of the different 'Hydrotopographical Elements' within each wetland 'Situation Type'.

Situation-type / Hydrotopographical element	Basin wetlands	Lakeside wetlands	Coastal-plain / Flood-plain wetlands	Plateau-Plain wetlands	Valleyhead wetlands	Hillslope wetlands
General topogenous wetland	+++	+++	+++	+++	+	
Alluvial wetland		+	+++		+	
Waterfringe wetland	+++	+++	++			
Sump wetland	+++	+++	+++	+++	+	
Percolating wetland	+++	+	+++	+	+++	
Water track	+		++	+	++	
Sloping wetland	++	++	+	+	+++	+++
Spring-fed wetland	++	++	+	++	+++	+++
Run-off wetland	+	+	+	+	+++	+++
Soakway					++	+++
Topogenous bog	+++	++	+++	+++	+	
Hill bog	+	+	+	+	+	+++

+++ particularly characteristic of the 'situation type'
++ sometimes occurs within the 'situation type'
\+ of minor importance, or peripheral

2.3.4 Habitat Conditions

As an overlay for the main hydrotopographical classification suggested here, it is further proposed that for NRA purposes, the wetland types identified should be sub-divided in order to give some indication of the habitat conditions of a site and which help to indicate restoration potential of damaged sites. Simplified categories currently in use in Sheffield are shown in Tables 2.5 - 2.9. These are useful as a 'basic' classification which can be carried out fairly simply in the field. Note that the categories are not mutually exclusive - more than one category can apply to each site.

a. Base status

Table 2.5 suggests pH limits for a subdivision of British wetlands based upon base richness (see Appendix 1.2.3)

Table 2.5 Base status classes

	pH
extremely base poor	<4.5
base poor	4.5 - 6.0
base rich	>6.0

b. Substratum characteristics

Table 2.6 provides a simple, broad classification of wetland substratum types which can be applied quite easily.

Table 2.6 Wetland substratum classes

- Shallow peat (< 0.5 m)
- Deep peat (>0.5 m)
- Alluvium
- Peaty Alluvial Soils
- Peaty and Humic Gleys
- Marl / tufa
- Estuarine sediments

c. Site condition

Drainage Status and Land Utilisation classes (Tables 2.7 & 2.8) provide a basis for Wetland Modification classes Table 2.7. These categories do not attempt to encompass all possible forms of modification to wetlands but include those which are most frequent and which are perceived as being particularly significant from the point of view of diversity of wetland species. Note that these categories are intended for use primarily as a statement of observed *condition*, not as some statement of *damage* (*i.e.* modification from the natural condition or conservational value). This is not least because in some cases the 'natural state' of the wetland is far from obvious and because in many wetlands perceived high conservational value is often associated with some form of modification to their natural state.

Assessment of these wetland characteristics will almost certainly require some direct site investigation. The need for site survey as part of any wetland inventory is dealt with in R&D Note 377.

Table 2.7 Drainage status classes

- ± undrained
- poorly drained
- drained, seasonally wet
- well drained, normally dry
- rewetted
- reflooded

Table 2.8 Land utilisation classes

- Not used/abandoned
- Rough land (not used for agriculture)
- Extensive farmland
- Intensive farmland
- Forestry
- Peat extraction
- Past peat extraction
- Mineral extraction
- Building / roads
- Water management
- Waste treatment
- Nature management

Table 2.9 Wetland modification classes

- ± undisturbed wet land
- managed wet land
- derelict wet land
- scrub-invaded wetland
- enriched wet land
- part drained, semi-natural, many wetland species
- part drained, semi-natural, some wetland species
- drained, semi-natural, few wetland species
- farmland - wetland species in drains etc.
- farmland with ± no wetland species
- plantation - wetland spp in drains or rides
- plantation - ± no wetland species
- active peat workings, few wetland species
- active peat workings, residual wetland species
- recolonised peat workings - flooded
- recolonised peat workings - moist
- recolonised peat workings - dry
- new wetland

2.4 Use of the classification

This report proposes a classification for British wetlands based on their situation type and hydrotopographical elements such as water supply. It is further possible to superimpose upon this base classification other elements based on the condition of the site. Additional information such as ecology and archaeology can be added as required for descriptive purposes. This hierarchy of overlay data is shown in Table 2.1.

Each of these layers demands a certain level of site information. Some can be obtained from desk based studies to classify a wetland according to situation type (Table 2.2) and perhaps some hydrotopographical elements (Table 2.3) but as the level of descriptive detail is refined so field reconnaisance data is required (Tables 2.4 - 2.8). (Further detail of the various site categories is provided in the Appendices to this report).

The need for site survey depends very much on the NRA's interest in the site. For identification purposes detailed site survey may not be required although a site reconnaissance visit is advised and is likely to be essential for detailed classification of hydrotopographical elements. For entry into any Wetland Inventory the level of data is dependent on the likely use of such a data-base. The more detailed the entry the more widely usable the Inventory is likely to be although detailed ecological survey of sites simply to complete such an Inventory is not seen as being the role of the NRA (see R&D Note 377). Detailed site survey is seen as being a requirement of NRA case-work rather than an end in itself.

The preceding tables show the categories into which wetlands can be placed and the range of information that canbe used to classify a site. The situation type is readily ascertainable from basic map data or a preliminary site visit. The hydrotopographical elements should then be identified to refine the classification. Table 2.10 presents a provisional key to these elements which allows the user to work from the basic hydrotopographical status of the site (A - D) through in increasing detail to a final named sub-type (italics). It is envisaged that this key would be developed further, following field trials should the scheme be adopted.

The classification of a wetland to this level is envisaged as the first stage in general purpose site description for whatever reason. It is essential that wetlands can be classified or named accurately and consistently before more detailed assessments are undertaken. More detailed site condition, ecological and archaeological information can be overlain as a further refinement or according to the needs of the NRA for example in case-work or entry into a Wetland Inventory. This is dealt with in R&D Note 377.

This structured approach is designed to be easy to follow yet it facilitates a basic need for wetland identification and classification.

Table 2.10 Provisional key to wetland classification by hydrotopography

A	Wetlands in which high water level is maintained by impeded drainage (detention) of water inputs. Water inputs may include precipitation, land-drainage, river flooding, run-off and groundwater. Impeded drainage is typically a product of landscape configuration, but it may also be induced by river water levels or the topography of the wetland itself.	**TOPOGENOUS WETLANDS**	**1.**
B	Wetlands primarily kept wet by supply of telluric water with little impedance to outflow. Most typical of relatively steep slopes where groundwater or run-off input produces surface-wet conditions. (Excludes spring-fed wetlands on flat surfaces unless characterised by rates of water through-flow comparable to that on the steeper slopes). Often have thin deposits of peat and water movement is often more by surface flow than percolation through the peat.	**SOLIGENOUS WETLANDS**	**2.**
C	Wetlands, or parts of wetlands, with surfaces kept wet primarily because of high rates of supply of precipitation input with part-autogenic impeded drainage of this.	**OMBROGENOUS WETLANDS**	**3.**
D	Wetlands created by human activity and maintained specifically by this. (But excluding many of the wetlands that have been produced deliberately or incidentally by human activity)	**ARTIFICIAL WETLANDS**	**4.**

1. TOPOGENOUS WETLANDS

Topogenous wetland where source of water is not known, not obvious or in which no particular water source is dominant	**General topogenous wetland** [default category for topogenous wetlands]	**1.1**
Topogenous wetland irrigated by overbank flooding of watercourses; can be quite extensive, but more usually forms a quite narrow ribbon alongside rivers *etc.* substratum usually with a considerable fraction of mineral material (silts *etc.*)	**Alluvial wetland**	**1.2**
Wetland fringing open water of lakes and pools, typically of rather small extent. [In principle, waterfringe wetlands can also occur alongside rivers, but examples in the UK are usually extremely narrow and fragmentary.]	**Waterfringe wetland**	**1.3**
± flat-surfaced wetland, usually in depressions, where precipitation, drainage or run-off water collects or where water level is maintained by a high groundwater level, but with little net through-flow of water. Often characterised by substantial water level flux, the ecological effects of which depend *inter alia* upon base-line water levels and the vertical mobility (if any) of the vegetation / substratum.	**Sump wetland**	**1.4**
Gently sloping wetland irrigated by groundwater percolating from marginal soligenous slopes, or by groundwater discharge into the peat mass; often situated between land margins and rivers or pools; sites range from being small to very large; probably very widespread, but recognition may require hydrological/topographical/stratigraphical studies though it can sometimes be deduced by the position of the mire in the landscape.	**Percolating wetland**	**1.5**
Topogenous wetlands of varying character in which much or all of the water supply is artificially contrived.	**Maintained topogenous wetland**	

	Trackways of preferential water movement through topogenous wetlands.	**Water track or soakway**	
1.1	Sites with ± permanently high water levels	*General topogenous fen*	
	Seasonally wet sites	*General topogenous marsh*	
1.2	Sites with ± permanently high water levels	*Alluvial fen*	
	Sites with strongly fluctuating water levels	*Alluvial marsh*	
	Land liable to occasional or controlled flooding	*Flood lands*	
	Wetlands forming in a deltaic environment, e.g. resulting from a stream flowing into a lake	*Deltaic wetlands*	
1.3	Areas where vegetation development has been through encroachment by rooting into the substratum	*Littoral wetland*	
	Areas where vegetation development has been through encroachment by rafting over water	*Floating wetland*	
1.4	Sump wetland with solid peat infill with little vertical mobility	*Firm sump wetland*	
	Sump wetland with loose or floating peat infill with vertical mobility	*Floating sump wetland*	
	Wetlands around temporary pools or other sites which periodically flood and dry	*Seasonal pool wetland*	
1.5	Wetland with ± solid peat infill; water movement mostly confined to upper horizons	*Firm percolating wetland*	
	Wetland with loose or floating peat infill; water movement throughout much of peat infill, or sometimes beneath it	*Floating percolating wetland*	
2.	**SOLIGENOUS WETLANDS**		
	Soligenous wetland where the main source of water is not known, or in which no particular water source is dominant or where there is an evident and complex mosaic of areas fed by springs and by surface run-off	**Sloping wetland** [default category for soligenous wetlands]	2.1
	Irrigated primarily by groundwater discharge; often sloping and frequently small.	**Spring-fed wetland**	2.2
	Hillslope wetland irrigated primarily by surface run-off; principally found in the wetter regions of Britain where low-permeability bed-rock coupled with high precipitation permits the development of, sometimes extensive, wetlands fed primarily by run-off and rainfall.	**Run-off wetland**	2.3
	Tracks of preferential water-movement through sloping wetlands	**Water track or soakway**	

2.1	Area ± permanently wet	*Sloping fen*
	Seasonally wet slope	*Wet slopes*
2.2	Domes of peat and mineral material (especially calcite) developed upon the sites of strong springs; much size variation; sometimes large	*Spring mound*
	Open vegetation upon skeletal substratum, with much water movement, developed around and below point sources of groundwater discharge lacking obvious doming	*Spring flush*
	Peat-based wetland developed below springs and groundwater seepage, lacking obvious doming	*Seepage fen*
	Very small, discrete point-source of water discharge into spring-fed wetlands	*Spring head*
	Spring-fed sites in which much, or all, of the summer water supply originates from artificial supplementation of the water supply.	*Supplemented spring wetland*
2.3	Relatively slow water-movement; peat-based.	*Run-off fen*
	Relatively rapid water-movement; skeletal substratum	*Run-off flush*
	Scalariform (ladder-like) sloping mires.	*Ladder-fen*
	Slopes which are not permanently wet	*Seasonal wet slope*

3 OMBROGENOUS WETLANDS

	Rain-fed peatlands in hollows, flats and gentle slopes; peat surface raised slightly above the level of any groundwater level, fen peat or mineral soil, often to produce a (slight) dome of peat that is sometimes independent of subsurface topography.	**Topogenous bog**
	Rain-fed peatlands on sloping ground; peat surface raised slightly above the level of underlying fen peat or mineral soil, usually conforming quite closely to subsurface topography.	**Hill bog**

4 ARTIFICIAL WETLANDS

	Wetlands constructed to treat domestic and industrial effluent.	**Root Zone beds**

ACKNOWLEDGEMENTS

The following people kindly commented on an earlier draft of this report, or provided valuable discussion on wetland classification:

A.G. Agnew (University of Aberystwyth), D. Boeye (University of Antwerp), W. J. Fojt (English Nature), D. Gilvear (University of Stirling), N.T.H. Holmes (Alconbury Environmental Consultants), J. Hooke (University of Portsmouth), R. Howell (NRA), H.A.P. Ingram (University of Dundee), L. Jenkins (NRA), G. Mason (NRA), R. Meade (English Nature), P.D. Moore (University of London), M.C.F. Proctor (University of Exeter), M. Succow (University of Griefswald), R. van Diggelen (University of Groningen), G. van Wirdum (Institute of Forestry and Nature Research, Wageningen), R. Wright (English Nature), T. Zimmerman (University of Griefswald)

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GLOSSARY OF TERMS

Note that the definitions relate to the way in which the terms are used in this document, and should not be taken as general definitions. Words underlined also appear in the glossary.

Terms given in bold relate to the wetland types described in the proposed classification. (ST = situation type; HE = Hydrotopographical element; HEs = sub-categories of hydrotopographical elements).

acrotelm	the uppermost, 'active layer' of an undamaged raised bog, comprising the living plant cover passing downwards into recently-dead plant material and thence to fresh peat. It forms the largely oxygenated surface layer with high hydraulic conductivity, within which the water level fluctuates and the main water movement occurs.
allochthonous	of imported origin (*cf.* autochthonous).
allogenic	caused by external factors (*cf.* autogenic).
Alluvial wetland (HE)	topogenous wetland irrigated by overbank flooding of watercourses; can be quite extensive, but more usually forms a quite narrow ribbon alongside rivers *etc.* substratum usually with a considerable fraction of mineral material (silts *etc.*) (Sub-categories: alluvial fen, alluvial marsh and flood-lands).
Alluvial fen (HEs)	Alluvial wetland sites which retain a high water-table year-round. This will either be because they are flooded very regularly or because other water sources keep them wet. The latter examples are likely to have a strongly peat-based infill.
Alluvial marsh (HEs)	Alluvial wetland sites largely dependent on river-flooding for their water supply. Show considerable seasonal flux of water levels and have a substratum composed largely of alluvium.
anoxic	lacking oxygen.
ARTIFICIAL WETLANDS	Wetlands created by human activity and maintained specifically by this. This category does *not* include many of the wetlands that have been produced deliberately or incidentally by human activity, as many of these (*e.g.* clay pits, reservoirs) occur in, or mimic, various natural 'situation-types' and support similar 'hydrotopographical elements and they are most appropriately classified as man-made examples of the appropriate natural types. However, there are other wetlands which have not only been deliberately engineered but are also maintained by an artificial supply of water and these seem best allocated to a separate category.
aquifer	water-bearing substratum, at full moisture capacity.
autochthonous	formed *in situ* (*cf.* allochthonous).
autogenic	'self-made'. [caused by reactions of organisms themselves,] (*cf.* allogenic).
basin mire	used variously to describe 'hollows' in the landscape - these may occur at various scales, from great synclinal basins, through the basins of large lakes and lochs, to small depressions. The term *basin mire* seems to be used by some authors to refer to this latter situation, though it is not clear why size alone should predicate fundamental distinctions of 'hydrotopography', nor what constitutes, in the minds of the authors, the upper size limit to basin mires.
BASIN WETLANDS (ST)	associated with discrete basins and ground hollows (*e.g. Delamere Forest Mires, Border Mires*).
bog	general term for ombrotrophic mires (but sometimes used colloquially for minerotrophic mires).
bulk density	the amount of solid material per unit volume.
catotelm	the lower 'inert' layer of the peat of an undamaged raised bog. The catotelm underlies the acrotelm, and is permanently saturated, mainly anoxic and of low hydraulic conductivity.
centripetal	tending towards a centre.
climax ecosystem	the mature or stabilised stage in a successional series of communities.

COASTAL AND FLOOD PLAIN WETLAND (ST)	associated with river flood-plains and coastal plains, including active examples and inactive ones (when their inactivity is largely a product of drainage and water management) (*e.g. Suffolk and Norfolk Broadland*).
Deltaic wetlands (HEs)	alluvial wetlands forming in a deltaic environment, e.g. resulting from a stream flowing into a lake.
diplotelmic	'Two - layered'. In raised bogs, this refers to the typical occurrence of an uppermost 'active layer' (the *acrotelm*) and lower 'inert layer' (the *catotelm*).
discharge zone	zone of groundwater water movement into a wetland.
draw-down	refers to the fall in water level caused by a steepened hydraulic gradient, for example as a result of water movement to drains or ditches.
eutrophic	nutrient - enriched (not necessarily base-rich).
evapotranspiration	loss of water from the soil by evaporation from the surface and by transpiration from the plants growing thereon; the volume of water lost in this way.
fen	general term for minerotrophic mires (see *rich fen* and *poor fen*).
Flood Lands (HEs)	Alluvial wetland with land liable to occasional or controlled flooding.
Flood-plain mire	this is a generic term that has been used to refer to wetlands developed on river flood-plains, though it has tended to exclude examples that are groundwater-fed.
FLOOD-PLAIN WETLANDS (ST)	see Coastal and Flood Plain wetlands.
Flush	Hillslope wetland with an open vegetation and skeletal substratum with runnels and rapid surface water movement.
fluvial deposition	material deposited by a water course.
fluviogenous wetlands	riverside wetlands that are directly flooded with river water, in whole, or part.
grazing marshes	this term often particularly applies to areas of (partly) claimed flood-plain wetlands which are summer dry; it is not, however, specific to these.
Headwater Fen	Haslam (1965) used this term in much the same sense as 'valleyhead wetland' is used here.
HILLSLOPE WETLANDS (ST)	on sloping ground and hillslopes (*numerous soligenous fens: 'blanket bog'*).
Hill bog (HE)	rain-fed peatlands on sloping ground; peat surface raised slightly above the level of underlying fen peat or mineral soil, usually conforming quite closely to subsurface topography (*Sub-types have yet to be clearly defined).*
hover development	formation of a semi-floating raft of vegetation over water or fluid muds (rafting). (Also known as *schwingmoor*).
Floating wetlands (HEs)	waterfringe wetlands developed by rafting (=*schwingmoor*).
humification (von Post scale)	degree of decomposition (of peat) [production of humus from the decay of organic matter as a result of microbial action].
hydraulic conductivity [K; K_{sat}]	the rate at which water moves through a material. K_{sat} denotes saturated hydraulic conductivity - i.e. the rate at which water moves through a saturated material.
hydraulic gradient	the change in hydraulic head or water surface elevation over a given distance.
hydraulic head	the difference in pressure-head between two hydraulically-connected points.
hydromorphology	used here synonymously with hydrotopography.
hydroperiod	the pattern of water level fluctuation in a wetland
hydrosere (hydroseral)	autogenic terrestrialisation of open water. Occurs through gradual infilling with accumulating plant (± mineral) material. May occur *via* initial formation of a floating raft.
hydrostatic pressure	the pressure created by the weight of water acting upon itself.
hydrotopographical element	unit with distinctive water supply and, sometimes, distinctive topography in response to this. Many wetlands will contain a number of such elements, and the same element may occur in wetlands belonging to different situation types.

hydrotopography	an ill-defined term which is usually used to mean the 'shape' of the wetland and its situation with respect to the cause(s) of its wetness (*i.e.* apparent sources of water).
'Ladder fen'	(see run-off wetland).
lacustrine wetland	A generic term for wetlands around lakes and pools.
LAKESIDE WETLANDS (ST)	associated with lakes: although this 'situation' can be readily recognised, it may better subsumed within the other categories, such as basins and flood-plains, rather than being given a separate identity.
littoral colonisation	encroachment of vegetation by rooting on accumulating peat and muds.
Littoral wetlands (HEs)	waterfringe wetlands developed by the littoral process of terrestrialisation.
macrofossils	plant or animal remains preserved in peat which can be identified without the use of a high-powered microscope (e.g. stems, leaves & roots but not pollen grains).
mesotrophic	of moderate nutrient status
minerotrophic	fed by groundwater.
minerotrophic mire	mire whose surface is irrigated both by precipitation and groundwater.
mire	a general term applied to peat-producing ecosystems which develop in sites of abundant water supply.
mire macrotope	mire complex which has been formed by the fusion of isolated mire *mesotopes* which originated from separate centres of mire formation.
mire mesotope	mire system developed from one original centre of peat formation. May join together into a *macrotope* .
mire microtope	small-scale topographical features associated with the mire surface, for example a regular arrangement of ridges and hollows.
morphometry	
oligotrophic	nutrient poor (not necessarily base-poor).
ombrotrophic	supplied solely by water derived from the atmosphere (rain, snow, fog etc.).
ombrotrophic bog	bog whose surface is irrigated more-or-less exclusively by precipitation inputs.
OMBROGENOUS WETLANDS	rain-fed peatlands in hollows, flats and gentle slopes; peat surface raised slightly above the level of any groundwater level, fen peat or mineral soil, often to produce a (slight) dome of peat that is sometimes independent of subsurface topography.
ontogeny	history of development.
Open water transition mire	Used by Goode (1972) and Ratcliffe (1977) but not clearly defined. Perhaps mostly refers to hydroseral wetlands, but not exclusive to these. Not clear how these authors distinguish it clearly from *basin mires*.
palaeoecology	the study of the relationship between past organisms and the environment in which they lived.
paludification (paludosere)	the development of wetland directly over mineral ground through impeded drainage and / or increase in water supply.
paludology	study of wetlands (literally, of marshes).
perched water mound	refers to the water mound developed within a raised bog as a result of impeded drainage and storage of water derived solely from precipitation (i.e. *perched* above the level of regional groundwater levels).
Percolating wetland (HE)	gently sloping wetland irrigated by groundwater percolating from marginal soligenous slopes, or by groundwater discharge into the peat mass; often situated between land margins and rivers or pools; sites range from being small to very large; probably very widespread, but recognition may require hydrological / topographical / stratigraphical studies though it can sometimes be deduced by the position of the mire in the landscape. Sub-categories: *Firm percolating wetland: wetland with ± solid peat infill; water movement mostly confined to upper horizons;* *Floating percolating wetland: wetland with loose or floating peat infill; water movement throughout much of peat infill, or sometimes beneath it.*
permeability	the capacity of a porous medium for transmitting water.

