Natural England Commissioned Report NECR222

Development of a Risk Assessment Tool to Evaluate the Significance of Septic Tanks Around Freshwater SSSIs

Phase 2 – Risk screening of 20 potentailly vulnerable SSSIs

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Nutrient enrichment from diffuse sources is a major issue for freshwater SSSI sites not meeting favourable condition and for water bodies not meeting good ecological status under the Water Framework Directive (WFD). Therefore, failure to tackle diffuse water pollution effectively presents a significant risk to the delivery of Biodiversity2020 and the WFD.

There is growing evidence that small sewage discharges (SSDs), in practice mainly septic tank systems, may pose a significant environmental risk to freshwater habitats in certain situations and under certain conditions. However, the extent of this risk and its potential impact across the freshwater sites of special scientific interest (SSSI) series are not well understood. Similarly, on a site-specific basis it has often been difficult to confidently identify where new SSDs can be located without causing unacceptable risks to freshwater SSSIs. Natural England considers that it is important to address this evidence gap to improve the future management of SSDs in the catchments of vulnerable SSSIs. Part of this process is the identification of designated sites at the greatest risk, where interventions are most needed. This information is also important to inform the development and implementation of Diffuse Water Pollution Plans (DWPPs).

To help address this evidence gap, Natural England commissioned the Centre for Ecology & Hydrology (CEH) in 2014 to undertake a map-based risk assessment for 20 freshwater SSSIs thought to be at significant risk from SSDs on the basis of available information.

The assessment was based on a risk framework previously developed by CEH for Natural England (NECR170 and NECR171). For each site examined there were two main outputs:

- A risk zone map, based on prevailing environmental characteristics, such as slope and soil type, indicating the likelihood that an SSD may pose a significant risk to the SSSI.
- An estimate of the number and distribution of SSDs within these zones.

These outputs will enable Natural England to better identify those sites where further investigation, and possibly interventions, are required to appropriately manage the risk posed by SSDs. Furthermore this information will allow Natural England to provide better advice in response to future consultations about the locations of new SSDs. At sites where the eutrophication risk posed by SSDs has been predicted to be potentially significant, further analysis at the local-level is now required to ground truth the findings of this study.

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Further information
This report can be downloaded from the Natural England website: **www.gov.uk/government/organisations/natural-england**. For information on Natural England publications contact the Natural England Enquiry Service on 0300 060 3900 or e-mail **enquiries@naturalengland.org.uk**.

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Summary

There is growing evidence suggesting that small sewage discharges (SSDs), in practice mainly septic tank systems but also including package treatment plants, may pose a significant environmental risk to freshwater habitats in certain situations and under certain conditions (e.g. Jarvie & others, 2010; Withers & others, 2011; Withers & others, 2012; May & others, 2015a; May & others, 2015b). However, the extent of this risk and its potential impact across the freshwater site of Special Scientific Interest (SSSI) series are not well understood. For this reason, there is limited information with which to make evidence based decisions on where such systems can be located safely in rural areas.

Currently, about 166 freshwater SSSIs are included in Diffuse Water Pollution (DWP) plans that has been assigned to all, or part, of the site. Many of these have identified discharges from SSDs as a potential source of nutrients. To understand the significance of SSDs as a source of phosphorus (P) pollution, and to identify locations where action may be needed to reduce impacts, a better understanding of the risk that they pose to the freshwater environment is needed.

The overall aim of this project was to develop a general methodology that could be used to estimate the number and location of SSDs within the catchment of freshwater SSSIs and assess their relative likelihood (low, moderate, high) of causing phosphorus (P) pollution to those waterbodies. The assessment was a desk study focusing on the use of nationally available datasets and did not involve sampling trips or site visits. It focused on three main factors: proximity to a surface waterbody forming part of the catchment drainage system, slope of the terrain and depth to high water table. Information on more site specific factors that affect the level of P discharged from these systems, such as system design, level of maintenance and/or the lifestyle choices of the householders (CHMC 2006; Kinsley and Joy 2005) were not included because this information is not available at a national scale and, therefore, could not be included in a large scale screening tool.

The risk assessment procedure developed in this project builds on that originally proposed by May and others (2015a) and incorporates data and knowledge that have been gained from other studies undertaken since this original method was proposed (eg May & others, 2015a). Changes include the following:

- Better inclusion of hydrological connectivity to groundwater.
- The use of nationally available digital map data to enumerate and locate properties that are likely to use SSDs for sewage treatment.
- A revised method for combining levels of risk associated with different factors that are determined by SDD location.

The project focused on 20 freshwater SSSI demonstration sites, as agreed with Natural England in consultation with local site officers.

The risk assessment methodology was developed and applied across a wide range of freshwater SSSI sites. These varied greatly in terms of catchment area, the smallest being Hawes Water ($2.5km^2$) and the largest being the River Avon above Southampton ($1,669km^2$). They also varied in terms of geographical location and waterbody type: ie river, lake or wetlands.

Catchments for this study were defined using topographical data and, as such, represent the surface water catchment, only. Several of these sites (especially the Meres, Broads and Marshes) are likely to be influenced by groundwater, too. However, groundwater catchments, which are very difficult to determine using national scale data, were not included in the assessment process. The only link to groundwater was the inclusion of depth to high water table.

The main output from the project is a series of three ArcGIS map layers for each SSSI and its catchment. These comprise:

1) Surface water catchment boundary.
2) Map of low, moderate and high risk zones for SDD locations within the catchment.
3) Map showing the likely locations of SSDs within the SSSI and its catchment and the relative level of risk that they pose in terms of causing eutrophication problems in a SSSI waterbody through P pollution.

These map layers can be used separately or in combination to improve the management of SSDs in unsewered areas and reduce the likelihood of them causing P pollution to freshwater SSSIs. For example, the map of low, moderate and high risk zones within the catchment could be used to help identify areas that may be unsuitable for siting new SSDs during rural development. The map of likely SDD locations and relative risk can be used to identify existing systems that may be causing pollution problems and help target mitigation more effectively.

The map layers are based on nationally available data and, as such, need to be tested and validated at the local scale. This is because there are some limitations on the accuracy of national scale data. For example, identifying likely SDD locations as being properties in unsewered areas does not take into account that some unsewered properties still exist in sewered areas if individual owners have chosen not to connect.

It is recommended that the map based information on SDD locations and risk to water quality produced by this project is distributed to local site officers to be tested operationally over a 12-18 month period to collect information on:

1) The accuracy of the data when applied at the local scale.
2) The operational usefulness of the data, including its format and accessibility.
3) Recommendations for improvement.

Following testing and validation at the 20 sites included in this study, consideration should be given to addressing any issues raised and rolling this risk assessment process out across all of the freshwater SSSIs that have P pollution issues. If testing and validation are successful, rolling out the risk assessment process at the national scale would also enable Natural England to identify and prioritise SSSIs where P pollution from SSDs is likely to pose the highest risk to water quality. This would also enable limited resources to be targeted effectively at the national scale. This risk based approach reflects the general aspirations of the new general binding rules approach to the management and control of SDD discharges, which was introduced in England in January 2015. Although developed for use in England, this approach may also be of interest to conservation agencies and regulatory authorities in other countries with similar problems, especially Wales and Scotland.

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1 Introduction

1.1 There is now a growing body of evidence suggesting that small sewage discharges (SSDs), in practice mainly septic tank systems but also including package treatment plants, may pose a significant environmental risk to freshwater habitats in certain situations and under certain conditions (eg Jarvie & others, 2010; Withers & others, 2011; Withers & others, 2012; May & others, 2015a; May & others, 2015b). However, the extent of this risk and its potential impact across the freshwater Site of Special Scientific Interest (SSSI) series are not well understood. For this reason, there is limited information on which to make evidence based decisions on where to locate such systems safely in rural areas.

1.2 Currently, about 166 freshwater SSSIs are included in Diffuse Water Pollution (DWP) plans that have been assigned to all or part of the site. Many of these have identified discharges from SSDs, such as those from septic tanks and package treatment plants, as potential sources of nutrient pollution. To understand the significance of SSDs as a source of phosphorus (P) pollution, and to identify locations where action may need to be taken to reduce any impacts, a better understanding of the risk that they pose to the freshwater environment is needed.

1.3 The overall approach that we have taken in this study, in terms of identifying areas where SSDs are at high risk of causing P pollution of waterbodies, is based on that originally developed within the US by CHMC (2006) and Kinsley & Joy (2005). In outline, these studies identified a range of locational factors that were likely to affect the likelihood of SDD effluent contaminating waterbodies. The most important of these were soil type, lot size (or SDD density), depth to the water table, aquifer conductivity and proximity to surface water. Using five levels of risk rating (ie 0 = no risk to 5 = very high risk) for each, the authors combined these factors to produce risk maps from large spatial datasets.

1.4 Kinsley & Joy (2005) and CHMC (2006) based their risk assessment methodology on readily available US data, but these data are not available within the UK. However, May and others (2015a) showed that these datasets do have UK equivalents that could be adapted for use within this overall approach, ie:

- UK Hydrology of Soil Types (HOST) classification data at 1km resolution (Boorman & others, 1995).
- Digital terrain model data at 50m resolution (Morris & Flavin, 1990; 1994).
- Watercourses data at 1:50,000 scale (Moore & others, 1994).
- Lake shoreline data (Ordnance survey data © Crown copyright).

1.5 May and others (2015a) demonstrated that these datasets could be used to develop a prototype UK version of the risk assessment framework described by Kinsley & Joy (2005) and CHMC (2006), by applying it to two subcatchments of the Broads. Although there is no technical reason why the approach could not be applied more widely across the UK, the authors noted that further refinement of the risk assessment method, and of the parameter values used, would be required before the method could be developed into an operational tool. This became the focus of subsequent work that investigated the horizontal and lateral movement of effluent P through the aerated zone of the soil soakaway (May & others, 2015b).

1.6 The draft risk assessment procedure that May and others (2015a) produced was based on SDD location. The main features that were deemed to be associated with that risk are summarised in Table 1. As the initial values used were based on information from the US, where soil types, advice on septic tank management, and climate differ from those in the UK, May and others (2015a) concluded that further research would be needed to refine these values before this draft risk assessment protocol could be used operationally within the UK.

Table 1 Factors associated with geographical location that may affect the risk of septic tanks contaminating nearby waterbodies with phosphorus laden effluent (adapted from previous report by May & others, 2015a)

	LEVEL OF RISK			
ATTRIBUTE	**HIGH**	**MODERATE**	**LOW**	**REFERENCES**
Distance to watercourse	< 100 m	100 – 400 m	≥ 400 m	McGarrigle & Champ (1999)
Winter water table height	< 1m	1-2m	>2m	Canter & Knox (1985)
Soil percolation rate	< 15 mm or > 100 mm drop in water height every second[1]		15-100 mm drop in water height every second	The Building Regulations (2000)
Slope	≥ 20%	5% - < 20%	< 5%	Canter & Knox (1985)

1.7 A follow on project focused on improving our understanding of the how far P in SDD effluent travels vertically and horizontally within the aerated part of a soil soakaway system (May & others, 2015b). The drainage fields of 11 SSDs in four different geographical areas of England were surveyed and the initial results suggested that P originating from SDD discharges could move laterally through this part of the soil profile for about 30m, and further under some conditions. The study concluded that the risk of pollution posed by these systems would be moderate to high if:

- they were relatively close to a receiving water body; and/or
- they were affected by enhanced hydrological connectivity between the soakway and any ground or surface water transport pathway.

1.8 The current project focuses on improving the methodology developed by May and others (2015a) by incorporating knowledge gained since then (eg May & others, 2015) and applying it to 20 freshwater SSSIs with P pollution problems. The resultant risk assessment tool is used to explore the level of risk posed by SSDs located within these SSSIs and their catchments. The results are presented on a site specific basis and will be used to help determine the balance of actions needed within the catchment over time, to address overall P loading issues.

[1] Building regulations percolation test results (EHS, SEPA and EA 2006). Tests are performed in a 30 cm deep hole filled with water and the rate of water level drop is measured. Values of less than 15 mm s^{-1} are deemed to allow untreated effluent to percolate into the ground too quickly for adequate treatment to occur and values greater than 100 mm s^{-1} are deemed to provide inefficient soakage that may lead to surface ponding.

2 Methods

Sources of data and information

2.1 The approach used in this study was to estimate the level of risk of SDD discharges contaminating downstream freshwater SSSIs on the basis of a series of pre-defined risk factors. These were slope, proximity to the nearest waterbody that forms part of the catchment drainage network, and depth to the high water table. Within the project, these risk factors were derived from national scale datasets using the methods described below and combined to generate an overall level of risk map for each catchment. Likely locations of existing SSDs, again derived from national scale datasets, were then mapped on these areas of high, moderate and low risk to assess the level of risk that existing systems may pose to the downstream SSSI.

2.2 The data used in this study, and their sources, are summarised in Table 2. Most of these data were readily available. However, the high water table data were specifically derived for this project and provided by a subcontractor (ESI Ltd, http://esinternational.com/). This subcontractor supplied spatial data showing the unsaturated zone thickness during a typical winter (ie a 1 in 1.3 year event) at 50m resolution. Groundwater level in the bedrock and superficial deposits were assessed and included in the dataset. The data were supplied under licence for use by CEH and Natural England, but only within the scope of this project.

Table 2 Data used in the project and their sources

DATASET	SOURCE
SSSI boundaries	Natural England
Surface water catchment boundaries	Natural England or CEH
Digital elevation data	Geostore (http://www.geostore.com/PGA/)
Sewered area boundaries, sewered properties, or approximate SDD locations	Water utility companies
Map data for backdrops	OS VectorMap® District data; OS Open Street View®
Locations of properties within the catchment	OS AddressBase®
Depth to high water table	ESI International Ltd (subcontractor)

2.3 Additional, site specific, information was obtained from local Natural England site officers who, in some cases, consulted with local Environment Agency staff, Catchment Sensitive Farming Officers and relevant water utility companies. We provided them with a map showing the SSSI of interest and the outflow point and catchment boundaries that we had generated from national scale digital elevation data, to check whether these were correct. We also requested a small amount of site specific information to allow us to compare the results of the study with local perception on any problems associated with SDD discharges.

2.4 The information requested was as follows:

- Where is the outflow of your SSSI?
- Does the map provided agree with your understanding of the extent of the SSSI and its catchment?
- Why do you think that the site may have a problem with septic tank discharges?
- Are there any septic tanks (a) within the SSSI itself or (b) within the wider catchment?
- Are there any known/suspected problems (especially direct discharges to water/ditches) that we need to be aware of?
- Are any areas within the catchment being earmarked for future development of unsewered properties?

2.5 The responses to these questions, which are the personal views of the site officers, are summarised in Section 3. They are also compared to the outputs from this project.

Catchment scale risk mapping

2.6 Level of risk of SSDs causing P pollution of waterbodies within each SSSI was calculated for three key risk parameters: slope, proximity to water, and depth to high water table (‘groundwater’). Mapping of these values was undertaken at the catchment scale for each SSSI.

2.7 Analyses of the spatial datasets listed above were performed using the GIS software FME Desktop (http://www.safe.com/fme/fme-desktop/). This was used because it allows automation, repeatability and self-documentation of workflows.

2.8 Summary map data from the project were converted to ArcGIS shape files for operational use.

Slope

2.9 Slope was estimated from 5m resolution digital elevation data that were re-sampled to 20m resolution to reduce the volume of data and to increase processing speed. Slope was expressed as a percentage for each pixel. To simplify the very complex outputs, values were then rounded down to the closest multiple of 5 (eg 1 was rounded to 0; 8 was rounded to 5) and values higher than 25 were changed to 25. Groups of pixels in any given area that had the same rounded values were merged into polygons. This resulted in polygons with unique scores representing each of the 6 slope classes shown in Table 3.

2.10 A slope risk category was then assigned to each slope class, as shown in column 3 of Table 3,. These values were based on an equation published by Haggard and others (2005), which describes the relationship between slope and percentage runoff for a silty loam, grass covered soil receiving 50mm of rain per hour over a 20 minute period (Figure 1). It was assumed that, on steeper slopes with higher runoff values, SDD discharges would be more likely to result in P laden runoff than on shallower slopes, as suggested by Canter and Knox (1985). The values were grouped into low, moderate and high categories on a relatively arbitrary basis, as shown in Figure 1.

Table 3 Slope, slope score and risk category assigned to areas of the catchments draining to freshwater SSSIs

SLOPE (%)	SLOPE SCORE	SLOPE RISK CATEGORY
0 to < 5	0	Low
5 to < 10	1	Low
10 to < 15	2	Low
15 to < 20	3	Moderate
20 to < 25	4	Moderate
≥ 25	5	High

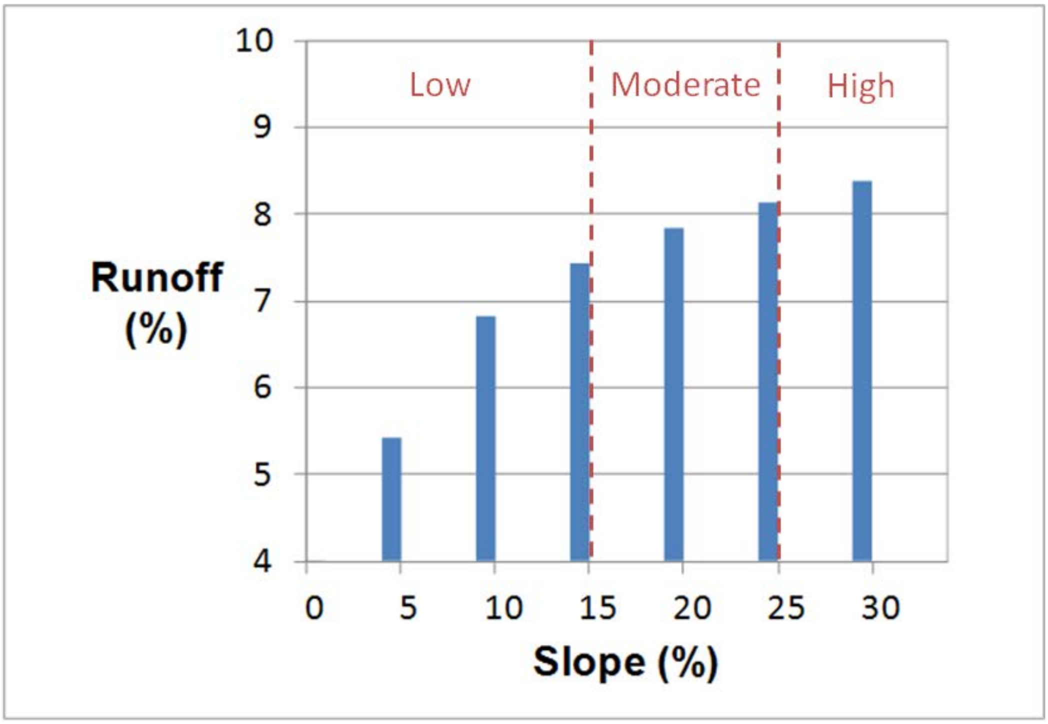


Figure 1 Relationship between runoff and slope based on an equation published by Haggard and others (2005) for a silty loam, grass covered soil indicating slope risk categories assigned in this project

Proximity to watercourse

2.11 Proximity to water within the catchment of each SSSI was derived from OS Vectormap® District data (https://www.ordnancesurvey.co.uk/opendatadownload/products.html). These data included line water features, such as rivers and drains, and polygon water features, such as lakes and wetlands. Together, they comprise the catchment drainage system. To harmonise these different types of data and allow them to be combined, a 0.5m buffer zone was created around both types of data and the resulting polygons were merged.

