Report by Dr Jo Parmenter, Director of The Landscape Partnership.

An Ecological Summary

CATFIELD ABSTRACTION LICENCE RENEWAL – ECOLOGICAL SUMMARY

INTRODUCTION

This submission has been prepared by Dr Jo Parmenter, Director of The Landscape Partnership. Dr Parmenter is an Environmental Consultant, and has a background in ecology, landscape archaeology and environmental sciences. Dr Parmenter is a Chartered Environmentalist and a member of both the Institute of Ecology and Environmental Management and the Institute of Environmental Management and Assessment.

Dr Parmenter has been in practice with The Landscape Partnership since May 2002 and has over 25 years' experience as an ecologist, 20 of which have been spent in consultancy. She leads the Ecology team within the practice. She has been involved in providing ecological services to a wide range of developments, from major housing and infrastructure projects to minerals and waste schemes, and has a particular interest in the creation, development and management of landscapes and ecosystems, both natural and man-made, with an academic specialism in wetland landscapes and ecosystems.

Dr Parmenter is a graduate of the University of Sussex (BSc (Hons.)) and subsequently completed a PhD, which focussed on wetland development in response to environmental and socio-historical factors in the Broadland Fens, at The University of East Anglia. Relevant published and unpublished work includes:

DRISCOLL, R. J. and PARMENTER, J.M. 1994 Robert Gurney's 1908/1909 vegetation survey of Broadland. *Transactions of the Norfolk and Norwich Naturalists' Society* **30**(1), 71-79

PARMENTER, J.M. 1995 *Report of the 1991-1994 Broadland Fen Resource Survey (*11 Vols). Broads Authority.

PARMENTER, J.M. 1995 *A summary of the historical distribution of nationally rare and scarce plant species in the Broadland fens*. Unpublished report to the Broads Authority.

PARMENTER, J. M. and DRISCOLL, R. J. 1996 The Broadland Fen Resource Survey, 1991-1994. A brief summary. *Transactions of the Norfolk and Norwich Naturalists' Society* **30**(5), 564-574

PARMENTER, J, M. and DRISCOLL, R.J. 1996 The vegetation at Honing Common: a century of change. Transactions *of the Norfolk and Norwich Naturalists' Society* **30**(5), 578-586.

PARMENTER, J.M. 1996 *Upton Fen & The Doles Management Plan 1996-2001*. Unpublished report to Norfolk Wildlife Trust and Norwich Union.

PARMENTER, J.[M.] 1999 *Redgrave and Lopham Fen NNR. Report on the fen vegetation monitoring programme August 1999.* Unpublished Ecological Associates report to the Suffolk Wildlife Trust.

PARMENTER, J.M. 2000 *The development of the wetland vegetation of the Broadland region: A study of the sociohistorical factors which have influenced and modified the development of fen vegetation in Broadland.* PhD thesis. Centre of East Anglian Studies, University of East Anglia. December 2000.

THE LANDSCAPE PARTNERSHIP 2013 *Ecological and Stratigraphic Review, Catfield Fen,* on behalf of Mr & Mrs Tim Harris. May 2013

THE LANDSCAPE PARTNERSHIP and RICHES, O.P. 2014 CATFIELD FEN: A *Response to the AMEC Technical* Note*: Notes on the Management of Catfield Fen*. July 2014

THE LANDSCAPE PARTNERSHIP 2014 *Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3.* June 2014

EXECUTIVE SUMMARY

The Environment Agency's recent 'minded to' decision to refuse the renewal of the agricultural abstraction licences is a positive step in ensuring long-term protection of Catfield Fen, however this decision, although correct, fails to take into account a number of very important ecohydrological factors as set out below.

This submission considers a number of points relating specifically to the ecology, eco-hydrology and management of Catfield Fen, a component site of the Ant Broads and Marshes, SSSI, Norfolk, The Broads Special Area of Conservation (SAC), Broadland Special Protection Area (SPA) and Broadland Ramsar.

It draws upon a number of observations on the documentation used to support the Environment Agency's licensing decision, which are detailed in the remainder of the paper and elsewhere.

The significance of the following points are considered in particular detail: the impact of pH change upon fen invertebrates; condition assessment; the effect of management; the ecohydrological guidelines; and summarising new work.

A selection of the documents which underpin the report, and which have been made available by the Environment Agency, have also been reviewed, focussing on material produced since 2012, and including comment on the draft determination report.

CONTEXT

This submission responds to a number of points raised in the documentation used to support the Environment Agency's 'minded-to' decision with respect to two licences to abstract groundwater from sites in the vicinity of Catfield Fen. Responses have been invited to consider:

i. whether there is anything that is perceived to be inaccurate in the draft determination report;
ii. has the EA failed to consider anything that it should have; and
iii. has information become available in the time that has elapsed since a previous consultation in 2012?

It is important to note that there is clear evidence that rapid ecological change is taking place in Units 3 and 11, and this change has become apparent since the 1980s[1].

In addition, the RSPB and The Landscape Partnership have reported changes indicating declines in Ellenberg indices for reaction and wetness, and a reduced frequency of a number of species indicative of more calcareous and wetter conditions[2].

In the light of recent evidence of vegetation change, Natural England (NE) have advised that Unit 3 should be reclassified as being in "unfavourable declining" condition[3] (previously unfavourable

[1] Natural England 2014 Natural England Report 6. (post Appropriate assessment) to the Environment Agency 20.6.14
[2] Natural England 2014 Report 5. Natural England advice to the Environment Agency on Condition Assessment at Catfield Fen: consideration of recent trends in distribution of *Potamogeton* and *Liparis* in Unit 3. Provided by Mr Harris 24 June 2014
[3] Natural England 2014 Report 5. Natural England advice to the Environment Agency on Condition Assessment at Catfield Fen: consideration of recent trends in distribution of *Potamogeton* and *Liparis* in Unit 3. Provided by Mr Harris 24 June 2014

recovering) and the classification was subsequently formally updated[4]. Units 3, 10, 11 and 35 are identified as being under hydrological threat.

It is generally agreed that Catfield Fen (within the Ant Broads and Marshes SSSI) is a complex hydrological system (AMEC Report, Oct. 2014; p. 24) with a complex geology (AMEC Report, Oct. 2014 p. 115). However, several points should be emphasised:

Catfield Fen is a groundwater dependent ecosystem. Calcium-rich groundwater has played a major role in the development of the fen vegetation within the internal fen system, including the fen communities for which the SAC is designated[5]. The inference is that Catfield Fen would be significantly affected, if not irreversibly degraded, if groundwater availability were to vary beyond the normal (baseline) range of fluctuation[6], as increasingly appears to be the case. Both Units 3 and 11 have been recognised by Natural England as being vulnerable to hydrological threat[7].

Catfield Fen was formerly considered to be a hydrologically 'sealed' system, with little or no connectivity between the fen peats and the underlying Crag. This was predicated on the assumption that a thin clay layer covered the upper surface of the Crag. However, there appear to be windows in the clay[8], and recent transects across Catfield Hall Fen found that, whilst some clay is present, the composition of the upper zones of the Crag was typically ~ 50% sand and gravel, and in many places the clay was absent. Consequently there are only a very few points at Catfield where the crag-clay might be considered truly impermeable[9]. Thus the stratigraphic evidence indicates hydraulic connectivity between the peat and the Crag, with the inference that the fen is either groundwater-dependent or groundwater-fed[10].

