South Oxfordshire and Vale of White Horse
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# South Oxfordshire and Vale of White Horse Joint Local Plan: Net Zero Carbon Study

## Task 6: Renewable Energy Spatial Assessment – methodology

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Bioregional

Written by: Alex McCann (Sustainability Consultant)
Checked by: Marina Goodyear (Senior Consultant) and Lewis Knight (Director of Sustainable Places)

# Contents

# Introduction

Bioregional has been commissioned by South Oxfordshire and Vale of White Horse District Councils (South & Vale) to produce a Renewable Energy Spatial Assessment (RESA).

The scope of the RESA is to identify suitable broad locations for renewable energy development. It is not intended to pinpoint specific locations for renewable energy sites at a granular level.

It is important to note that this study does not intend to rule out areas for renewable energy development where they have been found to be unsuitable. It is the right of the renewable energy developer to produce a case to justify whether a specific site is suitable or not, under site-specific conditions at a more granular level than the RESA addresses, which subsequently may comprise an area identified as unsuitable in this study. However, for the purpose of planning decision-making, the RESA acts as a mechanism to accord with paragraph 160(b) of the National Planning Policy Framework, that states local plans should "consider identifying suitable areas for renewable and low carbon energy sources, and supporting infrastructure, where this would help secure their development".

The intended use of the RESA is for Development Management officers and renewable energy developers to ensure a common resource is available to enable consistent decision-making, encourage applications and help secure development of renewable energy schemes in South & Vale.

All renewable energy development remains subject to detailed assessment at the planning application stage, and that being situated in an appropriate location does not immediately determine an application suitable and recommended for permission.

The RESA assesses various renewable energy technologies, which are as follows:

- Ground-mounted solar photovoltaics (PV) – various sizes
- Onshore wind – various sizes
- Battery energy storage systems
- District heating
- Hydropower

This study is complemented by *the Landscape Sensitivity Assessment for Wind and Solar Development* (LSA), recently produced by Land Use Consultants (LUC).

Drawing on the outputs of the LSA, the RESA takes into account planning, spatial and technical constraints of the various technologies. The methodology process is set out below, with additional justification on input and layer selection found in Appendix 1. To visualise the mapping process, Appendix 2 sets out sample maps for each technology.

# Methodology

## Ground-mounted solar PV

Ground-mounted solar PV development consists of a large number of solar panels often located in rural areas away from urban settlements. Areas of suitability for ground-mounted solar PV will be determined at different sizes according to five thresholds of solar PV development sites, which are derived from the LUC report[1]:

| Code name | PV site size | Approximate MW capacity |
|---|---|---|
| PV1 | Up to 1 hectare | <1 MW |
| PV2 | 1 – 5 hectares | 1 – 4 MW |
| PV3 | 5 – 20 hectares | 5 – 15 MW |
| PV4 | 20 – 50 hectares | 16 – 40 MW |
| PV5 | 50 – 120 hectares | 41 – 100 MW |

The LSA outputs show different sensitivity levels of 14 identified Landscape Character Types (LCTs), according to a 5-tier scoring system:

1. High sensitivity (i.e. less suitable)
2. Moderate-high sensitivity
3. Moderate sensitivity
4. Low-moderate sensitivity
5. Low sensitivity (i.e. more suitable)

Based on the LSA, the assumption made for this RESA is that all levels but level 1 (high sensitivity) are potentially suitable for ground-mounted solar PV development. It is important to note that this study does not intend to strictly rule out LCTs scored as level 1 but such areas can be determined to be less suitable due to their landscape impact and are therefore excluded from this exercise.

The methodology described as follows provides multiple outputs to South & Vale to use. These begin with the key primary constraints layer that intends to provide a strong view on whether areas are suitable or not. Subsequent layers will explore additional scopes of suitability that involve technical performance of solar PV and secondary constraints that should be considered at the planning application stage. Two key Search Area outputs are produced, after Layer 2 and Layer 5.

The following methodology for ground-mounted PV is applied to all five thresholds of solar PV development sites[2].

### 1. Primary constraints

Layer 1 directly addresses ruling out designated areas considered to be unsuitable at a national level. Additionally, any land that already has an operational or consented renewable energy development site is excluded. The following areas are therefore ruled out for ground-mounted solar PV development:

a. Special Areas of Conservation (SAC)
b. National Nature Reserves
c. Registered Historic Parks and Gardens
d. Registered battlefields
e. Site of Special Scientific Interest (SSSI)
f. Scheduled monuments
g. Operational/consented renewable energy development sites
h. Bodies of water (rivers, canals, lakes and reservoirs)

Special Protection Areas and RAMSAR sites were considered in the development of the methodology but are not included in the final outputs as none of either are located within South & Vale.

Layer 1 also rules out any LCT that is scored as high sensitivity (level 1) in the LSA. Areas scored as levels 2 – 5 are considered suitable for step 2.

### 2. Buffer and exclusion zones

Layer 2 intends to minimise potential impacts on residents or infrastructure by applying various buffers onto Layer 1.

The following buffers or exclusion zones are applied:

a. Ancient woodland – 15 metres to avoid root damage
b. Residential and non-residential buildings – 20 metres to avoid disruption
c. Major and minor transport infrastructure (open roads and railway lines) – 20 metres

[1] More information on the methodology used to determine landscape sensitivity can be found in the LSA study.

[2] Additional justification for the selected inputs is found in Appendix 1.

d. MoD sites and safeguarded zones – specific buffer zones according to site size (not included in publicly available outputs due to sensitivity reasons)
e. Airports/aerodromes

### Key output: Search Area 1

Search Area 1 combines the constraints from Layers 1 and 2 to produce an output of potentially suitable and unsuitable and land for ground-mounted solar PV development.

Any land identified as potentially suitable for Search Area 1 that does not meet the minimum size (measured in hectares) associated with the 5 sizes of solar PV development are removed. For example, for the PV5 Search Area 1, any potentially suitable land that does not exceed 50 hectares is removed from the final output in order to ensure that any remaining potentially suitable land is able to accommodate the MW capacity associated with the estimated land area for that solar PV development size threshold.

Land identified as unsuitable in the Search Area 1 output is highly unlikely to be suitable for solar PV development in any case. Search Area 1 should be used as a tool to determine whether planning applications for renewable energy development are located in suitable areas.

## 3. Technical performance

Layer 3 draws on Layer 2 by mapping landscape factors that impact solar PV technical performance to ensure that subsequent land identified as suitable in Layer 2 is appropriate from an efficiency perspective.

It is important to note that it is the choice and responsibility of the renewable energy development to determine whether a suitable area would enable high solar PV efficiency. However, Layer 3 is a useful resource for both Development Management officers and renewable energy developers to better understand the potential technical performance of suitable areas.

The following assumptions have been made and mapped:

- All areas with inclinations of 0 – 3 degrees from the horizontal are assumed suitable and optimal for solar PV development.
- For areas with inclination between 3 – 15 degrees from the horizontal, only south-west to south-east facing areas are assumed to be suitable for solar PV development.
- All other areas (15 degrees inclination or higher) were deemed unsuitable for solar PV development.

## 4. Secondary constraints

Layer 4 addresses additional secondary constraints that will impact planning application decision making, but do not strictly rule out areas that have been identified by preceding layers.

The following secondary constraints will be applied and mapped for Layer 4:

a. National Landscapes
b. Flood Zones 2 and 3
c. Green Belt
d. Conservation Areas
e. Best and most versatile agricultural land (only includes grades 1 and 2 as 3a and 3b were not defined in dataset)
f. Oxford View Cones

## 5. Grid constraints

Layer 5 addresses the feasibility of grid connection. As with the assumptions made in Layer 3, it is the decision of the renewable energy developer to determine which areas are feasible and viable for a renewable energy development site, in liaison with the Distribution Network Operator. However, Layer 5 is a useful addition to preceding layers to understand the likelihood of whether a suitable area determined by Layers 1 – 5 is suitable in terms of grid connection availability.

The following data was extracted from Scottish and South Electricity Networks and UK Power Networks databases for Layer 5:

- Primary Substation Supply Areas

Any areas with more than 5% over capacity are determined to be constrained at the time of this study. These areas should be monitored and checked in future decision making as grid upgrades may occur.

### Key output: Search Area 2

The final output, Search Area 2, combines all layers produced as above for ground-mounted solar PV development by presenting potentially suitable and unsuitable areas of land. Potentially suitable land under this output represents a higher level of suitability than Search Area 1 for solar PV because no identified constraints are present. However, it is important note that some constraints may have not been identified by this methodology.

In contrast to the Search Area 1 output, unsuitable land in the Search Area 2 output should not be determined to be as immediately unsuitable and rejected for solar PV proposals because many of the inputs from Layers 3-5 are subject to local circumstances and should be assessed on a case-by-case basis.

## Onshore wind

Onshore wind development consists of wind turbines placed inland, often in remote rural areas away from urban settlements. Areas of suitability for onshore wind will be determined according to five thresholds of onshore wind development sites, which are derived from the LUC report[3]:

| Code name | Onshore wind turbine size – tip height | Approximate MW capacity |
|---|---|---|
| OW1 | <25 metres | <250 kW |
| OW2 | 25 – 60 metres | <500 kW |
| OW3 | 60 – 100 metres | 500 kW – 1 MW |
| OW4 | 100 – 150 metres | 1 – 2.5 MW |
| OW5 | 150 – 220 metres | >2.5 MW |

As above, in comparison to ground-mounted solar PV, onshore wind will be determined according to turbine size rather than a whole onshore wind development site

The LSA outputs show different sensitivity levels of 14 identified Landscape Character Types (LCTs), according to a 5-tier scoring system:

1. High sensitivity (i.e. less suitable)
2. Moderate-high sensitivity
3. Moderate sensitivity
4. Low-moderate sensitivity
5. Low sensitivity (i.e. more suitable)

Based on the LSA, the assumption made for this RESA is that all levels but level 1 (high sensitivity) are potentially suitable for onshore wind development. It is important to note that this study does not intend to strictly rule out LCTs scored as level 1, but such areas can be determined to be less suitable due to their landscape impact and are therefore excluded from this exercise.

The methodology described as follows provides multiple outputs to South & Vale to use. These range from the key primary constraints layer that intends to provide a strong view on whether areas are suitable or not. Subsequent layers, using the primary constraints layer as a foundation, explore additional scopes of suitability that involve technical performance of onshore wind and secondary constraints that should be considered at the planning application stage.

The following methodology for onshore wind is applied to all five thresholds of onshore wind development sites.[4]

### 1. Primary constraints

Layer 1 directly addresses ruling out designated areas considered to be unsuitable at a national level. Additionally, any land that already has an operational or consented renewable energy development site is excluded. The following areas are therefore ruled out for onshore wind development:

a. Special Areas of Conservation (SAC)
b. National Nature Reserves
c. Registered Historic Parks and Gardens
d. Registered battlefields
e. Site of Special Scientific Interest (SSSI)
f. Scheduled monuments
g. Operational/consented renewable energy development sites
h. Bodies of water (rivers, canals, lakes and reservoirs)

Special Protection Areas and RAMSAR sites were considered in the development of the methodology but are not included in the final outputs as none of either are located within South & Vale.

Layer 1 also rules out any LCT that is scored as high sensitivity (level 1) in the LSA. Areas scored as levels 2 – 5 are considered suitable for step 2.

### 2. Buffer and exclusion zones

Layer 2 intends to minimise potential impacts on residents or infrastructure by applying various buffers onto Layer 1.

The following buffers are applied:

a. Ancient woodland – 15 metres to avoid root damage
b. Residential and non-residential buildings
   - Noise buffer:
     - **OW1-2**: 300m
     - **OW3**: 400m
     - **OW4**: 500m

[3] More information on the methodology used to determine landscape sensitivity can be found in the LSA study.

[4] Additional justification for the selected inputs is found in Appendix 1.

- **OW5**: 600m
  - Topple distance – tip height + 10%

c. Major and minor transport infrastructure (open roads and railway lines)
  - Topple distance – tip height + 10%

d. MoD sites and safeguarded zones – specific buffer zones according to site size (not included in publicly available outputs due to sensitivity reasons)

e. Airports/aerodromes

## Key output: Search Area 1

Search Area 1 combines the constraints from Layers 1 and 2 to produce an output of potentially suitable and unsuitable and land for onshore wind development.

Land identified as unsuitable in the Search Area 1 output is highly unlikely to be suitable for onshore wind development in any case. Search Area 1 should be used as a tool to determine whether planning applications for renewable energy development are located in suitable areas.

## 3. Technical performance

Layer 3 draws on Layer 2 by mapping factors that impact onshore wind technical performance to ensure that subsequent land identified as suitable in Layer 2 is appropriate from an efficiency perspective.

It is important to note that it is the choice and responsibility of the renewable energy development to determine whether a suitable area would enable high onshore wind efficiency. However, Layer 3 is a useful resource for both Development Management officers and renewable energy developers to better understand the potential technical performance of suitable areas.

Using average wind speed, with speed measured at 50m above ground level, it is assumed that 5.0 metres/second is sufficient to determine an area as suitable for onshore wind development from a technical performance perspective.

## 4. Secondary constraints

Layer 4 addresses additional secondary constraints that will impact planning application decision making but do not strictly rule out areas that have been identified by preceding layers.

The following secondary constraints will be applied and mapped for Layer 4:

a. National Landscapes
b. Flood Zones 2 and 3
c. Green Belt
d. Conservation Areas
e. Oxford View Cones

## 5. Grid constraints

Layer 5 addresses the feasibility of grid connection. As with the assumptions made in Layer 3, it is the decision of the renewable energy developer to determine which areas are feasible and viable for a renewable energy development site, in liaison with the Distribution Network Operator. However, Layer 5 is a useful additional to preceding layers to understand the likelihood of whether a suitable area determined by Layers 1 – 4 is suitable in terms of grid connection availability.

The following data was extracted from Scottish and South Energy Networks and UK Power Networks databases for Layer 5:

- Primary Substation Supply Areas

Any areas with more than 5% over capacity are determined to be constrained at the time of this study. These areas should be monitored and checked in future decision making as grid upgrades may occur.

## Key output: Search Area 2

The final output, Search Area 2, combines all layers produced as above for onshore wind development by presenting potentially suitable and unsuitable areas of land. Potentially suitable land under this output represents a higher level of suitability than Search Area 1 for onshore wind because no identified constraints are present. However, it is important note that some constraints may have not been identified by this methodology.

In contrast to the Search Area 1 output, unsuitable land in the Search Area 2 output should not be determined to be as immediately unsuitable and rejected for onshore wind proposals because many of the inputs from Layers 3-5 are subject to local circumstances and should be assessed on a case-by-case basis.

## Battery storage

Battery storage development, or battery energy storage systems, consists of a number of batteries that store electricity, often generated by renewable energy sources. This electricity can be stored during periods of high electricity generation and dispatched during periods of high consumer demand.

Suitable areas for battery energy storage systems (BESS) will be broadly determined by the following mapping exercises. Since BESS sites can vary significantly by size from 1 – 30 acres, broad suitable locations are identified. Additionally, the technology has not been assessed in the LUC LSA study. Therefore, the methodology for battery storage is not informed by different levels of development size[5].

For areas found to be suitable for battery storage, approximately 4MW of storage can be developed in an area of 1 acre. This is a rule of thumb reference to understand what scale of capacity may be possible for areas identified as suitable for battery storage. The below methodology does not assume a certain level of battery storage capacity.

### 1. Primary constraints

Layer 1 directly addresses ruling out designated areas considered to be unsuitable at a national level. Additionally, any land that already has an operational or consented renewable energy development site is excluded. The following areas are therefore ruled out for BESS sites:

a. Special Areas of Conservation (SAC)
b. National Nature Reserves
c. Registered Historic Parks and Gardens
d. Registered battlefields
e. Site of Special Scientific Interest (SSSI)
f. Scheduled monuments
g. Operational/consented renewable energy development sites
h. Bodies of water (rivers, canals, lakes and reservoirs)

Special Protection Areas and RAMSAR sites were considered in the development of the methodology but are not included in the final outputs as none of either are located within South & Vale.

### 2. Buffer and exclusion zones

Layer 2 intends to minimise potential impacts on residents or infrastructure by applying various buffers onto Layer 1.

The following buffers are applied:

a. Ancient woodland – 15 metres to avoid root damage
b. Residential and non-residential buildings – 100 metres noise buffer and to minimise disruption to residents
c. Major and minor transport infrastructure (open roads and railway lines) – 20 metres
d. MoD sites and safeguarded zones – specific buffer zones according to site size (not included in publicly available outputs due to sensitivity reasons)
e. Airports/aerodromes

### Key output: Search Area 1

Search Area 1 combines the constraints from Layers 1 and 2 to produce an output of potentially suitable and unsuitable and land for battery storage development.

Land identified as unsuitable in the Search Area 1 output is highly unlikely to be suitable for battery storage development in any case. Search Area 1 should be used as a tool to determine if planning applications for renewable energy development are located in suitable areas.

### 3. Slope angle suitability

Layer 3 draws on Layer 2 by mapping landscape factors that impact suitability of BESS sites. The primary factor is slope angle, since BESS sites must be situated on flat land. Therefore, the following assumption is made:

- All areas with inclinations of 0 – 3 degrees from the horizontal are assumed suitable and optimal for BESS sites.

### 4. Secondary constraints

Layer 4 addresses additional secondary constraints that will impact planning application decision making but do not strictly rule out areas identified by preceding layers.