2.12 Concentric buffers were then created around all water features, at 10m intervals, up to a distance of 50m. This upper value was chosen because May & others (2015b) had recorded a measureable impact of SDD discharges on soil and porewater P at a distance of up to 30m from a source, a weak signal from some SSDs up to 40m from source, and no signal from any SSDs beyond 50m from source. This buffering resulted in polygons with five possible distance values (Table 4). A distance to water score and an associated risk category were assigned to each class interval. Polygons were not created for distances greater than 50m from a water feature because it was assumed that SSDs at this distance posed a very low risk of causing P pollution (May & others, 2015b). It should be noted, however, that these distance criteria apply only to the aerated soil zone above the water table, not to the saturated zone.

Table 4 Buffer zones created around water features and the scores and risk categories assigned to them, based on the results of May and others (2015b)

DISTANCE TO WATER (M)	DISTANCE SCORE	RISK CATEGORY	JUSTIFICATION
0 to < 10	5	High	Most SSDs had an impact on soil and porewater P
10 to < 20	4	High	Most SSDs had an impact on soil and porewater P
20 to < 30	3	Moderate	Some SSDs had an impact on soil and porewater P
30 to < 40	2	Moderate	Some SSDs had an impact on soil and porewater P
40 to < 50	1	Low	No SSDs had an impact on soil and porewater P

Depth to high water table

2.13 Groundwater depths were supplied by ESI Ltd as 25m resolution raster data. Similar to the classification of slope, values were rounded down to the nearest 0.5m and values above 2.5m were assigned a value of 2.5. This created six groundwater depth classes. Scores and risk categories were assigned as shown in Table 5, taking into account the findings of May and others (2015b) and the recommendations of Canter and Knox (1985). May and others (2015b) reported high P concentrations in the upper 1m of soil in an SDD soakway, moderate levels of P in the soil at 1-2m depth, and very low levels of P in the soil at more than 2m depth. From this it was concluded that P moving vertically through the soil column would only reach groundwater if the water table impinged on these upper soil layers.

Table 5 Depth to groundwater categories, and the scores and risk categories assigned to them

GROUNDWATER DEPTH (M)	GROUNDWATER SCORE	RISK CATEGORY	JUSTIFICATION
0 to < 0.5	5	High	High P levels recorded in soil soakaway at this depth (May & others, 2015b)
0.5 to < 1.0	4	High	High P levels recorded in soil soakaway at this depth (May & others, 2015b)
1.0 to < 1.5	3	Moderate	Moderate P levels recorded in soil soakaway at this depth (May & others, 2015b)
1.5 to < 2.0	2	Moderate	Moderate P levels recorded in soil soakaway at this depth (May & others, 2015b)
2.0 to < 2.5	1	Low	Low P levels recorded in soil soakaway at this depth (May & others, 2015b)
≥2.5	0	Low	Low P levels recorded in soil soakaway at this depth (May & others, 2015b)

Combined risk scores

2.14 To combine the three parameters and provide an overall value for the risk screening process, polygons from each of the above were overlaid and the scores from each layer were summed to produce a total, combined, score. A combined risk category was assigned to the total score, as shown in Table 6.

2.15 This combined risk category was then compared with the separate risk values from the individual layers and the highest of these was used for mapping purposes. For example, if the scores were 5 (high), 1 (low) and 1 (low), for water proximity, slope and water table depth, respectively, the value for combined risk would be 7, ie moderate (see Table 6). However, because the risk category for water proximity was high and that for combined risk was moderate, the high risk for water proximity was deemed to over-ride the lower value for overall risk and the location was classified as high risk even though the combined risk category was moderate.

Table 6 Risk categories assigned to combined risk scores

TOTAL SCORE	RISK CATEGORY	DESCRIPTION OF RISK CATEGORY
0 to 5	Low	Unlikely to cause P pollution problems
6 to 10	Moderate	May cause P pollution problems
11 to 15	High	Very likely to cause P pollution problems

Location of small domestic discharges of phosphorus

2.16 The number and location of SSDs within each SSSI and its surrounding catchment are unknown because few records are kept. So, for project purposes, this information was derived by combining two sets of data. The first was the OS AddressBase® data, which contains the locations of all properties within the area of interest. The second was the sewered area boundary data, which were derived from data supplied by the relevant water utility companies (Table 7). If the data supplied were sewer network (line) data, a sewered area boundary was created by constructing a 50m buffer around the line features supplied. This process made the assumption that properties situated more than 50m way from a mains sewer pipe would not be connected.

2.17 It was assumed that all properties outside of a sewered area were unsewered and that all properties within a sewered area were sewered. It should be noted, however, that some limitations on the accuracy of the results are imposed by this method. In particular, not every property within a sewered area is connected to the public sewerage system. This is because some owners have chosen not to connect, preferring to continue relying on private facilities even though opportunities to connect have been offered. Nevertheless, results derived in this way probably give a good indication of where the majority of private SSDs are likely to be located. In the absence of site specific information to the contrary, it was also assumed that all SSDs discharge to soakaway and that there are no direct discharges to water. In reality, this is unlikely to be the case and SSDs that discharge directly to water are likely to be high risk. In Scotland, for example, where there is a registration system in place, more than 23% of registered SDD discharge directly to water (O'Keeffe and others, 2015), putting them at high risk of polluting freshwater systems.

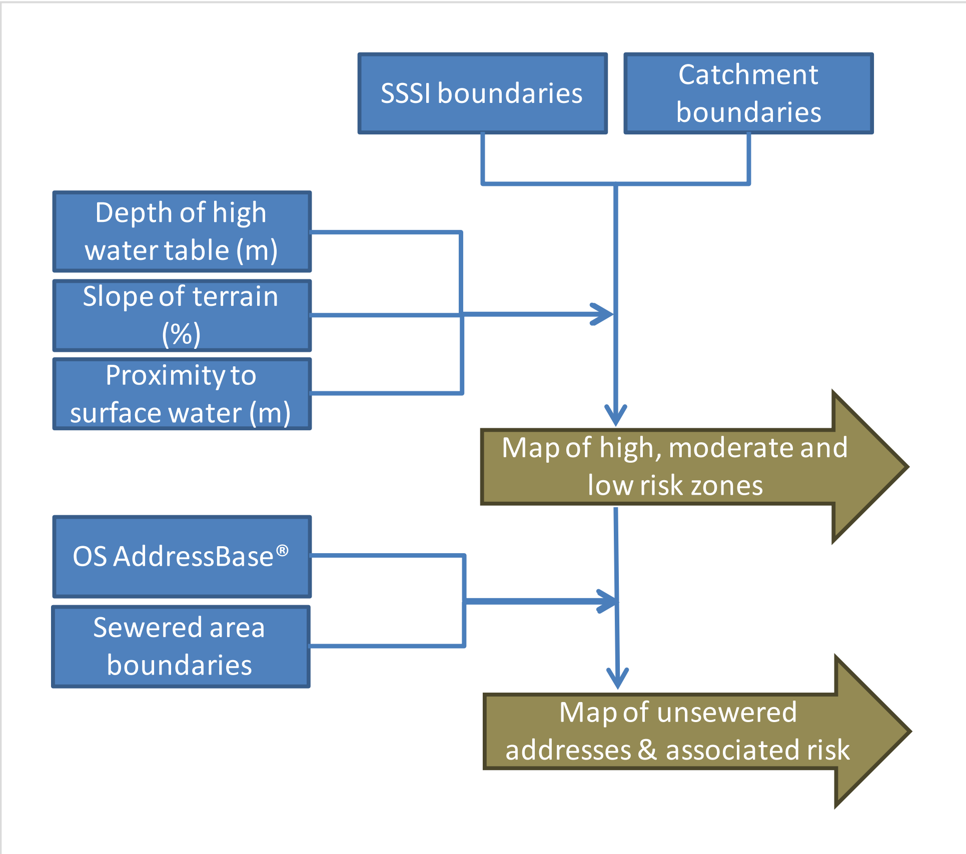
Table 7 Type of data supplied by water utility companies per site (n/a = not applicable; no sewage treatment works in this catchment)

SITE NUMBER	NAME	SEWERED AREA	SEWER NETWORK	WATER COMPANY
01	Leighton Moss	n/a	n/a	United Utilities
02	Hawes Water	n/a	n/a	United Utilities
03	Yare Broads & Marshes	Y	N	Anglian Water
04	Upper Thurne Broads & Marshes	Y	N	Anglian Water
05	River Till	N	Y	Northumbrian Water
06	West Sedgemoor	Y	N	Wessex Water
07	Tealham & Tadham Moors	Y	N	Wessex Water
08	Bassenthwaite Lake	N	Y	United Utilities
09	River Camel & Tributaries	Y	N	Southwest Water
10	River Avon System	Y	N	Wessex Water
11	River Clun	Y	Y	Severn Trent
12	Dacre Beck	N	Y	United Utilities
13	River Itchen	Y	N	Southern Water
14	Oak Mere	N	Y	United Utilities
15	River Mease	Y	Y	Severn Trent
16	River Lambourn	N	Y	Thames Water
17	Ant Broads & Marshes	Y	N	Anglian Water
18	River Axe	Y	N	Southwest Water
19	River Lugg	Y	Y	Welsh Water
20	Ullswater	N	Y	United Utilities

Combining the data to produce catchment scale risk maps

2.18 The results of the catchment scale risk mapping undertaken and the likely locations of unsewered properties (SSDs) derived from the OS AddressBase® dataset were combined to produce an overall map of risk zones at the catchment scale, and the potential risk posed by individual SSDs. An overview of this process is shown in Figure 2 and the results are shown in Figures 3 to 22.

Figure 2 Overview of the catchment mapping and risk assessment process



2.19 In addition to the map output from the process outlined above, the underlying catchment characteristics and SDD risk statistics were summarised for each catchment and SSSI.

Improvements to methods used by May and others (2015a)

2.20 A number of improvements were incorporated into the methodology used in this project in comparison with that proposed by May and others (2015a). These were:

- Better inclusion of factors relating to hydrological connectivity.
- Improved method for locating properties likely to have SSDs.
- Revised method for combining levels of risk.

2.21 These improvements are described in detail, below.

Better inclusion of factors relating to hydrological connectivity

2.22 One of the key factors identified by May and others (2015a) as being very important in determining whether discharges from SSDs would affect the quality of nearby waterbodies is the hydrological connectivity between the source of the discharge and the receiving water. In the initial development of the risk assessment tool (May & others, 2015a), this was derived by combining distance from a watercourse with the hydrological properties of the surrounding soil, as indicated by the UK Hydrology of Soil Types (HOST) dataset (Boorman & others, 1995). In the current project, this part of the effluent transport process has been updated to include the results from soil cores collected from beneath SDD effluent distribution pipes and across soil soakaways by May and others (2015b) and limited additional information from the literature (eg Zanini & others, 1998; Lombardo, 2006).

2.23 Soil profile data from these reports and publications suggested that, beneath the effluent distribution pipes, there was a marked decline in soil P content over the upper 1-1.5m of aerated soil, with soil P concentrations reaching almost background levels by a depth of 1.5-2m. Within the limited data available, these values were broadly similar across all types of soil, from calcareous to non calcareous. This suggested that, in a well drained soil, a proportion of the P in effluent would reach the water table (groundwater) only if it was less than 2m from the soil surface. If the water table was below this level, the risk of P contaminating groundwater would be relatively low. It was also assumed that there would be a moderate risk of P reaching groundwater if the high water table was between 1m and 2m below the soil surface, and a high risk if that water table was less than 1m below the surface. To incorporate this information into the risk screening process, the very coarse HOST classes data used in the original method (1km resolution) was replaced by higher resolution data on depth to annual maximum height of water table (50m resolution) that was provided by ESI Ltd.

2.24 Distance from water is also a key factor that affects hydrological connectivity. In the method proposed by May and others (2015a), this was incorporated as a series of setback distances based on values suggested by other studies such as Canter and Knox (1985), McGarrigle & Champ (1999) and Robertson (2003). The values used by May and others (2015a) are shown in Table 1; these were applied to all SSDs. In the present study, and based on the results of May and others (2015b), distance to water (and hence hydrological connectivity) has been subdivided into two categories (1) vertical distance to groundwater/high water table and (2) horizontal distance to surface water. Vertical distance to groundwater is incorporated into the changes outlined above. Horizontal distance to surface water was changed to apply only to the aerated soil zone, ie above the water table. In the current project, the results from May and others (2015) have been used to revise the distance to surface water risk categories (*cf*. Tables 1 and 4). In addition, it was assumed that any P entering the groundwater would eventually make its way to the SSSI, so this risk was not classified according to distance from source. It should be understood that this is a very precautionary assumption.

Improved method for locating properties likely to have SSDs

2.25 To provide a detailed risk assessment of individual properties within each catchment, based on their geographical location, it was necessary to derive the number of unsewered properties from readily available map data and include this in the risk assessment procedure. This approach replaced that used in the earlier study (May & others, 2015a), which involved the manual interpretation of aerial photography and was a very time consuming task. The method used in the current project was based on that originally described by May and others (1999), but incorporated the more detailed datasets that are now widely available. A number of assumptions that affect the accuracy of the derived data are:

- Addresses include domestic and non-domestic properties.
- All properties outside of sewered areas are unsewered.
- All properties within sewered areas are sewered.
- All SSDs discharge to a soil soakway and not directly to water.
- Once P enters a drainage channel in any part of the catchment, it flows to the SSSI.

These assumptions reflect the limitations imposed by the available data.

2.26 In addition to the number and location of unsewered properties, the density of these properties within the catchment was also calculated. This was because density of SSDs within a catchment also affects the risk of effluent polluting local watercourses (CMHC, 2006). In general, lower densities of tanks tend to cause less contamination of downstream waterbodies than higher densities (Arnscheidt & others, 2007). This is because areas with lower densities provide greater potential for P adsorption onto soil particles. They also generate more runoff, which provides greater dilution potential for these discharges within the receiving watercourses. Although these values were calculated to allow comparison across sites, they have not been incorporated into the risk assessment process. However, comparison with the values suggested by May and others (2015a) (Table 8) suggest that, at the catchment scale at least, most of the geographical areas considered in this study are low risk in terms of SDD densities. The highest value recorded was 41.5km^{-2}, in the catchment of Oak Mere SSSI. That said, however, there are probably local clusters of SSDs within each catchment that pose a greater risk than is suggested by catchment scale figures alone.

Table 8 Risk rating in relation to tank density (after May & others, 2015a)

DENSITY OF TANKS (km^{-2})	RISK RATING
>2500	5
800 - 1500	4
400 - 700	3
200 - 300	2
<200	1

Revised method for combining levels of risk

2.27 May and others (2015a) proposed a simple, additive method for combining risks posed by hydrological connectivity, distance from a waterbody and the slope of the terrain on which each property is located. In the current project, this method was further refined to take into account the fact that a single high risk factor associated with a given site (such as a very high slope or high water table) might over-ride the importance of other risk factors. So, a more comparative approach was used. This is described in the paragraphs 1.20 and 1.21 (Combined risk scores).

3 Results

3.1 An overview of the results of the analyses and the mapped data are presented in Figure 3 and Table 9. Figure 3 allows all of the catchments to be compared in terms of the proportion of unsewered addresses in each catchment and the relative risks associated with their geographical locations. The catchments that drain to each SSSI vary enormously in size, the largest being the River Avon (1,669km^2) and the smallest being Hawes Water (2.5km^2). The area of each pie chart in Figure 3 is proportional to the average density of all addresses within the catchment and clearly demonstrates an increase in population density from the northwest towards the southeast of the country. In the more densely populated areas, a greater proportion of the properties are sewered.

3.2 Table 2 summarises the characteristics of all properties within the catchment of each SSSI in terms of their total number, the number within and outside of sewered areas, and their relative risk to water quality. The total number of properties in each catchment ranged from 33 (Hawes Water) to 162,348 (Yare Broads and Marshes), with the number of properties likely to be unsewered ranging from 33 (Hawes Water) to 11,940 (River Avon). In terms of density, the values for unsewered properties ranged from 3.3km^{-2} (River Till) to 41.5km^{-2} (Oak Mere), with the average being about 10km^{-2}.

3.3 Detailed descriptions of the data and associated maps are given for individual sites, below. It should be noted that 'sewered' properties are defined as those that fall within the sewered boundaries provided by the water utility companies and 'unsewered' properties are defined as those that are located outside of the sewered areas. However, these assumptions introduce a certain amount of uncertainty into the data. While it can be assumed that properties in unsewered areas are very likely to have some form of SDD to process domestic waste, it cannot be assumed that all properties within sewered areas are connected to the main sewerage system. This is because, in some places, owners will have chosen not to connect. For this reason, the estimates of unsewered properties given for each catchment in this report are likely to be underestimates of their real numbers and reflect the best case scenario in terms of their risk of polluting freshwater SSSIs. This is in contrast to some of the other assumptions in this project, which are based on a worst case scenario, eg the assumption that all P discharged from these systems is transported to the SSSI if it reaches the water table or drainage network.

