Habitats Regulations Assessment for Oxfordshire Minerals Planning Strategy

Technical Supplement

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by
Land Use Consultants and Maslen Environmental

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CONTENTS

TABLES

FIGURES

APPENDICES

Appendix A: Maps

Appendix B: Dewatering Calculations

1 Introduction

OXFORDSHIRE MINERALS AND WASTE CORE STRATEGY

1.1 Oxfordshire County Council is preparing its Minerals and Waste Core Strategy, to replace the Minerals and Waste Local Plan. The Core Strategy includes the planning strategy for minerals extraction and waste development, which comprises a vision, objectives, policies and preferred spatial strategy for minerals extraction and waste development, as well as nine common core policies for both minerals and waste.

1.2 Consultation on the draft Minerals Planning Strategy to 2030 ended on the 31st October 2011. The consultation document included the preferred spatial strategy and policies for sand and gravel, soft sand and crushed rock extraction. Five areas have been identified for sand and gravel extraction, three for soft sand extraction and three for crushed rock extraction. Within these areas specific sites have been nominated for inclusion as allocated mineral extraction sites in the Site Allocations DPD.

HABITATS REGULATIONS ASSESSMENT WORK UNDERTAKEN TO DATE

1.3 Habitats Regulations Assessment (HRA) Screening work for the Minerals Core Strategy was undertaken by the Council with a Screening Report issued to Natural England in February 2011. The February 2011 Screening Report describes the purpose of HRA and the tasks involved in the HRA process. The report identified the Natura 2000 sites in Oxfordshire that could be affected (there are seven Special Areas of Conservation (SACs)), the reasons for their designations, conservation objectives and likely impacts from mineral workings and waste management both alone and in combination.

1.4 The initial HRA Screening report concluded that there would be no likely impact from mineral working on six of the SACs within Oxfordshire (Hartslock Wood, Hackpen Hill, Little Wittenham, Chiltern Beechwoods, Aston Rowant or Cothill Fen). However, it could not rule out likely significant effects on Oxford Meadows SAC from mineral extraction within the Eynsham/Cassington/Yarnton area.

1.5 Natural England provided a number of comments on this report, requiring amendments to the conservation objectives, a request for more information about the potential hydrological impacts of mineral working on Oxford Meadows and Cothill Fen SACs and a request that the Council identified the site nominations it believes are unlikely to have an impact on Oxford Meadows SAC, and provide evidence on the lack of hydrological pathway to support screening out these site nominations.

1.6 The Council submitted a revised HRA Screening Report in August 2011 seeking to respond to Natural England's comments. This report also included the screening assessment for the waste planning strategy options that had been prepared by this stage. The revised Screening Report concluded that

"…using the source-pathway-receptor screening assessment, and taking into account the other plans and policies which are relevant to this assessment, … mineral extraction from some of the site options within the Eynsham/Cassington/Yarnton area could impact on the conservation objectives of Oxford Meadows SAC through a hydrological pathway…" but that "…No other areas included in the preferred strategy for minerals extraction are likely to have impacts on the SACs in Oxfordshire…".

1.7 It also noted in relation to the waste planning strategy that a proposal for a residual treatment plant in the Abingdon/Didcot /Wantage/Grove area, if located within 10km of Cothill Fen, Oxford Meadows or Little Wittenham SACs, may require a further screening opinion and a full appropriate assessment may be required. This assessment will need to take place during preparation of the Waste Site Proposals and Policies DPD, which is another DPD within the Oxfordshire Minerals and Waste Development Framework, and is therefore not addressed in this report.

HRA WORK REQUIRED

1.8 Natural England responded to the August 2011 revised HRA Screening Report and requested that the evidence base be improved, with a particular requirement for an assessment by professional hydrogeologists/ecologists of the likely impact of mineral extraction in the nominated sites within 5km of Oxford Meadows and Cothill Fen SACs. This report responds to the additional HRA work required in relation to the Minerals Planning Strategy.

1.9 Oxfordshire County Council commissioned LUC and Maslen Environmental to improve the hydrological and ecological evidence base for the HRA to inform the selection of the preferred minerals spatial strategy in the Minerals and Waste Core Strategy, in particular, whether the Eynsham/Cassington/Yarnton area for sand and gravel should be retained/deleted or modified and whether the Tubney/Marcham/Hinton Waldrist[1] area for soft sand should be retained/deleted or modified. The location of these preferred areas and nominated mineral sites in relation to the Oxford Meadows SAC and Cothill Fen SAC is shown in **Map 1** in **Appendix A**.

Stages in HRA

1.10 **Table 1.1** summarises the stages involved in carrying out a full HRA.

[1] Note that this area was renamed 'North and south of the A420 to the west of Abingdon' in the Minerals Planning Strategy Consultation draft September 2011, and has been referred to as such in the rest of this report.

Table 1.1: Stages in HRA

Stage	Task	Outcome
Stage 1: Screening	Description of the plan Identification of potential effects on European sites Assessing the effects on Natura 2000 sites	Where effects are unlikely, prepare a 'finding of no significant effect report'. Where effects judged likely, or lack of information to prove otherwise, proceed to Stage 2.
Stage 2: Appropriate Assessment	Gather information (project/plan and Natura 2000 sites) Impact prediction Evaluation of impacts in view of conservation objectives Where impacts considered to affect qualifying features, identify alternative options Assess alternative options If no alternatives exist, define and evaluate mitigation measures where necessary	Appropriate assessment report describing the project/plan, Natura 2000 site baseline conditions, the adverse effects of the project/plan on the Natura 2000 site, how these effects will be avoided through, firstly, avoidance, and secondly, mitigation including the mechanisms and timescale for these mitigation measures. If effects remain after all alternatives and mitigation measures have been considered proceed to Stage 3.
Stage 3: Assessment where no alternatives exist and adverse impacts remain taking into account mitigation	Identify 'imperative reasons of overriding public interest' (IROPI) Identify potential compensatory measures	This stage should be avoided if at all possible. The test of IROPI and the requirements for compensation are extremely onerous

Sources: DCLG (2006)

1.11 It is normally anticipated that an emphasis on Stages 1 and 2 of this process will, through a series of iterations, help ensure that potential adverse effects of development on Natura 2000 sites are identified and eliminated through the inclusion of mitigation measures designed to avoid or reduce effects. The need to consider alternatives could imply more significant changes to a plan, likely to require further detailed consultation and assessment. It is generally understood that so called 'imperative reasons of overriding public interest' (IROPI) are likely to be justified only very occasionally and would involve engagement with both the UK Government and European Commission.

1.12 The HRA should be undertaken by the 'competent authority', in this case Oxfordshire County Council. The Council undertook early iterations of the HRA (reports dated February and August 2011), and LUC with Maslen Environmental have been commissioned to provide further hydrogeological and ecological assessment to complete the HRA for this stage of the Minerals and Waste Core Strategy.

1.13 HRA also requires close working with Natural England (NE) as the relevant statutory nature conservation body in order to obtain the necessary information, agree the process, outcomes and mitigation proposals. Under Regulation 102 (2) of the Conservation of Habitats and Species Regulations

2010[2] the competent authority must consult NE and have due regard to any representations made. As described earlier, NE has been consulted on both the February and August 2011 HRA Screening Reports, and has since been involved in two meetings between Oxfordshire County Council, LUC and Maslen Environmental to discuss the approach and early draft of this report. Oxfordshire County Council is also seeking a formal consultation response on this report. In addition, the Environment Agency has been consulted on the early draft of this report, and their advice has been sought with respect to hydrological and ecological data in relation to the two SACs.

STRUCTURE OF REPORT

1.14 This report is a technical supplement to the HRA Screening Reports already prepared by Oxfordshire County Council for the Oxfordshire Minerals and Waste Core Strategy in February and August 2011. It provides an updated screening opinion (i.e. whether there is likely to be a significant effect on either Oxford Meadows and Cothill Fen SACs) from mineral extraction in either Eynsham/Cassington/Yarnton area for sand and gravel or the North and south of the A420 to the west of Abingdon area for soft sand, or the eleven nominated sites within 5km of the SACs. It also describes the more detailed work undertaken for those nominated mineral sites where a significant effect is considered likely. The report should be read alongside the two earlier HRA Screening Reports, and is structured as follows:

Section 2: Method – describes the method used to improve the hydrological and ecological evidence base and carry out the revised screening and additional HRA work.

Section 3: Hydrogeological Assessment – provides the results of the hydrogeological assessment including conceptual models of the hydraulic connectivity between the minerals sites and SACs.

Section 4: HRA Revised Screening – identifies whether significant effects upon the relevant SACs are likely for each of the nominated minerals sites within 5km of the SACs and the Eynsham/Cassington/Yarnton area for sand and gravel or the North and south of the A420 to the west of Abingdon area for soft sand.

Section 5: Appropriate Assessment – assesses whether the impacts identified in the Revised Screening Stage are likely to result in adverse effects on the integrity of the SAC, either alone, or 'in-combination' with other plans and projects.

Section 6: Conclusions - summarises the overall conclusions of the HRA of the Minerals Planning Strategy.

[2] *The Conservation of Habitats and Species Regulations 2010.* SI No. 2010/490.

2 Method

2.1 The method used to improve the hydrological and ecological evidence base for the HRA of the Minerals Planning Strategy is described below. The work has focused on the Eynsham/Cassington/Yarnton area for sand and gravel and the North and south of the A420 to the west of Abingdon area for soft sand, as well as the 11 mineral sites nominated within 5km of the Oxford Meadows and Cothill Fen SACS (nine within 5km of Oxford Meadows and two within 5km of Cothill Fen). The location of the preferred areas and the nominated mineral sites in relation to the Oxford Meadows SAC and Cothill Fen SAC is shown in **Map 1** in **Appendix A**.

2.2 In order to improve the evidence base for the screening opinion and conclude whether the 11 nominated sites would have an adverse effect on the integrity of the two SACs, the research has focused on the following questions:

RESEARCH QUESTIONS

Screening Stage

1. What is the hydraulic connectivity between the nominated mineral extraction sites and the SACs?
2. What is the expected effect on water chemistry, quality, level, turbidity, sedimentation and pollution at Oxford Meadows SAC and Cothill Fen SAC as a result of mineral working at the nominated sites within 5km?
3. Are the impacts identified likely to result in significant effects to the SAC?
4. What other plans and/or projects could affect the SAC 'in-combination' with the nominated minerals sites?
5. Which nominated mineral sites are unlikely to result in significant effects to the SAC and can therefore be screened out from further assessment?
6. Which nominated mineral sites are likely to result in significant effects to the SAC, or there is a lack of information to prove otherwise, and therefore require appropriate assessment.

Appropriate Assessment Stage

7. Are these potential impacts/changes likely to have a significant effect on the integrity of the SAC qualifying features, either alone or in-combination with other plans and projects?
8. For any nominated mineral extraction sites where significant effects on the integrity of the SAC qualifying features cannot be ruled out, can modification (e.g. to site boundaries) or mitigation provide sufficient evidence to enable a conclusion of no adverse effect on integrity?

REVIEW OF EXISTING INFORMATION

2.3 An initial review was undertaken of site information collated to date (with respect to conservation objectives and the conditions required to maintain these) as well as any published additional information (in addition to studies which have been used to support the earlier HRA Screening work). This information has been used to inform the HRA conclusions.

HYDROGEOLOGICAL ASSESSMENT

2.4 Quarrying of stone or unconsolidated sand and gravel deposits can potentially have a variety of impacts on the hydrological environment, including:

- Drawing down of the water table by quarry dewatering, potentially leading to a reduction in baseflow to (or the drying up of) rivers and streams, and the drying of springs, lakes and wetlands. Pre-existing water abstractions may also be affected, with boreholes going dry (or becoming more expensive to pump), and surface water bodies drying up.
- Modification of groundwater and surface water flow paths – this may be through dewatering activities and/or discharges.
- Increased vulnerability of groundwater through removal of overburden, with the risk of direct contamination (e.g. by fuel hydrocarbons).
- Excavation linking formerly separate aquifer layers, with the potential for cross-contamination (e.g. creation of a direct flow pathway between contaminated made ground and an underlying natural aquifer).
- Contamination of surface water bodies by fine-grained sediment and/or chemicals (e.g. fuel hydrocarbons).
- Increased evaporative loss of water through its exposure to the atmosphere in flooded quarry workings.
- Increased flood risk resulting from the discharge and/or storage of water, or the creation of new flow pathways.

2.5 Outline hydrogeological conceptual models were prepared for the two SACs to provide an understanding of the surface and groundwater issues surrounding each site and possible areas of sensitivity.

Method

2.6 The tasks undertaken as part of the outline hydrogeological assessment comprised:

- Carrying out a desk-based review of relevant information relating to the SACs and nominated mineral sites.
- Developing a hydrogeological conceptual model of each SAC, including:
    a. Geological framework (aquifers and aquitards).
    b. Groundwater levels and flow directions.

c. Interaction between groundwater and surface water.

d. Surface water and/or groundwater catchment area(s) supporting the SAC.

- Considering the hydrogeological context of the nominated mineral sites and their hydraulic connectivity to the SACs.
- Identifying nominated mineral sites with a hydraulic connection (or possible connection) to the SACs.
- Considering potential impacts on water levels and flows in the SACs (e.g. as a result of quarry dewatering), the potential for impacts on water quality (chemical contamination of groundwater and surface water, and release of sediment into water bodies) and also the impact from restoration measures such as the construction of groundwater obstructions which could change groundwater catchments..
- Using the Source – Pathway – Receptor framework (e.g. Environment Agency, 2004; Nathanail and Bardos, 2004) to assess the risks posed by contamination and sediment release.
- Assessing the likely magnitude of impacts for individual nominations and also for the cumulative effect of multiple nominations.
- Making high-level recommendations regarding possible mitigation measures.

Data Sources

2.7 The assessment made use of information from the following sources:

- Information from Oxfordshire County Council on the spatial strategy for minerals, including:
    - Broad areas identified for mineral extraction.
    - Locations of nominated sites.
    - Site nomination forms submitted to the Council by operators and landowners.
- Topography and surface water drainage network:
    - Ordnance Survey (OS) mapping (digital OS OpenData).
- Rainfall:
    - UK Hydrometric Register (Marsh and Hannaford, 2008).
    - Flood Estimation Handbook (FEH) CD-ROM (CEH, 2009).
- Soils:
    - 1:250,000 scale mapping by the Soil Survey of England and Wales (1983).
- Geology:
    - British Geological Survey (BGS) 1:50,000 geology mapping: Sheets 236 (Witney) and 253 (Abingdon).
    - Borehole data from the BGS online borehole archive.

- BGS Regional Geology Guide: "London and the Thames Valley" (Sumbler, 1996).

- Hydrogeology:
  - Aquifer classification and water quality.
- SAC designations:
  - Defra and Natural England websites.
- Previous reports:
  - Environment Agency (undated) 'Habitats Directive Stage 2 Report: Cothill Fen cSAC'.
  - Dixon (2005) 'The Hydrology of Oxford Meadows SAC'.
  - Reports on a proposed sand quarry at Upwood Park (Baker Shepherd Gillespie, 2009; Atkins, 2011).

2.8 Other sources are referenced in the text list at the end of this report.

REVISED SCREENING

Identification of other plans and projects which may have 'in-combination' effects

2.9 Regulation 102 of the Conservation of Habitats and Species Regulations 2010 requires plan making authorities to make an appropriate assessment of the implications of the land use plan for Natura 2000 sites, where the plan is not directly connected with or necessary to the management of the site but likely to have a significant effect on the site, either alone or 'in combination with other plan or projects'.

