# Private Water Supply Zones Feasibility Project DWI 70/2/318

## Technical Report

Defra

October 2018

# Notice

This document and its contents have been prepared and are intended solely as information for Defra in relation to the Private Water Supply Zones Feasibility Project DWI 70/2/318.

Atkins Limited assumes no responsibility to any other party in respect of or arising out of or in connection with this document and/or its contents.

This document has 56 pages including the cover, plus 24 pages in Appendix A and 27 pages in Appendix B.

## Document history

| Revision | Purpose description | Originated | Checked | Reviewed | Authorised | Date |
|---|---|---|---|---|---|---|
| 1.0 | Draft for client comment | RD, MS | HS | DR | DR | 31/08/18 |
| 2.0 | Draft for client comment | RD, MS | HS | DR | DR | 05/09/18 |
| 3.0 | Updated following client comment received 15/10/18 | RD | HS | DR | DR | 26/10/18 |
| | | | | | | |
| | | | | | | |

# Contents


| Chapter | Page |
|---|---|
| **Executive Summary** | **4** |
| **1. Introduction** | **5** |
| 1.1. Background | 5 |
| 1.2. Objectives | 5 |
| 1.3. Report structure | 6 |
| **2. Data collation and review** | **7** |
| **3. Selection of the two trial areas** | **11** |
| **4. Approach to defining conceptual zones and application of this method to the trial areas** | **12** |
| 4.1. Overview | 12 |

4.2. Groundwater conceptual areas 12
4.3. Surface water conceptual areas 27
4.4. Catchment counts 28
4.5. Contamination sources 29
**5. Validation of conceptual zones using historical water quality data 29**
5.1. PrWS water quality data for England and Wales 29
5.2. Validation approach for two trial areas 33
5.3. Statistical significance test 37
5.4. Conclusions of validation of conceptual zones 43
5.5. Radioactivity 43
**6. Potential cost savings from undertaking reduced PrWS monitoring 49**
6.1. Approach to estimating cost savings 49
6.2. Estimate cost savings 50
**7. Conclusions and recommendations 51**
7.1. Conclusions 51
7.2. Recommendations 53
**8. References 54**
**Appendix A. Trial area selection – technical methodology 56**
**Appendix B. Defining conceptual areas – technical methodology 47 7**
**Appendix C. Summary of cost estimates for laboratory water quality analysis 48**
**Appendix D. List of water quality determinands 51**

## Tables

Table 2-1 – Summary of data collated 8
Table 4-1 – Sum of conceptual catchments by type 23
Table 5-1 - Summary count of determinands, sample points and results by trial LA 24
Table 5-2 - Count of excluded sample points by trial LA 24
Table 5-3 - Count of sample points by conceptual zones for the simplified approach 25
Table 5-4 - Count of sample points by conceptual zones for the detailed approach 26
Table 5-5 - Results of Kruskal-Wallis tests for Conwy 31
Table 5-6 - Results of Kruskal-Wallis tests for West Dorset 32
Table 5-7 - Number of sample points with five or more results for Conwy conceptual zones 33
Table 5-8 - Number of sample points with five or more results for West Dorset conceptual zones 34
Table 6-1 - Annual sampling rate for determinands where a reduction in sampling might be justified for Conwy 39
Table 6-2 - Annual sampling rate for determinands where a reduction in sampling might be justified for West Dorset 40
Table 6-3 - Annual sampling saving for Conwy 40
Table 6-4 - Annual sampling saving for West Dorset 40

## Figures

Figure 4-1 – Schematic of theoretical groundwater conceptual zones 13
Figure 4-2 – WFD Operational Groundwater Catchments in: a) Conwy, b) West Dorset 15
Figure 4-3 - Indicative geological cross section for West Dorset showing simplified approach to

groundwater conceptual zones 16
Figure 4-4 – Defining detailed groundwater conceptual areas for bedrock geology 17 Figure 4-5 - Indicative geological cross section for West Dorset showing detailed approach to groundwater conceptual zones 19
Figure 4-6 - Defining groundwater conceptual areas for superficial geology 20
Figure 4-7 – Surface water conceptual areas in Conwy 21
Figure 4-8 – Surface water conceptual areas in West Dorset 22
Figure 5-1 - Timeseries data for conductivity across the conceptual zones in Conwy 29
Figure 5-2 – Example box and whisker plot for iron in Conwy 34
Figure 5-3 - Example box and whisker plot for iron in West Dorset 35
Figure 5-4 – Monitoring for radioactivity in public water supplies in West Dorset 37
Figure 5-5 – Monitoring for radioactivity in public water supplies in Conwy 38

# Executive Summary

Local Authorities (LAs) in England and Wales have a legal requirement to monitor Private Water Supplies (PrWS) to protect public health. In 2016 LA records contained details of 36,565 PrWS in England, and 14,981 in Wales (DWI, 2017a, 2017b). From 2017, amendments to the Drinking Water Directive have provided LAs an opportunity to monitor drinking water parameters in PrWS using a more flexible risk-based approach. This project seeks to develop these approaches further.

The objective of this project was to investigate whether it is feasible to group PrWS together to reduce monitoring by sampling from a source which is representative of the water quality across a defined area. Limitations and risks of this approach along with potential cost savings have also been identified as part of this project.

Grouping criteria for PrWS were developed separately for surface and groundwater sources using delineations such as Water Framework Directive water bodies, bedrock geology and aquifer vulnerability. Criteria were grouped in two different ways, one simpler and the other more complex. The homogeneity of water quality within these zones, and differences between them, were then assessed using historical water quality data from PrWS in two trial LAs: Conwy and West Dorset.

Historical water quality data were interrogated using a number of methods to determine whether the source water quality was consistent for the conceptual zones. Summary statistics for the conceptual zones and determinands were produced but were not very useful in proving or disproving the hypothesis that the zones were consistent. Kruskal-Wallis tests for differences were used to determine whether the results from sample points within conceptual zones came from different distributions, however, it was found that there were not enough data per determinand per sample point to complete enough analyses over the LAs in order validate the conceptual zoning method.

For a limited number of conceptual zones and determinands evidence of homogeneity was found. These zones and determinands were taken forward to assess whether sampling rates could be reduced. If all the results for a conceptual zone and determinands were below 60% of the Prescribed Concentration or Value (PCV) then the number of sample points and the annual sampling rate was analysed. Based on this statistical approach, and taking account of risk, the annual cost savings by reducing sampling and/or individual analyses were found to be are negligible. Results indicated that savings would only be achieved in the laboratory as the sample points would still need to be visited to collect samples for other determinands.

While it would be possible to either modify the existing method to increase potential savings or even to develop a different method, it is unlikely that a statistically robust method could be developed that will make significant savings across the two trial LAs.

If further investigation of conceptual zoning approaches is to be followed up, it is recommended:

- The feasibility of defining zones is reassessed in 4 or 5 years' time when more data are available.
- That LAs with a higher density of PrWS are investigated to ensure that lack of data is less of an issue and that there is a greater probability of identifying potential savings.
- The method applied here excludes some of the historical water quality data for reasons including quality assurance and uncertainty over the source of the water. Undertaking some further work in liaison with the LA could resolve some of these issues and would allow more data to be used in the assessment.
- Consideration is given to alternative methods for PrWS zone definition; in particular, datadriven approaches as opposed to the conceptually driven approach that was the brief for this project.

# 1. Introduction

## 1.1. Background

Under the Private Water Supplies (England) Regulations 2016, the Private Water Supplies (England) (Amendment) Regulations 2018 and the Private Water Supplies (Wales) Regulations 2017 which transpose the Drinking Water Directive and Euratom Directive, there is a legal requirement for Local Authorities (LAs) to monitor private water supplies (PrWS). The Regulations set standards for drinking water and the aim is to protect public health from the adverse effect of any contamination by ensuring water for human consumption is wholesome and clean. Depending on the Regulation classification of each PrWS up to a total of 48 microbiological, chemical and indicator parameters must be monitored and tested regularly.

The Directives allow for monitoring frequencies to apply, based on volume distributed within a supply zone. This is defined as a geographically defined area, within which water intended for human consumption comes from one or more sources and within which water quality may be considered as being approximately uniform or within a given range. Under current domestic legislation, each PrWS has been designated as a water supply zone for the purposes of monitoring. This results in the frequencies of monitoring being applied to each individual supply.

In 2016, LA records contained the details of a total of 36,565 private supplies in England, and 14,981 private supplies in Wales, of which 66% and 81% serve a single household respectively (DWI, 2017a, 2017b).

The purpose of the monitoring is the final verification step, which proves the successful supply of safe drinking water. The safe and secure supply is managed by undertaking a risk assessment to determine appropriate control measures. If identified hazards are not manifesting or are adequately controlled within a supply, it will be possible to reduce monitoring requirements using the new approach in the revised Annex II of the Drinking Water Directive. The European Commission adopted amendments to Annexes II and III of the Drinking Water Directive in October 2015, which was transposed into national legislation in late 2017.

## 1.2. Objectives

The research aim of this project is to investigate whether PrWS can be grouped together in order to simplify the requirements for monitoring the quality of the supplies. There may be opportunities to group PrWS within a LA area based on geological or other characteristics so that water quality sampling from one private supply would be deemed representative of the water quality across multiple supplies in the group. This would help reduce the burden of monitoring for LAs, the costs to relevant persons involved and facilitate the evidence gathering required to qualify for a reduced monitoring frequency or cessation for particular parameters that will be introduced in 2017 by the revised Annex II of the Drinking Water Directive.

The specific project objectives are as follows:

1. Investigate what criteria could be used to delineate and form the basis of PrWS groups or zones. This could be based on geology, groundwater body or other characteristics.
2. Consider whether historical water quality data should be used to delineate the PrwS zones by defining areas of broadly consistent groundwater quality. Propose criteria for determining what defines broadly consistent water quality data and explore options for how monitoring could be reduced within these areas. Determine whether these zones would be fixed, or whether data would need to be refreshed, if so at what frequency.
3. Appraise and report on the limitations and any potential risks which could be attributed to this approach; including an understanding of which water quality parameters and which types of sources (groundwater, surface water or springs) and types of supplies (Regulation 9 and/or Regulation 10 supplies and/or or single domestic dwellings) this approach would be suited to.
4. Scope potential cost savings which could be made for each scenario identified in point 3 (where this approach might be applied) should those PrWS be grouped into zones.

## 1.3. Report structure

The report is structured as follows:

- Data collation and review;
- Selection of the two trial areas;
- Approach to defining conceptual zones and application of this method to the trial areas;
- Validation of conceptual zones using historical water quality data; ☐ Potential cost savings from undertaking reduced PrWS monitoring; and ☐ Conclusions and recommendations.

# 2. Data collation and review

Table 2-1 lists the data collected by the project, which can be split into three main data types as follows:

1. Historical water quality data from PrWS;
2. Hydrogeological data describing the physico-chemical characteristics of PrWS sources; and
3. Contamination risk data describing the vulnerability of PrWS to impacts from pollution.

**Table 2-1 – Summary of data collated**

| Source | Dataset | Comment |
|---|---|---|
| Defra | PrWS water quality monitoring data | Historical PrWS water quality monitoring data from 2010 to 2016 inclusive for England and Wales. Data for 2017, including radioactivity parameters, was provided separately for just the two selected trial areas. All monitoring data included site grid reference, source type and monitoring results. |
| | Laboratory water quality testing costs for tests stated in Schedule 1 of the Private Water Supplies Regulations | Sample analyses quotes from five laboratories. |
| | Public water supply radioactivity monitoring results | Radioactivity water quality monitoring data for 2009-2017 that was collected by the water companies supplying the two selected trial areas. |
| | PrWS risk assessments | Completed risk assessment status for each PrWS in the two selected trial areas. |
| | Radon risk map | Excerpt of radon concentration classes in public groundwater supplies in England and Wales |
| Environment Agency | Detailed river network | River centrelines |
| Centre for Ecology and Hydrology (CEH) | LCM2015 (published in 2017) | Landcover mapping derived from satellite images and digital cartography providing land cover information for the entire UK. Land cover is based on UK Biodiversity Action Plan Broad Habitat classes. |
| British Geological Survey (BGS) | 625k Geology and Hydrogeology (bedrock and superficial) | Generalised digital geological mapping data |

| Source | Dataset | Comment |
|---|---|---|
| | Groundwater vulnerability | An assessment of the vulnerability of groundwater to a pollutant discharged at ground level based on the hydrological, geological, hydrogeological and soil properties within a one kilometre square grid. |
| | Borehole Index | The Single Onshore Boreholes Index (SOBI) is an index of over one million records of boreholes, shafts and wells from all forms of drilling and site investigation work held by the BGS. |
| | BGS mining hazard (excluding coal) | The voids resulting from past underground mining activity pose a possible hazard. The mining hazard data (excluding coal) datasets draw together a diverse range of material derived from geology, which constrains distribution, supplemented by literature searches for historical locations and expert knowledge to assemble, interpret, and organise this information. The data provides an assessment of the likelihood that past underground mining may have occurred in the area. |
| | Soil Parent Material Model | The Soil Parent Material Model details the distribution of physiochemical properties of the weathered and unweathered parent materials of the UK to:<br>• facilitate spatial mapping of UK soil properties;<br>• identify soils and landscapes sensitive to erosion;<br>• provide a national overview of our soil resource; and<br>• develop a better understanding of weathering properties and processes. |
| | Superficial deposits thickness models | The BGS Geology: superficial deposits thickness model 1 km hex grid shows the variation of the thickness of superficial (Quaternary age) deposits across Great Britain. |
| National Soil Resources Institute, Cranfield University | NatMap1000 | National Soil Map of England and Wales. A soil series (soil type) based, 1km$^2$ 'gridded vector' spatial dataset that provides relative percentage of each soil series per polygon. |

| | | |
|---|---|---|
| Data.gov.uk, Lle.go.uk; & National Resources Wales (NRW) | LA boundaries | Defines the areas the LAs are responsible for. Includes unitary authorities, district councils, London Borough councils, metropolitan district councils and county councils. |
| | Water Framework Directive (WFD) operational catchment boundaries (for surface water and groundwater) | Operational catchments are a way of grouping WFD waterbodies together |
| | Landfill locations | Historical and current landfill sites |
| | Mining | Inventory of Closed Mining Waste Facilities |
| | Nitrate Vulnerable Zones (NVZ) | NVZ dated 2017 |
| | Pesticides | Monitoring of Pesticides and Trace Organics in Water (1992 – 2008) |
| | Pollution | Environmental pollution incidents |

| Source | Dataset | Comment |
|---|---|---|
| | Source Protection Zones (SPZ) | SPZ dated 2017 |
| | Statutory main rivers | River lines |
| Public Health England | Indicative radon maps | Indicative radon maps for the whole of the United Kingdom http://www.ukradon.org/information/ukmaps Accessed 11/04/2018. |

