Improvement Programme for England's Natura 2000 Sites (IPENS) – Planning for the Future IPENS050

Case Studies for Delivering Ammonia Measures

Annexes

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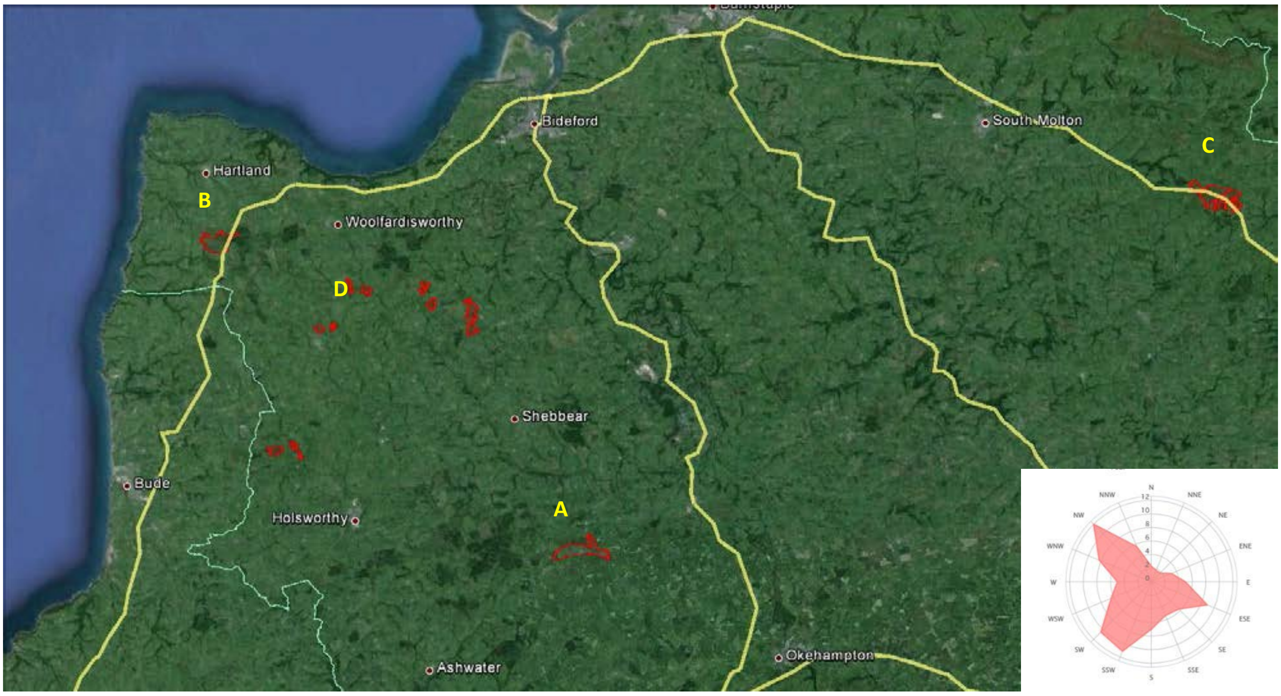
Annex 1: Culm Measures case study report

1. Introduction

The Culm Measures (approx. grid reference SS3215) are acidic clay soils, poorly drained, which have given rise to a unique grassland habitat known as Culm grassland in Northwest Devon. While much of the area has been drained and improved for agricultural production, there are some remaining areas, including those designated as Natura 2000 sites (Fig. 1). Agriculture in the area is predominantly grassland based dairy, beef and sheep production, although a few intensive pig and poultry units also exist. Prevailing wind direction is SW. This case study focusses on four sub-sites within the Culm Measures catchment, identified as A to D in Figure 1.

Figure 1. Culm Measures case study site. Red lines indicate SAC boundaries. Studied sub-sites: A, Hollow Moor; B, Bursdon Moor; C, Rackenford; D, Bradworthy Common; Inset : wind rose for Great Torrington (www.windfinder.com)



2. Identification of major emission sources

A list of potential emission sources within an approximate 2 km buffer of each of the focus sub-sites, identified through using Google Earth, was established, which was then refined using the local knowledge of the Catchment Sensitive Farming Officer (CSFO, Louise Davis).

A. Hollow Moor

Seven potential emission sources were identified around Hollow Moor (Fig. 2). Feedback from the CSFO indicated that these were all generally small family farms which would not contribute in a major way to N deposition at the SAC, that a good buffer of low intensity use grassland surrounds the site and that there is little scope for implementation of mitigation measures (Table 1).

Figure 2. Potential emission sources around Hollow Moor

NB: Figure differs from that given in Project IPENS 049 because the identification of potential emission sources were made independently in the two projects by different people

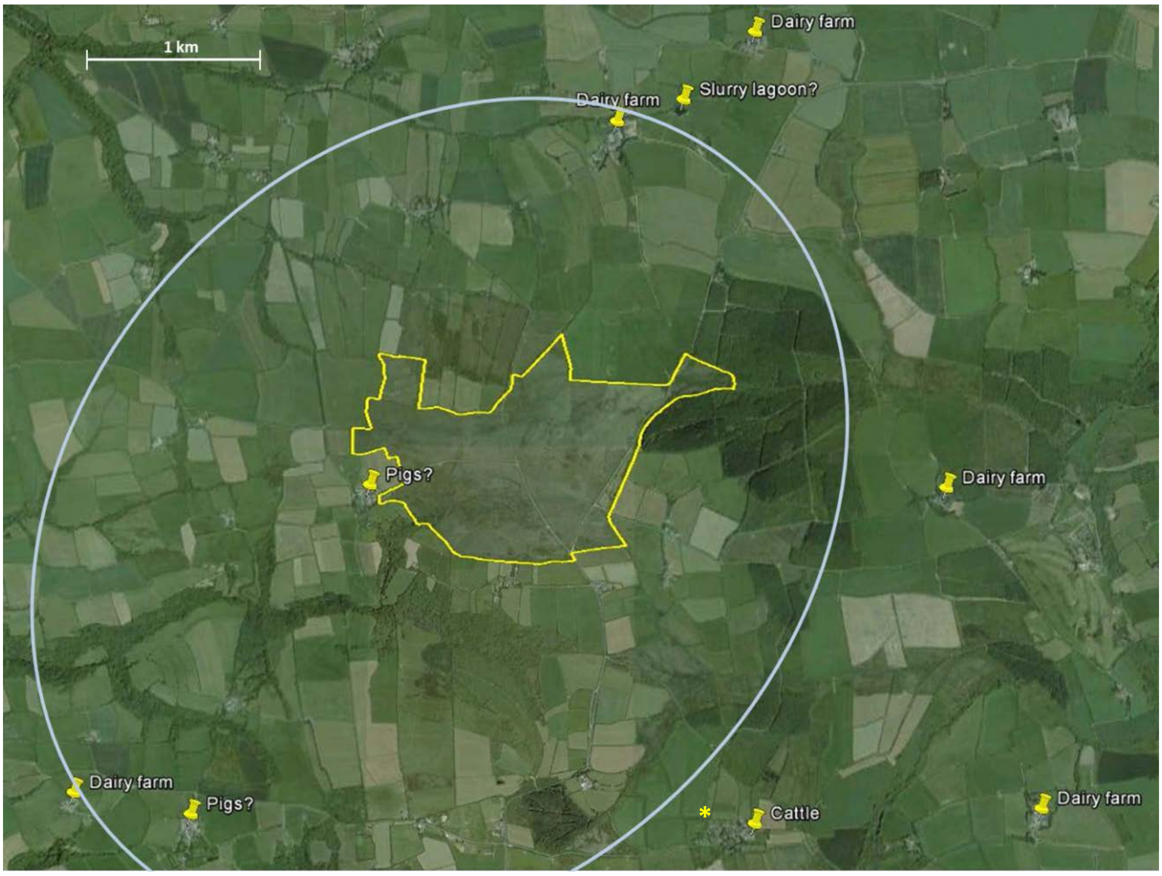
Table 1. Potential emissions sources around Hollow Moor

Initial source identification using Google Earth	CSFO feedback
Dairy farm with uncovered slurry tank	Unknown
Livestock farm – possibly pigs, FYM heaps	Beef and sheep
Livestock farm – possibly pigs, FYM heaps	Beef and sheep
Cattle housing - FYM	2 farms, 1 dairy (slurry), yard roofed over
Cattle housing - FYM	Unknown
Dairy farm with uncovered slurry tank	Unknown
Dairy farm with uncovered slurry tank	Unknown

B. Bursdon Moor

Eight potential emission sources of concern were initially identified around the Bursdon Moor site (Fig. 3), in addition to a number of other sites which were apparently less intensive livestock housing and so of less concern. Feedback from the CSFO highlighted three of the identified eight sites as being of more importance in terms of potential emissions and also mentioned an additional site that imports and spreads large volumes of slurry (Table 2).

