THE ENVIRONMENTAL PROJECT CONSULTING GROUP

EMER BOG AND BADDESLEY COMMON

Hydrological Desk Study

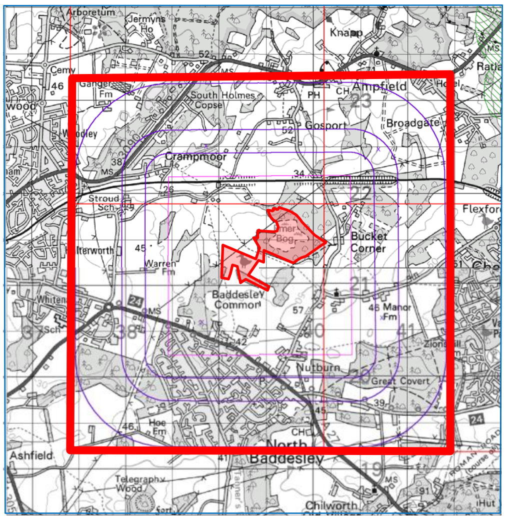


Figure 1. Project study area (red square) and showing boundary of Emer Bog and Baddesley Common (pink).

Prepared by Ron Allen for
Hampshire and Isle of Wight Wildlife Trust
And
Test Valley Borough Council

R H Allen BSc Hons Geol (Lond), ARSM, CBiol, CEnv, CSci, EurProBiol, MSB, MIEnvSc, MCIEEM **6 February 2017**
The Environmental Project Consulting Group
44A Winchester Road, Petersfield, Hampshire GU32 3PG
Tel: 01730 266966 Email: ra@epcg.co.uk
Webpages: www.epcg.co.uk, www.hydro-ecology.co.uk, www.soilandwater.co.uk

This page deliberately vacant.

EMER BOG AND BADDESLEY COMMON

Hydrological Desk Study

CONTENTS

This page deliberately vacant

NON-TECHNICAL SUMMARY

1.0 Introduction

1.1 This desk study uses extensive information from maps and data (variously sourced from the Ordnance Survey, Environment Agency, Geological Survey and many other organisations and including from previous surveys) to assess the hydrology of Emer Bog and Baddesley Common Special Area of Conservation and Site of Special Scientific Interest (<u>the site</u>). This information is then used to assess the implications of any land-use change or development proposals that could adversely affect their hydrological integrity.

2.0 Water sources and catchments

2.1 Open water, mire, swamp and other wetland habitats within Emer Bog and Baddesley Common depend on a variety of water sources that arise from a relatively small area of land (<u>the catchment</u>). The catchment comprises land that slopes down towards the site and is bounded by ridges of higher ground beyond which are adjoining catchments in which water flows in different directions away from Emer Bog and Baddesley Common.

2.2 Water reaches **Emer Bog** from both surface streams and groundwater arising from a relatively small area of land. There are several surface stream courses feeding Emer Bog, but many of these are only likely to flow following prolonged winter rainfall. Groundwater rises directly into the two peat basins that support Emer Bog and also emerges as springs and seepages on sloping land. These springs and seepages (that feed small watercourses that in turn feed into the open water and wetland habitats) flow in winter from sloping areas where groundwater saturated sandy strata (<u>aquifers</u>) occur at the land surface. Water that ultimately leaves Emer Bog flows north into a stream called the Tadburn Lake.

2.3 The adjacent grassland area of **Baddesley Common** is fed by a small stream and which in turn is fed by surface water shed off the surrounding land and which land has clayey soils. The clayey nature of the soils and their underlying geological strata means that the grasslands are dependent upon surface water arising from rainfall and stored in the soils for their wetness. Excess rain water, that cannot soak into the soil, flows overland into the stream course. Water leaving the Baddesley Common stream flows into a larger tributary stream that in turn flows into the **Tadburn Lake** stream.

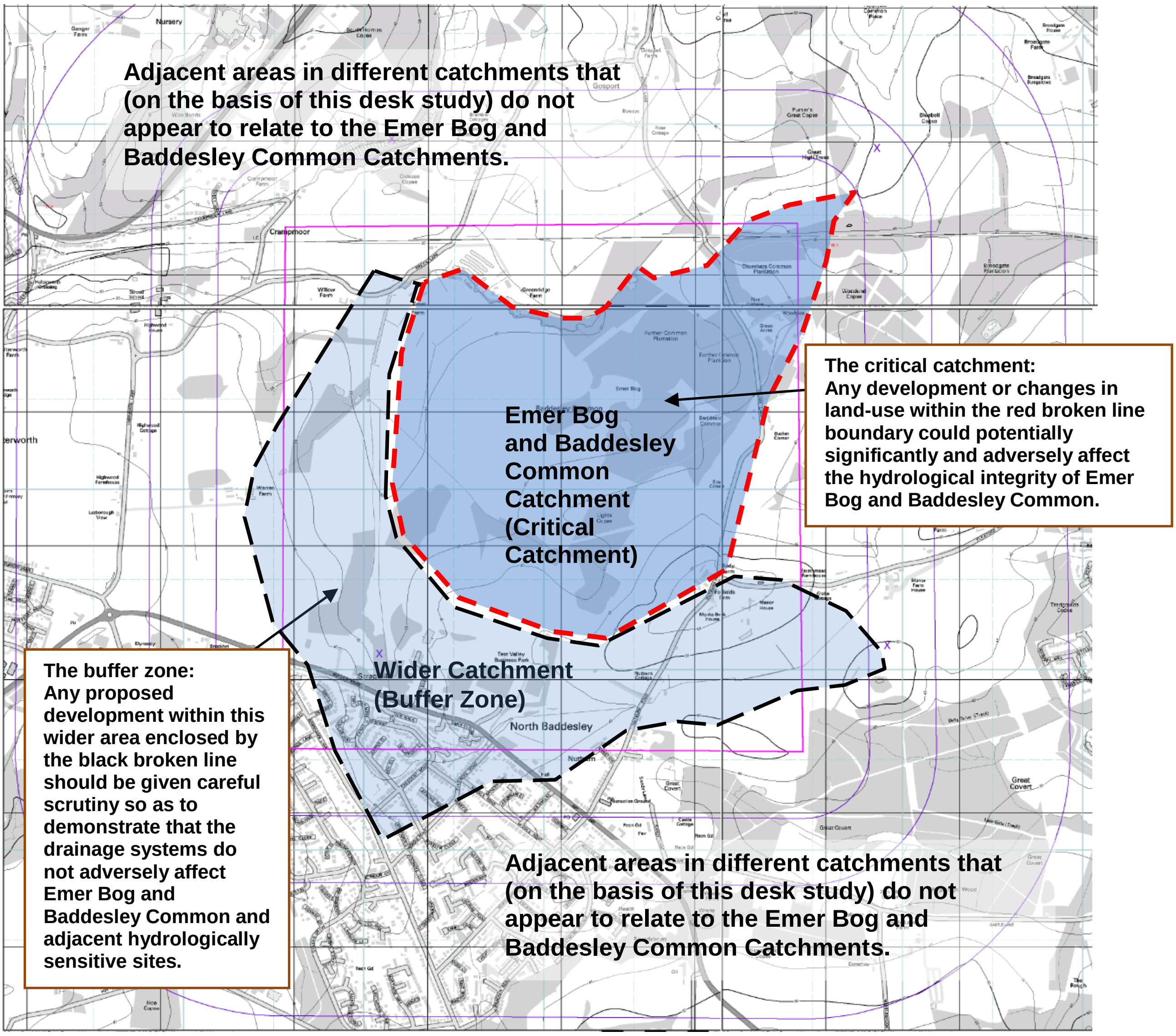
2.4 The Tadburn Lake stream is supported by a larger catchment (of which the catchments of Emer Bog and Baddesley Common are a significant part) and is itself bounded by other catchments that feed streams flowing away from the site.

3.0 Critical and Buffer Zone catchments

3.1 The area of land that directly supplies surface and ground water to the adjacent small catchments of Emer Bog and Baddesley Common is here referred to as the '**critical catchment**'. This is the darker blue area shown on **Summary Drawing A**.

3.2 An area of adjoining land to the south and west of the critical catchment feeds surface water into and along a southern tributary of the Tadburn Lake and while this area does not appear to be critical to supporting the surface water hydrology of Emer Bog and Baddesley Common, it is close to the critical area. It is also possible that this area could provide a source of groundwater to the critical catchment This area of land is shown in pale blue and identified as the '**Buffer Zone'** in **Summary Drawing A**.

3.3 Surrounding the Critical Catchment and Buffer Zone is a much wider area of land comprising the upper parts of a series of catchments that feed water away from Emer Bog and Baddesley Common. These catchments are shown in more detail in **Summary Drawing B** and comprise those of the remaining small part of the southern Tadburn Lake catchment, the Test Valley to the west, the Tanner's Brook to the south, and the two upper arms of the Monk's Brook to the east.

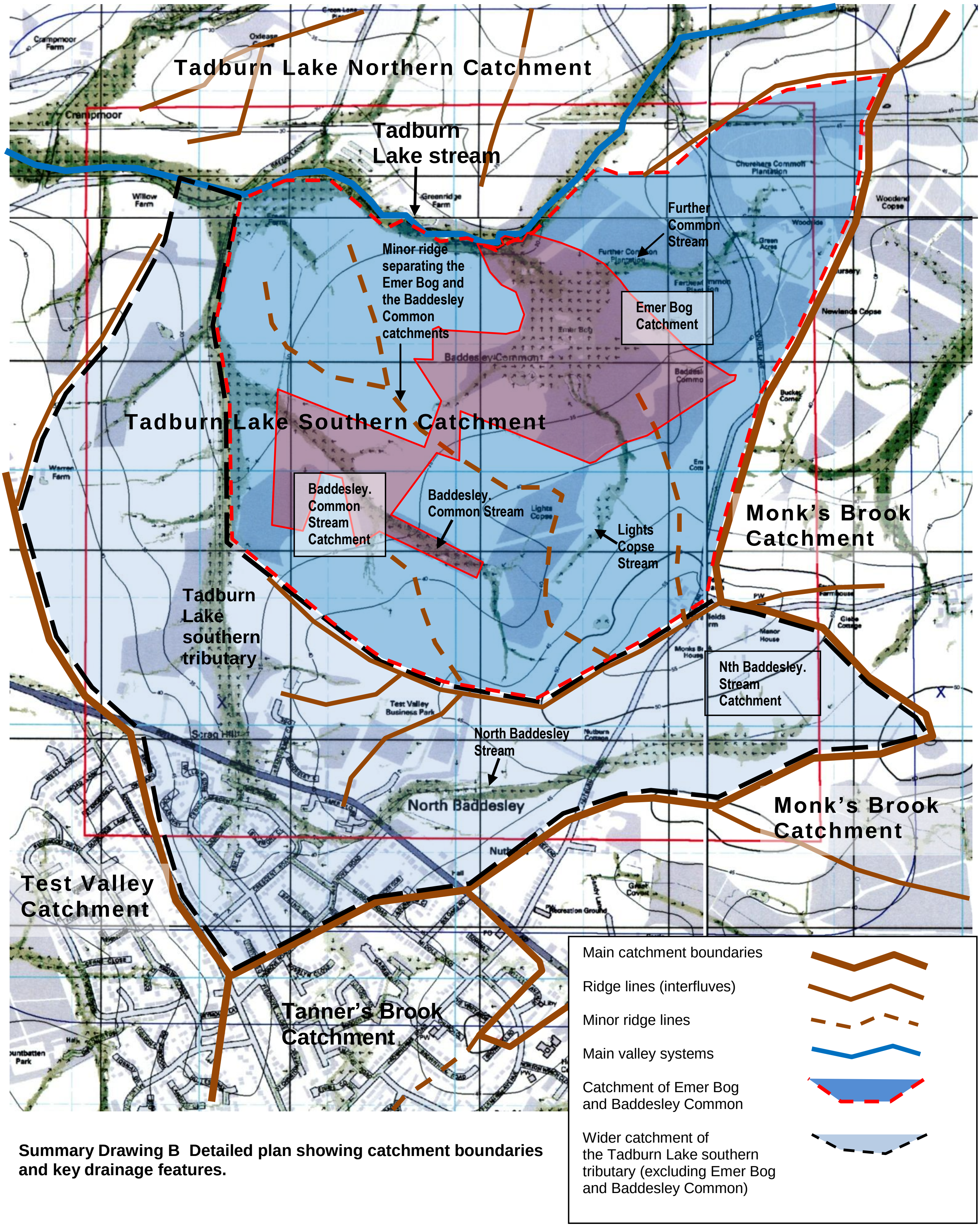


Summary Drawing A. The two surface water catchment groupings critical to understanding the hydrology of Emer Bog and Baddesley Common and the potential for adverse effects from built or other development. This drawing has been adapted and simplified from Summary Drawing B.

4.0 Water quality and fertility

4.1 The wetland habitats and their plant communities across the site depend upon low levels of plant nutrients in the ground and surface waters that support them. The peaty soils in the more sensitive open mire habitats in Emer Bog have been shown to be unusually highly fertile and this means that they will be very sensitive to increased levels of plant nutrients in their supporting waters.

4.2 Earlier studies have suggested that wetlands at Emer Bog vary greatly from those that are strongly acidic (lacking calcium) to those that are mildly alkaline (containing calcium). Also, that the surface waters and sediments are often rich in both phosphorus and nitrogen. Large amounts of these two nutrients can reduce the biodiversity of otherwise nutrient poor habitats. While the sources of the phosphorus and nitrogen remain unknown it is important that these levels do not rise, and preferably should lessen, if biodiversity is not to decline. Any land-use change or development (such as housing, commercial or industrial development, or even a golf course or change from permanent grassland to cultivation) has the potential to influence or exacerbate the nutrient input into the system.



Summary Drawing B Detailed plan showing catchment boundaries and key drainage features.

5.0 Monitoring

5.1 In order to further assess any changes in hydrology it is important to undertake monitoring and it is recommended that mapping of critical plant communities be undertaken and periodic water sampling be undertaken at key boundary and internal locations for determination of levels of phosphorus and various forms of nitrogen.

5.2 In addition, water level monitoring at key locations will provide critical information about just how wet and seasonal the wetlands are. Surface flooding can be measured directly and subsurface water levels can be determined from dipwells.

6.0 Climate Change

6.1 The Tier 1 wetland tool has been used to assess the probability of the impact of climate change. The Tier 1 tool does not provide a detailed prediction for a particular wetland. It provides a generalised regional indication of the potential likelihood and magnitude of climate change impacts on wetlands and is suitable for risk screening and investigating uncertainty.

6.2 On the basis of the Tier 1 assessment, the overall probability of climate change impact by the 2050s is Low. Low probability applies particularly to hydrological water level change and to most seasonal impacts on birds. High probability of impact relates most often to annual water balance, departure from plant water level requirements, and to some historic environment soil saturation periods.

6.3 The least impacted habitats are mire and swamp communities and the most impacted habitats are wet grassland and wet heath communities.

7.0 Conclusions[1]

7.1 Any development or changes in land-use[2] within the dark blue area bounded by the red broken line in **Summary Drawings A and B** (the 'critical catchment') could potentially significantly and very probably adversely affect the hydrological integrity of Emer Bog and Baddesley Common. This could be so even if sustainable drainage schemes (SUDS) are proposed. Any proposals for development or changes to drainage flows and drainage water chemistry in this critical area should either be avoided or receive particularly critical assessment. Such critical assessment would involve detailed monitoring of water flows and water chemistry in order to demonstrate lack of impact.

7.2 Any proposed development or land-use change within the pale blue area enclosed by the black broken line (the buffer zone) should be given careful scrutiny to ensure that arising drainage waters do not affect Emer Bog and Baddesley Common and adjacent hydrologically sensitive sites.

7.3 Adjacent land outside of the blue areas (ie. those outside of the red and black broken lines) falls variously into the catchments of the Monk's Brook, the Tanner's Brook and the Test Valley. These catchments support streams that flow away from Emer Bog and Baddesley Common and this means that drainage off developments here (on the evidence from this desk study) are unlikely to affect Emer Bog and Baddesley Common.

7.4 The potential for impact from climate change by 2050 is assessed overall as low. However, some specific features of the site could be affected by medium impact and in some instances there is potential for a high change. Avoidance of some of these higher impacts may require changes in management of parts of the site.

[1] On the basis of the desk study.
[2] Development refers to proposals such as for housing, commercial, or industrial development that can change the volume and chemistry of surface and ground water. Land-use change refers to (for instance) changes from low level grassland to high intensity arable agriculture, golf courses, fish farms and other changes affecting the way water flows across the catchment and its nutrient status.

1.0 PROJECT DATA AND BRIEF

1.1 PROJECT DATA

Joint clients:

Hampshire and Isle of Wight Wildlife Trust
Beechcroft House, Vicarage Lane, Curdridge, Hampshire SO32 2DP
Lead: Martin De Retuerto

Test Valley Borough Council
Planning Policy and Transport Service
Beech Hurst, Weyhill Road, Andover, Hampshire SP10 3AJ
Lead: Karen Eastley

Project Confirmation:

19 May 2016	Hampshire and Isle of Wight Wildlife Trust
10 June 2016	Test Valley Borough Council

Project start date:	27 June 2016
First draft submitted:	31 August 2016
Amended draft submitted:	4 November 2016
Amended draft submitted:	8 December 2016
Final draft report submitted:	1 February 2017
Final report submitted	6 February 2017

1.2 BRIEF

This is the brief as set out by the joint clients Hampshire and Isle of Wight Wildlife Trust and Test Valley Borough Council.

1 Introduction

The role of this study is to update the evidence base held in relation to hydrological matters linked to Emer Bog / Baddesley Common in North Baddesley. The study area is shown in **Figure 1**.

This study is jointly commissioned by Test Valley Borough Council (the Council) and the Hampshire and Isle of Wight Wildlife Trust (the Wildlife Trust). Natural England also forms part of a steering group with the two other organisations in relation to this designated site and may input into the production of the study.

The objectives of this study include:

a) The definition of the catchment of Emer Bog / Baddesley Common in terms of hydrological function and water quality / resource integrity;
b) Identification of the susceptibility to current and future changes in hydrology (including in relation to development in the catchment);
c) Identification of the spatial catchment on a map in order to define a buffer for Emer Bog / Baddesley Common which can be used to inform consideration of where proposals / changes could influence the hydrology of the designation;
d) Assessment of the potential impact of climate change on this designation (focusing on hydrological considerations) and how this might affect the application and consideration of the spatial buffer (referred to in point b).

Background information on Test Valley can be found at www.testvalley.gov.uk.

2 Context

Emer Bog / Baddesley Common, located to the north of the village of North Baddesley (within the Borough of Test Valley) is designated as a Special Area of Conservation (SAC) and a Site of Special Scientific Interest (SSSI). The majority of the designated site comprises a nature reserve managed by the Wildlife Trust[3].

The designation as a SAC[4] is as a result of the presence of transition mires and quaking bogs. On this basis, an understanding of the hydrology affecting this site is important to inform the management of the site and consider the potential implications of development proposals in the vicinity of the designation.

Two reports have previously been produced providing a hydro-ecological appraisal of this designation – they comprise:

- Hydro-Ecological Appraisal of Emer Bog cSAC, North Baddesley, Hampshire, The Environmental Project Consulting Group, 2002[5]; and
- Surface Water Quality and Hydro-Ecological Regime of Emer Bog cSAC, The Environmental Project Consulting Group, 2003[6]

It is intended to update the current understanding of the hydrology of Emer Bog / Baddesley Common in the context of previous work and more recent data sources to inform the understanding of the key organisations involved and to aid in the fulfilment of their duties in relation to this site.

3 Scope and Outputs of Project

The objectives of the hydrological study are as set out in section 1 of this brief of requirements.

In relation to the identification of a spatial catchment, it would be expected that previous studies on this matter should be reviewed, including the surface water discharge constraint map identified in the 2002 study referred to above. Consideration should also be given to how groundwater and water quality impacts (e.g. from consented activities, urban edge effects, etc) would be accounted for / addressed.

It would be beneficial to review the monitoring protocol identified in the 2003 study. This should inform the establishment of an initial draft protocol for the Wildlife Trust to undertake within its nature reserve in relation to water and nutrients. The study should consider whether phosphorus and nitrogen can be attributed to external activities and the pathway (e.g. surface water, groundwater), whether this can be monitored and the implications for the pH values.

As part of the review of the site to sensitivities to surface water and groundwater change, consideration should be given to a 2km catchment (from a centre point in Emer Bog / Baddesley Common).

In considering susceptibility to climate change, a tier 1 assessment using the CEH Wetland Tool should be undertaken.

[3] See http://www.hiwwt.org.uk/reserves/emer-bog-and-baddesley-common.
[4] SAC EU Code: UK0030147
[5] Available at: http://www.testvalley.gov.uk/assets/files/302/DeskStudyHydroEcologicalAppraisalOfEmerBog.pdf
[6] Available at: http://www.testvalley.gov.uk/assets/files/303/ReviewOfConsents-SurfaceWaterQualityEmerBogSAC.pdf

1.3 Layout of this report

Within this report:

Non-technical summary
provides a brief plain English summary of the project's main conclusions.

Sections 1 – 4 set out the brief, scope of the project and a summary of the report's content and conclusions and includes a glossary of the main technical terms used in the report.

Sections 5 – 8 provide the base line data on which the general conclusions of the report are derived and includes sections on location, hydrology, geology and soils.

Sections 9 – 12 use the base line data to evaluate the hydrology and hydrogeology of the site's characteristics and catchments.

Section 13 assesses the potential susceptibility to climate change.

Section 14 discusses each of the outputs required by the project brief.

2.0 SUMMARY OF RESULTS

This summary

2.1 This study presents the results of detailed desk study of available hydrological and drainage sources including those from the Environment Agency, other sources and also from previous reports in 2002 and 2003; the 2003 report providing the results of a detailed field investigation of Emer Bog.

2.2 This summary provides a concise plain English description of the catchment characteristics of Emer Bog and Baddesley Common and the potential of different areas to have adverse effects given development or land-use change.

Catchments

2.3 Water sources to Emer Bog and Baddesley Common SAC and SSSI (**the site**) are located within a relatively small area and within catchments that remain undeveloped with mainly low-grade grassland and woodland and only very small arable headwater sources.

2.4 There are two adjacent surface water catchments supplying Emer Bog and Baddesley Common respectively. Both catchments are relatively small and together form part of the southern catchment of the Tadburn Lake stream to the north of the site.

2.5 The Tadburn Lake southern catchment (which contains the site's catchments) is defined by a series of topographic ridges (interfluves) that separate it from the Test Valley Catchment to the west, the Tanner's Brook Catchment to the south and the Monk's Brook Catchment to the east. The Tadburn Lake stream to the north is taken as the northern boundary of the catchment.

Emer Bog

2.6 Emer Bog is situated within a bowl shaped landscape feature open to the north and served by a small catchment with four seasonal flow-ways arising off the surrounding land; the flow-way from the south being the most important.

2.7 Emer Bog contains a southern wooded upper and a northern lower open peat basin. The upper peat basin is fed by springs from off sandy strata on higher land and a small stream. The lower peat basin is fed partly by stream flow and partly by groundwater perched on the underlying clayey substrata.

2.8 Water exits the system mainly by a small stream in the north flowing into the Tadburn Lake stream with a smaller seasonal flow exiting to the northeast. Some of the inflowing waters are intercepted by two open lakes.

2.9 Previous studies have shown that the various seasonal flow-ways within the Emer Bog sub-catchment do not necessarily flow directly into Emer Bog, but rather that the flows are intercepted by a series of boundary drains that redirect water around and into the site.

Baddesley Common

2.10 The Common in contrast, is on more level land and contains a small stream fed by four minor flow-ways within a small catchment to the southwest of the adjacent Emer Bog catchment.

2.11 The Common is underlain by clayey slowly permeable substrates and water is derived from seasonal surface flows off land to either side of the stream.

2.12 The Baddesley Common stream flows northwest into a small north-flowing tributary of the Tadburn Lake stream. This Tadburn Lake southern tributary arises in a separate catchment to the south of the site and passes through the urban area of North Baddesley.

Water in this system bypasses the Emer Bog and Baddesley Common catchments and appears not to contribute to the site.

Geology and soils

2.13 Geological maps and borehole records indicate that the site and surrounding land is underlain by the Wittering Formation and which comprises mainly clays and sandy clays but with variable seams of fine sand. Rising land in the south of Emer Bog has more sandy strata. The wetlands at Emer Bog are developed over a southern and northern area of deep peat which overlies the Wittering Formation. Baddesley Common is on more level land over Wittering Formation with a thin strip of overlying alluvium along a narrow stream floodplain.

2.14 At the surface, the Wittering Formation gives rise to generally clay-rich slowly permeable soils with seasonal surface waterlogging. When saturated, these soils can flood and pass surface water along small valleys (flow-ways) towards the streams and peat basins.

Hydrology and Hydrogeology

2.15 The Wittering Formation is a secondary aquifer supporting predominantly lower permeability layers which stores and yields limited amounts of groundwater due to thin permeable horizons. It is these limited amounts of groundwater that source the wetlands in Emer Bog. The nearest principle aquifer is the Chalk, but this underlies the Wittering Formation (and other deposits) at considerable depth and is separated by clayey strata that prevent upward transmission of water into the site.

2.16 At the detailed level, the hydrology and hydro-geology of the site is dependent on topography. In the southern higher part of Emer Bog, seams of sandier strata (within the more clayey deposits) slowly transmit small amounts water that generate springs and seepages sourcing the wet woodlands of the upper peat basin. This water passes generally down slope to the lower peat basin where it builds up over the Wittering Formation clays as a perched water table sourcing the mire vegetation.

2.17 Excess water, that cannot be contained within the soils and peat deposits, feeds northwards as mainly seasonal surface water flows towards the Tadburn Lake stream.

Fertility

2.18 The open mire in the lower peat basin at Emer Bog has been shown to be highly fertile in that the peaty soils are capable of supporting high rates of growth in the laboratory. This high level of fertility is unusual in the types of habitats on the site. The reason for this fertility remains unknown.

Water chemistry

2.19 Earlier studies have suggested that wetlands at Emer Bog vary greatly from those that are strongly acidic to those that are mildly alkaline. Also, that the surface waters are often rich in both phosphorus and nitrogen. While the sources of the phosphorus and nitrogen remain unknown, they may be sourced from the feeder streams or, could be generated from within the wetlands themselves.

Climate change

2.20 A Tier 1 assessment (of the Centre for Ecology and Hydrology's Wetland Tool) has been undertaken to assess the potential impacts of climate change in the 2050s over a range of hydrological, vegetation and bird scenarios[7].

[7] It is important to note that The Tier 1 tool does not provide a detailed prediction for a particular wetland. It provides a generalised regional indication of the potential likelihood and magnitude of climate change impacts on wetlands by 2050 and is suitable for risk screening and investigating uncertainty.

2.21 The factors used in the Tier 1 assessment do not fit well with the hydrology and vegetation at Emer Bog and Baddesley Common and so I have made judgements as to the best fit situation.

2.22 Overall, the hydrological risk from climate change by the 2050s is assessed as Low but in some particular cases the risk rises through Medium to High.

2.23 On the basis of the Tier 1 assessment, the overall probability of climate change impact on the wetland habitats at Emer Bog and Baddesley Common by the 2050s is Low. Low probability applies particularly to hydrological water level change and to most seasonal impacts on birds. High probability of impact relates most often to annual water balance, departure from plant water level requirements, and to some historic environment soil saturation periods.

2.24 The least impacted habitats are mire and swamp communities. The most impacted habitats are wet grassland and wet heath communities.

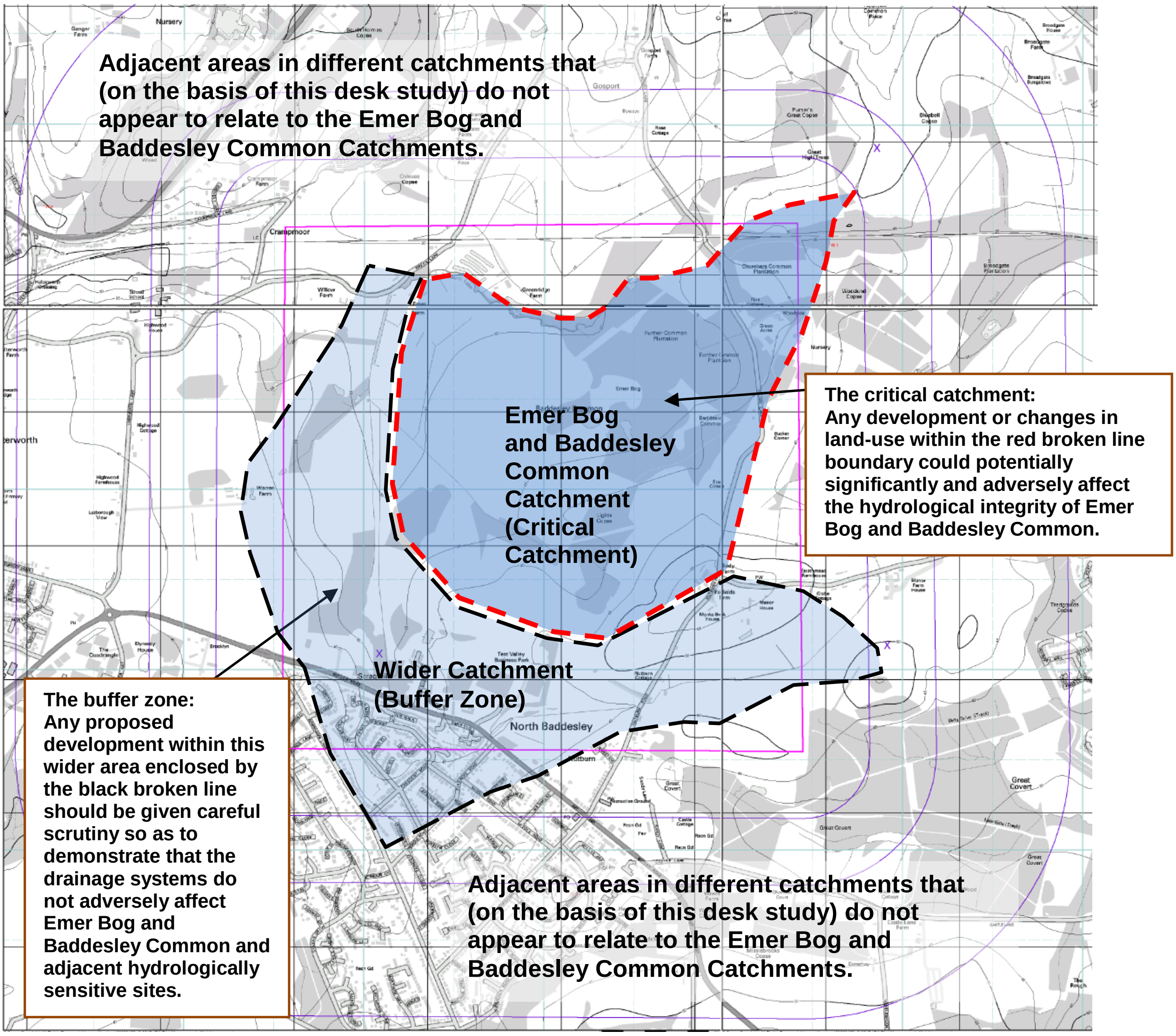
Monitoring

2.25 In order to further assess any changes in hydrology it is important to undertake monitoring and it is recommended that mapping of critical plant communities be undertaken and periodic water sampling be undertaken at key boundary and internal locations for determination of levels of phosphorus and various forms of nitrogen.

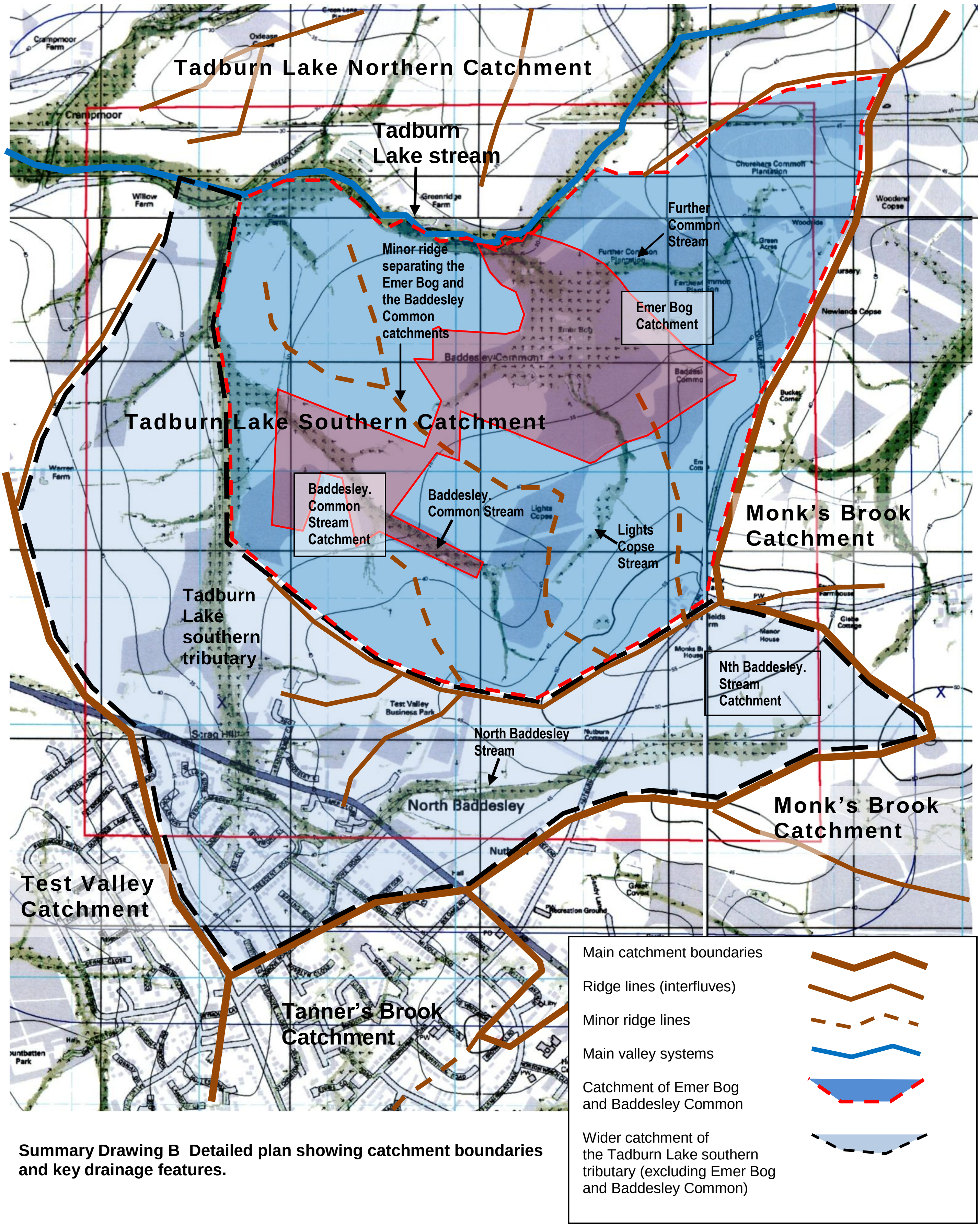
2.26 In addition, water level monitoring at key locations will provide critical information about just how wet and seasonal the wetlands are. Surface flooding can be measured directly and subsurface water levels can be determined from dipwells.