# 3. Selection of the two trial areas

The trial area selection process was undertaken using the PrWS sampling water quality results reported by England and Wales LAs between 2010 and 2016. The process was undertaken in four main steps as outlined below:

1. The quality of the PrWS water quality sampling dataset was quantified within each LA by applying a number of pass/fail validation tests. This resulted in an improved dataset that better assigned each sample result to a specific uniquely referenced site location. It also enabled LAs with relatively poor quality site location data to be excluded from consideration as trial areas.

2. Next LAs that contained a suitable number and mixture of source type PrWS sites were quantifiably identified. This involved finding LAs with a reasonable number of groundwater and surface water PrWS per square kilometre that had a wide range of parameters regularly tested. This enabled LAs with few sites or little water quality data to be excluded from consideration as trial areas.

3. The output of the above two steps was a 'long list' of 12 LA that could be used as trial areas for the project. This long-list was reduced to a short-list of six, based on a qualitative assessment of the conceptual characteristics of each LA. Since most of the PrWS across England and Wales are dominated by groundwater and spring supplies, most weight was placed on the hydrogeological setting of each LA. The assessment included consideration of aquifer type, bedrock geology and superficial geology as well as the spatial distribution of groundwater, spring and surface water supplies within the LA.

4. Following consultation with Defra two LA were selected from the short-list to be used as the projects trial areas, these were:
   - **Conwy**: The only LA on the short-list with significant numbers of surface water supplies (50 no.). Although PrWS in England and Wales are dominated by groundwater and spring supplies, some LAs do exploit surface water resources for private supply. These LAs tend to be located in rural upland areas such as north-west Wales and parts of north-west England. For these LAs, it is important that the feasibility of grouping surface water supplies to potentially reduce the amount of water quality monitoring is investigated. This required at least one of the trial areas to have significant numbers of surface water supplies. As well as surface water, Conwy also contains groundwater (34 no.) and spring (43 no.) supplies. These exploit at least three different bedrock units (Caradoc, Wenlock and Ludlow Rocks) which are classified as low productivity aquifers (fracture flow) and possibly some superficial deposits. Therefore, Conwy provides the opportunity to test the zoning methodology on secondary aquifers where fracture flow dominates.
   - **West Dorset**: This LA has a significant number of groundwater (169 no.) and spring (82 no.) supplies and has a very different geological setting to Conwy, located in the south-west of England where the bedrock geology is dominated by Jurassic and Cretaceous stratigraphy. The groundwater and spring sources are well distributed across the LA and are associated with some of the principal aquifers of the UK – the Chalk and the Great Oolite Group. PrWS are also located on less productive secondary aquifers such as the parts of the Lias Group. This variety of bedrock geology provides the opportunity to delineate multiple groundwater/spring catchments, within which supplies can potentially be grouped. Although the coverage of superficial deposits in this LA is minor, there is potentially some scope for developing small groupings of supplies associated with superficial deposits. This LA has two surface water supplies.

The trial area selection process ensured that the proposed trial areas contained enough data for the next stage without being so complex and densely analysed that they were not representative of the majority of LAs in England and Wales. It also ensured the selected LAs would have a history of repeated water quality sampling of a range of parameters at established sites, had a reasonable mixture of known PrWS types (i.e. sources) and that the PrWS were not so sparsely located that zoning would be unfeasible. A full technical description of the trial area selection methodology is included in Appendix A.

# 4. Approach to defining conceptual zones and application of this method to the trial areas

## 4.1. Overview

This Section outlines how the trial areas were split into smaller conceptual areas that grouped together PrWS that were conceptually similar.

The criteria used to delineate conceptual zones for groundwater PrWS was geology, both bedrock and superficial deposits. River catchments were used to delineate conceptual zones for surface water supplies. Separate conceptual areas were developed for groundwater bedrock, groundwater superficial deposits and surface water supplies. Compared to the other catchments groundwater bedrock catchments are relatively complex to define. Consequently, there are a relatively large number of datasets representing different conceptual variables that could be used to define them. Therefore, two different approaches were developed for defining groundwater catchments – a detailed method (many small catchments) and a simplistic method (fewer larger catchments). This was undertaken so that the impact of the conceptual catchment size on the projects objectives could be evaluated at a later stage.

## 4.2. Groundwater conceptual areas

The objective of the groundwater conceptualisation process was to distinguish individual areas that can be grouped into different broad types of groundwater catchment as shown in Figure 4-1. This figure shows the different theoretical groundwater settings that could exist within a LA and whether with the information we have on each groundwater PrWS[1] it would be possible to determine which aquifer (bedrock or superficial deposit) the PrWS was abstracting from, as the specific aquifer source will impact on the resultant water quality. The three types of catchment identified on Figure 4-1 are:

- Bedrock conceptual areas:
  - **BED1**: Unproductive superficial deposits over productive bedrock; and
  - **BED2**: Productive bedrock with no superficial deposit cover.
- Superficial deposit conceptual area:
  - **SUP1**: Productive superficial deposits over unproductive bedrock.

A further consideration of the groundwater conceptualisation was to create sub-catchments within BED1 and BED2 that would distinguish between areas that are known to be vulnerable to contamination (either due to pollution source proximity or because of the presence of unhindered pollution pathways [i.e. hydrogeological conditions that allow pollution to spread]) and those that

[1] For each groundwater PrWS information was not available on the depth of the installation (well or borehole) or construction details (e.g. plain casing, open hole or screened sections) and hence the aquifer from which the PrWS was abstracting.

are not. The SUP1 catchments were found to typically be too small to meaningfully sub-divide further based on contamination vulnerability, see Section 4.5 for further information.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **SUPERFICIAL DEPOSITS** | ▲● | ▲● | | | | | **NO SUPERFICIAL DEPOSITS** | | | |
| **BEDROCK** – **Shallow (outcrop)** | | ▲● | △● | | | | | | ▲● | |
| **BEDROCK** – **Deep** | | | | | | ○ | ○ | | | |
| **AREA NDWATER EPTUAL** – **Likely to contain** – **Springs** ▲ | Y | Y | Y superficial / bedrock contacts | | N | N | N | N | Y | |
| **Likely to contain** – **Boreholes/wells** ● | Y | Y | Y | | N | ? – PrWS boreholes unlikely to be deep due to drilling costs | | N | Y | |
| **Groundwater Vulnerable to pollution** | Catchments too small to divide further | | Y | N | | | | | Y | N |
| **Description** | **SUP1 -** Productive superficial deposits. Unproductive bedrock. Both vulnerable and not vulnerable. | Productive superficial deposits and bedrock | **BED1 -** Unproductive superficial deposits. Productive bedrock. Both vulnerable and not vulnerable. | | Unproductive superficial deposits and bedrock | Unproductive superficial deposits and shallow bedrock Productive deep bedrock | No superficial deposits Unproductive shallow bedrock. Productive deep bedrock | No superficial deposits Unproductive bedrock | **BED2 -** No superficial deposits Productive bedrock | |
| **Assumptions** | PrWS exploit superficial deposits | PrWS exploit superficial deposits and bedrock | PrWS exploit bedrock | | No PrWS | | | | PrWS exploit bedrock | |
| **Included in conceptual grouping** | **YES** | **NO – uncertain source** | **YES** | **YES** | **NO – unlikely to be PrWS present, but if there are these are of uncertain character and unsuitable for zoning** | | | | **YES** | **YES** |

▲ *Springs likely* △ *Springs possible* ● *Boreholes or wells likely* ○ *Boreholes or well possible*

*Productive bedrock or Unproductive bedrock or superficial*
*deposit superficial deposit*

**Figure 4-1 – Schematic of theoretical groundwater conceptual zones**

### 4.2.1. Groundwater bedrock conceptualisation - simplified approach

Simplified groundwater catchments were defined using the WFD operational groundwater catchments dataset. These show how for: "*WFD work [areas are] grouped geographically for practical management purposes. The Groundwater operational catchments comprise collections of groundwater bodies"* [2].

These WFD operational groundwater bodies are a simplification however the following points are noted:

- They comprise a spatial extent that represents the geology, this may not be perfect, but these are a readily available simplified spatial layer.
- They do not necessarily account for groundwater vulnerability, so the understanding of vulnerability in conceptual zoning is lost.
- Some of the complexities of the local geology are omitted.
- The layer represents a simplified relationship between superficial deposits and bedrock i.e. the GIS layer selects the predominant productive aquifer.
- For the most part these WFD groundwater bodies are unified 2-dimensional areas that do not reflect the 3-dimensional character of aquifers.

Figure 4-2a shows that West Dorset LA intersects 11 WFD operational groundwater catchments and Figure 4-1b shows that Conwy intersects five WFD operational groundwater catchments.

In some cases, groundwater PrWS points did not have a WFD groundwater operational catchment associated with the location. In this case, further GIS analysis was completed to find its nearest WFD groundwater operational catchment and this was used if the geology data indicated that the point was located on similar productive geological strata. This only applied to a small number of PrWS, none in Conwy and 25 in West Dorset.

Figure 4-3 presents an indicative geological cross section for West Dorset showing this simplified approach to groundwater conceptual zones.

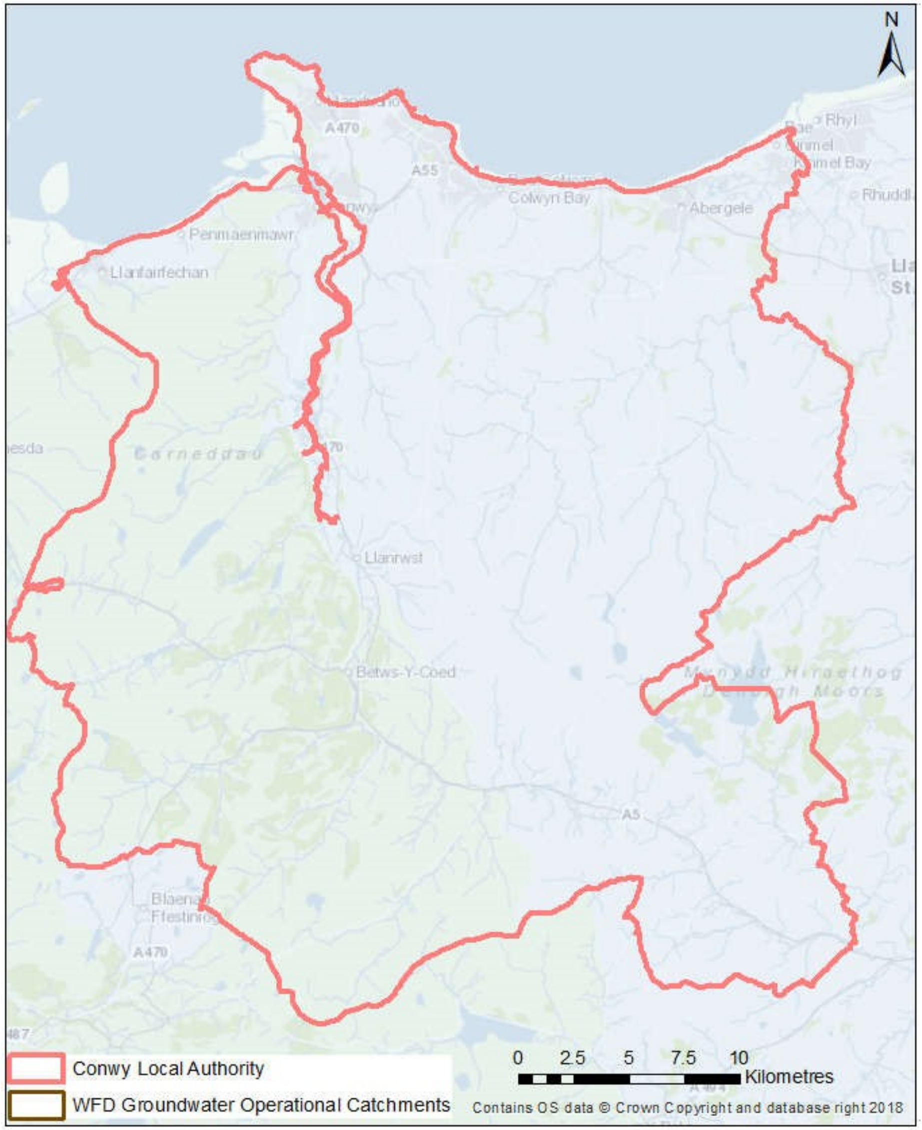
Superficial deposit conceptual areas, described in Section 4.2.3, were subtracted from the simplified bedrock conceptual areas so that a groundwater PrWS would only be counted in one catchment type.