The following secondary constraints will be applied and mapped for Layer 4:

1. National Landscapes
2. Flood Zones 2 and 3
3. Green Belt
4. Conservation Areas
5. Best and most versatile agricultural land
6. Oxford View Cones

[5] Additional justification for the selected inputs is found in Appendix 1.

## 5. Grid constraints

Layer 5 addresses the feasibility of grid connection. As with the assumptions made in Layer 3, it is the decision of the renewable energy developer to determine which areas are feasible and viable for a renewable energy development site, in liaison with the Distribution Network Operator. However, Layer 5 is a useful additional to preceding layers to understand the likelihood of whether a suitable area determined by Layers 1 – 4 is suitable in terms of grid connection availability.

The following data was extracted from Scottish and South Energy Networks and UK Power Networks databases for Layer 5:

- Primary Substation Supply Areas

Any areas with more than 5% over capacity are determined to be constrained at the time of this study. These areas should be monitored and checked, in liaison with the DNO, for future decision making as grid upgrades may occur.

### Key output: Search Area 2

The final output, Search Area 2, combines all layers produced as above for battery storage development by presenting potentially suitable and unsuitable areas of land. Potentially suitable land under this output represents a higher level of suitability than Search Area 1 for battery storage because no identified constraints are present. However, it is important note that some constraints may have not been identified by this methodology.

In contrast to the Search Area 1 output, unsuitable land in the Search Area 2 output should not be determined to be as immediately unsuitable and rejected for battery storage proposals because many of the inputs from Layers 3-5 are subject to local circumstances and should be assessed on a case-by-case basis. because many of the inputs from Layers 3-5 are subject to local circumstances and should be assessed on a case-by-case basis.

## District heating

District heating, also known as heat networks, is a system for distributing heat generated in a centralised location for residential and commercial heating requirements such as space heating and water heating. Heat has typically been obtained from a combined heat and power from burning fossil fuels or biomass, but geothermal heating and large heat pumps are being increasingly selected as heat generation sources for district heating.

District heating works by generating heat, or using waste heat, and feeding this to consumers through a system of highly insulated pipes.

District heating systems can provide higher efficiencies and better pollution control than individual unit boilers. They are a particularly attractive option in dense urban areas and represent one approach to tackle fuel poverty and reduce housing maintenance costs.

In the UK, there is considerable support for the expansion of such heating networks. As the UK transitions to net zero over the coming decades, more connections to district heating networks are expected.

Please note that this study does not support the development of new gas-powered combined heat and power district heating networks. This study supports the development of large-scale heat pump heat networks, alongside geothermal networks where appropriate.

It is important to state that heat pump district heating networks are only zero carbon if powered entirely by renewable energy. If powered by the electricity grid, these networks are considered low carbon as the UK grid is currently still partially powered by fossil fuels.

### Heat density

To determine suitable areas for district heating opportunities in South & Vale, heat density is primarily assessed. For this study, heat density is defined by the number of units of heat demanded by buildings per km$^2$. More buildings in dense areas with high demand for heat (i.e. industrial buildings) results in a higher heat density.

Heat density is assessed by dividing the annual heat demand (kWh) of individual units by the number of hours in a year (8760), which results in a kW value for annual heat demand. The threshold assumption to determine whether a district heating network could be feasible and/or viable is set at **3000 kW/km$^2$**. The metric and value have been industry standard since it was set out in a report for the UK government in 2009.

The dataset used provides annual heat demand of individual domestic and non-domestic buildings, which is represented as a kWh value. A kW value determined from the dataset by dividing the annual heat demand in kWh by 8760, which enables a direct comparison to the assumption stated above.

To assess whether areas of South & Vale meet the assumed threshold, a 1km$^2$ grid is set, with the heat density of units falling within each 1km grid square combined. 1km$^2$ is set as grid area as this aligns with the heat density assumption used, which is measured as kW/km$^2$. Any 1km grid squares with a heat density above the threshold are determined to be heat network opportunity areas.

As above, the mapping process was as follows:

1. Input heat demand data per building throughout South & Vale
2. Create 1km$^2$ grid layer covering South & Vale
3. Combine the building-level heat demand input layer and the 1km$^2$ layer
4. Calculate the cumulative heat demand of all buildings falling in each respective 1km grid square
5. Any grid square with a heat density of at least 3000 kW/km$^2$ is identified as a heat network opportunity area

### Opportunities from heat waste sites

To identify opportunities for use of waste heat, existing facilities are identified from uses such as anaerobic digestion plants and data centres. These plants generate heat when producing energy and therefore present an opportunity for district heating in some cases. A 1km buffer is applied to identified sites to determine whether any 1km grid squares that have sufficient heat density fall within this range.

The following sites have been identified as potential heat waste sites:

- Didcot Power Station B
- Wallingford Anaerobic Digestion Plant
- Didcot Data Centre

### Locational factors

Locational factors can impact the potential for district heating networks as constraints may be evident that limit pipework to end users. Such implications are likely to primarily consist of transport infrastructure and surface water. Therefore, the following layers are presented on the map alongside heat density and heat waste opportunities:

- Major and minor transport infrastructure (open roads and railway lines)
- Bodies of water (e.g. lakes, rivers, reservoirs etc.)

These layers are not assessed further as assumptions around district heating pipework are highly variable based on the specific scheme. They should also not be viewed as hard constraints since surface water features can also provide opportunities for water-source heat pumps.

### Previously identified district heating opportunities

Previously identified opportunities for district heating from the Didcot Garden Town Heat Mapping and Energy Masterplanning by AECOM in 2017 will be exported as an output. Although the study was produced in 2017, the opportunity areas are likely to still be suitable for heat networks. The five clusters identified listed below are mapped as Key Existing Areas of Interest:

- Culham
- North Didcot
- Harwell
- South Gateway
- Science Vale Cluster (possible interlinkage between Culham and North Didcot)

### Water-source heat pump opportunities

Potential opportunities where water-source heat pumps could be utilised for district heating networks are determined by identifying where large bodies of water are adjacent to strategic site allocations where significant development is likely to occur in the near future. The following sites have been identified:

- Culham residential site allocation (River Thames)
- Berinsfield residential site allocation (Queensford Lakes)

## Hydropower

Hydro power is a form of electricity generation that occurs through the movement of water. Opportunities have been identified at a high level through identifying river obstacles, which are the following features:

- Waterfalls
- Weirs
- Locks

These river obstacles offer potential opportunities for hydro technology to be installed as these are features that often result in enhanced water flow.

Please note that the identification of these river obstacles does not determine a site suitable for hydro power. Further site-specific investigation and feasibility assessments will be required to determine whether a river obstacle site is suitable in practice for hydro power development.

## Data limitations

The methodology developed for this desk-based study is appropriate for locating high-level suitable areas for renewable energy generation technologies. Local conditions and factors at a granular level have not been taken into accounted, whilst no site visits of identified suitable locations have occurred. The outputs produced are directly informed by the methodology set, with no further analysis undertaken on suitable areas. Therefore, it is possible that some areas identified as suitable will be found to be unsuitable once site-level detail has been considered.

No manual data cleaning of the GIS shapefiles downloaded has been undertaken. Therefore, some data inaccuracies may occur and result in constraints not being visible on areas where constraints are in fact present upon a site visit or once a site-specific assessment has been completed.
Additional levels of detail and increased consideration of the local setting should be applied when assessing an area identified as suitable in this study. For example, the river data used is line data and does not consider the full width of rivers in practice, although a 5m buffer is applied to account for some river extent. Additionally, some data may be missing in particularly dynamic river areas where flow levels vary significantly.

# Appendix 1: Justification of mapping inputs

## Ground-mounted solar PV

| Layer | Input | Reason |
|---|---|---|
| **Primary constraints** | Special Areas of Conservation (SAC) | This is a national nature conservation designation and therefore not a suitable location for solar PV development and has subsequently been excluded. |
| | National Nature Reserves | This is a national nature conservation designation and therefore not a suitable location for solar PV development and has subsequently been excluded. |
| | Historic Parks and Gardens | This is a designated heritage asset and therefore not a suitable location for solar PV development and has subsequently been excluded. |
| | Registered battlefields | This is a designated heritage asset and therefore not a suitable location for solar PV development and has subsequently been excluded. |
| | Site of Special Scientific Interest | This is a national nature conservation designation and therefore not a suitable location for solar PV development and has subsequently been excluded. |
| | Scheduled monuments | This is a designated heritage asset and therefore not a suitable location for solar PV development and has subsequently been excluded. |
| | Operational/consented renewable energy sites | This land already contains renewable energy development and is therefore not available land for solar PV development. |
| | LUC high sensitivity areas | This land is assumed to be unsuitable for solar PV development. The other 4 sensitivity levels are not ruled out but will be assessed in more detail at the application stage.[6] |
| | Bodies of water (rivers, canals, lakes and reservoirs) | Unsuitable for renewable energy development. Innovative renewable energy technologies such as floating solar PV have been developed but are typically less economical and feasible than alternative renewable energy generation methods and are therefore not considered. A 5m buffer is applied to the line data used for rivers to ensure that some extent of river extent and width is accounted for. |
| **Buffer and exclusion zones** | Ancient woodland | These are defined in the NPPF as irreplaceable habitats and are therefore protected areas. As a result, they are not a suitable location for solar PV development and have subsequently been excluded. |

[6] [6] More information on the methodology used to determine landscape sensitivity can be found in the LSA study.

| | | |
|---|---|---|
| | | Government guidance suggests a minimum 15m buffer from the boundary of the woodland to avoid root damage (known as the root protection area). Additional buffers may be set where appropriate for specific applications. |
| | Residential and non-residential buildings[7] | These areas are already developed and therefore would not be available for solar PV development.<br>A 20m buffer is set as this is considered to be a reasonable distance to ensure that solar PV development is not located directly adjacent to identified buildings or land immediately surrounding them, alongside mitigating risks from effects such as glare. Additional buffers may be set for specific applications. |
| | Major and minor transport infrastructure[4] | Major and minor transport infrastructure includes open roads and railway lines.<br>A 20m buffer is set as this is considered to be a reasonable distance to avoid disruption to transport infrastructure from the development and operation of solar PV sites. Situating solar PV sites any closer to infrastructure would increase safety risk and could impact those using transport infrastructure due to glare from solar panels for example. Additional buffers may be set for specific applications. |
| | MoD sites and safeguarded zones | This layer is not included as part of the final outputs as the data is publicly sensitive. However, it will be considered for individual applications throughout the internal decision-making process to ensure development does not fall in any designated sites or zones.<br>The MoD sets various boundaries as exclusion zones for different types of development in proximity to MoD sites. For solar PV, additional risks posed by panels could be from glare, which may interfere with airfield operations.<br>The MoD may be consider allowing development of renewable energy within its estate. This would however be considered on a case-by-case basis. Direct consultation with the MoD would be required to determine the potential suitability of renewable development in or near its estate. |
| | Airports/aerodromes | This land already contains development and is therefore unsuitable for solar PV development. |
| **Technical performance** | Slope and aspect assumptions[4] | Specific assumptions, as set out under Layer 3, have been made to rule out areas technically not suitable for renewable energy development. The subsequent suitable areas identified are likely to be looked at by renewable energy developers whilst other areas would be ruled out.<br>The assumptions have been selected because solar PV panels are most efficient when facing south and not placed on steep slopes. Land identified as fairly flat (between 0-3 degrees) is suitable because the PV panels can be orientated south. Steeper land (3-15 degrees) is only identified as suitable when it faces SE-SW – i.e. PV panels orientated south on a north-facing slope would result in an inefficient solar PV development due to shading from the slope. |
| **Secondary constraints** | National Landscapes | These inputs are designations where development may not be suitable on but will not strictly rule out development proposed. Suitability of developments relating to these outputs will be assessed on a case-by-case basis. It is likely that exceptional circumstances would have to be demonstrated by renewable energy development proposals to justify development on these designations. |
| | Flood Zones 2 and 3 | |

[7] This assumption has been made as a guideline from Bioregional judgement and is aligned to industry standard.

| | | |
|---|---|---|
| | Green Belt<br><br>Conservation Areas<br><br>Best and Most Versatile agricultural land (defined as grade 1, 2 or 3a of the Agricultural Land Classification) | It is important to consider higher risk flood zones to ensure that renewable energy development in these areas can be safely developed without increasing flood risk elsewhere. Any proposed renewable energy sites in Flood Zones 2 and 3 would be subject to a flood risk assessment to justify its location within a flooding context. Although not a hard constraint, it is important that proposed renewable energy sites demonstrate that there are no safer alternative sites and that the development provides wider sustainability benefits that outweigh risks from floods. To enhance flood resilience, solar PV and on-site infrastructure could be installed on raised platforms.<br><br>Due to the need for the UK to meet its net zero and renewable energy targets, setting National Landscapes and Conservation Areas as primary constraints, and therefore excluding renewable energy development, would be overly restrictive. Additionally, current planning policy does not prohibit renewable energy development in National Landscapes to the same degree of the primary constraints.<br><br>Specifically for Green Belt land, there is an established precedent for solar PV development being approved within designated land as such development was not deemed to affect the 'openness' of the designation. Exceptional circumstances have been granted to many solar PV development as a result of their environmental benefit, outweighing any other potential impacts to Green Belt land.<br><br>When considering Best and Most Versatile agricultural land, the May 2024 Written Ministerial Statement sets out that due weight must be given to the proposed use of such land. Impacts to these agricultural classifications should be minimised and use of poorer quality land should be preferred. High quality land should always be considered as least appropriate. However, Best and Most Versatile agricultural land is not entirely ruled out when considering its use for solar PV development where it can be demonstrated that negative impacts are not widespread. |
| | Oxford View Cones | The Oxford View Cones are a set of ten protected viewpoints around Oxford that offer iconic views of the city's historic skyline. These views are cherished for their cultural and historical significance, showcasing Oxford's unique architectural heritage.<br><br>The View Cones are used in this study to show where renewable energy development may be visible from Oxford, which may impact the historic character of the city and therefore may not be suitable in identified areas. Specific circumstances may have to be demonstrated to justify development in visible areas. |
| **Grid constraints** | Primary substation supply areas | This input informs grid connection suitability of areas identified as suitable for renewable energy development in Layers 1-4. The data represents a high-level indication of suitability, which should be clarified with the Distribution Network Operator in the specific case of the proposed renewable energy site. This study considers grid connection suitability as whether there is available grid capacity for new renewable energy development to connect to. If no capacity is available, the area is not suitable for grid connection as the additional energy would overload the local grid. Suitable areas are considered to have some level of headroom for additional connection.<br><br>Renewable energy development can connect to the grid through a number of methods, such as through connecting to a primary substation. Alternative options other than primary substations are possible for some schemes but using primary substation supply areas represents an accurate proxy of available grid capacity in South & Vale. Additionally, large scale renewable energy sites require a 33kV connection, which is the voltage primary substations operate at. Therefore, the input used for this layer ensures that a wide variety of renewable energy development size is applicable.<br><br>This input is not considered to be a restriction to renewable energy development as grid capacity upgrades may occur after the publication of this study. |

## Onshore wind

| Layer | Input | Reason |
|---|---|---|
| **Primary constraints** | Special Areas of Conservation (SAC) | This is a national nature conservation designation and therefore not a suitable location for onshore wind development and has subsequently been excluded. |
| | National Nature Reserves | This is a national nature conservation designation and therefore not a suitable location for onshore wind development and has subsequently been excluded. |
| | Historic Parks and Gardens | This is a designated heritage asset and therefore not a suitable location for onshore wind development and has subsequently been excluded. |
| | Registered battlefields | This is a designated heritage asset and therefore not a suitable location for onshore wind development and has subsequently been excluded. |
| | Site of Special Scientific Interest | This is a national nature conservation designation and therefore not a suitable location for onshore wind development and has subsequently been excluded. |
| | Scheduled monuments | This is a designated heritage asset and therefore not a suitable location for onshore wind development and has subsequently been excluded. |
| | Operational/consented renewable energy sites | This land already contains renewable energy development and is therefore not available land for onshore wind development. |
| | LUC high sensitivity areas | This land is assumed to be unsuitable for renewable energy development. The other 4 sensitivity levels are not ruled out but will be assessed in more detail at the application stage. |
| | Bodies of water (rivers, canals, lakes and reservoirs) | Unsuitable for renewable energy development. A 5m buffer is applied to the line data used for rivers to ensure that some extent of river extent and width is accounted for. |
| **Buffer and exclusion zones** | Ancient woodland | These are defined in the NPPF as irreplaceable habitats and are therefore protected areas. As a result, they are not a suitable location for onshore wind development and have subsequently been excluded.<br>Government guidance suggests a minimum 15m buffer from the boundary of the woodland to avoid root damage (known as the root protection area). Additional buffers may be set where appropriate for specific applications. |
| | Residential and non-residential buildings[8] | These areas are already developed and therefore would not be available for onshore wind development.<br>Noise buffers are applied based on turbine size, as larger turbines will create more noise than smaller turbines. These assumptions have been based on a judgement of typical wind turbine requirements in order to mitigate audible impacts from onshore wind |

[8] These assumptions have been made as a guideline from Bioregional judgement and are aligned to industry standard.