Figure 3. Potential emission sources around Bursdon Moor; blue line shows indicative target zone for implementation of mitigation measures



NB: Figure differs from that given in Project IPENS 049 because the identification of potential emission sources were made independently in the two projects by different people

Table 2. Potential emission sources around Bursdon Moor

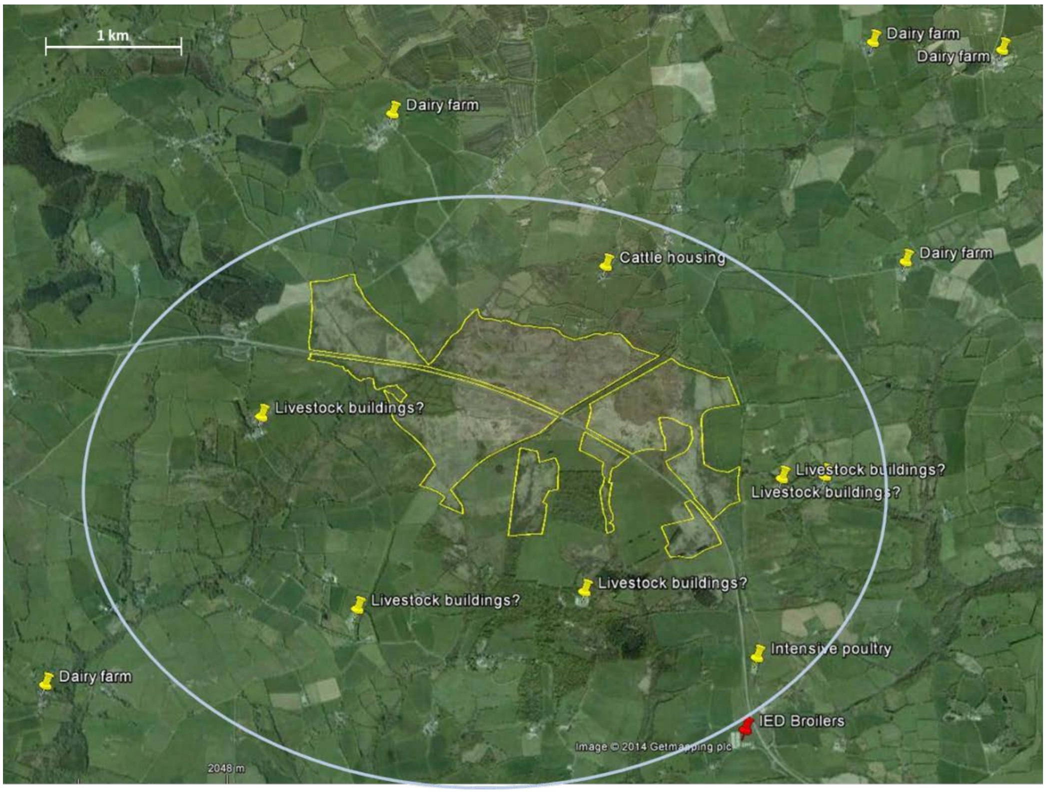
Initial source identification using Google Earth	CSFO feedback
Dairy farm with what looks like slurry lagoon	Downwind, less concern
Possibly a large slurry lagoon associated with nearby dairy farm	Downwind, less concern
Dairy farm with uncovered slurry tank	Downwind, less concern
Dairy farm with uncovered slurry tank	Large intensive dairy farm
Dairy farm with what looks like slurry lagoon	
Large intensive livestock farm – possibly pigs	Large intensive dairy farm
Dairy farm with uncovered slurry tank	
Large intensive livestock farm – possibly pigs	Sheep and arable, but large FYM store very close to Bursdon Moor
Cattle farm – thought to be unimportant	This site spreads a lot of imported slurry

C. Rackenford

This site is split by a major road (A369, N Devon link road) and surrounded by a large number of potential emission sites which appear to be predominantly dairy and beef production (Fig. 4). An Environment Agency permitted poultry unit, under the Industrial Emissions Directive, is also located close to this site. There are a number of cattle housing sites (details of all of which were not known by the CSFO) which will contribute to an elevated ammonia concentration at the SAC. The area is a mix of small traditional farms with a mix of sheep and beef cattle or suckler herds and bigger land holdings with larger, more intense sheep and beef units. There are also a large number of holiday homes or small holdings with very little inputs. There are some dairy farms which are more intensive. There is one large dairy farm who owns land in this area but the main farm is further south. Level of inputs and grazing differ by holding, but the CSFO doesn't have in depth knowledge of these.

Thirteen emission sources of potential concern were identified in the initial mapping.

Figure 4. Potential emission sources around Rackenford; blue line shows indicative target zone for implementation of mitigation measures



NB: Figure differs from that given in Project IPENS 049 because the identification of potential emission sources were made independently in the two projects by different people

Table 3. Potential emission sources around Rackenford

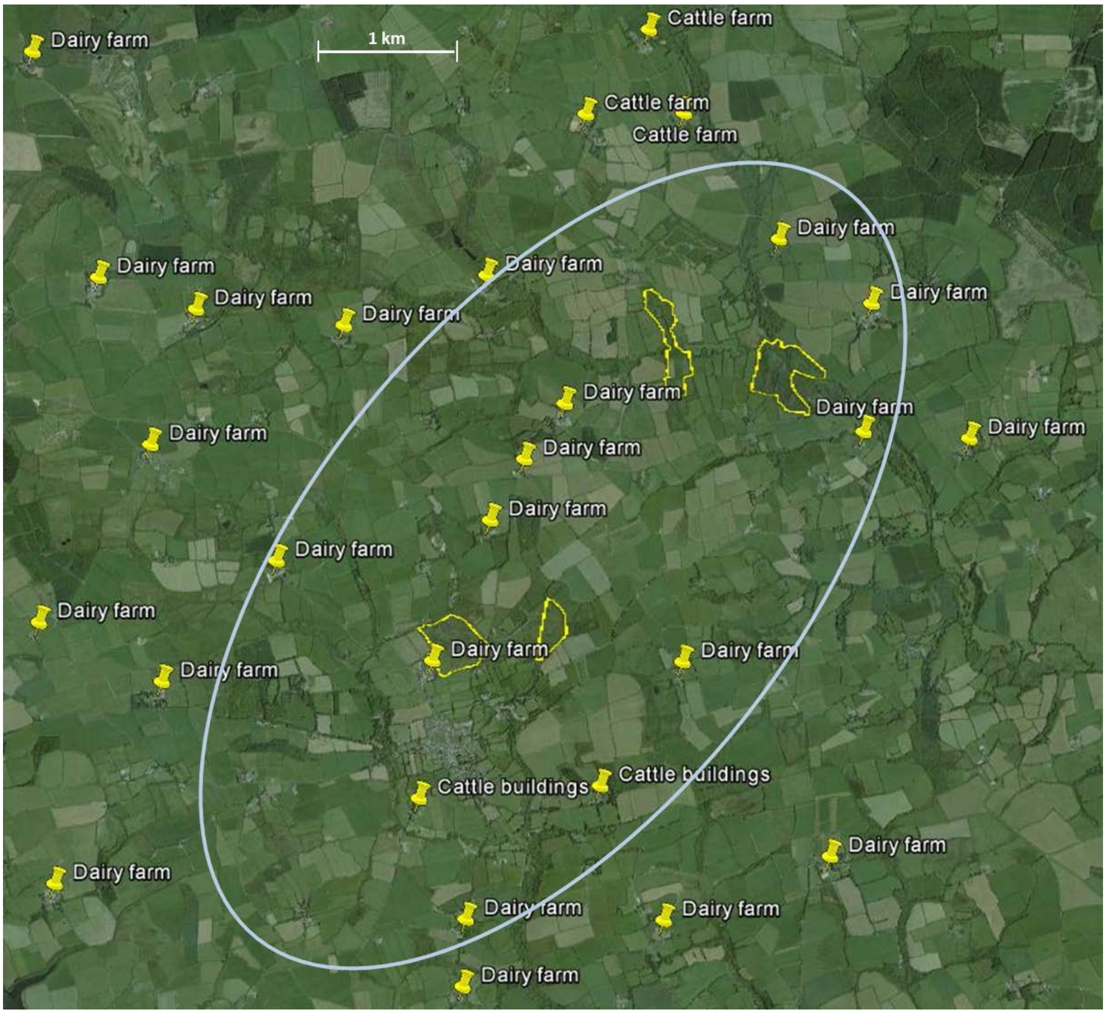
Initial source identification using Google Earth	CSFO feedback
Dairy farm with uncovered slurry tank	Unknown
Dairy farm with uncovered slurry tank	Unknown, downwind so less concern
Dairy farm with uncovered slurry tank	Now a deer farm
Dairy farm with uncovered slurry tank	Dairy farm, unsure of details. CSFO has been involved in fencing along stream.
Cattle housing	Unknown
Possible livestock buildings – close proximity to site	Unknown
Possible livestock buildings – close proximity to site	Unknown

Intensive poultry – what happens to the manure?	Poultry – details not known
An IED site, 136,000 broilers – EA noted 'no adverse effect'	Poultry – details not known
Possible livestock buildings – close proximity to site	Sheep sheds, possibly cattle
Livestock buildings, FYM	Sheep sheds, possibly cattle
Dairy farm, slurry lagoon	Unknown
Possible livestock buildings – close proximity to site	Sheep on slats and cattle

D. Bradworthy Common and associated sites

This sub-site is surrounded by many dairy farms, several with slurry lagoons (Fig. 5).

Figure 5. Potential emission sources around Bradworthy Common; blue line shows indicative target zone for implementation of mitigation measures



NB: Figure differs from that given in Project IPENS 049 because the identification of potential emission sources were made independently in the two projects by different people

There are some large dairy units and several are owned/operated by the same farmer (Table 4). The area is predominantly grassland, with a small area of maize grown. There is no knowledge (or indication) of any pig or poultry units. Dairy units are largely slurry-based systems, with splash plate spreading as and when conditions allow. CSF has been in this area for 2 or 3 years so many have taken the opportunity to improve yard infrastructure, generally with a view to separating dirty water and reducing the volume of slurry. Last year the EA also had a diffuse pollution scheme in some of these areas which offered soil audits, infrastructure audits and small amounts of capital. However some of the large dairy farms do still have run-off issues especially from yard areas. The CSFO has worked with a lot of these large dairy farms on other aspects, e.g. scrub management, county wildlife sites, HLS, but is of the opinion that it would be hard to convince many of these larger units to factor in consideration regarding ammonia emissions.

Table 4. Potential emission sources around Bradworthy Common

Initial source identification using Google Earth	CSFO feedback
Cattle farm with yards	Details unknown
Cattle farm with yards	Unknown
Cattle farm with yards	Beef and sheep, extensive grazing, in HLS
Dairy farm with slurry lagoon/weeping wall	Large dairy, one of 5 belonging to the same farmer. Cattle out in summer, no specialist spreading equipment used.
Dairy farm with slurry lagoon/weeping wall	Large intensive dairy, cattle out in summer. Very busy farmer who owns several other dairy units. Room for a lot of improvement to cope with the numbers of cattle.
Dairy farm, dirty yards and slurry tank	Unknown
Dairy farm with slurry lagoon/weeping wall	Unknown
Dairy farm with slurry tank	Yard belongs to another farm, buildings just used for storage/few sheep
Dairy farm with 2 large slurry tanks	Large intensive dairy, cattle out over summer. Very close to SAC and not aware of any measures implemented to protect it (e.g. buffer zone)
Dairy farm with slurry lagoon/weeping wall	Unknown
Dairy farm, dirty yards and slurry lagoon/weeping wall	Farmer not cooperative, so little information. Directly SW of SAC.
Dairy farm with slurry tank	Unknown
Dairy farm with slurry tank	Large dairy farm.
Dairy farm, dirty yards and slurry lagoon/weeping wall	Unknown
Dairy farm, dirty yards and slurry tank	Large dairy farm, slurry system, some yard improvements through CSF.
Dairy farm, dirty yards and slurry lagoon/weeping wall	Dairy farm with dirty yards. Large muck heap spilling onto road causing run off.
Dairy farm, small dirty yard	Unknown
Dairy farm, dirty yards and slurry lagoon/weeping wall	Large dairy, carried out roofing/concrete works through CSF, slurry system, good manure/nutrient planning.
Dairy farm with slurry lagoon	Large dairy, cattle out in summer, recently built new lagoon which has been covered, and uses disc injector. Issues wrt to ammonia emissions onto nearby SAC already picked up by Natural England. Cattle tracks applied for in latest round of CSF.
Dairy farm with slurry tank	Dairy farm with large slurry lagoon, previously had leakages but system improved. Cow tracks applied for this year.