There is evidence of marked spatial differences in the proportions of base-rich and base-poor waters in the rooting zone at Catfield Fen. This has implications for the ecology of the wetland, which has evolved in response to a fragile balance between the relative contributions of the principal water source: calcareous groundwater and the more acidic waters derived from precipitation.

The ecological significance of the balance between the relative contributions of precipitation and groundwater to the surficial (near-surface) of the fen is critical to assessing (and quantifying) the impact of groundwater abstraction on the fen.

In this situation, certain deep-rooting calcareous tall herb fen species may be rooted through the shallow rainwater table and into the minerotrophic water table below, whereas the bryophyte community and shallow-rooted herbs are predominantly influenced by the perched rainwater table. As the two water types have contrasting hydrochemistries, an acid bog vegetation characterised by *Sphagnum* is found beneath a layer of rich-fen tall herbs. These are the prevailing conditions in *Dryopteris cristata* - *Sphagnum* fens found in the Norfolk Broads, for which Catfield is the type locality.

[4] http://designatedsites.naturalengland.org.uk/SiteUnitList.aspx?SiteCode=s1000501&SiteName=&countyCode=&responsiblePerson=

[5] The Landscape Partnership 2013 Notes of meeting held on 21/11/13: Catfield Fen - summary of meeting held between EA, NE and Mr & Mrs Harris. 10/12/13

[6] The Landscape Partnership 2013 Notes of meeting held on 21/11/13: Catfield Fen - summary of meeting held between EA, NE and Mr & Mrs Harris. 10/12/13

[7] http://www.sssi.naturalengland.org.uk/Special/sssi/unitlist.cfm?sssi_id=1000501

[8] Gilvear, DJ, PJK Sadler, JH Tellam, JW Lloyd. 1997. Surface water processes and groundwater flow within a hydrologically complex floodplain wetland, Norfolk Broads, UK. Hydrology and Earth System Sciences, 1, 115-135.

[9] The Landscape Partnership 2013 Ecological and Stratigraphic Review, Catfield Fen on behalf of Mr & Mrs Tim Harris. May 2013

[10] The Landscape Partnership 2013 Ecological and Stratigraphic Review, Catfield Fen on behalf of Mr & Mrs Tim Harris. May 2013

In order to understand the impact of groundwater abstraction, it is important to consider not only wetland water levels, but also the balance between precipitation and groundwater within the rooting zone (i.e. in the specific area where the hydrology will influence the ecology). The hydrology of this rooting zone varies spatially (both laterally and horizontally) and temporally.

In addition to *Liparis loeselii* ssp l*oeselii*, which occurs at the site, a number of other fen species of national importance due to their restricted distribution or range exhibit a preference for more base-rich conditions and are likely to be at risk if there is any reduction in the groundwater contribution to the fen and the current trend towards acidification continues. These include *Potamogeton coloratus, Carex appropinquata, Dactylorhiza traunsteineroides* (the Broadland plants are now considered to be *Dactylorhiza praetermissa* ssp. *schoenophila* RM Bateman & Denham[11]; an infraspecific taxon distinct from northerly *D traunsteineroides* populations, and confined to southern England) and *Pyrola rotundifolia.* Both the RSPB and The Landscape Partnership have reported changes in vegetation communities and commensurate declines in Ellenberg indices for reaction (pH), and also a markedly reduced frequency of a number of the above species and also other fen plants which have a preference for more calcareous conditions[12].

It has been noted by Natural England, amongst other interested parties, that to date, there has been a significant lack of work linking the hydrology and the ecology of the fen. This has created a number of uncertainties when considering the impact of local groundwater abstraction.

CONSIDERATION OF SPECIFIC ECOLOGICAL AND ECO-HYDROLOGICAL ISSUES

Water level requirements of wetland vegetation.

In general the documentation presented by the Environment Agency fails to draw upon new research in wetland ecology, and the accuracy of some of the statements on the hydrological requirements of specific plants is questionable. For example, the AMEC groundwater report[13] states that the water requirements of the 'ecological features' at Catfield Fen are a winter water table at around the fen surface and a summer water table of "*no lower than 30-40cm below the fen surface*". It is suggested that the source for this statement is the "Ecohydrological Guidelines" (Wheeler *et al*., 2004 (updated 2010)). However, Wheeler *et al.,* (2004) state that the mean summer table for S24 communities is -16.7cm rather than -30-40 cm below ground surface. Wheeler *et al* also note that "It is often difficult to know to what extent 'summer-dry' stands are natural or represent remnants of formerly wetter S24". Wheeler *et al* further note "…*that different sub-communities* [of S24] *tend to be associated with rather different sets of* [hydrological] *conditions*". There is a significant disparity between the mean water tables given by Wheeler *et al* and those stated in the EA report.

S27 and the wettest and richest S24 sub-communities are associated with water table levels ranging between just above ground-level to just below ground-level. In this context, a consistent drawdown of a few centimetres constitutes a significant change, and might be expected to bring about loss of species of wetter conditions (often the most highly valued), and a change in sub-community.[14]

[11] Bateman, R.M. & Denholm, I., 2012, Taxonomic reassessment of the British and Irish tetraploid marsh-orchids, *New Journal of Botany* 2.1 37-55

[12] Natural England 2014 Report 5. Natural England advice to the Environment Agency on Condition Assessment at Catfield Fen: consideration of recent trends in distribution of *Potamogeton* and *Liparis* in Unit 3. Provided by Mr Harris 24 June 2014

[13] Amec 2014f Main Groundwater Report.

[14] Natural England 2014 Natural England Report 6. (post Appropriate assessment) to the Environment Agency 20.6.14

Thus, use of a generic 5cm drawdown as 'low risk' is questionable, as this measurement is derived from data for a wide range of wetland types, most of which are significantly less sensitive to hydrological change than the vegetation communities which are present at Catfield Fen. [15]

It should also be noted that although some data from other East Anglian sites indicates minimum water tables of -26.2cm for S24d vegetation, this – and indeed other water level ranges quoted in the Guidelines - **cannot necessarily be regarded as an acceptable minimum water level**. The fen sites from which the water table data in the Ecohydrological Guidelines were drawn occur across East Anglia, and include fen sites in both optimum and sub-optimum condition. The Wetland Framework acknowledges that "lower water-tables may be a feature of some sites, but it is difficult to establish whether this is a 'natural' state of affairs or remnant of formerly wetter S24". Consequently statements in the draft determination report regarding the ecohydrological guidelines are questionable, and there is significantly greater uncertainty in these data than the report suggests.

pH change

The ecology of Catfield reflects the spatial and temporal variability in the hydrochemistry of waters in the rooting zone. Until recently the pH of waters in this zone have been relatively neglected. pH is a logarithmic measure of the availability of hydrogen ions, and recent empirical data from Catfield indicate that there have been marked changes in pH, and in the proportion of base-rich and base-poor waters in the rooting zone at Catfield Fen[16] over the last ~30 years. The degree to which these changes can be 'modelled' is questionable (English Nature have expressed misgivings about the methodology as noted below); few field-observations of pH are available for Catfield and hence model output cannot be verified, yet hydrochemistry correlates well with vegetation quality and should have been considered in more detail when seeking to quantify the effect of local groundwater abstraction.