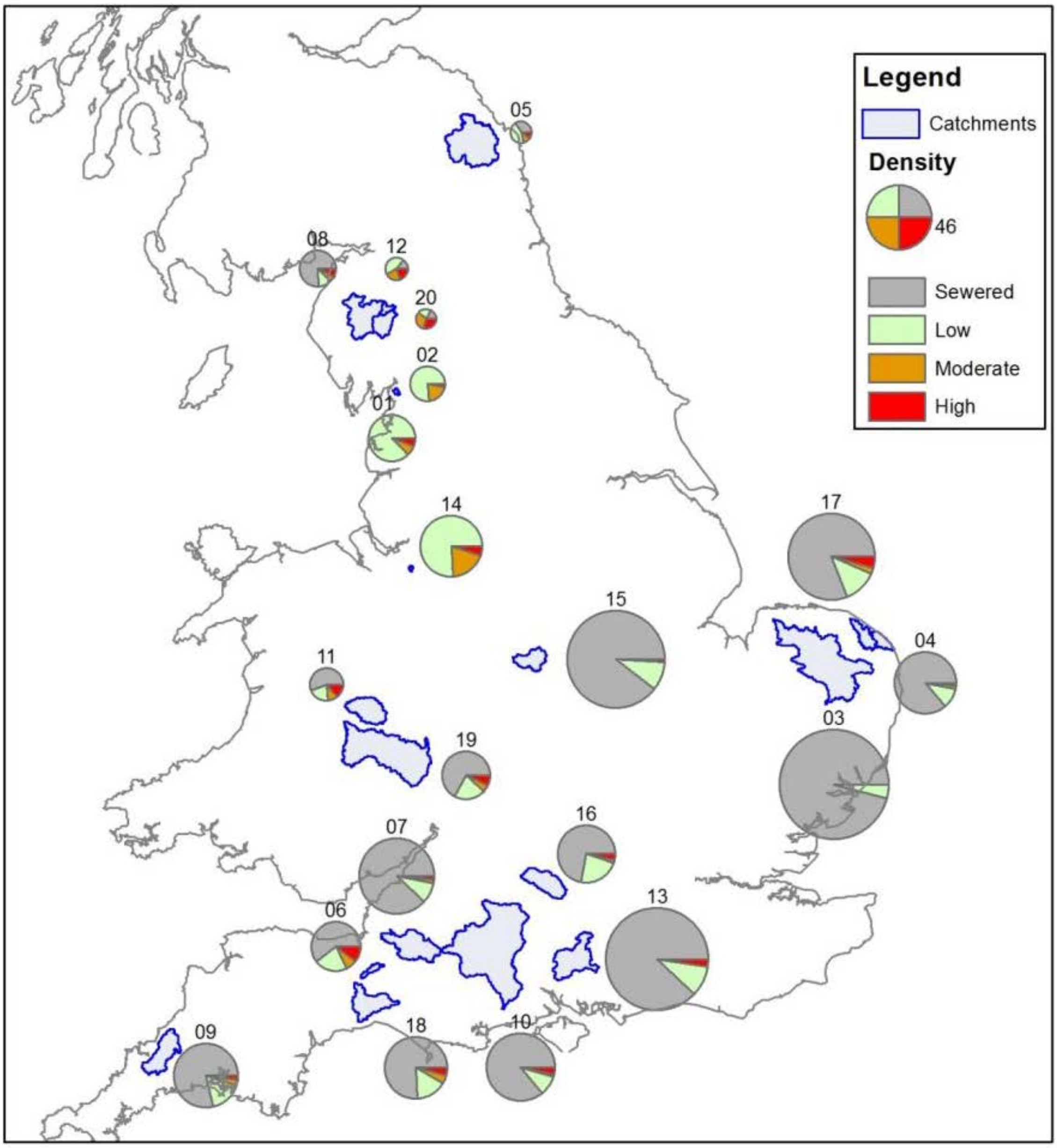


Figure 3 Locations of SSSI study sites and their topographically defined hydrological catchments. Pie charts show the proportions of sewered (grey) and unsewered (green, amber, red) properties within each catchment and the estimated level of risk to SSSIs (low, moderate, high) associated with the unsewered properties. The total area of each pie chart is proportional to the overall density of properties within each catchment. The numbers are codes associated with each SSSI, as follows:

Key to SSSIs:

01-Leighton Moss
02-Hawes Water
03-Yare Broads & Mosses
04-Upper Thurne Broads & Marshes
05-River Till
06-West Sedgemoor
07-Tealham & Tadham Moors
08-Bassenthwaite Lake
09-River Camel Valley & Tributaries
10-River Avon

11-River Clun
12-Dacre Beck
13-River Itchen
14-Oak Mere
15-River Mease
16-River Lambourn
17-Ant Broads & Marshes
18-River Axe
19-River Lugg
20-Ullswater

Table 9 Catchment area of each freshwater SSSI and characteristics of properties located within them

SSSI	NAME	CATCHMENT AREA (km^2)	TOTAL NUMBER	UNSEWERED DENSITY (km^{-2})	SEWERED	UNSEWERED	HIGH RISK ZONE	MODERATE RISK ZONE	LOW RISK ZONE
01	Leighton Moss	9.7	230	23.8	0	230	13	17	200
02	Hawes Water	2.5	33	13.4	0	33	1	7	25
03	Yare Broads & Marshes	1228.8	162,348	7.5	153,090	9,258	1,511	1,045	6,702
04	Upper Thurne Broads & Marshes	79.2	3,359	5.9	2,894	465	44	67	354
05	River Till	670.1	3,373	3.3	1,138	2,235	331	376	1,528
06	West Sedgemoor	41.1	1,102	9.9	695	407	124	34	249
07	Tealham & Tadham Moors	390.9	24,290	7.5	21,358	2,932	390	403	2,139
08	Bassenthwaite Lake	364.6	5,304	3.6	4,009	1,295	409	295	591
09	River Camel Valley & Tributaries	290.8	13,037	9.7	10,225	2,812	293	383	2,136
10	River Avon System	1668.8	85,450	7.2	73,510	11,940	2,930	1,133	7,877
11	River Clun	270.8	3,272	5.3	1,839	1,433	441	334	658
12	Dacre Beck	38.4	216	4.8	31	185	43	47	95
13	River Itchen	393.5	45,537	14.5	39,836	5,701	1,124	170	4,407
14	Oak Mere	5.6	233	41.5	0	233	12	44	177
15	River Mease	167.6	17,572	11.8	15,602	1,970	184	117	1,669
16	River Lambourn	264.4	9,584	10.1	6,916	2,668	355	140	2,173
17	Ant Broads & Marshes	124.5	10,327	16.0	8,340	1,987	419	233	1,335
18	River Axe	296.8	12,648	10.3	9,582	3,066	494	596	1,976
19	River Lugg	1079.7	27,738	8.4	18,618	9,120	1,899	1,404	5,817
20	Ullswater	147.5	665	3.7	112	553	201	205	147

01 - Leighton Moss & 02 - Hawes Water

Background

3.4 Leighton Moss is a lowland SSSI comprising fen, marsh and swamp. It has areas of open water, reed beds and wet woodland. The catchment of Hawes Water adjoins, and feeds into, that of Leighton Moss. The SSSI at Hawes Water has broadleaved, mixed and yew tree woodland in upland areas and fen, marsh and swamp in some lowland areas and calcareous, neutral and improved grassland in others. There are also areas of open water and drains.

Questionnaire response

3.5 Natural England provided a map showing the combined catchments of Leighton Moss and Hawes Water that had been produced by the Royal Society for the Protection of Birds in collaboration with a subcontractor (Environment, Land and People). This was larger than that generated from surface topography alone in the current project, and included areas of uncertainty in relation to the hydrological links associated with underlying limestone formations. For this project, the topographic catchment was extended manually to include these additional areas. A small area in the southwest of the catchment, which is drained by a ditch, was also removed on the advice of Natural England.

3.6 Local knowledge suggested that there were no mains sewage facilities anywhere within these catchments. Information from United Utilities has confirmed this. So, it has been assumed that all properties within the catchments of these SSSIs are unsewered. Information provided by local staff suggested that more than 30 properties within the area were known to have septic tanks. It was also noted that here are numerous properties around Hawes Water, in particular, that probably discharge into, or close to, the SSSI.

Project output

3.7 The area of the catchment that drains into Hawes Water was estimated to be about 2.5km^2 and that draining to Leighton Moss to be about 9.7km^2. The risk assessment map for these catchments is shown in Figure 4. Most of these areas are low risk in terms of SDD locations (Leighton Moss – 69%; Hawes Water - 84%), but there are some quite large areas with moderate and high risk. These are: Leighton Moss – 17% & 14%, respectively; Hawes Water - 10% & 6%, respectively. Areas of high risk were mainly due to a relatively high water table.

3.8 There are no centralised waste water treatment works (WWTWs) in this area. Within the Hawes Water catchment, which feeds into the Leighton Moss catchment, there are about 33 unsewered properties. Of these, 1 (3%) poses a high risk, 7 (21%) pose a moderate risk and 25 (76%) pose a low risk. There are no unsewered properties within Leighton Moss SSSI itself, but there is 1 on the boundary of the site that poses a moderate risk of causing pollution. There are a further 230 unsewered properties within the immediate catchment. Of these, 13 (6%) pose a high risk, 17 (7%) pose a moderate risk and 200 (87%) pose a low risk.

3.9 Overall, there are likely to be about 263 unsewered properties in these combined catchments; far more than the 30 properties known to have on site SSDs in the area (see above). The average densities of SSDs in these two catchments were 23.8km^{-2} for Leighton Moss and 13.4km^{-2} for Hawes Water.

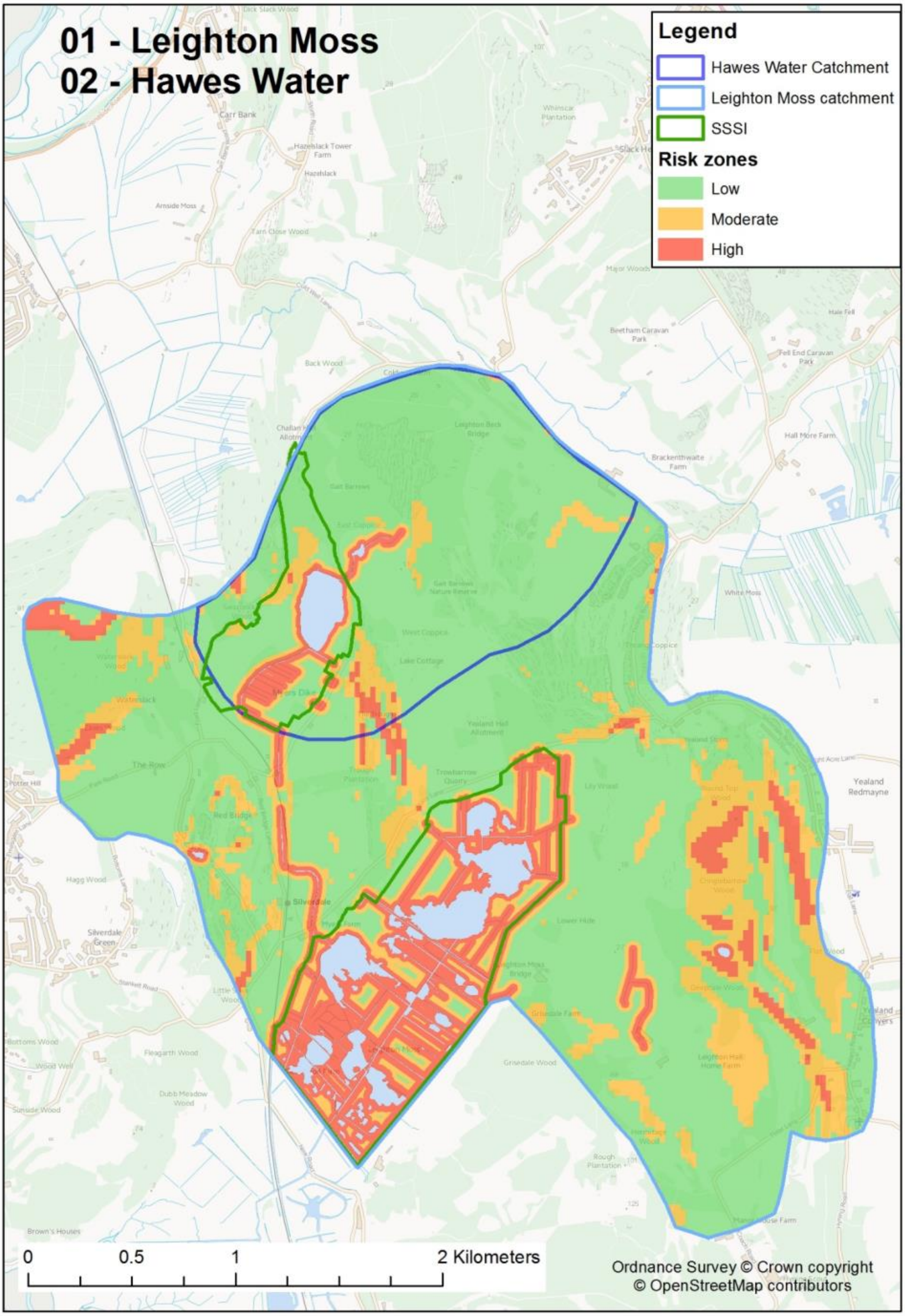


Figure 4 Catchments of Leighton Moss and Hawes Water SSSIs showing high, moderate and low risk zones for locating small domestic discharges

03 - Yare Broads & Marshes

Background

3.10 The Yare Broads and Marshes is a small SSSI downstream of a large catchment that includes many sewage treatment works and the large town of Norwich. The SSSI itself comprises fen, marsh and swamp in the lowlands, together with broadleaved, mixed and yew woodland on higher ground. There are also areas with standing water and field drains. An area that spans both banks of the River Yare downstream of Norwich includes a number of nature reserves and there are a number of open water areas, such as Rockland broad. The river itself is not part of the SSSI. The outflow from the SSSI site is unclear; local staff reported that it could be in one of several locations.

Questionnaire response

3.11 Local staff reported that they were not aware of any particular problems with SSDs in this area, but this may be because their locations are unknown. It is believed that any SSDs that do exist are all within the wider catchment rather than the SSSI itself. Over the last 5 years, 24 domestic sewage pollution incidents have been recorded in an area of 100km^2 around the broad.

3.12 Anglian Water has a programme of connecting unsewered properties to the sewage network in this area. There are currently such schemes in place at Neatishead, Ormesby St Michael, Stokesby, East Ruston and Great Ellingham. All of these were subject to environmental impact assessment reports before work commenced and are due to be completed by March 2015. New development in the area is guided by Site Allocation DPDs and almost all are restricted to sewered areas. Where developments are outside of current settlements, there is a commitment to ensure that water disposal is considered holistically. Away from these sites, however, replacement builds may occur on existing plots that currently have – and could continue to have – SSDs.

Project output

3.13 The catchment that potentially drains to the Yare Broads and Marshes SSSI, as defined by the methods used in this study, covers an area of about 1,229km^2. It should be noted, however, that this catchment does not align with that used for Catchment Sensitive Farming in this area. The latter covers a much wider area to the south and west of the SSSI, and much less to the north. The reason for this discrepancy is unclear.

3.14 A risk assessment map of the catchment as identified in this project is shown in Figure 5. About 79% of the area is low risk, with areas of moderate and high risk accounting for about 6% and 15% of the catchment, respectively. Areas of high risk mostly have a high water table.

3.15 There are a very large number of SSDs and sewage treatment works upstream of the SSSI, but none within it. There are, however, approximately 8 unsewered properties around the edge of the SSSI that pose a high risk and a further 3 unsewered properties that pose a moderate risk.

3.16 The SSSI is downstream of a large catchment area that contains an estimated 162,348 properties. About 153,090 of these properties are served by mains sewerage and the remaining 9,258 (6%) probably have SSDs. So, any P pollution problems are likely to come from a large number of sources and from a wide area. Within the wider catchment, 1,511 (16%) of the SSDs have been identified as being at high risk of causing water pollution, while 1,045 (11%) pose a moderate risk and 6,702 (73%) pose a low risk. The average density of unsewered properties within this catchment is about 7.5km^{-2}.

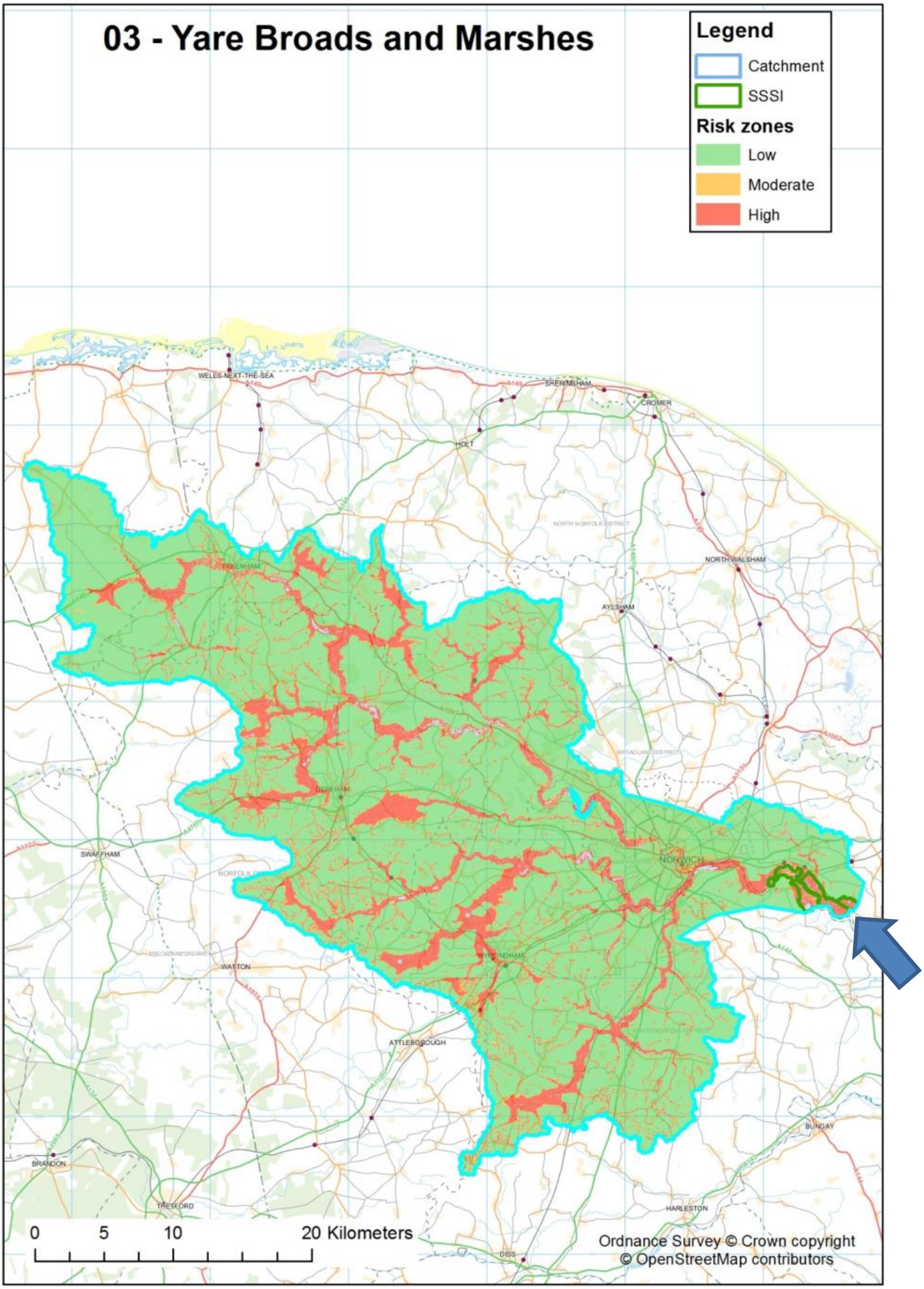


Figure 5 Catchment of the Yare Broads and Marshes SSSI showing high, moderate and low risk zones for locating small domestic discharges; the location of the outflow point, as used to generate the catchment outline, is indicated with an arrow

04 - Upper Thurne Broads & Marshes

Background

3.17 The Upper Thurne Broads and Marshes comprise fen, marsh and swamp in the lowlands, with broadleaved, mixed and yew woodland. There are also areas of standing open water and drains. The area includes a number of large standing waters, including Hickling Broad, and surrounding areas of marshland and woodland. The whole of the Upper Thurne catchment is pump drained. The catchment boundaries are unknown and the outflow from the system is unclear.

Questionnaire response

3.18 Although the number and locations of SSDs in the area are unknown, they are not believed to be a problem. In general, local members of staff believe that there are no SSDs within the SSSI itself but noted there may be several within the wider catchment. A couple of SDD discharge problems have occurred within the Upper Thurne, one at Rollesby Broad (Septic tank - 04/02/11) and one at Cromes Broad (Septic tank; first reported 12/12/13 and, as yet, unresolved). Of 10 sewage pollution incidents recorded in the 64km^2 area around the broad over the past 5 years, only two have been attributed to domestic sewage pollution incidents. The programme of connecting unsewered properties to the sewer network that has been put in place by Anglian Water (outlined above for the Yare Broads and Marshes) also applies to this area of the Broads.

Project output

3.19 The catchment of the SSSI (Figure 5) covers an area of about 79km^2, and falls within the wider catchment used for catchment sensitive farming activities in this area. Of the 79km^2, about 31% was identified as being high risk in terms of SSDs in this area having the potential to contaminate water. A further 11% was identified as posing a moderate risk, with the remaining 58% posing a low risk.

3.20 Within this area there are approximately 3,359 properties. Of these, there are 2,894 (86%) sewered properties and 465 (14%) unsewered properties. Of the latter, 44 (9%) are at high risk of contaminating waterbodies, 67 (14%) are at moderate risk and 354 (77%) are at low risk. Of those identified as being at high risk, four are on the outer boundary of the SSSI and one is within it. Five of those identified as having moderate risk are on, or very close to, the boundary of the SSSI. The density of SSDs in this area is 5.9km^{-2}.