PLATEAU-PLAIN WETLANDS (ST)	on flat or slightly undulating ground without close association with lakes, rivers; or discrete, shallow basins; kept wet by high rainfall, impermeable substratum, high groundwater level *etc.* Includes sites on *former* river flood-plains, terraces *etc.* (*e.g. Flanders Moss*).
poor fen	minerotrophic mire, typically of pH less than c. 5.5.
precipitation	deposition of water on the earth's surface by rain, snow, mist, frost, condensation etc.; the quantity of water so deposited.
recharge zone	zone within a wetland acting as a water supply.
rich fen	minerotrophic mire, typically of pH more than c. 5.5.
Root Zone beds (HE)	Artificial wetlands constructed to treat domestic and industrial effluent.
(surface) run-off	water that reaches (or leaves) a mire either by overland flow or percolation through the upper layers of the substratum (due to gravity).
Run-off wetland (HE)	hillslope wetland irrigated primarily by surface run-off; principally found in the wetter regions of Britain where low-permeability bed-rock coupled with high precipitation permits the development of, sometimes extensive, wetlands fed primarily by run-off and rainfall. Sub-categories: *Run-off fen: relatively slow water-movement; peat-based;* *Run-off flush: relatively rapid water-movement; skeletal substratum;* *Ladder-fen: scalariform sloping mires;* *Seasonal wet slope: slopes which are not permanently wet.*
scalariform	ladder-like.
'schwingmoor'	floating vegetation mat / raft (German.)
sere	plant successional sequence (as used in e.g. hydrosere, paludosere).
situation type	the position the wetland occupies in the landscape, with especial emphasis on principal water supply. May include several different hydrotopographical elements.
Sloping wetland (HE)	soligenous wetland where the main source of water is not known, or in which no particular water source is dominant or where there is an evident and complex mosaic of areas fed by springs and by surface run-off [default category for soligenous wetlands]. Sub-categories: *Sloping fen ± permanently wet;* *Sloping marsh seasonally wet slope.*
Soakway (HE)	tracks of preferential water-movement through sloping wetlands.
SOLIGENOUS WETLANDS	wetlands primarily kept wet by supply of telluric water with little impedance to outflow. Most typical of relatively steep slopes where groundwater or run-off input produces surface-wet conditions. Spring-fed wetlands on flat surfaces would often *not* be classified here unless characterised by rates of water through-flow comparable to that on the steeper slopes. Often have thin deposits of peat and water movement is often more by surface flow than percolation through the peat.
Spring-fed wetland (HE)	soligenous wetland irrigated primarily by groundwater discharge; often sloping and frequently small. Sub-categories: *Spring mound: domes of peat and mineral material (especially calcite) developed upon the sites of strong springs; much size variation; sometimes large;* *Spring flush: open vegetation upon skeletal substratum, with much water movement, developed around and below point sources of groundwater discharge lacking obvious dome;* *Seepage fen: peat-based wetland developed below springs and groundwater seepage, lacking obvious dome.*
Spring fen / Seepage fen	These are generic terms which include various types of soligenous wetlands. In the valleyhead wetland context authors have tended to use these term either generally to refer to the entire complex or specifically to refer to the seepage slopes.

(peat) stratigraphy	description of the layering within a peat deposit based on the composition and character of the peat and mineral content
Sump wetland (HE)	± flat-surfaced topogenous wetland, usually in depressions, where precipitation, drainage or run-off water collects or where water level is maintained by a high groundwater level, but with little net through-flow of water. Often characterised by substantial water level flux, the ecological effects of which depend *inter alia* upon base-line water levels and the vertical mobility (if any) of the vegetation / substratum. (Subcategories: *Firm sump wetland sump wetland with solid peat infill with little vertical mobility;* *Floating sump wetland sump wetland with loose or floating peat infill with vertical mobility;* *Seasonal pool wetland wetlands around temporary pools or other sites which periodically flood and dry.*
telluric water	water derived from the earth, e.g. river water.
terrestrialisation	transition from open water to 'solid' ground through the process of hydroseral succession.
Topogenous Wetlands	wetlands in which high water level is maintained by impeded drainage (detention) of water inputs. Water inputs may include precipitation, land drainage, river flooding, run-off and groundwater. Impeded drainage is typically a product of landscape configuration, but it may also be induced by river water levels or the topography of the wetland itself.
General topogenous wetland (HE)	topogenous wetland where source of water is not known, not obvious or in which no particular water source is dominant [default category for topogenous wetlands]. (Sub-categories: General topogenous fen and General topogenous marsh).
Topogenous bog (HE)	rain-fed peatlands in hollows, flats and gentle slopes; peat surface raised slightly above the level of any groundwater level, fen peat or mineral soil, often to produce a (slight) dome of peat that is sometimes independent of subsurface topography (*Sub-types have yet to be clearly defined).*
Tufa mounds	convex domes of peat and, particularly, calcite. Small examples are effectively calcite-based spring-heads but large examples can support a wide range of wetland vegetation and represent a rather different unit.
Valley Fen	This term has been used by various UK workers to refer to valleyhead wetlands, but it has also been used by other workers (*e.g.* Haslam, 1965) in a quite different sense. Haslam (1965) specifically used this term to refer to flood-plain systems, but this is not a common usage in the UK (Haslam used *headwater fen* to refer to the *valley fens* of some other UK workers).
VALLEYHEAD WETLANDS (ST)	associated with the upper reaches of valleys; mainly soligenous (*e.g. New Forest valley mires*).
Water meadow	Alluvial wetland with hydrological characteristics largely determined by a specific management regime.
Water track (HE)	trackways of preferential water movement through topogenous wetlands. Water tracks are essentially sluggish, have a muddy substratum beneath shallow surface water and support mire plant species and vegetation-types.
Waterfringe wetland (HE)	topogenous wetland fringing open water of lakes and pools, typically of rather small extent. [In principle, waterfringe wetlands can also occur alongside rivers, but examples in the UK are usually extremely narrow and fragmentary].

APPENDIX 1 INTRODUCTION TO WETLAND CLASSIFICATION

A1.1 On the nature of classification

The process of classification is essentially three-staged:

(i) derivation of categories that are in some sense 'meaningful' *i.e.* which are thought to be important for the purposes for which the classification will be used.

(ii) specification of the character of the categories so they can be recognised and described both by the originator of the classification and by other workers; such identification and communication of the identity of the classes is materially assisted if they are given a unique name;

(iii) allocation of individual items in this case wetland sites to the classification.

There are various difficulties in devising and evaluating classifications:

- the biggest difficulty of classification is that almost any feature can form a legitimate basis for it, depending on its purpose. Thus it would be possible - and perhaps for some purposes useful - to classify wetlands on their proximity to a public house. There is no 'right' or 'wrong' classification, just much scope for debating what is an acceptable basis of a classification for a particular purpose. For many biological or ecological purposes there is general agreement that the 'best' 'general purpose' classifications are those which group objects into classes in which the members are as similar to one another in as many respects as is possible; also that such classifications should be based on the intrinsic features of the objects themselves rather than on the properties of something outside them. A classification of wetlands based on their distance from a pub is unlikely to be satisfactory in either of these respects.

- classification can be approached as a rigorous scientific exercise with careful data analysis or as an intuitive, informal exercise;

- informal classifications can work well, but they are prone to confusion. This is because they often lack a critical awareness of their own purpose and they are often produced using criteria that are poorly defined and inconsistently used (non-comparable criteria used together in the same classification, leading to spurious alternatives, *e.g.* defining one wetland class on its morphometry, another on its hydrochemistry);

- a problem with many informal classifications is that the precise limits of classes are often not clearly specified (and sometimes cannot be). When types lack crisp definition, even though the classification may be conceptually 'sound', allocation of some samples to it may be difficult or arbitrary.

A1.2 'Hydrotopographical' classifications

A1.2.1 Introduction

One of the most widely-adopted subdivisions of wetlands and the one proposed in this report is based upon their 'hydrotopography' or 'hydromorphology'[1]. In this approach sites are broadly classified by their 'shape' and situation and, either directly or by implication, their presumed 'hydrological mechanisms'. The subdivision of mires into the categories of *topogenous, soligenous* and *ombrogenous* by von Post & Granlund (1926) was an early attempt at a hydrotopographical classification - and one which produced robust ('fundamental') units that have largely stood the test of time. Subsequent workers have attempted various elaborations upon this basic scheme, sometimes incorporating, directly or by implication, some recognition of the way by which the wetlands have developed. Details of some existing hydrotopographical classifications, for Britain and elsewhere, are summarised in Appendix 4.

The desire to classify wetlands by their shape, situation and water supply is beguiling, not least because it may appear to be simple and intuitive. Moreover, as the most distinctive feature of wetlands is that they are wet, a classification which takes some account of the nature and mode of their water supply has some claim to be exploring the 'fundamental' components of wetland typology (Sjörs, 1950a). However, there are considerable difficulties, both practical and conceptual, in the use of 'hydrotopography' as a basis for wetland classification, especially in its more elaborate implementations:

(i) the concept of 'hydrotopographical features' has been interpreted variously by different authors. Some use it to apply to the topographical feature in which the wetland is developed; others to the topography of the wetland; others to hydrotopographical features within the wetland; others to developmental structures within the wetland; and yet others have embroiled various different (and sometimes non-comparable) features within the same classification;

(ii) ('hydrotopography' is a composite concept and its two components (topography and hydrology) are not always well correlated[2]. In some cases, mires which belong to quite different topographical categories may have similar mechanisms of water supply;

(iii) the topography of individual sites can be very variable and difficult to characterise or quantify;

(iv) the main sources of water supply to wetlands are not always intuitively obvious, are more often guessed than measured and do not always clearly relate to wetland 'shape and situation';

(v) many sites are composed of several hydrotopographic elements (though see point (i));

[1] Here regarded as synonyms.

[2] Classifications are often poorly served by composite classes, which, although they may seem to increase precision, may engender confusion. Where the joint components are strongly related, composite classes may be useful, but this is often not the case. There is undoubtedly a relationship between hydrological mechanisms and topography in some wetlands, but it is by no means always the case. Moreover, the issue is further confused by the use of 'topography' to refer both to the 'shape' of the wetland and the 'shape' of the landscape in which it occurs. Again, these are not always well correlated.

(vi) on-going wetland development can change some aspects of the hydrotopography, in some instances changing the site from one hydrotopographical class to another (depending upon the identity and definition of the classes).

(vii) the (apparent) simplicity of 'hydrotopography' has led to the propagation of a variety of intuitive classifications which are frequently rather similar to one another, but not identical. They are not necessarily comprehensive and their units are sometimes informal and ill-defined.

Some of these limitations are inherent in the nature of wetlands and are unavoidable. However, any such 'natural' difficulties have been compounded by an *ad hoc*, informal approach to classification, which has resulted in classifications that are neither comprehensive or internally consistent. For example, a problem of various schemes (*e.g.* Goode, 1972; Ratcliffe, 1977) (see Appendix 4) is that some wetland 'types' refer both to entire wetland systems and to components within other types of wetlands. Difficulties are often enhanced by much nomenclatural confusion. Some terms are frequently used to refer to quite different mire types by different (or sometimes even the same) workers *e.g.* Heathwaite & Göttlich (1993) use the term *valley fen* to refer to four different hydrotopographical fen types.

Whilst 'hydrotopography' is widely regarded as an important basis for wetland classification, for various reasons it can be, in practice, difficult to apply with rigour. In the United Kingdom, some attempts at 'hydrotopographical' classification have essentially entailed the allocation of sites about which very little was known into classes which had not been clearly defined. Such a process is muddled and haphazard and it is not surprising that different workers may allocate the same site to different classes, nor that the process has sometimes produced more confusion than clarification. In such a situation, 'facts' derived from such classifications (*e.g.* area of a particular hydrotopographical type) must be treated with a great deal of caution.

Because of the difficulties of quantifying 'hydrotopographical' features, and because relevant 'hard' data are sparse, any 'hydrotopographical' classification is necessarily informal. However, it is possible to resolve some of the limitations of an informal approach by making it clear, consistent and comprehensive. This can help ensure that the classification can be implemented accurately and consistently. Chapter 2 of this report presents a clear and coherent 'hydrotopographical' classification with a logical rationale is developed.

A1.2.2 Hydrotopography and water supply

Any classification of wetlands by 'hydrotopography' requires an assessment, where possible, of why wetlands are wet. The occurrence of any wetland ecosystem requires that the substratum is kept in a suitably wet condition, either for part or all of the year as a result of interactions between landscape topography and sources of water.

The ultimate source of water supply to freshwater wetlands is precipitation. In ombrotrophic wetlands this is the primary water source to the mire surface. However, many wetlands (minerotrophic examples) are not just irrigated directly by precipitation, but receive water that has been much modified, both by natural processes (*e.g.* passage through bedrock) and artificial ones (*e.g.* application of fertilisers).

There are several potential sources of water input into minerotrophic wetlands: *precipitation, groundwater discharge*[1], *surface run-off, land-drainage, river water* and *lake water.* Of these, the water 'supply' associated with lakes and pools differs from the others as not only may they help supply adjoining wetlands with water, but they may also provide a direct template for the hydroseral development and expansion of wetland within, or across, the lake.

Many wetlands may have more than one source of water and the relative contribution of each source can vary considerably. It is important to recognise that mere proximity to a potential water source does not imply that this source is necessarily of direct importance to the water balance of the wetlands. For example, wetlands on river flood-plains are not always irrigated by river water. Different water sources may (but do not necessarily) vary considerably in their water quality and other associated characteristics (*e.g.* entrainment of alluvial silts) and can sometimes produce strikingly different environmental conditions, leading to considerable internal variability of vegetation composition within individual sites. In other situations, different sources show few salient differences with respect to the vegetation they sustain, whilst in yet others, sources become so mixed that it is difficult to distinguish their particular characteristics or effects.

Whilst the hydrodynamics of the landscape may determine the character and development of wetlands within it, they may also be materially influenced by this process, *e.g.* by the blocking of natural outfalls through peat formation or the development of areas of standing water which act as a store against summer water deficits. In oceanic climates, a minerotrophic wetland may so develop as to become exclusively watered by precipitation (*i.e.* ombrotrophic) and to some extent independent of the hydrological mechanisms of the original wetland.

The effects of different water sources upon the water balance of wetlands may be both *direct* and *supporting* (indirect). *Direct* supply of water is the proximate cause of waterlogging in the wetlands. A *supporting* supply is one that does not directly irrigate the wetland but which helps the wetland to retain water derived from other sources. Examples of this are found in some raised bogs over permeable substrata, where the groundwater level in the underlying mineral ground provides an 'impermeable' base to the bog, and thus helps to maintain the perched mound of water derived from precipitation (the direct supply) against downwards seepage. Similarly, in some riverside wetlands the main hydrological role of high river levels may be more to impede the drainage of mire water derived from other sources than as a direct contribution to the water budget. In some cases, the *supporting* water supplies may be as critical to the maintenance of the hydraulic balance of the wetlands as are the direct water inputs.

The derivation of specific water sources may vary considerably amongst sites. For example, Lloyd *et al.* (1993) identify six conceptual routes by which groundwater may discharge into wetlands in East Anglia, dependent amongst other things upon the deposits from which the water is derived (superficial *versus* main aquifer) and the direction of flow (vertical *vs.* lateral (or both)). These provide a basis for a classification of the sites by their 'hydrological mechanisms' (Appendix 1) which may be of considerable importance for predicting the effects of, say, groundwater abstraction from particular strata upon the water balance. It may be of less importance as part of a more general framework classification of wetlands, not least because

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[1] We use *groundwater* to refer to water that emerges from the ground, usually from an aquifer; *surface run-off* to refer to water that reaches the mire either by overland flow or percolation through the upper layers of the substratum; *land drainage* to refer to water that drains from the land in natural or artificial, more-or-less discrete channels or from mole drains *etc.* When not specifically cited, land drainage is included within the category of surface run-off. Precipitation is a component of the water balance of all British wetlands and is not specifically mentioned except for those wetland-types for which it is a critical, or exclusive, form of water supply.

there is little reason to suppose that other features of the sites (*e.g.* vegetation-types) are necessarily dependent upon the exact mechanism of water input.

Pathways of water movement through the substrata of fens have received little investigation in Britain and are likely to vary amongst sites. For example, where groundwater enters a wetland at its margins it may move *across* the site by surface flow, or *through* the substratum with movement either confined to the upper parts of the peat profile or occurring through much of the depth of the deposit. Which pathway predominates depends strongly upon the hydraulic conductivity of the deposit and its spatial variation. It is possible that, in a little-damaged fen, the uppermost peats may be more permeable than the lower ones (*i.e.* broadly comparable with the acrotelm / catotelm subdivision of a bog peat) and be the main focus of water movement, but this is not necessarily the case. Vertical variation in peat characteristics may reflect different composition and circumstances of formation as well as degree of decomposition and compaction and in some instances some lower horizons of the deposit may be more permeable than upper ones.

In sites that have been partly damaged, operations such as drainage, surface compaction and peat removal may have lead to substantial changes in the hydraulic characteristics of the uppermost peats. Moreover, ditches and dykes may intercept natural water flows and strongly influence the natural distribution of water through the deposit.

Such considerations suggest that the passage of water movement through fen sites should be seen more as a matter for investigation than one for assertion or speculation. Arrows indicating water movement in the figures in this paper should therefore be regarded as schematic rather than prescriptive.

A1.2.3 'Ecological' and 'Biological' classifications

'Situation types' and 'hydrotopographical elements' are here regarded as broad-based components of a classification based crudely on shape, situation and water supply. These are not the only ways of classifying wetlands. Features of hydrochemistry, biology and management are also important bases for classification (see Appendix 3). They are substantially independent of, but superimposable upon, the hydrotopographical framework.

a. Base status

Aspects of the chemical environment of wetland sites has long been considered to provide an important basis for their classification. Chemical variation in wetlands has been examined by numerous workers, but exact limits and categories have yet to be agreed. Base status of wetlands is quite easily estimated (*e.g.* by measurement of *p*H), but as yet there is no agreement amongst ecologists as to the identity of categories of base-status. This not least because base-richness shows continuous variation within wetlands (Sjörs, 1950b; Shaw & Wheeler, 1991) so any subdivisions are essentially arbitrary. Various categorisations exist:

Ratcliffe (1977) (UK):	pH
oligotrophic	4.0 - 7.0
mesotrophic	7.0 - 7.5
eutrophic	7.5 - 9.5

Succow & Jeschke (1986) (DDR):

acidic	2.5 - 4.8
weakly acidic *(subneutral)*	4.8 - 6.4
alkaline *(calcareous)*	6.4 - 8.0

Shaw & Wheeler (1991 and unpublished) (UK):

bog *(extremely base poor)*	<4.5
poor fen *(base poor)*	4.5 - 6.0
rich fen *(base rich)*	>6.0

The proposals of Succow & Jeshcke (1986) and Shaw & Wheeler (1991) are not strikingly different, and their differences probably just reflect different bases for subdivision. By contrast, the rationale for the pH class boundaries given by Ratcliffe (1977) (*Nature Conservation Review*) is not known. Wheeler (1993) has pointed out that 'they would seem to have little basis in field measurements, as water pH values in excess of 7.0 are uncommon in UK fens. Shaw & Wheeler (1991) examined 4975 water samples in UK fens and found that only 3% had pH values in excess of 7.0 and 0.5% in excess of 7.5. Thus the net effect of Ratcliffe's proposal is to classify virtually all British fens as oligotrophic!'

Ongoing analyses, in conjunction with M.C.F. Proctor (University of Exeter), will attempt to provide, in the near future, a substantiated subdivision of UK wetlands by base-status and it would be premature to present any firm proposals until this study has been completed.

b. Nutrient status

Ratcliffe's use of the terms *oligotrophic, mesotrophic* and *eutrophic* as categories for base status in wetlands reflects a long-standing confusion by paludologists between base-status and nutrient-status, which is itself probably partly related to different understandings of the concept of 'nutrient' by different individuals. Here 'nutrient status' is used to refer to the availability of major growth-constraining plant nutrients, *viz.* nitrogen, phosphorus and potassium. In British wetlands variation in base-status (as measured by pH, alkalinity, Ca concentration) is almost completely independent of variation in nutrient-status (as measured by soil fertility estimates and concentrations of NPK) (Wheeler & Shaw, 1995) (see Appendix A3.6). The combinations of nutrient and base status typically occurring in UK wetlands are shown in Table A1.1.

Table A1.1. Typical occurrence of bog, poor fen and rich fen under different conditions of trophic (nutrient) status in UK wetlands. The number of +'s gives a rough estimate of frequency of occurrence.

	'base status'		
'nutrient status'	**bog**	**poor fen**	**rich fen**
oligotrophic	+++	+++	++
mesotrophic	+++	+++	
eutrophic		+	+++

Although *oligotrophic* and *eutrophic* have been used by paludologists to refer to base-status rather than nutrient status (*e.g.* Weber, 1908), they are restricted here to refer specifically to nutrient status. However, it should be recognised that, even when such terms are used as nutrient status categories, there is no consensus as to their exact scope. This is not least because different measures have been used to estimate nutrient status (C:N ratio, soil fertility (estimated by bioassays) and biomass production).

APPENDIX 2 TOWARDS A HYDROTOPOGRAPHICAL CLASSIFICATION OF BRITISH WETLANDS.

A2.1 Introduction

There are several reasons why it might be wise *not* to try to classify British wetlands on the basis of their 'hydrotopographical' characteristics. First, as noted above, 'hydrotopographies' can be difficult to characterise and quantify, making the identification of meaningful categories difficult. Second, there is a dearth of factual information about the actual 'hydrotopographical' characteristics of British wetlands, making the development of a rigorous classification difficult without a great deal of data acquisition and similarly preventing the rigorous application of a classification imported from elsewhere. It may therefore be most appropriate to conclude that, given the present state of knowledge, a definitive classification of the hydrotopography of British wetlands cannot be produced!

Nonetheless, there is undoubtedly a widespread desire to describe wetlands in terms of their types of 'shape and situation'. If this is to be done at all, it seems important to ensure that the limitations of the process are fully recognised, both in terms of the character of the units defined and the difficulties of allocating individual wetlands, or parts of wetlands, to them. This is particularly important in practical terms, because whilst it is possible to devise sophisticated and elaborate classifications, these have little practical value if salient data are not available for the majority of sites to be classified. Thus, for example, at present it is *not* possible to classify British fens on the basis of their origins, as studies on developmental mechanisms are not available for most sites. Similarly it is *not* possible to classify most bogs on whether they form a dome independent of subsurface topography, as neither the shape of the dome or the subsurface topography has been investigated at more than a small number of sites.

The proposed solution to these questions suggested here has essentially been to develop a clear and consistent 'hydrotopographical' classification with a logical rationale, which, as far as possible, incorporates many of the existing ideas and classes of experienced wetland scientists. However, it is recognised that the natural variability of wetlands dictates that it is likely that no classification scheme will be applicable to *all* wetland sites. Moreover, the practicability of using the classification has also been considered, on the basis that no system is of practical value if salient data are not available (or easily obtainable) for its accurate implementation. [For example, despite the fact that it is quite widely cited as a feature of some 'hydrotopographical' classifications, it is currently *not* possible to classify many British bogs on whether they have a dome of peat that is independent of subsurface topography, as neither the shape of the dome or the subsurface topography has been investigated at more than a rather small number of sites.] However, it is also undesirable that 'important' features should be excluded from a classification simply because relevant data are currently unavailable. The conflict between 'desirability' and 'feasibility' has been addressed by introducing different levels of detail into the classification so that 'desirable' features can be recorded when appropriate information is available.

To assist the development of rigorous and comprehensive classifications of wetlands, the following propositions are made:

- that wetland classification can be based on a very wide variety of attributes. These do not have objectively greater or lesser 'importance', but their perceived 'importance' is defined subjectively by the purposes of the classification and the interests of the classifier. A comprehensive classification scheme for wetlands will take into account all those attributes for which there is reasonably comprehensive synoptic data.

- that different attributes upon which wetland classification can potentially be based should be seen as a series of 'overlays', that are potentially independent of one another. Thus, for example, variation in chemical conditions can be overlain upon hydrotopography. This approach does, of course, generate a multitude of potential combinations of attributes, some of which do not (and in some cases, cannot) ever occur. However, this may be regarded more as a benefit of such an approach, rather than a limitation, as it ultimately permits the *identification* of the combinations of attributes which regularly recur (and thereby constitute distinctive wetland types) rather than imposing these *a priori*, as has been the case with some existing classifications.

- that the attributes upon which a given classification is *actually* based should be stated clearly (for example, if hydrological mechanisms have not been measured directly but are based on surrogate evidence, such as inference from peat types, this needs to be made clear).

- that it should be possible for any given attribute to be considered and accommodated in the classification at various levels of refinement and detail, depending upon the nature of information available. The categories of 'not known' or 'not certain' should be admissible for any attribute.