Recent work undertaken by RSPB at Catfield Fen Unit 3 indicates a loss of 1.25ha[17] of S24e type vegetation and a commensurate increase in *Sphagnum*[18], indicative of an increase in acid conditions and loss of very wet base-rich conditions at the fen surface.[19]

The *Sphagnum* expansion has taken place not only over turbary, where buoyant vegetation rafts have formed, but also on areas of solid peat at the fen edge.[20] In the past, various researchers have theorised that the nature of the buoyant vegetation rafts means that *Sphagnum* is lifted above the influence of calcareous groundwater. The presence of *Sphagnum* on solid peat suggests that the prevailing water conditions at the fen surface are now sufficiently acidic for *Sphagnum* to thrive.

The peat horizon of particular concern is that which relates to the main rooting zone of the vegetation communities of particular interest. This is approximately the depth from the fen surface to -30cm[21]. Whilst reed, sedge and a number of the larger and more vigorous fen species undoubtedly root to greater depths, the majority of the key plants for which the fen is important root at shallower depths, and are thus likely to be vulnerable to reduced pH at, and close to the fen surface.

[15] Natural England 2014 Natural England Report 6. (post Appropriate assessment) to the Environment Agency 20.6.14
[16] The Landscape Partnership 2013 Notes of meeting held on 21/11/13: Catfield Fen - summary of meeting held between EA, NE and Mr & Mrs Harris. 10/12/13
[17] Natural England 2014 Report 5. Natural England advice to the Environment Agency on Condition Assessment at Catfield Fen: consideration of recent trends in distribution of *Potamogeton* and *Liparis* in Unit 3. Provided by Mr Harris 24 June 2014
[18] RSPB 2014 A survey of Sphagnum moss at Butterfly Conservation Catfield Fen and comparison with past surveys.
[19] Natural England 2014 Report 4. (post Appropriate assessment) to the Environment Agency 20.6.14
[20] Natural England 2014 Report 4. (post Appropriate assessment) to the Environment Agency 20.6.14
[21] NE Response to query from EA (meeting with Broads Authority, EA and NE June 2 2014)

Recent research demonstrates that the Crag occurs very close to the surface of the fen in Middle Marsh (within 40cm of the surface), with no intervening clay layer[22]. In theory, this should facilitate the upward flow of groundwater into the overlying peat. However the opposite seems to be the case. In the eastern part of Middle Marsh, levels of groundwater indicators (such as the calcium and magnesium in waters sampled near the surface in the upper Crag) are significantly lower than is the case across the rest of the Catfield Hall Estate, and it has been postulated that, as the upper layers of sandy crag are not saturated with groundwater, this allows rainwater to infiltrate and percolate to depth in the soil/peat profile and also the upper Crag. This process results in 'dry spots' and low ionic concentrations in the peat[23].

Recent field research at Catfield by the University of Utrecht provides important new evidence which helps to explain the changes in *Sphagnum* abundance, suggesting a hydrological mechanism that is supported by empirical evidence (rather than the speculative suggestion that the ecological changes are due to management, made in a number of documents). Results of fieldwork in 2014 at Catfield document a dramatic shift in surface water pH across the internal system, and the apparent reduction of upwelling calcareous groundwater. This has been demonstrated by the University of Utrecht (Pyne and Barendregt) in Unit 11 and similar results have also been recorded by Richard Mason (RSPB) in Unit 3.

A review of historic (1988[24]) and more recent (2005[25] and 2014[26]) surface pH data has shown a trend towards increasing acidification of water at the fen surface over the past c10 years. There is a distinct correlation between the hydrochemistry and the quality of vegetation. As calcareous fen vegetation quality decreases and bog conditions are stimulated, so do all indicators for groundwater flow.[27]

Recent evidence from the Netherlands demonstrates that, in Dutch wetlands that are similar in a number of respects to Catfield, in instances where there was a reduction in groundwater discharge due to local groundwater abstraction, rainwater infiltration occurs. This initiates the process of acidification: fen soils have buffering capacity to withstand this process for a number of years, but ultimately, the residual buffering capacity is exhausted. Within a short period (2 - 4 years) the pH of the upper layers of peat will change from a pH-value of 6-7 to 5 or less[28].

Recent and ongoing work by RSPB (Mason, in prep) includes the survey of pH levels in the interstitial soil water across Unit 3, to determine how this changes with depth. Data from a series of transects across the fen have been compared with data collected by Giller and Wheeler (1988).[29] The Giller and Wheeler data compared pH levels in *Sphagnum* dominated areas with areas of S2/S24e vegetation, in the mid 1980's, and found that beneath the latter two vegetation types, the pH both at the fen surface and in the interstitial water at depths down to -150cm remained entirely within the range pH7-pH8. In contrast, the *Sphagnum* dominated areas had surface pH values between 4 and

[22] The Landscape Partnership 2013 Ecological and Stratigraphic Review, Catfield Fen on behalf of Mr & Mrs Tim Harris. May 2013

[23] Pyne, E & Barendregt, A 2014 Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen

[24] Collins 1988; Atkins/HSI (2005); Ewan (2005). Data from these reports is reproduced at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/289540/Catfield_Appendix_F_5B1_5D_324668.pdf

[25] Collins 1988; Atkins/HSI (2005); Ewan (2005). Data from these reports is reproduced at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/289540/Catfield_Appendix_F_5B1_5D_324668.pdf

[26] The Landscape Partnership 2014 pH change at Catfield Fen. Unpublished report.

[27] Pyne, E & Barendregt, A 2014 Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen

[28] Barendregt, A 2013 Processes for fens and conditions in Catfield Fen. Uniblished report December 2013.

[29] Giller and Wheeler (1988). Acidification and Succession in a Flood-Plain Mire in the Norfolk Broadland, U.K. *Journal of Ecology (1988), 76, 849-866*

5, but pH quite rapidly increased with depth, so that pH7 was reached at c-65cm. Thereafter the interstitial pH beneath the *Sphagnum* polster remained within the pH7-pH8 range. Conversely, the recent RSPB survey has measured surface pH as low as pH3.5 in some *Sphagnum* dominated areas, with the pH at depth both beneath *Sphagnum* and elsewhere in the fen being typically well below pH7 (Mason, in prep).