Dairy farm with slurry lagoon	Unknown
Possible cattle buildings and yards	Unknown but doubt there is much going on in this yard.
Possible cattle buildings and yards	Not dairy. Not been able to visit but believe there are just beef cattle. Did have a visit through Environment Agency's diffuse pollution project.
Dairy farm with slurry tank	Unknown
Dairy farm with slurry lagoon	Moderate size dairy, recently made big improvements to yard infrastructure and currently covering lagoon. Interested in using soil aerator. Splash plate spreading as and when.
Dairy farm with slurry tank	Dairy, large slurry store and recent improvements to yard infrastructure through roofing and concreting.
Dairy farm with slurry tank	Large but very tidy dairy, ample slurry storage. Do spread a lot on maize fields which poses run off issues. Uses umbilical where possible. Applied for more roofing through latest CSF round.

Summary of major local emission sources

The Culm Measures area is predominantly grassland-based agriculture, including sheep, beef and dairy production. Of these, dairy production is considered to have the greatest potential for impact on the Natura 2000 sites through ammonia emission and subsequent deposition. Slurry-based systems are associated with greater emissions than straw-based FYM systems. The major emission sources are the dairy cubicle house, outdoor collecting and feeding yards, slurry storage (lagoons in particular) and slurry application to land. Proximity to the Natura 2000 sites, particularly with regard to the prevailing wind direction, was also an important consideration.

The initial mapping exercise identified many potential point sources including livestock housing, associated yards and manure storage. Local knowledge through the CSFO clarified the activity for many of these potential point sources, prioritising those considered to be of greatest importance. However, it was also evident that potential sites were identified which were unknown by the CSFO, and that for known sites full management details were not always available, so that further local information gathering would be required to establish a finalised priority list.

At two of the four sub-sites assessed in this case study there were few major emission sources identified; no major emission sources were identified around Hollow Moor and four important sources were identified around Bursdon Moor. At Rackenford, there was limited knowledge as to the importance of the potential emission sources identified, but the impression was that there were also few major emission sources impacting on this site. However, at the Bradworthy Common sites, there was a much larger number of emission sources of relatively high priority for which mitigation assessments could be made.

3. Mitigation measures

There are a number of potential ammonia mitigation measures applicable to dairy production systems (Table 5). The lower crude protein diet measure would be difficult to implement on largely forage-based diets and is a measure which is best implemented through the feed industry rather than with individual farmers. The housing measures are very expensive, the increased scraping not particularly effective and the implementation of grooved floor only suitable for new buildings. Washing down dairy cow collecting yards, while effective, is also an expensive measure (labour and water use, increased slurry volume) and might be difficult to monitor and verify implementation. However, general advice on keeping fouled concrete yard areas to a minimum is relevant to both air and water pollution

Table 5. Potential measures to reduce ammonia emissions within the Culm Measures study site

Measure	Mitigation effect	Cost†	Effect on diffuse water pollution
Lower crude protein diet	10%	Cost-neutral?	↓
Increased scraping frequency in cubicle house	0-20%	£39.70 per cow place	~
Grooved floors for dairy cubicle house	25-45%	£20.00 per cow place	~
Washing down of dairy cow collecting yards	50-90%	£32.48 per cow place	↓
Fit rigid cover to slurry tank	80%	£1.58 per m^3 slurry storage	↓
Floating cover on slurry stores	30-70%	£0.85 per m^3 slurry storage	~
Slurry bags for storage	95%	Cost-neutral at store replacement	↓
Sheet cover on FYM heaps	30-90%	£0.63 per tonne FYM storage	↓
Trailing shoe slurry application	20-80%	£0.58 per m^3 slurry applied	~
Shallow injection of slurry	50-90%	£0.69 per m^3 slurry applied	~
Rapid incorporation (within 4h) of surface spread slurry	30-80%	£0.15 per m^3 slurry applied	↓
Rapid incorporation (within 4h) of surface spread FYM	30-80%	£0.30 per tonne FYM applied	↓
Less intensively managed buffer zone around site			~

†Costs from a range of existing sources are indicative, but may vary widely depending on farm size and circumstances

The focus at the Culm Measures site should therefore be on measures to reduce emissions from manure storage and application to land. Solid manure storage (FYM) is only likely to be an issue if it is very close to the Natura 2000 site, in which case sheeting of the heap should be considered – but only if there is opportunity for rapid soil incorporation of the manure after spreading, otherwise any emission reductions during storage are offset by emission increases after spreading. Covering of slurry lagoons in particular (because of their larger surface area to volume ratio) and slurry tanks in close proximity to Natura 2000 sites should also be considered; coverings that exclude rainwater would be additionally beneficial in reducing the subsequent volume of slurry to be applied. Slurry application to grassland should be via trailing shoe or shallow injection – this might be achieved through use of contractors or shared machinery if single farm purchase is a barrier. Where possible, FYM should be spread to tilled land and rapidly incorporated.

Specific recommendations for the four sub-sites would be:

Hollow Moor – no action needed other than to maintain the low intensity use of the 'buffer zone' around the site

Bursdon Moor – potentially sheeting of FYM store close to SAC; encourage slurry storage covering and low emission slurry application methods for farms within the target zone (Fig. 3).

Rackenford – more detail of farming operations and practices close to the site are required, but generally ensuring that sufficient measures are in place to minimise housing emissions from the intensive poultry sites and that low emission application methods are used for slurry applications in the target zone (Fig. 4).

Bradworthy Common – many potential impacting sources, therefore engagement with a larger number of farms is required (this may be helped by the fact that some owners operate more than one site). Generally to encourage slurry storage covering and low emission application methods across farms within the target zone (Fig. 5).

4. Interaction with existing measures/schemes

Existing CSF measures within the catchment that might also contribute to reductions in ammonia emissions have largely consisted of improvements to yard infrastructure such as roofing over manure heaps and outdoor cattle yards and separating clean and dirty water flows to reduce volumes of slurry that require spreading. The slurry storage and spreading measures would potentially deliver to both the diffuse water pollution and ammonia emission reductions, but the CSFO reports that there has been little interest by farmers of uptake of these measures.

Manure applications in the area are largely governed by the weather and the need to empty slurry stores. Farmers are aware of the need to look after soils and avoid spreading under wet conditions, and equally are aware of the nutrient value of the manures, but circumstances can often lead to applications not being made at the most appropriate rates and timings. To date, financial incentives have not been available under CSF for spreading machinery, but this would undoubtedly raise interest and uptake. The use of aerators to improve soil condition, and thereby slurry infiltration into the soil reducing ammonia emissions and run-off, might also be considered in this context.

From interactions with farmers in the area, the CSFO says that the issue of ammonia emissions is likely to be a difficult selling point with farmers. More may be gained, therefore, by packaging the advice and potential measures under the general area of nutrient and manure management plans, which will be generally well received by farmers and also deliver to reducing diffuse water pollution and ammonia emissions.

5. Conclusions

The main emissions sources of concern within the study site were identified as relating to dairy production, primarily slurry-based systems. More detailed local information would be required to identify all emission sources and assess their potential significance and the cost-benefits of implementing specific measures.

Targeting of mitigation measures to specific farms/areas within 2 km of the Natura 2000 sites was recommended, based on likely source strength and prevailing wind direction. Covering of slurry stores (floating covers on slurry lagoons, fixed or floating covers on above-ground tin tanks) and use of low emission manure application techniques (slurry injections, trailing hose or trailing shoe; rapid incorporation of manures into soil by cultivation where applicable) were identified as the key mitigation measures to focus on.

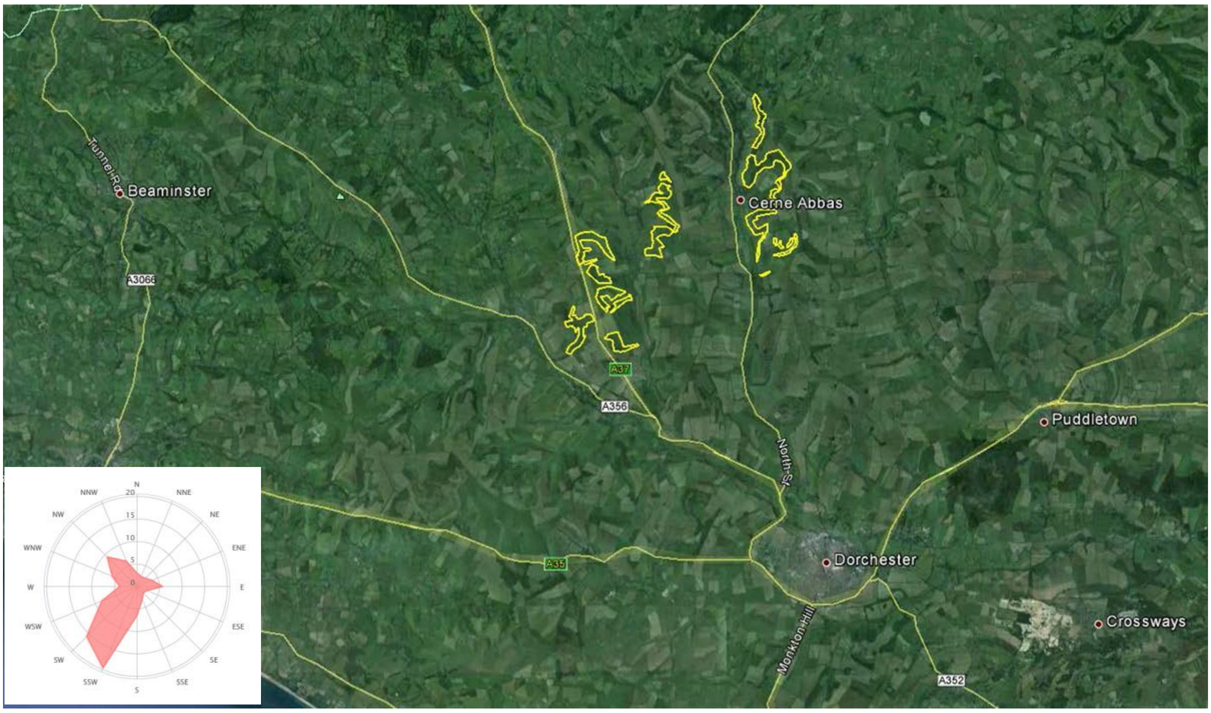
These mitigation measures align well with current efforts to minimise diffuse water pollution (although the specific target areas may differ) and for this case study CSF could be considered a potentially successful route by which to introduce ammonia emission reduction measures.