- that the recorded characteristics should be based upon observation, measurement or reasoned deduction rather than conjecture or supposition.

In making a broad overview of the 'hydrotopographical' types of wetlands in Britain, this classification concentrates on features for which information is likely to be quite readily available - particularly features which can be readily observed (though not always easily quantified) - or which can be deduced. This is a broad framework classification which provides a context for, and can be overlain by, more elaborate classifications based on other types of information, such as detailed hydrology, hydrochemistry and vegetation composition.

In this present approach to classification, the various strands of hydrotopography have been separated. The resulting classification thus distinguishes:

- the configuration of the landscape in which wetlands occur (their *situation-type*). Special emphasis is placed upon principal apparent sources of water supply. Many, but not all, wetlands can be referred to a single *situation-type*. The *situation-type* is a crude category which is as variable as the landscapes within which wetlands occur. It represents the first approximation for a wetland classification, but because of its variability it does not represent a very useful unit of wetland resource assessment, even in purely 'hydrotopographical' terms.

- the principal mechanisms of water supply to the major components of the wetland landscape coupled, where relevant, to the distinctive topographies of these components *when they result from, or are strongly related to, the mechanisms of water supply*. These components with distinctive water supply (and, if relevant, topography)are here termed *hydrotopographical elements*.

Implicit within this approach is the view that wetlands can be divided into several broad situation-types, based on their situation in the landscape and that each of these can contain one or more hydrotopographical elements.

This approach has not been developed to use, or fit sites into, predefined categories, but equally it is important not to 're-invent the wheel'. Where existing units seem to be appropriate, these have been adopted - and in large measure, the proposals made here provide a rationalisation, clarification and synthesis of the suggestions of other workers. Where appropriate existing terminology has been retained in the sense used by other authors and the proliferation of further terms has been avoided. However, in places it has proved necessary to use new combinations of terms or to define some existing terms in a more specific or new way. This has been done reluctantly and only because it seems likely to be more acceptable than the generation of a completely new wetland vocabulary.

A2.2 Topographical situation of British wetlands

The following sections, examine the main topographical situations in which wetlands occur in Britain. The main situations identified are referred to as 'situation-types'. These represent a broad, and inevitably crude, categorisation of the landscape with regard to the occurrence and development of wetlands. The identification of specific geomorphological features has been avoided and these can generally be seen as subsets of broader, less well defined constituents of the structure of landscapes, as far as wetland development is concerned.

It must be recognised that 'situation-types' are seen as a first approximation to the classification of wetlands. They are intended to be broad topographical units that can be easily recognised and there can be little doubt that many wetlands can be readily characterised in such terms. However, there are also circumstances in which the situation-type may not be readily evident. This may result from, for example, the complex variability of the landscape, some inherent properties of wetlands and some semantic considerations, including the precise concept of a 'wetland site'. For example, in 'flat' landscapes it is not always intuitively obvious whether a low-lying tract of wetland is part of a river flood-plain or is developed on poorly-drained substrata peripheral to it. Equally, it is possible to find very broad, shallow spring-fed 'pans' which may be, strictly speaking, basins or valleyheads but which are of quite different character to more distinctive examples. In addition, dynamic developmental process such as peat accumulation may effectively change the perceived situation-type. For example, peat accumulation can sometimes overtop basins in which it has been initiated leading to the coalescence of the peat deposit. In this situation, not only may the original situation-type no longer be visually-obvious, but also the resulting wetland 'situation' can no longer just be described as a 'basin wetland'.

The topographical situation types outlined in Table A2.1 are detailed in the following paragraphs (A2.2.1-A2.2.6) for descriptive purposes; they do not infer hydrological mechanisms. Within any one main situation category there may be more than one mechanism of water supply. The possible mechanisms of water supply then form the basis for the 'hydrotopographical' categorisation described in A2.3. There are frequently similarities between the situation types and their developmental processes and it will be noted that in the interests of clarity sections of text are repeated where necessary rather than referencing to their first usage.

Table A2.1 Main British topographical situation types

Situation-type	Description
Basin wetlands	Associated with discrete basins and ground hollows
Lakeside wetlands	Associated with lakes
Coastal-/Flood-plain wetlands	Associated with river flood-plains and coastal plains, including active examples and inactive ones (when their inactivity is largely a product of drainage and water management).
Plateau-Plain wetlands	On flat or slightly undulating ground without close association with lakes, rivers; or discrete, shallow basins; kept wet by high rainfall, impermeable substratum, high groundwater level *etc.*
Valleyhead wetlands	Associated with the upper reaches of valleys; mainly soligenous
Hillslope wetlands	On sloping ground and hillslopes

A2.2.1 Basin Wetlands

Various workers have recognised the occurrence of wetlands in basins as a discrete hydrotopographical type, sometimes as a generic type (*e.g. basin mires*, Ratcliffe, 1977), sometimes as a specific geomorphological basin-type (*e.g. kettle-hole mires*, Succow & Lange, 1984). There is difficulty in finding a sensible point of distinction between basin wetlands and lakeside wetlands and, to a lesser extent, certain other wetland types, *e.g. 'valley' wetlands.* This reflects the variability inherent in the concept of basin wetlands.

Situation

The word 'basin' is difficult to define. It is used variously to describe 'hollows' in the landscape which may occur at various scales, from great synclinal basins, through the basins of large lakes and lochs, to small depressions. The term *basin mire* seems to be used by some authors to refer to this latter situation, though it is not clear why size alone should predicate fundamental distinctions of 'hydrotopography', nor what constitutes, the upper size limit to basin mires. The term 'basin wetland' is perhaps best reserved for those situations where the wetland occupies (or once occupied) much or all of the basin area. This is because in very large landscape basins, where wetlands occupy only a small part of the total area, the wetlands can usually be more appropriately classified into a separate situation-type.

Basins which are largely filled by wetland have formed through a variety of processes. Many have been produced by glacial and periglacial processes - ice-scoured hollows, kettle holes, pingoes, *etc.* Others may represent solution or subsidence hollows; others, valleyheads that have become dammed by morainic debris, *etc.* They display great variety of form, in terms of area, depth, steepness and shape. Many basins are more-or-less circular or oval, but linear depressions also occur which, in terms of their hydrodynamics and development, are not sensibly different from their more symmetric counterparts. Some basins are more-or-less 'closed', *i.e.* they do not have discrete inflows and outflows, but the majority have at least some degree of water through-flow and every gradation can be found between basins that are completely closed to systems dominated by through-flow.

Figure 2.1 illustrates a range of topographical variation within basin wetlands. It also illustrates how sites of identical topography may or may not contain open water and the conceptual problems implicit in those classifications which would assign those examples with open water to a quite different topographical class (*e.g.* open water transition mire) to those without open water (*e.g.* basin mire), especially when it is recognised that open water may not be permanent feature of those sites in which it presently occurs.

Water supply

Wetlands in basins may receive telluric water inputs from three main sources, which vary in importance depending upon the configuration of the basin and the nature of the substrata.

a. Land - drainage

This depends strongly on the topography of the catchment. Many basin mires are fed by influent streams. These may introduce nutrient-rich water and water-borne silts into the wetland. Even where the influents are small, the amount of silt introduced can be surprisingly large and pervasive.

b. Surface run-off

This depends strongly upon the topography, geology and landuse of the adjoining catchment and both the quantity and quality of such inputs may vary considerably. Steep-sided basins in impermeable strata may receive much direct surface run-off. Where the adjoining land is used intensively for agriculture as well, this may be an important route for the import of nutrient-rich water and water-borne silts into the wetland.

c. Groundwater discharge

Some basin wetlands have no effective groundwater discharge, *e.g.* examples scooped from solid rock. In others, groundwater inputs may be significant ecologically, but difficult to detect *e.g.* the basin fens of the Scottish borders *appear* to receive calcareous water from the Silurian mudstones in which they are situated but the importance of this remains to be quantified. In others there may be free and obvious connection between the water in the basin wetlands and aquifers in adjoining substrata *e.g.* some kettle hole basins with no discrete inflows and outflows. In some cases, groundwater discharge occurs below the surface of the topogenous wetland, and is not visually obvious. In others, groundwater irrigates soligenous slopes peripheral to the main wetland; in yet other cases groundwater upwells through the bottom of the basin to form spring-fed fen.

d. Open water

Wetlands in basins may or may not contain open water, derived from any of the above sources. Where open water is *not* present this may be because (a) open water once occurred, but has disappeared in consequence of terrestrialisation (or drainage); or (b) open water has never occurred and the basin wetland is a paludification type or because, say, of the permeability characteristics of the basin is unable to retain any substantial depth of water.

Water level can fluctuate considerably, depending on the nature of the supply. Some basins are not permanently wet, for various reasons. Such temporary wetlands usually support a strikingly different biota to permanently-wet examples, depending upon the precise nature of hydroperiod.

There may sometimes be an obvious differentiation in water supply to parts of the wetlands, which becomes particularly evident during the progress of hydroseral succession as the widening band of wetland increasingly separates the lake water from marginal water sources. Numerous permutations can be envisaged. Consider, for example, hydroseral development in a lake primarily irrigated by river water, but with some marginal inputs of groundwater and land-drainage. The advancing front of the wetland is essentially irrigated by river water, but the margins become increasingly isolated from this and more influenced by marginal water sources. It is not uncommon to find examples of lakeside wetlands where the land margins are strongly influenced by groundwater discharge, or by small but distinctive fans of inwashed silt and are correspondingly quite different in character from the advancing edge. In other cases horizontal isolation from base-rich water sources (from either open water or land margins, depending on situation) may promote surface acidification and possible bog development.

Developmental processes

a. Origins

Basin wetlands may originate and develop in various ways, depending amongst other things upon basin shape and water source. Wetlands may develop both by terrestrialisation and paludification, depending on the situation. In some of the steep-sided, deep kettle-hole-type basins, most or all of the wetland has developed hydroserally, but in other examples paludification has predominated, or a mixture of the two, with paludification mires peripheral to hydroseral ones.

Hydroseral development in basins is potentially influenced by the same factors as is the hydrosere in lakes and similar comments apply - indeed, the point has already been made that there may be no sensible difference between the two. Because basin wetlands are not supplied by rivers or streams, fluvial deposition processes may be less extensive than is the case in river-fed lakes. Nonetheless, small influent streams may produce a comparable effect, though on a smaller scale.

Wetland development in subsidence hollows may be complex, in response to periodic subsidence events that deepen the basins. Tallis (1973) has addressed some aspects of this.

b. Hydroseral development

Whilst some pathways of hydroseral succession have been well documented, the relationship of these to basin morphometry has not been investigated to any great extent. Walker (1966) observed a tendency for different successional sequences to occur in small, closed basins rather than around large expanses of open water, but the difference was far from absolute.

Seral development by *littoral colonisation* is mainly a feature of shallow basins where the gently-shelving shoreline permits extensive spread of swamp communities. In deep, steep-sided basins the hydrosere is represented either by a very narrow (and essentially static) littoral fringe, or by floating rafts of vegetation (*hover*). Hydroseral infilling by rafting is most prominent in small basins, where the mats have some protection from wind and wave action. If such floating structures occur at all around larger bodies of open water, they are usually of very restricted extent and confined to well-sheltered bays. Floating raft development is not specific to deep basins, and examples over shallow water and muds (< 1m depth) are known. Such shallow examples are likely to fill with peat rather rapidly and thus lose their distinctive semi-floating character.

In some hydroseral sites, the marginal zones display apparent littoral colonisation, giving way to hover in the deeper, central parts. Development of floating rafts is sometimes centripetal, *i.e.* expansion of the raft outwards from the edge to encroach upon open water. However, in other cases, the zonation appears to be reversed, with the centre of the basin occupied by a fairly thick mat of peat, with much wetter margins forming a lagg-like moat. It is far from clear how such structures developed. Bellamy (1967), following Kulczynski (1949), relates it to the diversion of flow around an accumulating peat plug which, presumably by feedback processes, maintains or accentuates the zonation. He regards it as part of the normal process of mire development. However, in some cases comparable zonations may be due, at least in part, to marginal poaching by cattle.

In smaller sites, the outcome of hydroseral succession is the development of some form of fen (or bog) across the entirety of the lake. In sites that have become completely grown-over, their hydroseral status is often only evident by stratigraphical examination.

c. *Bog development*

Successional development has led to the formation of areas of bog within some basin wetlands. Acidification and *Sphagnum* establishment can occur at various points in the successional process (swamp, fen and fen carr, Walker, 1966). The critical factor in the initiation of bog is the development of a surface with some degree of isolation from base-rich water. This may be achieved either by horizontal or vertical isolation. The extent to which this is possible depends upon the hydrodynamics of the wetland and particularly the vertical and horizontal amplitude of flooding with base-rich water. Successions based on floating rafts often give more effective vertical isolation from flooding water, because of the vertical mobility of the raft. The diversion of water flow around a central plug of peat may also help to provide horizontal separation from base-rich water and form an initial moat ('proto-lagg') around an accumulating nutrient poor peat mass. The propensity for bog development may also be related to the hydrochemistry and hydrodynamics of the basins. In closed examples on acidic substrata (*e.g.* kettle holes in glacial sands), the irrigating water may be naturally acidic (or, at least, weakly buffered) and supports a poor fen vegetation which can develop into bog more readily than in those basins fed, say, by strong calcareous springs.

The extent of bog development is variable. In some examples the ombrotrophic surface is only slightly above the minerotrophic water level; in others, well developed ombrotrophic domes occur. These differences have scarcely been investigated in Britain. They may partly reflect stages in the natural evolution of the basins, but in some cases the current situation may be a result of removal of much of a previous dome of bog peat by peat extraction. In basins containing both hydroseral and paludification wetlands, bogs may develop across both components to form a continuous ombrotrophic surface. Bog development represents a situation where, as a result of peat accumulation, precipitation inputs take on a progressively more important role in maintaining saturated conditions and in determining the development of the wetland. However, the telluric sources that once sustained the fen may retain an important supporting role in the water balance of the bog.

Effects of water management

Basin wetlands have been variously claimed (*e.g.* for agriculture) and affected by management, though this depends considerably upon their topography. Some closed, steep sided basins in solid rock may be difficult to drain without recourse to elaborate engineering. The small size of some sites may also have protected them from drainage initiatives.

Some examples of water management operations are provided below:

(i) some sites have been largely claimed for agriculture *etc.* **Drainage** operations have sometimes been just sufficient to drain the uppermost peats, thus permitting use for summer grazing or afforestation.

(ii) **reduction of water level** in basins has had complex effects upon hydroseral wetlands, sometimes leading to a rapid expansion of the hydroseral belts consequent upon shallowing; this may also lead to (partial) drainage of adjoining peripheral pool wetlands.

(iii) it is often possible to **drain**, or partly drain, peripheral wetlands, or late-successional zones of hydroseral wetlands, whilst retaining (younger) hydroseral wetlands around open water (*e.g.* around some of the Shropshire meres).

(iv) some sites have been **drained** to facilitate former excavation of peat and, in some regions, marl. In the Scottish borders the value of the latter was such as to stimulate much elaborate engineering to drain the mires in the eighteenth century. This included the excavation of drainage tunnels through solid rock. In some cases, drainage is still effective and the sites support wet grassland (at a surface level several metres below that of the original wetland). In others, deterioration of the drainage systems has led to re-flooding and rejuvenation of the hydrosere to produce some of 'best' extant examples of basin fens for conservation, including some National Nature Reserves. In a few strongly spring-fed examples, the drainage remains functional preventing permanent flooding without draining the substratum. This has led to the production of what are essentially soligenous wetlands within the former basin.

(v) an increase of water level in basins by **damming** can have complex effects upon hydroseral wetlands: (a) vegetation in deep water may die; (b) floating mats may develop in response to shallow flooding; (c) peripheral wetlands may become flooded and then become hydroseral in character.

A2.2.2 Lakeside[1] Wetlands

Lakeside wetlands present a rather problematic category as a wetland 'situation-type'. This is because, although lakes and pools are widespread and frequently have associated wetlands, such bodies of open water often occur *within* other situation-types, especially within basin wetlands and flood-plain wetlands, and in many cases they can be readily accommodated within these. However, although it would be possible to regard all lakes as some form of basin, in certain cases, as with large and deep lakes (*e.g.* Lake Windermere), they are major topographical features in their own right, and their associated wetlands are often primarily features of the lake rather than of a wider wetland complex. It is therefore appropriate to retain 'lakeside wetlands' as an appropriate situation-type in these circumstances.

[1] We use the term *lakeside* as a generic term for the edge for any body of open water, irrespective of area.

This concept of lakeside wetland is *not* synonymous with the *open water transition mire* of Goode (1972) (see Appendix 3) or the *fringing fens* of some other workers. Rather these units are regarded not as 'situation-types', but as 'hydrotopographical elements' which can recur in a variety of wetland situations.

Situation

Lakes and pools vary considerably in their character, in terms of size, depth, steepness of basin and degree of water through-flow, and this may affect both the character and extent of their associated wetlands. Many lakes are both fed and drained by rivers. In some of the larger examples (*e.g.* many of the Scottish lochs) the main area of extensive wetland development is at the head of the lake, associated with fluvial deposits. Such systems may be little different to comparable riverside wetlands associated with similar fluvial processes. Similarly, some other pool systems may be little more than just broadening of rivers and again their flanking fens may be comparable with those found on the flood-plains of sluggish rivers. Yet other pools and small, shallow lakes have been formed within flood-plain wetlands, by natural processes (*e.g.* formation of ox-bow lakes) or artificial ones (*e.g.* peat extraction, as in the Norfolk Broads). In all of these situations there is potential difficulty in separating lakeside wetlands from flood-plain wetlands.

Other lakes and pools occur in basins which have either no discrete inflows and outflows or where these do occur, they are small and do not appear to have much influence on the hydrological and geomorphological processes within the basin. Basins of this sort may contain open water: in many examples, former open water has largely been replaced by autogenic and allogenic infilling process, in which case they clearly fall within the category of 'basin wetlands'(see above).

Some of the difficulties in specifying the character of lakeside wetlands is that wetlands beside lakes may have developed in two very different ways: (i) by autogenic colonisation of part (or all) of the open water of the lake; and (ii) by waterlogging of the land peripheral to the lake (*i.e.* not part of the (former) open water area). The occurrence of the second type of wetland may have little direct relationship with the presence of open water, *i.e.* it need not be directly dependent upon the lake as a source of water supply, being more comparable with some types of riverside wetland or paludification wetlands. By contrast, the first of these types (the hydroseral fringe) is directly dependent upon the open water of the lake. Such hydroseral wetlands are essentially features of pools rather than river systems and provide a point of distinction from riverside wetlands[1]. They do not, however, separate lakeside wetlands from basin wetlands, as in many cases the infill of basin wetlands is just a late successional development of that of open-water transition wetlands.

Water supply

The water supply to lakeside wetlands may depend strongly on whether the wetland is a primary, *hydroseral* type or a *peripheral* type (Figure 2.2).

a. Hydroseral lakeside wetlands

These are irrigated primarily by the pool water. The origin of this may vary, with the main components differing substantially in proportion between sites: river water, land-drainage water, surface run-off and groundwater. There are various possible routes by which

[1] Linear littoral fringes occur alongside some rivers but (in the UK) are much less well developed than examples around lakes and pools. Note also that some riverside wetlands can contain bodies of open water, which may have a littoral fringe.

groundwater may enter the pool, depending primarily on the character of the surrounding substrata (*e.g.* Lloyd *et al.*, 1993). Water level can fluctuate considerably, depending on the nature of the supply. Some bodies of open water are not permanently wet, for various reasons. Such temporary wetlands usually support a strikingly different biota to permanently-wet examples, depending upon the precise nature of the hydroperiod.

There may sometimes be differences in water supply to different parts of lakeside wetlands. This may become particularly evident during the progress of hydroseral succession as the widening band of wetland increasingly separates the peripheral wetlands from the diminishing lake or the lake from land-margin springs. Numerous permutations can be envisaged. It is not uncommon to find examples of lakeside wetlands where the land margin wetlands are strongly influenced by groundwater discharge, or by small but distinctive fans of inwashed silt. In other yet other cases horizontal isolation from base-rich water sources from either open water or land margins, depending on situation may promote surface acidification and possible bog development.

b. Peripheral pool wetlands (non-hydroseral)

There are several potential water inputs into these, which are likely to interact and vary in importance within and between sites:

c. Overbank flooding

This represents direct input of lake (river) water. Its importance varies enormously between sites. It may not occur at all in some examples, whilst in others it may be the main source of telluric water. In this latter case, the associated wetland may show strong fluctuation of water level, to the extent of being normally summer-dry and not peat-forming; in others silt may be deposited in the wetland, especially at the head of the lake associated with the main fan of deposited riverine material.

d. Ponding

Situations where high lake (river) water levels (seasonally or continuously) make no direct ingress into the wetland, but impede drainage from the wetland of water derived from other sources.

e. Land - drainage / surface run-off

The influence of these will depend strongly upon the topography, geology and landuse of the adjoining catchment; both the quantity and quality of such inputs may vary considerably. Where the adjoining land is used intensively for agriculture, they may introduce nutrient-rich water and water-borne silts into the wetland.

f. Groundwater discharge

Some lakeside wetlands have no effective groundwater discharge. In others there may be free connection between the water in lakeside wetlands and aquifers in adjoining substrata. Groundwater discharge may make both a direct and supporting contribution to the water balance, though its importance may not be intuitively obvious. In some sites it helps to maintain wet conditions above the level of influence of lake water and may be expressed as soligenous fen developed on slopes or terraces above the main wetland that is maintained exclusively by groundwater discharge. In extreme cases almost the entire 'lakeside' wetland may be groundwater-fed, as when drainage of the intervening land has severed its former connection with the lake.

Developmental processes

a. Origins

The development of wetlands associated with lakes is potentially complex, and may involve processes concerned with the infilling of open water (hydroseral processes, deposition of imported material) as well as quite separate processes of development of peripheral wetlands. Whilst autogenic pathways of hydroseral succession have been quite well studied in Britain, rather less is known about the pathways of allogenic succession associated with alluvial deposition. Even less is known about the development of peripheral pool wetlands, and particularly their relationships to developmental processes within the pools proper. In many cases they may have formed, or expanded, by *paludification* consequent upon deteriorating drainage in the valleys. They may merge imperceptibly into the former lake basins so that their character can only be detected by careful stratigraphical investigations.

b. Hydroseral development

The pathways of hydroseral succession in lakeside wetlands shows many similarities to that of basin wetlands (see above).

Around larger lakes, such hydroseral encroachment as takes place usually occurs by *littoral*[1] colonisation. Littoral colonisation is not, however, confined to larger sites, but also occurs in some small, closed basin sites. In these examples it is not yet clear what favours each of the two processes, though the outward expansion of the littoral hydrosere is undoubtedly strongly controlled by basin morphometry and by wind and wave action. Vegetation expansion rates around many lakes may be very slow, or may be static (Spence, 1964), with greatest change often being associated with regions of fluvial deposition.

In at least the smaller sites, the outcome of hydroseral succession is the development of some form of fen or bog across the entirety of the lake. In sites that have become completely grown-over, their hydroseral status is often only evident by stratigraphical examination.

c. Bog development

Successional development has led to the formation of large areas of bog within some lakeside wetlands in appropriate climatic regions. Indeed, this represents the 'classic' situation for the development of *raised bogs* (Weber, 1908). [See Basin Wetlands, A2.2.1].

Effects of water management

Lakeside wetlands have been variously claimed for agriculture and affected by management, though generally to a lesser extent than have riverside wetlands. Similar comments apply as for basin wetlands (see A2.2.1). Some examples have been almost entirely claimed for agriculture *etc.*, sometimes when the flood-plain wetlands within which they were embedded have been claimed (*e.g.* Whittlesea Mere).