General conclusions

2.27 The surface water and groundwater catchments supplying Emer Bog and Baddesley Common are relatively small and form only a part of the much larger southern catchment supplying the Tadburn Lake Stream. The following **Summary Drawing A** illustrates the two key surface water catchment zones.



Summary Drawing A. The two surface water catchment groupings critical to understanding the hydrology of Emer Bog and Baddesley Common and the potential for adverse effects from built or other development. This drawing has been adapted and simplified from Summary Drawing B.



Summary Drawing B Detailed plan showing catchment boundaries and key drainage features.

2.28 Other surface water sources within or around the Tadburn Lake southern catchment (excluding Emer Bog and Baddesley Common) appear to bypass the site and either flow directly towards the Tadburn Lake stream or are directed towards external catchments flowing towards the Test or Itchen valleys and not towards the site. These are the pale blue and white areas on the **Summary Drawings A and B**.

2.29 The key catchments supporting the site are very vulnerable to changes in land use such as changes in agricultural systems or to built development. However, the critical surface water catchments (shown in dark blue on the **Summary Drawing**) are small and flows in the surrounding catchments appear to be directed away from the site.

2.30 Monitoring of water chemistry and water depth will provide critical information on the hydrology of the site and indicate how water chemistry and depth changes over time either naturally or because of external water sources.

On the basis of this study it is concluded that:

2.31 Any development or changes in land-use within the dark blue red broken line boundary (the critical zone) could potentially significantly and very probably adversely affect the hydrological integrity of Emer Bog and Baddesley Common. This could be so even if sustainable drainage schemes (SUDS) are proposed. Any proposals for development or changes to drainage flows and drainage water chemistry in this area should either be avoided or receive particularly critical assessment. Such critical assessment would involve detailed monitoring of water flows and water chemistry in order to demonstrate lack of impact.

2.32 Any proposed development within the pale blue area enclosed by the black broken line (the buffer zone) should be given careful scrutiny to ensure that arising drainage waters do not affect Emer Bog and Baddesley Common and adjacent hydrologically sensitive sites.

2.33 Adjacent land outside of the blue areas (ie. those outside of the red and black broken lines) falls variously into the catchments of the Monk’s Brook, the Tanner’s Brook and the Test Valley. These catchments support streams that flow away from Emer Bog and Baddesley Common and this means that (on the basis of this desk study) drainage off developments here would be unlikely to affect Emer Bog and Baddesley Common. However, development drainage systems in close vicinity to the boundaries of the critical catchment and buffer zone must demonstrate that the drainage systems do not affect Emer Bog and Baddesley Common and adjacent hydrologically sensitive sites.

3.0 GLOSSARY

This section provides concise definitions of the more technical terms used in this report.

The definitions provided are given in the context of their use within this report.

Aquiclude: A slowly permeable or impermeable subsurface geological layer that prevents the flow of groundwater.

Aquifer: A permeable subsurface geological layer through within which groundwater can accumulate and through which groundwater can flow. Principle (or major) aquifers store and transmit large amounts of water. Secondary (or minor) aquifers store and transmit only small quantities of water.

Bedrock deposits: Geological strata that were laid down prior to the Ice Ages. These strata are sometimes called 'solid' strata. They may be soft and unconsolidated (such as loose sand) or hard and rocky (such as sandstone).

BGS Lexicon: A portion of the British Geological Survey's website that describes the characteristics of named geological strata.

Borehole: A deep drilling into the earth undertaken to assess the character of the geology and water sources at the borehole location.

Catchment: The area of land into which water flows from within the surrounding interfluves (topographic ridges and higher land).

Culvert: A pipe laid below ground, usually below a track or garden (or sometimes below built development), through which drainage water can flow.

Development: In the context of this report, development implies housing, commercial and industrial construction projects and their related infrastructure and any other built project that requires areas of hard surfaces and likely to give rise variously to altered surface flows, altered groundwater flows and altered water chemistry (each of which can significantly affect wetland wildlife habitats).

Ditch: A shallow man-made watercourse along which water may flow, at least seasonally.

Drainage ditch: A man-made watercourse dug into the ground and designed to take water off surrounding land and allow drainage water to flow along it.

Envirocheck: A commercial source of environmental data provided by the Landmark Information Group Ltd.

Flow-way: A small valley system along which surface water flows, either permanently, seasonally, or from time to time according to extreme weather conditions.

Geology: The study of the soft and hard deposits that form the Earth including bedrock and superficial deposits, their origins and modes of development.

Groundwater: Water held within permeable subsurface strata and which can flow according to the arrangement of strata and surface landform.

Head: Superficial geological material that has accumulated on the surface of the ground following downward movement of materials during melting periods at the end of the ice ages.

Hydrogeology: The study of how water moves within the ground.

Hydrology: The study of how water moves over the ground surface such as by surface flow, and along streams and rivers.

Interfluve: The summit of a ridge or row of hills that separate the direction of flow of surface water. Sometimes called the 'watershed'.

Landform: A particular feature of the landscape such as a hill or valley.

Land-use change: In the context of this report, land-use change refers to any change that affects the way water flows across the land either in terms of flow rate, altered flow-ways, or water chemistry. Examples would be changes in agricultural land management (such as conversion of permanent grassland to ley-grassland or arable cultivation requiring fertilisers) or golf course developments (which require land remodelling, irrigation and fertilising).

Lithology: a description of the character of a geological material such as sand, clay or chalk for example.

Low-way: A small valley or minor linear depression in the landscape that may or may not contain a watercourse. Differs from a flow-way in that a flow-way will provide a route for water flow, either overland or through a minor stream channel or drain.

M5: The symbol for the *Carex rostrata – Sphagnum squarrosum* Mire as defined by the National Vegetation Classification, and which requires mildly acidic and rather nutrient poor waters. The M5 community is only found in a small area of the site.[8]

Perched groundwater: Groundwater held within permeable strata but held up above a less permeable (often clayey) layer.

Poorly drained soil: Soils that are affected by either high groundwater if permeable or by surface water if slowly permeable.

S27: The symbol for the *Carex rostrata - Potentilla palustris* tall-herb fen plant community as defined by the National Vegetation Classification[9], and which occurs on peaty soils with a surface or water pH between 5 and 7, a water table at or just below the surface, and sufficient base-rich and calcareous to prevent the formation of Sphagnum carpets found in the M5 community. This community occurs in the area of open fen on Emer Bog.

Saturation: The state of the ground when all the pores and voids within the ground are filled with water.

Seepage: The location where water seeps slowly out of the ground creating a zone of saturated soil, usually over an area of land rather than from a point source.

Soil: That material formed at the surface of the Earth from alteration of the underlying bedrock or superficial deposits (the substrate) by a variety of processes including (amongst others) water movement, chemical leaching and accumulation of organic matter.

Spring: The location where water emerges (issues) out of the ground, usually at a point location where the groundwater table intercepts sloping land.

Stream (in the lowlands): A usually man modified natural watercourse along which water can flow.

Sub-catchment: a small subdivision of a larger catchment identifying the area within which surface water flows are derived to specific parts of a catchment.

Superficial deposits: Geological strata laid down during or since the Ice Ages and which overlie bedrock strata and are usually loose (unconsolidated) or only lightly compacted.

Sustainable drainage system (SUDS); A system of artificial drainage that attempts to replicate natural drainage systems and usually incorporating various methods in which water is retained and only let out slowly and so as to avoid downstream flooding.

Syncline: a downfold of geological strata as opposed to an anticline that is an upfold of strata.

Topography: The arrangement of landforms to form a landscape.

---

[8] For more information see British Plant Communities Volume 4 Aquatic communities, swamps and tall-herb fens. J S Rodwell (editor), Cambridge University Press 1995.

[9] For more information see British Plant Communities Volume 2 Mires and Heaths. J S Rodwell (editor), Cambridge University Press 1991.

Tributary: A smaller stream that flows towards a larger stream.

Water table: The surface level of groundwater.

Well-drained soil: A permeable soil not affected by ground or surface water.

4.0 INTRODUCTION AND SCOPE, APPROACH, AND LIMITATIONS

INTRODUCTION AND SCOPE

4.1 This hydrological study provides baseline information about the surface and subsurface catchment of Emer Bog and Baddesley Common and also places that catchment in the context of the wider area extending to a radius of 2km from site centre.

4.2 The baseline information is then interpreted to: identify how the reserve may be susceptible to current and future changes in hydrology and water quality (such as might arise through land development); identify the spatial catchment on a map in order to define a protective buffer to the two sites; and to assess the potential impact of climate change and how this might affect land development in the vicinity of the reserve or any protective buffer area.

4.3 In addition to: consider a monitoring protocol that the Trust can undertake on the reserve and also the extent to which phosphorus and nitrogen might be attributed to external activities and the potential surface water and/or ground water pathways and the implication for pH values.

APPROACH

4.4 In undertaking this study, the approach includes:

1. A review of site sensitivities to surface and groundwater hydrological change based on previous reports;
2. A data search within an area of 2km radius from the centre point of the combined Emer Bog and Baddesley Common site (Based on an 'Envirocheck'[10] search) to include information from detailed 1:10,000 and 1:25,000 scale Ordnance Survey mapping, site sensitivities and sensitive land-uses, boreholes, flood screening data, river networks, flood risk data, geological mapping, and groundwater vulnerability and aquifer information; and
3. A Tier 1 assessment from the Centre for Ecology and Hydrology's Wetland Tool.

LIMITATIONS

4.5 The study has been limited to undertaking a desk study and drawing conclusions from that study. The desk study has taken into account previous reports on the hydrology of the two adjacent sites and a detailed appraisal of information from an 'Envirocheck' data search to include information on site sensitivity, geology, hydrology, boreholes, flood screening, groundwater vulnerability and other relevant information as available.

4.6 No site visits have been undertaken for this study, although a review of previous studies provides some site investigation information.

[10] A service of the Landmark Information Group Ltd

5.0 LOCATION OF THE STUDY AREA

2KM RADIUS STUDY AREA

5.1 **Figure 2** illustrates the total study area. The red line indicates the Envirocheck 2km search area and which extends from the east of Romsey eastwards to west of Chandler's Ford and from North Baddesley in the south to Ampfield in the north.

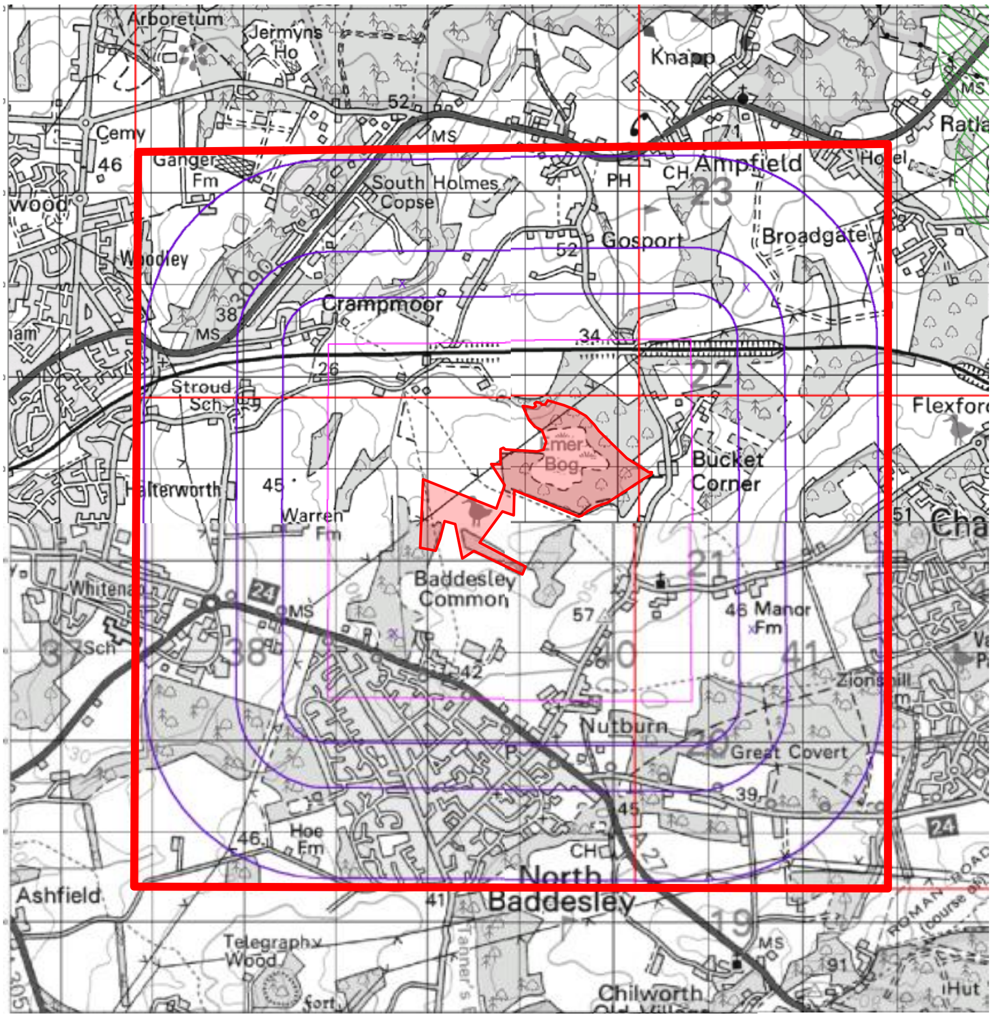


Fig. 2 Project study area. The outer purple line shows the 2km radius search area (enhanced by the red square). Emer Bog and Baddesley Common shown by outline and pale red tone.

BOUNDARY OF EMER BOG AND BADDESLEY COMMON

5.2 **Figure 3** shows the boundaries of Emer Bog SAC and Baddesley Common SSSI (taken from the MAgiC website[11]) and which sites are, for the most part, contiguous.

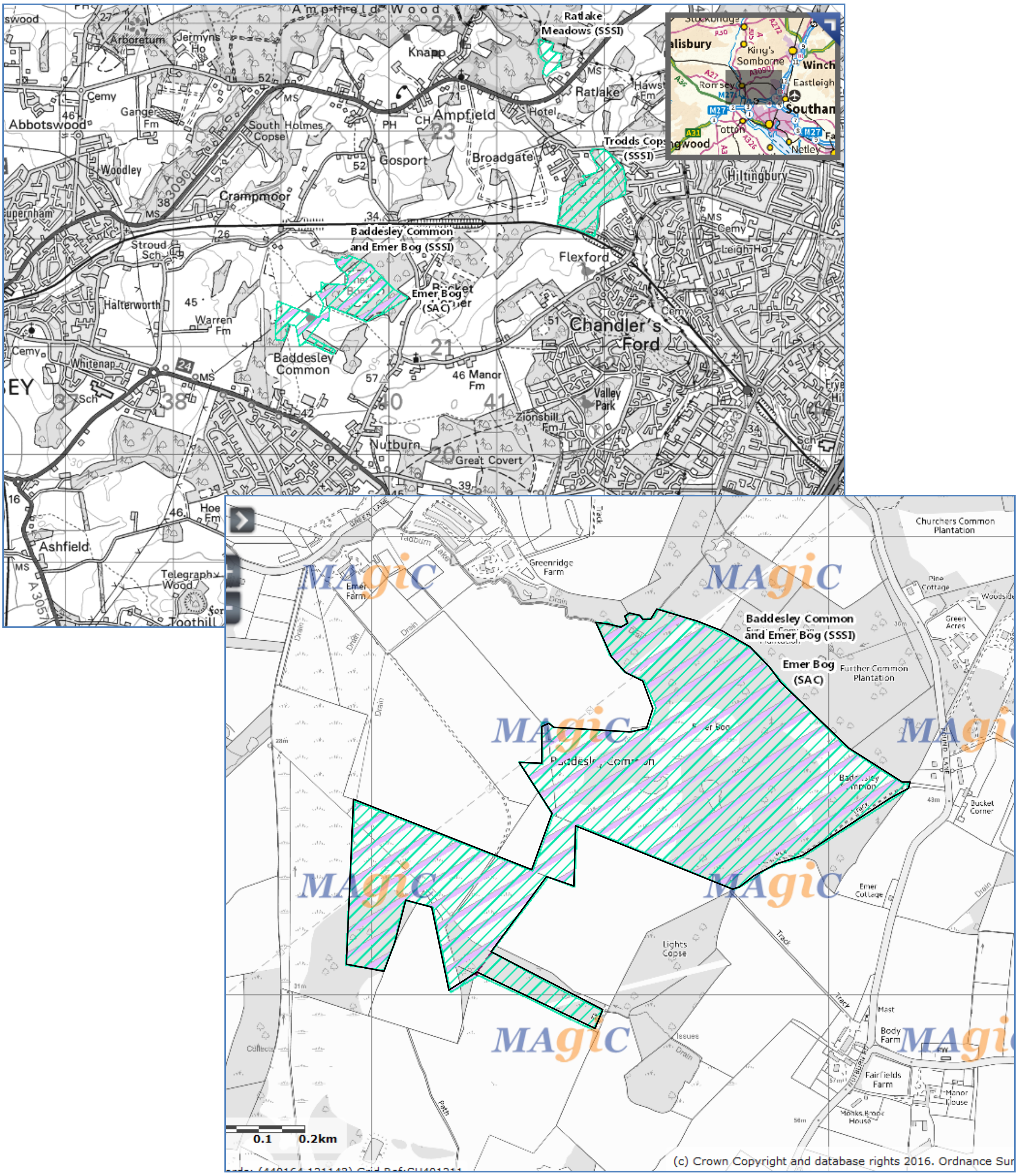


Fig. 3 Boundary of Emer Bog SAC (mauve stripes) and Baddesley Common SSSI (green hatching) taken from MAgiC website.

11 http://magic.defra.gov.uk/magicmap.aspx?startTopic=magicall&chosenLayers=sacIndex&sqgridref=SU394214&startscale=30000

6.0 HYDROLOGY

LANDFORM, WATERCOURSES AND CATCHMENTS

Contour line source and study area plans

6.1 Assessment of landform is critical to hydrological investigation. This involves assessing contours and slope directions from topographic maps and requires good topographic information.

6.2 A 1:10,000 scale Ordnance Survey map has been obtained (as part of the Envirocheck data search) for a 2km radius area round Emer Bog and Baddesley Common and which provides 5m contours (**Figure 4**).

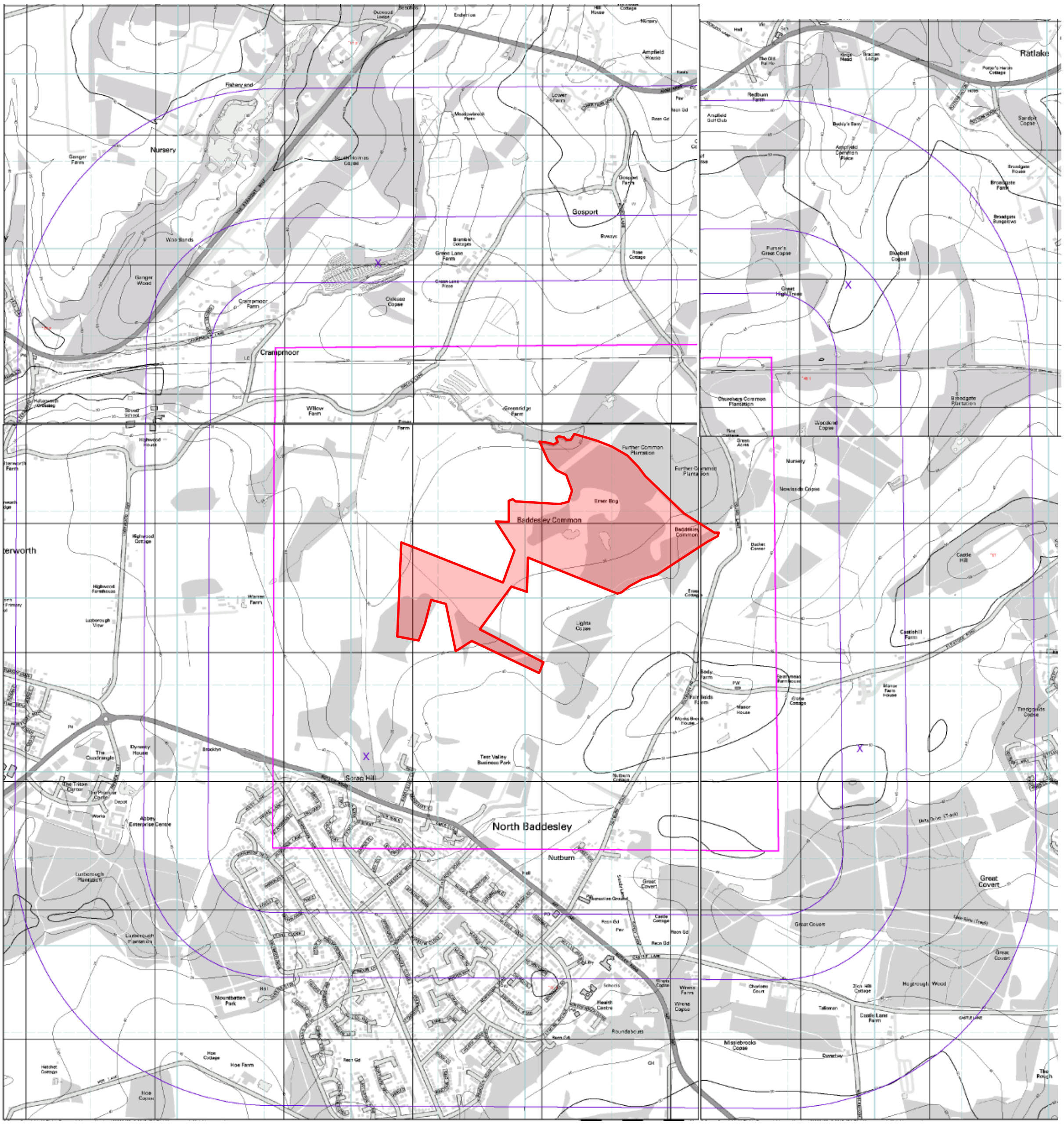


Fig. 4 1:10,000 scale Ordnance Survey Plan (From Envirocheck Flood Data report).

Regional Drainage System

6.3 **Figure 5** is taken from the Environment Agency website[12] and annotated to show the context of the study area in relation to the regional stream system of which the study area forms a part.

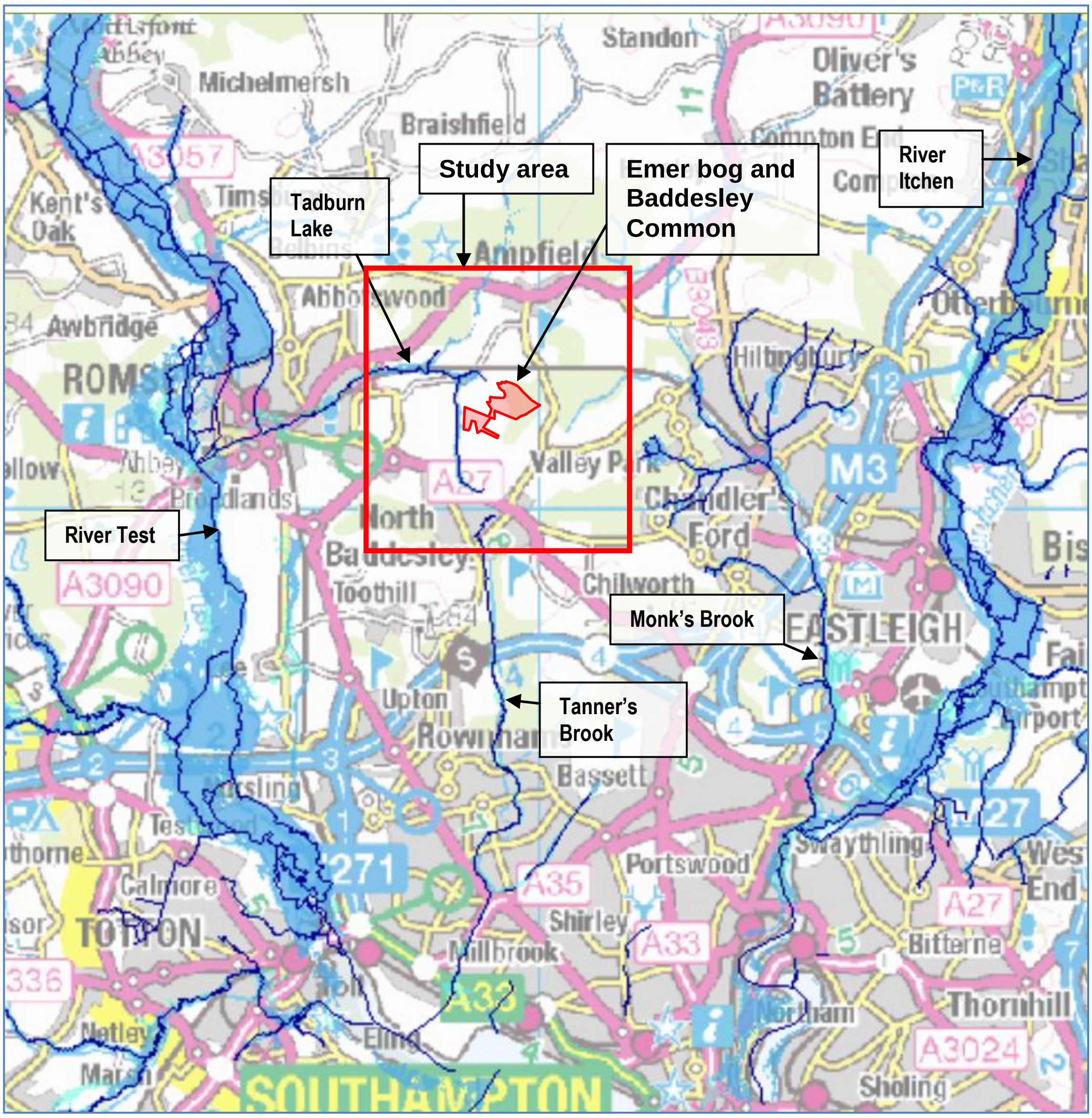


Fig. 5 Study area and Emer Bog / Baddesley Common in relation to the regional drainage system. Adapted from Environment Agency website.

[12] http://maps.environment-agency.gov.uk/wiyby/wiybyController?lang=_e&topic=floodmap&layer=default&ep=map&layerGroups=default&scale=6&x=440381&y=119066

INTERFLUVES, VALLEY SYSTEMS AND SURFACE WATER CATCHMENTS

6.4 **Figure 6** (based on the 1:10,000 scale Ordnance Survey Map), shows the main and minor interfluves and intervening valley systems affecting surface drainage in the study area.

6.5 Thick solid brown lines (interfluves) run between all of the higher points on the hills and along higher ridges and define the main catchment areas. Thinner brown lines indicate sub-catchment boundaries. Broken brown lines indicate minor ridges extending off the interfluves and separating minor valleys. Solid blue lines indicate the main valley bottom alignments and broken lines indicate minor tributary valley systems.

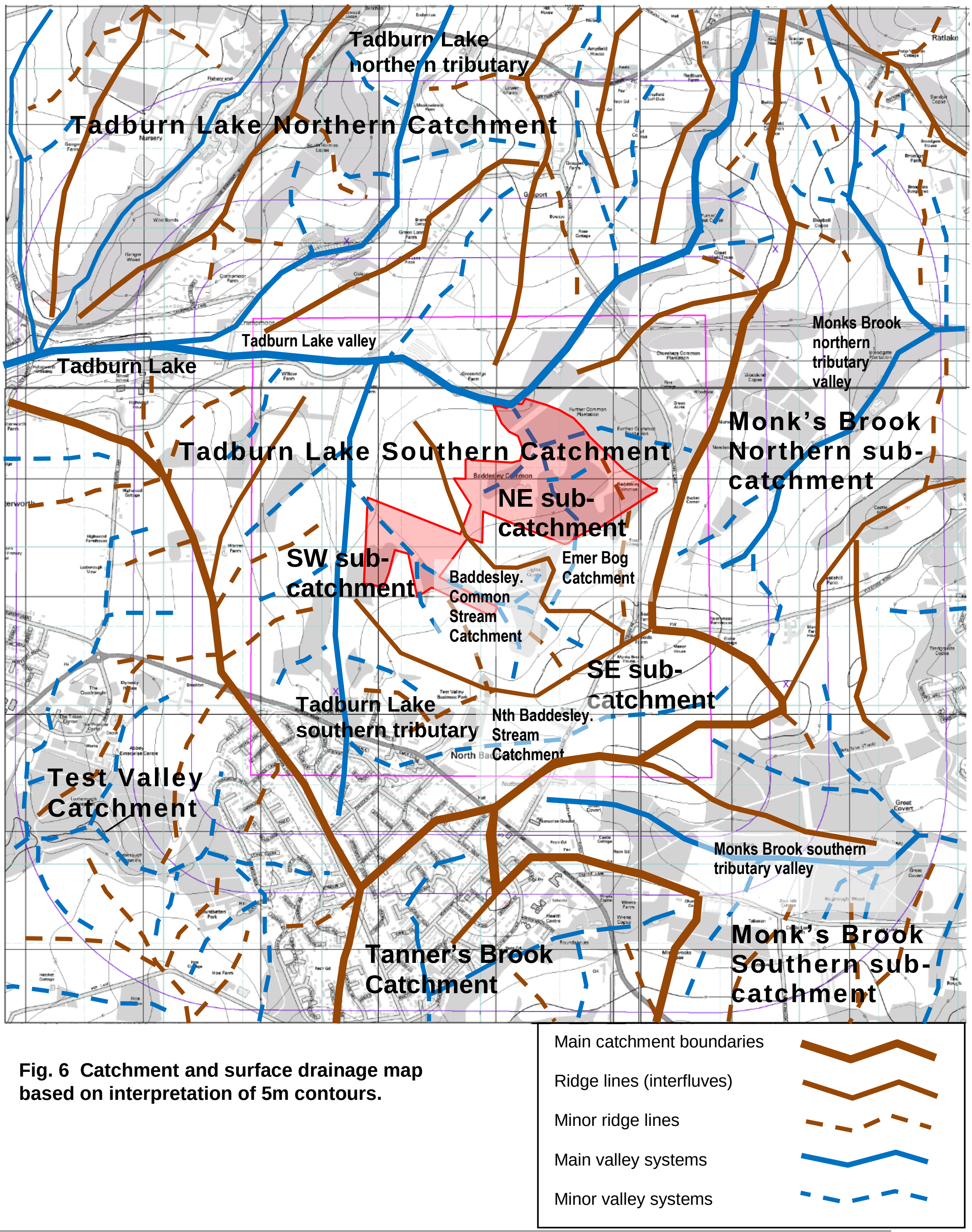


Fig. 6 Catchment and surface drainage map based on interpretation of 5m contours.

6.6 The gently undulating topography of the study area makes for a complex system of five main surface water catchments and many sub-catchments.

6.7 The thickest brown lines on **Figure 6** indicate the extent of the five different main catchments included within the study area:

1. Tadburn Lake catchment northern part
2. Tadburn Lake catchment southern part
3. Monk’s Brook catchment (divided into two sub-catchments)
4. Tanner’s Brook catchment
5. River Test catchment (excluding the Tadburn Lake).

Tadburn Lake catchment

6.8 The Tadburn Lake valley contains the main river system, the Tadburn Lake, flowing west towards the River Test. The catchment is divided into two parts:

I. a **northern catchment** in which the streams flow south towards the Tadburn Lake stream, and
II. a **southern catchment** (including Emer Bog and Baddesley Common) in which the streams flow north towards the Tadburn Lake stream.

6.9 The surface water northern catchment includes the main south flowing Tadburn Lake northern tributary and several small valley systems

6.10 The surface water southern catchment can be seen to be divided into:

a. a south-western sub-catchment feeding the north flowing valley of the Tadburn Lake southern tributary system, partly flowing through Baddesley Common and fed by;
b. a south-eastern sub-catchment passing through the urban area of North Baddesley; and also
c. a north-eastern sub-catchment directly feeding Emer Bog.

Monks Brook catchment

6.11 The Monks Brook flows east out of the study area forming a tributary of the River Itchen which it joins at Swaythling in Southampton. Within the study area there are two tributary arms which are fed by separate northern and southern sub-catchments.

Tanner’s Brook catchment

6.12 The upper-most catchment of the Tanner’s Brook arises in the south of the study area within the urban area of North Baddesley and flows south through Southampton to the Test Estuary.

Test Valley catchment (excluding Tadburn Lake)

6.13 Within the western part of the study area are several small minor valleys directed west towards the River Test. The Tadburn Lake valley also flows towards the Test and forms a larger tributary stream.

WATERCOURSES AND FLOW DIRECTION

6.14 **Figure 7** shows the watercourses (rivers, streams and drains) in the study area identified on Ordnance Survey Maps and used by the Environment Agency to define the Detailed River Network. Watercourses are classified as Primary, Secondary or Tertiary rivers according to their size. Lakes and reservoirs are also shown along with offline drainage features. Sources of the rivers, junctions and areas of sink are also shown as numbered nodes.