Using simplified bedrock conceptual areas means that data from PrWS with an uncertain source (see Figure 4-1), i.e. where there are productive superficial deposits over productive bedrock geology, are not excluded from the assessment. In contrast, in the detailed approach groundwater PrWS in this geological setting were excluded from further analysis during this project (see Section 4.2.2).

[2] https://data.gov.uk/dataset/5485381b-af3e-4719-89e7-f2e7908c2b7b/wfd-groundwateroperational-catchments-cycle-2 (Accessed 15 Aug 2018)

| Label | Catchment name |
|---|---|
| 1 | Lower Dorset Stour and Hampshire Avon |
| 2 | Lower Frome and Piddle |
| 3 | Lyme Regis |
| 4 | Dyrham Formation (North of Yeovil - Fragmented GWB) |
| 5 | Bridport Sands (West Alliton) |
| 6 | Corallian - Wincanton |
| 7 | Fullers Earth (Crewkerne) |
| 8 | Fullers Earth (Southeast Yeovil) |
| 9 | Winsham |
| 10 | Upper Frome and Piddle |
| 11 | Yeovil Bridport Sands / Inferior Oolite |

a)




b)

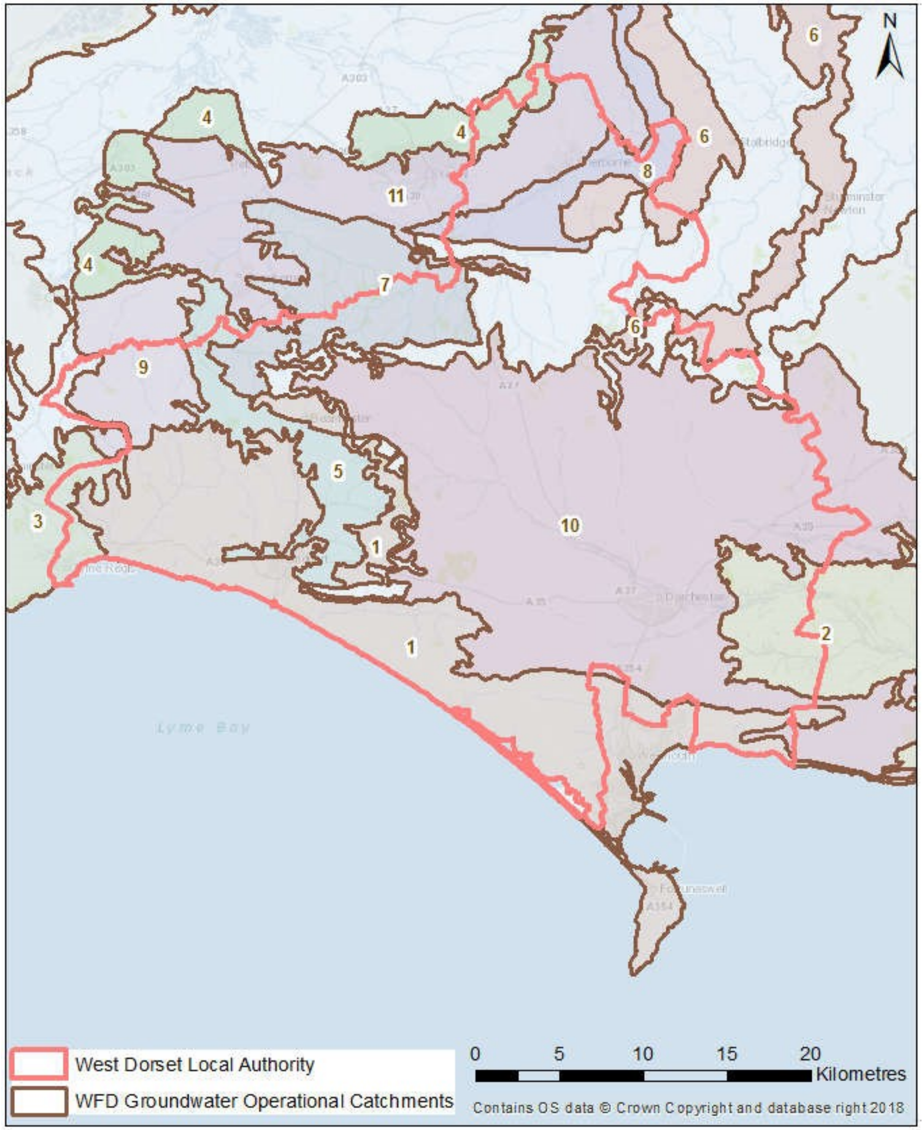



**Figure 4-2 – WFD Operational Groundwater Catchments in: a) Conwy, b) West Dorset**

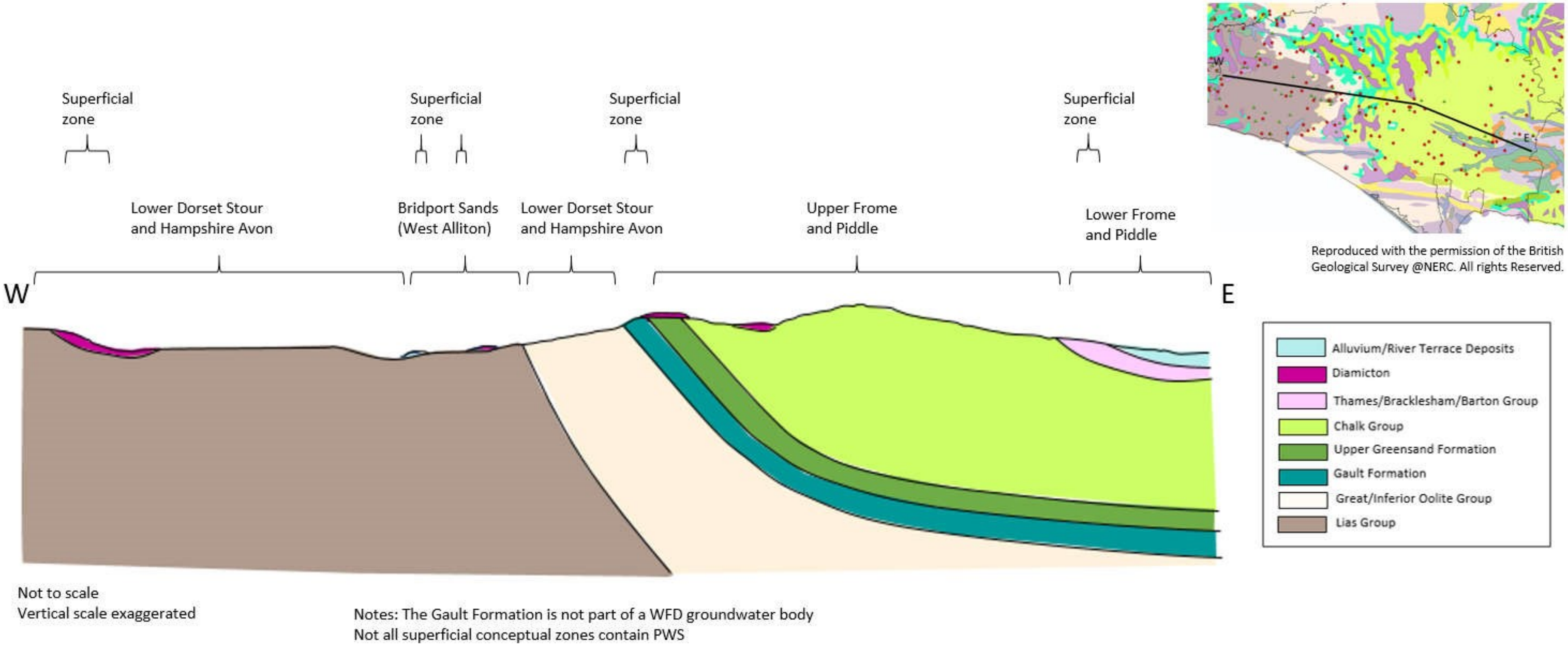


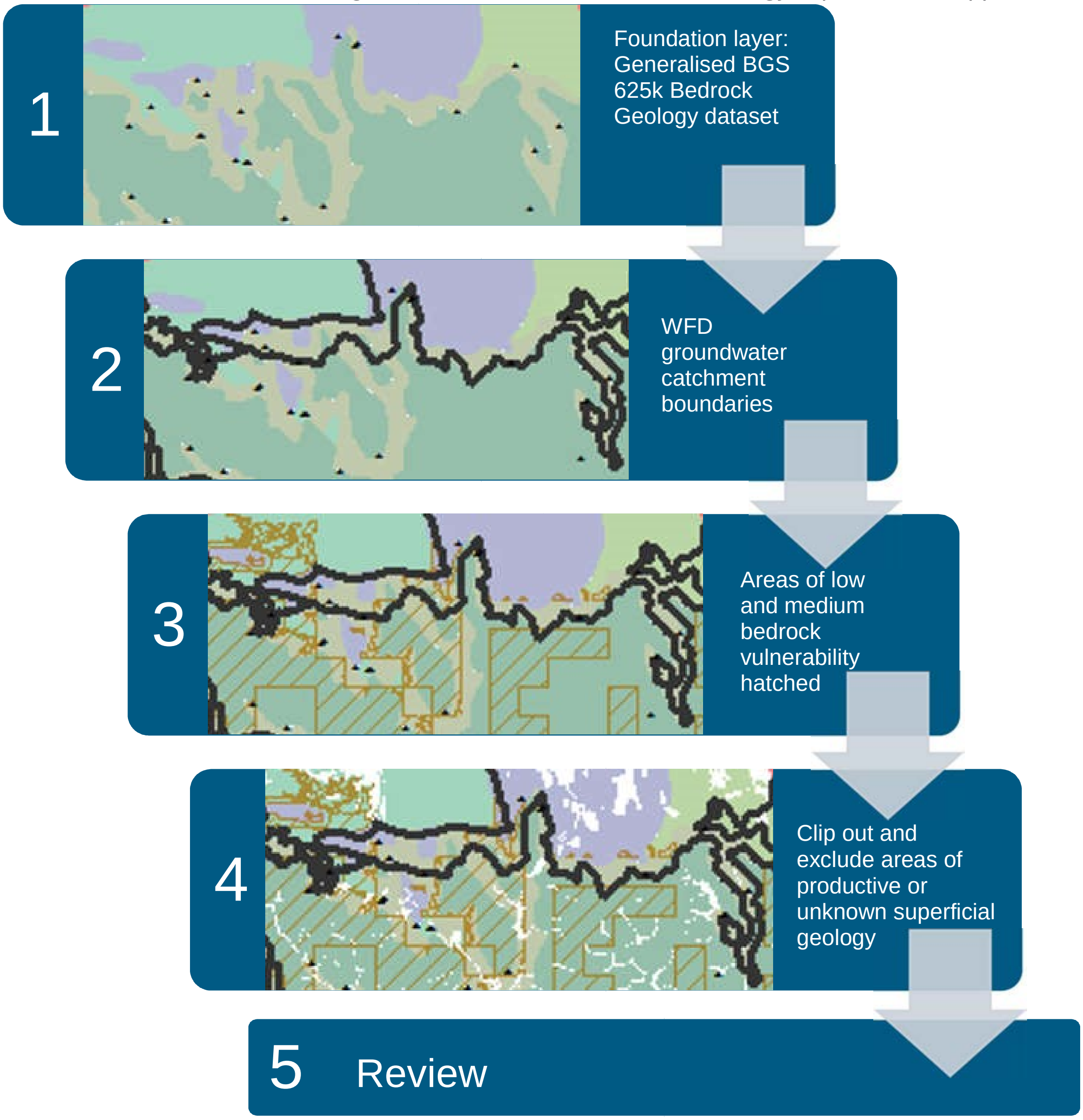

**Figure 4-3 - Indicative geological cross section for West Dorset showing simplified approach to groundwater conceptual zones**

## 4.2.2. Groundwater bedrock conceptualisation - detailed approach

The detailed method for delineating groundwater conceptual areas for bedrock geology can be split into the five steps outlined below:

1. Begin with the BGS 625k Bedrock Geology dataset (broad rock type attribute: RCS_D);
2. Divide the Bedrock Geology dataset up using WFD Groundwater Operational Catchments;
3. Divide each of these catchments into two sub-catchments based on areas of medium and low bedrock vulnerability or high and unknown vulnerability taken from the BGS Groundwater Vulnerability mapping;
4. From the output of step 3 clip out and exclude areas where superficial geology is productive (principal / secondary) or where productivity is unknown;
5. Review and 'sense check' conceptual areas.