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[1] Rooting on accumulating muds and peat

Proposals

The essential problems with the classification of lake-side wetlands are:

(i) that they include both *hydroseral* examples and *pool-peripheral* types;

(ii) they cannot always be clearly distinguished from *basin wetlands.* These latter may or may not contain open water, but the essential difference between examples with and examples without open water may often be just one of state of successional development, not of wetland 'hydrotopography';

(iii) they cannot always be clearly distinguished from *flood-plain wetlands.* Many examples of these latter contain bodies of open water.

Any resolution of these difficulties is likely to be arbitrary and unlikely to be completely satisfactory. One possibility would be to jettison 'lakeside wetlands' as a situation-type and to subsume all bodies of open water with associated wetlands into other wetland situation-types. However, this approach is not without some limitations and, on balance, the report recommends the following, workable compromise:

(i) to consider examples of open water within wetland sites that are regarded as basin wetlands or flood-plain wetlands to be classified with these;

(ii) to restrict the 'lakeside wetland' situation-type to refer to those lacustrine sites where the lake is not embedded within another wetland situation-type, or where this is very small relative to the size of the lake.

Note that in both (i) and (ii), the most distinctive feature of lakeside wetlands, *viz.* the (hydroseral) wetlands fringing the open water, would be classified as the same hydrotopographical element (waterfringe wetland) in both situations.

A2.2.3 Coastal plain and Flood-plain Wetlands

Wetlands on river floodplains provide some of the greatest complexities in identifying 'hydrotopographical' types. However, as they provide some of the most extensive wetlands in Britain, they merit careful consideration. The complexities reflect a range of influences upon their character.

Situation

The most extensive flood-plain wetlands are associated with mature rivers and are often located near sea level. The negligible gradients frequently promote waterlogging of the adjoining ground, unless artificially drained.

The typical 'flood-plain' wetland may be thought of as being largely flat across the width of the valley, though the actual configuration of most sites is not known. Even the 'flattest' sites may show some gradient from their upland margins to the river. In many cases the wetland of the flood-plain may be bordered with rising slopes that are kept waterlogged by groundwater discharge.

In many situations, even in wetlands that have been largely claimed for agriculture, it is obvious what is meant by a 'flood-plain wetland'. In others, it is less so. This is the case, for example, in flood-plains with well developed terraces - wetlands developed on upper terraces may have no continuity with the river. Similarly, in a number of places, extensive low-lying areas are contiguous with undoubted flood-plain wetlands, into which they drain, but are not themselves closely associated with a river.

Freshwater wetlands occurring near the sea may be more part of a coastal plain than a river flood-plain, but the distinction is often arbitrary. Coastal plains are essentially regarded as coastal areas with marine or estuarine sediments but, as with river flood-plains they sometimes grade into deposits less influenced by coastal processes (*e.g.* raised beaches) or into non-maritime flat-lands. Certainly not all low-lying coastal areas belong to a coastal plain, defined in this sense. Flattish areas of, say, morainic deposits may occur peripheral to the coastal plain and wetland developed upon these is regarded as occupying the plateau-plain situation-type. However, the difference may not always be obvious without detailed study, especially as sometimes such deposits may be intimately mixed with coastal sediments.

Flood-plains can be broadly subdivided into 'active' and 'inactive' types. 'Active' flood-plains, or 'active' parts of flood-plains have water levels that are strongly and regularly influenced by river water levels and may be subject to episodic overbank flooding. 'Inactive' flood-plains are those in which any influence the river would naturally have has been much reduced, or eliminated, by human activities (drainage and embankment). It seems important, conceptually at least, to recognise that wetlands not influenced by river water levels may be found on both current and former flood-plains. Note that, in some cases, even the latter may on rare occasion be strongly influenced by river flooding.

Water supply

Riverside wetlands can receive water from a number of inputs (Figure 2.3), which are likely to interact and to vary in importance within and between sites. In some cases, river water levels may have rather limited influence, direct or indirect, upon the water levels of the wetlands. This is particularly the case in very large river flood-plains where wetland areas distant from the river may have water levels primarily regulated by water sources other than the river:

a. Overbank flooding

This represents direct input of river water and often associated silts. Its importance varies enormously between sites. It may not occur at all in some examples, whilst in others it may be the main source of telluric[1] water. In this latter case the associated wetland may show strong fluctuation of water level, to the extent of being normally summer-dry and not peat-forming.

b. Ponding

In this case high river water levels (seasonally or continuously) make no direct ingress into the wetland, but impede drainage from the wetland of water derived from other sources.

c. Land - drainage / surface run-off

The importance and character of these will depend strongly upon the topography, geology and landuse of the adjoining catchment and both the quantity and quality of such inputs may vary considerably. Where the adjoining land is used intensively for agriculture, they may introduce nutrient-rich water and water-borne silts into the wetland.

[1] Derived from the earth.

d. Groundwater discharge

Some riverside wetlands may have no effective groundwater discharge. In others there may be free connection between the water in riverside wetlands and associated river gravels (*etc.*) and with aquifers in adjoining substrata. Groundwater discharge may make both a direct and supporting contribution to the water balance, though its importance may not be intuitively obvious. In some sites it helps to maintain wet conditions above the level of influence of river water. It may sometimes be expressed, in part, as soligenous fen developed on slopes or terraces above the main flood-plain wetland that are maintained exclusively by groundwater discharge. Much of this water may then drain through the topogenous wetlands of the flood-plain to the river. In extreme cases an entire riverside wetland may be largely groundwater-fed. This may occur even on flat flood-plain sites, such as where agricultural conversion has severed former river connections from wetlands near the edge of the floodplain (*e.g.* Upton Fen, Norfolk Broadland).

Developmental processes

a. Origins

The development of wetlands on river flood-plains is potentially very complex, being subject to the vagaries of fluvial development, including the interplay between the accumulation of peat and the deposition of river-borne sediments. Some of the largest examples of flood-plain wetlands are (or were) situated in the lower reaches of mature rivers and located just above sea level. These have often been subject to the influence of land:sea level changes and the development of some examples includes phases of saltmarsh intercalated within freshwater fen. In areas of progressive land sinking, on-going subsidence has permitted the accumulation of considerable depths of alluvial infill within the valleys. Where this is not the case only thin deposits of peat may have formed.

Many flood-plain wetlands are thought to have formed, or expanded, by paludification as a consequence of deteriorating drainage in the valleys. However, in some cases former lake basins may have become 'overgrown' and filled with peat or alluvium, to become incorporated, sometimes indistinguishably, into the flood-plain.

b. Open water

Natural processes of fluvial development and artificial diversion of former river courses can produce areas of open water within riverside wetlands (ox-bow lakes *etc.*). Peat extraction can have a similar effect. The 'broads' and 'turf-ponds' of the Norfolk Broadland are artificial water bodies excavated within the peat of a flood-plain wetland.

c. Bog development

Successional development has led to the formation of large areas of bog within some flood-plain wetlands in appropriate climatic regions. These are usually situated in areas remote from river-flooding. The formation of a bog surface requires isolation from telluric water inputs and ombrotrophic peat is raised above the general telluric water level. This therefore represents a situation where, as a result of peat accumulation, precipitation input takes on a progressively more important role in maintaining saturated conditions and in determining the development of the wetland. However, the telluric sources that once sustained the fen may retain an important supporting role in the water balance of the bog.

Effects of water management

Flood-plain wetlands have been variously drained for agriculture and affected by management:

- some (very large) examples have been almost entirely drained for agriculture *etc.*
- some examples have been partly claimed. Sometimes embankments have been constructed to retain water in unclaimed washlands alongside the river and to reduce flooding elsewhere so that the more landward parts could be used for agriculture. In other cases it is the landward margins that have not been drained. [This may be because they have been particularly wet (groundwater discharge?) and difficult to claim. Such wetland remnants are now often isolated from any river influence.]
- some examples are partly drained, usually to provide summer-dry conditions.
- embankment and maintenance of river margins has reduced the incidence of river-flooding, sometimes even upon examples of adjoining unclaimed wetland.
- where drainage of wetland has resulted in shrinkage and reduction of surface altitude, special provision may be required for water evacuation (pump drainage).
- in some areas (especially Norfolk Broadland) dykes, connecting to the rivers, have been cut through the wetlands, for compartmentalisation and transport. The hydrological effects of this are little known, but by helping to distribute river water towards the interior of the fens, even at times of low river levels, they *may* help maintain summer-wet conditions (compared to the undyked state).
- some sites have been subject to various elaborate, traditional methods for regulating water supply (water meadows *etc.*)

A2.2.4 Plateau-Plain Wetlands

Some topogenous wetlands occur in flattish situations where drainage is impeded but which are not closely associated with rivers, coasts, lakes or small basins. Such systems typically occupy poorly-drained flat, or gently undulating, tracts of land, sometimes peripheral to flood-plains *etc.* They are here grouped together under the general name of 'Plateau-Plain Wetlands'. Examples on 'plains' are most usually lowland wetlands whilst examples on plateaux are more typically upland, but the overall topographical similarities between the two situations, from the point of view of wetland development, are such that it seems desirable to regard them as a composite type. Note that the name of this situation-type does not imply that all wetlands on 'plateaux' are referable to it. In many cases, wetlands on plateaux are referable to other situation-types.

Situation

This 'hydrotopographical type' is to some extent a default grouping containing topogenous wetlands of landscape situations which do not obviously fit into other, better defined categories, but which are generally characterised by being relatively flat, poorly-drained land. In consequence, this is an intrinsically variable group and generalisation is correspondingly difficult.

Plateau-plain wetlands are sometimes found as an upland extension of the fringe of river flood-plains or coastal plains. In other cases, as illustrated in Figure 2.4, they occur on undulating ground which is, overall, more-or-less flat. In some of these cases the landscape situation could be regarded as very shallow basins or valleyheads and indeed, particularly in the case of examples on plateaux, they may grade into more distinct valleyhead or hillslope wetlands towards their margins. There is no absolute distinction between such sites and basins or valleyheads; the main differences are that the basins or valleyheads in a plateau-plain wetlands are shallow and ill-defined or that they form a linked complex which is more appropriately described, from the point of view of wetland development, as a composite site rather than a series of small discrete sites. Such areas are particularly appropriate to the plateau-plain situation-type when they contain wetland which was once confined to depressions (and would then have been, say, basin wetland) but which, because of changes in water tables and peat growth, has filled the depressions and coalesced across the intervening ridges. This is thought to have happened quite widely in the development of wetlands in regions of low relief and has involved the spreading of both fen and bog peat across the undulating surfaces.

Problems in the recognition of this type of wetland are enhanced because of a tendency to loosely associate such situations with features such as river flood-plains and lakes and to classify them under these headings and because some lowland examples have been much-modified by agricultural 'improvement'. Such difficulties mean that the nature and identity of plateau-plain wetlands requires further scrutiny.

Water supply

Plateau-Plain wetlands are generally kept wet either because of an impermeable substratum associated with high rates of water input or, when upon pervious substrata, because of a high groundwater level. Telluric water inputs may arise from various sources, which vary in importance depending upon the configuration of the site and the nature of the substrata.

a. Land - drainage

This depends strongly on the topography of the catchment. Many are fed by influent streams, which are usually small.

b. Surface run-off

This depends strongly upon the topography, geology and landuse of the adjoining catchment and both the quantity and quality of such inputs may vary considerably.

c. Groundwater

The role of groundwater discharge into this sort of wetland in the UK is little known. It is reasonable to presume that some sites do receive groundwater inputs and in some cases may be the primary cause of wetness, either directly or by *supporting* the water balance. Note that a high water level induced by groundwater does not necessarily make such sites soligenous *i.e.* irrigated by water flow. However, in some instances, focused upwelling water may produce areas of soligenous wetland, even in flat sites. Some of the wetlands of the Breckland-Fen margin seem to have hovered on the transition between plateau-plain fen and soligenous fen. Here such wetlands may be bordered by true soligenous slopes where they adjoin the rising upland.

d. Lakes and rivers

Although, by definition, plateau-plain wetlands are not directly fed with lake and river water, such water may act to impede drainage of water from other sources.

e. Precipitation

Precipitation is often an important water source to this type of wetland, especially in northern, western and upland areas. In such locations, topogenous bog is a characteristic development on plateau-plains.

Developmental processes

a. Origins

Little is known about the origins of these wetlands in Britain. It seems likely that, in some cases at least, plateau-plain wetlands were initiated by deteriorating drainage associated with cultural activities such as forest clearance. Similarly, natural changes in the height of the groundwater level may also have stimulated the development of such wetlands. In some cases also, changes in height and extent of water associated with lakes and rivers, and of riverside and lakeside wetlands, may have caused the initiation of plateau-plain wetlands peripheral to them. Such comments are largely speculative, it is, however, clear that plateau-plain wetlands are essentially paludification wetlands.

The topography of the land where plateau-plain wetlands occur, coupled with localised inputs of water, has meant that in many cases such systems have accumulated peat slowly and to shallow depth. The peat tends to be well humified and may contain a substantial inorganic fraction. Exceptions to these generalisations occur: (a) when they are part of a region showing progressive subsidence of land; (b) when they are part of a developing flood-plain system; and (c) when ombrotrophic peat has developed.

b. *Bog development*

In appropriate climatic regions, bogs can develop readily within the plateau-plain wetlands. Indeed, the absence of periodic inundation from lake and river water may be conducive to bog initiation. In some instances, bog has formed readily in this sort of situation, with only a brief phase of fen (sometimes just fen woodland separating the establishment of waterlogged conditions from the initiation of bog.

Effects of water management

(i) Many lowland examples of these sites (even those which retain some wildlife 'interest') have been partly drained, though not always with great success.

(ii) Very few examples of plateau-plain wetlands support undrained fen vegetation. They more often support wet grassland or fen meadow (*e.g.* Haxey Grange Meadows, Humberside).

A2.2.5 Valleyhead Wetlands

In numerous sites, slopes irrigated by spring discharge or surface runoff are organised into valley systems to produce a topographically-distinct wetland-type. This has been recognised by various British paludologists, often under the heading *valley mire* (Goode, 1972; Ratcliffe, 1977; Wheeler, 1984) (see Appendix 3). However, the term *valley mire* is a source of considerable confusion, as authors have used it in a variety of ways. And as it can be argued that, as a descriptive term, *valley mire* just means 'mire that occurs in valleys' (and most types do!), we prefer to adopt the terminology of Fojt (1990), *i.e. valleyhead wetlands.* Note, however, that we do not use this just to accommodate wetlands at the headwaters of valleys, but in contradistinction to the 'riverside' or 'flood-plain' wetlands that (generally) occur lower down the valleys. Thus the distinction is essentially one of 'upper valleys' *versus* 'lower valleys'. It is recognised that the distinction is inevitably arbitrary and that in some valleys *valleyhead wetlands* and *flood-plain wetlands* intergrade imperceptibly.

Situation

Valleyhead wetlands occupy the slopes and bottoms of upper reaches of small valleys. Fojt (1990) used this category with regard to spring-fed sites in East Anglia, but the concept can be broadened beyond these, to include, for example, valleyhead sites in north-west Britain that are fed mainly by surface run-off and precipitation. Valleyheads are, of course, extremely common throughout Britain, but many do not support wetlands. These are found only in situations where there are water inputs sufficient to maintain the slopes and valley bottoms in a waterlogged state for some of all of the year. Valleyheads show enormous variations in topography, ranging from narrow, steeply-incised gullies to broad troughs of negligible slope. Valleyhead fens can occur throughout this topographical range, though where the 'valleyheads' are extremely broad and shallow, they may be difficult to separate from the 'plateau-plain' situation-type. Valleyhead wetlands occur in association with many substrata, ranging from glacial debris through highly permeable rocks (sands *etc.*) to impermeable crystalline rocks.

Valleyhead wetlands differ from riverside wetlands in that they are not located alongside mature rivers; rather, they are often the source of streams. Where streams flow through them, these are not a principal water source, though they may sometimes irrigate the lower parts of the wetland. In some instances valleyhead wetlands grade imperceptibly into flood-plain wetlands downstream. The main difference between the two is that most of the water supply of a valleyhead wetland is soligenous and much of its surface area is (usually) obviously sloping.

Valleyhead wetlands differ from hillslope wetlands primarily in their valley-head configuration, that is, they are developed as linear systems along the valley slopes and, in some cases, bottoms. Three broad cross-sectional configurations can be identified (Figure 2.5): (i) water draining down the slopes discharges directly into an axial stream; such systems are essentially just elongate hillslope wetlands and are very widespread, though sometimes now fragmentary; (ii) water collects along the valley bottom to form an axial soakway (*e.g.* many New Forest mires); in such systems the juxtaposition of the soligenous slopes and the more topogenous soakway forms a very distinctive unit; (iii) water from the slopes discharges through a quite deep and extensive valley infill into either a stream or soakway (*e.g.* the Waveney-Ouse fens of the Suffolk-Norfolk border).

It is not always known what determines if the central axis of a valleyhead wetland is occupied by a definite stream or a soakway, though in some cases deliberate ditching is an obvious explanation. Soakways tend to occur where the gradient of the valley axis is small, and can be seen *par excellence* in some of the New Forest valleyhead mires. Streams tend to occur where the gradient is steeper, or where flushed slopes occur on just one side of the valley. The axial streams are often maintained by dredging and some streams may be canalised soakways.

Valleyhead wetlands are sometimes surprisingly difficult to separate from basin wetlands. This is because some basin sites are elongate, are 'open' (*i.e.* have a through-flowing stream) and have soligenous margins. In most such examples, however, the soligenous areas are small relative to the topogenous parts. Further complexities arise in some of the East Anglian wetlands where some shallow valleyhead sites are occupied by a complex mix of seepage slopes and shallow basins (collapsed pingoes) which are themselves groundwater-fed.

Water supply

The essential feature of water supply to valleyhead sites is that they are primarily irrigated by inputs of surface run-off or groundwater discharge. These maintain the slopes and bottom of the wetland in a waterlogged state. Their proportions, and mode of entry, varies considerably amongst the sites.

a. Groundwater discharge

Many valleyhead wetlands have groundwater as their major water source. The mechanism by which this enters the site may vary considerably (Lloyd *et al.*, 1993) and will determine the precise wetland configuration. In some instances springs and seepages occur quite high on the valley slopes and irrigate the whole sloping surface. In others, input occurs close to, or at, the bottom, leading to just local development of wetland. Some sites appear to be fed by more than one groundwater source. For example, the lower slopes may be fed by water from a deep aquifer whilst the upper slopes are irrigated by water from superficial deposits. Where the water quality is markedly different between the two sources, a striking juxtaposition of contrasting hydrochemical conditions (and vegetation-types) is produced (*e.g.* Buxton Heath, Norfolk)

b. Surface run-off
Surface run-off may supplement groundwater inputs in spring-fed sites. In other sites, particularly examples on crystalline rocks, it may be the primary water source. As many of these latter examples are in a peaty landscape, much of the surface run-off may be water derived from hill peats that has had only limited contact with mineral soils.

c. Land-drainage
Many valleyhead wetlands receive some land-drainage input *via* an axial stream. Where the stream is clearly defined, and the adjoining slopes steep, it may have little, if any, direct impact upon the adjoining mire. In flatter systems, it may affect conditions along the valley bottom, including some silt deposition. In other examples, lateral streams discharge into, or cut through, the seepage slopes. In the latter case particularly, they are sometimes associated with secondary mires lateral to the main valley.

d. Overbank flooding
The lower parts of some valleyhead wetlands that are alongside rivers may receive periodic inundation with river water, but this is not the major source of water.

Development

a. Origins
Very little is known about the origins of most valleyhead mires in Britain. This is partly because they have been little studied, probably because many examples contain little peat infill. In some sites the shallow depth of peat may be a reflection of their soligenous character, and perhaps even young age, but in other examples it is because much peat has been removed for domestic fuel.

A few sites, particularly examples in wider valleys, are known to have deeper infills. For example, Redgrave & Lopham Fens (Suffolk/Norfolk), which are usually regarded as 'valleyhead fens' have developed, in part, over late-glacial lakes.

As many valleyhead fens are critically dependent upon surface run-off and groundwater discharge for their wetness, their formation is undoubtedly related to the former supply of these. Many of the New Forest valleyhead wetlands are thought to have been initiated as a result of increased groundwater levels, owing to increased precipitation or forest clearance.

b. Bog development
Development of bog is not a feature of most valleyhead fens, on account of their small size and relatively steep slopes. However, in some of the broader examples small-scale bog development may be possible. Parts of Cranesmoor (New Forest) come close to being ombrotrophic in their character. These areas may represent incipient bog or, possibly, the relicts of a bog that has been largely removed by domestic peat cutting.

Note also that many valleyhead wetlands over non-reactive rocks may support extreme poor-fen vegetation which contains many of the species typically found in bogs. Some of these are also bordered upslope by hill bog.

Effects of water management

Effects of water management depend critically upon the sources of water and their contribution to the water budget.

(i) A reduction of water input is likely to lead to some drying of the soligenous slopes; the valley bottom may also dry, or its main sources of water may change (in some cases effectively changing the system into a river-fed wetland). Such water level reductions may be induced by groundwater abstraction. This is suspected to be a potentially widespread problem for the water balance of many valleyhead wetlands in some lowland regions of the UK, though it has been rarely demonstrated (Harding, 1993).

(ii) The seepage slopes may be directly drained. Where they are fed by strong springs this may be difficult - and it is probably because of this that many valleyhead wetlands have been comparatively little-drained (in lowland England, many examples have been designated as 'Poor's Land'). In some situations where valleyhead wetlands were once contiguous with downstream riverside fens, the latter have been drained leaving the valleyhead sites as residual wetland *e.g.* Waveney valley, East Anglia.

(iii) Deepening of the axial stream channels may have variable effects upon valleyhead wetlands. In situations such as Figure A3.5 (a), where the slopes are fed by strong springs, it may have rather little impact upon the wetness of the slopes. However, in situations such as those depicted in Figures A3.5 (b) and (c), deepening is likely to affect the water balance of the wetland proximate to the channel, and, depending on the topography and volume of groundwater, this effect may extend back to the seepage slopes.

(iv) In some larger valleyhead fens it may be possible to drain and claim the wetland close to the stream leaving the seepage slopes or margins as isolated units maintained by groundwater discharge.

A2.2.6 Hillslope Wetlands

Situation

Hillslope wetlands form the most widespread and extensive category of wetlands in Britain. This category essentially includes all wetlands on sloping ground, except for those that can be accommodated within valleyhead wetlands. Their distinctive feature is not so much that they occupy slopes, more that their drainage is not impeded by topographical constraints.

Much of the British landscape is sloping to some degree. Most slopes do not support wetland vegetation. Those which do are usually not waterlogged because of topographically-impeded drainage, but because of large and consistent water inputs.

Hillslope wetlands vary considerably in their character, depending primarily upon their topography and water source. They range from waterlogged patches of a few square metres area around a spring, through extensive run-off fed mires on gentle hill slopes to the very large areas of hill bog that blanket many northern and western hills. Together, these provide a diverse range of wetlands which share the feature that they are formed and maintained more by water supply than by water detention.