Annex 2: Cerne and Sydling Downs case study report

1. Introduction

The Cerne and Sydlings Downs SAC are located in west Dorset, just north of Dorchester (approx.. grid ref ST6601). The site consists of a large area of semi-natural dry grassland over the west Dorset chalk. This type of calcareous grassland is almost entirely restricted to parts of Wiltshire and Dorset. Agriculture in the area is mixed, with a lot of cereal crop production but also dairy, beef and sheep production and some intensive pig production units. Prevailing wind direction is SW. The SAC is split across a number of sites, which are considered together in this assessment (Fig 1).

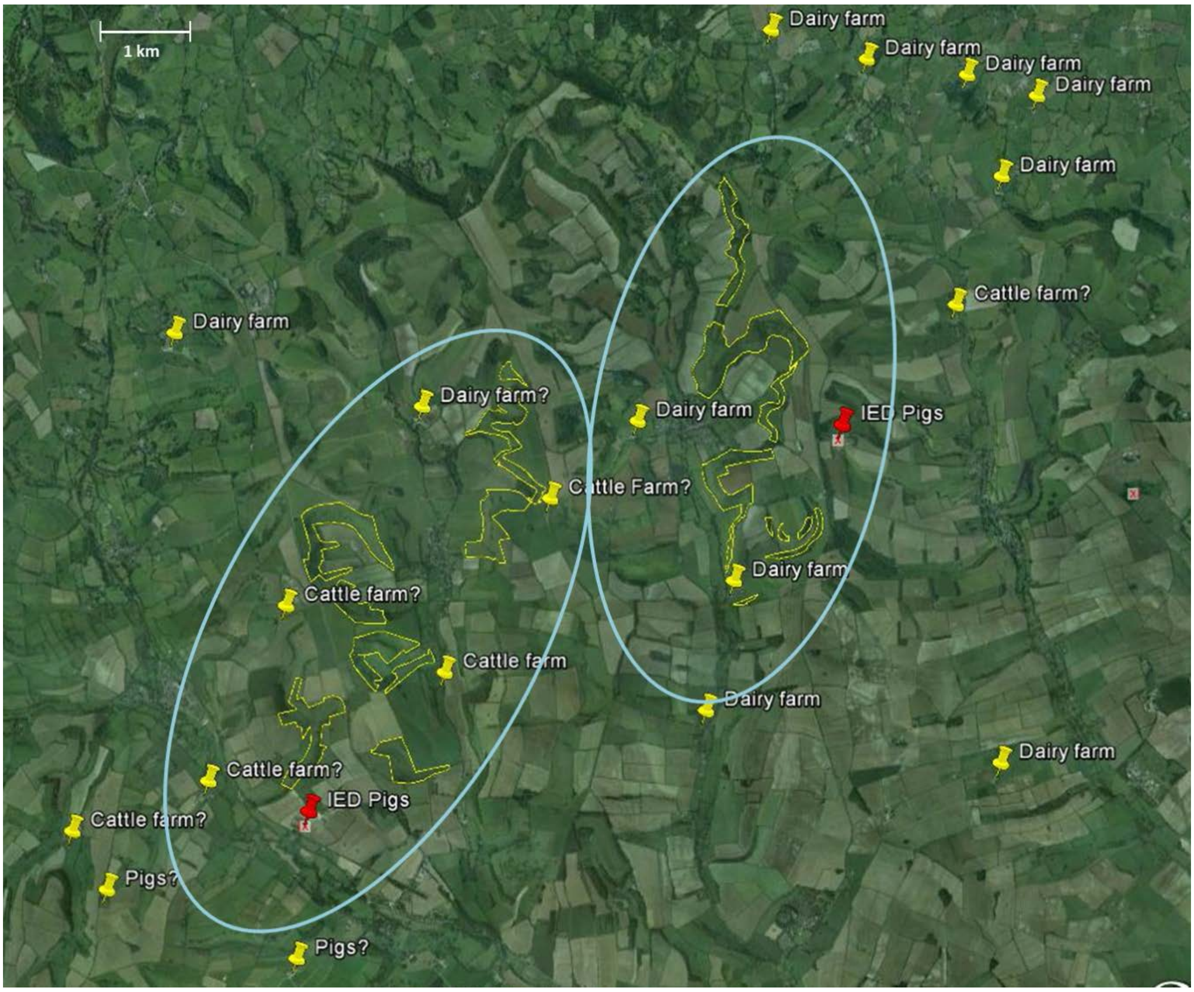
Figure 1. Cerne and Sydling Downs SAC (outlined in yellow). Inset: wind rose for Dorchester (www.windfinder.com)



2. Identification of major emission sources

A list of potential emission sources within an approximate 2 km buffer of the SAC was established using Google Earth, which was then refined using the local knowledge of the Catchment Sensitive Farming Officer (CSFO, Charlotte Woodford).

Figure 2. Potential emission sources around Cerne and Sydling Downs SAC; red pins indicate sites permitted by the Environment Agency under the Industrial Emissions Directive; blue line shows indicative target zone for implementation of mitigation measures



A total of 21 potential emission sources were initially identified using Google Earth (Table 1). However, it was evident for this case study site that the ‘remote’ approach using Google Earth did not agree well with ‘on the ground’ local knowledge. Several of the apparent livestock housing sites were now redundant and there were some livestock farms which were known to the CSFO but had not been identified via Google Earth. Of those identified, many were considered to be of low risk, being low intensity sheep or beef farms. There were three dairy units with an anaerobic digester within 5 km that had not been identified, and it was known that digestate was spread to land closer to the site.

Several of the farms were downwind of the sites and considered to be of little concern when considered as point sources. Beef cattle would mostly be housed on deep straw, with the resulting FYM being field heaped to be spread to stubbles for ploughing in during August and September. Dairy slurry applications are more variable, with some to grass in early spring, some to maize ground to be ploughed in April and the rest to after-cut grass and some cereal stubbles. Pig slurry, in particular, may be moved some distance from the farm for spreading.

Table 1. Potential emissions sources around Cerne and Sydling Downs SAC

Initial source identification using Google Earth	CSFO feedback
Dairy farm, outdoor yards	Redundant unit
Dairy farm, outdoor yards	OK
Dairy farm, outdoor yards	Pig / ex-pig unit
Dairy farm, slurry lagoon and tank	OK
Dairy farm with slurry lagoon	Beef and arable
Dairy farm with slurry tank	Organic dairy farm
Possible cattle housing	Beef and arable
Dairy farm	Was a dairy farm – no longer in production
Dairy farm	Thought to be a beef farm
An IED site, 3,000 sow unit	Correct
Possible cattle housing	Not dairy
Possible cattle housing	Not dairy
Dairy farm	Cattle, not dairy
Possible cattle housing	Ex-dairy
Dairy farm	OK
Dairy farm with slurry lagoon	OK
Possible cattle housing	Not sure
Possible cattle housing	Beef and arable
An IED site, 2,600 sows plus 15,000 finishing pigs	OK
Possible intensive pig housing	Ex-pig unit
Possible intensive pig housing	Cattle

Summary of major local emission sources

The range of agricultural activities in the area are likely to result in an elevated background ammonia concentration at the SAC, but there were relatively few specific sources identified as having a major impact. The intensive pig housing is permitted by the EA and presumably therefore has any necessary emission reduction techniques already in place. Manure storage and applications close to the SAC (500 m being the likely distance within which emissions from these sources will contribute significantly to local deposition at the site) are likely to represent the main emission sources, and, particularly, sources for which existing mitigation practices might be implemented. Fertiliser management of the arable crops in fields bordering the SAC is unknown, but if used in significant quantities, emissions from urea fertiliser applications may also have some impact on the site.

3. Mitigation measures

Manure storage and spreading operations close to the SAC sites (within 500 m), which represent the major local emission sources contributing to elevated concentrations at the SAC, could be the focus for mitigation, for which a number of potential mitigation measures exist (Table 2). Any slurry tanks or lagoons within this area could be covered. Any field heaps of solid manure should be covered with sheeting after establishment, although this is only beneficial where the manure can be rapidly incorporated into the soil after spreading, otherwise emission reductions made at the storage stage will be offset by higher emissions after spreading. The shallow soils and underlying chalkland of this area mean that slurry injection is associated with an increased risk of leaching and contamination of ground water. Therefore, although less effective as an ammonia emission reduction measure, trailing shoe application of slurry to grassland is recommended rather than shallow injection. Trailing hose application could be used for slurry applications to growing arable crops and any slurry or solid manure applied to cereal stubbles could be rapidly incorporated into the soil (within 4-6 h). Use of urea fertilisers could be minimised, or used in conjunction with a urease inhibitor.

