Comments from Mr Harris

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1. The Context

All parties now agree that Catfield Fen is drying out and there is a significant risk of degradation of its unique flora and fauna. In 2008 this was far from being accepted and its recognition represents some progress. The critical question now is "what is to be done?" and in addressing this issue Dr Mason's report is important. Given the delay from 2008 and the risks, this is a time for action in accordance with the precautionary principle.

2. The Harris' meeting with Dr Mason on 27 February 2012

This was a constructive meeting lasting well over two hours, covering factual as well as interpretative issues and it would have been useful to have gone on longer because we didn't cover all of the ground. However, it should have happened earlier in the process. The draft report is incorrect in stating "*this has included an initial consultation with interested parties, inviting their comments and welcoming discussion*". With the Harrises this never happened, despite written and verbal requests that a meeting with Mr Harris would be welcome. There must always be a risk once a draft report is prepared and issued that its author will feel obliged to defend it come what may. It is hoped that in this case Dr Mason will be broadminded enough, as he displayed at our meeting, to include properly the issues discussed.

3. Executive Summary

Although the report includes much interesting and relevant information, the problem is that the Executive Summary is specific in its conclusions. "*These two factors can explain the recent drying out of the Fen*". I won't repeat Prof Gilvear's precise analysis on page (vi) which makes quite clear in polite academic language that this is nonsense but the dangers are real. Many people including the experts only read the conclusions. In my experience at Catfield very few people, including in the relevant bodies, are actually familiar with the detail and literature of what is acknowledged to be a complex site. This topic was discussed extensively at our meeting with Dr Mason.

Conclusion
Although the Report gathers together a great deal of useful data, the Executive Summary is not a fair summary of the Report, lacks balance and exhibits much greater certainty than is merited from the evidence. It needs changing because many people, given time constraints and the complexity of the site, will only consider its findings.

4. Too much emphasis on post 2008

We made the following points:

i. There has been a longstanding concern about the effects of drying out on the Fen which is not properly reflected in the report. The letter from Clive Doarks, dated 11 August 1993 (***Appendix D***), should be included because it highlights not only English Nature's but also refers to National Rivers Authority's concerns at that time.

2. The report includes no reference to the photographic evidence which is unambiguous that in the early 1970s the reed growth and depth of water was significantly higher than today. Natural England refer to this evidence in the Compendium.

3. The call to action in 2008 by the Harrises was the conclusion of a rising concern identified by the Norfolk & Norwich Naturalists over a number of years going back to the early 2000s when they first visited the site. I suggest, knowing Alec Bull quite well, that his comments about post 2008 which are quoted, reflect a growing concern that no attention was being paid to the issue when the evidence for its degradation was becoming ever more apparent. It was a call to action!

Conclusion
The report overemphasises the post 2008 period. In fact this is a longstanding problem going back over many years.

5. The "New" Mason Hypothesis (increased leakage from the internal system)

We made the following points:

1. In our view and that of others familiar with the site is, there is nothing "new" about the condition of the low-lying Bund at the Southern end of Catfield Fen. We have used it for over 15 years as our main access point to the Southern Rond. It has mature trees growing on it and there is no sign of erosion around their roots. None has fallen over.

2. Any water crossing the Southern Bund flows into Sharp Street Fen not the External System as is suggested in the Report.

3. Much prominence is given to the importance of the intrusion of seawater on two occasions in the Internal System.
   However;

   i. this is nothing new, the overtopping of the Rond has always been foreseen in the literature (Wheeler et al)

   ii. there may be minor leakage at the sluices particularly the 5 Bar Gate sluice, but this is most unlikely to be a major issue.

   iii. the "seawater" is given much greater prominence than the "Type 3" water presumably because the former supports Dr Mason's new hypothesis, whereas the latter emphasises the importance of groundwater to the Fen and hence abstraction.

4. The Report includes minimal references to springs. As was covered at our meeting, it has long been accepted that there is one in the Glebe, probably another in Middlemarsh and interestingly Dr Mason himself has found a new one near the Southern end of the Rond. Their significance and potential relationship with abstraction needs exploring properly in the Report.

6. Reported decline – differences between Internal and External systems

This is a key part of Dr Mason's new hypothesis - but do schedules E4 and E9 actually show what he suggests and support the hypothesis he puts forward?

E9 appears to show:

i. Major differences between the Internal and External Systems persisting into 2010 and beyond. There is <u>no</u> apparent decline in the spread of the differences recorded between the two systems.

ii. However, a different declining trend is suggested by the figures in that it appears that the Internal System is becoming more often lower than the External System than happened in earlier years.

iii. Furthermore, the position in summer requires at least as much attention as winter. It is in summer that the damage to the Fen will be occurring and is the time when the irrigation abstraction is taking place.

Point i. suggests that the Rond is less leaky than Dr Mason proposes. Given Dr Mason's "breach" theory, one would expect such differences to be equalised through the "breach" but this doesn't appear to happen.

Wouldn't an "abstraction" theory not fit the evidence better? We know from the geology and water chemistry that the connectivity between the Crag and Fen is likely to be higher in the Eastern / Internal System rather than the Western / External System and that the chemistry of the dykes shows Type 3 water particularly in summer and autumn. Consequently, if abstraction is having an increased effect and irrigational abstraction has increased dramatically in recent years (see Section 8 of this report), this would be consistent with the data, in particular the relative decline in the Internal System while significant differences between the Internal and External Systems persist.

It is also relevant that page 21 "the water levels do appear to have been higher prior to 2004/5 than they have been since. This is not simply a feature of the Internal System as it also applies to the External System".

Doesn't this again fit better with an "abstraction" than a "breach" hypothesis? Dr Mason's suggested link to the water levels of Barton and Hickling Broad look statistically suspect, inconsistent at very least as regards the rainfall data and unconvincing. I understand that there is no such general trend across the Broads.

Conclusions

1. Do E4 and E9 actually show what Dr Mason is suggesting in the text?
2. Is the continuation of such differences, particularly if in summer, more supportive of an abstraction hypothesis rather than leaky Rond hypothesis?

It is relevant that on page 23 Dr Mason says:

"*It is of note that in winter and spring there is little potential for groundwater movement between them and that in summer and autumn there is potential for upward groundwater flow within the Crag."*

It is the disruption of this flow to the surface which could be causing the problem.

More attention should be paid to what may be happening in summer when the summer irrigation abstraction takes place.

7. Water Chemistry

This is a most interesting section of the Report, particularly regarding Type 3 waters:

page 28 "*Type 3 waters tend to occur in the dykes bordering or close to the eastern margins of Catfield Fen and have a chemistry that is indicative of a significant component from shallow and middle crag groundwater.*
It is worth noting that such waters within Collins' sampling occur at locations when the dykes are believed to have been cut into the Crag"

page 29 *"It would appear that Type 3 waters have a significant groundwater element".*
It is interesting that as late as 2010 many including Natural England were still of the opinion that a clay layer separated the crag from the fen. It required Prof Gilvear's paper to show that the literature referred to windows in the clay. This is now confirmed comprehensively by Dr Masons' Report.

Conclusions

1. The new Mason "breach theory" is based on only two incidences of seawater in the water chemistry. The literature always envisaged that such breaches could occur, it is unsurprising that they have occurred twice in the last few years when there have been tidal surges.

2. The Type 3 groundwater incidence in the dykes confirms the links with the Crag. Wouldn't balance require that its implication be properly analysed?

3. Why have the relevance of springs and their implication not been more fully analysed?

8. Water Quantities

i. Long term data of Crag Water levels

Why has Dr Mason been unable to supply a long term data set which would have been able to ascertain whether there has been some long term regional lowering of crag water levels. This

would seem to be the most basic information and is missing from the Report. This omission needs to be explained and commented on. Why cannot the EA and its customers provide this information?

ii. The Growth in Abstraction volumes and its potential greater relevance in summer

We made the following points:

i. Schedules G2 and G3 are inadequate and potentially misleading because they do not show clearly the growth in summer abstractions in recent years
ii. They do not make clear the essential difference between the PWS year round abstraction and the summer abstractions. To even the trained eye G2 downplays the apparent relevance of the irrigational as compared to the Public Water volumes
iii. In 2009 the highest summer abstractions coincided with the lowest dyke levels. The Report does not explore this adequately

Conclusion

The Report does not treat this issue in a balanced and informative way. ***Appendix B*** which is an extract from Dr Mason's 2010 Report is much better, although it still omits the Overton volumes. ***Appendix C*** shows the growth in summer abstractions in graphic form.