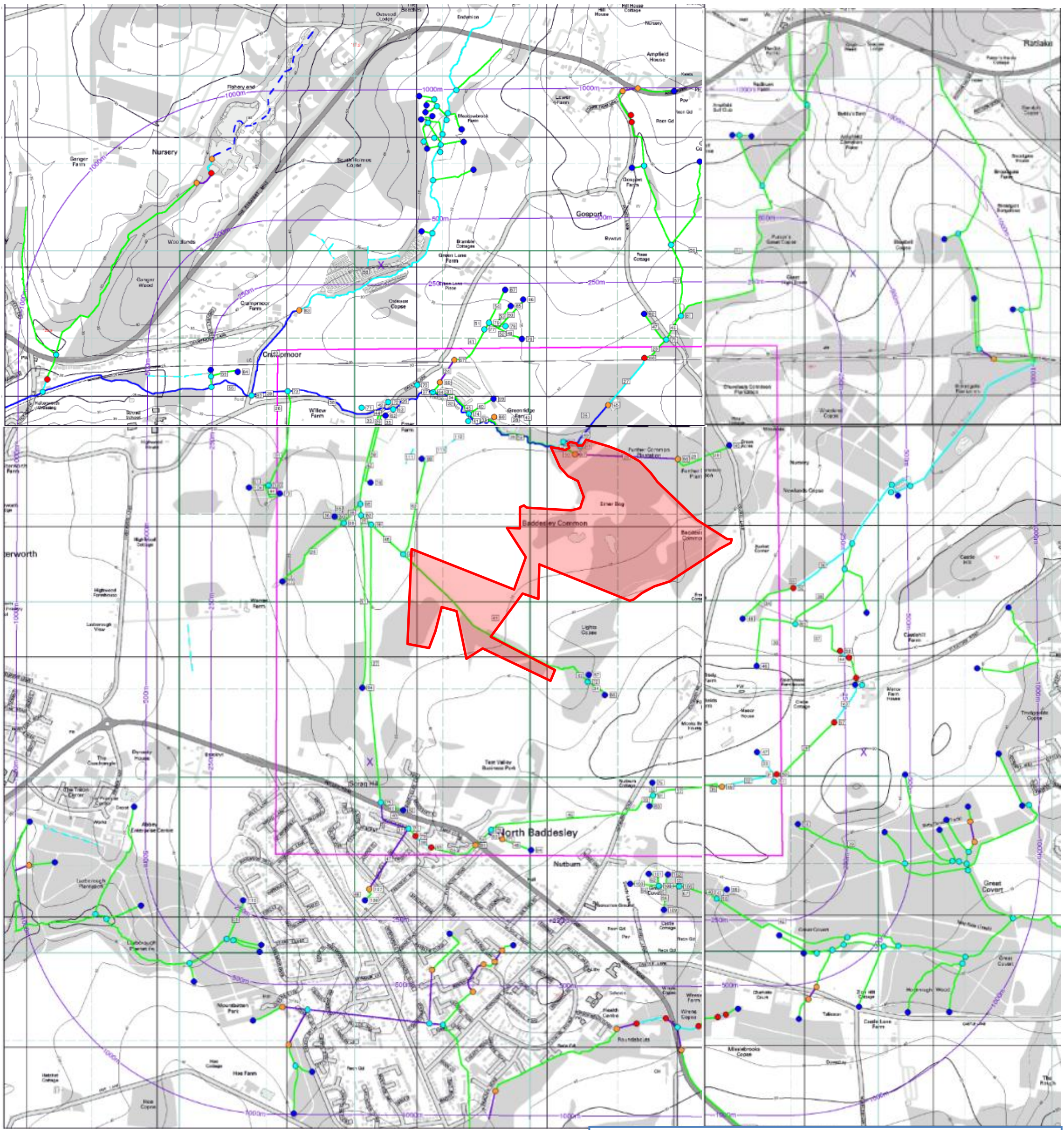
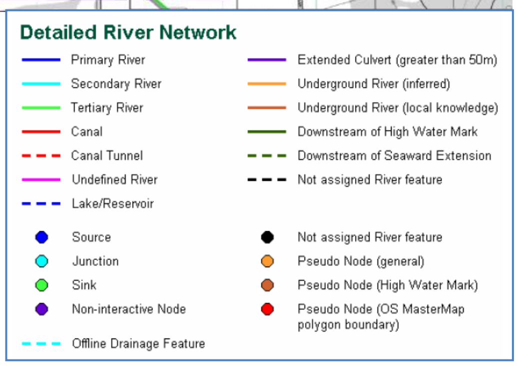
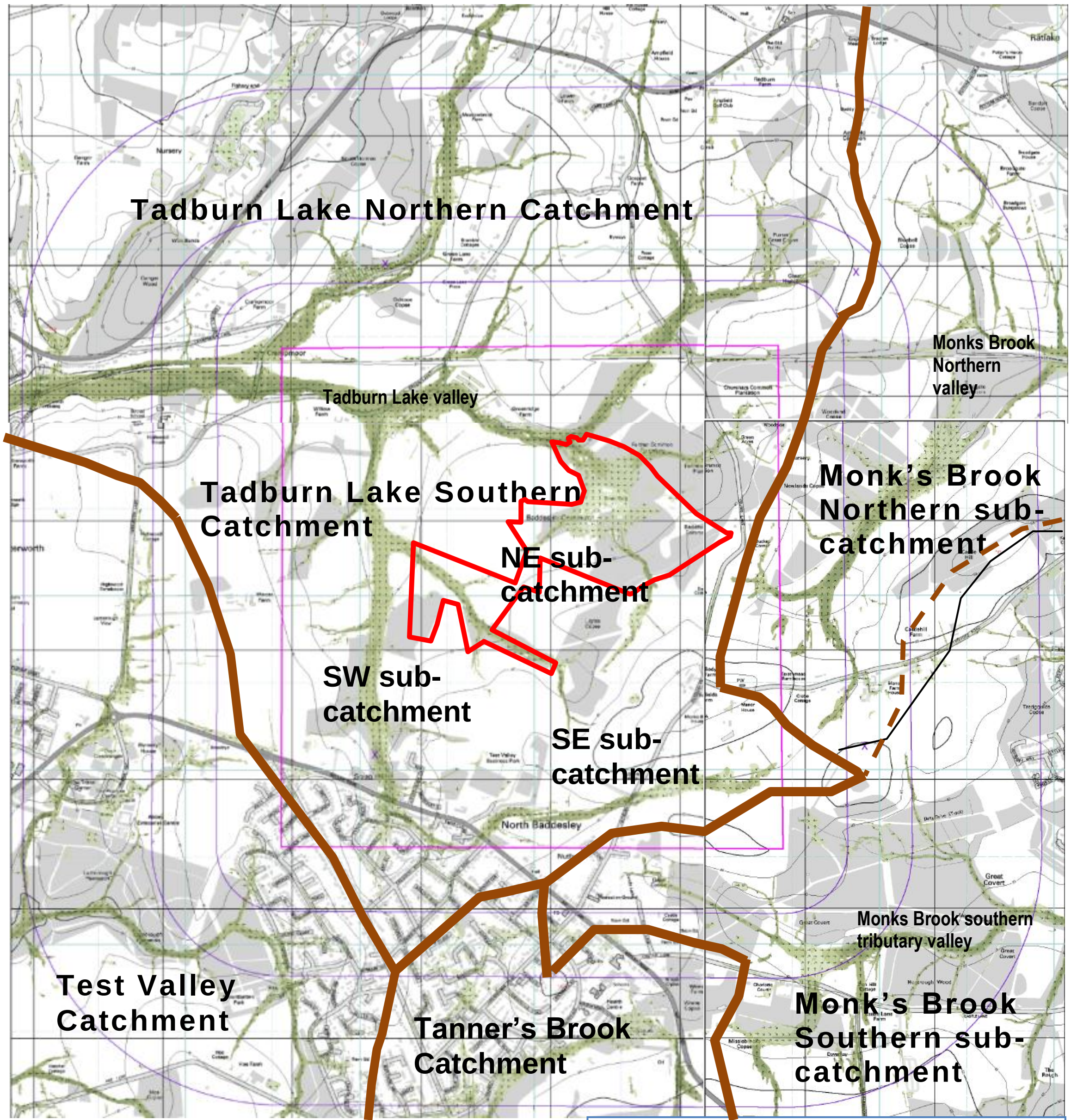


Fig. 7 Environment Agency Detailed River Network map with site location shown in red.



6.15 **Figure 8** provides the Environment Agency's surface water 1000 year return map indicating those areas most likely to flood as a result of surface water flows and also surface water velocity and direction of flow. Detailed maps for the area around Emer Bog and Baddesley Common are provided in **Section 12**. Of the series of maps available illustrating various return periods (75, 100, 200 and 1000), the 1000 year return maps have been chosen as showing the most extreme conditions and picking up potential flow-ways in the most detail. I have added the boundaries of the main surface catchments in brown.



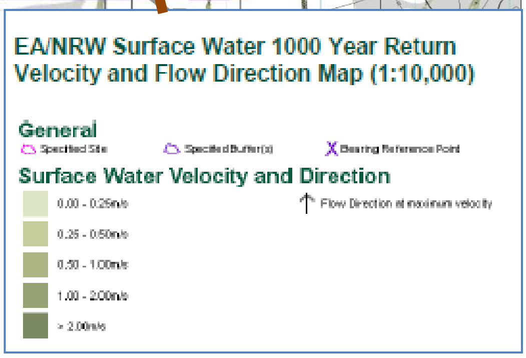


Fig. 8 Environment Agency Surface Water 1000 year Return Velocity and Flow Direction Map with major catchment boundaries added.

RISK OF FLOODING FROM RIVERS

6.16 **Figure 9** illustrates the risk of flooding from rivers as shown on the Environment Agency's Flood Data Map (Flood Map for Planning).

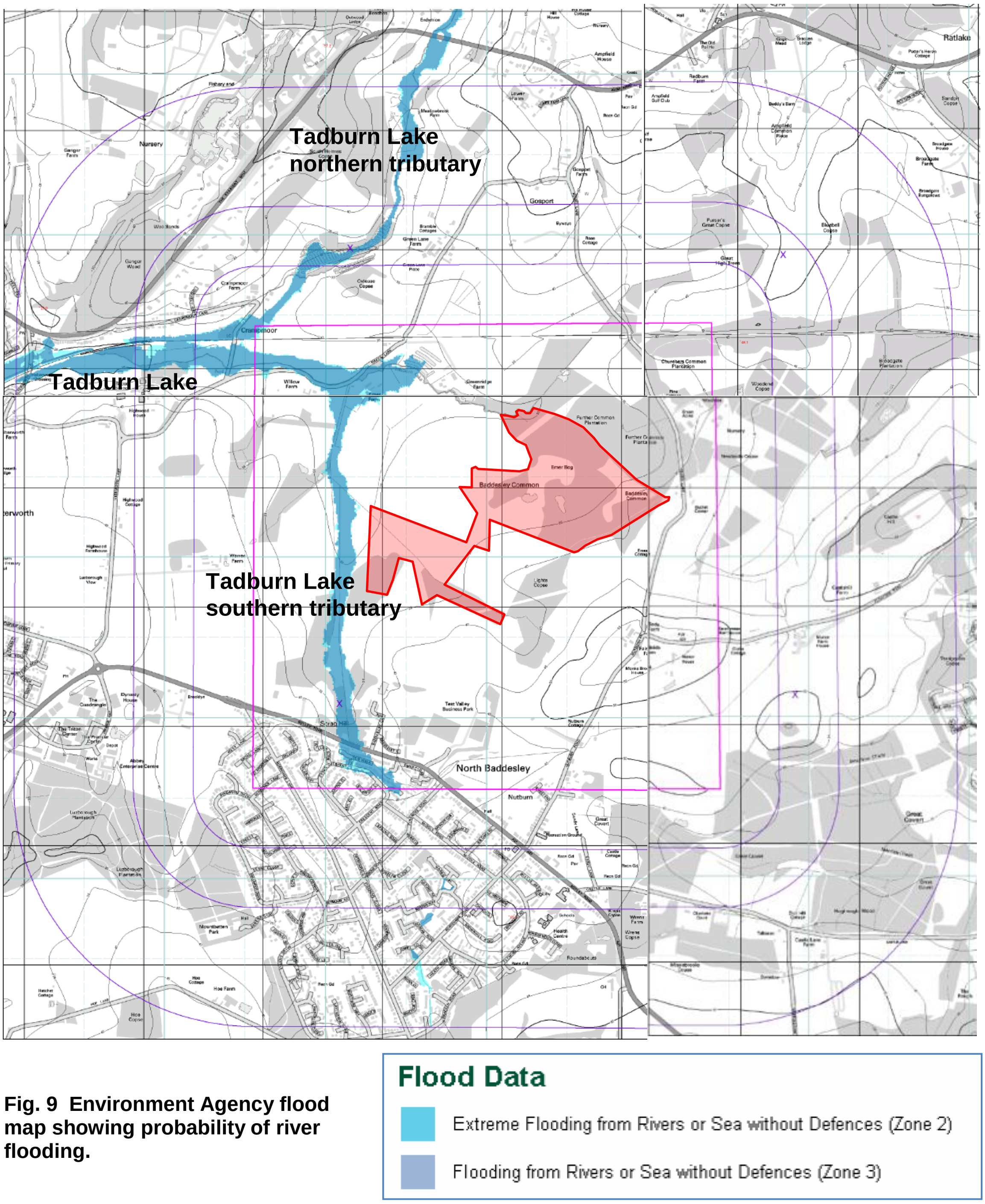


Fig. 9 Environment Agency flood map showing probability of river flooding.

6.17 This map shows that over most of the area, risk of flooding from rivers is minimal. The only areas shown are the flood plains of the western part of the Tadburn Lake and its main northern and southern tributaries and which are shown as in Flood Zone 3.

6.18 The Environment Agency website indicates that (in relation to rivers):

A floodplain is the area that would naturally be affected by flooding if a river rises above its banks, or high tides and stormy seas cause flooding in coastal areas.

There are two different kinds of area shown on the Flood Map for Planning (in relation to rivers). They can be described as follows:

- **Flood Zone 3** shows the area that could be affected by flooding from rivers if there were no flood defences. This area could be flooded from a river by a flood that has a 1 per cent (1 in 100) or greater chance of happening each year.
- **Flood Zone 2** shows the additional extent of an extreme flood from rivers. These outlying areas are likely to be affected by a major flood, with up to a 0.1 per cent (1 in 1000) chance of occurring each year.

These two categories show the extent of the natural floodplain if there were no flood defences or certain other manmade structures and channel improvements.

- Outside of these flood zone categories, flooding from rivers and the sea is very unlikely. There is less than a 0.1 per cent (1 in 1000) chance of flooding occurring each year. The majority of England falls within this area. (For planning and development purposes, this is **Flood Zone 1**)

RISK OF GROUNDWATER FLOODING

6.19 **Figures 10 and 11** show the predicted risk of groundwater flooding for the study area from two different sources.

6.20 **Figure 10** is from the 'risk of flooding' maps provided by ESI (GeoSmart Information Ltd) and provides a predicted risk of groundwater flooding occur in Great Britain. Their 1:50,000 scale map classifies groundwater flood risk for each 50m x 50m square into four categories: negligible, low, moderate or high. These classifications are based on the level of risk, combining severity and uncertainty that a site will suffer groundwater flooding **within a return period of about 200 years**.

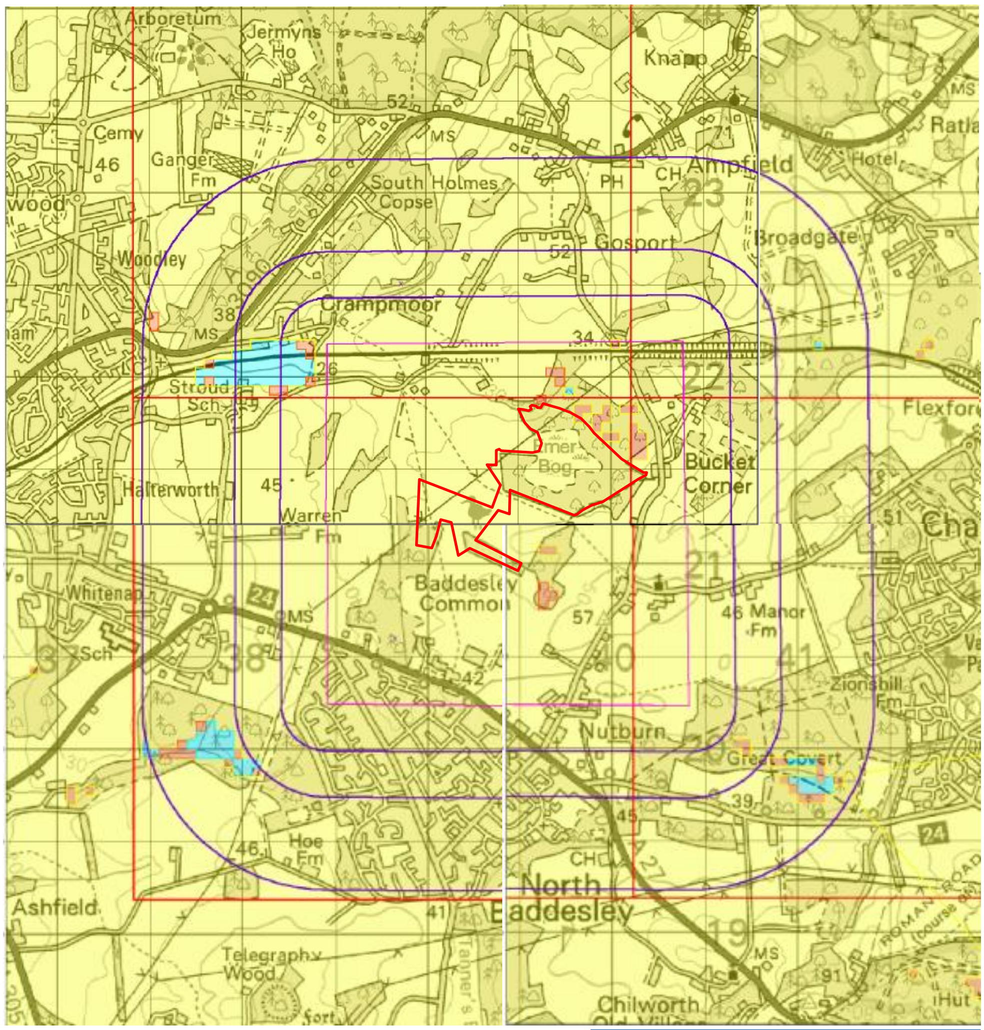
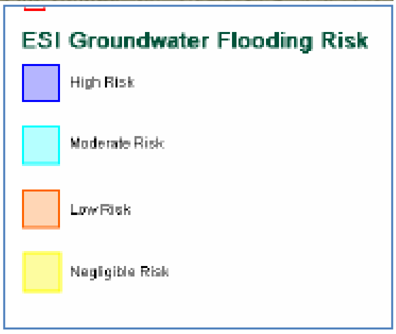


Fig. 10 ESI Groundwater Flood Map showing risk of flooding for 1 in 200 year event.



6.21 The map shows relatively few areas at risk of groundwater flooding within a return period of 1 in 200 years and none within the Emer Bog and Baddesley Common boundary or immediately adjacent areas.

6.22 **Figure 11** is the British Geological Surveys 1:50,000 scale Flood Data map which assesses groundwater flooding susceptibility.

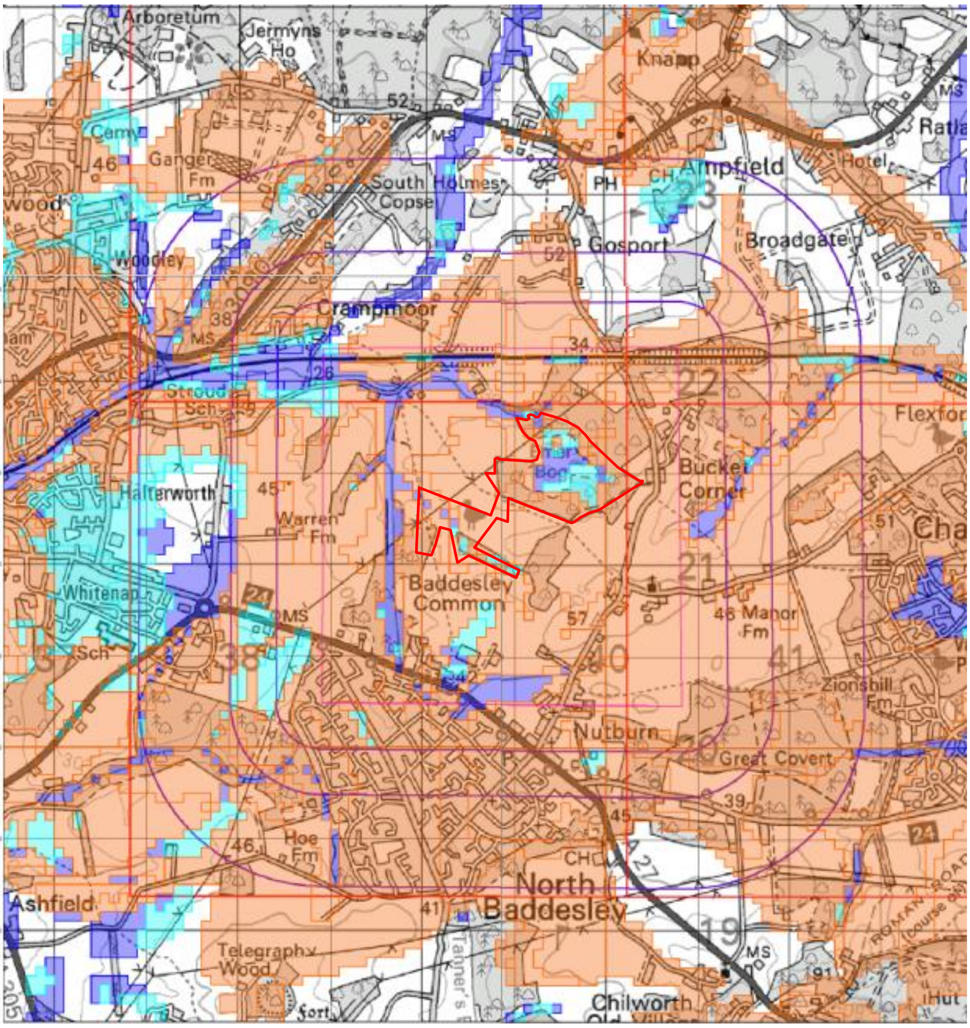


Fig. 11 British Geological Survey Groundwater Flooding Susceptibility Map

BGS Groundwater Flooding Susceptibility

- Potential for Groundwater Flooding to Occur at Surface
- Potential for Groundwater Flooding of Property Situated Below Ground Level
- Limited Potential for Groundwater Flooding to Occur

6.23 The map shows the susceptibility that land will flood due to rising groundwater. Groundwater flood susceptible areas are shown are along the river valleys and some minor valley systems as well as the wetland area at Emer Bog with some below ground level flooding in the valley system at Baddesley Common. Generally, the area (apart from localised areas) is not widely susceptible to flooding from rising groundwater.

7.0 GEOLOGY

GEOLOGICAL MAPPING

7.1 The 1:10 000 and 1:50 000 scale geological maps have been obtained through the Envirocheck data search. Geology is the study of rocks and sediments, their distribution and derivation. The disposition and lithology of different strata affects how water flows below and over the ground. **Figures 12, 13 and the legend in Figure 14** illustrate the combined bedrock and superficial geology of the study area at 1:50,000 scale and **Figures 15 and 16** provide the more detailed 1:10,000 scale. **Figure 15** also shows borehole locations.

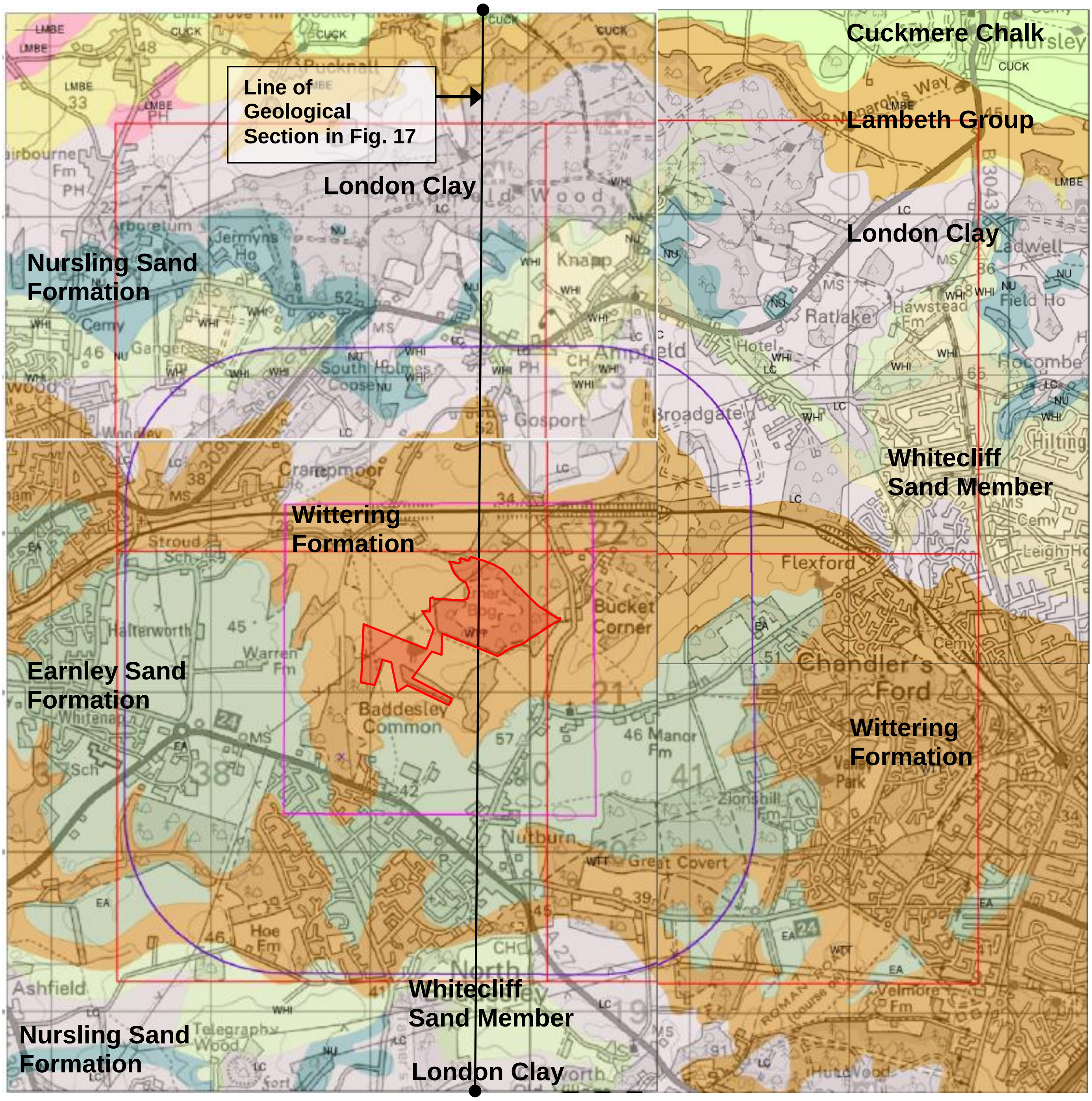


Fig. 12 1:50, 000 scale British Geological Survey Map showing Bedrock deposits only. Also showing the line of section used to derive the cross section in Figure 17.

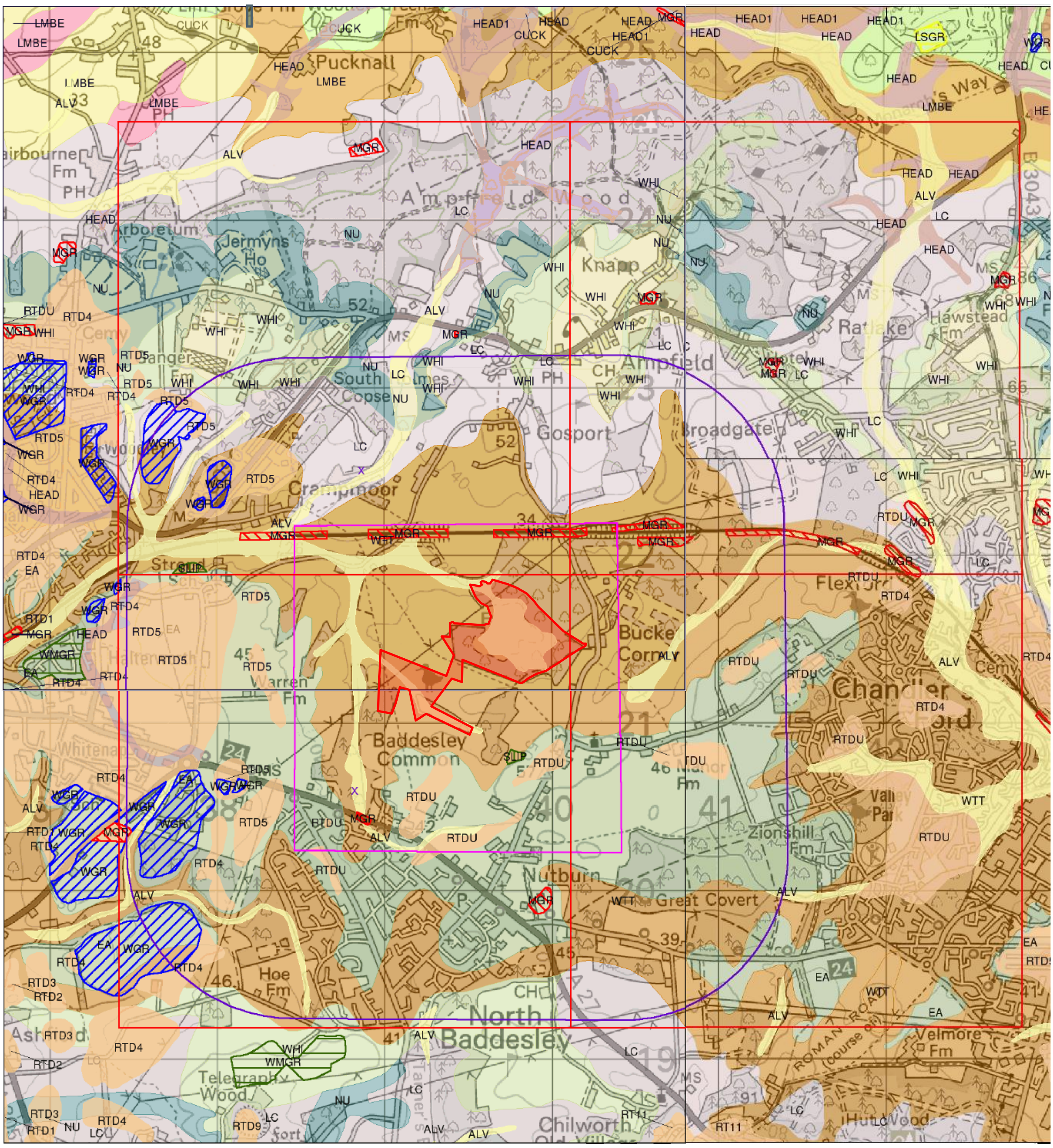


Fig. 13 1:50, 000 scale British Geological Survey Map showing combined Bedrock and Superficial Geology.

Geology 1:50,000 Maps Legends

Artificial Ground and Landslip

Map Colour	Lex Code	Rock Name	Rock Type	Min and Max Age
	WMGR	Infilled Ground	Artificial Deposit	Cenozoic - Cenozoic
	MGR	Made Ground (Undivided)	Artificial Deposit	Holocene - Holocene
	WGR	Worked Ground (Undivided)	Void	Holocene - Holocene
	SLIP	Landslide Deposit	Unknown/Unclassified Entry	Quaternary - Quaternary

Superficial Geology

Map Colour	Lex Code	Rock Name	Rock Type	Min and Max Age
	ALV	Alluvium	Clay, Silt, Sand and Gravel	Flandrian - Flandrian
	RTD5	River Terrace Deposits, 5	Sand and Gravel	Quaternary - Quaternary
	HEAD	Head	Gravel, Sand, Silt and Clay	Quaternary - Quaternary
	RTD4	River Terrace Deposits, 4	Sand and Gravel	Quaternary - Quaternary
	HEAD	Head	Clay, Silt, Sand and Gravel	Quaternary - Quaternary
	RTD1	River Terrace Deposits, 1	Sand and Gravel	Quaternary - Quaternary
	RTDU	River Terrace Deposits (Undifferentiated)	Clay and Silt	Quaternary - Quaternary
	HEAD1	Head, 1	Clay, Silt, Sand and Gravel	Quaternary - Quaternary

Bedrock and Faults

Map Colour	Lex Code	Rock Name	Rock Type	Min and Max Age
	EA	Earnley Sand Formation	Sand, Silt and Clay	Lutetian - Lutetian
	WTT	Wittering Formation	Sand, Silt and Clay	Lutetian - Ypresian
	LC	London Clay Formation	Clay, Silt and Sand	Eocene - Eocene
	LMBE	Lambeth Group	Clay, Silt and Sand	Paleocene - Paleocene
	LMBE	Lambeth Group	Sand, Gravelly [Unlithified Deposits Coding Scheme]	Paleocene - Paleocene
	LMBE	Lambeth Group	Sand	Paleocene - Paleocene
	NU	Nursling Sand Member	Clay, Silt and Sand	Palaeogene - Palaeogene
	WHI	Whitecliff Sand Member	Sand, Gravelly [Unlithified Deposits Coding Scheme]	Palaeogene - Palaeogene
	WHI	Whitecliff Sand Member	Sand	Palaeogene - Palaeogene
	CUCK	Culver Chalk Formation	Chalk	Campanian - Campanian

Fig. 14 Legend to the 1:50, 000 scale British Geological Survey Map (combined Bedrock and Superficial Geology) provided by Envirocheck.

