Defra project AQ0834 - Identification of Potential "Remedies" for Air Pollution (nitrogen) Impacts on Designated Sites (R.A.P.I.D.S.)

Appendix 6 – Case studies to illustrate source attribution and assessment of potential mitigation measures ('remedies') to reduce N pollution impacts on UK SACs and A/SSSIs

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Summary

- Seven case study sites were selected, in discussion with the Steering Group, to illustrate the approach suggested for the draft framework, using the pilot source attribution assessment of UK designated sites.

- One case study each was selected for each Scenario, with the exception Scenario 5 (remote sites affected by long-range transport), where three examples were chosen by the Steering Group.

Introduction

Seven case study sites were selected, in discussion with the project Steering Group (StG), to illustrate the approach suggested for the draft framework, following the pilot source attribution assessment of UK designated sites (see main report Section 4.6.1. and ***Appendix 5*** – Scenario Allocation Pilot, for details). These case studies were chosen to represent the range of scenarios and sites across the UK, as well as the size range, from small sites of ~ 1 km^2 to whole mountain ranges.

One case study is discussed here for the first four Scenarios, with three examples chosen for Scenario 5, to illustrate the range of pressures on larger and more diverse designated sites:

1. Lowland agriculture (many diffuse sources)
2. Agricultural point sources
3. Non-agricultural (point) sources (inc. shipping)
4. Roads
5. Remote (mainly upland) sites affected by long-range transport

Most sites are allocated to at least two Scenarios, therefore multiple suites of measures targeted at the main N threats may need to be assessed, to identify the most effective remedies for each site. The main exception to the multi-scenario allocation to sites is the diffuse agriculture Scenario, which is the most common single Scenario. This does not come as a surprise, however, as diffuse agriculture (i.e. all agricultural sources apart from large pig & poultry housing) is the single largest source of N emissions to the atmosphere in the UK, larger than combustion or road transport.

N.B. Site condition reports, showing vulnerability to N, could be used to link the need to identify N threats and measures to reduce them with observed site condition and threat – this could be a next step, beyond the remit of the RAPIDS project, where the case study aspect aimed to demonstrate identification of N threats and possible measures to reduce them are presented in an indicative way, rather than focusing on specific designated features, i.e. habitats and species.

Some liberty is taken with the site descriptions and preliminary desk-based assessment of the surrounding area, as no detailed research into actual sources and associated emissions at a landscape scale has been carried out as part of this project. (Further work towards this goal is undertaken as part of follow-on projects for England under the IPENS[1] programme from spring 2014.)

Table 1 gives a short overview of the main N threats at the seven (un-named) case study sites, showing the national-scale source attribution assigned to each of them, together with distances to the nearest major road and IED intensive livestock farm. Colour coding is used to show scenarios that apply at the site (in red), and those that do not apply (in green), from the initial scenario allocation. For two sites, there is ambiguity in the scenario allocations for roads (colour coded in grey). In the first case, the % source allocation threshold for the roads scenario is exceeded but major roads (i.e. motorways, primary and A-roads) are not within 200m of the site boundary, In the second case, a major road intersects the site but the % scenario allocation threshold for roads is not exceeded at the 5 km grid resolution of the source attribution database (see detailed section for Scenario E below for a discussion).

[1] Improvement Programme for England's Natura 2000 sites
http://www.naturalengland.org.uk/ourwork/conservation/designations/sac/ipens2000.aspx

Table 1 - Summary information on case studies (A-E): number of scenario(s) allocated to each case study, **total N deposition** (maximum for site, using FRAME 2005, consistent with source attribution data) and source attribution, using national scale 5 km grid data**.** The **deposition type** refers vegetation-specific N deposition estimates, with 'woodland' values appropriate for any woodland habitats present at the designated site, and 'semi-natural' for other (low-growing) semi-natural vegetation, such as grassland, heathland etc. When adding up **percentage scenario contributions**, wet deposition should not be added to the other categories (roads, agriculture and non-agricultural) as these contain wet deposition contributions already. Scenario totals will not add up to 100%, due to rounding and other small source categories, which are not included in the scenario definitions (e.g. dry deposition from imported emissions and offshore installations). The **colour coding** shows allocated scenarios in red, scenarios below the threshold in green, and ambiguous allocations in grey (e.g. % source attribution for roads is below the threshold, but a major road intersects the site).

Case study	Deposition Type #	Scenarios allocated (number, IDs)	Total max. N for site (kg N ha^{-1} yr^{-1})	Scenario allocations in **red**				Nearest feature (m) Close proximity of sources in **bold**	
				Total wet N deposition (% of total N deposition)	Source Attribution (% of total N deposition)				
				Long Range N deposition (Sc5)	Roads (Sc4)	Non-Agricultural sources (Sc3)	Agriculture (fertiliser & livestock) (Sc1,2)	Major Road (Sc4)	IED Intensive farm (Sc2)
A	Woodland	1 (**Sc1**)	57	13	8	17	**69**	> 200	> 2,000
	Semi-natural		31	21	5	16	**72**		
B	Woodland	2 (**Sc2**,1)	50	16	3	10	**80**	> 200	**530**
	Semi-natural		29	23	2	11	**78**		
C	Woodland	2 (**Sc3,4**)	39	17	29	**50**	11	> 200	> 2,000
	Semi-natural		20	31	22	**49**	13		
D	Woodland	2 (**Sc4**,3)	49	19	**22**	**53**	15	**0 (Intersects site)**	> 2,000
	Semi-natural		24	36	**15**	**52**	17		
E1	Woodland	2 (**Sc5**, 3)	34	**74**	8	**39**	18	> 200	> 2,000
	Semi-natural		21	**88**	7	**37**	**20**		
E2	Woodland	4 (**Sc5**,1,3,4)	57	**57**	**11**	**32**	**30**	**0 (Intersects site)**	> 2,000
	Semi-natural		33	**73**	8	**28**	**33**		
E3	Woodland	3 (**Sc5**,1,3)	36	**73**	8	**30**	**34**	**0 (Intersects site)**	> 2,000
	Semi-natural		27	**87**	7	**28**	**33**		

- N.B. Differences between % source allocation to the scenarios (columns 5-8) are due to a combination of reasons, including differences in deposition velocity between NO_x and NH_3 to different vegetation types, with small differences also due to the calibration approach for the deposition data. The larger differences in the contribution of wet deposition to total deposition to woodland and other semi-natural vegetation types are due to woodland receiving larger amounts of dry deposition, with similar wet deposition input to both vegetation types, hence the relative differences.

The following sections illustrate the case studies in detail, each with an aerial image, sample description of surrounding emission sources, and sample data flow diagrams for the Scenario allocation. The flow diagrams provide walk-through examples of the RAPIDS framework for site action plans, with detailed examples on the quantification of N threats, using the approach outlined in the main report (Section 3.6.1.) and shown in detail in ***Appendix 5***. These two reports explain the derivation of the % source attribution values for the initial scenario allocation in Table 1, the subsequent case study tables and the flow diagrams are derived from the UK source attribution dataset.

A detailed assessment of sample measures is provided for the two agricultural scenarios only. This is due to a re-prioritisation of resources (requested by the Steering Group) towards further example scenario allocations for larger sites remote sites allocated to Scenario 5 (case studies E1, E2, E3).

Case study A

Scenario allocation:

1 – Lowland agriculture (many diffuse sources)

Figure 1 – Case Study A: Scenario 1 – Lowland agriculture (many diffuse sources)

Site area: ~ 0.3 km^2

Habitat types: woodland features of UK and European importance

Landscape context: intensive lowland agricultural landscape in England

Main N sources identified: large cattle farms and the associated NH_3 sources of landspreading of manures, fertiliser application and livestock grazing right up to the site boundary, and several cattle sheds within 0.5-1 km of the site boundary, both to the W and NE of the site.

Source attribution calculations: Diffuse agricultural NH_3 emissions from these activities are the major source of N deposition at the site, with the contribution to the surrounding 5 km grid square from diffuse agriculture at ~ 70% of total N deposition (**Table 2**). The nearest major road is > 1 km away, and the nearest large poultry farm is at nearly 4 km distance from the site, with wet deposition contributing ~15% of the total atmospheric N input to the site. The total annual N deposition estimated for woodland features in the 5 km grid square containing the site is ~57 kg N ha^{-1}, which is well in excess of the Critical Load. Given the 5 km grid resolution (i.e. representing average conditions across the square) and the large spatial variability of N at the landscape scale in reality, this average grid square value is likely to be an underestimate in close proximity to sources, especially if these are near the site boundary. **Figure 3** shows how the initial scenario allocation was derived, with Scenario 1 – lowland agriculture (many diffuse sources) - being identified as the main threat to the site. This can be confirmed from an atmospheric NH_3 monitoring site in close proximity to the site, which shows elevated NH_3 concentrations during the spring peak in slurry and manure spreading (Graph in **Figure 4**, Step 3).

Table 2 – Scenario allocation inc. quantification of main N threats from national scale source attribution data at a 5 km grid resolution (2005 data) for Case Study A.

Case study	Deposition Type	Scenarios allocated (number, IDs)	Total max. N deposition for site (kg N ha^{-1} y^{r-1})	Scenario allocations (in **red**)				Nearest feature (m)	
				Total wet N deposition	Source Attribution (% of total N deposition)			Close proximity of sources in **bold**	
				Long Range N deposition	Roads	Non-Agricultural sources	Agriculture (fertiliser & livestock)	Major Road	IED Intensive farm
A	Woodland	1 (**Sc1**)	57	13	8	17	**69**	> 200	> 2,000
	Semi-natural		31	21	5	16	**72**		

Selection of potential measures: Given the dominance of cattle farming and associated grassland and fodder crop production (**Figure 4** – work flow shows more detailed source analysis for the surrounding area), the main candidate measures for reducing local NH_3 emissions and associated concentrations and dry deposition are those targeted at *efficient manure management* (example in **Figure 5**). Such measures include *minimising emissions from cattle housing, manure storage and application of slurries and manures to land*, together with *general nutrient efficiency measures* such as accounting for N in manures when calculating mineral fertiliser application rates.

In addition, *buffer zones* with reduced or no application of N in the immediate vicinity of the site and tree belts around animal houses and manure stores to re-capture/disperse NH_3 emitted would also reduce elevated NH_3 concentrations or deposition to the site. Given the location of the site among a multitude of diffuse agricultural sources causing elevated NH_3 concentrations for the wider surroundings, *conversion of agricultural fields* surrounding the site to e.g. mixed native woodland as a shelter belt to take the brunt of the leading edge of incoming atmospheric N may also be worth considering.

Potential co-benefits of measures: Many of the above listed measures would also deliver considerable reductions to nitrate leaching risks at the site, among other co-benefits. However, the tree belt options close to the site boundary would need to be evaluated thoroughly to eliminate potential detrimental change to the designated features, e.g. species composition and potential effects on the hydrological state of the site would have to be carefully evaluated.