9. Impact of Licensed Abstraction

We discussed the major inadequacies of the measuring systems at our meeting. The key points we made were as follows:

9.1 Plumsgate Road Abstraction (144B)

Relevant measuring equipment

815 d close to borehole – working and shows abstraction effects

815a, 815b, 815c page 39 - "data collected in 2011 has not been good enough quality to assess the impact of groundwater abstractions"

Middle Marsh page 41 – Dr Mason comments on the failure following his 2010 to install a dipwell but adds "*such is the distance that any direct impact on dipwell water levels would unlikely to be discernible*". He also commented that he had been informed that the Harrises had declined to install such a dipwell. This is factually incorrect - the responsibility for the gross inadequacy of the monitoring lies with the EA and the abstractors.

NW Corner of Fen working but in 2012 Report reported no effect from abstraction. However in his 2010 report Dr Mason (***Appendix A*****)** commented*:*

"Evidence of an impact on groundwater levels is particularly evident in the deeper piezometers where groundwater levels were lowered by about 10cm due pumping".

"A comparison of the North West Fen monitoring with the Plumsgate Road abstraction about 1700m away, also appears to show some impact on groundwater levels."

This suggests that the assessment of the impact of abstraction is quite arbitrary.

As a general observation Dr Mason's report is remarkably free of numbers and any form of statistical analysis.

Conclusion

As far as the Plumsgate Road monitoring equipment is concerned, it either doesn't work or is in the wrong place. Consequently to draw any conclusions about the effect of abstraction is unsound.

9.2 Ludham Road Abstraction (141c)

Relevant Monitoring Equipment

805 the lack of any water level response to abstraction from the borehole which is 60m away shows the data to be deficient and should be discounted

815 100m from SSSI margin (including Fen not just Church Wood) shows significant effect from abstraction – but discounted as there is "good water conductivity which aids recovery". Conversely this suggests good water conductivity beneath the Fen too but the implications of this are not explored!

OP4 and OP5 E31, E32 and E33 show:

- broken sequences - P5 most of 2009 – P4 summer 2010
- erratic data - P4 erratic data logger subsequently removed July 2009
- the literature and this Report page 43 and Appendix A show a consistent pattern of problems and flawed data,
  eg Appendix A - "*This drying out may be a reason for the very erratic logger readings observed during the summers of 2006 and 2008 (2009 logger data not being available after May 2009)*
  Conclusion - any conclusion drawn from these devices must be suspect

dykes Schedules E34, E36 and E37 are said to show no "*discernible effects".* This is understood to be a judgemental assessment by Dr Mason.
To the untutored eye they appear to show the opposite with periods abstraction coinciding quite clearly with periods of depletion. There is no attempt to assess the mathematical significance of the data - its all opinion!

Conclusion to Ludham Road
Clearly the Ludham Road abstraction has some effect on neighbouring measuring devices and consequently the Fen - the question is how much? In his Jan 2010 report Mr Sharpin suggested that 141c might be the cause of a 10% decrease in upward groundwater flow to the Fen.

9.3 Public Water Supply

On page 44

"*E57 provides an indication of which abstraction might have an impact on the Fen, though it does not enable the significance of the impact to be determined*".
"*Whether or not this impact is significant is not known"*
10cm internal / external difference coincides with lower Ludham PWS abstraction - "*though groundwater abstraction may have contributed to this, other exploration such as leakage or overflow from the internal system may be more significant factors".*

Conclusions
…or they may not! Why is Dr Mason choosing one hypothesis as fact and discounting another on this evidence? Again this suggests a lack of balance in the Report.

9.4 Inadequacies of Measurement Data

1. Much of the measurement equipment is deficient and cannot provide adequate data for assessing the potential effects of abstraction

2. More of it is in the wrong place, eg N W Corner of the Fen

3. The assessment of correlation with abstraction is judgemental and therefore potentially quite arbitrary, eg Dr Mason comes to quite different conclusions in 2012 to 2010 on the same data. There is no mathematical assessment of the correlations anywhere – its all opinion! Overall the Report is remarkably free of numerical analysis.

4. On Dr Mason's own admission one wouldn't expect to see a direct effect from abstraction page 41 "*but such is the distance that any direct impact on dipwell water levels would be unlikely to be discernible".* But still the lack of an obvious effect is taken as relevant in his conclusions!

5. Dr Mason recommends new measuring steps for the future but he is too kind on the paucity of data he has had to work with.
   i. Why was more not done by the EA since 2008 to sort out the maintenance of existing devices despite frequent promptings by the Harrises?
   ii. What were the abstractors' own obligations under their licences? Have they complied properly?

10. The Report's Conclusions and Recommendations

These need to be rewritten because in their present form they are neither balanced nor accurately reflect the content of the Report. This is important because realistically many people will only read these sections as well as the Executive Summary.

The redraft of the Conclusions and Recommendations should in my view take account of the following:

1. There is no proper analysis of the factors that could be causing the drying of the Fen. In the analysis all possible factors including abstraction should be given the same priority as the leakage theory and not just be dismissively discounted.

2. The leakage hypothesis needs to be more rigorously examined both scientifically and statistically. The Report should acknowledge that the Southern Bund has not altered in the last fifteen plus years. There needs also to be greater emphasis on the longstanding concerns about drying - this is not just a post 2008 issue.

3. The level of uncertainly with regard to the quality of the data should be given greater prominence. The recommendations represent a damning critique of the monitoring of the abstractions, in particular what is missing and what has not worked. It is relevant to establish where the responsibility for this deficiency lies - with the EA? with the abstractors? have they been complying with the conditions of their licences?

4. If climate change is playing a role and the Report produces no satisfactory evidence that it is involved, then the potential effects of abstraction should be reviewed in the light of climate change and low recharge rates.

5. The Report fails to acknowledge properly the complexity of the site and how this complexity precludes a definitive conclusion. In these circumstances, there are no clearly defined solutions and the precautionary principle becomes particularly appropriate.

6. While it may be desirable to investigate leakage around the sluices and to improve the Southern Bund as a safety precaution, we believe that any further investigations should be done during a moratorium period of say five years, during which no further abstraction for agricultural purposes should take place and the abstraction for the PWS in Ludham is at the very least significantly reduced. These investigations should include a detailed monitoring of the ecological state of the Fen, as has been suggested by the Harrises to Natural England, so that its condition and hopefully recovery can be properly monitored.

It is now four years since my wife and I highlighted the deterioration of Catfield Fen from drying. The site is too valuable to risk and no-one can want Catfield Fen to become the next East Ruston. Decisive action is now required!

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[Appendices A-D to these comments are shown below]

clay interval (see Section 5)[3], or it could be due to differences in datum surveys, the installations not all being surveyed at the same time. The latter may be more likely, but a re-survey of all the piezometers, gaugeboards and dipwell in this area would clarify the relationship between them.

Groundwater levels observed at NTG3270P4 and NTG3270P5 (P4 & P5) are shown in Figure D8, and again show the potential for upward groundwater flow. It should be noted that the levels recorded at P5 are probably limited during winter (or non-summer) months by the groundwater head being at ground level, and that during some summer months it may be that the piezometers goes dry. This drying out may be a reason for the very erratic logger readings observed during the summers of 2006 and 2008 (2009 logger data not being available after May 2009).

The impact of the Miles's Loke and Plumsgate Road spray irrigation abstractions on monitored water levels has been briefly investigated by comparing the observed water level data with the daily abstractions during 2009. The abstractions and daily rainfall are shown in Figures D9 and D10. As noted in Table 6.1, the totals abstracted from the Plumsgate Road borehole was about three times that abstracted from the Miles's Loke borehole. They are about 1000m and 650m respectively from the nearest points of Catfield Fen.

In order to illustrate what impact can occur, the hydrographs of the two Plumsgate Road 3.5m and 15m piezometers are shown in Figure D11, and compared with the Plumsgate Road abstraction about 275m away. (Abstraction licence 144B is located approximately 1000m from the nearest point of Catfield Fen). Evidence of an impact on groundwater levels is particularly evident in the deeper piezometers where groundwater levels were lowered by about 10cm due pumping. The impact at shallower levels is more subdued, and unfortunately a gap in the data hinders the assessment.