Table 2. Potential measures to reduce ammonia emissions around the Cerne and Sydling Downs SAC

Measure	Mitigation effect	Cost†	Effect on diffuse water pollution
Fit rigid cover to slurry tank	80%	£1.58 per m^3 slurry storage	↓
Floating cover on slurry stores	30-70%	£0.85 per m^3 slurry storage	~
Slurry bags for storage	95%	Cost-neutral at store replacement	↓
Sheet cover on FYM heaps	30-90%	£0.63 per tonne FYM storage	↓
Trailing shoe slurry application	20-80%	£0.58 per m^3 slurry applied	~
Trailing hose application of slurry	0-50%	£0.47 per m^3 slurry applied	~
Rapid incorporation (within 4h) of surface spread slurry	30-80%	£0.25 per m^3 slurry applied	↓
Rapid incorporation (within 4h) of surface spread FYM/poultry manure	30-90%	£0.30-£1.50 per tonne manure applied	↓
Switching from urea/UAN fertiliser to ammonium nitrate	65-80%	£0.15 per kg N applied	~
Use of a urease inhibitor with urea/UAN fertiliser	40-70%	£0.15 per kg N applied	~

†Costs from a range of existing sources are indicative, but may vary widely depending on farm size and circumstances

4. Interaction with existing measures/schemes

There is a long history of farmer engagement in this catchment regarding measures to mitigate diffuse water pollution and the SAC lies within the CSF target area for water pollution, which should enhance opportunities for any synergistic measures. The whole of the Sydling Valley is in stewardship (HLS) with overwintering bird options and arable reversion. Current activities which may also mitigate ammonia emissions include delivery of advice on improved nutrient management and capital investment for roofing over of outdoor cattle yards. However, the CSFO cautioned that farmers in the catchment are already dealing with a number of issues and introducing another one that they should be concerned about, ammonia emission/deposition, might prove to be one too many and raise difficulties with further farmer engagement. A focus on improved manure and nutrient management, which would be beneficial to reducing both water and air pollution, is likely therefore to be the best approach.

5. Conclusions

Remote identification of potential emission sources using e.g. Google Earth can be quite misleading and should always therefore be used in combination with local knowledge.

A range of potential point and diffuse emission sources were identified within this mixed farming region. The main sources impacting on the SAC were considered to be any manure storage facilities and manure applications to field close to the individual SAC sites.

Targeting of mitigation measures to manure storage facilities and applications to fields within 500 m of the SAC is recommended. This would include covering of slurry stores (floating covers on slurry lagoons, fixed or floating covers on above-ground tin tanks) and the use of low emission manure application techniques (trailing hose or trailing shoe; rapid incorporation of manures into soil by cultivation where applicable).

Shallow injection was not recommended as a slurry application mitigation technique because of the risk of increasing pollution of groundwater given the shallow soils above chalkland in this region.

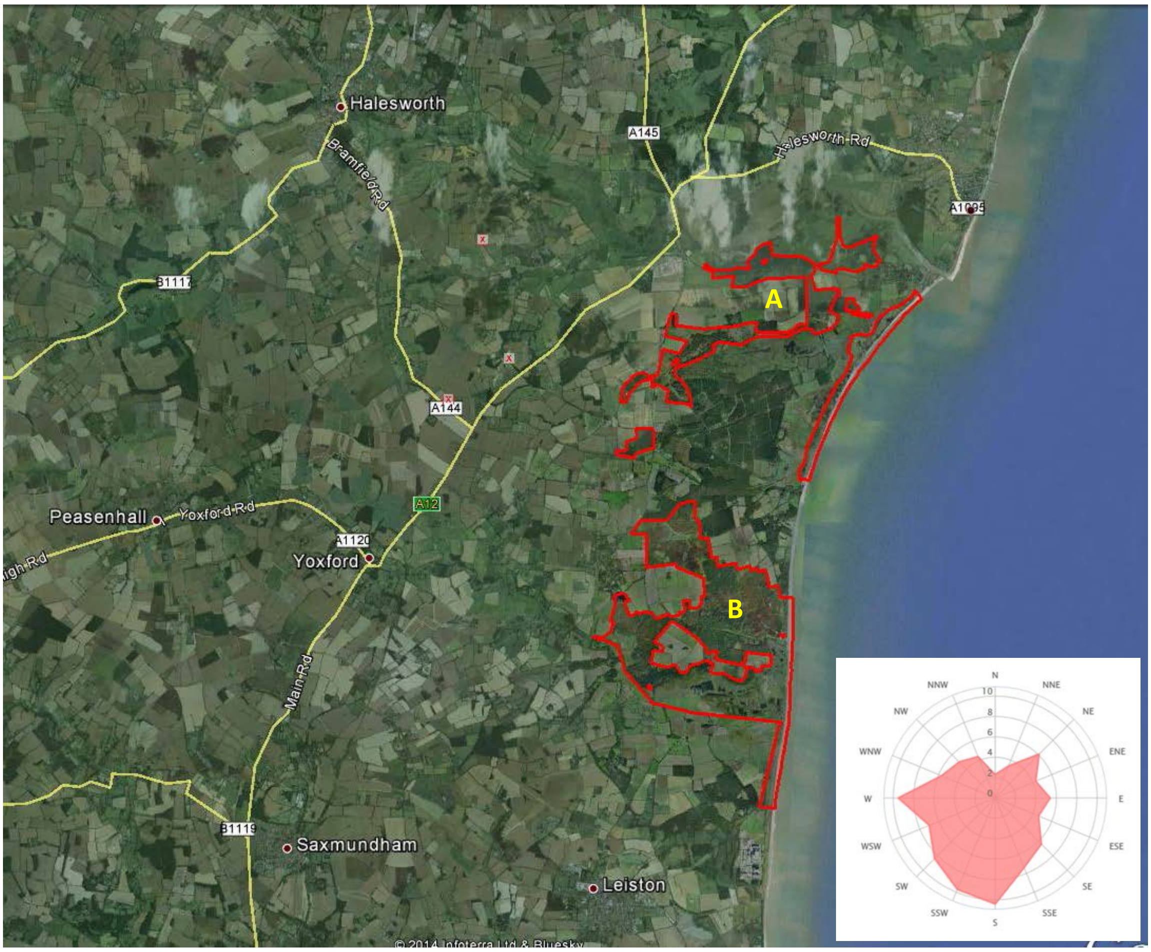
For this case study CSF could be considered a potentially successful route by which to introduce ammonia mitigation measures, particularly those relating to improved manure and nutrient use management which would benefit both water and air pollution and for which farmers can see clear benefits.

Annex 3: Minsmere and Walberswick case study report

1. Introduction

The Minsmere-Walberswick Heaths and Marshes are located on the North Sea coast between Southwold and Sizewell in Suffolk (approx.. grid reference TM4771), extending over an area of coastline of approximately 11 km in length. It includes a range of habitats, being made up of a complex mosaic of marshes, reed beds, shingle banks and lowland heath. Agriculture in the area is predominantly arable, outdoor pig production and a number of intensive indoor pig and poultry units. Prevailing wind direction is SW. This case study includes the whole of the SAC, assessed in two parts identified as sites A and B in Figure 1.

Figure 1. Minsmere and Walberswick case study site (outlined in red). A and B refer to the sub-sites. Inset: wind rose for Leiston/Lowestoft (www.windfinder.com)



2. Identification of major emission sources

A list of potential emission sources within an approximate 2 km buffer of each of the sub-sites, identified through using Google Earth, was established, which was then refined using the local knowledge of the Catchment Sensitive Farming Officer (CSFO, Robert Camps).

Sub-site A.

Nine potential emission sources were identified around sub-site A (Fig. 2). Feedback from the CSFO indicated that the outdoor pig herds and associated manure applications were the major sources of concern close to the site (Table 1). There are few data regarding ammonia emissions from outdoor pigs; the current emission factor (25% of the readily available N excreted by the pigs) is based on very few measurements and is likely to be influenced greatly by soil and weather conditions. The proportion of the N deposition at the site arising from the outdoor pigs is therefore very uncertain, but likely to be of significance.

The livestock farms to the west of the SAC shown in Figure 2 are too distant for their emissions to significantly contribute when considered as point sources (livestock housing or manure storage), although emissions from these and other agricultural activities in the area will contribute to the elevated background ammonia concentration at the site. Fertiliser applications to fields around the site may represent a significant local emission source, particularly if urea fertiliser is used as it is associated with a much higher emission factor than other N fertiliser types. Livestock manure applications to fields close to the site are also likely to be a major local emission source. The CSFO noted that some spreading of biosolids (abattoir and poultry processing waste) occurs close to the SAC at high application rates (250 m^3 ha^{-1}). Although this waste is injected, at such high application rates much of it oozes back out of the slots onto the surface and would represent a significant emission source.

Figure 2. Potential emission sources around Site A; red pins indicate sites permitted by the Environment Agency under the Industrial Emissions Directive

Table 1. Potential emissions sources around sub-site A

Initial source identification using Google Earth	CSFO feedback
Outdoor pigs	Approx. 2000 sows and progeny rotate around many of the fields bordering the site. Manure from tents and arcs is spread on service areas and non-paddock field areas; generally autumn applications, spring cultivation (beet or maize). Other outdoor pig herds also in the vicinity.
An IED site, 150,000 broilers	Litter is mostly transported west of the farm for field application.
An IED site, 340,000 broilers	No knowledge, but relatively close in an upwind direction, so will contribute to an elevated background concentration.
An IED site, 85,000 broilers	Litter spread locally.
Possible livestock housing	Nothing major here – beef cattle grazed in the area.
Possible livestock housing	Dairy farm (c. 150 cows), slurry applied to grassland and maize.

Sub-site B.

Five potential emission sources of concern were initially identified around sub-site B (Fig. 3). Feedback from the CSFO again highlighted the outdoor pigs and manure applications close to the site being the major concerns (Table 2).

Table 2. Potential emission sources around sub-site B

Initial source identification using Google Earth	CSFO feedback
Outdoor pigs	Same herd as for Site A
Possible livestock housing	Nothing of significance known here.
Cattle housing - FYM	Nothing of significance known here.
Possibly intensive pigs	Nothing of significance known here.
Indoor pigs	150 sows and finishers, FYM spread to arable land 50:50 autumn/spring

Figure 3. Potential emission sources around sub-site B

Summary of major emission sources

The main local emission sources impacting on the Minsmere and Walberswick SAC were identified as being the diffuse emission sources due to the rearing of outdoor pigs, using many of the fields bordering the SAC (particularly at the northern end) and manure applications, including injection of biosolids at very high application rates, to land close to the site. A number of point emission sources were identified, including intensive poultry housing, but these were discounted as having a significant impact on the site due to their location and the fact that assessments regarding impact have been made by the Environment Agency under IED compliance. Fertiliser management of the arable crops in fields bordering the SAC is unknown, but if used in significant quantities, emissions from urea fertiliser applications may also have some impact on the site.