Water supply

Hillslope wetlands are irrigated by three main sources of water. The proportionate contribution of each of these may provide a basis for subdividing these mires (Figure 2.6).

a. *Groundwater*

One source of water for hillslope wetlands is from springs and seepages and for some examples this is the predominant water supply. Such sites are sometimes referred to as *spring fens*. Springs and spring-lines are often of small extent and spring-fed wetlands are sometimes extremely small. In larger examples groundwater may either discharge at various points down a slope or may provide a point source at the top of the wetland, so that the lower portions are effectively fed by spring water trickling down, either through the substratum or across its surface. Complex spring-fed slopes can support quite large wetlands, such as Great Close Mire, Malham (W. Yorkshire). As water flows downslope there is often a tendency for it to form flow paths (discrete *runnels* and more diffuse *water tracks*). These can lead to the development of a wetland comprised of a mosaic of dry(-ish) hummocks separated by runnels and associated mire.

Some hillslope wetlands receive groundwater from more than one source. Where the different sources emanate from rocks of contrasting lithology, the hydrochemical characteristics of the water can show much variation, for example, in base status. This can lead to the occurrence, in close juxtaposition, of contrasting vegetation types. This is seen clearly in some of the spring-fed wetlands of valley slopes in the North York Moors *e.g.* Jugger Howe Beck Mire.

b. *Surface run-off*

Surface run-off may supplement the water supply to spring-fed systems and, where it is of contrasting quality to the groundwater source, may help create a clear zonation of contrasting hydrochemical conditions. In some sites, especially on slopes associated with impervious rocks, surface run-off may be the main source of telluric water. Its properties will largely depend upon the nature of the substrata with which it has contact. In some hill peat areas much surface run-off may have been derived primarily from ombrotrophic peats and thus represents rainwater that has had little contact with mineral soils (although the chemical composition may be transformed to some degree by its passage across, or through, the peat).

In some run-off-fed wetlands, there may be a downslope tendency for the water flow to focus into flow-paths (discrete *runnels* or more diffuse *water-tracks*).

c. *Precipitation*

Precipitation inputs supplement the water supply provided by both groundwater and surface run-off. In some of these, especially the run-off-fed wetlands it may be critical in maintaining wet surface conditions. The extreme development of this is found in the north and west of Britain where precipitation inputs are sufficient to maintain hillslope ombrogenous wetlands. Such wetlands are frequently known as *blanket bogs* or *hill bogs*.

Blanket bog sometimes forms very large areas of visually-uniform wetland. In other cases, it is interspersed with wetland that receives some telluric water inputs. For example, much of Rannoch Moor in Scotland, which is often referred to as 'blanket bog', is actually weakly minerotrophic (influenced by numerous 'islands' of mineral ground) in intimate association with truly ombrotrophic peats. In such situations, the difference between bog and fen is often slight and sometimes difficult to detect, not least because all of the bog plants also grow in the poor fens and because in these highly oceanic mires some fen species also grow on ombrotrophic surfaces, especially, but by no means exclusively, in zones of water movement. The term *blanket mire* may be used to refer to such mixtures of true blanket bog and poor fen. Even in areas of *blanket bog*, the surface flow of water may become funnelled into more-or-less discrete soakways and water tracks, which are distinct from the main expanse of mire. These often have floristic similarities with poor-fen. It is presumed that in some cases they are irrigated by water that has passed through or across the blanket peat and that its concentration of flow in the water-tracks provides a hydrochemical environment suitable for some fen plants which do not usually grow on ombrotrophic surfaces. In other cases, the water-tracks may be supplemented by upwelling telluric water. It is often difficult to guess the source of water in such water tracks. However, it is clear that in some situations blanket mire can be seen as a complex of ombrotrophic, ombro-rheotrophic and minerotrophic elements.

Development

a. Origins

Rather little is known about the origins of hillslope fens in Britain. Many examples have accumulated little peat (or this has been removed by domestic peat cutting). In some instances, establishment of surface-wet conditions is almost certainly a result of an elevation of the water level or an increase in rates of surface run-off or land-drainage, caused either by precipitation increase or by such processes as deforestation. Succow & Lange (1984) suggest that in Germany 'sloping mires' are of quite recent (sub-atlantic) origin. They are uncertain of the ages of 'spring mires', but again consider that some are relatively recent.

b. Bog formation

Hill bogs have accumulated various depths of peat and have received much more palaeoecological study than have hillslope fens. Dates of initiation show considerable variability and few geographical trends, but some were initiated *c.* 7000 BP. Initiation is believed be due to waterlogging induced by climatic change (wetter, colder) or human perturbation (forest clearance). Views vary on the precise importance of each of these.

A2.3 Hydrotopographical Elements of Wetlands

A2.3.1 Introduction

The preceding consideration of the main 'situations' in which British wetlands occur has led to five broad conclusions:

(i) that it is possible to recognise broad 'situations', in which wetlands occur, though these are variable and not easily identified with precision;

(ii) that some of these 'situation-types' correspond broadly with the 'hydrotopographical-types' recognised by some other authors, whilst others do not;

(iii) that within a single situation-type it may be possible to distinguish several further types of wetland, based upon differences in their water supply, or topography; these are referred to as 'hydrotopographical elements';

(iv) some of these 'hydrotopographical-elements' recur in several 'situation-types';

(v) that many examples of wetlands contain several 'hydrotopographical elements'.

This report identifies some of the main 'hydrotopographical elements' that have some general validity for British wetlands and describe their characteristics. As far as possible these units have been developed to be compatible with units proposed by some other workers. Table A2.2 indicates the relationship of these units to some others that have been described, with reference to their distinctive causes of surface wetness. For minerotrophic (fen) elements, the primary division is between sites kept wet primarily by impeded drainage (retention) of water and those with relatively little restriction of water outflow but kept wet by constancy of water supply. These two divisions broadly correspond to the categories of topogenous and soligenous fen. Ombrogenous elements (bogs) may occur in much the same range of topographical situations as do fens, and often originate from within fens, but differ in that they are isolated vertically from telluric water and surface wetness is maintained more-or-less exclusively by precipitation inputs.

Table A2.2. Some terms that have often been used to describe hydrotopographical components of wetland sites in relation to features of gross topography and distinctive causes of surface-wet conditions. Terms used loosely for several categories (*e.g.* valley mire) or which refer primarily to landscape features (*e.g.* basin mire) have been excluded. Terms in bold type are those adopted in the present classification. Note that the terms listed together are not always exact synonyms.

Distinctive cause of surface wetness	Topogenous sites (or parts of sites)	Sloping sites (or parts of sites)
Open water of lakes and pools	**Waterfringe wetland**; open water transition mire; fringing fen; limnogenous mire	
Overbank flooding from rivers and streams	**Alluvial wetland**; transgression mire; fluviogenous mire	
Confined groundwater (strong point-source discharge)	**Spring-fed wetland**; spring fen; tufa mound	**Spring-fed wetland**; spring fen; tufa mound
Confined groundwater flow (from margins or diffuse upwelling)	**Percolating wetland**; headwater fen	**Seepage fen**
Run-off or local groundwater	**Sump wetland**; swamping mire; kettlehole mire; telmatogenous mire	**Run-off fen**; sloping fen; ladder fen
Precipitation	**Topogenous bog**; raised bog; blanket bog	**Hill bog**; blanket bog
Discrete zones of water flow	Soakways and water tracks	Soakways and water tracks; runnels

The following sections describe and characterise individual 'hydrological elements' and Table A2.3 also provides examples of their occurrence and characteristic vegetation types.

Table A2.3. Hydrotopographical wetland elements, with examples of sites in which they occur and characteristic vegetation-types (codes refer to communities of the National Vegetation Classification).

Hydro-topographical element	Description	Occurrence	Characteristic vegetation types in base-poor conditions	Characteristic vegetation types in base-rich conditions
TOPOGENOUS WETLANDS				
General topogenous wetland	topogenous wetland where source of water is not known, not obvious or in which no particular water source is dominant.	Extremely widespread *e.g.* Norfolk Broads	[default category for topogenous wetlands].	
Alluvial wetland	irrigated by overbank flooding of watercourses; substratum usually with a considerable fraction of mineral material (silts *etc.*).	Widespread, but often not very extensive but more usually forms a quite narrow ribbon alongside rivers *etc. e.g. Yare valley (Norfolk); Test Valley (Hampshire); Millers Dale (Derbyshire), Wood of Cree (Wigtownshire).*		S5: *Glyceria maxima* swamp (nutrient - rich conditions); S28 *Phalaris arundinacea* fen; M27: *Filipendula ulmaria - Angelica sylvestris* mire. S25: *Phragmites - Eupatorium* fen.
Waterfringe wetland	wetland fringing open water of lakes and pools, typically of rather small extent.	Widespread; Includes wetlands around artificial water bodies (*e.g.* reservoirs) *Norfolk Broads, Shropshire meres.*	'Swamp' communities *e.g.* S4 *Phragmites australis* swamp & reed-beds; S9 *Carex rostrata* swamp; S10 *Equisetum fluviatile* swamp; S19 *Eleocharis palustris* swamp; S27: *Carex rostrata - Potentilla palustris* fen;	'Swamp' communities *e.g.* S3 *Carex paniculata* sedge-swamp; S4 *Phragmites australis* swamp & reed-beds; S6 *Carex riparia* swamp; S8 *Scirpus lacustris* ssp. *lacustris* swamp; S9 *Carex rostrata* swamp; S10 *Equisetum fluviatile* swamp; S11 *Carex vesicaria* swamp; S12 *Typha latifolia* swamp; S13 *Typha angustifolia* swamp;

Sump wetland	± flat-surfaced wetland, usually in depressions, where precipitation, drainage or run-off water collects or where water level is maintained by a high groundwater level, but with little net throughflow of water. Often characterised by substantial water level flux.	Very widespread, in ground hollows, flood-plains etc. *Many Broadland fens;Tarn Moss (Cumbria); Black Lake (Cheshire), Cornard Mere (Suffolk).*	S10 *Equisetum fluviatile* swamp; S27 *Carex rostrata - Potentilla palustris* fen; M1 *Sphagnum auriculatum* bog pool; M2 *Sphagnum cuspidatum/ recurvum* bog pool M3 *Eriophorum angustifolium* bog pool; M5 *Carex rostrata - Sphagnum squarrosum* mire;	'Swamp' communities *e.g.* S1 *Carex elata* sedge-swamp; S6 *Carex riparia* swamp; S10 *Equisetum fluviatile* swamp; S13 *Typha angustifolia* swamp; S27 *Carex rostrata - Potentilla palustris* fen; S24 *Phragmites australis - Peucedanum palustre* fen (especially in flood plain situation).
Percolating wetland	gently sloping wetland irrigated by groundwater percolating from marginal soligenous slopes, or by groundwater discharge into the peat mass; often situated between land margins and rivers or pools; sites range from being small to very large.	Distribution not know, but probably widespread; most characteristic of valleyhead wetlands and spring-fed basins, but also includes parts (or sometimes all) of flood-plain wetlands. *Cors Goch (Anglesey); Redgrave & Lopham Fens (East Anglia); Somerset Levels; Whitlaw Mosses (Selkirk); Hartland Moor (Dorset); Crymlyn Bog (Glamorgan);*		M9 *Carex rostrata - Calliergon cuspidatum* mire; *Cladium-Carex elata* fen.
Water track or soakway	trackways of preferential water movement through topogenous wetlands.	New Forest mires.	M29: *Hypericum elodes - Potamogeton polygonifolus* soakway; (M30).	

SOLIGENOUS WETLANDS

Sloping wetland	soligenous wetland where the main source of water is not known, or in which no particular water source is dominant or where there is an evident and complex mosaic of areas fed by springs and by surface run-off.	[default category for soligenous wetlands].		
Spring-fed wetland	irrigated primarily by groundwater discharge; often sloping and frequently small.	Very widespread. *Weston Fen (Suffolk); Tarn Moor (Cumbria); Aylesbeare Common (Devon);Roydon Common (Norfolk); Clean Moor (Somerset).*	M21 - *Narthecium ossifragum - Sphagnum papillosum* valley mire; M14: *Schoenus nigricans - Narthecium ossifragum* mire.	M13 *Schoenus nigricans - Juncus subnodulosus* mire; M10 *Carex dioica -Pinguicula vulgaris* mire; Fen meadow (e.g. M22 *Juncus subnodulosus - Cirsium palustre* fen meadow).

Run-off wetland	hillslope wetland irrigated primarily by surface run-off; principally found in the wetter regions of Britain where low-permeability bed-rock coupled with high precipitation permits the development of, sometimes extensive, wetlands fed primarily by run-off and rainfall.	Distribution in lowlands not well known, but possibly rather infrequent. Very widespread over crystalline rocks in the north and west. *Ringinglow Bog (Derbyshire);*	M6 *Carex echinata - Sphagnum recurvum/auriculatum* mire; *Juncus effusus - Sphagnum* communities; many *Molinia* grasslands.	Most base-rich wetlands on slopes seem to be spring-fed. Run-off from base-rich rocks proably produces similar vegetation.
Water track or soakway	tracks of preferential water-movement through sloping wetlands.	Widespread - often associated with other wetland types *New Forest mires;*	M4 *Carex rostrata - Sphagnum recurvum* mire; M7 *Carex curta-Sphagnum russowii* mire; M29: *Hypericum elodes - Potamogeton polygonifolus* soakway; (M30).	

OMBROGENOUS WETLANDS

Topogenous bog	rain-fed peatlands in hollows, flats and gentle slopes; peat surface raised slightly above the level of any groundwater level, fen peat or mineral soil, often to produce a (slight) dome of peat that is sometimes independent of subsurface topography.	Widespread, but now mainly in north and west. *Glasson Moss; Thorne Moors;Cors Caron (Dyfed); Cors Fochno (Dyfed))*	M18 *Erica tetralix-Sphagnum papillosum raised and* blanket mire.
Hill bog	rain-fed peatlands on sloping ground; peat surface raised slightly above the level of underlying fen peat or mineral soil, usually conforming quite closely to subsurface topography.	Widespread and extensive, especially in north and west. *much of Dartmoor; Kinder Scout*	M17 *Scirpus cespitosus - Eriophorum vaginatum* blanket mire; M19 *Calluna vulgaris - Eriophorum vaginatum* blanket mire; M20 *Eriophorum vaginatum* blanket & raised mire.
Artificial wetlands	Wetlands created by human activity and maintained specifically by this.	Root zone beds.	Vegetation often reedbeds or other single-species stands (see water-fringe and sump wetlands).

A2.3.2 Minerotrophic Hydrotopographical Elements

Minerotrophic wetlands are irrigated, in part, by telluric water inputs, which may originate from various sources. The 'hydrotopography' of elements of minerotrophic wetlands is primarily determined by the topography of the situations in which they occur, their water supply and the interactions between the two. Thus the form of minerotrophic elements is in large measure a reflection of their topographical context, and the recognition of these elements largely depends upon an assessment of the topographical characteristics of their situation and their principal mechanism of water supply. Both of these properties are sometimes visually obvious, but in many instances the 'hydrological mechanisms' are not amenable to simple assessment. However, sometimes various other features can be used to deduce the broad mechanisms, with varying degrees of reliability.

A2.3.3 Topogenous Wetlands

Wetlands in which high water level is maintained by impeded drainage (detention) of water inputs. Water inputs may include precipitation, land-drainage, river flooding, run-off and groundwater. Impeded drainage is typically a product of landscape configuration, but it may also be induced by river water levels or the topography of the wetland itself.

a. General topogenous wetlands

Synonymy: *paludification mires* sensu lato.

Characteristics

- Topogenous wetlands which are not obviously referable to other, better defined, hydrotopographical elements.
- May occur in a wide variety of situations (on river flood-plains, around lakes, in basins), and are often peripheral to transgression wetlands and waterfringe wetlands.
- May be supplied by various direct sources of water and may be strongly dependent upon indirect sources for maintenance of the water balance.
- Peat depth is very variable, but is shallow in many examples.

Exclusions

- Topogenous wetlands which can be referred to other, better defined, hydrotopographical elements.

Rationale

- This is largely a 'dustbin group' containing topogenous wetlands that are not referable to other units, particularly examples for which little information is available.

Sub-types

- In view of its rather nebulous and broad character, it would be desirable to sub-divide this hydromorphological element into some better-defined sub-units, but at present it is not fully clear how best this can be achieved. Two obvious sub-types are based upon the permanence of the water supply:

'General' topogenous fen
Peat-based sites that remain wet year-round.

'General' topogenous marsh
Sites that are naturally seasonally dry, usually being waterlogged (sometimes flooded) during the winter months. Usually have little or no peat. [Sites that are summer-dry because they are artificially well-drained do not belong to this category.]

Occurrence
- Extremely widespread.

b. Alluvial Wetland

Synonymy: transgression mires; *Überflutungsmoore*.

Characteristics
- These are riverside (and some lakeside) sites where the water-level is maintained by primarily episodic overbank flooding.

- Overbank flooding is marked by periodic inundation and, in sites with no additional main water sources, by periodically-low water levels.

- Most examples receive inputs of alluvial material during flooding episodes, and their peat has a high mineral component and sometimes appears banded with mineral deposits (exceptions to this generalisation may occur when the entire river course is located within a peatland catchment).

Exclusions
- Riverside sites which do *not* receive direct input of river water.
- Riverside sites with water levels regulated indirectly by river water levels (*i.e.* not by direct input).
- Riverside sites which receive occasional inundation by river water but where this is a rare event or cannot be regarded as the normal reason for high water levels.

Rationale
- The suggested inclusions and exclusions are based upon both ecological and practical considerations, *viz.* sites which receive some mineral inputs are often quite different from those which do not (often more fertile); also the presence of mineral material in the sediments provides a tangible means of identifying the wetland type without detailed hydrological investigation.

- One source of uncertainty is the possibility of water supply from the river *via* transmission through the peat (rather than overbank flooding). This would constitute *direct supply* - though one of very different ecological character to overbank flooding - and wetlands supplied thus could be regarded as a sub-type of transgression wetlands. Due to lack of information we are unable to form a view of the likely role of this process in maintaining the water balance of riverside wetlands.

Sub-types

Alluvial fen
Sites which retain a high water-table year-round. This will either be because they are flooded very regularly or because other water sources keep them wet. The latter examples are likely to have a strongly peat-based infill and will be transitional between alluvial wetlands and other types.

Alluvial marsh
Sites largely dependent on river-flooding for their water supply. Show considerable seasonal flux of water levels and have a substratum composed largely of alluvium.

Flood lands
Lands liable to occasional or controlled flooding.

Deltaic wetlands
Wetlands forming in a deltaic environment, *e.g.* resulting from a stream flowing into a lake.

Occurrence

- Widespread, but often not very extensive, alongside some streams and rivers. Many large flood-plain complexes (*e.g.* Norfolk Broadland) do not necessarily have alluvial wetland, or it forms a relatively narrow strip along the river. Deltaic wetlands are sometimes well developed at the heads of lakes *etc.* In some cases the deltaic material helps to pond-back water behind it, as a form of sump wetland.

c. Waterfringe Wetlands

Synonymy: open-water transition mires; Ancient lake mires; *Verlandungsmoore.*

Characteristics

- Wetlands developed around the margins of open water of lakes and pools.
- May form part of a static zonation around lakes or part of an active hydroseral terrestrialisation process.
- When hydroseral, may show one or both of two main terrestrialisation mechanisms: ***rooting*** (*littoral colonisation* - rooting on accumulating muds and peat) or ***rafting*** (*hover* or *schwingmoor* development - formation of a semi-floating raft of vegetation over water or fluid muds).
- Of very variable extent, sometimes just narrow bands (littoral colonisation of deep-water sites) or extremely large units, where terrestrialisation of (typically shallow) lakes is well advanced.
- The waterside margin is irrigated primarily by lake water, but the older portions become progressively more isolated from this direct source and may become more dependent upon other sources (groundwater input, run-off, precipitation). [The lake water itself may, of course, have originated mainly from some of these sources.]
- Peat depth ranges from being very shallow to deep, depending mainly on successional age and basin topography.

Exclusions

- Lake sites where terrestrialisation has completely occluded open water. Although such wetlands may have originated from open water, once this has disappeared they are patently no longer *waterside wetlands*, both by definition and because their main proximate water source has been lost.
- Waterside sites developed *upon* the alluvial deposits associated with rivers entering the lake (these are *deltaic wetlands*). However, hydroseral units marginal to these could form *waterside wetlands.*

Rationale

- Waterfringe wetlands form a quite discrete unit that has been widely recognised, under a variety of names. They are restricted here to lake and pool-side situations, rather than rivers, as the littoral fringe of most UK rivers is narrow and of rather different character to the more lentic examples. It would, however, be quite feasible to recognise such fringes as a separate hydromorphological element if this was thought to be desirable.

Sub-types

Littoral wetlands
Waterfringe wetlands developed by a littoral process of terrestrialisation.

Floating wetlands
Waterfringe wetlands developed by rafting (= *Schwingmoor*)

Occurrence

- A very widespread wetland type around pools and lakes, sometimes of only small area. Includes wetlands around artificial waterbodies - reservoirs, ponds, peat pits *etc.*

d. Sump Wetland

Synonymy: includes *paludification mires, swamp mires, Grundwassweranstiegmooren, kettle-hole mire*

Characteristics

- ± flat-surfaced, topogenous wetland, usually in depressions or on flat surfaces.
- Occur in situations where precipitation, drainage or run-off water collects or where water level is maintained by a high groundwater level, but with little net through-flow of water.
- Often characterised by substantial water level flux during a given year and between years, the ecological effects of which depend *inter alia* upon base-line water levels and the vertical mobility (if any) of the vegetation / substratum.
- Sometimes dry-out seasonally. Such examples typically have little peat, or shallow accumulations of strongly humified peats.
- Waterfringe wetlands may developed serally into this unit when terrestrialisation of open water is complete.

Exclusions

- Sump areas with a fairly constant supply and through-flow of water (*percolating wetlands*).

Rationale

- This category essentially contains topogenous wetlands which act as natural sumps and accumulate water. It includes sites where wetland development has been stimulated by a natural, general rise in the groundwater level and others which are fed mainly by surface run-off and precipitation. Some sumps influenced by high groundwater levels may have a comparatively stable water level, whereas those fed by run-off may be characterised by strong seasonal water level flux. All examples are characterised by restricted water through-flow. This is most evident in closed basin sites but parts of some flood-plain wetlands can also be assigned to this category, for example parts of the Norfolk Broadland. In these valleys, *transgression mires* (in the sense adopted here) appear to be of limited extent in that there is little evidence that overbank flooding is the primary mechanism for the irrigation of much of these mires. Rather, it seems that the hydrological role of the rivers may, for much of the year at least, be more that it impedes drainage of water from other sources. These other sources must be a combination of groundwater discharge, surface run-off, land-drainage and precipitation. If the Broadland fens were supplied by strong, marginal groundwater inputs then they could be called *percolating mires* (*q.v.*). However, there is no evidence that either of these conditions are fulfilled in most of the Broadland valleys (East Ruston Common is a possible exception) and they seem best regarded as sump fens. [Note, however, that rather little is known about hydrological mechanisms of most Broadland fens.]

- As used here, this category includes the 'kettle-hole mires' of Succow & Lange (1984). As far as we can ascertain (Succow, *pers. comm.*), 'kettle-hole mires' have the same basic water supply mechanisms as do sump wetlands but differ in the interaction that their distinctive topography has with their water supply (which generally results in a more permanently high water level).

Sub-types

Firm sump wetland

- Sump wetland with solid peat infill with little vertical mobility.

Floating sump wetland

- Sump wetland with loose or floating peat infill with vertical mobility.

Seasonal pool wetland

- Wetlands around temporary pools or other sites which periodically flood and dry; Most tend to become dry during the summer months, but some show an erratic behaviour (*e.g.* meres of Breckland - these are examples of types fed by vertical flux of groundwater).