A comparison of the north-west Fen monitoring with the Plumsgate Road abstraction, about 1700m away, also appears to show some impact on groundwater levels (Figure D12). This is clearest during the September-October abstraction period when abstraction appears to have lowered groundwater levels, for example, by about 7cm in P1. An impact can also be seen in TG32/616d, and possibly a small impact of perhaps 2-3cm on dipwell water levels. It should be noted, however, that these possible abstraction impacts are less obvious during the earlier abstraction periods in 2009, and a fuller assessment of impact will be gained from investigating daily abstractions and daily water level data from other years, both past and future. The influences of rainfall, evapotranspiration, and of other groundwater abstractions will need to be considered.

The impact on dyke water levels is much less obvious than for groundwater (see Figure D12), and cannot be clearly discerned. Fluctuations of up to about 10cm appear to occur during abstraction periods, unrelated to variations in abstraction, and unrelated to rainfall recorded at the Barton Hall rain gauge, approximately 1.5km northwest of these installations in the northwest part of the Fen (see Figure D9). Whether these fluctuations are related to rainfall events not recorded at Barton Hall, or to other unknown influences, has yet to be determined.

[3] The thick clay interval was not recognised in the borehole log prepared by JDIH (Appendix D), but stiff clay intervals of greater thickness than shown on the log are shown on most other Crag logs in the area. The JDIH logs are considered to be "light" on clay identification. The thicknesses referred to are from the geology at the AWS Ludham PWS site.

being cut through the clay into the Crag in places (Figure C2). The means by which the windows were identified, whether by augering or geophysics, is not known.

6. Licensed Abstractions

There are three licensed groundwater abstractions in the vicinity of Catfield Fen and in addition one licence is held for surface water abstraction.

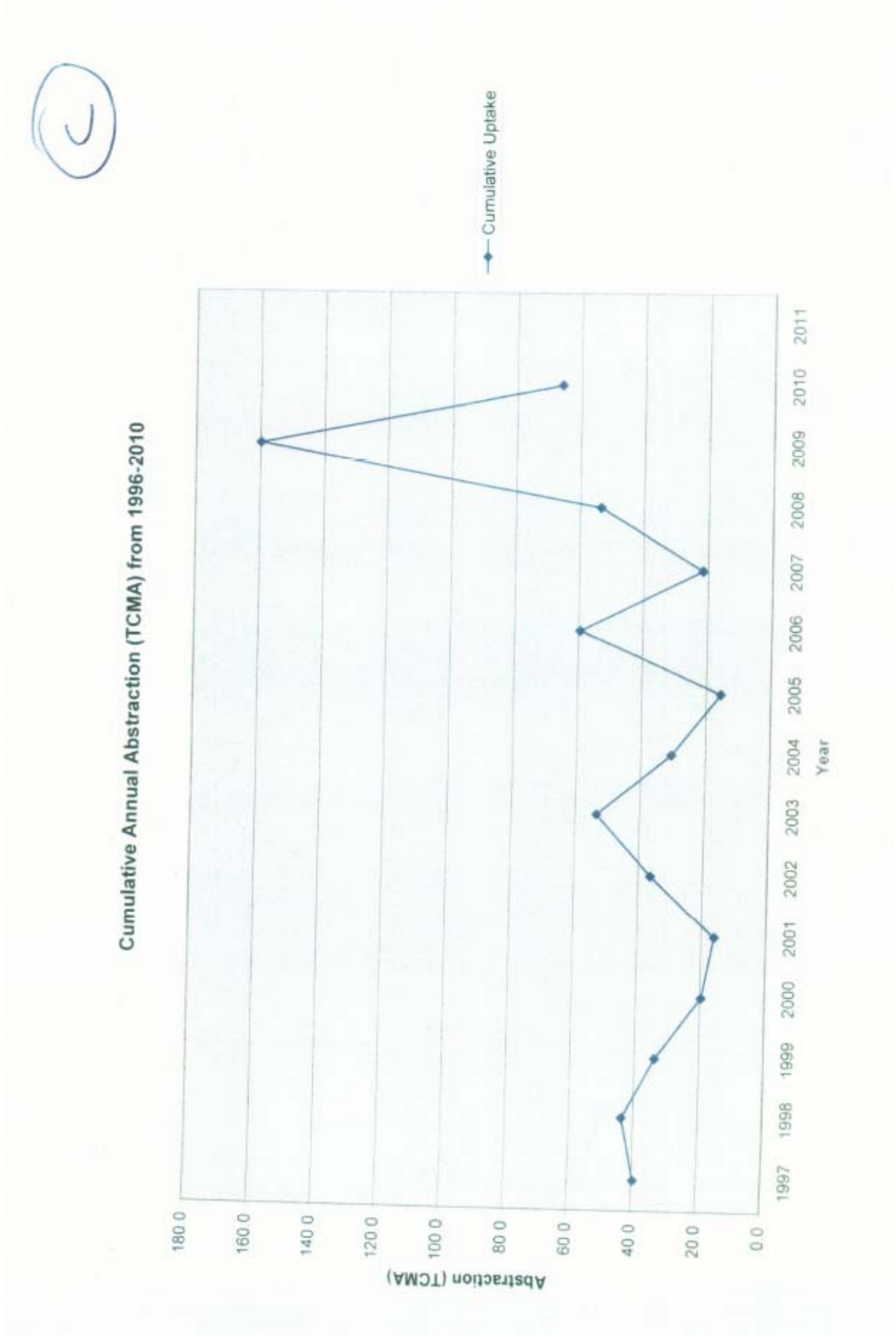
Two of the licences are held by Mr A. Alston for the purposes of spray irrigation during the period April to October, and are of particular concern to Mr and Mrs Harris. These were renewed for a time-limited period of two years (expiring 31 March 2012) and given new licence numbers of AN/034/0009/009 (formerly 7/34/09/*G/0141C) and AN/034/0009/008 (formerly 7/34/09/*G/0144B). However, for ease of reference with previous reports, the old licence numbers will be used in this Technical Note (as agreed by Anna De'Ath, Environment Agency).

Licence 7/34/09/*G/0141C is located on a track called Miles's Loke, about 650m ESE of the nearest part of Catfield Fen, and is authorised to abstract 800m^3/day and 22,700m^3/a. Licence 7/34/09/*G/144B is located about 100m south of Plumsgate Road, about 1000m NNE of the nearest part of the Fen, and is authorised to abstract 1,090m^3/day and 68,000m^3/a. The actual quantities abstracted during 1997 to 2009 are shown in Table 1.

Table 1 **Annual Actual Abstraction from Licences 7/34/09/*G/141C (Miles's Loke) and 7/34/09/*G/144B (Plumsgate Road) (Environment Agency, 2010)**

Year	Abstraction from 7/34/09/*G/141C (Miles's Loke) (m^3)	Abstraction from 7/34/09/*G/144B (Plumsgate Road) (m^3)	
1997		18,183	18,183
1998		24,883	24,883
1999	8,129	14,935	23,064
2000	9,196	7,625	16,821
2001	9,715	5,285	15,000
2002	20,491	11,612	32,103
2003	22,177	26,050	48,227
2004	17,387	8,034	25,421
2005	10,028	5,051	15,079
2006	21,414	23,501	44,915
2007	4,160	15,912	20,072
2008	22,910	21,331	44,241
2009	22,100	65,211	87,311

The other major abstractor in the area is Anglian Water Services, their Ludham public water supply (PWS) source being located about 900m SE of the nearest part of the Fen. The Ludham PWS source is part of licence 7/34/09/*G/0091 which allows 2,270m^3/day and 680,000m^3/a


Cumulative Annual Abstraction (TCMA) from 1996-2010
Cumulative Uptake
Abstraction (TCMA)
180 0
160 0
140 0
120 0
100 0
80 0
60 0
40 0
20 0
0 0
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year

cc Richard Wright, EN Hydrologist

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Comments from Mr Alston

AW Alston's response to AMEC report on abstraction at Catfield. March 2012

The report captures all the finer water movement issues and is very similar to previous reports. So we must conclude that it is a correct assumption that my abstraction from both boreholes is not having any effect on the Catfield Fen SSSI. I also believe strongly that it is in every body's interest to get the Catfield Fen SSSI back into favourable condition.