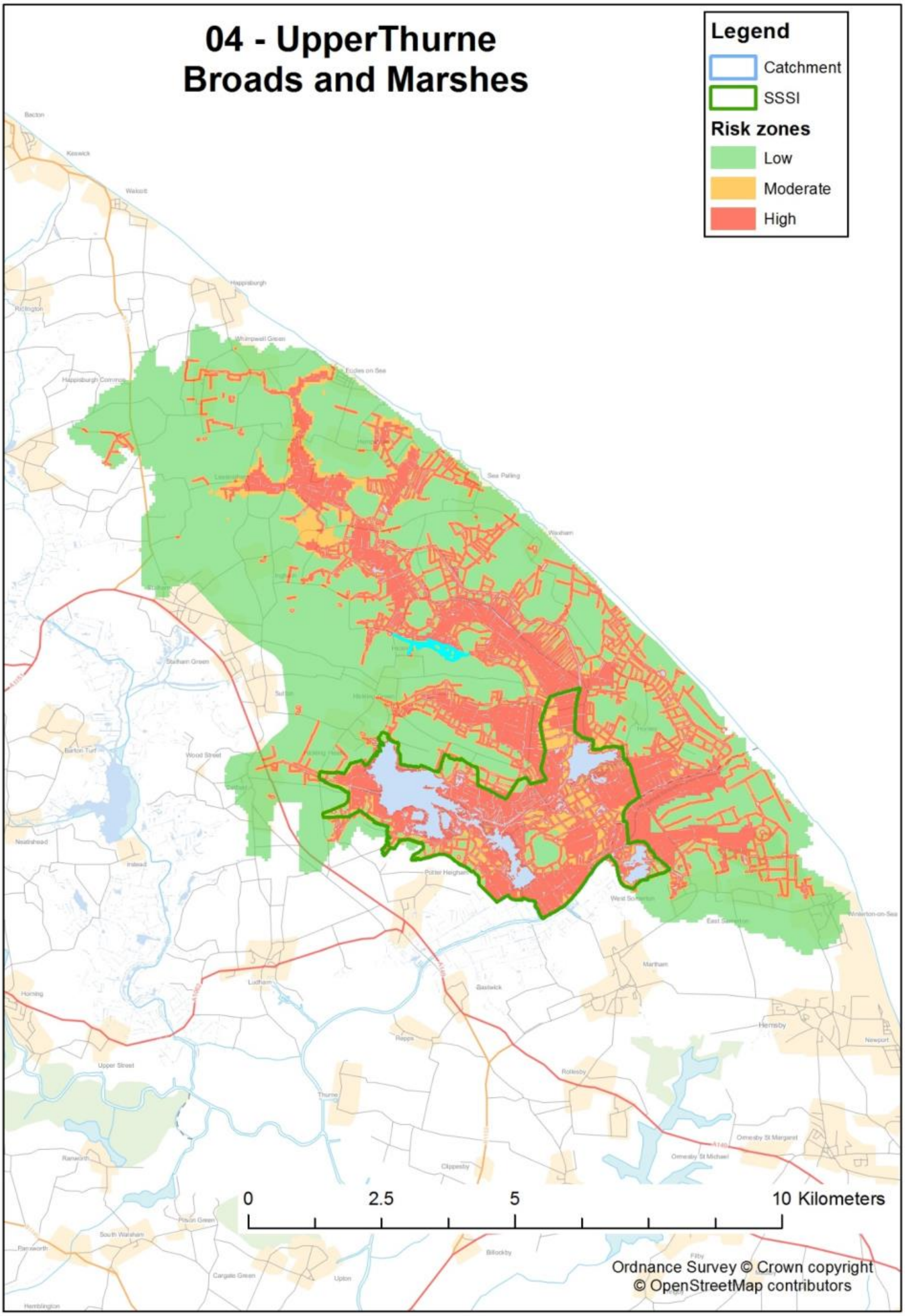


Figure 6 Catchment of the Upper Thurne and Broads Marshes SSSI showing high, moderate and low risk zones for locating small domestic discharges

05 - River Till

Background

3.21 The River Till freshwater SSSI comprises rivers and streams that pass through a number of other SSSIs. The SSSI itself is not large in terms of area, but a much larger catchment drains into it. The River Till meets the River Tweed at Tillmouth, but the exact location of the outflow from the SSSI is unknown.

Questionnaire response

3.22 The wider catchment has a known issue with SDD discharges. Only one town (Wooler) has a sewage treatment works, but many villages in the area have package treatment plants. Several of these discharge directly into drainage ditches where there is evidence of sewage fungus. The catchment is sparsely populated with farms and cottages, but there is little information on where their sewage effluent discharges to and how it is being treated. Some farm buildings have been converted to dwellings over the last few years, creating more sewage discharges within the system but, in general, the situation regarding SSDs discharges within this catchment is unclear. Although there are no known SSDs in the river channel that forms the SSSI, there are many within the wider catchment. The only major development work planned for the future is 50 new houses in Wooler; these will be connected to the sewage works.

Project output

3.23 The catchment that drains to the River Till SSSI is 670km^2 in area (Figure 7). Thirty-one percent of this is high risk in terms of SDD locations, while 23% is moderate risk and 46% is low risk.

3.24 Analyses suggested that there are 3,373 properties within the catchment. Of these, an estimated 1,138 (34%) are likely to be sewered and 2,235 (66%) unsewered. Of the unsewered properties, 331 (15%) were identified as being in a high risk location, 376 (17%) in a moderate risk location and 1,528 (68%) in a low risk location. The average density of unsewered properties within the catchment was estimated to be about 3.3km^{-2}.

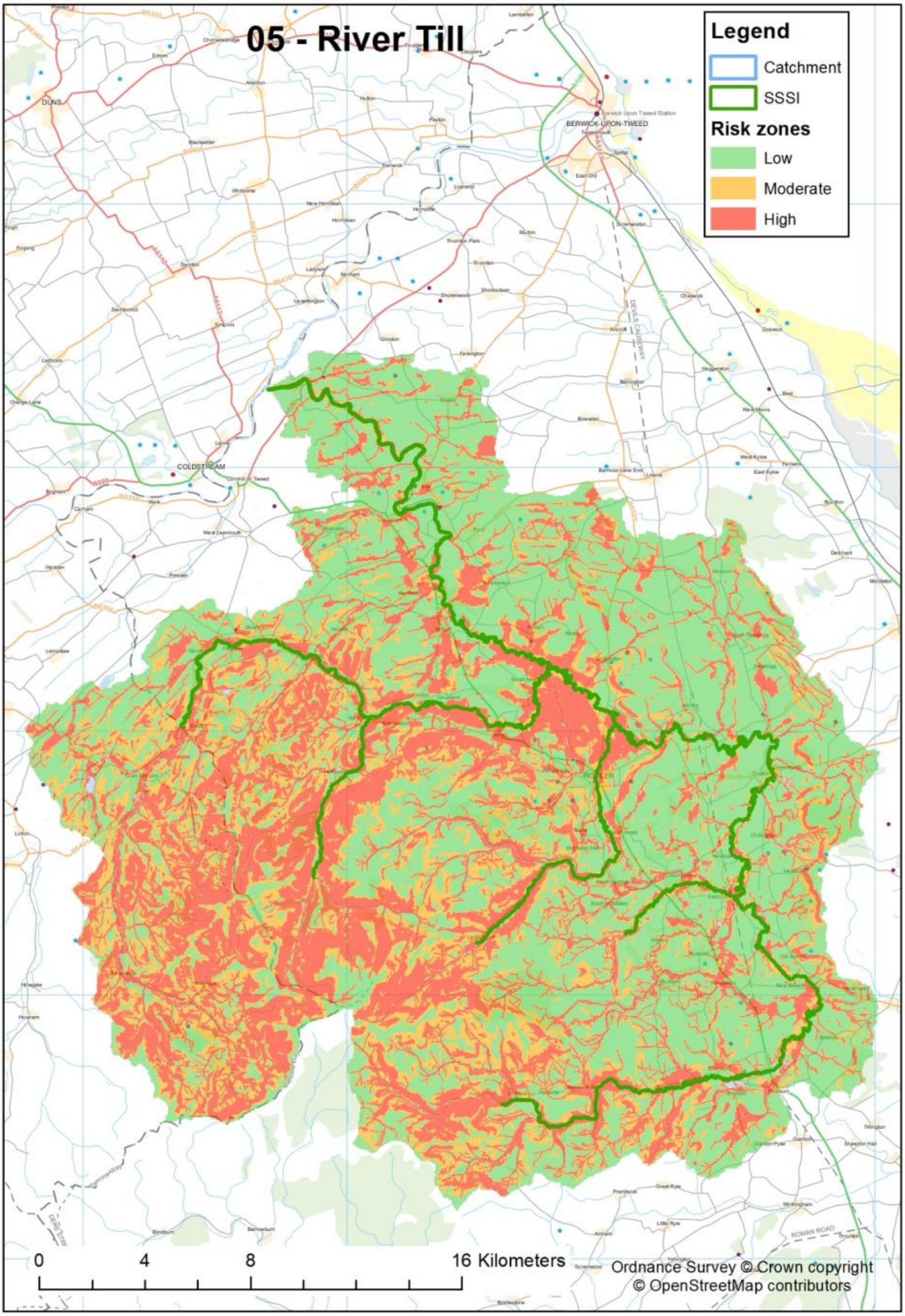


Figure 7 Catchment of the River Till SSSI showing high, moderate and low risk zones for locating small domestic discharges

06 - West Sedgemoor

Background

3.25 The freshwater SSSI at West Sedgemoor comprises a lowland area of neutral grassland with an artificial drainage system.

Questionnaire response

3.26 The catchment is known to have areas not connected to the sewer and several septic tanks that the EA is currently investigating due to pollution issues. It is thought that the surrounding soils in the catchment are heavy clay and properties are therefore unsuited to soakaways and directly discharge to watercourses.

3.27 Within the SSSI itself it is thought that there are only two farms which have septic tanks. There are a larger number of farms and dwellings adjacent to the SSSI which are also all thought to have septic tanks. It is not thought that there are any planned developments for the catchment in the near future.

Project output

3.28 The catchment analyses identified an area of about 41km^2 draining into this SSSI (Figure 8). Due to the artificial drainage network in this area providing a high level of hydrological connectivity, a large proportion of the catchment (44%) was estimated to be at high risk of SSDs located degrading water quality. A further 11% of the catchment was identified as being at moderate risk and the remaining 45% as being at low risk.

3.29 The total number of properties within the catchment was estimated to be about 1,102 (Table 2). Of these, 695 (59%) appear to be within a sewered area. Of the remainder, 124 (31%) are in an area of high risk, 34 (8%) in an area of moderate risk and 249 (61%) in an area of low risk. The average density of SSDs in this area was estimated to be about 9.9km^{-2}.

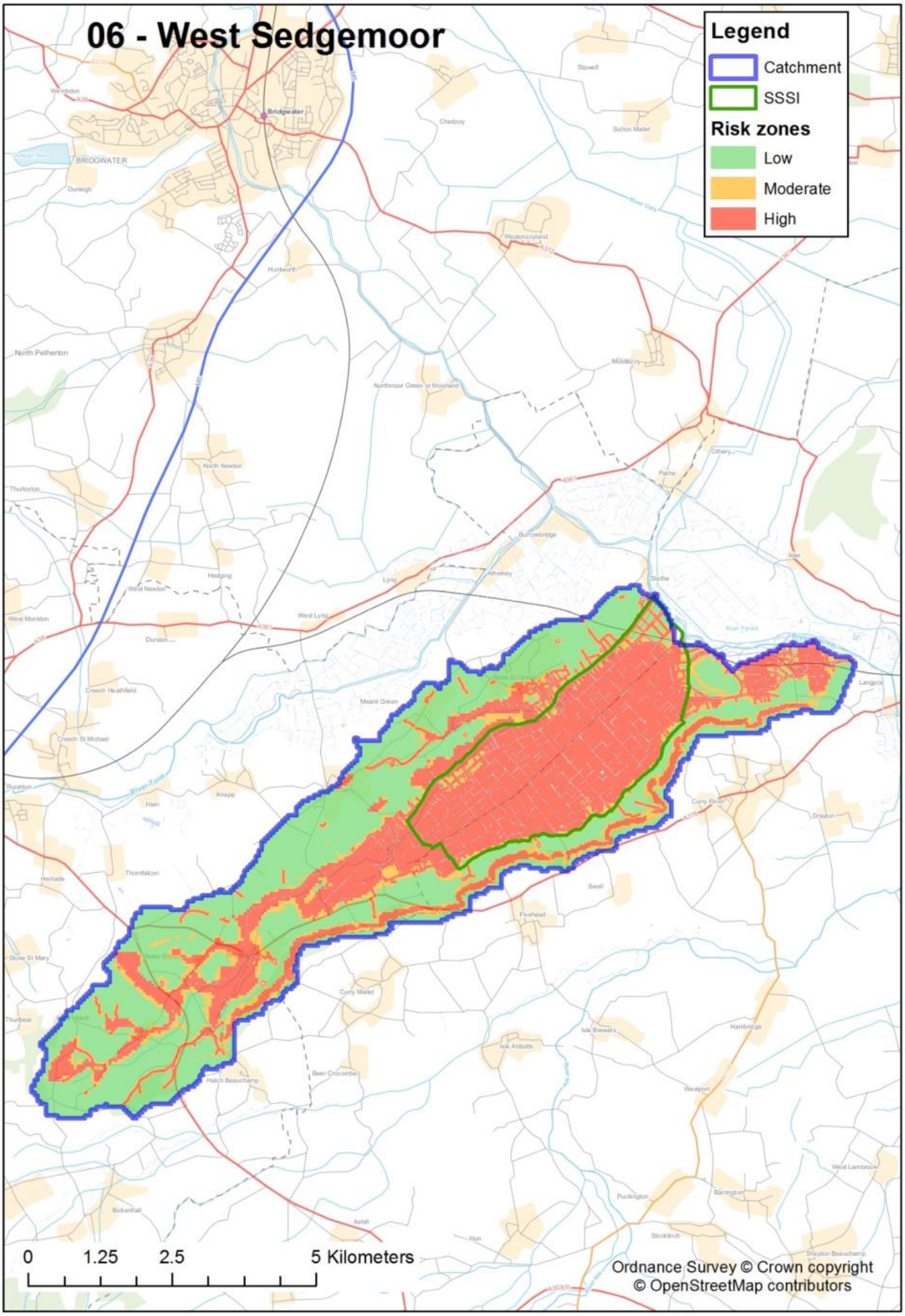


Figure 8 Catchment of West Sedgemoor SSSI showing high, moderate and low risk zones for locating small domestic discharges

07 - Tealham & Tadham Moors

Background

3.30 The freshwater SSSI at Tealham and Tadham Moors is an area of lowland neutral grassland with standing waters and an artificial drainage system.

Questionnaire response

3.31 There are a number of known villages and isolated dwellings which are not connected to the sewer in the wider catchment. It is unclear whether the contribution from these unsewered properties is significant as there are sewage treatment works and agricultural related pollution in the catchment.

3.32 Within the SSSI itself there is a small business, a number of farms and some small dwellings that are not connected to a sewer. There are no known planned developments within the catchment in the near future.

Project output

3.33 The surface water catchment of this SSSI was found to be about $391km^2$ in area (Figure 9). Most of this (63%) was identified as having low risk in terms of SDD location and 14% was identified as having moderate risk. A further 23%, mainly in the north-west of the catchment and relatively close to the SSSI, was identified as having high risk.

3.34 The catchment contains about 24,290 properties and several sewage treatment works. Of these, 21,358 appear to be connected to mains sewerage systems. Of the remaining 2,932 properties, identified as likely to be using SSDs, 390 (13%) are located in areas where there is a high risk of these systems causing water quality problems and 403 (14%) are located in areas of moderate risk. The remaining 2,139 (73%) are in low risk areas. The average density of SSDs in this area was estimated to be about $7.5km^{-2}$.

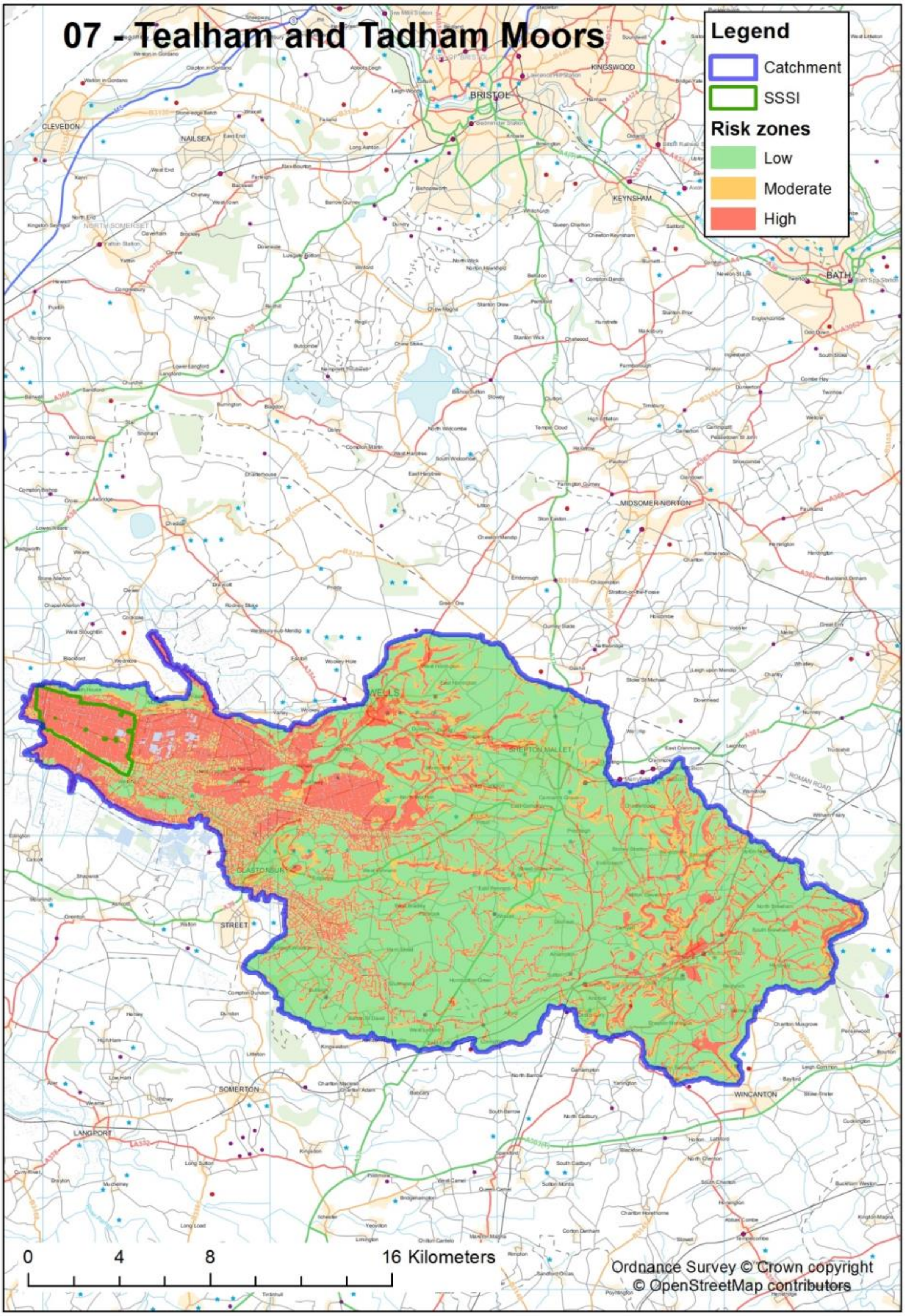


Figure 9 Catchment of Tealham and Tadham Moors SSSI showing high, moderate and low risk zones for locating small domestic discharges

08 - Bassenthwaite Lake

Background

3.35 Bassenthwaite Lake is a SSSI in its own right, and a sub-catchment of the River Derwent and Bassenthwaite Lake Special Area of Conservation (SAC). It is fed by, and flows into, the River Derwent and Tributaries SSSI. The Bassenthwaite Lake SSSI is failing Common Standards Monitoring targets for total phosphate.