| | | |
|---|---|---|
| | | turbines to building occupiers. In practice, the required minimum distance between a wind farm and residential properties is site-specific, influenced by the proposed turbine and the ambient background noise.<br>Topple distances are also applied to ensure that building structures are not damaged in the unlikely event of a wind turbines toppling over. A 10% buffer is included on the turbine tip height for additional safety measures.<br>Additional buffers may be set for specific applications. |
| | Major and minor transport infrastructure[9] | Major and minor transport infrastructure includes open roads and railway lines.<br>Topple distances are also applied to ensure that transport infrastructure is not damaged in the unlikely event of a wind turbines toppling over. A 10% buffer is included on the turbine tip height for additional safety measures.<br>No noise buffer is set as audible impact from wind turbines is not considered to be significant to the uses of transport infrastructure.<br>Additional buffers may be set for specific applications. |
| | MoD sites and safeguarded zones | This layer is not included as part of the final outputs as the data is publicly sensitive. However, it will be considered for individual applications throughout the internal decision-making process to ensure development does not fall in any designated sites or zones.<br>The MoD sets various boundaries as exclusion zones for different types of development in proximity to MoD sites. For onshore wind, additional risks posed by turbines could be from radar interference, which may interfere with airfield operations.<br>The MoD may be consider allowing development of renewable energy within its estate. This would however be considered on a case-by-case basis. Direct consultation with the MoD would be required to determine the potential suitability of renewable development in or near its estate. |
| | Airports/aerodromes | This land already contains development and is therefore unsuitable for onshore wind development. |
| **Technical performance** | Wind speed[6] | Specific assumptions, as set out under Layer 3, have been made to rule out areas technically not suitable for renewable energy development. The subsequent suitable areas identified are likely to be looked at by renewable energy developers whilst other areas would be ruled out.<br>Wind speed is the crucial factor when assessing onshore wind technical suitability. The minimum commercially viable average wind speed benchmark ranges from 5 m/s to 7 m/s at 50 meters above ground level. In practice, most developers currently focus on sites with wind speeds exceeding 6 m/s, prioritising the windiest locations. The threshold wind speed is largely influenced by electricity prices and available financial incentives. As the windiest sites are developed, progressively lower wind speeds are likely to be considered.<br>Technically, areas with wind speeds of 5 m/s or higher at 50m above ground level are suitable for onshore wind turbines. This is the standard approach in the UK wind industry. Setting the threshold value at the lower limit of 5 m/s ensures that future opportunities assessed by this study are not unfavoured due to current efficiency conditions. |
| **Secondary constraints** | National Landscapes | These inputs are designations where development may not be suitable on but will not strictly rule out development proposed. Suitability of developments relating to these outputs will be assessed on a case-by-case basis. It is likely that exceptional |

[9] These assumptions have been made as a guideline from Bioregional judgement and are aligned to industry standard.

| | | |
|---|---|---|
| | Flood Zones 2 and 3 | circumstances would have to be demonstrated by renewable energy development proposals to justify development on these designations.<br>It is important to consider higher risk flood zones to ensure that renewable energy development in these areas can be safely developed without increasing flood risk elsewhere. Any proposed renewable energy sites in Flood Zones 2 and 3 would be subject to a flood risk assessment to justify its location within a flooding context. Although not a hard constraint, it is important that proposed renewable energy sites demonstrate that there are no safer alternative sites and that the development provides wider sustainability benefits that outweigh risks from floods. To enhance flood resilience, onshore wind turbines and on-site infrastructure could be installed on raised platforms to ensure the base of the turbine is not impacted by flooding.<br>Due to the need for the UK to meet its net zero and renewable energy targets, setting National Landscapes and Conservation Areas as primary constraints, and therefore excluding renewable energy development, would be overly restrictive. Additionally, current planning policy does not prohibit renewable energy development in National Landscapes to the same degree of the primary constraints.<br>Specifically for Green Belt land, there is an established precedent for onshore wind development being approved within designated land as such development was not deemed to affect the 'openness' of the designation. Exceptional circumstances have been granted to many onshore wind developments as a result of their environmental benefit, outweighing any other potential impacts to Green Belt land.<br>Best and Most Versatile agricultural land is not included in the methodology for onshore wind as agricultural activity can occur alongside onshore wind development. |
| | Green Belt | |
| | Conservation Areas | |
| | Oxford View Cones | The Oxford View Cones are a set of ten protected viewpoints around Oxford that offer iconic views of the city's historic skyline. These views are cherished for their cultural and historical significance, showcasing Oxford's unique architectural heritage.<br>The View Cones are used in this study to show where renewable energy development may be visible from Oxford, which may impact the historic character of the city and therefore may not be suitable in identified areas. Specific circumstances may have to be demonstrated to justify development in visible areas. |
| **Grid constraints** | Primary substation supply areas | This input informs grid connection suitability of areas identified as suitable for renewable energy development in Layers 1-4. The data represents a high-level indication of suitability, which should be clarified with the Distribution Network Operator in the specific case of the proposed renewable energy site. This study considers grid connection suitability as whether there is available grid capacity for new renewable energy development to connect to. If no capacity is available, the area is not suitable for grid connection as the additional energy would overload the local grid. Suitable areas are considered to have some level of headroom for additional connection.<br>Renewable energy development can connect to the grid throughout a number of methods, such as through connecting to a primary substation. Alternative options other than primary substations are possible for some schemes but using primary substation supply areas represents an accurate proxy of available grid capacity in South & Vale. Additionally, large scale renewable energy sites require a 33kV connection, which is the voltage primary substations operate at. Therefore, the input used for this layer ensures that a wide variety of renewable energy development size is applicable.<br>This input is not considered to be a restriction to renewable energy development as grid capacity upgrades may occur after the publication of this study. |

## Battery storage

| Layer | Input | Reason |
|---|---|---|
| **Primary constraints** | Special Areas of Conservation (SAC) | This is a national nature conservation designation and therefore not a suitable location for battery storage development and has subsequently been excluded. |
| | National Nature Reserves | This is a national nature conservation designation and therefore not a suitable location for battery storage development and has subsequently been excluded. |
| | Historic Parks and Gardens | This is a designated heritage asset and therefore not a suitable location for battery storage development and has subsequently been excluded. |
| | Registered battlefields | This is a designated heritage asset and therefore not a suitable location for battery storage development and has subsequently been excluded. |
| | Site of Special Scientific Interest | This is a national nature conservation designation and therefore not a suitable location for battery storage development and has subsequently been excluded. |
| | Scheduled monuments | This is a designated heritage asset and therefore not a suitable location for battery storage development and has subsequently been excluded. |
| | Operational/consented renewable energy sites | This land already contains renewable energy development and is therefore not available land for battery storage development. |
| | LUC high sensitivity areas | This land is assumed to be unsuitable for renewable energy development. The other 4 sensitivity levels are not ruled out but will be assessed in more detail at the application stage. |
| | Bodies of water (rivers, canals, lakes and reservoirs) | Unsuitable for renewable energy development. A 5m buffer is applied to the line data used for rivers to ensure that some extent of river extent and width is accounted for. |
| **Buffer and exclusion zones** | Ancient woodland | These are defined in the NPPF as irreplaceable habitats and are therefore protected areas. As a result, they are not a suitable location for battery storage development and have subsequently been excluded.<br>Government guidance suggests a minimum 15m buffer from the boundary of the woodland to avoid root damage (known as the root protection area). Additional buffers may be set where appropriate for specific applications. |
| | Residential and non-residential buildings[10] | These areas are already developed and therefore would not be available for battery storage development. |

[10] This assumption has been made as a guideline from Bioregional judgement and is aligned to industry standard.

| | | |
|---|---|---|
| | | A 100m noise buffer is set as this is considered to be a reasonable distance to mitigate audible impacts to residents during the lifetime of battery storage development. Additional buffers may be set for specific applications. |
| | Major and minor transport infrastructure[11] | Major and minor transport infrastructure includes open roads and railway lines.<br>A 20m buffer is set as this is considered to be a reasonable distance to avoid disruption to transport infrastructure from the development and operation of battery storage sites. Situating battery storage sites any closer to infrastructure would increase safety risk and could impact those using transport infrastructure. Additional buffers may be set for specific applications. |
| | MoD sites and safeguarded zones | This layer is not included as part of the final outputs as the data is publicly sensitive. However, it will be considered for individual applications throughout the internal decision-making process to ensure development does not fall in any designated sites or zones.<br>The MoD sets various boundaries as exclusion zones for different types of development in proximity to MoD sites.<br>The MoD may be consider allowing development of renewable energy within its estate. This would however be considered on a case-by-case basis. Direct consultation with the MoD would be required to determine the potential suitability of renewable development in or near its estate. |
| | Airports/aerodromes | This land already contains development and is therefore suitable for battery storage development. |
| **Slope angle suitability** | Slope inclination[8] | Specific assumptions, as set out under Layer 3, have been made to rule out areas technically not suitable for renewable energy development. The subsequent suitable areas identified are likely to be looked at by renewable energy developers whilst other areas would be ruled out.<br>The assumptions have been selected because battery storage cannot be placed on steep slopes due to operational access and installation difficulties that would arise with building concrete bases on steep slopes. |
| **Secondary constraints** | National Landscapes | These inputs are designations where development may not be suitable on but will not strictly rule out development proposed. Suitability of developments relating to these outputs will be assessed on a case-by-case basis. It is likely that exceptional circumstances would have to be demonstrated by renewable energy development proposals to justify development on these designations.<br>It is important to consider higher risk flood zones to ensure that renewable energy development in these areas can be safely developed without increasing flood risk elsewhere. Any proposed renewable energy sites in Flood Zones 2 and 3 would be subject to a flood risk assessment to justify its location within a flooding context. Although not a hard constraint, it is important that proposed renewable energy sites demonstrate that there are no safer alternative sites and that the development provides wider sustainability benefits that outweigh risks from floods. To enhance flood resilience, battery storage units and on-site infrastructure could be installed on raised platforms.<br>Due to the need for the UK to meet its net zero and renewable energy targets, setting National Landscapes and Conservation Areas as primary constraints, and therefore excluding renewable energy development, would be |
| | Flood Zones 2 and 3 | |
| | Green Belt | |
| | Conservation Areas | |

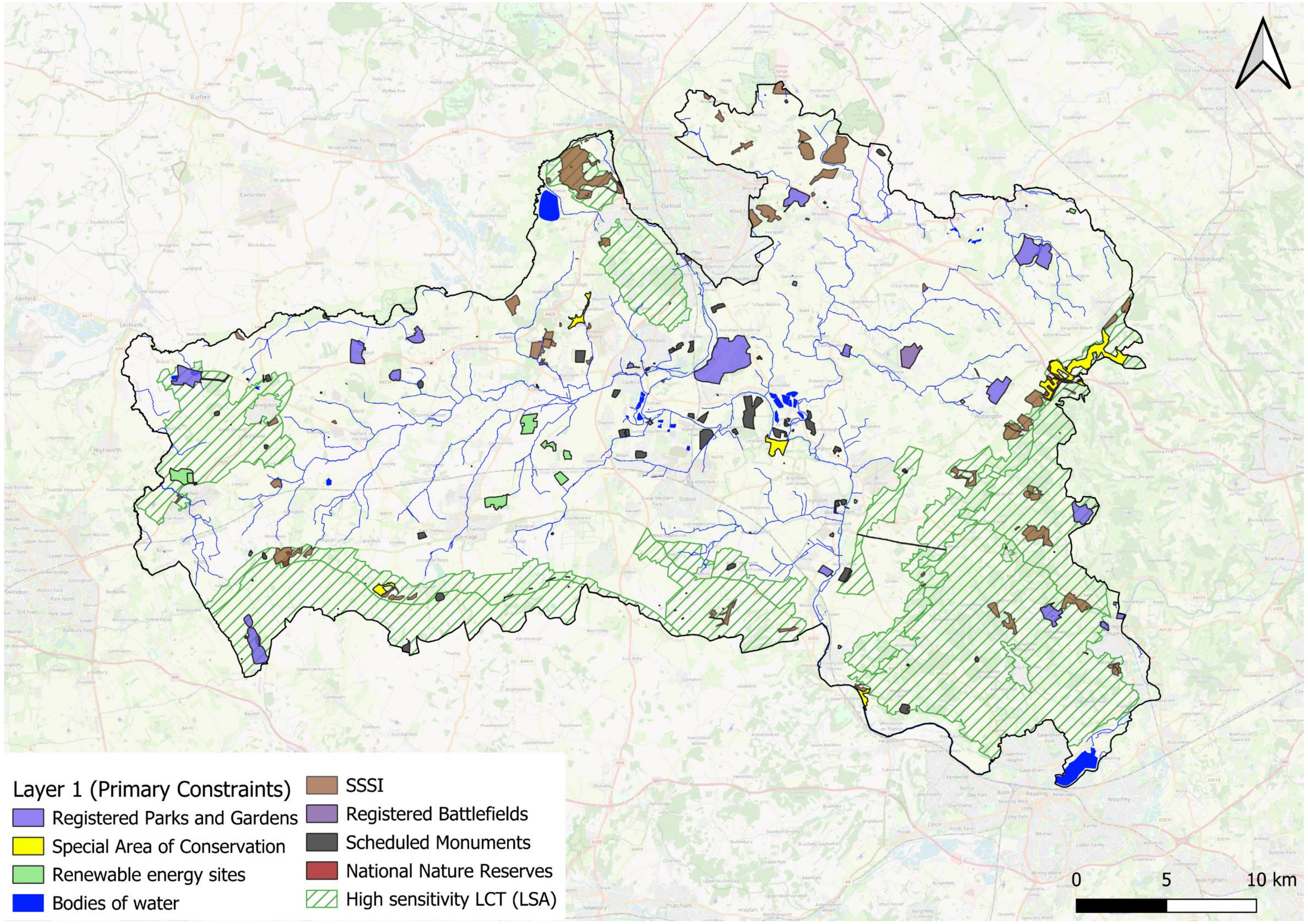
[11] These assumptions have been made as a guideline from Bioregional judgement and are aligned to industry standard.

| | | |
|---|---|---|
| | | overly restrictive. Additionally, current planning policy does not prohibit renewable energy development in National Landscapes to the same degree of the primary constraints.<br>Specifically for Green Belt land, there is an established precedent for battery storage development being approved within designated land as such development was not deemed to affect the 'openness' of the designation. Exceptional circumstances have been granted to many battery storage development as a result of their environmental benefit, outweighing any other potential impacts to Green Belt land. |
| | Best and Most Versatile agricultural land (defined as grade 1, 2 or 3a of the Agricultural Land Classification) | When considering Best and Most Versatile agricultural land, the May 2024 Written Ministerial Statement sets out that due weight must be given to the proposed use of such land. Impacts to these agricultural classifications should be minimised and use of poorer quality land should be preferred. High quality land should always be considered as least appropriate. However, Best and Most Versatile agricultural land is not entirely ruled out when considering its use for battery storage development, on sites it supports solar PV, where it can be demonstrated that negative impacts are not widespread. |
| | Oxford View Cones | The Oxford View Cones are a set of ten protected viewpoints around Oxford that offer iconic views of the city's historic skyline. These views are cherished for their cultural and historical significance, showcasing Oxford's unique architectural heritage.<br>The View Cones are used in this study to show where renewable energy development may be visible from Oxford, which may impact the historic character of the city and therefore may not be suitable in identified areas. Specific circumstances may have to be demonstrated to justify development in visible areas. |
| **Grid constraints** | Primary substation supply areas | This input informs grid connection suitability of areas identified as suitable for renewable energy development in Layers 1-4. The data represents a high-level indication of suitability, which should be clarified with the Distribution Network Operator in the specific case of the proposed renewable energy site. This study considers grid connection suitability as whether there is available grid capacity for new renewable energy development to connect to. If no capacity is available, the area is not suitable for grid connection as the additional energy would overload the local grid. Suitable areas are considered to have some level of headroom for additional connection.<br>Renewable energy development can connect to the grid throughout a number of methods, such as through connecting to a primary substation. Alternative options other than primary substations are possible for some schemes but using primary substation supply areas represents an accurate proxy of available grid capacity in South & Vale. Additionally, large scale renewable energy sites require a 33kV connection, which is the voltage primary substations operate at. Therefore, the input used for this layer ensures that a wide variety of renewable energy development size is applicable.<br>This input is not considered to be a restriction to renewable energy development as grid capacity upgrades may occur after the publication of this study. |