The method is summarised in Figure 4-4 and a full technical methodogy is provided in Appendix B.

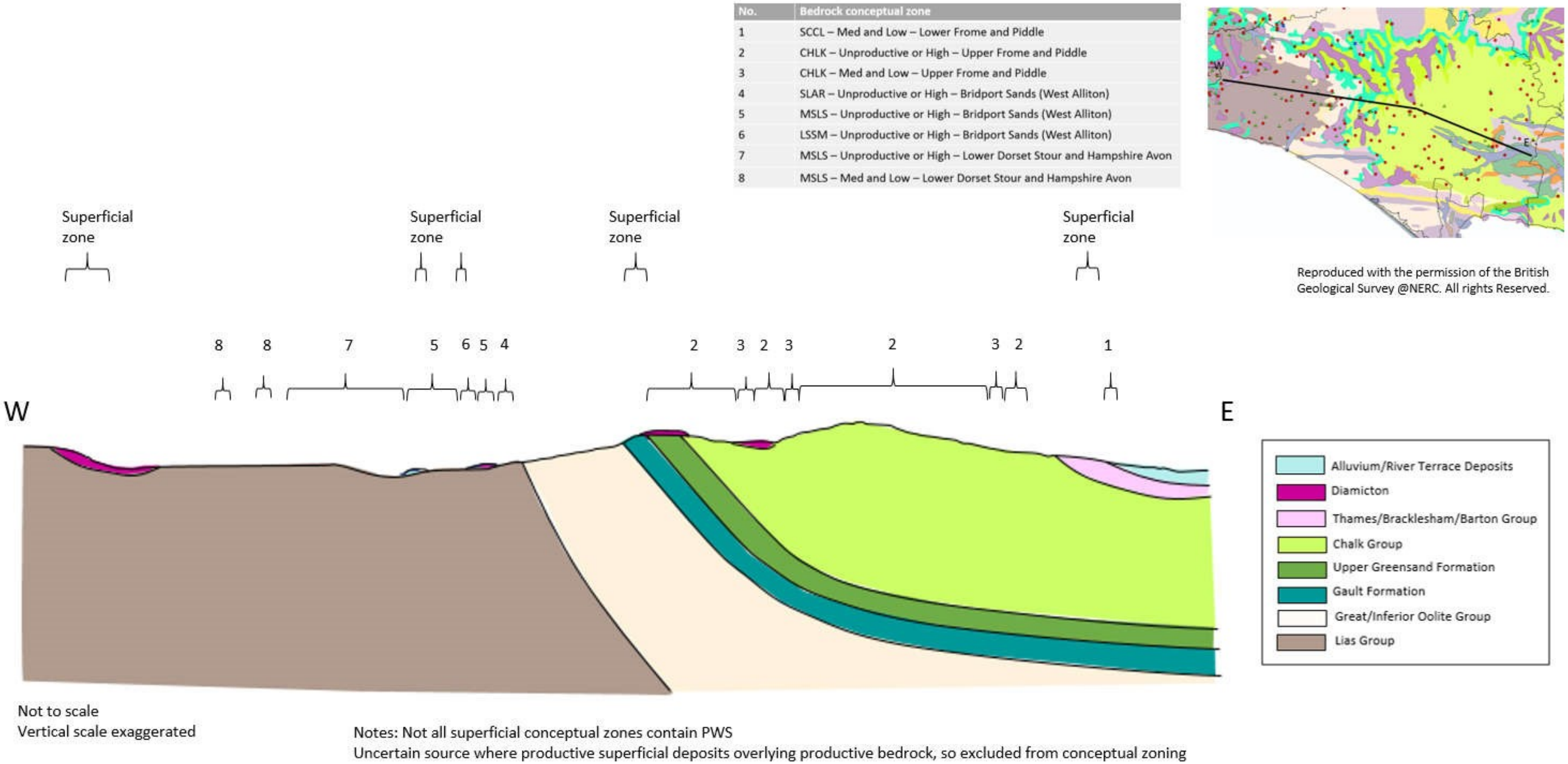


*Note - Points on above map insets show groundwater PrWS (for reference only)*

**Figure 4-4 – Defining detailed groundwater conceptual areas for bedrock geology**



Figure 4-5 presents an indicative geological cross section for West Dorset showing this detailed approach to groundwater conceptual zones, of which on this transect alone there are eight groundwater conceptual zones, in comparison to five for the simplified approach (see Figure 4-3).




| No. | Bedrock conceptual zone |
|---|---|
| 1 | SCCL – Med and Low – Lower Frome and Piddle |
| 2 | CHLK – Unproductive or High – Upper Frome and Piddle |
| 3 | CHLK – Med and Low – Upper Frome and Piddle |
| 4 | SLAR – Unproductive or High – Bridport Sands (West Alliton) |
| 5 | MSLS – Unproductive or High – Bridport Sands (West Alliton) |
| 6 | LSSM – Unproductive or High – Bridport Sands (West Alliton) |
| 7 | MSLS – Unproductive or High – Lower Dorset Stour and Hampshire Avon |
| 8 | MSLS – Med and Low – Lower Dorset Stour and Hampshire Avon |

**Figure 4-5 - Indicative geological cross section for West Dorset showing detailed approach to groundwater conceptual zones**

Note for bedrock conceptual zones the acronyms are for the BGS 625k Bedrock Geology dataset broad rock type attribute: RCS_D as follows: MDSS: Mudstone, siltstone and sandstone, FTUFF: Felsic Tuff, LSSA: Limestone with subordinate sandstone and argillaceous rocks, SCON: Sandstone and conglomerate, interbedded, MFIR: Mafic igneous-rock, FLAVA: Felsic Lava, MSLS: Mudstone, siltstone, limestone and sandstone, CHLK: Chalk, MDSL: Mudstone, sandstone and limestone, SLAR: Sandstone, limestone and argillaceous rocks, LSSM: Limestone, sandstone, siltstone and mudstone, SSCL: Sand, silt and clay, CLSSG: Clay, silt sand and gravel.

### 4.2.3. Groundwater superficial deposit conceptual areas

The method for defining groundwater conceptual areas for superficial geology is summarised in the five steps below:

1. Identify unproductive bedrock;
2. Identify productive superficial geology (principal / secondary);
3. Calculate areas where there is productive superficial geology over unproductive bedrock;
4. Group the resulting polygons into areas of similar superficial deposits using the WFD groundwater operational catchments;
5. Review and 'sense check' conceptual areas.

The method is summarised in Figure 4-6 and a full technical methodogy is provided in Appendix B.

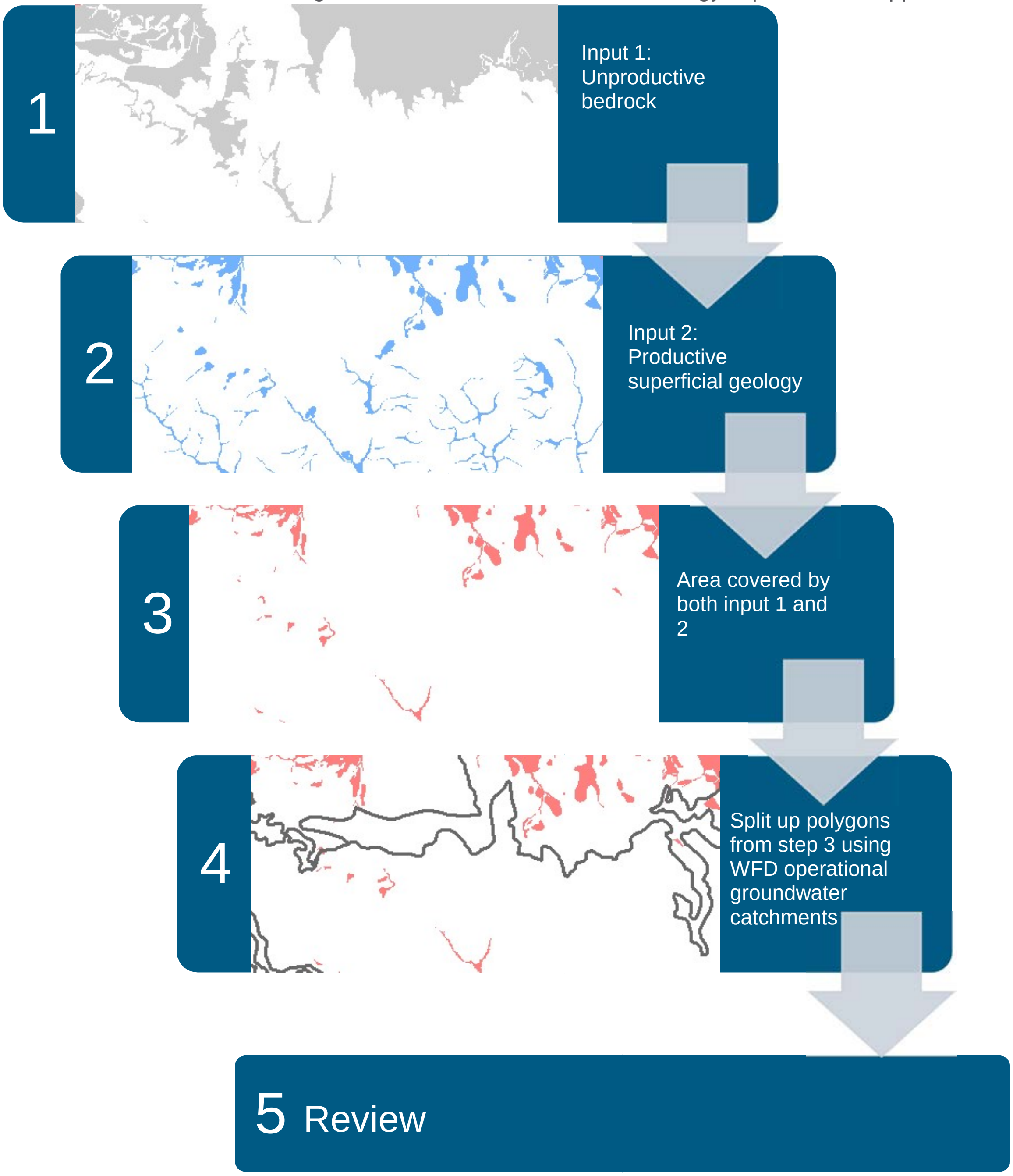



**Figure 4-6 - Defining groundwater conceptual areas for superficial geology**

## 4.3. Surface water conceptual areas

In contrast to the groundwater catchments the surface water catchments were relatively straightforward to conceptualise to an appropriate level of detail relative to the typical number of surface water PrWS in a LA.

The assessment of surface water conceptual areas uses existing WFD surface water operational catchments (cycle 2). These catchments are shown in Figure 4-7 and Figure 4-8 for Conwy and West Dorset respectively.

