Ant Broads and Marshes, Alderfen Broad and Broad Fen - Site Action Plan

31.01.2010

Document Ref:	ANT B&M_SAP 6	Version:	6
Author:	Sue Hogarth / Eleanor Bellotti	Date:	31.01.2010
Reviewed By:	Amanda Elliott / Katie Critchley		
Approved By:			
For Environment Agency:			
Name:		Name:	
Signature:		Signature:	
Date:		Date:	

Revision History

Version Number	*Description of Change*	*Author*	*Approved by*	*Date Approved*	*Original Version Number*	*Issue Date*
1	Initial draft – WQ parts sent to NE	Sue Hogarth			1.0	19.06.08
2	Second draft – updated following comments from NE, and DWF calculation changes. Sent to NE	Sue Hogarth				20.10.08
3	Third draft – WQ section updated after further information on river flows from WR.	Sue Hogarth				21.08.09
4	Fourth draft WR input	Eleanor Bellotti				21.10.09
5	Review by AHDC		Amanda Elliott			06.01.10
6	Review by RHDC		Katie Critchley			End Jan 2010

Hyperlink Index

Section A: Stage 3 Overview

- Summary of outcomes of Appropriate Assessments
- Map of site, showing location of permissions in Stage 4

Stage 3 Summary of Issues

- Water Quality
- Water Resources
- Waste Management
- Air Quality
- Radioactive Substances

Section B: Outcomes required for Ant Broads and Marshes, Alderfen Broad and Broad Fen SSSIs

- Overall Environmental Outcome Statement
- Feature / species specific Environmental Outcomes
- Water Quality
- Water Resources
- Waste Management
- Air Quality

Section C: Options available

- Water Quality
- Water Resources
- Waste Management
- Air Quality

Summary of options for Ant Broads and Marshes, Alderfen Broad and Broad Fen SSSIs

Section D: Consultation Process

- Table D1 Communications Log

Introduction

Stage 4 requires the Environment Agency to affirm, modify or revoke permissions assessed within the Appropriate Assessment at Stage 3 of the Habitats Regulations Review of Consents (RoC) process. Those permissions that were found not to be having an adverse effect on site integrity at Stage 3 will be affirmed. However, for those that could not be shown to have no adverse effect, it is necessary to identify the most appropriate course of action to enable a conclusion of no adverse effect on site integrity to be reached. This Site Action Plan (SAP) details options identification and appraisal for all such permissions for the Ant Broads and Marshes SSSI and follows the principles and process outlined in the Environment Agency Habitats Directive Handbook and TAG paper WQTAG152.

Details of the decisions to affirm, modify or revoke permissions are given in the attached Appendix 19 tables, and this SAP provides the justification for coming to these decisions.

This SAP covers the SAC / SPA features of the Ant Broads and Marshes SSSI, Alderfen Broad and Broad Fen SSSI, and is consistent with the approach in the Stage 3 Appendix 21s.

These SSSIs are considered together in this SAP as the majority of the licences / discharge consents are the same for both – all of the water quality discharge consents brought forward for Broad Fen are also being considered for the Ant Broads and Marshes.

SECTION A: STAGE 3 OVERVIEW

Site details

Broad Fen SSSI
Broad Fen SSSI is a 36.8ha area of floodplain fen located in the upper part of the River Ant valley, 3km west of Stalham (TG 343253). The site supports a mixture of fen, fen meadow, open water and carr woodland communities.

The River Ant near the site is canalised as the North Walsham and Dilham Canal (Dilham Canal), and flows southwards forming much of the boundary of the eastern edge of the site. Tyler's Cut comprises the southern boundary of the site. The former Dilham Broad is in the southern part of the site and is now terrestrialised consisting of a thick, buoyant mat of vegetation over fluid lake muds. There are four ponds in the north-western part of the site.

Ant Broads and Marshes SSSI
The Ant Broads and Marshes SSSI is part of the Broads SAC and Broadland SPA. It is an area on the east and west banks of the River Ant (TG 362213) and extends for approximately 5.5km down the River from the southern edge of Stalham and finishing 2km to the north of Ludham Bridge. The habitats on site include dykes, fen, reedbeds, carr woodland and open broads.

Alderfen Broad SSSI
Alderfen Broad SSSI is a 21ha site located between the Rivers Ant and Bure, 2km to the north of Horning village at TG 355195.

The site comprises a 5ha broad surrounded by fringing swamp and fen, and backed by woodland. It is bordered to the northeast and southeast by a series of roads and tracks. The eastern boundary is formed by the transition to arable fields on the upland. The western boundary follows a dyke that runs northwest to southeast through the carr.

The Norfolk Wildlife Trust owns the majority of the site and manages it as a nature reserve.

The site is isolated from the IDB drainage system by water control structures and water quality in the broad has been improving over the years since water was diverted and mud pumping carried out.

The designated SAC and SPA features for the sites are:

	Ant Broads and Marshes	Alderfen Broad	Broad Fen
Natural Eutrophic Lakes	✓		✓
Hard Oligo-mesotrophic waters	✓		✓
Molina Meadows	✓		
Alluvial Forests	✓	✓	✓
Calcareous Fens	✓		✓
Transition Mires and Quaking Bogs	✓	✓	
Fen Orchid	✓		✓
Otter	✓	✓	✓
Desmoulin's Whorl Snail	✓	✓	✓
Bittern	✓	✓	✓
Marsh Harrier	✓	✓	✓
Hen Harrier	✓	✓	✓
Gadwall	✓	✓	✓
Shoveler	✓	✓	✓
Great Crested Grebe	✓	✓	✓
Cormorant	✓	✓	✓
Teal	✓	✓	✓
Pochard	✓	✓	✓
Tufted Duck	✓	✓	✓
Coot	✓	✓	✓
Assemblage	✓	✓	✓

In addition there are sub-features important for the SPA bird species and these are swamp, fen, reedbed, wet woodland, open water and fen meadow with ditches and water bodies.

Table A1: Draft Stage 3 conclusions for licences

Function		No adverse effect on site integrity can be shown.	No adverse effect on site integrity cannot be shown
Water Quality	Ant Broads and Marshes	112	14
	Broad Fen	82	10
	Alderfen Broad	8	0
Water Resources	Ant Broads and Marshes	70	16
	Broad Fen	33	39
	Alderfen Broad	42	1
Waste		0	0
PIR: discharges to water		Considered under Regulation 48	0
PIR: discharges to air		Considered under Regulation 48	0
Radioactive Substances Regulation		0	0

Therefore only water resources and water quality will be considered further in this site action plan.

Maps of sites

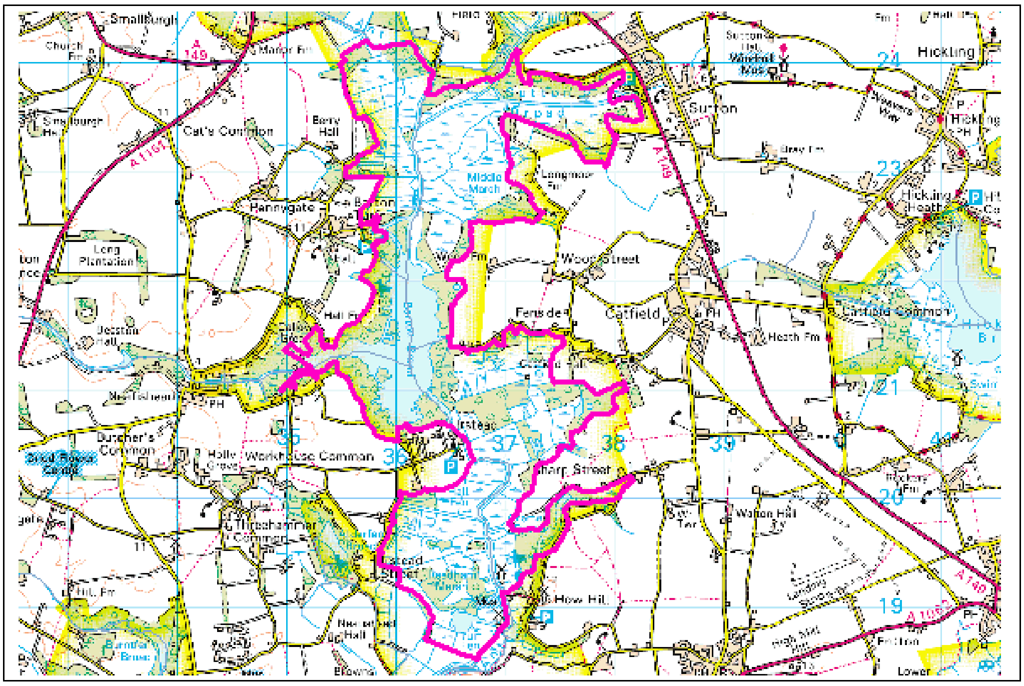


Figure A1: Detailed map of Ant Broads and Marshes

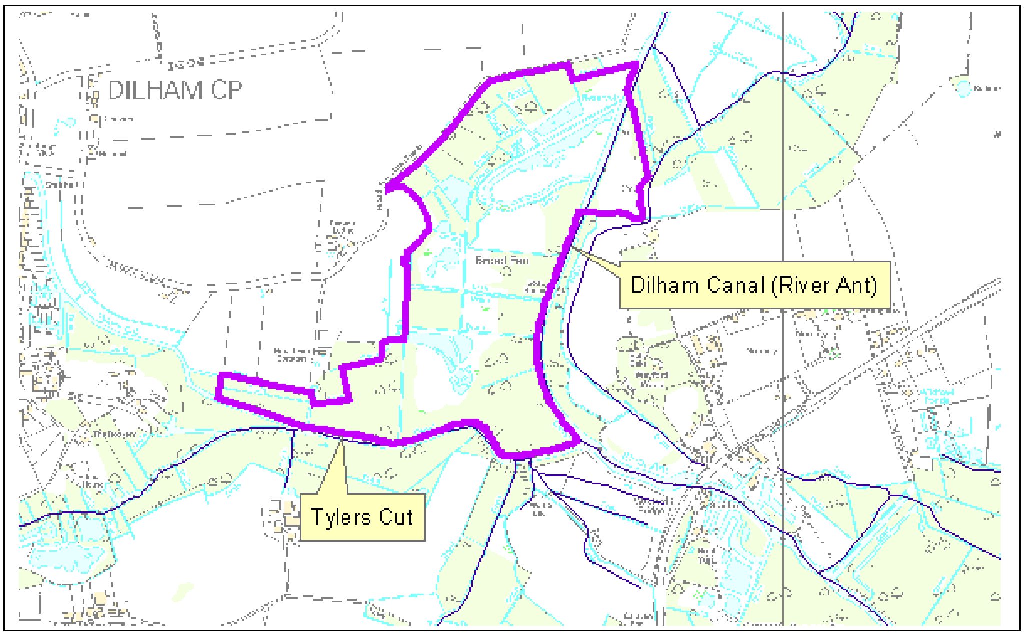


Figure A2: Detailed map of Broad Fen

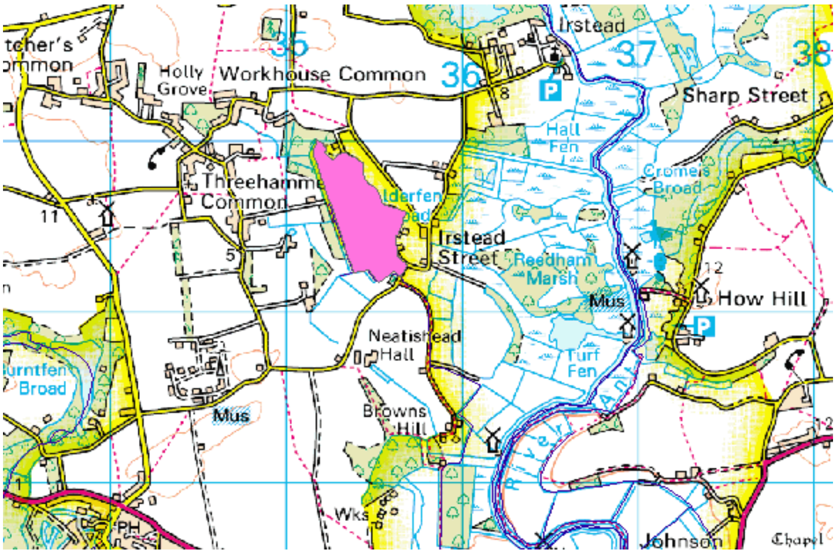


Figure A1. 3: Detailed map of Alderfen Broad

FUNCTIONAL SPECIFIC STAGE 3 OUTCOMES

A1 WATER QUALITY

Alderfen Broad SSSI

Eight consented discharges were brought forward from Stage 2 of the RoC process. The discharges to water were assessed, together with subsequent Appendix 11 and 12 discharges, and it has been concluded that they will not cause an adverse impact on the interest features of Alderfen Broad SSSI alone or in combination because P concentrations in the inlet stream are sufficiently low as to meet the SPA target.

The discharges to land have also been assessed and due to their size, nature and location it has been concluded that they also will not cause an adverse impact on the interest features of Alderfen Broad SSSI alone or in combination.

Natural England were consulted at Stage 3 and are in agreement with these conclusions.

Broad Fen SSSI

Much of the site is hydraulically connected to the Dilham Canal (River Ant) in the east. Ponds and drains away from the influence of the Canal are believed to be fed by shallow groundwater from the drift / crag aquifer. Ditches linking to the Tyler's Cut are silted up and there is little or no hydraulic connection between this watercourse and the site. Winter flooding and bank seepage also provide significant inputs of water to parts of the site adjacent to the watercourses. Rainfall and runoff also contribute water to the site.

Four of the SAC features have a requirement for good water quality and had specific targets set at Stage 3 by English Nature – these are natural eutrophic lakes, hard oligo-mesotrophic waters, otter and Desmoulin's whorl snail.

The eutrophic lake features are ponds in the west of the site and dykes in the centre of the site. Ponds in the north and south of the site comprise the oligo-mesotrophic feature.

The discharges were considered unlikely to influence pH, salinity, thermal or physical conditions, and the Appropriate Assessment concluded that the discharges would have no adverse effect alone or in combination on the interest features with regards toxic contamination or turbidity / siltation. Furthermore, 80 consents were found to have no adverse effect on site integrity alone or in combination, and these consents are to be affirmed (see Appendix 19).

It was not possible to conclude no adverse effect on the interest features of Broad Fen for 10 consents, due to their contribution to elevated phosphorus concentrations.

SIMCAT and ISIS modelling at Stage 3 indicated that nutrient targets for SAC lakes (0.05mg/l total P) and oligo-mesotrophic waters (0.03mg/l) would not be met at fully consented conditions.

The 10 largest discharges comprise 91.5% of point source phosphorus and these were brought forward for further assessment at Stage 4.

Ant Broads and Marshes SSSI

Across the majority of the site the water supply to the features is dominated by the surface water component supplied by the river. Hence, any water level fluctuations and changes in water quality experienced by the majority of features in the Ant Broads and Marshes are likely to originate from changes in river level and quality. Only water levels in the eastern half of Catfield Fen and the area surrounding Crome's Broad will not be, as these are controlled by the Smallburgh Internal Drainage Board.

Four of the SAC features have a requirement for good water quality and had specific targets set at Stage 3 by English Nature – these are natural eutrophic lakes, hard oligo-mesotrophic waters, otter and Desmoulin's whorl snail.

The eutrophic lakes features are Barton Broad and dykes throughout the site. Two turf ponds in Catfield Fen comprise the oligo-mesotrophic feature, these ponds are isolated from the river under normal conditions though may be affected by winter river flooding. The areas of open water, fen and drains are the habitats of value to the SPA interest features, with Crome's Broad and Reedham Water identified as of particular importance.

There were no discharges that were expected to alter the thermal regime or pH, or lead to physical damage or siltation, or discharge sodium chloride. Toxic contamination and nutrient enrichment were considered in the assessment, as there were 6 discharges liable to contain toxic substances and discharges are a major input of phosphate.

As a result of the assessment it was concluded that the consents are unlikely to have any toxic impact on the interest features of the Ant Broads and Marshes.

Modelled results (SIMCAT) predicted that at fully licensed conditions phosphorus concentrations will just exceed 0.1mg/l in the River Ant at the upstream edge of the site. The targets of 0.05mg/l for SAC lakes or 0.03mg/l for oligo-mesotrophic waters will be exceeded within the site.

Of the point source inputs 91% of phosphorus comes from the 11 largest discharges, therefore these were brought forward for further assessment at Stage 4. In addition there are 3 discharges to land. These were assessed previously under Regulation 48 at current volumes, but at Stage 3 it could not be concluded that they will not affect the interest features of the site in combination with other nutrient inputs due to high possible maximum volumes. They will be considered in combination at Stage 4, however any conclusions will be taken forward via Regulation 48, when information from RoC will be considered alongside other information gathered as part of the permitting process.

Details of consents considered at Stage 4 for both SSSIs are shown in Table A1.1 and figure A1.1 below.

Table A1.1 Consents considered at Stage 4

Consent code	Broad Fen	Ant Broads and Marshes	Consent name and comments
PR4NF1560	✔	✔	Private discharge
PR4NF568	✔	✔	Private discharge
PRENF327	✔	✔	Private discharge
PR4NF270	✔	✔	Private discharge
AEENF1312	✔	✔	Stalham STW
AW4NF807		✔	Horning STW
AW4NF1091X	✔	✔	Sloley
AEENF12002	✔	✔	East Ruston STW
AW4NF637X	✔	✔	Smallburgh
AWENF103	✔	✔	Ridlington
Permissions considered under Regulation 48 but considered at Stage 3 in combination with those in the review			
AEELF12300		✔	Water company to land assessed under Regulation 48
AEELF12298		✔	Water company to land assessed under Regulation 48
AEELF12296		✔	Water company to land assessed under Regulation 48
PR4NF660X	✔	✔	Private discharge – assessed under Regulation 48, but considered in-combination here

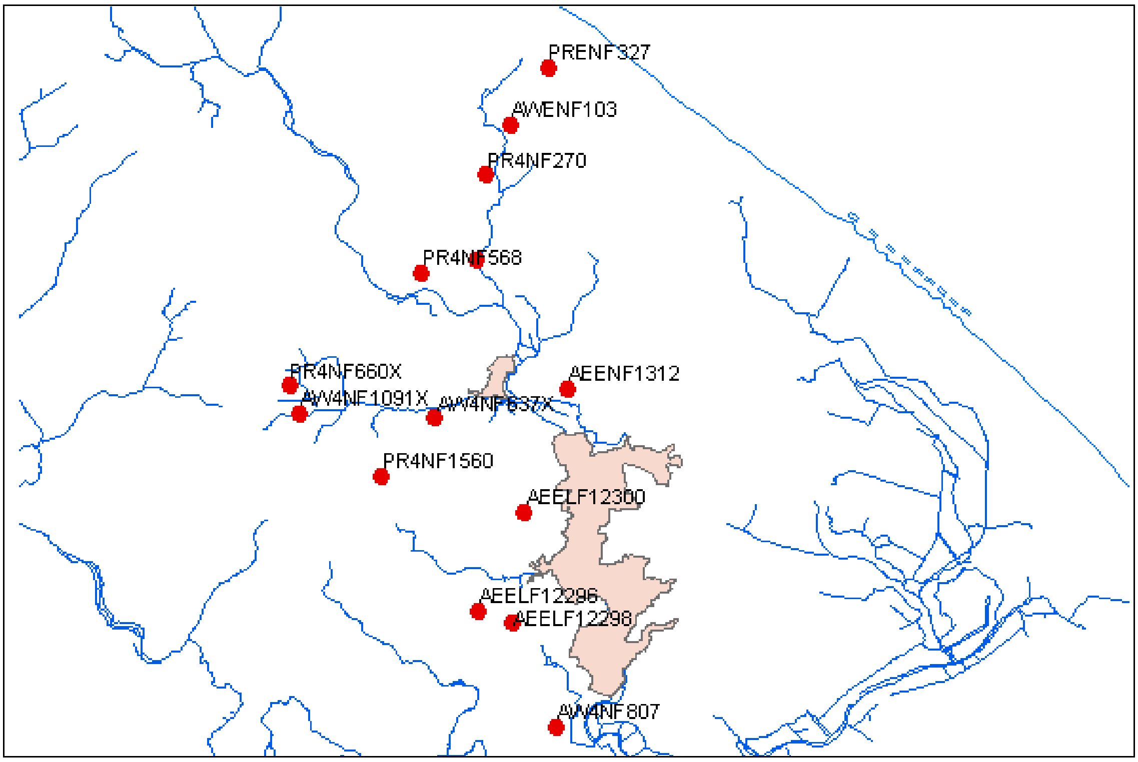


Figure A1.1: Map of site, showing location of permissions in Stage 4

Table A1.1 Outcomes of Stage 3 Appropriate Assessment and issues identified for the Ant Broads and Marshes, and Broad Fen.

Number	AEOI alone or in-combination	Known impact or perceived risk	Actual (A), Modelled (M) or Suspected (S) impact	Hazard posed	Known effects from other sources?
PR4NF1560	In-combination	Known impact on water quality standards	A and M	Nutrients (phosphorus)	Yes
PR4NF568	In-combination	As above	A and M	As above	Yes
PRENF327	In-combination	As above	A and M	As above	Yes
PR4NF270	In-combination	As above	A and M	As above	Yes
AEENF1312	In-combination	As above	A and M	As above	Yes
AW4NF807	In-combination	As above	A and M	As above	Yes
AW4NF1091X	In-combination	As above	A and M	As above	Yes
AEENF12002	In-combination	As above	A and M	As above	Yes
AW4NF637X	In-combination	As above	A and M	As above	Yes
AWENF103	In-combination	As above	A and M	As above	Yes
AEELF12300	Regulation 48 permission				
AEELF12298	Regulation 48 permission				
AEELF12296	Regulation 48 permission				
PR4NF660X	Regulation 48 permission				

All are not relevant to any other sites.

Table A1.2 Known effects from other sources

Ref to Table A1.1	Known effect	Another CA* responsible	No other CA* responsible, future regulation / management realistically achievable	No other CA* responsible, future regulation / management <u>not</u> realistically achievable
A1	Nutrient enrichment	Yes – Defra Diffuse inputs from agriculture		
A2	Nutrient enrichment		Defra and Environment Agency - some agricultural and small un-consented discharges	Some agricultural and other diffuse inputs. Regulation of small discharges

A2 WATER RESOURCES

A2.1 Outcomes of Stage 3 Appropriate Assessment and issues identified

Ant Broads and Marshes SSSI and Alderfen Broad SSSI

Much of the information in this section of the Site Action Plan is taken from the issue 2 Site Option Plan for Ant Broads and Marshes SSSI and Alderfen Broad SSSI (Entec, June 2009).