3. Mitigation measures

There is a complete lack of knowledge regarding the impact of management practices for outdoor pigs on ammonia emissions, and therefore there are no documented mitigation measures specific to this source. However, one potential measure to mitigate impact would be to relocate the pig such that they were at least 500m from the SAC boundary, with a buffer of arable fields between the pigs and the SAC site. Whether this is practical depends on land ownership and management agreements. Alternatively, more frequent movement of the pigs between paddocks and rapid cultivation of paddocks vacated by pigs may reduce emissions. Other than this, mitigation measures with the most potential to impact the site are those targeting manure applications to land, storage of manure heaps very close to the site and use of urea fertiliser on land close to the site (Table 3).

Table 3. Potential measures to reduce ammonia emissions within the Culm Measures study site

Measure	Mitigation effect	Cost†	Effect on diffuse water pollution
Trailing hose application of slurry	0-50%	£0.47 per m^3 slurry applied	~
Rapid incorporation (within 4h) of surface spread slurry	30-80%	£0.25 per m^3 slurry applied	↓
Rapid incorporation (within 4h) of surface spread FYM/poultry manure	30-90%	£0.30-£1.50 per tonne manure applied	↓
Sheet cover on FYM heaps	30-90%	£0.63 per tonne manure stored	↓
Switching from urea/UAN fertiliser to ammonium nitrate	65-80%	£0.15 per kg N applied	~
Use of a urease inhibitor with urea/UAN fertiliser	40-70%	£0.15 per kg N applied	~

†Costs from a range of existing sources are indicative, but may vary widely depending on farm size and circumstances

It is recommended for this site, therefore, that resources should be focussed on the immediate surroundings to the site (within 500m) rather than on specific installations such as pig or poultry housing and manure storage facilities located further away. Within this zone, field heaps of pig or poultry manure should be sheeted after establishment to reduce emissions during the storage period. However, this is only beneficial where the manure can be rapidly incorporated into the soil after spreading, otherwise emission reductions made at the storage stage will be offset by higher emissions after spreading. Where possible, all poultry manure and pig/cattle FYM should be rapidly incorporated into the soil directly after spreading (within 4h). Slurry applications to tilled land should also be rapidly incorporated, but it is more likely that slurry will be applied to growing crops. In this case, application by trailing hose is most appropriate, with the wide boom widths available being compatible with controlled trafficking on arable fields (generally not an option with slurry injection or trailing shoe). Application of biosolids by injection should be at agronomically appropriate rates and timings. Use of urea fertilisers should be minimised, unless used in conjunction with a urease inhibitor.

4. Interaction with existing measures/schemes

Current CSFO activities within the area besides general promotion of the stewardship options have included Pigwise visits, focussing on soil suitability for outdoor pigs, engagement with the Ecopig project assessing a number of different management options for outdoor pigs, and the encouragement of soil and manure analyses. There has been uptake of measures aimed at reducing N leaching and run-off where there is clear physical evidence, peer pressure or the threat of prosecution, but engagement regarding ammonia emission/deposition might be much harder. The view of the CSFO was that farmers are more likely to engage where there are clear benefits to their farming operation (i.e. win/win scenarios) and that manure spreading options, such as rapid incorporation, which can be packaged as manure nutrient use efficiency measures were likely to be the most successful.

5. Conclusions

The main emissions sources of concern within the study site were identified as the outdoor pig production bordering much of the site and manure applications to land close to the site boundary. Potential emission sources located further away, including intensive pig and poultry housing and manure storage facilities were deemed to be less important.

There are limited data on emissions from outdoor pig production and the impact of management practices, therefore it was not possible to give specific mitigation measures for this source.

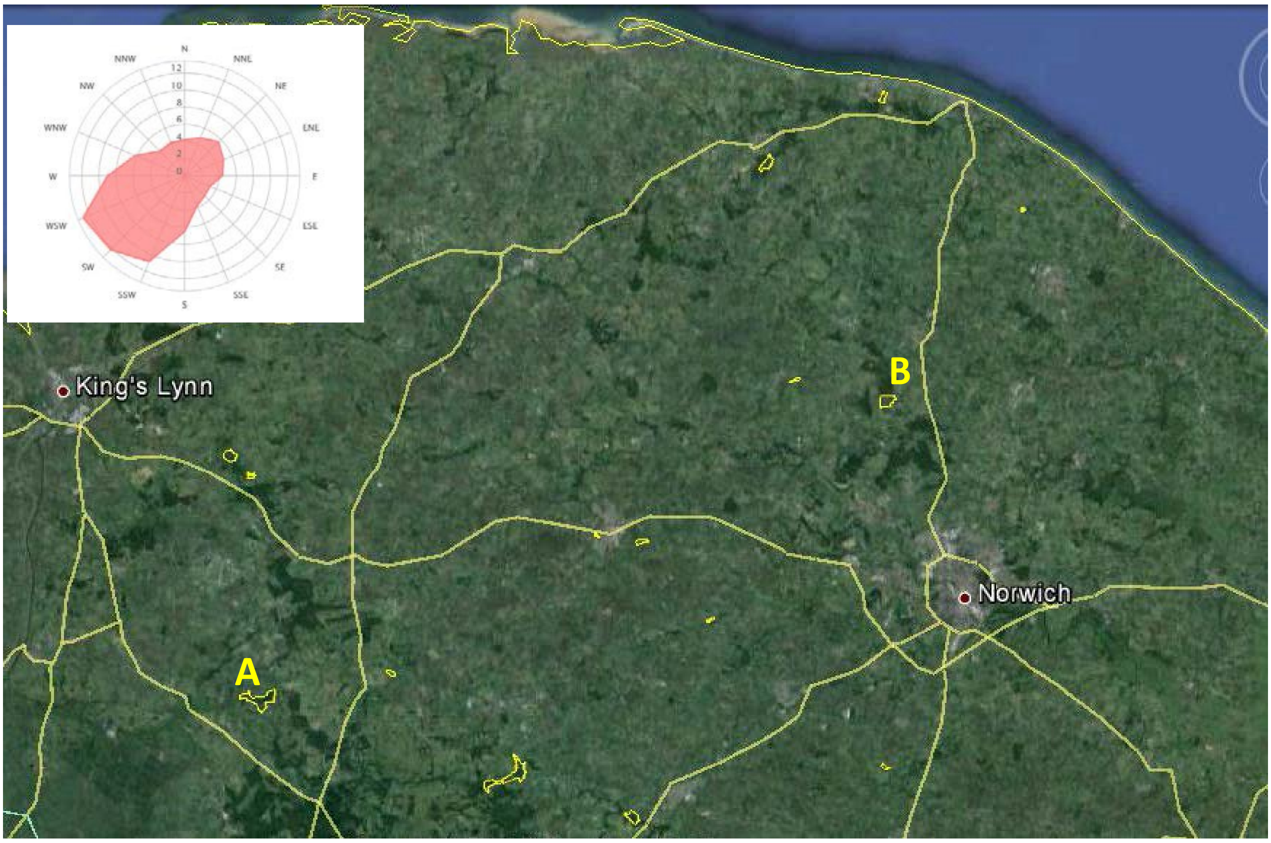
Rapid incorporation of manure applications to land (within 4-6 h of spreading) and spreading of slurry by trailing hose to arable crops were identified as the main mitigation measures to focus on within a 500m buffer zone around the site. Additionally, sheeting of manure heaps immediately after establishment close to the site boundary and minimising urea fertiliser use within this zone were also recommended.

Annex 4: Norfolk Valley Fens case study report

1. Introduction

Norfolk Valley Fens SAC (approx. grid reference TL7896) comprises scattered sites (Fig. 1), primarily designated for the presence of rare spring fed alkaline fens which support a rich floral assemblage, in addition to strong populations of narrow-mouthed whorl snail and Desmoulin's whorl snail. The SAC supports a diverse range of other Annex 1 habitats including; northern Atlantic wet heaths, European dry heaths, semi-natural dry grasslands and scrubland facies on calcareous substrates, Molinia meadows on calcareous, peaty or clayey-silt-laden soils, calcareous fens and alluvial forest. The sites sit within a predominantly arable agricultural landscape but associated with a large number of intensive pig and poultry units. Sub-sites A and B have been taken as representative of the SAC for the purposes of this study. Prevailing wind direction is SW.

Figure 1. Norfolk Valley Fens SAC. Studied sub-sites: A, Foulden Common; B, Buxton Heath; Inset : wind rose for Norwich Airport (www.windfinder.com)



2. Initial identification of potential emission sources

A list of potential emission sources within an approximate 2 km buffer of each of the sub-sites, identified through using Google Earth, was established. The Catchment Sensitive Farming Officer

(CSFO) for this site was not available, so limited input was obtained from the CSFO (Eric Popp) from a neighbouring site with similar characteristics.

A. Foulden Common

Fifteen potential emission sources were identified around Foulden Common (Fig. 2) of which 5 are known IED permitted sites, but a number of others would appear also to be intensive pig or poultry farms but presumably of a size below the IED permitting threshold (Table 1).

Figure 2. Potential emission sources around Foulden Common; blue line shows indicative target zone for implementation of mitigation measures

Assuming a prevailing SW wind, then the main focus should be on activities in that direction from the site – in particular any uncovered slurry storage facilities, manure heaps and slurry/manure applications to land. Some of the farms are almost certainly far enough away not to contribute significantly to emissions as point sources (outside the indicative target zone in Fig. 2), but manure from these farms may be spread closer to the site.

Table 1. Potential emission sources around Foulden Common

Details
An IED site, 160,000 broilers – noted by EA as 'no adverse effect'
Outdoor pigs
Possible intensive pig/poultry farm
Large FYM heap in field – may no longer be there, but an example of what typically occurs?
Possible intensive pig/poultry farm
IED site, c. 13,000 weaners and finishing pigs – noted by EA as 'no impact identified at Foulden'
Possible intensive pig/poultry farm
Outdoor pigs
IED site, 450,000 broilers - noted by EA as 'no impact identified at Foulden'
Possible intensive pig/poultry farm
An IED site, 360,000 broilers – noted by EA as 'no adverse effect'
An IED site, 80,000 broilers – noted by EA as 'no adverse effect'
Possible intensive pig/poultry farm
Large pig farm – FYM store
Possible intensive pig/poultry farm

B. Buxton Heath

Fewer potential local emission sources were identified around Buxton Heath, which was largely surrounded by arable fields and woodland (Fig. 3). There were 3 IED-permitted sites and 3 additional sites (Table 2) that appeared to be intensive pig or poultry (but presumably below the IED size threshold). One of these is very close to the SAC. Two are further away and from a prevailing wind perspective on the downwind side and are therefore unlikely contribute significantly as point sources, although manure from these sites may be spread closer to the SAC.