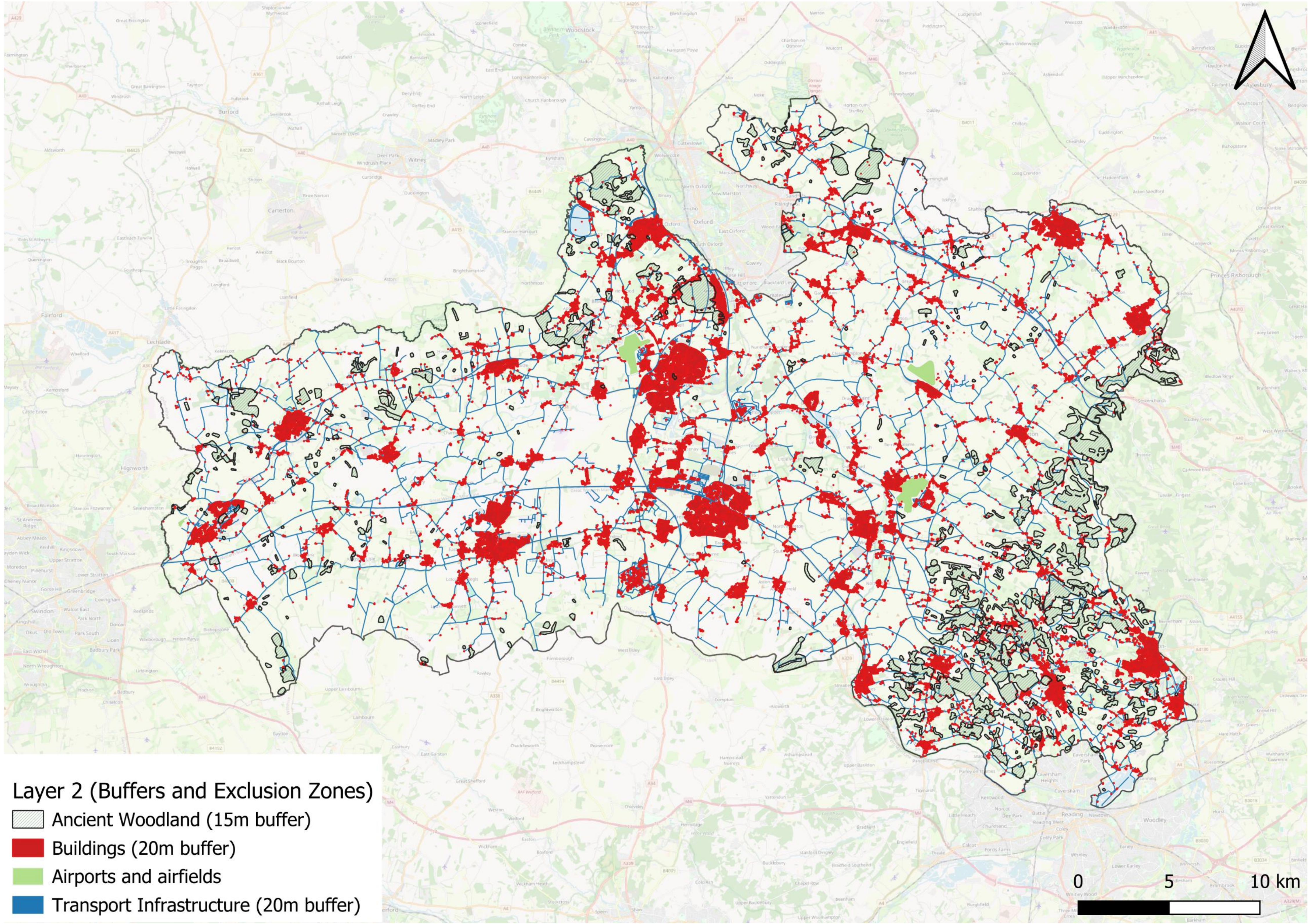
## Appendix 2: Mapping process

### Ground-mounted solar PV (PV3)

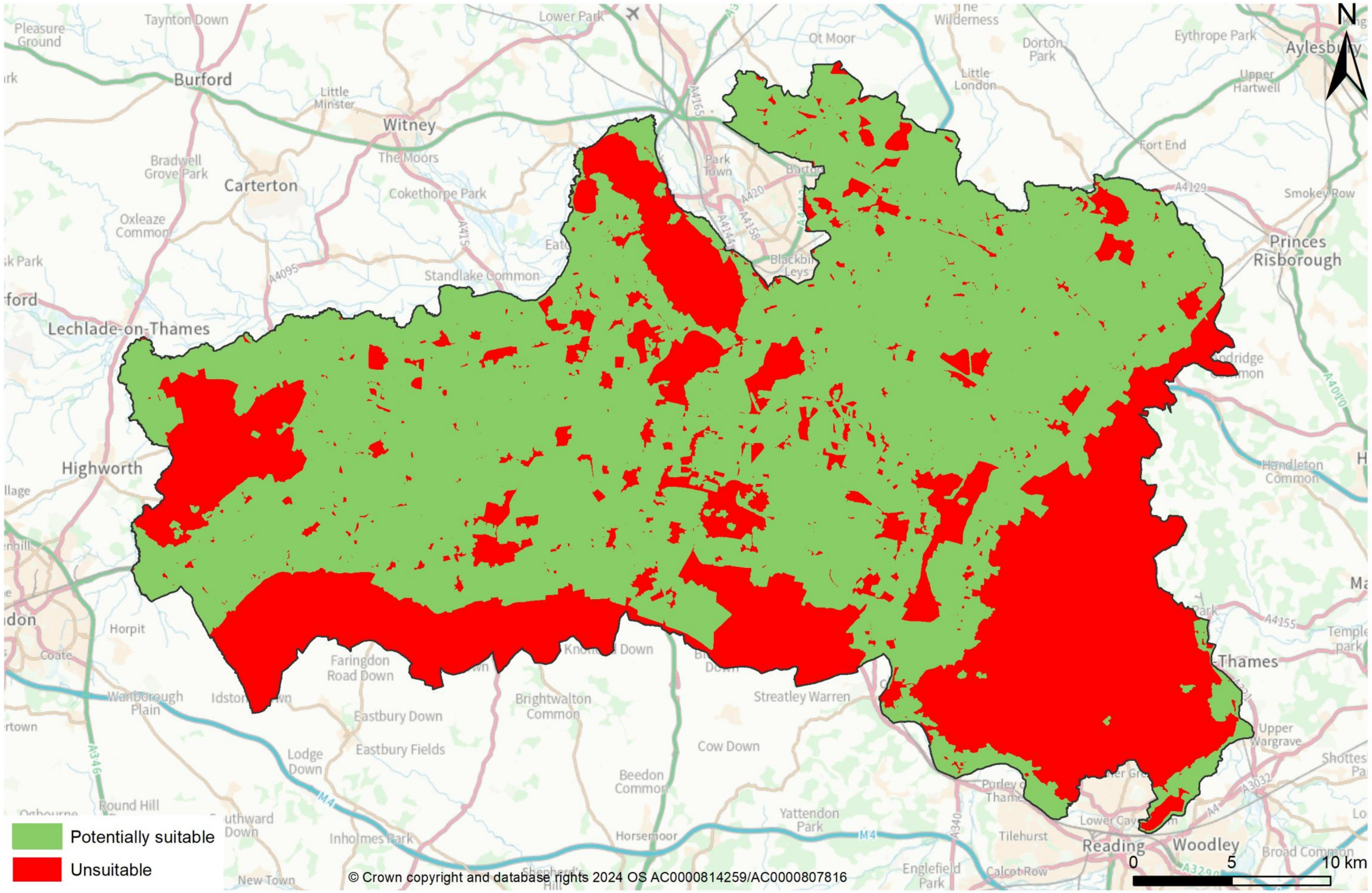
**Layer 1 (Primary Constraints)**



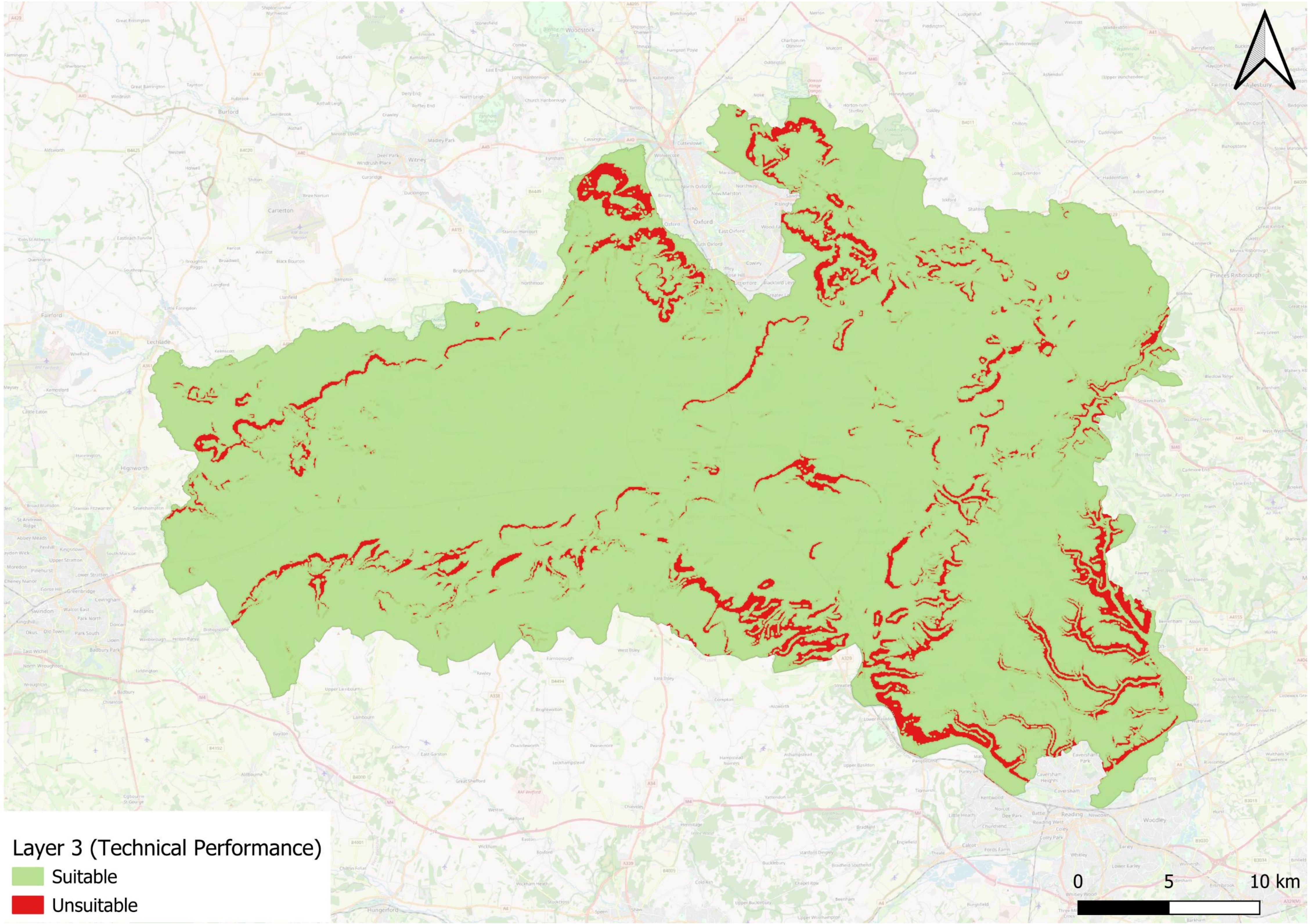
**Layer 2 (Buffers and Exclusion Zones)**