A. 2.1 Outcomes of Stage 3 Appropriate Assessment and issues identified

A.2.1.1 Hydro-ecological understanding

The Ant Broads and Marshes SSSI is located in the tidal Ant catchment. The River Ant runs through the middle of the site. Alderfen Broad SSSI is situated to the west of the Ant Broads and Marshes SSSI.

Alderfen Broad SSSI is underlain by peat, glacio-fluvial gravels, crag and chalk. The Ant Broads and Marshes SSSI is underlain by similar geology to the west of the River Ant, but to the east the crag and chalk are separated by the Eocene Clay. The Eocene Clay boundary is thought to run through the catchment following the River Ant but new evidence suggests that the boundary may meander more sharply east to west through the site rather than following the river valley. While the Ant Broads and Marshes SSSI is drained by ditches which flow towards the River Ant, Alderfen Broad is drained by a non-pumped IDB drain system which is cut-off from the broad itself by a water control structure.

The main sources of groundwater to Alderfen Broad SSSI and the Ant Broads and Marshes SSSI, to the west of Eocene Clay contact, are from lateral flow of groundwater from the drift deposits and upward flow from the crag and chalk aquifers. To the east of the Eocene Clay contact, the Ant Broads and Marshes SSSI is fed from lateral flow of groundwater from the drift deposits and upward flow from the crag aquifer. The wetlands owe their existence to seepages where the water table intercepts the ground surface creating areas of permanent seepage and river irrigation via ditches and runoff.

The Ant Broads and Marshes comprise 9 main sub-units of hydrological interest: Sharp Street, Barton Broad, Barton Fen, Catfield Fen, Crome’s Broad, Hall Fen, Reedham Marshes, Sutton Broad and Sutton Fen. Alderfen Broad is a smaller separate SSSI but is situated several hundred metres to the southwest adjacent to the Ant Broads and Marshes SSSI boundary separated by a couple of small agricultural fields.

A.2.1.2 European features and Stage 3 targets

The wetland European features for which Ant Broads and Marshes and Alderfen Broad SSSIs are included in the Broads SAC and Broadland SPA, the representative SSSI notified features, are presented in Table A.1.1, below.

The European features at Ant Broads and Marshes SSSI are considered to be critically dependent on groundwater with baseflow making a significant contribution to flows in the River Ant. Groundwater has been identified as the main supply of water to the site, except for those features whose levels and flows are directly linked to the River Ant. With groundwater being identified as the main supply of water to the site, the European features on Alderfen Broad SSSI are also considered to be critically dependent on groundwater.

At Stage 3 of the Review of Consents, the potential effect of abstraction on the European features of the component SSSIs was assessed against targets derived from available information on the hydrological regimes required to maintain or restore the favourable condition of those features on the site. At Ant Broads and Marshes SSSI and Alderfen Broad SSSI, in the absence of any dipwell data indicating the actual hydrological regime within the communities on-site, these targets were derived from Natural England's Favourable Condition Table for the site and from the Ecohydrological Guidelines for Lowland Wetland Plant Communities.

The hydrological targets, used for the RoC Stage 3 Appropriate Assessment at Ant Broads and Marshes SSSI and Alderfen Broad SSSI, are presented in Table A.2.1.

TableA.2.1 European Features, and representative SSSI features, at Ant Broads and Marshes SSSI / Alderfen Broad and Stage 3 Hydrological Targets

European Feature	**Stage 3 Hydrological Target**
Ant Broads and Marshes and Alderfen Broad – SAC Features	
Alluvial Forests Represented by: **W2** (*Salix cinerea - Betula pubescens - Phragmites australis*); **W5** (*Alnus glutinosa – Carex paniculata)* and; **W6** *(Alnus glutinosa – Urtica dioica)* woodland NVC communities.	Generic target hydrological regime for alluvial woodland W5 and W6 comprises winter water-levels at or very near the ground surface, being maintained within 5cm of the ground surface through the spring establishment period. Summer maximum and minimum levels should be between 5 and 45cm below the ground surface, accepting that optimal seedling growth occurs with water levels between 10 and 30cm below ground level. This should maintain the typical canopy and under-storey species
Transition Mires Represented by **S27** (*Carex rostrata-Potentilla palustris*) tall herb fen; **M5** (*Carex rostrata-Sphagnum squarrosum)* and; **M9** (*Carex rostrata - Calliergon cuspidatum / giganteum*) mire communities	For transition mire communities located in non-floating situations water levels should not fluctuate more than 30cm annually; additionally the water table should be continuously high with levels ranging between +1cm and +9cm above ground level for the transition mire communities.
Desmoulin's whorl snail (*Vertigo moulinsiana*)	No target as the requirements of this species will be adequately covered by the other SAC features
Otter (*Lutra lutra)*	No target as the requirements of this species will be adequately covered by the other SAC features
Ant Broads and Marshes SAC Features	
Calcareous Fen Represented by **S24** (*Phragmites australis-Peucedanum palustre*) tall herb fen and; **S25** (*Phragmites australis – Eupatorium*	For the S24, the target identified is that the summer water table should be between 3cm above and 36cm below ground level in the summer months (July-September). This is the mean water level for S24 on a number of sites across East Anglia 1SD (but curtailing

cannabinum) tall herb fen	the maximum water table to water at 4cm above ground level as measured). Winter water levels are expected to be at the surface. Note that the target for S24 covers all of the communities that contribute to the calcareous fen feature.
Natural Eutrophic Lakes with *Magnopotamion* or *Hydrocharition*-type vegetation Represented by: Grazing marsh ditch communities, fen ditch communities and communities of open waterbodies	Natural Eutrophic Lakes in ditches not connected to rivers or Broads For this feature targets have been developed related both to flushing flows and levels. With respect to flushing flows the proposed target is that the monthly flow through the ditch system should be twice the volume of system (i.e. flushing rate of 2 weeks) in summer. However, where the flushing rate drops below 6 weeks, it is considered that there is a greater potential for changes is water level , which are otherwise considered likely to be maintained at, or exceed, the level of an outfall when the flushing period is shorter than 6 weeks. Therefore after this period, assessment of the effects on ditch water levels is also undertaken. No target has been set for winter. With respect to water level, English Nature recommends a water level regime that retains high water levels, not more than 45cm below marsh level, year round. With respect to the magnitude of effect that would be considered potentially adverse, whilst it is considered that plants are not highly sensitive to fluctuations in water level, it is suggested that the potential to affect species rooted in the ditch banks means that a conservative target is required to ensure that variation does not result in adverse effect. Therefore it is suggested that mean reductions in level of up to 10% of ditch depth are acceptable in the spring and summer months (March – September) although the 45cm below marsh level is the threshold below which EN would indicate that targets are not being met irrespective of the level of abstraction. To this end a 10% reduction will be allowed unless reductions of 10% would breach the 45cm threshold. ***Natural Eutrophic Lakes in the Broads and Ditches Linked to the River*** It is not considered reasonable to define a level target in tidally influenced waterbodies such as the Ant (Barton Broad and linked ditch systems). It is therefore considered that the target should relate to river flows, noting that the flow rate will also influence level. In the absence of a robust stage discharge relationship between river flow and river level having been defined at Stage 3 the target that was set was precautionary and was that abstraction should not amount to more than 10% of the naturalised Q95 flow.
***Molinia* Meadows** Represented by:	For M24 water table should be between 10 and 41cm below ground level in the summer months (July-

M24 (*Molinia caerulea – Cirsium dissectum*) fen meadow community and; **M25** (*Molinia caerulea - Potentilla erecta*) fen meadow communities	September). Winter water levels to be nominally just sub-surface. Note that the target for M24 has been assumed to be acceptable for M25 also.
Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.	EN favourable condition tables indicate that *'water level change downwards is acceptable only in dry years. If lake level lowers due to outside water demands such as aquifer abstraction then counter measures need to be instigated'*. As a precautionary approach it is suggested that an effect will be considered adverse if it results in a change in level of more than 10% of the waterbody depth.
Fen orchid (*Liparis loeselii*)	Fen orchid is associated with the calcareous fen and *Molinia* meadows features at Sutton Broad and Catfield Fen respectively. The targets for these features are therefore applied to the fen orchid in these locations.
Ant Broads and Marshes and Alderfen Broad – SPA Features	
Habitats for the populations of Annex 1 bird species: Bittern, marsh harrier and hen harrier	No Target set – assumed to be adequately covered by SAC features
Habitats for the populations of Annex 1 bird species: Shoveler and gadwall	No Target set – assumed to be adequately covered by SAC features
Habitats for the populations of waterfowl that contribute to the wintering bird assemblage of European importance: coot, pochard, teal, great crested grebe, cormorant and tufted duck.	No Target set – assumed to be adequately covered by SAC features

A.2.1.3 Results of the Stage 3 Appropriate Assessment

The Regulation 50 Appropriate Assessment was completed in September 2006. The Review of Consents Stage 3 work concluded that there was a potential for adverse effect on the site from water resource permissions for both Ant Broads and Marshes SSSI and Alderfen Broad SSSI.

The following conclusions were reached for the **Ant Broads and Marshes SSSI**:

- For 6 groundwater abstraction licences it was concluded that 'no adverse effect **could not** be shown' on the European features of Ant Broads and Marshes SSSI in-combination
- For one groundwater abstraction licence (7/34/09/*G/0091) it was concluded that 'no adverse effect **could not** be shown' on the European features of Ant Broads and Marshes SSSI alone and in-combination
- The Stage 3 report and Appendix 21 concluded that there is no risk to Ant Broads and Marshes SSSI associated with surface water abstraction licences
- Five permissions had been considered under Regulation 48

The following conclusions were reached for the **Alderfen Broad SSSI**:

- For 1 groundwater abstraction licence (7/34/09/*G/0059,) it was concluded that 'no adverse effect **could not** be shown' on the European features of Alderfen Broad SSSI in-combination. One licence has since been deregulated.
- For 6 surfacewater and 36 groundwater licences it was concluded that 'no adverse effect on site integrity **could be** shown."

Therefore: there is potential for adverse effect on the European interest features of Ant Broads and Marshes SSSI alone and in combination and for Alderfen Broad SSSI in-combination from water resource permissions.

Table A.2.2 Outcomes of Stage 3 Appropriate Assessment for Ant Broads and Marshes SSSI

Permission Number	Permission Name	Purpose	No adverse effect on site integrity cannot be shown		Impact (I) or a Risk (R) if cannot conclude there is no impact	Impact type: Actual (A), Modelled (M), of Suspected (S)	Nature of Impact	Permission relevant to another site? If Yes list site
			Alone	In combination				
7/34/09/*G/0058	Simply Strawberries Ltd	General Farming and Domestic		☐	RISK	M		Alderfen Broad, Ant Broads and Marshes, Broad Fen, Calthorpe Broad, Priory Meadows, Shallam Dyke Marshes, Upper Thurne
7/34/09/*G/0059	J H and P E Nicholson Ltd	Spray irrigation - direct		☐	RISK	M		Alderfen Broad, Ant Broads and Marshes, Bure Broads and Marshes, Ludham to Potter Heigham, Shallam Dyke Marshes
7/34/09/*G/0073	Ames	General Farming and Domestic		☐	RISK	M		Ant Broads and Marshes, Broad Fen, Calthorpe Broad, Priory Meadows, Smallburgh Fen
7/34/09/*G/0088	A G Meale and Sons Ltd	Spray irrigation - direct		☐	RISK	M		Ant Broads and Marshes, Broad Fen, Smallburgh Fen
7/34/09/*G/0091	Anglian Water Services Ltd AWS Ludham Source	Potable Water Supply	☐	☐	RISK	M	Up to 72cm water level drawdown	Alderfen Broad, Ant Broads and Marshes, Broad Fen, Bure Broads and Marshes, Ludham to Potter Heigham, Shallam Dyke Marshes, Smallburgh Fen
7/34/09/*G/0092	Worstead Farms Ltd	Spray Irrigation - direct		☐	RISK	M		Alderfen Broad, Ant Broads and Marshes, Broad Fen, Smallburgh Fen
7/34/09/*G/0094	Barton Hall Farms	Spray Irrigation - direct		☐	RISK	M		Alderfen Broad, Ant Broads and Marshes, Broad Fen, Bure Broads and Marshes, Smallburgh Fen
7/34/09/*G/0106	Ames	General Farming and domestic		☐	RISK	M		Ant Broads and Marshes , Broad Fen, Calthorpe Broad, Priory Meadows, Upper Thurne
7/34/09/*G/0113	Brown	Spray Irrigation - Storage		☐	RISK	M		Ant Broads and Marshes, Broad Fen, Smallburgh Fen

7/34/09/*G/0139	Boardman	General Farming and domestic		☐	RISK	M		Alderfen Broad, Ant Broads and Marshes, Bure Broads and Marshes, Ludham to Potter Heigham, Shallam Dyke Marshes, Upper Thurne
7/34/10/*G/0009	Ritchie	General Farming and Domestic		☐	RISK	M		Alderfen Broad, Ant Broads and Marshes, Bure Broads and Marshes, Upper Thurne
7/34/10/*G/0111	H A Overton and Sons	Spray Irrigation - direct		☐	RISK	M		Alderfen Broad, Ant Broads and Marshes, Ludham to Potter Heigham, Priory Meadows, Shallam Dyke Marshes, Upper Thurne
7/34/09/*G/0059	J H and P E Nicholson Ltd	Spray Irrigation - direct		☐	RISK	M		Alderfen Broad, Ant Broads and Marshes, Bure Broads and Marshes, Ludham to Potter Heigham, Shallam Dyke Marshes
7/34/09/*G/0060 (deregulated)	J H and P E Nicholson Ltd	General Farming and Domestic					Up to 12.9cm water level drawdown	Alderfen Broad, Ant Broads and Marshes, Bure Broads and Marshes, Ludham to Potter Heigham, Shallam Dyke Marshes
Permissions considered under Regulation 48 but considered at Stage 3 in combination with those in the review								
7/34/09/*G/0138A (renewed as 7/34/09/*G/0138C)	J H and P E Nicholson Ltd	Spray Irrigation - direct						Ant Broads and Marshes, Alderfen Broad, Bure Broads and Marshes, Ludham to Potter Heigham, Shallam Dyke Marshes
7/34/09/*G/0141A (renewed as 7/34/09/*G/0141C)	Alston	Spray Irrigation – direct						Alderfen Broad, Ant Broads and Marshes, Upper Thurne, Bure Broads and Marshes, Ludham to Potter Heigham, Shallam Dyke Marshes
7/34/09/*G/0144 (renewed as 7/34/09/*G/0144B)	Alston	Spray Irrigation - direct						Alderfen Broad, Ant Broads and Marshes, Broad Fen, Calthorpe Broad, Ludham to Potter Heigham, Priory Meadows, Shallam Dyke Marshes, Upper Thurne
7/34/09/*G/0146 (renewed as 7/34/09/*G/0146B)	W J Bracey Ltd	Spray Irrigation - direct						Ant Broads and Marshes, Broad Fen, Calthorpe Broad, Smallburgh Fen
7/34/09/*G/0147 (renewed as	Barton Hall Farms	Spray Irrigation -						Alderfen Broad, Ant Broads and Marshes, Broad Fen,

7/34/09/*G/0147B)		direct						Bure Broads and Marshes, Smallburgh Fen, Upper Thurne

A2.3 Broad Fen, Dilham SSSI

Much of the information in this section of the Site Action Plan is taken from the issue 2 Site Option Plan (SOPi2) for Broad Fen SSSI (Entec, May 2009).

A2. 3.1 Outcomes of Stage 3 Appropriate Assessment and issues identified

A.2.3.1.1 Hydro-ecological understanding

Broad Fen is located at the confluence of a tributary of the River Ant, the Tyler's Cut with the North Walsham and Dilham Canal (the River Ant) upstream of Honing Lock gauging station. The site is underlain by the chalk aquifer and near surface deposits comprising clays, sands and gravel (possibly crag) and peat. The thickness of the peat increases towards the south of site and is thought to be linked to a former lake or broad on site.

Broad Fen is predominantly kept wet via surface water flows from the North Walsham and Dilham Canal which is directly connected to the site via the arterial drain and pipes in the riverbank. However groundwater input contributes more importantly to the maintenance of water quality of the site. This is because during summer, this area is flushed more slowly by surface water inputs and evaporation precipitates out more salts in the water. Groundwater therefore flushes out the ponds when surface water inputs are lower from the canal.

The main sources of groundwater to the site are from lateral flow of groundwater from the drift deposits and upward flow from the chalk aquifer.

The notified and European features at this site are calcareous fen (S24), alluvial woodland (W2, W5 and W6), natural eutrophic ditches, hard oligo-mesotrophic water with *Chara spp*., Desmoulin's whorl snail, otter and fen orchid. The southern part supports calcareous fen that has developed, through natural succession, over what was previously a broad whilst the drains and turf ponds on site support the natural eutrophic lakes and hard oligo-mesotrophic waters with *Chara* features.

A.2.3.1.2 European features and Stage 3 targets

The European features on the site are considered to be critically dependent on either groundwater or baseflow dependent (River Ant – 87% baseflow at Honing Lock 2.5km upstream of site). Groundwater has been identified as a significant supply of water to the site, except for those features whose levels and flows are directly linked to the River Ant.

At RoC Stage 3, the potential effect of abstraction on the features was assessed against targets derived from available information on the hydrological regimes required to maintain or restore the favourable condition of those features on the site. At Broad Fen SSSI, in the absence of any dipwell data indicating the actual hydrological regime within the communities on-site, these targets were derived from Natural England's Favourable Condition Table for the site and the Ecohydrological Guidelines for Lowland Wetland Plant Communities (Wheeler, B.D.; Shaw, S.C.; Gowing, D.J.G.; Mountford, J.O.; and Money, R.P., 2004). The hydrological targets used for the Stage 3 Appropriate Assessment at Broads Fens are presented in Table A2.3.1.

Table A.2.3.1 European Features, and Representative SSSI Features, at Broad Fen SSSI and Stage 3 Hydrological Targets

European Feature	Stage 3 Hydrological Target
Alluvial Forests Represented by: **W5** (*Alnus glutinosa – Carex paniculata)*; **W6** *(Alnus glutinosa – Urtica dioica*) and; **W2** (*Salix cinerea - Betula pubescens - Phragmites australis*) woodland NVC communities.	Alluvial woodland W5 and W6: winter water-levels at or very near the ground surface, being maintained within 5cm of the ground surface through the spring establishment period. Summer maximum and minimum levels should be between 5 and 45cm below the ground surface
Calcareous Fen Represented by: **S24** (*Phragmites australis – Peucedanum palustre)* tall herb fen	Summer water levels between 3cm above and 36cm below ground surface. Winter water levels to be at the ground surface.
Natural Eutrophic Lakes (Ditches) with *Magnopotamion* or *Hydrocharition*-type vegetation Represented by: Broads grazing marsh dyke communities **A1-A5a** and standing water communities (turf ponds)	***Natural Eutrophic Lakes not connected to rivers or Broads*** For the natural eutrophic lakes feature, English Nature's favourable condition tables indicate that hydrology involves not only water levels but flushing rates. It is not however relevant to define a flushing rate target for this feature on site as it is located in turf ponds and hence only a water level target has been defined. Therefore, whilst it is considered that plants are not highly sensitive to fluctuations in water level, it is suggested that the potential to affect species rooted in the turf ponds, which tend to be shallow water bodies, means that a conservative target is required to ensure that variation does not result in adverse effect. Therefore it is suggested that reductions in level of up to 10% of water body depth are acceptable in the spring and summer months (March-September). ***Natural Eutrophic Lakes in the Broads and Ditches Linked to the River*** It is considered that the target should relate to river flows, noting that the flow rate will also influence level. It has not been possible at this stage to define a robust stage discharge relationship between river flow and river level. The target that has been set therefore is precautionary and is that abstraction should not amount to more than 10% of the naturalised Q95 flow.
Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp	Favourable condition tables indicate that *'water level change downwards is acceptable only in dry years. If lake level lowers due to outside water demands such as aquifer abstraction then counter measures need to be instigated'*. As a precautionary approach it is suggested that an effect will be considered adverse if it results in a change in level of more than 10% of the waterbody depth.
Fen orchid (*Liparis loeselii*)	Fen orchid is associated with the calcareous fen and the target for this feature was considered applicable for fen orchid.
Desmoulin's whorl snail (*Vertigo moulinsiana*)	No target has been set for this feature as it will be adequately covered by those for other SAC features.
Otter (*Lutra lutra)*	No target has been set for this feature as it will be adequately covered by those for other SAC features.

Habitats for the populations of Annexe 1 bird species (bittern *Botaurus stellaris*, marsh harrier *Circus aeruginosus*, hen harrier *Circus cyaneus*,: Includes open water, swamp, fen, fen meadow with ditches and water bodies	No target set - assumed to be adequately covered by SAC features
Habitats for the populations of migratory bird species (gadwall *Anas strepera* and shoveler *Anas clypeata*): Includes open water, swamp, fen and fen meadow with ditches and water bodies.	No target set - assumed to be adequately covered by SAC features.
Habitats for the populations of waterfowl that contribute to the wintering waterfowl assemblage of European importance: Includes open water, swamp, fen and fen meadow with ditches and water bodies	No target set - assumed to be adequately covered by SAC features.

Broad Fen: results of Stage 3 Appropriate Assessment

The Regulation 50 Appropriate Assessment was completed in September 2006. For the 67 abstraction licences included (14 surfacewater and 53 groundwater) the following conclusions were reached:

- 4 groundwater abstraction licences within 5km could have an adverse effect on the site in-combination (7/34/09/*G/0082, 7/34/09/*G/0088, 7/34/09/*G/0092, 7/34/09/*G/0113)
- A further 25 groundwater licences and 10 surface water licences in the upstream surface water catchment of the River Ant could also have an adverse effect on the site in-combination via impact on flows in the North Walsham and Dilham Canal (canalised River Ant)
- 11 licences have now been deregulated or lapsed
- 2 licences have been considered under Regulation 48

Therefore: there is potential for adverse effect on the European interest features of Broads Fens SSSI <u>in combination</u> from water resource permissions.

The licences are presented in Table A2.3.2 below and are identified on Figure 2.1 in the Site Option Plan issue 2 (Entec, 2009).

Natural England were consulted on the Stage 3 conclusions and were in agreement with them. The licences are presented in Table A.1.2 below and are identified on Figure 2.2 in the Site Option Plan issue 2 (Entec, 2009)[1].

[1] Habitats Directive Review of Consents Stage 4. Site Options Plan: Ant Broads and Marshes SSSI / Alderfen Broad SSSI. Entec June 2009.