Occurrence

- Very widespread, in ground hollows, flood-plains *etc.* Sites that dry-out in summer are especially widespread. Includes some of the 'basin mires' of Ratcliffe (1977), as with examples in closed kettle holes. Artificial wetlands (*e.g.* examples in clay or sand pits) frequently belong to this category.

e. **Percolating wetland**

Synonymy: *Durchströmungsmoore*; 'riverside valley fens'.

Characteristics

- Widespread, small to very extensive areas of fens which serve to separate a river, lake or other wetland type from strong peripheral water sources (especially groundwater).
- Water percolates through the (uppermost layers ?) of the peat of this wetland element from sources of groundwater towards the adjoining river, lake *etc.* These are therefore effectively topogenous mires fed by soligenous water.
- The water balance of percolating mires may be strongly influenced by water levels in adjoining rivers *etc.*
- Typically have a gentle slope.
- Waterfringe wetlands may develop serally into this unit.

Rationale

- The category of *percolating mires* has generally not been recognised by UK paludologists, but this is not because wetlands with the characteristics of this type do not occur. For example, Wheeler & Shaw (1992) recognised that in some East Anglian valleyhead fens (*e.g.* Redgrave & Lopham Fens) there was a need to distinguish much of the valley infill as a unit separate from the spring mires along the peripheral slopes; but they also realised that it could not be specified as a river-fed wetland, not least because in the Redgrave & Lopham example it was the source of the river! They thus adopted the informal unit of 'riverside valley fens' (as distinct from 'valleyside valley fens') which, it was subsequently recognised, corresponds to the *percolating mires* of some continental authors.

- Percolating mires are probably very widespread in the UK, but often their status is uncertain. This is because neither the topography of most mires (*viz.* the presence of a slope from edge to river or lake) or their hydrological characteristics (*viz.* occurrence of substantial groundwater inputs) are known. The Waveney-Ouse fens are exceptional in this respect, though even here groundwater input is sometimes guessed rather than known.

- Succow & Lange (1984) specify that *percolating mires* are fed by confined groundwater. However in some regions of Britain analogous wetlands occur, fed from the margins by surface run-off. For example, parts of the 'valley fens' of NW Scotland can be considered to be *percolating mires* fed by run-off.

- Percolating mires can be recognised by various surrogate features, such as situation in the landscape (between soligenous slopes and a river). Even when the precise water source of a topogenous wetland is not obvious, the presence of a permanent outflow is often suggestive of a percolating wetland. Separation from soligenous slopes is primarily a matter of degree of slope (shallower), depth of peat (deeper) and rate of water through-flow (slower) though it is not possible to specify exact separating limits.

Occurrence

- Distribution not fully known, but almost certainly very widespread. Most characteristic of valleyhead wetlands and spring-fed basins, but also includes parts (or sometimes all) of flood-plain wetlands. Many wetlands referable to this category have been dug for peat or marl, but few artificial wetlands belong to it.

f. Maintained topogenous wetlands

Characteristics

- Topogenous wetlands of varying character in which much or all of the water supply is artificially contrived.
- Previously referable to other hydrotopographical elements but with water supply now so modified that it has little relationship to former condition.

Exclusions

- Wetland sites in which natural mechanisms of water supply have been partly modified by human activity.

- Wetland sites in which natural water sources are maintained by artificial constructs (dams, sluices *etc.*).

Rationale

- The hydrodynamics of many wetland sites has been much modified by human activity. Many examples have been drained to some degree and even in ostensibly 'undrained' sites ditches and dykes may intercept some natural water flows or distribute water around the wetland in a manner different to that of their natural state. However, many such sites are still usually referable to one (or more) of the 'natural' hydrotopographical elements, though sometimes it may be a different one to that of the former state of the wetland (*e.g.* some flood-plain wetlands near the margin of the flood-plain may now be largely irrigated by groundwater discharge because land drainage has isolated them from possible river sources). Although the hydrotopography of such sites has been much influenced by man, they are not regarded as being largely 'man-maintained'.

- However, the hydrological context of some other wetland sites has become so modified that their 'natural' sources of water have either disappeared or are insufficient to retain the wetland in a waterlogged state. This is most obviously the case where wetlands have been deliberately drained and the usual consequence is that site has dried-out (and often converted to agricultural use). In a few cases, however, where areas are considered to be of particular conservation importance, attempts have been made to maintain, or recreate, saturation in the wetland by the deliberate introduction of water from artificial sources, usually either by input from ditches or by pumping. Such intervention is, in hydrotopographical terms, different from conservation initiatives which aim to retain natural water sources upon wetland areas by sluices and dams and it seems to warrant recognition as a separate, if artificial, hydrotopographical category.

Occurrence

- Artificial maintenance is particularly by characteristic of sites where wetland remnants have been left as upstanding blocks elevated above the surrounding landscape and, often, above the surrounding water levels. This has usually occurred because of peat extraction from the surrounding land or because of its agricultural conversion and subsequent shrinkage. Examples are not widespread, because provision of artificial maintenance can have quite high resource requirements and it is most characteristic of sites of high conservation importance. Examples include a remnant of 'topogenous bog' on Shapwick Heath NNR (Somerset) which is irrigated by pumped groundwater (and which supports fen vegetation). Sites such as Woodwalton Fen (Cambridgeshire) also come into this category.

g. Water tracks and soakways

Trackways of preferential water movement through topogenous wetlands. See under 'Soligenous wetlands'

A2.3.4 Soligenous wetlands

Wetlands primarily kept wet by supply of telluric water with little impedance to outflow. Most typical of relatively steep slopes where groundwater or run-off input produces surface-wet conditions. Groundwater-fed wetlands on flat surfaces would often *not* be classified here unless characterised by rates of water through-flow comparable to that on the steeper slopes. Often have thin deposits of peat and water movement is often more by surface flow than percolation through the peat.

a. Sloping wetland

Synonymy: soligenous fens, flushes.

Characteristics

- Sloping, minerotrophic wetlands which are not obviously referable to other, better defined hydrotopographical elements.

- Sloping, minerotrophic wetlands where the main source of water is not known, or in which no particular water source is dominant or where there is an evident and complex mosaic of areas fed by springs and by surface run-off.

Exclusions

- Sloping wetlands which can be referred to other, better defined, hydrotopographical elements.

Rationale

- This is essentially just a default category for soligenous wetlands, to be used when no other alternative is obvious or when there are insufficient data to specify another type. Note that the term 'sloping mire' is used by Succow & Lange (1984) to refer specifically to sloping wetlands fed by run-off water; this, however, seems to be unsatisfactory as groundwater-fed fens also occur on slopes.

In view of its rather nebulous and broad character, various subdivisions of this type are possible. Two obvious sub-types are based on the permanence of water supply.

Sloping fen
± permanently wet.

Seasonally wet slope
Hill slopes (*etc.*) which are wet or waterlogged during the winter months but which largely dry-out during the summer because of insufficient run-off and precipitation inputs.

b. **Spring-fed wetlands**

Synonymy: Spring mires (fens); seepage slopes; *Quellmoore.*

Characteristics
- Wetlands irrigated primarily by discharge of groundwater from springs and seepages.

- Most often on slopes, but may also occur in basins and on valley bottoms where there is upwelling of confined groundwater.

- Usually quite small, but some examples may be elongated along valley slopes.

- Often form skeletal seepage slopes, with runnels and thin accumulations of strongly humified peat. Base-rich examples precipitate calcite.

- Some examples form discrete mounds, maintained by the hydrostatic head of groundwater, comprised of peat and, in some base-rich examples, much calcite.

Exclusions
- Flattish sites which are not the primary focus of groundwater discharge but which may receive much groundwater input from adjacent spring fens.

- Other hydrotopographical units which are spring-fed.

Rationale
- This is generally a very distinct hydrotopographical unit which has been recognised by various authors. Some workers, including Wheeler (1984), have restricted the term to small, discrete spring-fed sites and have used the term *valley fen* to refer to examples elongated along valley slopes. However, we now prefer to abandon the term *valley fen* because of confusion of usage and to regard its successor (*valleyhead fen*) as a 'situation-type' within which spring fen is a major, but not exclusive, hydrotopographical component.

- The water from spring mires may pass, by surface-flow or percolation, into various other hydrotopographical units, including lakes, basins and riverside wetlands. We recognise the category of *percolating mire* to accommodate gently sloping valley-bottom sites through which water derived from adjoining spring fens percolates towards a river or lake.

- It may sometimes be difficult to know if a hillslope wetland is fed by groundwater discharge or by surface run-off. The nature of the associated bedrock may provide one of the most reliable guides, but many sloping fen sites may be fed by both groundwater and run-off, in similar (or unknown) quantity. These may be referred to a type of *sloping wetland.*

Sub-types

Spring mound
Domes of peat and mineral material, particularly calcite, developed upon the sites of strong springs; much size variation; sometimes large. Small examples are effectively calcite-based spring-heads but large examples can support a wide range of wetland vegetation.

Spring flush
Spring fed wetland with an open vegetation and skeletal substratum with runnels and rapid surface water movement, developed around and below point sources of groundwater discharge, lacking obvious doming.

Seepage fen
Spring-fed mire with a largely peat-based substratum, developed below springs and groundwater seepage, lacking obvious doming.

Spring head
A very small, discrete point-source of water discharge into spring-fed wetlands. May develop small convex domes of peat and mineral material buoyed up by pressure of water discharge, which are transitional into spring mounds.

Supplemented spring wetlands
Spring fed sites in which much, or all, of the summer water supply originates from artificial supplementation (usually piped water) provided to mitigate effects of a reduction of aquifer water levels and smaller spring flows consequent upon, for example, groundwater abstraction from boreholes. Such sites were previously referable to one of the preceding sub-types.

Occurrence

- Very widespread. One of the most frequent types of wetland. Not most typically associated with artificial wetlands, but there are some good examples of spring-fed mires that have developed on the slopes and floors of quarries (especially limestone).

c. <u>Run-off wetland</u>

Synonymy: sloping fens; *Hangmoore* [Note: we consider the name *sloping mires* proposed by Succow to be unsatisfactory as various other mire types may also occupy slopes.]

Characteristics

- Mires on hillslopes irrigated primarily by surface run-off (some may receive minor groundwater inputs from superficial substrata).
- Often small, but can be extensive in appropriate locations.
- Peat usually thin and often well humified; sometimes interrupted by runnels, undulations of the underlying mineral ground and boulders.
- Primarily found upon impervious substrata. Extremely widespread on slopes and gullies on the crystalline rocks of northern and western Britain.

Exclusions

- Sloping wetlands that are referable to another mire type (*e.g.* spring fen; blanket bog).

Sub-types

Run-off fen

As the type, described above, usually with a fairly uniform peat-based substratum and relatively slow water-movement.

Run-off flush

Hillslope wetland with an open vegetation and skeletal substratum with runnels and relatively rapid surface water movement.

'Ladder fen'

[Hillslope wetlands with a ladder-like (scalariform) arrangement of peaty ridges separated by pools, hollows and runnels. Some small mires have been described as *ladder fens* from within blanket bog in northern Scotland. It is not known how closely they conform to larger ladder fens described from other countries. It may be noted that similar scalariform patterning can be observed within various hillslope fens and it is not yet clear if the UK 'ladder fens' represent a distinctive sub-type or just a topographical curiosity.]

Occurrence

- Distribution in lowlands not well known, but possibly rather infrequent. Very widespread over crystalline rocks in the north and west.

d. Soakways and Water tracks

Characteristics

- Linear systems which represent preferential paths for focused surface water movement within wetlands.
- Particularly associated with the drainage axes of some linear wetlands, sometimes forming the main focus of water movement, sometimes lateral to a small stream.
- Particularly typical of sites over an impermeable substratum, or where the mire water level provides an 'impermeable' base to the water track.
- Usually narrow (1-3 m) but wider (20m+) examples are known.
- Shallow to deep (1m +) infill, sometimes a treacherous fluid detrital mud.
- Vegetation cover ranges from sparse to dense, sometimes loosely rooted on the mud surface and sometimes forming a raft.

Exclusions

- Streams and runnels. There is no sharp distinction between streams, runnels and water-tracks. Water tracks are essentially sluggish, have a muddy substratum beneath shallow surface water and support mire plant species and vegetation-types.

Rationale

- Water tracks have not been widely recognised in classifications of wetlands. This may be because they are often small and rarely occur in isolation from other wetland types, leading paludologists either to ignore them or to allocate them surreptitiously to some other unit. Certainly, in some situations, water tracks have obvious affinities to other wetland types. For example, strongly sloping examples may have clear affinities to hillslope fens. However, many other examples, especially those which follow the drainage axes of valleyhead wetlands (as in the New Forest mires) are not obviously referable to any other wetland unit. As they can also be found as distinct entities in several 'situation-types', we propose them as an independent 'hydrotopographical' unit.

Sub-types

- The present limited knowledge of water tracks precludes identification of distinctive sub-types.

Occurrence

- Almost always in association with some other wetland type. Widespread, but probably lost from many sites through shallow ditching.

A2.3.5 Ombrotrophic hydrotopographical elements

Minerotrophic hydrotopographical elements require telluric water inputs to maintain their wetness. Their form is therefore usually very largely determined by, and reflects, the topography and geomorphological processes of the landscape in which they occur. By contrast, ombrotrophic hydrotopographical elements are, by definition, more-or-less exclusively irrigated by water derived from precipitation and occur in those climatic regions where a precipitation excess is sufficient to permit the accumulation of peat above the level of the soil water level. This gives them some independence from landscape form and telluric water supply and their 'hydrotopography' is in some measure a product of their own accrual of peat and internal hydrological processes.

It is possible to overestimate the 'independence' of ombrotrophic hydrotopographical elements from the surrounding landscape. In some instances the water balance of the bog deposits may be materially influenced indirectly by hydrological events in the substrata around or beneath them. The range of topographical situations in which they can develop (especially degree of slope) is also restricted, and is regulated by climate. Nonetheless, it is clear that, in some situations, the 'hydrotopography' of a bog is, in part, an intrinsic feature of the bog itself and has to be taken into account in the identification of appropriate elements.

Traditionally, two main 'types' of bog have been recognised from the British Islands, *raised bog* and *blanket bog*, but, although *blanket bog* is a special feature of British wetlands, paludologists have been rather coy about specifying the salient distinctive features of two types, so the terms have often been employed in a rather *ad hoc* and uncritical way. There has been a tendency to categorise sites *a priori* on the basis of their location with little, if any consideration, of their actual hydrotopographical (or other) features - *e.g.* bog sites in the far north of Scotland tend to be called blanket bog because bog sites in the far north of Scotland are always called blanket bog!

The 'classic' concept of a raised bog is that of an elliptical dome of peat, on a flat(-tish) surface (often a terrestrialised lake), where the doming is largely independent of the sub-surface topography (Weber, 1908). This is undoubtedly applicable to some sites (such as those developed from a flat surface of fen) but not to others. It is not difficult to find stratigraphical sections which show that British sites which are usually called raised bogs are often situated on slightly convex surfaces or have a dome, or some other aspect of surface configuration, that is closely related to the sub-surface topography, or that they do not really have a 'dome' at all.

It is more difficult to identify a 'classic' concept of blanket bog. The concept of blanket bog presented in the *Guidelines for Sites of Special Scientific Interest* (Appendix 3) is 'hydrotopographically' heterogeneous. In this concept, blanket bog comprises entire peatland complexes, largely irrespective of their topography, and encompasses a quite wide variety of 'hydrotopographies' from different areas of the peatland. A consequence of this is that, as thus recognised, the concept of 'blanket bog' encompasses the known 'hydrotopographical' range of raised bogs. For example, topographical sections across some Flow Country 'blanket bogs' are strikingly similar to some of those from raised bog sites from northern England and central Scotland. Likewise, peatland elements with striking 'hydrotopographical' similarity to 'raised bogs' (even to the extent of showing some doming independent of the underlying substratum topography), but still called 'blanket bog', occur in hollows and flat(-tish) areas embedded within broader tracts of bog with a different 'hydrotopographical' character but which is also described as 'blanket bog'. This confusing situation has been accommodated to some extent by the recognition of specific sub-types of blanket bog in the *SSSI Guidelines* but, because the resulting broad concept of blanket bog spans the 'hydrotopographical' characteristics of so-called 'raised bogs', its logical consequence is that all ombrotrophic mires must belong to a single, if variable, 'hydrotopographical' category. In view of this, it is far from clear how 'raised bogs' and 'blanket bogs' are *actually* separated by workers attempting to apply the *SSSI Guidelines*. There is little reason to suppose that it can be based upon their specific, intrinsic, 'hydrotopographical' features.

There are two responses to this situation. One is to suggest there *is* no substantive 'hydrotopographical' difference between 'raised bog' and 'blanket bog' and that they should all be encompassed within a single category of 'ombrogenous bog'. The other is to search for 'real' differences, which, in effect, means splitting the undoubtedly heterogeneous *SSSI Guidelines* concept of blanket bog. As the range of 'hydrotopographical' variability within all ombrogenous mires seems to be less than that within some individual 'hydrotopographical' elements of fen, we do indeed wonder if there really is a fundamental difference between blanket bog and raised bog. However, if a split is to be made at all, we incline to the view that on the basis of their known characteristics, the main 'hydrotopographical' divide within ombrotrophic mires is essentially that between examples located in basins, flats or gentle slopes and examples on steeper slopes[1]. On this analysis, the blanket *mire* landscape can be seen as being comprised of the two elements interspersed (sometimes also including some fen types),

[1] This view was advanced by M.C.F. Proctor. There is considerable (and accumulating) evidence to suggest that in terms of their origin, peat characteristics, vegetation composition and surface patterning, ombrotrophic sites in flat(-ish) areas, gentle slopes and hollows are considerably, and apparently consistently, different from those on more strongly sloping ground. Note, however, that where the flat areas, hollows *etc.* are very small, there may be little difference between the features of the bogs developed upon them and those of the bogs on adjoining sloping ground.

thus providing a classificatory approach comparable to that of fen situation-types. To avoid confusion with the terms raised bog and blanket bog as used in the *SSSI Guidelines* we here follow the terminology of the *Scottish Peat Survey*, which separated bogs on similar principles to those which we advocate, by recognising *topogenous bog* and *hill bog*.

a. Topogenous Bog

Synonymy: raised bog, *Hochmoore (in part)*, Blanket bog *(in part)*, Saddle mire*(in part)*, Watershed-valleyside mire *(in part)*, Spur mire *(in part)*, Watershed mire *(in part)*.

Characteristics

- Mires where surface wetness is maintained directly and ± exclusively by precipitation inputs.
- Developed as a 'raised' accumulation of ombrotrophic peat above the limit of telluric water influence. Depth of bog peat varies considerably (especially with age), typically between some 0.5 - 4 m.
- Bog peat sometimes forming some type of dome, whose character is largely dependent upon the depth of accumulated bog peat and the topography of the landscape in which it is situated. Old examples in small basins often have a pronounced, near-elliptical dome, but flatter 'domes' are characteristic of larger examples. The dome may have an autogenic origin, or may be a reflection of subsurface contours, or both.
- Bog peat is typically rather little humified in the upper parts of the profiles.
- Typically located in basins, over terrestrialised lakes, on alluvial flats and on shallow slopes, or on undulating surfaces that have little overall slope, having usually developed over various fen 'hydrotopographical' elements.
- Preceding fen elements may have developed both by terrestrialisation and paludification.
- Much precipitation input is removed by surface or shallow-subsurface flow, towards the edge of the dome (where domed). Undamaged surfaces have mechanisms for hydrological self-regulation which can mitigate effects of periodic drought, should these occur.
- Water flow may sometimes be funnelled into discrete water tracks.

Exclusions

- Areas of fen! This exclusion is inserted because the *Scottish Peat Survey* used the term *topogenous bog* to include some areas of topogenous fen as well as ombrotrophic bog. We suggest that the term 'topogenous bog' should be restricted to mean specifically topogenous *bog*.
- Water tracks.

Rationale

- The rationale for the distinction of raised bog from blanket bog is given above. Sites on flat surfaces, in basins and on shallow slopes have a greater propensity to develop ombrogenous domes than do sites on steeper slopes.

Sub-types

Various hydromorphological sub-types of raised bogs have been recognised based upon the nature of doming and other features. Some of these show distinctive distributions within Northern Europe (Moore & Bellamy, 1974) but it is difficult at present to assess their significance within Britain (especially the extent to which they represent 'fundamental' sub-types as opposed to morphological curiosities). Some examples of raised bogs are very distinctive and almost certainly require separation as specific sub-types, but more comprehensive and comparative data are required for this to be attempted in more than an arbitrary way.

'Plateau bogs'

This term is widely used to refer to large, 'flat-topped' raised bogs that are typical of the western seaboard of Europe. Some (Continental) workers consider that all UK raised bogs are referable to this category.

'Domed bogs'

Some UK bogs are very strikingly domed. This is particularly evident in some small basin sites, where the small scale may make it easier to see the doming and where the bog deposit may also have been able to develop more closely to its 'hydrological limit' and attain a hemi-elliptical profile (Clymo, 1991). In other instances, doming may reflect sub-surface topography.

'Eccentric bogs'

This refers to bogs where the doming is not concentric. Such 'types' are widespread in parts of northern Europe (Moore & Bellamy, 1974) and essentially seem to relate to situations in which a dome of bog peat has accumulated on sloping terrain. In such situations, downslope the surface microtopography may tend to become aligned across the direction of slope. This feature is found in some Scottish topogenous bogs. Eccentric doming is certainly a feature of some British raised bogs but in some cases it seems to relate to the disposition of the subsurface topography (*e.g.* Flanders West Moss).

'Saddle mire, Watershed mire, Spur mire, Valleyside mire, Watershed-valleyside mire'

These are all varieties of blanket bog according to the *Guidelines for Selection of Biological SSSIs* but which seem to represent what is essentially topogenous bog, in whole or in part. That this is not just a maverick view on our part is suggested by the fact the *locus classicus* of 'raised bog' hydrological studies (Dun Moss) occupies the position of a 'saddle mire'. However, until these units are better characterised their value as sub-units of topogenous bog cannot be assessed.

Whilst it is possible that some meaningful sub-types of topogenous bog may be recognised, the present degree of comparative information available would make their identification an haphazard exercise.

Occurrence

- Widespread, but nowadays mainly north and west. Formerly more widespread in parts of S and E England. Some individual examples are very large.

b. Hill Bog

Synonymy: blanket bog *(in part)*

Characteristics

- Mires where surface wetness is maintained directly and ± exclusively by precipitation inputs.
- Developed as a 'raised' accumulation of ombrotrophic peat above the limit of telluric water influence. Depth of bog peat varies considerably (especially with age), typically between some 0.5 - 3 m.
- Bog peat not forming some type of dome, except as a reflection of the subsurface contours. Peat surface generally tends to follow subsurface conformation.
- Peat profile is typically rather well humified throughout (especially in comparison with topogenous bog).
- Typically located on slopes, sometimes peripheral to other 'hydrotopographical' elements, (which may include topogenous bog).
- May sometimes have developed from a short-lived phase of minerotrophic wetland, but in many situations there is little evidence for this.
- Most precipitation input is removed by surface or shallow-subsurface flow downslope. Importance of mechanisms for hydrological self-regulation not well known, but appears to be more critically dependent upon large and regular precipitation inputs than is topogenous bog.
- Water flow may sometimes be funnelled into discrete water tracks.

Exclusions

- Areas of 'blanket bog' *sensu lato* classified here as *topogenous bog.*
- Water tracks within hill bog.
- Areas of minerotrophic fen (such as run-off fen) in complex mosaics with *hill bog.* [The mire complex (macrotope) of hill bog / topogenous bog/ run-off fen may be referred to as 'blanket *mire*'.]