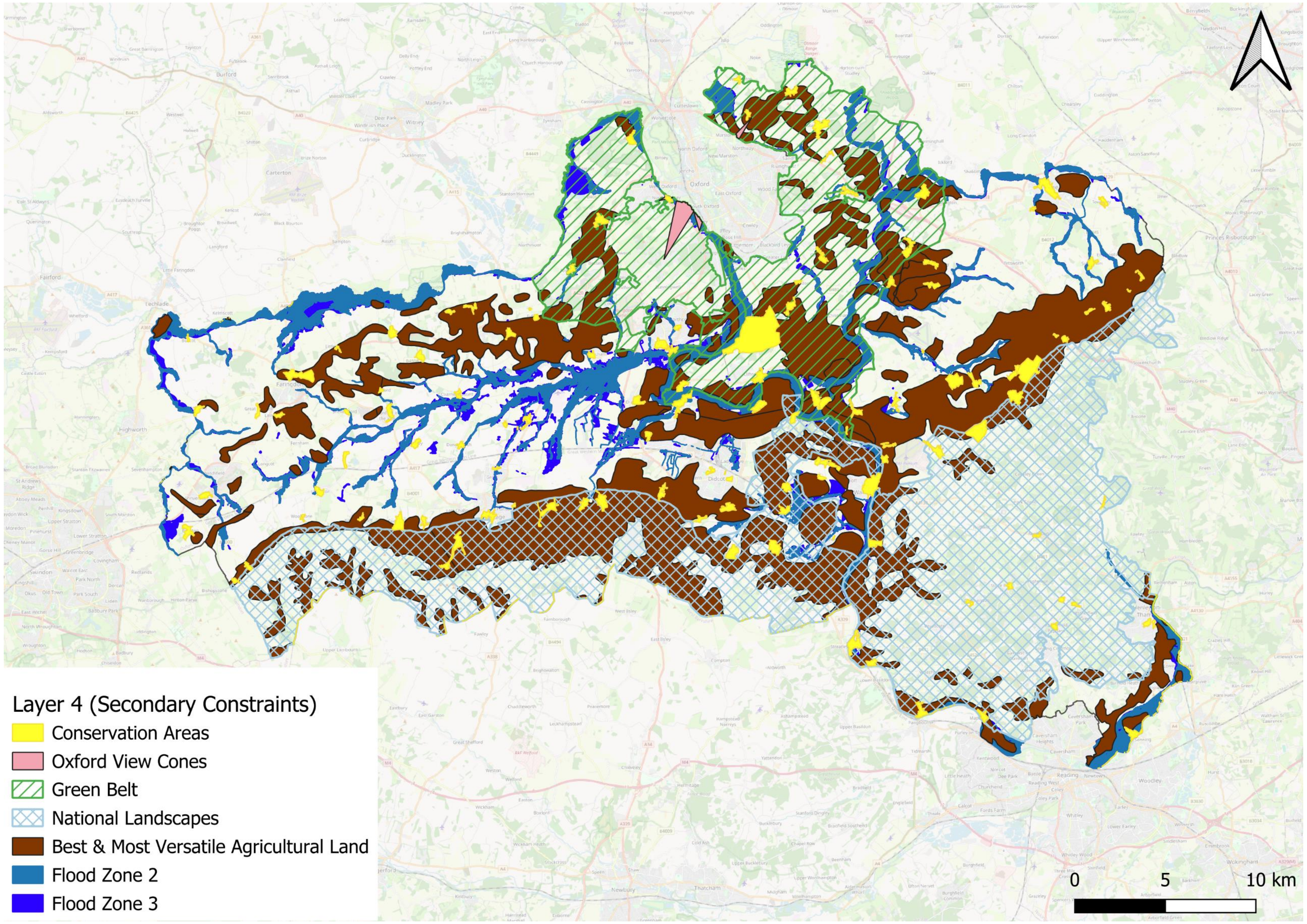
**Search Area 1**



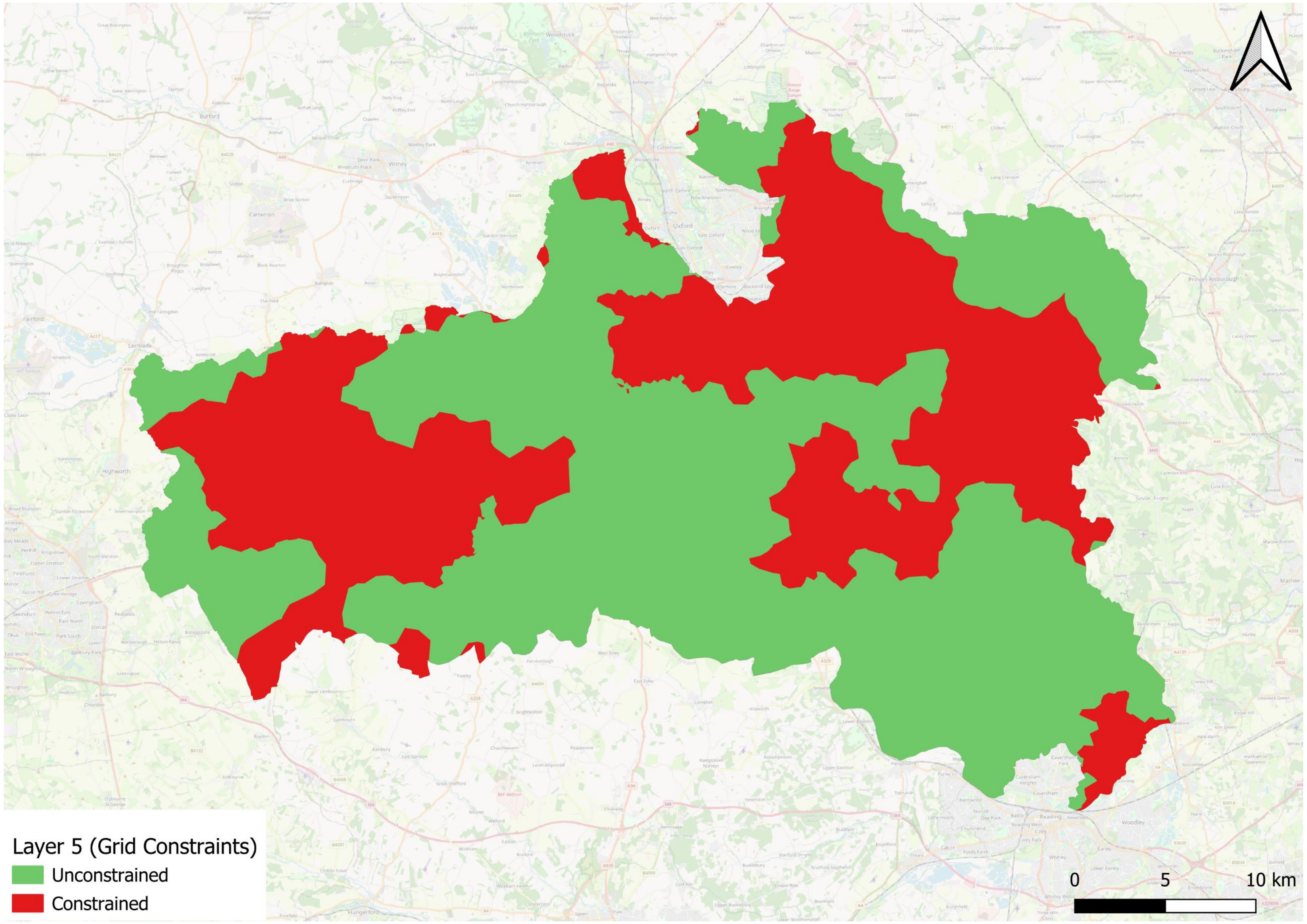
**Layer 3 (Technical Performance)**



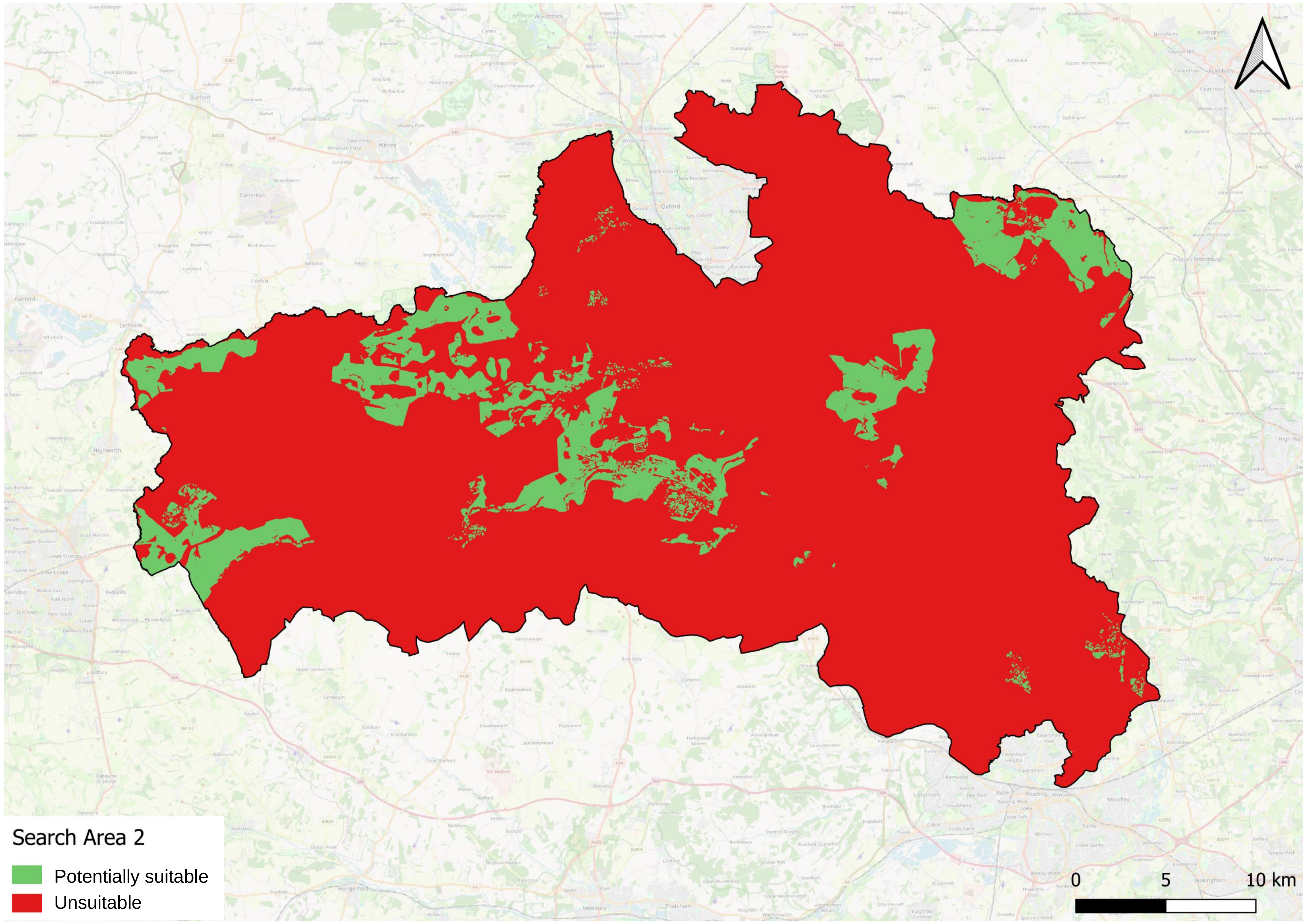
## Layer 4 (Secondary Constraints)



**Layer 5 (Grid Constraints)**

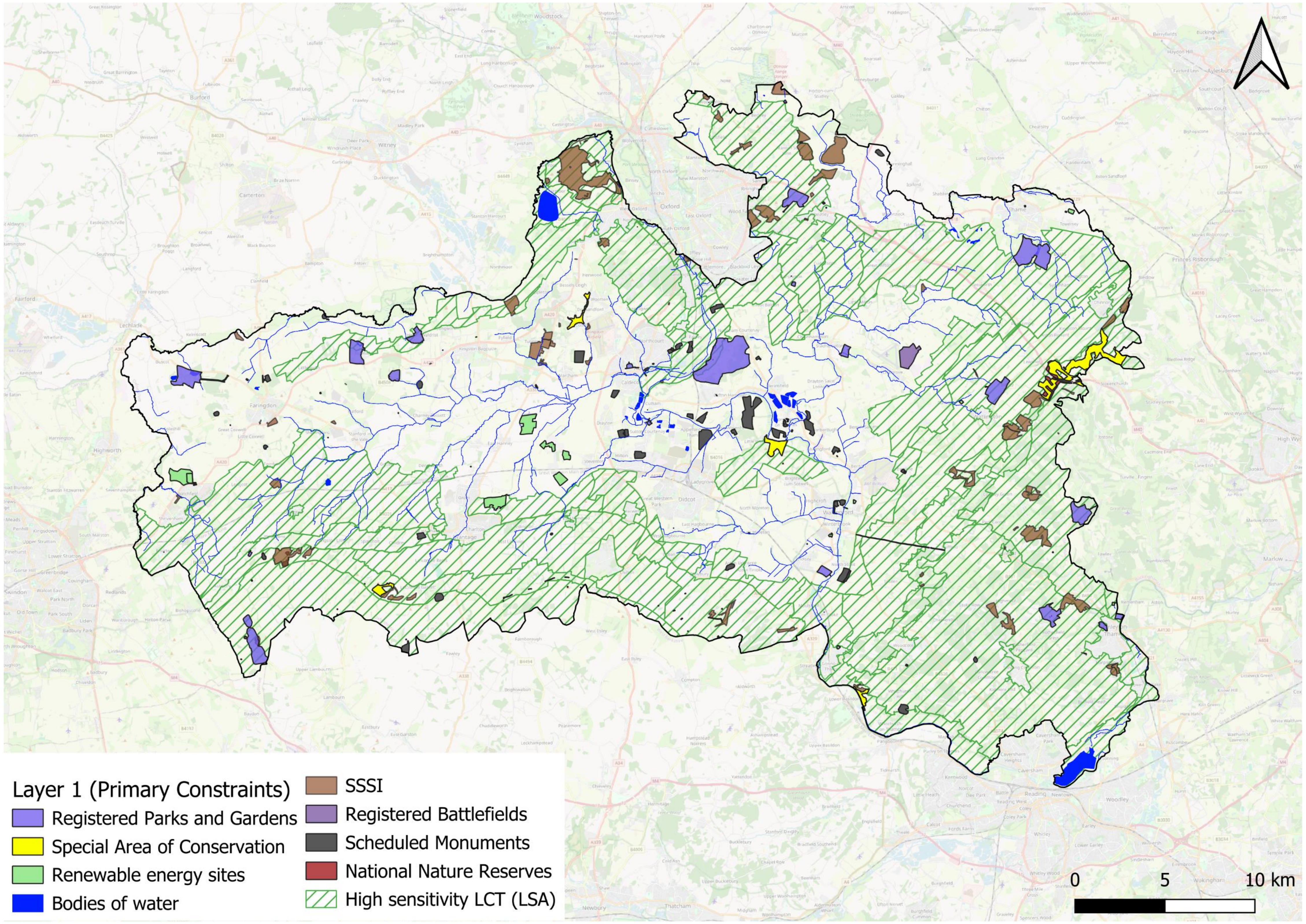


**Search Area 2**

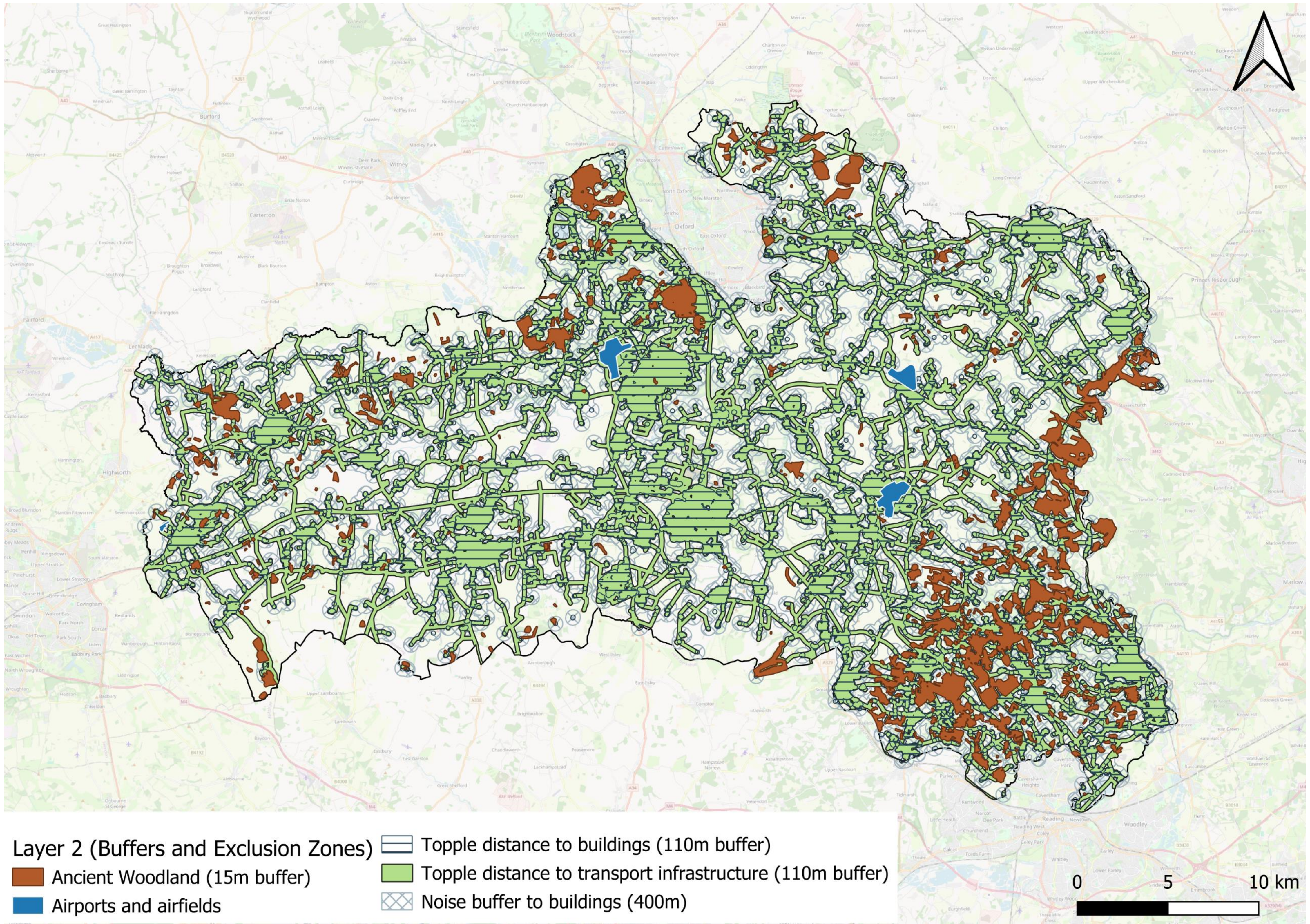


## Onshore wind (OW3)

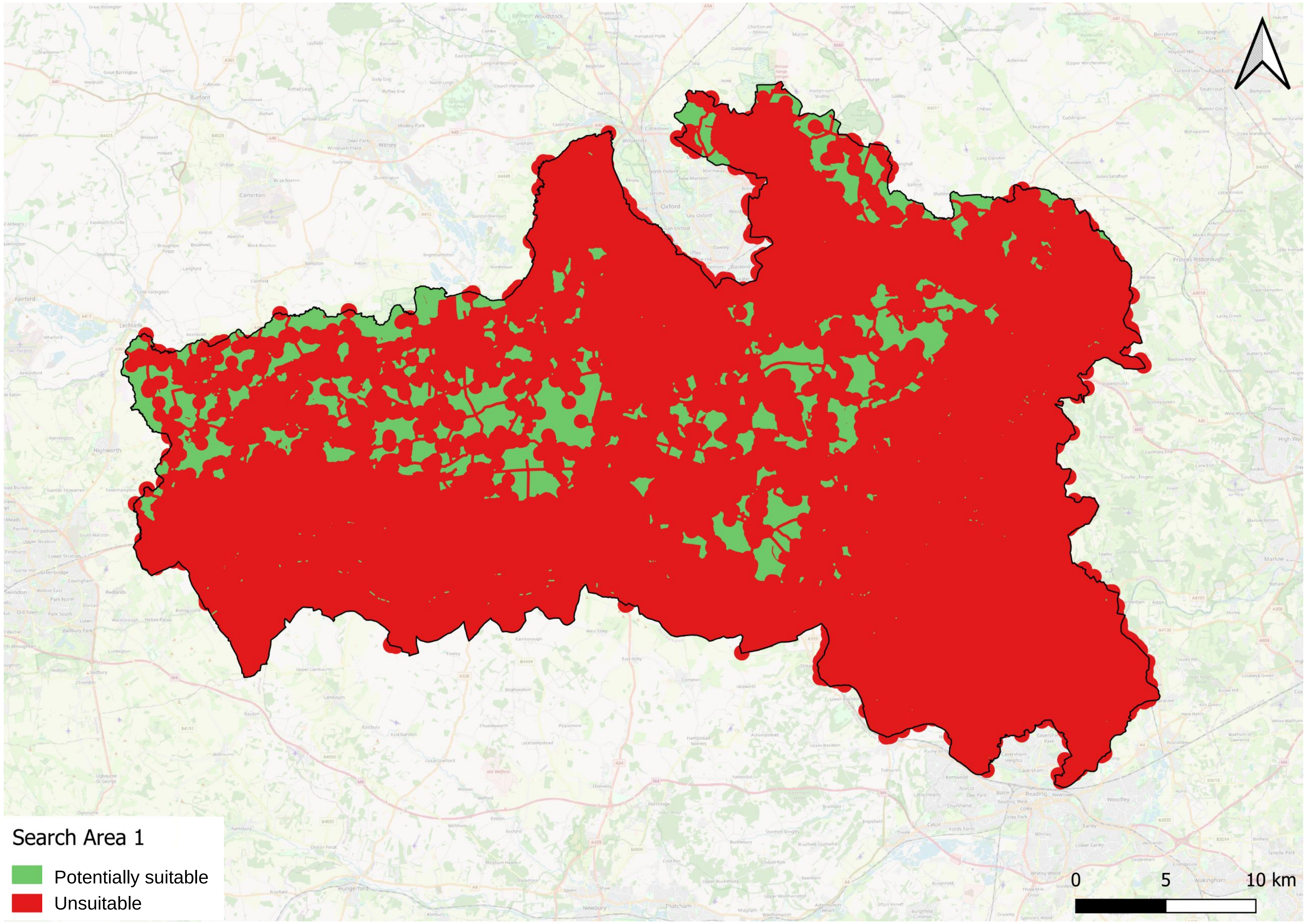
### Layer 1 (Primary Constraints)