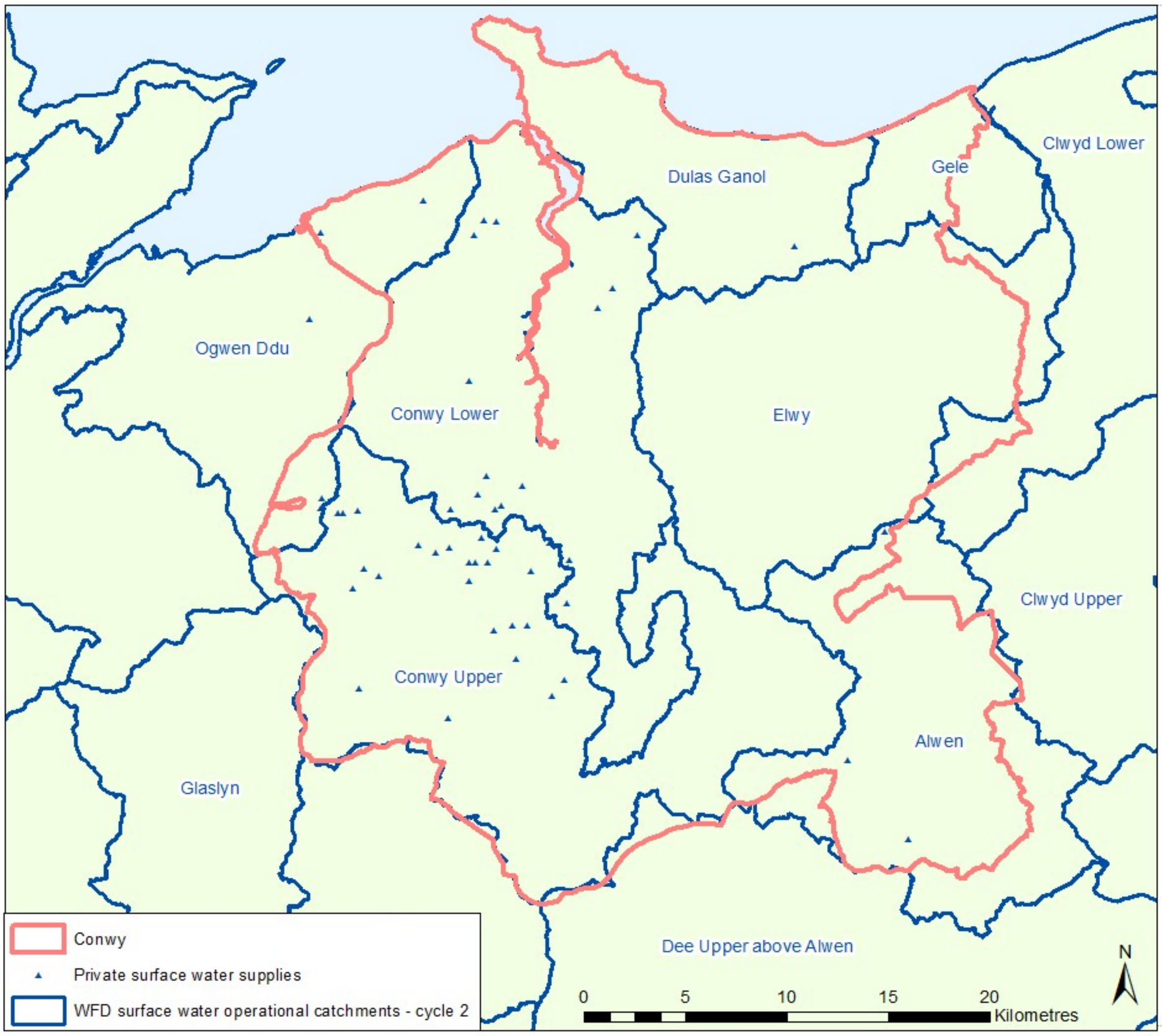



**Figure 4-7 – Surface water conceptual areas in Conwy**

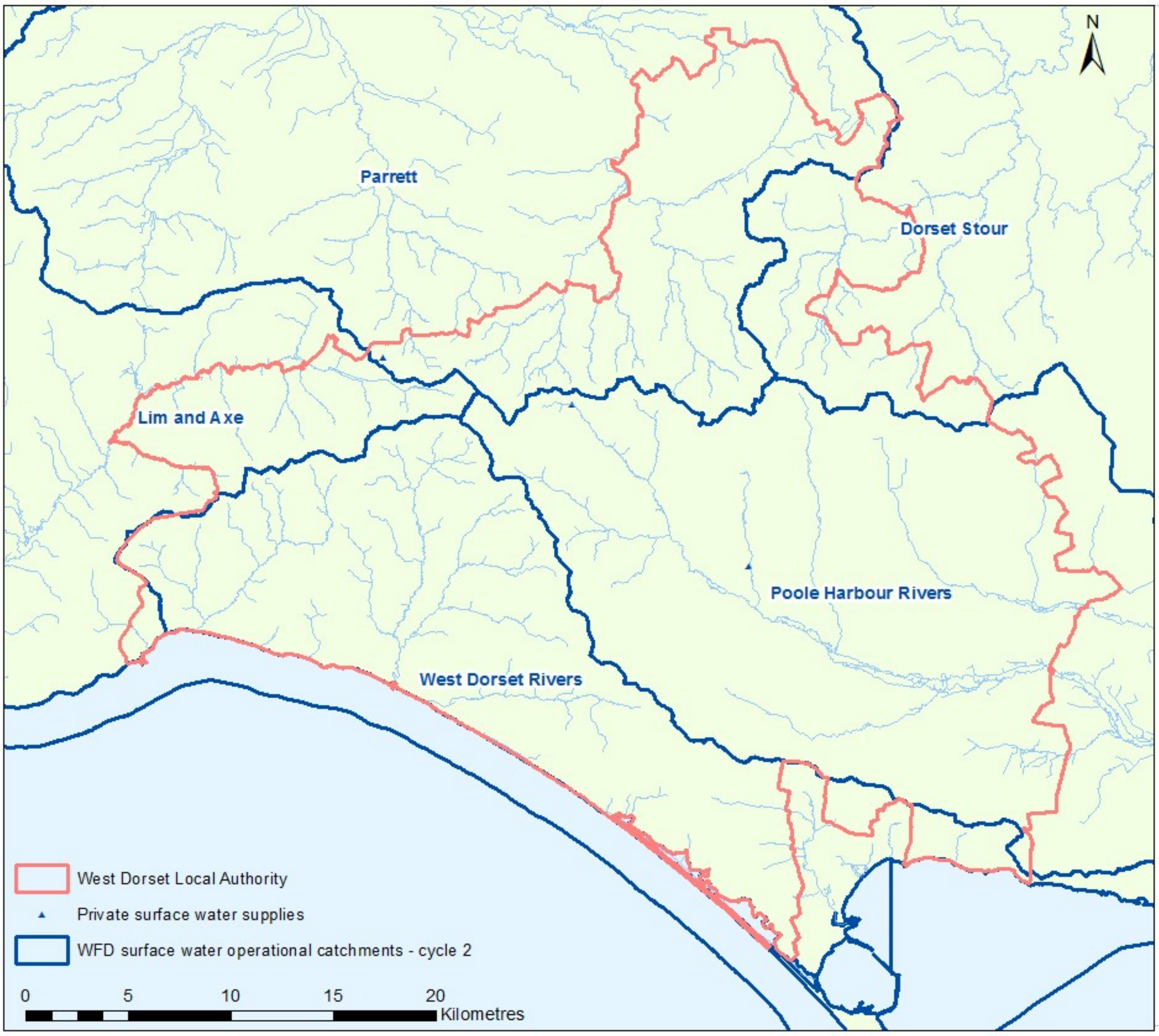



**Figure 4-8 – Surface water conceptual areas in West Dorset**

## 4.4. Catchment counts

Table 4-1 shows the number of each type of conceptual catchment produced by the methods outlined above. The groundwater superficial conceptual areas and surface water catchments are the same regardless of the method used to derive the groundwater bedrock conceptual areas. When comparing the number of groundwater bedrock conceptual areas, there are notably more (over three times more) for both Conwy and West Dorset when using the detailed approach compared to the simplified approach.

**Table 4-1 – Sum of conceptual catchments by type**

| Catchment type | Number of conceptual areas in **Conwy** containing at least one PrWS | Number of conceptual areas in **West Dorset** containing at least one PrWS |
|---|---|---|
| Simplified groundwater bedrock conceptual areas | 4 | 9 |

| | | |
|---|---|---|
| Detailed groundwater bedrock conceptual areas | 15 | 31 |
| Groundwater superficial conceptual areas | 0 | 2 |
| Surface water catchments | 5 | 2 |

## 4.5. Contamination sources

The methodology for delineating the conceptual areas is based on datasets that are readily available to LAs and, to avoid creating too many subdivisions relative to the number of PrWS, is largely concerned with the receptor and pathway components of a source-pathway-receptor risk assessment approach. Consideration of impacts from contamination sources is included in the detailed groundwater catchments by the inclusion of bedrock vulnerability boundaries. It was found that using additional contamination data created too many catchments of too many different types to be useful. This meant the following datasets were not used to define conceptual areas: landcover type, soil, PrWS risk assessments, landfill location, pollution incident locations, mining areas, nitrate vulnerability zones, source protection zones and pesticide monitoring data.

# 5. Validation of conceptual zones using historical water quality data

## 5.1. PrWS water quality data for England and Wales

As summarised in Table 2-1 a copy of PrWS sampling water quality results reported by England and Wales LAs between 2010 and 2016 was provided to inform this project. The data for the two trial LAs, Conwy and West Dorset, were extracted from this dataset with data from 2017 added, resulting in data from 2010-2017 inclusive. The count of determinands, sample points and results are shown in Table 5-1.

**Table 5-1 - Summary count of determinands, sample points and results by trial LA**

| LA | Count of Determinands | Count of Sample Points | Count of Results |
|---|---|---|---|
| Conwy | 85 | 141 | 6,660 |
| West Dorset | 96 | 272 | 18,588 |

As part of the quality assurance on the data it was checked whether individual PrWS site names were linked to distinct location coordinates. A similar process was followed to check that individual location coordinates were assigned to distinct site IDs.

Where a single site ID was linked to multiple coordinates, a single set of coordinates was rationalised for the site ID, this was based on the set of coordinates appeared first in the dataset. Similarly, where multiple site IDs were indicated at a single set of coordinates a single ID was applied. Where an individual site ID or set of coordinates could not be identified these points were excluded from further analysis. The count of excluded sample points is shown in Table 5-2.

**Table 5-2 - Count of excluded sample points by trial LA**

| LA | Count of Excluded Sample Points |
|---|---|
| Conwy | 41 |
| West Dorset | 98 |

It should be noted that it has been assumed the PrWS water quality data are representative of raw water samples, even though most of the samples are taken from PrWS consumer taps. This is because not all PrWS will have treatment and where it is installed it tends to be minimal e.g. filtration and UV disinfection (pers. comm. Richard Phillips, Defra, April 2018).

### 5.1.1. Assigning Conceptual Zones to PrWS

Individual sample points were assigned to surface water or groundwater categories based on their sampling code which was attached as part of each result in the dataset. Where a sample point had both surface water and groundwater codes associated with it, the sample point was assigned the type based on the type of code that had the largest proportion of results.

Using GIS software, geology and WFD waterbody data were linked to each site based on their location coordinates. Using the methods described in Section 4, these data were used to define the conceptual zones that each point could be considered a part of, whether it was a bedrock, surface water or superficial deposit type.
As described in Section 4, if a point was located on productive superficial deposits which overlie productive bedrock then these points were excluded from the analysis as the source of the water being abstracted could not be determined.

As reported in Section 4.2.1 and 4.2.2 two methods were developed for defining the groundwater bedrock conceptual zones, which were analysed in parallel throughout this project. These are referred to as the 'detailed' and 'simplified' approaches and the count of sample points by conceptual zone is shown in Table 5-3 and Table 5-4.

**Table 5-3 - Count of sample points by conceptual zones for the simplified approach**

| Conceptual Zone | LA | Count of Sample Points |
|---|---|---|
| Bedrock Aquifer - Dee Silurian/Ordovician | Conwy | 10 |
| Surface water - Ogwen Ddu | Conwy | 5 |
| Surface water - Conwy Upper | Conwy | 26 |
| Surface water - Conwy Lower | Conwy | 17 |
| Bedrock Aquifer - Conwy OC | Conwy | 25 |
| Bedrock Aquifer - Clwyd Silurian | Conwy | 7 |
| Bedrock Aquifer - Llyn and Eryri | Conwy | 4 |
| Surface water - Dulas Ganol | Conwy | 1 |
| Surface water - Alwen | Conwy | 3 |
| Bedrock Aquifer - Winsham | West Dorset | 2 |
| Bedrock Aquifer - Lyme Regis | West Dorset | 9 |

| | | |
|---|---|---|
| Bedrock Aquifer - Lower Dorset Stour and Hampshire Avon | West Dorset | 37 |
| Bedrock Aquifer - Bridport Sands (West Alliton) | West Dorset | 24 |
| Surface water - Parrett | West Dorset | 1 |
| Bedrock Aquifer - Upper Frome and Piddle | West Dorset | 72 |
| Bedrock Aquifer - Fullers Earth (Crewkerne) | West Dorset | 7 |
| Surface water - Poole Harbour Rivers | West Dorset | 2 |
| Bedrock Aquifer - Yeovil Bridport Sands / Inferior Oolite | West Dorset | 9 |
| Superficial Aquifer - Lower Dorset Stour and Hampshire Avon | West Dorset | 1 |
| Superficial Aquifer - Fullers Earth (Crewkerne) | West Dorset | 2 |
| Bedrock Aquifer - Dyrham Formation (North of Yeovil - Fragmented GW | West Dorset | 1 |
| Bedrock Aquifer - Lower Frome and Piddle | West Dorset | 2 |