2.10 Oxfordshire County Council's August 2011 HRA Screening Report listed a number of projects and plans that were considered to have potential to result in effects on the SACs within Oxfordshire in combination with the Minerals and Waste Core Strategy. Table 3 in the August 2011 report lists the emerging Oxfordshire LDF Core Strategies (Cherwell, West Oxfordshire, South Oxfordshire, Vale of White Horse), Oxford City Core Strategy and neighbouring authorities' LDFs, and provides a 'Red, Amber, Green' assessment of their potential impacts on European sites.

2.11 Some of the plans were identified as having potential impacts on one or more of the SACs in Oxfordshire, but the only plans identified as having a potential impact on Oxford Meadows SAC and/or Cothill Fen SAC were the four Oxfordshire LDFs (potential impacts generally on any of the SACs were identified due to pressure on recreational facilities and open space in the County plus impacts on air and water quality), and:

- Oxford City (Oxford Meadows SAC only – due to pressure on recreational facilities which are accessible to Oxford, the proximity of new employment land to Oxford Meadows SAC (the Northern Gateway), and associated traffic generation and air pollution).
- Oxford Local Transport Plan (Cothill Fen SAC only – due to landtake, construction process and water contamination associated with upgrading the A415 from the A34 to A40).

2.12 These plans have therefore been looked at in more detail as part of the revised screening (see **Section 4**) to determine the likelihood of in-combination effects with the Oxfordshire Minerals and Waste Core Strategy. In addition, the following catchment abstraction management plans have been reviewed, and consideration given to existing or permitted mineral extraction sites in proximity to the two SACs:

- Vale of the White Horse.
- Cherwell.
- Thames.

Assessment of 'Likely Significant Effects'

2.13 As required under Regulation 61 of the Conservation of Habitats and Species Regulations 2010, an assessment of the 'likely significant effects' of minerals extraction in the two preferred strategy areas on Cothill Fen SAC and Oxford Meadows SAC was undertaken, and conclusions reached about whether they may result in effects, either alone, or in-combination with other plans and projects.

2.14 While this HRA is focused on the Oxfordshire Minerals and Waste Core Strategy (and in particular two of the strategic areas identified where sand and gravel and soft sand extraction could occur subject to gaining planning permission), the work has included assessment of each of the 11 nominated minerals sites within 5km of the two SACs, as that enables a more detailed assessment to be undertaken. The nominated sites are being considered by Oxfordshire County Council as part of the preparation of the Site Allocations DPD, but the nominated mineral sites are not allocated within the Core Strategy and have only been used as background to help with identifying the strategic areas for mineral extraction. Therefore, further HRA may be required for these and other nominated sites as part of the Site Allocations DPD preparation.

2.15 A risk-based approach involving application of the precautionary principle was adopted in the assessment of likely significant effects, such that an assessment of 'no significant effect' was only made where it was considered very unlikely, based on current knowledge and information available, that the nominated minerals site(s) and strategic areas in question could have a significant effect on the integrity of the SACs.

2.16 The hydrogeological assessment was used to identify possible Source-Pathway-Receptor impacts between each of the nominated minerals sites, the strategic areas and the SACs. The purpose was to determine whether an effect was likely on the European sites. This required consideration of the sensitivities of the SACs and qualifying features, informed by supporting information such as the SAC conservation objectives, the findings of the hydrogeological assessment, and professional judgement.

2.17 A 'traffic light' approach was used to record the likely impacts of the nominated minerals sites on the SACs and their qualifying features (see **Section 4**), using the colour categories shown in **Table 2.1** below.

Table 2.1: Approach to identifying nominated minerals sites which may impact on the SACs

Red	There are likely to be significant effects.
Amber	There may be significant effects, but this is uncertain either due to lack of detailed proposals at this stage of the plan preparation or lack of data.
Green	There are unlikely to be significant effects.

APPROPRIATE ASSESSMENT

Assessing the Effects on Site Integrity

2.18 While not technically required for the Minerals and Waste Core Strategy, this report has set out an Appropriate Assessment matrix for the nominated minerals sites whose impacts are judged likely to have a significant effect on the qualifying features of either SAC, or where insufficient certainty regarding this remained at the screening stage.

2.19 At the Appropriate Assessment stage, a conclusion needs to be reached as to whether or not minerals working at the nominated extraction sites would adversely affect the integrity of either the Cothill Fen SAC or Oxford Meadows SAC due to the potential to:

- Delay the achievement of conservation objectives for the SAC.
- Interrupt progress towards the achievement of conservation objectives for the SAC.
- Disrupt factors that help to maintain the favourable conditions of the SAC.
- Interfere with the balance, distribution and density of key species and habitats that are the indicators of the favourable condition of the SAC.

2.20 An Appropriate Assessment matrix (see **Table 5.1**) was used to assess whether the 'likely significant effects' identified in the Revised Screening stage for some of the nominated sites (see **Table 4.1**) could, in the light of existing information and mitigation proposals, result in adverse effects on the integrity of the SAC, either alone, or in-combination with other plans and projects.

3 Hydrogeological Assessment

3.1 This section assesses the hydraulic connectivity (i.e. whether there is a connected pathway for water to move above or below ground) between the Oxford Meadows and Cothill Fen SACs and the eleven nominated sites within 5 km of the two SACs. It also presents and describes the hydrogeological conceptual models for the Oxford Meadows and Cothill Fen SACs.

COTHILL FEN SAC

Site Description and Qualifying Features

3.2 Cothill Fen SAC is a lowland valley mire located some 2.5 km northwest of Abingdon in Oxfordshire. Cothill Fen shows the succession from open water to fen, scrub, carr and wet woodland (Natural England website). In the context of the European Commission Habitats Directive, the Fen has been designated as a SAC because of its extensive alkaline fen vegetation, and its location in central England, where such vegetation is rare (Defra website). Indeed, the site is considered to be one of the best areas in the UK for alkaline fen (Defra website; Environment Agency, undated). Qualifying features include:

Annex I habitats present as a qualifying feature and a primary reason for selection:

- Alkaline fen

Annex I habitats present as a qualifying feature, but not a primary reason for selection:

- Alluvial forests with alder Alnus glutinosa and ash Fraxinus excelsior

3.3 Natural England has determined the following Conservation Objectives for Cothill Fen (Baker, Shepherd Gillespie, 2009):

- There should be no reduction in the total combined extent of fen, marsh and swamp (calcareous fen).
- In general there should be no reduction in the extent of wet woodland, although some small-scale clearance may be acceptable if it is undertaken to extend the area of open fen vegetation.

3.4 Although the conservation objectives do not explicitly mention water levels or flows, the vegetation type is known to be dependent on water levels within the site, and these levels are maintained by groundwater flow (Environment Agency, undated).

3.5 For the purposes of management, the SSSI is divided into six units. In 2011, a condition assessment by Natural England found all but one of the units to be in "favourable" condition. The exception (Unit 2: Parsonage Moor and Ruskin Reserve) was found to be "unfavourable recovering".

Topography and Climate

3.6 Cothill Fen occupies a topographic depression running approximately NNE-SSW. It includes part of the river valley of Sandford Brook, and also the low-lying areas of Parsonage Moor and Ruskin Reserve in the southwest. Ground surface elevations range from about 94 to 73m AOD.

3.7 The Sandford Brook catchment receives on average more than 800mm annual rainfall (CEH, 2009) with gauging station 39081 (Abingdon) recording 653mm annual rainfall (UK Hydrometric Register - Marsh and Hannaford, 2008).

Geology and Soils

Solid (Bedrock) Geology and Structure

3.8 Cothill Fen SAC is underlain by bedrock belonging to the Upper Jurassic (Oxfordian) Corallian Group (See **Table 3.1** and **Map 7** in **Appendix 1**). The Corallian shows an upward progression from clay, via silty sandstone to clean sandstone; the succession is capped by coralline limestone. It is the upper part of the Corallian (consisting of sandstone and limestone) that crops out in the vicinity of Cothill Fen. The sandstone is generally soft, but locally contains hard calcite-cemented concretions known as 'doggers' (BGS, 1982). Underlying the Corallian is the Upper Jurassic Oxford Clay Formation, which is dominated by mudstone (**Table 3.1**).

3.9 The Jurassic strata dip eastwards at a low angle (BGS 1971, 1982). No faults are indicated on the 1:50,000 scale published geology mapping (BGS 1971, 1982).

Table 3.1: Cothill Fen Regional Stratigraphy

Age	Unit		Description	Thickness (m)
Quaternary	Quaternary Drift Deposits	Peat	PEAT	c. 2 to >4 m [Maximum peat thickness 4.3 m]
		Alluvium	Calcareous SILT (locally peaty) with sandy CLAY and traces of fine limestone gravel. Described as "marl" in the SSSI citation.	
Upper Jurassic	Corallian Group	Upper Corallian Limestone (Coral Rag)	LIMESTONE: small reefs of coralline limestone and associated reef talus deposits	7 - 9
		Upper Corallian Sandstone	Well-sorted soft SANDSTONE with cemented concretions ("doggers")	0 - 20
		Lower Corallian Silt [Lower	Fine-grained silty SANDSTONE with many clay partings.	0 - 15

Age	Unit		Description	Thickness (m)
		Calcareous Grit]		
		Lower Corallian Clay	CLAY	0 - 22
	Oxford Clay Formation		Mainly MUDSTONE; subordinate thin silt and limestone bands and horizons of septarian nodules.	90- 100
Sources: BGS (1971, 1982, 1996) SSSI citation (Natural England website) *Borehole SU49NE138 (National Grid Reference 446150 199870) [held in the BGS online borehole archive] proved 2.1 m of superficial deposits overlying Corallian Limestone. The alluvium and peat infilled a former lake up to 4 m deep (Baker Shepherd Gillespie, 2009).				

Superficial (Drift) Geology

3.10 Regionally, superficial (drift) deposits are commonly absent (see **Map 8** in **Appendix 1**), with bedrock present directly beneath the soil (or, rarely, exposed at the ground surface). However, within the boundary of Cothill Fen the bedrock is overlain by deposits of peat and alluvium (**Map 8** and **Table 3.1**). A borehole on Parsonage Moor proved 2.1m of peat and alluvial deposits overlying Corallian limestone (**Table 3.2**).

3.11 The peat reaches a maximum thickness of 4.3m in Morland's Meadow (Natural England website). The underlying alluvial deposits are dominated by silt and sandy clay, but also include limestone gravel; in the SSSI citation they are referred to as 'marl' (which means calcareous mudstone)

Table 3.2: Borehole Log for Borehole at Parsonage Moor (BGS ref SU49NE138; NGR 446150; 199870)

Classification	Description	Thickness
Peat	Peat	0.5
Alluvium	Greenish black peaty SILT with sandy CLAY and a trace of fine limestone gravel.	0.4
	Greenish black clayey SILT, becoming very sandy.	1.2
Corallian (Coral Rag)	Very hard LIMESTONE	Not penetrated
Source: BGS online borehole archive: http://www.bgs.ac.uk/data/boreholescans/home.html		

Soils

3.12 Cothill Fen is underlain by a variety of soil types. Mapping by the Soil Survey of England and Wales (1983) indicates the presence of soils of the Elmton 1 and Fyfield 2 Series. The former includes shallow, well-drained, brashy, calcareous fine loamy soils, whilst the latter includes well-drained coarse loamy and sandy soils at risk of water erosion (Soil Survey of England and

Wales, 1983). The SSSI citation (Natural England website) notes the presence of peat soils, and also humic gleys of the Halford Series.

Surface Water Hydrology

Surface Water Drainage Network

3.13 Sandford Brook, a tributary of the Ock, flows through the site from north to south. A number of other small watercourses, including several drainage ditches, cross the south-western part of the site and join Sandford Brook. One of these watercourses flows southwards from two large fish ponds located northwest of Cothill Fen.

3.14 Ordnance Survey 1:10,000 mapping shows three ponds within the SAC boundary: two of these appear to be linked to Sandford Brook via inflows and outflows; the third pond (in the Ruskin Reserve) lacks a surface water inflow, but discharges water into a tributary of Sandford Brook. There is a large pond immediately outside the north-western boundary of the SAC.

Surface Water Catchment

3.15 **Map 2** (see **Appendix A**) shows the surface water catchment of Cothill Fen deduced from surface topography.

River Flooding

3.16 Environment Agency flood mapping shows that the part of Cothill Fen along Sandford Brook lies within Flood Zone 3, i.e. has at least a 1 in 100 chance of flooding in any one year (Environment Agency website).

Hydrogeology

Aquifers and Aquitards

3.17 The Corallian is classified by the Environment Agency as a Secondary A (formerly Minor) Aquifer. Yields of up to 800 m3/d have been obtained from boreholes near Abingdon (BGS, 1996). Groundwater flow within the Corallian is concentrated in the upper, more permeable part of the succession. Flow in the limestone is predominantly through fractures, whereas flow in the soft sand is predominantly intergranular. Underlying the Corallian is the Oxford Clay Formation, which acts as an aquitard (or aquiclude) and, together with the lower Corallian Clay, forms an effective base to the aquifer.

3.18 The more permeable superficial deposits (peat and sandy/gravelly alluvium) will act as aquifers; however, most of the alluvium consists of low permeability silt and clay. These lower permeability sediments will act as aquitards, restricting the degree of hydraulic connectivity between the underlying bedrock aquifer and the surface water drainage network.

Groundwater Catchment

3.19 It is likely that groundwater flow follows the topography, and that surface water and groundwater catchments approximately coincide (see **Map 2** in **Appendix A**). The Environment Agency (Vicky Fry, pers. comm.) notes that the northwestern boundary of the groundwater catchment may extent further westwards (towards Eaton) than the surface water catchment.

Groundwater Levels and Flow

3.20 The water table beneath Cothill Fen is at, or close to, the ground surface. A borehole drilled at Parsonage Moor in December 1974 (see Table 3.2) struck water 0.5m below ground level. Where springs discharge, the groundwater level is equal to the ground surface elevation.

3.21 The main recharge area for groundwater is the area of relatively high ground to the north, northwest and west of the Fen; however, some of the groundwater is sourced from a smaller area to the east of Sandford Brook (see the catchment outline in **Map 2** in **Appendix A**). The main discharge area for groundwater is in the Fen itself: groundwater from the Corallian aquifer flows into the peat and alluvial deposits, into the wetlands and ponds, and eventually into Sandford Brook.

Groundwater / Surface Water Interaction

3.22 Groundwater from the Corallian aquifer discharges from springs, entering Cothill Fen and Sandford Brook. The relatively low permeability alluvial silt and clay will to some extent restrict the degree of hydraulic connectivity between the Brook and Corallian groundwater; however, the alluvial deposits are thin and are unlikely to form a major barrier to flow.

Groundwater Quality

3.23 Cothill Fen is underlain by groundwater belonging to the Shrivenham Corallian water body, which has good quantitative status, but poor chemical status (Environment Agency website).

Groundwater Vulnerability and Protection

3.24 The Environment Agency has classified the groundwater beneath Cothill Fen as having high vulnerability (Environment Agency website). This reflects the presence of relatively thin, permeable soils and shallow groundwater. There are no groundwater Source Protection Zones in the vicinity of Cothill Fen.