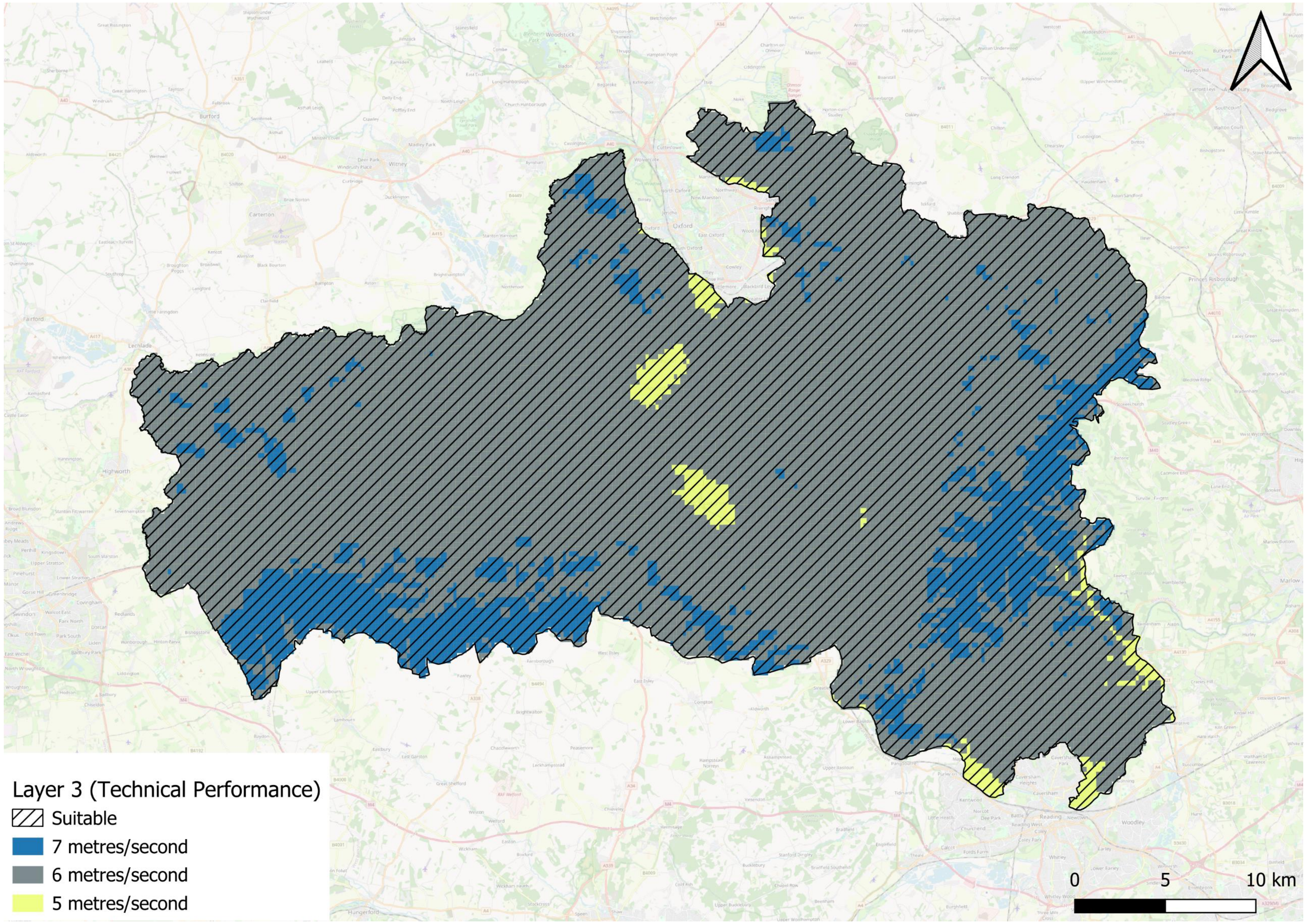
**Layer 2 (Buffers and Exclusion Zones)**