Table 2. Potential emission sources around Buxton Heath

Details
Possible intensive pig/poultry farm
Possible intensive pig/poultry farm
Possible intensive pig/poultry farm
An IED site, 400,000 turkeys – noted by EA as 'impact at Buxton Heath, IC to reduce ammonia emissions'
An IED site, 10,000 turkeys – noted by EA as 'impact at Buxton Heath, IC to reduce ammonia emissions'
An IED site, 290,000 broilers – noted by EA as 'no impact identified'

Figure 3. Potential emission sources around Buxton Heath; blue line shows indicative target zone for implementation of mitigation measures

Summary of major emission sources

The intensive pig and poultry farms around the Norfolk Valley Fens SAC represent the major potential local point sources for ammonia emissions, although more local knowledge is required to confirm those identified using Google Earth. In addition to these, the major local emissions are likely to be from any manure storage and application to land close to the SAC (within 500 m). Fertiliser management of the arable crops in fields bordering the SAC is unknown, but if used in significant quantities, emissions from urea fertiliser applications may also have some impact on the site.

3. Mitigation measures

Mitigation measures which could potentially be introduced to reduce ammonia emissions around the Norfolk Valley Fens include those targeted at intensive pig or poultry housing, manure storage, manure application to land and the use of urea fertiliser (Table 3).

Table 3. Potential measures to reduce ammonia emissions around the Norfolk Valley fens SAC

Measure	Mitigation effect	Cost†	Effect on diffuse water pollution
Partially-slatted floors with reduced pit area for pig housing	10-50%	£6.68 per animal place	~
Frequent slurry removal from pig housing	25%	Cost-neutral for new build	~
Floating balls on manure surface of below slat pig slurry store	25%	£1.50 per animal place	~
Acid scrubbers fitted to mechanically ventilated pig/poultry housing	70-90%	£10.00, £0.20 and £0.25 per animal place for pigs, layers and other poultry, respectively	~
Air drying of layer manure on belts	0-70%	£0.32 per animal place	~
Under-floor litter drying for other poultry	30%	£0.08 per animal place	~
Fit rigid cover to slurry tank	80%	£1.58 per m^3 slurry storage	↓
Floating cover on slurry stores	30-70%	£0.85 per m^3 slurry storage	~
Slurry bags for storage	95%	Cost-neutral at store replacement	↓
Sheet cover on FYM heaps	30-90%	£0.63 per tonne FYM storage	↓
Shallow injection of slurry	50-90%	£0.69 per m^3 slurry applied	~
Trailing shoe slurry application	20-80%	£0.58 per m^3 slurry applied	~
Trailing hose application of slurry	0-50%	£0.47 per m^3 slurry applied	~
Rapid incorporation (within 4h) of surface spread slurry	30-80%	£0.25 per m^3 slurry applied	↓
Rapid incorporation (within 4h) of surface spread FYM/poultry manure	30-90%	£0.30-£1.50 per tonne manure applied	↓
Switching from urea/UAN fertiliser to ammonium nitrate	65-80%	£0.15 per kg N applied	~
Use of a urease inhibitor with urea/UAN fertiliser	40-70%	£0.15 per kg N applied	~

†Costs from a range of existing sources are indicative, but may vary widely depending on farm size and circumstances

Many of the housing measures for intensive pig and poultry are expensive or not suitable for retro-fitting to existing buildings and therefore suited to new build only – these include partially slatted floor systems, frequent slurry removal and acid scrubbers. For pig housing, building design and management, particularly regarding ventilation system, are very important in maintaining clean pigs and low emissions, and guidance on this in relation to the potential mitigation measures should be given. Cascading of best practice as implemented on IED farms to below-threshold size farms could be encouraged, but cost is likely to be a large barrier to uptake.

Therefore while the CSFO should have a good awareness of potential measures for intensive livestock housing, and any new facilities within the vicinity of the SAC would certainly have to include emission reduction measures, the main focus for engagement with farmers is more likely to be regarding measures to reduce emissions from manure storage and applications to land. Field heaps of poultry and pig manure are likely to be common given the number of intensive units in the region, and efforts should be made to cover these with sheeting. This should be combined with rapid incorporation (within 4-6 h) into the soil by cultivation after manure application to land to maximise the benefit of reduced emissions at storage. For slurries, shallow injection or trailing shoe application to grassland and trailing hose application to growing cereal crops should be encouraged. Use of urea fertilisers should be minimised, unless used in conjunction with a urease inhibitor.

4. Interaction with existing measures/schemes

Little was known about current CSFO activities within this area, but experiences from the similar neighbouring area can be brought to bear. To date, CSF has not dealt with the large poultry producers as the issues there are more specifically focussed on air pollution rather than water. An improved link between IED permitting and CSF could be beneficial in this respect. There is also a disconnect between the intensive housing and subsequent manure management, as the manure is commonly exported to neighbouring arable farms for storage and application. Encouragement of uptake of improved manure management measures, which would mitigate both water and air pollution, requires engagement with the large intensive livestock producers, manure spreading contractors and the arable farmers.

5. Conclusions

Of the four case studies, least local information and knowledge was available for this site and the conclusions are therefore more generic, based on experience of the CSFO for a neighbouring catchment.

Improved knowledge of potential measures to reduce emissions from intensive pig and poultry housing by CSFOs is required and good communication between the EA and CSFO regarding IED permitting of installations within the catchment is recommended.

Targeting manure storage and land spreading are likely to be the most cost-effective measures, although engagement with farmers could be difficult because of the disconnect between manure production and manure application.

Annex 5: Reducing the impact of agricultural ammonia emissions on Natura 2000 sites: A guidance note for Catchment Sensitive Farming Officers

Background

- Nitrogen deposition affects plant communities that have evolved on nutrient poor habitats by increasing the amount of plant available nitrogen in the soil. The extra nitrogen can increase the growth of some species (e.g. grasses and heathers) which replace other species that have lower N requirements. Lichens are good indicator species and Figure 1 shows an example of a nitrogen loving species which will flourish in areas of high deposition and of a species which is intolerant to nitrogen deposition and will only flourish at clean sites. Ammonia deposition is currently above the critical load for a number of semi-natural habitats across the UK.

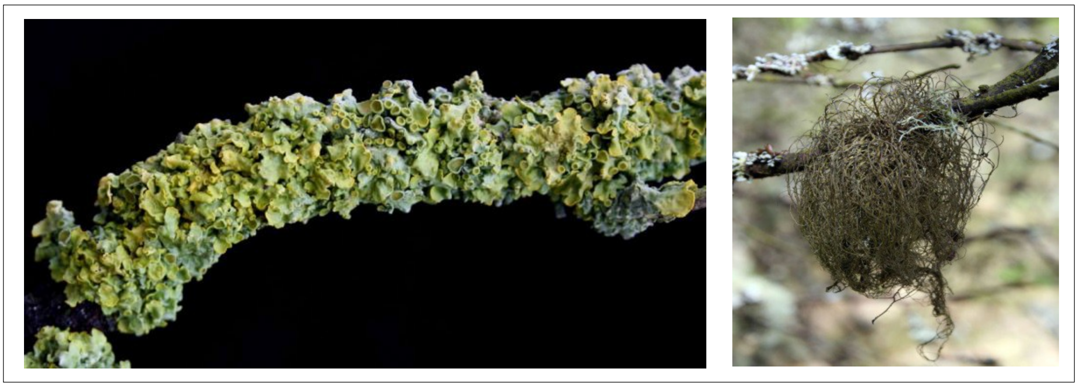


Figure 1. Nitrogen loving Xanthoria near a poultry farm (Left) and nitrogen intolerant Bryoria fuscens (Right)

- Nitrogen emissions which give rise to deposition are as oxide of nitrogen (NO and NO2) arising mostly from motor vehicles and combustion, and as ammonia (NH3) arising predominantly from agricultural sources. These gases may be re-deposited directly, through dry deposition, or may react in the atmosphere to form particles and aerosols which can be transported over long distances and are mainly deposited through rainfall, a process known as wet deposition (Fig. 2).

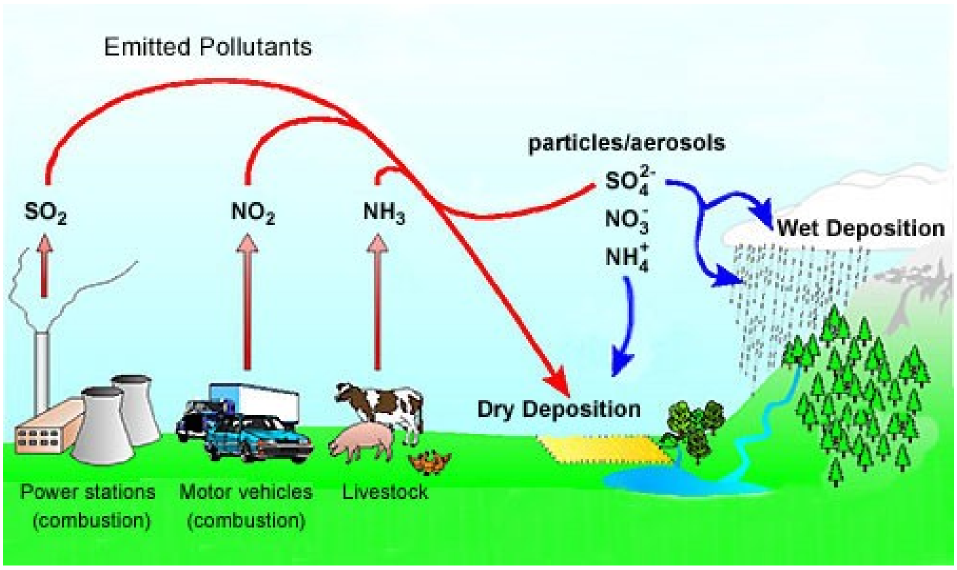


Figure 2. Pollutant emission and deposition processes (from APIS www.apis.ac.uk)

- Agriculture is the main source of ammonia (NH_3) emissions in the UK accounting for *c.*85% of total UK emissions. The management of livestock manures during housing, storage and land spreading are the main source of ammonia losses, accounting for around 70% of agricultural emissions (Fig. 3).