Table A.2.3.2 Outcomes of Stage 3 Appropriate Assessment for Broad Fen SSSI

Permission Number	Permission Name	Purpose	No adverse effect on site integrity cannot be shown		Impact (I) or a Risk (R) if cannot conclude there is no impact	Impact type: Actual (A), Modelled (M), of Suspected (S)	Nature of Impact	Permission relevant to another site? If Yes list site
			Alone	**In-combination**				
7/34/09/*G/0082	John Paterson (Dilham) Ltd	General farming and domestic		√	Risk	M	>1mm drawdown alone and in combination	Ant Broads and Marshes SSSI ??
7/34/09/*G/0088	A. G Meale and Sons Ltd	Spray irrigation - direct		√	Risk	M		Ant Broads and Marshes SSSI
7/34/09/*G/0092	Worstead Farms Ltd	Spray irrigation - direct		√	Risk	M		Ant Broads and Marshes SSSI
7/34/09/*G/0113	Brown A I	Spray irrigation - storage		√	Risk	M		Ant Broads and Marshes SSSI
Licences upstream of Broad Fen affecting flows in the River Ant								
7/34/08/*G/0017 Deregulated	Dye S W	General farming and domestic					Impacting on upstream flows in the River Ant	
7/34/08/*G/0030 Deregulated	Barrat Brothers	General farming and domestic						
7/34/08/*G/0031 Lapsed licence	H L Foods Ltd	General use relating to secondary category (medium loss) Non-evaporative cooling						
7/34/08/*G/0032 Lapsed licence	Initial Healthcare Services	General use relating to secondary category (medium loss)						
7/34/08/*G/0033	Worstead Farms Ltd	Spray irrigation - direct		√	Risk	M		
7/34/08/*G/0037	Buckingham M N	Spray irrigation - direct		√	Risk	M	Impacting on upstream flows in the River Ant	
7/34/08/*G/0038	Iceni Anglia Ltd	General farming and domestic Drinking, cooking, sanitary, washing, small garden, household		√	Risk	M		
7/34/08/*G/0039	Amies	Spray irrigation - direct Spray irrigation - storage		√	Risk	M		
7/34/08/*G/0041	Clan farms Limited	General farming and domestic Spray irrigation - direct		√	Risk	M		
7/34/08/*G/0049	HS Hicks and Sons	Spray irrigation - direct		√	Risk	M		
7/34/08/*G/0050	A W Ditch and Son	General farming and domestic Spray irrigation - storage		√	Risk	M		
7/34/08/*G/0053 Deregulated	Trustees of R G Cubitt	General farming and domestic						
7/34/08/*G/0057 Deregulated	Wayware Ltd	Spray irrigation - direct						
7/34/08/*G/0093	Anglian Water Services	Potable water supply - direct		√	Risk	M		

7/34/08/*G/0094	Rose Centre Retail Park Ltd	Spray irrigation - direct		√	Risk	M		
7/34/08/*G/0095	Hammond W J	Spray irrigation - direct		√	Risk	M		
7/34/08/*G/0096	H S Hicks and Sons	Spray irrigation - direct		√	Risk	M		
7/34/08/*G/0097	Lewis E J	Spray irrigation - direct		√	Risk	M		
7/34/08/*G/0098	Knapton Farming Co	Spray irrigation - direct		√	Risk	M		
7/34/08/*G/0099 Deregulated	Lewis Williams (Farming)	General farming and domestic						
7/34/08/*G/0103	Banham Poultry Ltd	General farming and domestic		√	Risk	M		
7/34/08/*G/0106	C B Arnold Ltd	Spray irrigation - direct		√	Risk	M		
7/34/08/*G/0111 Revoked licence	Moore D M	Drinking, cooking, sanitary, washing, small garden, household						
7/34/08/*G/0112 Now AN/034/0008/001 Permission considered under Regulation 48 but considered at Stage 3 in combination with those in RoC.	Banham Poultry Ltd	General farming and domestic					Impacting on upstream flows in the River Ant	
7/34/08/*G/0114 Deregulated	C B Arnold Ltd	General farming and domestic						
7/34/08/*G/0115 Deregulated	Pegge SJ	Spray irrigation - direct						
7/34/08/*G/0116 Now 7/34/08/*G/0116A Permission considered under Regulation 48 but considered at Stage 3 in combination with those in RoC.	Moore D M	Spray irrigation - direct						
7/34/08/*S/0036	Buckingham M N	Spray irrigation - anti-frost Spray irrigation - direct		√	Risk	M		
7/34/08/*S/0040	H E Alston Bradfield Ltd	Spray irrigation - direct		√	Risk	M		
7/34/08/*S/0042	F J Clabon and Partners	Spray irrigation - direct		√	Risk	M		
7/34/08/*S/0044	F J Clabon and Partners	Spray irrigation - direct		√	Risk	M		

7/34/08/*S/0045	A Clarke (Trunch)	Spray irrigation - direct		√	Risk	M		
7/34/08/*S/0048	F J Clabon and Partners	Spray irrigation - direct		√	Risk	M		
7/34/08/*S/0050	AW Ditch and Son	Spray irrigation - direct		√	Risk	M		
7/34/08/*S/0051	Howes Bros	Spray irrigation - direct		√	Risk	M		
7/34/08/*S/0055	John Paterson (Dilham) Ltd	Spray irrigation - direct		√	Risk	M		
7/34/08/*S/0108 Deregulated	Colpro (UK) Ltd	Spray irrigation - direct						

A.2.1.4 Known effects from other sources

Previously licensed abstractions which are now deregulated, and abstractions which are exempt from regulations where these are known, were included in the Regional Groundwater Model at Stage 3.

A.2.1.5 Other Environment Agency regulated inputs for consideration as part of the prevailing environmental conditions

New licences assessed under Regulation 48 were included in the modelling as part of the prevailing environmental conditions at Stage 3. However as they have been considered within Regulation 48 no conclusions will be reached under the review. Information from the review will be considered along side other information gathered as part of the licensing process when permissions come up for renewal. Currently exempt activities, e.g. trickle irrigation and dewatering, in the search area of the site, will be assessed as new consents under Regulation 48.

SECTION B: OUTCOMES REQUIRED

Overall Environmental Outcome Statement

Natural England has put forward an Environmental Outcome for the Broads SAC and Broadland SPA, which includes Broad Fen, Alderfen and the Ant Broads and Marshes SSSIs, as follows:

Water quality

Nutrients

The appropriate total phosphorus threshold for Broads natural eutrophic lakes, ditches and dykes is 50ug/l P as these lakes fall into the high alkalinity, very shallow (<3m mean depth) type. The ditches support the same features as the lakes and there is no evidence to suggest the ditch features are any less sensitive to eutrophication (Clarke S and Doarks C 2006, Local variation of ditch phosphorus targets: an interim approach).

There is a reasonably large body of data (water quality and biological) available for many of the Broads sites. These data have been investigated as a means of setting a 'Broads specific' threshold using the method being employed for Water Framework Directive (WFD). This local approach was considered worth investigating due to the availability of the data and an acknowledgement that the Broads have particular characteristics which may influence the relationship between phosphorus load and biological response. This analysis using WFD methods supports a threshold value of 50ug/l. However, it does indicate that there may be some biological change at 40ug/l, further analysis and monitoring is required to determine the significance of this lower value and whether it reflects external (i.e. nutrient load) or internal (grazing) processes.

The total phosphorus threshold for hard oligo-mesotrophic waters with benthic vegetation of *Chara* formations remains unchanged at 30ug/l P.

Water Resources
Details regarding the component SSSIs and associated features that are affected by water resources licences are listed in the Appendix 21 Appropriate Assessment for the Broads SAC and Broadlands SPA. Site descriptions and details of feature locations can be found in the site characterisation reports for the component SSSIs of the Broads SAC and Broadlands SPA.
Environmental Outcomes for each feature are in the feature specific Environmental Outcomes below:

Air Quality
No exceedance of the relevant critical loads and levels.

Feature / species specific Environmental Outcomes – water resources

Alkaline Fen
Functionality criteria underpinning Environmental Outcomes:
a) High groundwater table to support shallow rooting (*Carex* species) and mosses (with no or very limited functional water transport tissue) throughout the year.
b) Continuous groundwater discharge in winter and summer (non-drought years); the supply of calcium rich often supersaturated groundwater needs to FLUSH the soil, so that the right chemical (i.e. redox and Ca) balance in the soils is maintained.
c) The competition processes that determine the required (M13) vegetation are dominated (Source: Bryan Wheeler, Sheffield University) by exclusion processes (exclude species) rather than inclusion (i.e. enough water to grow optimally). This exclusion process is mainly due to the anoxic – low REDOX soil conditions with high concentrations of toxins such as sulphide. This in its turn is dependent upon a continuous high water table throughout the year.

For M13 groundwater level targets have been used:
1) The average 'normal year' shallow groundwater table should throughout a normal year not drop more than 10cm below ground level.
2) The variability of the groundwater level in a 'normal year' should not drop under 1 SD from 10cm below ground level, e.g. -22.4cm.
3) The duration, frequency and intensity of drought periods should not be significantly increased by abstraction or surface water management.

Alluvial Forests
The generic water level target for alluvial woodland W5 and W6 is:
1) Winter water levels at or very near the ground surface.
2) Spring water levels should be maintained within 5cm of the ground surface.
3) Summer maximum and minimum levels should be between 5 and 45cm below the ground surface, accepting that optimal seedling growth occurs with water levels between 10 and 30cm below ground level. This should maintain the typical canopy and under-storey species.

No data are available on the requirements of W2 woodland, which also contributes to the European feature. It is therefore proposed that the target regime described above applies to this community.

Calcareous Fen With *Cladium* spp.

For the S24, the target identified is:

1) Summer water table should be between 3cm above and 36cm below ground level in the summer months (July-September). This is the mean water level for S24 on a number of sites across East Anglia ±1SD (but curtailing the maximum water table to water at 4cm above ground level as measured).
2) Winter water levels are expected to be at the surface.

Note that the target for S24 covers both of the communities that contribute to the calcareous fen feature.

Natural Eutrophic Lakes in Drainage Systems

For this feature targets have been developed related both to flushing flows and levels.

1) For flushing flows the target is that the monthly flow through the ditch system should be twice the volume of system (i.e. flushing rate of 2 weeks) in summer. However, where the flushing rate drops below 6 weeks, it is considered that there is greater potential for changes in water level, which are otherwise considered likely to be maintained at, or exceed, the level of an outfall when the flushing period is shorter than 6 weeks. Therefore after this period assessment of the effects on ditch water levels are also assessed. No target has been set for winter.
2) A water level regime that retains high water levels, not more than 45cm below marsh level, year round is recommended. With respect to the magnitude of effect that would be considered potentially adverse, whilst it is considered that plants are not highly sensitive to fluctuations in water level, it is suggested that the potential to affect species rooted in the ditch banks means that a conservative target is required to ensure that variation does not result in adverse effect.

Therefore it is suggested that mean reductions in level of up to 10% of ditch depth are acceptable in the spring and summer months (March-September) unless reductions of 10% would breach the 45cm threshold.

Natural Eutrophic Lakes

Level targets are not considered reasonable in large tidally influenced waterbodies and there are insufficient data for this site to identify a target with respect to the overall water-budget. However, it is possible to determine the effect of abstraction on the amount of groundwater flowing into the site. Therefore, it is proposed that the target should be that groundwater inflow to the site should not be reduced by more than 10%.

Hard Oligo-Mesotrophic Waters With Benthic Vegetation of *Chara spp*. in Drainage Systems

On Broadland sites the *Chara spp*. communities often occur in the same ditches as the natural eutrophic lakes feature. As a result, the water flow target for natural eutrophic lakes will also apply to the *Chara* spp. feature.

As a precautionary approach it is suggested that an effect will be considered adverse if it results in a change in level of more than 10% of the ditch depth, or water levels are lower than 45cm.

Transition Mires and Quaking Bogs

The transition mire community M5 occurs on the fen surface (not floating) and is thus potentially sensitive to water level fluctuations. Water levels should not fluctuate more than 30cm annually.

***Molinia* Meadows**

The target for the M24, which is derived from the '*Ecohydrological Guidelines*' is that the summer water table should be between 10 and 41cm below ground level in the summer months (July-September). This is the mean water level for M24 on a number of sites across East Anglia ±1SD (but curtailing the maximum water table to water at 10cm below ground level as measured)[2].

Desmoulin's Whorl Snail

The target requires the water table to remain within 0.2m of the ground surface for 9 months of the year, with a critical minimum level of -0.5m below ground level in the summer. Flooding to 0.6m depth is acceptable for limited periods in some locations.

Fen Orchid

This was also considered sensitive but where present was generally associated with either *Molinia* meadows or calcareous fen habitat and therefore these habitat features targets are to be used.

[2] For normally distributed data this range will pick up 70% of the occurrences of situations for M24.

B1 WATER QUALITY

B1.1 Features impacted and risk of impact:

The designated features may be adversely affected directly (e.g. oligo-mesotrophic lakes) or indirectly (food for bird species) by elevated concentrations of phosphorus.

B1.2 Outcomes required and calculation of RoC target:

B1.2.1 Environmental Outcomes

The Environmental Outcome is what must be achieved in order to conclude that there is no Adverse Effect On Integrity (AEOI) of the site (WQTAG152, section 5.2).

The table below summarises the water quality Environmental Outcomes.

Table B1.1 List of water quality Environmental Outcomes

Feature	Water quality target
Natural eutrophic water (SAC lakes)	Total phosphate concentrations 0.05mg/l or below
Natural eutrophic water (ditches and dykes)	Total phosphate concentrations 0.05mg/l (new Natural England target) or 0.1mg/l or below (original target at Stage 3)
Hard oligo-mesotrophic waters	Total phosphate concentrations 0.03mg/1 or below
SPA lakes	Total phosphate concentrations 0.1mg/l or below

To achieve these targets appropriate action on all sources of phosphorus is required. To lead to no adverse effect on site integrity from the discharge consents, the proportion of P from point sources leading to the exceedance of the Environmental Outcome must be removed – this results in a RoC target being set. When this RoC target is met then no adverse effect from Environment Agency discharge consents can be concluded.

Guidance in WQTAG152 is that 2000 should be used as a base year, so that so that improvements delivered by AMP3 and AMP4 schemes can be acknowledged as contributing towards the delivery of the RoC target. Earlier years can be used if other recent schemes need to be taken into account (e.g. as was used for the Ouse Washes SAP). For the Ant Broads and Marshes and Broad Fen sites there have been no AMP3 schemes on the discharges in Stage 3 (after Stage 2 screening) and no AMP4 planned. However two of the largest discharges had schemes in before this – 1mg/l effective from 21 November 1997 at AEENF1312 (Stalham) and from 23 January 1998 at PR4NF660X (as part of its consideration under Regulation 48), though P stripping has been present at Stalham since 1977. Therefore data from before 1998 will be used as a baseline as this takes into account the later improvements made at these sites and is consistent with the approach used at other sites.

Therefore for AEENF1312 and PRENF660X data used will be 1995 to 1997 and the proportion of P inputs from point and diffuse sources calculated then, so that so that these improvements can be acknowledged as contributing towards the delivery of the RoC target.

B1.2.2 Identifying the relevant Environmental Outcome to use

Information from Natural England is that action is being taken on many Broads areas to improve the functionality of the site. For Broad Fen dams will be removed and the connection of the fen ditch network will be improved or re-connected. This will mean that the floodplain fen, ditches and waterbodies are in greater hydrological connectivity with the River Ant (Dilham Canal). The natural eutrophic features present in ponds and lakes in the west of the site are linked to the river. An Environmental Outcome of 0.05mg/l is therefore required at Broad Fen to protect these features.

The work described above will not affect the oligo-mesotrophic ponds. The *Chara* in the turf ponds is stable and increasing the connectivity would be undesirable. These ponds are usually isolated, and are not affected by river P concentrations, therefore the 0.03mg/l Environmental Outcome does not need to be considered further (Clive Doarks, meeting 29 November 2007).

Recent information from the SOP version 1 (EA 2007) states that the canalised River Ant (Dilham Canal) is connected to all other ditches on site and is the main artery. The ditches in the site are not connected directly to the Tyler's Cut as they are silted up. Therefore the target for the site relates to the River Ant / Dilham Canal only and a target for Tyler's Cut is not required as consents to this watercourse will not impact the site.

However, Natural England have expressed concerns that water from the Tyler's Cut could enter the Dilham Canal and by backing up, access the site. Therefore this will also be considered and the same target used in the Dilham Canal at the confluence of Tyler's Cut, to assess this.

For the Ant Broads and Marshes site, dams will be removed and the connection of the fen ditch network will be improved or re-connected. This will mean more that the floodplain fen, ditches and waterbodies are in greater hydrological connectivity with the River Ant. As detailed above, again this work will not affect the turf ponds in this site also, therefore the 0.03mg/l target does not need to be considered further.

A target of 0.1mg/l in the river will protect the SPA broads which are directly or indirectly linked to the river i.e. Crome's Broad and Reedham Water. However Barton Broad is a SAC lake and linked to the river and the target here is 0.05mg/l therefore the target in the river overall needs to be 0.05mg/l.

Therefore the Environmental Outcome to use is 0.05mg/l TP in the River Ant / Dilham Canal at both sites.

B1.2.3 Methodology and modelling

The SIMCAT model used at Stage 3 has been extended to encompass all of Broad Fen and the Ant Broads and Marshes sites area. It has been run to calibrate using original data and then at fully consented conditions to obtain the baseline concentrations predicted in the river at the site. A range of scenarios have been run to identify options.

B1.2.4 Converting the total P Environmental Outcome to Ortho P

The Environmental Outcome target is for total P but the SIMCAT model uses Ortho P (OP) because this is the standard determined for P monitored in rivers and there is more data for this enabling the model to be correctly set up and calibrated. Therefore the total P Environmental Outcome target needs to be expressed as an OP target so that it can be used in the modelling scenarios.

Monitoring points nearby can be used to calculate the ratio. Figure B1.1 shows the monitoring points in or near to the sites.

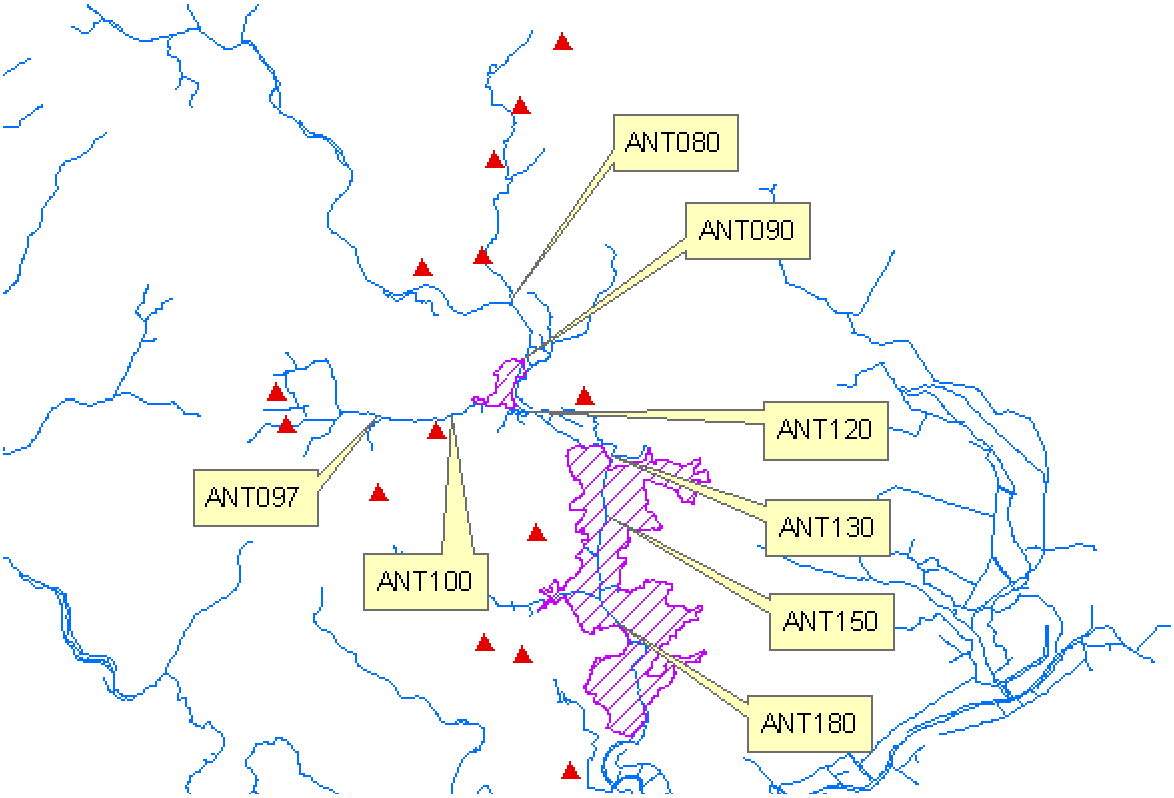


Figure B1.1 – sampling points

Broad Fen
ANT080 is just upstream of the site on the Dilham Canal, ANT097 and ANT100 are upstream on Tyler's Cut, and ANT090 is within the site. There is not enough OP and TP data at ANT090 and ANT100 for a comparison of both to be made. ANT080 and ANT097 have more data and will be used. Total P and Ortho P results (mg/l) for these river sites is shown in the tables below:

Table B1.2a Monitored results at ANT080

Site	2001	2002	2003	2004	2005	2006
ANT080 OP	0.035	0.032	0.025	0.038	0.036	0.026

ANT080 TP	0.068	0.044	0.069	0.050	0.044	0.056
OP:TP ratio	0.515	0.727	0.362	0.760	0.818	0.464

Table B1.2b Monitored results at ANT097

Site	**2006**	**2007**
ANT097 OP	0.116	0.122
ANT097 TP	0.170	0.214
OP:TP ratio	0.682	0.570

The ratio range is from 0.362 to 0.818, with a midpoint of 0.590. This can be used to convert the total P Environmental Outcome to an OP one for use in modelling scenarios.

Environmental Outcome target = 0.05mg/l TP
Using the ratios above this equates to 0.030mg/l OP

Ant Broads and Marshes
ANT120 is upstream of the site and ANT130 at the edge of the site, ANT150 and ANT180 are within the site. ANT150 is an old sampling point with no data since 1999, and ANT180 only has OP data available. Both OP and TP data are available from ANT120 and ANT130, therefore results from these sites can be examined to look at the relationship between OP and TP.

Total P and Ortho P results (mg/l) for these river points are shown in Tables B1.3 and B1.4 below.

Table B1.3 Monitored results for ANT120

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**20007**
ANT120 OP	0.042	0.036	0.035	0.029	0.031	0.036	0.036
ANT120 TP	0.081	0.073	0.056	0.047	0.040	0.051	0.053
OP:TP ratio	0.519	0.493	0.625	0.617	0.775	0.701	0.679

The ratio range is from 0.493 to 0.775, with a midpoint of 0.634.