The one thing the Catfield area is not short of is water. For most of the year the whole area relies on the IDB drainage pumps to prevent the area from flooding. Most of the marshes have some form of sluice or boards (or Rond) to control water depths. Therefore man has to control the water in the whole area as the management at Catfield Hall used to be but there is little evidence now that any water level management occurs.
I would like to draw the Environment Agency's attention to the following details, which may or may not have been taken into account.

1.A profile sketch should be included in the report showing water movement is under pressure below the impermeable clay in the groundwater 15m deep. The sketch should also indicate horizontal water movement from the upland arable, across Catfield Hall Estate towards the Catfield Fen SSSI. This will give casual observers of this excellent report an immediate indication of how the water moves underground. It will also show the different water movement above and below the impermeable clay layer. My bores are pumping from the water below the clay layer.

2.At a meeting in Norwich's EA office in August 2011, Sarah Dawkins promised to get a survey completed (with the EA as contractors) of the height of the Catfield Fen SSSI. I am not aware that this has been carried out. If it has, the evidence should be presented. Following the heavy rain on 4-5th March the Catfield Hall Fen has been over topping into the course of the old riverbed. This is now the maximum water height achievable in the Catfield Fen SSSI. (For the gauge just inside the Rond NTG3261G1 on the LHS; 5.6, for the gauge TG32/71 near the mill; 6.4 and for the gauge at the entrance to the Catfield Fen Reserve NTG3261G3; 6.5). Most of the marshes in the Catfield Fen SSSI now have a surface height above the maximum water height. So it is impossible to let water onto the marshes.

3.The water quality test carried out inside the Rond and outside the Rond on 9th July 2011 show higher levels of Phosphate inside the Rond that outside. I will go into the probable causes of this in another document.

4. Both my groundwater bores have a Red Ochre issue and the samples taken on 9th July 2011 have much higher Iron levels than Catfield Hall Fen SSSI. If groundwater was entering the Fen it would be very obvious and there would be orange stains, there are not. But in the Entec report of a site visit to Catfield Hall Estate on 22nd May 2010 "*Mr Harris and his farm manager Mr Trevor Dodson did not know of any clear seepages or springs which might indicate groundwater discharges to the site*". On a site visit to Catfield on 10th Nov I took Dr Mason to various areas I knew there to be seepage from the groundwater, every single seepage showed Red Ochre. I have also shown Sarah Dawkins the same sites.
If this groundwater were getting into the Catfield Hall Fen, Natural England would be trying to prevent it from entering the site because of the high Iron content.

5.Changes in land use on Catfield Hall Estate will be discussed in another paper, with recommendations for improvements in land management with the objective of improving the Catfield Hall Fen SSSI.

6.The Rond was originally built by hand as a barrier. The aim was to use windmills to pump the water from inside the Rond and improve the land for agriculture. They knew there was a clay barrier preventing groundwater entering the site, hence the massive engineering project in those days. As the Fen would have had a thick layer of peat on it, was this removed before the Rond was constructed? Later mechanical diggers were used to make the Rond wider. Question: If the peat was not removed, can the water in Catfield Fen escape through the Rond? Soil cores should be taken along the Rond to see what it is constructed of. If there is peat, then this is probably a route by which water can escape.

7.In around 1920, the Catfield Fen marsh had the top foot taken off it by hand, dried along the Rond and sold to the villagers as a fuel source. It was taken back to the village in wheel barrows. Trees are relatively new in Catfield as most had been cut down for fuel. In fact 30 years ago one could see the other side of Barton Broad quite easily. It's only the new oil fired central heating systems that have changed the demand. So this 80 year cycle has happened before and the marsh needs careful management. North Marsh had the top cut off 12 years or so ago, and water management is better in that area but still higher than it used to be. How do we know this? The road at Fenside is constantly under water, it never used to be. So we know the water level is being kept at a level higher that is has historically been kept.

8.The Catfield Fen SSSI relies on rainfall to fill it and can resist dry weather in the summer months for 6-8 weeks. After this time the reed photosynthesis which uses 3-5mm of water per day will begin to drop ditch levels. Traditionally water would have been let onto the marsh to keep it topped up as the marsh cannot survive without human help now the Rond is in place. With the current height of the marsh, it is impossible to let water onto the Catfield Fen marsh and flood the reed beds which 25 years ago were the pride of Norfolk. Percy Neave and Douglas McDougal spent hours each day letting water too and fro through the sluice. Today's management policy seems to be "lock the sluice and do nothing".

9.Natural England are under an obligation to restore the Catfield Fen SSSI into favourable condition. My solicitor copied a letter to Helen Philips on 4th October 2010 pointing out its obligations under the Natural Environment & Rural Communities Act 2006 and the EU Habitat Directive. I'm not aware that any changes to management of the Catfield Hall Fen have taken place. Action needs to take place now and restore the Fen.

10.The irrigation licence 7/34/09/S/0084 should be revoked under the Review of Consents as it obviously is causing a problem to the integrity of the site. It makes no difference if it's a used licence or not, it should be revoked.

11.Is the gauge board near Catfield Hall measuring useful data? It seems higher up than the marsh. Clive Doarks document seems to back up this suggestion.

12.Peat deposition is obviously the big issue on the Catfield Fen SSSI. The Fen used to be burnt regularly and I was under the impression that it was banned. But Natural England can issue licences under the Heather Burning Regulations. This was a very useful management tool and should be introduced to burn trash and on occasions reed beds.

13.What has the effect of the work BESL has done over the last 10-15 years had on the water levels of Barton Broad? The report talks about lower water levels but as a farmer I'm not aware that my land is any drier than it used to be, if anything its much wetter. So I'm not convinced

by any arguments that the Broad levels have dropped. The broad is cleaner now than it was 20 years ago.

14.The "groundwater" below the impermeable clay layer is under pressure, hence the recharge after any abstraction is almost immediate. There is a positive pressure of around 500mm all year round. The "surface" water above the impermeable clay layer is not under pressure but moves horizontally down hill. Proof of this is by my piezometers near Plumsgate Rd. If there was groundwater input into Catfield Fen, the water levels should be much higher. They are not.

Catfield Hall Estate HLS agreement

On a quick visit on 7th March 2012, I noticed that very little sedge/reed cutting had occurred recently. Perhaps as little as 3 acres on the whole marsh and much of the sedge was just piled up rotting. This is very hard work and I can quite understand why there is little enthusiasm to cut the marshes when there are warmer jobs on a farm elsewhere. The HLS agreement talks about how the marshes are to be managed, "mow half to one third of the reed annually during the winter months and remove cut material". "Water levels must be raised to previous levels straight after cutting". This indicates that the levels must have been lowered before cutting. And therefore variable water level management. It talks about cutting the reds for thatch and draining the reedbeds slowly at least 3 weeks beforehand, to allow aquatic wildlife to move to deeper water.

The HLS agreement is correct but is it being followed down on the marsh? I questioned this in my solicitors letter in 2010. My observations on 7th March are that the water levels are not being adjusted ever, the marshes are not being mowed with the correct frequency, the trash is not being burnt and the marshes are 12-18 inches too high.

Compendium of Ecological & Eco-hydrological Evidence from Catfield Fen

Although not part of Dr Geoff Mason Report, I feel I must comment on this compendium. There seems to be one report conveniently missing from the collection of evidence and that is the one written by Wheeler BD & Giller KE (1982 a 7 b) which looks at the quantity of above ground plant material. That report should be included in the compendium to give a balance debate on the future management of the site.

Wheeler BD & Shaw SC (2006) were also commissioned by the Environment Agency to work on Catfield Fen. Have these unbiased papers been taken into account when writing the compendium?

Paper by Alex Bull. My only comment is that this person does not know his water subject as he is talking about water "extraction" not "abstraction". He also comments on a Muntjac deer being the only one he has ever seen there. Believe me when I say they are at pest levels and need to be controlled. Generally the assumptions he has made are not backed up by any hydrological evidence.

Paper by Natural England-name blacked out. 31.1.2011

The evidence the writer uses is "a Natural History of Catfield Hall" which has no hydrological facts to back suggestions up. Most of this report backs up what I have said earlier about the marsh rising out of the water.

Ecology Land & People Report

Seems to fail to take into account water used in photosynthesis by reedbeds and other plants. However the writer does back me up to say small changes in water levels are crucial, but fails to mention sluice control as the tool used.