Questionnaire response

3.36 Historically, Keswick waste water treatment works has contributed a high P input to the lake and this has dominated the external P loading for many years. However, internal recycling of P also contributes to phytoplankton growth and biomass accumulation and, therefore, the high chlorophyll *a* levels that are causing failures to meet water quality objectives.

3.37 May and others (1999) attributed 18% of the P input to the lake from its catchment to be coming from SSDs. If recalculated using more recent data, that percentage would be much higher because point sources of P within the catchment have been reduced. There are no known areas within the catchment that are earmarked for future development of unsewered properties.

Project output

3.38 Bassenthwaite Lake has a catchment area of about 365km^2 (Figure 10). Of this, 61% was identified as posing a high risk in terms of SDD location – mainly because of the steepness of the terrain. In addition, 18% was found to pose a moderate risk. Only 21% posed a low risk.

3.39 Within this area there are approximately 5,304 properties. Of these, 4009 appear to be served by mains sewerage schemes. Of the 1295 unsewered properties, 409 (31%) are at high risk of contaminating waterbodies, 295 (23%) are at moderate risk and 591 (46%) are at low risk. The density of SSDs in this area is about 3.6km^{-2}.

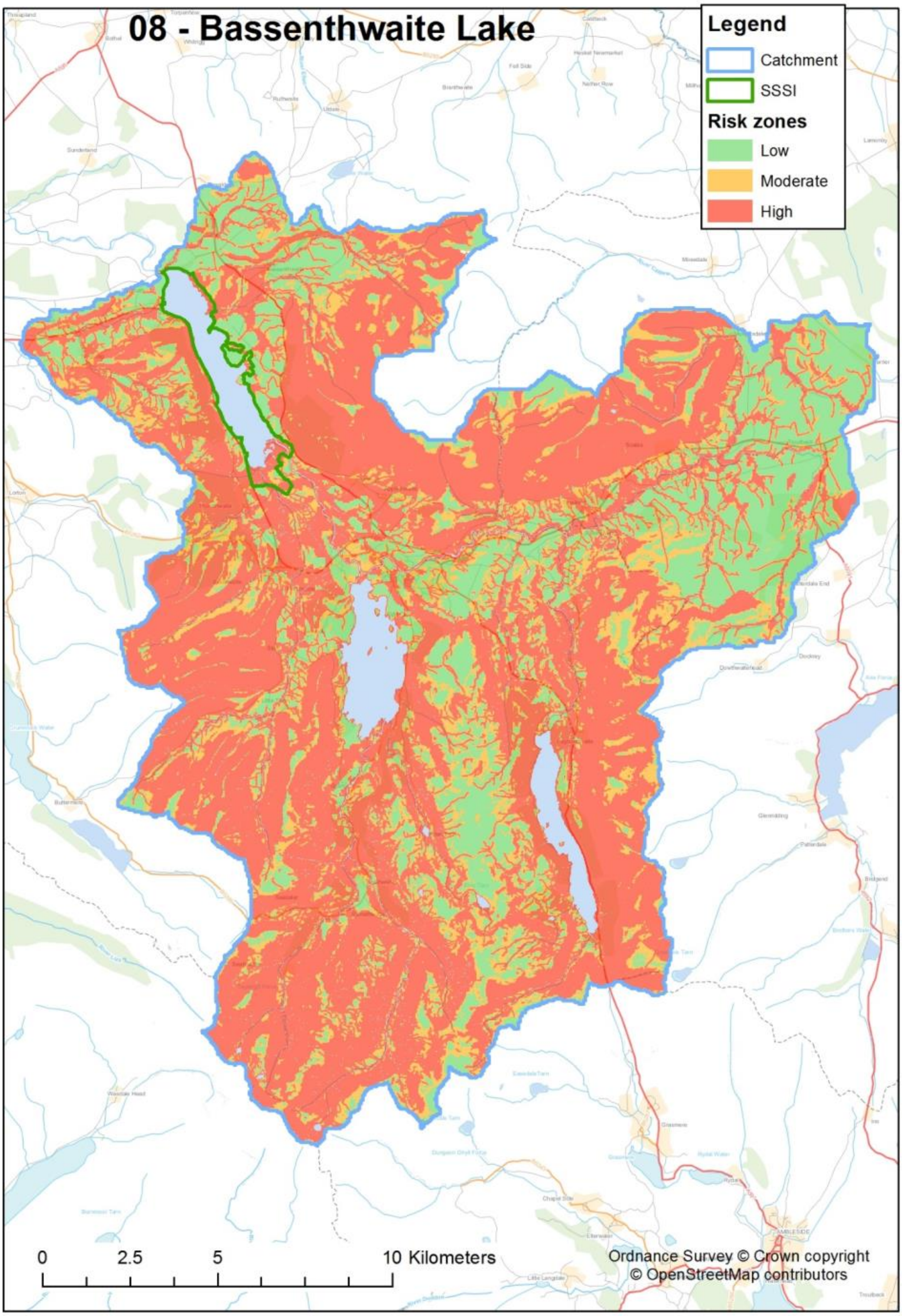


Figure 10 Catchment of Bassenthwaite Lake SSSI showing high, moderate and low risk zones for locating small domestic discharges

09 - River Camel

Background

3.40 The River Camel and its tributaries SSSI comprises rivers and streams in areas of acid grassland in upland areas and neutral grassland in lowland areas. There are also broadleaved, mixed and yew woodlands in the lowlands. The river and stream system passes through a number of other SSSIs.

Questionnaire response

3.41 It is thought that septic tanks have been contributing P to the Camel catchment historically. SSDs were recently picked up on in a report conducted by the West Country Rivers Trust in February 2015 for Natural England. The report highlights the Allen River in particular as having potential issues with septic tank pollution.

3.42 The current extent of SSDs in the catchment are not known by the local staff, but it is thought that a number exist on properties adjacent to the watercourse and close to the SSSI, as well as a large number in the wider catchment. A walkover conducted by APEM in 2014 looked to identify areas of outflow from SSDs, but due to the timing and high flows only one was identified. There is no known future housing development in the area.

Project output

3.43 The catchment that drains to the SSSI was estimated to cover an area of about 291km^2 (Figure 11). Of this, 73% was estimated to pose a low risk of water quality degradation if SSDs are located there. In addition, 13% of the area was found to pose a moderate risk and a further 14% a high risk.

3.44 A total of 13,037 properties were estimated to be located within the catchment. Most (10,225 – 78%) of these are probably connected to mains sewerage but an estimated 2,812 (22%) probably use SSDs to treat their domestic sewage. Of the latter, 293 (10%) are located in areas where there is a high risk of these systems causing water quality problems and 383 (14%) are located in areas of moderate risk. The remaining 2,136 (76%) are in low risk areas. The average density of SSDs in this area is about 9.7km^{-2}.

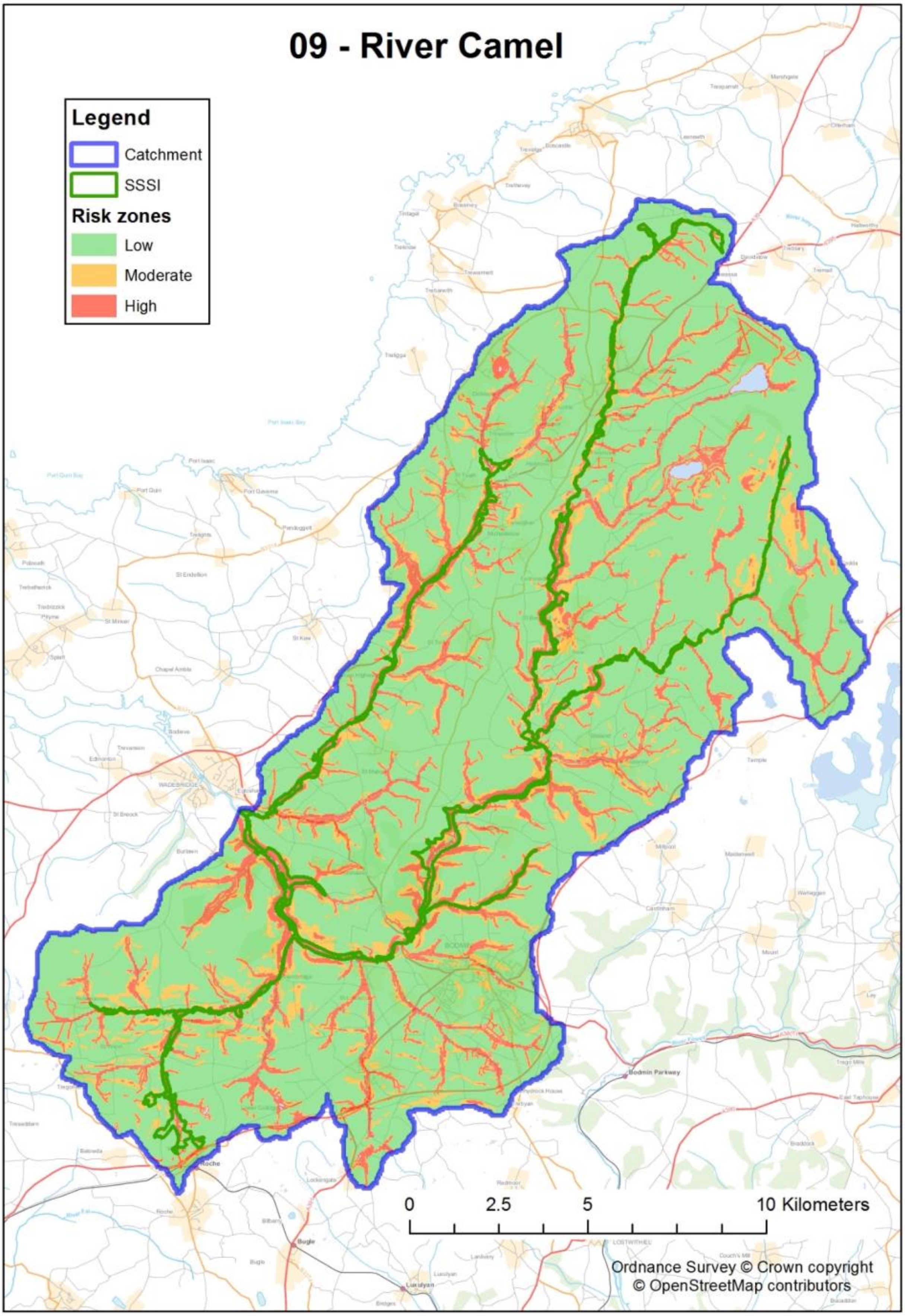


Figure 11 Catchment of the River Camel SSSI showing high, moderate and low risk zones for locating small domestic discharges

10 - River Avon

Background

3.45 The River Avon SSSI comprises rivers and streams in an area of fen, marsh and swamp, neutral grassland, and broadleaved, mixed and yew woodland. The only part of the River Avon SSSI included in this study was that above the large town of Christchurch. Below this point, it was assumed that discharges from large sewage works would be the main driver of water quality degradation.

Questionnaire response

3.46 Local knowledge indicated that almost all of the River Avon SAC/SSSI is failing P concentration targets. Following reductions in P discharges from the main waste water treatment works in the area, it has now been suggested that future management of P inputs to the river should take account of all sources of P within the catchment, including the unsewered population. This has been estimated to be about 14% across the River Avon catchment as a whole, although this varies across sub-catchments.

3.47 Package treatment plants are being used in new housing developments. Many are also being installed to replace traditional septic tanks across unsewered parts of the catchment, but this is happening in a rather ad hoc manner. Overall, the proportion of the unsewered population that is served by package treatment plants is unknown. Also, it is unclear whether package treatment plants input more P per head of population to the river system than traditional tanks. This may be the case where they discharge directly to watercourses, thus by-passing any attenuation by soil or chalk geology in the soakaway.

3.48 High water tables can affect soakaway systems in the main valley bottoms and more widely across the Vale of Pewsey (western and eastern Avon), which is associated with an underlying geology of Upper Greensand that can also be a source of P.

3.49 Previous studies on small, rural subcatchments of the River Avon SSSI have suggested the following:

- Upper Wylye (448km^2; 27% of the River Avon SSSI catchment): 1,875 unsewered houses (5% of population); estimated P load 0.85t a^{-1} to 2.7t a^{-1}, depending on the method of calculation (May & others, 2015).
- Upper Nadder (216km^2; 13% of the River Avon SSSI catchment): 1,257 unsewered houses (17% of population); estimated P load 0.63t a^{-1} and 1.6t a^{-1} (WRc, 2011; May & others, 2015).

3.50 Most properties are believed to be outside of the SSSI boundary, although many settlements are close to watercourses in the valley bottom; some are on the river's edge. There are suspected SDD discharge problems at Dockens Water, Huckles Brook, Upper Ebble and Middle Wylye. Future housing development in the area is mainly restricted to sewered areas.

Project output

3.51 The catchment that drains to the part of the River Avon SSSI, as included in this study, is shown in Figure 12. It covers an area of about 1,669km^2. Within this, it was estimated that SSDs located in about 14% of the catchment would pose a high risk of contamination to water courses, with 9% posing a moderate risk and 77% posing a low risk.

3.52 Analyses indicated that there were about 85,450 properties in this area, of which 11,940 are likely to be unsewered. Of these, 2,930 (25%) appear to be located in areas where they may pose a high risk to water quality, 1,133 (9%) are in areas of moderate risk and 7,877 (66%)

are in areas of low risk. The average density of unsewered properties across this catchment was calculated to be about 7.2km^{-2}.

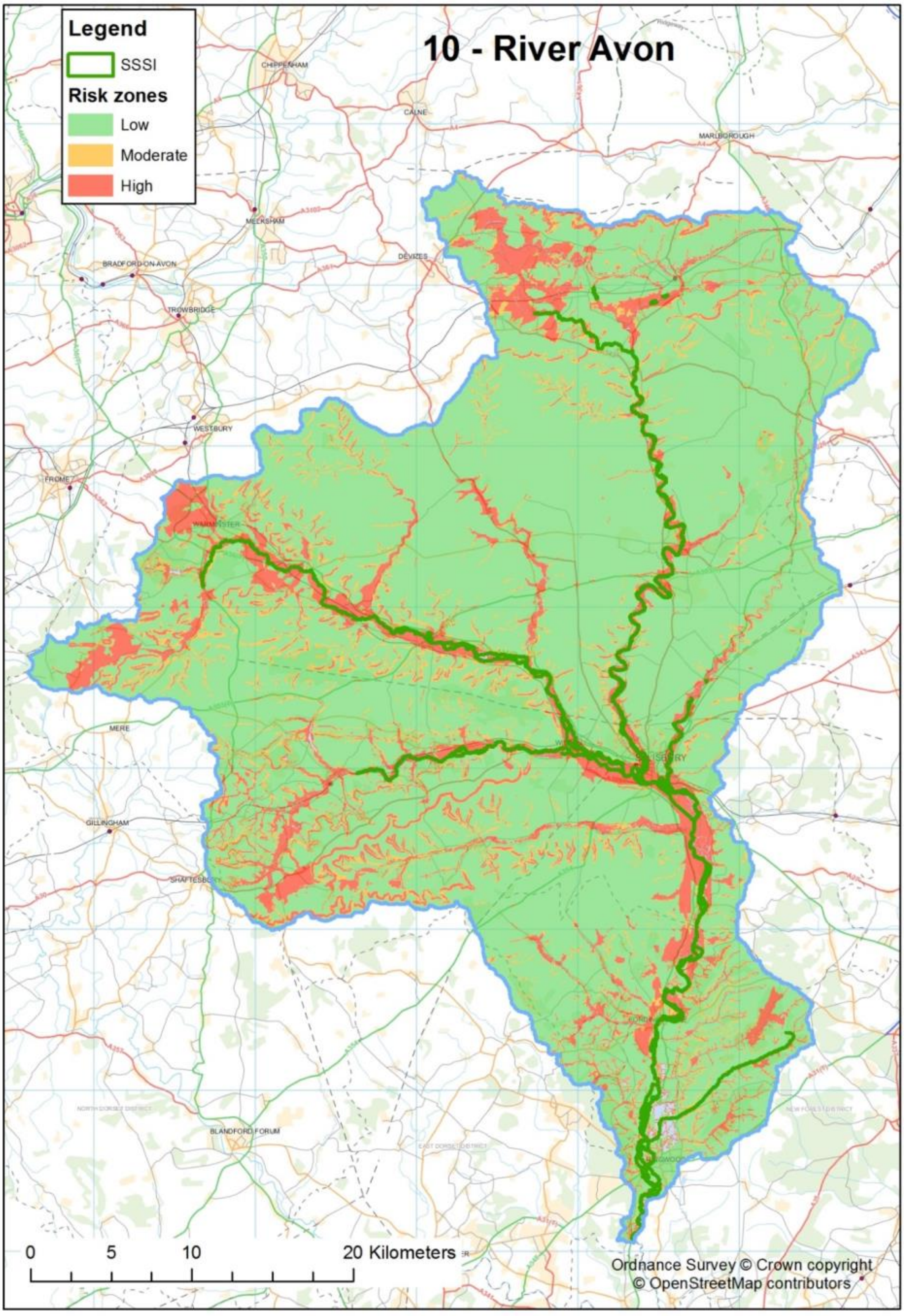


Figure 12 Catchment of the River Avon showing high, moderate and low risk zones for locating small domestic discharges

11 - River Clun

Background

3.53 The River Clun SSSI comprises rivers and streams. The recently produced nutrient management plan (Atkins 2014) for the River Clun suggests that properties that are outside of sewered areas are served by SSDs. It also states that volumes of septic tank discharges to soakaways are generally very small, invariably below 5m^3 day^{-1}. Due to the rural nature of the catchment, up to 50% of the population are likely to be served by private sewage treatment plants or septic systems. Atkins (2014; Table J.2) also suggest that there are probably about 456 SSDs within this catchment and that discharges from these systems may not pose a big pollution problem. However, no evidence is given to support this statement. In general, the locations of SSDs within the area are largely unknown.

Questionnaire response

3.54 The number of planned new housing developments within the catchment is unknown, but some screening criteria have been set for new developments in the area.

Project output

3.55 The current project identified an area of about 271km^2 upstream of the outflow point of the River Clun SSSI (Figure 13). Of this, 45% was in the 'low risk' category, 26% in the moderate risk category and 29% in the high risk category, in terms of the likelihood of effluent from SSDs located in these areas causing P pollution of freshwater sites.

3.56 Within the catchment, a total of 3,272 properties were identified. Of these, 1,839 (56%) appear to be sewered and 1,433 (44%) were identified as unlikely to be sewered. When considering their locations in relation to the areas of risk identified, it was found that 441 (31%) of the SSDs associated with unsewered properties posed a high risk, 334 (23%) a moderate risk and 658 (46%) a low risk. The average density of unsewered properties across the catchment was estimated to be about 5.3km^{-2}.