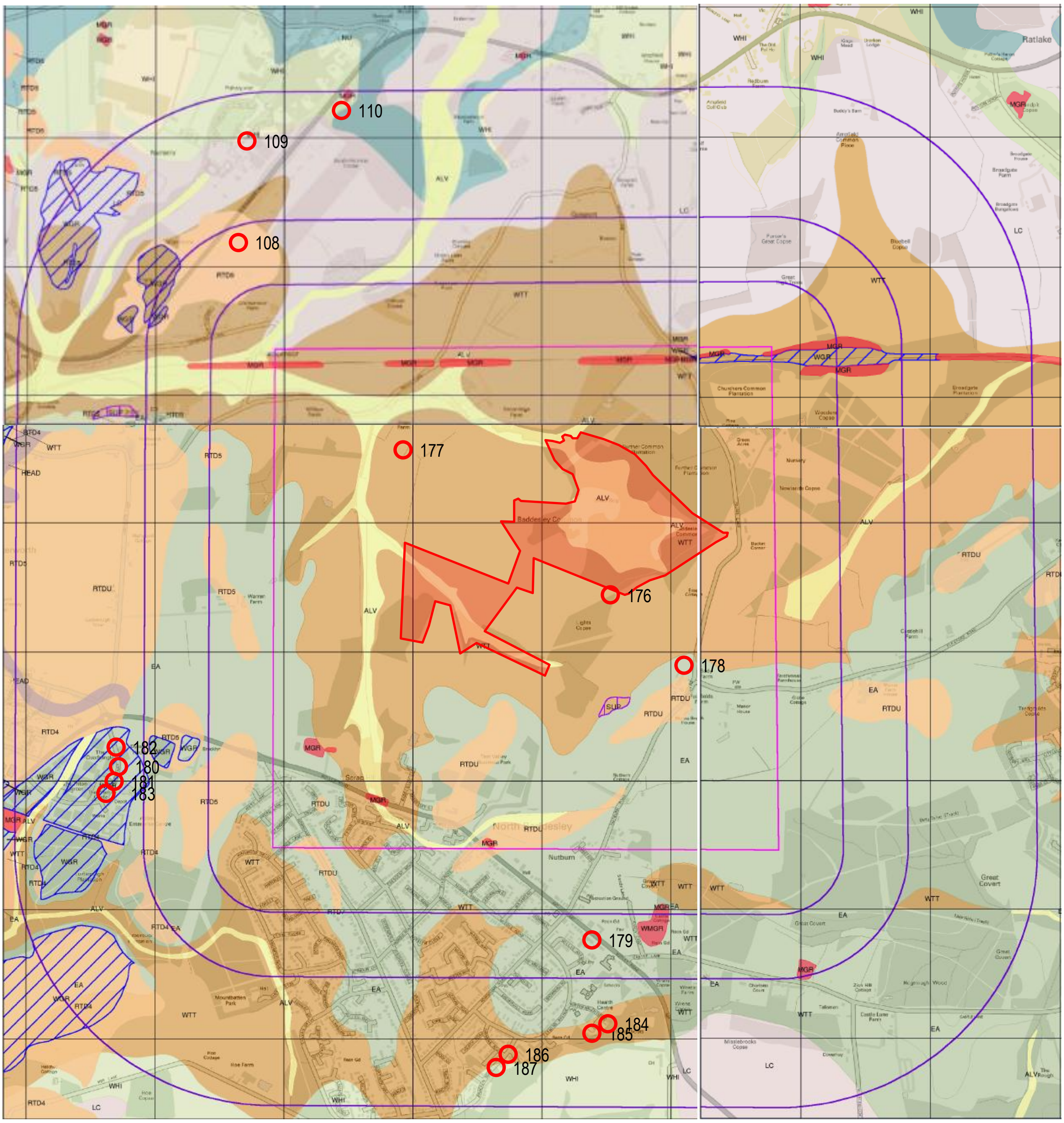


Fig. 15 1:10, 000 scale British Geological Survey Map (combined Bedrock and Superficial Geology) and also showing location of British Geological Survey boreholes. A key to the geology is provided in Figure 16. Information provided by Envirocheck.

Geology 1:10,000 Maps Legends

Artificial Ground and Landslip

Map Colour	Lex Code	Rock Name	Rock Type	Min and Max Age
	MGR	Made Ground (Undivided)	Artificial Deposit	Holocene - Holocene
	WGR	Worked Ground (Undivided)	Void	Holocene - Holocene

Superficial Geology

Map Colour	Lex Code	Rock Name	Rock Type	Min and Max Age
	ALV	Alluvium	Sand, Silt and Clay	Flandrian - Pleistocene
	ALV	Alluvium	Silt	Flandrian - Pleistocene
	RTDU	River Terrace Deposits (Undifferentiated)	Sand and Gravel	Quaternary - Ryazanian
	RTD4	River Terrace Deposits, 4	Sand and Gravel	Quaternary - Ryazanian
	RTD6	River Terrace Deposits, 6	Sand and Gravel	Quaternary - Ryazanian

Bedrock and Faults

Map Colour	Lex Code	Rock Name	Rock Type	Min and Max Age
	EA	Earnley Sand Formation	Sand	Lutetian - Lutetian
	WTT	Wittering Formation	Sand, Silt and Clay	Lutetian - Ypresian
	WTT	Wittering Formation	Clay, Sandy	Lutetian - Ypresian
	LC	London Clay Formation	Clay, Silt and Sand	Eocene - Eocene

Fig. 16 Legend to the 1:10, 000 scale British Geological Survey Map (combined Bedrock and Superficial Geology) provided by Envirocheck.

GEOLOGICAL DESCRIPTION

Stratigraphy

7.2 Stratigraphy refers to the arrangement of geological strata in the order of deposition. The strata are arranged in order of their age and defined according to their lithology (proportions of sand, silt, clay, chalk and other mineral content) and fossil assemblages. Note that the names of the strata vary from source to source. Where possible I have used the names recognised in the BGS Lexicon of Named Rock Units[13]

7.3 The stratigraphic geology and sediment type (lithology) of the general area is complex, although in the immediate vicinity of Emer Bog and Baddesley Common the situation is much simpler.

7.4 Bedrock strata (also known as Solid strata) form the basis of the geological materials and were laid down prior to the last Ice Ages. Bedrock strata may be hard (eg. sandstone or chalk) or soft (eg. clay or sands and gravels).

7.5 Superficial strata were laid down during the Ice Ages and in more recent times and overlie the bedrock strata. For the most part, superficial strata are soft and unconsolidated.

7.6 **Table 1** sets out the stratigraphy of the bedrock deposits in the wider area. Those strata within the vicinity of Emer Bog and Baddesley Common are highlighted. **Table 2** sets out the superficial strata in the same area.

[13] http://www.bgs.ac.uk/lexicon/home.html

Table 1. Stratigraphy of the bedrock deposits (youngest at the top)[14]

Age		Formation	Lithology
Tertiary	**Bracklesham Group**	**Earnley Sand Formation**	**Glauconitic silty sands and sandy silts.**
		Wittering Formation	**Mainly greyish brown laminated clay; wavy- to lenticular-bedded sand interbedded with clay in equal proportions; clayey sands, beds of fine- to medium-grained sparsely glauconitic sand.**
	London Clay Group	London Clay Formation	Bioturbated or poorly laminated, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay. It commonly contains thin courses of carbonate concretions ('cementstone nodules') and disseminated pyrite. It also includes a few thin beds of shells and fine sand partings or pockets of sand, which commonly increase towards the base and towards the top of the formation.
		Whitecliff Sand Member	Yellowish brown medium to fine-grained sands, silty sand, and overlain by pebbly sand in places
		Nursling Sand Member	Very fine grained sands to extremely silty and clayey very fine-grained sands, some shelly, calcareous sandstone beds.
		Lambeth Group	Vertically and laterally variable sequences mainly of mottled clay, some silty or sandy, with some sands and gravels, minor limestones and lignites and occasional sandstone and conglomerate.
Cretaceous	White chalk Subgroup (Upper Chalk)	Culver Chalk Formation	Soft white chalk, relatively marl free, with flint seams. Flints are generally large and, in the upper part, tabular.

Table 2. Superficial Deposits

Superficial deposit	Description
Alluvium	Silty and clayey deposits laid down on river floodplains.
Head	Mixed deposits laid down on footslopes and valley bottoms by slumping of materials from higher upslope.
Terrace deposits	Sand and flint gravel, sometimes with more clayey layers.

General geological description

7.7 The 1:50,000 scale geological map in **Figures 12 and 13** shows the general distribution of the different geological strata in the general vicinity of Emer Bog and Baddesley Common. The 1:10,000 scale map in **Figure 15** provides more detail. The north-south cross section in **Figure 17** shows the general layering of the strata. Short descriptions of the strata are provided in **Tables 1 and 2**. [15]

7.8 The oldest strata are shown at the top of the map (north) and strata become successively younger southwards with a reversal of the sequence to the south. Each youngest strata overlies the next oldest in turn.

7.9 In the vicinity of Emer Bog and Baddesley Common the dip of the strata is perhaps about 1-2 degrees to the south with a reversal of about 1 degree to the north further to the south. This implies that the geological structure forms a very shallow syncline[16].

[14] Lithology taken from the BGS Lexicon of Named Rock Types or from legends on geological maps and with additional information from Allen 2002/2003.
[15] Note: The names for geological strata used in this report are updated from those used in the 2002 and 2003 reports and use the names provided in the BGS Lexicon of Named Rock Types.
[16] Syncline: a downward pointing shallow fold in which the youngest strata occur at the centre.

7.10 To the north of the study area is an outcrop of the **Culver chalk Formation**, Cretaceous white chalk with flints[17].

7.11 Moving successively south, the chalk is overlain by a succession of Tertiary strata within the Bracklesham and London Clay Groups. These are very variable deposits and while most layers are clayey, they often include finely laminated sandy strata and sometimes thicker layers of sandy or sandstone materials.

7.12 South of the chalk outcrop is a swathe of the oldest Tertiary strata, the **Lambeth Group**[18]. The Lambeth Group is primarily layers of mottled clay, silty clay or sandy clay, with some interspersed layers of sand and sandstone. In the west of the study area, these deposits become increasingly sandy. South again is a broad swathe of the **London Clay Group**, primarily olive grey clay, sandy and silty clays of the **London Clay Formation** but including small layers of sandy and sandy silt deposits. This area also includes some sandstone and limestone beds variously of the **Nursling Sand Member** and **Whitecliff Sand Member**.

7.13 Further south is a broad central swathe of the **Wittering Formation** (which underlies Emer Bog and Baddesley Common). This very variable formation mainly comprises greyish brown laminated clays with wavy to lenticular bedded sand that are interbedded with clay in equal proportions, along with clayey sands, and beds of fine to medium-grained sparsely glauconitic sand.

7.14 Sitting on the Wittering Formation around Nutburn village (in the core of the syncline) is a shallow outcrop of the **Earnley Sand Formation**, silty sands and sandy silts. These deposits spread out over a wider area to the west around Halterworth and Whitenap. South from Nutburn, the sequence reverses on the southern limb of syncline passing back to the Wittering Formation and then the London Clay. In this southern area, the London Clay is locally overlain by fine sandy strata of the Whitecliff and Nursling Sands.

7.15 **Figure 17** is a schematic geological cross-section taken north-south through Emer Bog and Baddesley Common. The line of section is shown on **Figure 12** above. It can be seen that the Wittering Formation laminated clays (on which Emer Bog and Baddesley Commons sit) overlie the London Clay in a shallow downfold of the strata (shallow syncline).

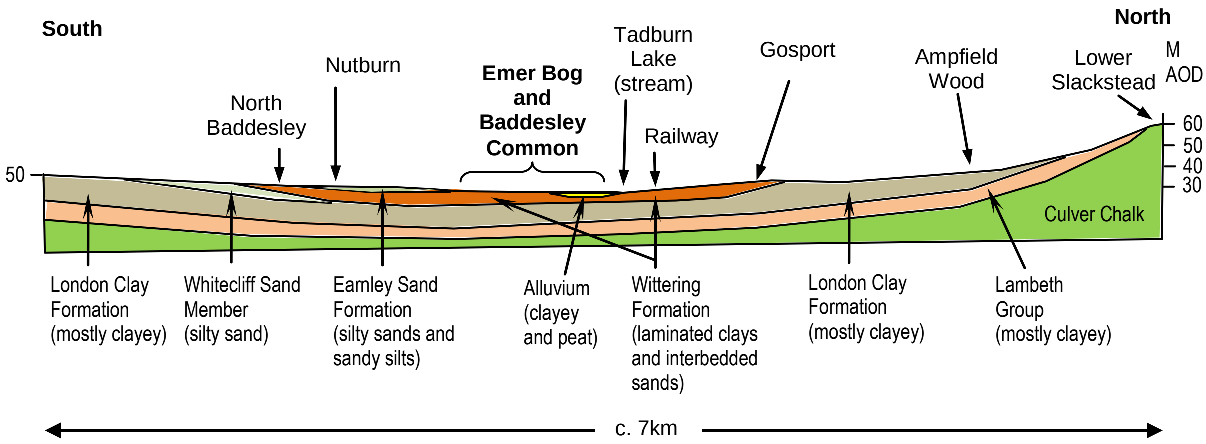


Fig. 17 Schematic geological cross section north-south through Emer Bog and Baddesley Common showing the arrangement of strata. Precise dip of strata at Emer Bog is uncertain. Based on 1:50,000 scale geological map. Vertical scale exaggerated. Not to scale.

7.16 These bedrock deposits are variously overlain by mixed Head deposits and in the valleys by Alluvium while sandy gravelly Terrace Deposits overlie the bedrock strata in the west.

[17] Referred to as Upper Chalk in 2002 and 2003 reports.
[18] Referred to as the Reading Formation in 2002 and 2003 reports.

Summary borehole information

7.17 The locations of British Geological Survey recorded boreholes and trial pits are indicated in **Figure 15**. The descriptions below are summarised from the borehole logs.

A. Boreholes in northwest of study area

108 RM Camp, South Holmes Copse, Romsey Extra

Terrace gravels over Bracklesham Beds (Wittering Formation) over London Clay over Lambeth Group over Chalk

2-22m	Sand over very sandy clay (Bracklesham Beds)
22-36m	Sand and pebbles over sand
36-110m	Mainly blue clay but with bands of very sandy clay, sandy clay and stones (London Clay Group)
110.0-126.0m	Mottled clay, coloured clay with mottled clay, sand and stones (Lambeth Group)
126-146m	Chalk and flints (Culver Chalk)

<u>Summary</u>: Sand and very sandy clay (Wittering Formation)
Blue clay with bands of sandy clay and stones (London Clay)
Mottled clay with bands of sand and stones (Lambeth Group)
Chalk and Flints (Culver Chalk)

109 Adjacent fishery lake

Located adjacent to fishery lake

Boundary of London Clay and Whitecliff Sand Members of London Clay Group

- Extremely clayey fine-grained sand and extremely sandy clay. London Clay over
- Flint pebble beds in extremely sandy clay matrix. Whitecliff Sand over
- Clean medium grained sand.

<u>Note</u>: Depths not readable on log.

<u>Summary</u>: Clayey fine-grained sand and extremely sandy clay (London Clay) over clayey flint pebbles over clean sand

110 Disused sand pit in South Holmes Copse

Drift over Whitecliff Sand over Nursling Sand.

- Medium-grained sand with pebbles (Drift).
- Clean medium-grained sand (Whitecliff Sand Member).
- Extremely clayey fine to very fine-grained sand (Nursling Sand Member).

<u>Note</u>: Depths not readable on log.

<u>Summary</u>: Medium-grained sand (White Cliff Sand) over clayey fine-grained sand (Nursling Sand)

B. Boreholes in central area close to Emer Bog and Baddesley Common

176 Near Lights Copse

Located on southern boundary of Emer Bog on northern tip of Lights Copse

Wittering Formation

1.45-2.65m	Glauconitic medium-grained sand, orange-brown stained in places and with a few more clayey bands
2.65-2.95m	Clean glauconitic medium-grained sand.

<u>Summary</u>: mostly medium grained sand.

177 Baddesley Common, Green Lane Farm

Wittering Formation

2.30-2.70m	Soft very to extremely clayey fine-grained sand.
3.55-3.95m	Extremely sandy clay with indistinct patchy areas and more extensive areas of extremely clayey sand.

<u>Summary</u>: Mostly very clayey fine-grained sand over extremely sandy clay or clayey sand.

178 Body Farm, North Baddesley

On Earnley Sand outcrop over Wittering Formation

1.45-1.85m	Sand
2.30-2.70m	Firm to moderately firm sandy to slightly sandy plastic clay with bands of fine-grained sand.
3.40-3.80m	Very sandy moderately firm clay with partings and bands of fine-grained sand with lignitic fragments.
5.40-5.80m	Fairly firm very to extremely sandy clay with partings, pods and irregular lenses of fine-grained sand.
7.40-7.80m	Clean medium-grained sand with a few thin bands of extremely sandy clay.
8.45-8.85m	Firm very sandy clay with lenticles and partings of very fine-grained sand, scattered lignite fragments in places.
10.45-10.85m	Firm very sandy clay with thin lenses and partings of fine-grained sand, basal 10mm of glauconitic sand.
12.45-12.85m	Glauconitic medium-grained sand with a few thin bands of sandy clay.

Summary: Mostly sandy clay with partings, bands and lenses of fine-grained sand and some layers of medium-grained sand.

C. Boreholes in south of study area in eastern North Baddesley

179 Gainsborough Court, North Baddesley

Excavated into the urban area of North Baddesley over Earnley Sand Formation

0.00-1.40m	Topsoil, concrete and brick rubble.
1.40-3.10m	Soft, firm or stiff silty sandy clay.
3.10-10.0m	Very compact dense silty clayey fine sand, increasingly silty with depth, occasional clay layers to 100mm thickness.

Note: despite being located on the Earnley Sand, no clean sand was located in the 10m borehole.

Summary: Silty sandy clay over compact silty clayey fine sand with some clay layers.

184 Fleming Avenue, North Baddesley

Wittering Formation

0.00-2.60m	Silty clay with some partings and zones of fine sand.
2.60-15.0m	Stiff fissured and laminated silty clay with partings and zones of fine sand

Note: groundwater seepages at 2.3 and 13.5m depth.

Summary: Silty clay with partings and zones of fine sand.

185 Fleming Avenue, North Baddesley

Wittering Formation

0.20-2.30m	Very silty clay with some gravel
2.30-9.00m	Firm/stiff fissured very silty clay with some lenses and zones of fine sand.
9.00-13.00m	Compact or firm/still thinly laminated silty very clayey fine sand or very sandy clay.

Note: groundwater seepage at 9.2m.

Summary: Very silty clay and laminated clay with lenses of fine sand and sandy clay

186 North Baddesley

Edge of Wittering Formation and Whitecliff Sand Member of the London Clay Group

0.00-1.90m	Soil and rubble fill.
1.90-3.00m	Soft/firm silty clayey sand and sandy clay.
3.00-6.30m	Firm/stiff or compact laminated sandy clay or clayey sand.

Note: Seepage at 3.4m

Summary: Silty clayey sand and sandy clay and laminated sandy clay/clayey sand

187 North Baddesley

Edge of Wittering Formation and Whitecliff Sand Member of the London Clay Group

0.30-3.20m	Soft/firm sandy silty clay
3.20-13.4m	Firm/stiff or very compact laminated silty fine sandy clay with some partings and zones of fine sand.
13.40-15.50m	Very compact silty fine and medium sand with some bands of clay.

Note: Seepages at 1.0m and 4.5m.

Summary: Mostly very compact laminated silty fine sandy clay and silty clay with bands of sand and clay.

D. Trial Pits in southwest of study area off Premier Way, Whitenap, in former excavation, now developed

180 Trial pit in worked ground, now developed.
0.00-1.70 Fill Material. Silty sandy clay and carbonaceous material.

181 Trial pit in worked ground, now developed.
0.00-2.10 Fill Material. Organic rich silty clay over medium dense re-worked gravel.

182 Trial pit in worked ground now developed.
0.00-3.00 Fill Material. Variously: clayey loose silt, silty clay, or silty loose sand.

183 Trial pit in worked ground, now developed.
0.00-2.00 Fill Material. Soft silty clay with organic material over clayey cobbly gravel.

Summary: Shallow trial pits infill material.

8.0 SOILS

SOIL

8.1 Soil is that material at the surface of the ground in which plants root (and which provides support, nutrients and moisture) and which extends typically to 1-2m depth. Soil characteristics control the way surface water flows over or percolates into the substrate and so are important in hydrological appraisal.

8.2 Soils are derived from the underlying rock substrate by various ‘soil forming processes’. These processes typically include physical weathering (breakdown of the substrata), chemical weathering and leaching (changes to the substrate by chemical processes including downward movement of acidified water from rain and vegetation), gleying (grey colours or mottling produced by the reducing and oxidising effects of bacteria reacting with soil moisture and the soil atmosphere), the shrinking and swelling of any clay particles and the accumulation of organic matter at the surface from the decay of plant litter.

8.3 Soil materials are also affected by the action of plant and tree roots in breaking open the soil and chemically changing the root environment. They can also be substantially altered by (for instance) agriculture, mineral extraction and land development.

8.4 **Figure 18** is an extract from the 1:250,000 scale National Soil Map[19] and which provides a generalised picture of soil types in the area. At this scale it is not possible to show the detailed distribution of soil types, but rather the main characteristics of the soils in each map unit.

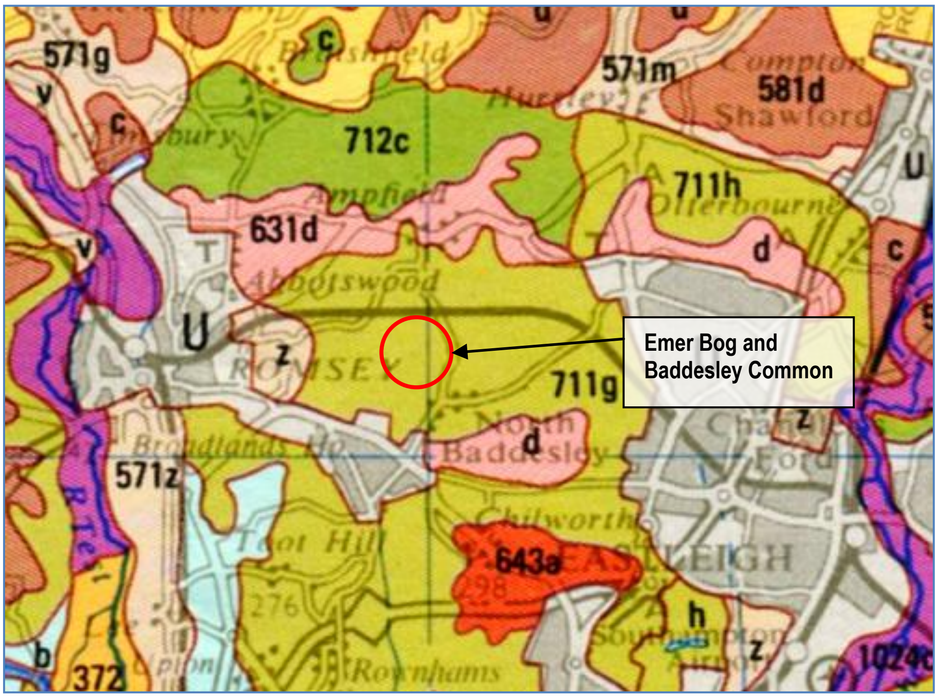


Fig. 18 Extract from the 1:250,000 scale national soil map showing soil associations in the general area of Emer Bog and Baddesley Common.

Pale green (711g) = seasonally waterlogged loamy over clayey soils with impeded drainage.
Dark green (712c) = seasonally waterlogged clayey soils with impeded drainage.
Pink (631d) / Pale brown (571z) = well drained sandy soils / well drained silty soils.
Red (643a) = seasonally waterlogged sandy over clayey soils.
Yellow (343h) = well drained soils on chalk.
Dark brown (581d) = well drained silty over clayey soils on clay-with-flints.
Pale blue (841b) = loamy permeable soils affected by groundwater on terrace gravels
Purple (1024c) / Amber (372) = humified peat soils and soils on calcareous tufa, both on floodplains.

[19] Soils of England and Wales Sheet 6 South East England. Ordnance Survey for the Soil Survey of England and Wales 1983.

SOIL TYPES

8.5 Map units in this map (**Figure 18**) comprise named Soil Associations[20] and the soil types broadly follow the distribution of their geological substrates.

Well drained soils on Chalk

In the north are areas of shallow chalk soils (343h Andover Association) with thin shallow silty layers over chalk bedrock with deeper silty soils in valley bottoms. Disbursed across the chalk on higher land are well-drained mostly silty over clayey soils on Clay-with-flints (581d Carstens Association).

Poorly drained soils on London Clay Group (Lambeth Group and London Clay Formation)

South of the chalk is a broad band of slowly permeable soils on clays, usually with severe impeded drainage and seasonal waterlogging. These soils (in the 712c Windsor Association) are frequently clayey but can have variable thicknesses of fine loamy and fine silty upper layers overlying the substrate clay.

Well-drained sandy soils on Whitecliff Sands Group and Earnley Sand Formation

Where the Whitecliff Sands occurs at the surface, and also on parts of the Earnley Sand, there are well-drained acidic sandy soils with a bleached subsurface horizon (podzols of the 631d Shirrell Heath Association). These soils originally developed under heathland.

Poorly drained soils on Wittering Formation (and underlying Emer Bog and Baddesley Common)

These mainly poorly drained loamy over clayey soils (711g Wickham Association) occur on the Wittering Formation and are characteristically seasonally waterlogged and lie wet during winter (as on much of Baddesley Common). The component soils are extremely variable; locally there are soils with slight seasonal waterlogging, while elsewhere prolonged or permanent waterlogging leads to the development of soils with peaty topsoils or even deep peats (as on Emer Bog).

Poorly or moderately drained soils on Whitecliff Sands Group

In the south of the area to southeast of North Baddesley, where the Whitecliff Sands thin over London Clay, are acidic sandy over clayey soils with slowly permeable substrates (643a Holidays Hill Association). Typically these soils have slight seasonal waterlogging but they may also have prolonged seasonal or permanent waterlogging leading to the development of peaty topsoils. Deeper sandy soils affected by high groundwater occur locally.

Poorly drained soils in the Test and Itchen Valleys (peripheral to the study area)

These valleys include: organic soils on humified peat (1024c Adventurers Association) and soils on calcareous tufa (372 Willingham Association) both affected by high groundwater on floodplains and also gravelly loamy soils (841b Hurst Association) affected by high groundwater on river terraces.

[20] Soil Associations: Geographic areas identified by and named after their most frequently occurring soil type (soil series). For detailed descriptions see: Soils and their Use in South East England, Soil Survey Bulletin No 15, M G Jarvis, R H Allen, S J Fordham, J Hazleden, A J Moffat and R G Sturdy. Harpenden 1984.

9.0 SURFACE WATER CATCHMENT CHARACTERISTICS

CATCHMENT AND GEOLOGY

9.1 This section examines the characteristics of each of the catchments identified in **Section 6.2** in terms of their topography, hydrology, geology and soils.

9.2 **Figure 19** superimposes the catchment boundaries onto the geological map.

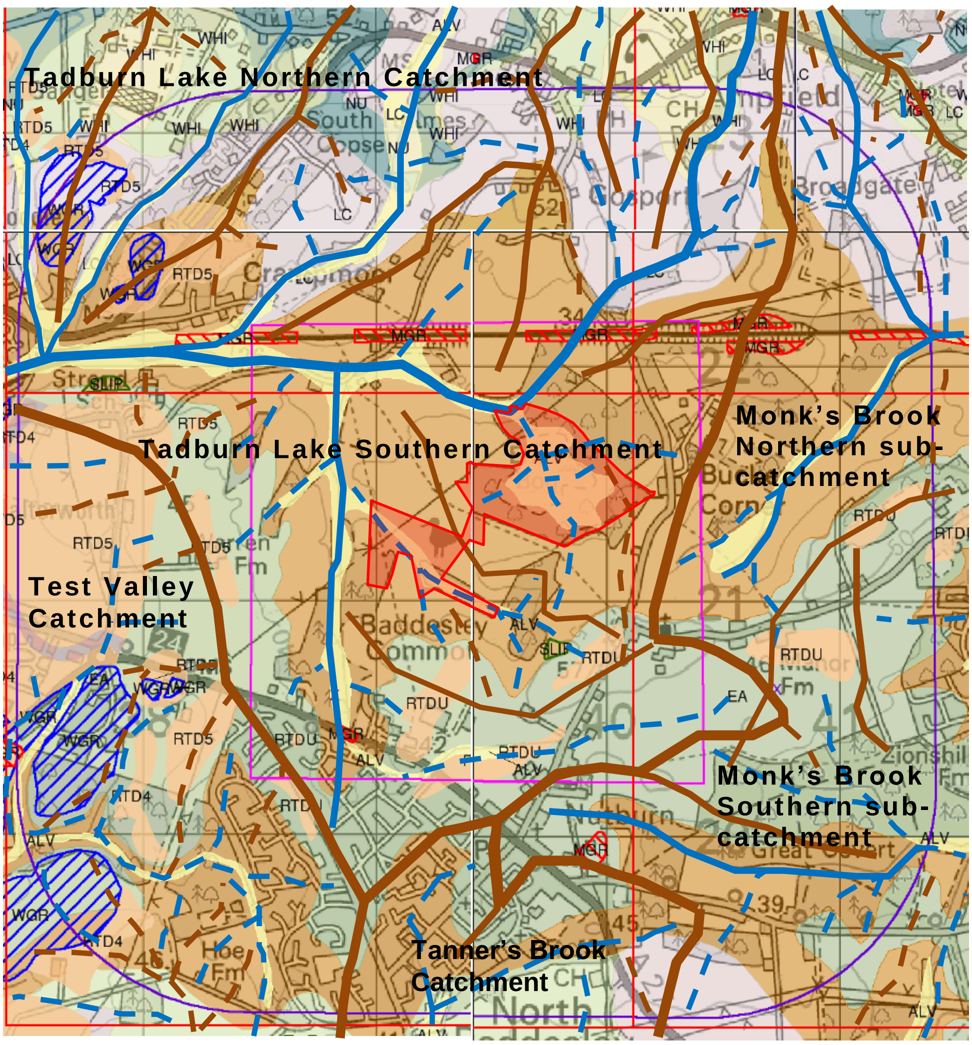


Fig. 19 Catchment and surface drainage lines superimposed on 1:50 000 scale combined bedrock and superficial geological map.
See geological legend in Figure 14.

9.3 From **Figure 19** it can seen that the northern area of the study area has catchments with streams sourced off the London Clay and the associated sandier strata of the Whitecliff Sand and Nursling Sand Members. In contrast, the larger southern area is developed over the Wittering Formation (laminated clays) and the Earnley Formation (sands and silty sands). The Test Catchment to the southwest overlies a large area of River Terrace Deposits.

9.4 Surface water on the chalk rapidly filters downwards into the chalk aquifer and so valleys tend to be dry or only wet during extremely wet winters. The Lambeth Group is mainly clayey although some minor sandier layers occur. This means that some streams can arise from springs on these deposits but for the most part streams are fed by surface waters of the slowly permeable clayey soils which means that the streams can vary in level after rainfall.

9.5 Streams passing over the London Clay Formation have clayey valleys and are fed by drains taking surface water off the slowly permeable soils. This means that the flow varies considerably between rainfall storm events causing rapid flows after heavy rain and reduced flows during drier periods (ie. the streams are 'flashy').

9.6 The sandier strata within the London Clay Group, the Earnley Sand and White Cliff Sand members will contain perched ground water arising at the surface as springs and seepages and feeding many streams.

9.7 The large area of Wittering Formation has complex soils and geological lithologies and while the formation is primarily clayey, fine sandy layers within the clays contain small volumes of water and which, on suitable topography, gives rise to many small springs and seepages sourcing or feeding the streams.

Catchment descriptions

9.8 The **Tadburn Lake** stream arises as small spring fed streams and drains in the northeast of the study area off a small area of Whitecliff Sand to pass over the London Clay and so to the central belt of the Wittering Formation where it flow west towards the River Test developing a distinct floodplain.

Tadburn Lake Northern Catchment

9.9 The northern catchment arises ultimately off dry valleys from the chalk to the north of the study area with the streams developing over the slowly permeable London Clay and the laminated clays of the Wittering Formation.

9.10 The main northern tributary arises as a series of dry valleys off the chalk but rapidly flows south across the London Clay and the more sandy members of the London Clay Group towards the Tadburn Lake.

9.11 Other small tributaries arise off the London Clay Group with some minor streams arising off the Wittering Formation.

Tadburn Lake Southern Catchment

9.12 The catchment is located in the south over the sands and sandy silts of the Earnley Formation with the streams passing north over the laminated clays of the Wittering Formation with other smaller streams (including those feeding Emer Bog) arising directly off the Wittering Formation and passing northwards towards the Tadburn Lake.

Monk's Brook Catchment

9.13 The north-western part of the catchment arises as two stream systems occupying the eastern side of the study area. The northern-most stream arises off the Nursling Sand and Whitecliff Sand members of the London Clay and pass over the London Clay Formation while the southern tributary arises off the laminated clays of the Wittering Formation.

9.14 The south-western part of the catchment arises off streams variously off the Earnley Formation sands and silty sands, or off the laminated clays of the Wittering Formation.

Tanner's Brook catchment

9.15 The small northern part of the catchment with south flowing streams is located over a complex area of the Earnley Formation sands and silty sands and the laminated clays of the Wittering Formation.

River Test Catchment (excluding the Tadburn Lake)

9.16 The small area of the catchment included in the west of the study area has small streams arising variously off the sands and silty sands of the Earnley Formation and off a wide spread of sandy and gravelly River Terrace Deposits, some of which have been excavated for sand and gravel.

10.0 HYDROGEOLOGY

HYDROGEOLOGAL LAND CLASSIFICATION

Hydrogeology

10.1 Hydrogeology is the study of how water moves through geological materials.

10.2 Water falling as rain passes through permeable soil and geological materials and accumulates in permeable rock strata known as 'aquifers'. Water will rise within an aquifer up to the level known as the water table, the surface shape of which usually reflects the overlying landform. Impermeable strata which impede the flow of water are known as 'aquicludes'. Where groundwater sits on an impermeable layer, the water is said to be 'perched'. Where water flows underground between aquicludes, it is said to be 'confined' and may be under pressure. An aquifer that can be tapped for water is said to be 'productive'.

Aquifer types

10.3 Different types of aquifer are defined by the Environment Agency[21] as follows:

Principal Aquifers
These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer.

Secondary Aquifers
These include a wide range of rock layers or drift deposits with an equally wide range of water permeability and storage. Secondary aquifers are subdivided into two types:

Secondary A - permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

Secondary B - predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.

Secondary Undifferentiated - has been assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.

Unproductive Strata
These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

Groundwater vulnerability

10.4 The land above the different aquifers has been classified into datasets by the Environment Agency according to its groundwater vulnerability[22]. The Environment Agency websites explain that:

[21] http://apps.environment-agency.gov.uk/wiyby/117020.aspx
[22] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/414084/Groundwater_vulnerability_map_report.pdf

'*These datasets provide information on a range of soil properties such as moisture content, soil clay content and carbon content. Initial work found that the soil leaching class provided the best assessment of vulnerability*.'

10.5 The soil leaching classes used are:

• **High (H):** Soils of high leaching potential with little ability to attenuate diffuse source pollutants and in which non-adsorbed diffuse source pollutants and liquid discharges have the potential to move rapidly to underlying strata or groundwater.

Three subclasses are recognised:

- (H1) soils that readily transmit liquid discharges because they are either shallow, or susceptible to rapid flow;
- (H2) deep, permeable, coarse-textured soils that readily transmit a wide range of pollutants because of their rapid drainage and low attenuation potential; and
- (H3) coarse-textured or moderately shallow soils that rapidly transmit non-adsorbed pollutants and liquid discharges, but which have some ability to attenuate adsorbed pollutants because of their clay or organic matter content.

