Biosolids Landbank Assessment

Project report by Grieve Strategic

in association with RSK ADAS

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Executive Summary

1. Five different scenarios based on the PR24 WINEP drivers were developed and modelled to understand the effect of increasingly stringent environmental restrictions on Anglian Water Services (AWS) landbank. These were modelled using an updated version of the ALOWANCE GIS modelling tool with AWS's current Sludge Treatment Centre (STC) configuration. The outputs are summarised in the tables below.
2. For Scenarios 1 – 3 there is sufficient available agricultural land within at most 60 kilometres of AWS's STCs. For Scenarios 4 and 5 there is likely insufficient available agricultural land for all biosolids in Great Britain. For Scenario 4 there is an almost 5-fold increase in landbank required and for Scenario 5 there is an over 10-fold increase (based on an increase over Scenario 3).
3. The key factors which result in the increase in landbank required (between Scenario 3 and Scenarios 4 and 5) are a ban on applications in the autumn to winter cereals, increased restrictions on phosphate management and increased quantity and P content of biosolids. Restrictions on biosolids use on grassland, rules in/around sensitive sites and a decrease in farmer acceptance also have a negative effect.
4. Producing an enhanced treated biosolids at almost all the sites would significantly reduce the landbank required, leading to a reduction of almost 1 million hectares. However, the key determining factor is still the environmental restrictions and in particular if biosolids can be applied in the autumn before winter cereals. Changing the rules around phosphorus restrictions and the quantity and quality of biosolids produced also have a significant effect, but the effect is dwarfed by the impact of a possible ban on autumn applications. There are possible alternative technologies that could be useful in reducing the required landbank, however, they are not yet proven commercially (e.g. thermal processes or carbon efficient pelletisation) or have practical limitations that make their benefits questionable (e.g. pelletisation or composting).
5. The potential ban on biosolids applications in the autumn to winter cereals was and is still greatly debated. Given the significant effect this one change has on the agricultural landbank and the fact the Secretary of State for the Environment introduced Statutory Guidance on the interpretation of the Farming Rules for Water at least partly to not apply this interpretation, the possible use of this approach in the future must be reviewed. It is essential biosolids recycling does not harm the environment, but if the interpretation is not scientifically justified, it would result in the water industry (including AWS) spending millions (or billions) to change the way they treat and recycle biosolids for no overall environmental benefit (e.g. a small reduction in nitrate leaching compared with increased ammonia emissions and risk of compaction and associated impacts) at a time when water bill payers are facing huge pressures due to the rise in the cost of living.

Summary of estimated maximum distances (km) to access suitable landbank from the scenario maps, Figures 1 to 5

Data	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Figure	*1*	*2*	*3*	*4*	*5*
Amount to land (tds)	90,400	92,300	95,000	103,900	108,400
Landbank required (ha)	204,200	415,100	505,800	2,142,400	3,863,100
Frequency of application (years)	1.5	2.4	2.2	3.5	3.7
Maximum distance to access suitable landbank (km)	24	37	57	>500	>500
Average distance to access suitable landbank (km)	17	26	40	>350	>350

Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

Contents

1. Background

The most recently representative data available at the time this work began suggests Anglian Water Services (AWS) produce *c.*90,000 tds (tonnes dry solids) of sewage sludge per annum, which is recycled to agricultural land. Therefore it is assumed that maintaining a sustainable agricultural landbank to be able to recycle their biosolids is strategically important for AWS. Any changes to the total amount of sludge produced, the type of treatment process used or the outlet selected may vary the demand for agricultural land.

Grieve Strategic previously undertook a landbank assessment for AWS in 2018. Since then there have been a number of updates to the ALOWANCE software tool, which may have a significant impact on the assessment of a) landbank requirement and b) landbank availability. These include updated data from the Agricultural Survey (where possible), updated NVZ areas and livestock nitrogen (N) production standards, the inclusion of information on 'competing' non-farm organic material quantities (i.e. biosolids, compost, digestate, paper crumble) and taking account of soil pH and heavy metal concentrations on landbank availability.

This updated landbank assessment will inform AWS's WINEP resilience assessment and plans for PR24 and beyond including investigating the effects of unprecedented uncertainty surrounding the regulations governing the recycling of organic manures to agricultural land. This approach fits with Ofwat's favoured approach of minimising expenditure until absolutely necessary while maintaining resilience. Moreover, although Ofwat's key parameters (climate change, technology, population and environmental ambition) appear not to apply to bioresources, these and other factors have been considered when evaluating the landbank assessments. In terms of pressure on landbank, although the Farming Rules for Water appears to have reached a positive conclusion, there is still uncertainty around certain requirements and what may happen in the future. Phosphate management is likely to continue to come under renewed focus possibly leading to a tightening of rules beyond what is currently allowed under the Biosolids Nutrient Management Matrix. Finally the exact form of the EA Sludge Strategy is still being decided, but it is likely to have a significant impact on the process, logistics and operations associated with the recycling of biosolids to agricultural land as well as other potential threats (including poly- and perfluoroalkyl substances (PFAS), microplastics and antimicrobial resistance). The report outputs and recommendations will inform biosolids recycling strategies and asset management planning.

2. Methodology

The landbank assessment was undertaken using the ALOWANCE software tool in conjunction with Graphical Information System (GIS) to produce spatial and graphical estimates of current and future landbank availability under various scenarios (i.e. possible future biosolids quantities and properties, and increasingly stringent environmental restrictions). The landbank assessment is composed of two key parameters; the land available and the land required. The outputs from the quantitative modelling is in the form of maps and tables, which extend beyond the boundaries of the AWS region as determined by the scenarios.

2.1. Available agricultural land

The agricultural landbank is calculated using data from the Agricultural Survey, which is then reduced to account for ALOWANCE restrictions (e.g. legislative and physical restrictions including topography, watercourses, Groundwater Source Protection Zones, Environmentally Sensitive Areas, Sites of Special Scientific Interest, National Nature Reserves, Nitrate Vulnerable Zone (NVZ) restrictions, account is taken of the nutrients supplied by livestock manures (whether directly deposited or managed) and organic manures (e.g. anaerobic digestate, compost, paper crumble), organically managed farmland, soil pH, and soil heavy metal concentrations), the exclusion of ready to eat crops and peas/beans and a voluntary odour buffer zone of 50 metres. Finally, the rotational exclusions (e.g. those specified by the whisky distilling industry which stipulate that biosolids must not be applied within crop rotations including malting barley) further reduce the remaining landbank to give the amount of available land. The available agricultural land can be further reduced by a tightening of the restrictions, particularly the environmental and legislative controls.

2.2. Landbank required

To assess the landbank requirement for each outlet within the AWS region (i.e. each STC), it was necessary to assess the probable acceptability of biosolids products on farm, the application rate and the minimum frequency of return to land.

The rotational landbank requirement was calculated based on the Biosolids Nutrient Management Matrix return periods (Table 1) (including information on cross compliance soil types and soil P Index), along with estimates on biosolids acceptability (depending on product type) and application rate (225 kg N/ha giving a mean rate of *c*.5 tds/ha). The rotational landbank was larger than the area that would be required each year based on limitations on frequency of application.

Table 1. Biosolids Nutrient Management Matrix

ADAS soil P Index	Maximum potential application of *lime stabilised biosolids* [a]	Maximum potential application of *all other biosolids* types
0/1/2	250kg/ha total N in any twelve month period	250kg/ha total N in any twelve month period
3	250 kg/ha total N in any twelve month period – application 1 year in 4 on sandy soils and 1 year in 2 on all other soils	250 kg/ha total N in any twelve month period – application 1 year in 2 on sandy soils [b]
4	250 kg/ha total N in any twelve month period – application 1 year in 5 on sandy soils and 1 year in 3 on all other soils	250 kg/ha total N in any twelve month period – application 1 year in 4 on sandy soils [c] and 1 year in 3 on all other soils
5 and above	No application	No application

[a] Lime addition rate >5% w/w on a dry solids basis
[b] Composted biosolids can be applied annually and
[c] Can be applied 1 year in 2

Notes:

- Soil extractable P analysis must be less than 5 years old (0-15cm soil sampling depth on arable land; 0-7.5cm on grass).
- Soil types based on Cross Compliance soil categories.
- No biosolids applications directly in front of legumes (e.g. peas, beans), except for composted biosolids which is very low in readily available N.
- Septic tank sludge is not included within the scope of the Matrix.

The required agricultural land can be further reduced by a tightening of the restrictions, particularly an increase in the phosphate return period and a reduction in farmer acceptance. By way of example, the annual landbank requirement for Cambridge STC which applied *c*.5,600 tds to agricultural land (N content *c.*4.8% dry weight and application rate of 4.7 tds/ha applying 225 kg N/ha) was calculated as *c*.1,200 ha – i.e. the annual landbank requirement. The calculated landbank is then adjusted based on farmer acceptability and Biosolids Nutrient Management Matrix compliance (e.g. cross compliance soil type, the P index of the receiving soil and the biosolids product type). These restrictions increased the amount of land required to apply the *c*.5,600 tds from *c.*1,200 ha to *c.*11,700 ha i.e. the rotational landbank requirement.

The available agricultural land can be further reduced by a tightening of the restrictions, particularly the environmental and legislative controls.

The landbank availability maps will represent the theoretical maximum distance (to the nearest 1 km) to access both suitable and sufficient agricultural land for recycling biosolids from that site. The model uses the UK road network, to calculate the maximum distance to reach the required landbank. The road distance methodology initially uses major roads (motorways, A and B classification roads) and assumes any available land within 100 metres of the road is accessible, until land is surrounded by those major roads, then the model assumes that all available land is accessible.