The transition community with *Sphagnum fallax* is present in many locations in Catfield Hall Fen, and is characterized by accumulation of rainwater, with the groundwater input at surface being reduced. It is surmised that in recent years buffered groundwater discharge has reduced and as a consequence acid rainwater plays an increased role in the upper peat layers, stimulating *Sphagnum* growth. The balance in input with rainwater and groundwater has changed at many locations in favour of acid rainwater, thence decreasing suitability for rich fen vegetation. [30]

The number of locations in the east of Catfield Fen in which calcium-rich water is present at the surface is very limited (as of spring 2014). Measurements in the upper peat layers contrast markedly with findings from the deeper deposits; the deeper layers in the peat in general were found to have higher electrical conductivity and higher calcium concentrations.[31] The higher concentration of chloride and sodium at these locations prove previous discharge of groundwater that has passed through saline layers. The absence of rich fen conditions, including vegetation, at many locations is recent and the most likely explanation for the change is reduced groundwater input. [32]

AMEC[33] have modelled the change in pH resulting from the drawdown levels identified in their hydrological model as being 0.16 of a pH unit between naturalised and historical conditions. Natural England have expressed significant misgivings about the methodology used and shortcomings in the hydrological model itself[34] and are unable to indicate whether or not this value may be ecologically significant nor whether changes in pH predicted are likely to be an indication of the scale of impact of abstraction. Contrary to a statement in an AMEC report on fen management[35], increased summer rainfall only leads to a significant change in water chemistry if there is a loss of base rich groundwater at the same time, for example as a consequence of abstraction[36]. Natural England further note that the model indicates that there may be a potential path of change from water table changes to potential changes in pH,[37] and that, although the model has indicated that changes are small, the modelled decrease in pH is consistent with the direction of change in vegetation, which clearly shows a shift from species of more base-rich conditions to those of more acidic conditions.

The EA has argued that Catfield Fen is a highly sensitive site that has long been known to be prone to surface acidification, such that very small changes in fen surface elevation, could alter the hydrological conditions at the fen surface sufficiently to reach a tipping point. In these circumstances, even a subtle change in the balance of water supplying the fen surface, could potentially lead to quite dramatic ecological changes. A more likely explanation for this phenomenon is the shift in surface water pH across the internal system, and the quite dramatic reduction in

[30] Pyne, E & Barendregt, A 2014 Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen
[31] Pyne, E & Barendregt, A 2014 Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen
[32] Pyne, E & Barendregt, A 2014 Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen
[33] Amec (2014h) Addendum to Main GW Report (2 documents)
[34] Report 7 (post EA appropriate assessment). The Environment have asked for NE's view on water chemistry aspects featured in the final Report on the Assessment of Abstraction within the Ludham-Catfield area in the vicinity of Ant Broads and Marshes SSSI (22 Aug 2014)
[35] Amec (2014e) Site Management Technical Note
[36] The Landscape Partnership and Riches, O P 2014 CATFIELD FEN: A Response to the AMEC Technical Note: Notes on the Management of Catfield Fen. July 2014
[37] Report 7 (post EA appropriate assessment). The Environment have asked for NE's view on water chemistry aspects featured in the final Report on the Assessment of Abstraction within the Ludham-Catfield area in the vicinity of Ant Broads and Marshes SSSI (22 Aug 2014)

upwelling calcareous groundwater as demonstrated by Erin Pyne in Unit 11 and Richard Mason in Unit 3.

The work undertaken by AMEC and the Environment Agency to date makes no reference to aluminium toxicity or phosphate deficiency and it appears that this aspect of acidification on rich fen plant communities has not been considered.

Aluminium becomes soluble as the trivalent cation in waters lower than c. pH6, (with dramatically increasing solubility occurring below pH 5.5), and can subsequently be absorbed by plants[38]. Aluminium is known to inhibit root growth (root tip mitosis) and also binds readily with phosphates to form an insoluble aluminium phosphate complex; which can also lead to phosphate deficiency[39] [40].

Aluminium-sensitive plants; typically calcicoles, therefore show signs of root stunting and phosphorus deficiency. Conversely, calcifugous plants have evolved a physiological tolerance to these acid soil conditions. This is demonstrated *in vivo* by the replacement of the calcicole *Potamogeton coloratus* by the calcifuge *P. polygonifolius* at around pH6.

Common reed (*Phragmites australis*) is considered to be a good indicator of environmental conditions as it is provides an accurate representation of metals present in sediment[41]. Areas of common reed at Catfield Fen have been observed to be showing signs of decline, e.g. reduced vigour, slower growth rate, etc, which has taken place concurrently with increasing acidity and it is possible that bioaccumulation of aluminium is the cause[42]. Further research is needed to determine whether this is the case.

It has already been discovered the acidification of Catfield Fen has led to the displacement of *Potamogeton coloratus* with *Potamogeton polygonifolius*, and other key species of flora at risk of being negatively affected by pH levels below 6 include *Liparis loeselii*, *Carex appropinquata* and *Pyrola rotundifolia*.

Implications for fen plant species

The internal fen system at Catfield supports the main population of the SAC Annex II species fen orchid. It also supports the majority of the other fen species for which the SSSI was designated[43].

Catfield Fen supports over 50% of the population of *Liparis loeselii* var *loeselii* and is the largest and most important colony of this species in the UK. There are two further sites for this plant in the UK, one of which, Sutton Fen, is also potentially threatened by water abstraction. Together, these two sites support around 95% of the UK population[44].

[38] Kabata-Pendias A (2011) *Trace Elements in Soils and Plants, Fourth Edition*. p325-327. Taylor & Francis Group, Boca Raton.
[39] McCormick LH & Yates Borden F (1972) Phosphate fixation by aluminium in plant roots. *Soils Society of America Proceedings*. 38: 799-802.
[40] Batty LC, Baker AJM & Wheeler BD (2002) Aluminium and Phosphate uptake by Phragmites australis: the Role of Fe, Mn and Al Root Plaques. *Annals of Botany*. 89(4): 443-449.
[41] Štrbac S, Šajnović A, Kašanin Grubin M, Vasić N, Dojčinović B, Simonović P & Jovančićević B (2014) Metals in sediment and Phragmites Australis (common reed) from Tisza River, Serbia. *Applied Ecology and Environmental Research*. 12(1): 105-122.
[42] Ayeni, O, Ndakidemi P, Snyman R & Odendaal J (2012) Assessment of Metal Concentrations, Chlorophyll Content and Photosynthesis in Phragmites australis along the Lower Diep River, CapeTown, South Africa. *Energy and Environment Research*. 2(1): 128-139.
[43] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014
[44] RSPB 2014 An assessment of sphagnum moss and Fen orchid on Mill Marsh West and Mill Marsh East at Butterfly Conservation Catfield Fen. Unpublished, Royal Society For The Protection of Birds, 2014

At a UK level, JNCC consider the fen orchid to have a 'Bad' conservation status[45] due to its declining range (a short term decrease of over 1% per year, with the range also considered to be declining in the longer term).

Liparis loeselii var *loeselii* appears to be at urgent risk from the continuing expansion of *Sphagnum* communities in Unit 3 at Catfield Fen[46]. The expansion in *Sphagnum* is likely to reflect the reduced availability of calcium-rich water at the fen surface and consequent reduced pH. A further threat to *Liparis* in the internal fen system is the acidification of the surface waters[47]. *Liparis* will not tolerate water below pH 6.38[48].

There is evidence that part of the fen orchid colony at Catfield Fen has already been lost, along with a significant area of the habitat which it favours, to the expanding area of *Sphagnum*[49].

It is significant to note that were the *Sphagnum* area to continue to spread into the main *Liparis* colony then *Liparis* is likely to be lost if it is unable to colonise other areas of the site because the water chemistry is no longer conducive to its establishment and growth. This will clearly have a major negative impact on the Catfield population, and hence upon its UK population. [50]

Consideration of replicated quadrat data from 2007-2012 further showed that of the 8 rare and scarce indicator species (used in Condition Assessment to assess species objectives) which occur within Unit 3, 5 had declined[51].