• **Intermediate (I):** Soils of intermediate leaching potential that have a moderate ability to attenuate diffuse source pollutants or in which it is possible that some non-adsorbed[23] diffuse source pollutants and liquid discharges could penetrate the soil layer.

Two subclasses are recognised:

- (I1) soils that can potentially transmit a wide range of pollutants; and
- (I2) Soils that can potentially transmit a wide range of pollutants and liquid discharges but are unlikely to transmit adsorbed pollutants.

• **Low (L):** Soils in which pollutants are unlikely to penetrate the soil layer because either water movement is largely horizontal or they have a significant ability to attenuate diffuse source pollutants.

10.6 **Figure 20** shows the Environment Agency's Bedrock Aquifer Designation according to the type of aquifer present. I have included both the main search area and the area to the north which includes the principal Chalk aquifer.

<u>Note that</u>: the map of groundwater vulnerability below in **Figure 21** uses an older classification of aquifers into Major and Minor types. The Environment Agency is in the process of updating their maps to take into account their revised aquifer types and these new maps are not yet available.

10.7 This map shows a principal aquifer (purple) in the north on the Cuckmere Chalk with large areas of unproductive strata (grey) on the London Clay.

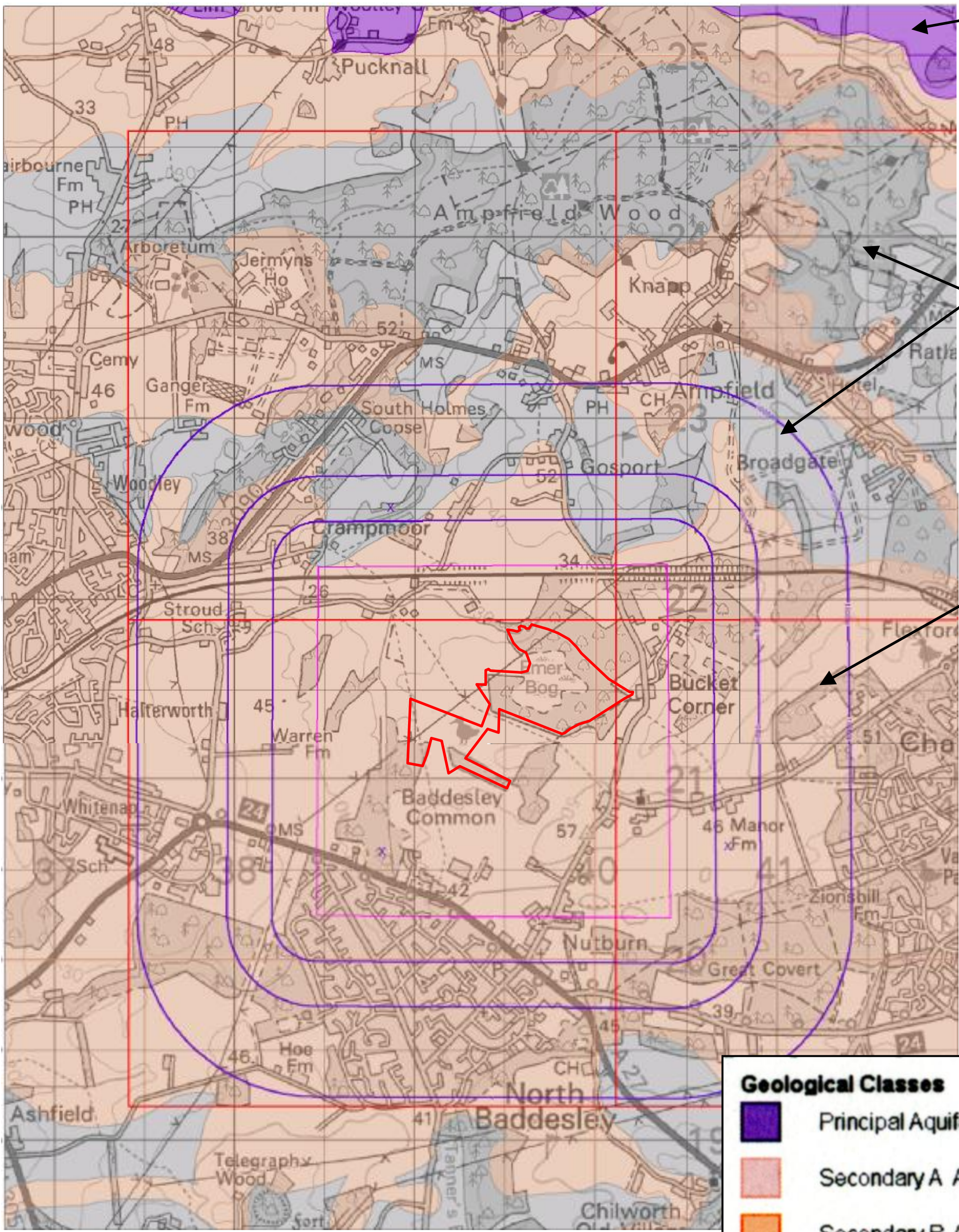
10.8 The largest area shown as pale brown and including Emer Bog and Baddesley Common and on the Wittering and Earnley Formations is indicated as being of Secondary A aquifer:

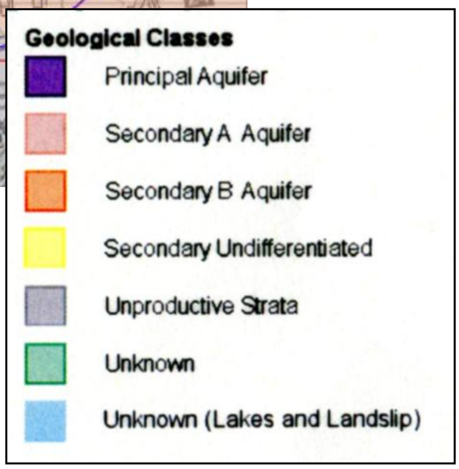
> *permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.*

<u>Note that</u> the Wittering and Earnley Formations are not distinguished on this map and it is likely that the Wittering Formation will have a lower permeability than the Earnley Formation.

[23] Adsorbed – being adhered to a surface. Non-adsorbed – not being adhered to a surface.

Bedrock aquifer designations





Principal Aquifer

Usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.

Unproductive strata

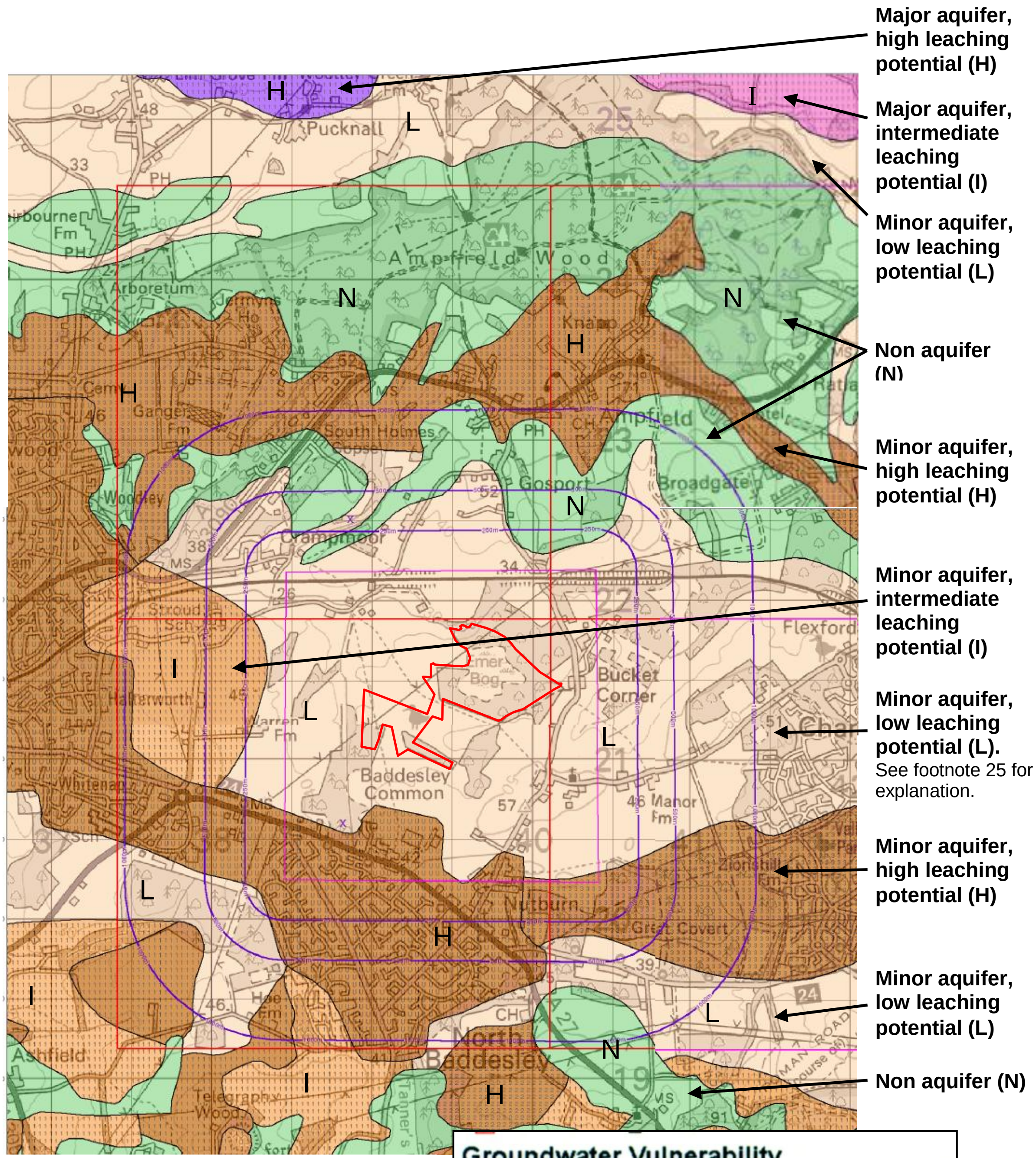
These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

Secondary A Aquifer

Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

Fig. 20 Environment Agency Bedrock Aquifer Designations.

Groundwater vulnerability



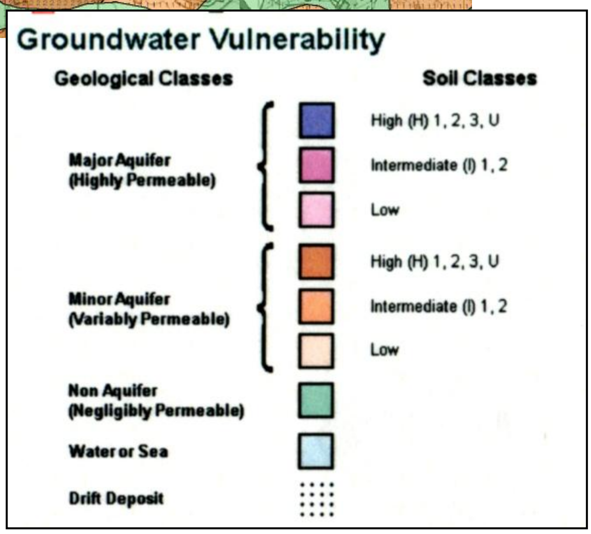


Fig. 21 Environment Agency Groundwater Vulnerability map

10.9 This map (**Figure 21**) is based on a variety of parameters, especially aquifer type and soil leaching potential (Soil Class).

10.10 Aquifer type and leaching potential are indicated on the side boxes. Soil Classes are shown as capital letters. Definitions are provided in **Sections 10.3** and **10.5** above.

10.11 A strip of land in the north is a highly permeable major aquifer with higher or intermediate leaching potential.

10.12 Coming successively south the land is shown as a variably permeable minor aquifer with low leaching potential (pale brown) or as non aquifer (green) with no leaching potential and with a central area of variably permeable minor aquifer and high leaching potential (dark brown).

10.13 Land in the central area, including Emer Bog and Baddesley Common is shown as a variably permeable minor aquifer with low leaching potential. [24]

10.14 Land to the south reverses the pattern with land variously of high, intermediate, low or no leaching potential.

<u>Note that:</u> Major Aquifer = Principal Aquifer and that Minor Aquifer = Secondary Aquifer A+B.

[24] This map is a fairly coarse interpretation of the geology and the large area of pale brown around Emer Bog and Baddesley Common and labelled L (and indicative of a minor aquifer of low leaching potential) in actuality combines an area of Wittering beds (of mostly of low permeability and leaching potential in the north and an area of Earnley Sand in the south of much greater permeability and leaching potential. While both comprise a minor aquifer, the two deposits have contrasted permeabilities.

11.0 HYDROGEOLOGICAL MODEL

11.1 Hydrogeology is that part of the earth sciences that deals with the distribution and movement of groundwater in the soil and rocks of the Earth's crust (commonly in aquifers).

11.2 This descriptive model combines topography, surface hydrology, geological and soil characteristics with aquifer characteristics and groundwater to describe the broad hydrogeological relationships of the study area.

11.3 The hydrogeology of the different catchments depends on the permeabilities and dip of the different geological substrates (see **Section 7**). The Tadburn Lake Northern Catchment has streams arising off dry valleys off the chalk but for the most part the Catchment is over slowly permeably clayey strata preventing groundwaters from the chalk rising into the surface streams. The Tadburn Lake Southern Catchment, Monks Brook and Tanners Brook catchments variously are formed over the laminated clays of the Wittering Formation (which gives rise to small springs and seepages) or over the sandier strata of the Earnley Sand which can provide a better source of spring water and locally perched groundwater.

11.4 By way of example, **Figure 22** provides a north-south geological cross-section through Emer Bog and Baddesley Common and indicates their geological bedrock aquifer characteristics and surface catchments.

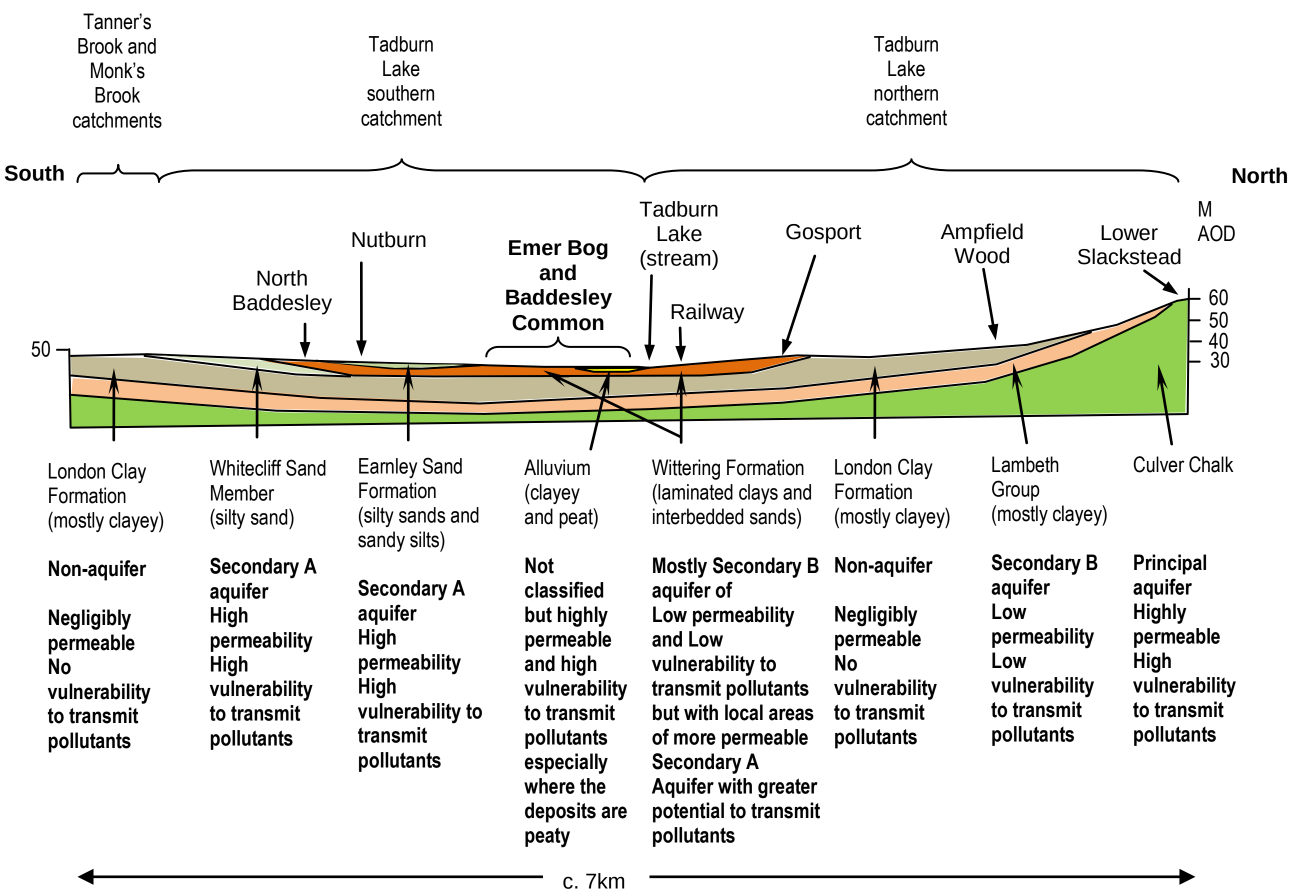


Fig. 22 Schematic geological cross section north-south through Emer Bog and Baddesley Common showing the arrangement of strata. Precise dip at Emer Bog and Baddesley Common is uncertain. Based on 1:50,000 scale geological map. Vertical scale exaggerated. Not to scale.

11.5 Working along the geological cross section from north to south:

11.6 The highly permeable **Culver Chalk** forms a principle aquifer that is overlain mostly by only shallow well-drained soils making the aquifer highly vulnerable to contamination or pollution from surface events. Surface water (from rain) will percolate through the soils into the chalk where it builds up as groundwater. The groundwater will flow according to pressures in the ground generally down the shallow dip of the strata. Where the chalk is covered by less permeable aquicludes, the water would be expected to be confined and under pressure.

11.7 The chalk is overlain by the mostly clayey strata of the **Lambeth Group**. The inclusion of thin sandy strata means that the deposit forms a minor aquifer capable of supplying water in some areas. However, there is unlikely to be much interchange between groundwater in the chalk and the Lambeth Group and so the Lambeth Group forms at best a weak aquiclude containing the chalk groundwater at depth.

11.8 Land over the **London Clay Group** can be complex. The mainly clayey strata of the **London Clay Formation** provide a very effective aquiclude preventing any water rising from the Chalk at depth below. However, included within the London Clay are much sandier strata, the **Whitecliff Sand Member** (mostly sand) and the **Nursling Sand Member** (mostly clayey sand and sandy clay). These sandy strata provide local aquifers, either from more permeable seams within the London Clay at depth or providing perched water sources where they occur at the surface.

11.9 The **Bracklesham Group** (Earnley and Wittering Formations) strata are also very complex.

11.10 The **Wittering Formation** comprises mainly laminated clayey and fine sandy clayey strata of low permeability; however, it also contains layers of fine sandy material that can hold small amounts of water and a borehole at Lights Copse (near Emer Bog) revealed sandy strata. Previous field investigations also showed sandier material on higher land south of Emer Bog.

11.11 This variability in lithology means that parts of the Wittering Formation are capable of very slowly transmitting small amounts of perched groundwater and which give rise to many springs and seepages where hillsides intercept the sandier strata. Sandy strata on higher land that rises to the south of Emer Bog is a likely source of seasonal spring and seepage water.[25]

11.12 The **Earnley Formation**, overlying the Wittering Formation, has permeable silty sands and sandy silts and can hold perched groundwater that often arises on hillsides and valley bottoms.

[25] While the area around Emer Bog and Baddesley Common is shown on Environment Agency maps as the less permeable Aquifer B (such as in Figure 21 above), there are areas that equate more with the permeable Aquifer A.

12.0 CHARACTERISTICS OF THE EMER BOG AND BADDESLEY COMMON CATCHMENTS

SURFACE WATER CATCHMENT BOUNDARY

Map derivation and catchment discussion

12.1 The maps in **Figures 23 and 25** have been derived from the catchment map **(Figure 6**) in **Section 6**.

12.2 These two figures illustrate more clearly the catchments Emer Bog, Baddesley Common and of the Tadburn Lake southern tributary and their separation from the surrounding catchments of the Test Valley, Tanner's Brook and Monk's Brook.

12.3 The catchment of Emer Bog and Baddesley Common is shown in a darker blue shade bounded by a red broken line and it can be seen that the Emer Bog and Baddesley Common occur in two separate small catchments.

12.4 **Emer Bog** has a well defined but small catchment also forming the NE sub-catchment of the Tadburn Lake Southern Catchment.

12.5 **Baddesley Common** is part of the SW sub-catchment of the Tadburn Lake Southern Catchment and particularly that part alongside the Baddesley Common Stream and which is a tributary of the Tadburn Lake southern tributary.

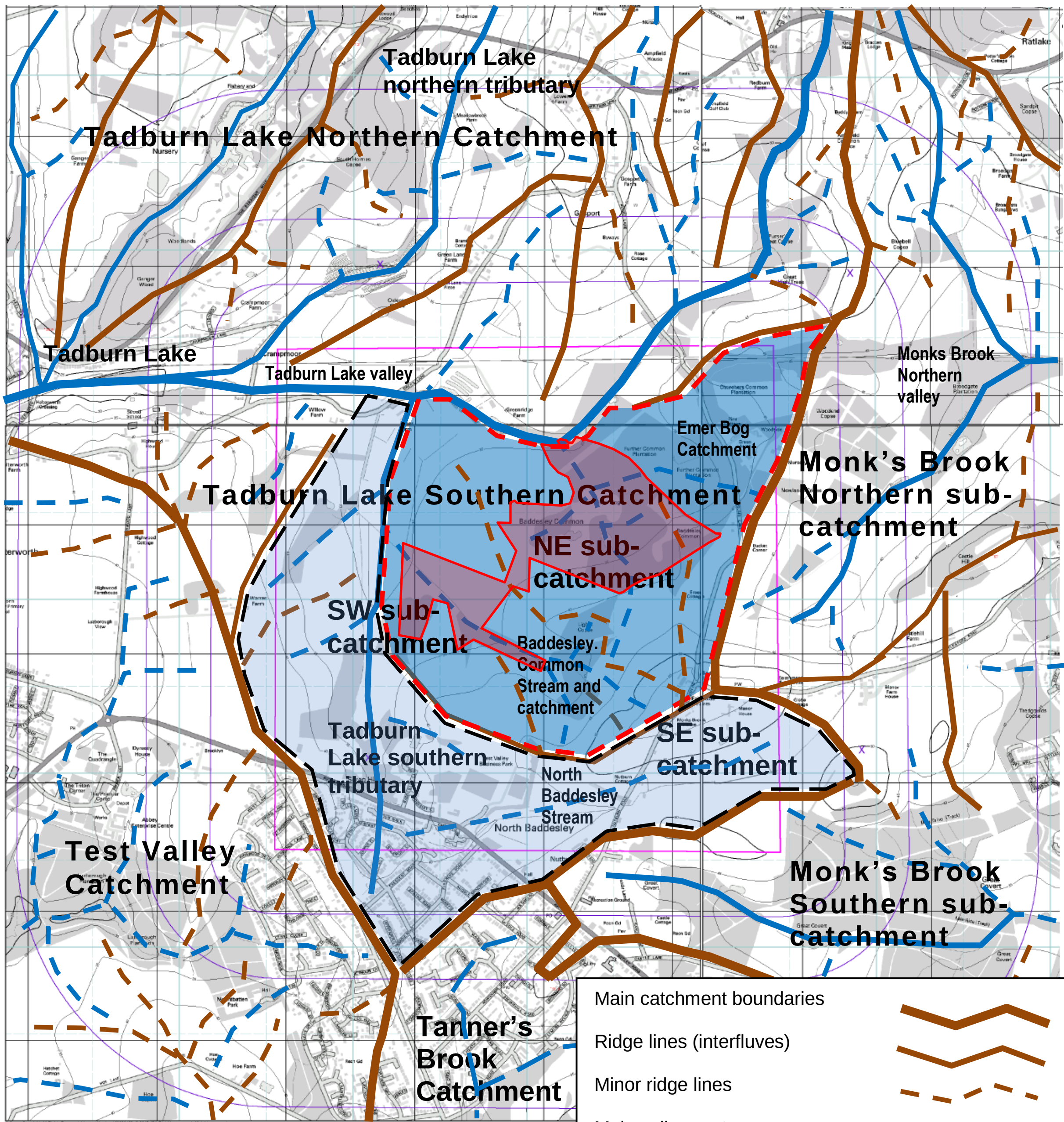
12.6 The catchment of the **Tadburn Lake Southern Tributary** (excluding Emer Bog and Baddesley Common) is shown in a paler blue tone (bounded by a broken black line) and which also forms a significant part of the SE sub-catchment of the Tadburn Lake Southern Catchment.

12.7 It is the darker blue area that forms the most critical hydrological zone for Emer Bog and Baddesley Common.

12.8 **Figure 24** shows the flow directions of the various streams and flow-ways and provides names where this is helpful.

Catchment map

12.9 **Figure 23** shows that part of southern surface water catchment of the Tadburn Lake which is critical to the hydrology of Emer Bog and Baddesley Common.



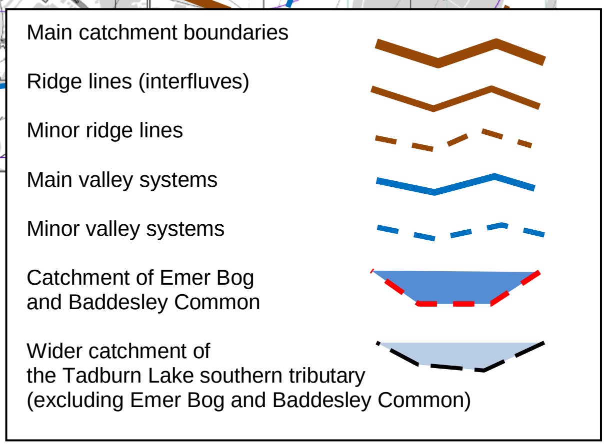


Fig. 23 Catchment containing Emer Bog and Baddesley Common superimposed on the surface drainage map.

Surface water flow routes[26] given extreme rainfall

12.10 On **Figure 24**, I have taken an extract from the Environment Agency's Surface Water 1000 Year Return Velocity and Flow Direction Map for the immediate area around Emer Bog and Baddesley Common and added the catchment and sub-catchment boundaries, to provide a clear view of the way water flows across and around the site given extreme rainfall events, the worst case scenario. The map clearly shows the flow-ways[27] across the site.

12.11 The surface flows into and through Emer Bog and Baddesley Common are divided between the two parts of the site:

- Emer Bog itself is contained within the small Northeast sub-catchment of the Tadburn Lake Southern Catchment.
- Baddesley Common is fed by the Baddesley Common Stream flowing through a separate minor sub-catchment within the Southeast sub-catchment, the stream feeding the Tadburn Lake Southern Tributary.

Surrounding this system to the west and southwest is the:

- Tadburn Lake southern tributary fed by its upstream tributary, referred to here as the North Baddesley Stream. The North Baddesley Tributary Stream passes through North Baddesley and may be partly culverted before joining the main Tadburn Lake Southern Tributary.

Broader catchment affecting Emer Bog and Baddesley Common

12.12 On **Figure 25** I have shown in pale blue (enclosed by broken black lines) that part of the Tadburn Lake southern catchment that excludes Emer Bog and Baddesley Common.

12.13 This area is clearly defined by the boundaries of the Monk's Brook, Tanner's Brook and the Test Valley catchments and by the Tadburn Lake stream which area is modified by two small ridge lines separating surface flows away from Emer Bog and Baddesley Common.

12.14 As well as the valley systems and associated streams this area includes a large area of the Wittering Formation which provides slow seepage groundwater to Emer Bog.

Critical catchment affecting Emer Bog and Baddesley Common

12.15 On the same **Figure 25**, I have shown in darker blue (enclosed by narrow red broken lines) a smaller area of land that is immediately critical to Emer Bog and Baddesley Common.

12.16 This area includes all land between enclosing ridges to the east and south and also the watercourses of the Tadburn Lake (to the north) and its main southern tributary to the west.

12.17 This land includes: a) the stream that passes through Baddesley Common and its upstream tributary source streams; and also b) the surface water catchment of Emer Bog and the immediate land over the Wittering Formation that is likely to supply groundwater to the Bog.

12.18 This smaller area excludes the western part of the southwest catchment of the Tadburn Lake southern tributary and also its feeder stream to the southeast (in the Southeast sub-catchment). This exclusion is because these streams appear to circumvent the critical valley forms feeding Emer Bog and Baddesley Common.

[26] Flow-routes shown are the routes that water would take in extreme 1000yr events.
[27] I have used the term 'flow-way' to denote the land over which surface water would flow during extreme rainfall (1:1000yr) events. These are valley systems that do not necessarily support permanent streams, parts of which may remain dry for long periods.

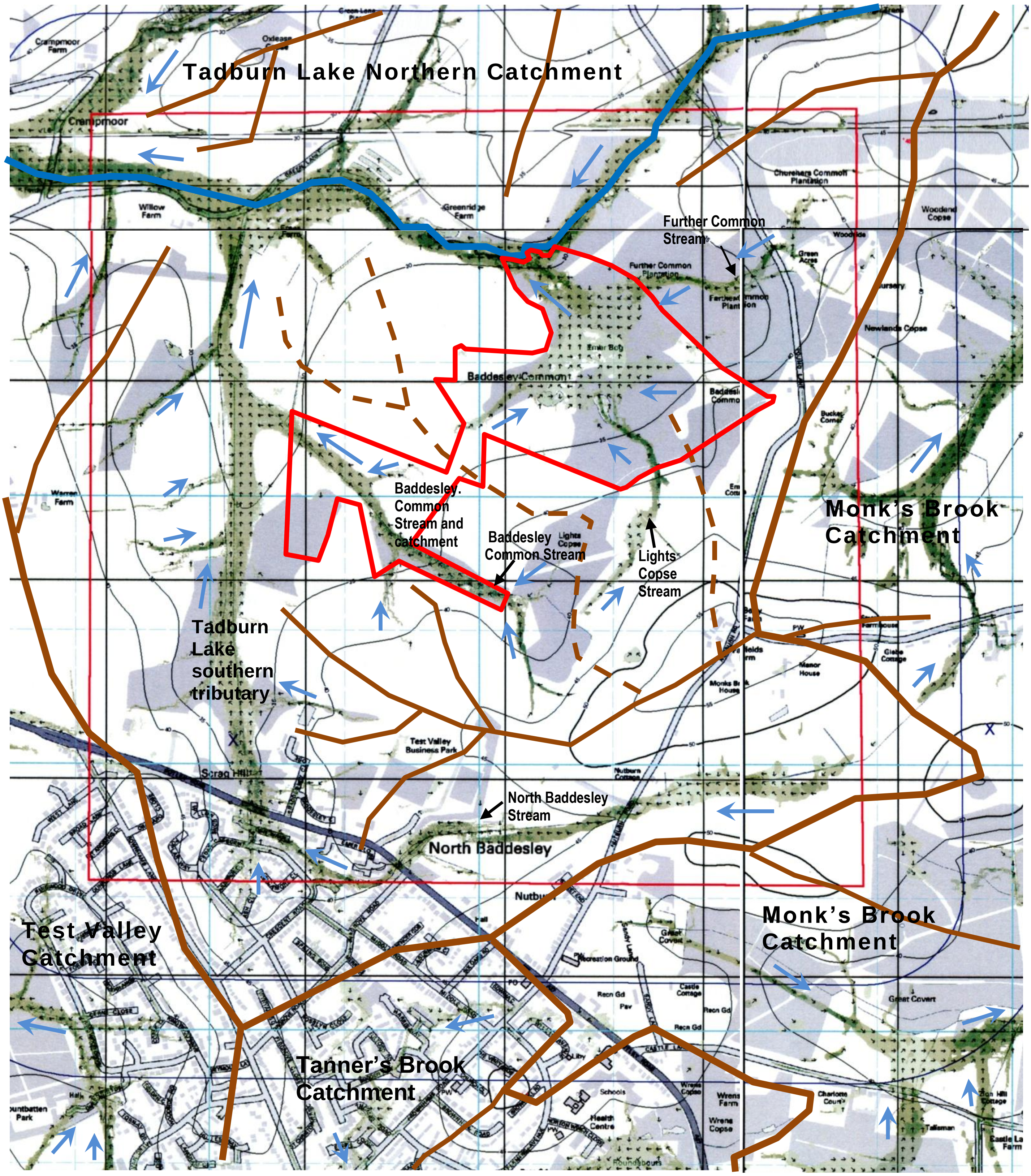


Fig. 24 Catchment boundaries superimposed on the EA 1000 year return flow direction map for the immediate area of Emer Bog and Baddesley Common. Green areas indicated land subject to flows in the direction of the small arrows. I have added larger blue arrows to clarify the flow directions.
A key to catchment boundaries is in Figures 23 and 25.

<u>Note that</u> these flow directions are computer generated and do not allow for local drainage redirections such as the perimeter drains around Emer Bog or along culverted stream sections in urban areas. In reality, the Further Common stream is diverted around a boundary drain before reaching Emer Bog.