Where STC 'radials' overlap a bespoke merging process allows the radials to fairly represent the landbank requirement for each STC. This assessment will (where necessary) cross over regional boundaries and may include (and show) landbank out with the AWS region.

2.3. Landbank scenarios

A range of increasingly stringent landbank scenarios were modelled based on the Price Review 2024 (PR24) Water Industry National Environment Programme (WINEP) drivers, as detailed below. The scenarios outlined below, and as detailed in full in Appendix I, include increasingly stringent restrictions including interpretation of the Farming Rules for Water (FRfW), agricultural demand for biosolids, physical restrictions, farmer acceptance, etc.

Scenario 1: Baseline – business as usual: existing assets (Table 2) and regulatory controls (i.e. current Biosolids Assurance Scheme (BAS) restrictions).

Table 2. STC outputs, treatments and production standards: 2020

STC Name	Total to land (TDS)[1]	Treatment/Product	Standard	Phosphate content (%)
Basildon	6,200	Advanced digested cake	Conventional	4.3
Cambridge	5,600	Advanced digested cake	Conventional	7.1
Chelmsford	1,100	Digested cake	Conventional	5.8
Cliff Quary	6,800	Advanced digested cake	Conventional	5.9
Colchester	8,400	Advanced digested cake	Conventional	5.8
Cotton Valley	11,200	Advanced digested cake	Conventional	8.2
Great Billing	12,700	Advanced digested cake	Conventional	7.3
Stamford[2]	6,400	Advanced digested cake	Conventional	7.3
Kings Lynn	4,000	Advanced digested cake	Conventional	6.6
Thetford[3]	2,900	Advanced digested cake	Conventional	6.6
Boston[3]	1,100	Advanced digested cake	Conventional	6.6
March	8,400	Lime treated cake	Conventional	2.8
Pyewipe	5,900	Advanced digested cake	Conventional	5.6
Canwick[4]	2,900	Advanced digested cake	Conventional	5.6
Whitlingham	6,800	Advanced digested cake	Conventional	7.3
Total	**90,400**			

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

Scenario 2: Baseline post FRfW – minimal restrictions: increased sludge volumes (predicted 2025 levels and properties – Table 3), restrictions in line with the initial 20 measures in response to concerns regarding the Farming Rules for Water.

Table 3. STC outputs, treatments and production standards: 2025

STC Name	Total to land (TDS)[1]	Treatment/Product	Standard	Phosphate content (%)
Basildon	6,300	Advanced digested cake	Conventional	4.7
Cambridge	5,700	Advanced digested cake	Conventional	7.8
Chelmsford	1,200	Digested cake	Conventional	6.3
Cliff Quary	7,000	Advanced digested cake	Conventional	6.5
Colchester	8,600	Advanced digested cake	Conventional	6.4
Cotton Valley	11,400	Advanced digested cake	Conventional	9.1
Great Billing	13,000	Advanced digested cake	Conventional	8.1
Stamford[2]	6,500	Advanced digested cake	Conventional	8.1
Kings Lynn	4,100	Advanced digested cake	Conventional	7.2
Thetford[3]	2,900	Advanced digested cake	Conventional	7.2
Boston[3]	1,100	Advanced digested cake	Conventional	7.2
March	8,600	Lime treated cake	Conventional	3.1
Pyewipe	6,000	Advanced digested cake	Conventional	6.2
Canwick[4]	3,000	Advanced digested cake	Conventional	6.2
Whitlingham	6,900	Advanced digested cake	Conventional	8.0
Total	**92,300**			

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

Scenario 3: AMP8 low change – modest restrictions: increased sludge volumes (predicted 2030 levels and properties – Table 4), slightly increased restrictions on phosphate additions (e.g. no application at index 4 and above and matching offtakes at index 3), reduced farmer acceptance (to model concerns over contaminants (e.g. PFAS and microplastics or regulatory uncertainty) and restrictions in line with the 20 measures in response to concerns regarding Farming Rules for Water.

Table 4. STC outputs, treatments and production standards: 2030

STC Name	Total to land (TDS)[1]	Treatment/Product	Standard	Phosphate content (%)
Basildon	6,500	Advanced digested cake	Conventional	5.1
Cambridge	5,800	Advanced digested cake	Conventional	8.5
Chelmsford	1,200	Digested cake	Conventional	6.9
Cliff Quary	7,200	Advanced digested cake	Conventional	7.1
Colchester	8,900	Advanced digested cake	Conventional	6.9
Cotton Valley	11,700	Advanced digested cake	Conventional	9.9
Great Billing	13,400	Advanced digested cake	Conventional	8.8
Stamford[2]	6,700	Advanced digested cake	Conventional	8.8
Kings Lynn	4,200	Advanced digested cake	Conventional	7.9
Thetford[3]	3,000	Advanced digested cake	Conventional	7.9
Boston[3]	1,200	Advanced digested cake	Conventional	7.9
March	8,800	Lime treated cake	Conventional	3.4
Pyewipe	6,200	Advanced digested cake	Conventional	6.8
Canwick[4]	3,100	Advanced digested cake	Conventional	6.8
Whitlingham	7,100	Advanced digested cake	Conventional	8.8
Total	**95,000**			

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

Scenario 4: AMP8 medium change – significant restrictions: increased sludge volumes (predicted 2040 levels and properties – Table 5), increased restrictions on phosphate additions (e.g. no application at index 4 and above, matching offtakes at index 2 and 3), further reduced farmer acceptance (to model concerns over contaminants (e.g. PFAS and microplastics or regulatory uncertainty), restrictions in line with the 20 measures in response to concerns regarding Farming Rules for Water, restrictions on applications in sensitive catchments, no applications within 500m of sensitive sites or within SPZ2 and increased restrictions on applications to grassland.

Table 5. STC outputs, treatments and production standards: 2040

STC Name	Total to land (TDS)[1]	Treatment/Product	Standard	Phosphate content (%)
Basildon	7,100	Advanced digested cake	Conventional	6.0
Cambridge	6,400	Advanced digested cake	Conventional	9.9
Chelmsford	1,300	Digested cake	Conventional	8.1
Cliff Quary	7,800	Advanced digested cake	Conventional	8.3
Colchester	9,700	Advanced digested cake	Conventional	8.1
Cotton Valley	12,900	Advanced digested cake	Conventional	11.5
Great Billing	14,600	Advanced digested cake	Conventional	10.3
Stamford[2]	7,300	Advanced digested cake	Conventional	10.3
Kings Lynn	4,600	Advanced digested cake	Conventional	9.2
Thetford[3]	3,300	Advanced digested cake	Conventional	9.2
Boston[3]	1,300	Advanced digested cake	Conventional	9.2
March	9,700	Lime treated cake	Conventional	4.0
Pyewipe	6,700	Advanced digested cake	Conventional	7.9
Canwick[4]	3,400	Advanced digested cake	Conventional	7.9
Whitlingham	7,800	Advanced digested cake	Conventional	10.2
Total	**103,900**			

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

Scenario 5: AMP8 high change – plausible worst-case: increased sludge volumes (predicted 2050 levels and properties – Table 6), no application at index 4 and above, matching P to crop offtakes, limited farmer acceptance (to model concerns over contaminants (e.g. PFAS and microplastics or regulatory uncertainty), restrictions in line with the 20 measures in response to concerns regarding Farming Rules for Water, no applications in sensitive catchments, no applications within 500m of sensitive sites or within SPZ2, reduced application rates (as a result of concerns over nitrate leaching) and restrictions on applications to grassland.

Table 6. STC outputs, treatments and production standards: 2050

STC Name	Total to land (TDS)[1]	Treatment/Product	Standard	Phosphate content (%)
Basildon	7,400	Advanced digested cake	Conventional	6.4
Cambridge	6,700	Advanced digested cake	Conventional	10.7
Chelmsford	1,400	Digested cake	Conventional	8.7
Cliff Quary	8,200	Advanced digested cake	Conventional	8.9
Colchester	10,100	Advanced digested cake	Conventional	8.7
Cotton Valley	13,400	Advanced digested cake	Conventional	12.4
Great Billing	15,300	Advanced digested cake	Conventional	11.0
Stamford[2]	7,600	Advanced digested cake	Conventional	11.0
Kings Lynn	4,800	Advanced digested cake	Conventional	9.8
Thetford[3]	3,500	Advanced digested cake	Conventional	9.8
Boston[3]	1,300	Advanced digested cake	Conventional	9.8
March	10,100	Lime treated cake	Conventional	4.3
Pyewipe	7,000	Advanced digested cake	Conventional	8.5
Canwick[4]	3,500	Advanced digested cake	Conventional	8.5
Whitlingham	8,100	Advanced digested cake	Conventional	11.0
Total	**108,400**			

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

The use of these scenarios will enable AWS to demonstrate the limitations on its landbank even under current restrictions and why its bioresources costs are as they are. The increasingly onerous scenarios will allow AWS to understand the effects of increasing restrictions on its landbank, assess resilience and where interventions will be required and are necessary to minimise overall bioresources treatment/recycling costs. For all scenarios, the same restrictions that apply to AWS's biosolids will also apply to biosolids produced by other WaSCs.