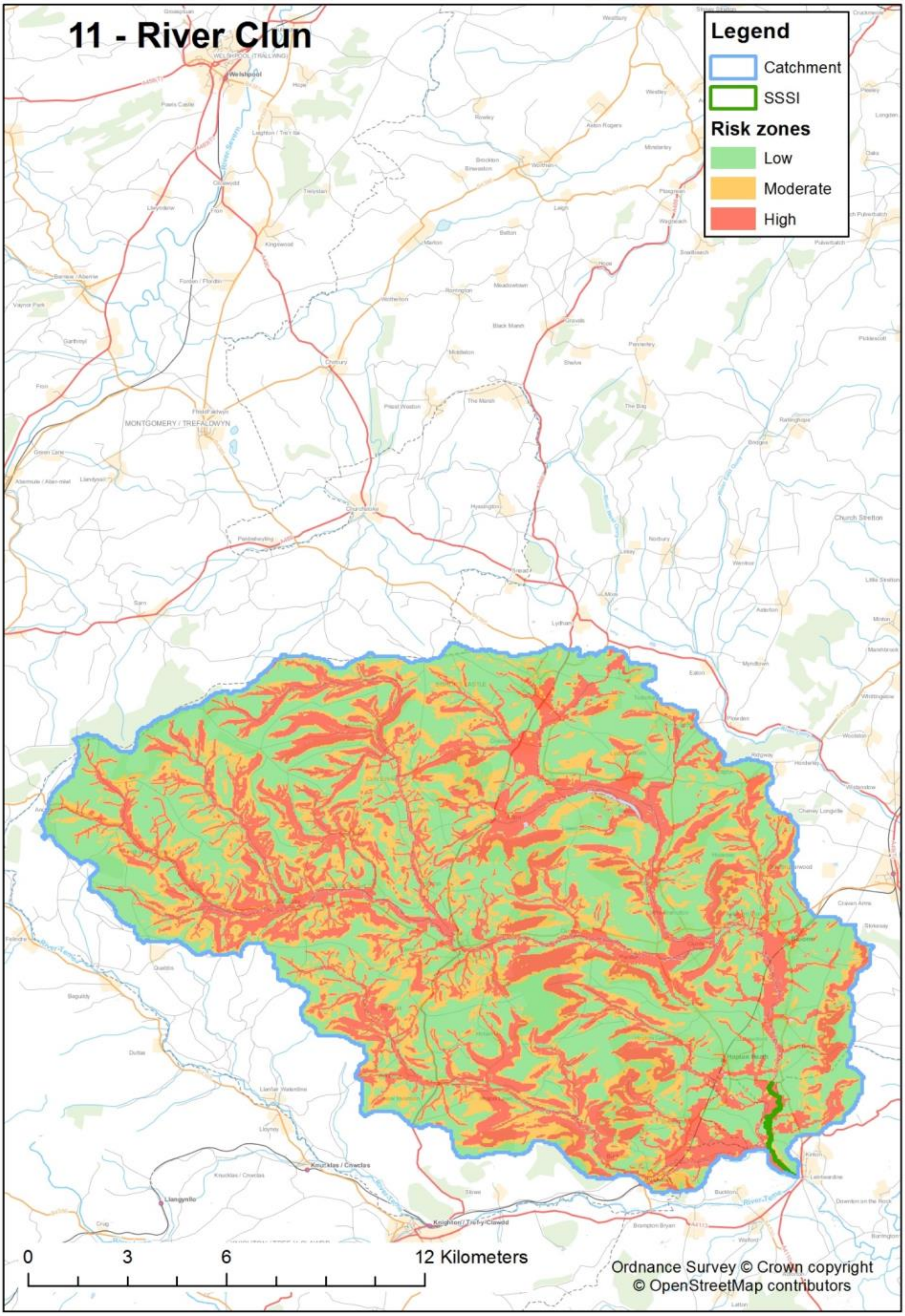


Figure 13 Catchment of the River Clun SSSI showing high, moderate and low risk zones for locating small domestic discharges

12 - Dacre Beck

Background

3.57 Dacre Beck is part of the River Eden & Tributaries SSSI; it is a small river that joins the River Eamont just north of Ullswater.

Questionnaire response

3.58 The beck has failing water quality targets for the SSSI and an EA Review of Consents has suggested that localised, non-sewered sources may be an issue in some areas. Little additional information is available for this catchment. Local members of staff are unaware of any areas within the catchment that are earmarked for future development of unsewered properties.

Project output

3.59 The catchment that drains to this SSSI was shown to be about 38km^2 in area (Figure 14). Of this, most (58%) was assessed to be low risk in terms of SSDs discharges to soakaway causing P pollution of waterbodies within the SSSI. In addition, SSDs within 19% of the catchment were assessed to be in areas where they posed a moderate risk and 23% a high risk.

3.60 Analyses indicated that there were about 216 properties in this area. Of these 31 appear to be sewered and 185 are likely to be unsewered. Forty-three (23%) of unsewered properties are located in areas of the catchment where they may pose a high risk to water quality, 47 (26%) are in areas of moderate risk and 95 (51%) are in areas of low risk. The average density of unsewered properties across this catchment was calculated to be about 4.8km^{-2}.

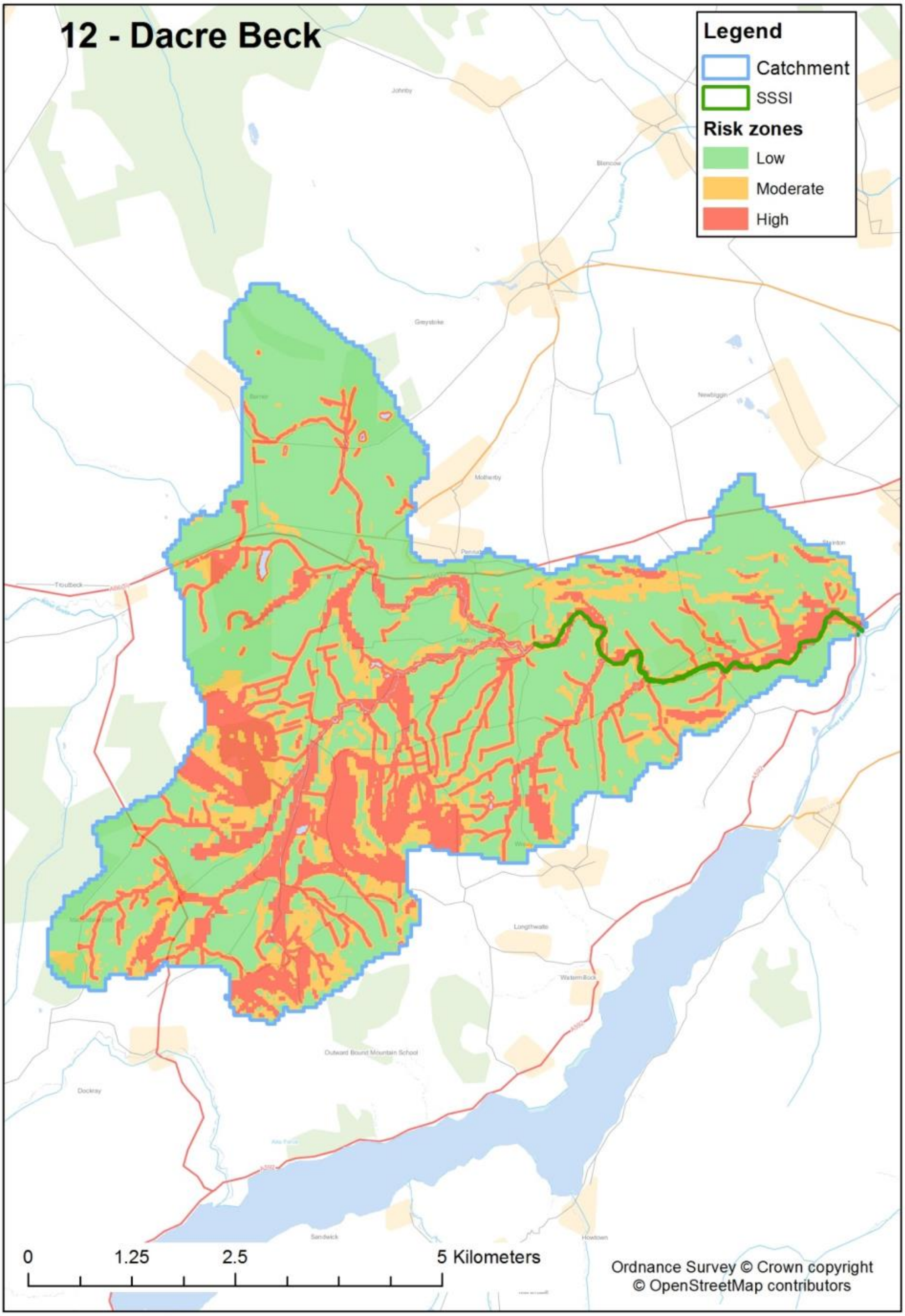


Figure 14 Catchment of Dacre Beck SSSI showing high, moderate and low risk zones for locating small domestic discharges

13 - River Itchen

Background

3.61 The River Itchen SSSI flows to the tidal limit of the river and, shortly downstream of that point, becomes the Southampton Water/Solent (SPA/Ramsar/SAC). This has problems with algal mats on the mudflats, which impedes wader feeding. The problem is caused by high levels of nitrates. However, the upper part of the river is failing P targets and algal growth and diatom growth on aquatic macrophytes are very noticeable there.

Questionnaire response

3.62 The River Itchen SSSI/SAC is P limited and it is possible that discharges from SSDs may contribute to high P concentrations in this river. An initial sediment fingerprinting study (carried out by ADAS in 2014 indicated that a significant proportion of sediment in the upper Itchen was coming from septic tanks. The upper part of the catchment is believed to have a large number of SSDs; there are also many within the SSSI itself and across the wider catchment. Future development of unsewered properties within the catchment is unlikely because this is 'ecologically constrained'.

Project output

3.63 The project focused on the main part of the catchment above the sewage works that is located in the south west of the catchment. The catchment above this point was found to have an area of about 394km^2 (Figure 15). Of this, 86% was in the low risk in relation to SDD locations, 4% was in the moderate risk category and 10% was in the high risk category.

3.64 Approximately 45,537 properties were found in this area. About 39,836 (87%) of these were identified as likely to be sewered, and 5,701 (13%) as likely to be unsewered. Of the latter, 1,124 (20%) were located in areas of high risk, 170 (3%) in areas of moderate risk and 4,407 (77%) in areas of low risk. Many of the high risk locations were close to the edge of the river channel. The average density of SSDs across the catchment was estimated to be about 14.5km^{-2}.

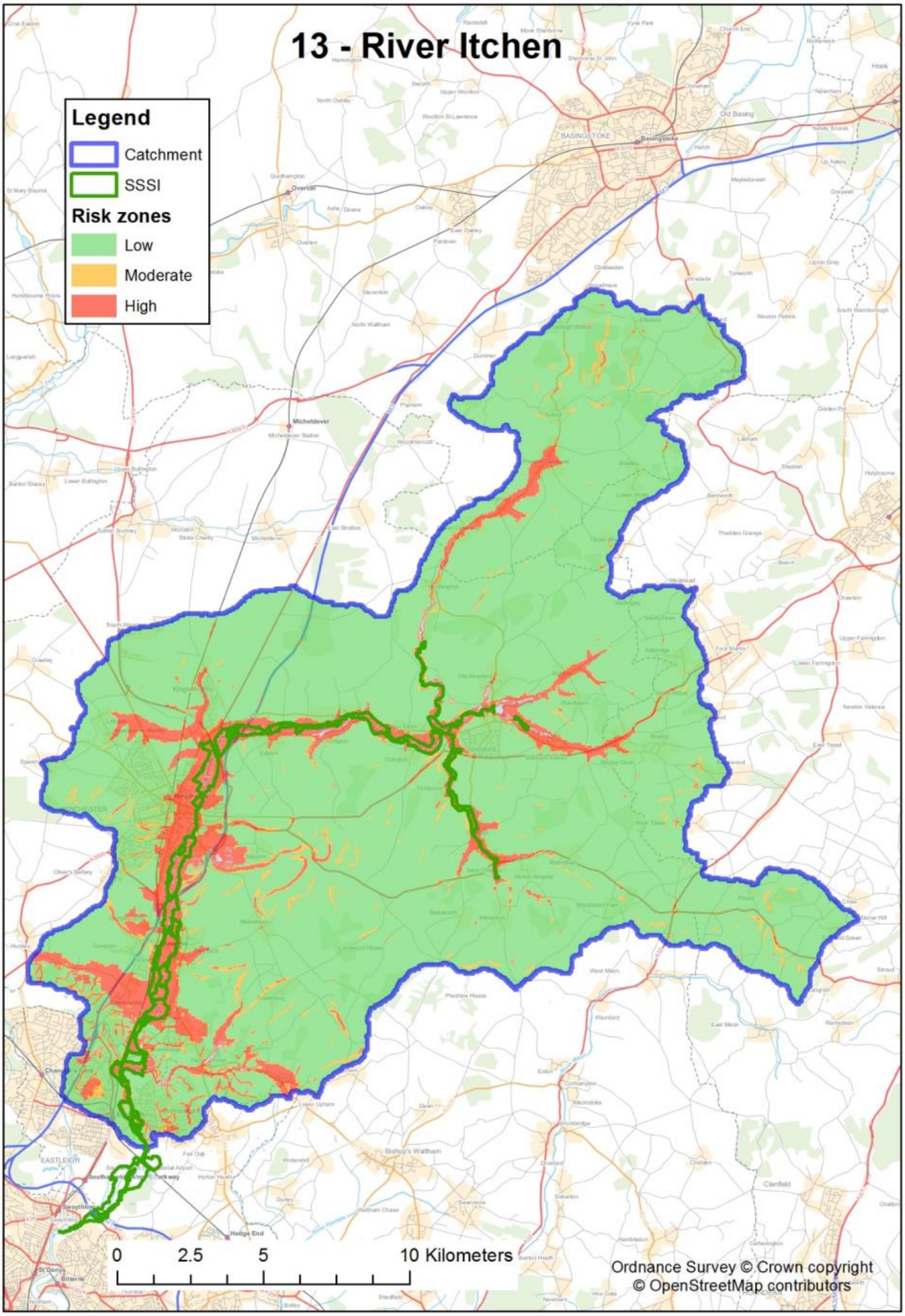


Figure 15 Catchment of the River Itchen SSSI showing high, moderate and low risk zones for locating small domestic discharges

14 - Oak Mere

Background

3.65 Oak Mere SSSI is a standing water feature linked to some artificial drainage. It is surrounded by woodland and grassland. It lacks direct inflows or outflows and its hydrology is believed to be supported almost entirely by direct precipitation, shallow subsurface flow and groundwater inputs.

Questionnaire response

3.66 A site specific study (ECUS, 2001) suggested that the surface water catchment of this mere was slightly smaller than used in this study. As both were determined from a desk study, but using different calculation methods, it was unclear which of these was the most accurate. The catchment boundary derived for this study was used because, being larger than that defined by Savage et al. (1992), which was only 2.56km^2 in area, it represents the worst case of the two catchment scenarios.

3.67 Oak Mere is designated as an oligotrophic lake, with a P target of 10µgL^{-1}. The mean annual P concentration recorded between 2005 and 2009 was 73µgL^{-1}, which is much higher. The source of this enrichment is unclear, but the diffuse water pollution plan for this site identifies discharges of P from SSDs as a potential problem. An issue was raised concerning properties to the north of Oak Mere, which may use SSDs that discharge into the catchment. There are no known plans to build unsewered properties within the catchment.

Project output

3.68 The catchment of Oak Mere, as defined by the method used in this project, was estimated to be about 5.6km^2 (Figure 16). Of this, 77% was found to be low risk in relation to the location of SSDs, 9% was found to be moderate risk and the remainder (14%) was found to be high risk.

3.69 Analyses suggested that there are about 233 properties within the catchment, none of which are sewered. Of these, 12 (5%) are located in areas of high risk, 44 (19%) in areas of moderate risk and 177 (76%) in areas of low risk. The average density of SSDs across the catchment was estimated to be about 41.6km^{-2}.

3.70 All of the high and moderate risk SSDS, as identified by the current study, fell within the boundaries of the ECUS (2001) catchment and that defined in the present study.

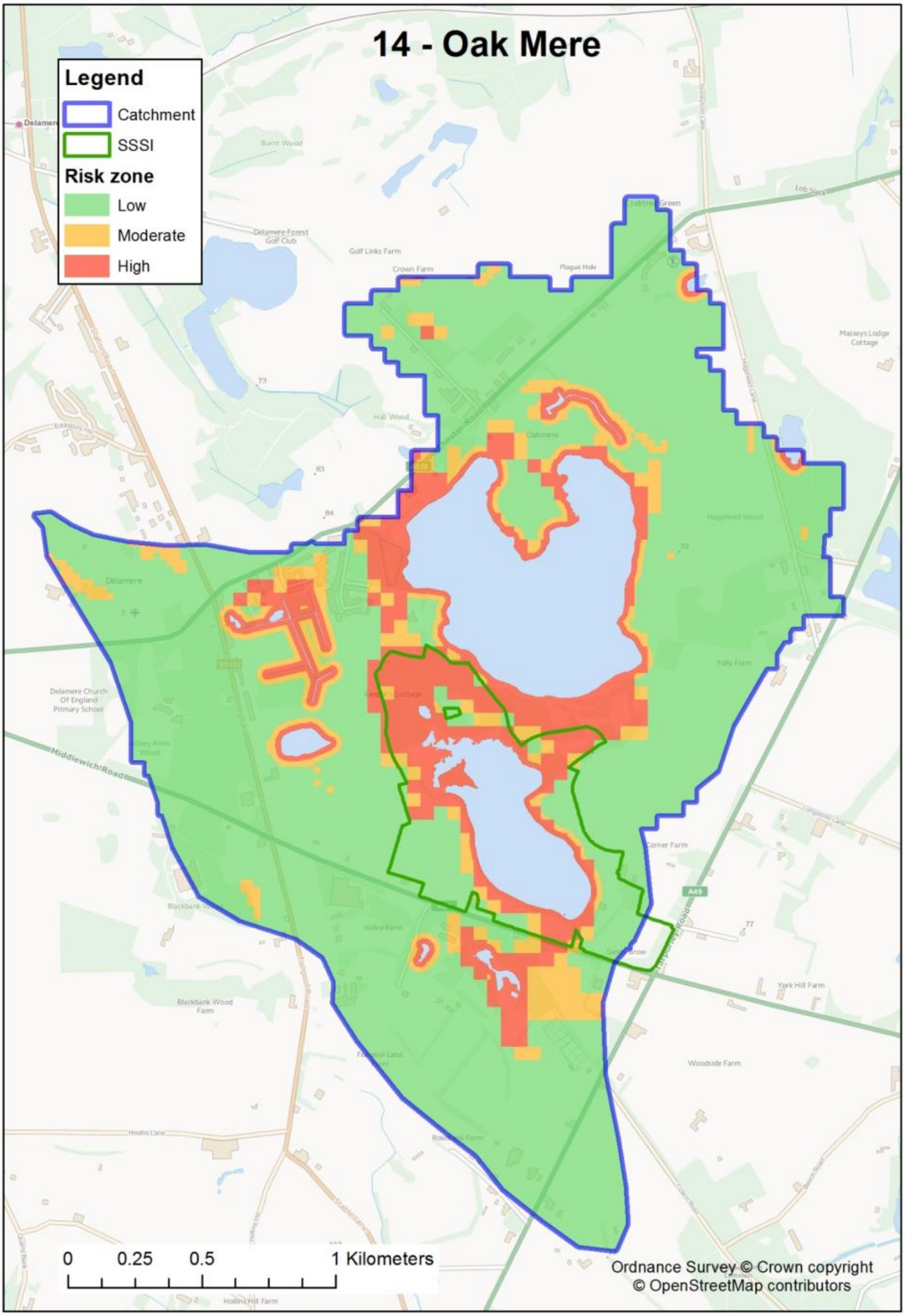


Figure 16 Catchment of Oak Mere SSSI showing high, moderate and low risk zones for locating small domestic discharges

15 - River Mease

Background

3.71 The River Mease SSSI designation applies only to the main river; its tributaries are excluded.

Questionnaire response

3.72 Local knowledge suggests that there are some areas that are known to use SSDs. In other areas the situation is less clear. In general, only a few were marked on the map by the local site officer. Most of these were along the area close to the main river channel. New properties are built occasionally in unsewered areas.