Comparison of the results of two vegetation surveys for Catfield Fen- Clive Doarks
The writer backs my theory up that the Catfield Hall Fen is higher than the British Butterfly Conservation marsh. This has been managed by Andy Hewitt a reed cutter and appears to have a good covering of water achieved by regular cutting of good quality sedge and reed. However at certain times of the year it needs to be lower but the higher ground at Catfield Hall dictates the water is kept too high.
He sees no evidence of major shifts in NVC community within Catfield Fen

Conclusion: the top of the marsh at Catfield Hall SSSI needs to be reduced by 12-18 inches. I also believe that a management plan for Catfield Fen should be drawn up involving all local landowners, local householders, local Reed & Sedge cutters. We are getting nowhere blaming different bodies for the state of the SSSI. The cost of all these consultations should be put into actually doing some work on Catfield Fen. Natural England should ensure that the correct advice be given to the various landowners and ensure than this advice is followed to ensure the Fen is restored to its former state.

Comments from Mr Overton

From: Jan Overton [ojanrich@aol.com]
Sent: 08 March 2012 19:10
To: Corporate Services
Subject: Catfield Fen Investigation

Dear Jonathan

I'm afraid I don't have a lot of knowledge about Catfield Fen. However, it's seems to me that the change of use at Catfield Hall Farm, intomore permanent grass land from a conventional farming rotation, may have contributed towards the drying out of the fen.

The permanent grassland would be taking moisture from the land surrounding the fen on a constant basis. Also, the nitrates would be higher in the water, due to the run off from muck produced by the cattle grazed on this land. This would in turn encourage the grass on the fen to grow quicker, therefore taking even more moisture from the fen.

Having spoken to senior members of our family, they recall similar situations in the past, where changes in farming practices have led to a knock on effect to surrounding areas. Although these people have no formal qualifications in this field, they have a wealth of lifetime experiences.

I hope my opinions may provide a more 'practical' view point, as I am certainly not a expert, but sometimes there is a more obvious answer to a problem.

Kind regards

Richard

Richard Overton
H A Overton & Sons.

Comments from Anglian Water Services (Alison Selby)

From: Selby Alison [aSelby@anglianwater.co.uk]
Sent: 09 March 2012 17:29
To: Corporate Services
Subject: Catfield Fen

Thank you for the opportunity to comment on this report.

The report describes a complicated fen system where not all of the hydraulic pathways are well understood. It seems clear that there is some loss in the ability of the internal fen (Catfield Fen) to retain winter water levels and that this could possibly be due to a general reduction in water levels in Barton Broad and the external fen to the west. I share Professor Gilvear's concerns that this has been labelled 'climate change', without any real evidence as to how. However, I would agree with the conclusions of the report that there does seem to be some leakage of water from the internal to the external fen and that lower water levels in Barton Broad may have increased this.

The report describes concerns about a general drying out of Catfield Fen, but did not focus on any particular season. There seems to be little discussion on how the change in practice for summer operation of the sluices since the 1980s may have impacted on the fen. There is mention of photographs indicating greater scrubbing up of the fen since the early 1980s, but not on whether this is caused by drier conditions or whether this in itself is accelerating the drying out of the fen.

The modelling of the impact of the AWS Ludham abstraction on the water levels in the upper Crag, indicated that there could be some reduction of heads during a drought, however this was not reflected in the water level data collected since 1996. Whilst this does not rule out a small impact on water levels in the upper Crag (and hence a theoretical connection to some of the dykes in the eastern part of Catfield Fen), the degree of contribution has not been established. We therefore support AMECs conclusions that there may be a small effect, but it cannot be seen in the observed data. I note that generally the water levels in the dykes are higher towards the east of the fen, which is closer to both AWS Ludham and the Ludham Road abstraction. The AWS Ludham abstraction licence was also reduced in 2011 and it is not clear whether the Fully Licensed model run used this new figure or not.

Alison Selby
Water Resources Specialist (Licensing)

Comments from Natural England (Sarah Wilson)

09 March 2012

Our ref: 46390_EA Catfield Fen Investigation

Your ref:

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BY EMAIL ONLY
Jonathan Thompson
Team Leader Environment Planning
Environment Agency
Iceni House
Cobham Road
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Suffolk
IP3 9JD

Dear Jonathan

Environment Agency Catfield Fen Hydrological Investigation

Thank you for sending us the draft report 'Catfield Fen Investigation, 10 February 2012', and for inviting comments. Thank you also for the opportunity to discuss the report with the author, Dr Mason, on the 27th February 2012.

Natural England welcomes every opportunity to work with the Environment Agency to improve our understanding of this important site. We will continue to work with you, and with the landowner and other stakeholders, to ensure that the requirements for protection and enhancement of this site are met. We aim to have an evidence based approach to decision making, and we will work with you to develop the most sustainable solutions.

Ecological background

An Ecological compendium was compiled in April 2011 where Natural England concluded:

"Natural England sees no evidence of major shifts in NVC community within Catfield Fen, hence at this time serious, probably irreversible damage has not occurred on site; We cannot however conclude that damaging shifts in the vegetation quality are not occurring on account of the time lag between adverse environmental conditions and its manifestation in NVC community present on site;

There is evidence to show an increase in woody species within the open herbaceous fen communities
that have remained in continuous cutting and clearing management;

The increase in woody species could be due to a number of individual or several factors in combination, these include drying conditions increasing opportunities for germination or changes in
the management of the open fen."

As part of our monitoring strategy, a site 'Condition Assessment' was completed by Natural England on 8th November 2011, and units 3 and 11 (Catfield Fen) are still assessed as 'unfavourable no change'. There is an associated 'Restoring Sustainable Abstraction' remedy, and Dr Mason's report forms part of this remedy. If these investigations show that abstractions have a significant impact on the site this may result in the EA needing to revoke or amend abstraction licences.

The three key objectives of the hydrological investigation were to:

- Assess how the Fen functions hydrologically and hydrogeologically
- Assess the Fen's sensitivity to water abstraction
- Comment on possible causes for the site drying out

In our opinion these have largely been achieved. However, what is clear is that this is a complex site and that there are no simple answers to the concerns being raised, in particular the possible causes of the site drying out.

Natural England generally accepts the contents of the report. We believe it provides a useful overview of the investigations that have taken place to date and a comprehensive analysis of the hydrology of the Fen. We do, however, have some comments and specific queries.

Comments and specific queries

- The report gives the impression that concerns about the drying out of Catfield Fen have only been raised since 2008. However, concerns had been raised earlier than this, for example in 1993 when the previous owner of Catfield Fen, Mr Mc Dougal, alerted Clive Doarks of the issue.

- In the **Executive Summary**, and in **Section 5**, Dr Mason suggests that the lower water levels in Barton Broad are due to climate change. The data presented, however, suggests that there has been no significant difference in rainfall over the long term, and similarly the data shown in figure C6 would indicate that Potential Evapotranspiration (PE) has also not been significantly different. It is not clear, therefore, what the basis is for this conclusion as there does not appear to have been any significant long term climatic trend. We note that water levels in both Barton Broad and Hickling Broad have followed a similar pattern (Figure E6). Do these patterns correspond with generally wetter years or drier years, or is there the potential for there to be other causes for changes in these water levels?

- Paragraph 4 p50 states "With the lower Barton Broad levels and increased seepage/leakage from the internal system, water levels in winter/spring water levels within the internal system have fallen. These two factors can explain the recent drying out of the Fen."

- We agree that changes in levels of Barton Broad on a weekly / monthly to longer term basis (rather than daily) probably do influence levels across the fen system. This is demonstrated by the similar water level patterns in Figure E7 and the apparent lag between changes in levels in the Broad and within the Fen. It may be important to consider how the prevailing climatic conditions may have influenced this, however. In our opinion, there does not appear to be clear evidence of a general lowering of water levels within the Broad over time. While figure E5 shows several periods with general trends (eg roughly 2001 to 2006), there does not appear to be a consistent overall trend.

- We agree with the conclusions in **Section 8**, that there are number of possible reasons for the fen drying out, and that they are likely to be acting 'in combination'. As suggested, the system may well be 'leaky', and medium to long term changes in the

levels of Barton Broad may well affect water levels within the Fen as a consequence. We are not sure that there is evidence of increased seepage / leakage from the internal system, however.