**Table 5-4 - Count of sample points by conceptual zones for the detailed approach**

| Conceptual Zone | LA | Count of Sample Points |
|---|---|---|
| MDSS - High Vuln - Dee Silurian/Ordovician | Conwy | 3 |
| Surface water - Ogwen Ddu | Conwy | 5 |
| Surface water - Conwy Upper | Conwy | 26 |
| Surface water - Conwy Lower | Conwy | 17 |
| FTUFF - High Vuln - Conwy OC | Conwy | 5 |
| LSSA - High Vuln - Conwy OC | Conwy | 2 |
| MDSS - High Vuln - Conwy OC | Conwy | 7 |
| MDSS - Low or Med Vuln - Conwy OC | Conwy | 9 |
| MDSS - Low or Med Vuln - Clwyd Silurian | Conwy | 5 |
| MDSS - Low or Med Vuln - Dee Silurian/Ordovician | Conwy | 6 |
| MDSS - High Vuln - Clwyd Silurian | Conwy | 1 |
| MDSS - Low or Med Vuln - Llyn and Eryri | Conwy | 1 |
| SCON - Low or Med Vuln - Conwy OC | Conwy | 1 |
| SCON - Low or Med Vuln - Clwyd Silurian | Conwy | 1 |
| Surface water - Dulas Ganol | Conwy | 1 |

| | | |
|---|---|---|
| MFIR - Low or Med Vuln - Llyn and Eryri | Conwy | 1 |
| Surface water - Alwen | Conwy | 3 |
| FLAVA - High Vuln - Llyn and Eryri | Conwy | 2 |
| SCON - High Vuln - Conwy OC | Conwy | 1 |
| SCON - Low or Med Vuln - Dee Silurian/Ordovician | Conwy | 1 |
| MSLS - Low or Med Vuln - Winsham | West Dorset | 2 |
| MSLS - Low or Med Vuln - Lyme Regis | West Dorset | 4 |
| MDSL - High Vuln - Lyme Regis | West Dorset | 3 |
| MSLS - High Vuln - Lower Dorset Stour and Hampshire Avon | West Dorset | 24 |
| MSLS - Low or Med Vuln - Lower Dorset Stour and Hampshire Avon | West Dorset | 2 |
| MSLS - High Vuln - Bridport Sands (West Alliton) | West Dorset | 14 |
| CHLK - High Vuln - Bridport Sands (West Alliton) | West Dorset | 1 |
| Surface water - Parrett | West Dorset | 1 |
| MDSL - Low or Med Vuln - Upper Frome and Piddle | West Dorset | 9 |
| MDSL - High Vuln - Fullers Earth (Crewkerne) | West Dorset | 3 |
| SLAR - High Vuln - Bridport Sands (West Alliton) | West Dorset | 4 |
| SLAR - High Vuln - Lower Dorset Stour and Hampshire Avon | West Dorset | 3 |
| LSSM - High Vuln - Bridport Sands (West Alliton) | West Dorset | 4 |
| MDSL - High Vuln - Lower Dorset Stour and Hampshire Avon | West Dorset | 4 |
| Conceptual Zone | LA | Count of Sample Points |
| MDSL - High Vuln - Upper Frome and Piddle | West Dorset | 16 |
| Surface water - Poole Harbour Rivers | West Dorset | 2 |
| CHLK - High Vuln - Upper Frome and Piddle | West Dorset | 35 |
| MSLS - High Vuln - Yeovil Bridport Sands / Inferior Oolite | West Dorset | 7 |
| CHLK - Low or Med Vuln - Upper Frome and Piddle | West Dorset | 10 |
| SLAR - High Vuln - Yeovil Bridport Sands / Inferior Oolite | West Dorset | 1 |
| MDSS - High Vuln - Lower Dorset Stour and Hampshire Avon | West Dorset | 2 |
| MSLS - High Vuln - Lyme Regis | West Dorset | 1 |

| | | |
|---|---|---|
| Superficial Aquifer - Lower Dorset Stour and Hampshire Avon | West Dorset | 1 |
| MDSL - Low or Med Vuln - Fullers Earth (Crewkerne) | West Dorset | 1 |
| CHLK - High Vuln - Fullers Earth (Crewkerne) | West Dorset | 1 |
| SLAR - Low or Med Vuln - Lower Dorset Stour and Hampshire Avon | West Dorset | 2 |
| SLAR - High Vuln - Upper Frome and Piddle | West Dorset | 2 |
| Superficial Aquifer - Fullers Earth (Crewkerne) | West Dorset | 2 |
| MSLS - High Vuln - Dyrham Formation (North of Yeovil - Fragmented GW | West Dorset | 1 |
| LSSM - High Vuln - Yeovil Bridport Sands / Inferior Oolite | West Dorset | 1 |
| SSCL - High Vuln - Lower Frome and Piddle | West Dorset | 1 |
| CLSSG - High Vuln - Lower Frome and Piddle | West Dorset | 1 |
| MDSL - Low or Med Vuln - Lyme Regis | West Dorset | 1 |
| MSLS - Low or Med Vuln - Bridport Sands (West Alliton) | West Dorset | 1 |
| SLAR - High Vuln - Fullers Earth (Crewkerne) | West Dorset | 2 |

Note for groundwater bedrock conceptual zones the acronyms are for the BGS 625k Bedrock Geology dataset broad rock type attribute: RCS_D as follows: MDSS: Mudstone, siltstone and sandstone, FTUFF: Felsic Tuff, LSSA: Limestone with subordinate sandstone and argillaceous rocks, SCON: Sandstone and conglomerate, interbedded, MFIR: Mafic igneousrock, FLAVA: Felsic Lava, MSLS: Mudstone, siltstone, limestone and sandstone, CHLK: Chalk, MDSL: Mudstone, sandstone and limestone, SLAR: Sandstone, limestone and argillaceous rocks, LSSM: Limestone, sandstone, siltstone and mudstone, SSCL: Sand, silt and clay, CLSSG: Clay, silt sand and gravel.

Both approaches result in conceptual zones with low counts of sample points, however, the simplified approach had far fewer zones with a single PrWS; the simplified approach has four conceptual zones with a single PrWS across both LAs, while the detailed approach has twenty-one. In order to validate the conceptual zones at least two PrWS are required for comparison of whether they are similar, therefore, for the rest of this report only data from the simplified approach shall be presented as the lack of multiple PrWS in so many zones of the detailed approach would reduce the data available for validation.

## 5.2. Validation approach for two trial areas

A feature of this data set is that it has three dimensions to it which makes it difficult to summarise in a concise but inclusive format. These are:

- Spatial, i.e. sample point location: 139 sample points for Conwy and 267 for West Dorset. These are then grouped into conceptual zones, nine conceptual zones in Conwy and 13 in West Dorset using the simplified approach;
- 118 determinands were sampled in the two trial LAs; and
- ☐ Temporal, measured by the date and time of the sample.

The source data were investigated, and where it was found that a result was below the limit of detection a value of half the limit of detection was applied. As a key piece of the exercise is to investigate whether PrWS within conceptual zones abstract from similar water sources, the loss variability from applying a single value where data were below the limit detection was a concern for the quality of the analyses. To focus relevant data, sample points with 50% or more results below the limit of detection for a specific determinand were excluded from further analyses.

A number of methods were used to investigate the validity of using the conceptual zones to characterise water quality spatial trends. Initially, summary statistics were produced for each conceptual zone and determinand. These included:

- Sample count by determinand, calculated for conceptual zones and for individual sample points;
- Maximum and minimum results by conceptual zone and determinand; and
- Average and standard deviation results by conceptual zone and determinand.

The count of sample results by determinand was completed by both conceptual zone and PrWS sample points. While for conceptual zones there was often a reasonable amount data per determinand, the count of data per determinand for PrWS sample points is much lower, often less than five results per determinand. This was not the case for microbiology data which were by far the highest represented in the data set. However, microbiology results were considered to be poor as a basis for validating conceptual zones. Risk factors for microbiology in groundwater and surface water are considered to be local to the source and therefore were not be considered useful in determining whether sample points within a conceptual zone are abstracting water from the same overall source of water. Analysis therefore focused on physico-chemical determinands.

Of the summary statistics, the most useful were the maximum values recorded as these could be used with a risk-based approach. However, this measure does not give a sense of the homogeneity of the sample points within the conceptual zones which is key in validating the conceptual zones. The standard deviation measures this across the zone but does not take in to account whether sample points differ from one another.

To take in to account temporal differences the correlation of sample results with time was assessed. While this gives an overall impression of a trend, without a graphical presentation of the timeseries it is difficult to assess whether the trend is meaningful or not. To address this a timeseries chart was created, however, due to the large number of conceptual zones this was hard to interpret (Figure 51). While only showing a single conceptual zone at a time would be clearer, it would be difficult to infer trends across the entire LA by interpretation of a large number of independent time series charts.

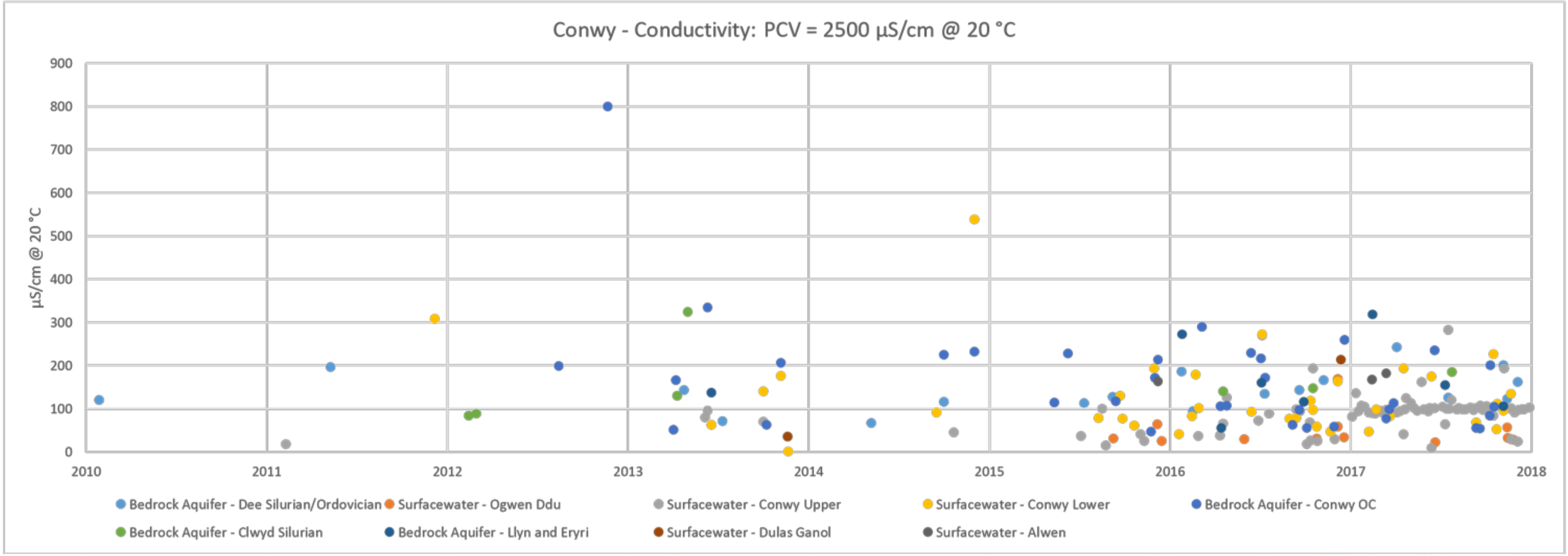



**Figure 5-1 - Timeseries data for conductivity across the conceptual zones in Conwy**

## 5.3. Statistical significance test

### 5.3.1. Overview

The analyses described above in Section 5.2 provided useful information about the conceptual zones but were inconclusive in verifying whether the water quality data variance validates the conceptual zoning. Having considered a range of techniques the Kruskal-Wallis test for differences was selected as the most appropriate for assessing the homogeneity of the sample points across the conceptual zones. The Kruskal-Wallis test was chosen as it does not assume a specific distribution of data and because it can give useful results even for relatively low sub-group counts (greater than five results).

The Kruskal-Wallis test works by using statistical significance to test whether sub-groups of data within a larger dataset are different from each other. This test was applied to the PrWS data by using a conceptual zone as the main group and sample points as the sub-groups to be tested for differences. When the test does not find a difference then it indicates that the sub-groups (in this case PrWS sample points within the conceptual zone) might be similar. As the test measures difference rather than similarity, it should be noted that not finding a difference is evidence that the PrWS sample points within a conceptual zone are similar but not proof.

To ensure the test result were valid, only sample points/determinands with five or more results were included (as required for the Kruskal-Wallis test). It should be noted that five results per sub-group is still a relatively low number of results to perform this kind of test.

If a large proportion of conceptual zones are shown to be similar across a class of determinand (e.g. physico-chemical parameters) then this validates the approach of defining conceptual zones, at least for those determinands. For example, if for iron, for 70% of conceptual zones the KruskalWallis test detected no difference, this would be evidence that the conceptual zones are a meaningful spatial delineation for iron. If this result was repeated across other physico-chemical determinands then this would be evidence that PrWS sample points within conceptual zones are abstracting water from a source with similar water quality properties.

### 5.3.2. Kruskal-Wallis results

This test was completed for the all the water quality results collected across West Dorset and Conwy (2010-2017). The Kruskal-Wallis test calculates the ascending order for each result (1$^{st}$, 2$^{nd}$, 3$^{rd}$ etc.) across the main group and then compares the distribution of the orders across each subgroup. Where results are below the limit of detection the actual order of results is unknown and thus reduces the variability that can be measured between sub-groups and reduces the validity of the Kruskal-Wallis test. Therefore, PrWS sample points were only included in the analysis if they had five or more results for that determinand and less than 50% of their results for that determinand were below the limit of detection.