Conceptual Model

Water Supply: Wetland Mechanisms

3.25 Although the conservation objectives do not explicitly mention water levels or flows, the most important vegetation types within the qualifying features for the Cothill Fen SAC are known to be dependent on water levels within the site, and these levels are maintained by groundwater flow from the underlying Corallian aquifer (Environment Agency, undated). Waterlogged areas are fed by calcareous springs rising from the Corallian aquifer and draining into Sandford Brook (Baker Shepherd Gillespie, 2009). The calcareous nature of the Fen reflects the composition of the groundwater which, in turn, reflects the presence of carbonate minerals in the Corallian bedrock and overlying superficial deposits. In WETMECs (Wetland Mechanisms) terminology (Environment Agency, 2009) Cothill Fen is a

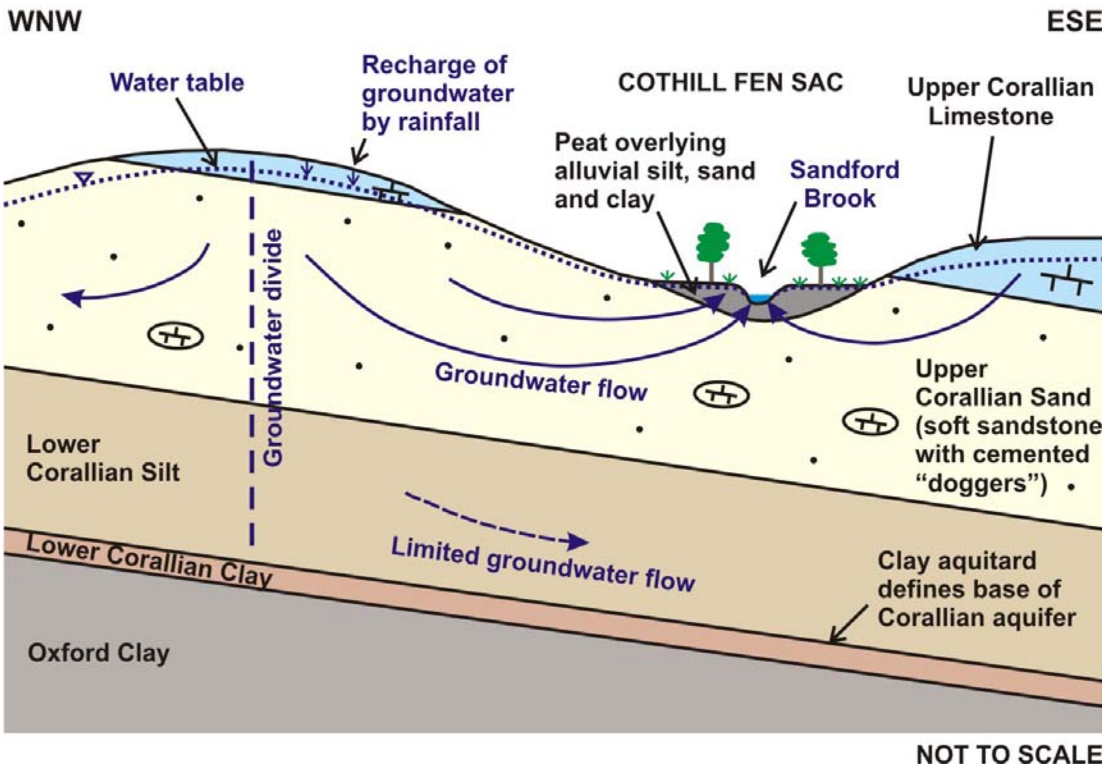
'Groundwater-Fed Bottom' fen. Other less important sources of water feeding Cothill Fen include river flooding (from Sandford Brook) and direct rainfall.

Summary of Conceptual Understanding

3.26 **Figure 3.1** illustrates the hydrogeological conceptual model proposed for Cothill Fen SAC. The approximate line of the cross-section is shown on **Map 2** in **Appendix A**. The main features of the conceptual model are summarised below:

- Cothill Fen is a calcareous fen designated as a Special Area of Conservation (SAC) and a Site of Special Scientific Interest (SSSI). Part of it is also designated as a National Nature Reserve (NNR).
- Cothill Fen occupies a narrow topographic depression running approximately NNE-SSW. It includes part of the river valley of Sandford Brook, and also the low-lying areas of Parsonage Moor and Ruskin Reserve in the southwest.
- The Fen is directly underlain by peat and alluvium (mainly silt) of Quaternary age; these rest on Upper Jurassic bedrock belonging to the Corallian Group. The Jurassic strata dip eastwards at a low angle to the horizontal.
- The upper part of the Corallian Group consists of hard coralline limestone overlying soft sand containing hard calcite-cemented concretions ('doggers'). The lower part of the Corallian is dominated by clay and fine-grained silty sandstone with clay partings.
- Groundwater flow within the Corallian aquifer is concentrated in the upper, more permeable part of the succession. Flow in the limestone is predominantly through fractures, whereas flow in the soft sand is predominantly intergranular. Underlying the Corallian is the Oxford Clay Formation, which acts as an aquitard (or aquiclude) and, together with the lower Corallian Clay, forms an effective base to the aquifer.
- Cothill Fen is fed by groundwater from the underlying Corallian aquifer, and its WETMECs classification is 'Groundwater-Fed Bottom'. As such, it is potentially sensitive to changes in groundwater level or water quality.
- It is likely that groundwater flow follows the topography, and that surface water and groundwater catchments approximately coincide (see **Map 2** in **Appendix A**). The main recharge area for groundwater is the area of relatively high ground to the north, northwest and west of the Fen; however, some of the groundwater is sourced from a smaller area to the east of Sandford Brook.
- Groundwater discharges from the Corallian aquifer, via Cothill Fen and its associated Quaternary deposits, into Sandford Brook.

Figure 3.1: Hydrogeological Conceptual Model of Cothill Fen SAC (schematic and not to scale)



Mineral Planning Units: Impact Assessment

Hydrogeological Context of the Proposed Mineral Extraction Sites

3.27 Two potential soft sand extraction sites are proposed in the vicinity of Cothill Fen (see **Map 2** in **Appendix A** and **Table 3.3**). Both are located on the Corallian aquifer in areas where superficial deposits are absent (BGS, 1971). The Tubworth Barn site (SS-01) is located on Corallian sandstone and siltstone, whereas the Kingston Bagpuize site (SS-05) is located on Corallian limestone (overlying sandstone) (BGS, 1971).

3.28 D.K. Symes Associates, who propose sand extraction at the Tubworth Barn site, report on their nomination form the findings of a borehole survey carried out at the site. Sand occurs immediately beneath some 0.4 to 0.5m of soil. Working would be undertaken to a maximum depth of 6 to 7m, with an average of 3 to 4m. Only limited dewatering would be required (only for the deeper pockets of sand) as the water table is relatively deep. None of the boreholes encountered water, although the drilled depths of the holes are not known. A nearby borehole at Fyfield Vicarage (BGS borehole archive ref. SU49NW3), some 320m west of the site, encountered water at 4.6m below ground level in March 1977. In March, groundwater levels would be expected to be at, or close to, their annual maximum.

3.29 Hills Quarry Products Ltd., who propose sand extraction at the Kingston Bagpuize site, provide little hydrogeological information on their nomination form. They propose working to a depth of 5m, and note that dewatering would be required. Records from a borehole at Josca's School (now Abingdon Prep. School), Frilford, suggest that the water table is relatively deep (BGS borehole ref. SU49NW5). Quoted depth to groundwater include 7.92m (August 1978) and 8.4m (1991). However, the borehole is some 1,200m from the site and so may not give reliable information about ground conditions in the proposed extraction area. The presence of lakes adjacent to the site (and absence of any alluvium indicated on the geology map – BGS, 1971) suggests that the water table is close to the surface and that dewatering is likely to be required.

Hydraulic Connectivity and Impacts

3.30 Neither of the proposed sites is in the same surface water or groundwater catchment as the Fen (**Map 2** in **Appendix A**). This means that there is not currently a flow pathway between the nominated sites and the SAC. However, dewatering activities associated with the mineral working could potentially move (or lower the level at) the groundwater divide(s) separating the workings from the Fen, altering groundwater levels and flow patterns, and the magnitude of baseflow discharge to the surface water drainage network.

3.31 Quarry dewatering will draw down the water table, forming a 'cone of depression' around the abstraction (pump). This cone of depression will expand until it captures enough recharge to sustain the pumping rate. Recharge may include infiltrated rainfall and/or water provided by a river or stream. A river or stream can act as a 'recharge boundary', effectively halting the expansion of the cone of depression by providing a source of water.

3.32 Both of the proposed mineral sites are separated from Cothill Fen by surface watercourses. These may act as recharge boundaries, preventing further expansion of the cone of depression and protecting the Fen from the influence of dewatering. However, the watercourses are both small, and so may not be able to provide enough water to form effective recharge boundaries. Also, they may be perched above the water table within their own alluvial deposits, and so not connected to groundwater in the Corallian aquifer. For the purposes of the assessment it is prudent to assume that the watercourses will not prevent the growth of the cone(s) of depression.

3.33 Rough hydrogeological calculations (see **Appendix B**) have been carried out to estimate the likely radius of influence of dewatering at the proposed extraction sites (i.e. the radius of the cone of depression once it has expanded to its maximum extent). For the Kingston Bagpuize site the calculated radius is about 1,800m; for the Tubworth site it is about 900m. These estimates are likely to be conservative because:

- The calculations assume that the entire area of each site would be dewatered at once, whereas in reality the dewatering would most likely be restricted to the area of (then) current working. The dewatering scenario is therefore 'worst case'.
- The calculations use a relatively high hydraulic conductivity (1x10-4 m/s) corresponding to clean sand. In reality, there will be less permeable layers present (clay layers and cemented sand layers).

3.34 It should be noted that the calculations assume that the cone of depression is circular in plan view. Strictly, this will only be true for an idealised homogeneous isotropic (uniform) aquifer with no regional hydraulic gradient (i.e. a horizontal water table) before pumping starts. Where there is an initial slope on the water table the cone of depression will extend further up-gradient than down-gradient. A more detailed analysis of the situation would require a more sophisticated groundwater model (ideally a calibrated numerical model). Nevertheless, the approximate calculation presented here is suitable for broad-scale assessment.

3.35 **Table 3.3** summarises the hydraulic connectivity between the nominated mineral sites and Cothill Fen. Given that the need for dewatering at the Tubworth site is likely to be limited, and that the dewatering calculation suggests a radius of influence of the dewatering of only 900m (compared to a distance to the Fen of 2,100m), it is very unlikely that mineral working at this site would affect the Fen. Although significant dewatering is likely to be required at the Kingston Bagpuize site, the calculated radius of influence of the dewatering (1,800m) is only half the distance to the Fen (3,500m). It is therefore unlikely that dewatering at this site would impact on the Fen.

3.36 During dewatering, groundwater flow would take place towards the mineral workings. Given the lack of a surface water drainage connection, there would not be a Source – Pathway – Receptor linkage for any contamination originating at the workings to find its way into Cothill Fen. Even after cessation of dewatering, there would probably not be a flow pathway between the mineral workings and the Fen. This is because the flow regime would revert back to something similar to the present situation, in which there is no connection.

3.37 Given the above, it is concluded that the working of soft sand at the nominated sites would be unlikely to have any impact on water levels or water quality at Cothill Fen SAC.

Table 3.3: Hydraulic Connectivity Between Nominated Mineral Sites and Cothill Fen SAC

Nomination	Distance from Cothill Fen (km)	Hydraulic Connectivity Yes/No	Comment
SS-01 Tubworth Barn, Tubney	2.1	Possibly	Not in the same groundwater catchment as Cothill Fen. Separated from the Fen by a surface watercourse – this may or may not act as a hydraulic boundary. Likely to have only limited dewatering. Calculations suggest that the cone of depression would not extend as far as Cothill Fen.
SS-05 Land at Kingston Bagpuize	3.5	Possibly	Not in the same groundwater catchment as Cothill Fen. Separated from the Fen by a surface watercourse – this may or may not act as a hydraulic boundary. Calculations suggest that the cone of depression would not extend as far as Cothill Fen.

OXFORD MEADOWS SAC

Site Description and Qualifying Features

3.38 Oxford Meadows SAC covers 265.9km^2 of lowland hay meadows of humid, mesophile and improved grassland extending along the floodplain of the River Thames to the west of Oxford (**Map 3** in **Appendix A**). In a downstream direction, the SAC comprises Cassington Meadow SSSI, Yarnton and Pixey Meads SSSI, Wolvercote Meadow SSSI and Port Meadow SSSI. The majority of the baseline description and conceptualisation is based on Dixon (2005).

3.39 Qualifying features include:

Annex I habitats present as a qualifying feature and a primary reason for selection:

- Lowland hay meadows

Annex II species present as a qualifying feature and a primary reason for selection:

- Creeping Marshwort Apium repens

3.40 The site includes vegetation communities that are perhaps unique in the world in reflecting the influence of long-term grazing and hay-cutting on lowland hay meadows. The site has benefitted from the survival of traditional management, which has been undertaken for several centuries, and so exhibits good conservation of structure and function. Port Meadow, for example, has been internationally recognised as the single known UK site supporting a long term, non-introduced population of Apium repens (creeping marshwort), a protected species (Macdonald et al. 2007).

3.41 These grassland habitats are dependent upon frequent seasonal flooding, with both groundwater and surface water flooding contributing hydrological and nutrient inputs to the system. For this reason it is necessary to understand the interactions between these hydrological pathways, their water sources and the subsequent effects upon surface water and groundwater properties at the site as a response to changing land use.

Topography and Climate

Topography

3.42 The topography of the valley floor upon which these floodplains are situated is generally flat, with elevation falling down valley from ≈59.5m AOD at Cassington Meadow to ≈57.0m AOD at the southern extent of Port Meadow (Dixon 2005).

3.43 Given the predominantly flat elevation, small variations in elevation can significantly affect soil water concentrations and thus the frequency of waterlogging as a result of direct rainfall, surface water and groundwater flow inputs.

Climate

3.44 The wider catchment receives on average >800mm annual rainfall (Marsh and Hannaford 2008). However, the effective rainfall – that which remains after losses from evapotranspiration and is subsequently routed through surface and subsurface hydrologic pathways – is approximately 300mm.

Geology and Soils

Solid (Bedrock) Geology and Structure

3.45 The site is underlain by the Upper Jurassic Oxford Clay Formation (see **Map 9** in **Appendix A**) which can extend up to 75m thick, dipping in a south-easterly direction. Beneath this are the Ancholme and Corallian Jurassic sediments which can be up to 1.5km thick and typically dip eastwards (BGS 1982). These sequences consist of clays, shales, limestones and sandstones.

Table 3.4: Oxford Meadows Regional Stratigraphy

Age	Unit		Description	Thickness
Quaternary	Quaternary Drift Deposits	Alluvium	Silty Clay	1 - 4
		River Terrace	Sands and gravels	5m +
Jurassic	Oxford Clay Formation		Mainly MUDSTONE; subordinate thin silt and limestone bands and horizons of septarian nodules.	75 m
	Ancholme and Corallian Jurassic sediments		Clays and shales, with harder limestones and sandstones	1.5 km
Sources: BGS (1982), Dixon (2005)				

Superficial (Drift) Geology

3.46 Quaternary Alluvium of fluvial origin, deposited during the Holocene, underlies much of the SAC (see **Map 10** in **Appendix A**). It is composed of predominantly yellowish-brown clay and some silt of a variable thickness along the river channel, with depths between 1 and 4m (Dixon, 2005).