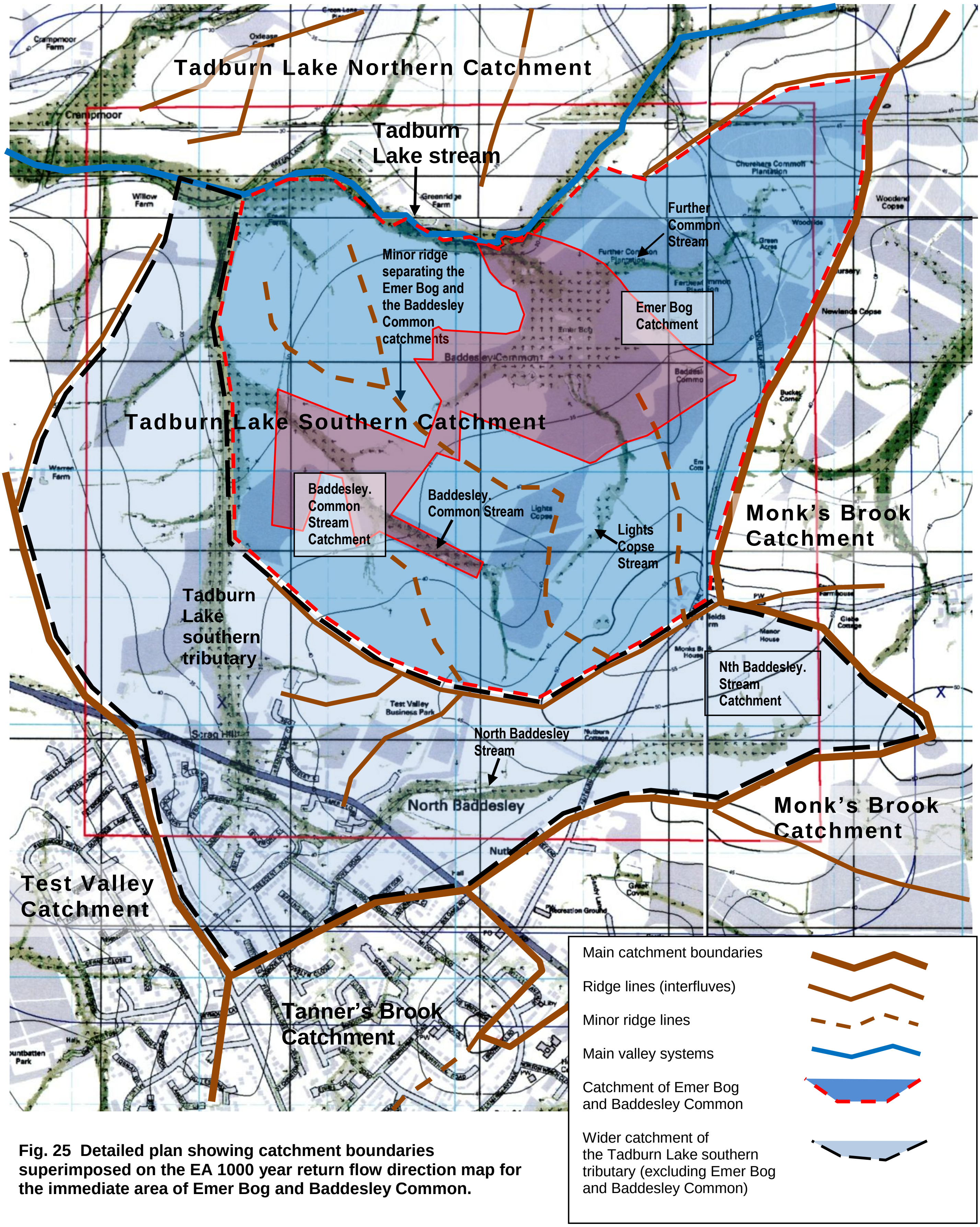


Fig. 25 Detailed plan showing catchment boundaries superimposed on the EA 1000 year return flow direction map for the immediate area of Emer Bog and Baddesley Common.

Sources feeding Emer Bog and Baddesley Common

12.19 On **Figure 26** I have numbered the flow-ways[28] leading into the site for ease of reference. Flow-ways 1-4 feed the Baddesley Common Stream (5) and flow-ways streams 6-9 feed Emer Bog (10). **Figure 27** shows these same lines superimposed on an aerial photograph to show land-use around the flow-ways.

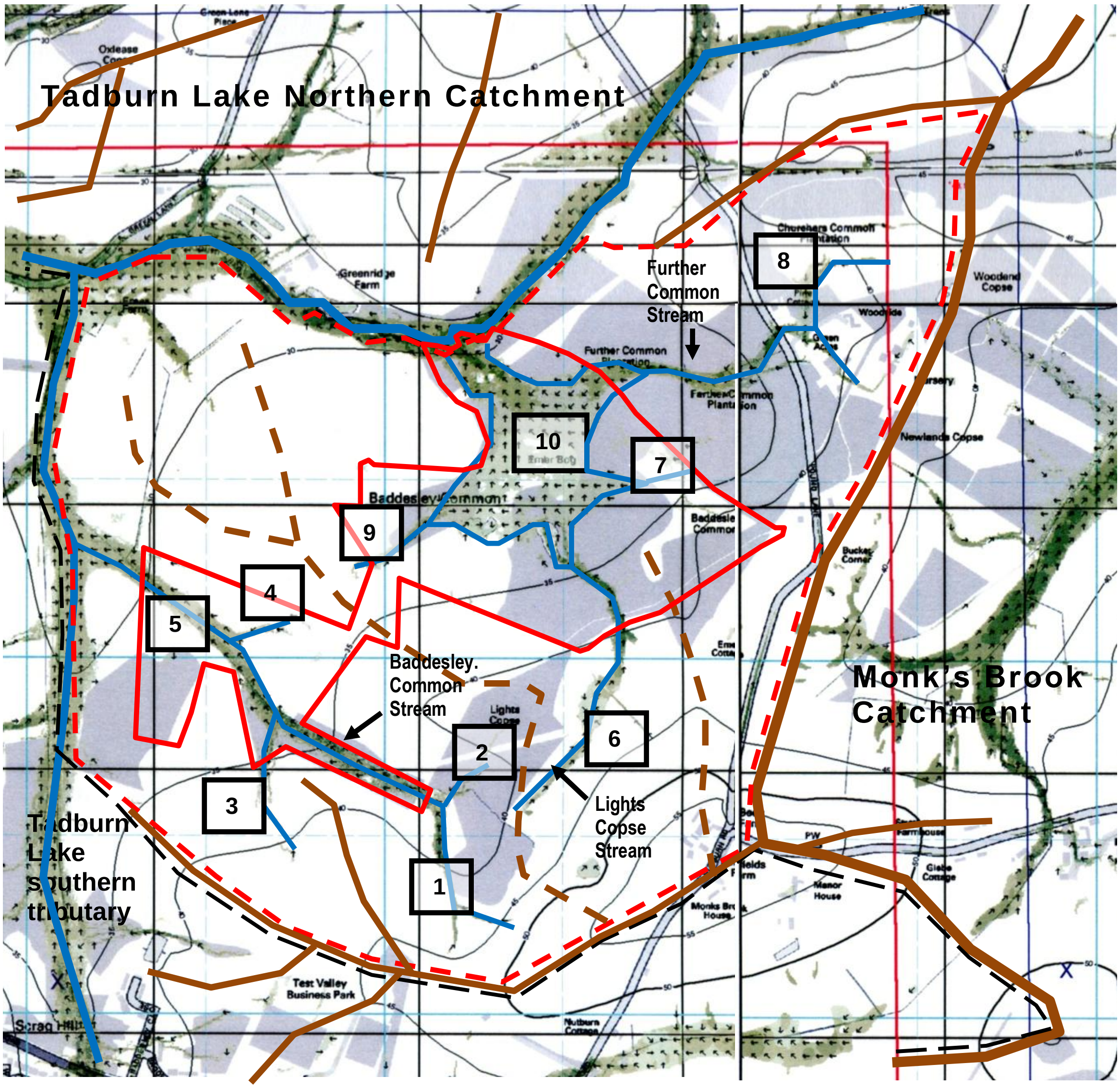


Fig. 26 Numbered tributary flow-ways feeding Emer Bog and Baddesley Common. A key to catchment boundaries is provided in Figures 23 and 25.

[28] I have used the term 'flow-way' to denote the land over which surface water would flow during extreme rainfall (1:1000yr) events. These are valley systems that do not necessarily support permanent streams.

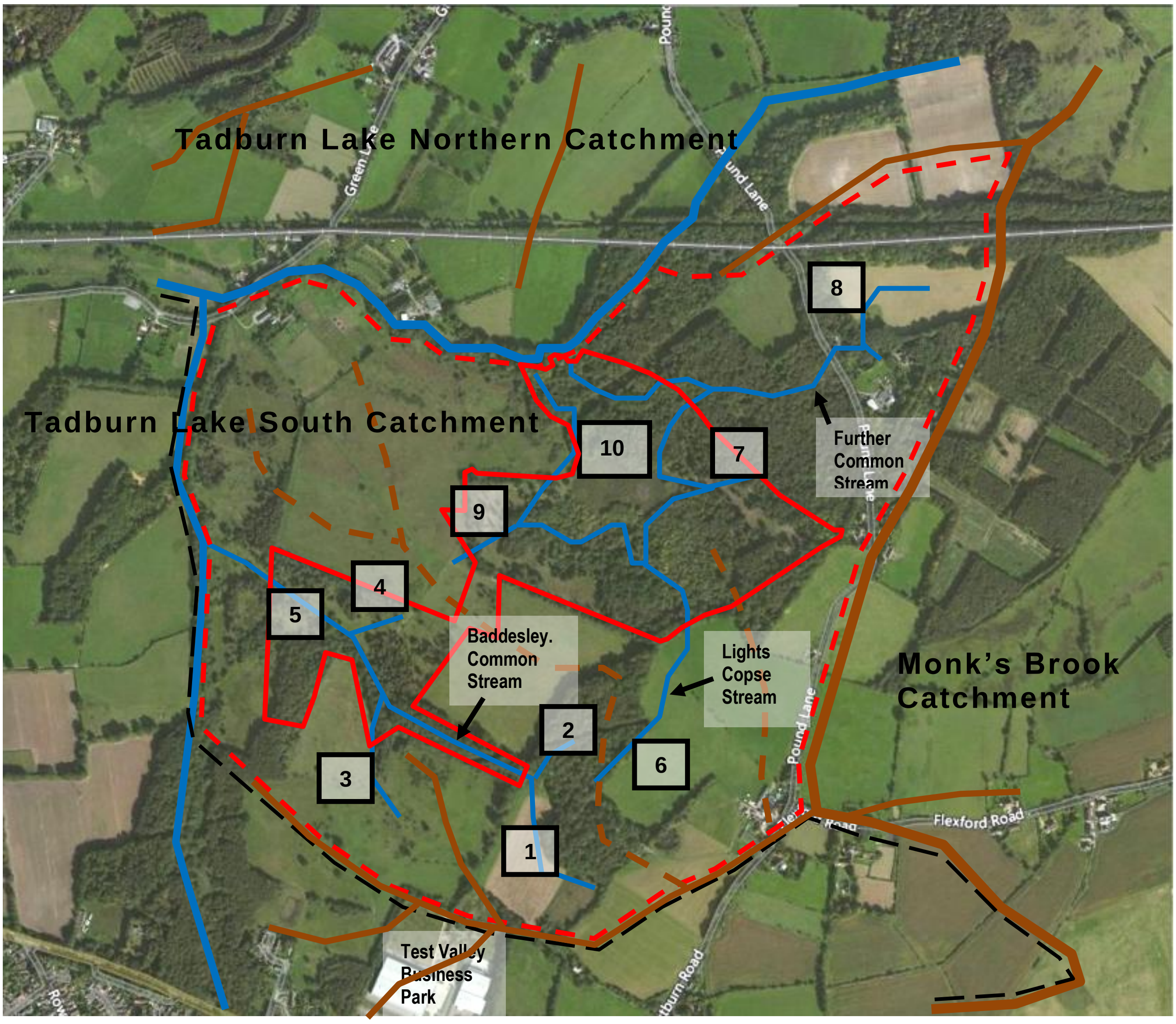


Fig. 27 Numbered tributary streams/flow-ways feeding Emer Bog and Baddesley Common superimposed on an aerial photograph.

12.20 From **Figures 26 (map) and 27 (aerial photograph)** it can be seen that:

12.21 The Baddesley Common stream (5) is sourced from:

- a tributary from the southeast arising off arable and grassland (1);
- an adjoining tributary in the northeast arising off woodland (2); and
- two further tributaries arising from the north and south off grassland (3+4).

Note. The Test Valley Business Park is close to tributary 3 of the Baddesley Common Stream.[29]

12.22 Emer Bog (10) is sourced from:

- a stream to the south arising off woodland at Lights Copse and through grassland (6) the Lights Copse Stream;
- a small stream arising off woodland in the east (7);
- a stream arising off arable land and passing through woodland to the northeast (8), the Further Common Stream[30] although diverted around the bog by a boundary drain; and
- a small stream arising off grassland to the southwest (9).

[29] Small streams have been given names purely to enable identification in this report.
[30] This stream meets the boundary drain to Emer Bog and flows divert north rather than into the Bog.

CATCHMENT CHARACTERISTICS OF EMER BOG, BADDESLEY COMMON AND SOURCE FLOW-WAYS

The joint catchments

12.23 From the preceding sections, the desk study sources indicate that the **joint catchment** of both Emer Bog and Baddesley Common is located over land that is:

1. within the southern catchment of the Tadburn Lake, a tributary stream of the River Test (**Figure 6**);
2. contained within two adjacent sub-catchments (**Figure 23**):
    a. that containing Emer Bog draining north to the Tadburn Lake stream and
    b. that containing Baddesley Common draining west to the Tadburn Lake southern tributary;
3. not at risk of flooding from rivers, although the Tadburn Lake southern tributary is at flood risk within its floodplain (**Figure 9**);
4. at negligible risk of groundwater 1 in 200yr flooding events (**Figure 10**);
5. not susceptible to groundwater flooding except in certain flow-ways such as along the Baddesley Common Stream and the lowermost areas of Emer Bog (**Figure 11**);
6. located over the Wittering Formation, a geological stratum of clays and fine sandy clays but containing thin layers and inclusions of fine sand; with small areas of alluvium along the Baddesley Common Stream and within Emer Bog(**Figures 12-15**);
7. on land with predominantly seasonally waterlogged loamy over clayey soils with impeded drainage, although soils on alluvium and peat may be subject to seasonally high perched groundwater (**Figure 18**);
8. underlain by a Secondary Aquifer most likely to be of low permeability and storing water in localised thin permeable horizons and of low leaching potential (**Figure 20**);
9. subject to the slow transmitting of small amounts of water in sandy layers sufficient to give rise to springs and seepages on hillsides; and
10. on land where surface water flows, arising off seasonally waterlogged soils, pass overland along minor flow-ways to small (often seasonal) streams.

Baddesley Common catchment characteristics

Surface Water Hydrology

12.24 The general area of Baddesley Common (including the nature reserve area) comprises gently undulating land with low ridges between which several minor valleys and flow-ways collect water from off the seasonally waterlogged soils. These seasonally wet flow-ways pass the water to the Baddesley Common Stream and flows northwest forming a tributary of the larger Tadburn Lake Southern Tributary.

12.25 From **Figures 26 and 27**, it can be seen that the Baddesley Common stream (5) is sourced from:

- A tributary from the southeast arising off arable and grassland (1);
- An adjoining tributary in the northeast arising off woodland (2); and
- Two further tributaries arising from the north and south off grassland (3+4).

Groundwater hydrology (hydrogeology)

12.26 The Wittering Formation is a secondary aquifer primarily of low permeability but with fine sandy layers capable of supplying small quantities of water and providing small local areas of perched groundwater. It is possible that some of this water enters the streams or provides small seepages on low angle slopes.

Emer Bog catchment characteristics and internal flows

Surface Water Hydrology

12.27 Emer Bog is located in a low-lying bowl-shaped area of land open to the north. Four feeder flow-ways reach the wet area of Emer Bog from the southeast, east, northeast and southwest directions, each flow-way opening out towards the bog giving the bog a star-shaped outline. These flow-ways are only significant in wet winter conditions, the southeast flow-way being the most significant.

12.28 The hydrology of the nature reserve area of Emer Bog has been described in detail in Allen (2003)[31] and **Figure 28** showing Surface Drainage is taken from that report. This map was based on detailed site survey based on an accurate and specially commissioned topographic survey from which it is possible to locate site hydrological features in detail. The report indicated that:

- Land within and around Emer Bog is underlain by slowly permeable clays and sandy clays that give rise to seasonally waterlogged soils.
- Extensive areas of wetland have developed over an upper and a lower peat basin.
- Water is sourced from a small catchment via seasonal streams, springs and seepages and also from perched groundwater within the peat bodies. Slow lateral flows through sandier seams and deposits on higher ground to the south give rise to seasonal springs feeding the wetlands.
- Water levels in the wetlands vary seasonally with winter flooding reduced in summer by drainage to the north and/or slow downward percolation.

Relationship of external surface water flow-ways to Emer Bog

12.29 Comparing the Emer Bog hydrological map (**Figure 28**) with the catchment flow-ways map (**Figure 26**) indicates a high degree of correlation. I have added the flow-way numbers from **Figure 26** to the Emer Bog map (**Figure 28**) for ease of comparison. Red arrows indicate the main (seasonal) surface water flow routes through and around Emer Bog.

12.30 From **Figures 26 and 28**, it can be seen that Emer Bog is sourced from:
- a stream to the south arising off woodland and through grassland (6);
- a small stream arising off woodland in the east (7);
- a stream arising off arable land and passing through woodland to the northeast (8); and
- a small stream arising of grassland to the southwest (9).

12.31 Detailed 2003 field mapping demonstrated that the flow-ways do not simply provide a direct source of stream water into Emer Bog, but that there are varied sources around the perimeter of the site that are fed by these flow-ways. **Some of these flow-ways feed boundary drains and may not source Emer Bog. All of these boundary sources appear to be seasonal and may only become active after prolonged winter rainfall.**

12.32 **The main external seasonal source of water into Emer Bog is from the southeast off flow-way 6 via a small stream leading northwest and feeding the East Pond. Flow-way 9 provides a seasonal source of surface water from the southwest. Flow-ways 7 and 8 appear to have little impact on the surface water-sourcing of Emer Bog.**

[31] Surface water quality and hydro-ecological regime of Emer Bog cSAC. R H Allen 22 April 2003.

12.33 Along the south-eastern boundary, Flow-way 6 is main source of surface water into Emer Bog. Water enters the site here at two adjacent locations: Streams A and B:

Main south-western inflow Stream A
via:
- a small pool outside of the boundary feeding into a boundary ditch;
- a field under-drain feeding into the boundary ditch from a broken headwall; and
- surface flows off the field.

This drain feeds East Pond within the reserve, the outflow from which pond flows north and disperses into the main area of open fen/mire[32].

Secondary southern inflow Stream B
via:
- a woodland drain;
- a field under-drainage brick outfall; and
- a boundary drain.

This small drain feeds into the reserve and from where water disperses in the general direction of the main inflow stream and so to East Pond.

12.34 Along the eastern boundary at flow-way 7, any surface water arising off adjacent woodland passes to a boundary drain that fills in winter and takes water north-northwest along the north-eastern boundary of Emer Bog. There is no clear point of surface water entry to Emer Bog from this flow-way, other than perhaps minor seepage through the drain channel.

12.35 Along the north-eastern boundary at flow-way 8, water off the flow-way meets the Emer Bog boundary drain, passing water northwest towards the Tadburn Lake stream. At this point, water off the bog also enters the boundary ditch and flows northwest. This means that water off this flow-way is intercepted and in normal conditions does not flow into the Bog. Indeed, the boundary ditch here accepts water arising off the Bog and so provides a bog-water exit point. Given extreme storm conditions however, it is possible that water off flow-way 8 could overflow the drain and enter Emer Bog.

12.36 Along the south-western boundary at flow-way 9, surface water appears to feed the south-western boundary drain along which flows are to the northwest before being diverted east to feed a complex of seasonal pools within willow carr and which in turn feed water into the main open fen/mire.

12.37 Within the Emer Bog reserve, the south-eastern and south-western sources feed the open fen/mire (outlined as a green broken line on **Figure 28**).

Outflows from the open fen/mire

12.38 Two internal flow-ways lead away from the open fen/mire, the main flow-way being to the northwest and so to the Tadburn Lake stream, the lesser flow-way being to the north and feeding the north-eastern boundary drain and so indirectly to the Tadburn Lake to the north.

[32] I have used the term fen/mire because both terms ‘fen’ and ‘mire’ have been variously used for the open area. A fen can be considered as a type of mire.

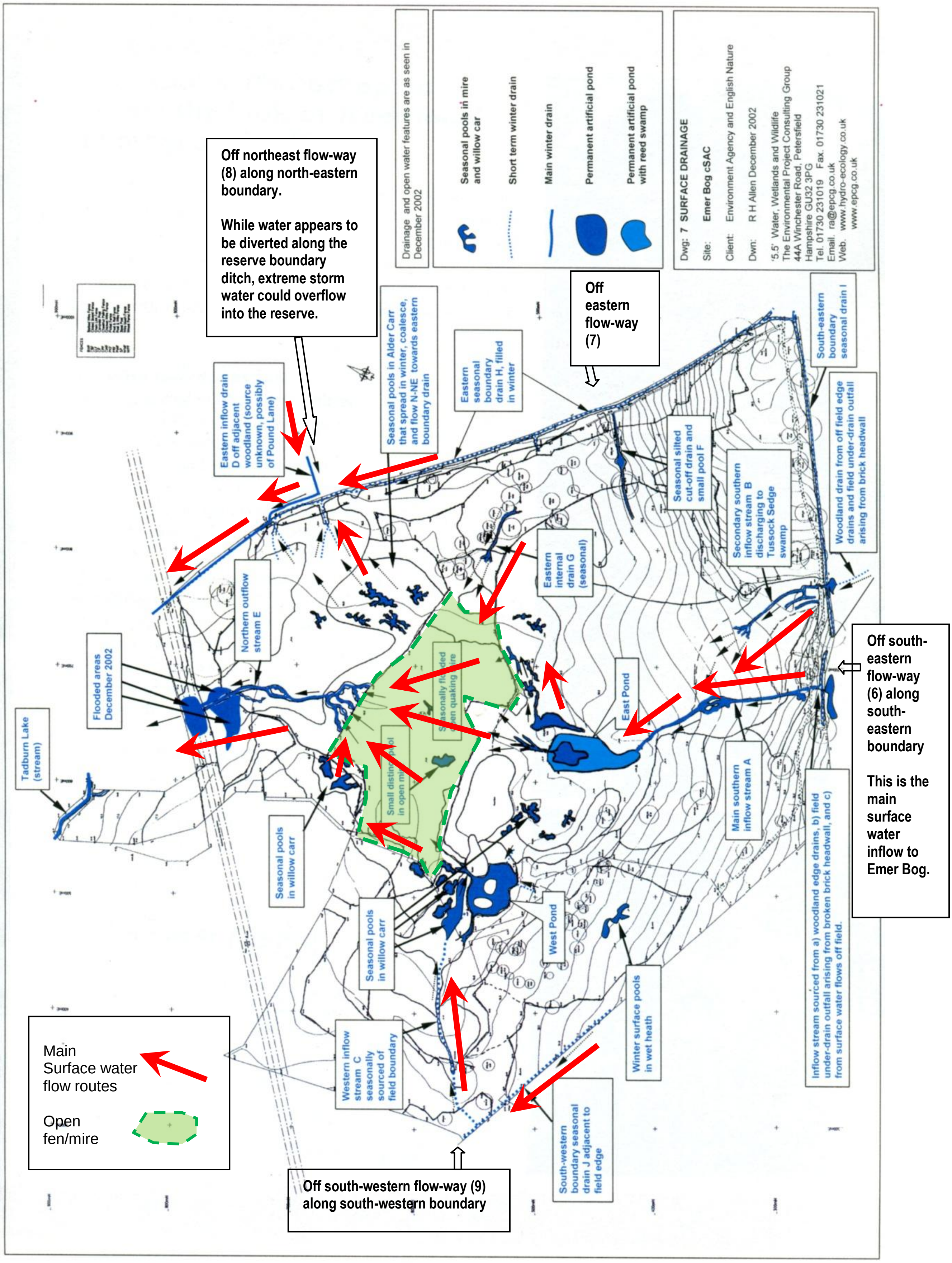


Fig. 28 The Emer Bog hydrological map (showing the situation in 2002) annotated to show off-site flow-ways (boxes on boundary), internal flow directions (red arrows), and the area of open fen/mire (green area).

Groundwater hydrology (hydrogeology)

12.39 It seems unlikely that all of the water in Emer Bog is sourced from the seasonal boundary flow-ways. Instead, a high proportion of the water sourcing the wetlands (wet woodland and open fen/mire) is most likely to be fed from groundwater held within sandy seams within the Wittering Formation.

12.40 The dip of the strata is very low and given the synclinal structure of the area, the dip below Emer Bog is likely to be very gently to the south and so flows through the Wittering Beds (albeit very slowly) are likely to be to the south. Allen (2002)[33] suggests that:

> '*In relation to Emer Bog, given that the dip is very gentle, it is likely that the detailed disposition of sandier seams within the Wittering Formation is more important in determining the direction of locally confined groundwater flows.*'

12.41 Topographically, Emer Bog is on land that slopes at first moderately steeply from the south at about 25-30m AOD and then levels off just above the main area of open fen/mire at 18m AOD and reaches the Tadburn Lake at about 17m. Within this area are two main peat basins, one set into the sloping land west of East Pond and the other in the north central area of the reserve (see **Figure 29**).

12.42 It is very likely that:

- The wooded upper peat basin is fed predominately by northerly slow-flowing groundwater emerging as seepages on the sloping land.

- The lower peat basin below the open fen/mire appears to be fed both by water seeping off the upper wooded mire and by perched groundwater held above the underlying Wittering Formation. There is the possibility that some groundwater may rise into the more level open fen/mire area from sandy layers within the Wittering Formation, especially during wet conditions.

FERTILITY AND SURFACE WATER CHEMISTRY OF EMER BOG

Fertility

12.43 Wheeler and Shaw (March 2003)[34] discuss the fertility of samples taken at Emer Bog. Two soil samples (from an area of S27[35] vegetation towards the western end of the open basin and from a patch of M5[36] near the eastern end of the open basin) were taken on 20 August 2002. Replicate soil samples were collected for phytometric assay, which used the test species *Phalaris arundinacea* grown on the samples in standard conditions for 10 weeks.

12.44 As a result of these studies, Wheeler and Shaw indicate that:

> *'The substratum here is extremely fertile. The value for S27 is almost three times the national average for this community whereas that for M5 is more than twice the national average for this community. Moreover, the values for S27 put this sample in the top 2% of the fertility scale for all the samples assayed from UK fens.'*
>
> *'There is no doubt about the high fertility of this mire, but the cause remains unknown.'*

12.45 Wheeler and Shaw conclude that:

> ***'There really is a problem here, but at present its nature is not really known.'***

[33] Investigation into the water quality and hydro-ecological regime of Emer Bog cSAC. Emer Bog cSAC: Review of Consents. R H Allen 6 March 2002.
[34] Fertility Determinations at Emer Bog Interim Draft Report B D Wheeler and S C Shaw, Department of Animal and Plant Sciences, University of Sheffield March 2003
[35] S27 *Carex rostrata - Potentilla palustris* tall-herb fen. For more information see also in the Glossary Section 3.
[36] M5 *(Carex rostrata - Sphagnum squarrosum mire* For more information see also in the Glossary Section 3.

Water chemistry

12.46 Allen (2003)[37] provided a detailed account of water chemistry of the bog based on various sampling dates between 1996 and 2002. **[38]**

12.47 This report concluded (Sections 8.0 and 9.0) that:

- Water in the mire and associated wetlands varies from strongly acidic to mildly alkaline and is rich in phosphorus and nitrogen creating highly fertile conditions.
- Phosphorus and nitrogen levels are both high in open water habitats suggesting possible enrichment.
- Phosphorus levels are particularly high in the mire surface waters although the high levels of nitrogen (compared to open waters) are likely to be derived from natural processes operating within the mire and may or may not be indicative of enrichment.
- High nutrient levels in the mire water are likely to be mostly generated within the mire system with only small inputs from surface waters arising from agricultural land outside of the site. The reasons for high nutrient levels remain unknown although it could be the result of accumulations from off agricultural land over time.

12.48 The evidence from Allen (2003) is that the system appears to be both hydrologically and hydrochemically dynamic and that it is only possible to surmise as to the causes of change.[39]

12.49 Further, it is not clear if the changes observed during different sampling periods reflect normal variation in the mire or reflect distinct changes caused by external influences.

Acidity

12.50 Surface water in the wetlands and open waters vary from strongly acidic to mildly alkaline. Evidence is that the bog was more acidic in 1996 than 2001. However, the system is complex.

12.51 Examination of the drawings in Allen (2003) indicated that in November 1996 the pond waters were slightly acidic and the open fen/mire was mildly to moderately acidic while in August 2002 the pond waters and the main flow-ways through the fen/mire were circum-neutral. In December 2002 the conditions were more intermediate with most of the fen/mire area being slightly acidic

12.52 **It may be that summer drying and presence of acidifying *Sphagnum* bog-mosses may restore acidity in the soils every summer only to be replaced by less acidic and more nutrient rich conditions as the area becomes wetter during the winter.**

Alkalinity

12.53 August and December 2002 sampling showed that there was a belt of high and very high alkalinity (ie. water rich in calcium) arising from the source stream B, passing through East Pond and on through the fen/mire to the stream exiting towards the Tadburn Lake stream. This probably explains the high acidity values at the same time.

[37] Surface water quality and hydro-ecological regime of Emer Bog cSAC. R H Allen 22 April 2003.
[38] This study only examined surface waters. A more detailed study to include interstitial water held within the substrate rooting zone would provide additional information about the site's fertility. The chemistry of small pools of shallow water are likely to be influenced by the chemistry of the surrounding sediments and while not directly comparable with larger open water bodies, they do provide conditions for particular plant and animal communities adapted to them.
[39] Wheeler and Shaw (March 2003) in Peer Review of a draft of the April 2003 report make helpful suggestions on the interpretation of the water chemistry data. I have incorporated their cautionary notes into this report.

Phosphorus

12.54 Phosphorus chemistry in mires and fens with shallow water is complex and wetland plants may be taking up phosphorus from a rooting zone within substrate sediments and algae will be taking up phosphorus from the open water. To complicate matters, there may be interchange of phosphorus between the solid state in sediments and the soluble state in waters depending on the reduction/oxidation state of the sediments, temperature, wind disturbance and also from turbulence resulting from water flows or heavy rainfall. These environmental conditions change seasonally leading to contrasted winter and summer phosphorus values.

12.55 Total phosphorus from filtered water samples in August and December 2002 was very high in fen/mire and wet woodland with values indicative of possible enriched conditions.

12.56 Orthophosphorus (as total reactive phosphorus) December 2002 values were also very high and mostly above the ecological threshold level (for headwater rivers in the absence of threshold values for mires), the level at which detrimental changes can occur and cause increasing habitat vulnerability. However, August 2002 levels in the source streams A and B and in the two lakes were much lower than in the fen/mire indicating that phosphorus levels were sourced from within in the fen/mire rather than from the inflowing streams. By December 2012, levels of reactive phosphorus had reduced, perhaps indicative of flushing by higher winter water levels and flows.

Nitrogen

12.57 Nitrogen occurs in many forms and as nitrate can arise from fertiliser sources and as ammonia can also be generated within bodies of peat and organic soils. Total inorganic Nitrogen levels (Nitrate+Ammonia N) were higher in August 2002 (often with high ammonia) than in December 2002 when total inorganic nitrogen levels had decreased. This decrease may be a result of dilution by flushing from higher winter water levels and flows and reduced effect from interchange with substrate conditions.[40]

12.58 In relation to plant communities, Allen (2003) suggests that:

> '***The varied chemistry of the water, both in seepages and across the flooded ground in winter, has led to the development of a suite of plant communities that are dependent upon groundwater conditions and on soil and peat conditions. The soils appear to be naturally acidic and so it is only when the site becomes flooded in winter with less acidic groundwater, that the complex water relations of the site become apparent***.'

[40] Wheeler and Shaw 2003 note that many mires can have high N values, not necessarily the result of enrichment.

HYDROLOGICAL CONCEPTUAL MODEL FOR EMER BOG

12.59 The text box to Drawing 24 in Allen (2003) (Box 3) sets out a conceptual model for Emer Bog. The full Drawing 24 is scanned in **Figure 29** [41] and on which I have indicated the two peat basins and the area of open fen/mire.

> Emer Bog sits within a bowl-like structure on the Tertiary Wittering Formation, open to the north, and that rises 13m from the out-flowing stream to the highest point on the SSSI. The basin contains a lower mostly level area underlain by up to 2m of peat and a higher gently sloping area containing further peat. The peat is more permeable than the underlying Tertiary substrate and so controls the flow of water across the site.
>
> Surface inflows from the south and west arise from agricultural drains and under-drainage outfalls. In winter, these flows pass in irregular shallow channels into and across the upper peat basin to artificial ponds and on into the open mire and lower peat basin. Further flows arise from springs in the east. These water sources recharge shallow perched water within the two peat bodies, and which are acidic to the east and slightly acidic to circum-neutral in the south and west. Water outflows through a northern channel and (in wet weather) from easterly surface flows, and ultimately reaches the Tadburn Lake stream. The peat upper basin is also likely to be fed by seepages off the underlying Tertiary deposits and the lower peat basin contains perched groundwater held above the Tertiary substrate.
>
> The agriculturally sourced flows tend to be only slightly acidic and the spring flows are strongly acidic. These contrasted flows create pH gradients across the site and which is reflected in plant community composition.
>
> Open waters in the site are generally rich in nitrogen and phosphorus. Soluble phosphorous exceeds targets for headwaters of cSAC streams and total nutrients are all high. There is no evidence that these high nutrient levels are sourced from surface waters and so the source appears to be primarily from within the mire system itself, perhaps from the underlying peats or from nutrient rich groundwater.

Box. 3 Summary description of the Conceptual Model taken from Drawing 24 in Allen (2003).

[41] In the final paragraph of Box 3 I refer to targets for cSAC headwater streams. These targets were used in the absence of specific targets for mire systems.