Potential Outcome*:* In discussion with local site managers, agricultural advisors and agri-environment scheme managers on local farm management practices, site characteristics and prevailing SW wind conditions, it could be considered whether farmers would sign up to low-emission landspreading options (with agreed maximum application rates) under HLS, in an area of 500 m surrounding the site, with the zone extended to ~ 1 km upwind, i.e. to the southwest of the site. Other measures that could be considered are covering slurry lagoons (using the CSF[2] Capital

[2] The potential for implementing atmospheric ammonia measures via CSF capital grants is to be investigated for a number of case studies in CSF areas under IPENS, due to report in summer 2014

Grant Scheme), placing manure stored in field heaps no closer than 500 m from the site boundary, and farmers could apply for woodland grant schemes to plant and maintain both farm and site-focused tree shelter belts.

Measures of these types are not currently available specifically for targeting atmospheric N under existing delivery mechanisms, although measures available under the CSF Capital Grant Scheme and woodland grant schemes can provide co-benefits, if spatially optimised, and could be the basis for introducing specific targeted and spatially optimised atmospheric N mitigation options (key measures listed in Appendix 3).

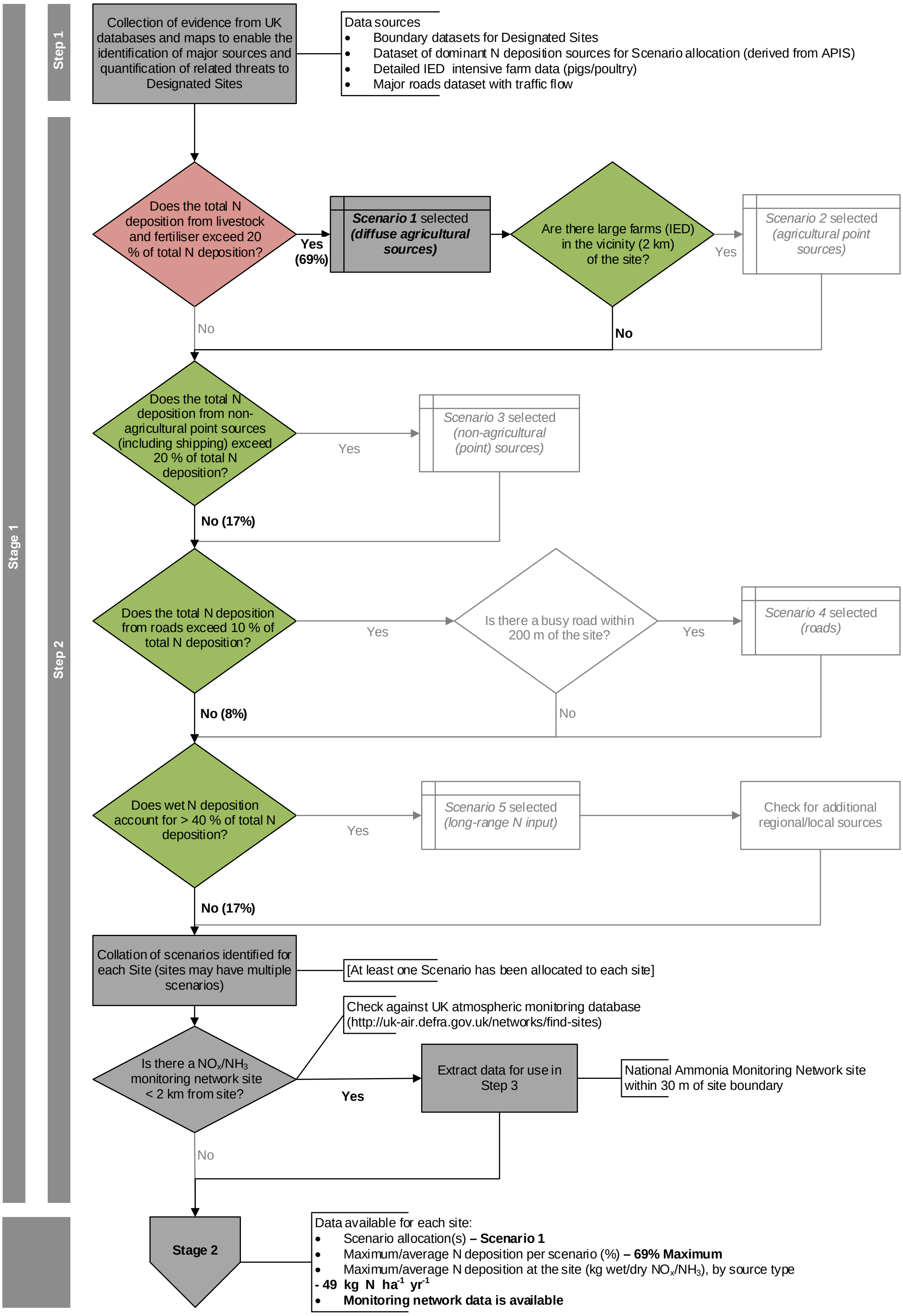

Figure 3 – Example work flow for source attribution and allocation of scenarios for Case study A: Scenario 1 – Lowland agriculture (many diffuse sources) (site designated for woodland). Step 2 has been fully automated, but is shown here in detail to explain the underlying data processing.

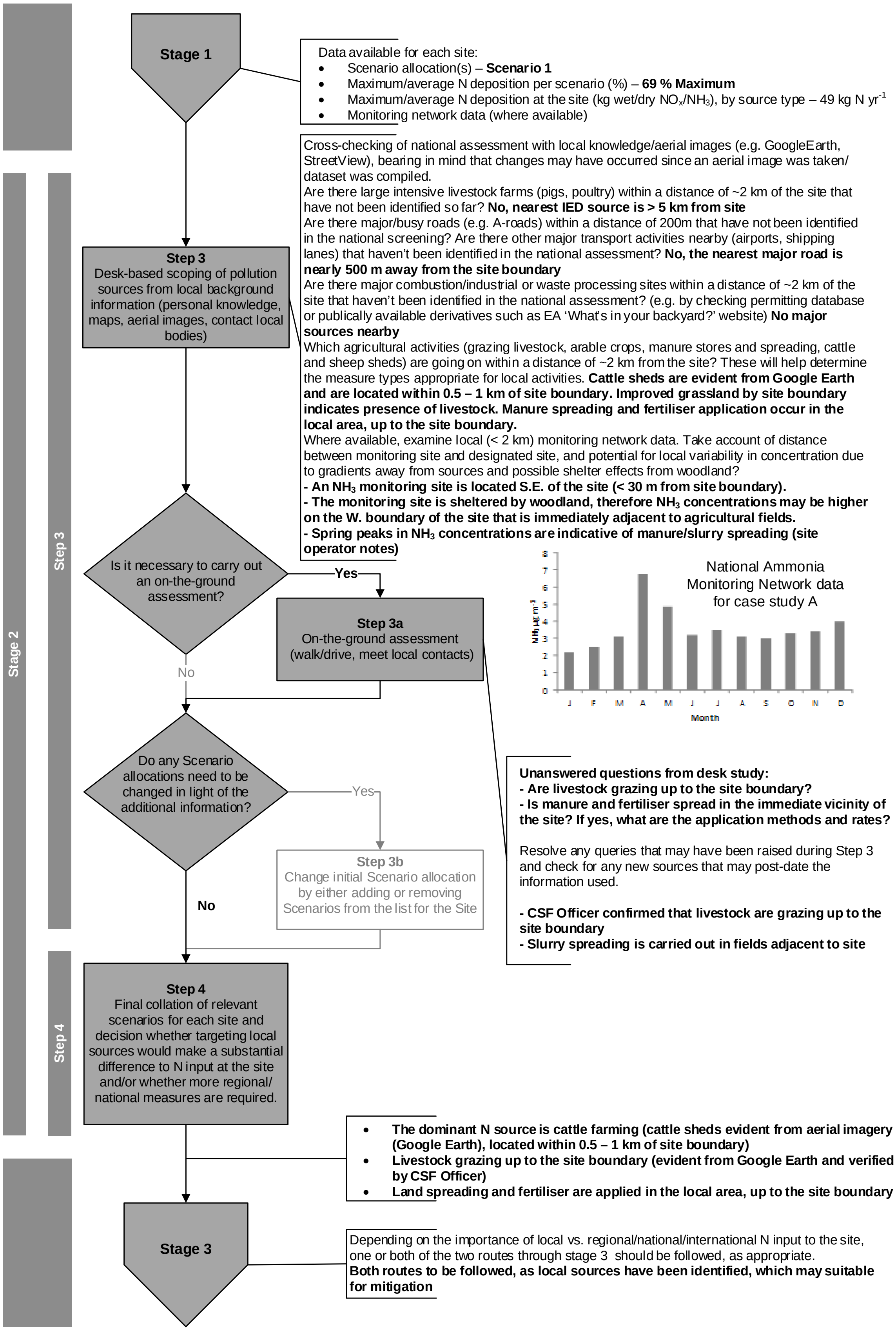

Figure 4 – Example work flow for detailed desktop and on-the-ground assessments for Case study A: Scenario 1 – Lowland agriculture (many diffuse sources) (site designated for woodland).