Project output

3.73 This study showed that the area of the catchment that drains to the River Mease SSSI is about 168km^2 (Figure 17). Of this, 76% was found to be low risk in terms of the siting of SSDs, 8% was found to be moderate risk and 17% was found to be high risk.

3.74 A total of 17,572 properties were located in this area. Of these, 15,602 (89%) were in sewered areas but at least 1,970 were likely to be unsewered (11%), with 184 (9%) of these unsewered properties being in areas of high risk, 117 (6%) in areas of moderate risk and 1,669 (85%) in areas of low risk. The average density of SSDs across the catchment was estimated to be about 11.8km^{-2}.

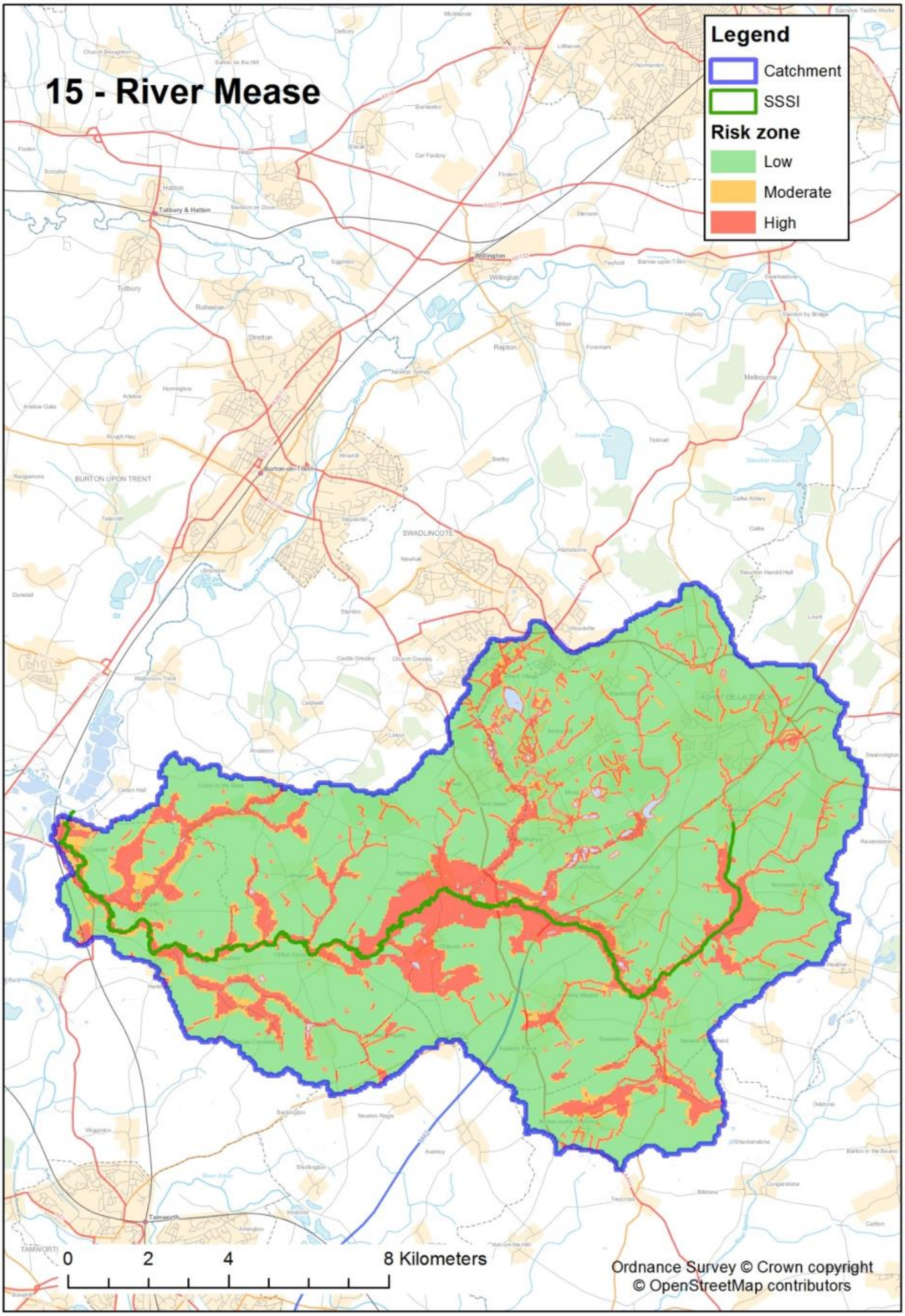


Figure 17 Catchment of the River Mease SSSI showing high, moderate and low risk zones for locating small domestic discharges

16 - River Lambourn

Background

3.75 The River Lambourn freshwater SSSI comprises rivers and streams, with the main river passing through a number of other SSSIs. The SSSI itself is focused on the main river channel, but this drains a much wider catchment.

Questionnaire response

3.76 There have been some problems with overgrowth of algae in the lower reaches of the river in recent years, though no obvious agricultural source of nutrients. Most of the algal growth has been at times of low flow and high temperatures, which may indicate a problem with point sources. It has been suggested that effluent discharges associated with unsewered properties may be contributing, at least in part. There are plans for a small number of new properties within the unsewered areas of this catchment.

Project output

3.77 The catchment upstream of the River Lambourn SSSI covers an area of about $264km^2$ (Figure 18). Most (89%) of the catchment is low risk in terms of the siting of SSDs, while 6% is moderate risk and 5% is high risk.

3.78 Approximately 9,584 properties were found to be located within this catchment. Of these, about 6,916 (72%) are likely to be connected to mains sewerage systems. Of the remainder (2,668 – 28%), 355 (13%) were located in high risk areas, 140 (5%) in moderate risk areas and 2,173 (82%) in low risk areas. Most of the high risk areas were very close to the main river channel. The average density of unsewered properties across the catchment was found to be about $10.1km^{-2}$.

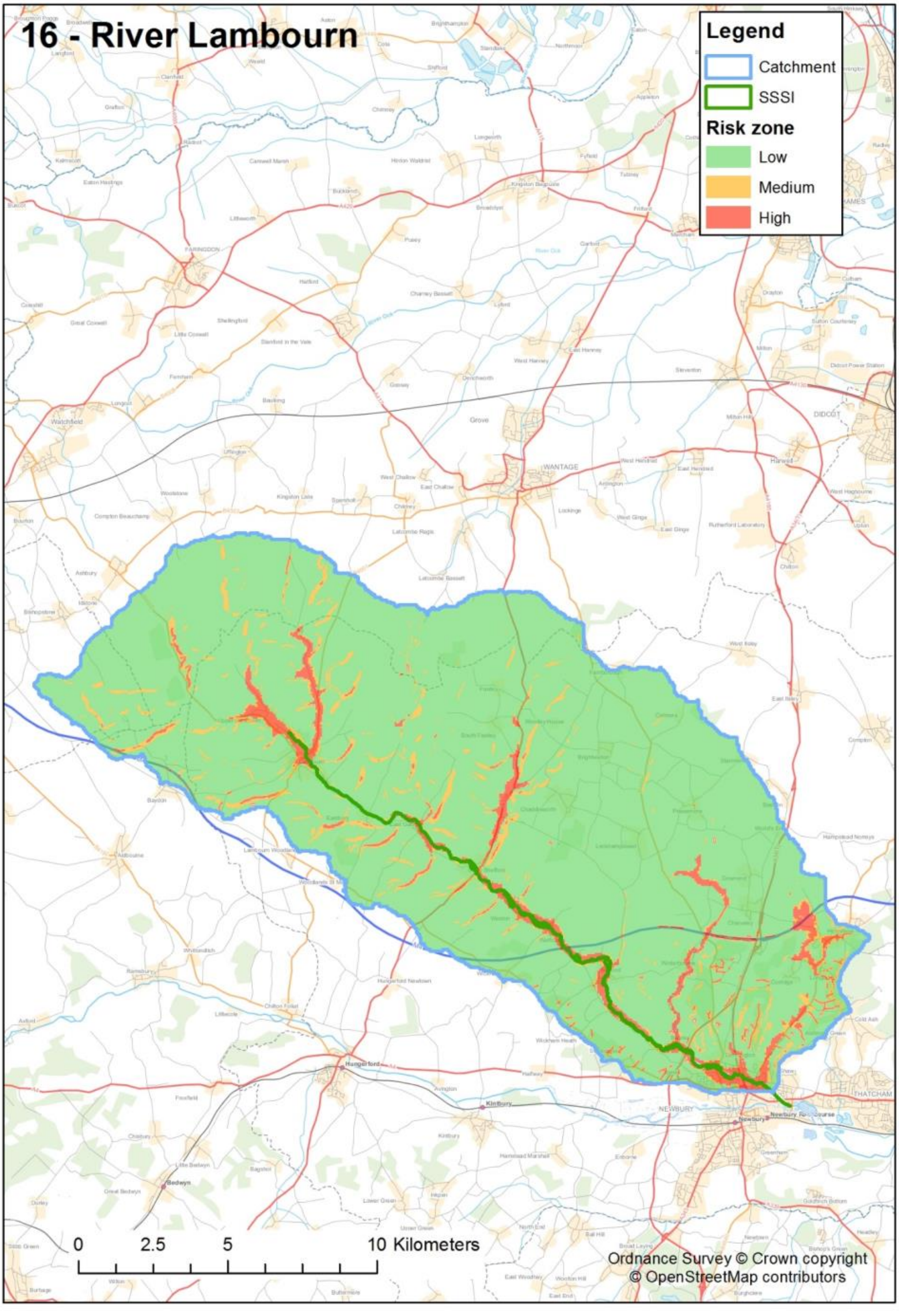


Figure 18 Catchment of the River Lambourn SSSI showing high, moderate and low risk zones for locating small domestic discharges

17 - Ant Broads and Marshes

Background

3.79 The outflow from the Ant Broads and Marshes SSSI is principally the River Ant, which drains towards the south.

Questionnaire response

3.80 The hydrology of the site is complex. The floodplain is irrigated by a combination of river water, surface water from the upland, and/or abstracted groundwater. Some of this water returns to the river and some is retained within the valley. There is a need to continue addressing diffuse sources of P in the area because the site has yet to meet the SAC targets for this lake.

3.81 The Diffuse Water Pollution Plan for the Ant, which deals primarily with the immediate catchment of the SSSI, includes the following statements:

- Large consented discharges are no longer a problem, but diffuse sources may need to be addressed.
- There is an on-going sewerage scheme in parts of the catchment where use of SSDs has been identified as being a problem; it is currently proposed that this should be completed by 2015, but a detailed programme of work has yet to be finalised.
- Within the upper Ant catchment (above Honing Lock), septic tank discharges of P were estimated to be more than 17 times that from WWTWs and 9.5 times that from agriculture (May & others, 2015).

3.82 There have been widespread reports of pollution problems caused by SDD discharges across the area.

Project output

3.83 The catchment of the Ant Broads and Marshes SSSI covers an area of about 125km^2 (Figure 19). Analyses suggested that about 74% of the catchment is low risk in terms of the placement of SSDs with soakaways; a further 7% of the area was identified as posing a moderate risk and a further 18% as posing a high risk.

3.84 A total of 10,327 properties were identified within the catchment. Of these, about 8,340 (81%) were in sewered areas and the remaining 1,987 (19%) were assumed to be unsewered. Of these, 419 (21%) were found to be located in areas of high risk, 233 (12%) in areas of moderate risk and 1,335 (67%) in areas of low risk. Many were along the edge of the SSSI itself. The density of unsewered properties in the catchment was found to be about 16km^{-2}.

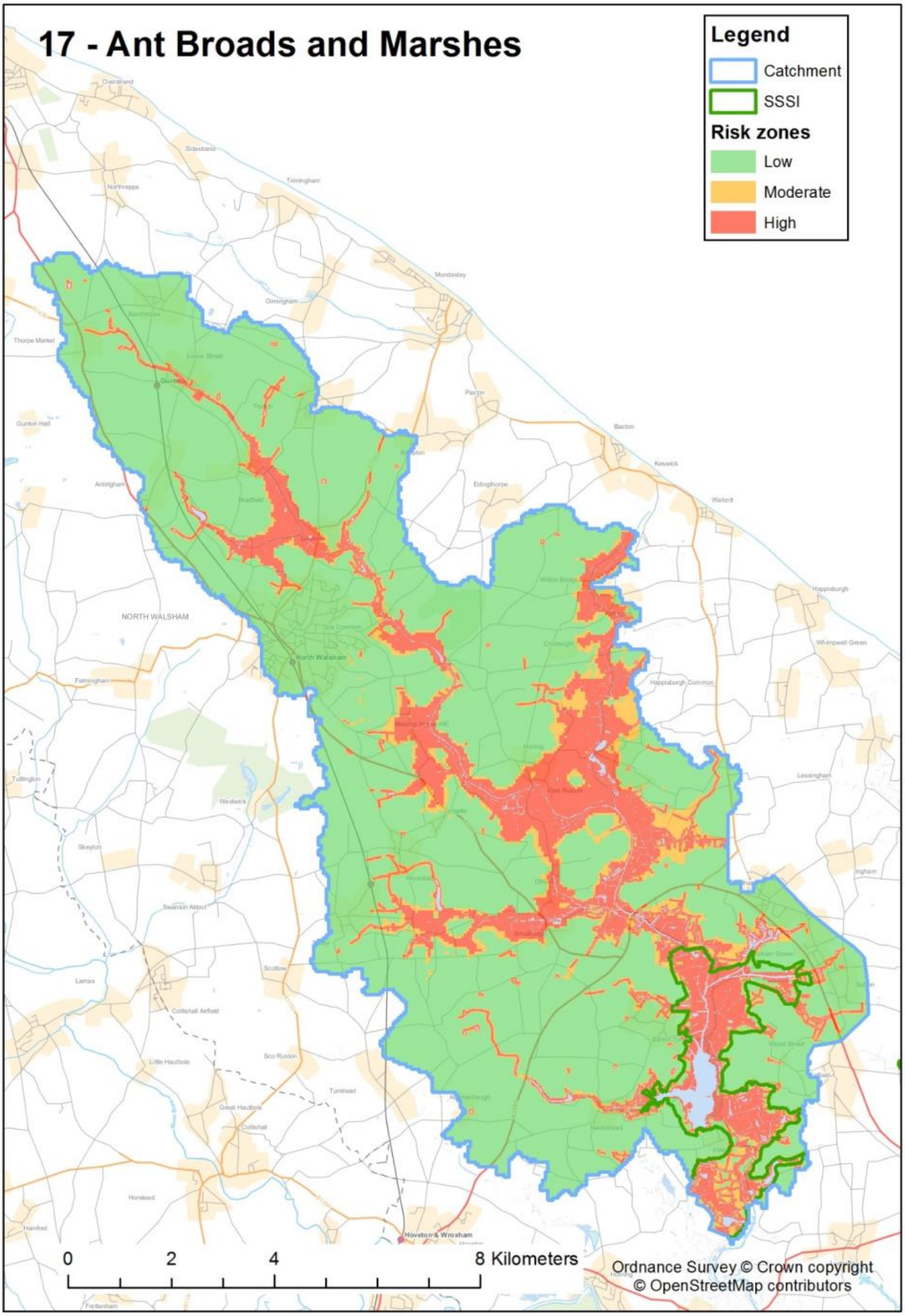


Figure 19 Catchment of the Ant and Broads Marshes SSSI showing high, moderate and low risk zones for locating small domestic discharges

18 - River Axe

Background

3.86 The River Axe SSSI is designated for its rivers and streams, and earth heritage.

Questionnaire response

3.87 Local knowledge suggests that there is some anecdotal evidence of septic tanks causing pollution problems in this area. It is believed that there are no SSDs in the SSSI itself, although there are many across the catchment. Their exact number and location is unclear. Nevertheless, it has been estimated that P discharges from these systems account for 2% of the P load from diffuse sources across the catchment and may account for an elevation of about $2\mu gL^{-1}$ in P concentrations in the receiving waters (Murdoch, 2010). There are no known plans for the future development of unsewered properties in the area.

Project output

3.88 The area of catchment that drains to the River Axe SSSI covers an area of about $297km^2$ (Figure 20). Within this, 19% of the area was classified as high risk in relation to the location of SSDs, while 17% was classified as moderate risk and 64% as low risk.

3.89 The analysis suggested that there were approximately 12,648 properties within the catchment of which only 9,582 (76%) were sewered. Of the remaining 3,066, 494 (16%) are located in areas of high risk, 596 (19%) in areas of moderate risk and 1,976 (65%) in areas of low risk. The average density of SSDs across this catchment was estimated to be $10.3km^{-2}$.