Rationale

- The rationale for the distinction of raised bog from blanket bog is given above. Sites on slopes may have less capacity for hydrological self-regulation than topogenous sites (some workers have questioned whether sloping blanket peats have an acrotelm with the same regulatory function as that reported from topogenous bogs) and they are more critically dependent upon high and frequent precipitation input.

Sub-types

'Saddle mire, Watershed mire, Spur mire, Valleyside mire, Watershed-valleyside mire'

These have been proposed as varieties of blanket bog in the *Guidelines for the Selection of Biological SSSIs,* but in the current proposals they would probably be classed, in whole or part, as a sub-type of topogenous bog. As their characteristics have not been clearly or comprehensively described, their true relationships remain obscure.

Whilst it is highly likely that some meaningful sub-types of hill bog may be recognised, the present degree of comparative information available would make their identification an haphazard exercise.

Occurrence

- Widespread and very extensive in the north and west.

A2.3.7 Artificial Wetlands

Wetlands created by human activity and maintained specifically by this. This category does *not* include many of the wetlands that have been produced deliberately or incidentally by human activity, as many of these (*e.g.* clay pits, reservoirs) occur in, or mimic, various natural 'situation-types' and support similar 'hydrotopographical elements' and they are most appropriately classified as man-made examples of the appropriate natural types. However, there are other wetlands which have not only been deliberately engineered but are also maintained by an artificial supply of water and these seem best allocated to a separate category.

Root Zone beds Wetlands constructed to treat domestic and industrial effluent.

APPENDIX 3 SOME EXISTING 'HYDROTOPOGRAPHICAL' CLASSIFICATIONS OF WETLANDS

A3.1 Proposals of Goode (1972) and the *Nature Conservation Review*

One of the most influential hydrotopographical classifications of British wetlands was that proposed by Goode (1972). It was subsequently incorporated into the *Nature Conservation Review* (Ratcliffe, 1977) and has shaped the approaches of conservationists and other workers.

Goode's classification, although rather *ad hoc*, was an important contribution. It has three main limitations:

(i) it is not comprehensive;
(ii) its categories are not clearly defined or described, nor is the basis or generality of some of them clear;
(iii) it seems inconsistent in its approach; some categories are obviously characterisations of the topography of the landscape in which wetlands occur (*e.g.* valley mire, basin mire) but others (*e.g.* open water transition mires, raised bog), whilst ranked equal as 'mire types', are frequently elements *within* various topographical wetland types This leads to the unsatisfactory - and avoidable - situation of having the same unit to refer, on the one hand to a topographical 'whole-mire'-type and, on the other, to just part of a separate 'whole-mire'-type.

Main 'hydromorphological' types of wetland following Goode (1972) and the Nature Conservation Review

- Flood-plain mire
- Soligenous mire
- Raised mire
- Basin mire
- Valley mire
- Blanket bog
- Open water transition mire

Various sub-units are recognised for some of these types (Figure A3.1):

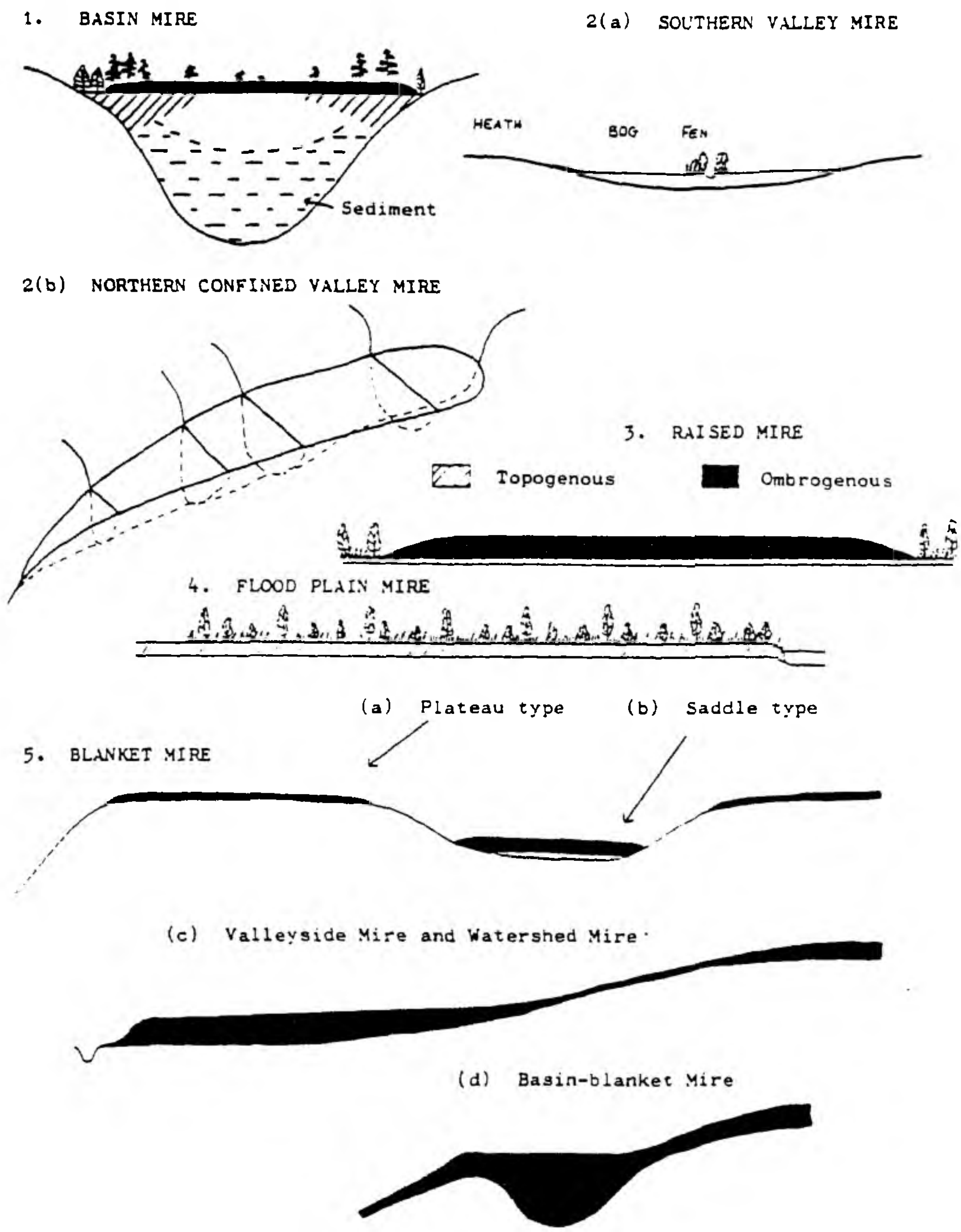


Figure A3.1 Main topographic types of wetland in Britain identified by Goode (1972).

A3.2 'British Fens: a Review': Proposals of Wheeler (1984)

Wheeler (1984) explored the use of hydrotopographical wetland types as a 'handle' by which to describe the floristic variation of British fens. The categories were essentially those of Goode (1972) see above, slightly adapted. Wheeler (1984, 1993) was uneasy about the use of such a typology and identified some of its limitations (some of which had, in fact, already been recognised by its author), but nonetheless made no attempt at a substantial revision. This was because his interest was primarily in the vegetation-types of fens (which have been identified quite clearly) and not in 'mire-types'. His attitude to 'hydrotopographical classifications' was essentially a recognition that the units were neither clearly defined nor consistent with one another, but that they did broadly describe the 'sort of situation' in which fens occur and could be loosely used for this for this purpose. Such *laissez faire* is perhaps acceptable when 'mire-types' are just being used as crude and convenient descriptive 'handles'. It is not acceptable if one wishes to identify units that will have some serious or scientific purpose, *e.g.* resource assessment. The hydromorphological types of fen identified by Wheeler (1984) are shown in Figure A3.2.

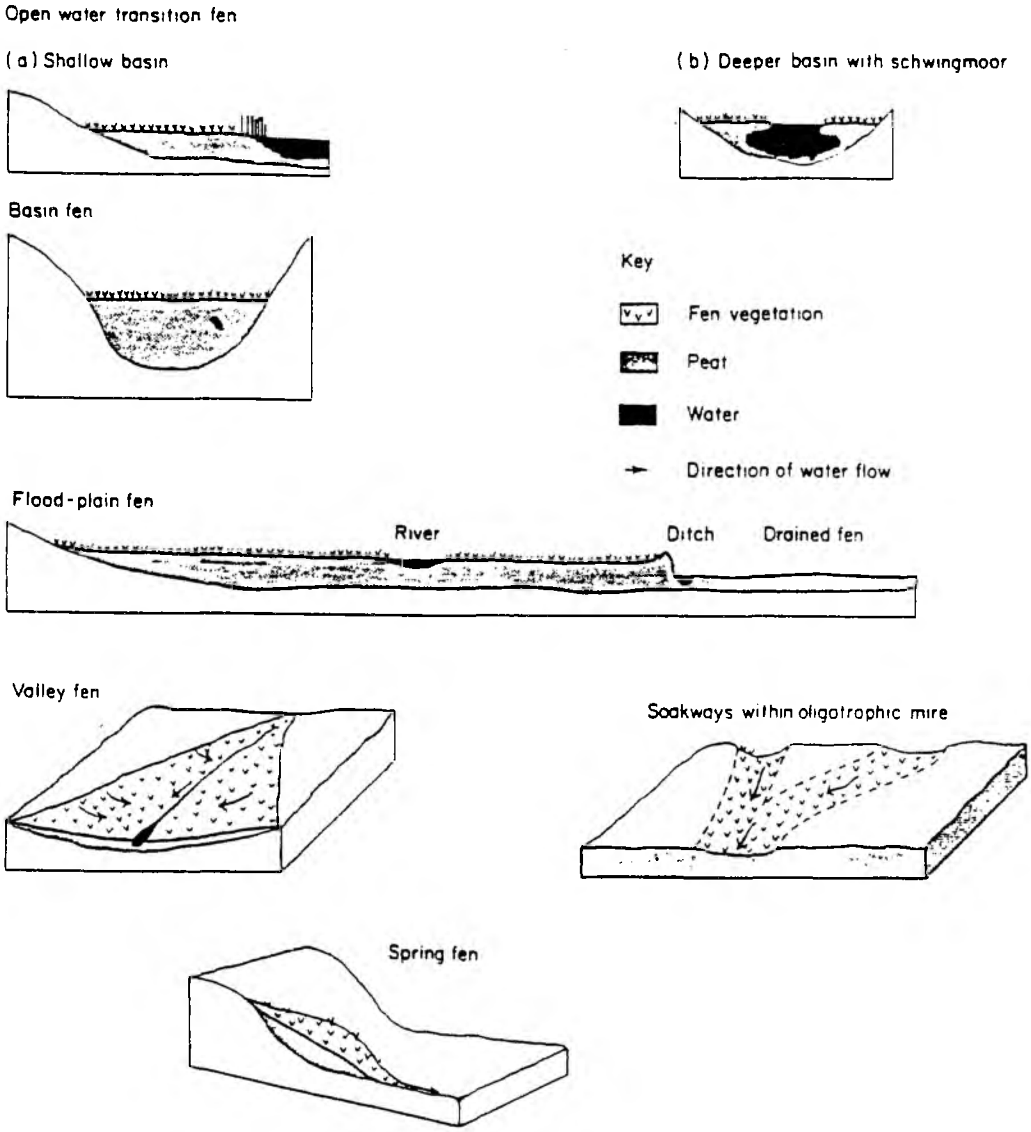


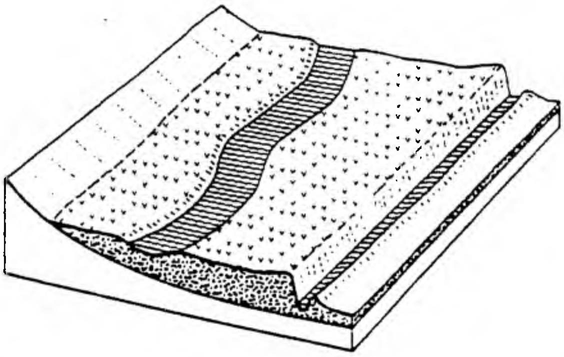
Figure A3.2 Diagrammatic profiles of some hydromorphological types of fen (from Wheeler, 1984) (Reproduced courtesy of Academic Press Ltd.)

A3.3 Guidelines for the selection of biological SSSIs (NCC. 1989)

Various criteria and typologies have been used to recognise wetland types relevant to the selection of Sites of Special Scientific Interest, representing different facets of the perceived importance of wetlands to conservation. Many of the proposed guidelines are based around 'hydrotopographical' units. The hydrotopographical classification used is essentially an expansion, or formalisation, of the approach in the *Nature Conservation Review* (see above). The classification of fens is expanded by insertion of a new category of 'ladder fen'. Raised bogs are explicitly divided into three types, depending upon the situation in which they are found (a logic which is somewhat sullied by recognition of a fourth 'type' (cut-over raised bog) which is more of a management-type and not specifically related to situation - and which thus provides a splendid example of the 'pick-and-mix' approach to informal classification). Sub-types of blanket bog are also recognised, but are not clearly described, based upon their situation within the landscape.

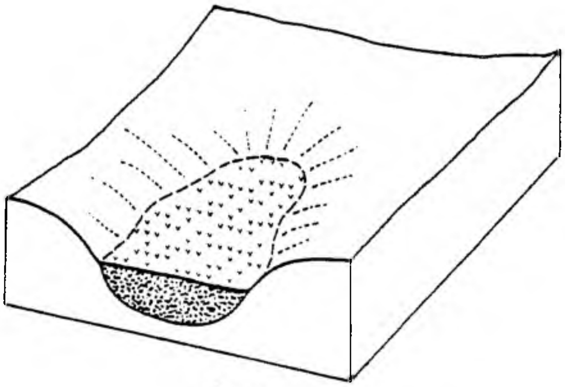
This classification inherits some of the limitations of its predecessors, but it also attempts to resolve some of these, such as by identifying the different topographical circumstances in which (three types of) raised bogs occur. However, even here it does not seem to grasp the 'real' issue, *viz.* the distinction between landscape topography and mire-type. The use of the three classes 'typical raised bog', 'estuarine raised bog' and 'basin raised bog' suggests that there are three distinct types of raised bog - whereas a more accurate assessment would be that there is one 'hydrotopographical type' of raised bog which is found in three different topographical situations. The question of rank also effects the fens: 'ladder fens' (which are represented by a small number of tiny sites) are given a similar rank to flood-plain fens *etc.*

Hydromorphological types of wetlands identified in 'Guidelines for Selection of Biological SSSIs' (NCC, 1989) are presented in Figures A3.3 (Fens) & A3.4 (Bogs).



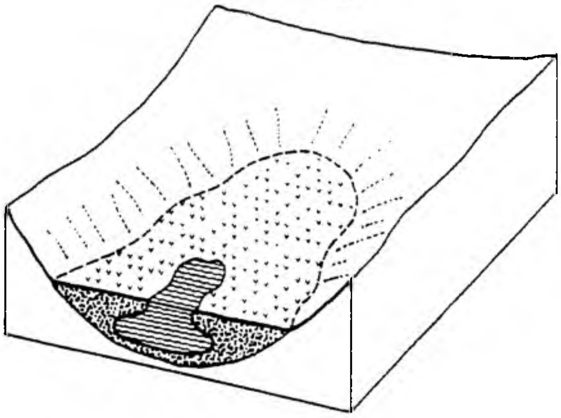
Flood-plain fen

This type of fen develops on a waterlogged, often periodically inundated flood-plain adjacent to a river or stream.



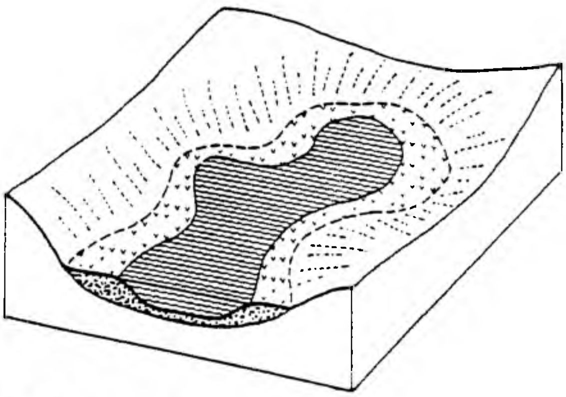
Basin fen

This type develops in a waterlogged basin with limited through-flow of water. Within the basin the water table is level, but small flushes may occur along the basin's sides. The proportion of open water, if present, is small.



Basin fen - <u>Schwingmoor</u> type

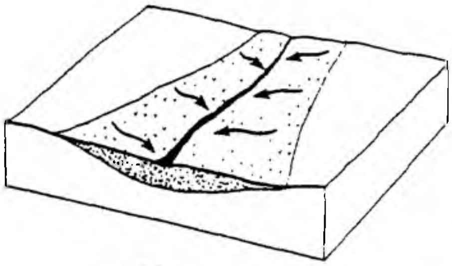
A raft of vegetation colonising an open water surface eventually sinks to form a layer of peat. This process is repeated, giving rise to a semi-floating structure formed by layers of peat alternating with semi-liquid lenses.



Open water transition fen

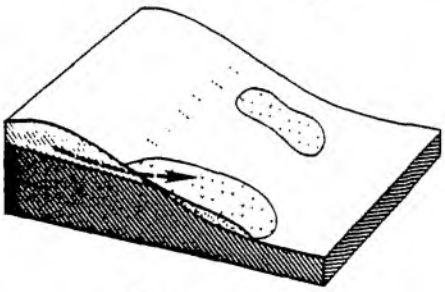
This type of fen develops around a body of open water. The proportion of open water is large.

Figure A3.3a The main hydromorphological types of fens identified by NCC (1989) (after Wheeler 1984) (Reproduced courtesy of English Nature)



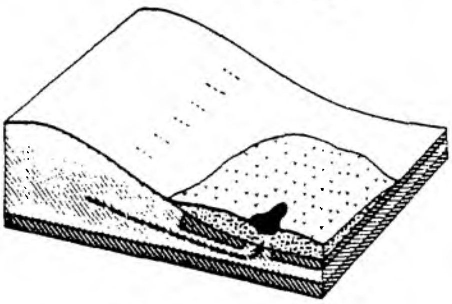
Valley fen

This type of fen develops along the lower slopes and floor of a small valley where there is some water movement. Springs and seepage from the valley sides provide the main source of water. The topography of the valley often also helps to maintain a high water tablé.



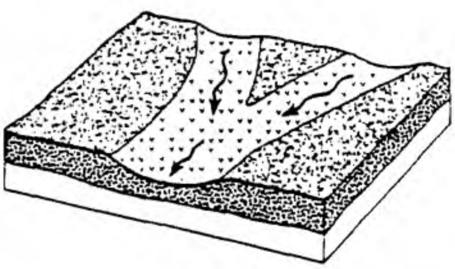
Spring fen

This type arises on a slope beneath a spring or line of water seepage. The fen is discrete and not part of an elongated mire along a valley.



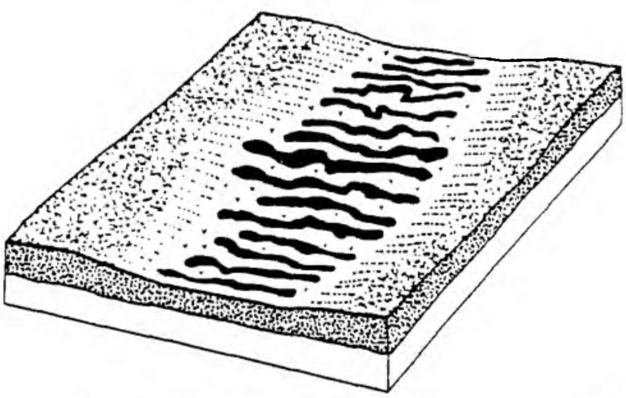
Spring fen

Water reaching the surface under artesian pressure gives rise to a small dome of mire, usually on flat ground.



Soakway within an oligotrophic mire

This type of fen occupies channels and areas of lateral movement within oligotrophic peatlands.



'Ladder fen'

This recently identified type of fen is exclusively associated with sloping, elongated depressions within blanket mire which have a degree of enhanced lateral water movement. A series of pools separated by narrow ridges lies across the main direction of water flow. There is no evident central water-track.

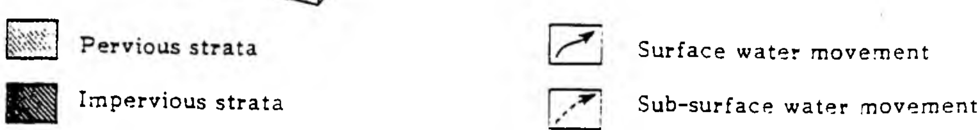


Figure A3.3b The main hydromorphological types of fens identified by NCC (1989) (after Wheeler 1984) (Reproduced courtesy of English Nature)

Bogs: Raised bogs

Four 'mesotopes' are identified:

i) Typical raised bog

ii) Estuarine raised mire (sic!)

iii) Basin raised bog

iv) Cut-over raised bog

Blanket bog: see Figure A3.4

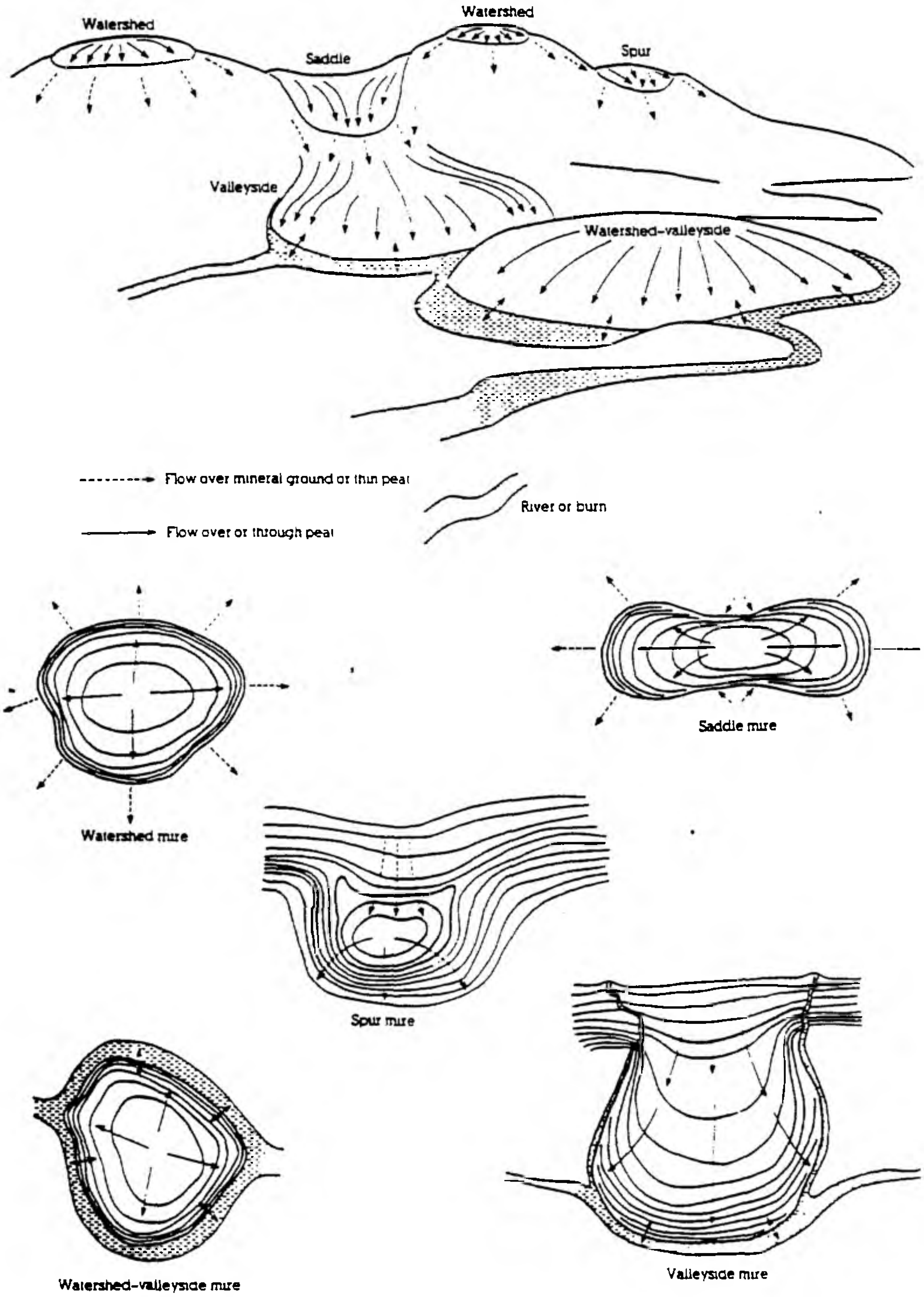


Figure A3.4 Hydromorphological bog types - generalised location within the landform, with an indication of surface water flow patterns and generalised pattern of surface water 'flow-nets' (Ivanov 1981) (NCC, 1989) (Reproduced courtesy of English Nature).