3. Modelled distance to available landbank from each STC/outlet

The rotational landbank required for each STC or outlet was calculated using the methodology described in the previous section. To ensure the model was as accurate as possible for each STC, the amount of biosolids that could be applied to the grass landbank was restricted based on data supplied by AWS for each STC. The landbank availability maps will represent the theoretical maximum distance (to the nearest 1 km) to access both suitable and sufficient agricultural land for recycling biosolids from that site.

3.1. Landbank scenarios

The results for five landbank scenarios are shown below:

Table 7 and Figure 1: Scenario 1 with baseline STC configuration with the return periods calculated as once in every 1.5 years.

Table 7. Rotational landbank required for each STC (Scenario 1)

STC Name	Total to land (TDS)[1]	Treatment/Product	Acceptance (%)	Hectares
Basildon	6,200	Advanced digested cake	15	15,000
Cambridge	5,600	Advanced digested cake	15	11,700
Chelmsford	1,100	Digested cake	15	2,700
Cliff Quary	6,800	Advanced digested cake	15	16,700
Colchester	8,400	Advanced digested cake	15	19,600
Cotton Valley	11,200	Advanced digested cake	15	24,900
Great Billing	12,700	Advanced digested cake	15	27,800
Stamford[2]	6,400	Advanced digested cake	15	13,900
Kings Lynn	4,000	Advanced digested cake	15	8,600
Thetford[3]	2,900	Advanced digested cake	15	6,200
Boston[3]	1,100	Advanced digested cake	15	2,400
March	8,400	Lime treated cake	10	21,200
Pyewipe	5,900	Advanced digested cake	15	12,100
Canwick[4]	2,900	Advanced digested cake	15	6,000
Whitlingham	6,800	Advanced digested cake	15	15,400
Total	**90,400**			**204,200**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

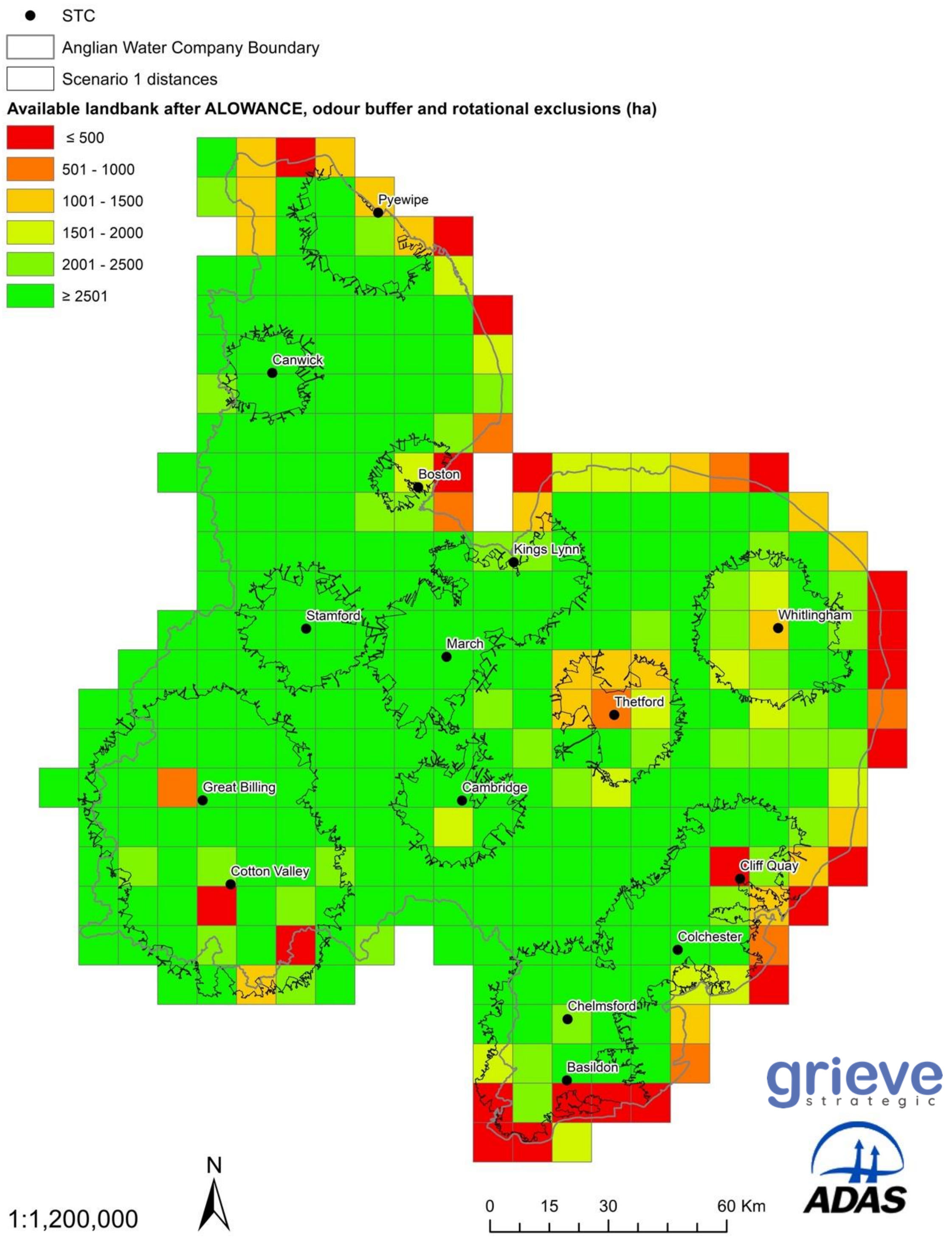

Figure 1. Scenario 1 baseline STC configuration.

Table 8 and Figure 2: Scenario 2 with baseline STC configuration with the return periods calculated as once in every 2.4 years.

Table 8. Rotational landbank required for each STC (Scenario 2)

STC Name	Total to land (TDS)[1]	Treatment/Product	Acceptance (%)	Hectares
Basildon	6,300	Advanced digested cake	14	31,000
Cambridge	5,700	Advanced digested cake	14	24,200
Chelmsford	1,200	Digested cake	14	5,600
Cliff Quary	7,000	Advanced digested cake	14	32,400
Colchester	8,600	Advanced digested cake	14	40,500
Cotton Valley	11,400	Advanced digested cake	14	51,200
Great Billing	13,000	Advanced digested cake	14	57,400
Stamford[2]	6,500	Advanced digested cake	14	28,700
Kings Lynn	4,100	Advanced digested cake	14	17,800
Thetford[3]	2,900	Advanced digested cake	14	12,800
Boston[3]	1,100	Advanced digested cake	14	5,000
March	8,600	Lime treated cake	10	39,200
Pyewipe	6,000	Advanced digested cake	14	25,000
Canwick[4]	3,000	Advanced digested cake	14	12,500
Whitlingham	6,900	Advanced digested cake	14	31,800
Total	**92,300**			**415,100**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

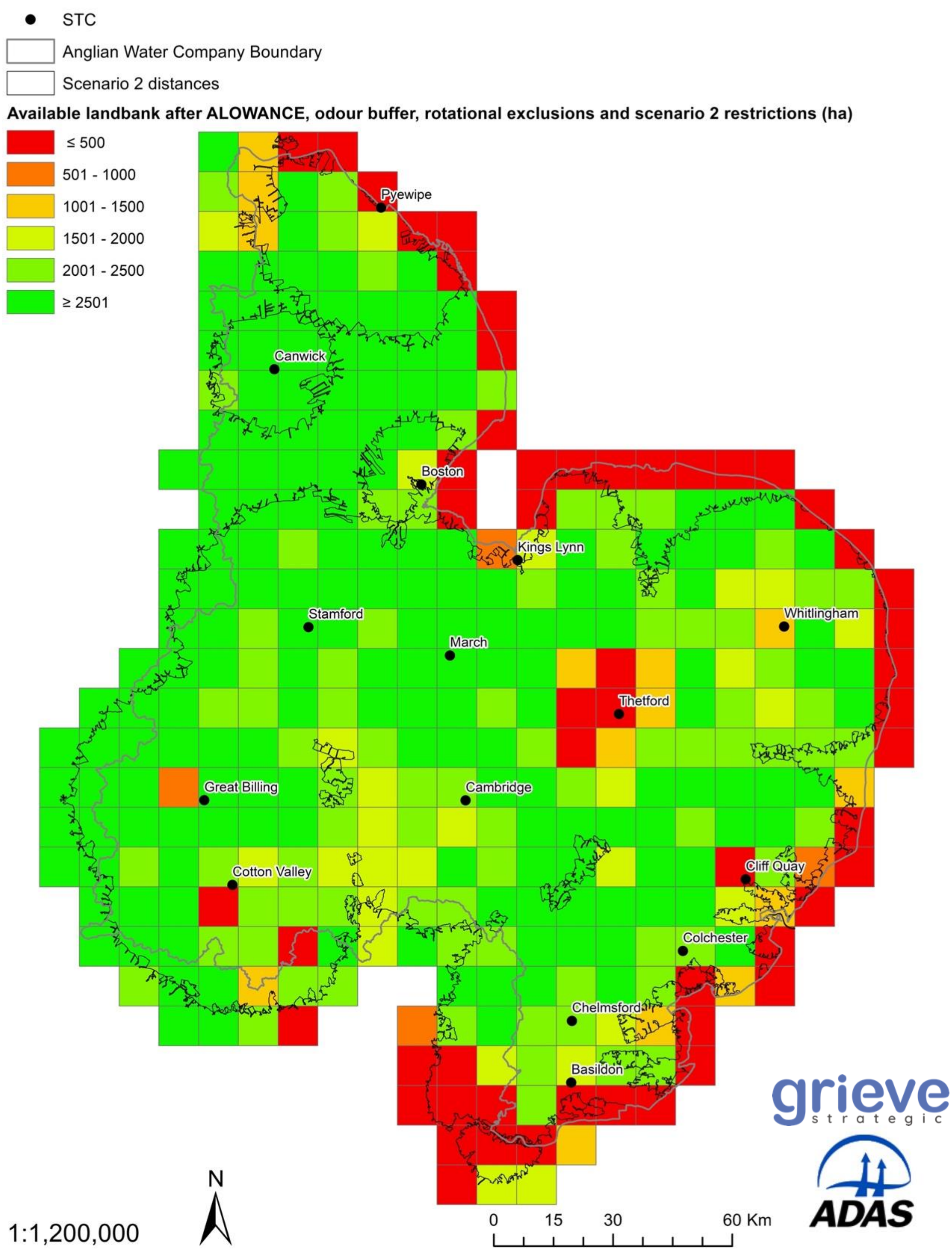

Figure 2. Scenario 2 baseline STC configuration.