- **Section 4** provides a helpful overview of investigations and understanding of the geology and superficial sediments at the site, but highlights the discontinuous nature of most of the clay layers. In addition, some of the clays are not very thick and may well not provide significant hydraulic separation as a consequence. Mr Harris has identified some springs on his land and Dr Mason also found a spring or groundwater seepage during his site visits. Groundwater influences may therefore be more significant on this site than previously considered and reductions in groundwater levels and flows could consequently adversely affect the condition of the Fen.

- We do not agree that the data provided indicates no impact from the irrigation abstractions on the Fen. At best it is inconclusive. **Section 7** indicates that there are concerns about the data from the observation boreholes. For example, the depth of some of the boreholes in relation to the screened intervals of the abstraction boreholes may not correlate adequately (eg TG32/805), and the lack of water level response in others makes the data from these questionable (eg TG32/815a, b & c). In our view, this leads to a lack of confidence in the observation data, and thus over any conclusion about whether the irrigation abstractions could be having an impact on the Fen.

- In **Section 7** Dr Mason states that beyond certain distances the abstractions are likely to have no discernable effect on groundwater levels, but the evidence to support these statements is not clear. Is this conclusion reached based on the data from the observation boreholes, or is it based on other analysis such as calculations based on hydrogeological principles? Note that while the impact of the irrigation abstractions may be small, the impact will inevitably occur when the Fen is most sensitive, ie in dry periods when water levels are already likely to be low and the vegetation suffering from stress. Any impact from these abstractions would have to be considered in combination with other factors, including other abstractions, rather than simply alone. In our opinion the potential impact of the Ludham PWS abstraction is likely to need re-visiting based on the data presented.

- Dr Mason states (Para 6 p50) “The Ludham Road abstraction may have a localised effect on groundwater levels near Church Wood, but it is considered that this will be small and short-lived, and any reduction in groundwater input to the Fen will not be significant. The impact of the abstraction, being small, localised and short-lived, is not considered to be the cause of the observed drying out of the Fen.” Natural England believes that there are number of possible reasons for the fen drying out, and that they are likely to be acting ‘in combination’. As the irrigation abstractions occur at the most sensitive time of year and during critical hydrological conditions, even a small impact can be significant.

- As a consequence of the uncertainties, in our view the recommendations presented at the end of the report should be considered further, to confirm that they would help to improve confidence in the analysis of abstraction impacts. Natural England would be happy to discuss these with the Environment Agency to agree a way forward.

Natural England Key Conclusions and Recommendations:

We agree that the site is very complex and that there may be more than one reason for the site drying out. Dr Mason’s report is a valuable and useful contribution to the debate, and we welcome the opportunity to comment on it.

We have some queries about the conclusion that the lower water levels in Barton Broad are due to climate change. In our opinion there does not appear to be clear evidence of a general

lowering of water levels within the Broad over time, and we would welcome further clarification.

We agree with the report conclusion that there are number of possible reasons for the fen drying out, and that they are likely to be acting 'in combination'. It is probably not possible to isolate the significance of individual factors, and consequently we believe that the impacts from abstraction should not be discounted as they may be having an impact on water levels. In our view, the information provided indicates that groundwater may be a more significant factor in the functioning of this site than previously considered. We therefore do not agree with the confidence of the statements in the draft report concluding no impact from the irrigation abstractions.

We would welcome further clarification about the stated view that beyond certain distances the abstractions are likely to have no discernable effect on groundwater levels.

We agree that further work is probably required in order to improve confidence in the analysis of abstraction impacts, and to support the recommendations of the report. We therefore support the recommendation to improve confidence in the water level data. In particular we agree with the proposals to check the functioning of the observation boreholes, and to review the levelling of the gauge boards. We also support the view that additional monitoring may be required within Catfield Fen, closer to the abstractions. These recommendations highlight the gaps in current data and understanding of the site, and in our view this leads to uncertainty about the conclusions that have been drawn.

As a consequence of the queries and uncertainties highlighted above, we would welcome a further review of the report recommendations. Natural England would be happy to discuss this with the Environment Agency to agree a way forward.

We hope this is helpful at this stage, and we believe it is important that there is also further discussion between Natural England and the Environment Agency prior to the commencement of the abstraction renewal consultation to agree the interpretation of the evidence base that will underpin any such consultation.

Yours sincerely

Sarah Wilson (Mrs)

Area Manager Norfolk and Suffolk

Natural England

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Comments from Broads Authority (Andrea Quality)

Catfield Fen – Hydrological investigation
Broads Authority comments on AMEC's final draft report

5 March 2012

Firstly I would like to thanks the Environment Agency for involving the Broads Authority in this consultation. This shows exemplar practice to ensure that the interests of and all evidence pertaining to the Broads floodplain fen, covered under European WFD and Habitats Regulations, are considered.

The Authorities interests are to protect and enhance the Broadland fens, which are the richest wildlife sites within our boundary, which has equivalent status to a National Park. Almost all fens are internationally and nationally important for nature conservation and through their relative isolation from river pollutants have retained diversity and species abundance that has been lost from the river and lake habitats. In addition we own and area of fen as well as managing around a quarter of the open fen in the Broads and our highest conservation priority is the strategic and operational management of fen habitats in particular. The Authority is also owners of How Hill including Cromes Broad to the south of Catfield Fen. As site owners and consultees under our Broads Act on this and other water abstractions in the Broads executive area we have a significant interest in this hydrological investigation.

The interaction of fen vegetation with its environment is complex and influenced by a number of factors. Catfield Fen is one of the most studied fens in the Broads. It is also managed to maintain vegetation quality, reduce nutrient input from the surrounding upland and to retain site water levels. Despite this there is well documented deterioration in the quality of the vegetation demonstrating that the site is drying out.

I have a number of specific comments and queries arising from this draft report:

1. There is an acknowledgement of how important water is for Catfield Fen and the international designated features it supports. This is evidenced by a large volume of literature which should include the Fen Ecological Survey (2010) and the Broads Biodiversity Audit (2011). Thus any factor that is reducing the capacity for Catfield Fen to retain and be supplied with water within the semi-arid climate of East Anglia should be treated equally and in accordance to robust scientific evidence in the context of this report. I recommend that the draft report be amended to ensure an equal and scientifically robust treatment of the likely factors contributing to drying.

2. The final report needs to be amended to refer to the levels of uncertainty in the data. It appears that trends have been inferred from graphs without appropriate statistic interpretation. In this regard, the conclusion weights the contribution of seepage between the river and internal system too highly considering the lack of data available and its level of analysis. Seepage rates are currently unmeasured and would probably be difficult to quantify. The information presented in the report does not suggest that there is anything more than an uncertain and negligible contribution by seepage to the hydrology of the fen.

3. In the absence of any knowledge of the contribution of the seepage rates to the fen hydrology, this topic needs further investigation to be included in scientific report and I recommend as a minimum the following is done:
    - statistical analysis is employed over the time series of hydrological data
    - climatic data is used in conjunction with the assessment of water level assessments seasonality / trends
    - the fen vegetation in other river connected fens in the Ant and Thurne is also assessed to look for the effects of the lower river levels as I would expect to

see similar drying effects in all river connected sites if this is the case. It is worth noting that NE have reported that the River Yare fens are getting wetter not drier.

Without such modifications the seepage issue is simply a hypothesis which does not have sufficient grounds to be drawn into the conclusion with any level of certainty.

4. If climate change is indeed found to be directly contributing to the drying of the site (and indeed other fens in the area - by reference to other studies, including the Fen Ecologic Survey 2007-2010) the effect of water abstraction needs to be examined within this context. As the assessment progresses through the Habitat Regulations the plan or project will require sufficient data to be judged and not climate change itself. The climate altered situation will form a new baseline for assessments.

5. It is certain from water chemistry and the proven relationships of the surface fen and groundwater, as well as the modelling of volumes of water taken from the surrounding abstractions, that there appears to be a link on the site between water abstraction. This is also documented in previous hydrological reports and would appear to relate to the ecological research that reports the long-term drying out of the site. It seems that the extent of this impact has yet to be determined and that is the major outstanding issue that has not been answered by this report.

6. The final report should have reference to the potential errors in the Review of Consents data. The issues raised over confidence in response of the fen and any masking of the impact as a result of the placement of the monitoring locations need to be fully addressed in the final report.

7. The Figures that refer to the agricultural abstractions do not show the actual seasonal water use. In addition further analysis of the seasonal impact of abstraction is required. The impact on the water that it is provided and stored during winter recharge period and is critical to provide water resource and resist drying in the semi-arid climate of East Anglia. Thus an assessment of seasonal sensitivity and threshold effects are required.