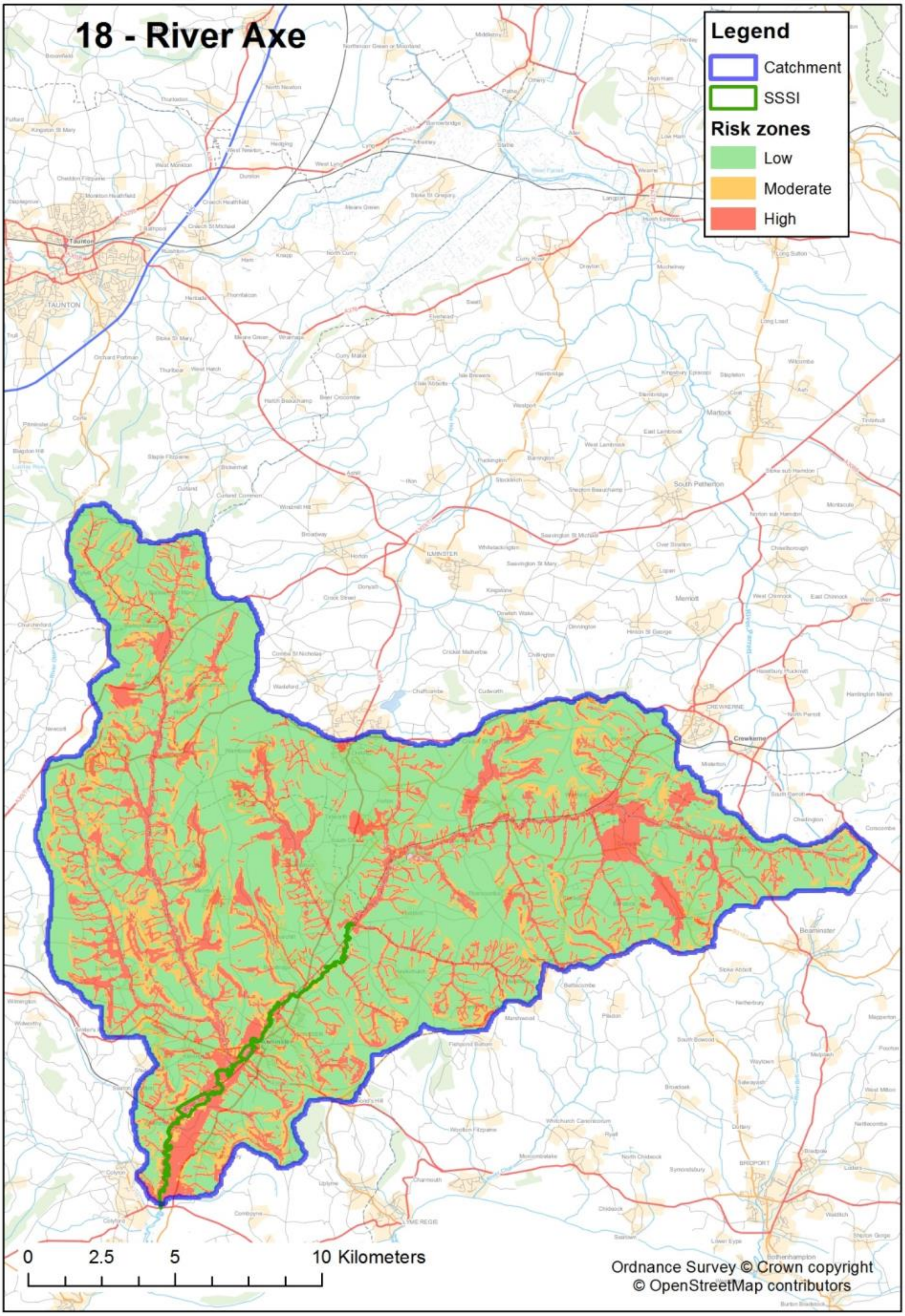


Figure 20 Catchment of the River Axe SSSI showing high, moderate and low risk zones for locating small domestic discharges

19 - River Lugg

Background

3.90 The River Lugg SSSI runs along about 50km of the River Lugg.

Questionnaire response

3.91 The catchment that drains to this SSSI is very rural and high P levels have been recorded in the lower reaches of the river. This is believed to be partly due to SSDs, but there are also to small number of treatment works within the catchment that do not have P stripping in place. The number and locations of SSDs within the catchment are unknown, but areas around the larger towns (ie Hereford, Leominster, Ross on Wye, Kington and Bromyard) are likely to be sewered. There are some plans to build up to 100 dwellings in unsewered areas of this catchment, namely at Leintwardine and Colwall. There may be others.

Project output

3.92 This study identified a catchment area of about 1,080km^2 draining to the River Lugg SSSI (Figure 21). Of this, 25% was identified as a high risk area for locating SSDs, while 17% posed a moderate risk and 57% a low risk.

3.93 The number of properties in this catchment was 27,738. Of these, 18,618 (67%) were in sewered areas and the remaining 9,120 (33%) appeared to be unsewered. Of the latter 1,899 (21%) were in high risk areas, 1,404 (15%) were in moderate risk areas and 5,817 (64%) were in low risk areas. The overall density of SSDs in this catchment was estimated to be about 8.4km^{-2}.

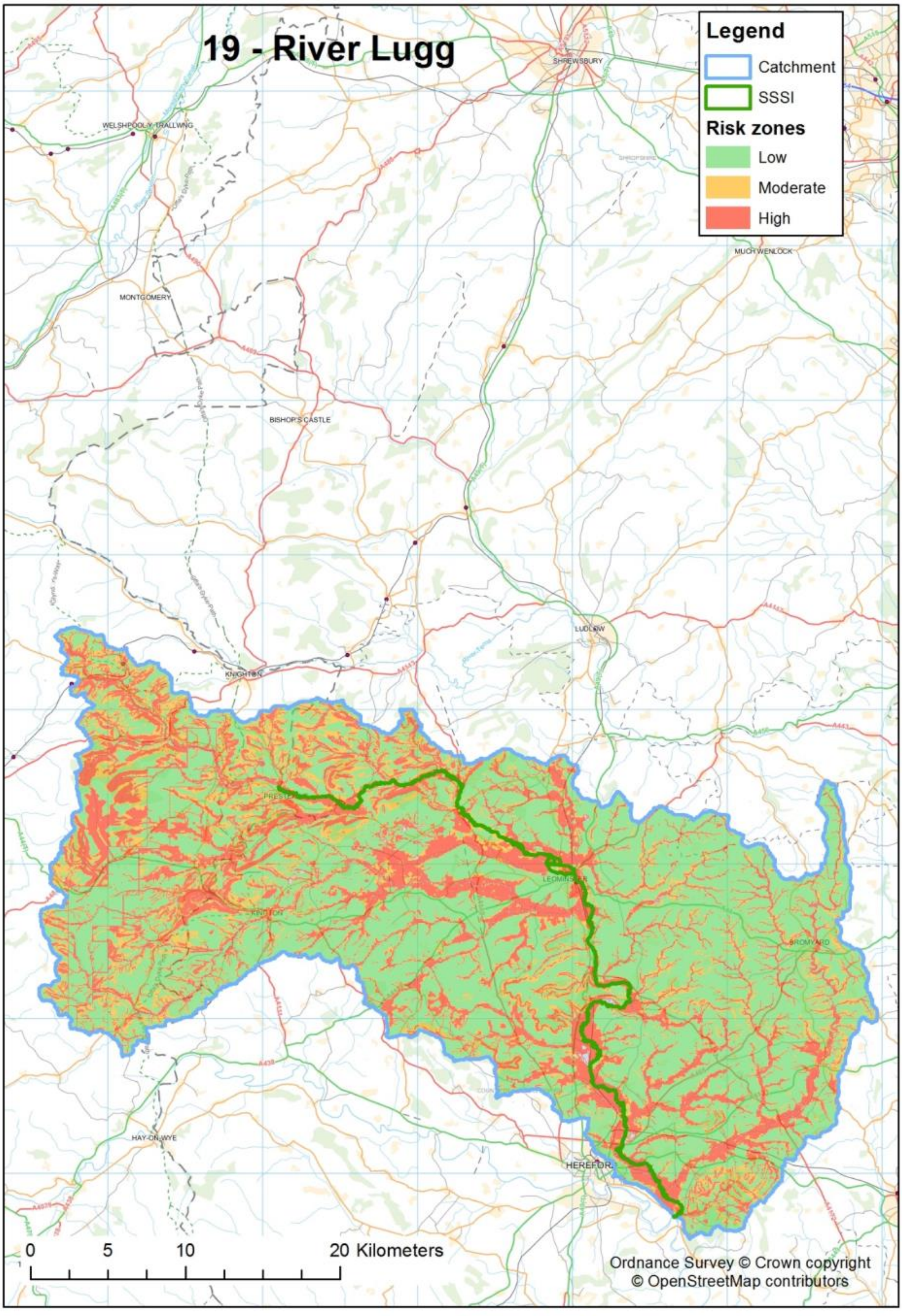


Figure 21 Catchment of the River Lugg SSSI showing high, moderate and low risk zones for locating small domestic discharges

20 - Ullswater

Background

3.94 Ullswater SSSI only includes the main water body and the outflow - not the rivers and streams feeding into Ullswater. It is a subcatchment of the River Eden & Tributaries SSSI.

Questionnaire response

3.95 Water quality at the site fluctuates around the pass/fail boundary in terms of its Common Standards Monitoring P target, which is a concern for a lake of this size.

3.96 Source apportionment modelling has been undertaken recently at this site; this shows that the waste water treatment works capacity within this catchment has a population equivalent (PE) of about 283. In contrast, the resident and non-resident population, including day visitors to amenities, can rise to a PE of 12,401 during peak visitor periods. Whilst this may exaggerate use of these facilities by day visitors, even the PE of residents alone is 582.

Project output

3.97 Within the current study, a catchment covering an area of about 148km^2 was identified as draining to this SSSI (Figure 22). Most (70%) of this catchment was identified as a high risk area in terms of the siting of SSDs, mainly because of the steepness of the terrain. A further 16% of the catchment was identified as posing a moderate risk and 14% as a low risk.

3.98 About 665 properties were identified within the catchment. Of these, 112 (17%) appear to be connected to mains sewerage. Of the SSDs identified, 201 (36%) are in an area of high risk, 205 (37%) in an area of moderate risk and 147 (27%) in an area of low risk. The average density of SSDs in this area was estimated to be about 3.7 km^{-2}.

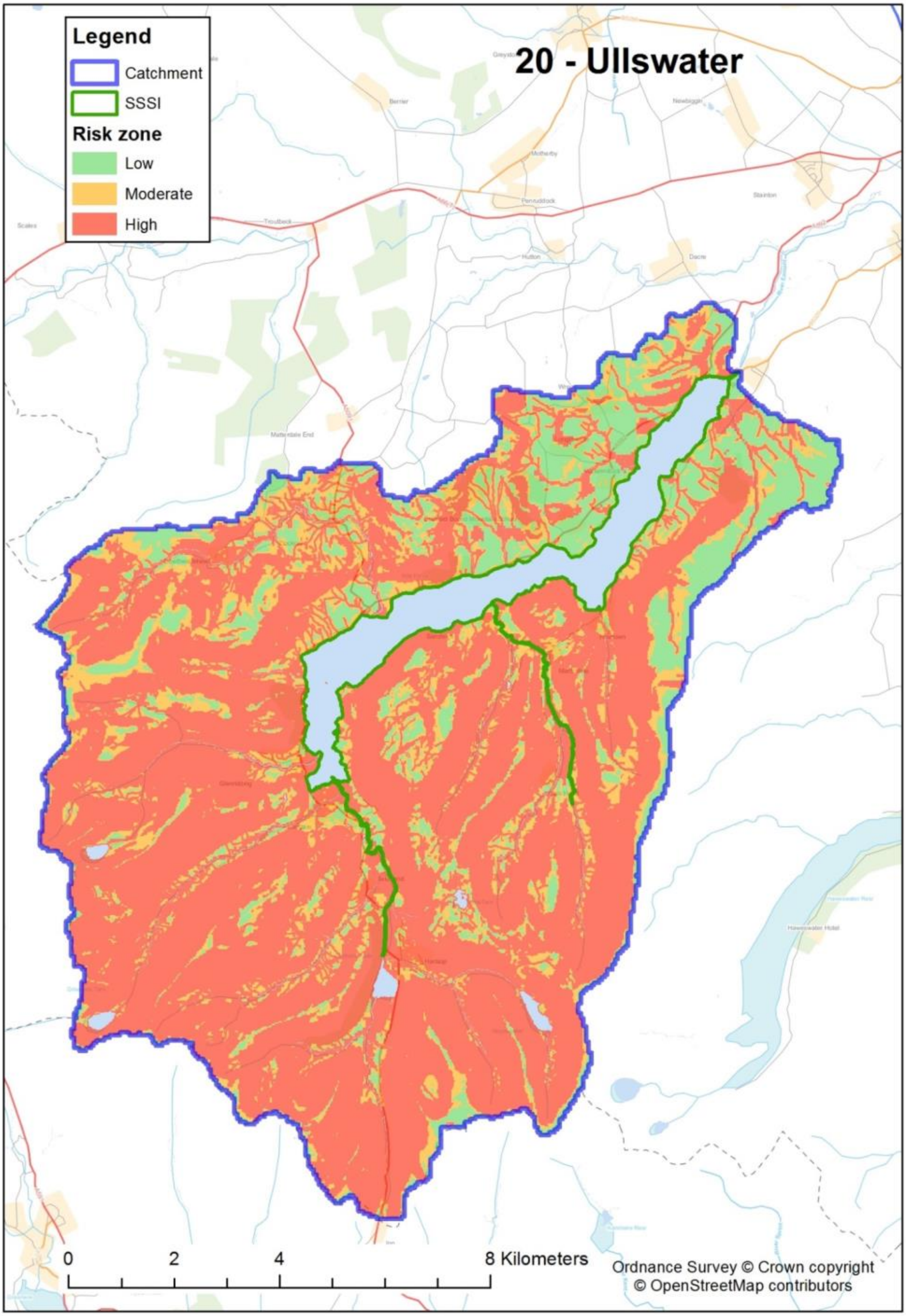


Figure 22 Catchment of Ullswater SSSI showing high, moderate and low risk zones for locating small domestic discharges

4 Discussion

4.1 The overall aim of this project was to develop a general methodology that could be used to estimate the number and location of SSDs within the catchment of freshwater SSSIs and assess their relative likelihood (low, moderate, high) of causing phosphorus (P) pollution. The assessment was a desk study that focused on the use of nationally available datasets. It did not involve sampling trips or site visits.

4.2 Twenty freshwater SSSIs were chosen as case studies. These represented several different types of waterbody: rivers, lakes and wetlands. Case study sites were agreed with Natural England at the beginning of the project, in consultation with local site officers. In response to a questionnaire, local site officers provided regional and local knowledge, highlighting any known P pollution problems. This information was used as a validation check on the site specific results generated from national scale datasets by the risk assessment tool.

4.3 The catchments for this study were defined from 5m resolution topographic data and, as such, represent the surface water catchment that drains to each SSSI. They ranged greatly in size; Hawes Water (2.5km^2) was the smallest and the River Avon above Southampton (1,669km^2) was the largest. Several of these sites (especially the meres, broads and marshes) are likely to be influenced by groundwater intrusion. However, because groundwater catchments, and their hydrological connectivity with surface water systems, are very difficult to determine through national scale screening this information was not included in the assessment process. The only factor linking risk to groundwater was depth to high water table.

4.4 In general, the catchment outlines defined from the surface topography were found to be the same as, or very similar to, those in use by the local site officers. However, there were a couple of exceptions. These were Leighton Moss and Hawes Water, where the catchment map derived from national level data in this study did not include local knowledge of the hydrological connectivity of underlying limestone) and the Ant Broads and Marshes, where the catchment map derived in this study did not include a large number of irrigation channels). This type of information can only be added at a site specific scale as it requires local knowledge.

4.5 In terms of known problems associated with SSDs at each site, the information collected from local sources indicated that that discharges of P from SSDs were likely to be entering and degrading SSSI waterbodies at many sites. However, in most cases, the number and locations of SSDs in SSSI catchments were unknown to local site officers. Where numbers were given, they varied greatly from those determined in this study. For example, in the Leighton Moss and Hawes Water catchments, the local estimate of SDD numbers was about 30 whereas the project data showed that the real number was probably closer to 266. Similarly, in the Clun catchment, where the number of SSDs has been estimated by the Environment Agency to be about 456 the results of this project suggest that there are probably about 1,433. In other catchments, numbers of SSDs were almost completely unknown to local site officers, despite there being several thousand SSDs within the catchment in some cases (eg Yare Broads and Marshes – 9,258; River Axe – 3,066; River Lugg – 9,120; River Avon – 11,940).

4.6 At the catchment scale, upstream areas that have the highest density of tanks are likely to pose the highest overall risk to downstream freshwater SSSIs, especially if those where SSDs discharge into high risk zones. Estimated SDD densities across the 20 catchments ranged from 3.3km^{-2} (River Till) to 41.5km^{-2} (Oak Mere), with the average being about 11km^{-2}. For the most part, SDD densities tended to be highest in the north west of England and lowest in the south east. This reflects the fact that a greater proportion of properties are likely to be sewered in more densely populated areas.

4.7 The main output from the project is a series of ArcGIS map layers for each SSSI and catchment. These comprise:

1) Surface water catchment boundary.
2) Map of low, moderate and high risk zones in relation to the safe siting of SSDs within the catchment.
3) Map showing the likely locations of SSDs within the SSSI and its catchment and the relative level of risk that they pose in terms of eutrophication due to P pollution.

4.8 The map layers could be used separately, or in combination, to improve the management and control of P-laden discharges from SSDs in unsewered areas to reduce the likelihood of pollution impacts on freshwater SSSIs. For example, the map of low, moderate and high risk zones within the catchment could help identify areas that may be unsuitable for the siting of new SSDs and where more detailed site evaluation should be undertaken. The map of likely SDD locations and relative risk could be used at the site specific scale to identify existing systems that may be causing pollution problems with a view to targeting any necessary mitigation measures more cost-effectively.

4.9 At the national, cross site, scale, sites with higher densities of SSDs situated in high risk areas could be prioritised over those with lower densities of SSDs in high risk areas so that limited resources for assessment and improvement could be targeted more effectively. For example, the density of SSDs in high risk areas across all sites is greatest in the Oak Mere catchment (7.8km^{-2}) and smallest in the River Itchen catchment (0.4km^{-2}). This would suggest that, if these two sites were compared, the highest priority for mitigation of potential impacts would be Oak Mere even though the actual number of SSDs in the Itchen catchment (5,701) far exceeds that in the Oak Mere catchment (233).

4.10 As the map layers have been derived from nationally available data, they need to be tested and validated at the local scale before use at the site specific scale. This is because there are some limitations on the accuracy of data derived from national datasets and the relative importance of uncertainties associated with these data needs to be assessed. It is recommended that the map based information on SDD locations and risk to water quality from this project is distributed to local site officers to be validated over a 12-18 month period and that feedback from this validation exercise should include:

1) The accuracy of the SDD location data at the local scale.
2) The level of accuracy of the assumption that all SSDs discharge to soakaway.
3) An investigation of water quality data in waterbodies, especially, rivers, up and down stream of SDD locations that are appear to be in high risk locations.
4) The operational usefulness of the data derived from the national scale mapping exercise at the local scale, including its format and accessibility.
5) Recommendations for improvement.

4.11 Following testing and validation at the 20 sites included in this study, consideration should be given to the cost effectiveness of addressing any issues raised and rolling this risk assessment methodology out across all of the freshwater SSSI series that have P pollution issues. Although developed for freshwater SSSIs in England, this approach may also be of interest to conservation agencies in other countries that are facing similar problems, especially Wales and Scotland.

4.12 Overall, an important conclusion from this study is that, while a general methodology can be applied at national scale, the management of each catchment to reduce SDD impacts on receiving waters requires a more bespoke approach to be implemented on the ground.

5 Conclusions

5.1 The risk assessment process considered some of the factors associated with SDD locations that affect their likelihood of delivering P to nearby waterbodies. These are setback distance, slope and the height of the water table. Information on site specific factors that affect the level of P discharge from these systems, such as system design, level of maintenance and/or the lifestyle choices of the householders were not included. This is because these data are not available at a national scale and, as such, are not suitable for inclusion in a large scale screening tool.

5.2 The risk assessment procedure developed in this project builds on that originally proposed by May and others (2015a) and incorporates data and knowledge that have been gained from other studies since this original method was proposed (eg May & others, 2015b). Changes include the following:

- Better inclusion of hydrological connectivity to groundwater.
- The use of nationally available digital map data to enumerate and locate properties that are likely to use SSDs for sewage treatment.
- A revised method for combining levels of risk associated with different factors associated with SDD location.

5.3 The application of this improved methodology to 20 freshwater SSSIs and their catchments in various parts of England provides proof of concept with a view to making the tool available for more widespread use in the future. However, a process of validation, testing and improvement (if necessary) of the method and its outputs needs to be undertaken before the process is rolled out to a much larger number of sites. In particular, it is important that the modelled outputs are validated at the site specific scale to determine the accuracy and usefulness of the outputs in providing local staff with a greater ability to target limited resources and mitigation strategies more effectively.

5.4 If testing and validation are successful, rolling out the risk assessment process at the national scale should be considered to enable Natural England to identify SSSIs where P pollution from SSDs is likely to pose the highest risk at the national scale. This will also enable limited resources to be targeted more effectively at the national scale.

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