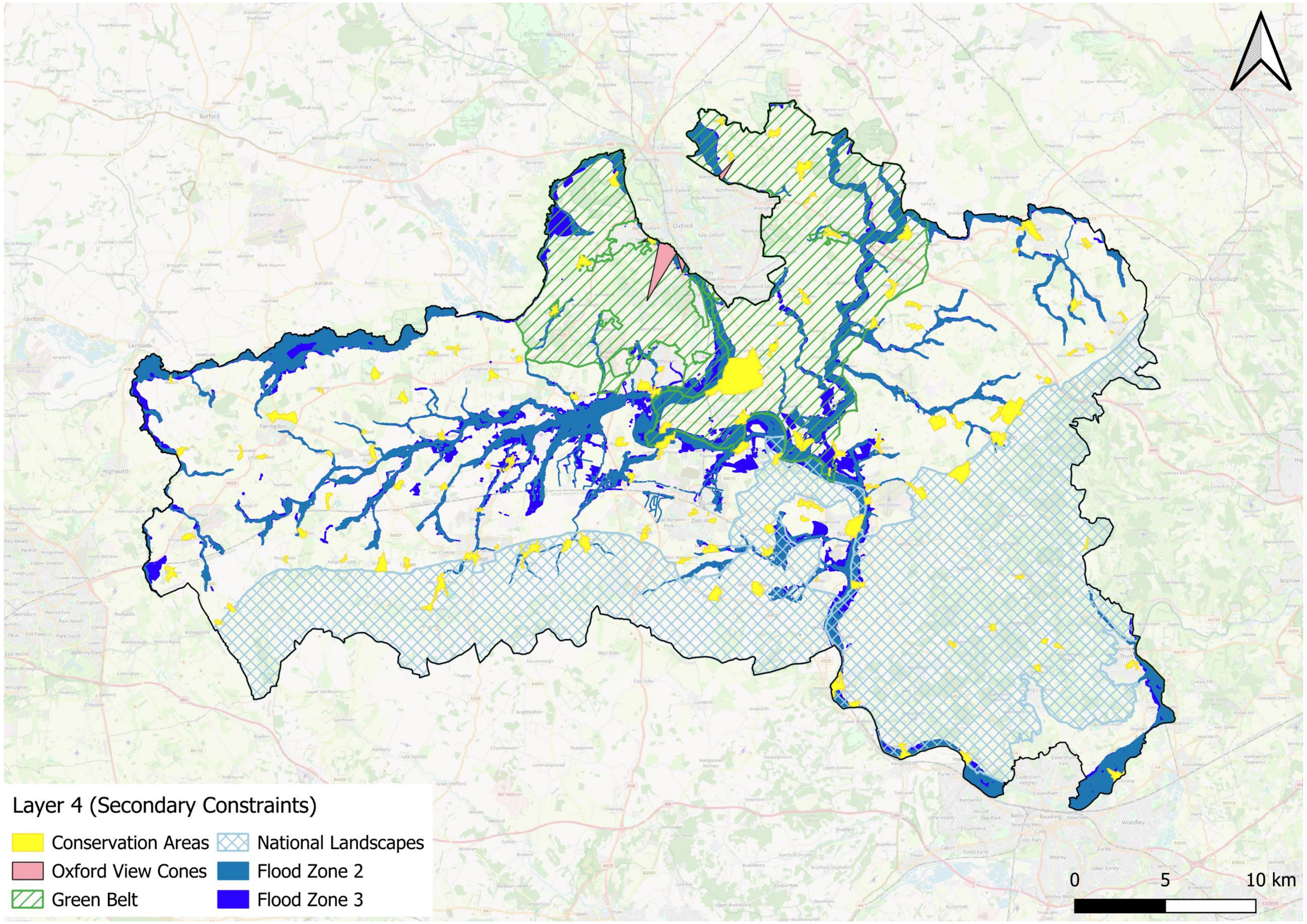
**Search Area 1**



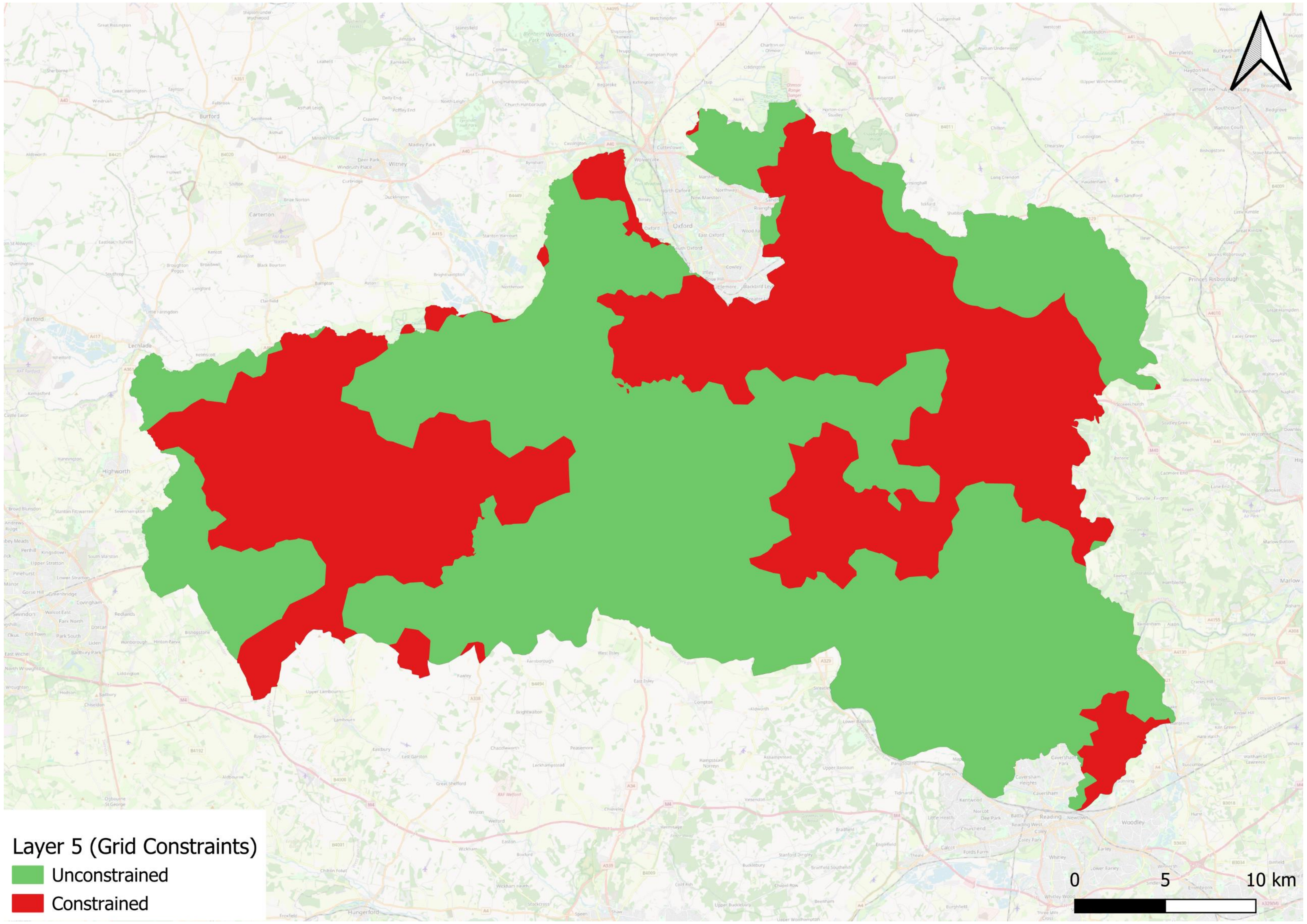
**Layer 3 (Technical Performance)**



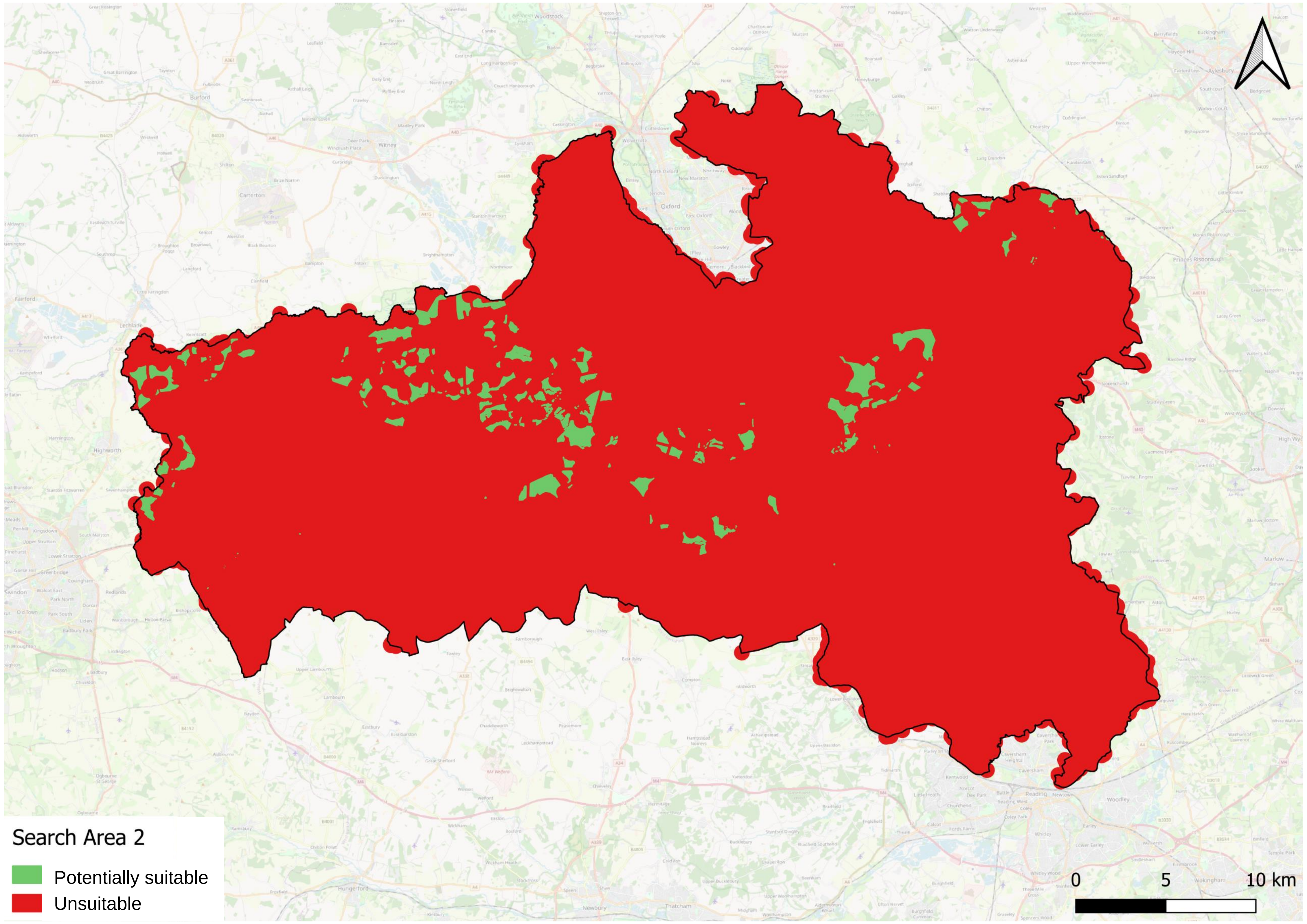
**Layer 4 (Secondary Constraints)**



**Layer 5 (Grid Constraints)**

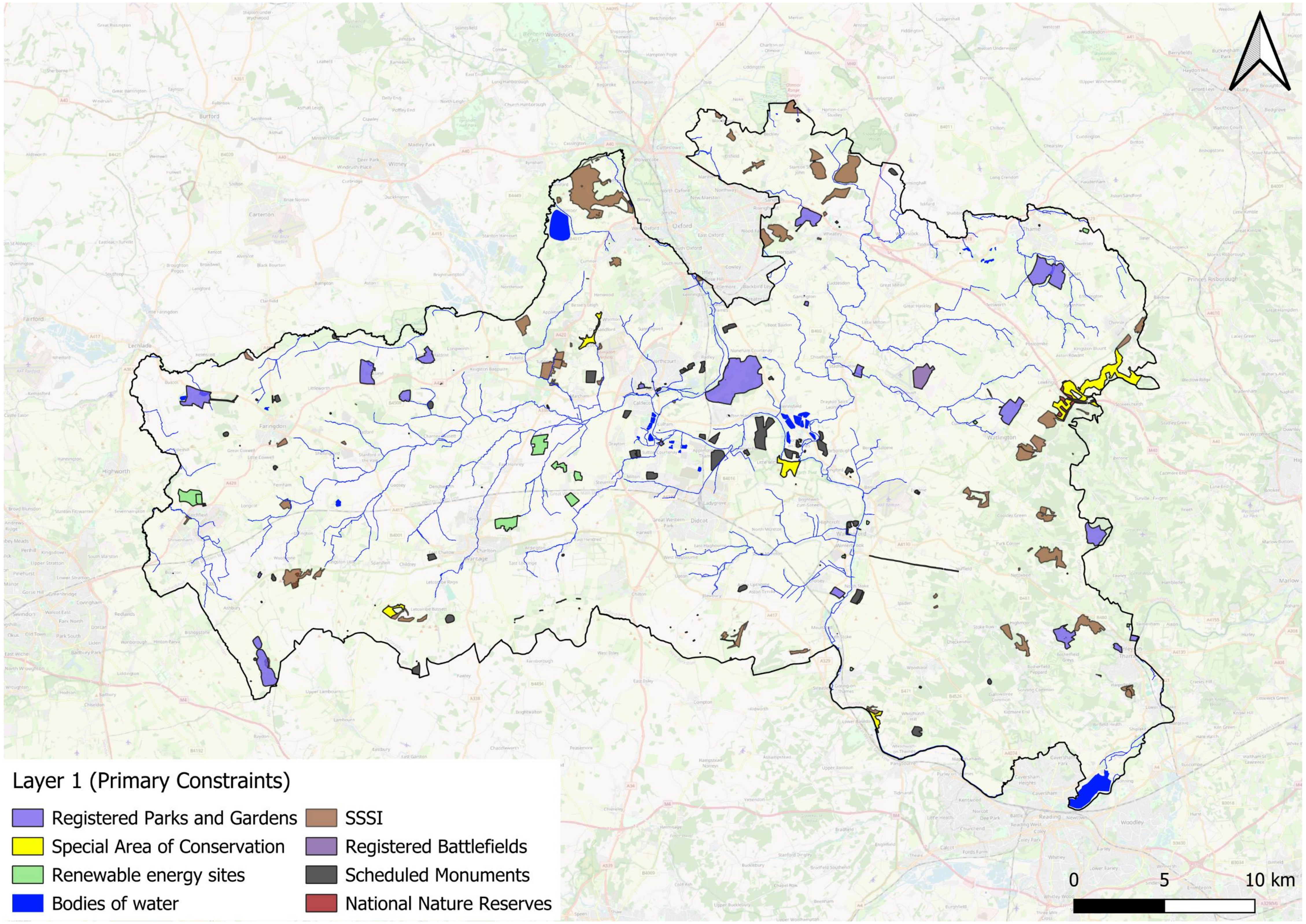


## Search Area 2

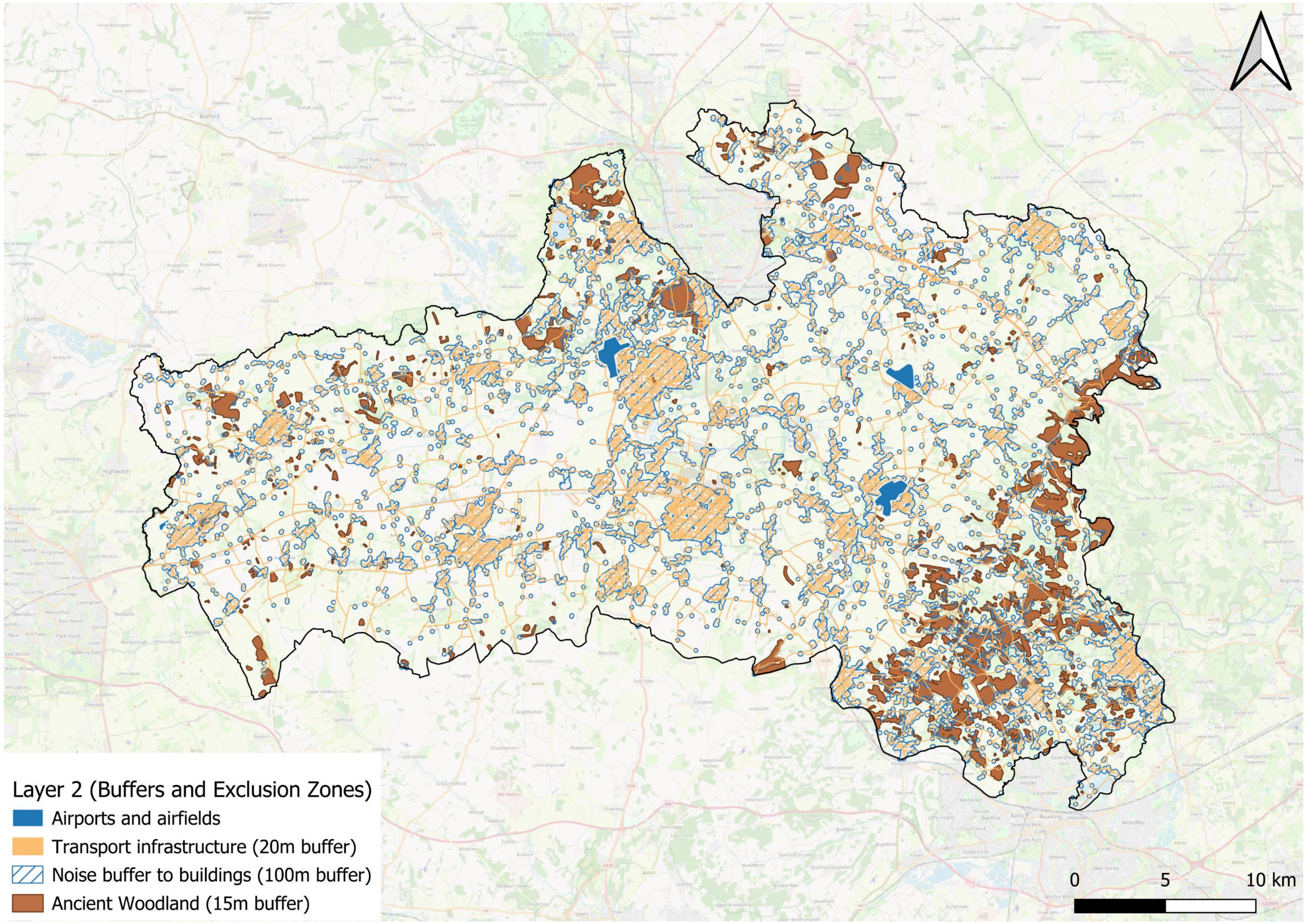


## Battery storage

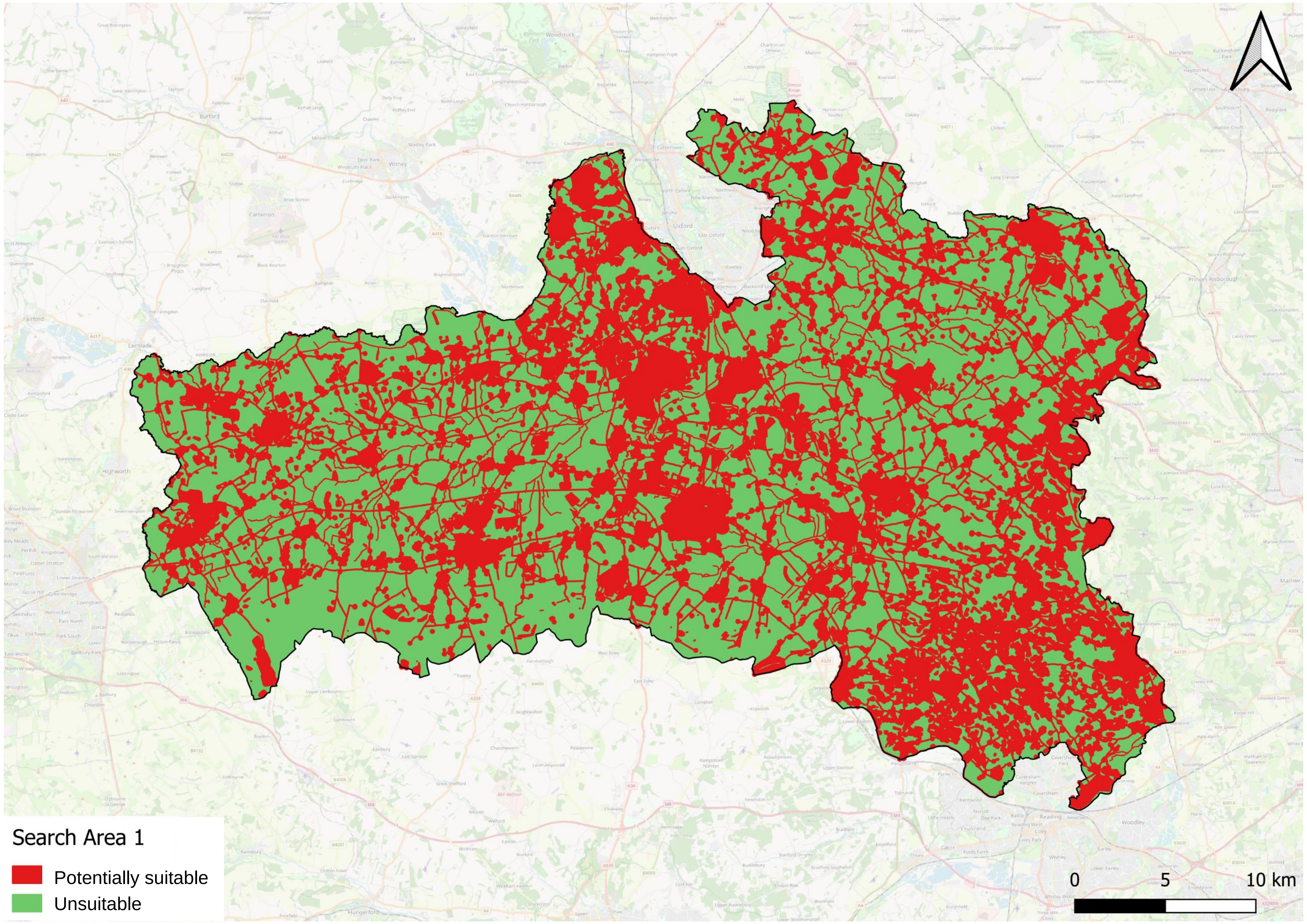
**Layer 1 (Primary Constraints)**



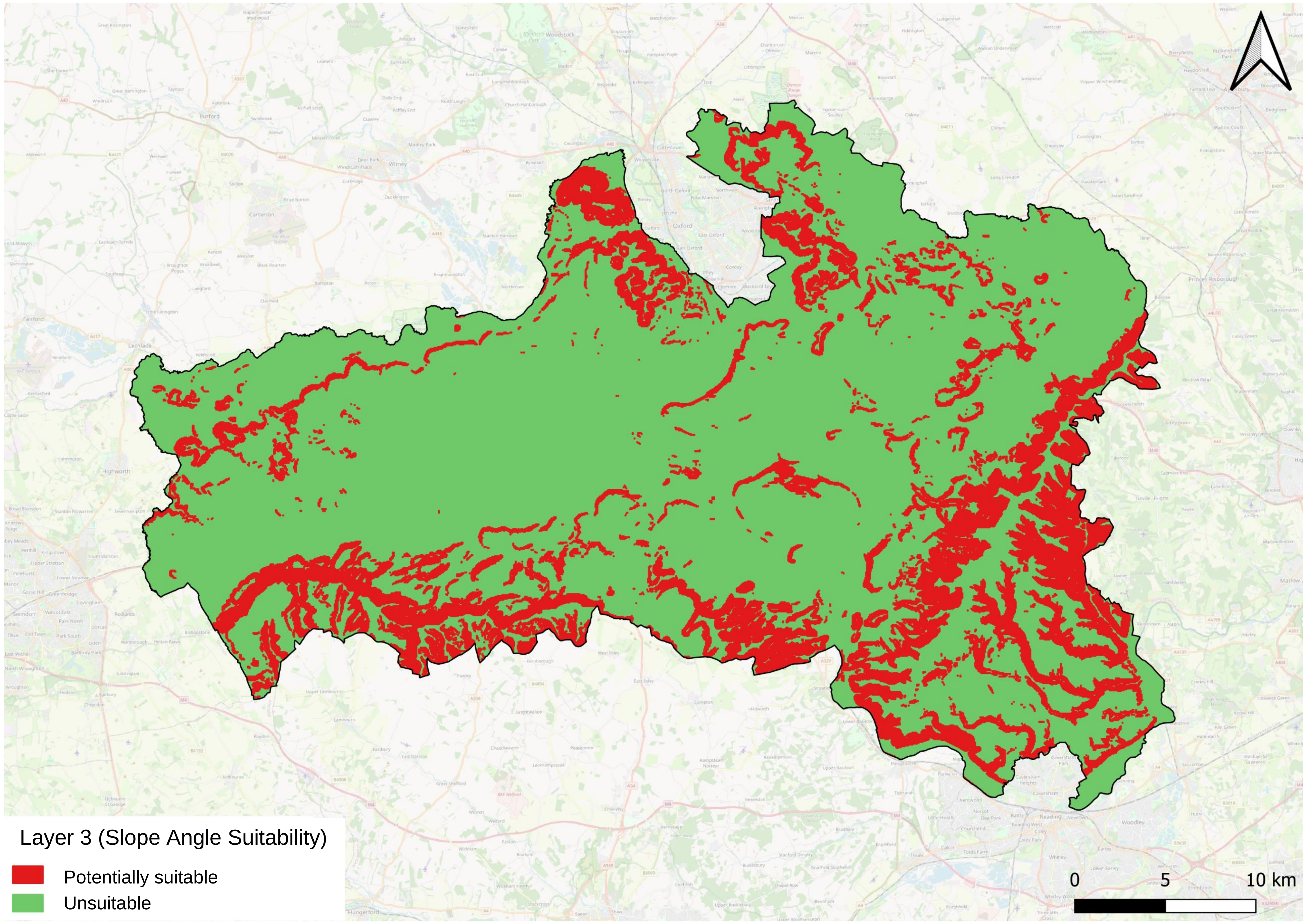
**Layer 2 (Buffers and Exclusion Zones)**