A similar exercise comparing 1991 and 2013 data from Catfield Unit 11 (Catfield Hall Estate) showed that 4 out of 5 indicator species had shown significant decline[52].

Potamogeton coloratus, a nationally scarce plant species and a SSSI designated feature, has apparently been lost from the internal fen system[53] and several of the other species for which the SSSI is designated, and which occur within the internal system, including *Carex appropinquata* and *Pyrola rotundifolia,* also exhibit a preference for base-rich conditions, and are likely to be at risk if the current trend towards acidification continues[54].

At Sutton Fen, which is under broadly similar management regimes to Catfield Unit 3, all indicator species present at this site have increased (Richard Mason, RSPB, pers. comm.).

[45] JNCC 2013 *Third Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2007 to December 2012 Conservation status assessment for Species: S1903 - Fen orchid (Liparis loeselii)* http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/S1903_UK.pdf.

[46] RSPB 2014 An assessment of sphagnum moss and Fen orchid on Mill Marsh West and Mill Marsh East at Butterfly Conservation Catfield Fen. Unpublished, Royal Society For The Protection of Birds, 2014

[47] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014

[48] http://www.ecoflora.co.uk/search_ecochars.php?plant_no=2030330010

[49] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014

[50] Natural England 2014 Report 4. (post Appropriate assessment) to the Environment Agency 20.6.14

[51] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014

[52] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014

[53] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014

[54] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014

Implications for fen invertebrate species

The AMEC report[55] correctly identifies that the Appropriate Assessment is required to consider invertebrate species and assemblages detailed in the Ramsar citation. The citation records that The Broads Ramsar site "supports outstanding assemblages of rare plants and invertebrates including … 136 British Red Data Book invertebrates". Natural England have advised that wetland hydrology has a very significant influence upon the W31 (permanent wet mire) invertebrates, to which assemblages W313 and W314 belong and thus the AMEC report focusses upon these assemblages. It does not, however, look in detail at the component species of these assemblages.

Catfield Fen is possibly the most important site in the Broads in terms of its invertebrate assemblage. Many of the species present are vulnerable to hydrological change. Water chemistry appears not to have been considered, although it is going to be critical, for example, for any species characteristic of pools and runnels.

Wetland hydrology has a very significant influence upon W31. However, there is no definition available of the water chemistry requirements for the W31 (permanent wet mire) invertebrates. There is however a broad indication that species representative of W314 (assemblages associated with Page 44 of 76 DRAFT – Minded To Consultation rich fen) prefer alkali rich conditions whilst species representative of W313 (assemblages associated with mesotrophic fen) prefer alkali poor conditions.

AMEC[56] state that these assemblages are in favourable condition because recent survey data indicate that they exceed minimum threshold values for assigning favourable condition. There is no attempt, however, to identify whether future changes in the fen (for example the rapid changes which might result from a tipping point having been reached), will impact invertebrate communities in future. This is important given work by Lott *et al.*, 2010[57] who found that invertebrate assemblages in fen compartments which dried out in the summer contained fewer specialist permanent wet mire species. It is likely that fen hydrology is the most important variable since it also controls/influences other variables such as management (i.e. cutting or grazing is limited on permanently wet compartments) and vegetation structure (AMEC, 2014h)[58].

The EA consider that the effects of fully licensed abstraction on invertebrates would not be significant on the basis that the model indicates that the number of days when the fen surface is wet or dry would not vary between naturalised and historical conditions. However, the Appropriate Assessment[59]

a) Does not take into account recorded changes in higher plant frequency and abundance i.e. reduction on calciphile species (some of the less common invertebrate species present at the site are specific to plant species which are themselves in apparent decline at the site)

b) Does not consider whether a switch to a Sphagnum dominated vegetation at the site might affect the invertebrate assemblage, either due to

   i) chemistry (it would be reasonable to assume that a change to highly acidic Sphagnum dominated vegetation at the fen surface would have a very dramatic impact upon the W314 assemblage) or

[55] Amec (2014h) Addendum to Main GW Report (2 documents)
[56] Amec (2014h) Addendum to Main GW Report (2 documents)
[57] Lott, D.A., Drake, C.M. and Lee, P. 2010. *Broads Fen Invertebrate Survey*. Broads Authority, Norwich.
[58] Amec (2014h) Addendum to Main GW Report (2 documents)
[59] Environment Agency 2014c Addendum to the Appropriate Assessment, 17th November 2014

ii) vegetation structure. Sphagnum polsters or lawns do not offer the same micoclimate and structure as, say, litter in the base of a reedbed.

c) Does not consider the impact of abstraction upon the two specific invertebrate species for which The Broads SAC is designated and also erroneously identifies one of these species, citing Shining Ramshorn Snail *Segmentina nitida* as an Annex II species. The second species for which the SAC is designated is in fact a different ramshorn snail; *Anisus vorticulus*, but this species is not known to occur at Catfield.

The Broads is "the main stronghold of Desmoulin's whorl snail *Vertigo moulinsiana* in East Anglia". Desmoulin's Whorl Snail, a UK Red List species, is known to occur on Unit 3 (Butterfly Conservation Land). JNCC describes Desmoulin's Whorl Snail as "restricted to calcareous wetlands", whilst the Conchological Society record that it lives "in wet areas with high pH and calcium content". It normally lives on reed, grasses and sedges, such as reed sweet-grass *Glyceria maxima* and tussocks of greater pond-sedge *Carex riparia* and lesser pond-sedge *C. acutiformis*. This species is therefore dependent upon maintenance of vegetation structure. "Like all Annex II *Vertigo* species, it is highly dependent on maintenance of existing local hydrological conditions" and is thus be very sensitive, not only to acidification of the surface waters, but also to changes in vegetation composition and structure resulting from acidification (for example the replacement of reed and sedge fen by *Sphagnum* dominated communities). The habitat extent objective of the Favourable Condition Tables (FCT) for Desmoulin's Whorl Snail is "no more than 25% reduction from baseline in core habitat area or abundance of food plant" and the FCT also requires that the distribution of the species as identified by a survey carried out in 2000/2001 must be maintained. The species has been known from Catfield from at least the mid 1980s, and was recorded at Unit 3 (TG368212) most recently in 2007. This part of the fen currently exhibits surface pH values of between 5.0 and 6.0; conditions which cannot be considered to be either 'high pH' or 'calcareous'.

d) Does not attempt to determine whether the invertebrate assemblages, or indeed individual species frequency/distribution at Catfield have changed, because historic invertebrate data (for example from the 1980s and 1990s surveys (Lott, Foster & Proctor 2002)[60] was not considered, and

e) Does not consider other rare invertebrate species which have previously been recorded from Catfield Fen, including the Globally Threatened Red List species *Bidessus unistriatus;* and *Graphoderus bilineatus* (although this latter species is now presumed extinct in the UK)

Fen management

The recent ecological changes at Catfield Fen are attributed by a number of documents prepared by the Environment Agency and their consultants, AMEC, to the management regime and the EA[61] has concluded that "*land management within the Ant Broads and Marshes SSSI has the potential to contribute towards changes in species distribution. Land management practices can promote the onset of terrestrialisation which may result in the infilling of former pond areas and a general rise in the ground surface. Terrestrialisation has the effect of both lowering the water table and can lead to the spread of other species which are less sensitive to changes in water table*."