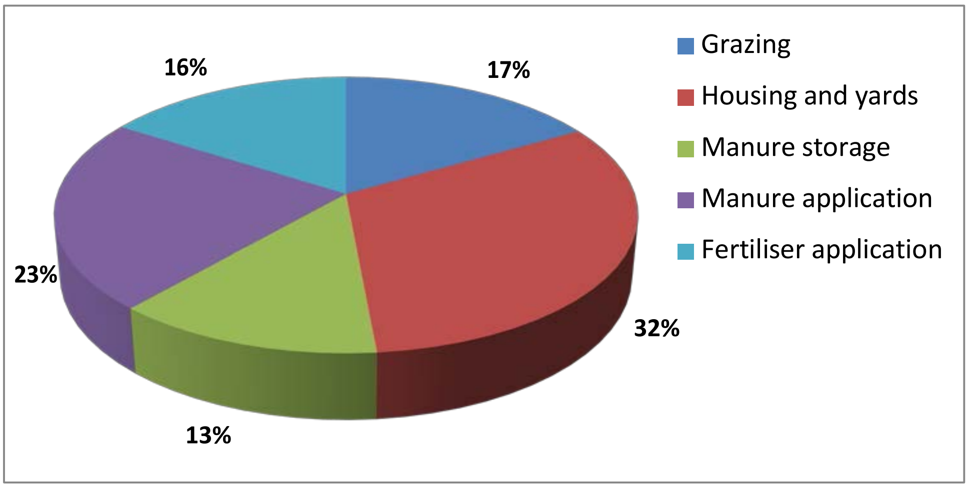


Figure 3. Sources of ammonia emissions from UK agriculture

- Ammonia emissions from livestock systems occur when dung, urine or manure are exposed to the atmosphere.
- Ammonia emissions following application of urea based fertiliser products are typically greater than from ammonium nitrate.
- Measures to minimise ammonia emissions can increase manure N use efficiencies (and reduce the need for manufactured fertiliser N applications) as well as reduce agriculture's impact on the environment.
- Ammonia emissions typically have greatest impact within a relatively short distance downwind of the source (within hundreds of metres to a few kilometres), depending on source strength, topography and prevailing wind direction; an example is shown in Figure 4, where the concentration plume from a poultry house added in the SW corner on the right hand picture can clearly be seen.

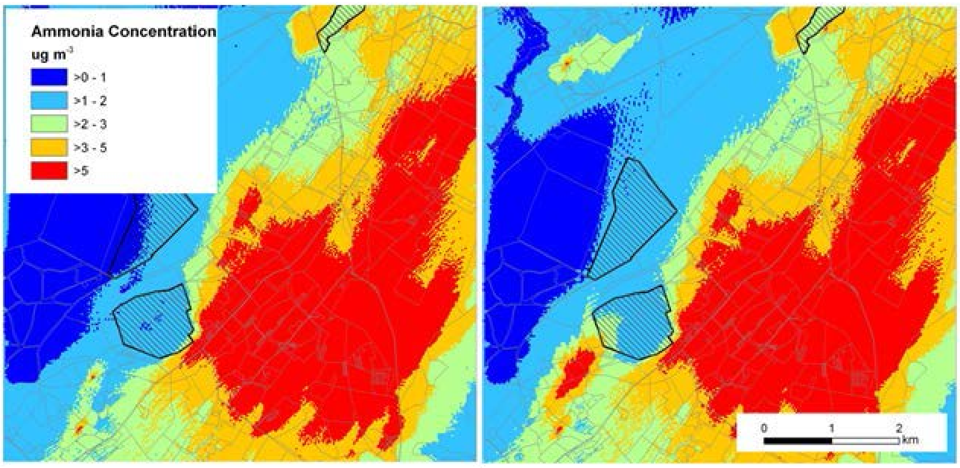


Figure 4: Concentrations of atmospheric NH_3 in a landscape with poultry, beef and sheep farming in the vicinity of SSSIs, Left: baseline concentrations and Right: basline concentrations plus an additional poultry shed added in the SW corner, 1km from the nearest SSSI. SSSI areas are delineated with diagonal hatching. Landscape data source: NitroEurope project

Identification of major local ammonia emission sources and potential mitigation measures based on site characteristics

- Site specific plans will identify the priority target areas for implementation of mitigation measures to reduce the effects of nitrogen deposition for specific Natura 2000 sites. Typically the target area will extend up to 2 km in the upwind direction and 0.5 km in the downwind direction of the Natura 2000 site boundary. The major local emission sources and potential mitigation measures will depend on the type of agriculture in the area and on potentially constraining features such as soil type and slope.
- Measures to mitigate NH_3 emissions from land application of livestock manures are among the most cost-effective (per kg of NH_3 emission abated), practical and easily-implemented of measures aimed at reducing emissions from agriculture and, although differing in detail, applicable across all sites.
- Housing measurements are generally the most expensive, and often not possible to retro-fit. However, specific options may arise within a given catchment and all options should therefore be considered as potential at the outset.
- The strongest focus regarding uptake of options should be in the priority target area, but adoption of options more widely within a given catchment will all contribute to reducing elevated NH_3 concentrations.
- Consideration must be given to any *secondary impacts* of the measures to be implemented; these may be positive, e.g. also reducing water pollution ('win-win') or negative, e.g. risking an increase in water pollution ('pollution swapping').

Predominantly grassland areas

These areas will be typically dominated by dairy, beef and sheep production. Larger, more intensive, dairy farms are likely to represent the major emission sources including slurry-based cattle housing, outdoor yards used for feeding/collecting cattle, slurry storage tanks and lagoons and manure applications to land.

Land application of manures

- ➢ Opportunities for rapid incorporation of applied manure into the soil are likely to be limited, but to be encouraged where tillage operations occur
- ➢ Low emission slurry application techniques (Fig. 5):
    - o shallow injection is most effective, but cannot be used on stony soils, shallow soils overlying chalk or clay soils under 'plastic conditions' where injection slots become channels for slurry transport/run-off
    - o band spreading of slurry by trailing shoe (places slurry on the soil surface beneath the grass canopy); applicable for grassland where shallow injection cannot be used

Figure 5. Low emission spreading techniques suitable for grassland: shallow injection (left) and trailing shoe (right)

Manure storage

- Fit covers to above-ground slurry tanks (Fig. 6); effective at reducing ammonia emission and will also exclude rainfall from the store, reducing the volume of slurry requiring spreading
- Apply floating covers (e.g. expanded clay balls) to slurry tanks and lagoons; less effective than solid covers and won't exclude rainfall, but less costly and a practical option for lagoons
- Cover solid manure heaps with sheeting; only an effective measure if the manure can be rapidly incorporated into the soil after spreading, otherwise emission savings during storage are lost after spreading

Figure 6. Slurry store covers; rigid cover on above ground slurry tank (left) and floating cover of expanded clay granules (right)

Housing

- Where new buildings are being planned, the opportunity could be taken to include emission reducing features such as efficient manure removal (scraper) systems
- Minimise the area of concrete floor (in house and yards) that is fouled by cattle excreta
- Roofing of outdoor yards will reduce emissions to some extent and is also recommended as a measure to reduce diffuse water pollution

Predominantly arable areas

In arable areas, mitigation measures will largely be targeted at manure and fertiliser application. Livestock manures and other biosolids (e.g. digestates) might be imported and spread to arable fields close to the Natura 2000 site from further afield.

Land application of manures

- Where manures are applied to cereal stubble or bare soils, rapidly incorporate into the soil within 4-6 h of application by plough (most effective) or other form of cultivation (Fig. 7)
- Low emission slurry application techniques:
  - Band spreading by trailing hose is most suitable for applications to growing cereal crops, where wide-boom machinery can make use of established cropping tramlines (Fig. 7)
  - deep injection may be applicable prior to crop establishment, but not for stony or shallow soils, particularly if overlying chalk

Fertiliser application

- Switch from urea-based fertilisers (associated with a high emission factor) to other types e.g. ammonium nitrate, or use a urea-based fertiliser product which incorporates a urease inhibitor

Figure 7. Band spreading of slurry to cereal crops (left) and rapid incorporation of applied manure by plough (right)

Intensive livestock housing

Larger intensive pig and poultry units are likely to have already been assessed and implemented appropriate emission reduction technology as part of complying with the Industrial Emissions Directive. However, there may be further potential for adoption of emission reduction measures on such units and on smaller (below IED-threshold) units.

- Mitigation measures for pig and poultry housing are often expensive and/or difficult to retrofit. However, where new buildings are being planned, the opportunity could be taken to include emission reducing features such as floor design for pig housing, rapid slurry removal or slurry acidification systems, manure drying systems for poultry housing and air scrubbers for pig or poultry housing.
- Covering of slurry tanks and lagoon or the use of slurry storage bags for new/increased storage provision (Fig. 8)
- The establishment of tree belts around intensive housing and/or slurry storage can give some emission reduction (up to c. 20%) through reducing air flow around the emission source and direct canopy recapture of emitted NH_3, but may not be appropriate for all situations/landscapes and will take some years to establish

Figure 8. Slurry storage bag

Integrated messages

CSF has primarily focussed on Diffuse Water Pollution from Agriculture. Extension to focus on atmospheric pollution may result in confusion over the aims of the project in the minds of some farmers. Care is needed to avoid any misunderstanding of messages, emphasising the links between reducing nitrogen losses to air and water and particularly the benefits that improvements in manure nitrogen use efficiency can bring.

Further reading

Ammonia in the UK. Defra publications available from
http://adlib.everysite.co.uk/resources/000/109/544/ammonia_uk.pdf

APIS The Air Pollution Information System (www.apis.ac.uk)

Newell-Price, J.P., Harris, D., Taylor, M., Williams, J.R., Anthony, S.G., Duethmann, D., Gooday, R.D., Lord, E.I., Chambers, B.J., Chadwick, D.R. and Misselbrook, T.H. (2011) *Mitigation Methods User Guide.* An inventory of mitigation methods and guide to their effects on diffuse water pollution greenhouse gas emissions and ammonia emissions from agriculture