Table 9 and Figure 3: Scenario 3 with baseline STC configuration with the return periods calculated as once in every 2.2 years.

Table 9. Rotational landbank required for each STC (Scenario 3)

STC Name	Total to land (TDS)[1]	Treatment/Product	Acceptance (%)	Hectares
Basildon	6,500	Advanced digested cake	13	37,700
Cambridge	5,800	Advanced digested cake	13	29,500
Chelmsford	1,200	Digested cake	13	6,800
Cliff Quary	7,200	Advanced digested cake	13	39,500
Colchester	8,900	Advanced digested cake	13	49,300
Cotton Valley	11,700	Advanced digested cake	13	62,200
Great Billing	13,400	Advanced digested cake	13	69,900
Stamford[2]	6,700	Advanced digested cake	13	34,900
Kings Lynn	4,200	Advanced digested cake	13	21,600
Thetford[3]	3,000	Advanced digested cake	13	15,600
Boston[3]	1,200	Advanced digested cake	13	6,100
March	8,800	Lime treated cake	9	48,300
Pyewipe	6,200	Advanced digested cake	13	30,500
Canwick[4]	3,100	Advanced digested cake	13	15,200
Whitlingham	7,100	Advanced digested cake	13	38,700
Total	**95,000**			**505,800**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

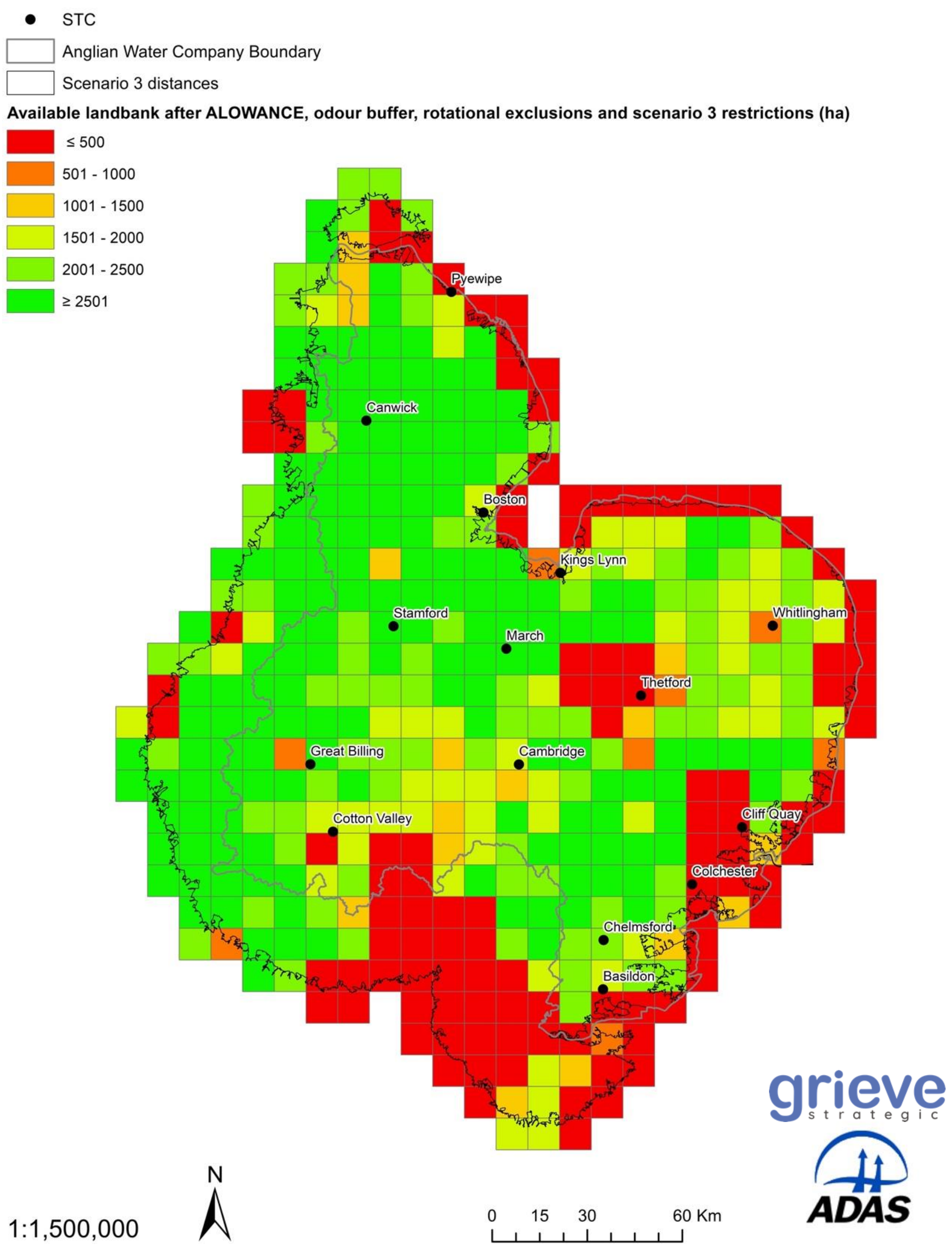

Figure 3. Scenario 3 baseline STC configuration.

Table 10 and Figure 4: Scenario 4 with baseline STC configuration with the return periods calculated as once in every 3.5 years. Please note: there is insufficient landbank available, hence there is no radial ring shown on Figure 4.

Table 10. Rotational landbank required for each STC (Scenario 4)

STC Name	Total to land (TDS)[1]	Treatment/Product	Acceptance (%)	Hectares
Basildon	7,100	Advanced digested cake	11	163,300
Cambridge	6,400	Advanced digested cake	11	127,500
Chelmsford	1,300	Digested cake	11	29,400
Cliff Quary	7,800	Advanced digested cake	11	171,000
Colchester	9,700	Advanced digested cake	11	212,400
Cotton Valley	12,900	Advanced digested cake	11	265,000
Great Billing	14,600	Advanced digested cake	11	300,400
Stamford[2]	7,300	Advanced digested cake	11	150,200
Kings Lynn	4,600	Advanced digested cake	11	93,400
Thetford[3]	3,300	Advanced digested cake	11	67,200
Boston[3]	1,300	Advanced digested cake	11	26,100
March	9,700	Lime treated cake	8	173,100
Pyewipe	6,700	Advanced digested cake	11	131,600
Canwick[4]	3,400	Advanced digested cake	11	65,800
Whitlingham	7,800	Advanced digested cake	11	166,000
Total	**103,900**			**2,142,400**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