In response, it is important to note that Natural England has confirmed that Catfield Fen Unit 11 (Catfield Hall Fen) is well-managed in full accordance with the High Level Stewardship Scheme. There has been no major change in fen management since the site was acquired by Mr & Mrs Harris.

[60] Lott DA, Procter D, Foster AP 2002 *East Anglian Fen* invertebrate *survey*. English Nature Research Report 477.
[61] Environment Agency 2014c Addendum to the Appropriate Assessment, 17th November 2014

Commercial reed and sedge management continued for almost a decade following purchase of Fenside and Sedge Fen by Butterfly Conservation. The fens are still cut on a regular rotational system and the majority of the internal fen system, including all but one of the areas in which *Sphagnum* now occurs, has never been managed as commercial reed [62].

It is notable that there has been a general and widespread increase in long-rotation conservation management at other sites in the Ant valley, including Reedham Marshes, as well as at Catfield Fen. Reedham Marshes also has areas of *Sphagnum* dominated vegetation, however this vegetation type is only recorded as expanding at Catfield[63]. Other sites throughout the broads are also likely to be subject to gradual terrestrialisation, but similarly, Catfield is the only site where acidification of the fen surface and dramatic *Sphagnum* proliferation has been recorded.

The response of the EA to this point is to query whether a similar level of recording effort and scrutiny of the data has been undertaken for other sites in the Ant valley, the implication being that were such effort to be expended, other sites might be found which exhibited a similar trend. The EA is correct in that a similar *Sphagnum* mapping exercise has not been undertaken elsewhere. However, casual observations made over a 2-week period by Dr Parmenter in 2013 at fen sites throughout the Ant valley is that *Sphagnum* areas elsewhere in the fen system had not noticeably expanded. The purpose of these 2013 site visits was to assist a survey, coordinated by the Natural History Museum, for *Dryopteris cristata*, a species which is notable for its close association with *Sphagnum*. The 2013 survey found that a number of former sites for this species in the Ant valley had actually been lost, along with the associated *Sphagnum* dominated communities.

All of the marshes within Catfield Unit 11 are mown on a rotational basis and the litter removed. Parmenter[64] notes that the percentage of litter on Middle Marsh in 1991 averaged 25% while in 2013 it averaged 10%; which would indicate that the current management practice is much more successful in removing litter than the previous regime and thus would tend to slow the rate of terrestrialisation.

Similarly, recent Condition Assessments of both Unit 3 and 11 have not identified any deficiency in the current management of the internal fen system, which is notable for a wide heterogeneity of fen vegetation communities. Condition Assessment includes consideration of litter accumulation, with levels in excess of 25% being considered as indicative of insufficiently frequent management; and it is notable that both the 2009 and 2013 assessment visit to Catfield Hall Fen found litter levels to be below 10%.

NE have stated that the Fen is currently managed under a High Level Stewardship Scheme between NE and the landowner for conservation purposes. NE have confirmed that the management agreement is being adhered to[65]. An Integrated Site Assessment visit in 2012 found Unit 11 to be well managed, in compliance with Natural England's management prescriptions, and meeting many of the indicators of success for reedbed and fen maintenance specified for the site[66].

Cessation of burning has also been cited as a possible reason for the increase in *Sphagnum* at Catfield Fen. Following SSSI designation in 1989, burning was listed as a PDO. Consequently,

[62] The Landscape Partnership and Riches, O P 2014 CATFIELD FEN: A Response to the AMEC Technical Note: Notes on the Management of Catfield Fen. July 2014

[63] The Landscape Partnership and Riches, O P 2014 CATFIELD FEN: A Response to the AMEC Technical Note: Notes on the Management of Catfield Fen. July 2014

[64] Parmenter, Jo. 1995 *The Broadland Fen Resource Survey: volumes I-5 - report of the 1991-94 Broadland Fen Resource Survey.* Broads Authority.

[65] Natural England, 2014g Site management comments.

[66] The Landscape Partnership and Riches, O P 2014 CATFIELD FEN: A Response to the AMEC Technical Note: Notes on the Management of Catfield Fen. July 2014

burning would not have taken place from at least this date onwards anywhere within the fen system. Whilst it is common practice to rake off and burn piles of non-commercially viable reed and sedge litter, wholesale burning has **never** been part of the historic management regime for Catfield Hall Fen (including Middle Marsh), nor the Butterfly Conservation land (pers. comm. Keith MacDougall, former owner of Catfield Hall Fen and the Butterfly Conservation land), and burning therefore cannot have been a mechanism by which *Sphagnum* growth would have been discouraged in the past. Whilst frequent mowing management would result in decreases in both available nutrients and base levels, where hydrology remains unmodified, calcium etc which is removed from the site in fen biomass would be replenished by upward groundwater movement[67].

The Addendum to the Appropriate Assessment does not consider the impacts from surface water management but the EA states that it is unable to rule it out as being a contributory factor to vegetation change on site, with the level of contribution being unknown. It is reiterated that the central feature of the management of water in the internal system now, and in the past, has been the use of the two sluices to maintain water levels on the fen. The current water management regime is as proposed by Natural England, on the advice of Dr Bryan Wheeler, and reflects previous water management by earlier owners. While it is conceivable that the sluice might facilitate the retention of slightly acidic water on the fen following heavy rainfall events; this is not a factor which has have changed over the past 30-40 years given that sluice management has not altered. Hence, sluice management cannot explain the dramatic changes in the pH of the underlying fen peat, which can only be explained by reduced upflow of groundwater.

All the information summarised above is accepted by Natural England, either specifically or implicitly given an absence of evidence to the contrary. Natural England however maintain that 'at a very high level' the changes as described in site management may have contributed to changes in vegetation that have occurred and are still occurring across the Catfield Fens and note that much of the information provided on management change is anecdotal and difficult to verify, so has limited value in demonstrating cause and effect[68]. It is not considered that this caveat is justified, particularly given that acidification appears restricted to the internal fen system, and occurs across two different land holdings, Units 3 and 11, which have had different management histories over the past 20 years.

There has been no formal or informal acknowledgement or agreement from the Environment Agency on any of the issues raised above, other than an acceptance that the fen vegetation "*may be heterogeneous* and subject to varied management practises as appropriate to each area of the fen, not limited to reedbed management only." However, as a result of comments received and reviewed by NE in response to the Site Management Technical Note[69] the EA has clarified its position with regard to land management, and has acknowledged that a number of the assumptions made within the Technical Note have been shown to be incorrect.

Use of Condition Assessment

Condition Assessment is inadequate for identifying early impacts of abstraction at Catfield. Most importantly, because the designated features are themselves broadly defined, there can be significant change within vegetation communities before this is picked up by CSM/CA. For example, fen condition assessment does not look at changes in the boundaries of NVC communities at a unit level, and this is a major shortcoming of the process[70]. The majority of the factors considered in the site-

[67] The Landscape Partnership and Riches, O P 2014 CATFIELD FEN: A Response to the AMEC Technical Note: Notes on the Management of Catfield Fen. July 2014

[68] Report 3 (Appropriate Assessment) . Addendum to NE advice to EA Appropriate Assessment. Comments Appendix E Catfield Fen Notes on the Management of Catfield Fen. 13.06.14

[69] Amec (2014e) Site Management Technical Note

[70] Parmenter, J M 2014 *Use of Condition Assessment at Catfield Fen.* Unpublished report on behalf of the Catfield Hall Estate.

specific definitions are concerned with identifying unfavourable management and/or physical damage, and are not designed or intended as a mechanism by which harmful hydrological change might be identified in its early stages.