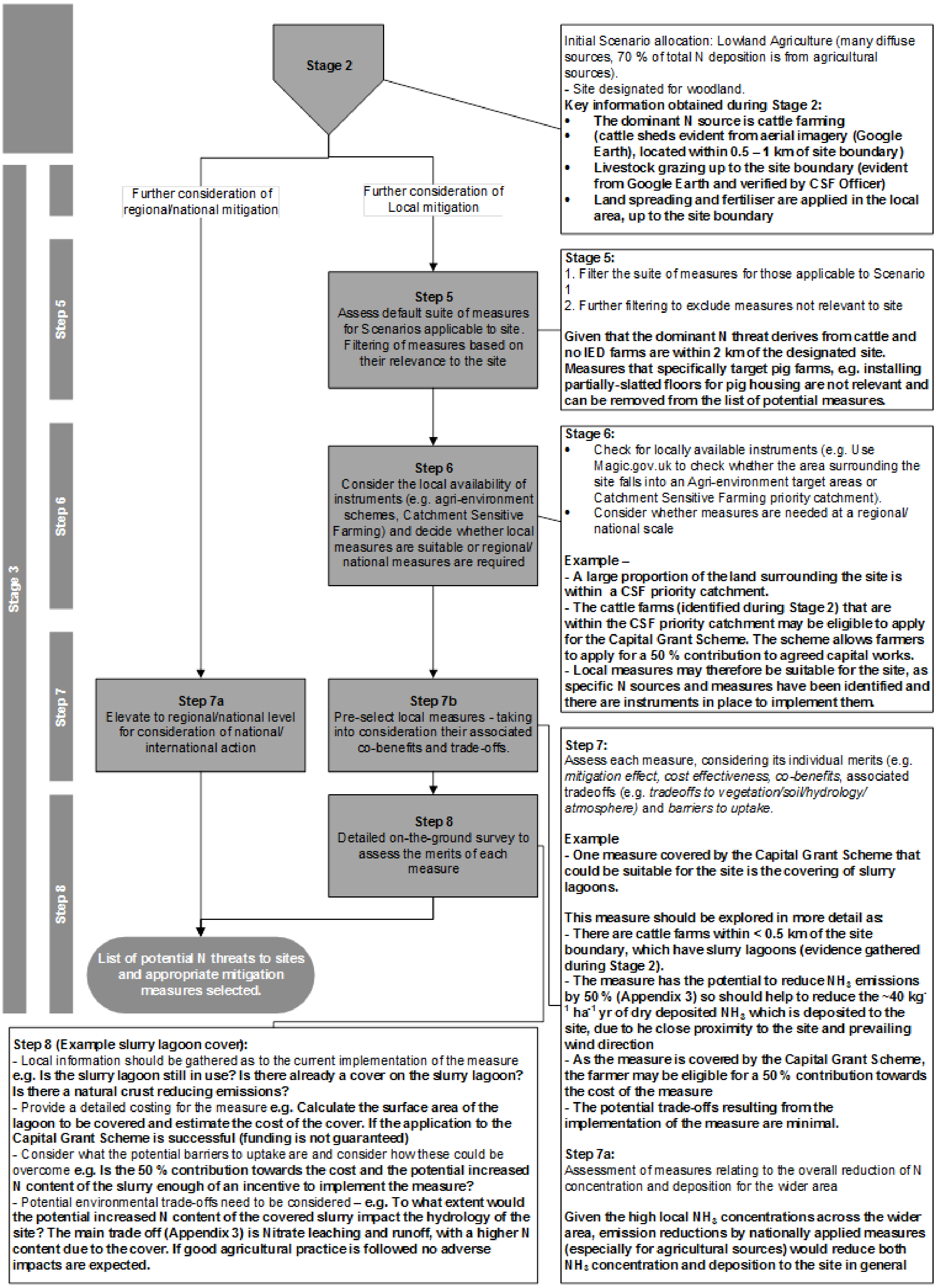

Figure 5 – Example work flow for identifying suitable N mitigation measures for Case study A: Scenario 1 – Lowland agriculture (many diffuse sources) (site designated for woodland).

Case study B: Scenario 2 – Agricultural point sources

Scenario allocation:

2 – Agricultural point sources

1 – Lowland agriculture (many diffuse sources)

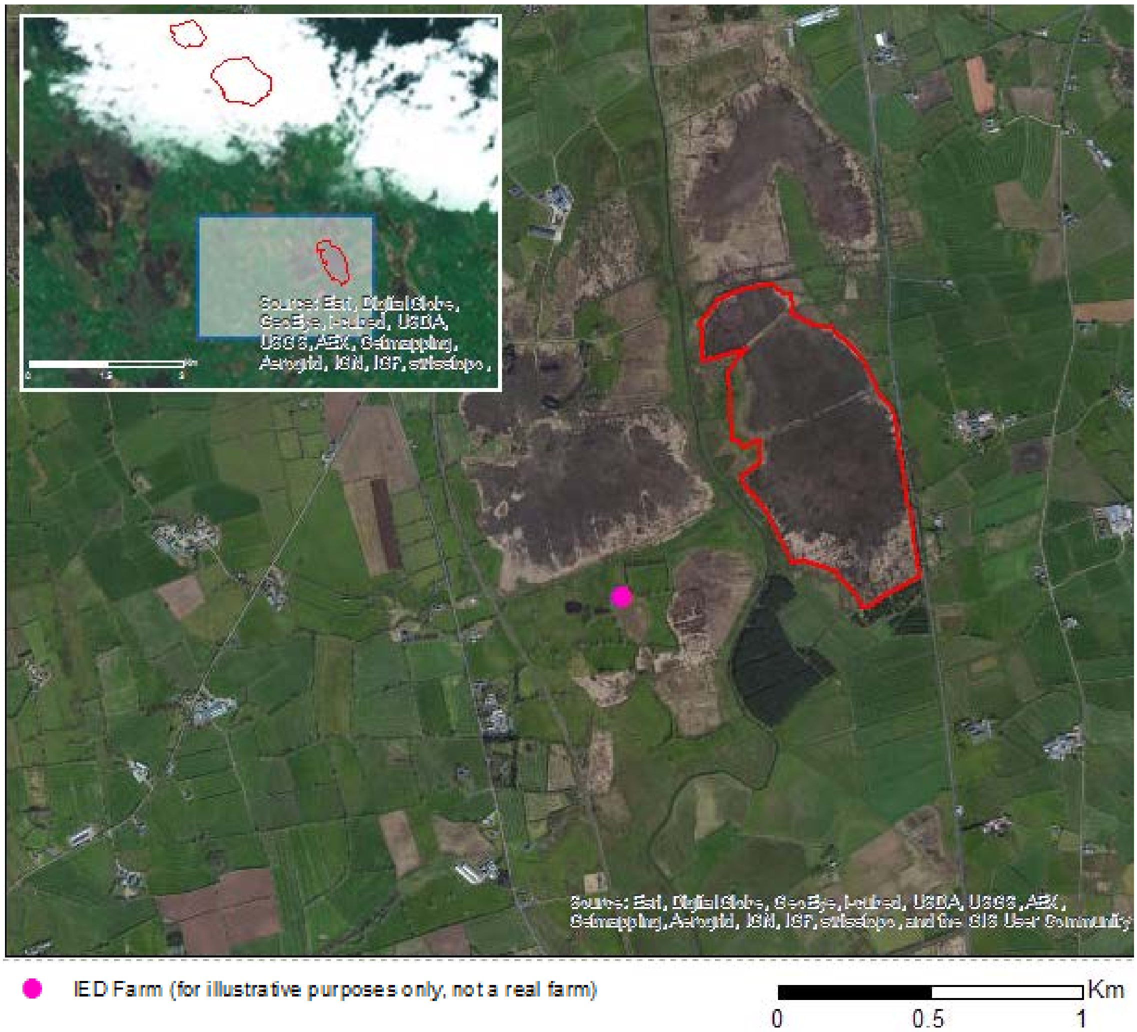

Figure 6 – Case Study B: Scenario 2 – Agricultural point sources

Site area: sub-site: ~0.5 km^2, total site (consisting of three parts) 1.8 km^2

Habitat types: bog/heathland features of UK and European importance

Landscape context: intensive lowland agricultural landscape in Northern Ireland

Main N sources identified: a large poultry farm approx. 500 m from the boundary of the site, to the SW (i.e. upwind of prevailing winds), with cattle farms and the associated NH_3 sources of landspreading of manures, fertiliser application and livestock grazing right up to the site boundary, and several cattle sheds within 0.2 km of the site boundary.

Source attribution calculations: Agricultural NH_3 emissions from these activities are the major source of N deposition at the site, with the contribution to the surrounding 5 km grid square from agriculture at ~ 80% of total N deposition (**Table 3**). The nearest major road is > 1 km away, with roads contributing very little to local deposition (2-3% in the relevant 5 km grid square of the national source attribution dataset), and wet deposition contributing ~20% of the total atmospheric N input to the site. The total annual N deposition estimated for semi-natural features (bog, heathland) in the 5 km grid square containing the site is ~30 kg N ha^{-1} yr^{-1}, which is well in excess of the Critical Load. Given the large spatial variability of N at the landscape scale, this value is likely to be an underestimate in close proximity to sources such as the large poultry farm upwind of the site. **Figure 7** shows how the initial scenario allocation was derived, with Scenarios 2 – agricultural point sources and 1 – lowland agriculture (many diffuse sources) being identified as the main threats to the site. No atmospheric monitoring data are available for the site.

Table 3 – Scenario allocation inc. quantification of main N threats from national scale source attribution data at a 5 km grid resolution (2005 data) for Case Study B

Case study	Deposition Type	Scenarios allocated (number, IDs)	Total max. N deposition for site (kg N ha^{-1} yr^{-1})	Scenario allocations in **red**				Nearest feature (m)	
				Total wet N deposition (%)	Source Attribution (% of total N deposition)			Close proximity of sources in **bold**	
				Long Range N deposition	Roads	Non-Agricultural sources	Agriculture (fertiliser & livestock)	Major Road	IED Intensive farm
B	Woodland	2 (**Sc2**,1)	50	16	3	10	**80**	> 200	**530**
	Semi-natural		29	23	2	11	**78**		

Selection of potential measures: Given the size and location of the poultry farm, both in terms of distance and position with regard to prevailing winds, one measure that could be suitable for the site is planting a *tree belt* downwind of the poultry farm, i.e. between the farm and the designated site. There may be potential for *improving manure management* at the farm, both in terms of technical measures (such as *manure drying facilities*), or *spatial measures*, such as not storing manures in heaps outside of the sheds, and only applying manures to fields further away from the site (i.e. applying a low-emission buffer zone around the site). *Manure spreading and storage measures* (including low-emission techniques) could also be explored for the cattle farming activities close to the site. The work flow in **Figure 9** shows a more detailed analysis for the surrounding area, with an example measure described in detail, *conversion of agricultural fields* surrounding the site to e.g. mixed native woodland as a shelter belt to take the brunt of the leading edge of incoming atmospheric N.

Potential co-benefits and trade-offs of measures: Many of the above listed measures would also deliver considerable reductions to nitrate leaching risks at the boundary of the site, among others co-benefits.

Potential Outcome: In discussion with local site managers, agricultural advisors and agri-environment scheme managers on local farm management practices, site characteristics and prevailing SW wind conditions, it could be considered whether farmers would sign up to low-emission landspreading options. This could be achieved by setting agreed maximum application rates under an agri-environment scheme, in an area of 500 m surrounding the site, with the zone extended to ~ 1 km upwind, i.e. to the southwest of the site. Other measures that could be considered are covering manure stored in field heaps and placing them no closer than 500 m from the site boundary.

In addition to measures to reduce emissions to air (such as most of the technical measures), a potentially valuable measure for removing NH_3 emitted in the atmosphere, are tree belts - farmers could apply for woodland grant schemes to plant and maintain both farm and site-focused tree shelter belts. It should be noted that there would be a lag period of 10-20 years (depending on tree species) between planting the woodland and it reaching maximum efficiency for re-capturing NH_3

from the atmosphere and/or dispersing it. Therefore woodland creation measures alone are unlikely to provide substantial N benefits in the short term.

Measures of these types are not currently available specifically for targeting atmospheric N under existing delivery mechanisms, although measures available under the woodland grant schemes can provide co-benefits, if spatially optimised, and could be the basis for introducing specific targeted and spatially optimised atmospheric N mitigation options (key measures listed in Appendix 3).