3.47 Beneath the alluvium lies Quaternary Post-Anglian terraces, locally classified as 'Northern Drift', that represent ancient floodplain deposits. These are composed of gravel and sand, with the former comprising fine to coarse tabular limestone with subrounded quartz and occasionally flint, and the latter ranging in grade between fine and coarse. **Map 10** shows areas where the river terrace sand/gravel deposits occur at the surface (or directly below the soil).

Soils

3.48 Sheet 6 of the 1:250,000 Soil Map of England and Wales indicates that Oxford Meadows is underlain by Thames soils, a predominantly calcareous, clayey, stoneless soil. On flat topography it is particularly prone to groundwater flooding.

Surface Water Hydrology

Surface Water Drainage Network

3.49 The Oxford Meadow SAC surface water network is dominated by the River Thames (**Map 3** in **Appendix A**). The Thames is regulated by a series of locks and weirs along this stretch. There are two main streams which split from the Thames in this section (and bypass the weirs on the main river) before rejoining the river further downstream: the Wolvercote Mill Stream and the Seacourt Stream. In addition, there are four main tributaries in the area: the River Evenlode (to the west); two small tributaries at Cassington which cross the western most section of the SAC; and Kingsbridge Brook. Kingsbridge Brook enters the site from the north, and is contained within a siphon under Wolvercote Mill Stream before it joins it on the downstream side of a weir.

Surface Water Catchments

3.50 The surface water catchment for the SAC consists of the Thames valley catchment upstream of Oxford. Within the SAC and the surrounding areas are a number of smaller rivers and tributaries. Most of these will have their own smaller sub-catchments; however Wolvercote Mill Stream is perched and artificial and therefore its surface water catchment will be limited.

Flooding

3.51 The area is prone to groundwater and surface water flooding (Macdonald et al. 2007, Environment Agency 'What is in Your Backyard' website) and this supplies water to the SAC habitats.

Hydrogeology

Aquifers and Aquitards

3.52 The system consists of:

- A relatively low permeability layer of alluvial silty clay 1 to 4m thick.
- A river terrace gravel and silty sand layer (>5m thick) beneath, which acts as a high permeability leaky aquifer.
- The Oxford Clay, which acts as an aquitard at the base of the system.

3.53 The Environment Agency (website) indicates the alluvial and river terrace superficial deposits as a Secondary A aquifer. The relatively low permeability alluvial layer acts to semi-confine the underlying river terrace layer. At depth, beneath the Oxford Clay lies the Cornbrash, Forest Marble and Great and Inferior Oolites, consisting of mudstone and limestone strata. These are however isolated from the Oxford Meadow groundwater system by the Oxford Clay.

Groundwater Levels and Flow

3.54 Groundwater monitoring (Dixon 2005) shows that the groundwater table lies within the alluvial or river terrace levels. This is dependent upon the thickness of the alluvium and the relative heights of the groundwater boundaries (see **Paragraph 3.60**). In winter, groundwater levels can be very close or at the surface leading to groundwater flooding and waterlogging in the lower lying areas. The direction of groundwater flow is complex and often controlled by a series of hydrogeological boundaries including gaining and losing streams. Groundwater flow direction is generally from losing streams and higher surrounding ground, to gaining streams within the floodplain (these boundaries are indicated in **Map 4** in **Appendix A**).

Groundwater / Surface Water Interaction

Losing Streams

3.55 Water levels in the River Thames and in Wolvercote Mill Stream have been artificially raised by a series of weirs and are generally elevated above local groundwater levels (See **Map 4** in **Appendix A**). This means that these watercourses are either perched above the local water table (if the bed is of low permeability) or lose water to the ground (if the bed is permeable) (Dixon 2005) (See **Map 4**). It also means that certain areas of the site are susceptible to groundwater flooding e.g. parts of Pixey Mead and Yarnton Mead (Dixon 2005).

Gaining Streams

3.56 Both the Seacourt Stream and the Kingbridge Brook are gaining streams. This is because they bypass the weirs; therefore their typical stage levels are lower than the surrounding groundwater.

Cassington Tributaries

3.57 The western tributary arises from the perched second terrace gravels in this area. The eastern tributary arises 4km north of the Thames at Blacken Heath.

Cassington Pit

3.58 Extraction of sand and gravel occurred at Cassington Pit from 1989 on the northern side of the A40 (Dixon 2005). Groundwater modelling and monitoring showed groundwater drawdown occurring during dewatering across the SAC until a clay hydraulic cut-off was built and keyed into the underlying Oxford Clays (See **Map 4** in **Appendix A**). This stopped the drawdown but led to concerns about rising water levels on the mead, which led to the cutting of an additional drain to lower water levels (called the Eastern Discharge Drain in Dixon 2005). These observations clearly show that the sand and gravel deposits have the potential to form a good hydraulic connection between the SAC and nearby mineral workings, and to transmit the water table drawdown caused by dewatering.

Soil Moisture Controls

3.59 The depth to the groundwater table and the thickness of the alluvium are important controls on soil moisture levels and thus water availability for plants. Where groundwater levels drop below the base of the alluvium, upward supplies of water to plants reduce. This is due to the small capillary fringe in the coarse river terrace gravels (relative to the much finer-grained alluvium). A map of where groundwater levels are already close to the bottom of the alluvium is contained within Dixon (2005). These vulnerable areas to plant water stress, in Dixon (2005) are stated as being around the North West part of Oxey Mead and through Cassington Meadows.

Groundwater Catchment

3.60 Due to the SAC's location within the Thames Valley, the full groundwater catchment is extremely large (i.e. the whole Thames groundwater catchment). **Map 4** in **Appendix A**, however, indicates significant hydraulic boundaries within the surrounding areas. These include:

- The surface water network classified as Gaining, Losing or Perched streams.
- Groundwater Divides (defined by topography).

- Clay Bund built to hydraulically isolate an area of quarry working from the SAC (see **Paragraph 3.58**).
- Additionally the general influence of the River Thames upstream and downstream will form effective western and south-eastern boundaries to the alluvial/river terrace system.

3.61 These in combination show the important boundary controls for the SAC.

Groundwater Vulnerability and Protection

3.62 No Groundwater Source Protection Zone are located within the vicinity of Oxford Meadows.

Conceptual Model

Water Supply: Wetland Mechanisms

3.63 Oxford Meadows has a complex system of mechanisms that supply the habitats with water. There are four main mechanisms:

- Direct rainfall.
- Groundwater supplied through the losing sections of the River Thames – this can lead to alluvial groundwater flooding in some locations.
- Surface water flooding.
- Groundwater flow from the surrounding high ground – notably the flow from the upper river terrace gravels underlying parts of Oxford to the east of the southern half of the SAC.

3.64 These supply mechanisms create areas of waterlogging and ephemeral areas of openwater during the summer. Through the summer, the vegetation is dependent on the soil moisture content which, in turn, is dependent upon the height of the water table and the thickness of alluvium. In areas where the groundwater table is contained within the alluvium throughout summer months, soil moisture content levels are relatively higher compared to areas where the groundwater table lies within the river terrace gravels. This leads to a mosaic of habitats forming across the SAC.

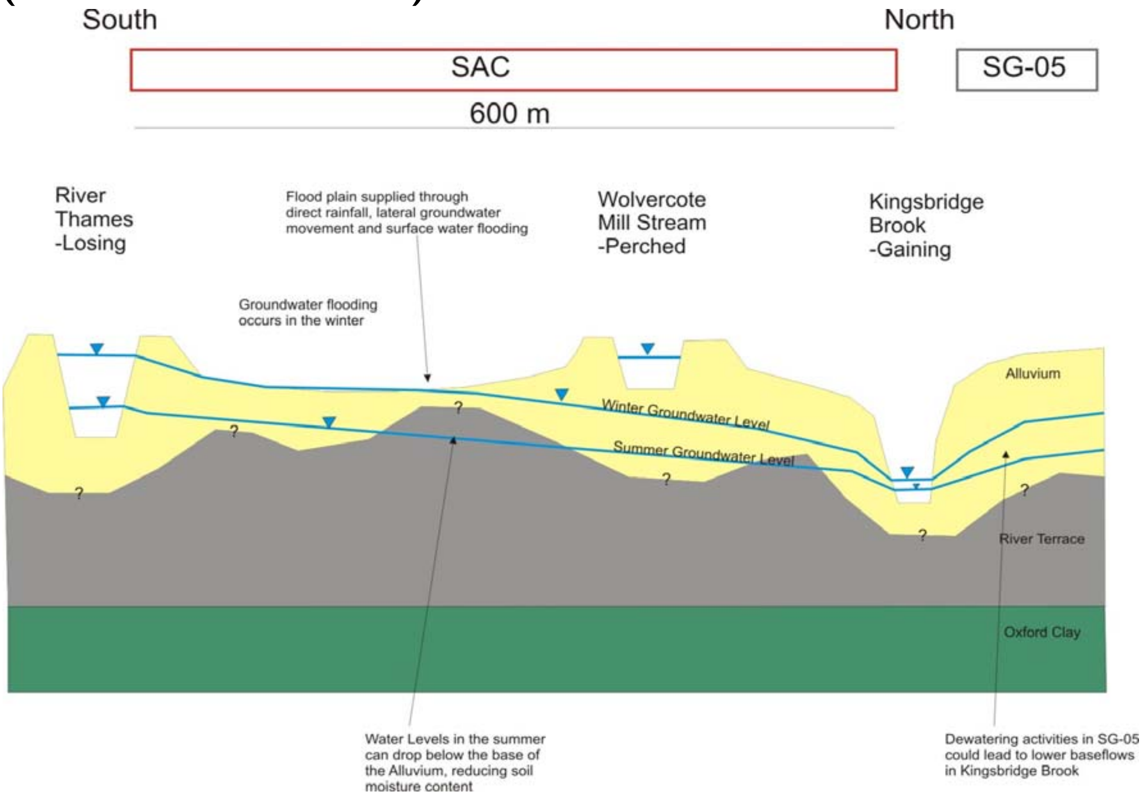
Summary of Conceptual Understanding

3.65 **Figure 3.2**, **Maps 4, 5 and 6** in **Appendix A** and the subsequent description summarise the conceptual model which has been devised for the site through interpretation of the information presented above. It is not a definitive model and should be revised as new data are collected. **Map 5** shows the approximate line of the cross-section depicted in **Figure 3.2,** which only includes a small section of SG-05 for illustration.

- The SAC is located on the River Thames flood plain.
- The river terrace gravels beneath the site act as a leaky aquifer, semi-confined by the alluvial deposits above.
- The site is underlain by Oxford Clays which form an effective aquitard and form the base of the shallow groundwater system.

- The stage in the River Thames is elevated above the surrounding groundwater, through a series of weirs, which leads to certain sections losing water to the ground.
- There are a number of small watercourses on the floodplain. Two of these, Seacourt Stream and Kingsbridge Brook, act as gaining rivers.
- The Wolvercote Mill Stream appears to be a perched stream with little or no interaction with surrounding groundwater levels.
- Water is supplied to the SAC habitats through direct rainfall, lateral groundwater movement (from the Thames and from surrounding higher ground) and surface water flooding.
- Soil moisture content is controlled partly through the summer by the position of the groundwater table relative to the substrate. Where the groundwater table is contained within the alluvial layer, soil moisture content tends to be higher.

Figure 3.2: Oxford Meadows SAC Conceptual Site Model (schematic and not to scale)



Mineral Planning Units: Impact Assessment

Screening of Nominated Sites for Impacts on Water Levels, Flows and Quality

3.66 All the site nominations listed in **Table 3.5** are located upstream of the SAC. Many of the sites are isolated from the SAC through hydraulic boundaries (See **Map 4** in **Appendix A**). Some of these hydraulic boundaries are rivers or streams. None of the hydraulic boundaries used in the assessment are rivers that are perched or otherwise hydraulically isolated from the shallow aquifer.

Table 3.5: Hydraulic Connectivity Between Nominated Mineral Sites and Oxford Meadows

Nomination	Distance from Oxford Meadows (km)	Hydraulic Connectivity Yes/No	Comment
SG-04	0.5	Possible	This nomination is divided from the site by the Kingsbridge Brook, which is a gaining stream (Dixon, 2005). In its present condition the Brook will form a hydraulic barrier to shallow groundwater flow. During quarry dewatering, the Brook may act as a 'recharge boundary', preventing the expansion of the cone of depression and protecting the SAC from water table drawdown. However, a large abstraction at the quarry site could potentially deplete flow in the Brook, reducing its effectiveness as a hydraulic boundary. Groundwater obstructions, such as clay bunding, built as part of site operations or restoration measures could result in the reduction of baseflow to the Brook.
SG-05	0.04	Possible (further assessment is certainly required due to the proximity of the nomination to the SAC)	This nomination is very close to the SAC; however, it is divided from it by the Kingsbridge Brook, which is a gaining stream. The same comments apply as to SG-04 above.
SG-16	0.4	Possible	This nomination is divided from the site by the Kingsbridge Brook. The same comments apply as to SG-04 above.
SG-08	2.4	No	This nomination is divided from the site by the River Evenlode, which is likely to form a hydraulic boundary*, preventing both the movement of contaminants across it, and the expansion of a cone of depression beyond it. However, mitigation measures may be required if groundwater abstraction at the site is likely to significantly deplete flow in the river.
SG-20	1.3	No	This nomination is divided from the site by the River Evenlode*. The same comments apply as to SG-08 above.
SG-20a	0.3	Yes (eastern side) – requires further assessment	The western half of the nomination is divided from the site by the River Evenlode*; however, there is no strong hydraulic boundary between the eastern half of SG-20a and the most western part of the SAC.
SG-20b	1.5	No	This nomination is divided from the site by the River Evenlode*. The same comments apply as to SG-20 above.
SG-29	4.2	No	This nomination is divided from the site by the River Evenlode* and the Wharf Stream. It is also some 5km upstream of the SAC.

Nomination	Distance from Oxford Meadows (km)	Hydraulic Connectivity Yes/No	Comment
SG-31	3.9	No	This nomination is divided from the site by the River Evenlode* and the Wharf Stream. It is also some 4.5km upstream of the SAC.
* The River Evenlode is a moderately-sized river and is therefore likely to form a barrier to shallow groundwater flow. The groundwater flow system in the sand/gravel aquifer is likely to be relatively shallow, with its base defined by the top of the Oxford Clay. A shallow flow field makes it more likely that the river can act as a barrier to groundwater flow. However, if the Evenlode is surrounded by lower permeability alluvial silt and clay then it may not be very well connected to the groundwater system.			

Further Nomination SAC Interaction Analysis

3.67 This section assesses in further detail the relationship between the SAC and nominations assessed as requiring further assessment in **Table 3.5**.

SG-04 and SG-16

3.68 **Map 5** in **Appendix A** shows the spatial relationship between SG-04, SG-16 and the SAC. These nominations are separated from the SAC by Kingsbridge Brook, which is a gaining stream (Dixon, 2005). The Brook will form a hydraulic barrier, at least to shallow groundwater flow. During quarry dewatering, the Brook may act as a 'recharge boundary', preventing the expansion of the cone of depression and protecting the SAC from water table drawdown. However, a large abstraction at the quarry site could potentially deplete flow in the Brook (or even dry it out). The influence of dewatering could then potentially impact on the SAC – either directly through expansion of the cone of depression, or indirectly through the lowering of water levels in the Brook. This could potentially be avoided by discharging abstracted groundwater into the Brook in order to maintain the flow (after cleaning the abstracted groundwater to remove fine sediment and any other contaminants).