8. Topographic levels are needed for the whole of the site including reference to the levels in the watercourses. This would allow the piezometer data, stratigraphy, and the vegetation data to be tied together. The sediment core and vegetation sample data both have very precise locational information which would allow their topographic level to be determined. Tying together the three data sets would allow a much more certain interpretation of the hydrology and ecology of the site and provide a data set and understanding almost unparalleled in the Broads. This will not be possible and neither the remit of this report. However this report should provide recommendations to further work to ensure that the site is fully understood. This will also help assess how the hydrology of the south of Catfield fen works alongside the north of Catfield. The Environment Agency owns the Lidar data for the site.

Three further points which are beyond the scope of this hydrological report, however need to be considered at a future relevant stage are the following. The Broads Authority considers it is appropriate to simply raise these issues now in order that the bigger picture is retained through this assessment.

9. The impact of any changes to the water management regime would require an assessment of wider effect on adjacent sites. Particular concerns would be an excessive increase in water levels, or a sluice management regime which led to stagnant conditions in the peat body by maintaining too high a level for too prolonged a season.

10. It is important that any solutions proposed for the drying of Catfield are sustainable and deal with the cause of the problem. As authors of the Broads Fen Strategy, we advise that a re-wetting solution is required to a fen that is in the process of drying out. We cannot agree that surface peat removal is a solution.

    Once prolonged drying out has occurred, such has occurred in other Broads sites as a result of public water abstraction (Mown Fen and Redgrave and Lopham Fens), then extensive peat extraction is indeed required to lower the surface and remove the oxidised peat. However the recovery of some early sucessional fen communities via turf ponding would enhance the condition of the fen vegetation providing they could be sustained by an adequate
    hydrology.

11. We advise the Environment Agency that the precautionary principle needs to be applied under the Habitat Regulations. Catfield contains European Union priority habitat - calcareous fens with *Cladium mariscus* (Code 7210 of. Annex I of the Habitats Directive). Extensive analysis of these designated features has clearly demonstrated that the site is drying out. Extensive analysis of the hydrology has however proved inconclusive to the exact cause of drying. Before the continued drying results in irreversible damage to this fen and peat substrates, the precautionary principle needs to be applied and the adequate controls on water abstraction need to be applied.

We are willing to continue to work together to on the correct process and assessments for this important fen site.

Andrea Kelly
Senior Ecologist

Comments from Environment Agency

Comments on Catfield Fen Investigation, Final Draft Report

Section 1: Introduction
No comments.

Section 2: Data Considered in this Report
No comments.

Section 3: Overview of Catfield Fen and its Setting
Page 6, 4th paragraph, last sentence: Do we know any details about the new wide dyke especially in terms of construction depths and strata it is cutting in to? When was it put in? Why was it put in? Is it hydrologically relevant to Catfield Fen and possible influencing the water levels in the external and internal system or the relationship between external and internal system?

Section 4: Geology
It would be useful to add a conceptual cross section to illustrate the multi-layered nature of the aquifer system. This cross section would also help to better understand the respective water level responses in individual monitoring installations in Sections 5 and 7.

Section 5: Hydrology and Hydrogeology

Section 5.2, page 13, 3rd paragraph: It would be useful not only to point out the dry years which may be indicative for low shallow water levels but also the particularly wet years to put the subsequent water level observations into context. As indicated by Figure C6, the wet winter of 2000/2001 was followed by a summer with rainfall exceeding PEgrass. This resulted in a major recharge event across the region with extremely high groundwater levels in most locations and local groundwater flooding in spring 2001. Since then, regional groundwater levels have been declining gradually due to overall less recharge to the aquifer systems.
Our analysis suggests that the apparent downward trend in the Barton Broad and Hickling Broad water levels is due to the way in which storage can persist in the Crag for several years. Due to the significant recharge to the aquifer in the upstream Ant catchment in 2000/2001, and, although tidal effects and run-off events are superimposed on the trend in Barton Broad, the water levels are generally higher in 2001, declining slowly over the following few years. It is thought that this would explain the apparent declining trend in Barton Broad water levels since 2004. There was then another large, albeit not so large, recharge event in 2006/2007, and that is also visible in the Barton Broad levels.
The water levels in the years following these two winters are elevated by the persistent storage in the Crag, so a year-by-year analysis is not appropriate for the main aquifer and the river system receiving baseflow. The year-by-year analysis may however be appropriate for shallow groundwater systems and dyke water levels on the fens which are likely to be more influenced by direct rainfall and actual evaporative demand at the time.

We suggest that the above explanation for the apparently declining water levels since 2004 is considered throughout the report and changes to relevant text are made where appropriate.

Section 5.2, page 13, in reference to Prof. Gilvear's comments: In our understanding, the report does not use the argument of "overall long-term trend towards drier summers" to explain the drying out of the fen. In the 4th paragraph on page 13, the report actually states: "This approach….. does not indicate any clear long-term trend showing increasing or decreasing net rainfall."

Section 5.4, page 15: It might be useful to give a description of regional water level responses to illustrate 'natural' seasonal variations and trends, such as generally dry years with low water levels and normal seasonal fluctuations. This would help to put the subsequent analysis of local water level data for Catfield Fen into an overall context and to draw out any 'deviations' from the normal regional pattern that might be due to abstraction or other local influences.

Section 5.4.1, page 15: It would be useful to indicate in Table 5.1 in the column for 'Monitored Horizon' if a monitoring installation is screened in the upper, middle or basal Crag unit (if known). This will help to interpret the water level response in individual boreholes, e.g. by indicating likely unconfined, semi-confined or confined aquifer conditions and by indicating if monitored water levels are in the same unit as abstraction and hence likely scale of response to abstraction.

Section 5.4.2, p.19 paragraph 4: The wording in this paragraph suggesting that the variation is of "climatic origin" is different to the wording in the Executive Summary, which suggests that the levels have declined "in response to *changes* in climatic conditions" (italics added). Our comments on the consequences of the wet 2000/2001 period made for Section 5.2, page 13, 3rd paragraph, should be taken into account and it should be made clearer throughout the text that it is considering climatic variations between years rather than overall "climate change".

Section 5.4.2, p.20 paragraph 5: We agree that Figure E8 shows a change in pattern in the difference between water levels in the internal and external system since about 2008.

Section 5.4.2, p.21: in reference to Prof. Gilvear's comment: We do not think that the report is suggesting overall "climate change" as the reason for declining water levels in Barton Broad and Hickling Broad. As suggested in previous comment this should be made clearer to avoid misunderstanding.

Section 5.4.3, p.21, last paragraph and p.23, in reference to Prof. Gilvear's comment: The basis of the finding of the University of Birmingham study that "normally the peat water levels are above the drainage ditch water levels" is not clear. Is this a one-off observation in 1989 or were observations made over several months or years? In order to allow correct interpretation the

observation also needs to be put into context of climatic conditions, river and groundwater levels, and sluice management practice at the time.

Section 5.4.3, p.23: In reference to Professor Gilvear's comment: if the dykes being cut into the Crag provide the best hydraulic connection between the Crag and the water levels on the Fen, a reversal in flow direction between the peat and the dykes would not be consistent with a decrease in Crag groundwater levels caused by abstraction because the dyke water levels would be expected to be lowered more than the water levels in the peat. However, it also needs to be considered that a reversal in flow direction (with peat water levels being lower than the dyke water levels) would not be consistent with leakage from the dykes being the main cause of the drying of the Fen.

Section 5.4.4, p.24 3rd paragraph: In a typical groundwater flow system one expects a discharge zone with upward flow in the valleys close to the river and recharge zone with downward flow away from the rivers with increasing topography. Whilst the observation boreholes in the NW corner of the fen are clearly located in an discharge zone (where upward flow would be expected) the observation boreholes at Sharp Street may already be located close to or in the recharge zone (where downward flow would be expected). It might be possible that the abstraction at AWS Ludham which has been abstracting from the Crag since 1973 has lowered the deeper Crag water levels and therefore increased the vertical head gradient and the potential for downward flow at Sharp Street.

Section 5.5.2, p.27: In reference to Professor Gilvear's comment: it is not clear why Professor Gilvear thinks that leakage/seepage is likely to be restricted to periods when there is a large head difference. We might expect leakage/seepage to increase approximately in proportion to differences in head between the internal and external systems, but we would still expect leakage in periods of lower head differences. Any head difference will drive flow if there is a pathway for flow. Therefore, at any time when the water level in the internal system are higher than in the external system, we would expect some leakage/seepage out of the internal system to occur following the pathways that were available for inflow of saline water into the internal system during the tidal surges.