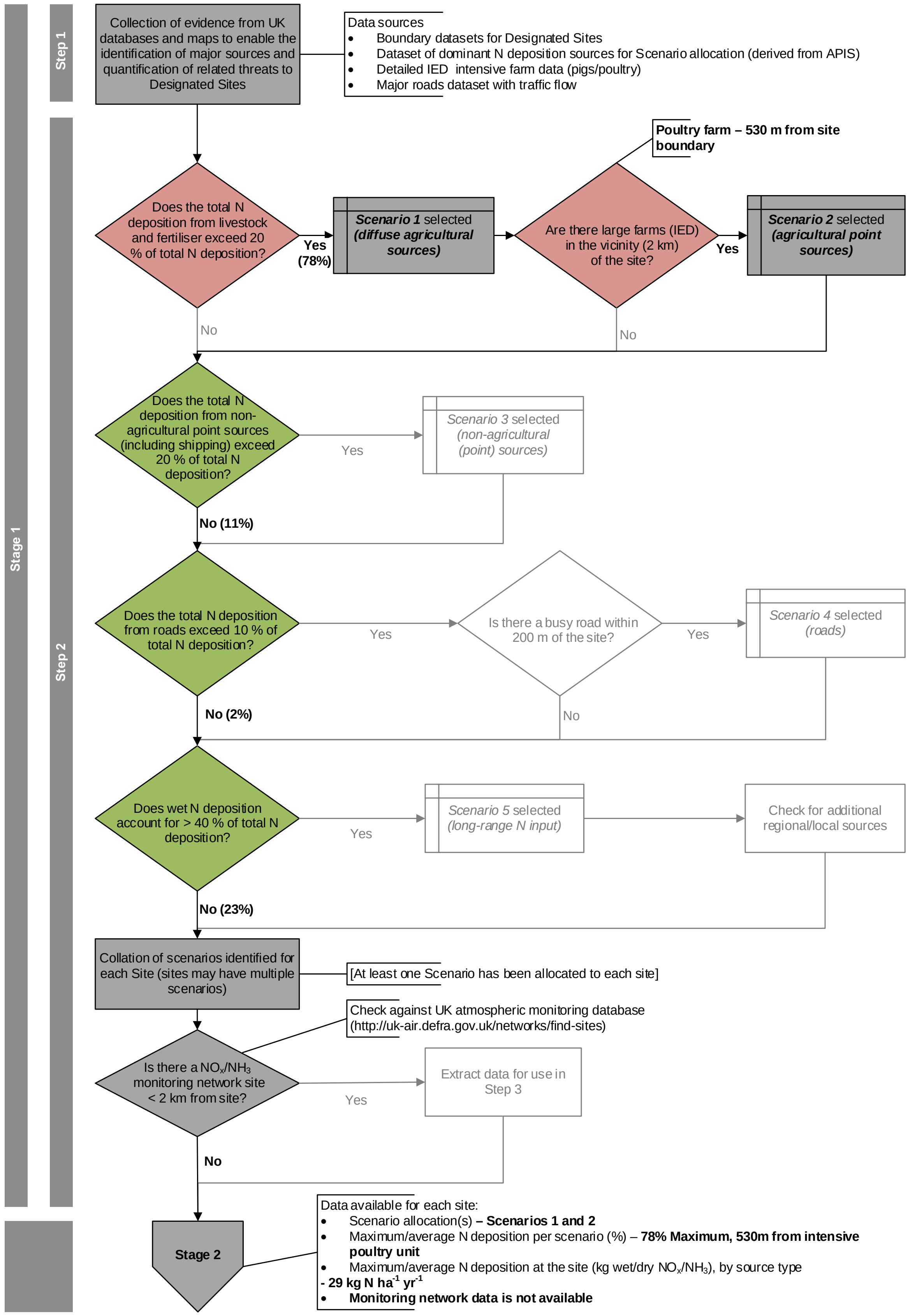

Figure 7 – Example work flow for source attribution and allocation of scenarios for Case study B: Scenario 2 – Agricultural point sources (site designated for semi-natural vegetation).

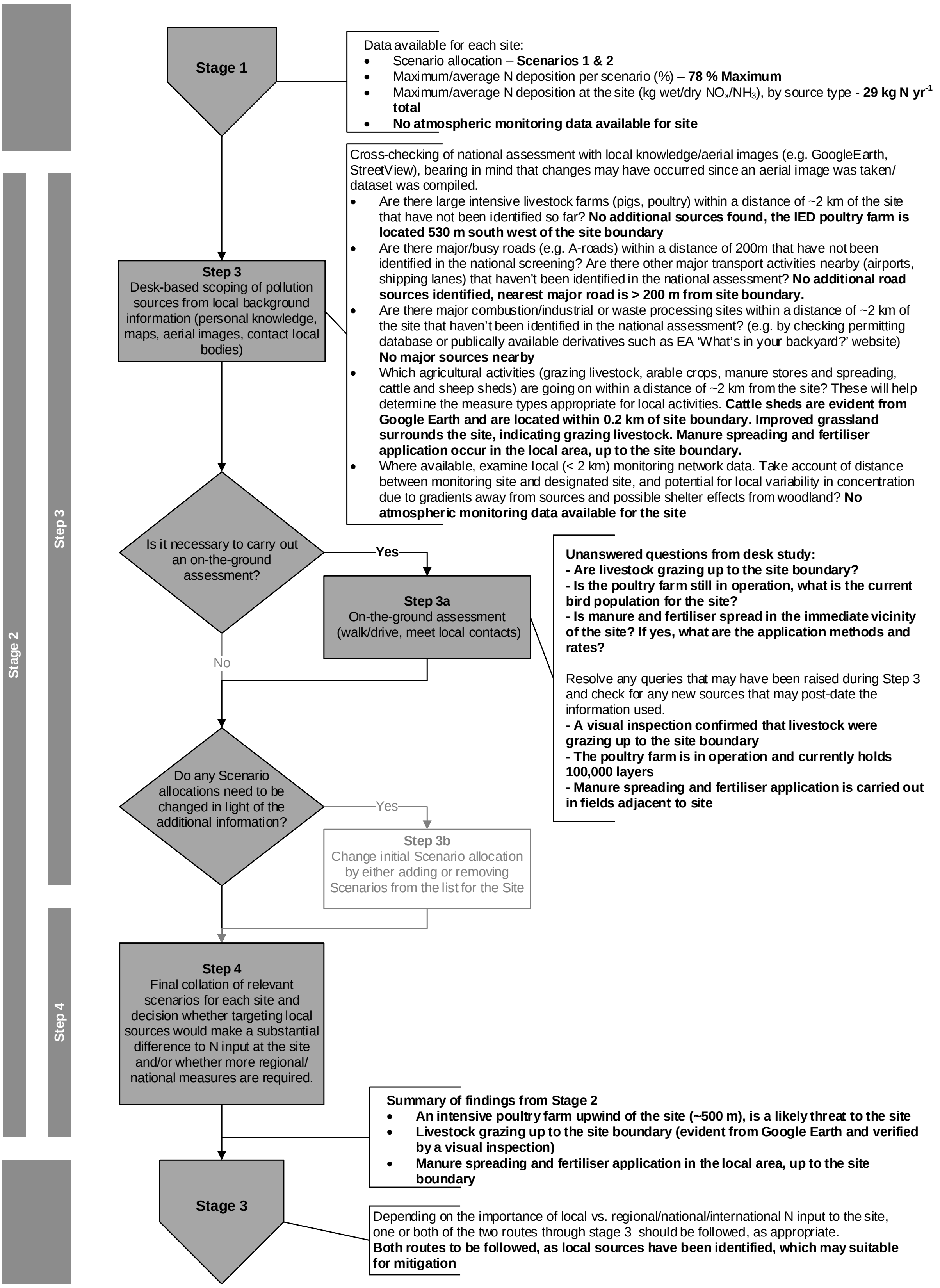

Figure 8 – Example work flow for detailed desktop and on-the-ground assessments for Case study B: Scenario 2 – Agricultural point sources (site designated for semi-natural vegetation).

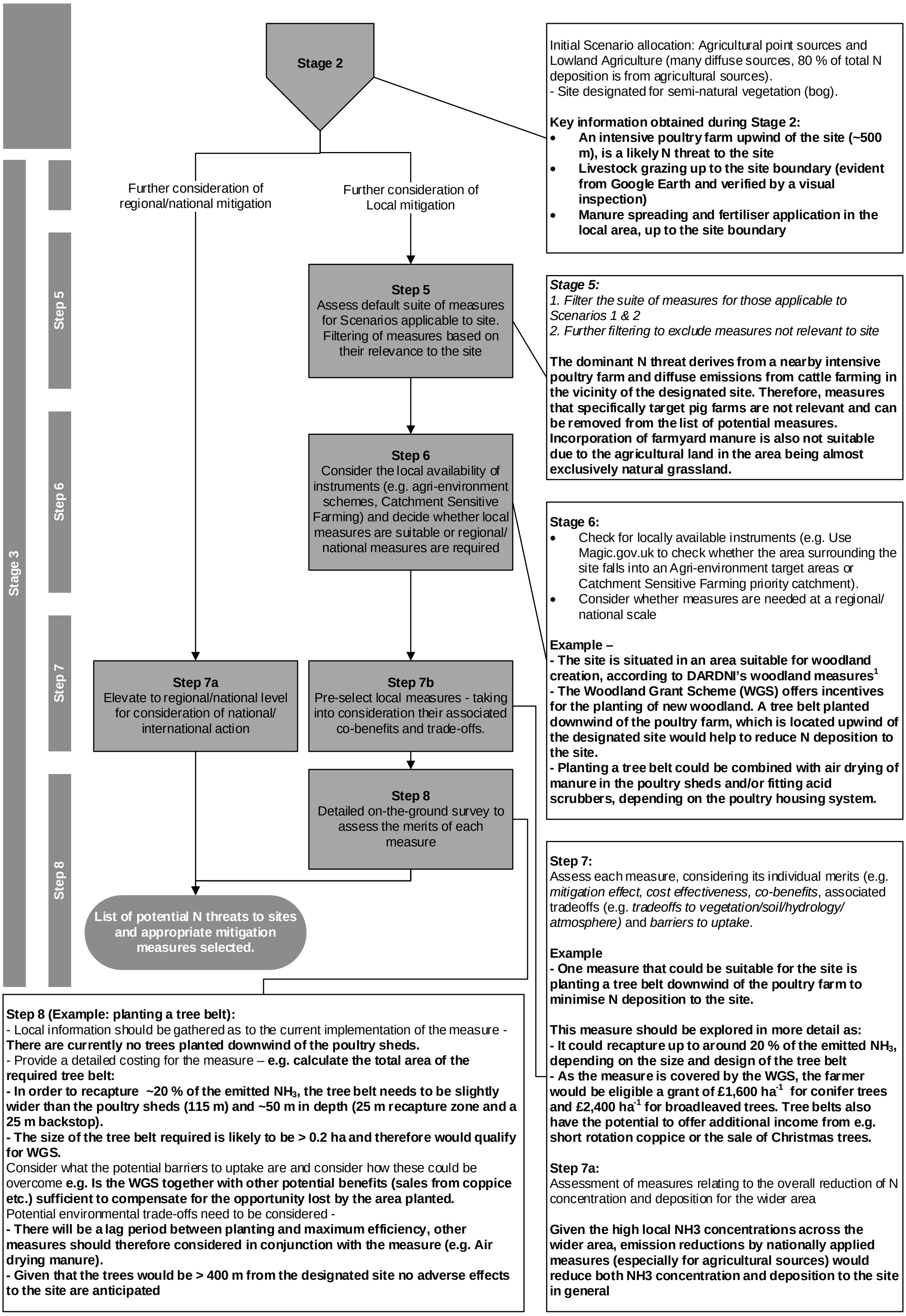

Figure 9 – Example work flow for identifying suitable N mitigation measures for Case study B: Scenario 2 - Agricultural point sources (site designated for semi-natural vegetation).