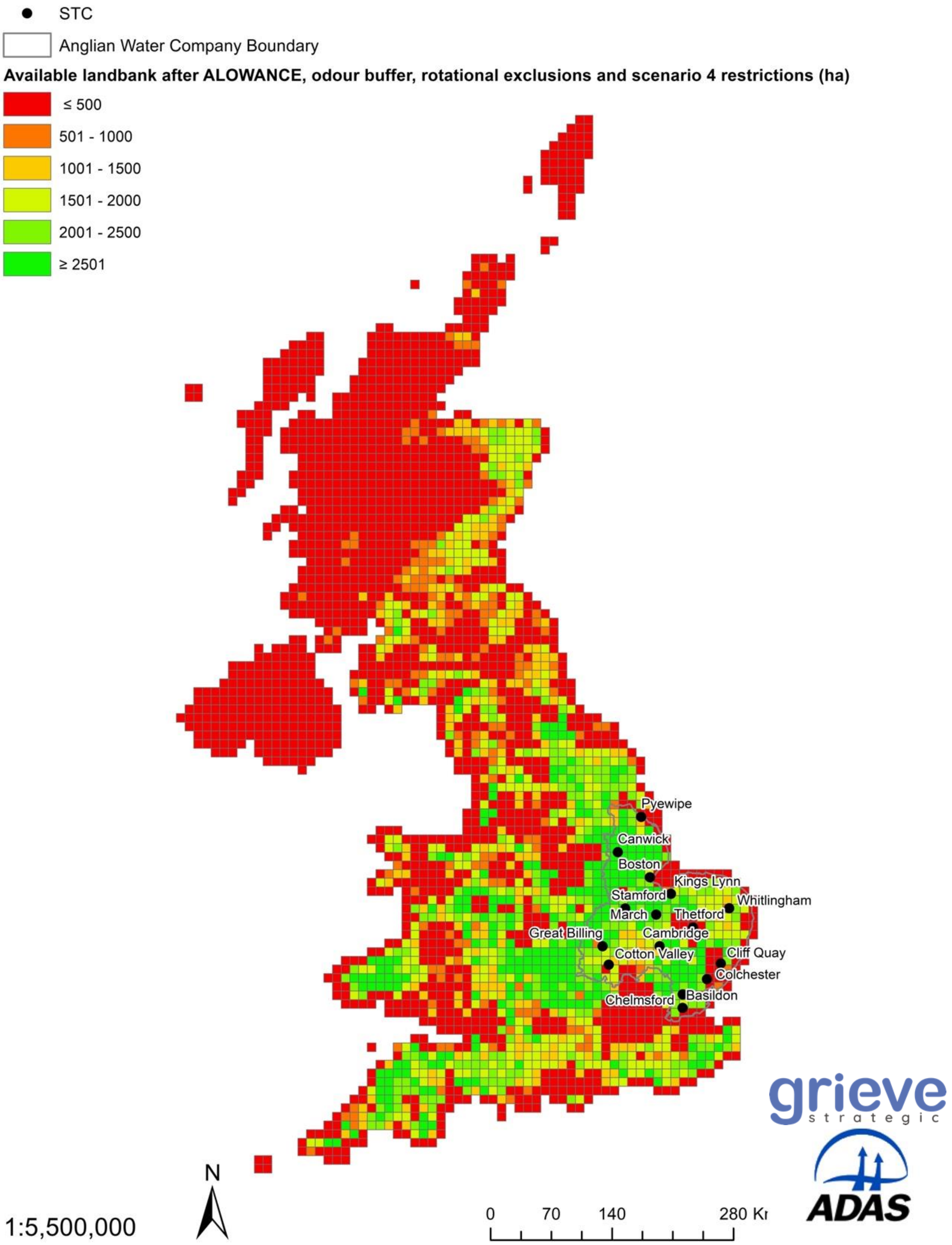

Figure 4. Scenario 4 baseline STC configuration.

Table 11 and Figure 5: Scenario 5 with baseline STC configuration with the return periods calculated as once in every 3.7 years. Please note: there is insufficient landbank available, hence there is no radial ring shown on Figure 5.

Table 11. Rotational landbank required for each STC (Scenario 5)

STC Name	Total to land (TDS)[1]	Treatment/Product	Acceptance (%)	Hectares
Basildon	7,400	Advanced digested cake	9	292,200
Cambridge	6,700	Advanced digested cake	9	228,100
Chelmsford	1,400	Digested cake	9	52,700
Cliff Quary	8,200	Advanced digested cake	9	305,800
Colchester	10,100	Advanced digested cake	9	380,000
Cotton Valley	13,400	Advanced digested cake	9	474,500
Great Billing	15,300	Advanced digested cake	9	537,500
Stamford[2]	7,600	Advanced digested cake	9	268,700
Kings Lynn	4,800	Advanced digested cake	9	167,100
Thetford[3]	3,500	Advanced digested cake	9	120,300
Boston[3]	1,300	Advanced digested cake	9	46,800
March	10,100	Lime treated cake	6	339,200
Pyewipe	7,000	Advanced digested cake	9	235,400
Canwick[4]	3,500	Advanced digested cake	9	117,700
Whitlingham	8,100	Advanced digested cake	9	297,100
Total	**108,400**			**3,863,100**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

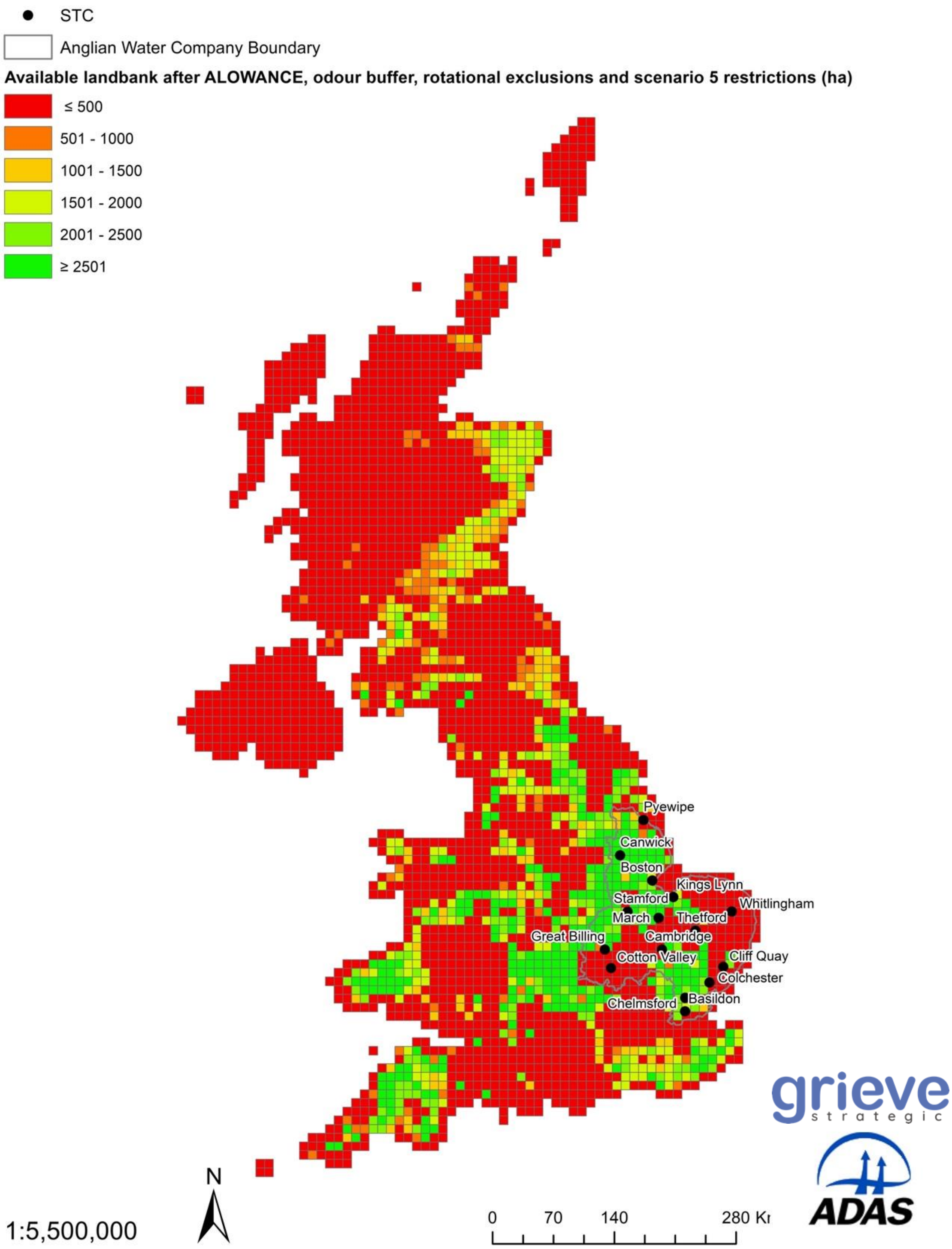

Figure 5. Scenario 5 baseline STC configuration.

The data on biosolids quality and landbank required across the five scenarios is summarised in Table 12 and estimated maximum distances to access suitable landbank are summarised in Table 13.

Table 12. Summary of data for scenarios 1 – 5 with baseline STC configuration.

Data	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Figure	*1*	*2*	*3*	*4*	*5*
Amount to land (tds)	90,400	92,300	95,000	103,900	108,400
Landbank required (ha)	204,200	415,100	505,800	2,142,400	3,863,100
Frequency of application (years)	1.5	2.4	2.2	3.5	3.7

Table 13. Summary of estimated maximum distances (km) to access suitable landbank for scenarios 1 – 5 with baseline STC configuration.

STC	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Figure	*1*	*2*	*3*	*4*	*5*
Basildon	25	40	60	>500	>500
Cambridge	20	40	60	>500	>500
Chelmsford	25	40	60	>500	>500
Cliff Quay	25	40	60	>500	>500
Colchester	25	40	60	>500	>500
Cotton Valley	35	40	60	>500	>500
Great Billing	35	40	60	>500	>500
Stamford[1]	20	40	60	>500	>500
Kings Lynn	25	40	60	>500	>500
Thetford[2]	20	40	60	>500	>500
Boston[2]	15	20	40	>500	>500
March	25	40	60	>500	>500
Pyewipe	25	40	55	>500	>500
Canwick[3]	15	20	35	>500	>500
Whitlingham	25	40	60	>500	>500

[1] Stamford is a distribution location for biosolids produced at Great Billing.

[2] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[3] Canwick is a distribution location for biosolids produced at Pyewipe.

3.2. Landbank required

As detailed in Section 2, the landbank required is a key parameter in determining how far biosolids has to be transported to find sufficient land. However, due to the nature of the scenarios and the spatial resolution of some of data, the landbank required includes some additional restrictions, particularly related to restrictions on certain crops (e.g. no applications in advance of winter cereals in the autumn under scenarios 4 and 5) and certain soils types (e.g. restrictions on sandy and shallow soils in scenario 2 onwards). This does not change the validity of the modelling as that land needs to be excluded in order to comply with the requirements laid out in those scenarios. However, if AWS were to use this larger landbank required amount to calculate costs to manage their landbank, it would be an over estimate. To enable AWS to undertake these calculations, Table 14 below details the 'active landbank' which AWS would need to manage for each scenario.