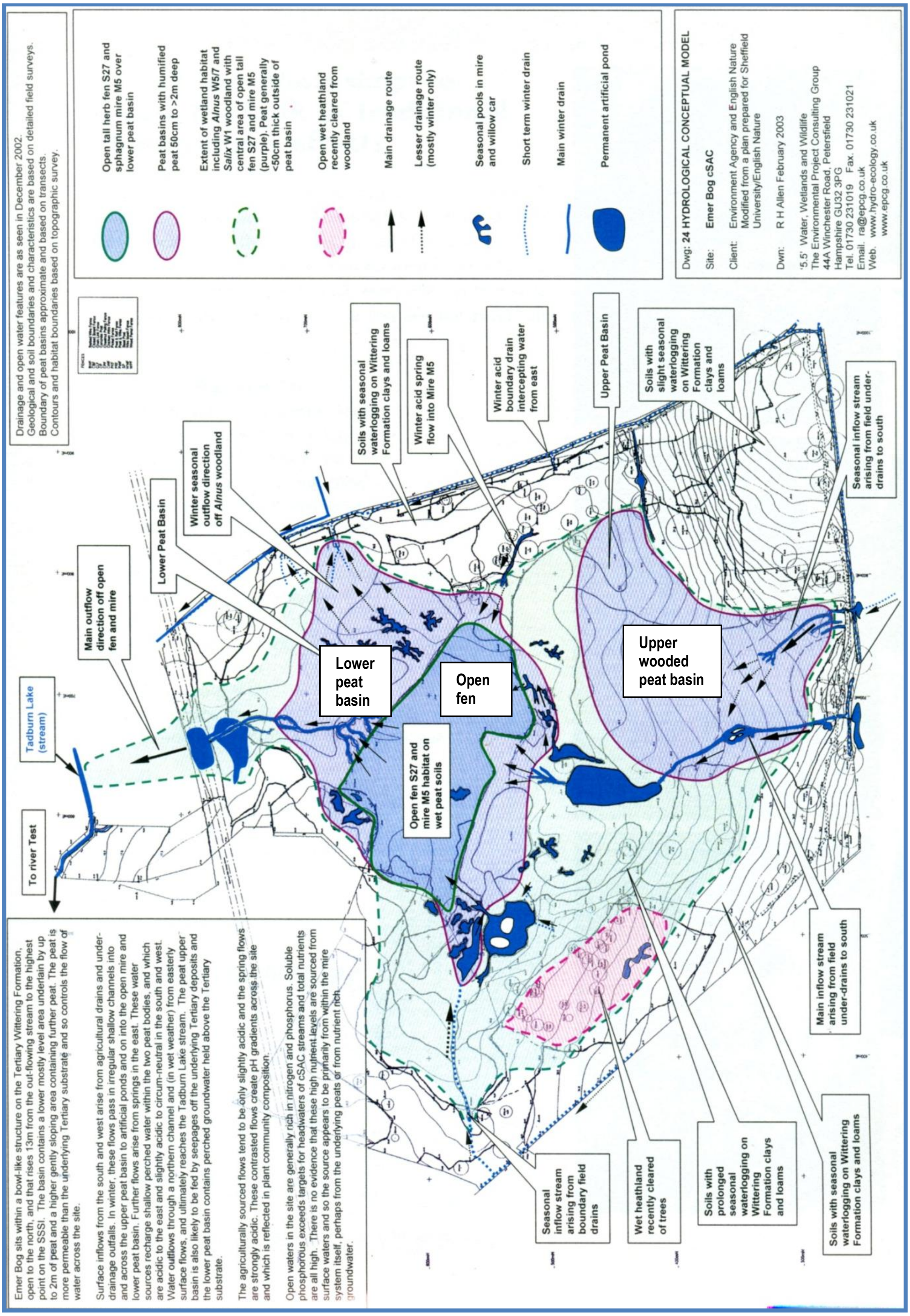


Fig. 29 Emer Bog hydrological model from Allen (2003) annotated to show the upper and lower peat basins and the open fen/mire area. The descriptive boxed text is enlarged in Box 3 above.

13.0 POTENTIAL SUSCEPTIBILITY TO CLIMATE CHANGE

INTRODUCTION

13.1 Objective d) of the brief requires an assessment of the potential impact of climate change on this designation (focusing on hydrological considerations) and how this might affect the application and consideration of the spatial buffer (referred to in point b).

13.2 Section 3 of the brief indicates that: In considering susceptibility to climate change, a tier 1 assessment using the CEH Wetland Tool should be undertaken.

CEH WETLAND TOOLKIT

13.3 This wetland toolkit has been developed by the Centre for Ecology and Hydrology (CEH) and which organisation is part of the UK Natural Environment Research Council.

13.4 The CEH website[42] indicates that: '*We have developed a web-based tool to help wetland managers in England and Wales understand the impacts of climate change in the next 50 years. The tool was developed by Scientists at the Centre for Ecology & Hydrology and its partners (Open University, British Geological Survey, University College London and University of Exeter) with sponsorship from the Wetland Vision partnership (led by the Environment Agency with Natural England, English Heritage, Wildlife Trusts, RSPB, Wildfowl and Wetlands Trust).*'

13.5 Detailed information on the Toolkit is provided in CEH 'Guidance on using the Wetland Toolkit for Climate Change'[43] and *'... guides the user in the application of tools developed to assess how climate change in the 2050s (2041-2070) might impact on wetland ecohydrology in England and Wales.'*

13.6 The toolkit provides three levels (tiers) of increasing complexity and detail. Tier 1 provides a 'General rapid assessment using broad level scoping with predefined results for a few generic wetland types for 2050s medium emissions scenarios. Tier 2 provides an intermediate assessment for specific location representing general wetland processes using large data sets and simple models. Tier 3 provides a detailed assessment and relies on large data sets and complex models'. Full details can be found in the CEH guidance referred to above.

13.7 For this study, the Tier 1 approach has been used, Tiers 2 and 3 being both time consuming and requiring large data sets that may not be available for Emer Bog and Baddesley Common.

TIER 1 ASSESSMENT

13.8 The guidance explains that: '*This is a very simple tool to use, it is based on the results of models that have already been run and does not require the user to undertake modelling*.' The tool requires the following information about the wetlands:

- geographical location – the UKCP09 (Water Framework Directive, WFD) river basin region within which the wetland is located
- water source – whether rain-fed, river-fed (surface water dominated catchment), river-fed (groundwater dominated catchment) or groundwater-fed (according to bedrock aquifer type)
- wetland type – wet grassland, wet heath, raised mire etc.
- interest feature – the wetland feature(s) for which the investigation is being undertaken *e.g.* vegetation community, birds, historic environment.

[42] http://www.ceh.ac.uk/our-science/projects/wetland-tool-climate-change
[43] http://nrfaapps.ceh.ac.uk/wetland_tool/guidance_on_using_the_wetland_toolkit_for_climate_change.pdf

Interest Features

13.9 The Interest Features are listed as (Box 1 in the guidance document):

1. Site hydrology

Hydrology is the single most important feature of a wetland, periodic saturated conditions and/or surface water make wetlands different from terrestrial and fully aquatic habitats. The hydrological regime forms a generic interest feature that indicates general site conditions independently from individual species, communities or other elements.

2. Plant communities

Wetlands are characterised by specialist plants that can tolerate aeration stress. Plants tend to occur in assemblages or communities that have been described in the National Vegetation Classification (NVC) by Rodwell (2000). The communities are often associated with specific wetland water sources. In this study we include the following NVC types as distinct interest features.

Rain-fed wetland

7 NVC types (M16, M21, MG4 (Ecohydrological guidelines subtypes B and K), MG13 (Ecohydrological guidelines subtypes High and Low porosity), M24)

River-fed wetlands

7 NVC types (MG8, S4, MG4 (Ecohydrological guidelines subtypes B and K), MG13 (Ecohydrological guidelines subtypes High and Low porosity), S24

Groundwater-fed wetlands

4 NVC types (M13, M21, M24, S24).

3. Historic environment

Wetlands are critically important for conserving aspects of the historic environment, such as the pollen record or human remains. The historic environment is a key interest feature considered in this study.

4. Birds

Wetlands support many different bird species. The two most important groups are over-wintering birds, especially waterfowl, during November to March, and breeding birds, especially waders during April to June. We include these two groups as interest features in this study.

Wetland types explanation

13.10 The guidance explains that:

'*Some wetlands are fed directly by precipitation and the major loss of water is through evaporation. The hydrology of such wetlands will be impacted directly by changes in climate. Other wetlands are fed by river water, thus modifications to their hydrology will depend on how climate change alters river flows, which will be conditioned by the movement of water from precipitation through catchment soils and along the river channel. Likewise, wetlands fed by groundwater will depend on how climate change will alter water levels in aquifers, mediated by recharge processes. For example, aquifers may be recharged by winter rainfall, thus climate change involving wetter winters may increase aquifer levels, which could provide more water to groundwater-dependent wetlands in the summer. In contrast, rain-fed wetlands may become drier in summer due to reductions in summer rainfall; much will depend on a more immediate balance of water supply and evaporation*.'

'*Where the wetland is fed by more than one source, e.g. both rain and groundwater, the assessment must be run separately for each water source. A judgement is then required based on site knowledge of the relative importance of the two sources and therefore the contribution of changes. Likewise, at sites where more than one feature is of interest, the assessment can be repeated separately for each feature*.'

Interest features and metrics

13.11 The guidance explains as follows:

'The relationship between the hydrological regime and interest features is complex, such that it is not possible to define a single hydrological index that is uniquely critical to conserve the feature. Thus in this study, we defined a set of metrics for each interest feature, the form of which was constrained by nature of the models we employed (for example, the models simulate water table level and not soil moisture, so soil moisture could not be a metric). In addition, the hydrological regime of wetlands is often complex, varying from day to day, month to month and year to year. We need to select some specific measures of hydrological regime'. Below we define the metric under each interest feature.

Hydrology

There is a multitude of possible metrics to describe the hydrological regime of a wetland. We used 8 that were considered most significant.

- Minimum water table level (mean of 30 annual minima)
- Minimum water table level (minimum of 30 year record)
- Maximum water table level (mean of 30 annual maxima)
- Maximum water table level (maximum of 30 year record)
- Number of months per year with positive or neutral water balance (mean of 30 years)
- Number of months per year with positive or neutral water balance (minimum of 30 years)
- Gross annual water balance: rainfall - evaporation (mean of 30 annual balances)
- Gross annual water balance: rainfall - evaporation (minimum of 30 year record).

Historic environment

Historical features may be at different levels in the soil profile. Therefore we have defined four metrics for this interest feature in two sets, to cover artefacts at 35 cm and 70 cm below the soil surface.

- Number of months per year with water table level at 35 cm depth (mean of 30 years)
- Number of months per year with water table level at 35 cm depth (minimum of 30 years)
- Number of months per year with water table level at 70 cm depth (mean of 30 years)
- Number of months per year with water table level at 70 cm depth (minimum of 30 years)

Plant communities

Water requirements of wetland plant communities have been defined by Wheeler et al. 2004. These define, for each community, zones of desired water table level, zones of tolerable water table for short periods and zones of unacceptable water table level. These diagrams (see Figure 5 in the guidance) were used to quantify the botanical relevance of water table levels. We defined 2 metrics that were applied to each of the NVC interest features (see Para 13.9 above).

Birds

Two periods of the year were considered to be critical for birds: November to March for over-wintering birds, especially waterfowl, and April to June for breeding birds, especially waders. Over-wintering wetland birds require surface inundation, whereas breeding birds need water at or near the surface. We have defined one pair of metrics for wintering birds and 3 pairs for breeding birds.

- Number of months, November to March, without surface water (mean of 30 years)
- Number of months, November to March, without surface water (maximum of 30 years)
- Number of months, April to July, with surface water (mean of 30 years)

- Number of months, April to July, with surface water (maximum of 30 years)
- April water table level (mean of 30 years)
- April water table level (minimum of 30 years)
- June water table level (mean of 30 years)
- June water table level (minimum of 30 years)

Results

13.12 The results of the assessment are presented as three colour-coded (traffic light) classes in relation to the significance of the change or to indicate that they are a concern[44]:

(green)	Green	Minor change in metric, High suitability for climate change and/or requiring only low management.	low probability of impact
(amber)	Amber	Intermediate change in metric, Medium suitability for climate change and/or requiring medium management.	medium probability of impact
(red)	Red	Major change in metric, Low suitability for climate change and/or requiring high management.	high probability of impact

13.13 The guidance indicates that:

'It is important to recognise that although a high impact may indicate a low degree of suitability of the projected hydrological regime to the current interest feature, it could alternatively indicate a need for a high degree of management of the wetland to adapt to climate change.'

'It is important to remember that the results of the Tier 1 Wetland Tool for Climate Change are intended to be general and should not be used as the basis of major decisions about the management of specific sites. If the Tier 1 assessment suggests that any particular wetland will be significantly impacted, and hence major action should be taken, it would be advisable to undertake a more detailed analysis with a Tier 2 or Tier 3 approach to produce results with more certainty. Tier 2 models can also be used to run other climate change scenarios such as high emissions or for other periods e.g. the 2020s or 2080s.'

THE TIER 1 ASSESSMENT

13.14 The Assessment uses a small set of National Vegetation Classes (13.9/2 above) and these are compared with those occurring on the Emer Bog[45] and Baddesley Common[46] in **Table 3**. The Tier 1 classes are the nearest match only and may not be directly comparable.

13.15 Accordingly, the Tier 1 programme has been run on:

Mire communities:

M13	*Schoenus nigricans – Juncus subnodulosus* mire	Table 4
M16	*Erica tetralix – Sphagnum compactum* wet heath	Table 5
M24	*Molinia caerulea – Cirsium dissectum* fen meadow	Table 6

Mesotrophic grassland communities:

MG13,	*Agrostis stolonifera – Alopecuris geniculata* grassland	Table 7

Swamp and tall herb fen communities:

S4	*Phragmites australis* swamp and reed beds	Table 8
S24	*Phragmites australis-Peucedanum palustre* tall herb fen	Table 9

[44] According to the climate change projections for 2050s (2040-20169) using the baseline time period 1961-1990 and the emissions scenario Medium (IPCC SRES A1B). Other UKCPO9 emissions scenarios (High and Low) might produce a different result and would be needed for a fuller impact assessment.
[45] HBIC Ian Ralphs August 2008 Baddesley Common HWT Reserve and other surveys.
[46] HBIC Ian Ralphs July 2015 Emer Bog and Baddesley Common SSSI and other surveys.

13.16 Tabulated results of the assessments are provided in **Tables 4-9** below. These tables provide a summation of each of the individual assessments. The tables relate to those communities listed as for South East England. The final column headed 'Predominant impact class' provides the traffic light system used in the Tier 1 programme and defined in paragraph 13.12 above.

Note that: for clarity, the colour blocks have been simplified to show the predominant classes only. Also, that the order of the colours represents the approximate direction of change as indicated in the Tier 1 programme.

Table 3 Site NVC classes compared to Tier 1 NVC classes

Location	Open wetland habitats Site NVC	% site area of main habitats	Tier 1 NVC nearest best fit
Baddesley Common	M23a Juncus effusus/acutiflorus-Gallium palustre Rush-pasture	7%	M13
	M24c Molinia caerulea-Cirsium dissectum Fen Meadow	20%	M24
	M25b Molinia caerulea-Potentilla erecta mire	1%	M24
	M27 Filipendula ulmaraia-Angelica sylvestris mire	1%	M13
	MG10 Holcus lanatus-Juncus effusus rush-pasture	5%	MG13
	S14 Sparganium erectum swamp	1%	S4
	S22 Gylceria fluitans water-margin vegetation	3%	S4
	S23 Other water-margin vegetation	2%	S4
Emer Bog	M5 Carex rostrata-Sphagnum squarrosum (Transition) Mire	2%	M16
	M6 Carex echinata-Sphagnum recurvum/auriculatum Mire (Mesotrophic Flushed Bog)	2%	M16
	M16 Erica tetralix-Sphagnum compactum wet heath	6%	M16
	M23 Juncus effusus/acutiflorus-Gallium palustre Rush pasture	5%	M13
	M25a/b Molinia caerulea-Cirsium dissectum/ Potentilla erecta mire	25%	M24
	S3 Carex paniculata Swamp	2%	S4
	S4 Phragmites australis swamp and reed beds	7%	S4
	S11 Carex vesicaria swamp	2%	S4
	S14 Sparganium erectum swamp	2%	S4
	S27 Carex rostrata-Potentilla palustris tall-herb fen	20%	S24

Limitations of the Tier 1 Wetland Tool for Climate Change

13.17 The guidance lists the following limitations:

- The Tier 1 tool does not provide a detailed prediction for a particular wetland. It provides a generalised regional indication of the potential likelihood and magnitude of climate change impacts on wetlands suitable for risk screening and investigating uncertainty.
- Only the 'medium' emissions scenario and 2050s timeslice from UKCP09 are considered. Other emissions scenarios ('high' and 'low') might produce a different result and would be needed for a fuller impact assessment, although climate change is predicted to be relatively insensitive to emissions scenario until about 2040 (Murphy et al., 2009, p.42). Other timeslices (2020s and 2080s) are also available.'
- Metric impact thresholds have been defined according to current literature and expert consensus. Users should consider whether these thresholds are appropriate for the particular wetland being assessed.
- The Tier 1 tool only considers hydrologically-driven impacts of climate change. Other non-hydrological factors influencing interest feature sustainability, such as changing migratory patterns for bird species, are not considered.
- Existing site management has not been considered for the baseline period nor projected into the climate change future timeslice. For example winter water storage or management of ditch water levels to retain water could make an existing wetland more sustainable under baseline conditions and mitigate future climate change impacts.

- Direct effects of, for example, temperature and carbon dioxide changes on plant physiology, as projected for the climate change scenario and timeslice, have not been considered.
- Multiple water sources to the wetland have not been explicitly considered. As discussed below, multiple water sources should be assessed separately and the results should then be considered in combination using site understanding.
- Water quality/nutrients have not been explicitly considered. As discussed below, it may be possible to use site understanding to infer impacts under climate change. For example, if the water balance metrics show increasing groundwater supply from a Chalk aquifer, the wetland base-richness may well increase.

Table 4 Percentage probability of impact on M13 Mire[47] Groundwater fed (Chalk)[48]. South East England

Location	Water source	Tier 1 nearest equivalent National Vegetation Classification	Feature of interest	Metric	Percentage probability of impact Decreasing and increasing metric given as appropriate	Predominant Impact class Green = low Amber = medium Red = high
Baddesley Common and Emer Bog	Ground-water fed (Chalk) NB. The only option allowed in Tier 1 is for Chalk ground-water fed habitat	M13 *Schoenus nigricans – Juncus subnodulosus* mire	Hydrology (maximum and minimum water levels)	Min. Water level (mean annual; m)	76% Low impact 24% Medium impact <0.05% High impact	
				Min. Water level (11yr:m)	92% Low impact 8% Medium impact	
				Max. water level (mean annual;m)	100% Low impact Increasing <0.5% Medium impact	
				Max. water level (11yr;m)	100% Low impact Increasing <0.5% Medium impact	
			Hydrology (eco-related)	May water level (mean annual;m)	79% Low impact Decreasing 21% Medium impact	
				August water level (mean annual;m)	100% Low impact decreasing <0.5% Medium impact	
				August water level (11yr min;m)	91% Low impact Decreasing 9% Medium impact	
			Hydrology (water balance)	No. months with positive/neutral water balance (mean annual)	50% Low impact 50% Medium impact	
				No. months with positive/neutral water balance (11yr min	53% Medium impact 47% Low impact	
			Plant communities	Departure from water level requirements regime (mean annual)	75% Medium impact Increasing 24% Low impact 1% High impact	
				Departure from water level requirements regime (11yr max.)	77% Medium impact Decreasing 20% Low impact Increasing 3% High impact	
			Historic environment	No. months soil saturation at 35cm bgl (mean annual)	98% Low impact Decreasing 2% Medium impact	
				No. months soil saturation at 35cm bgl (mean annual)	98% Low impact 1% Medium and 1% High impact	
				No. months soil saturation at 70 cm bgl (mean annual)	100% Low impact	
				No. months soil saturation at 70cm bgl (30yr min)	100% Low impact	
			Birds	No. months (Apr-Jul) with surface water (mean annual)	100% Low impact	
				No. months (Apr-Jul) with surface water (11yr max)	100% Low impact	
				No. months (Nov-Mar) with no surface water (mean annual)	83% Medium impact decreasing 17% Low impact	
				No. months (Nov-Mar) with no surface water (11yr max)	100% Low impact	
				April water level (mean annual; m)	55% Medium impact Increasing 3% High impact decreasing 40% Low impact	

[47] Nearest Tier 1 equivalent to M23 rush pasture and M27 mire.
[48] The Tier 1 option only allows for Groundwater-fed over Chalk. Not strictly appropriate to Emer Bog and Baddesley Common. Options for surface water fed and river fed are not available.

				April water level (11yr min; m)	90%% Low impact Decreasing 10% Medium impact	
				June water level (mean annual; m)	55% Medium impact decreasing 41% Low impact increasing 3% High impact	
				June water level (11 yr min; m)	91% Low impact decreasing 9% Medium impact	

Table 5a Percentage probability of impact on M24 Fen Meadow[49], Rain-fed water source. South East England

Location	Water source	Tier 1 nearest equivalent National Vegetation Classification	Feature of interest	Metric	Percentage probability of impact	Predominant Impact class Green = low Amber = medium Red = high
Emer Bog and Baddesley Common	Rain-fed	M24 Fen meadow	Hydrology (maximum and minimum water levels)	Min. Water level (mean annual; m)	96% Low impact 4% Medium impact	
				Min. Water level (30yr:m)	100% Low impact	
				Max. water level (mean annual;m)	100% Low impact	
				Max. water level (30yr;m)	100% Low impact	
			Hydrology (eco-related)	May water level (mean annual;m)	100% Low impact	
				August water level (mean annual;m)	100% Low impact	
				August water level (30yr min;m)	100% Low impact	
			Hydrology (water balance)	No. months with positive/neutral water balance (mean annual)	100% Low impact	
				No. months with positive/neutral water balance (30yr min	100% Low impact	
				Gross annual water balance: Rain-AE (mean annual;mm)	47% Low impact , decreasing 16% Medium and 2% High increasing 23% Medium 12% High	
				Gross annual water balance: Rain-AE (30yr min;mm)	7% Low impact , decreasing 4% Medium and 60% High increasing 3% Medium 26% High	
			Plant communities	Departure from water level requirements regime (mean annual)	96% Medium increasing 4% High	
				Departure from water level requirements regime (30yr max.)	98% High Decreasing 2% Medium	
			Historic environment	No. months soil saturation at 35cm bgl (mean annual)	99% Medium Decreasing 1% High	
				No. months soil saturation at 35cm bgl (mean annual)	55% High 45% Medium	
				No. months soil saturation at 70 cm bgl (mean annual)	100% Low	
				No. months soil saturation at 70cm bgl (30yr min)	100% Low	
			Birds	No. months (Apr-Jul) with surface water (mean annual)	100% Low	
				No. months (Apr-Jul) with surface water (30 yr max)	100% Low	
				No. months (Nov-Mar) with no surface water (mean annual)	100% Low	
				No. months (Nov-Mar) with no surface water (30 yr max)	100% Low	
				April water level (mean annual; m)	98% Low Decreasing 2% Medium	
				April water level (30 yr min; m)	100% Low	
				June water level (mean annual; m)	55% Medium 45% Low	
				June water level (30 yr min; m)	100% Low	

[49] Nearest Tier equivalent to M24/M25
Only water source options allowed are Rain-fed (Table 5a) or Groundwater-fed on chalk (Table 5b) only.

Table 5b Percentage probability of impact on M24 Fen Meadow, Groundwater fed water source (Chalk)[50]. South East England

Location	Water source	Tier 1 nearest equivalent National Vegetation Classification	Feature of interest	Metric	Percentage probability of impact	Predominant Impact class Green = low Amber = medium Red = high
Emer Bog and Baddesley Common	Groundwater-fed (chalk)	M24 Fen meadow	Hydrology (maximum and minimum water levels	Min. Water level (mean annual; m)	42% Low impact Decreasing 38% Medium impact and 19% High impact	
				Min. Water level (11yr:m)	65% Low impact Decreasing 30% Medium impact and 5% High impact	
				Max. water level (mean annual;m)	98% Low impact Increasing 2% Medium impact and <0.5% High impact	
				Max. water level (11yr;m)	99% Low impact Increasing 1% Medium impact and <0.5% High impact	
			Hydrology (eco-related)	May water level (mean annual;m)	99% Low impact Increasing 1% Medium impact and <0.5% High impact	
				August water level (mean annual;m)	84% Low impact Decreasing 15% Medium impact and 2% High impact	
				August water level (30yr min;m)	63% Low impact Decreasing 31% Medium impact and 5% High impact	
			Hydrology (water balance)	No. months with positive/neutral water balance (mean annual)	60% Medium impact 40% Low impact	
				No. months with positive/neutral water balance (30yr min	56% Medium impact 44% Low impact	
			Plant communities	Departure from water level requirements regime (mean annual)	70% Low Increasing 28% Medium and 4% High impact	
				Departure from water level requirements regime (11yr max.)	51% High Decreasing 21% Medium 28% Low	
			Historic environment	No. months soil saturation at 35cm bgl (mean annual)	99% Medium Decreasing 1% High	
				No. months soil saturation at 35cm bgl (11 yr min)	63% High Increasing 8% Medium and 29% Low	
				No. months soil saturation at 70 cm bgl (mean annual)	95% Low impact Decreasing 5% Medium impact	
				No. months soil saturation at 70cm bgl (11yr min)	95% Low impact Decreasing 2% Medium impact and 3% High impact	
			Birds	No. months (Apr-Jul) with surface water (mean annual)	97% Low impact Increasing 1% Medium impact and 2% High impact	
				No. months (Apr-Jul) with surface water (30 yr max)	94% Low impact Increasing 1% Medium impact and 5% High impact	
				No. months (Nov-Mar) with no surface water (mean annual)	100% Low impact	

[50] The Tier 1 option only allows for Groundwater-fed over Chalk. Not strictly appropriate to Emer Bog and Baddesley Common. Options for surface water fed and river fed are not available.

				No. months (Nov-Mar) with no surface water (30 yr max)	100% Low	
				April water level (mean annual; m)	40% Low impact Decreasing 33% Medium impact Increasing 21% Low, 5% Moderate and 1% High impact	
				April water level (11 yr min; m)	60% Low impact Decreasing 33% Medium impact and 6% High impact	
				June water level (mean annual; m)	40% Medium Increasing 26% Low impact Decreasing 34% High	
				June water level (11 yr min; m)	62% Low impact Decreasing 32% Moderate and 6% Low impact	

Table 6a Percentage probability of impact on MG13 (lower porosity) wet grassland[51]
Rain-fed water source. South East England

Location	Water source	Tier 1 nearest equivalent National Vegetation Classification	Feature of interest	Metric	Percentage probability of impact	Predominant Impact class Green = low Amber = medium Red = high
Baddesley Common	Rain-fed	MG13 (Lower porosity) Wet grassland	Hydrology (maximum and minimum water levels)	Min. Water level (mean annual; m)	55% High impact 33% Medium impact Increasing 12% Low	
				Min. Water level (30yr:m)	90% Low impact Decreasing 10% Medium impact	
				Max. water level (mean annual;m)	100% Low impact	
				Max. water level (30yr;m)	100% Low impact	
			Hydrology (eco-related)	May water level (mean annual;m)	61% Low impact Decreasing 37% Medium impact and 1% High impact	
				August water level (mean annual;m)	44% Low impact Decreasing 39% Medium impact and 17% High impact	
				August water level (30yr min;m)	90% Low impact Decreasing 10% Medium impact	
			Hydrology (water balance)	No. months with positive/neutral water balance (mean annual)	100% Low impact	
				No. months with positive/neutral water balance (30yr min	100% Low impact	
				Gross annual water balance: Rain-AE (mean annual;mm	31% High impact 24% Medium impact 22% Low impact Increasing 11% Medium impact and 11% High impact	
				Gross annual water balance: Rain-AE (30yr min;mm	95% High impact Increasing 2% Medium impact, 2% Low impact, <0.5% Medium and <0.5% High impact	
			Plant communities	Departure from water level requirements regime (mean annual)	85% Medium impact Increasing 15% Low impact	
				Departure from water level requirements regime (30yr max.)	55% High impact 45% Medium impact	
			Historic environment	No. months soil saturation at 35cm bgl (mean annual)	100% High impact	
				No. months soil saturation at 35cm bgl (30 yr min)	100% High impact	
				No. months soil saturation at 70 cm bgl (mean annual)	75% Medium impact 25% High impact	
				No. months soil saturation at 70cm bgl (11yr min)	98% High impact Increasing 2% Medium impact	
			Birds	No. months (Apr-Jul) with surface water (mean annual)	100% Low impact	
				No. months (Apr-Jul) with surface water (30 yr max)	100% Low impact	
				No. months (Nov-Mar) with no surface water (mean annual)	88% Low impact Increasing 12% Medium impact	
				No. months (Nov-Mar) with no surface water (30 yr max)	100% Low	
				April water level (mean annual; m)	85% Low impact Decreas15% Medium	

[51] The nearest Tier 1 equivalent to MG10 rush pasture. There is no option for River-fed (surface-water) for South East England nor for Groundwater-fed water sources.

					impact	
				April water level (30yr min; m)	97% Low impact Decreasing 3% Medium impact	
				June water level (mean annual; m)	68% Medium impact Increasing 6% Low impact Decreasing 25% High	
				June water level (11 yr min; m)	97% Low impact Decreasing 3% Moderate impact	

Table 6b Percentage probability of impact on MG13 (lower porosity) wet grassland[52] River-fed (groundwater) source. South East England

Location	Water source	Tier 1 nearest equivalent National Vegetation Classification	Feature of interest	Metric	Percentage probability of impact	Predominant Impact class Green = low Amber = medium Red = high
Baddesley Common	River-fed (groundwater)	MG13 (Lower porosity) Wet grassland	Hydrology (maximum and minimum water levels)	Min. Water level (mean annual; m)	100% Low impact	
				Min. Water level (30yr:m)	100% Low impact	
				Max. water level (mean annual;m)	66% Low impact Increasing 24% Medium impact and 10% High impact	
				Max. water level (30yr;m)	81% Low impact Increasing 17% Medium impact and 2% High impact	
			Hydrology (eco-related)	May water level (mean annual;m)	100% Low impact	
				August water level (mean annual;m)	100% Low impact	
				August water level (30yr min;m)	100% Low impact	
			Hydrology (water balance)	No. months with positive/neutral water balance (mean annual)	100% Low impact	
				No. months with positive/neutral water balance (30yr min	100% Low impact	
			Plant communities	Departure from water level requirements regime (mean annual)	100% Medium impact	
				Departure from water level requirements regime (30yr max.)	97% High impact increasing 3% Medium impact	
			Historic environment	No. months soil saturation at 35cm bgl (mean annual)	98% High impact Decreasing 2%	
				No. months soil saturation at 35cm bgl (30 yr min)	100% High impact	
				No. months soil saturation at 70 cm bgl (mean annual)	100% Medium impact	
				No. months soil saturation at 70cm bgl (30yr min)	100% Medium impact	
			Birds	No. months (Apr-Jul) with surface water (mean annual)	100% Low impact	
				No. months (Apr-Jul) with surface water (30 yr max)	100% Low impact	
				No. months (Nov-Mar) with no surface water (mean annual)	100% Low impact	
				No. months (Nov-Mar) with no surface water (30 yr max)	100% Low impact	
				April water level (mean annual; m)	92% Low impact Decreasing 5% Medium impact Increasing 4% Medium impact	
				April water level (30yr min; m)	100% Low impact	
				June water level (mean annual; m)	93% Low impact Decreasing 7% Medium impact	
				June water level (30 yr min; m)	100% Low impact	

[52] The nearest Tier 1 equivalent to MG10 rush pasture. There is no option for River-fed (surface water) source.

Table 7 Percentage probability of impact on M16 wet heath / mire[53] Rain-fed source[54]. South East England

Location	Water source	Tier 1 nearest equivalent National Vegetation Classification	Feature of interest	Metric	Percentage probability of impact	Predominant Impact class Green = low Amber = medium Red = high
Baddesley Common	Rain-fed [49]	MG16 Wet Heath	Hydrology (maximum and minimum water levels)	Min. Water level (mean annual; m)	80% Low impact Increasing 20% Medium impact	
				Min. Water level (30yr:m)	100% Low impact	
				Max. water level (mean annual;m)	100% Low impact	
				Max. water level (30yr;m)	100% Low impact	
			Hydrology (eco-related)	May water level (mean annual;m)	100% Low impact	
				August water level (mean annual;m)	99% Low impact Decreasing 1% Medium impact	
				August water level (30yr min;m)	100% Low impact	
			Hydrology (water balance)	No. months with positive/neutral water balance (mean annual)	96% Low impact Decreasing 4% Medium impact	
				No. months with positive/neutral water balance (30yr min	100% Low impact	
				Gross annual water balance: Rain-AE (mean annual;mm)	53% low impact Increasing 21% Medium and 8% High risk Decreasing 16% Medium and 1% High risk	
				Gross annual water balance (30yrmn;mm)	35% low impact Increasing 9% Medium and 7% High risk Decreasing 20% Medium and 28% High risk	
			Plant communities	Departure from water level requirements regime (mean annual)	96% Low impact Decreasing 4% Medium impact	
				Departure from water level requirements regime (30yr max.)	100% High impact	
			Historic environment	No. months soil saturation at 35cm bgl (mean annual)	100% Medium impact	
				No. months soil saturation at 35cm bgl (30 yr min)	72% High impact Increasing 28% Medium impact	
				No. months soil saturation at 70 cm bgl (mean annual)	100% Low impact	
				No. months soil saturation at 70cm bgl (30yr min)	100% Low impact	
			Birds	No. months (Apr-Jul) with surface water (mean annual)	100% Low impact	
				No. months (Apr-Jul) with surface water (30 yr max)	100% Low impact	
				No. months (Nov-Mar) with no surface water (mean annual)	100% Low impact	
				No. months (Nov-Mar) with no surface water (30 yr max)	100% Low impact	
				April water level (mean annual; m)	97% Low impact Decreasing 3% Medium impact	
				April water level (30yr min; m)	100% Low impact	
				June water level (mean annual; m)	58% Low impact Decreasing 42% Medium impact	
				June water level (30 yr min; m)	100% Low impact	

[53] The nearest Tier 1 equivalent to M5 Carex rostrata-Sphagnum squarrosum (Transition Mire), M6 Carex echinata-Sphagnum recurvum/auriculatum mire (mesotrophic flushed bog), and M16 Erica tetralix-Sphagnum compactum wet heath.
[54] Rain-fed is the only Tier 1 water source option available and which is a poor match for Emer/Baddesley.

Table 8 **Percentage probability of impact on S4 Phragmites swamp and reed beds[55]**
River-fed (groundwater) source[56]. South East England

Location	Water source	Tier 1 nearest equivalent National Vegetation Classification	Feature of interest	Metric	Percentage probability of impact	Predominant Impact class Green = low Amber = medium Red = high
Baddesley Common	River-fed (groundwater) 51	S4 Phragmites swamp and reed beds	Hydrology (maximum and minimum water levels)	Min. Water level (mean annual; m)	100% Low impact	
				Min. Water level (30yr:m)	100% Low impact	
				Max. water level (mean annual;m)	68% Low impact Increasing 23% Medium impact and 8% High impact	
				Max. water level (30yr;m)	83% Low impact Increasing 15% Medium impact and 2% High impact	
			Hydrology (eco-related)	May water level (mean annual;m)	100% Low impact	
				August water level (mean annual;m)	100% Low impact	
				August water level (30yr min;m)	100% Low impact	
			Hydrology (water balance)	No. months with positive/neutral water balance (mean annual)	100% Low impact	
				No. months with positive/neutral water balance (30yr min	100% Low impact	
			Plant communities	Departure from water level requirements regime (mean annual)	100% Low impact	
				Departure from water level requirements regime (30yr max.)	100% Low impact	
			Historic environment	No. months soil saturation at 35cm bgl (mean annual)	76% Low impact Decreasing 24% Medium impact	
				No. months soil saturation at 35cm bgl (30 yr min)	76% High impact Decreasing 24% Medium impact	
				No. months soil saturation at 70 cm bgl (mean annual)	100% Low impact	
				No. months soil saturation at 70cm bgl (30yr min)	100% Low impact	
			Birds	No. months (Apr-Jul) with surface water (mean annual)	100% Low impact	
				No. months (Apr-Jul) with surface water (30 yr max)	100% Low impact	
				No. months (Nov-Mar) with no surface water (mean annual)	98% Low impact Increasing 2% Medium impact	
				No. months (Nov-Mar) with no surface water (30 yr max)	100% Low impact	
				April water level (mean annual; m)	93% Low impact Decreasing and Increasing 4% Medium impact	
				April water level (30yr min; m)	100% Low impact	
				June water level (mean annual; m)	94% Low impact Decreasing 6% Medium impact	
				June water level (30 yr min; m)	100% Low impact	

[55] The nearest Tier 1 equivalent to S14 Sparganium erectum swamp, S22 Glyceria fluitans water margin vegetation, S23 other water margin vegetation, S3 Carex paniculata swamp, S4 Phragmites australis swamp and reed beds, S11 Carex vesicaria swamp, and Sparganium erectum swamp.
[56] River-fed (groundwater) is the only Tier 1 water source option available for S4 in South East England.