Case study C

Scenario allocation:

3 – Non-agricultural (point) sources

(4 – Roads)

Figure 10 – Case Study C: Scenario 3 - Non-agricultural (point) sources

Site area: ~ 0.4 km^2

Habitat types: woodland and other semi-natural features of UK and European importance

Landscape context: lowland urban/suburban landscape in south-east England

Main N sources identified: urban/suburban area with large numbers of diverse non-agricultural NH_3 and NO_x sources and a dense and busy road traffic network surrounding the site

Source attribution calculations: Non-agricultural NH_3 and NO_x emissions are the major source of N deposition at the site, with the contribution to the surrounding 5 km grid square at ~ 50% of total N deposition (**Table 4**). While the nearest major road is > 400 m away, the average N input from roads to the relevant 5 km grid square in the source attribution dataset is >20% (29% for woodland habitats, 22% for other, low-growing semi-natural habitats). This is at the high end of UK N deposition contributions from roads to designated sites (see Figures 2 and 3 in **Appendix 5** for details).

The initial allocation of the roads Scenario is slightly ambiguous using the approach developed under RAPIDS, with the percentage contribution of road transport sources to the N deposition in the grid square exceptionally high for UK conditions, however the nearest major road is more than the threshold distance of 200m away from the site. This points towards the need to take account of more detailed information in the final scenario allocation, with the general density of road traffic emissions in large urban/suburban areas needing to be taken into account (which would not be picked up through the major roads dataset that consists only of motorways, primary and A-roads). In this case, maps from the UK Air Website (http://uk-air.defra.gov.uk/data/gis-mapping) were consulted, which showed that NO_x concentrations in the area were around 20-30 µg m^{-3}(background level, 1 km grid square dataset) with roadside concentrations of >50 µg m^{-3} along nearby A-roads.

By contrast, wet deposition contributes 17% (woodland) and 31% (other semi-natural habitats) of the total atmospheric N input to the relevant grid square. The total annual N deposition estimated for woodland features in the 5 km grid square containing the site is ~40 kg N ha^{-1} yr^{-1}, which is well in excess of the Critical Load, and 20 kg N ha^{-1} yr^{-1} for other semi-natural habitats. Given the large spatial variability of N at the landscape scale, these values are likely to be an underestimate if there are substantial local sources in close proximity, especially at near the site boundary.

Table 4 – Scenario allocation inc. quantification of main N threats from national scale source attribution data at a 5 km grid resolution (2005 data) for Case Study C

Case study	Deposition Type	Scenarios allocated (number, IDs)	Total max. N deposition for site (kg N ha^{-1} y^{r-1})	Scenario allocations in **red**				Nearest feature (m) Close proximity of sources in **bold**	
				Total wet N deposition (%)	Source Attribution (% of total N deposition)				
				Long Range N deposition	Roads	Non-Agricultural sources	Agriculture (fertiliser & livestock)	Major Road	IED Intensive farm
C	Woodland	2 (**Sc3,4**)	39	17	**29**	**50**	11	> 200	> 2,000
	Semi-natural		20	31	**22**	**49**	13		

Selection of potential measures: Given the dominance of non-agricultural (point) sources and road traffic in the source attribution data, further investigation using more detailed datasets of nearby emission sources is required to distinguish the wide range of potential NH_3 and NO_x sources included in Scenario 3. The main candidate measures for reducing local N emissions and associated concentrations and deposition at this site are those targeted at combustion, industry and road transport. These include *selective catalytic and non-catalytic reduction and other modifications to combustion processes* (see ***Appendix 3*** for a list of potential measures) where these have not been introduced already (such as large combustion plants). An inclusion of medium sized combustion plants into future regulatory approaches may result in improvements for sites in similar situations. To reduce deposition due to road transport in the area surrounding the site, installation of barriers and planting of tree belts next to roads and around the designated site may be a useful strategy to decrease impacts from emissions. Newer generations of catalytic converters filtering through the vehicle fleet are likely to reduce emissions the wider area in due course, but faster progress could be made with traffic measures including behavioural change to reduce traffic levels.

Potential co-benefits of measures: Many of the above listed measures would also deliver considerable improvements to human health, in particular respiratory conditions.

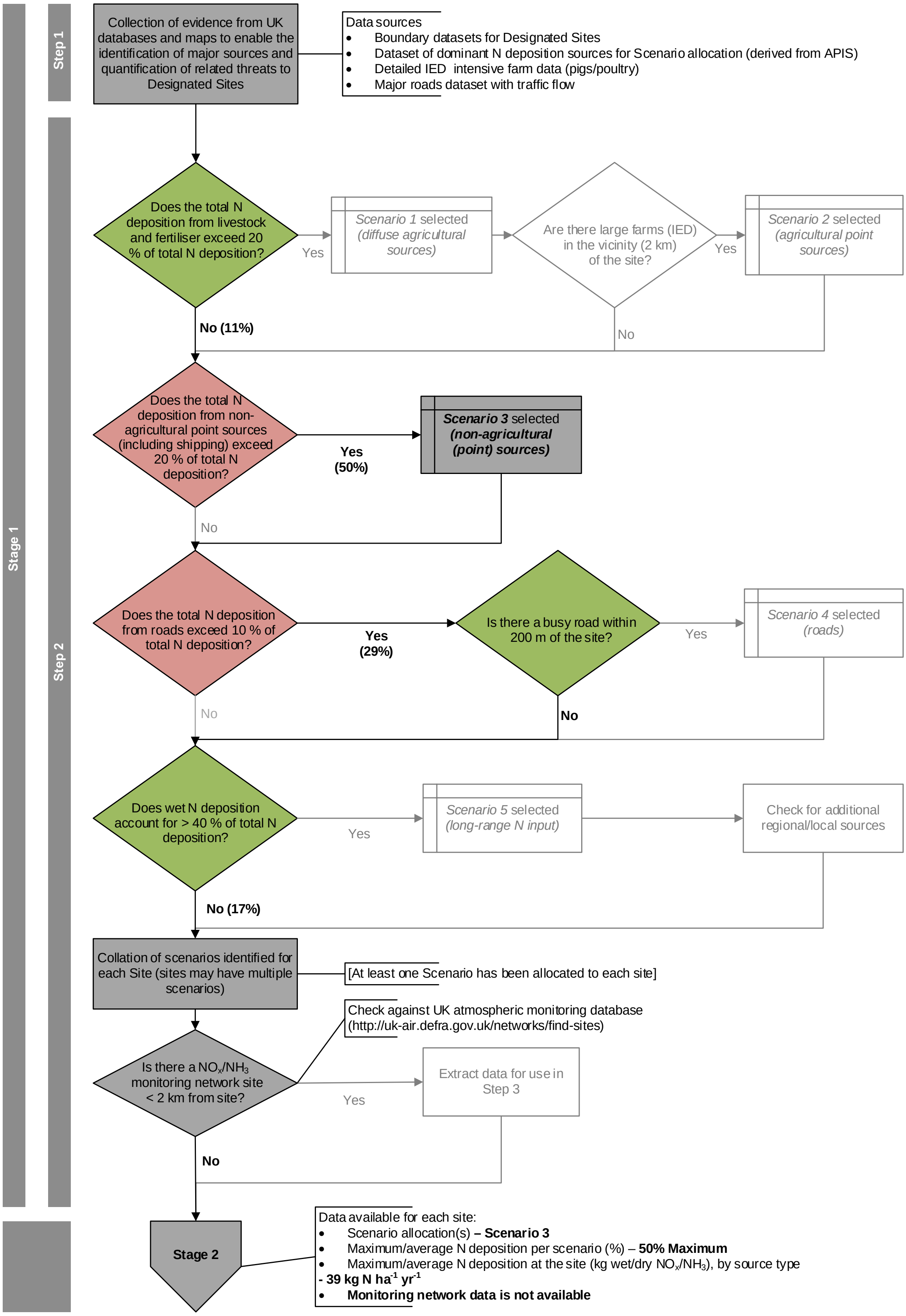

Figure 11 – Example work flow for source attribution and allocation of scenarios for Case study C: Scenario 3 – Non-agricultural (point) sources

Case study D: Scenario 4 – Roads

Scenario allocation:

4 - Roads

3 – Non-agricultural (point) sources

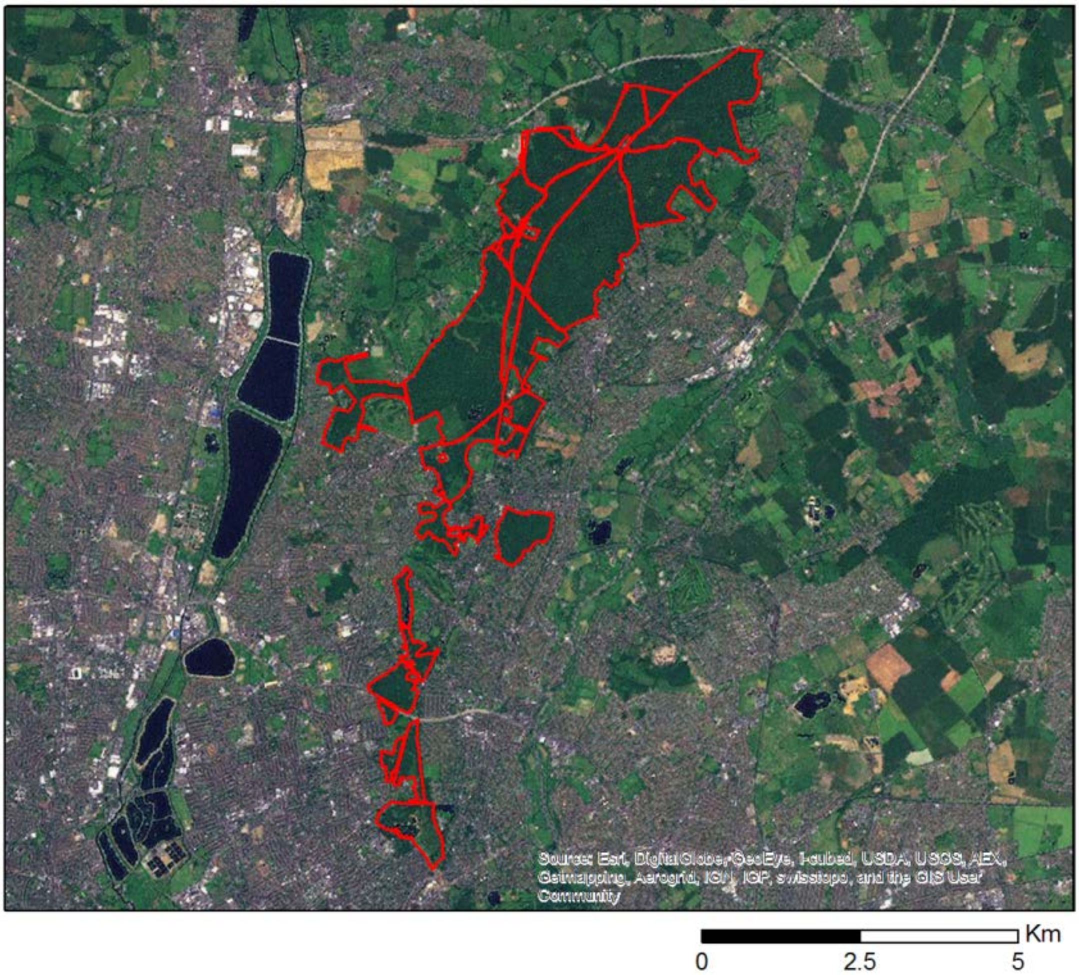

Figure 12 – Case Study D: Scenario 4 – Roads

Site area: ~ 17 km^2

Habitat types: woodland and other semi-natural features of UK and European importance

Landscape context: lowland urban/suburban landscape in south-east England

Main N sources identified: urban/suburban area with a dense and busy road traffic network, including major roads dissecting and bordering the site, and large numbers of diverse non-agricultural NH_3 and NO_x sources in the wider area surrounding the site.