Section 5.6, p.32, in reference to Prof. Gilvear's comments: We think that, to this point, the report has not been "making definitive conclusions as to the site not being impacted by groundwater abstraction". We feel that the report acknowledges that groundwater plays a role in the hydrological functioning of the fen alongside other mechanisms.
We understand from the report that the inflow of saline water during the tidal surges occurred when water levels were high but not exceptionally high. Therefore the statement of Prof. Gilvear that it happened "when there was a high head" might not be correct. We agree with the report that leakage from the internal system (following the same pathways as the saline water entering the internal system) could lead to an overall reduced retention of water in the internal system which may lead to lower water levels also in summer.

However, we acknowledge that any leakage from the internal system, although we think the concept is plausible, has not been directly observed or measured yet.

Section 5 – Summary: The summary of hydrological data provided in this section is very detailed, and synthesises the various data sources into a coherent conceptual model of the Fen. The work on the conductivity of the waters in 5.5.2 shows that there has been movement between the internal and the external systems at water levels that are not particularly high, and when the sluices were closed, so *there must be leakage at similar water levels when the internal system is higher than the external system*, even though the available data cannot possibly show that leakage directly.
We generally agree with the findings of this section but we have made some suggestions for further analysis or different presentation that may help to draw out the findings more clearly.

Section 6: Licensed Abstractions

p.33 paragraph 5: "the currently used licence numbers and identifying names" should be changed to "the commonly used licence numbers and identifying names used in this report", since the Alston abstractions now have different numbers.

Section 7: Impact of Licensed Abstractions

Section 7, general comment: When analysing and interpreting the hydrographs, more consideration should be given to the borehole construction details and local geology at the individual observation points and the relationship to the hydrogeological unit from which abstraction takes place (reference to info in Table 5.1).

It would be useful if the natural characteristics of the hydrographs (e.g. natural groundwater level recession; confined/semi-confined/confined aquifer response) and any unusual features (e.g. logger malfunctioning) were pointed out before identifying impacts from abstraction which will occur on top of those natural characteristics and unusual features. This is especially important because abstraction for spray irrigation occurs at times without rainfall when shallow groundwater table and dyke water levels are likely to decline 'naturally'. It should be explained in the report how the impacts from abstraction are identified as 'deviation' from the natural pattern, e.g. short-term troughs and immediate recovery in response to short periods of abstraction or steepening of the 'natural' recession .

In order to illustrate the overall regional climatic conditions and 'natural' response of the groundwater and surface water system it might be useful to look at water level records from boreholes of the regional monitoring network, possibly introduced in Section 5.

It would be useful if the examples for abstraction impacts were highlighted on the related figures e.g. with circles or arrows.

Section 7.2, p.38: It would be useful to insert a table to summarise the impacts from the Plumsgate abstraction estimated from the observed water levels at the three observation boreholes i.e. at different distances from the abstraction and at different depths/aquifer units. If possible on the basis of these observation data, it would also be useful to estimate how far the cone of depression in the upper Crag unit is likely to extend from the Plumsgate abstraction point towards the fen.

Section 7.2, p.39, 2nd paragraph and following: Although the logger data obtained during 2011 may suggest lack of responsiveness to rainfall events and therefore to abstraction signals, we would suggest further analysis before a firm conclusion about the lack of responsiveness is drawn and the observations are discarded as not useful for the assessment of abstraction impacts.
It should be considered that 2011 was exceptionally dry and that during the period for which logger data are available recharge to the groundwater table in this location may have been minimal or nil despite of some rainfall events. It should also be considered that the depth to water table in these locations is in the order of 4-6m below ground level and therefore any response to rainfall events will be quite different to locations where the water table is close to ground surface e.g. as close to the fen. In addition, if the piezometers are sited in the sandy deposits with an unconfined water table responses might be subdued in scale compared to other 'semi-confined' piezometers responding with changes in pressure rather than actual storage changes.
Also, Figure E27 suggest that the three boreholes, which are at different distances from the Plumsgate abstraction, are showing a very similar long-term pattern. In our view this suggests that, overall, they are responding to the same climatic and recharge conditions and should therefore also capture any long-term impacts from the Plumsgate abstraction even if it was confirmed through further investigation that there was a lack of responsiveness to short-term abstraction signals.

Section 7.2, p.39, last paragraph: It might be possible to confirm the depth of the screened section in the Alston Ludham abstraction borehole by downhole camera inspection or similar means. If observation borehole TG32/805 is screened in the shallow Crag unit and the abstraction borehole in the middle Crag unit which are separated by a clay layer, this may explain the apparent "lack of responsiveness" to individual abstraction events. Observations in TG32/805 would still be useful to determine how the impacts in the abstracted horizon propagate upwards into the shallow Crag unit which also underlies the fen. However, responses to short-term abstraction events would unlikely be observed as short-term fluctuations as would be in the pumped middle Crag unit but would probably be more subdued and delayed, if detectable at all.

Section 7.2, p.41, 3rd paragraph: When looking at dyke levels in the internal system it would be useful to re-emphasise that some of the dykes are thought

to cut through to the upper crag unit. They would therefore show responses to impacts from abstraction on the upper Crag unit before any impacts would become apparent in dipwells installed in the peat.

Section 7.2: We would like to see further analysis of the data as suggested in comments above before we form a final view on observed impacts from the two Alston abstractions.

Section 7.3: The analysis of impacts from abstraction at the AWS Ludham source based on observed data for the period 1996-201 and signal testing in 2002, 2003 and 2007 has various limitations. The abstraction started in 1973 and has been operating more or less continuously since then. Therefore, any abstraction impacts will have become part of the 'background' conditions. There is no pre-1973 monitoring data available that would allow a comparison with the more recent water levels. During the signal tests it was also not possible to switch off the abstraction completely to see the full recovery of water levels, which would have indicated the full scale of impact.
The signal tests were based on a slight increase in abstraction rate over a limited period of time. These time periods may not have been long enough to show the full impact from abstraction in the middle/basal Crag unit propagated up into in the upper Crag unit and the fen deposits.

Section 7.3, p.45, last paragraph and in reference to Prof. Gilvear's comments: We agree that the available observation data do not provide evidence for impacts from the AWS Ludham abstraction on the fen. However, based on the limitations described in the comment on Section 7.3 above, we do agree with Prof. Gilvear that the data is "no good evidence either way" and that they have significant limitations with regards to identifying long-term impacts from this abstraction. We think that the report actually comes to the same conclusion but the wording probably is not clear enough.

Section 8: We think the reports draws together the different plausible mechanisms that may have contributed to the fen drying out in a very considerate way. The report is restricted to the information and data available and therefore there remain uncertainties about the quantitative contribution of each mechanism.

Section 9 and in reference to Prof. Gilvear's comments:
We agree with Prof. Gilvear's final comment "…that although no evidence can be seen of individual abstraction episodes on the fen hydrology it does not mean that the fen is not sensitive to groundwater abstraction".
We do also think that the report also appears to agree with this statement but some wording may have been misunderstood.
We think that, due to the hydrogeological situation, it is conceptually *possible* that groundwater abstraction can lead to water level changes in the dyke water levels and to a lesser extent in the peat water levels on the fen. However, whether or not these water level changes on the fen *do actually occur and to what scale* does depend on the abstraction quantity, the abstraction periods, the aquifer unit from which the abstraction takes place and the distance between the abstraction and the fen.

Whilst we have suggested some further analysis of the evidence that looks at the impacts from the Alston Plumsgate and Ludham Road abstractions, we tend to agree with the draft report at the moment that the impacts from those comparably small seasonal abstractions on the fen water levels are likely to be comparably small and short-lived or even not detectable.
With regards to the evidence for the AWS Ludham abstraction we do have greater concerns about the limitations of the data available. We think that the currently available data is not sufficient enough to allow assessment of any long-term impacts since 1973 when the abstraction commenced.

We do agree with the report that there is evidence that increased leakage/seepage from the internal system is potentially contributing to the fen drying out, at least since 2008. We suggest that all possible causes for the fen drying out that have been identified by the report are given further consideration in order to protect Catfield Fen.