Table 14. Active landbank (hectares)

STC Name	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Basildon	15,000	25,600	27,700	54,000	75,800
Cambridge	11,700	20,000	21,600	42,100	59,200
Chelmsford	2,700	4,600	5,000	9,700	13,700
Cliff Quay	15,700	26,800	29,000	56,500	79,300
Colchester	19,600	33,600	36,400	70,800	99,400
Cotton Valley	24,900	42,700	46,200	89,900	126,300
Great Billing	27,800	47,700	51,600	100,400	141,000
Stamford[1]	13,900	23,800	25,800	50,200	70,500
Kings Lynn	8,600	14,700	15,900	31,000	43,500
Thetford[2]	6,200	10,600	11,500	22,300	31,300
Boston[2]	2,400	4,100	4,500	8,700	12,200
March	21,200	32,400	35,500	57,200	88,000
Pyewipe	12,100	20,700	22,400	43,600	61,200
Canwick[3]	6,000	10,300	11,200	21,800	30,600
Whitlingham	15,400	26,400	28,600	55,600	78,100

Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[1] Stamford is a distribution location for biosolids produced at Great Billing.

[2] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[3] Canwick is a distribution location for biosolids produced at Pyewipe.

For the avoidance of doubt, the 'active landbank' area should only be used for financial planning for considerations associated with the costs of managing the landbank required (e.g. how many farm advisors are required etc.). For all other considerations and calculations, including but not limited to, determining if there is sufficient landbank nationally, considering the benefit of different STC configurations/product types, the total (larger) landbank figure must be used.

3.3. Average haulage distances

The ALOWANCE software tool uses the landbank required and the landbank available to calculate how far biosolids has to be transported to find sufficient land, it is these distances that are shown earlier in this report. However, in order to calculate the cost-benefit of various options, it would be helpful to AWS to know the average haulage distances. Average haulage distances were modelled using geometric calculations from the maximum haulage distances and are shown in Table 15. As a result of calculating the average distance from the maximum haulage distances, it is not possible to account for the spatial distribution of the available land. The geometric calculations effectively assume the available land is equally distributed through the landbank, which is not necessarily the case. However, we do not believe that the available land is so unequally distributed that it would result in a significantly different average haulage distance.

Table 15. Calculated average haulage distances (kilometres)

STC Name	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Basildon	18	28	42	>350	>350
Cambridge	14	28	42	>350	>350
Chelmsford	18	28	42	>350	>350
Cliff Quay	18	28	42	>350	>350
Colchester	18	28	42	>350	>350
Cotton Valley	25	28	42	>350	>350
Great Billing	25	28	42	>350	>350
Stamford[1]	14	28	42	>350	>350
Kings Lynn	18	28	42	>350	>350
Thetford[2]	14	28	42	>350	>350
Boston[2]	11	14	28	>350	>350
March	18	28	42	>350	>350
Pyewipe	18	28	39	>350	>350
Canwick[3]	11	14	25	>350	>350
Whitlingham	18	28	42	>350	>350

[1] Stamford is a distribution location for biosolids produced at Great Billing.

[2] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[3] Canwick is a distribution location for biosolids produced at Pyewipe.

4. Alternative modelling scenarios

To provide further information to allow AWS to evaluate their options, additional scenarios have been undertaken investigating alternative treatment options and different environmental scenarios to those shown in Section 3.

4.1. Enhanced treated biosolids

AWS operate advanced digestion facilities at the majority of its STCs and lime treatment at another, which are all capable of producing enhanced treated biosolids (as defined by the Biosolids Assurance Scheme) subject to limitations that may be present at individual sites. Enhanced treatment of biosolids makes recycling to grassland more viable as the return periods are much shorter than those that apply to conventionally treated biosolids. Moreover, although the harvest intervals remain the same as for arable crops, it has been found that farmers are more accepting of enhanced treated biosolids which results in an overall reduction in landbank required. As a result, the maximum amount of biosolids that can be recycled to grassland has been increased (from negligible to a maximum of 20%) and the farmer acceptance has also been increased for enhanced treated biosolids. These changes have reduced the rotational landbank required as shown in Table 16 below.

Table 16. Rotational landbank required for enhanced treated biosolids (Scenario 4)

STC Name	Total to land (TDS)[1]	Treatment/Product	Acceptance (%)	Hectares
Basildon	7,100	AAD cake (enhanced)	20	92,900
Cambridge	6,400	AAD cake (enhanced)	20	72,600
Chelmsford	1,300	AD cake (conventional)	11	29,400
Cliff Quary	7,800	AAD cake (enhanced)	20	97,300
Colchester	9,700	AAD cake (enhanced)	20	121,900
Cotton Valley	12,900	AAD cake (enhanced)	20	154,800
Great Billing	14,600	AAD cake (enhanced)	20	173,000
Stamford[2]	7,300	AAD cake (enhanced)	20	86,500
Kings Lynn	4,600	AAD cake (enhanced)	20	53,400
Thetford[3]	3,300	AAD cake (enhanced)	20	38,400
Boston[3]	1,300	AAD cake (enhanced)	20	14,900
March	9,700	Lime treated cake (enhanced)	15	91,100
Pyewipe	6,700	AAD cake (enhanced)	20	75,100
Canwick[4]	3,400	AAD cake (enhanced)	20	37,500
Whitlingham	7,800	AAD cake (enhanced)	20	95,800
Total	**103,900**			**1,234,600**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

The production of enhanced treated biosolids decreases the quantity of landbank required from approximately 2.14 to 1.23 million hectares.

4.2. Increased phosphorus restrictions

One of the key environmental restrictions that affects biosolids recycling is the constraints associated with phosphorus, which is particularly important as biosolids is a highly valuable source of phosphate. This scenario considers the most stringent phosphorus restrictions i.e. a longer return period at index 2, very tight restrictions at index 3 (i.e. crop offtakes exceeding inputs) and no applications at index 4 and above (i.e. as per Scenario 5) with all the other restrictions as per Scenario 2; the results are shown in Table 17.

Table 17. Rotational landbank required for each STC with increased phosphorus restrictions (Scenario 2)

STC Name	Total to land (TDS)[1]	Treatment/Product	Acceptance (%)	Hectares
Basildon	6,300	Advanced digested cake	14	55,700
Cambridge	5,700	Advanced digested cake	14	43,500
Chelmsford	1,200	Digested cake	14	10,000
Cliff Quary	7,000	Advanced digested cake	14	58,300
Colchester	8,600	Advanced digested cake	14	72,900
Cotton Valley	11,400	Advanced digested cake	14	92,100
Great Billing	13,000	Advanced digested cake	14	103,300
Stamford[2]	6,500	Advanced digested cake	14	51,700
Kings Lynn	4,100	Advanced digested cake	14	32,000
Thetford[3]	2,900	Advanced digested cake	14	23,000
Boston[3]	1,100	Advanced digested cake	14	9,000
March	8,600	Lime treated cake	10	64,000
Pyewipe	6,000	Advanced digested cake	14	45,000
Canwick[4]	3,000	Advanced digested cake	14	22,500
Whitlingham	6,900	Advanced digested cake	14	57,200
Total	**92,300**			**740,200**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

The landbank required increased by approximately 300,000 hectares from the 415,100 hectares required under Scenario 2 to 740,200 when the strictest phosphorus restrictions are included.

4.3. No applications at P index 4 and above

As per the previous section, phosphorus restrictions have a significant effect on biosolids recycling. This scenario consider a ban on applications at index 4 and above, but the other restrictions for phosphorus and other restrictions remain the same as per Scenario 2; the results are shown in Table 18.

Table 18. Rotational landbank required for each STC with no applications at P index 4 (Scenario 2)

STC Name	Total to land (TDS)[1]	Treatment/Product	Acceptance (%)	Hectares
Basildon	6,300	Advanced digested cake	14	45,100
Cambridge	5,700	Advanced digested cake	14	35,200
Chelmsford	1,200	Digested cake	14	8,100
Cliff Quary	7,000	Advanced digested cake	14	47,200
Colchester	8,600	Advanced digested cake	14	58,900
Cotton Valley	11,400	Advanced digested cake	14	74,400
Great Billing	13,000	Advanced digested cake	14	83,500
Stamford[2]	6,500	Advanced digested cake	14	41,800
Kings Lynn	4,100	Advanced digested cake	14	25,800
Thetford[3]	2,900	Advanced digested cake	14	18,600
Boston[3]	1,100	Advanced digested cake	14	7,200
March	8,600	Lime treated cake	10	54,200
Pyewipe	6,000	Advanced digested cake	14	36,400
Canwick[4]	3,000	Advanced digested cake	14	18,200
Whitlingham	6,900	Advanced digested cake	14	46,200
Total	**92,300**			**600,800**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

The landbank required increased by approximately 175,000 hectares from the 415,100 hectares required under Scenario 2 to 600,800 when no applications are allowed at P index 4 but the other restrictions remain the same.

4.4. Environmental restrictions without change in biosolids quality and quantity

One of the restrictions that is included in the scenarios is the effect of increased population, and therefore the quantity of biosolids produced, but also the increased need for phosphorus removal from final effluent that also increases the quantity of biosolids produced as well as the phosphate content of the biosolids. The change has been modelled for Scenario 3 (Table 19), Scenario 4 (Table 20) and Scenario 5 (Table 21).