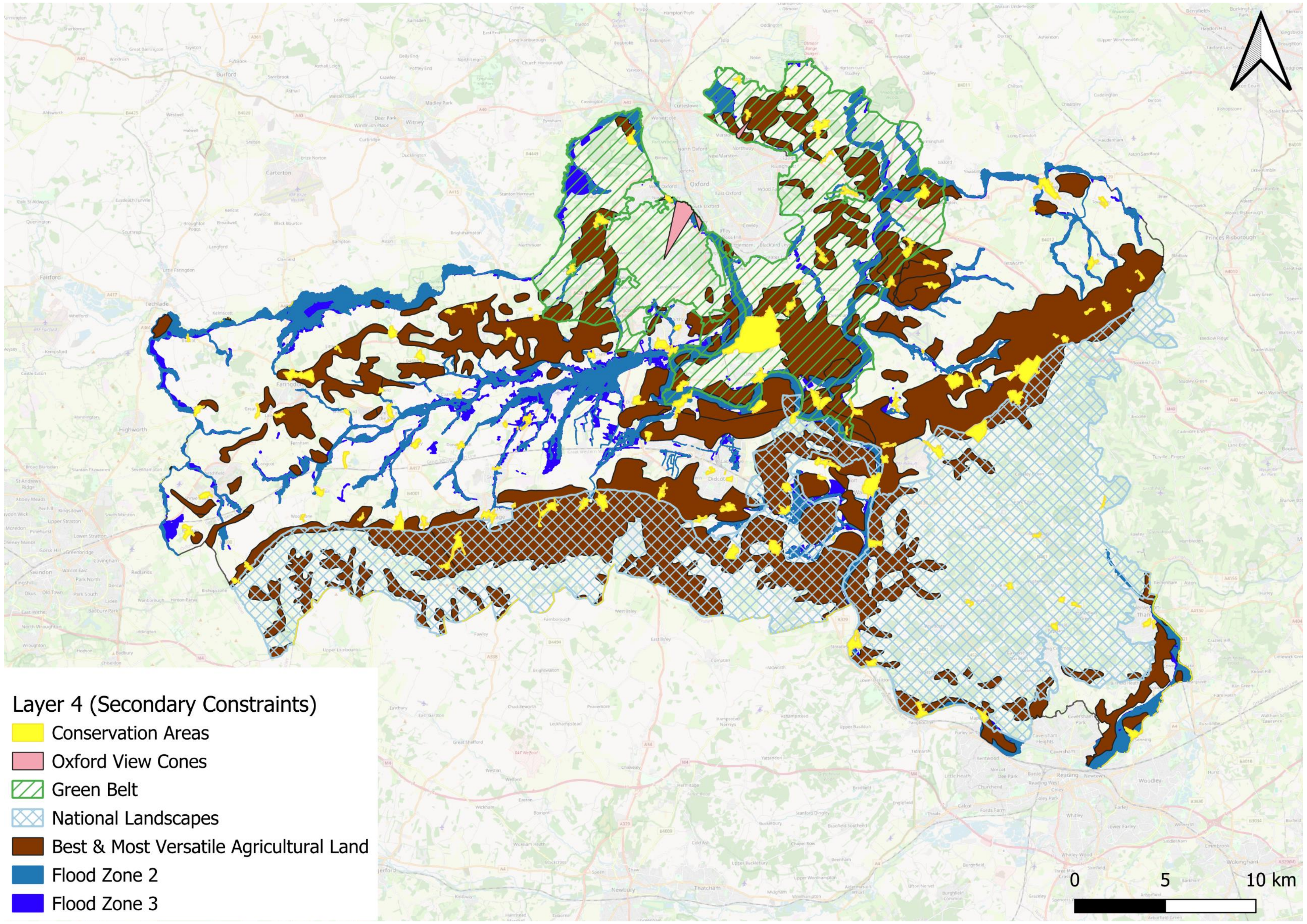
**Search Area 1**



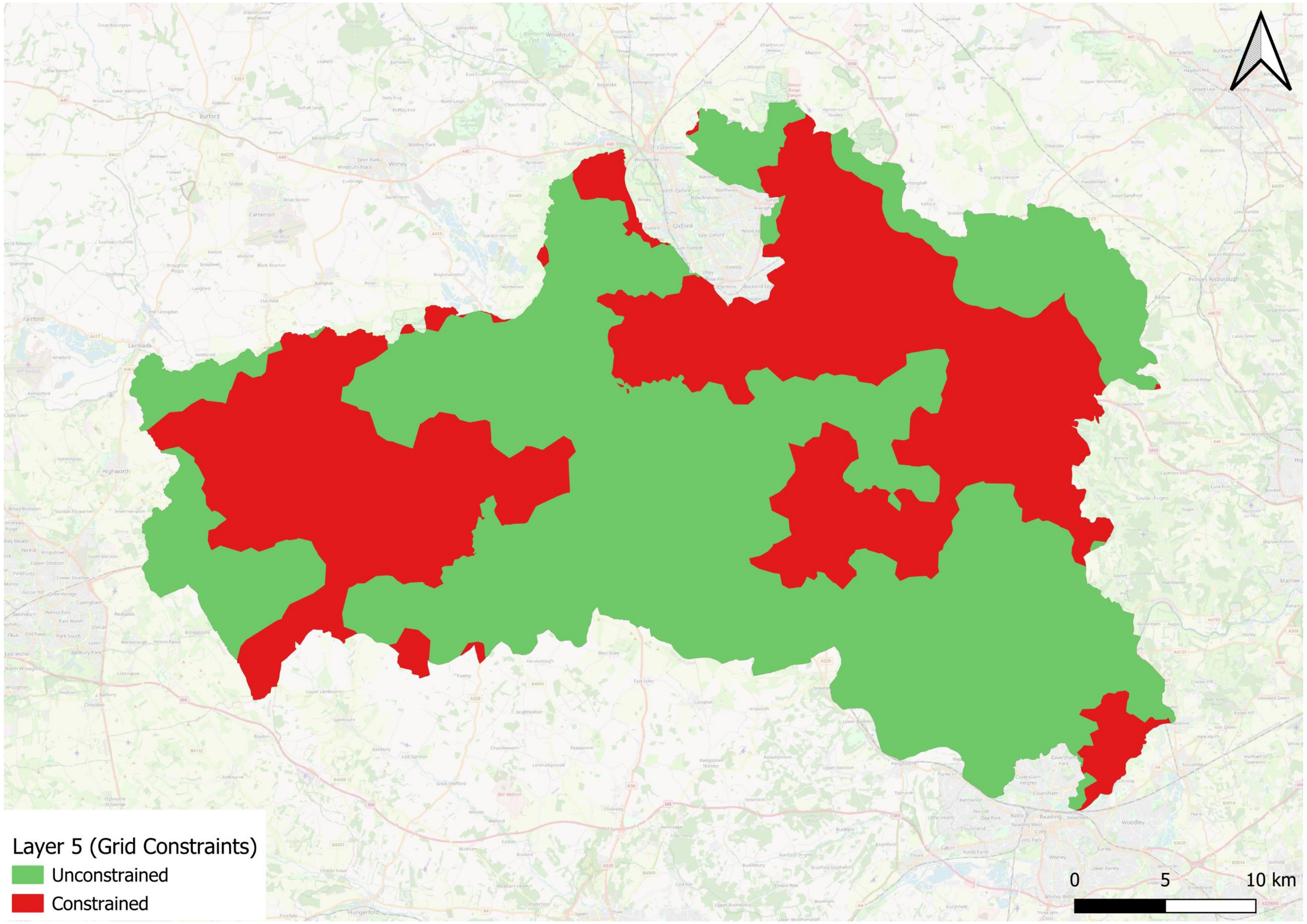
**Layer 3 (Slope Angle Suitability)**



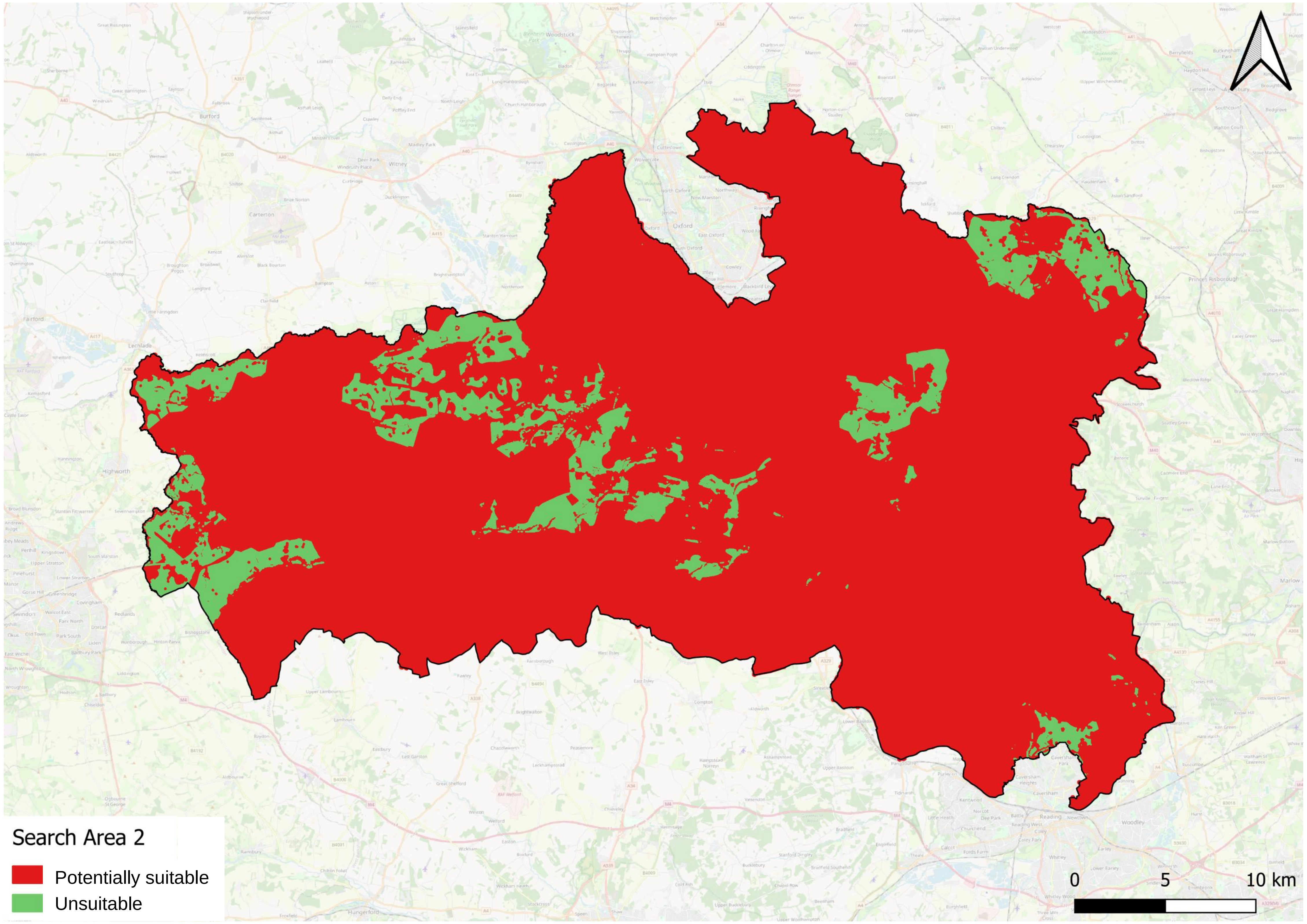
## Layer 4 (Secondary Constraints)



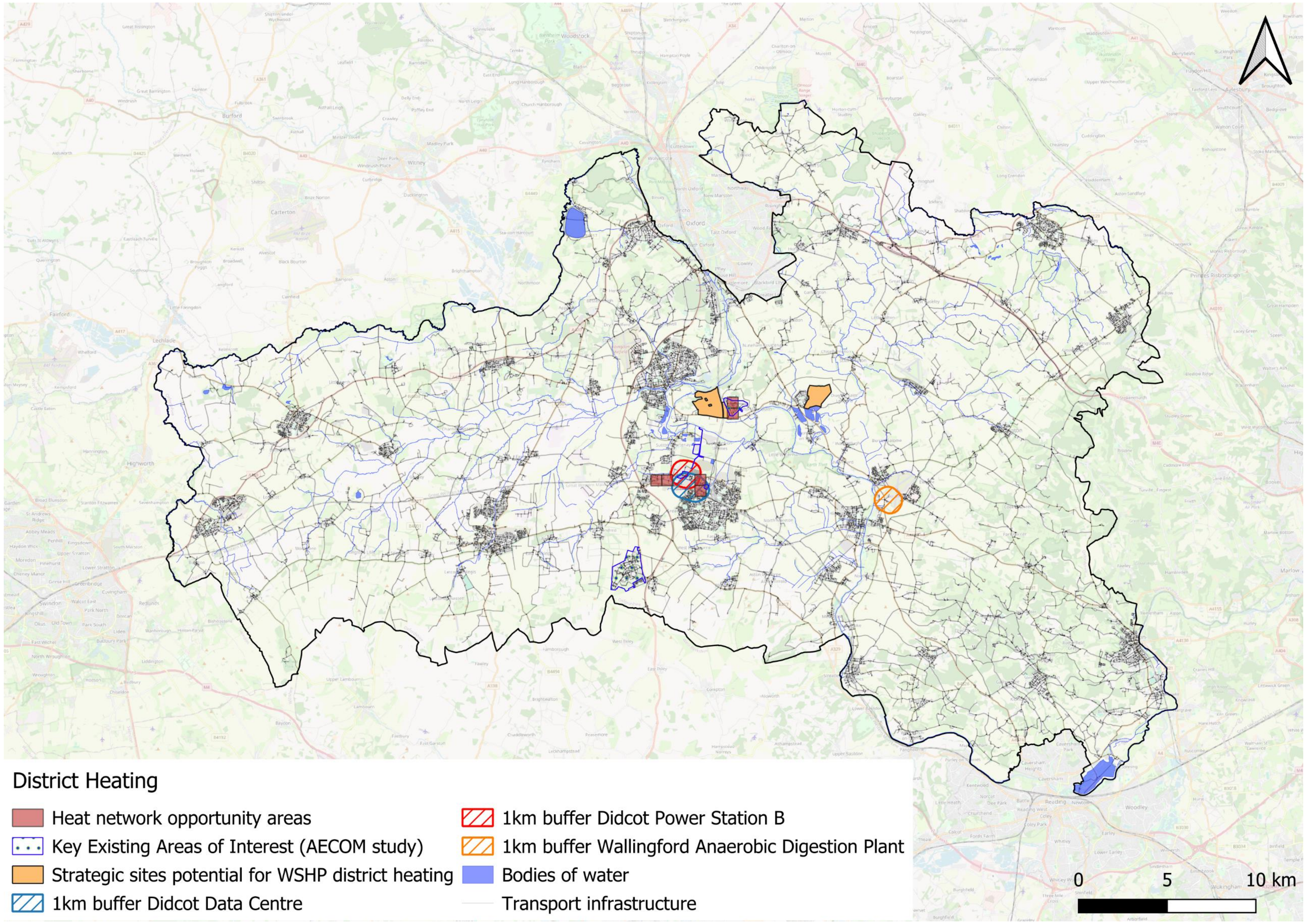
**Layer 5 (Grid Constraints)**

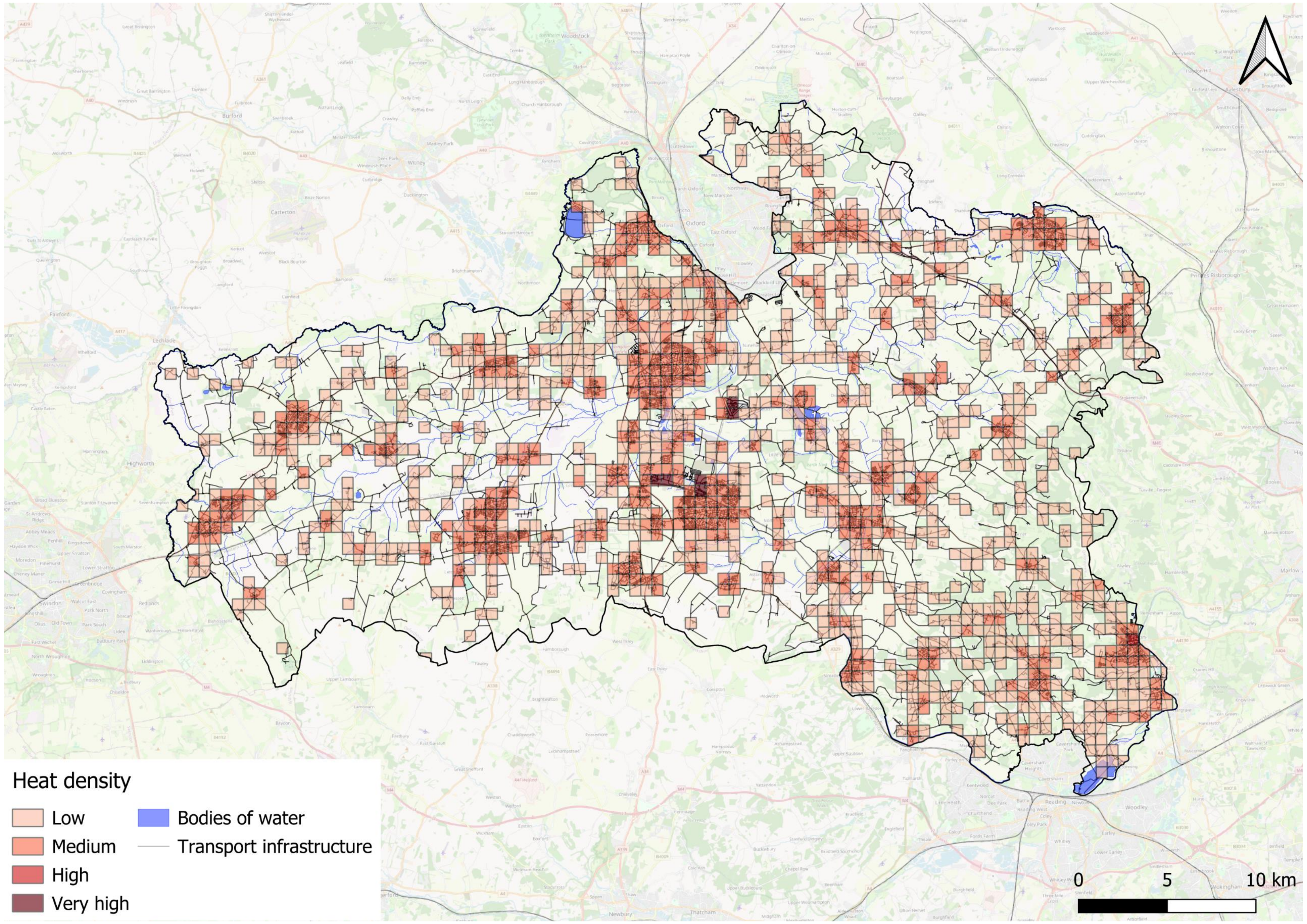


**Search Area 2**

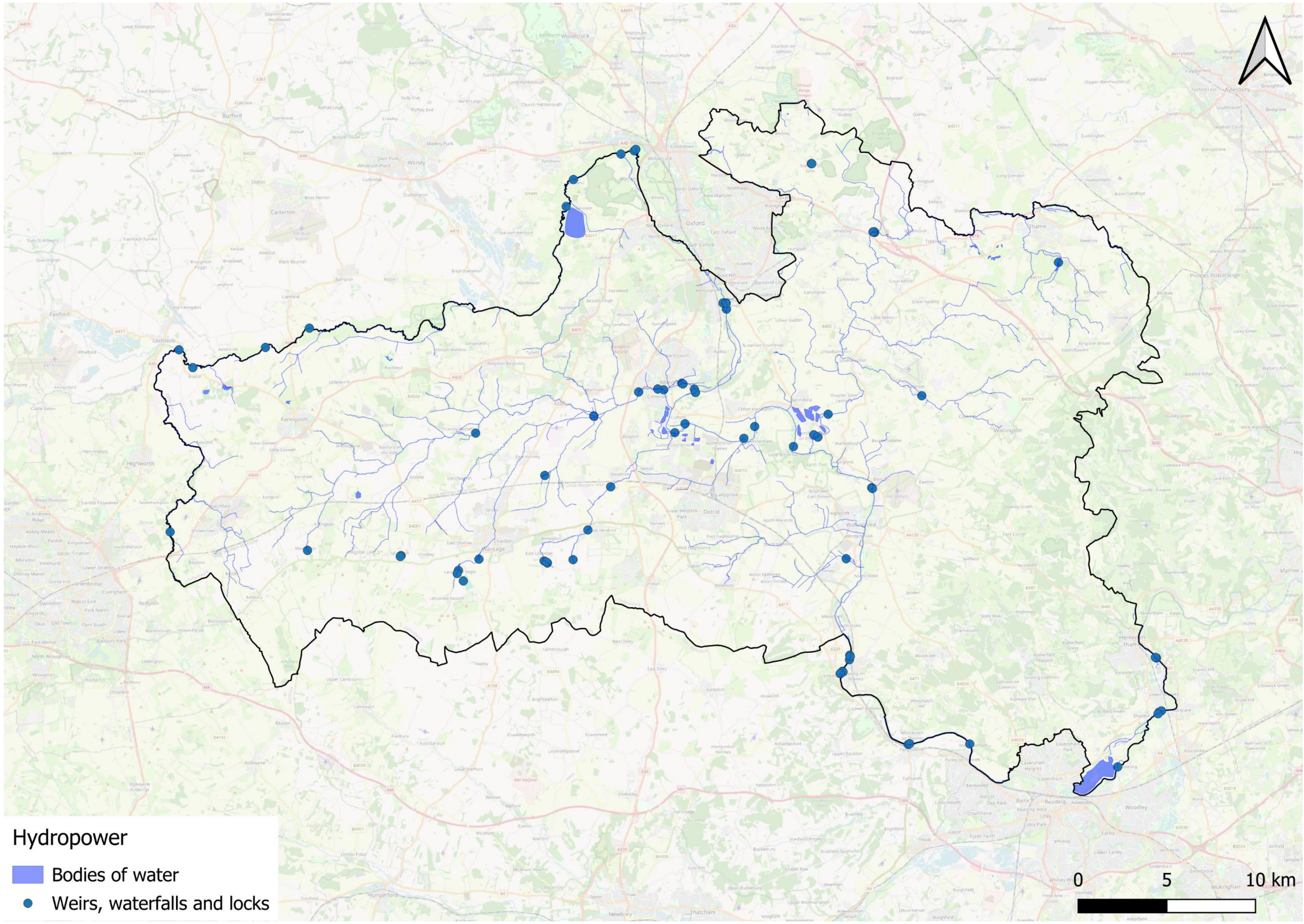


## District heating




Heat density
Low
Medium
High
Very high
Bodies of water
Transport infrastructure
0
5
10 km

## Hydropower


Hydropower
Bodies of water
Weirs, waterfalls and locks
0
5
10 km