Source attribution calculations: The main sources of N deposition for this larger site are non-agricultural NH_3 and NO_x emissions, with road transport contributing ~20% of the total N deposition to the surrounding 5 km grid square, which is at the high end of UK N deposition contributions from roads to designated sites (see Figures 2 and 3 in **Appendix 5** for details). There are multiple major roads intersecting the site, with supplementary information from the Defra UK-Air website giving roadside concentrations of > 60 µg m^{-3} and background levels for the wider site of >10 µg m^{-3} up to

40 µg m^{-3}). A further ~ 50% of the total N deposition to the relevant 5 km grid square is due to non-agricultural (point) sources (**Table 5**).

By contrast, wet deposition contributes 19% (woodland) and 36% (other semi-natural habitats) of the total atmospheric N input to the relevant grid square. The total annual N deposition estimated for woodland features in the 5 km grid square containing the site is ~49 kg N ha^{-1} yr^{-1}, which is well in excess of the Critical Load, and 24 kg N ha^{-1} yr^{-1} for other semi-natural habitats. Given the large spatial variability of N at the landscape scale, these values are likely to be an underestimate if there are substantial local sources in close proximity, especially at near the site boundary.

Table 5 – Scenario allocation inc. quantification of main N threats from national scale source attribution data at a 5 km grid resolution (2005 data) for Case Study D

Case study	Deposition Type	Scenarios allocated (number, IDs)	Total max. N deposition for site (kg N ha^{-1} y^{r-1})	Scenario allocations in **red**				Nearest feature (m)	
				Total wet N deposition (%)	Source Attribution (% of total N deposition)			Close proximity of sources in **bold**	
				Long Range N deposition	Roads	Non-Agricultural sources	Agriculture (fertiliser & livestock)	Major Road	IED Intensive farm
D	Woodland	2 (**Sc4**,3)	49	19	**22**	**53**	15	**0 (Intersects site)**	> 2,000
	Semi-natural		24	36	**15**	**52**	17		

Selection of potential measures: Given the high contribution of road transport in the source attribution data and the very high roadside NO_x concentrations along the major road passing through the site, the main candidate measures to reduce emissions from road transport and screens and barriers to prevent roadside emissions from dispersing further into the site. To reduce deposition due to road transport in the area surrounding the site, installation of barriers and planting of tree belts next to roads and around the designated site may be a useful strategy to decrease impacts from emissions. Newer generations of catalytic converters filtering through the vehicle fleet are likely to reduce emissions in due course, but faster progress could be made with behavioural change resulting in reduced traffic levels.

As Scenario 3 (non-agricultural (point) sources) is shown to be a substantial contributor to N deposition in the area, further investigation is required to distinguish between the wide range of potential NH_3 and NO_x sources using more detailed datasets of nearby emission sources. The main candidate measures are those targeted at combustion, industry and road transport. These include *selective catalytic and non-catalytic reduction and other modifications to combustion processes* (see ***Appendix 3*** for a list of potential measures) where these have not been introduced already (such as measures targeting large combustion plants, which are covered under IED). An inclusion of medium sized combustion plants into future regulatory approaches may result in improvements for sites in similar situations.

Potential co-benefits of measures: Many of the above listed measures would also deliver considerable improvements to human health, in particular respiratory conditions.

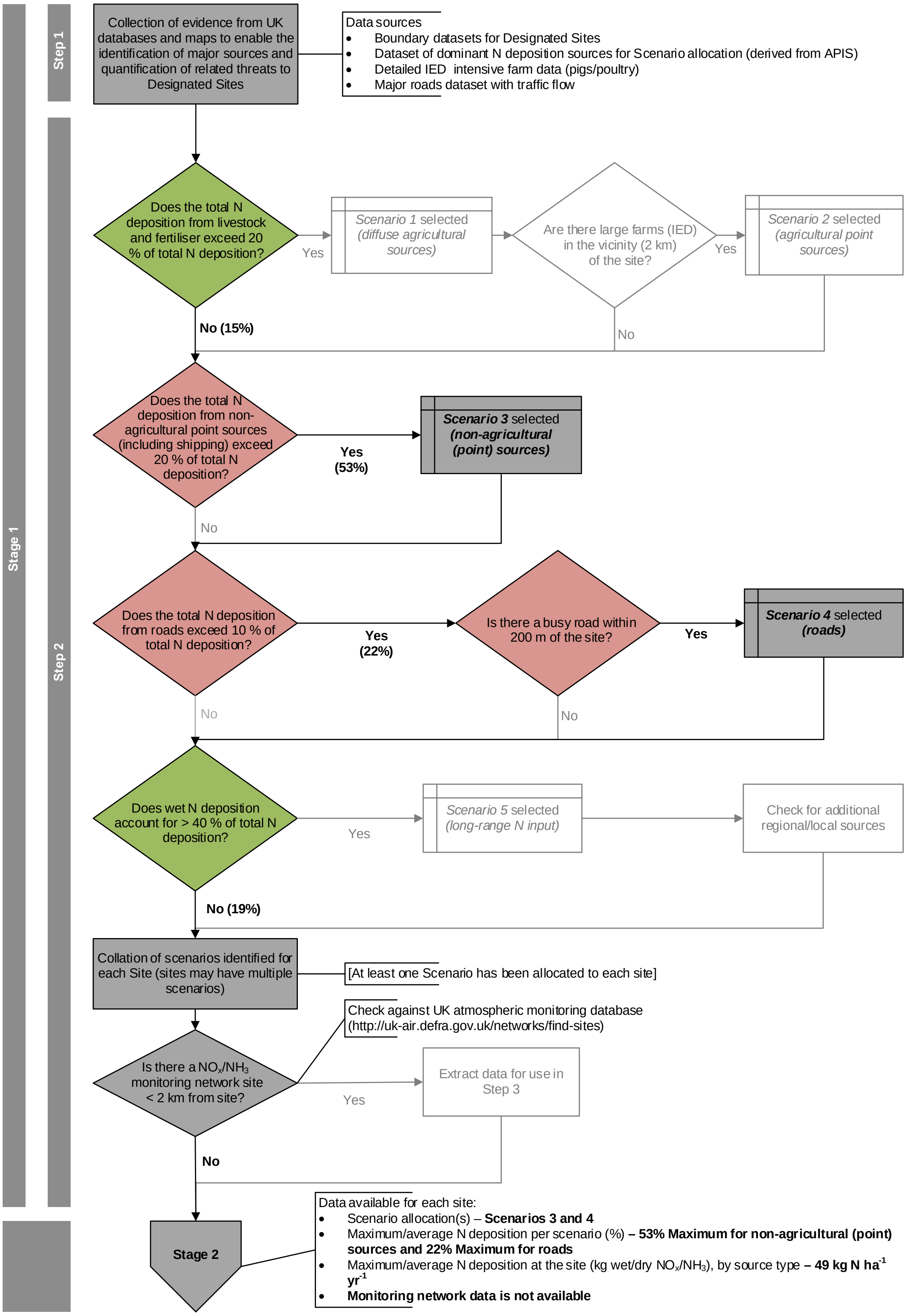

Figure 13 – Example work flow for source attribution and allocation of scenarios for Case study D: Scenario 4 – Roads

Case study E1: Scenario 5 – Remote (mainly upland) sites affected by long-range transport

Scenario allocation:

5 - Remote (mainly upland) sites affected by long-range transport

3 – Non-agricultural (point) sources

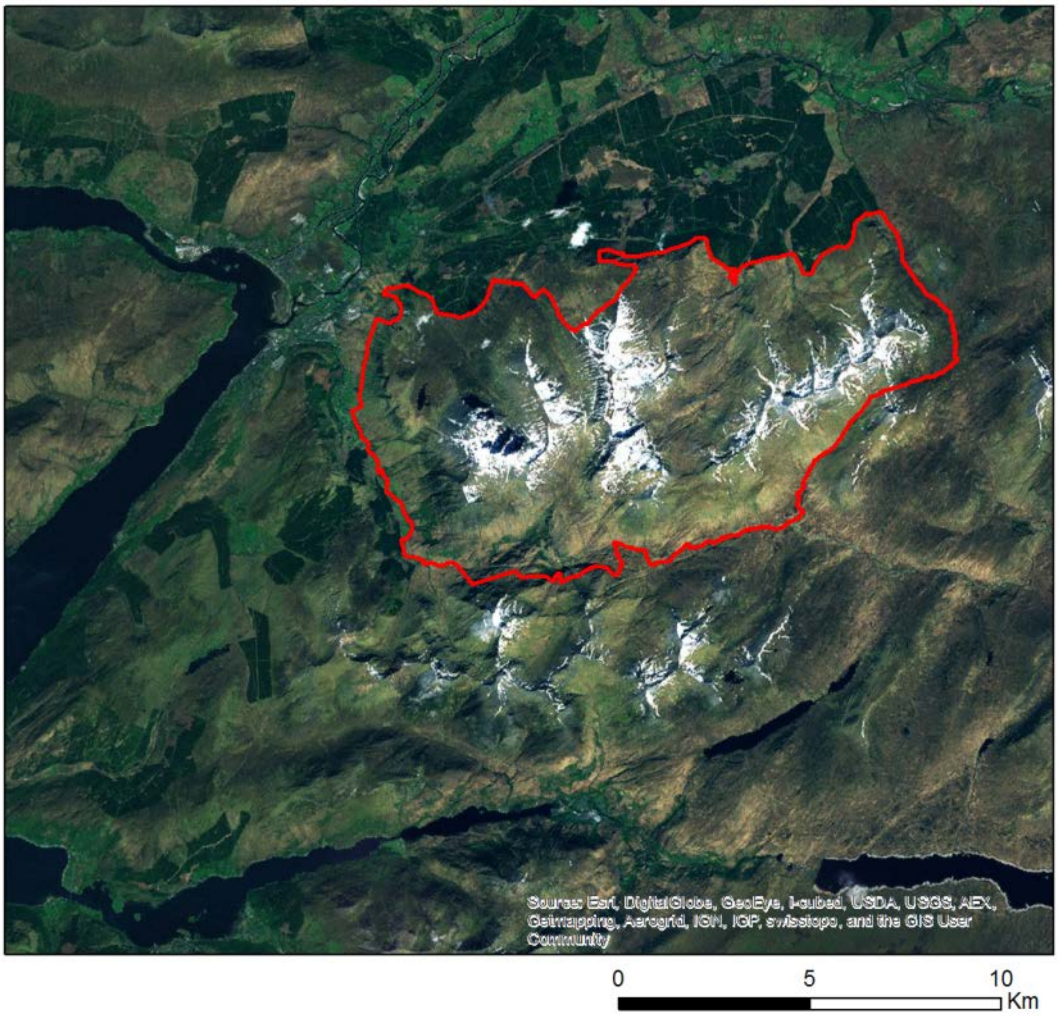

Figure 14 – Case Study E1: Scenario 5 – Long range N input

Site area: ~ 100 km^2

Habitat types: mainly upland habitats of UK and European importance

Landscape context: remote upland landscape in Scotland

Main N sources identified: wet deposited N contributes the majority of N input to the site, with non-agricultural sources providing the largest input in the source attribution dataset.