3.69 Groundwater obstructions, such as clay bunding, built as part of site operations or restoration measures could result in the reduction of baseflow to the Brook. Due to the position of the nominations on the far side of the Brook (relative to the SAC) groundwater obstructions such as clay bunding would not be a suitable restoration measure to protect the SAC as it would reduce flows in the Brook.

SG-05

3.70 **Map 5** in **Appendix A** shows the spatial relationship between SG-05 and the SAC and **Figure 3.2** is a conceptual cross section of the area. Both the SAC and SG-05 are within the outcrop of the alluvial aquifer. Dividing them from each other is the Kingsbridge Brook, which is a gaining stream; this receives shallow groundwater from both banks and is therefore likely to act as a hydraulic boundary between the two.

3.71 Dewatering of SG-05 would draw water out of, or reduce baseflow to, Kingsbridge Brook. This would lower the stage of the brook, and increase the hydraulic gradient, thereby lowering groundwater levels on the SAC side. This impact could probably be avoided through mitigation measures such as discharging cleaned water back to the brook at a position upstream of the SAC. However, this might have the unintended consequence of raising water levels in the Brook, so that it gains less from the SAC.

3.72 It should be noted that the mineral workings site nomination form for this nomination states that excavations would take place to an average of 4.65m depth and that excavations beneath the water table would be wet. Wet working is not likely to result in a large impact on groundwater, compared to dewatering. There may be some impact due to increased evaporation from open water.

SG–20a

3.73 The lower river terrace groundwater flow in the area between the eastern part of SG-20a (east of the River Evenlode) and the western most part of the SAC is generally towards the main rivers (River Evenlode and River Thames). It is currently unclear whether the two Cassington tributaries are incised into the river terrace gravels and therefore form a discharge boundary to the aquifer. There is not a hydraulic boundary between the SAC and SG-20a (see **Map 6** in **Appendix A**); however, the direction of groundwater flow means that groundwater passing under one will not pass under the other, i.e. the SAC and the nominated site are not connected by groundwater flow lines, which means that there would not be a pathway between them via which pollutants or sediments could flow from the extraction site to the SAC.

3.74 Due to the lack of a hydraulic boundary, dewatering activities in SG-20a could change and reduce the groundwater catchment for the SAC, leading to a reduction in groundwater levels in the area.

3.75 Extraction activities in SG-20a would not lead to the creation of source-pathway-receptor linkages to the SAC because of the direction of groundwater movement (currently and during dewatering). Groundwater obstructions, such as clay bunding, built as part of site operations or restoration, are unlikely to reduce groundwater supplies to the SAC. This is because such obstructions built on the nominated site would be unlikely to change the size and shape of the groundwater catchment supplying the SAC.

3.76 It should be noted that the western half of SG-20a is isolated from the SAC by the River Evenlode.

3.77 The mineral workings site nomination form for this nomination states that excavations would take place to approximately 4.5m depth and that excavations may be wet or dry as the method of extraction has yet to be determined.

Cumulative Impacts

3.78 If nominated sites SG-04, SG-05 and SG-16 were to be worked and dewatered simultaneously then there would potentially be a greater impact on the surrounding water environment (with greater and/or more widespread water table drawdown and greater depletion of baseflow to surface watercourses). However, quarry operators commonly undertake phased dewatering, with only the current workings being actively dewatered. In this case the area affected by dewatering is generally much smaller, and the impacts correspondingly lower. If one operator were to have permission to extract from all three nominations then they might not work all three sites simultaneously and this impact would be avoided.

Restoration Phase

3.79 Any restoration proposals would need to be considered on a site-specific basis, but sand and gravel pits are commonly restored as lakes and wetlands. The old Cassington Pit immediately north of Oxford Meadows provides an example of this kind of restoration scenario; it now consists of several ponds.

3.80 Flooded gravel pits provide wildlife habitats and public amenity. From a hydrogeological perspective the potential impacts of flooded gravel pits are:

- Greater vulnerability of groundwater to pollution:
    - This greater vulnerability is due to the removal of overburden materials and the direct exposure of what is effectively the water table. Appropriate pollution prevention measures would need to be employed.
- Changes to the groundwater flow regime:
    - Significant changes are unlikely in gravel-floored pits lacking surface water inflows/outflows, as the water level would generally reflect the surrounding groundwater level (which would have rebounded following cessation of dewatering). However, accumulation of silt at the base of a flooded pit may decrease the hydraulic connectivity between the pit and the surrounding groundwater. This could allow a significant head difference to develop and drive new patterns of groundwater flow.
    - If pits are interconnected by surface watercourses and/or if significantly different water levels are maintained in adjacent pits or in pits and adjacent watercourses then there may be changes to the groundwater flow regime.

3.81 If pits are infilled, or partly infilled, with low permeability overburden materials (e.g. alluvial silt and clay) then the groundwater flow regime is likely to be modified. This is because high permeability aquifer has been replaced by lower permeability material. Infilled pits may therefore act as barriers (or partial barriers) to groundwater flow.

CONCLUSIONS FROM HYDROGEOLOGICAL ASSESSMENT

Cothill Fen

3.82 Cothill Fen SAC is dependent on groundwater from the underlying Corallian aquifer.

3.83 Although both sites nominated for soft sand extraction in the vicinity of Cothill Fen SAC (SS-01 and SS-05) are located on the Corallian aquifer, quarrying at these sites would be unlikely to impact on the SAC. The distances involved mean that the water table drawdown resulting from quarry dewatering would be unlikely to extend far enough to affect the Fen. In the case of SS-01 (Tubney Barn), only limited dewatering is proposed, with most quarrying taking place above the water table. Both mineral sites are separated from the SAC by surface watercourses that may act as hydraulic barriers, separating the sites from the SAC. No significant Source – Pathway – Receptor pollutant linkages have been identified between the proposed mineral sites and Cothill Fen SAC.

Oxford Meadows

3.84 Oxford Meadows SAC is dependent on groundwater input from river terrace sand and gravel deposits, as well as direct rainfall and river flooding.

3.85 Four nominations for sand and gravel extraction (SG-04, SG-05, SG-16 and SG-20a) have been shown to have a hydraulic connection (or possible connection) with the SAC. There is therefore the potential that mineral working at these sites could affect (i) water levels at the SAC (through dewatering of the sand and gravel, and drawdown of the water table) and/or (ii) water quality at the SAC (through release of sediment and/or chemical contaminants).

3.86 Mitigation measures could limit the significance of the potential impacts and should be part of planning conditions for these areas.

3.87 If nominations SG-04, SG-05 and SG-16 were to be worked and dewatered simultaneously then there would potentially be a greater impact on the surrounding water environment (with greater and/or more widespread water table drawdown and greater depletion of baseflow to surface watercourses). However, quarry operators commonly undertake phased dewatering, with only the current workings being actively dewatered. In this case the area affected by dewatering is generally much smaller, and the impacts correspondingly lower.

3.88 Any restoration proposals would need to be considered on a site-specific basis, but sand and gravel pits are commonly restored as lakes and wetlands. Flooded gravel pits may increase the vulnerability of groundwater in connected gravel aquifers, although this risk can be managed through proper pollution controls. Infilling of pits with lower permeability materials (e.g. alluvial silt/clay overburden) may modify the groundwater flow regime.

4 Revised Screening Findings and Conclusions

4.1 This section uses the findings of the hydrogeological assessment, described in **Section 3**, to answer the Screening Stage Research Questions (1-6) identified in **Section 2** and inform the Revised Screening findings for the Eynsham/Cassington/Yarnton area, the North and south of the A420 to the west of Abingdon area, and each of the eleven nominated sites. These Revised Screening findings are summarised in **Table 4.1**.

COTHILL FEN SAC

4.2 This section concludes whether the preferred North and south of the A420 to the west of Abingdon soft sand extraction area, and the two nominated sites within 5km of Cothill Fen SAC are likely to have a significant effect on the SAC qualifying features. The Screening Stage Research Questions are discussed below.

1) What is the hydraulic connectivity between the nominated mineral extraction sites and Cothill Fen?

4.3 Neither of the nominated sites (SS-01 and SS-05) is located in the same groundwater catchment as Cothill Fen SAC. In addition, they are separated from the SAC by a surface watercourse which may or may not act as a hydraulic boundary. Calculations as part of the hydrogeological assessment indicate that the dewatering cone of depression, associated with extraction of soft sand at both of the nominated sites, would not extend as far as Cothill Fen SAC. However, the eastern parts of the preferred North and south of the A420 to the west of Abingdon soft sand extraction area identified in the Draft Minerals Planning Strategy would be in the same groundwater catchment as Cothill Fen SAC (see **Map 2**, **Appendix A**) and therefore mineral extraction in this area could be hydraulically connected to the SAC.

2) What is the expected effect on water chemistry, quality, level, turbidity, sedimentation and pollution at Cothill Fen SAC as a result of extraction at the nominated mineral sites within 5km?

4.4 No significant effects on water chemistry, quality, level, turbidity, sedimentation and pollution are predicted to occur from extraction at the two nominated sites as they are not hydraulically connected to the SAC. However, if extraction took place in the very eastern parts of the preferred North and south of the A420 to the west of Abingdon soft sand extraction area currently identified in the Draft Minerals Planning Strategy there could be impacts on water quality etc. as extraction sites would be in the same groundwater catchment as Cothill Fen SAC (see **Map 2**, **Appendix A**).

3) Are the impacts identified likely to result in significant effects to Cothill Fen SAC?

4.5 No significant effects to Cothill Fen SAC are predicted as a result of extraction at the two nominated mineral sites because they are not hydraulically connected. However, significant effects could occur if mineral extraction occurred in the very eastern parts of the preferred North and south of the A420 to the west of Abingdon soft sand extraction area currently identified in the Draft Minerals Planning Strategy as they could be in the same groundwater catchment as Cothill Fen SAC (see **Map 2**, **Appendix A**).

4) What other plans and projects could affect Cothill Fen SAC 'in-combination with the nominated minerals sites?

4.6 The strategic areas proposed for housing/employment development in the Vale of White Horse and South Oxfordshire Core Strategies are not in close proximity to the Cothill Fen? SAC and therefore considered unlikely to have in-combination effects with the Oxfordshire Minerals and Waste Core Strategy. The only proposed development in other plans or projects in proximity to the Cothill Fen SAC are the proposed upgrades to the A415 in the Oxfordshire Local Transport Plan 3 (2011-2030). These are unlikely to result in in-combination effects with extraction at either the two nominated sites or the rest of the North and south of the A420 to the west of Abingdon soft sand area because the A415 is located approximately 2.5km to the south of the Cothill Fen SAC surface and groundwater catchment area, therefore the upgrades are also unlikely to affect the SAC.

5) Which nominated mineral extraction sites are unlikely to result in significant effects to Cothill Fen SAC and can therefore be screened out from further assessment?

4.7 Both of the nominated sites (SS-01 and SS-05) within 5km of Cothill Fen SAC can be screened out from further assessment as part of the HRA of the Minerals Planning Strategy.

4.8 As stated above, significant effects could occur if mineral extraction occurred in the eastern-most parts of the preferred North and south of the A420 to the west of Abingdon soft sand strategic area currently identified in the Draft Minerals Planning Strategy as they could be in the same groundwater catchment as Cothill Fen SAC.

6) Which nominated mineral sites are likely to result in significant effects to the SAC, or there is a lack of information to prove otherwise, and therefore require appropriate assessment?

4.9 Neither of the two nominated mineral sites is likely to result in significant effects to Cothill Fen SAC.

OXFORD MEADOWS SAC

4.10 This section concludes whether the preferred Eynsham/Cassington/Yarnton sharp sand and gravel extraction area currently identified in the Draft Minerals Planning Strategy, and in particular, the nine nominated sites within 5km of Oxford Meadows SAC are likely to have a significant effect on the SAC qualifying features. The Screening Stage Research Questions are discussed below.

1) What is the hydraulic connectivity between the nominated mineral extraction sites and Oxford Meadows SAC?

4.11 Five of the nominated sites (SG-08, SG-20, SG-20b, SG-29 and SG-31) are not hydraulically connected to Oxford Meadows SAC. They are separated by the River Evenlode which is likely to form a hydraulic barrier (see **Map 3**, **Appendix A**).

4.12 Four of the nominated sites (SG-04, SG-05, SG-16 and SG-20a) have been shown to have a hydraulic connection (or possible connection) with Oxford Meadows SAC. In addition, the south eastern part of the preferred Eynsham/Cassington/Yarnton sharp sand and gravel extraction area (i.e. east of the River Evenlode) are also likely to have a hydraulic connection (see **Map 4**, **Appendix A**).

2) What is the expected effect on water chemistry, quality, level, turbidity, sedimentation and pollution at Oxford Meadows SAC as a result of extraction at the nominated mineral sites within 5km?

4.13 No effect on water chemistry, quality, level, turbidity, sedimentation or pollution is predicted from the five sites which are not hydraulically connected (SG-08, SG-20, SG-20b, SG-29 and SG-31).

4.14 Four of the nominated sites (SG-04, SG-05, SG-16 and SG-20a) as well as the south eastern part of the preferred Eynsham/Cassington/Yarnton sharp sand and gravel extraction area are likely to have a hydraulic connection with Oxford Meadows SAC. Extraction of sharp sand and gravel at these sites or in the south eastern part of the strategic area has the potential to affect the water chemistry, quality, levels, turbidity, sedimentation and pollution at Oxford Meadows SAC, with consequent effects on the qualifying features (see below).

3) Are the impacts identified likely to result in significant effects to Oxford Meadows SAC?

4.15 The qualifying features of Oxford Meadows SAC (lowland hay meadows and creeping marshwort) are dependent upon groundwater input from river terrace sand and gravel deposits as well as seasonal flooding (winter flooding supplies nutrients to the grassland habitats). The lowland hay meadow habitat, comprises the MG4 grassland community (*Alopecurus pratensis – Sanguisorba officinalis*) which is species-rich, containing up to 18 different grasses plus a few sedges and rushes.

4.16 MG4 grassland is dependent upon an aerated root zone during the growing season, i.e. spring/summer and an adequate water supply so as not to limit plant growth early in summer. Therefore, excess water during spring/summer may be particularly detrimental[3]. The Environment Agency's Review of Consents[4] potentially affecting the Oxford Meadows SAC (another requirement under the Habitats Regulations) suggests that the main threat to

[3] Wheeler B.D, Gowing D.J.G, Shaw S.C, Mountford J.O, and Money R.P, (2004) Ecohydrological Guidelines for Lowland Wetland Plant Communities (Eds A.W. Brooks, P.V. Jose, and M.I.Whiteman,). Environment Agency (Anglian Region)

[4] Dated 2005 – supplied by the Environment Agency for this study.

the Oxford Meadows SAC from mineral extraction is from a lowering of the water table during dewatering and raised ground water levels during operation and restoration.

4.17 The interest features on Oxford Meadows SAC have been identified as susceptible to the effects of eutrophication (in the EA Review of Consents report). Increased nutrients will generally lead to a loss of species diversity as more aggressive and competitive species dominate. While sand and gravel extraction may result in changes to sediment levels within ground and surface water, it is unlikely to affect water chemistry via addition of nutrients such as phosphorus or nitrogen, therefore is considered unlikely to have a significant effect on the SAC in terms of eutrophication.

4.18 Four of the nominated sites (SG-04, SG-05, SG-16 and SG-20a) as well as the south eastern part of the preferred Eynsham/Cassington/Yarnton sharp sand and gravel extraction area have been shown to have a hydraulic connection with Oxford Meadows SAC.