Table 19. Rotational landbank required for each STC with no change in biosolids quality and quantity (Scenario 3)

STC Name	Total to land (TDS)[1]	Treatment/Product	Acceptance (%)	Hectares
Basildon	6,300	Advanced digested cake	13	37,100
Cambridge	5,700	Advanced digested cake	13	29,000
Chelmsford	1,200	Digested cake	13	6,700
Cliff Quary	7,000	Advanced digested cake	13	38,900
Colchester	8,600	Advanced digested cake	13	48,500
Cotton Valley	11,400	Advanced digested cake	13	61,100
Great Billing	13,000	Advanced digested cake	13	68,700
Stamford[2]	6,500	Advanced digested cake	13	34,400
Kings Lynn	4,100	Advanced digested cake	13	21,300
Thetford[3]	2,900	Advanced digested cake	13	15,300
Boston[3]	1,100	Advanced digested cake	13	6,000
March	8,600	Lime treated cake	9	47,400
Pyewipe	6,000	Advanced digested cake	13	30,000
Canwick[4]	3,000	Advanced digested cake	13	15,000
Whitlingham	6,900	Advanced digested cake	13	38,000
Total	**92,300**			**497,400**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

Table 20. Rotational landbank required for each STC with no change in biosolids quality and quantity (Scenario 4)

STC Name	Total to land (TDS)[1]	Treatment/Product	Acceptance (%)	Hectares
Basildon	6,300	Advanced digested cake	11	148,900
Cambridge	5,700	Advanced digested cake	11	116,200
Chelmsford	1,200	Digested cake	11	26,800
Cliff Quary	7,000	Advanced digested cake	11	155,800
Colchester	8,600	Advanced digested cake	11	198,500
Cotton Valley	11,400	Advanced digested cake	11	241,500
Great Billing	13,000	Advanced digested cake	11	273,700
Stamford[2]	6,500	Advanced digested cake	11	136,900
Kings Lynn	4,100	Advanced digested cake	11	85,100
Thetford[3]	2,900	Advanced digested cake	11	61,300
Boston[3]	1,100	Advanced digested cake	11	23,800
March	8,600	Lime treated cake	8	157,800
Pyewipe	6,000	Advanced digested cake	11	119,900
Canwick[4]	3,000	Advanced digested cake	11	60,000
Whitlingham	6,900	Advanced digested cake	11	151,300
Total	**92,300**			**1,957,500**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

Table 21. Rotational landbank required for each STC with no change in biosolids quality and quantity (Scenario 5)

STC Name	Total to land (TDS)[1]	Treatment/Product	Acceptance (%)	Hectares
Basildon	6,300	Advanced digested cake	9	255,100
Cambridge	5,700	Advanced digested cake	9	199,100
Chelmsford	1,200	Digested cake	9	46,000
Cliff Quary	7,000	Advanced digested cake	9	267,000
Colchester	8,600	Advanced digested cake	9	331,700
Cotton Valley	11,400	Advanced digested cake	9	414,300
Great Billing	13,000	Advanced digested cake	9	469,300
Stamford[2]	6,500	Advanced digested cake	9	234,600
Kings Lynn	4,100	Advanced digested cake	9	145,800
Thetford[3]	2,900	Advanced digested cake	9	105,000
Boston[3]	1,100	Advanced digested cake	9	40,800
March	8,600	Lime treated cake	6	295,500
Pyewipe	6,000	Advanced digested cake	9	205,500
Canwick[4]	3,000	Advanced digested cake	9	102,800
Whitlingham	6,900	Advanced digested cake	9	259,400
Total	**92,300**			**3,371,900**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Stamford is a distribution location for biosolids produced at Great Billing.

[3] Thetford and Boston are distribution locations for biosolids produced at Kings Lynn.

[4] Canwick is a distribution location for biosolids produced at Pyewipe.

The landbank required decreases by approximately 10,000 hectares for Scenario 3 (i.e. 497,400 ha versus to 505,800 ha), by approximately 200,000 hectares for Scenario 4 (i.e. 1,957,500 ha versus 2,142,400 ha) and by approximately 500,000 hectares for Scenario 5 (i.e. 3,371,900 ha versus 3,863,100 ha).

4.5. Potential for alternative treatment technologies to recycle biosolids more efficiently

There are limited viable alternative options to recycling biosolids to agricultural land; these included incineration, composting and pelletisation.

Incineration (and other thermal treatment options such as pyrolysis, gasification and hydrothermal carbonisation, provide several benefits, but are not yet proven at an operational scale on biosolids). However, this is a less than ideal option given the loss of nutrients (unless nutrient extraction can be developed operationally) and the loss of organic matter. Moreover, there would be a significant cost and incineration is not a popular technology, so finding locations for sites is likely to be difficult.

Composting has been mentioned as a possible solution as compost has a much lower and potentially negligible readily available nitrogen (RAN) content meaning it is likely (although not certain) that it could still be applied in the autumn and thus avoid the potential ban on applications to winter cereals (i.e. crops which do not have an autumn manufactured nitrogen recommendation). However, there are some significant issues which would have to be overcome. Composting biosolids would likely require the addition of at least the same volume of green waste, which will already be being beneficially utilised elsewhere and subject to existing contractual restrictions. Moreover, composting sewage sludge with green waste would likely double the amount of biosolids requiring an outlet, so increasing the amount of landbank required, as legislation controlling application rates is based on total nitrogen rather than readily available nitrogen. In addition, composting sewage sludge with green waste is very unlikely to 'removal' all the readily available nitrogen in biosolids, which would mean that although a composted biosolids would contain less readily available nitrogen, it would likely still be subject to the autumn restriction on applying nitrogen containing sources to crops without a manufactured fertiliser nitrogen requirement.

There is currently great interest in the benefits of pelletisation and indeed this is used at sites in Scotland (i.e. thermally dried granules), however, the carbon footprint and financial cost is significant given the processes utilise large quantities of natural gas to dry the biosolids before producing granules. There are existing technologies to pelletise biosolids, but again the water has to be removed often requiring external drying, although some technologies are being tested that utilise novel processes and waste heat from combined heat and power units so as to prevent the need for external energy sources (e.g. natural gas). If biosolids can be efficiently pelletised then in theory they can be top-dressed onto a growing crop without damaging the crop, as pellets should be able to be applied via conventional fertiliser application equipment (e.g. spinning disc spreaders) operating from tramlines, as is the case for manufactured fertiliser. However, the application rate will be significantly higher for biosolids pellets than manufactured nitrogen fertilisers. Ammonium nitrate (the dominant source of manufactured nitrogen fertiliser) contains 34% available nitrogen (or 340 kg/t fw) whereas biosolids contains approximately 4.5% total nitrogen (or 40 kg/t fw). Although biosolids provides other benefits, it would still be applied at or around the maximum rate of 250 kg total N/ha to provide nitrogen and the other benefits. Ammonium nitrate is typically be applied at around 0.25 t/ha (supplying around 80 kg of readily available nitrogen) whereas pelletised biosolids would be applied around 6 t/ha. Given the capacity of most modern fertiliser spreaders are *c*.3 tonnes, this means each spreader could cover *c*.12 hectares applying ammonium nitrate and *c*.0.5 hectares applying biosolids. In ideal soil conditions this is unlikely to be an issue as a tractor and spreader combined applying ammonium nitrate are likely to weigh approximately 12 tonnes, much less than the approximately 40 tonnes for spreading biosolids cake. However, if soils are damp, as is often the case in the spring, repeated driving over tramlines would lead to soil compaction and affecting the farmer's ability to accurately and evenly apply other materials (e.g. fertiliser and agricultural chemicals) for the rest of the spring. This could well mean a significant number of farming customers may be unwilling to top-dress pelletised biosolids, although more modelling and discussions could investigate this further.

5. Discussion

It is clear from the statistics and the mapping that as the environmental scenarios (and the quantity/quality of biosolids) increase, so does the landbank required and the available land decreases. This results in haulage distances increasing from the those in the baseline scenario (of *c.*24 kilometres) to the point that there is insufficient available agricultural land in Scenarios 4 and 5. For Scenarios 1 – 3 the landbank required is at the maximum just over 500,000 hectares and the restriction on the available land means there is comfortably sufficient available agricultural land within *c.*60 kilometres of AWS's STCs.

For Scenario 4, there is a reduction in the available land, but the key change is the vast, almost 4-fold, increase in the landbank required (i.e. an increase of more than 1,500,000 hectares). For Scenario 5 the landbank required increases yet further, almost twice what it was, to over 3.9 million hectares. For Scenarios 4 and 5, due to the enormous amount of landbank required, there is insufficient available agricultural land in Great Britain meaning haulage distances cannot be calculated.

The key 'inflection point' is the change in landbank required (and to a lesser extent the reduction in landbank available) between Scenarios 3 and 4. Within the scenarios there are a number of factors that become increasingly restrictive between Scenarios 3 and 4 (see Appendix I), however, the key parameters are summarised below:

- Ban on applications in the autumn to winter cereals: well over 1 million hectares of the increase in landbank required (or the majority of the difference between Scenarios 3 and 4), is due to the ban on applications to arable crops in the autumn which do not have an autumn crop nitrogen requirement (e.g. winter cereals). This requirement is based on the EA's interpretation of the Farming Rules for Water, and something the water industry (and agriculture industry) dispute. However, the Statutory Guidance provided by Defra which effectively prevents this interpretation does not expire automatically, but is subject to review by September 2025 at the latest.
- Increased restrictions on phosphate management: the restrictions on phosphate applications increases across all the scenarios, but the change between Scenarios 3 and 4 accounts for a little under 100,000 hectares as a result of the return period increasing from an application on average every two years to every three years.