A3.4 Hydrological classification of East Anglian wetlands (Lloyd *et al.*, 1993)

Lloyd *et al.* (1993) published an interesting classification of East Anglian wetlands based upon an unpublished study by Gilvear *et al.* (1989). Their work essentially attempts to classify East Anglian wetlands by (conceptual) 'hydrological mechanisms'. As such, it is not a hydrotopographical classification, but rather it identifies the types of hydrological mechanisms that may occur in specific hydrotopographical contexts. As their basis for the latter these authors adopt a hydrotopographical classification of uncertain provenance - they attribute it to Goode (1977) (*ex Nature Conservation Review*) but reproduce the diagrams of Wheeler (1984) and include some significant changes and additions to both of these sources. This classification exemplifies one of the problems of hydrotopographical classifications, namely the way by which workers are prone to generate various *ad hoc* 'hydrotopographical' units which are not really comparable with one another. For example, these authors distinguish (at the same rank) '*schwingmoor*'[1] from '*basin fen*' without recognising that '*schwingmoor*' (in the sense shown) is a development *within* many basin fens. Likewise they separate a '*fluctuating mere*' from a '*non-fluctuating mere*', although such a difference relates more to the hydrodynamics of the wetland than to its 'hydro-topography' *Lloyd* et al. *(1993)*

a. Hydromorphological Classification (based on Ratcliffe, 1977)

- Open water transition mire (+ non-fluctuating mere)
- Schwingmoor
- Basin fen
- Flood-plain fen
- Valley fen
- Spring fen
- Fluctuating mere
- Soakway

NB. These authors do not describe the nature of these categories.

b. Proposed classification of wetlands in East Anglia:

see Table A3.1 & Figure A3.5.

[1] Formation of a semi-floating raft of vegetation over water or fluid muds.

Table A3.1 Hydrological and hydrogeological classification for East Anglian wetlands (Lloyd *et al.*, 1993). (see Figure A3.5).

Class	Input	Topography	Geology in catchment
A	Surface water runoff only	Often in topographic hollow, also valley	Clay predominates
A'	Overbank flooding	Low relief adjacent to river	Clay predominates
B	Leaky aquifer and some surface-water	Shallow valley	Low permeability but mixed - sand may exist; tufa?
C	Groundwater from superficial deposits	Shallow valley	Mixed typical clay-sand-gravel drift
D	Groundwater from superficial deposits and underlying main aquifer	Valley or closed depression	Sands and gravel over clays over main aquifer
E	Leaky aquifer	Closed depression, e.g. pingo	Clay overlying major aquifer, lateral isolated typical 'pingo'
F	Unconfined main aquifer	Wide range	No superficials. Main aquifer rock outcropping
G	Unconfined superficial aquifer	Shallow valley	Superficial sands and gravels overlying clays.

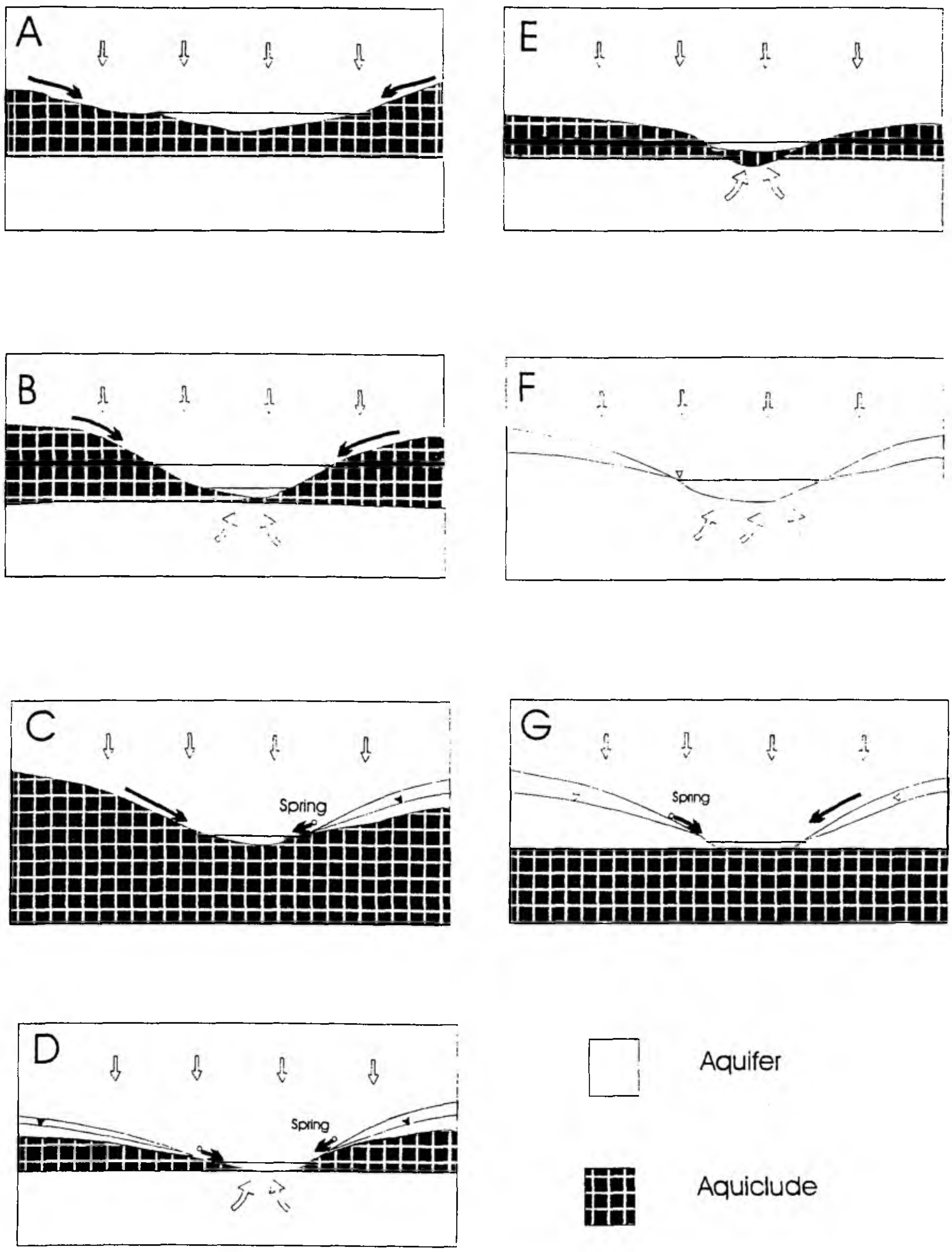


Figure A3.5 Hydrological classification of Lloyd *et al* (1993). (see Table A3.1). (Reproduced courtesy of Academic Press Ltd.)

A3.5 'Hydrologic-biogenetical' classification of German mires (M. Succow)

Succow & Lange (1984) and Succow (1988) have provided a clear classification of German mires, with particular reference to the NE German lowlands. Succow adopts an interesting two-layered approach. The first layer is a 'hydrologic-biogenetical', *i.e.* based upon the ontogeny of the mires and the nature of their water supply. The second layer identifies 'ecological mire types' and is superimposed on the first. The 'ecological mire types' are based on estimates of the nutrient content and base-status of the water supply. Succow's approach has the benefit of clarity, not least in separating present ecological conditions from the sources of mire water supply and development. Here we consider only these latter components of the classification.

The hydrologic-biogenetical component of Succow's scheme provides one of the most significant and valuable attempts to provide a typology of a wide range of mire types. The characteristics of the main types identified are discussed below, but it is important also to appreciate some overall features (and limitations) of this approach. The following notes have been derived from an assessment of the various published works and, particularly, from comments and explanations provided by M. Succow during a visit to a number of mire sites in NE Germany (June, 1994).

- it is a combined hydromorphological-genetic classification, which considers both the development of the mire and their (sometimes changing) water supply mechanisms.

- it is based on a wide comparison of a large number of mires; many peat cores have been taken (far more than has been the case in the UK) and the broad development patterns of many sites are quite well known.

- water supply mechanisms have not generally been measured but have been inferred from (a) visual evidence; (b) position of the mire in the landscape; (c) mire development and peat types; (d) present vegetation (at least, where the mire is not too modified).

- the basis of the classification is not entirely consistent. Most of the 'types' represent distinctive hydrologic-genetic types which may occur in combination to form entire mire sites. However, some 'types', in particular 'kettle-hole mires', represent distinctive landscape features rather than distinctive water-supply mechanisms.

- one reason for this apparent inconsistency is the composite nature of the 'types'. The classification has generated 'types' characterised by more than one feature, rather than treating the features as being independent of one another. This is doubtless because the features are *not* independent of one another, especially in the mires considered by Succow and his typology largely reflects the features that *do* occur rather than those which *could* occur. This has produced what seems to be a satisfactory classification of the mires of the German lowlands, as it has resulted in distinctive types defined by more than one feature. However, this also makes the classification less 'exportable', especially to situations where other combinations of features may occur.

Ancient lake mires
These refer to mires that have developed hydroserally across open water. Once the water has been occluded, completely, or in part, other mire types may sometimes develop over the

'ancient lake mire' surface and, in appropriate topographical situations, may 'bury' it quite deeply.

Transgression mires

These develop because of 'over-flooding' by rivers. Such mires (or parts of mires) are likely to have a strongly-fluctuating water level, especially when the river is the only real source of water. The possibility of water transmission from the river into the adjoining peatland (as opposed to over-flooding) does not seem to form part of this concept, perhaps because it is considered that low hydraulic conductivity's of the peat and alluvium may make this a negligible component of the water balance.

Swamp mires

This category seems to refer to topogenous wetland sites fed primarily by surface run-off. The variability of run-off input means that in wet periods the sites can be quite deeply flooded but that on other occasions they may become quite dry. Peat production (if it occurs at all) is therefore often dependent upon a series of wet years and net accumulation depends on a suitable balance between conditions favouring production *versus* those favouring decomposition. *Swamping mire* peat is typically thin and well humified. Historically, it has provided a basis upon which other mire types have been able to develop.

Kettle-Hole mires

These are distinctive mires developed in deep kettle-holes which are thought to be fed primarily by surface run-off but which nonetheless have a more stable water level than is found in *swamping mires*, possibly on account of basin morphology. Not all mires in kettle-holes are necessarily *kettle-hole mires* - some can be *swamping mires* and, indeed, some *kettle-hole mires* have developed from an early phase of *swamping mire*, presumably in consequence of local hydrological changes. *Kettle-hole mires* often develop as a form of *schwingmoor*, but this is not always the case - some show little evidence of any open water phase. They differ considerable in the amount of open water still present, which may be a function of rate of water inflow as well as of successional age. It is not really clear what actual hydrological features distinguish *kettle-hole mires* from *swamping mires* though it is possible that, in some cases at least, there may be some influence of groundwater in maintaining stability in the former. However, if such basins were strongly groundwater fed, they would then belong the category of *percolating mires*.

Spring mires

This term is used to refer to mires developed under the influence of strong, localised groundwater discharge. In some situations, such mires may form large domes formed from a mixture of peat, tufa and various other solids. Presumably the term is also applicable to lesser discharges where groundwater oozes out onto valley sides, without any development of a substantial cupola.

Percolating mires

This is a very important type of wetland, which may occur in a wide variety of situations ranging from small basins to very extensive riverine mires. The feature common to all of them is that surface conditions are kept wet as a consequence of lateral water movement from the margins across the mire expanse. The mire surface is characterised by a small, but significant, gradient. This, coupled with the position of the mire in relation to known marginal sources of groundwater discharge (springs) and the characteristics of the peat, seems to provide the basis for recognition of this mire type, which essentially seems to represent a *topogenous mire* fed by *soligenous water.* It is considered that such mires are fed by groundwater inputs along the margins of the mire which then flows through the upper, more permeable horizons of the (often quite deep) peat. Flow through lower horizons, or inputs from upwelling groundwater from the floor of the mire, seems to be discounted on the basis of the frequent low permeability of the deeper peats. However, there seems to be little direct evidence for this and it is far from clear if, in the larger examples at least, flow rates from the margins would be sufficient to maintain surface wet conditions. The possibility that 'hydrological windows' may provide important sources of groundwater discharge into the mire at points other than margins, requires further consideration.

Sloping mires
This category is used to contain wetlands developed on hillslopes that are fed primarily by surface run-off. In some situations such systems are prone to periodic drying and typically accumulate rather thin, well-humified, layers of peat. Sloping mires may form complexes with spring mires.

Raised bogs
The term raised bog refers to areas of ombrogenous peat. Mature raised bogs may have developed serally upon various preceding minerotrophic mire types and can cover large areas. However, much smaller, embryonic raised bogs also occur within various types of fen.

A3.5.1 Application to Britain

Although some aspects of Succow's 'hydrologic-biogenetical' classification seem to be based more on presumption than measurement, at least as far as its application to some individual sites is concerned, in general it is a thorough, logical and (mostly) consistent approach to the classification of mires, based on a great deal of site data (especially ontogenic studies). It is probably the most well thought-out classification that is likely to be applicable to at least some British sites and therefore demands very serious consideration. There are, however, some limits to the extent to which it can be exported to the British situation:

The frequency of certain combinations of site topographies, hydrological mechanisms and ontogenic processes may well be different in British wetlands than in the range of mires studied by Succow, leading to rather different emphases in a typology. However, in practice, this consideration has little importance because;

- very few stratigraphical data exist for most British wetlands and hence the ontogenesis of many sites (and possible pointers that peat stratigraphy may give to hydrological mechanisms) is generally unknown.

- hydrological mechanisms of individual wetland sites in Britain are often not known and the relative importance of certain mechanisms (*e.g.* surface run-off *versus* groundwater discharge) may be difficult to establish without detailed study. Moreover, such differences may sometimes be less significant, in broad ecological terms, than in the German lowlands. For examples, sites fed by surface run-off in the wetter regions of Scotland *may* have a water supply of comparable constancy to groundwater-fed mires of drier regions of England. And when, for example, the origin of both surface and ground water is from a limestone catchment, the two sources *may* be of comparable composition.

These constraints mean that it is both difficult and probably undesirable to try to apply Succow's classification directly and uncritically to British mires. However, it is important, where possible, to take full recognition of the concepts he has emphasised. These have therefore been built into the framework of the proposed typology of British wetlands, though very often with the caveat that adequate data may not be available for them to be applied rigorously.

A3.6 'Ecological' and 'Biological' classifications

Wetlands can, in principle, be classified by a wide variety of environmental variables and biological features. However, many 'general purpose' classifications are likely to focus upon environmental variables that show considerable variation within wetlands and which are considered to be important with regard to the wildlife that the wetlands support. As some environmental variables are strongly correlated with one another, there may be little need to consider all variables in a general purpose classification.

For example, Wheeler & Shaw (1995) have shown that much of the variation in floristic composition of British fens could be accounted for in terms of three main suites of environmental variables (Figures A3.6 and A3.7), *viz.* base-richness, nutrient-richness and water level.

In this study, the primary axis of floristic variation (derived from a Canonical Correspondence Analysis) was essentially associated with base-richness variation. pH, Ca, HCO_3 and electrical conductivity were all strongly positively correlated, whilst concentration of Al and Fe (which is partly, though not exclusively, regulated by pH) varied in the opposite direction along the same basic axis. Whilst the correlations amongst the variables that comprise this axis is by no means exact, for many general purposes the location of vegetation-types along this axis would be characterised adequately just by measurements of water or soil pH. The importance of this environmental gradient in relation to vegetation composition is not surprising, as wetland ecologists have long recognised base-richness as a primary determinant of the composition of mire vegetation, as reflected in the gradient of bog ➔ poor fen ➔ rich fen (*e.g.* Du Rietz, 1949; Sjörs, 1950a, b).

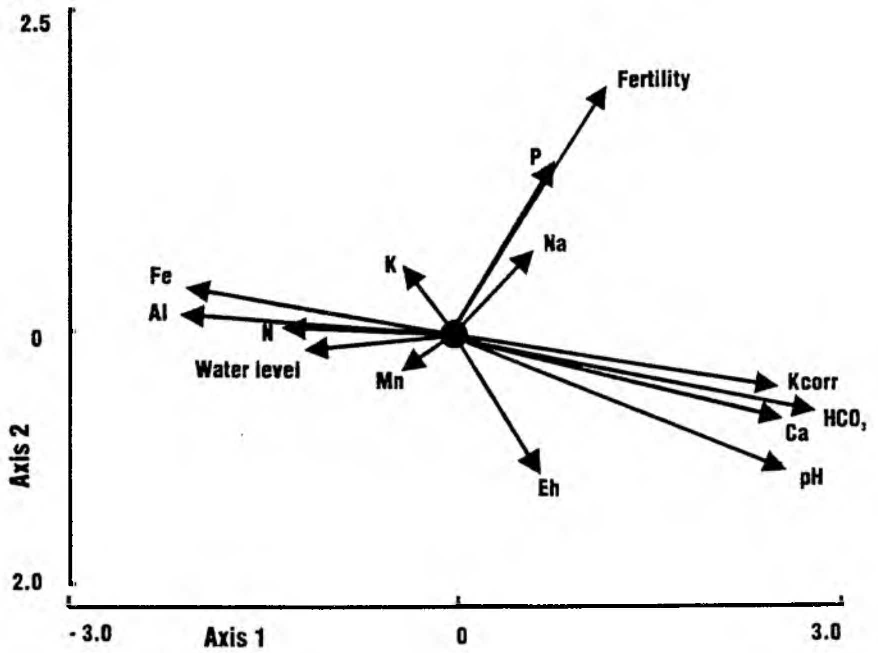


Figure A3.6 Axes 1 and 2 of a Canonical Correspondence Analysis ordination of floristic data and environmental variables in the vegetation of British fens.

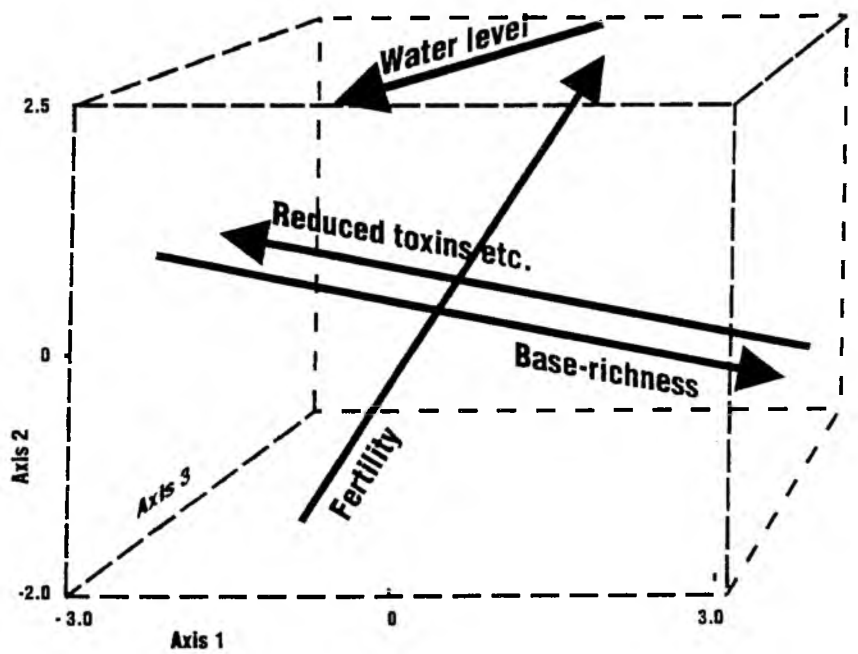


Figure A3.7 Main environmental gradients related to floristic composition of herbaceous vegetation in British fens. Schematic summary of gradients on axes 1,2 and 3 of a Canonical Correspondence Analysis ordination.

The second main axis of variation recognised by Wheeler & Shaw (1995) is related to the fertility[1] of the substratum. Two important points may be noted about the gradient of fertility:

(i) that of the chemical determinands, only P concentration was strongly correlated with phytometric fertility; and

(ii) the fertility gradient was almost orthogonal to the axis of base-richness. This latter point is important because in the past, ecologists have sometimes regarded pH as a measure of fertility, which it clearly is not. Fertility is, however, quite difficult to characterise. Simple measurements of N, P and K concentration do not provide an adequate estimate of fertility in wetland soils (Wheeler, Shaw & Cook, 1991). And whilst phytometric assays can be used for broad surveys (Wheeler & Shaw, 1987; Shaw & Wheeler, 1990) they do not have the simplicity of measurement of, say, pH. Nonetheless, the importance of fertility as a determinant of vegetation composition, means that it is a desirable component of wetland classifications (*e.g.* Succow & Jeshcke, 1986).

The third main axis recognised by Wheeler & Shaw (1995) was water level. The significance of water level in relation to species composition does, of course, depend strongly upon the range of wetness variation encompassed by a given study. When, as in the case of Wheeler & Shaw's study, attention is focused upon 'undrained' wetlands, it is not surprising that water level is not the primary determinant of variation in species composition. If a study was to encompass drained wetland sites as well, it seems likely that the water level would be of greater importance in accounting for variation in species composition. Water level is undoubtedly an important component of an environmental classification of wetlands, but it suffers from the limitation of considerable liability, which means that quite detailed time-series measurements may be needed to characterise adequately the 'typical' water regime of a given wetland site.

Wheeler & Shaw (1995) also indicate that management regimes can have a profound effect upon the character of wetland sites. Types of management and degree of site 'damage' can form important components of a wetland classification.

Sites can also be classified, at least in principle, on the basis of their species composition and vegetation. However, although both species and vegetation taxonomies exist for Britain, little attempt has yet been made to recognise wetland types (as opposed to vegetation types) based upon the species that occur within them, though it seems probable that sufficient survey data currently exist for an attempt to be made at such a classification.

In the present document, some proposals are made for possible environmental classifications of wetlands in Britain, based on available information (Chapter 3). However, the main thrust of this report is concerned with the development of a hydrotopographical classification and further development of environmental and biological classifications is not dealt with.

[1] 'fertility' was assessed phytometrically by growing seedlings of test species on soil samples in controlled conditions and was accompanied by measurement of extractable concentrations of N, P and K from soil samples, see Wheeler, Shaw & Cook (1991)