Table B1.4 Monitored results for ANT130

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**20007**
ANT130 OP	0.034	0.039	0.054	0.036	0.031	0.031	0.035
ANT130 TP	0.080	0.081	0.078	0.051	0.043	0.089	0.061
OP:TP ratio	0.425	0.481	0.692	0.706	0.721	0.348	0.573

The ratio range is from 0.348 to 0.721, with a midpoint of 0.535.

These ratios are similar and the midpoint, using both, is 0.585. This can be used to convert the total P Environmental Outcome to an OP one for use in modelling scenarios.

Environmental Outcome target = 0.05mg/l TP
Using the ratio above this equates to 0.03mg/l OP.

Therefore the Environmental Outcome expressed as OP is 0.03mg/l at Broad fen, and 0.03mg/l at Ant Broads and Marshes.

B1.2.5 Inputs from point and diffuse sources

In order to calculate the RoC target the relevant proportions from point and diffuse sources are needed.

For both sites the SIMCAT model is used to provide an estimate of the relative proportions from point and diffuse sources. It is run with all modelled discharges switched off. Then a correction factor is used to account for the small discharges not in the model.

For Broad Fen, this gives a value of 58% for point sources at points ANT080 and ANT090. This is (as expected) very similar to that calculated at Stage 3 when export co-efficient calculations were used.

ANT120 is in the Dilham Canal at its confluence with Tyler's Cut, and this point will also be considered so that any effects of water from Tyler's Cut backing up and so accessing the site can be assessed. At ANT120 there is 71% from point sources.

For the Ant Broads and Marshes using figure B1.1, the most relevant points are ANT150 and ANT180 as these are within the site. SIMCAT modelling indicates 77% from point sources at ANT150 and ANT180.

Percentages of point and diffuse are used with the OP Environmental Outcome to calculate a RoC target in the river.

B1.2.6 Calculating the RoC target

As discussed above, from the overall Environmental Outcome, the proportion accountable for consented point sources (the RoC target) needs to be calculated. Guidance states that predictions for the baseline years are used in these calculations, as described above in B1.2.1.

Broad Fen
At ANT080 the fully modelled concentration is 0.027mg/l OP. This is below the Environmental Outcome, therefore the river at this point complies with the Environmental Outcome at fully consented conditions.

At ANT090 the fully consented modelled baseline concentration is 0.032mg/l OP. This is above the OP Environmental Outcome, and a RoC target can be calculated as shown below.

(mg/l OP)	ANT090
Modelled concentrations	0.032

Environmental target	0.030
P to be removed	0.032 – 0.030 = 0.002
58% of the P removal should be achieved by point sources	58% x 0.002 = 0.001
Therefore the RoC target should be	**0.032 – 0.001 = 0.031**

Therefore the RoC target is 0.031mg/l.

This shows that a reduction of 0.001 is required. This decrease is negligible and well within the confidence limits of the SIMCAT model at the fully consented concentration, and is therefore not a significant difference.

At ANT120 the fully modelled baseline concentration is 0.0891mg/l. This is above the OP Environmental Outcome, and a RoC target can be calculated as shown below.

(mg/l OP)	**ANT120**
Fully consented SIMCAT modelled prediction (pre-2000)	0.0891
Environmental target	0.030
P to be removed	0.0891 – 0.030 = 0.0591
71% of the P removal should be achieved by point sources	71% x 0.0591 = 0.042
Therefore the RoC target should be	**0.0891 – 0.042 = 0.047**

Therefore the RoC target is 0.047mg/l.

The modelled fully consented baseline concentration is 0.0891mg/l at ANT120 as shown above. The fully consented concentration currently is 0.038mg/l at ANT120, this takes into account improvements at private and water company discharges. This is below the RoC target, therefore the river at this point already complies with its RoC target at fully consented conditions.

Therefore the derived RoC target is met at Broad Fen and no further action is required on the discharge consents for this site.

Ant Broads and Marshes
Calculation of RoC targets can be carried out for the two monitoring points within the site: ANT150 and ANT180. SIMCAT modelling results at fully consented conditions are used in the calculations below.

(mg/l OP)	**ANT150**	**ANT180**
Fully consented SIMCAT modelled prediction	0.124	0.059
Environmental Outcome (OP)	0.030	0.030
P to be removed	0.124 – 0.030 = 0.094	0.059 – 0.030 = 0.029
77% of the P removal should be achieved by point sources	0.094 x 77% = 0.072	0.029 x 77% = 0.022
Therefore the RoC target is	0.124 – 0.072 = **0.052**	0.059 – 0.022 =

		0.037

Therefore the RoC target is 0.052 at ANT150 and 0.037 at ANT180.

The modelled pre-AMP2 fully consented concentration is 0.124mg/l at ANT150 and 0.059mg/l at ANT180 as shown above. The fully consented concentration currently is 0.084 at ANT150 and 0.040 at ANT180. These concentrations are above the RoC targets and therefore scenario options will need to be considered and modelled in SIMCAT.

B2 WATER RESOURCES

B.2.1 New information since Stage 3 at Ant Broads and Marshes and Alderfen Broad

Since the Stage 3 Appropriate Assessment was completed additional information has been used to enhance the conceptual understanding, reduce uncertainties within numerical modelling of the site and in the identification of appropriate thresholds and criteria against which to assess acceptable levels of abstraction. This is detailed in Section 2.4 of the Site Options Plan issue 2 (Entec, 2009) and summarised below in Table B.2.1.

Table B2.1 New information since Stage 3

Aspect	New information
Hydrological Modelling	
Use of the Regional Groundwater Model	The Phase 2 Regional Groundwater Model, designed to take account of all regionally active groundwater bodies within the Waveney study area, provides better representation of chalk groundwater levels and the interaction with overlying drift on a regional scale than the methods used for the Stage 3 Appropriate Assessment. Further detail regarding the construction of the model, its calibration and its representation of the hydrological functioning of Broad Fen can be found in Chapter 4 of the Site Options Plan Issue 1 (Scott Wilson and Entec, 2008).
Licence characterisation	Details of abstraction licences have been collated and verified. A particular requirement was to ensure awareness of any time-limited licence expiry dates and any licence conditions to ensure that all licences were properly represented in the Regional Groundwater Model and to eliminate any "double counting".
Groundwater	
Boreholes, piezometers and dipwells	Four boreholes, 9 dipwell transects (of five dipwells each) and 12 gaugeboards are used to monitor groundwater and surface water levels within Ant Broads and Marshes SSSI. All locations are monitored on a monthly basis with manual dips and electronic loggers have been installed at key installations. Nine pairs of shallow dipwells and ten gaugeboards were installed at Ant Broads and marshes in 2006. These dipwells were installed close to or in the locations of the European features to establish the elevation of groundwater levels in direct contact with the features. Gaugeboards and EC divers were located in adjacent ditches to measure ditch levels in comparison to groundwater elevations in nearby European features. One gaugeboard was also installed in the main River Ant channel to measure river levels and tidal influences upstream of Barton Broad. Two gaugeboards were originally installed at Catfield Fen during AMP3 investigations but had divers installed on them after July 2006 to assist RoC investigations (manual dips only previously). Spot flow measurements were attempted in the main River Ant channel to create an accretion profile, but due to health and safety issues connected to boat traffic, and land access issues, these were

	abandoned.
	Hydrochemical samples were taken across the Ant Broads and Marshes SSSI from tributaries entering Barton Broad, ditches and smaller broads units during June 2006. Concentrations for a sample inventory were compared by location to check for indicative crag or peat groundwater signatures feeding wet features across the site.
No monitoring has been installed at Alderfen Broad SSSI	

B.2.2 Environmental Outcomes required for the site

At Stage 3 of RoC, generic targets for European features were used. The generic targets have however been replaced by site-specific hydrological criteria to decide on acceptable levels of abstraction. The hydrological criteria are linked to the Stage 4 Environmental Outcomes provided by Natural England. The Environmental Outcomes for the Broads SAC and Broadland SPA as supplied by Natural England on 17 January 2008. For each SSSI in the Broads, the Environmental Outcomes defined by Natural England cover the requirements of all of the European features. There are no targets for otter, but it is considered that provided the hydrological requirements of the botanical features associated with the broads and dykes are met, that the habitats will be suitable for otter. The same is applicable to the contribution of the sites to the Broadland SPA.

Advice on functionality of Ant Broads and Marshes and Alderfen Broad component sites within the Broads SAC and Broadland SPA.
Where man's interventions on sites have been more recent or where a more-natural functioning has been maintained the Environmental Outcome should be to increase natural functioning. Particularly where this is beneficial to the interests of Natura 2000 or makes the site more ecologically sustainable. Past actions on sites, such as isolation, damming, embankment and pumping have been undertaken to overcome the symptoms of eutrophication and adverse hydrological regimes. However it is now acknowledged that while these measures have been mostly effective at moderating the initial threats to the site, it has resulted in significant secondary impacts such as reduced natural functioning and resilience. For sites to again function with integrity both the initial impact and impact of the secondary measures need to be addressed. The following table identifies sites where such actions are required, the type of actions required and the resulting functional consequence.

SSSI name	Type of action required	Change in functionality
Alderfen Broad	Remove dam and bypass ditch	Water from catchment would flush Alderfen Broad and reduce residence times.
Ant Broads and Marshes	Remove dams and reconnect / improve connection of fen ditch network to the River Ant	Floodplain fen, ditches and water bodies in greater hydrological connectivity with the River Ant

Natural England suggest that where man's interventions on sites have been more recent or where a more natural functioning has been maintained the Environmental Outcome should be to increase natural functioning. For instance at Broad Fen, where action would not result in an adverse affect to designated interests, effort should be made to reconnect / improve hydrological connectivity of fen and fen ditch network to the River Ant.

Feature specific Environmental Outcomes

Alluvial Forests

The generic water level target for alluvial woodland W5 and W6 is:

1) Winter water-levels at or very near the ground surface
2) Spring water levels should be maintained within 5cm of the ground surface
3) Summer maximum and minimum levels should be between 5 and 45cm below the ground surface, accepting that optimal seedling growth occurs with water levels between 10 and 30cm below ground level. This should maintain the typical canopy and under-storey species.

No data are available on the requirements of W2 woodland, which also contributes to the European feature. It is therefore proposed that the target regime described above applies to this community.

Calcareous Fen With *Cladium* spp.

For the S24, the target identified is:

1) Summer water table should be between 3cm above and 36cm below ground level in the summer months (July-September). This is the mean water level for S24 on a number of sites across East Anglia $\pm$1SD (but curtailing the maximum water table to water at 4cm above ground level as measured).
2) Winter water levels are expected to be at the surface.

Note that the target for S24 covers both of the communities that contribute to the calcareous fen feature.

Natural Eutrophic Lakes and Hard Oligo-Mesotrophic Waters With Benthic Vegetation of *Chara* spp. in Drainage Systems

The target for these two lake types requires that inflow to the site should not be reduced by more than 10% of naturalised Q95 river flow. As a precautionary approach it is suggested that for ditches an effect will be considered adverse if it results in a change in level of more than 10% of the ditch depth, or water levels are lower than 45cm.

Transition Mires and Quaking Bogs

The transition mire community M5 occurs on the fen surface (not floating) and is thus potentially sensitive to water level fluctuations. Water levels should not fluctuate more than 30cm annually.

***Molinia* Meadows**

The target for the M24, which is derived from the '*Ecohydrological Guidelines*' is that the summer water table should be between 10 and 41cm below ground level in the summer months (July-September). This is the mean water level for M24 on a number of sites across East Anglia ±1SD (but curtailing the maximum water table to water at 10cm below ground level as measured)[3].

Desmoulin's Whorl Snail
The target requires the water table to remain within 0.2m of the ground surface for 9 months of the year, with a critical minimum level of -0.5m below ground level in the summer. Flooding to 0.6m depth is acceptable for limited periods in some locations.

Fen Orchid
This was also considered sensitive but where present was generally associated with either *Molinia* meadows or calcareous fen habitat and therefore these habitat features targets are to be used.

Table B.2.3 below summarises the water resources feature-specific Environmental Outcomes for Ant Broads and Alderfen Broad SSSIs and sets out the specific hydrological criteria to be used to appraise abstraction scenarios, more detail can be found in section 5.2 of the Site Options Plan issue 2 (Entec, 2009).

[3] For normally distributed data this range will pick up 70% of the occurrences of situations for M24.

Table B.2.3 Summary of Environmental Outcomes and Criteria for Assessing Acceptable Levels of Abstraction

Interest feature location	**Description of flora and fauna under European designation**	**Spatial distribution / quality / historical problems**	**Natural England specific Environmental Outcomes** (Broads SAC)	**Hydrological functioning**	**Model cell(s) used at Stage 3**	**Model criteria used to assess adverse effect at Stage 3**	**Model cell(s) used at Stage 4**	**Primary model criteria used at Stage 4**
Reedham Marshes (B) **Sharp St (C)** **Catfield Fen (G)**	Calcareous Fen (S24)	Refer to map Figure 3.16a-b No apparent problems in non-drought years (or drought years) under historical levels of abstraction.	Target identified is that the summer water table should be between 3cm above and 36cm below ground level in the summer months (July-September).	Areas of permanent seepage and shallow water table supported by upward groundwater flow from the drift / crag aquifers.	Six layer Regional Groundwater Model used. Cells equivalent to R145C304, R141C306 and R137C308	Summer water table (July-September) to fall no more than 36cm below the surface. Winter water levels to be at no higher than 3cm above the ground surface.	**Cell 'B', R145C304** **Cell 'C' R141C306** **Cell 'G' R137C308**	For non-drought summers: Soil moisture content, kept above stress threshold For drought summers: Water level in uppermost model layer above lowest historical water level
Sutton Broad (E) **Barton Fen (F)**	*Molinia* Meadows (M24)	Refer to map Figure 3.16a-b No apparent problems in non-drought years under historical levels of abstraction.	Water table should be between 10 and 41cm below ground level in the summer months (July-September). Winter water levels to be nominally just sub-surface.	Areas of permanent seepage and shallow water table supported by upward groundwater flow from the drift / crag aquifers.	Six layer Regional Groundwater Model used. Cells equivalent to R123C309 and R122C299	Water table should be between 10 and 41cm below ground level in the summer months (July-September). Winter water levels to be nominally just sub-surface.	**Cell 'E' R123C309** **Cell 'F' R122C299**	For non-drought summers: Soil moisture content, kept above stress threshold For drought summers: Water level in uppermost model layer above lowest historical water level

Table B2.3 (continued) Summary of Environmental Outcomes and Criteria for Assessing Acceptable Levels of Abstraction

Interest feature location	**Description of flora and fauna under European designation**	**Spatial distribution / quality / historical problems**	**Natural England specific Environmental Outcomes** (Broads SAC as supplied 17 January 2008)	**Hydrological functioning**	**Model cell(s) used at Stage 3**	**Model criteria used to assess adverse effect at Stage 3**	**Model cell(s) used at Stage 4**	**Primary model criteria used at Stage 4**
Alderfen Broad (A) Barton Broad (D) Barton Fen (F)	Alluvial woodland (W2, W5 and W6)	Refer to map Figure 3.16a-b and 3.17 No apparent problems in non-drought years under historical levels of abstraction.	Winter water-levels at or very near the ground surface, being maintained within 5cm of the ground surface through the spring establishment period. Summer maximum and minimum levels should be between 5 and 45cm below the ground surface, accepting that optimal seedling growth occurs with water levels between 10 and 30cm below ground level.	Areas of permanent seepage and shallow water table supported by upward groundwater flow from the drift / crag aquifers.	Six layer Regional Groundwater Model used. Cells equivalent to R142C297, R135C299 and R122C299	Summer water table (July-September) to fall no more than 45cm below the surface. Winter water levels to be within 5cm of ground surface.	**Cell 'A' R142C297** **Cell 'D' R135C299** **Cell 'F' R122C299**	For non-drought summers: Soil moisture content, kept above stress threshold For drought summers: Water level in uppermost model layer above lowest historical water level
Catfield Fen (Ditches) Crome's Broad (Ditches) Alderfen Broad Barton Broad	Natural Eutrophic Ditches (Turf ponds / broad and ditches)	Refer to map Figure 3.16a-b and 3.17 No apparent problems in non-drought years (or drought years) under historical levels of abstraction.	Mean reductions in level of up to 10% of ditch depth are acceptable in the spring and summer months (March – September) although the 45cm below marsh level is the threshold below which EN would indicate that targets are not being met irrespective of the	Shallow water table supported by upward groundwater flow from the drift / crag aquifers and inflow from surface water via field drains	Six layer Regional Groundwater Model used. Turnover calculations over area of hydrological units that contain features	A 10% reduction will be allowed unless reductions of 10% would breach the 45cm threshold. Abstraction should not amount to more than 10% of the naturalised Q95 flow (Barton Broad only).	Stream cells representing accretion flow at downstream end of drainage area or exit flow from broads	For drought summers: lowest accretion and highest turnover rate in historical scenario

			level of abstraction. To this end a 10% reduction will be allowed unless reductions of 10% would breach the 45cm threshold. Abstraction should not amount to more than 10% of the naturalised Q95 flow (Barton Broad only).					

Table B.2.3 (continued) Summary of Environmental Outcomes and Criteria for Assessing Acceptable Levels of Abstraction

Interest feature location	**Description of flora and fauna under European designation**	**Spatial distribution / quality / historical problems**	**Natural England specific Environmental Outcomes** (Broads SAC as supplied 17 January 2008)	**Hydrological functioning**	**Model cell(s) used at Stage 3**	**Model criteria used to assess adverse effect at Stage 3**	**Model cell(s) used at Stage 4**	**Primary model criteria used at Stage 4**
Catfield Broad Crome's Broad	Natural Eutrophic Lakes	Refer to map Figure 3.16a-b and 3.17. No apparent problems in non-drought years (or drought years) under historical levels of abstraction.	Target proposed is that depth of water body the site should not be reduced by more than 10% from the naturalised level.	Shallow water table supported by upward groundwater flow from the drift / crag aquifers	Not assessed at Stage 3	Not assessed at Stage 3	Discharge to stream flow over area of Zone budget for hydrological units Catfield Fen and Crome's Broad	For drought summers: lowest historical discharge to stream For non-drought summers: lowest historical discharge to stream

B.2.3 Model-based hydrological criteria

The Stage 4 assessment has moved away from the generic hydrological targets used at Stage 3 for assessment of risk of impact to European features. A standardised methodology for the assessment of abstraction-related impacts of groundwater-dependent habitats has been developed within Anglian region. The current methodology uses a refined Regional Groundwater Model together with new information obtained since Stage 3. The approach adopted, using the Regional Groundwater Model, is detailed in the Site Options Plan issue 2 (Entec 2009).

The Environmental Outcomes provided by Natural England for the Broads SAC and Broadland SPA are focused on maintaining the European features in a favourable condition along with the habitat for designated bird species.

The specific Environmental Outcomes for groundwater-dependent features are based on typical groundwater levels at a variety of locations, as reported in the Ecohydrological Guidelines. The Environmental Outcomes for ditch and broad features are also generalised, based on appropriate turnover rates required to maintain adequate water quality in the surface water system. The groundwater levels, ditch levels and flushing rates that have been described above cannot directly be used to define hydrological thresholds for assessing acceptable levels at the Ant Broads and Alderfen Broad SSSIs. This is because:

- The guidelines do not take into account the specific conditions that exist at Ant Broads and Marshes and Alderfen Broad SSSIs;
- Where vegetation stands are less species rich, hydrological requirements are likely to be less exacting, in that water tables are likely to fluctuate more, probably leading to summer dry conditions (greater than those outlined in the Ecohydrological Guidelines);
- Very little observed data was available for Alderfen Broad SSSI or to the west of Ant Broads and Marshes SSSI to allow local model calibration. Dipwells have been installed within the vicinity of the features but less than one year of data was available;
- The modelled groundwater level in the top active layer represents a 200m x 200m area within which, in reality ground elevation, soil conditions, geology, water levels and flows can vary significantly;
- The modelled water levels in the uppermost layer of the Regional Groundwater Model do not exactly represent the real water table;
- The water levels observed in dipwells may not correspond with water levels reported in the Ecohydrological Guidelines because different methods are used to measure the water table;
- Flushing rates through drainage systems will not be consistent across a whole drainage network, since some drains will be better connected than others;
- The model estimates of stream discharges (used to calculate flushing rates) may not exactly represent the real rate of leakage, because the routing network is based only on a 200m x 200m grid size and cannot represent detailed drainage networks;
- The water levels and flow through the drainage networks are influenced by tidal fluctuations, and this is not represented in the Regional Groundwater Model;

- Turnover times using stream cell flows exiting broads on site may be longer than the one month time-step and do not take into account lake dynamics or storage in upstream stream cells.

The proposed model-based hydrological criteria for deciding acceptable levels of abstraction therefore relate to:

- For groundwater level dependent features, maintaining a continued adequate supply of groundwater to the site to ensure it remains in, or is restored to favourable or recovering condition;
- For surface water features, maintaining a continued adequate supply of both groundwater and surface water to the site (through discharge to stream on a cell or zone budget scale) to ensure it remains in, or is restored to, favourable or recovering condition.

Acceptable levels of abstraction for Ant Broads and Marshes and Alderfen Broad SSSIs will be assessed using the groundwater model to appraise the effect of abstraction scenarios with regard to:

- Continued discharge of groundwater to the site - assessed by the relative volume of groundwater discharge to stream cells and zone budget areas;
- Maintenance of an upward hydraulic gradient from the chalk to the near surface deposits – assessed by the relative elevations of groundwater levels within the chalk (layers 5 and 6) and the top active layer in the model (layer 1);
- Maintenance of an upward flow of groundwater from the crag / chalk to the near surface deposits – assessed by the relative volume of flow to the top active layer in the model;
- Impacts on groundwater level in the top active layer of the model as an indicator of abstraction effects on the depth to the water table;
- Impacts on soil moisture characteristics, especially with regard to stress thresholds and winter saturation, for features dependent on maintenance of a shallow water table.

The Environmental Outcomes indicate that some features are more sensitive to changes in the hydrology of the site than others (e.g. to near surface groundwater levels and to flushing). The most sensitive features have been chosen for analysis per unit, on the basis that the requirements of other features will then be adequately covered.