**Table 9 Percentage probability of impact on S24 Phragmites australis-Peucedanum palustre tall herb fen[57]
River-fed (groundwater) source[58]. South East England**

Location	Water source	Tier 1 nearest equivalent National Vegetation Classification	Feature of interest	Metric	Percentage probability of impact	Predominant Impact class Green = low Amber = medium Red = high
Baddesley Common	River-fed (groundwater)	S24 Phragmites australis-Peucedanum palustre tall herb fen	Hydrology (maximum and minimum water levels)	Min. Water level (mean annual; m)	100% Low impact	
				Min. Water level (30yr:m)	100% Low impact	
				Max. water level (mean annual;m)	67% Low impact Increasing 24% Medium impact and 9% High impact	
				Max. water level (30yr;m)	82% Low impact Increasing 16% Medium impact and 2% High impact	
			Hydrology (eco-related)	May water level (mean annual;m)	100% Low impact	
				August water level (mean annual;m)	100% Low impact	
				August water level (30yr min;m)	100% Low impact	
			Hydrology (water balance)	No. months with positive/neutral water balance (mean annual)	100% Low impact	
				No. months with positive/neutral water balance (30yr min	100% Low impact	
			Plant communities	Departure from water level requirements regime (mean annual)	100% Low impact	
				Departure from water level requirements regime (30yr max.)	85% Medium impact Decreasing 15% Low impact	
			Historic environment	No. months soil saturation at 35cm bgl (mean annual)	77% Medium impact Increasing 25% Low impact	
				No. months soil saturation at 35cm bgl (30 yr min)	76% Medium impact Increasing 23% Low impact, Decreasing <0.5% Low impact	
				No. months soil saturation at 70 cm bgl (mean annual)	100% Low impact	
				No. months soil saturation at 70cm bgl (30yr min)	100% Low impact	
			Birds	No. months (Apr-Jul) with surface water (mean annual)	100% Low impact	
				No. months (Apr-Jul) with surface water (30 yr max)	100% Low impact	
				No. months (Nov-Mar) with no surface water (mean annual)	98% Low impact Increasing 2% Medium impact	
				No. months (Nov-Mar) with no surface water (30 yr max)	100% Low impact	
				April water level (mean annual; m)	92% Low impact Decreasing and Increasing 4% Medium impact	
				April water level (30yr min; m)	100% Low impact	
				June water level (mean annual; m)	93% Low impact Decreasing 7% Medium impact	
				June water level (30 yr min; m)	100% Low impact	

57 The nearest Tier 1 equivalent to S27 Carex rostrata-Potentilla palustris tall herb fen.
58 This is the only water source available in the Tier 1 programme.

Discussion of the Tier 1 assessment results

Best fit communities

13.18 **Table 3** above lists the best fit Tier 1 equivalent NVC classes to those occurring at Emer Bog and Baddesley Common. **Tables 4-9** provide the detailed Tier 1 assessments and the traffic light impact class summaries.

M23 Rush pasture and M27 mire

13.19 The Tier 1 M13 Mire (**Table 4**) appears to be the best fit for M23 rush pasture and M27 mire communities. The only water source option for this M13 community is that for chalk groundwater fed and so the fit is not good.

13.20 The predominant impact class is Low with some features in the Medium impact category.

- Low impact applies to 'hydrology minimum and maximum water levels', 'hydrology eco related', and 'historic environment' interest features.
- The Medium impact applies to 'water balance', 'plant communities' and to some aspects for 'birds'.

13.21 Overall, the probability of impact of climate change is mostly Low with some Medium impacts.

M24 Fen meadow and M25 mire

13.22 The Tier 1 M24 fen meadow (**Tables 5a rain-fed and 5b chalk groundwater fed**) appears to be the best fit for the M24 fen meadow and the M25 mire communities. The only water source options are for rain-fed and chalk groundwater fed sources neither of which are good fits.

13.23 The predominant impact class is Low with some features in the Medium and some in the High impact range (especially in the groundwater fed water source).

- Low impact applies in both instances primarily to 'hydrology maximum and minimum water levels', 'hydrology eco-related' and most of the 'hydrology water balance features' as well as much of the 'historic environment' and 'birds' features of interest.
- Medium and High impact applies to gross annual water balance, plant communities and some of the historic environment interest features and for groundwater fed sources additionally for the April and June 'bird' water level metrics.

13.24 Overall the probability of impact of climate change is mostly Low but with significant features in the Medium and High probability of impact categories.

M5 Transition mire, M6 mire and M16 wet heath

13.25 The Tier 1 M16 wet heath (**Table 7**) appears to be the best fit for the M5 transition mire, M6 mire and M16 wet heath communities. The M16 community is a drier community than for the M5 and M6 communities and the Tier 1 scheme only allows for a rain fed source and so the fit is not good. Possibly the Tier 1 M24 fen meadow may be a better fit although not ideal.

13.26 The predominant impact class is Low with some features in the Medium and some in the High impact range.

- Low impact applies primarily to 'hydrology maximum and minimum water levels', 'hydrology eco-related' and most of the 'hydrology water balance' features as well as much of the 'historic environment' and 'birds' features of interest.
- Medium and High impact applies to 'gross annual water balance', part of the 'plant communities' and some of the 'historic environment' interest features.

13.27 Overall the probability of impact of climate change is mostly Low but with significant features in the Medium and High probability of impact categories especially in relation to plant communities and the historic environment.

MG10 Rush pasture

13.28 The best fit for the MG10 rush pasture appears to be the Tier 1 MG13 lower porosity wet grassland (**Tables 6a Rain fed source and 6b river-fed groundwater source**). Neither of the two water source options provide an ideal fit.

13.29 While the predominant impact class is Low there are significant features in both the Medium and the High impact ranges.

- Low impact applies in both water source instances primarily to 'hydrology maximum and minimum water levels', 'hydrology eco-related' and some of the 'hydrology water balance features' as well as the 'birds' features of interest.
- Medium and High impact applies particularly to the rain-fed water source with High impact given to 'Hydrology minimum water level', 'gross annual water balance', and both 'plant communities' and 'historic environment' interest features.

13.30 Overall the probability of impact of climate change is mostly Low but with many significant features in the Medium and High probability of impact categories.

S3 *Carex paniculata* swamp, S4 reed beds, S11 swamp, S14 swamp, S22 water margin vegetation and S23 other water margin vegetation

13.31 Tier 1 S4 *Phragmites australis* swamp and reed beds (**Table 8**) appears to be the best fit for the S3 *Carex paniculata* swamp, S4 reed beds, S11 swamp, S14 swamp, S22 water margin vegetation and S23 other water margin vegetation communities. The only water source option is for River-fed (groundwater) and this seems a reasonable fit for swamp communities.

13.32 The predominant impact class is Low over most of the features of interest with only a few metrics in the Medium and one in the High impact ranges.

- Low impact applies almost throughout the features of interest.
- Medium impact applies only in part to two categories in the 'Hydrology maximum water level' categories and High impact applies only to the 'Historic environment 35cm soil saturation period'.

13.33 Overall the probability of impact of climate change is Low with only a few features in the Medium category and only one in the High probability of impact categories.

S27 Tall herb fen community

13.34 The best fit for the S27 tall herb fen community appears to be the Tier 1 S24 tall herb fen (**Table 9**). The only water source option is for River-fed (groundwater) and this seems a reasonable fit (although not ideal) for this fen community.

13.35 The predominant impact class is Low over most of the features of interest with only a few metrics in the Medium impact range.

- Low impact applies almost throughout the features of interest.
- Medium impact applies only in part to two categories in the 'Hydrology maximum water level' and to parts of the Plant communities and Historic environment categories. There are indications for High impact.

13.36 Overall the probability of impact of climate change is Low with only a few features in the Medium impact class.

14.0 DISCUSSION IN RELATON TO PROJECT OUTPUTS

OBJECTIVES, SCOPE AND OUTPUTS

14.1 The Test Valley Brief of Requirements (see **Section 1.2**) sets out the objectives, scope and outputs of the study. In this section of the report I summarise my conclusions in relation to each of these items.

> It is important to understand that the conclusions of this report are based upon a desk study. While it is reasonable to assume that the data behind the desk study is accurate (given the limitations discussed within this report), the data has not been checked on the ground.

Objective a)

Definition of the catchment of Emer Bog / Baddesley Common in terms of hydrological function and water quality / resource integrity.

Definition of the Catchment of Emer Bog and Baddesley Common in terms of hydrological function

14.2 There are two types of catchment associated with Emer Bog / Baddesley Common:

1. a hydrological surface water catchment (based on topography and soil permeability); and
2. a hydrogeological subsurface water catchment (based on the substrate permeability and geological structure of the area).

Surface water catchment

14.3 I discuss the surface water catchment of Emer Bog and Baddesley Common in **Section 12** above. Surface water catchments are delineated by the ridges of higher ground (interfluves) that surround them and that contain the internal stream systems.

14.4 **The combined Emer Bog and Baddesley Common catchments** are included within the Tadburn Lake Southern Catchment (**Figure 6**) and which is bounded to the north by the Tadburn Lake Northern Catchment, to the west by the Test Valley Catchment, to the south by the Tanner's Brook Catchment, and to the east by the Monk's Brook Catchment.

Immediate catchment

14.5 **The Tadburn Lake Southern Catchment** (see **Figure 6**) is itself divisible into a southeast sub-catchment feeding the North Baddesley Stream, a southwest sub-catchment feeding both the Tadburn Lake Southern Tributary and the Baddesley Common Stream, and northeast sub-catchment feeding Emer Bog.

14.6 The catchment encompassing both Emer Bog and Baddesley Common is shown in detail in **Figure 25** and which the catchment is divisible into the:

1. Baddesley Common Stream Catchment encompassing the Baddesley Common Stream feeding through Baddesley Common; and the
2. Emer Bog Catchment encompassing Emer Bog and its two main feeder flow-ways, the Lights Copse Stream and the Further Common Stream.[59]

14.7 **Together, these two catchments contain the Baddesley Common and Emer Bog surface water systems.**

[59] Further Common Stream, Lights Copse Stream, Baddesley Common Stream and the North Baddesley Stream names are designated only for convenience in the context of this report.

Wider catchment

14.8 Bounding the combined Baddesley Common and Emer Bog Catchments are the western and southern parts of the Tadburn Lake Southern Tributary catchment and the catchment of its tributary, the North Baddesley Stream.

14.9 Note that: this wider surface water catchment system does not contribute directly to Emer Bog and Baddesley Common but rather bypasses them to the south and west. They do however, feed the Tadburn Lake Southern Tributary into which the Baddesley Common Stream feeds.

Sub-surface ground water

14.10 The hydro-geological system supporting springs, seepages and groundwater resources to Emer Bog and Baddesley Common is based upon the characteristics of the underlying Wittering Formation (see **Section 11**).

14.11 For the most part, this geological Formation comprises low permeability clays and sandy clays, but included within it are a variety of thinner and thicker seams of fine sand and which seams are capable of transmitting very slow groundwater flows. These slow subsurface flows emerge on valley sides as seasonal springs and seepages supporting the upper peat basin and small flushed areas of land, and also the perched groundwater system supporting the lower peat basin.

14.12 Note that: this groundwater catchment is very local and appears to be contained within the boundaries of the surface water catchments indicated in dark blue and pale blue (and outlined by red and black broken lines respectively) on **Figures 23 and 25**. It is possible however, that that the groundwater component could be partly sourced from the wider area.

Definition of the catchment of Emer Bog and Baddesley Common in terms of water quality / resource integrity

Surface water catchments

14.13 Both surface water catchments of Emer Bog and Baddesley Common are sourced from flow-ways outside of the immediate SSSI/SAC boundaries.

14.14 The aerial photograph in **Figure 27** indicates that both Emer Bog and Baddesley Common's surface water flow-ways are sourced mainly through woodland and grassland but that both the Further Common Stream (sourcing Emer Bog) and the Baddesley Common Stream headwater (sourcing the Baddesley Common Stream) also have small arable sources.

14.15 Pound Lane crosses the Further Common flow-way and the road surface could contribute small oil contaminated flows to the stream during the first flush effect of heavy rainfall. It is unlikely that any such contaminated flows (in normal conditions) would adversely affect Emer Bog because flows off the Further Common flow-way are diverted around Emer Bog via boundary ditches and also because part of the flows off Emer Bog are directed towards that part of the boundary. However, given the occurrence of substantial flows off the Further Common flow-way (following particularly prolonged heavy rainfall), it is possible that the boundary drain could overflow leading to overbank flooding into Emer Bog. This would be particularly so if the boundary drains were to become silted and partially or wholly infilled by lack of management.

14.16 The Test Valley Business Park is close to the head of one of the Baddesley Common Stream's headwaters and, if there are any water using processes here, could potentially affect the catchment. This catchment also supports Sites of Importance for Nature Conservation (SINCs) which should also be taken into account given development proposals or land-use changes.

14.17 Any enhanced nutrient status and enhanced alkalinity/pH (indicative of adverse water quality) arising from the agricultural sources of these streams, is likely to be seasonal and depending upon both the timing and quantity of fertiliser/lime applications and winter rainfall. However, the two small arable headwater sources are distant from Emer Bog and Baddesley Common meaning that surface water flows, sourced from the arable fields, are only likely after extreme prolonged rainfall conditions in some years.

14.18 Unless permanent grassland is converted to short-term grassland/arable cultivations (coupled with fertiliser/liming regimes) it seems unlikely that the small Emer Bog and Baddesley Common catchments will be contributing adverse nutrients and alkalinity. **However, it is important to be cautious and to monitor all of the inflowing sources during winter to check on adverse conditions from these flow-ways.**

14.19 The Tadburn Lake Southern Tributary is the most sensitive to adverse water quality changes because it is partly sourced from within the urban area of North Baddesley. However, this water system bypasses the Emer Bog and Baddesley Common catchments and so is unlikely to adversely affect the critical areas.

<u>Groundwater catchment</u>

14.20 The groundwater resources passing through the Wittering Formation could also be affected by any fertilising/liming regime across the catchment such that any enhanced fertility from downward percolating soil water and groundwater could emerge in springs, seepages and the perched groundwaters sourcing Emer Bog and possibly the stream passing through Baddesley Common. While the critical groundwater catchment appears to be that area contained within the dark and light blue areas (within the red and black broken lines respectively) on **Figures 23 and 25**, it is possible that that the wider area could also contribute at least some groundwater resources to Emer Bog and Baddesley Common.

14.21 This would only apply where the more permeable components of the Wittering Formation are at the surface. Elsewhere, the clayey character of the deposits would most likely prevent downward percolation of nutrient surface waters.

14.22 The extent to which any such pollution may be currently or historically significant is very difficult to assess or quantify. This is because of the lack of historical information on land-use and the use of the surrounding land.

<u>Objective b)</u>

Identification of the susceptibility to current and future changes in hydrology (including in relation to development in the catchment);

14.23 The current catchment of both Emer Bog and Baddesley Common (the dark blue area on **Figures 23 and 25**) is within an area of essentially low-intensity farmland, primarily permanent or ley grassland with small areas of arable land and woodland.

14.24 **Changes in land-use within the adjoining small catchments of Emer Bog and of Baddesley Common would be potentially damaging to the hydrological regime of both sites if they provided for increased stream flows especially if they contained nutrient-rich or calcium-rich substances in solution (solutes) or other pollutants/contaminants or suspended particles (such as solid soil materials).**

14.25 Changes in agricultural regime such re-seeding, liming and fertilising could potentially affect the surface water and groundwater catchments.

14.26 Development within the catchments that could lead to enhanced surface flows (such as from sustainable drainage schemes – SUDS) could be damaging because flows off concrete surfaces tend to be rich in calcium and lead to enhanced alkalinity, increased pH and particularly the reduced availability of iron and aluminium that would otherwise characterise more acidic waters. **This means that any drainage schemes that may be**

proposed for these catchments should be given particular scrutiny, not simply for flows but also for critical water chemistry.

14.27 **Figures 26 and 27** show the main flow-ways leading towards Emer Bog.

14.28 The key surface water inflow into Emer Bog is from Flow-way 6, the Lights Copse Stream, and which has a relatively large catchment. This stream currently appears to have a purely grassland source and any land-use change (such as grassland to arable) or hard development (such as housing, commercial, industrial) that could introduce potential sources of contamination would have a high probability of adversely affecting Emer Bog.

14.29 Flow-way 8, the Further Common Stream, also has a long catchment arising off a small area of arable land, passing through woodland and crossing Pound Lane. It is possible that agricultural fertilisers, or oils off Pound Lane, could reach Emer Bog. In normal conditions, flows are diverted around the boundary of Emer Bog, but given extreme rainfall, water could overflow the drain and enter Emer Bog. Any proposals for housing or other hard development in the catchment should therefore be avoided unless accompanied by adequate hydrological assessment.

14.30 Flow-ways 7 and 9 are relatively short but agricultural or housing (or other hard land-use) land-use change within their catchments would very likely affect flows into Emer Bog during heavy rainfall events.

Objective C)

Identification of the spatial catchment on a map in order to define a buffer for Emer Bog and Baddesley Common and which can be used to inform consideration of where proposals / changes could influence the hydrology of the designation.

Critical Area, Wider Buffer Zone and Adjacent Areas

14.31 I have discussed the spatial catchments of Emer Bog and Baddesley Common as components of the Southern Tadburn Brook catchment in **Section 12**.

14.32 **Figure 30** is a simplified diagram of the boundaries of the relevant critical and buffer zone catchments without showing the hydrological detail. Development is defined in **Section 3 Glossary**.

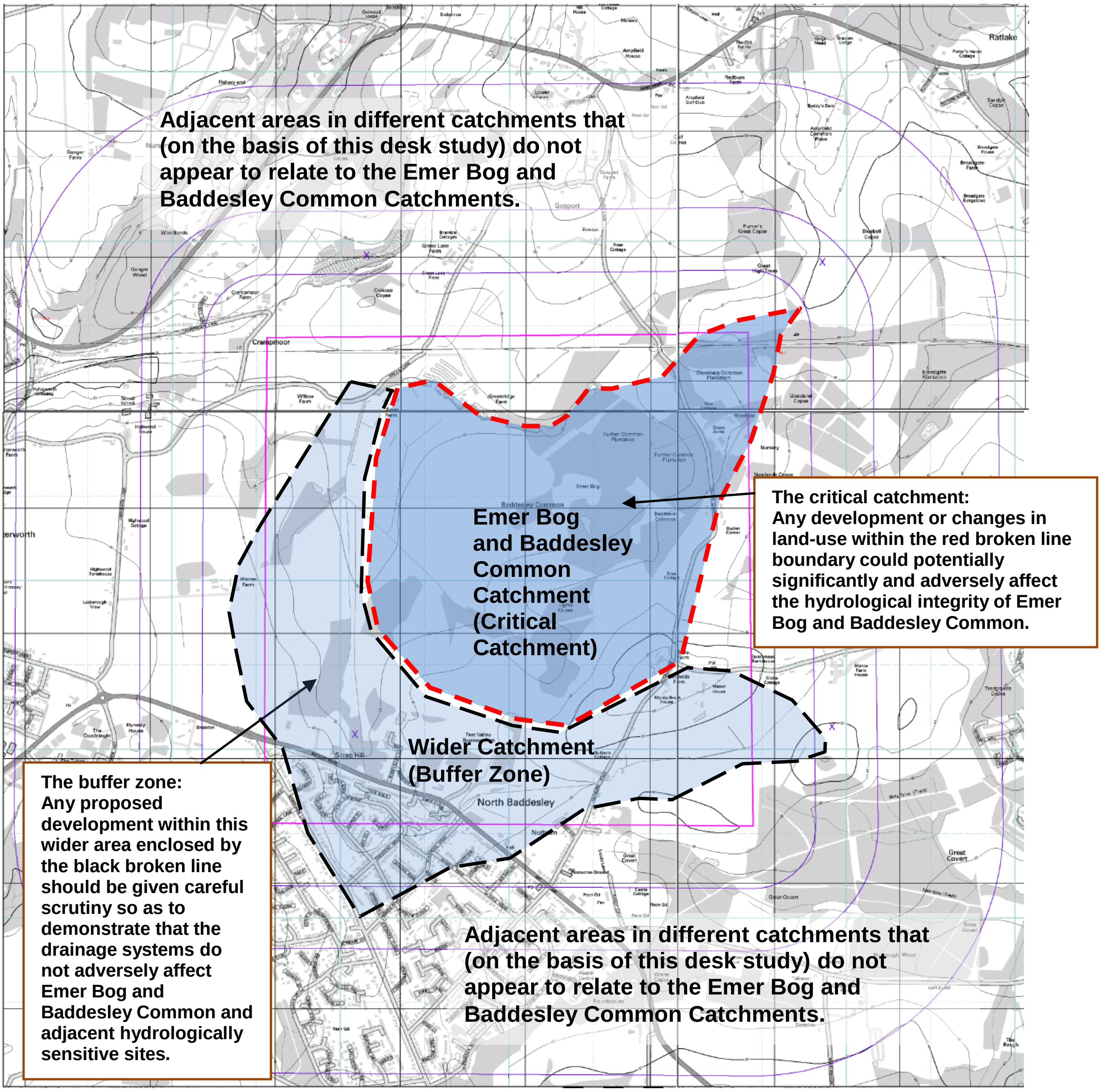


Fig. 30 The two catchment groupings critical to the hydrology of Emer Bog and Baddesley Common. This drawing has been simplified from Figure 25 and which figure shows greater detail.

Emer Bog and Baddesley Common Catchment (Critical Catchment)

14.33 **Figures 23, 25 and 30** illustrate the combined boundary of the Emer Bog and Baddesley Common catchments in darker blue bounded by a red broken line. This is the area where development or land-use change could very probably lead to adverse hydrological effects.

Any built development (such as for housing, commercial or industrial use) or changes in land-use (such as conversion of low-intensity grassland to fertilised ley grassland or arable use) on land within the red broken line boundary could potentially significantly and adversely affect the hydrological integrity of Emer Bog and Baddesley Common. This could be so even if sustainable drainage schemes (SUDS) are proposed. Any proposals for development or changes to drainage flows and drainage water chemistry in this area should either be avoided or receive particularly critical assessment. Such critical assessment would involve detailed monitoring of water flows and water chemistry in order to demonstrate lack of impact.

Wider Catchment (Buffer Zone)

14.36 **Figures 23, 25 and 30** also show a wider area in pale blue that extends to the west and south and being delineated by a black broken line. This extended area includes most of the catchment of the Tadburn Lake southern tributary including its own small headwater tributary, the North Baddesley Stream.

14.37 Examination of the flow-ways in this extended area suggests that surface water in this wider area bypasses Emer Bog and Baddesley Common along the Tadburn Lake southern tributary system en route north to the Tadburn Lake stream.

14.38 Surface water arising off development within this wider area is unlikely to reach the Emer Bog and Baddesley Common catchments because of landform slope direction and flow-way routing. However, this area does contain land designated as Sites of Importance for Nature Conservation (SINCS) that could potentially be affected by drainage schemes.

Any proposed development (such as for housing, commercial or industrial use) within this wider area enclosed by the black broken line must demonstrate that the drainage systems do not affect Emer Bog and Baddesley Common and adjacent hydrologically sensitive sites.

14.39 There will need to be scrutiny in this area because the data on which these conclusions are based are derived from a desk study of available information and which have not been checked on the ground.

Adjacent Areas

14.40 Adjacent land outside of the blue areas (ie. those areas outside of the red and black broken lines and shown in **Figure 30**) falls variously into the catchments of the Monk's Brook, the Tanner's Brook and the Test Valley. These catchments support surface streams that flow away from Emer Bog and Baddesley Common and this means that drainage off developments here (on the basis of this desk study) would be unlikely to affect Emer Bog and Baddesley Common.

On the evidence presented in this desk study, development within these outer catchments (which feed water away from Emer Bog and Baddesley Common) would be unlikely to affect the hydrological integrity of Emer Bog and Baddesley Common. However, development drainage systems in close vicinity to the boundaries of the critical catchment and buffer zone must demonstrate that the drainage systems do not affect Emer Bog and Baddesley Common and adjacent hydrologically sensitive sites.

Objective d)

Assessment of the potential impact of climate change on this designation (focussing on hydrological considerations) and how this might affect the application and consideration of the spatial buffer (referred to in point b).

14.42 An assessment of the potential impact of climate change on the hydrology of the wetland main habitats at Emer Bog and Baddesley Common has been made using the Tier 1 tool of the Centre for Ecology and Hydrology's Wetland Tool. This tool uses the medium emissions scenario to assess the percentage probability of low, medium and high impact for the 2050s.

14.43 The Tier 1 tool does not provide a detailed prediction for a particular wetland. It provides a generalised regional indication of the potential likelihood and magnitude of climate change impacts on wetlands suitable for risk screening and investigating uncertainty.

14.44 The tool uses a combination of location, different water sources, wetland type (NVC class) and interest features (hydrological, ecology, historic environment, plant communities and birds) to provide a programme that assesses the probability of a low, medium or high impact.

14.45 Only a small range of vegetation classes (NVC) and water sources are used by the programme, few of which are directly relevant to the situation at Emer Bog and Baddesley Common. In view of this, I have made judgements about the best fit of the options available and provided a traffic light system identifying the probability of Low (green), Medium (amber) and High (red) impacts.

14.46 Where a high probability of impact is assessed, the impact may be mitigated by changes in site management.

On the evidence presented from the Tier 1 assessment, the overall probability of climate change impact by the 2050s is Low. This Low probability applies particularly to hydrological change in terms of maximum and minimum annual and mean water levels, to some saturation depth durations and to many summer and winter impacts on birds. In some instances, there is a probability of Medium Impact and there are some categories with a High probability of impact. High probability of impact relates most often to gross annual water balance, departure from plant water level requirements, and to some historic environment soil saturation periods. The least impacted habitats are mire and swamp communities. The most impacted habitats are wet grassland and wet heath communities.

FURTHER REQUIREMENTS

14.47 Section 3 'Scope and Outputs of Project' of the TVBC Brief of Requirements indicates (in paragraphs 3.2 – 3.5) that:

Brief of Requirements Para 3.2

> In relation to the identification of the spatial catchment, it would be expected that previous studies on this matter be reviewed, including the surface water discharge constraints map identified in the 2002 study referred to above. Consideration should also be given to how groundwater and water quality impacts (e.g. from consented activities, urban edge effects, etc) would be accounted for / addressed.

Discussion

14.48 The constraints map in the 2002 report[60] was the result of a scoping study utilising 1:25000 scale mapping alone. This current 2016 desk study used many more detailed data sources at a scale of 1:10 000 to better identify the catchment of Emer Bog and Baddesley Common.

14.49 The result of this more detailed study was very similar to that of the 2002 report but with minor differences. In the 2002 report I excluded the built up area of North Baddesley in the south (this area having already been developed) and took the railway line in the north as a convenient boundary line (and so included some land north of the Tadburn Brook stream). There were also minor differences of alignment along the western and eastern boundaries.

14.50 This (2016) report tidies up the earlier boundaries and defines:

- an inner critical catchment including both the Emer Bog and Baddesley Common catchments within which any development is very likely to have adverse effects on the site's hydrological integrity; and also
- a wider buffer zone area within which the hydrological impact of development should be given careful hydrological assessment.

Brief of Requirements Para 3.3

> It would be beneficial to review the monitoring protocol identified in the 2003 study. This should inform the establishment of an initial draft protocol for the Wildlife Trust to undertake within its nature reserve in relation to water and nutrients. The study should consider whether phosphorus and nitrogen can be attributed to external activities and the pathway (e.g. surface water, groundwater), whether this can be monitored and implications for the pH values.

14.51 Section 7 of the 2003 report made recommendations for further studies, monitoring and management of Emer Bog. In particular, the recommendations were for:

2003 Section 7.2 Vegetation survey

14.52 A detailed survey of the M5 *Carex rostrata – Sphagnum squarrosum* Mire acidic plant community to include both the boundary and botanical composition so that changes in critical species abundance and distribution can be assessed over time. The boundaries can be accurately plotted from the detailed topographic survey available coupled with aerial photography.

Discussion

14.53 The M5 community is the most sensitive plant community on site to changes in pH and nutrient conditions. This makes the M5 community a good indicator of changes in water

[60] Drawing 11 Area of discharge constraint to protect key habitats within Emer Bog

chemistry on site. Wheeler and Shaw (2003)[61] indicate this community already has a very fertile substratum, and so it could be adversely affected if fertility was to further increase.

14.54 Monitoring the boundary of this community and plant composition would assist in not only monitoring the M5 community, but also provide an alert to the wider area.

2003 Section 7.3 Hydrochemical survey data

14.55 Three alternative schemes were suggested:

Minimum scheme: pH only

A minimum scheme of pH monitoring at regular intervals throughout the year in different wetland habitats and particularly around the M5 community, the feeder streams and the ponds. The number of sampling points would decrease as the site dries out during the summer and so it would be important to survey the extent of open water throughout the year.

Discussion

This survey could be undertaken using a simple battery operated pH meter. However, it is important that the meter is kept clean and set up correctly against pH standards prior to each use in order to get accurate and consistent results.

Intermediate scheme and Advanced scheme: Water chemistry

Nutrient analysis of water samples from key streams, springs and drains and along a transect from acidic to less acidic habitats.

Discussion

There are four alternative options.

Option 1 Laboratory sampling from water samples and tested as a minimum for SRP (Soluble reactive phosphorus) and nitrogen (as nitrate N, nitrite N and ammonia N). Ideally analytical determination methodology should match the standards used by the Environment Agency. This is the best option, but likely to be the most expensive method (unless external funding could be achieved).

Option 2 Use field assessment methods for phosphorus and nitrogen. There are various test kits available. One to consider is the PacTest used by the Freshwater Habitats Trust ‘Clean Water for Wildlife’ survey[62]. Given care, these kits can be used by non-specialist staff and volunteers.

Option 3 Laboratory for field test determinations of water chemistry from the rooting zone by sampling from water flowing into holes excavated into saturated deposits. Monitoring of root zone interstitial water will give a better indication of habitat fertility, especially where the habitat is influenced by groundwater as opposed to (or in addition to) surface water.

Option 4 To combine the above with: a) assessing water levels above and below the surface from 1.5m deep dipwells inserted by hand (or light tracked machine) into a range of locations across the site, and b) assessing ground

[61] Fertility Determinations at Emer Bog Interim Draft Report B D Wheeler and S C Shaw, Department of Animal and Plant Sciences, University of Sheffield March 2003

[62] http://freshwaterhabitats.org.uk/projects/clean-water/ and http://freshwaterhabitats.org.uk/projects/clean-water/clean-water-science/

water levels and water chemistry from one or more deep (5m-10m) boreholes on site (a costly option).

Discussion and recommendation

14.56 I suggest that an appropriate scheme would be to test water every two months through the year for soluble reactive phosphorus (SRP), nitrate N, nitrite N and ammonia N from:

- the inflowing water sources at or just within the boundary of Emer Bog and at the sources to the Baddesley Common stream (to check external surface water sources);
- the outfalling streams at Emer Bog and Baddesley Common (to check for sources arising within the site);
- the two lakes (as permanent water bodies); and
- a series of key flooded locations within Emer Bog.

Additionally to:

- install a series of 1.5m dipwells from which to measure above and below groundwater levels through the year.

Optionally:

- to commission a deep borehole to record deep groundwater water chemistry and levels.

Brief of Requirements Paragraph 3.4

As part of the review of the site to sensitivities to surface water and groundwater change, a consideration should be given to a 2km catchment (from a centre point in Emer Bog / Baddesley Common).

Discussion

14.57 A minimum 2km catchment boundary has been used throughout this report.

Brief of Requirements Paragraph 3.5

In considering susceptibility to climate change, a tier 1 assessment using the CEH Wetland Tool should be undertaken.

Discussion

14.58 A Tier 1 assessment has been undertaken for a range of hydrological, vegetation and bird scenarios. It is important to note that The Tier 1 tool does not provide a detailed prediction for a particular wetland. It provides a generalised regional indication of the potential likelihood and magnitude of climate change impacts on wetlands by 2050 and is suitable for risk screening and investigating uncertainty.

14.59 The factors used in the Tier 1 assessment do not fit well with the hydrology and vegetation at Emer Bog and Baddesley Common and so I have made judgements as to the best fit situation.

14.60 Overall, the hydrological risk from climate change by the 2050s to Emer Bog and Baddesley Common is assessed as Low but in some particular cases the risk rises through Medium to High.

14.61 On the basis of the Tier 1 assessment, the overall probability of climate change impact by the 2050s is Low. Low probability applies particularly to hydrological water level change and to most seasonal impacts on birds. High probability of impact relates most often to annual water balance, departure from plant water level requirements, and to some historic environment soil saturation periods.

14.62 The least impacted habitats are mire and swamp communities. The most impacted habitats are wet grassland and wet heath communities.

This document has been prepared by Ron Allen BSc Hons (Lond), ARSM, CEnv, CBiol, CSci, EurProBiol, MIEEM, MSB, MIEnvSc
Environmental Consultant, Chartered Environmentalist, Chartered Scientist and Chartered Biologist.
Specialist in Hydrological and Wetland Habitat Assessment.

Ron Allen can be contacted at:
The Environmental Project Consulting Group
44A Winchester Road, Petersfield, Hampshire GU32 3PG
Tel. 01730 266966
Email. ra@epcg.co.uk
Web. www.epcg.co.uk, www.soilandwater.co.uk, www.hydro-ecology.co.uk