In recognition of this, Natural England has stated that the reference in the 2013 condition assessment which records that "*water levels were reported to be consistent with the hydrological needs of the communities*" should be regarded as 'a snapshot in time', and not implied to mean that water levels are generally acceptable. It should also be noted that the 2013 condition assessment survey was carried out after a particularly wet year. The statement simply reflects that at the time of the assessment water levels were at a level usually expected for this vegetation community.

The 2013 Condition Assessment failed to identify the risk to the *Liparis* population from the expanding *Sphagnum* dominated community[71]. The 2013 Condition Assessment also failed to identify the loss of *Potamogeton coloratus* at Sedge Fen (Unit 3)[72]. Favourable Condition may therefore meet the requirements of SSSI surveillance, but it does not provide evidence to support the detailed assessment required to judge the impact of water abstraction on fen vegetation[73], and this is acknowledged by Natural England.

The Conservation Objectives and definitions of favourable condition for features on the SSSI may be used to inform the scope and nature of any 'appropriate assessment' under the Habitats Regulations. However, appropriate assessment also requires consideration of issues specific to the individual plan or project. The habitat quality definitions used in Condition Assessment do not by themselves provide a comprehensive basis on which to assess plans and projects as required under Regulations 20-21, 24, 48-50 and 54 – 85, and further, are tailored towards assessment of management condition: they are not designed as a tool to assess hydrological change[74], and the assessment of, for example, Unit 11 as being in 'favourable' condition is, at least in part, a recognition of its being favourably managed, and cannot in itself be taken to imply that there are no known threats to favourable conservation status; this being acknowledged by the decision by Natural England, in the light of recent evidence of vegetation change, to identify Units 3, 10, 11 and 35 as being under hydrological threat.

Rate of change and urgency of action

There is clear evidence for rapid ecological change taking place in Units 3 and 11 and this change has become apparent since the 1980s[75]. This may be indicative of a tipping point / threshold being reached in *Sphagnum* colonisation. Previously gradual change becomes relatively more rapid due to the positive feedback *Sphagnum* exerts on its own environment through the action of cation exchange[76].

Experience from work on comparable Dutch fen ecosystems, published in internationally recognised peer-reviewed literature (and confirmed by Dutch experts) suggests that Catfield Fen is experiencing accelerated succession. This is understood to be a process which is very difficult to reverse, and which can be only be managed by a cessation of groundwater abstraction in the surrounding area.

[71] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014
[72] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014
[73] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014
[74] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014
[75] Natural England 2014 Natural England Report 6. (post Appropriate assessment) to the Environment Agency 20.6.14
[76] Natural England 2014 Report 4. (post Appropriate assessment) to the Environment Agency 20.6.14

Given the multi-dimensional complexity and dynamism of the fen, the effects of reduced pH (indicative of reduced input of groundwater) are difficult to predict – in some places there may be no effect, in others which are on the brink of a critical pH threshold it may contribute to an effect. [77]

Middle Marsh has long been recognised for having a lower pH than other parts of the fen, and it is this which creates conditions suitable for S27 (Annex I habitat 7140 Transition mires and quaking bogs) and M24 (6410 Molina meadow on calcareous soils is an Annex 1 qualifying feature). Given the lower pH, Middle Marsh is potentially more vulnerable to even minor reductions in groundwater discharge, being closer to the 'tipping point' at which *Sphagnum* starts to proliferate.

From 1978 (when it was first mapped by Ken Giller), there appears to have been only gradual change in *Sphagnum* distribution for 25 years[78]. However, after 2003, over the space of only 10 years, the main area of *Sphagnum* on Fenside underwent a dramatic change, more than trebling in size[79] [80]. This suggests that a 'tipping point' has been reached, and urgent measures are required to safeguard the fen. Drawing upon Dutch experience, Dr Barendregt emphasises that this process can only be controlled by maintaining a continued upward groundwater flux to the surface of the wetland.

Liparis loeselii is at urgent risk from the continuing expansion of *Sphagnum* communities in Unit 3 at Catfield Fen[81]. *Liparis* is unable to grow and thrive in *Sphagnum* dominated vegetation. There is evidence that part of the internationally important fen orchid colony at Catfield Fen has already been lost, along with a significant area of the habitat which it favours, to the expanding area of *Sphagnum*[82]. A further threat to *Liparis* in the internal fen system is the ongoing acidification of the surface waters[83], with some areas already having a surface pH which fen orchid is unable to tolerate (*Liparis* will not tolerate water below pH 6.38[84]), thus reducing the area in which the plant can grow.

The urgency of the situation is reflected in a recent decision by Natural England to reclassify Unit 3 as being in "unfavourable declining" condition[85] (previously unfavourable recovering). Units 3, 10, 11 and 35 are identified by Natural England as being under hydrological threat[86].

CONSIDERATION OF DRAFT DETERMINATION REPORT (17 November 2014)

AMEC[87] have modelled the change in pH resulting from the drawdown levels identified in their hydrological model as being 0.16 of a pH unit between naturalised and historical conditions. Natural England have expressed significant misgivings about the methodology used and shortcomings in the

[77] Report 7 (post EA appropriate assessment). The Environment have asked for NE's view on water chemistry aspects featured in the final Report on the Assessment of Abstraction within the Ludham-Catfield area in the vicinity of Ant Broads and Marshes SSSI (22 Aug 2014)

[78] RSPB 2014 A survey of Sphagnum moss at Butterfly Conservation Catfield Fen and comparison with past surveys.

[79] RSPB 2014 A survey of Sphagnum moss at Butterfly Conservation Catfield Fen and comparison with past surveys.

[80] Natural England 2014 Report 4. (post Appropriate assessment) to the Environment Agency 20.6.14

[81] RSPB 2014 An assessment of sphagnum moss and Fen orchid on Mill Marsh West and Mill Marsh East at Butterfly Conservation Catfield Fen. Unpublished, Royal Society For The Protection of Birds, 2014

[82] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014

[83] The Landscape Partnership 2014 Condition Assessment at Catfield Fen: consideration of recent trends in distribution of Potamogeton and Liparis in Unit 3. June 2014

[84] http://www.ecoflora.co.uk/search_ecochars.php?plant_no=2030330010

[85] Natural England 2014 Report 5. Natural England advice to the Environment Agency on Condition Assessment at Catfield Fen: consideration of recent trends in distribution of *Potamogeton* and *Liparis* in Unit 3. Provided by Mr Harris 24 June 2014

[86] http://designatedsites.naturalengland.org.uk/SiteUnitList.aspx?SiteCode=s1000501&SiteName=&countyCode=&responsiblePerson=

[87] Amec (2014h) Addendum to Main GW Report (2 documents)

hydrological model itself[88] and are unable to indicate whether or not this value may be ecologically significant nor whether changes in pH predicted are likely to be an indication of the scale of impact of abstraction. Contrary to a statement in the AMEC report on fen management[89], increased summer rainfall only leads to a significant change in water chemistry if there is a loss of base rich groundwater at the same time, for example as a consequence of abstraction[90]. Natural England further note that the model indicates that there may be a potential path of change from water table changes to potential changes in pH,[91] and that, although the model has indicated that changes are small, the modelled decrease in pH is consistent with the direction of change in vegetation, which clearly demonstrates shows a shift from species of more base-rich conditions to those of more acidic conditions; this finding is also commensurate with recent field research which indicates a reduction in the upflow of calcareous groundwater and acidification of the upper layers of peat[92] (Mason in prep).