The model criteria and associated thresholds to be used to assess acceptable levels of abstraction for Ant Broads and Alderfen Broad SSSIs are related to the Environmental Outcomes and hydrological functioning of the site. The Primary Criteria represent ‘hard’ targets based partly on Natural England observations of site conditions in drought and non-drought years. The Secondary Criteria inform further judgement and are related to other hydrological mechanisms that support water supply to the European Features and to the less critical period of the seasonal cycle. A secondary criteria is applied because European Features require certain wetness conditions during winter months and that full recovery to saturated conditions generally occur each winter. The site specific criteria for Ant Broads and Marshes and Alderfen Broad SSSIs are outlined in Tables B.2.4a – B.2.4j below.

Table B.2.4a Summary of Criteria and Thresholds for Alderfen Broad (Model Cell 'A') – Alluvial Woodland

	Soil Moisture Content	Modelled Water Level in Uppermost Layer	Modelled Upward Flow into Uppermost Layer	Modelled Discharge to Stream Cell
Non-drought Summer	**> Stress threshold**	> Lowest historical in non-drought summers August 1972 = 0.1mAOD	August 1972 = 65.606m^3/d	August 1972 = -22.006m^3/d
Drought Summer	> Stress threshold	**> Lowest historical in drought summers July 1976 = -0.165mAOD**	July 1976 = 71.768m^3/d	July 1976 = 0m^3/d
Non-drought Winter	Return to saturation	> Lowest winter peak in non-drought winters February 2005 = 0.515mAOD	February 2005 = 46.473m^3/d	February 2005 = -63.515m^3/d
Drought Winter	Return to saturation	> Lowest winter peak in drought winters February 1973 = 0.271mAOD	February 1973 = 31.171m^3/d	February 1973 = -39.083m^3/d

(shaded)	= **primary criteria**
	= secondary criteria

Table B.2.4b Summary of Criteria and Thresholds for Reedham Marshes – Ant Broads and Marshes (Model Cell 'B') - Calcareous Fen

	Soil Moisture Content	Modelled Water Level in Uppermost Layer	Modelled Flow into System	Modelled Discharge to Stream Cell
Non-drought Summer	**> Stress threshold**	> Lowest historical in non-drought summers September 2003 = -0.395mAOD	September 2003 = 17.934m^3/d	September 2003 = 0m^3/d
Drought Summer	> Stress threshold	**> Lowest historical in drought summers July 1976 = -0.532mAOD**	July 1976 = 17.753m^3/d	July 1976 = 0m^3/d
Non-drought Winter	Return to saturation	> Lowest winter peak in non-drought winters February 2005 = 0.098mAOD	February 2005 = -3.5559m^3/d	February 2005 = -5.8154m^3/d
Drought Winter	Return to saturation	> Lowest winter peak in drought winters February 1973 = -0.131mAOD	February 1973 = 3.7763m^3/d	February 1973 = 0m^3/d

(shaded)	= **primary criteria**
	= secondary criteria

Table B.2.4c Summary of Criteria and Thresholds for Sharp Street – Ant Broads and Marshes (Model Cell 'C') – Calcareous Fen

	Soil Moisture Content	Modelled Water Level in Uppermost Layer	Modelled Upward Flow into Uppermost Layer	Modelled Discharge to Stream Cell
Non-drought Summer	**> Stress threshold**	> Lowest historical in non-drought summers October 1972 = -0.024mAOD	October 1972 = 4.6512m^3/d	October 1972 = -10.585m^3/d
Drought Summer	> Stress threshold	**> Lowest historical in drought summers August 1976 = -0.085mAOD**	August 1976 = -3.021m^3/d	August 1976 = -4.508m^3/d
Non-drought Winter	Return to saturation	> Lowest winter peak in non-drought winters March 2005 = 0.062mAOD	March 2005 = 22.77m^3/d	March 2005 = 19.212m^3/d
Drought Winter	Return to saturation	> Lowest winter peak in drought winters February 1973 = 0.004mAOD	February 1973 = 17.02m^3/d	February 1973 = -13.395m^3/d

(shaded)	= **primary criteria**
	= secondary criteria

Table B.2.4d Summary of Criteria and Thresholds for Barton Broad – Ant Broads and Marshes (Model Cell 'D') – Alluvial Woodland

	Soil Moisture Content	Modelled Water Level in Uppermost Layer	Modelled Upward Flow into Uppermost Layer	Modelled Discharge to Stream Cell
Non-drought Summer	**> Stress threshold**	> Lowest historical in non-drought summers October 1972 = -0.511mAOD	October 1972 = 17.432m^3/d	October 1972 = 0m^3/d
Drought Summer	> Stress threshold	**> Lowest historical in drought summers July 1976 = -0.73mAOD**	July 1976 = 10.625m^3/d	July 1976 = 0m^3/d
Non-drought Winter	Return to saturation	> Lowest winter peak in non-drought winters February 2005 = -0.043mAOD	February 2005 = -0.555m^3/d	February 2005 = -11.697m^3/d
Drought Winter	Return to saturation	> Lowest winter peak in drought winters February 1973 = -0.268mAOD	February 1973 = 2.8266m^3/d	February 1973 = 0m^3/d

(shaded)	= **primary criteria**
	= secondary criteria

Table B.2.4e Summary of Criteria and Thresholds for Sutton Broad – Ant Broads and Marshes (Model Cell 'E') – *Molinia* Meadows

	Soil Moisture Content	Modelled Water Level in Uppermost Layer	Modelled Upward Flow into Uppermost Layer	Modelled Discharge to Stream Cell
Non-drought Summer	**> Stress threshold**	> Lowest historical in non-drought summers September 2003 = -0.334mAOD	September 2003 = 83.638m^3/d	September 2003 -31.614m^3/d
Drought Summer	> Stress threshold	**> Lowest historical in drought summers July 1976 = -0.532mAOD**	July 1976 = 84.159m^3/d	July 1976 = -11.771m^3/d
Non-drought Winter	Return to saturation	> Lowest winter peak in non-drought winters February 2005 = 0.083mAOD	February 2005 = 59.524m^3/d	February 2005 = -73.332m^3/d
Drought Winter	Return to saturation	> Lowest winter peak in drought winters February 1973 = -0.05mAOD	February 1973 = 57.573m^3/d	February 1973 = -59.988m^3/d

(shaded)	= **primary criteria**
	= secondary criteria

Table B.2.4f Summary of Criteria and Thresholds for Barton Fen – Ant Broads and Marshes (Model Cell 'F') – *Molina* Meadow / Alluvial Woodland

	Soil Moisture Content	Modelled Water Level in Uppermost Layer	Modelled Upward Flow into Uppermost Layer	Modelled Discharge to Stream Cell
Non-drought Summer	**> Stress threshold**	> Lowest historical in non-drought summers September 2003 = 0.489mAOD	September 2003 = 52.961m^3/d	September 2003 -6.855m^3/d
Drought Summer	> Stress threshold	**> Lowest historical in drought summers July 1976 = 0.190mAOD**	July 1976 = 54.86m^3/d	July 1976 = 0m^3/d
Non-drought Winter	Return to saturation	> Lowest winter peak in non-drought winters February 2005 = 0.923mAOD	February 2005 = 37.41m^3/d	February 2005 = -50.305m^3/d
Drought Winter	Return to saturation	> Lowest winter peak in drought winters February 1973 = 0.736mAOD	February 1973 = 30.489m^3/d	February 1973 = -31.597m^3/d

(shaded)	= **primary criteria**
	= secondary criteria

Table B.2.4g Summary of Criteria and Thresholds for Catfield Fen – Ant Broads and Marshes (Model Cell 'G') – Calcareous Fen

	Soil Moisture Content	Modelled Water Level in Uppermost Layer	Modelled Upward Flow into Uppermost Layer	Modelled Discharge to Stream Cell
Non-drought summer	**> Stress threshold**	> Lowest historical in non-drought summers September 2003 = 0.101mAOD	September 2003 = 18.904m^3/d	September 2003 28.923m^3/d
Drought summer	> Stress threshold	**> Lowest historical in drought summers** **July 1976 = -0.05mAOD**	July 1976 = 19.258m^3/d	July 1976 = 30m^3/d
Non-drought winter	Return to saturation	> Lowest winter peak in non-drought winters February 2005 = 0.48mAOD	February 2005 = -4.91m^3/d	February 2005 = -8.95m^3/d
Drought winter	Return to saturation	> Lowest winter peak in drought winters February 1973 = 0.373mAOD	February 1973 = -5.59m^3/d	February 1973 = 1.725m^3/d

(shaded)	= **primary criteria**
	= secondary criteria

Table B.2.4h Summary of Criteria and Thresholds for Natural Eutrophic Lakes and Ditches using Accretion Flows and Turnover Rates

	Accretion	Turnover Time
Alderfen Broad **Model Cell R143C298** **drought summer**	July 1976 = 0.068m^3/d	July 1976 = 763 days
Ant Broads and Marshes SSSI		
Barton Broad **Model Cell R136C302** **drought summer**	July 1976 = 21.966m^3/d	July 1976 = 59.35 days
Catfield Fen **Model Cells R135C304 and R137C306** **drought summer**	September 1997 = 0.204m^3/d	September 1997 = 57 days
Crome's Ditches **Model Cell R143C306** **drought summer**	July 1996 = 0.037m^3/d	July 1996 = 536 days

(shaded)	= **primary criteria**
	= secondary criteria

Table B.2.4i Summary of Criteria and Thresholds for Natural Eutrophic Lakes using Discharge to Stream for Catfield Broad – Ant Broads and Marshes SSSI

	Modelled Discharge to Stream - Catchment Scale (Ml/d)
Non-drought summer	September 2003 = 60.154m^3/d
Drought Summer	August 1976 = 155.5m^3/d

(grey)	= **primary criteria**
	= secondary criteria

Table B.2.4j Summary of Criteria and Thresholds for Natural Eutrophic Lakes using Discharge to Stream for Crome's Broad – Ant Broads and Marshes SSSI

	Modelled Discharge to Stream - Catchment Scale (Ml/d)
Non-drought summer	August 1975 = 8.705m^3/d
Drought Summer	July 1976 = 127.14m^3/d

(grey)	= **primary criteria**
	= secondary criteria

B.2.4 Results of groundwater modelling

Since the completion of the Stage 3 Appropriate Assessment in September 2006, a standardised methodology for the assessment of abstraction-related impacts on groundwater-dependant habitats has been progressively developed within Anglian region for the RoC process. This has employed the use of Regional Groundwater Models that weren't available during Stage 3 or that have since been further refined, plus new information about each site derived from continued monitoring activity. This new approach is more risk-based, taking account of the effects of historic abstraction regimes, site condition and professional judgement.

The Regional Groundwater Model has been used to simulate the effects of abstraction under several abstraction scenarios for the 35 year period from 1970 to 2004. The basic scenarios were "naturalised", "historical" abstraction and "real fully licensed (RFL)" abstraction. The modelling scenarios are described in detail in sections 6.1 and 7.1 of the Site Options Plan issue 2, (Entec, 2009). The RFL scenario includes abstractions at fully licensed rates but takes account of aggregate limitations within the licence conditions. The abstractions from individual sources within the aggregate are weighted such that the maximum abstraction takes place from the sources in closest proximity to the site.

The criteria detailed in Tables B.2.4a – B.2.4j based on soil moisture content or lowest modelled historical groundwater levels, are used for comparison with time series modelled for different abstraction scenarios which are all based on the same climatic time series for the 35 year period from 1970 up to the end of 2004.

Historical Abstraction

The modelled historical situation over the period 1970-2005 has been taken as the basis for the thresholds against which each scenario and criteria are judged. This is because there is no clear evidence that either SSSI has been adversely affected by past actual abstractions. Therefore by definition the historical abstraction scenario appears to be acceptable although it is noted that the ecological time-series on which this assumption is based is very limited.

Real Fully Licensed Scenario

Soil moisture does not fall below the stress threshold during any non-drought summers.

Water levels do fall beneath the respective threshold for all features during one drought summer (consistently 1976). The stress threshold itself is breached during the drought summer of 1976 for Cell B (S24 at Reedham Marshes) only. The lowest winter peak water table is not reached in one non-drought winter (2005) for all cells and not achieved in one drought winter (1973) in all cells, or achieved in 1974 (drought winter) for Cells A and C.

It is considered that abstraction at the full licensed rates does not pose a problem for Ant Broads and Marshes and Alderfen Broad SSSIs during non-drought periods because:

- The stress threshold is not breached during all non-drought summers;

- Soil moisture content returns to full saturation in winter in all drought and non-drought years, i.e. no “cumulative” depletion of soil moisture store.

Table B.2.5a Assessment of Abstraction Scenarios against Model-based Hydrological Criteria – Cell 'A' Alderfen Broad

Interest Feature Location	Historical Model-based Hydrological Criteria	Historical	Real fully Licensed
Alderfen (Model Cell 'A')	Non-drought summers: **Soil moisture content above stress threshold** August 1972 lowest water level (0.1mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled soil moisture content does not drop below stress threshold in any non-drought summer** Water level breaches the threshold in one non-drought summer by max of 3.7cm. Lowest upward flow not reached in 10 non-drought summers; lowest stream discharge flow threshold is exceeded in one non-drought year (1972).
	Drought summers: **July 1976 lowest water level (-0.165mAOD)**, and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled water levels fall below the threshold in one drought year by max. of 5.7cm** Lowest upward flow is exceeded in 9 drought summers; lowest stream discharge flow threshold is not exceeded in any drought summer. Soil moisture content drops below stress threshold in 1 drought summer
	Non-drought winters: Return to saturation; February 2005 lowest peak water level (0.515mAOD and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all non-drought winters except 2005. The lowest upwards flow is reached in all non-drought winters; lowest stream discharge threshold is attained in all non-drought years except 2005.
	Drought winters: Return to saturation; February 1973 (0.271mAOD) lowest peak water level and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all drought winters except 1973 and 1974. The lowest upwards flow is reached in all drought winters; lowest stream discharge threshold is reached in all drought winters except 1973 and 1974.

Note: Primary Criteria indicated in **bold**

Table B2.5b Comparison of Abstraction Scenarios against Model-based Hydrological Criteria – Cell 'B' Reedham Marshes – Ant Broads and Marshes

Interest Feature Location	Historical Model-based Hydrological Criteria	Historical	Real fully Licensed
Reedham Marshes (Model Cell 'B')	Non-drought summers: **Soil moisture content above stress threshold** September 2003 lowest water level (-0.395mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled soil moisture content does not drop below stress threshold in any non-drought summer** Water level breaches the threshold in two non -drought by max. of 1.1cm. Lowest upward flow not reached in all non-drought summers; lowest stream discharge flow threshold is not reached (the cell dries) in all non-drought years except 1987 and 2001.
	Drought summers: **July 1976 lowest water level (-0.532mAOD)**, and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled water levels fall below the threshold in one drought year by max. of 1.2cm** Lowest upward flow is not reached in all drought summers; lowest stream discharge flow threshold is not reached (the cell dries) in all drought years. Modelled soil moisture content does drop below stress threshold in one drought summer.
	Non-drought winters: return to saturation; February 2005 lowest peak water level (0.098mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all non-drought winters except 2005. The lowest upwards flow is reached in all non-drought winters; lowest stream discharge threshold is reached in all non-drought years except 2005.
	Drought winters: return to saturation; February 1973 (-0.131mAOD) lowest peak water level; and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all drought winters except 1973. The lowest upwards flow is reached in all drought winters; lowest stream discharge threshold is reached in all drought winters except 1973, 1974 and 1976.

Note: Primary Criteria indicated in **bold**

Table B2.5c Comparison of Abstraction Scenarios against Model-based Hydrological Criteria – Cell 'C' Sharp Street

Interest Feature Location	Historical Model-based Hydrological Criteria	Historical	Real fully Licensed
Sharp Street (Model Cell 'C')	Non-drought summers: **Soil moisture content above stress threshold** October 1972 lowest water level (-0.024mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled soil moisture content does not drop below stress threshold in any non-drought summer** Water level breaches threshold in four non-drought summers by max. of 3.5cm. Lowest upward flow exceeded in 20 non-drought summers; lowest stream discharge flow threshold is exceeded in four non-drought years.
	Drought summers: **August 1976 lowest water level (-0.085mAOD)** and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled water levels fall below the threshold in one drought year by max. of 1.9cm** Lowest upward flow exceeded in all drought summers except 1989, 1992 and 1995; lowest stream discharge flow threshold is exceeded (or not reached) in two drought years (1974 and 1976). Modelled soil moisture content does drop below stress threshold in 1 drought summer.
	Non-drought winters: Return to saturation; March 2005 lowest peak water level (0.062mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all non-drought winters except 2005. Upwards flow reaches the threshold in all years; discharge reaches the lowest threshold in all non-drought winters.
	Drought winters: Return to saturation; February 1973 (0.004mAOD) lowest peak water level; and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all drought winters except 1973 and 1974. Upwards flow reaches the threshold in all drought winters except 1973; discharge reaches the lowest threshold in all drought winters except 1973, 1974 and 1976.

Note: Primary Criteria indicated in **bold**

Table B2.5d Comparison of Abstraction Scenarios against Model-based Hydrological Criteria – Cell 'D' Barton Broad

Interest Feature Location	**Historical Model-based Hydrological Criteria**	**Historical**	**Real fully Licensed**
Barton Broad (Model Cell 'D')	Non-drought summers: **Soil moisture content above stress threshold** October 1972 lowest water level (-0.511mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled soil moisture content does not drop below stress threshold in any non-drought summer** Water level breaches the threshold in four non-drought summers by max. of 8.1cm. Lowest upward flow is not reached in all non-drought summers; lowest stream discharge flow threshold is not reached (the cell dries) in all non-drought years except 2001.
	Drought summers: **July 1976 lowest water level (-0.73mAOD)**, and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled water levels fall below the threshold in one drought year by max. of 3.2cm** Lowest upward flow reached in all drought summers except 1992; lowest stream discharge flow threshold is exceeded (the cell dries) in all drought years. Modelled soil moisture content drops below stress threshold in 1 drought summer.
	Non-drought winters: Return to saturation; February 2005 lowest peak water level (-0.043mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all non-drought winters except 2005. The lowest upwards flow is reached in all non-drought winters; lowest stream discharge threshold is attained in all non-drought years except 2005.
	Drought winters: Return to saturation; February 1973 (-0.268mAOD) lowest peak water level; and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all drought winters except 1973. The lowest upwards flow is reached in all drought winters; lowest stream discharge threshold is reached in all drought winters except 1973, 1974 and 1976.

Note: Primary Criteria indicated in **bold**

Table B2.5e Comparison of Abstraction Scenarios against Model-based Hydrological Criteria – Cell 'E' Sutton Broad

Interest Feature Location	**Historical Model-based Hydrological Criteria**	**Historical**	**Real fully Licensed**
Sutton Broad (Model Cell 'E')	Non-drought summers: **Soil moisture content above stress threshold** September 2003 lowest water level -0.334mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled soil moisture content does not drop below stress threshold in any non-drought summer** Water level breaches threshold in one non-drought summer (2003) by max. of 1cm. Lowest upward flow not reached in all non-drought summers except 2003; lowest stream discharge flow threshold is not reached in one non-drought year (2003).
	Drought summers: **July 1976 lowest water level (-0.532mAOD)**, and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled water levels fall below the threshold in one drought year by max. of 1.8cm** Lowest upward flow is note reached in all drought summers except 1995; lowest stream discharge flow threshold is exceeded in one drought year (1976). Modelled soil moisture content drops below stress threshold in 1 drought summer.
	Non-drought winters: Return to saturation; February 2005 lowest peak water level (0.083mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all non-drought winters except 2005. The lowest upwards flow is reached in all non-drought winters; lowest stream discharge threshold is attained in all non-drought years except 2005.
	Drought winters: Return to saturation; February 1973 (-0.05mAOD) lowest peak water level; and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all drought winters except 1973. The lowest upwards flow is reached in all drought winters; lowest stream discharge threshold is reached in all drought winters except 1973.

Note: Primary Criteria indicated in **bold**

Table B2.5f Comparison of Abstraction Scenarios against Model-based Hydrological Criteria – Cell 'F' Barton Fen

Interest Feature Location	**Historical Model-based Hydrological Criteria**	**Historical**	**Real fully Licensed**
Barton Fen (Model Cell 'F')	Non-drought summers: **Soil moisture content above stress threshold** September 2003 lowest water level (0.489mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled soil moisture content does not drop below stress threshold in any non-drought summer** Water level breaches threshold in three non-drought summers (1972, 1975 and 2003) by a max. of 1.5cm. Lowest upward flow is not reached in most non-drought summers except 1983, 1994 and 2003; lowest stream discharge flow threshold is not reached in three non-drought years (1972, 1975 and 2003).
	Drought summers: **July 1976 lowest water level (0.19mAOD)**, and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled water levels fall below the threshold in one drought year (1976) by max. of 2.0cm** Lowest upward flow is not reached in all drought summers; lowest stream discharge flow threshold is not reached in four drought years. Modelled soil moisture content drops below stress threshold in 2 drought summers.
	Non-drought winters: Return to saturation; February 2005 lowest peak water level (0.923mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all non-drought winters except 2005. The lowest upwards flow is reached in all non-drought winters; lowest stream discharge threshold is attained in all non-drought years except 2005.
	Drought winters: Return to saturation; February 1973 (0.736mAOD) lowest peak water level; and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all drought winters except for 1973. The lowest upwards flow is reached in all drought winters; lowest stream discharge threshold is reached in all drought winters except 1973.

Note: Primary Criteria indicated in **bold**

Table B2.5g Comparison of Abstraction Scenarios against Model-based Hydrological Criteria – Cell 'G' Catfield Fen

Interest Feature Location	Historical Model-based Hydrological Criteria	Historical	Real fully Licensed
Catfield Fen (Model Cell 'G')	Non-drought summers: **Soil moisture content above stress threshold** September 2003 lowest water level (0.101mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled soil moisture content does not drop below stress threshold in any non-drought summer** Water level breaches the threshold in two non-drought summers (1975 and 2003) by max. of 1.2cm. Lowest upward flow is not reached in all non-drought summers except 1983 and 2003; lowest stream discharge flow threshold is not reached in two non-drought years (1975 and 2003).
	Drought summers: **July 1976 lowest water level (-0.05mAOD)**, and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled water levels fall below the threshold in one drought year (1976) by max. of 2.7cm** Lowest upward flow is not reached in any drought summer except 1995; lowest stream discharge flow threshold is not reached in six drought years. Modelled soil moisture content drops below stress threshold in 2 drought summer.
	Non-drought winters: Return to saturation; February 2005 lowest peak water level (0.480mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all non-drought winters except 2005. The lowest upwards flow is reached in all non-drought winters; lowest stream discharge threshold is attained in all non-drought years except 2005.
	Drought winters: Return to saturation; February 1973 (0.373mAOD) lowest peak water level; and associated regime of upward flow to top active layer and stream discharge	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level achieved in all drought winters except 1973. The lowest upwards flow is reached in all drought winters; lowest stream discharge threshold is reached in all drought winters except 1973.