Source attribution calculations: Wet deposited N contributes the majority of N input to the site, at ~80% of total deposition, indicating that emission activities further afield rather than local emissions are likely to be the main sources of N. Overall, non-agricultural sources dominate in the source attribution dataset at <40%, with agricultural emissions not being flagged as a major issue, at around the 20% threshold (**Table 6**). The total annual N deposition estimated for woodland features in the 5 km grid square containing maximum deposition to the site is ~34 kg N ha^{-1} yr^{-1} for woodland habitats and 21 kg N ha^{-1} yr^{-1} for other semi-natural habitats, such as sensitive upland and mountain vegetation, with deposition well in excess of the Critical Load.

Table 6 – Scenario allocation inc. quantification of main N threats from national scale source attribution data at a 5 km grid resolution (2005 data) for Case Study E1

Case study	Deposition Type	Scenarios allocated (number, IDs)	Total max. N deposition for site (kg N ha^{-1} y^{r-1})	Scenario allocations in **red**				Nearest feature (m)	
				Total wet N deposition (%)	Source Attribution (% of total N deposition)			Close proximity of sources in **bold**	
				Long Range N deposition	Roads	Non-Agricultural sources	Agriculture (fertiliser & livestock)	Major Road	IED Intensive farm
E1	Woodland	2 (**Sc5**, 3)	34	**74**	8	**39**	18	> 200	> 2,000
	Semi-natural		21	**88**	7	**37**	20		

Selection of potential measures: Given the dominance of wet deposition and the associated long-range transport of N from the wider UK and internationally, the main candidate measures for reducing N deposition are those targeted at reducing emissions in a wider area, either through regulation or very large-scale incentive schemes of all source sectors. In terms of local sources, a more detailed assessment is required to assess whether there are measures that could be implemented more locally (beyond the remit of the RAPIDS project, as agreed with the Steering Group).

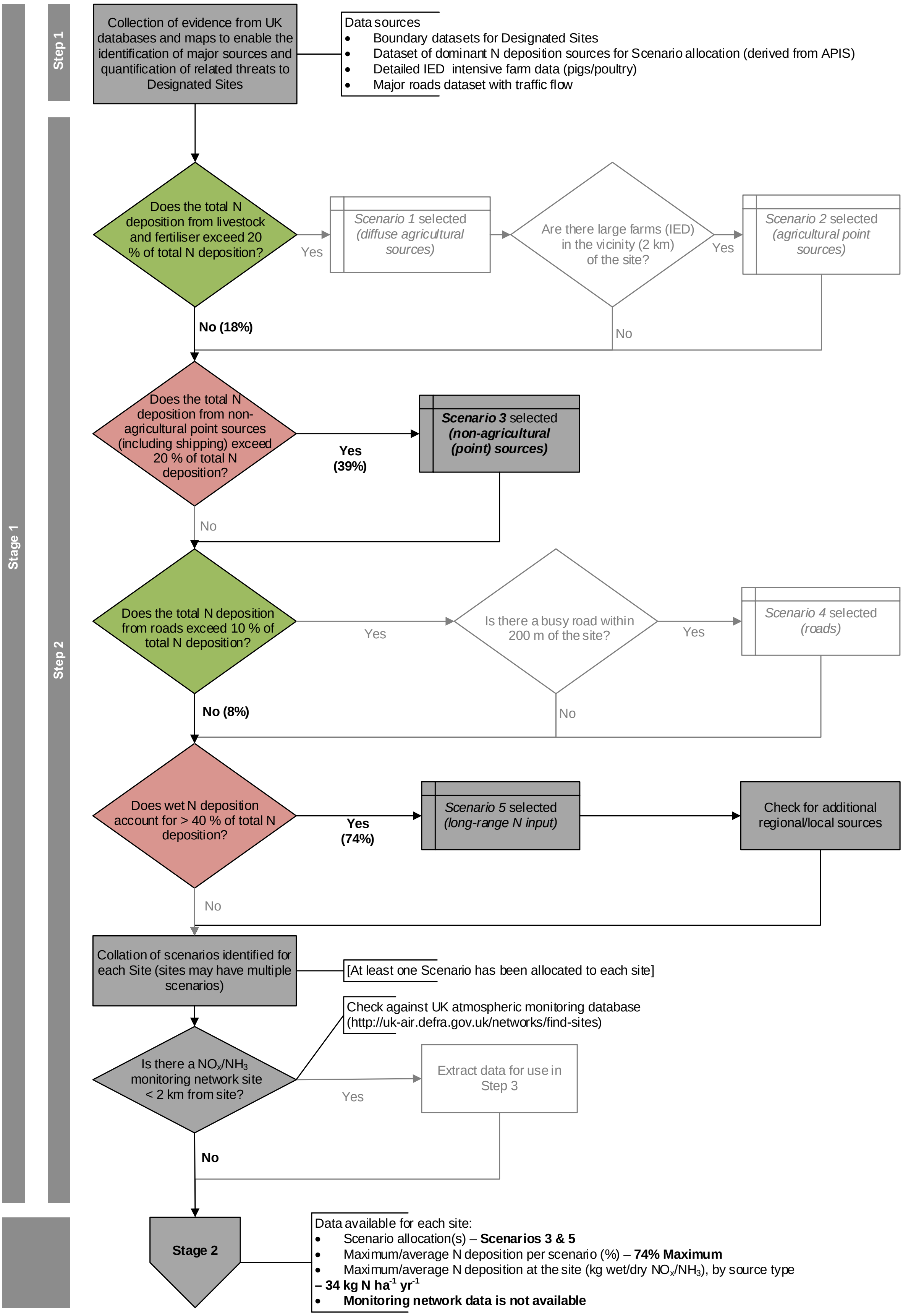

Figure 15 - Example work flow for source attribution and allocation of scenarios for Case study E1 Remote (mostly upland) sites affected by long-range N input

Case study E2: Scenario 5 – Remote (mainly upland) sites affected by long-range transport

Scenario allocation:

5 - Remote (mainly upland) sites affected by long-range transport

3 – Non-agricultural (point) sources

1 – Lowland agriculture (many diffuse sources)

4 - Roads

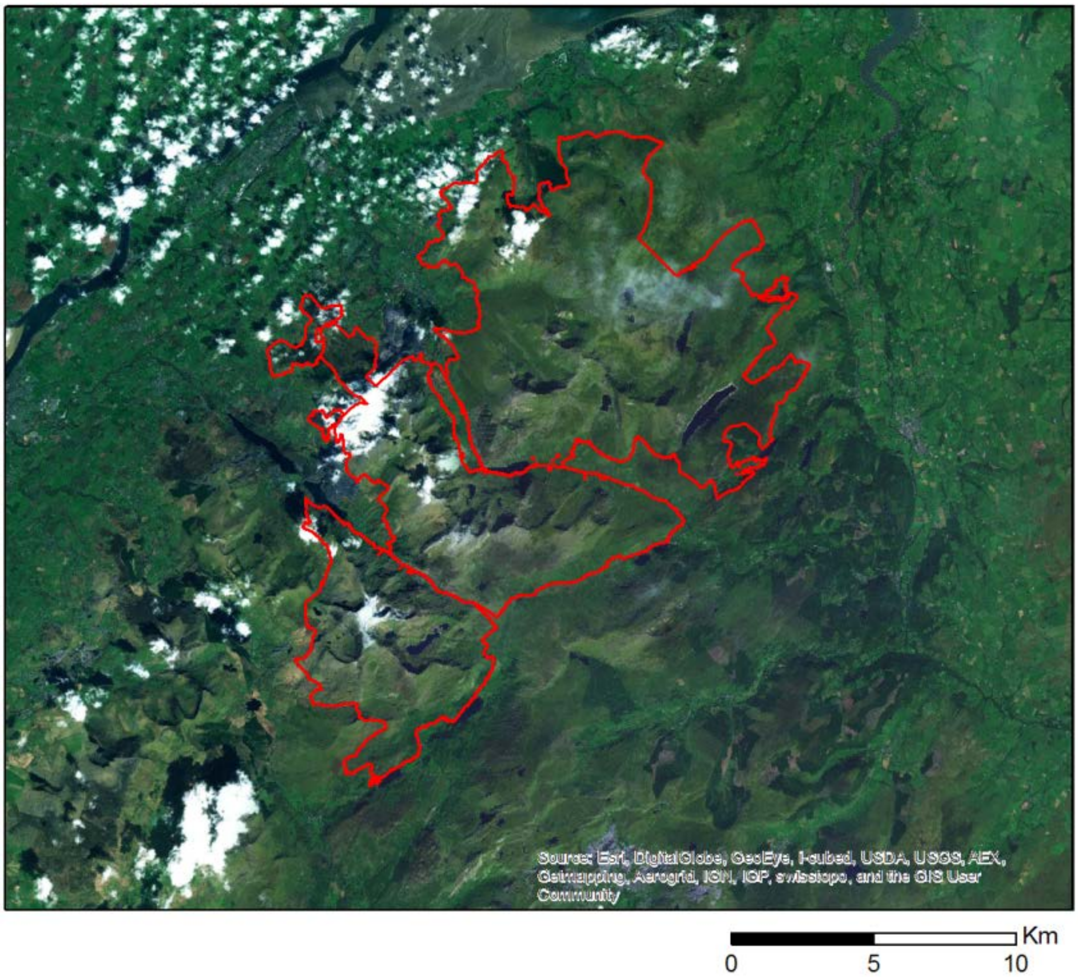

Figure 16 – Case Study E2: Scenario 5– Long range N input

Site area: ~ 200 km^2

Habitat types: woodland and semi-natural upland features of UK and European importance

Landscape context: upland landscape in Wales

Main N sources identified: wet deposited N contributes the majority of N input to the site, with non-agricultural sources and agriculture providing substantial N input, and some concern regarding road transport in the vicinity of major roads.