- Quantity of biosolids and phosphate content of biosolids: the increasingly stringent requirements of the Environment Act mean the quantity of phosphorus discharged into watercourses in final effluent must be reduced by 80% by 2035, this combined with predicted increases in population mean there is more biosolids to manage and that biosolids has a greater phosphate content. This results in a little under 100,000 hectares increase in the landbank required and as with the change to rules controlling phosphate management (as detailed above) result in the return period increasing from an application on average every two years to every three years.

The other changes include rules in/around sensitive sites and a decrease in farmer acceptance, increase the landbank required by *c.*100,000 hectares, but the above are the key parameters in increasing the landbank requirement between Scenario 3 (and below) and Scenarios 4 and 5. A study for the UK water industry, using the same scenarios and data from the eleven Water and Sewage Companies (WaSCs) found similar results to this study, namely that there was insufficient land at Scenario 4 for all biosolids to be recycled.

It cannot be ignored that, as detailed above, the one restriction that has the greatest affect on increasing the landbank required is the potential ban on the use of biosolids (and other organic manures) in advance of winter cereals in the autumn. There was a great furore when it became clear this was the EA's interpretation of the Farming Rules for Water in late summer/autumn 2020. This resulted in huge debate within the agricultural community, an EFRA committee hearing and various research studies[1] to understand the logic and possible implications of such an interpretation. This all resulted in the Secretary of State for the Environment introducing Statutory Guidance on how the Farming Rules for Water should be applied. It is vital the use of biosolids (or any nutrient source) provides benefit and does not cause harm to the environment. However, given the huge disagreement over this interpretation and the possible affects it would have on the environment (and agriculture more broadly), it would seem logical that before hundreds of millions of pounds (or even billions of pounds) are spent changing how much/how biosolids is produced, the need/benefit of this potential change must be fully investigated and understood to ensure it does provide benefit and that if it does, the same benefit cannot be provided with less unintended consequences and costs, particularly at a time when water bill payers (and society at large) are seeing their finances under greater and greater pressure as the cost of living increases.

[1] https://assuredbiosolids.co.uk/wp-content/uploads/2021/07/FRFW-biosolids-report.pdf
https://ahdb.org.uk/an-assessment-of-the-impact-of-farming-rules-for-water

Appendix I. Details of landbank scenarios

WINEP Spreadsheet Reference	Risk/Issue	Scenario 1 Historical: 2020	Scenario 2 Baseline: End AMP7	Scenario 3: 10 year Minimal Change	Scenario 4: 10 year Most Likely Change	Scenario 5: 10 year Plausible Maximum Change
1	Sludge (Use in Agriculture) Regulations 1989	Baseline %	Baseline %	-	-	-
7 / 8	EA Sludge Strategy – move to EPR	-	-	No change/changes do not reduce landbank (delays/ uncertainty of waste status do not reduce landbank)	Moderate reduction in farmer acceptance (to model delays/ uncertainty of waste status)	Significant reduction in farmer acceptance (to model delays/ uncertainty of waste status)
9	BAS compliance	Baseline %	Baseline %	Baseline	Baseline	Baseline
12 / 21 / 23	Farmer Acceptance	Baseline %	Small reduction (15%)	Slight reduction (15%	Moderate reduction (25%	Significant reduction (40%)
13	Public perception	Primarily addressed through farmer acceptance concerns, particularly regarding contaminants (see items 39, 42, 43). Any sector specific changes (e.g. a ban on a specific land uses) cannot be modelled as they are unforeseen events that cannot be predicted.				
17 / 57 / 58	Market competition affecting supply / demand of biosolids to land	Baseline	Baseline	Baseline (biosolids quantities will increase in-line with item 26)	Baseline (biosolids quantities will increase in-line with item 26)	Baseline (biosolids quantities will increase in-line with item 26)
18	Flooding (storage)	Cannot be modelled quantitatively as storage changes won't directly affect the quantity of available land				

WINEP Spreadsheet Reference	Risk/Issue	Scenario 1 Historical: 2020	Scenario 2 Baseline: End AMP7	Scenario 3: 10 year Minimal Change	Scenario 4: 10 year Most Likely Change	Scenario 5: 10 year Plausible Maximum Change
24	Climate Change Adaptation and Resilience	Cannot be modelled quantitatively as geographic distribution of any possible changes are unknown				
25 / 31 / 60 / 63	Changing Farming Practices Climate Change Disease (oil seed rape) Increase in low / no-till practices					
	Agricultural Demand for Biosolids - arable Restrictions on arable cropping (due to perceived nutrient concerns)	Baseline %	Reduction in autumn applications on sandy soils (in line with 20 Measures)	Increased restrictions in the autumn on high risk soils (e.g. shallow/lighter)	No autumn applications (except OSR)	No autumn applications (except OSR) and limits on spring cropping

WINEP Spreadsheet Reference	Risk/Issue	Scenario 1 Historical: 2020	Scenario 2 Baseline: End AMP7	Scenario 3: 10 year Minimal Change	Scenario 4: 10 year Most Likely Change	Scenario 5: 10 year Plausible Maximum Change
25 / 31 / 60 / 63	Agricultural Demand for Biosolids - grassland	Baseline %	Baseline %	Slight reduction in demand due to clarification on conventionally treated biosolids, longer no-harvest/grazed period and increased autumn restrictions (reduction in grassland max by 10%)	Severely limit on applications in the autumn, almost. Complete ban on conventional biosolids and longer return periods for enhanced (reduction in grassland max to model reduced grass availability by 20%)	No conventional biosolids to grassland and increased restrictions for enhanced including no autumn applications (reduction in grassland max of 30%)
26	Supply/demand balanced biosolids produced	2020	2025	Low increase (forecast uplift at 2030)	Medium increase (forecast uplift at 2040)	High increase (forecast uplift at 2050)
27	Physical restrictions	BAS Compliance	BAS Compliance	BAS 20 Measures	BAS 20 Measures	BAS 20 Measures
28 / 32 / 35 / 61 / 62	Water Framework Directive and Nutrient Neutrality	BAS Compliance	BAS 20 Measures	BAS 20 Measures	BAS 20 Measures	BAS 20 Measures

WINEP Spreadsheet Reference	Risk/Issue	Scenario 1 Historical: 2020	Scenario 2 Baseline: End AMP7	Scenario 3: 10 year Minimal Change	Scenario 4: 10 year Most Likely Change	Scenario 5: 10 year Plausible Maximum Change
30	Sensitive Catchments	BAS Compliance	Increased restrictions in sensitive catchments (in line with 20 Measures) Land in sensitive catchments will be reduced by 5%)	Greater restrictions in sensitive catchments Amount of available land will be reduced in the catchment by 15%	Tighter restrictions in sensitive catchments Land available in catchments feeding sensitive sites will be reduced by 25%	No spreading in sensitive catchments
61 / 32 / 62 / 29	Phosphorus restrictions	Baseline BNMM restrictions	Increased restrictions at P index 3&4 (in line with 20 Measures)	No application at P index 4 and above. Restrictions remain the same at index 0/1/2/3	No application at P index 4 and above, and increased return period at P index 3	No application at P index 4 and above, applying less than removed at P index 3 and increased restrictions at P index 2

WINEP Spreadsheet Reference	Risk/Issue	Scenario 1 Historical: 2020	Scenario 2 Baseline: End AMP7	Scenario 3: 10 year Minimal Change	Scenario 4: 10 year Most Likely Change	Scenario 5: 10 year Plausible Maximum Change
33	Designated sites / priority habitats	BAS Compliance	Increased restriction near sensitive sites and in SPZ2 (in line with 20 Measures) Land availability near sensitive sites and in SPZ2 will reduce by 5%	Increased restriction near sensitive sites and in SPZ2 (in line with 20 Measures) Land availability near sensitive sites and in SPZ2 will reduce by 15%	Greater restrictions near sensitive sites and in SPZ2 Land availability near sensitive sites and in SPZ2 will reduce by 25%	No spreading within 500m of sensitive sites or within SPZ2
37	25 year environment plan / Environment Act targets	Baseline biosolids composition N/P ratio	Small increase in P content (10%) Increased sludge quantity is covered in item 26	Slight increase in P content (20%) Increased sludge quantity is covered in item 26	Modest increase in P content (40%) Increased sludge quantity is covered in item 26	Sizable increase in P content (50%) Increased sludge quantity is covered in item 26
39 / 29	Chemical Investigation Programme	Baseline %	Baseline %	Slight reduction in farmer acceptance (to model concerns over contaminants)	Modest reduction in farmer acceptance (to model concerns over contaminants)	Reduction in farmer acceptance (to model concerns over contaminants

WINEP Spreadsheet Reference	Risk/Issue	Scenario 1 Historical: 2020	Scenario 2 Baseline: End AMP7	Scenario 3: 10 year Minimal Change	Scenario 4: 10 year Most Likely Change	Scenario 5: 10 year Plausible Maximum Change
42 / 29	Microplastics	Baseline %	Baseline %	Slight reduction in farmer acceptance (to model concerns over contaminants)	Modest reduction in farmer acceptance (to model concerns over contaminants)	Reduction in farmer acceptance (to model concerns over contaminants
43	PFAS	Baseline %	Baseline %	Slight reduction in farmer acceptance (to model concerns over contaminants)	Modest reduction in farmer acceptance (to model concerns over contaminants)	No applications in SPZ2

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