Note: Primary Criteria indicated in **bold**

Table B2.5h Comparison of Abstraction Scenarios against Model-based Hydrological Criteria – Accretion and Turnover

Interest Feature Location	Historical Model-based Hydrological Criteria	Historical	Real fully Licensed
Alderfen Broad (Model Cell R143C298) **drought summer**	Drought summers: lowest accretion and lowest turnover	No problem by definition	Accretion threshold is exceeded in two drought summers (1973 and 1976); turnover time is greater than the minimum threshold in two drought summers (1973 and 1976).
Ant Broads and Marshes			
Barton Broad (Model Cell R136C302) **drought summer**	Drought summers: lowest accretion and lowest turnover	No problem by definition	Accretion threshold is exceeded in two drought summers (1974 and 1976); turnover time is greater than the threshold in two drought summers (1974 and 1976).
Catfield Fen (Model Cells R135C304 and R137C306 **drought summer**	Drought summers: lowest accretion and lowest turnover	No problem by definition	Accretion threshold is exceeded in six drought summers; turnover time is greater than the threshold in six drought summers
Crome's Ditches (Model Cell R143C306) **drought summer**	Drought summers: lowest accretion and lowest turnover	No problem by definition	Accretion threshold is exceeded in one drought summer (1976); turnover time is greater than the threshold in one drought summer (1976).

Note: Primary Criteria indicated in **bold**

Table B2.5i Comparison of Abstraction Scenarios against Model-based Hydrological Criteria – Discharge to Stream on sub-Catchment Scale

Interest Feature Location	Historical Model-based Hydrological Criteria	Historical	Real fully Licensed
Ant Broads and Marshes SSSI			
Catfield Broad	Non-drought summers: lowest peak stream discharge	No problem by definition	Lowest stream discharge threshold is exceeded in six non-drought summers
	Drought summers: lowest peak stream discharge	No problem by definition	Lowest stream discharge threshold is exceeded in one drought summers (1976)
Crome's Broad	Non-drought summers: lowest peak stream discharge	No problem by definition	Lowest stream discharge threshold is exceeded in two non-drought summers
	Drought summers: lowest peak stream discharge	No problem by definition	Lowest stream discharge threshold is exceeded in one drought summer

Note: Primary Criteria indicated in **bold**

B.2.5.1 Summary of Anglian Region's Technical Approach for "Inland Sites"

This approach is detailed in Buss (2009) and summarised here.

For sites where we judge that historical levels of abstraction have been considered acceptable we use thresholds for model-based hydrological criteria which are based, for example, on the lowest modelled historical water level in the top active layer of the numerical model. The use of thresholds which are based on the historical time series and lowest historical groundwater heads and flows inherently results in at least one breach since fully licensed abstraction is generally greater than historical abstraction in most catchments. In addition to the one 'default' breach, there is often only a very small number of breaches (if any) and most of the breaches may only be in the order of millimetres or a few centimetres, a few percent of soil moisture content or a few litres per day of flow.

The historical time series is used as a baseline because this is the only 'scenario' which has been experienced in the past and therefore can be compared with ecological and hydrological observations. In reality, adverse effects on site integrity may only start to occur once water levels and flows are somewhat lower than experienced in the past. Since this situation is outside of the range of our experience it is difficult to identify absolute thresholds when adverse effect will start to occur. Licence modifications may therefore not be necessary if hydrological impacts from fully licensed abstraction are greater than under the historical scenario by only an insignificant amount, i.e. if the number and scale of breaches is small, and if the risk of adverse effects on the site integrity actually occurring is judged to be sufficiently low.

We are therefore applying a risk-based approach that scales the need for licence modifications according to the risk to the site and a decision table (or "risk matrix") has been developed as a generic tool.

The 'risk-matrix' is applied by assigning a 'risk category' to each site (generally component SSSIs if a SAC / SPA consists of more than one SSSI). The risk matrix takes into account the scale and frequency of breaches to primary criteria thresholds, in the context of the conceptual understanding and the model representation, changes to the overall hydrological functioning, the general level of fully licensed and historical abstraction in the catchment surrounding the site and uncertainties around the ecological 'evidence' available. Professional judgement will be applied to the interpretation of the risk matrix and in deciding on the appropriate risk category.

There is a presumption that, for sites which are assigned a 'low risk category', no abstraction licence modifications will need to be investigated through the options appraisal process. The assumption is that for those sites, the risk that adverse effects on site integrity would occur and the Environmental Outcomes cannot be achieved is sufficiently low despite some (small and infrequent) breaches of thresholds.

For sites in the 'medium risk' and 'high risk' categories abstraction licence modifications will be investigated during the options appraisal process. The presumption is that licences would need to be modified so that the site then falls into the ‘low risk’ category.

The difference between ‘medium risk’ and ‘high risk’ is the scale of abstraction licence modification. Most of the ‘medium risk’ sites may only require some restriction to actual abstraction in years with exceptionally dry conditions, whilst ‘high risk’ sites may require a general reduction in licensed quantity. However, the scale and detail of any modification will depend on the individual site and the licences implicated.

For SAC and SPAs with more than one component SSSI, the application of the risk matrix will direct the options appraisal work with regard to individual component SSSIs but does not preclude the overall Stage 4 conclusion for the European site. If necessary, sites in the ‘low risk’ category could be reconsidered at a later stage, although this is not expected to happen in general.

Natural England were consulted on our technical approach to inland sites and agreed with the approach for Ant Broads and Marshes and Alderfen Broad SSSIs in December 2008.

B.2.5.2 Conclusions from the risk matrix

Site Option Plan decision tables (or “risk matrices”) listing the hydrological criteria and the degree to which they are met for each scenario, are presented in Tables B.2.7 and B.2.8 for Ant Broads and Marshes SSSI and Alderfen Broad SSSI respectively. The modelling results which are most relevant are found the Site Options Plan issue 2 (Entec 2009).

The conclusions drawn from application of the new model-based hydrological criteria to the abstraction scenarios, in conjunction with the “Risk Matrix” decision tables B.2.7 and B.2.8 are that:

- Environmental Outcomes are **achieved** under recent historical abstraction (by definition)
- There is sufficiently low risk associated with real fully licensed abstraction that Environmental Outcomes are likely to be **achieved**.

This latter conclusion is consistent with the risk-based approach devised and adopted by Anglian Region during the development of Stage 4 of the Review of Water Resources Permissions. Natural England agreed with the assessment of this site as low risk on 15 December 2008.

Table B.2.7 Risk matrix for Ant Broads and Marshes, Barton Broad, Model Cell 'D' (where modelling has indicated the largest impact)

Criteria	Low	Site details	Medium	Site details	High	Site details
1) Performance against model-based hydrological criteria						
Scale of breach for water levels (related to threshold for drought summers)	≤ 5cm	5cm	≤ 10cm		> 10cm	
Frequency of breaches for water levels (related to threshold for drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)	1 out of 35	≤ 3 out of 10 (= ≤ 9 out of 35)		> 3 out of 10 (= > 9 out of 35)	
Scale of breach for soil moisture (related to threshold for non-drought summers)	≤ 5 %	none	≤ 10 %		> 10 %	
Frequency of breaches for soil moisture (related to threshold for non-drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)	none	≤ 3 out of 10 (= ≤ 9 out of 35)		> 3 out of 10 (= > 9 out of 35)	
Timing of breaches	droughts only	droughts only	non-droughts only		droughts AND non-drought periods	
Soil moisture returning to saturation in winters	always	always	not in a few winters		not in most winters	
Impact on overall hydrological functioning	not significantly impacted		impacted in some years	precautionary yes	significantly impacted in most years	
2) Appraisal of resources and abstraction scenarios						
Modelled water level under fully licensed scenario similar to naturalised / historical or close to 50% LTA recharge scenario	similar to naturalised or historical		between historical and 50% LTA recharge abstraction scenario	yes	close or above 50% LTA recharge abstraction scenario	
Fully licensed abstraction as percentage of long-term average recharge (it is important to consider over which area the comparison is made)	0-20%		20-40%	28%	>40%	
Sensitivity of modelled water table to changes in abstraction (difference between abstraction scenarios)	small		medium	medium	large	
Sensitivity to water table fluctuations indicated by field data (site generally wet?)	small		medium	medium	large	
3) Uncertainties						
Evidence to allow judgement of no ecological change available and clear?	available and clear	available and clear	available but not clear		not available	

Development of historical abstraction levels over last 15 years (enough time for ecological effects to become apparent?)	~ stable or decreasing	~ stable	slightly increasing		increasing	
Model representation adequate?	adequate	adequate	less adequate		not adequate	
Ecohydrological conceptual understanding clear and agreed?	clear and agreed	clear and agreed	less clear, not agreed		not clear, not agreed	
Field data available and sufficient?	available and sufficient	available and sufficient	available but not entirely sufficient		not available and not sufficient	
Further considerations that may influence the overall risk category:						
Add site specific considerations as appropriate…						
Example: Are the abstraction licences in the vicinity of the site in the majority seasonal (agricultural), annual abstractions or PWS abstractions?						

Note: If more than one assessment cell on a SSSI use the one with highest risk to decide on overall site risk category

Table B.2.8 Risk matrix for Alderfen Broad – Model Cell 'A'

Criteria	Low	Site details	Medium	Site details	High	Site details
1) Performance against model-based hydrological criteria						
Scale of breach for water levels (related to threshold for drought summers)	≤ 5cm		≤ 10cm	5.7cm	> 10cm	
Frequency of breaches for water levels (related to threshold for drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)	1 out of 35	≤ 3 out of 10 (= ≤ 9 out of 35)		> 3 out of 10 (= > 9 out of 35)	
Scale of breach for soil moisture (related to threshold for non-drought summers)	≤ 5 %	none	≤ 10 %		> 10 %	
Frequency of breaches for soil moisture (related to threshold for non-drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)	none	≤ 3 out of 10 (= ≤ 9 out of 35)		> 3 out of 10 (= > 9 out of 35)	
Timing of breaches	droughts only	droughts only	non-droughts only		droughts AND non-drought periods	
Soil moisture returning to saturation in winters	always	always	not in a few winters		not in most winters	
Impact on overall hydrological functioning	not significantly impacted		impacted in some years		significantly impacted in most years	
2) Appraisal of resources and abstraction scenarios						
Modelled water level under fully licensed scenario similar to naturalised / historical or close to 50% LTA recharge scenario	similar to naturalised or historical		between historical and 50% LTA recharge abstraction scenario	yes	close or above 50% LTA recharge abstraction scenario	
Fully licensed abstraction as percentage of long-term average recharge (it is important to consider over which area the comparison is made)	0-20%		20-40%	28%	>40%	
Sensitivity of modelled water table to changes in abstraction (difference between abstraction scenarios)	small		medium	medium	large	
Sensitivity to water table fluctuations indicated by field data (site generally wet?)	small		medium	precautionary medium	large	
3) Uncertainties						
Evidence to allow judgement of no ecological change available and clear?	available and clear	available and clear	available but not clear		not available	

Development of historical abstraction levels over last 15 years (enough time for ecological effects to become apparent?)	~ stable or decreasing	~ stable	slightly increasing		increasing	
Model representation adequate?	adequate	adequate	less adequate		not adequate	
Ecohydrological conceptual understanding clear and agreed?	clear and agreed	clear and agreed	less clear, not agreed		not clear, not agreed	
Field data available and sufficient?	available and sufficient		available but not entirely sufficient	Limited monitoring data, some further monitoring only started in 2007	not available and not sufficient	
Further considerations that may influence the overall risk category:						
Add site specific considerations as appropriate…						
Example: Are the abstraction licences in the vicinity of the site in the majority seasonal (agricultural), annual abstractions or PWS abstractions?						

B.2.5.3 Stage 4 Action

On the basis of new information available at Stage 4, it has been concluded that those water resources permissions included in the Habitats Directive Regulation 50 assessment are not likely to cause adverse effect on the **Ant Broads and Marshes SSSI and Alderfen Broad SSSI** component of the Broads SAC and Broadland SPA. Therefore all water resource permissions subject to the review will be **affirmed.**

B. 3 Broad Fen New information since Stage 3

Since the Stage 3 Appropriate Assessment was completed additional information has been used to enhance the conceptual understanding, reduce uncertainties within numerical modelling of the site and in the identification of appropriate thresholds and criteria against which to assess acceptable levels of abstraction. This is detailed in Section 2.4 of the Site Options Plan issue 2 (Entec, 2009) and summarised below in Table B.3.1.

Table B.3.1 New information since Stage 3

Aspect	New information
Hydrological Modelling	
Use of the Regional Groundwater Model	The Yare and North Norfolk model has been used more extensively in Stage 4 assessment of Broad Fen SSSI. The model provides better representation of chalk groundwater levels and the interaction with overlying drift on a regional scale than the methods used for the Stage 3 Appropriate Assessment. Further detail regarding the construction of the model, its calibration and its representation of the hydrological functioning of Broad Fen can be found in Chapter 4 of the SOPi2 (Entec, 2009).
Licence characterisation	Details of abstraction licences have been collated and verified. A particular requirement was to ensure awareness of any time-limited licence expiry dates and any licence conditions to ensure that all licences were properly represented in the Regional Groundwater Model and to eliminate any "double counting".
Groundwater	
Boreholes, piezometers and dipwells	There are no current monitoring data within Broad Fen. The data is limited to the period from 1992 to 1998 Minor works consisting of two shallow dipwells (BRF_25 and BRF_26) in the north and south of the site and three gaugeboards with conductivity loggers (BRF_15, BRF_16, BRF_17) located along the main arterial drain and one in a turf pond (BRF_28) at the southern end of the site are being installed in August 2007.
Surface Water	
Discharges	North Walsham Sewage Treatment Works had previously been modelled to the river but actually it is discharged to sea.
Auger Survey	7 holes were augered across Broad Fen in Feb 2007 to determine the thickness of peat and to identify the mineral soils to a depth of 1m thickness below the peat layer. The logs from the auger survey contribute to site scale cross sections and the use of the soil moisture model.
Groundwater and Surface water	Hydrochemistry assessments have been carried out by Anglian water Services Ltd as part of their AMP4

interaction	investigations (Aug 20006).
Off site – AMP Investigations	Anglian Water Services Ltd as part of AMP4 commissioned ‘Solo’ model runs for abstractions within the Ant catchment. The modelling concluded that there were no ‘alone’ impacts on Broad fen SSSI but that the abstractions could act in-combination with others upstream of Broad Fen.

B.3.1 Environmental Outcomes required for the site

At RoC Stage 3, generic targets for European Features were used. The generic targets have however been replaced by site-specific hydrological criteria to decide on acceptable levels of abstraction. The hydrological criteria are linked to the Stage 4 Environmental Outcomes provided by Natural England. The Environmental Outcomes for the Broads SAC and Broadland SPA as supplied by Natural England on 17 January 2008. For each SSSI in the Broads, the Environmental Outcomes defined by Natural England cover the requirements of all of the European features. There are no targets for otter, but it is considered that provided the hydrological requirements of the botanical features associated with the broads and dykes are met, that the habitats will be suitable for otter. The same is applicable to the contribution of the sites to the Broadland SPA.

Natural England suggest that where man's interventions on sites have been more recent or where a more-natural functioning has been maintained the Environmental Outcome should be to increase natural functioning. For instance at Broads Fen, where action would not result in an adverse affect to designated interests, effort should be made to reconnect / improve hydrological connectivity of fen and fen ditch network to the river Ant.

Table B.3.2 below summarises the water resources feature-specific Environmental Outcomes for Broad Fen SSSI and sets out the specific hydrological criteria to be used to appraise abstraction scenarios, more detail can be found in section 5.2 of the SOPi2 (Entec, 2009).

Table B.3.2 Summary of Environmental Outcomes and Criteria for Assessing Acceptable Levels of Abstraction

Interest feature location	**Description of flora and fauna under European designation**	**Spatial distribution / quality / historical problems**	**Natural England specific Environmental Outcomes** (Broads SAC as supplied 17 January 2008)	**Hydrological functioning**	**Model cell(s) used at Stage 3**	**Model criteria used to assess adverse effect at Stage 3**	**Model cell(s) used at Stage 4**	**Primary model criteria used at Stage 4**
Broad Fen	Calcareous Fen (S24)	Refer to map Figure 3.14 in SOPi2 Examples of S24 adjacent to turf ponds in south of site No apparent problems in non-drought years(or drought years) under historical levels of abstraction.	1) Summer water table should be between 3cm above and 36cm below ground level in summer months (July-September). This is the mean water level for S24 on a number of sites across East Anglia +/- 1SD (but curtailing the maximum water table to water at 4cm above ground level as measured) 2) Winter water levels are expected to be at the surface. Note: the target for S24 covers both of the communities that contribute to the calcareous fen feature. The duration, frequency and intensity of drought periods should not be significantly increased by abstraction or surface water management.	Areas of permanent seepage and shallow water table supported by upward groundwater flow from the drift / crag and chalk aquifers.	Six layer Regional Groundwater Model used. Cell equivalent to R115C291	Summer water table (July-September) to fall no more than 36cm below the surface. Winter water levels to be at no higher than 3cm above the ground surface.	Cell 'A', Figure 4.4. Cell R115C291	For non-drought summers: Soil moisture content, kept within 'ooziness' band For drought summers: Water level in uppermost model layer above lowest historical water level

Table B.3.2 (continued) Summary of Environmental Outcomes and Criteria for Assessing Acceptable Levels of Abstraction

Interest feature location	**Description of flora and fauna under European designation**	**Spatial distribution / quality / historical problems**	**Natural England specific Environmental Outcomes** (Broads SAC as supplied 17 January 2008)	**Hydrological functioning**	**Model cell(s) used at Stage 3**	**Model criteria used to assess adverse effect at Stage 3**	**Model cell(s) used at Stage 4**	**Primary model criteria used at Stage 4**
Broad Fen	Alluvial woodland (W2, W5 and W6)	Refer to map Figure 3.14 in SOPi2 Examples of alluvial woodland in north of site No apparent problems in non-drought years under historical levels of abstraction.	The generic water level target for alluvial woodland W5 and W6 is: 1) Winter water levels at or very near the ground surface 2) Spring water levels should be maintained within 5cm of the ground surface 3) Summer maximum and minimum levels should be between 5 and 45cm below the ground surface, accepting that optimal seedling growth occurs with water levels between 10 and 30cm below ground level. This should maintain the typical canopy and under-storey species. Note: this regime also applies to the W2 community. The duration, frequency and intensity of drought periods should not be significantly increased by abstraction or surface water management.	Areas of permanent seepage and shallow water table supported by upward groundwater flow from the drift / crag and chalk aquifers.	Six layer Regional Groundwater Model used. Cell equivalent to R112C292	Summer water table (July-September) to fall no more than 45cm below the surface. Winter water levels to be at or near ground surface.	Cell 'B', Figure 4.4. Cell R112C292	For non-drought summers: Soil moisture content, kept above stress threshold For drought summers: Water level in uppermost model layer above lowest historical water level

B.3.2 Model-based hydrological criteria

The Stage 4 assessment has moved away from the generic hydrological targets used at Stage 3 for assessment of risk of impact to European features. A standardised methodology for the assessment of abstraction-related impacts of groundwater-dependent habitats has been developed within Anglian region. The current methodology uses a refined Regional Groundwater Model together with new information obtained since Stage 3. The approach adopted, using the Regional Groundwater Model, is detailed in the SOPi2 (Entec, 2009).

The Environmental Outcomes provided by Natural England are based on typical groundwater levels as reported in the Ecohydrological Guidelines (Wheeler et al., 2004). The described groundwater levels and flows cannot directly be used to define hydrological thresholds to assess acceptable levels of abstraction for features within Broad Fen SSSI because:

- The guidelines do not take into account the specific conditions that exist at Broad Fen SSSI;
- Where stands are less species rich, hydrological requirements are likely to be less exacting, in that water tables are likely to fluctuate more;
- The modelled groundwater level in the top active layer represents a 200m x 200m area within which, in reality ground elevation, soil conditions, geology, water levels and flows can vary significantly;
- The modelled water levels in the uppermost layer of the Regional Groundwater Model do not exactly represent the real water table;
- The water levels observed in dipwells may not correspond with water levels reported in the Ecohydrological Guidelines because different methods are used to measure the water table.

The proposed model-based hydrological criteria for deciding acceptable levels of abstraction therefore will relate to maintaining a continued adequate supply of groundwater to the site to ensure the fen remains in, or is restored to favourable or recovering condition. Acceptable levels of abstraction for Broad Fen SSSI will be assessed using the groundwater model to appraise the effect of abstraction scenarios with regard to:

- Maintenance of an upward hydraulic gradient from the chalk to the near surface deposits – assessed by the relative elevations of groundwater levels within the chalk (layer 6) and the top active layer in the model;
- Maintenance of an upward flow of groundwater from the chalk to the near surface deposits – assessed by the relative volume of flow to the top active layer in the model;
- Impacts on groundwater level in the top active layer of the model as an indicator of abstraction effects on the depth to the water table;
- Impacts on discharge to stream layer of the model as an indicator of abstraction effects on the flows to the model cell / feature;
- Impacts on soil moisture characteristics, especially with regard to ‘ooziness’, stress thresholds and winter saturation.

For the RoC process it is essential that the Environmental Outcomes for the Broads SAC and Broadland SPA can be translated into one or more quantitative criteria specific to Broad Fen SSSI that can be predicted with the groundwater model. This is the only way in which options to achieve the Environmental Outcomes can be quantitatively assessed.

The approach to defining hydrological thresholds for Broad Fen SSSI takes into account the approach adopted for other similar sites in Anglian Region but also site-specific issues relating to the hydrological functioning of the site and to the current uncertainties in the model representation. This is described more fully in issue 2 of the Site Options Plan for Broad Fen SSSI (Entec,2009).

The general methodology developed for deciding acceptable levels of abstraction for Broads sites (Ursula Buss 2009) is applicable to sites where it can be agreed that historical levels of abstraction have not resulted in any long term adverse effect on the site. For Broad Fen SSSI, it is the best professional opinion of Natural England staff that the site is not under apparent water stress in non-drought years (under recent abstraction levels). **Based on this it is ascertained that abstraction at historical rates has not had an adverse effect on the site.**

The model criteria and associated thresholds to be used to assess acceptable levels of abstraction for Broad Fen SSSI are related to the Environmental Outcomes and hydrological functioning of the site. The Primary Criteria represent ‘hard’ targets based partly on Natural England observations of site conditions in drought and non-drought years. The Secondary Criteria inform further judgement and are related to other hydrological mechanisms that support water supply to the European Features and to the less critical period of the seasonal cycle. A secondary criteria is applied because European Features require certain wetness conditions during winter months and that full recovery to saturated conditions generally occur each winter. The site specific criteria for Broad Fen SSSI are outlined in Table B3.3 below.