4.19 Therefore extraction of sand and gravel at these sites or within the south eastern part of the strategic area has the potential to result in significant effects to Oxford Meadows SAC, primarily as a result of changes in ground water levels at the site.

4) What other plans and projects could affect Oxford Meadows SAC 'in-combination with the nominated minerals sites?

4.20 There is potential for the four sites with hydraulic connectivity to Oxford Meadows SAC to have a 'likely significant effect' on the SAC qualifying features in-combination with the 'Northern Gateway' and 'Summertown' proposals detailed in the Oxford Core Strategy. The Northern Gateway (Policy CS6) allocates a large mainly greenfield site to the north of Oxford City as a strategic location to provide an employment-led development with supporting infrastructure and complementary amenities. Parts of the Northern Gateway site are less than 500 metres from the Oxford Meadows SAC (see **Map 11** in **Appendix A**).

4.21 However, the Oxford Core Strategy includes strong policy caveats in the supporting text to the Northern Gateway Policy CS6 that seek to avoid any adverse effects occurring on the integrity of Oxford Meadows SAC, either from hydrological, air pollution or recreational impacts. For these reasons the Oxford Core Strategy HRA Report[5] was able to conclude that the policies in the Core Strategy would not have an adverse effect on the integrity of Oxford Meadows SAC.

4.22 The HRA of the Oxford Core Strategy also identified Policy CS10 'Land at Summertown' as resulting in possible impacts to Oxford Meadows SAC as a result of changes in water quality and balanced hydrological regime. The Land at Summertown is located approximately 1.4km to the east of the SAC (see **Map 11**) and involves the allocation of the area as a district centre with residential and retail development. The HRA concluded that the Summertown proposals would be unlikely to result in significant effects to the

[5] Oxford City Council (2008). *Oxford Core Strategy Habitats Regulations Assessment*.

Oxford Meadows SAC as a result of changes to the balanced hydrological regime. The HRA of the Oxford Core Strategy was able to conclude after consultation with the Environment Agency, (based on its HRA of the abstraction license at Farmoor reservoir) that water abstraction to serve proposed growth and development in Oxford (including Summertown and the Northern Gateway) and Swindon would be unlikely to have a significant impact on the Oxford Meadows SAC'.

4.23 With regard to water quality impacts from the 'Land at Summertown' policy in the Oxford Core Strategy, the HRA concluded that the Core Strategy is not proposing a level of development which exceeds the capacity of waste water treatment and also referred to strong policy caveats in the Core Strategy including the requirement for the production of Natural Resource Impact Analysis to ensure impacts associated with water quality are minimised. The HRA concluded that 'water quality impacts as a result of the Oxford Core Strategy are unlikely to have a significant effect of the Oxford Meadows SAC.

4.24 Therefore, it is considered unlikely that there will be in-combination effects on the Oxford Meadows SAC arising from proposals in the Oxford Core Strategy and the Oxfordshire Minerals & Waste Core Strategy.

4.25 The strategic areas proposed for housing/employment development in the Cherwell, Vale of White Horse, South Oxfordshire and West Oxfordshire Core Strategies are not in close proximity to the Oxford Meadows SAC and therefore considered unlikely to have in-combination effects with the Oxfordshire Minerals and Waste Core Strategy.

4.26 The Thames Corridor Abstraction Management Strategy states that the Upper Thames is categorised as 'over-abstracted' and that there is 'concern that during low flows, insufficient water is available to the Oxford Meadows SAC' to support the site's habitats. The Environment Agency has reviewed the impact of relevant abstraction licences on the Oxford Meadows SAC as part of its review of consents under the Habitats Directive. This review[6] concluded that 'there is no adverse effect on the integrity of the site alone or in-combination from water quality discharge consents or water resource permissions'.

5) Which nominated mineral extraction sites are unlikely to result in significant effects to Oxford Meadows SAC and can therefore be screened out from further assessment?

4.27 The five nominated sites which are not hydraulically connected (SG-08, SG-20, SG-20b, SG-29 and SG-31) can be screened out from further assessment within the HRA of the Minerals Planning Strategy.

4.28 However, because one of the four sites that are hydraulically connected to the SAC (SG-04, SG-05, SG-16 and SG-20a) is within the Eynsham/Cassington/Yarnton area for sand and gravel (SG-20a), the whole of

[6] Habitats Directive: Proforma for Stage 3 Assessment of Adverse Effect on Site Integrity - Review of Consents (2005) – Oxford Meadows SAC.

this sand and gravel area proposed in the Minerals Planning Strategy cannot be screened out.

6) Which nominated mineral sites are likely to result in significant effects to the SAC, or there is a lack of information to prove otherwise, and therefore require appropriate assessment?

4.29 The potential for the hydrological impacts identified to result in significant effects on the Oxford Meadows SAC from the four sites shown to have a hydraulic connection with Oxford Meadows SAC (SG-04, SG-05, SG-16 and SG-20a) cannot be ruled out at this stage. Therefore, appropriate assessment is required to determine whether they are likely to result in adverse effects on the integrity of the SAC and whether mitigation and/or modification to the Minerals Planning Strategy is required. This is described in **Section 5**.

REVISED SCREENING CONCLUSIONS

Cothill Fen SAC

4.30 Both of the nominated sites (SS-01 and SS-05) within 5km of Cothill Fen SAC can be screened out from further assessment as part of the HRA of the Minerals and Waste Core Strategy. However, HRA work may be needed at the planning application stage to ensure that the exact proposals for minerals extraction at these sites would not adversely affect the integrity of Cothill Fen SAC.

4.31 As stated above, significant effects could occur if mineral extraction occurred in the eastern parts of the preferred North and south of the A420 to the west of Abingdon soft sand strategic area currently identified in the Draft Minerals Planning Strategy as they could be in the same groundwater catchment as Cothill Fen SAC. Therefore, HRA work would have to be conducted at the planning application stage for any extraction sites proposed within the eastern parts of the soft sand strategic area to ensure that the exact proposals for minerals extraction at these sites would not adversely affect the integrity of Cothill Fen SAC. It has been shown from recent planning permissions, that mineral extraction can take place closer to the SAC (e.g. the Upwood Park extraction site adjacent to the SAC), but only with very stringent controls on site operations (e.g. robust monitoring and no mineral extraction below the water table).

Oxford Meadows SAC

4.32 Five of the nominated sites within the Eynsham/Cassington/Yarnton area are not hydraulically connected to Oxford Meadows SAC (SG-08, SG-20, SG-20b, SG-29 and SG-31) and can therefore be screened out from further assessment within the HRA of the Minerals Planning Strategy. However, HRA work may be needed at the planning application stage to ensure that the exact proposals for minerals extraction at these sites would not adversely affect the integrity of Oxford Meadows SAC.

4.33 The four nominated sites for which a finding of ‘no likely significant effect’ cannot be reached for Oxford Meadows SAC, and which therefore require further investigation as part of the Appropriate Assessment stage of the HRA are:

SG-04 Land at Mead Farm.

SG-05 Land to the east of Cassington Quarry.

SG-16 Land at Stonehouse Farm, north east of Cassington Quarry.

SG-20a Wharf Farm, Cassington.

4.34 These sites have been subject to a 'preliminary' appropriate assessment as described in **Section 5**. Further appropriate assessment may be needed if these sites are allocated within the Site Allocations DPD.

Table 4.1: Revised Screening Matrix

SOURCE		PATHWAY	RECEPTOR		SUMMARY
Proposed mineral extraction preferred area	Potential impacts	Pathways of Impact	Name of SAC (and component SSSIs)	Conservation objective of SAC	Likely significant effect?
SHARP SAND AND GRAVEL AREA					
Eynsham/ Cassington/ Yarnton	- Dewatering phase resulting in lowering of the water table. - Operation and restoration phase resulting in raised ground water levels due to interruption of ground water flow. - Insufficient sediment deposition. - Eutrophication from deposition of nutrient rich sediment during flood events (Diffuse and	- The nearest site nomination within the sand and gravel area is SG-20a which is located approximately 260m to the west of the Oxford Meadows SAC. Nominated sites SG-04, SG-05 and SG-16 are located outside the preferred area, approximately 400m, 40m and 480m from the SAC respectively. Pathways include: - Watercourses. - Surface water - Ground water. The hydrogeological assessment confirms that: i) the majority of nominated sites within this preferred area are not hydraulically	Oxford Meadows SAC *From NW to SE:* Cassington Meadows SSSI Pixey and Yarnton Meads SSSI Wolvercote Meadows SSSI Port Meadow with Wolvercote Common & Green SSSI	To maintain alluvial, species rich flood meadows and *apium repens* in a favourable condition. Condition summary 17/8/11 = 100% favourable Condition summary 3/10/11 = 100% favourable Condition summary 3/10/11 = 100% favourable Condition summary 3/10/11 = 98.72% favourable; 1.28% unfavourable recovering	**POTENTIALLY**[7] Sites SG-08, SG20, SG-20b, SG-29 and SG-31 are not hydraulically connected to the Oxford Meadows SAC, being separated by surface watercourses likely to form an effective hydraulic barrier. Therefore sharp sand and gravel extraction at these sites is unlikely to result in significant adverse effects to the SAC qualifying features as a result of changes in water level or water quality. However, four nominations for sand and gravel extraction (SG-04, SG-05, SG-16 and SG-20a) have been shown to have a hydraulic connection (or possible connection) with the Oxford Meadows SAC. Given that surface water flooding at the SAC is largely controlled by a series of locks, potential impacts associated with

Potential for significant effects to SAC	Significant effects to SAC unlikely

SOURCE		PATHWAY	RECEPTOR		SUMMARY
Proposed mineral extraction preferred area	Potential impacts	Pathways of Impact	Name of SAC (and component SSSIs)	Conservation objective of SAC	Likely significant effect?
	point sources). - Reduction in or water supply, particularly during early summer - Excess water.	connected to Oxford Meadows SAC; ii) Site SG-05 is probably not hydraulically connected to the Oxford Meadows SAC but further assessment is required to enable a finding of 'no likely impact'. iii) Site SG20a is hydraulically connected and further assessment is required.			water quality are considered unlikely. However, there is therefore potential for mineral workings at these sites to affect ground water levels at the SAC. The SAC qualifying feature lowland hay meadows is dependent upon an aerated root zone during the growing season and an adequate water supply so as not to limit plant growth early in summer[8]. Therefore changes in ground water levels, for example during dewatering has the potential to affect the SAC. One of the nominated sites (SG-20a) is within the Eynsham/Cassington/Yarnton sand and gravel area. Therefore, further assessment is required to determine whether there will be an adverse effect upon the integrity of the Oxford Meadows SAC (see **Table 5.1**). Identification of options for mitigation or modification of the minerals plan may be required to enable a conclusion of 'no adverse effect on site integrity'.

[8] Wheeler B.D, Gowing D.J.G, Shaw S.C, Mountford J.O, and Money R.P, (2004) Ecohydrological Guidelines for Lowland Wetland Plant Communities (Eds A.W. Brooks, P.V. Jose, and M.I.Whiteman,). Environment Agency (Anglian Region)

SOURCE		PATHWAY	RECEPTOR		SUMMARY
Proposed mineral extraction preferred area	Potential impacts	Pathways of Impact	Name of SAC (and component SSSIs)	Conservation objective of SAC	Likely significant effect?
Nominated Sites within 5km of Oxford Meadows SAC					
SG-04 Land at Mead Farm	As above	The hydrogeological conceptual model confirms that this site may be hydraulically connected to Oxford Meadows SAC.	As above	As above	**POTENTIALLY** This site nomination is separated from the Oxford Meadows SAC by a hydraulic barrier in the form of Kingsbridge Brook. However, mineral extraction could deplete flow in the Brook and reduce its effectiveness as a hydraulic boundary. Therefore, further assessment is required to determine the likelihood of adverse effects upon the integrity of the SAC (see **Table 5.1**). Identification of options for mitigation and/or modification of the minerals plan may be required to enable a conclusion of 'no adverse effect on integrity'.
SG-05 Land to the east of Cassington Quarry	As above	This site is situated adjacent to the Oxford Meadows SAC. The hydrogeological assessment confirms that these sites may be hydraulically connected.	As above	As above	**POTENTIALLY** As above (SG-04)
SG-08 Land at Lower Road, Church Hanborough	As above	The hydrogeological assessment confirms this site is not hydraulically connected to Oxford Meadows SAC, being divided by the River Evenlode which is likely to form a hydraulic barrier.	As above	As above	**NO** The hydrogeological assessment indicates that the SG-08 nominated site is unlikely to have a significant effect on the qualifying features of the Oxford Meadows SAC as a

SOURCE		PATHWAY	RECEPTOR		SUMMARY
Proposed mineral extraction preferred area	Potential impacts	Pathways of Impact	Name of SAC (and component SSSIs)	Conservation objective of SAC	Likely significant effect?
					result of hydrological impacts.
SG-16 Land at Stonehouse Farm, north east of Cassington Quarry	As above	The hydrogeological assessment confirms that this site may be hydraulically connected to Oxford Meadows SAC.	As above	As above	**POTENTIALLY** As above (SG-04)
SG-20 Land between Eynsham and Cassington	As above	The hydrogeological assessment confirms that this site is not hydraulically connected to Oxford Meadows SAC, being divided by the River Evenlode which is likely to form a hydraulic barrier.	As above	As above	**NO** The hydrogeological assessment indicates that the SG-20 nominated site is unlikely to have a significant effect on the qualifying features of the Oxford Meadows SAC as a result of hydrological impacts.
SG-20a Wharf Farm, Cassington	As above	The hydrogeological assessment confirms that this site is likely to be hydraulically connected to Oxford Meadows SAC.	As above	As above	**POTENTIALLY** The hydrogeological assessment concluded that there is no strong hydraulic boundary between the eastern half of SG-20a and the westernmost part of the Oxford Meadows SAC. Therefore, further assessment, is required to determine the likelihood of adverse effects upon the integrity of the SAC (see **Table 5.1**). Identification of options for mitigation and/or modification of the minerals plan may be required to enable a conclusion of 'no adverse effect

SOURCE		PATHWAY	RECEPTOR		SUMMARY
Proposed mineral extraction preferred area	Potential impacts	Pathways of Impact	Name of SAC (and component SSSIs)	Conservation objective of SAC	Likely significant effect?
					on integrity'.
SG-20b Land at Eynsham	As above	The hydrogeological assessment confirms This site is not hydraulically connected to Oxford Meadows SAC, being divided by the River Evenlode which is likely to form a hydraulic barrier.	As above	As above	**NO** The hydrogeological assessment indicates that the SG-20b nominated site is unlikely to have a significant adverse effect on the qualifying features of the Oxford Meadows SAC as a result of hydrological impacts.
SG-29 Sutton Farm, Sutton, Stanton Harcourt	As above	The hydrogeological assessment confirms This site is not hydraulically connected to Oxford Meadows SAC, being divided by the River Evenlode which is likely to form a hydraulic barrier.	As above	As above	**NO** The hydrogeological assessment indicates that the SG-29 nominated site is unlikely to have a significant adverse effect on the qualifying features of the Oxford Meadows SAC as a result of hydrological impacts.
SG-31 Land east of Sutton, Stanton Harcourt	As above	The hydrogeological assessment confirms This site is not hydraulically connected to Oxford Meadows SAC, being divided by the River Evenlode which is likely to form a hydraulic barrier.	As above	As above	**NO** The hydrogeological assessment indicates that the SG-31 nominated site is unlikely to have a significant adverse effect on the qualifying features of the Oxford Meadows SAC as a result of hydrological impacts.