A review of historic (1988[93]) and more recent (2005[94] and 2014[95]) surface pH data has shown a trend towards increasing acidification of water at the fen surface over the past c10 years.

Recent and ongoing work by RSPB is surveying pH levels in the interstitial soil water across Unit 3, to determine how this changes with depth. Data from a series of transects across the fen have been compared with data collected by Giller and Wheeler (1988).[96] The Giller and Wheeler data compared pH levels in *Sphagnum* dominated areas with areas of S2/S24e vegetation, and found that beneath the latter two vegetation types, the pH both at the fen surface and in the interstitial water at depths down to -150cm remained entirely within the range pH7-pH8. Conversely, the *Sphagnum* dominated areas had surface pH values between 4 and 5, but this gradually increased with depth, so that pH7 was reached at c-65cm. Thereafter the interstitial pH beneath the *Sphagnum* polster remained within the pH7-pH8 range. Conversely, the RSPB survey has measured surface pH as low as pH3.5 in some *Sphagnum* dominated areas, with the pH at depth both beneath *Sphagnum* and elsewhere in the fen being typically well below pH7 (Mason, in prep). The deeper layers in the peat in general have higher electrical conductivity and higher calcium concentrations. [97]

There is a distinct correlation between the hydrochemistry and the quality of vegetation. As calcareous fen vegetation quality decreases and bog conditions are stimulated, so do all indicators for groundwater flow.[98]

The transition community with *Sphagnum fallax* is present in many locations in Catfield Hall Fen, and is characterized by accumulation of rainwater, with the groundwater input at surface being reduced. It is surmised that in recent years buffered groundwater discharge has reduced and as a

[88] Report 7 (post EA appropriate assessment). The Environment have asked for NE's view on water chemistry aspects featured in the final Report on the Assessment of Abstraction within the Ludham-Catfield area in the vicinity of Ant Broads and Marshes SSSI (22 Aug 2014)
[89] Amec (2014e) Site Management Technical Note
[90] The Landscape Partnership and Riches, O P 2014 CATFIELD FEN: A Response to the AMEC Technical Note: Notes on the Management of Catfield Fen. July 2014
[91] Report 7 (post EA appropriate assessment). The Environment have asked for NE's view on water chemistry aspects featured in the final Report on the Assessment of Abstraction within the Ludham-Catfield area in the vicinity of Ant Broads and Marshes SSSI (22 Aug 2014)
[92] Pyne, E & Barendregt, A 2014 Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen
[93] Collins 1988; Atkins/HSI (2005); Ewan (2005). Data from these reports is reproduced at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/289540/Catfield_Appendix_F_5B1_5D_324668.pdf
[94] Collins 1988; Atkins/HSI (2005); Ewan (2005). Data from these reports is reproduced at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/289540/Catfield_Appendix_F_5B1_5D_324668.pdf
[95] The Landscape Partnership 2014 pH change at Catfield Fen. Unpublished report.
[96] Giller and Wheeler (1988). Acidification and Succession in a Flood-Plain Mire in the Norfolk Broadland, U.K. *Journal of Ecology (1988), 76, 849-866*
[97] Pyne, E & Barendregt, A 2014 Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen
[98] Pyne, E & Barendregt, A 2014 Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen

consequence acid rainwater plays an increased role in the upper peat layers, stimulating *Sphagnum* growth. The balance in input with rainwater and groundwater has changed at many locations in favour of acid rainwater, thence decreasing suitability for rich fen vegetation. [99]

The number of locations in the east of Catfield Fen in which calcium-rich water is present at surface is very limited (as of spring 2014). The higher concentration in chloride and sodium at these locations prove previous discharge of groundwater that has passed through saline layers. The absence of rich fen conditions, including vegetation, at many locations is recent and the most likely explanation for the change is reduced groundwater input. [100]

The Determination Report records that "It should be noted that no water chemistry variables were recorded in Lott et al. (2010) and therefore there is no definition available of the water chemistry requirements for the W31 (permanent wet mire) invertebrates which have been identified as being most sensitive to changes in water chemistry (Natural England, 2014l). There is, however, a broad indication that species representative of W314 (assemblages associated with Page 44 of 76 DRAFT – Minded To Consultation rich fen) prefer alkali rich conditions whilst species representative of W313 (assemblages associated with mesotrophic fen) prefer alkali poor conditions.

A change in water chemistry may affect the balance of invertebrates present on site, with more alkali poor conditions leading to a transition from W314 towards W313 and potentially to W312 (assemblages associated with Sphagnum bog) which prefers very alkali poor (including ombrotrophic), conditions (AMEC, 2014f). It is unknown what degree of change in alkali richness would cause this shift in invertebrate assemblage. The invertebrate assemblage is one of the features for which the site is notified.

[99] Pyne, E & Barendregt, A 2014 Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen
[100] Pyne, E & Barendregt, A 2014 Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen

CONCLUSIONS

Catfield Fen is a site of acknowledged global significance: it has a number of international wildlife designations, and has been described as the finest undrained floodplain fen ecosystem in Europe. The available data indicate that groundwater contributes to the water-budget of the site, and the variability in the local water-budget (including a groundwater contribution) undoubtedly accounts for the ecological diversity of the site.

There is compelling evidence for hydrological change at the site. Recent research has shown some evidence of desiccation or reduced water availability at the fen surface; however of potentially greater concern is an apparent shift from generally calcareous to often markedly acidic conditions at the fen surface, and, more worryingly, a change in the chemistry of the underlying peats, from predominantly calcareous to acidic, suggesting a dramatic reduction in groundwater upflow in the recent past.

A number of species and fen communities are at risk from these changes. In particular, *Liparis loeselii* has been demonstrated to be at urgent risk from the continuing expansion of *Sphagnum* communities in Unit 3 at Catfield Fen. *Liparis* is unable to grow and thrive in *Sphagnum* dominated vegetation. There is evidence that part of the internationally important fen orchid colony at Catfield Fen has already been lost, along with a significant area of the habitat which it favours, to the expanding area of *Sphagnum.*

Catfield Fen is possibly the most important site in the Broads in terms of its invertebrate assemblage, and many of the species present are vulnerable to hydrological change. The effects of water chemistry change on invertebrate communities or individual species appears not to have been considered previously, and there is no definition available of the water chemistry requirements for the W31 (permanent wet mire) invertebrates. It is not considered that the impact of abstraction upon fen invertebrates has been adequately assessed.

In summary, the Environment Agency's recent 'minded to' decision to refuse the renewal of the agricultural abstraction licences is a positive step in ensuring long-term protection of Catfield Fen, however this decision, although correct, fails to take into account a number of very important ecohydrological factors as set out in this submission.

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8th December 2014