Table B.3.3 Criteria and Thresholds for the assessment of Broad Fen SSSI

	Model Cell 'A' – Calcareous Fen				**Model Cell 'B' – Alluvial Woodland**				**'Local Catchment' – Natural Eutrophic Ditches**			
	Soil Moisture Content	Modelled water level in uppermost layer	Modelled upward flow into uppermost layer	Modelled discharge to stream cell	Soil Moisture Content	Modelled water level in uppermost layer	Modelled upward flow into uppermost layer	Modelled discharge to stream cell	Soil Moisture Content	Modelled water level in uppermost layer	Modelled upward flow into uppermost layer	Modelled discharge to stream cell
Non-drought Summer	**>stress threshold**	> lowest historical in non-drought summers = August 1993 = 0.667mAOD	Flow in August 1993 = 65.415m^3/d	Discharge in August 1993 = -40.729m^3/d	**> stress threshold**	> lowest historical in non-drought summers = August 1993 = 0.789mAOD	Flow in August 1993 = 13.002m^3/d	Not stream cell	N/A	N/A	Flow in September 2001 = 5.91m^3/d	N/A
Drought Summer	> stress threshold	**> lowest historical in drought summers = July 1976 = 0.413mAOD**	Flow in July 1976 = 96.116m^3/d	Discharge in July 1976 = -15.335m^3/d	> stress threshold	**> lowest historical in drought summers = July 1976 = 0.454mAOD**	Flow in July 1976 = 51.701m^3/d	Not stream cell	N/A	N/A	Flow in January 1989 = 49.76m^3/d	N/A
Non-drought Winter	Return to saturation	> lowest winter peak in non-drought winters = February 2005 = 1.07mAOD	Flow in February 2005 = 65.186m^3/d	Discharge in February 2005 = -80.991m^3/d	Return to saturation	> lowest winter peak in non-drought winters = February 2005 = 1.294mAOD	Flow in February 2005 = -7.1437m^3/d	Not stream cell	N/A	N/A	N/A	N/A
Drought Winter	Return to saturation	> lowest winter peak in drought winters = January 1973 = 0.859mAOD	Flow in January 1973 = 51.388m^3/d	Discharge in January 1973 = -59.933m^3/d	Return to saturation	> lowest winter peak in drought winters = February 1973 = 0.998mAOD	Flow in February 1973 = -2.4854m^3/d	Not stream cell	N/A	N/A	N/A	N/A

=primary criteria

The model Cell ‘A’ (R115 C291) was chosen to best represent the location of calcareous fen (S24) whilst model Cell ‘B’ (R112C292) was used to best represent alluvial woodland (W2, W5 and W6) as shown in Figure 4.4 of the Site Options Plan issue 2 for Broad Fen SSSI (Entec, 2009). Assessment of the Natural Eutrophic Lakes and Hard Oligo-Mesotrophic waters with benthic vegetation of *Chara spp*. was assessed by reference to the local catchment.

B.3.4 Results of groundwater modelling

Since the completion of the Stage 3 Appropriate Assessment in September 2006, a standardised methodology for the assessment of abstraction-related impacts on groundwater-dependant habitats has been progressively developed within Anglian region for the RoC process. This has employed the use of Regional Groundwater Models that weren't available during Stage 3 or that have since been further refined, plus new information about each site derived from continued monitoring activity. This new approach is more risk-based, taking account of the effects of historic abstraction regimes, site condition and professional judgement.

The Regional Groundwater Model has been used to simulate the effects of abstraction under several abstraction scenarios for the 35 year period from 1970 to 2004. The basic scenarios were "naturalised", "historical" abstraction and "real fully licensed (RFL)" abstraction. The modelling scenarios are described in detail section 7.2 of the SOP issue 2, (Entec, 2009). The RFL scenario includes abstractions at fully licensed rates but takes account of aggregate limitations within the licence conditions. The abstractions from individual sources within the aggregate are weighted such that the maximum abstraction takes place from the sources in closest proximity to the site.

The criteria detailed in Table C.3.4, based on soil moisture content or lowest modelled historical groundwater levels, are used for comparison with time series modelled for different abstraction scenarios which are all based on the same climatic time series for the 35 year period from 1970 up to the end of 2004. Details can be seen in table C.3.4.

Results for the Real Fully Licensed abstraction scenario

Model Cell A – Calcareous Fens
Under the Real Fully Licensed scenario, the Drought summer primary criteria of lowest modelled water level is failed in one drought year by 5.2cm.

Model Cell B – Alluvial Woodland
Under the Real Fully Licensed scenario, the Drought summer primary criteria of lowest modelled water level is failed in two our of 10 drought summers by up to 6.9cm

Local Catchment
The upward flow threshold (not a primary criteria) is breached twice in non-drought summers and once in drought summers.

Table B.3.4 Assessment of Abstraction Scenarios against Model-based Hydrological Criteria for Broad Fen SSSI

Interest Feature Location	Historical Model-based Hydrological Criteria	Historical	Real fully Licensed
Broad Fen (Model Cell 'A': R115_C291) Calcareous Fen (S24)	**Non-drought summers: Soil moisture content above stress threshold** August 1993 lowest water level (0.667mAOD); and associated regime of upward flow to top active layer and stream discharge	No problem by definition	**Modelled soil moisture content does not go below stress threshold in any non-drought summers.** Water level breaches threshold in 3 non-drought summers by maximum of 4.6cm. Lowest (minimum required) upward flow reached in all non-drought summers. Stream discharge threshold not reached in 3 non-drought summers.
	Drought summers: July 1976 lowest water level (0.413mAOD), and associated regime of upward flow to top active layer and stream discharge Soil moisture content above stress threshold	No problem by definition	**Modelled water levels fall below the threshold in one drought year (by a maximum of 5.2cm).** Soil moisture content exceeds stress threshold in 1 drought summer. Threshold for lowest upward flow not reached in 9 out of 10 drought summers; though naturalised flow also fails to reach the threshold in 8 drought years. Stream discharge threshold not reached in 1 drought summer.
	Non-drought winters: Return to saturation; February 2005 lowest peak water level (1.07mAOD); and associated regime of upward flow to top active layer	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level not achieved in 3 non-drought winters.
	Drought winters: Return to saturation; January 1973 (0.859mAOD) and associated regime of upward flow to top active layer	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak level not achieved in 2 drought winters

Table B. 3.4 Comparison of Abstraction Scenarios against Model-based Hydrological Criteria for Broad Fen SSSI

Interest Feature Location	Historical Model-based Hydrological Criteria	Historical	Real Fully Licensed
Broad Fen (Model Cell 'B': R112_C292) **Alluvial Woodland** (W2, W5, W6)	**Non-drought summers**: **Soil moisture content above stress threshold** August 1993 lowest water level (0.789mAOD); and associated regime of upward flow to top active layer	No problem by definition	**Modelled soil moisture content does not go below stress threshold in any non-drought summers.** Water levels do breach threshold in 3 non-drought summers by max of 6.2cm. Lowest (minimum required) upward flow not reached in 17 non-drought summers.
	Drought summers: July 1976 lowest water level (0.454mAOD), and associated regime of upward flow to top active layer Soil moisture content above stress threshold	No problem by definition	**Modelled water levels fall below the threshold in two drought years (by a maximum of 6.9cm).** Soil moisture content does not exceed stress threshold in any drought summers. Threshold for lowest upward flow not reached in 9 drought summers; though naturalised flow fails to reach the threshold in all drought years
	Non-drought winters: Return to saturation; February 2005 lowest peak water level (1.294mAOD); and associated regime of upward flow to top active layer	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak water level not achieved in 1 non-drought winter.
	Drought winters: Return to saturation; February 1973 (0.998mAOD) and associated regime of upward flow to top active layer	No problem by definition	Return to soil moisture saturation in all winters. Lowest winter peak level achieved in 10 drought winters

Table B.3.4 Comparison of Abstraction Scenarios against Model-based Hydrological Criteria Broad Fen Local Catchment for Broad Fen SSSI

Interest Feature Location	Historical Model-based Hydrological Criteria	Historical	Real Fully Licensed
Broad Fen (Local Catchment) (Natural Eutrophic Ditches)	**Non-drought summers:** September 2001: lowest historical upward flow to top active layer	No problem by definition	Threshold for lowest upward flow not reached in 2 non-drought summers;
	Drought summers: January 1989: lowest historical upward flow to top active layer	No problem by definition	Threshold for lowest upward flow not reached in 1 drought summer;
	Non-drought winters: May 1987: lowest peak winter historical upward flow to top active layer	No problem by definition	N/A
	Drought winters: June 1973: lowest peak winter historical upward flow to top active layer	No problem by definition	N/A

Note: Primary Criteria indicated in **bold**

B.3.5.1 Summary of Anglian Region's Technical Approach for "Inland Sites"

This approach is detailed in Buss (2009) and summarised here.

For sites where we judge that historical levels of abstraction have been considered acceptable we use thresholds for model-based hydrological criteria which are based, for example, on the lowest modelled historical water level in the top active layer of the numerical model. The use of thresholds which are based on the historical time series and lowest historical groundwater heads and flows inherently results in at least one breach since fully licensed abstraction is generally greater than historical abstraction in most catchments. In addition to the one 'default' breach, there is often only a very small number of breaches (if any) and most of the breaches may only be in the order of millimetres or a few centimetres, a few percent of soil moisture content or a few litres per day of flow.

The historical time series is used as a baseline because this is the only 'scenario' which has been experienced in the past and therefore can be compared with ecological and hydrological observations. In reality, adverse effects on site integrity may only start to occur once water levels and flows are somewhat lower than experienced in the past. Since this situation is outside of the range of our experience it is difficult to identify absolute thresholds when adverse effect will start to occur. Licence modifications may therefore not be necessary if hydrological impacts from fully licensed abstraction are greater than under the historical scenario by only an insignificant amount, i.e. if the number and scale of breaches is small, and if the risk of adverse effects on the site integrity actually occurring is judged to be sufficiently low.

We are therefore applying a risk-based approach that scales the need for licence modifications according to the risk to the site and a decision table (or "risk matrix") has been developed as a generic tool.

The 'risk-matrix' is applied by assigning a 'risk category' to each site (generally component SSSIs if a SAC or SPA consists of more than one SSSI). The risk matrix takes into account the scale and frequency of breaches to primary criteria thresholds, in the context of the conceptual understanding and the model representation, changes to the overall hydrological functioning, the general level of fully licensed and historical abstraction in the catchment surrounding the site and uncertainties around the ecological 'evidence' available. Professional judgement will be applied to the interpretation of the risk matrix and in deciding on the appropriate risk category.

There is a presumption that, for sites which are assigned a 'low risk category', no abstraction licence modifications will need to be investigated through the options appraisal process. The assumption is that for those sites, the risk that adverse effects on site integrity would occur and the Environmental Outcomes cannot be achieved is sufficiently low despite some (small and infrequent) breaches of thresholds.

For sites in the 'medium risk' and 'high risk' categories abstraction licence modifications will be investigated during the options appraisal process. The presumption is that licences would need to be modified so that the site then falls into the ‘low risk’ category.

The difference between ‘medium risk’ and ‘high risk’ is the scale of abstraction licence modification. Most of the ‘medium risk’ sites may only require some restriction to actual abstraction in years with exceptionally dry conditions, whilst ‘high risk’ sites may require a general reduction in licensed quantity. However, the scale and detail of any modification will depend on the individual site and the licences implicated.

For SAC / SPAs with more than one component SSSI, the application of the risk matrix will direct the options appraisal work with regard to individual component SSSIs but does not preclude the overall Stage 4 conclusion for the European site. If necessary, sites in the ‘low risk’ category could be reconsidered at a later stage, although this is not expected to happen in general.

B.3.5.2 Conclusions from the risk matrix

A Site Option Plan decision table (or “risk matrix”) listing the hydrological criteria and the degree to which they are met for each scenario, is presented in Table B.3.5. The modelling results which are most relevant are found in Figs 7.1 and 7.2 of the SOP issue 2 and the threshold breaches are summarised in Table 7.2 of the SOP issue 2 (Entec 2009).

The conclusions drawn from application of the new model-based hydrological criteria to the abstraction scenarios, in conjunction with the “Risk Matrix” decision table in Table B.3.5 are that:

- Environmental Outcomes are **achieved** under recent historical abstraction (by definition)
- There is sufficiently low risk associated with real fully licensed abstraction that Environmental Outcomes are likely to be **achieved**.

This latter conclusion is consistent with the risk-based approach devised and adopted by Anglian Region during the development of Stage 4 of the Review of water resources permissions. Natural England agreed with the assessment of this site as low risk on 15 December 2008.

Table B.3.5 Risk matrix for Broad Fen SSSI

	Risk Category					
Criteria	**Low**	***Site details***	**Medium**	***Site details***	**High**	***Site details***
1) Performance against model-based hydrological criteria						
Scale of breach for water levels (related to threshold for drought summers)	≤ 5cm		≤ 10cm	*6.9cm*	> 10cm	
Frequency of breaches for water levels (related to threshold for drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)	*1 out of 35*	≤ 3 out of 10 (= ≤ 9 out of 35)		> 3 out of 10 (= > 9 out of 35)	
Scale of breach for soil moisture (related to threshold for non-drought summers)	≤ 5 %	*none*	≤ 10 %		> 10 %	
Frequency of breaches for soil moisture (related to threshold for non-drought summers)	≤ 1 out of 10 (= ≤ 3 out of 35)	*none*	≤ 3 out of 10 (= ≤ 9 out of 35)		> 3 out of 10 (= > 9 out of 35)	
Timing of breaches	droughts only	*droughts only*	non-droughts only		droughts AND non-drought periods	
Soil moisture returning to saturation in winters	Always	*always*	not in a few winters		not in most winters	
Impact on overall hydrological functioning	not significantly impacted	*hardly impacted*	impacted in some years		significantly impacted in most years	
2) Appraisal of resources and abstraction scenarios						
Modelled water level under fully licensed scenario similar to naturalised / historical or close to 50% LTA recharge scenario	similar to naturalised or historical		between historical and 50% LTA recharge abstraction scenario		close or above 50% LTA recharge abstraction scenario	*yes*
Fully licensed abstraction as percentage of long-term average recharge (it is important to consider over which area the comparison is made)	0-20%		20-40%	*27%*	>40%	
Sensitivity of modelled water table to changes in abstraction (difference between abstraction scenarios)	Small	*small*	medium		large	

Sensitivity to water table fluctuations indicated by field data (site generally wet?)	Small	*small*	medium		large	
3) Uncertainties						
Evidence to allow judgement of no ecological change available and clear?	available and clear	*available and clear*	available but not clear		not available	
Development of historical abstraction levels over last 15 years (enough time for ecological effects to become apparent?)	~ stable or decreasing	*~ stable*	slightly increasing		increasing	
Model representation adequate?	Adequate	*adequate*	less adequate		not adequate	
Ecohydrological conceptual understanding clear and agreed?	clear and agreed	*clear and agreed*	less clear, not agreed		not clear, not agreed	
Field data available and sufficient?	available and sufficient		available but not entirely sufficient	*Limited monitoring data, some further monitoring only started in 2007*	not available and not sufficient	
Further considerations that may influence the overall risk category:						
Add site specific considerations as appropriate…						
Example: Are the abstraction licences in the vicinity of the site in the majority seasonal (agricultural), annual abstractions or PWS abstractions?						

Note: If more than one assessment cell on a SSSI use the one with highest risk to decide on overall site risk category

B.3.6 Stage 4 Action

On the basis of new information available at Stage 4, it has been concluded that those water resources permissions included in the Habitats Directive Regulation 50 assessment are not likely to cause adverse effect on the **Broad Fen SSSI** component of the Broads SAC and Broadland SPA. Therefore all water resource permissions subject to the review will be **affirmed.**

Other Influences on the site

Other influences and pressures on the site came to light during the work leading to the conclusions in this SAP but which were outside the remit of the Review of Consents to address.

This included local abstraction licences which had already been assessed under Regulation 48 as new permissions and as such cannot be reviewed under Regulation 50. Information from the review and also up to date information gathered as part of the licensing process will be considered in any licence renewal under Regulation 48.

SECTION C: OPTIONS AVAILABLE

C1 WATER QUALITY

As detailed in section B1 above, the following section relates only to the Ant Broads and Marshes site, as Broad Fen already complies with its derived RoC targets.

Therefore NAEOI can be concluded for all discharges in relation to Broad Fen.

These discharges also have the potential to affect the Ant Broads and Marshes and so are assessed for this site below.

All discharges brought forward to Stage 4 for the Ant Broads and Marshes have the potential to act in-combination and all fourteen are shown in Table A1.1. They will be assessed in turn in the sections below either by using SIMCAT modelling, calculations or other information.

C1.1 Assessment of discharges to land

Table C1.1 Discharges to land

Number	Location	Max. consented volume (m3/day)	NGR
AEELF12300	Barton turf	44.4	TG3492022490
AEELF12298	Neatishead	25.4	TG3466420130
AEELF12296	Neatishead	38.0	TG3392020380

These three discharges have been considered under regulation 48 but have been included for in combination purposes on a precautionary basis. AEELF12300 is not close to any watercourses and is isolated by peats; the assessment is that it is cut off from any direct inputs to watercourses.

AEELF12296 and AEELF12298 both enter is the Alderfen Stream, and this then reaches the River Ant downstream of the site. These permissions therefore do not need to be considered any further in combination with those in RoC.

C1.2 Discharges screened out as a result of assessment of Broad Fen SSSI

Five discharges enter the River Ant / Dilham Canal or its tributaries upstream of Broad Fen. These have been have been assessed in the SAP for Broad Fen. They are upstream of Broad Fen and Broad Fen is upstream of the Ant Broads and Marshes site. They have been assessed as causing no adverse effect on the features of Broad Fen, using the same Environmental Outcome of 0.05mg/l. Because they are further away from the Ant site than they are Broad Fen it is therefore concluded that they also will have no adverse effect on the Ant Broads and Marshes SSSI also.

Therefore NAEOI can be concluded for AEENF12002, AWENF103, PR4NF270, PRENF327 and PR4NF568 for the Ant Broads and Marshes site.

C1.3 Small discharges added to the SIMCAT model used for Ant Broads and Marshes

Small sewage works have been added to this model because population equivalent information (from Anglian Water) is available which allows an actual discharge volume to be calculated and used in calibration of the model. These are AW4NF1091X (Sloley STW) and AW4NF637X (Smallburgh STW). These will be assessed and options identified as part of the SIMCAT modelling process.

C1.4 Small discharge not in the SIMCAT model

There is a private discharge (PR4NF1560) which enters the same watercourse as Sloley STW but further upstream. It has not been possible to model PR4NF1560 in SIMCAT as there is no data on its actual volume or concentration, and using estimates based on its maximum volume would mean the calibration of the model is not accurate. It is approximately the same consented size as Sloley, therefore as it is further upstream of Sloley and a similar consented volume, results from Sloley will be used to give an precautionary estimate of its effect on river concentration.

C1.5 Discharges assessed for Ant Broads and Marshes using the SIMCAT model

These are the discharges in the original model plus the two small ones added (C1.3). Therefore are AW4NF1091X (Sloley), AW4NF637X (Smallburgh STW), AEENF1312 (Stalham STW), AW4NF807 (Horning STW), and PR4NF660X (Private discharge at Westwick). The last three have a P limit in their consents of 1mg/l. PR4NF660X is a Regulation 48 consent and will be considered in-combination only.

C1.6 Results of SIMCAT scenarios

Over 30 scenarios have been run to look at the effects of changing P limits, volumes and river flows. A summary of the SIMCAT scenarios carried out and the outcomes are shown in this section below. Details of the conditions used in each scenario can be found in the WQ appendix WQ2. Where the predicted concentration complies with the RoC target this is highlighted.

The RoC targets are 0.052 at ANT150 and 0.037 at ANT180.

Scenarios 1 to 3

These compare actual (calibrated) concentrations to fully consented (pre-1998 baseline) and fully consented (now).

Table name?

Number	**Scenario**	**Conc. at ANT150**	**Conc. at ANT180**	**Reduction from current fully consented (%)**		**Reduction from fully consented baseline (%)**	
				Ant150	Ant180	Ant150	Ant180
1	Calibrated	0.038	0.019				
2	Fully consented baseline (pre 1998)	0.124	0.059			0	0

3	Current fully consented (now)	0.084	0.040	0	0	32	15

The data shows that the in-river concentrations are compliant with the RoC target at current actual conditions.

The fully consented concentration now (Scenario 3) is considerably reduced compared to the pre-1998 baseline (Scenario 2). This is due to a 1mg/l P limit now in place at PR4NF660X, which has provided between a 15% to 32% reduction in P concentration. A 1mg/l P limit was also put in place at Stalham in 1997, however for some time previous to this (in the earlier 1990s) the average P in the discharge was already 1mg/l so the effect of putting a 1mg/l P limit in place has no effect when before and after at fully consented conditions, are compared. However there has been a considerable reduction when compared to concentrations in the effluent in the 1980s – then P concentrations were up to 10mg/l.

The fully consented concentration now is considerably higher than the actual (calibrated), particularly at ANT150. This is due to the good performance of the Stalham STW and a small amount of headroom in the volume of the STW consent. The consented P concentration is 1.0mg/l and the actual concentration (average for 2000 onwards) is 0.4mg/l. The consented DWF is 2600 m^3/day, and the current DWF is around 2400 m^3/day.

RoC targets are complied with under actual monitored conditions

Scenarios 4 to 8
These look at switching the discharges off individually.

The fully consented scenarios (2 and 3) are also shown so that changes to these can be compared.

Table name?

Number	Scenario	Conc. at ANT150	Conc. at ANT180	Reduction from current fully consented (%)		Reduction from fully consented baseline (%)	
				Ant150	Ant150	Ant150	Ant180
2	Fully consented baseline (pre 1998)	0.124	0.059				
3	Current fully consented (now)	0.084	0.040	0	0	32	15
4	Sloley switched off	0.083	0.040	1	0	33	15
5	Smallburgh switched off	0.082	0.040	2	0	34	15
6	Stalham off	0.038	0.018	55	55	69	69
7	Horning off	0.084	0.040	0	0	32	32
8	PR4NF660X off	0.081	0.039	4	3	35	34

Results show that switching off PR4NF660X has only a small effect at ANT150 and no real effect at ANT180, compared to the current fully consented concentrations. The only significant change from an individual discharge is when Stalham is switched off. PR4NF660X is shown here for comparison with other discharges only, individual consideration of PR4NF660X is not taken further as it has already been assessed individually under Regulation 48. It is used in further scenarios in-combination only.