Source attribution calculations: Wet deposited N contributes the majority of N input to the site, at ~60-70% of total deposition (depending on the habitat type, i.e. woodland or other semi-natural vegetation). This indicates that emissions from further afield are likely to contribute substantially to deposition at the site. The values shown in **Table 7** for the 5 km grid square with the largest N deposition across the site show that diffuse agricultural sources and non-agricultural (point) sources contribute approximately a third each to N deposition, whereas road transport emissions are likely to be of concern in the immediate vicinity of busy transport routes which intersect the site.

The total annual N deposition estimated in the 5 km grid square containing the maximum deposition values to the site are ~57 kg N ha^{-1} yr^{-1} for woodland habitats. For other semi-natural habitats, such as sensitive upland and mountain vegetation, N deposition for the 5 km grid square is estimated at 33 kg N ha^{-1} yr^{-1}, with deposition well in excess of the Critical Loads for both.

Table 7 – Scenario allocation inc. quantification of main N threats from national scale source attribution data at a 5 km grid resolution (2005 data) for Case Study E2

Case study	Deposition Type	Scenarios allocated (number, IDs)	Total max. N deposition for site (kg N ha^{-1} y^{r-1})	Scenario allocations in **red**				Nearest feature (m)	
				Total wet N deposition (%)	Source Attribution (% of total N deposition)			Close proximity of sources in **bold**	
				Long Range N deposition	Roads	Non-Agricultural sources	Agriculture (fertiliser & livestock)	Major Road	IED Intensive farm
E2	Woodland	4 (**Sc5**,1,3,4)	57	**57**	11	**32**	**30**	**0 (Intersects site)**	> 2,000
	Semi-natural		33	**73**	8	**28**	**33**		

Selection of potential measures: Given the large contribution from wet deposition and the associated long-range transport of N from the wider UK and internationally, the main candidate measures for reducing N deposition are those targeted at reducing emissions in a wider area, either through regulation or very large-scale incentive schemes of all source sectors. In terms of local sources, a more detailed assessment is required to assess whether there are measures that could be implemented more locally. Given the large size of the site (~200 km^2), and the mountainous nature of large parts of the site, different local sources may affect more limited areas around the fringes of the site. The values shown in **Table 7** for the 5 km grid square with the largest N deposition across the site are likely to differ from other 5 km grid squares covering the area (which are themselves average conditions across areas with the potential for spatial variability, especially of NH_3, but also NO_x concentrations near major roads). A more detailed assessment of potential N threats needs to be made with regard to the wider site, to identify areas where local sources are likely to dominate N input, so that relevant measures can be found.

The catalogue of potential measures for such a large site with multiple scenarios flagged up as potential threats ranges from measures for diffuse agricultural sources, wider national and international measures on agriculture, combustion and transport, to local solutions. Given the mixed grazing livestock agriculture dominating the area, agricultural measures would mainly be based on *efficient manure management for cattle housing, manure storage and application of slurries and manures to land*, together with *general nutrient efficiency measures* such as accounting for N in manures when calculating mineral fertiliser application rates. In addition, *buffer zones* with reduced or no application of N in the immediate vicinity of the site boundaries and tree belts around animal houses and manure stores and re-capture/disperse NH_3 emitted would also reduce elevated NH_3 concentrations or deposition to the site. For reducing road transport emissions, it may be possible to introduce shuttle bus systems and encourage visitors to this popular site to use these for visiting the area instead of using private transport. Such shuttle buses would have to be sufficiently convenient, and frequent to encourage uptake.

Case study E3: Scenario 5 – Remote (mainly upland) sites affected by long-range transport

Scenario allocation:

5 - Remote (mainly upland) sites affected by long-range transport

3 – Non-agricultural (point) sources

1 – Lowland agriculture (many diffuse sources)

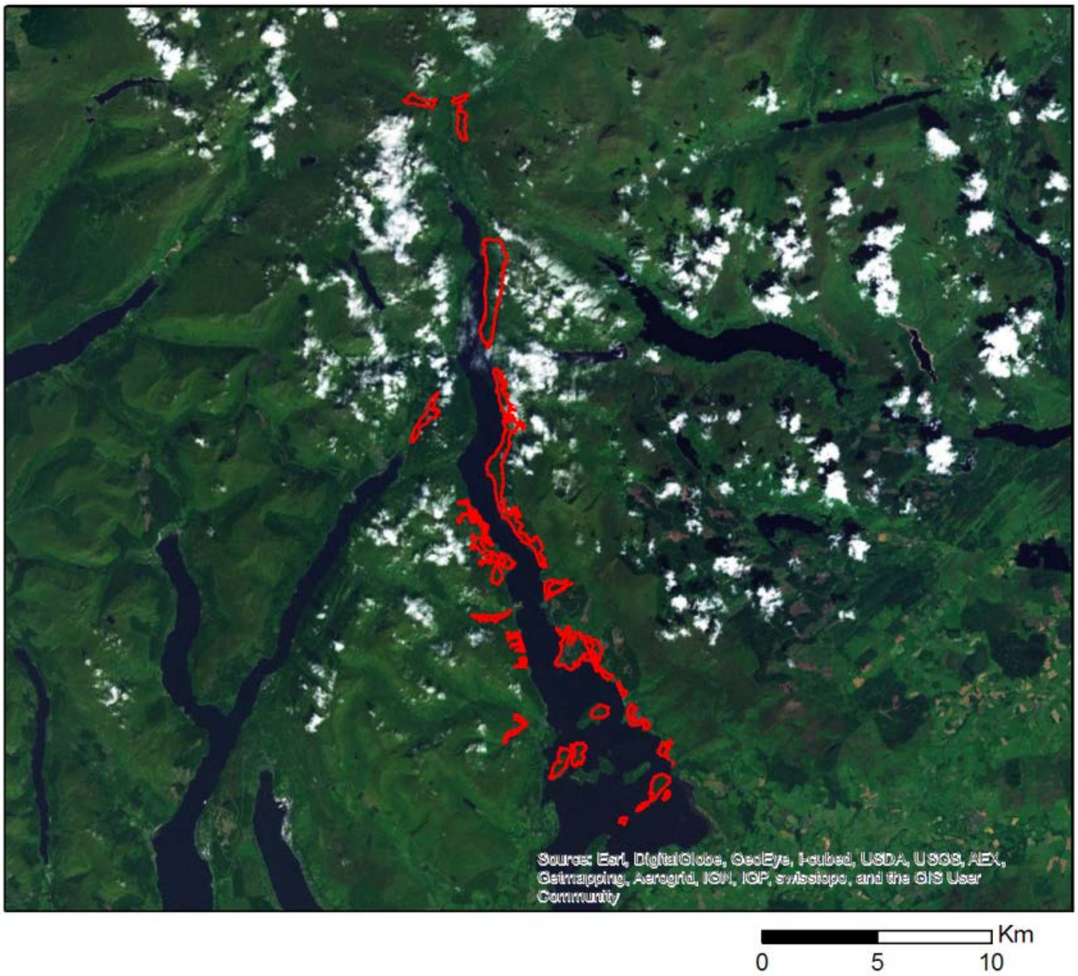

Figure 17 – Case Study E3: Scenario 5 – Long range N input

Site area: ~ 15 km^2

Habitat types: native woodland features of UK and European importance

Landscape context: native woodland landscape in Scotland

Main N sources identified: wet deposited N contributes the majority of N input to the site, with non-agricultural sources and agriculture providing substantial N input, and some concern regarding road transport in the vicinity of major roads.

Source attribution calculations: Wet deposited N contributes the majority of N input to the site, at ~75-85% of total deposition (depending on the habitat type, i.e. woodland or other semi-natural vegetation). This indicates that emissions from further afield are likely to contribute substantially to deposition at the site. The values shown in **Table 8** for the 5 km grid square with the largest N deposition across the site show that diffuse agricultural sources and non-agricultural (point) sources contribute approximately a third each to N deposition, whereas road transport emissions are likely to be of concern in the immediate vicinity of busy transport routes which intersect the site.

The total annual N deposition estimated for woodland features in the 5 km grid square containing the maximum deposition values to the site are ~36 kg N ha^{-1} yr^{-1} for woodland habitats and 27 kg N ha^{-1} yr^{-1} for other semi-natural habitats, such as sensitive upland vegetation, with deposition well in excess of the Critical Load.

Table 8 – Scenario allocation inc. quantification of main N threats from national scale source attribution data at a 5 km grid resolution (2005 data) for Case Study E3

Case study	Deposition Type	Scenarios allocated (number, IDs)	Total max. N deposition for site (kg N ha^{-1} y^{r-1})	Scenario allocations in red				Nearest feature (m)	
				Total wet N deposition (%)	Source Attribution (% of total N deposition)			Close proximity of sources in **bold**	
				Long Range N deposition	Roads	Non-Agricultural sources	Agriculture (fertiliser & livestock)	Major Road	IED Intensive farm
E3	Woodland	3 (**Sc5**,1,3)	36	**73**	8	**30**	**34**	**0 (Intersects site)**	> 2,000
	Semi-natural		27	**87**	6	**28**	**33**		

Selection of potential measures: Given the large contribution from wet deposition and the associated long-range transport of N from the wider UK and internationally, the main candidate measures for reducing N deposition are those targeted at reducing emissions in a wider area, either through regulation or very large-scale incentive schemes of all source sectors. In terms of local sources, a more detailed assessment is required to assess whether there are measures that could be implemented more locally. Given the large extent and distributed nature of the site (17 km^2 area spread over approx 25 km x 5 km in many small patches along the edges of a large loch), and the variation in altitude from near sea level to several 100 metres a.s.l., different local sources may affect different parts of the site. The values shown in **Table 7** for the 5 km grid square with the largest N deposition across the site are likely to differ from other 5 km grid squares covering the area (which are themselves average conditions across areas with the potential for spatial variability, especially of NH_3, but also NO_x concentrations near major roads). For example, agriculture is most likely to be a local source of importance near the southern parts of the site, whereas the major road dissecting the site is located on the western shore of the loch. Therefore a more detailed assessment of potential N threats needs to be made with regard to the wider site, to identify areas where local sources are likely to dominate N input, so that relevant measures can be found.

The catalogue of potential measures ranges from the potential for local measures for diffuse agricultural sources and road transport to wider national and international measures on agriculture, combustion and transport. Given the mixed grazing livestock agriculture dominating the southern part of the area, agricultural measures would mainly be based on *efficient manure management for cattle housing, manure storage and application of slurries and manures to land*, together with *general nutrient efficiency measures* such as accounting for N in manures when calculating mineral fertiliser application rates. In addition, *buffer zones* with reduced or no application of N in the immediate vicinity of the site boundaries and tree belts around animal houses and manure stores and re-capture/disperse NH_3 emitted would also reduce elevated NH_3 concentrations or deposition to the site. For reducing road transport emissions, it may be possible to encourage visitors to this popular site to use shuttle bus systems for visiting the area instead of using private transport.