Table 5-5 and Table 5-6 show the results of Kruskal-Wallis test for each LA and whether the test detected a difference, did not detect a difference (highlighted in green) or there was not enough data to complete the test; only determinands where there enough data to complete the test for at least one conceptual zone for the LA were included in the tables. For clarity, each conceptual zone was treated as the main group with the constituent PrWS being the sub-groups (results shown in the first three rows of Table 5-5 and Table 5-6) and then this was followed by an additional analysis of the LA as the main group and conceptual zones as the sub-group (result shown in last row of Table 5-5 and Table 5-6).

As can be seen in the tables, all determinands had only enough data to complete the test for less than half the conceptual zones of either LA regardless of result. The lack of data meant that for these LAs there were not enough data to validate the conceptual zones.

**Table 5-5 - Results of Kruskal-Wallis tests for Conwy**

| LA | Statistic | Iron | Escherichia coli E.coli | Clostridium perfringens | Colour | Ammonium | Turbidity | Hydrogen ion (pH) Indicator | Conductivity | Colony Counts After 3 Days At 22°c | Manganese | Coliform bacteria Indicator | Enterococci | Lead (10 - will apply 25/12/2013) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conwy | Detectable difference between sample points*1 | 0 | 1 | 1 | 1 | 0 | 2 | 1 | 1 | 2 | 1 | 1 | 0 | 1 |
| Conwy | No difference between sample points detected*2 | 1 | 3 | 2 | 2 | 2 | 0 | 1 | 1 | 2 | 0 | 2 | 4 | 0 |
| Conwy | Not enough data to perform difference test | 8 | 5 | 6 | 6 | 7 | 7 | 7 | 7 | 5 | 8 | 6 | 5 | 8 |
| Conwy | Detectable difference between conceptual zones*3 | Yes | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No | Yes | No | No |

*1 A result of 'detectable difference between sample points' indicates that there is a detectable difference between the PrWS within the conceptual zones at the 5% significance level. The results are shown as a count of zones with this result.

*2 A results of 'no difference between sample points detected means the Kruskal-Wallis test could not detect a difference between the PrWS within the conceptual zones hence the green shading indicates evidence of homogeneity was found within a number of conceptual zones. The results is shown as a count of zones with this results.

*3 A result of 'Yes' for detectable difference between conceptual zones indicates that some conceptual zones show evidence of being distinct from each other. It should be noted that due to the sparsity of data these results cannot be used to make conclusions about the data but are included for completeness.

**Table 5-6 - Results of Kruskal-Wallis tests for West Dorset**

| LA | Statistic | Iron | Escherichia coli E.coli | Clostridium perfringens | Aluminium | Turbidity | Hydrogen ion (pH) Indicator | Conductivity | Colony Counts After 3 Days At 22°c | Colony Counts After 48 Hours At 37°c | Manganese | Coliform bacteria Indicator | Nitrate | Copper | Nickel | Enterococci | Cadmium | Selenium | Turbidity – Indicator | Lead (10 - will apply 25/12/2013) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| West Dorset | Detectable difference between sample points | 0 | 2 | 2 | 0 | 0 | 2 | 3 | 1 | 4 | 2 | 3 | 3 | 3 | 2 | 2 | 0 | 0 | 0 | 2 |
| West Dorset | No difference between sample points detected | 2 | 4 | 2 | 1 | 1 | 2 | 1 | 4 | 1 | 1 | 3 | 0 | 1 | 1 | 3 | 1 | 1 | 1 | 0 |
| West Dorset | Not enough data to perform difference test | 11 | 7 | 9 | 12 | 12 | 9 | 9 | 8 | 8 | 10 | 7 | 10 | 9 | 10 | 8 | 12 | 12 | 12 | 11 |
| West Dorset | Detectable difference between conceptual zones | Yes | No | No | No | No | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | No | No | Yes | Yes | No |

*1 A result of ‘detectable difference between sample points’ indicates that there is a detectable difference between the PrWS within the conceptual zones at the 5% significance level. The results are shown as a count of zones with this result.

*2 A results of ‘no difference between sample points detected means the Kruskal-Wallis test could not detect a difference between the PrWS within the conceptual zones hence the green shading indicates evidence of homogeneity was found within a number of conceptual zones. The results is shown as a count of zones with this results.

*3 A result of ‘Yes’ for detectable difference between conceptual zones indicates that some conceptual zones show evidence of being distinct from each other. It should be noted that due to the sparsity of data these results cannot be used to make conclusions about the data but are included for completeness.

It can be seen in Table 5-5 and Table 5-6 that more conceptual zones for microbiological determinands had enough data to return a result from the Kruskal-Wallis test. As discussed in Section 5.2 microbiological determinands are considered to be less useful than physico-chemical determinands and thus will not be discussed further.

The data were further analysed to understand the number of sample points with enough data to be used in the Kruskal-Wallis test, i.e. sample points with five or more results for a determinand. Conwy had no more than two sample points per conceptual zone with enough data. For West Dorset, there were in general more sample points with enough data. Table 5-7 and Table 5-8 summarise the number of PrWS with enough data for conceptual zones and determinands for which results were returned Red numbers indicate a difference was detected by the Kruskal-Wallis test, green numbers indicate no difference was detected.

The tables show us that there are few determinands and conceptual zones with enough data to return a result. Determinands with a higher count of PrWS per conceptual zone were more likely to have a significant difference detected, and the Kruskal-Wallis test detected a difference for all determinands with more than five PrWS per conceptual zones. It could be inferred that there is a greater chance of dissimilarity between PrWS when the count is increased, suggesting the evidence of similarity shown in the data is a product of chance. Conversely, this might be evidence that conceptual zones with a higher count of PrWS cover too large an area and should be split to focus on PrWS abstracting from the same source waters; however, there are not enough data to draw firm conclusions about these results.

**Table 5-7 - Number of sample points with five or more results for Conwy conceptual zones**

| Conceptual Area | Sample Point Count | Iron | Colour | Ammonium | Turbidity | Hydrogen ion (pH) Indicator | Conductivity | Manganese | Lead (10 - will apply 25/12/2013) |
|---|---|---|---|---|---|---|---|---|---|
| Surfacewater - Conwy Upper | 26 | | 2 | | | | | | |
| Surfacewater - Conwy Lower | 17 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Bedrock Aquifer - Conwy OC | 25 | | 2 | 2 | 2 | 2 | 2 | | |

Note: Red indicates a difference between the sample points was detected for that determinand in the conceptual zone, green indicates no difference was detected.

**Table 5-8 - Number of sample points with five or more results for West Dorset conceptual zones**

| Conceptual Area | Sample Point Count | Iron | Aluminium | Turbidity | Hydrogen ion (pH) Indicator | Conductivity | Manganese | Nitrate | Copper | Nickel | Cadmium | Selenium | Turbidity – Indicator | Lead (10 - will apply 25/12/2013) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bedrock Aquifer - Lyme Regis | 9 | | 2 | | 4 | 5 | 4 | 4 | 4 | 4 | 2 | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bedrock Aquifer - Lower Dorset Stour and Hampshire Avon | 37 | 5 | | | 10 | 10 | 8 | 4 | 8 | 3 | | 2 | | 4 |
| Bedrock Aquifer - Bridport Sands (West Alliton) | 24 | | | | 3 | 3 | | | 2 | | | | | |
| Bedrock Aquifer - Upper Frome and Piddle | 72 | 2 | | 2 | 15 | 12 | 3 | 14 | 12 | 2 | | | 5 | 8 |

Note: Red indicates a difference between the sample points was detected for that determinand in the conceptual zone, green indicates no difference was detected.

While the lack of data meant the zoning approach could not be verified or rejected, for a limited set of determinands and conceptual zones the test showed evidence of homogeneity between PrWS sample points. While this could just be by chance, rather than the PrWS abstracting from water source/s with similar water quality and contamination risks, these groups were taken forward for further analysis. This was further investigated by viewing box and whisker plots showing the ranges of results for each sample point in a conceptual zone for a specific determinand. By assessing the box and whisker plots the limited nature of data for even the sample points determined to have enough data to run the test was revealed. This is because conceptual zones where no difference between the sample points had been detected by the Kruskal-Wallis test showed determinands without distributions that substantially overlapped. In reality it could be that the distributions are indeed different or that the low sample count has by chance resulted in the visual differences.

Figure 5-2 and Figure 5-3 both show conceptual zones for which the Kruskal Wallis did not detect a significant difference between the sample points. So for example in Figure 5-2 no difference was detected by the Kruskal-Wallis test but visually there is little overlap between the two PrWS distributions. Interrogation of the base data showed there was a single data point that overlapped between the two PrWS, combined with the low result count for each PrWS this meant a significant difference could not be detected. Figure 5-3 shows a more complex story, with obvious visual overlap of the five PrWS distributions especially between three of the PrWS, however, two of the PrWS are far more skewed than the others, which means concluding that the zone is homogenous is not a clear conclusion.

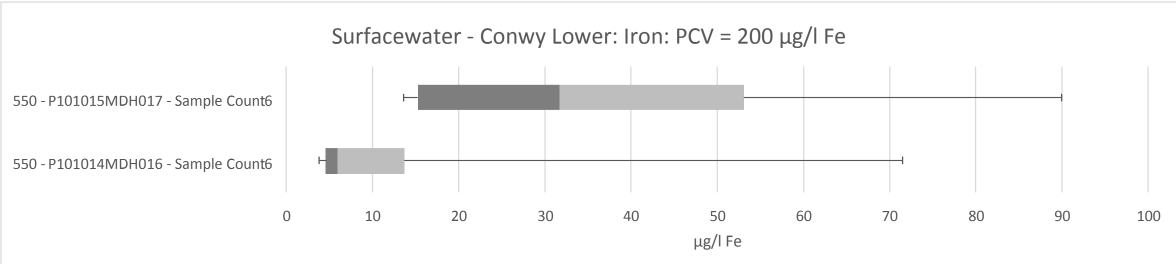



**Figure 5-2 – Example box and whisker plot for iron in Conwy**

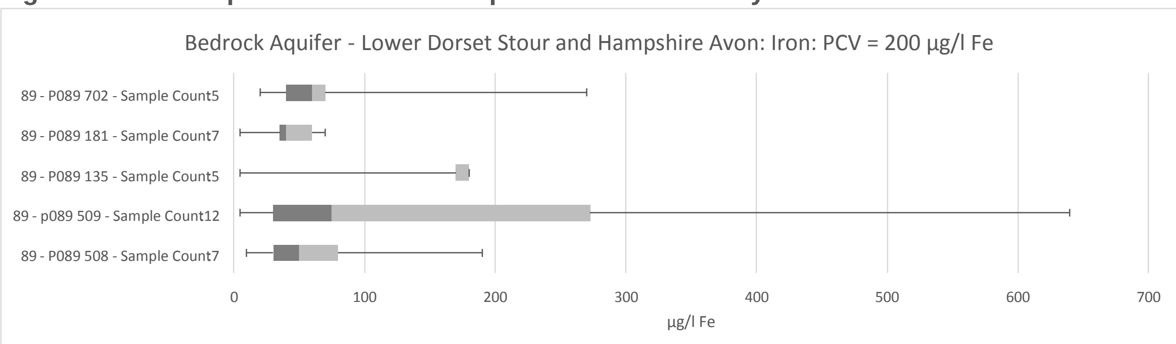



**Figure 5-3 - Example box and whisker plot for iron in West Dorset**

A second test was also designed to test whether the conceptual zones are distinct within the LA. This test could only be considered valid if enough zones were shown to be homogenous in the first test. As there was not enough data to show whether enough of the zones were homogenous this test could not be used for interpretation, however the results are still presented in the bottom row of Table 5-5 and Table 5-6 above.

## 5.4. Conclusions of validation of conceptual zones

The Kruskal-Wallis test was completed on all determinands for all conceptual zones.

Microbiological determinands had more data and therefore could return results for more conceptual zones than physico-chemical determinands but were considered less useful for validating the conceptual zoning approach, due to role of local factors in determining microbiology for PrWS.

By excluding sample points with less than five results for a specific determinand there was often a low count of PrWS sample points within a conceptual zone to complete the Kruskal-Wallis test on. This further erodes confidence in the test results.

For every determinand there were not enough data to complete the test for at least 50% of the zones. This meant there was not enough data to validate the conceptual zones. The tests did however show that for a limited set of determinands and conceptual zones there were enough data to show evidence of homogeneity. These results were taken forward to develop a method of reducing sampling for these conceptual zones and determinands.

## 5.5. Radioactivity

Radioactivity from several naturally occurring and anthropogenic (i.e. ‘man-made’) sources is present throughout the environment. Water contains a small and variable quantity of natural radioactivity from the decay of uranium and thorium and their daughters, together with potassium40. Anthropogenic radionuclides can also be found in natural waters as a result of authorised routine releases into the environment in small quantities in the effluent discharged from nuclear fuel cycle facilities. They are also released into the environment following their use in unsealed form for medical and industrial applications and as a result of past fallout contamination resulting from the explosion in the atmosphere of nuclear devices and accidents such as at Chernobyl (fallout from which affected the UK[2]).