SOURCE		PATHWAY	RECEPTOR		SUMMARY
Proposed mineral extraction preferred area	Potential impacts	Pathways of Impact	Name of SAC (and component SSSIs)	Conservation objective of SAC	Likely significant effect?
SOFT SAND AREAS					
North and south of the A420 to the west of Abingdon	- Changes to hydrology including water quality, water levels, sedimentation, and pollution.	The nearest proposed working (i.e. site nomination) within the soft sand area is 2.1km from Cothill Fen SAC. Pathways include: - Watercourses. - Surface water - Ground water. The hydrogeological assessment concluded that the nominated sites within this preferred area are: i) possibly hydraulically connected to Cothill Fen SAC; ii) not situated in the same groundwater catchment as Cothill Fen SAC; and iii) are separated from Cothill Fen SAC by a surface watercourse which may or may not act as a hydraulic barrier. Calculations suggest that the cone of	Cothill Fen SAC Cothill Fen SSSI	To maintain fen meadow, mire and swamp and broadleaved, mixed and yew woodland in a favourable condition. Condition summary 3/10/11 = 65.36% favourable; 34.64% unfavourable recovering.	**POTENTIALLY** The hydrogeological assessment showed that working of soft sand at the nominated sites within this preferred area would be unlikely to have a significant effect on water levels or water quality at Cothill Fen SAC. However, as specific proposals for mineral extraction at these sites come forward, they would still require assessment at the application stage to determine the likelihood of significant effects upon the Cothill Fen SAC. Significant effects could arise if mineral extraction occurred in the eastern-most parts of the preferred Tubney/Marcham/Hinton Waldrist soft sand extraction area currently identified in the Minerals and Waste Core Strategy as they could be in the same groundwater catchment as Cothill Fen SAC.

SOURCE		PATHWAY	RECEPTOR		SUMMARY
Proposed mineral extraction preferred area	Potential impacts	Pathways of Impact	Name of SAC (and component SSSIs)	Conservation objective of SAC	Likely significant effect?
		depression for each nominated site would not extend as far as Cothill Fen SAC.			
Nominated sites within the North and south of the A420 to the west of Abingdon area					
SS-01 Tubworth Barn, Tubney	- Changes to hydrology including water quality, water levels, sedimentation, and pollution.	Located 2.1km from Cothill Fen SAC. The hydrogeological assessment concluded that the Tubworth Barn site (SS-01) is: i) possibly hydraulically connected to Cothill Fen SAC; ii) not situated in the same groundwater catchment as Cothill Fen SAC; and iii) separated from Cothill Fen SAC by a surface watercourse which may or may not act as a hydraulic barrier. Calculations suggest limited dewatering and indicate that the cone of depression would not extend as far as Cothill Fen SAC.	As above	As above	**NO** The nominated site SS-01 is not in the same groundwater catchment as the Cothill Fen SAC and calculations suggest that the cone of depression would not extend as far as Cothill Fen SAC. Therefore, the Tubworth Barn nominated site is unlikely to have a significant effect on the qualifying features of the Cothill Fen SAC as a result of hydrological impacts.

SOURCE		PATHWAY	RECEPTOR		SUMMARY
Proposed mineral extraction preferred area	Potential impacts	Pathways of Impact	Name of SAC (and component SSSIs)	Conservation objective of SAC	Likely significant effect?
SS-05 Land at Kingston Bagpuize	- Changes to hydrology including water quality, water levels, sedimentation, and pollution.	Located 3.5km from Cothill Fen SAC. The hydrogeological assessment concluded that the Land at Kingston Bagpuize site (SS-05) is: i) possibly hydraulically connected to Cothill Fen SAC; ii) not situated in the same groundwater catchment as Cothill Fen SAC; and iii) separated from Cothill Fen SAC by a surface watercourse which may or may not act as a hydraulic barrier. Calculations suggest that the cone of depression would not extend as far as Cothill Fen SAC.	As above	As above	**NO** The nominated site SS-05 is not in the same groundwater catchment as the Cothill Fen SAC and calculations suggest that the cone of depression would not extend as far as Cothill Fens SAC. Therefore, the Land at Kingston Bagpuize nominated site is unlikely to have a significant effect on the qualifying features of the Cothill Fen SAC as a result of hydrological impacts.

5 Preliminary Appropriate Assessment

5.1 A 'preliminary' appropriate assessment has been undertaken focussing on the four nominated minerals sites whose impacts were considered likely to have a significant effect on the qualifying features of the Oxford Meadows SAC at the screening stage. The Appropriate Assessment Stage Research Questions identified in **Section 2** are discussed below.

5.2 The Appropriate Assessment matrix shown in **Table 5.1** attempts to assess whether the 'likely significant effects' identified at the Screening Stage could, in light of the SAC qualifying features and conservation objectives and mitigation proposals, result in adverse effects on the integrity of the SAC at the strategic planning level, either alone, or in-combination with other plans and projects.

5.3 It should be noted that this assessment is not required for the Minerals and Waste Core Strategy as it does not allocate any of these sites – that will happen through the Site Allocations DPD. However, as the nominated sites have helped to inform the identification of the preferred strategic areas for sharp sand and gravel and soft sand extraction, and they will be considered further during preparation of the Site Allocations DPD, it was considered useful to set out preliminary Appropriate Assessment findings in this report. These findings will need to be reviewed and updated in any HRA work for the Site Allocations DPD, and HRA is also likely to be required for any planning application that comes forward at these four sites.

7) Are these potential impacts/changes likely to have a significant effect on the integrity of the Oxford Meadow SAC qualifying features, either alone or in-combination with other plans and projects?

5.4 The main threats to Oxford Meadows SAC are lowering of the water table, leading to loss of the MG4 grassland communities and eutrophication from deposition of nutrient rich sediment during flood events.

5.5 The EA review of consents under the Habitats Directive[9] for Oxford Meadows SAC explains that the site's water levels are largely controlled by a series of locks. Therefore impacts associated with eutrophication during flooding are considered unlikely. The assessment describes the lowland hay meadows as being dependent upon 'occasional big flood events to replenish its available phosphorus concentrations'. In addition, while sand and gravel extraction may result in changes to sediment levels within ground and surface water, it is unlikely to affect water chemistry via addition of nutrients such as phosphorus or nitrogen, and therefore is considered unlikely to have a significant effect on the SAC in terms of eutrophication.

5.6 Given the hydraulic connectivity between the sites (identified through the hydrogeological assessment in Section 3), there is potential for sharp sand and gravel extraction to result in changes to the water levels at Oxford

[9] Habitats Directive: Proforma for Stage 3 Assessment of Adverse Effect on Site Integrity - Review of Consents (2005) – Oxford Meadows SAC

Meadows SAC. The lowland hay meadow habitat for which the SAC is in-part designated, is highly dependent upon maintenance of optimal water levels, requiring an aerated root zone during the growing season and an adequate water supply so as not to limit plant growth in early summer. Evidence from previous mineral extraction at Cassington Quarry has shown that there is potential for a reduction in water levels at the SAC during dewatering, followed by an increase in the water table during operation and restoration. The hydrogeological conceptual model has shown that the SAC may be located within the dewatering cone of depression for each of the four nominated sites with hydraulic connectivity to the SAC. Therefore, adverse effects on the integrity of the Oxford Meadows SAC as a result of changes to water levels cannot be ruled out if any of the four sites was allocated within the Site Allocations DPD.

5.7 There is also potential for mineral extraction sites operating at the same time to increase the likelihood of adverse effects upon the SAC as a result of in-combination effects associated with changes in ground water levels. However, no other relevant plans and projects have been identified which are considered likely to adversely affect the SAC in-combination with the Minerals Strategy, either because they are located a sufficient distance from the site to rule out likely significant effects or their relevant Habitat Regulations Assessment has concluded that they will not affect the integrity of the Oxford Meadows SAC.

8) For the nominated mineral extraction sites where significant effects on the integrity of the Oxford Meadows SAC qualifying features cannot be ruled out, can modification (e.g. to site boundaries) or mitigation provide sufficient evidence to enable a conclusion of no adverse effect on integrity?

5.8 Adverse effects on the integrity of Oxford Meadows SAC cannot be ruled out if mineral extraction occurs at nominated sites SG-04, SG-05, SG-16 and SG-20a due to the hydraulic connectivity between the nominated sites and the SAC. Recommendations for modifications that could be made to documents in the Minerals and Waste Development Framework and for mitigation measures that should be required for any proposals that come forward on these sites are listed in **Table 5.1** and in more detail in **Section 6**.

Table 5.1: Preliminary Appropriate Assessment Matrix for the four nominated sites with hydraulic connectivity to Oxford Meadows SAC

SITE INFO		SCREENING			APPROPRIATE ASSESSMENT		
Name of SAC and qualifying features	**Conservation objectives**	**Potential impact**	**Plans/ Projects with the potential for adverse in-combination effects**	**Significant effects likely?**	**Possible Mitigation**	**Are adverse effects on the integrity of the SAC likely, either alone or in-combination with other plans or projects at the strategic policy level?**	**Conclusions and recommendations**
SG-04 Land at Mead Farm							
Oxford Meadows SAC Qualifying features: - Lowland Hay Meadows (primary reason) - Creeping Marshwort (primary reason)	To maintain qualifying features in favourable condition.	Hydrological changes: - Water levels - Water quality (chemistry, sediment) - Nutrient enrichment	Oxford Core Strategy - Northern Gateway - Land at Summertown	Uncertain	- Best practice pollution prevention. - Control of water surface run-off. - Silt control. - Discharge treated water from quarrying abstraction back into the Kingsbridge Brook to maintain flow and act as a 'recharge boundary'.	Uncertain. Given the hydraulic connectivity between the sites, there is potential for sharp sand and gravel extraction to result in changes to the water levels at Oxford Meadows SAC. The lowland hay meadow habitat for which the SAC is in-part designated, is highly dependent upon maintenance of optimal water levels, requiring an aerated root zone during the growing season and an adequate water supply so as not to limit plant growth in early summer. Evidence from previous mineral extraction at Cassington Quarry has shown that there is potential for a reduction in water levels at the SAC during dewatering, followed by an increase in the water table during operation and restoration. The hydrogeological conceptual model has shown that the SAC may be located within the dewatering cone of depression for each of the four nominated sites with hydraulic connectivity to the SAC. Therefore, adverse effects on the integrity of the Oxford Meadows SAC as a result of changes to water levels cannot be ruled out if the site was allocated within the Site Allocations DPD. The Oxford Core Strategy HRA concluded 'no adverse effects' from either the Northern Gateway or Summertown proposals on Oxford Meadows SAC. A preliminary hydrogeological review of the Northern Gateway by PBA (July 2009) also concluded 'no adverse effects' on Oxford Meadows SAC as a result of hydrological change. Therefore potential in-combination effects are considered unlikely.	Adverse effects on the integrity of Oxford Meadows SAC cannot be ruled out if mineral extraction occurs at SG-04. As this site is not included within the preferred strategic area for sand and gravel at Eynsham/Cassington/Yarnton, there is no recommendation for the Oxfordshire Minerals and Waste Core Strategy. However, as the nominated site is being considered for allocation within the Site Allocations DPD, the following alternatives are recommended for consideration by Oxfordshire County Council: 1) Do not allocate this nominated site within the Site Allocations DPD. 2) Alternatively, undertake further hydrogeological assessment during preparation of the Site Allocations DPD to determine specific mitigation requirements that should be included in relevant policies for the site to ensure that they are addressed in any planning application that comes forward for minerals extraction at the site.
SG-05 Land to the east of Cassington Quarry							
As above	As above	As above	As above	Uncertain	As above	Uncertain. As above	Adverse effects on the integrity of Oxford Meadows SAC cannot be ruled out if mineral extraction occurs at SG-05. As this site is not included within the preferred strategic area for sand and gravel at Eynsham/Cassington/Yarnton, there is no recommendation for the Oxfordshire Minerals and Waste Core Strategy. However, as the nominated site is being considered for allocation within the Site Allocations DPD, the following alternatives are recommended for consideration by Oxfordshire County Council: 1) Do not allocate this nominated site within the Site Allocations DPD. 2) Alternatively, undertake further hydrogeological assessment during preparation of the Site Allocations DPD to determine specific mitigation requirements that should be included in relevant policies for the site to ensure

SITE INFO		SCREENING			APPROPRIATE ASSESSMENT		
Name of SAC and qualifying features	**Conservation objectives**	**Potential impact**	**Plans/ Projects with the potential for adverse in-combination effects**	**Significant effects likely?**	**Possible Mitigation**	**Are adverse effects on the integrity of the SAC likely, either alone or in-combination with other plans or projects at the strategic policy level?**	**Conclusions and recommendations**
							that they are addressed in any planning application that comes forward for minerals extraction at the site.
SG-16 Land at Stonehouse Farm, north east of Cassington Quarry							
As above	As above	As above	As above	Uncertain	As above	Uncertain. As above	Adverse effects on the integrity of Oxford Meadows SAC cannot be ruled out if mineral extraction occurs at SG-16. As this site is not included within the preferred strategic area for sand and gravel at Eynsham/Cassington/Yarnton, there is no recommendation for the Oxfordshire Minerals and Waste Core Strategy. However, as the nominated site is being considered for allocation within the Site Allocations DPD, the following alternatives are recommended for consideration by Oxfordshire County Council: 1) Do not allocate this nominated site within the Site Allocations DPD. 2) Alternatively, undertake further hydrogeological assessment during preparation of the Site Allocations DPD to determine specific mitigation requirements that should be included in relevant policies for the site to ensure that they are addressed in any planning application that comes forward for minerals extraction at the site.
SG-20a Wharf Farm, Cassington							
As above	As above	As above	As above	Uncertain	- Best practice pollution prevention. - Control of water surface run-off. - Silt control. - Limiting extraction to above the upper limits of the groundwater table. - Installing clay bunds to limit drawdown effect of dewatering.	Uncertain. As above	Adverse effects on the integrity of Oxford Meadows SAC cannot be ruled out if mineral extraction occurs at SG-20a. As this site is included within the preferred strategic area for sand and gravel at Eynsham/Cassington/Yarnton, it is recommended that the boundary for the strategic area in the Oxfordshire Minerals and Waste Core Strategy is modified so that it does not include the eastern part of the site (east of the River Evenlode). In addition, as the nominated site is being considered for allocation within the Site Allocations DPD, the following alternatives are recommended for consideration: 1) Do not allocate this nominated site within the Site Allocations DPD. 2) Modify boundary of site to include only the area to the west of the River Evenlode. The River is likely to form an effective hydraulic barrier between the sites and may enable a conclusion of no adverse effect. 3) Alternatively, undertake further hydrogeological assessment during preparation of the Site Allocations DPD to determine specific mitigation requirements that should be included in relevant policies for the site to ensure that they are addressed in any planning application that comes forward for minerals extraction at the site.

Uncertain – Significant adverse effects on the integrity of the SAC cannot be ruled out.

6 Conclusions

6.1 The HRA of the Oxfordshire Minerals and Waste Core Strategy, as informed by a strengthened hydrogeological/ecological evidence base, has concluded the following for the Cothill Fen and Oxford Meadows SACs. Relevant recommendations for the Core Strategy and Site Allocations DPDs are also provided.