Therefore all other discharges except Stalham can be considered to have NAEOI individually as a result of these scenarios.

Scenarios 9 and 10

These look at increasing river flows.

Table name?

Number	Scenario	Conc. at ANT150	Conc. at ANT180	Reduction from current fully consented (%)		Reduction from fully consented baseline (%)	
				Ant150	Ant180	Ant150	Ant180
2	Fully consented baseline (pre 1998)	0.124	0.059				
3	Current fully consented (now)	0.084	0.040	0	0	32	15
9	Fully consented – river flows increased by 11%	0.081	0.039	4	3	35	34
10	Fully consented – river flows increased by 20%	0.075	0.036	11	10	40	39

River concentrations show some effect with changes in flows. An increase in flow of 20% reduces the river P concentration by at least 10% from current fully consented conditions at both points. ANT180 meets the RoC target with a 20% increase in flow.

An increase in flow of 11% was modelled as this is the maximum increase in flows predicted if all water abstractions were switched off. There is little change in concentration as a result of this flow increase (between a 2.5 to 3.5 % decrease) in concentrations and this is within the confidence limits of the model.

Therefore an increase in flow of 11% results in a negligible effect on in-river concentrations.

Scenario 11

These look at changes in headroom at Stalham STW. Discharges with no effect individually when switched off are not considered here.

Table name?

Number	Scenario	Conc. at ANT150	Conc. at ANT180	Reduction from current fully consented (%)		Reduction from fully consented baseline (%)	
				Ant150	Ant180	Ant150	Ant180
2	Fully consented baseline (pre 1998)	0.124	0.059				
3	Current fully consented (now)	0.084	0.040	0	0	32	15
11	Stalham headroom removed – (DWF of 2400)	0.080	0.039	5	3	35	34

The new procedure for calculating DWF results in a volume of 2400 m³/day for Stalham. The estimated volume in the consent is 2600m³/day. Removal of the headroom volume at Stalham results in only a small reduction in concentrations in the river at ANT150, and no real change at ANT180, compared to current fully consented conditions. Neither point complies with the RoC target.

Therefore removal of headroom results in a negligible benefit.

Scenario 12

This looks at the effects of changing concentrations in discharges. Stalham and PR4NF660X both already have P limits of 1mg/l in the consents so any reduction in concentration would not generally be considered as this would be beyond BAT. However ‘realistic’ concentrations can be modelled. Generally the composition of final effluents cannot be designed to exactly meet consented limits due to inherent variability in the production and treatment processes. The risks of exceeding the consented limit are too great if operators were to aim for the consented amount. Therefore effluent processes are designed such that typical effluent concentrations are significantly less than consented limits. Anglian Water have confirmed that their STWs are operated so that the P concentration in the discharge is at least 0.3mg/l below the consented one. Therefore for a limit of 1mg/l the works would be run to not exceed 0.7mg/l P. Horning also has a P limit so is also considered in combination here.

Table name?

Number	**Scenario**	**Conc. at ANT150**	**Conc. at ANT180**	**Reduction from current fully consented (%)**		**Reduction from fully consented baseline (%)**	
				Ant150	Ant180	Ant150	Ant180
2	Fully consented baseline (pre 2000)	0.124	0.059				
3	Current fully consented (now)	0.084	0.040	0	0	32	15
12	Stalham, Horning and PR4NF660X at 0.7mg/l	0.068	0.033	19	18	45	44

This shows that there is a substantial reduction in concentration when realistic concentrations are used and ANT180 easily complies with the RoC target.

Scenarios 13 and 14

This looks at a combination of realistic concentrations in the discharge, together with an increase in river flows.

Table name?

Number	**Scenario**	**Conc. at ANT150**	**Conc. at ANT180**	**Reduction from current fully consented (%)**		**Reduction from fully consented baseline (%)**	
				Ant150	Ant180	Ant150	Ant180
2	Fully consented baseline (pre 2000)	0.124	0.059				
3	Current fully consented (now)	0.084	0.040	0	0	32	15
13	Horning and PR4NF660X at 0.7, +	0.066	0.033				

	Stalham at 0.5mg/l, + river flows increased by 11%						
14	Horning and PR4NF660X at 0.7, + Stalham at 0.5mg/l, + river flows increased by 20%	0.056	0.029				

The 11% increase in flow shows little change to scenario 12.

Even with all at realistic conditions and a 20% increase in flow the Roc target is not met at both points.

C1.7 Discussion of results and options

All options will be identified in this section and discussed. This uses results from the scenarios and other information.

The options are:

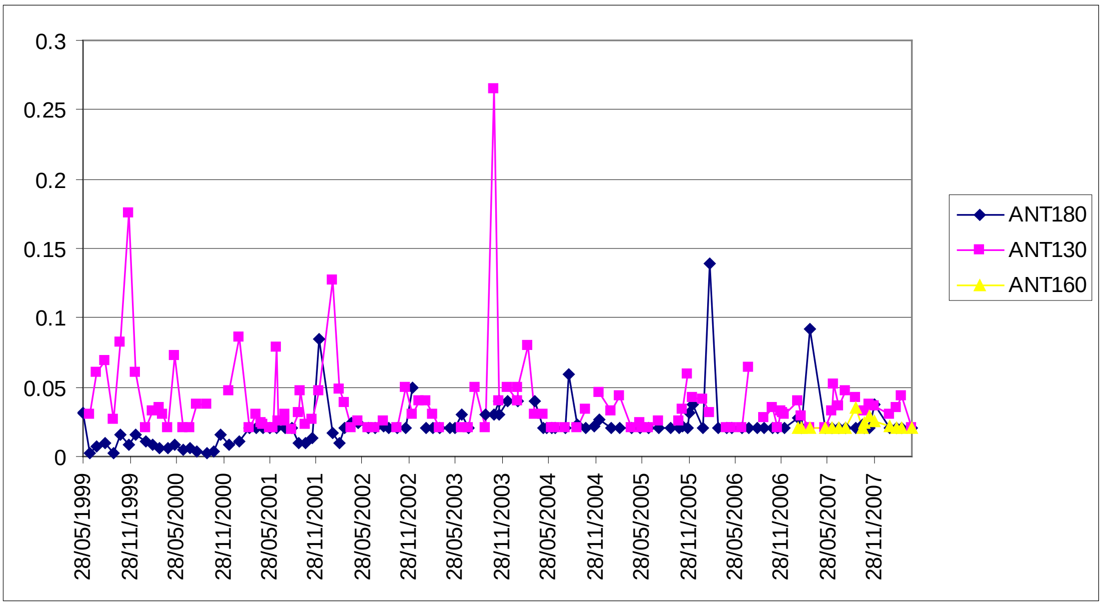
- No changes to consents and continue monitoring
- Revoke consents or move discharges
- Changes to headroom in consent volume
- Changes to P limits in the consent and consideration of ‘real’ concentrations
- Links to water resource work with flow increases in the river

1. No changes to consents and continue monitoring

Scenario 1 shows that the river currently complies with the RoC targets at both points. Recent concentrations are 0.038mg/l at ANT150 and 0.019mg/l at ANT180, and the RoC targets are 0.052 and 0.037 respectively so actual concentrations are well below.

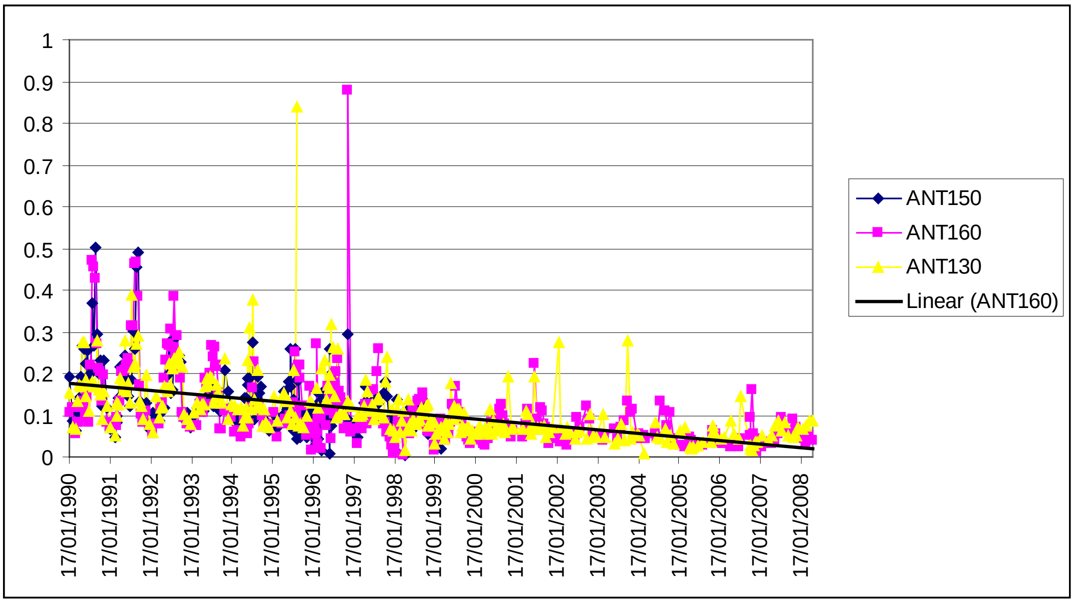
Figure C1.1 below shows the OP results, these are generally below the RoC targets. Many results are ‘less thans’ so the trend in these results cannot easily be seen but this means that the real OP results will be less than shown. ANT160 is Barton Broad.

Figure name?



TP can also be plotted and is shown in **figure C1.2**. The trend is downwards.

Figure name?



Some results indicate the points are already meeting the overall Environmental Outcome – ANT160 (Barton Broad) was 0.50mg/l in 2006 and 0.54mg/l in 2007, and ANT130 was 0.48mg/l in 2006.

Also the results from Barton Broad – the SAC lake within the site – tend to be lower than concentrations at ANT150, which is the point used in modelling. The most recent results where both are available are shown below:

Table name?

Year	ANT150 (River Ant)	ANT160 (Barton Broad)
1994	0.135	0.097
1995	0.122	0.119
1996	0.122	0.139
1997	0.119	0.097
1998	0.085	0.078

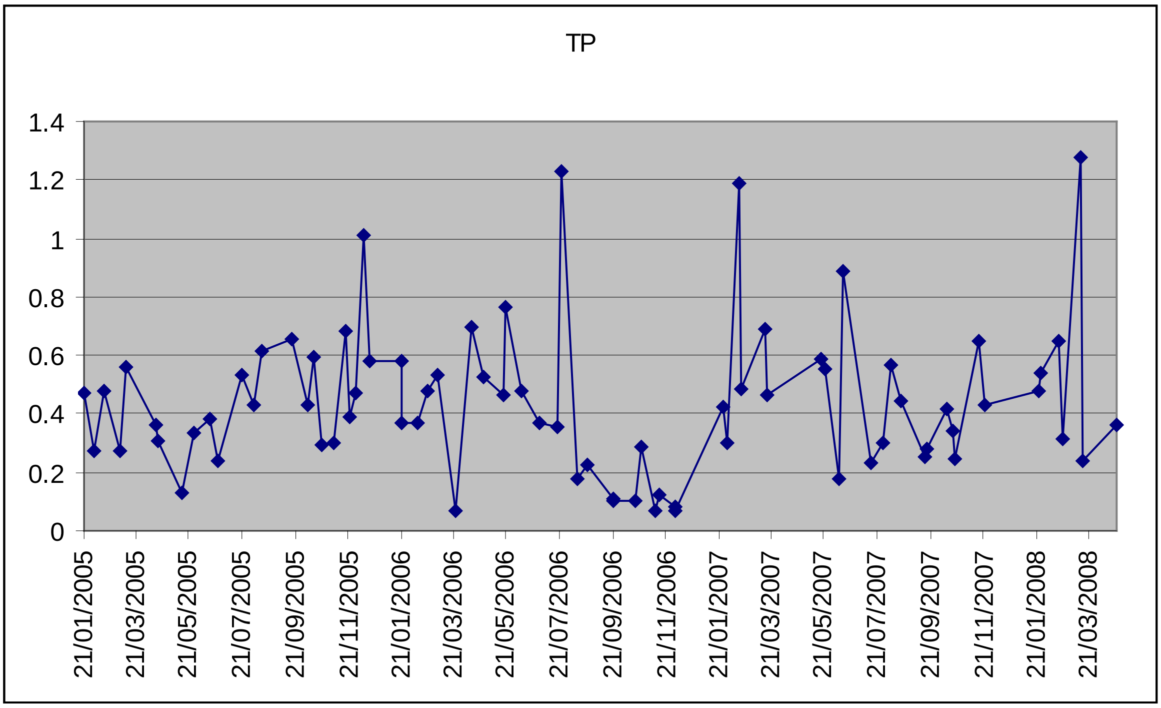
Concentrations used in modelling and calculating RoC targets for the river are therefore precautionary for the Broad.

P concentrations in the river are low because there have been many previous schemes in the River Ant with P removal at 3 works in the catchment – Stalham, Horning and PR4NF660X. All are at 1mg/l. These were put in previous to the AMP3 process, with removal starting in 1977 at Stalham and being updated in 1997 when a limit of 1mg/l P was put in place. The River Ant is designated a Sensitive Area (eutrophic) and studies have been carried out to assess the reductions in P loadings to the river due to changes in discharges. As a result of all the P reduction measures put in place there has been a 94% reduction in P loads to the River Ant.

As mentioned previously, current P concentrations are also low due to good performance at Stalham STW. This is the closest works to the site and discharges less than 1km upstream of the site boundary. Anglian Water have stated the good performance is because it is a relatively small works with large sand filters.

Therefore the good performance is a factor of the physical aspects of the works. Performance has remained consistently good averaging around 0.4mg/l P.

Figure C1.3 P concentration in the effluent of Stalham



In conclusion the RoC target is met at current operation. P concentration results are good and show a downward trend in the receiving water.

However there is a risk that the loading from the works could increase above the current situation – this could be if the concentration increases. This could mean that the RoC target may not be met. Therefore further options need to be considered to lower the risk of the RoC being exceeded in the future.

2. Revoke consents and move discharges

This was investigated in scenarios 4 to 8, where discharges were switched off. The only discharge to have a significant effect when switched off (i.e. revoked or moved) is Stalham. This is because it is close to the site. Removal of this discharge results in the RoC target being met. Therefore revocation or moving the discharge options need only to be considered for Stalham.

Revocation of the STW discharge consent would require the discharge to be subsequently re-consented elsewhere. This discharge couldn't go into adjacent catchments (e.g. Bure or Thurne) as they are still part of the Broads / Broadland SAC / SPA and there are nutrient issues in these sites. Alternatives are to move the discharge further downstream, or to the sea, or to another STW such as North Walsham which discharges to the sea.

Pumping downstream of the site would require a pipeline of at least 7km. Relocating the discharge downstream would not completely divert the Stalham STW effluent from the Ant Broads and Marshes due to the tidally influenced nature of the river at this point. Moreover, moving the discharge downstream of the site would move the discharge point closer to other constituent SSSIs of the Broadland SAC and Broads SPA and Breydon Water SPA, increasing phosphorus loads to these sites. Therefore re-location downstream is unlikely to be effective or an appropriate option.

Diverting the sewage from Stalham to North Walsham STW would require a pipeline of approximately 11km, or from Stalham to the coast approximately 7km. The initial capital cost for such a pipeline would be expected to be at least £10 million, this cost does not take into consideration land procurement, or any additional costs associated with laying pipeline in sensitive environments such as SACs. In addition to the capital costs, a pipeline of this kind would have operational costs for maintenance and pumping the effluent. Additionally the carbon footprint of construction and operating such a pipeline would be considerable. There would be disturbance associated with the pipe and it may cross SSSIs and archaeological sites. Therefore as a result of these financial and environmental costs pumping the discharge to sea or other STWs is not considered appropriate, particularly as RoC targets are currently met in monitored results from the river.

3. Changes to volume Headroom

This is shown in scenario 11. Removal of volume headroom at Stalham has only a small change at ANT150, with a 0.004mg/l change in concentration. The DWF at Stalham has been calculated using new agreed guidance (Regulation of sewage discharge flow, Policy Number: 385_07). This sets the definition of DWF as ‘the total daily flow value that is exceeded by 80% of the total daily flow values in any period of twelve months’. For Stalham using recent data this is 2400m³/day. Previous methods used an estimated volume per person , but infiltration rates are difficult to estimate and so these methods frequently underestimated the actual DWF. The consented DWF is 2600m³/day, a difference of 200m³/day (or 8%) from the actual volume. Advice from the Environment Management team is that this difference is considered negligible and reducing the DWF would not be considered appropriate. Additionally modelling shows that reducing the volume gives only a small decrease in concentration in the river, that is within the error of the model.

4. Changes to P limits in the consent and consideration of ‘real’ concentrations

Stalham was the only discharges that had any real effect on the river concentration when switched off, so this would be the only one that would have any effect with the concentration reduced. It is at 1mg/l already which is BAT for this works. Going further than BAT is not Environment Agency policy, therefore scenarios involving reductions to the P limit in the consents have not been considered further.

However realistic concentrations have been modelled as STWs are operated to ensure that the concentration in the discharge will not exceed the consented limit and this is at least 0.3mg/l lower than the consented limit. Therefore a works with a limit of 1mg/l means it is operated to be less than 0.7mg/l. This has been confirmed in discussions with Anglian Water. This results in a considerable reduction in concentration of around 19% from current fully consented conditions (and 45% from baseline conditions). This means the RoC target at ANT180 is easily met (Scenario 12).

5. Links to water resource work with flow increases in the river
Flow increases in the river have an effect on concentrations. New modelling has been carried out by contractors for the Environment Agency to re-model the groundwater and rivers. This provides more accurate information on the current and fully licensed conditions and whether there is enough water for features to be supported at sites under a range of scenarios.

The Site Option Plans for the Ant Broads and Marshes, and Broad Fen indicate that the 'hydrological functioning of the site is not significantly impacted by real fully licensed abstraction'. This means that if all the abstractions were used at their maximum allowed amounts there would be enough water to prevent adverse impact to the features of the sites. Therefore for both sites no changes to abstraction licences are planned.

However changes to abstraction licences are required to protect Smallburgh Fen. These will involve restricting the amounts of water that can be abstracted and is very likely to lead to a small increase in flow in the Dilham stream (at the top of the Ant Broads and Marshes area) compared to historic conditions.

As part of the new modelling the effects of switching off abstractions on river flows was considered. If all abstractions were switched off then the increase in river flows has been predicted as 11% (compared to historic). This is considered in scenario 9 and resulted in a small decrease in concentration, considered to be within the variation of the model and not considered to be a significant reduction.

C1.9 Conclusion and identification of preferred option

A summary of the main points from previous sections is given below:

- The RoC targets are met at current operating conditions and total P data shows a decrease over time;
- The approach being taken is that options should look at ways to reduce the risk of the RoC target being exceeded in the future;
- Previous P removal at point sources in this catchment prior to RoC has already resulted in a reduction of 94% of P loads;
- The works close to and capable of influencing the site are at BAT;
- The point used for modelling is in the river and so is precautionary for the SAC lake;
- Removing headroom at Stalham results in a very small predicted reduction in P concentration and is not a feasible option;
- Modelling at realistic conditions shows a reduction of 19% and the RoC target is met at one sample point;
- It is considered to be overly onerous to remove or re-direct the effluent (taking financial and environmental aspects into account) particularly as targets are currently met;
- Switching off all abstractions only results in a decrease of around 3% in the concentrations and is not considered significant or reasonable;
- Monitoring has been set up so that river points within the site and Barton Broad will be assessed for total P and Ortho P concentrations and acted on as part of the WFD process.

Diffuse inputs in this area are also being tackled as the River Ant is within a Catchment Sensitive Farming (CSF) area. The CSF initiative aims to reduce diffuse pollution from agriculture. Recent work has focused on the Hundred Stream, which joins the River Ant just upstream of Broad Fen. The outcomes of this work have included changes in management practices with less intensive farming; more farms in entry level and higher level stewardship schemes which include plans for arable conversion to grassland; and setting up of soil management plans. These changes should result in a reduction in the amounts of soil and nutrients lost from fields to the rivers. Work is continuing and is funded for another 2 years.

Therefore the preferred option is to:
- Affirm consents;
- Ensure P concentrations in the river within the site and in Barton Broad, are monitored and acted upon as part of the WFD process;
- Encourage further study of and control of diffuse sources.

It is considered that putting these measures in place means that the risk of exceeding the RoC targets is reduced and is very low.

C2 WATER RESOURCES

All permissions considered under Regulation 50 will be affirmed. Any local abstraction issues will be considered under regulation 48 when information from the review and any information gathered as part of the licensing process will be considered.

D1 Consultation process

Water Resources

A meeting to discuss the draft Site Options Plan (SOP) was held on 26 October 2007.

A meeting with Natural England to discuss the assessment methodology for Broads SAC / Broadland SPA and the RoC conclusions for the sites was held on 15 December 2008.

Table D1.1 Communications Log for water quality

Permission Reference	Permission holders name or contact	Document reference	Contact format	Date	NE / CCW consulted	EAW departments consulted												Reply requested?	If yes when?
						WQ	WR	PIR	Waste	EM	FRB	EAT	Hydrology	Hydrometry	Legal	**AHDC* contacted**	**RHDC ** contacted**		
Water Company discharges	Anglian Water Services	WQComAWS a1and a2	Meeting / Presentation	19-02-07		✔										✔	✔		
Water Company discharges	Anglian Water Services	WQComAWS d	Meeting	14-12-07		✔										✔	✔		
Water Company discharges	Anglian Water Services	WQComAWS e	Meeting	15-01-07		✔										✔	✔		
Water Company discharges	Anglian Water Services	WQComAWS f1 and f2	Meeting	08-02-08		✔										✔	✔		
Water Company discharges	Anglian Water Services	WQComAWS g1, g2 and g3	Meeting	18.3.08		✔										✔	✔		
Water Company discharges	Anglian Water Services	WQComAWS h	Meeting	25.4.08		✔										✔	✔		
Water Company discharges	Natural England	WQComNE a	Meeting	29.11.07	NE	✔										✔	✔		
All consents	Natural England	WQComNE b	Meeting	15.12.08	NE	✔										✔	✔		
Water Company discharges	National EA	National e-mail re WQSAP 19.6.08	E-mail	19.6.08		✔										✔	✔	From National	
Water Company discharges	National EA	National e-mail re WQSAP 20.10.08	E-mail	28.11.08		✔										✔	✔	From National	
Water Company discharges	Natural England	NE e-mail re WQSAP 19.6.08	E-mail	1.07.08	NE	✔										✔	✔		
Water Company discharges	Natural England	NE e-mail re WQSAP v3	E-mail	9.9.09	NE	✔										✔	✔		