COTHILL FEN SAC

6.2 The nominated sites within 5km of Cothill Fen SAC (SS-01 and SS-05) are not hydraulically connected to the SAC. Soft sand extraction at these sites is unlikely to result in significant effects to the qualifying features of Cothill Fen SAC alone or in combination with other plans or projects planned in the vicinity of the SAC. These sites have therefore been ruled out from more detailed assessment as part of the HRA of the Minerals and Waste Core Strategy. However, HRA work may be needed at the planning application stage to ensure that the exact proposals for minerals extraction at these sites would not adversely affect the integrity of Cothill Fen SAC.

6.3 Significant effects on the qualifying features of Cothill Fen SAC could occur if mineral extraction occurred in the eastern parts of the preferred North and south of the A420 to the west of Abingdon soft sand strategic area currently identified in the draft Minerals Planning Strategy, as they could be in the same groundwater catchment as Cothill Fen SAC (see **Map 2** in Appendix A).

Recommendations for Minerals and Waste Core Strategy

6.4 As the eastern parts of the preferred North and south of the A420 to the west of Abingdon soft sand strategic area are in the same groundwater catchment as Cothill Fen SAC, **it is recommended that the boundary for the strategic area in the Oxfordshire Minerals and Waste Core Strategy is modified so that it does not include the eastern part of the site that overlaps the groundwater catchment of Cothill Fen shown on Map 2.**

6.5 Even if the boundary of the strategic area is revised, it is recommended that HRA work would have to be conducted at the planning application stage for any extraction sites proposed within the eastern parts of the soft sand strategic area to ensure that quarry dewatering would not result in water table drawdown that would affect the SAC. This could be achieved by restricting dewatering or requiring extraction to take place above the water table. It has been shown from recent planning permissions, that mineral extraction can take place closer to the SAC (e.g. the Upwood Park extraction site adjacent to the SAC), but only with very stringent controls on site operations (e.g. robust monitoring and no mineral extraction below the water table).

6.6 Therefore, it is recommended that additional wording could be added to the third paragraph of Policy M3 in the Minerals and Waste Core Strategy, so that it reads:

"The principal locations for soft sand working, as shown in figure 7, will be:

- East and south east of Faringdon;
- North and south of the A420 to the west of Abingdon; and
- Duns Tew.

Permission for further working in the area north and south of the A420 to the west of Abingdon will only be permitted if it does not lead to changes in water levels at Cothill Fen SAC."

OXFORD MEADOWS SAC

6.7 Five of the nominated sites within 5km of Oxford Meadows SAC (SG-08, SG-20, SG-20b, SG-29 and SG-31) are not hydraulically connected to the SAC. Sharp sand and gravel extraction at these sites is unlikely to result in significant effects to the qualifying features of Oxford Meadows SAC. These sites have been ruled out from more detailed assessment as part of the HRA of the Minerals and Waste Core Strategy. However, HRA work may be needed at the planning application stage to ensure that the exact proposals for minerals extraction at these sites would not adversely affect the integrity of Oxford Meadows SAC.

6.8 Four of the nominated sites within 5km of Oxford Meadows SAC (SG-04, SG-05, SG-16 and SG-20a) are hydraulically connected to the SAC and are likely to result in significant effects to the Oxford Meadows SAC. It is unclear at this stage, whether such impacts can be successfully mitigated, therefore adverse effects on the integrity of the Oxford Meadows SAC cannot be ruled out.

6.9 At the screening stage, two policies within the Oxford Core Strategy (CS7: Northern Gateway and CS10: Summertown) were identified as potentially adversely affecting the Oxford Meadows SAC in-combination with the four nominated sites with hydraulic connectivity to the SAC. The HRA of the Oxford Core Strategy and subsequent hydrogeological assessment of the Northern Gateway project concluded that there would be no significant effect on the SAC as a result of hydrological changes. Other relevant plans have been considered in this study and no other proposals in these plans, or projects, have been identified which are considered likely to adversely affect the SAC in-combination with the Minerals Strategy, either because they are located a sufficient distance from the SAC to rule out likely significant effects or their relevant Habitat Regulations Assessment has concluded that they will not affect the integrity of the Oxford Meadows SAC. Therefore, a significant effect upon the integrity of the Oxford Meadows SAC as a result of in-combination effects is considered unlikely.

Recommendations for Minerals and Waste Core Strategy

6.10 As nominated site SG-20a is included within the preferred strategic area for sand and gravel at Eynsham/Cassington/Yarnton**, it is recommended that the boundary for the strategic area in the Oxfordshire Minerals and Waste Core Strategy is modified so that it does not include the eastern part of site SG-20a (i.e. that part of the site that is east of the River Evenlode). In addition, the whole of the strategic area**

boundary could be revised so that it does not include areas to the east of the River Evenlode. This could be achieved by shifting the long axis of the ellipsoid boundary of the strategic area so that it runs more north-south along the line of the site nominations to the west of the River Evenlode.

6.11 Additional wording could be added to the second paragraph of Policy M3 in the Minerals and Waste Core Strategy, so that it reads:

6.12 "Permission for further working within the Lower Windrush Valley and Eynsham / Cassington / Yarnton areas will not be permitted if it would lead to an increase in the overall level of mineral extraction or mineral lorry traffic above past levels within these areas combined**, and in the Eynsham / Cassington/ Yarnton area if it would lead to changes in water levels in the Oxford Meadows SAC**."

Recommendations for Minerals Site Allocations DPD

6.13 As nominated sites SG-04, SG-05, SG-16 and SG-20a are being considered for allocation within the Site Allocations DPD, the following alternatives are recommended for consideration by Oxfordshire County Council:

1) Do not allocate these nominated sites within the Site Allocations DPD.

2) For site SG-20a, the boundary of the site could be modified to only include the area to the west of the River Evenlode. The River is likely to form an effective hydraulic barrier between the sites and may enable a conclusion of no adverse effect.

3) Alternatively, undertake further hydrogeological assessment during preparation of the Site Allocations DPD to determine specific mitigation requirements that should be included in relevant policies for the site to ensure that they are addressed in any planning application that comes forward for minerals extraction at the site.

6.14 For each of these four nominated sites, it is important that the water levels in the watercourses hydraulically bounding the SAC are not impacted negatively. As water flows are linked to water levels, this also implies that water flows from the SAC are not increased and water flows into the SAC are not decreased. It is possible in nominations very close to the SAC that water courses in their own channels may not be in total hydraulic connection with the alluvium (which is a variable sediment) and so some dewatering impact may pass beneath the water course. This is only likely where the impact is very large and the mineral extraction very close.

6.15 It is also important that any water discharged from quarry workings to the surface water network is not contaminated or laden with a significant amount of suspended sediment. The Environment Agency will set conditions for this as part of the discharge consenting process.

6.16 If these four nominated sites were allocated in the DPD, mitigation requirements that could be included in relevant policies or site development briefs in the Site Allocations DPD are discussed below. Further assessment would therefore be required at the planning application stage to demonstrate that mineral extraction proposals would not adversely affect the integrity of the Oxford Meadows SAC.

SG-04 and SG-16

6.17 Mitigation measures should be agreed that do not lead to a significant reduction in flows in Kingsbridge Brook during and after dewatering stages.

SG-05

6.18 Mitigation measures should be agreed that do not lead to a significant reduction in flows in Kingsbridge Brook during and after dewatering stages.

SG-20a

6.19 Mitigation measures should be agreed that do not lead to a reduction in the groundwater catchment of the SAC. These measures could take the form of:

- Groundwater modelling and monitoring.
- Not extracting beneath the upper limits of the groundwater table.
- Installing clay bunds to limit the drawdown effect of dewatering outside the nomination.
- Mitigation measures so that there is no impact on water levels in the SAC.
- Mitigation measures so that the inflows to the SAC from the losing stretches of the river network remain the same.
- Mitigation measures so that the outflows from the SAC to gaining stretches of river, e.g. Cassington Tributaries are not increased so causing water to leave the SAC.

Land Use Consultants and Maslen Environmental

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Glossary of terms

Aquifer: A saturated permeable layer of rock or sediment that can store and transmit significant quantities of water under ordinary hydraulic gradient

Secondary A Aquifers: These are aquifers (formerly known as Minor Aquifers) classified by the Environment Agency as being "permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers" (Environment Agency website).

Aquiclude: A low permeability rock or sediment that cannot transmit significant quantities of water under ordinary hydraulic gradients.

Aquitard: A low permeability rock or sediment that allows slow groundwater seepage, i.e. it has properties intermediate between those of an aquifer and those of an aquiclude.

Baseflow: The "background" input of water to a river or stream that sustains flow during periods of dry weather. In most cases it consists of groundwater input and/or slow throughflow (lateral flow through the soil), although it may also include water discharged from reservoirs and sewage treatment works.

Baseflow Index (BFI): The proportion of total stream flow made up of baseflow (mostly groundwater input).

Capillary fringe: The zone, immediately above the water table, in which the pores are completely filled with water. The water is drawn up from the main saturated zone by capillary forces (this is analogous to water being drawn up a narrow capillary tube).

Catchment: The area of land supplying water to a river, stream, spring, borehole or other water feature.

Confined aquifer: An aquifer overlain by a low permeability layer (confining bed). Groundwater in the aquifer may be under pressure so that the water level in a well or borehole penetrating the aquifer rises above the top of the aquifer.

Darcy's Law: An empirical law (Darcy, 1856) describing fluid flow through a porous medium. The law states that the volumetric flow rate of groundwater is proportional to the hydraulic gradient and the cross-sectional area of flow. In one dimension it can be expressed mathematically as:

$$Q = -KA\frac{dh}{dl}$$

where Q = discharge [L3/T], K = hydraulic conductivity [L/T], A = cross-sectional area of flow [L2], h = hydraulic head [L] and l = distance along the flow path [L].

Dewatering: Artificial lowering of the water table (usually by pumping) so as to allow dry quarrying within what would normally be the saturated zone.

Discharge: Fluid flow expressed as the volume of fluid passing a given point per unit time, e.g. cubic metres of water per second. In general the units are [L3/T].

Gaining Streams: Streams that receive groundwater inflow through their bed and/or banks.

Groundwater-fed bottom: A wetland in a valley bottom fed by groundwater.

Groundwater: Subsurface water in the saturated zone.

Hydraulic conductivity: The proportionality constant, K, in Darcy's Law. Its value depends on the intrinsic permeability of the porous medium and also on the properties of the fluid.

Hydraulic connectivity: The existence of a pathway (such as a layer of permeable rock or a watercourse) by which hydraulic conditions at one location may influence those at another.

Hydraulic gradient: The rate of change of hydraulic head with distance in a given direction. In general, groundwater flows down the hydraulic gradient in the direction of decreasing hydraulic head.

However, the flow direction is also influenced by anisotropy (variation with direction) in hydraulic conductivity.

Hydraulic head: Groundwater has mechanical energy due to its elevation and pressure (groundwater velocities are generally very low, so kinetic energy can be neglected). The mechanical energy per unit weight is referred to as the hydraulic head. This is measured in units of length [L] and is equal to the level that the water can raise itself above a datum. Roughly speaking, the head is the level to which water will rise in a well.

Hydrogeological conceptual model: A summary of how a hydrogeological system is thought to operate, often expressed in diagrammatic and/or map form with accompanying text.

Losing Streams: Streams that lose water to the ground.

Permeability: The ability of a porous medium to transmit fluid. The higher the permeability, the easier it is for fluid to pass. A permeable medium allows fluid to pass; an impermeable medium is a barrier to fluid flow.

Pores: Void spaces, or holes, within a rock, sediment or other solid material.

Porous medium: A rock, sediment or other material containing void space through which water (and/or another fluid) can flow.

Recharge: Water that infiltrates into the ground, percolates downwards, and reaches the water table, thereby replenishing the aquifer.

Saturated zone: Beneath the water table all the interconnected pores are filled with water, and the rock or sediment is referred to as being saturated. This is the saturated zone; it is also known as the phreatic zone.

Source Protection Zones: Protection zones defined by the Environment Agency around public water supply boreholes. Within the zones, potentially polluting activities are controlled in order to protect the water supply.

Standard Percentage Runoff (SPR): The percentage of rainfall responsible for the short-term increase in river flow during and/or following a rainfall event (Boorman et al., 1995).

Transmissivity: The product of hydraulic conductivity and saturated thickness. It is equivalent to the groundwater discharge through a unit width of aquifer under a unit hydraulic gradient.

Unconfined aquifer: An aquifer that is not confined; it has a water table.

Unsaturated zone: The zone, above the water table and capillary fringe, in which the pores are partly filled with water and partly filled with air. It is also known as the vadose zone.

Watershed: The boundary of a surface water catchment.

Water table: The surface in a porous medium along which the pore water pressure is equal to atmospheric pressure.

Wet working: Quarrying below the water table with no dewatering.

Appendix A – Maps

Appendix B – Dewatering Calculations

Analytical Groundwater Model used to Simulate Quarry Dewatering

One-dimensional, steady radial flow to a fully penetrating pumped well in an unconfined aquifer can be modelled using the following equation (Rushton, 2003):

$$Q = \frac{\pi K (H^2 - h_w^2)}{\ln\left(\frac{R_o}{r_w}\right)}$$

Equation 1

where Q is the volumetric rate of flow, H is the head (measured relative to the base of the aquifer) at a radius R_o from the well, h_w is the head in the well, and r_w is the radius of the well. This equation is based on the Dupuit assumptions: that groundwater flow is horizontal and that the hydraulic gradient is equal to the slope of the water table. R_o is the "radius of influence" of the well and for the purposes of dewatering calculations is often estimated from (Preene *et al.*, 2000):

$$R_o = C(H - h_w)\sqrt{K}$$

Equation 2

where C is a constant, usually taken as 3000 if K is measured in m/s. For flow to a circular array of boreholes, r_w can be replaced by an equivalent radius, r_e, equal to the radius of the system; for rectangular arrays of plan dimensions a x b, r_e can be estimated from $r_e = (a+b)/\pi$ (Preene *et al.*, 2000). In fact, Q is relatively insensitive to the choice of R_o.

A dewatered quarry void can be approximated by a rectangular array of boreholes with dimensions (a x b) and equivalent radius $r_e = (a+b)/\pi$.

Estimation of the Radius of Influence of Quarry Dewatering

The radius of influence of quarry dewatering at nominated mineral sites SS-01 and SS-05 has been estimated in two ways:

1. By calculating R_0 using Equation 2 above (extremely approximate)
2. By calculating Q using Equation 1, then estimating the radius of influence, r, using

$$r = \sqrt{\frac{Q}{\pi . p}}$$

Equation 3

where p = recharge (with units of length/time). This gives the radius of the circular area needed to support the discharge rate Q. For the purposes of this study the recharge has been taken as 300 mm/yr (an effective rainfall figure – i.e. rainfall minus evapotranspiration - quoted in Sumbler, 1996), which is equivalent to 0.00082 m/day.

The results of the calculations are shown in **Table B.1**.

Table B.1: Hydrogeological Calculations (see text for discussion)

Parameter	Unit	SS-01 Tubworth Barn	SS-05 Land at Kingston Bagpuize
Hydraulic conductivity,	m/s	1×10^{-4}*	1×10^{-4}*

K			
Head, H, at radius R_0	m (datum = aquifer base)	7	30
Head, hw, at quarry	m (datum = aquifer base)	0	25
Radius of influence, R_0	m	210	150
Length, a, of quarry void	m	840	700
Width, b, of quarry void	m	430	500
Effective radius, re	m	404	382
Discharge, Q	m^3/d	2,031	7,986
Recharge, p	m/d (mm)	0.00082 (300)	0.00082 (300)
Recharge area, A	m^2	2,470,770	9,716,045
Radius, r, of circular recharge area	m	887	1,759
*Based on			