Since January 2017 LAs are required to monitor radioactivity in PrWS to ensure it does not contain radionuclides at activity concentrations which could present a risk to human health. The extent of monitoring is primarily informed by risk assessments and compared to most other determinands it is monitored at relatively few sites. The radioactivity sampling data for PrWS in the two trial areas has been collected. To provide some context to the small size of the PrWS dataset, this has been compared to the radioactivity monitoring results from the water companies that serve the two trial areas. Although this provides some context, the limitations of the comparison should first be understood:

- Public water supplies include surface water sources from major rivers. PrWS are typically from groundwater or smaller surface water sources;
- Public water supplies are typically undergo more complex treatment(s) than PrWS, which may not be treated at all, or only have minimal levels of treatment; and
- Public water supplies are monitored at treatment works, reservoirs and around the distribution network. These sites can be distant form the source in both time and space – this equates to increased opportunity for decay.

[2] http://dwi.defra.gov.uk/private-water-supply/regs-guidance/Guidance/info-notes/england/reg-11.pdf

Figure 5-4 and Figure 5-5 present radioactivity water quality monitoring data for 2009-2017 that were collected by the water companies supplying the two trial areas. The samples are taken from works, supply points around the distribution network and at consumer taps. The figures show that:

- Most gross alpha results are below the Prescribed Concentration or Value (PCV, in West Dorset 96% are less than half the PCV and in Conwy 99.6% are less than half the PCV); ☐ In both trial areas gross beta results are all substantially below the PCV.
- West Dorset has few tritium monitoring results. In Conwy most tritium results are at the limit of detection; which are substantially below the PCV.

A detailed assessment of the data has shown that none of the monitored radioactivity parameters monitored exhibit clear geographic trends. They are also not clearly related to the type of sample source (i.e. treatment works, supply point or consumer tap). It is noted that in both LAs gross alpha was on average lowest at the treatment works and highest at supply points, however the variation was not substantial.

West Dorset LA has not collected any radioactivity monitoring results for PrWS. Conwy has collected data from three different PrWS. Two sites have one tritium result and one site has a total of 14 results across tritium, gross alpha and gross beta.

The Conwy results are summarised as follows:

- Six tritium results were collected from PrWS in Conwy. All were at the limit of detection (<5 Bq/l) which is comparable to most of the water company results in this area;
- All five gross alpha results for PrWS in Conwy were below the limit of detection (<0.018 Bq/l);
- All five gross beta results for PrWS in Conwy were below 0.028 Bq/l – substantially below the maximum PCV of 1 Bq/l.

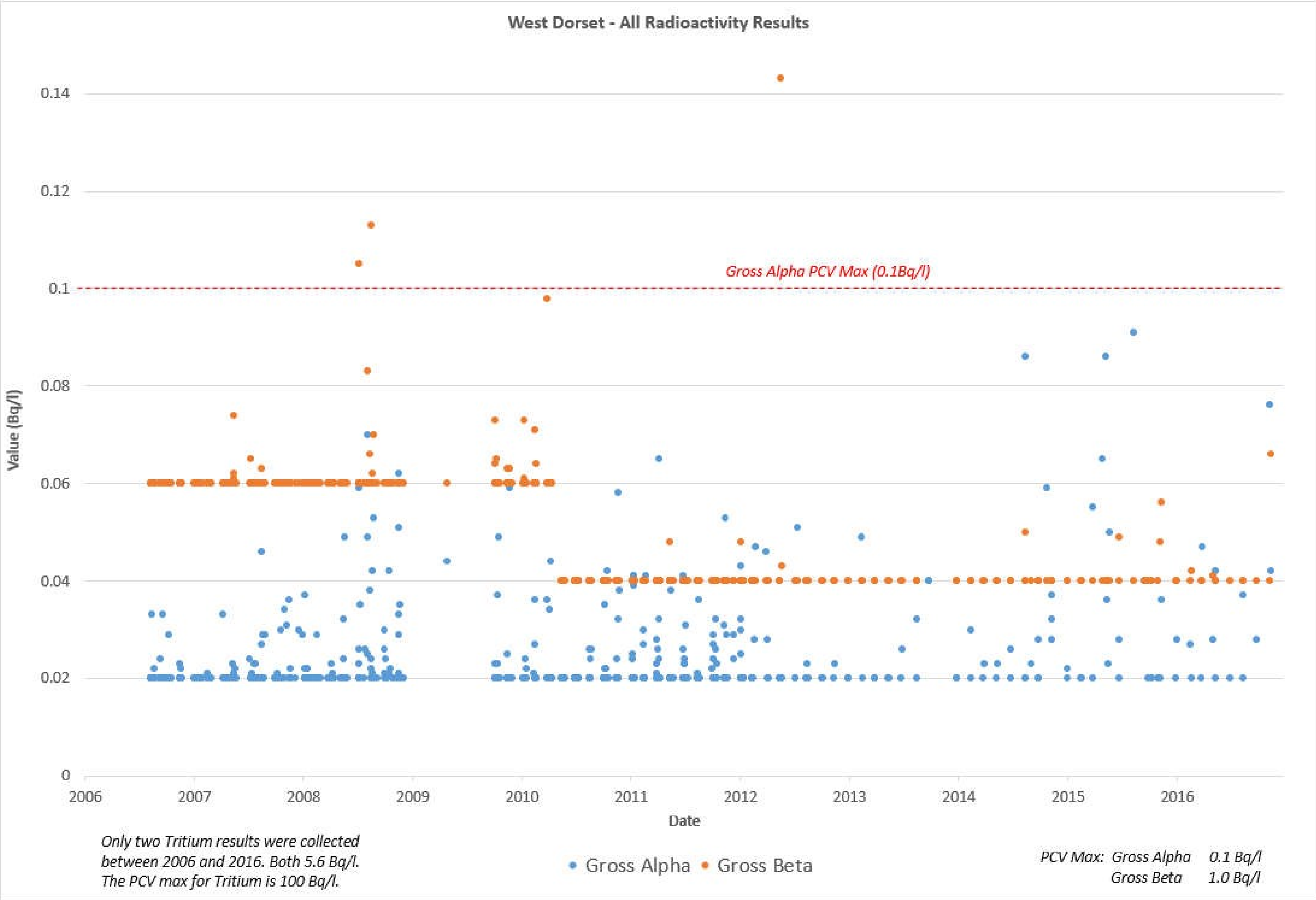

West Dorset - All Radioactivity Results
Value (Bq/l)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Gross Alpha PCV Max (0.1Bq/l)
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Date
Only two Tritium results were collected between 2006 and 2016. Both 5.6 Bq/l. The PCV max for Tritium is 100 Bq/l.
Gross Alpha
Gross Beta
PCV Max: Gross Alpha 0.1 Bq/l
Gross Beta 1.0 Bq/l

**Figure 5-4 – Monitoring for radioactivity in public water supplies in West Dorset**

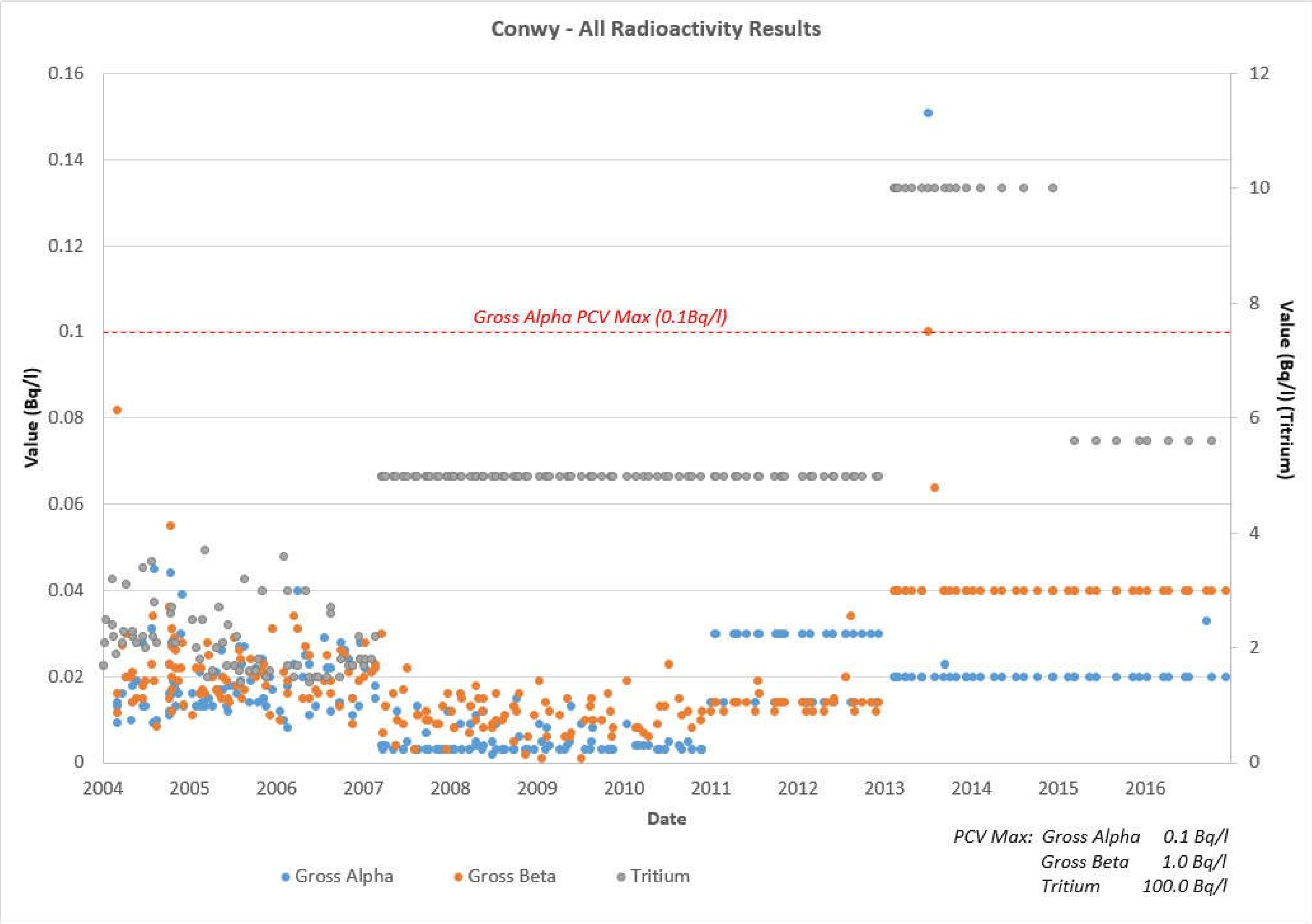



**Figure 5-5 – Monitoring for radioactivity in public water supplies in Conwy**

# 6. Potential cost savings from undertaking reduced PrWS monitoring

## 6.1. Approach to estimating cost savings

Using the results from the Kruskal-Wallis test described in Section 5, there were some conceptual zones and determinands that showed evidence of homogeneity. These were taken forward to show how potential cost savings could be achieved.

The method used to estimate sampling and analysis savings was as follows:

1. The conceptual zones and determinands that the Kruskal-Wallis test indicated homogeneity were identified.
2. The number of sample points within these zones with five or more results for the determinand were identified. These are the sample points that had been used in the Kruskal-Wallis test.
3. For these conceptual zones and determinands the maximum result was identified. If the maximum result was below 60% of the PCV this was considered low risk and the reduction in sampling was calculated (this is in line with the current guidance for LAs to reduce sampling at individual PrWS in DWI, 2016a, 2016b).
4. For these conceptual zones and determinands the number of samples per year was calculated across the dataset (2010-2017).
5. Due to the low number of sample points within each conceptual zone it was assumed that sampling for a determinand could only be stopped at one sample point.
6. Using the lab costs per determinand the annual cost savings were calculated. The average lab cost per determinand are presented in Appendix C. These were developed by calculating average prices from quotes provided by five separate laboratories in 2016.

The annual sampling rate for each determinand for which no difference was detected by the Kruskal-Wallis test and which has no result greater than 60% of the PCV is shown in Table 6-1 for Conwy and Table 6-2 for West Dorset. As can be seen in the tables, the number of determinands meeting these criteria and the annual sampling rates were low.

**Table 6-1 - Annual sampling rate for determinands where a reduction in sampling might be justified for Conwy**

| Conceptual Zone | Ammonium | Hydrogen ion pH) (Indicator | Conductivity |
|---|---|---|---|
| Surfacewater - Conwy Lower | 1.9 | 2.4 | 2.4 |
| Bedrock Aquifer - Conwy OC | 1.9 | - | - |

**Table 6-2 - Annual sampling rate for determinands where a reduction in sampling might be justified for West Dorset**

| Conceptual Zone | Hydrogen ion (pH) (Indicator) | Conductivity | Copper | Nickel | Cadmium | Selenium |
|---|---|---|---|---|---|---|
| Bedrock Aquifer - Lyme Regis | 5.5 | - | - | - | 3.0 | - |
| Bedrock Aquifer - Lower Dorset Stour and Hampshire Avon | - | - | - | - | - | 4.7 |
| Bedrock Aquifer - Bridport Sands (West Alliton) | 3.8 | 3.8 | 2.6 | - | - | - |
| Bedrock Aquifer - Upper Frome and Piddle | - | - | - | 3.0 | - | - |

## 6.2. Estimate cost savings

Using the method described in Section 6.1 the annual savings from reducing sampling is summarised in Table 6-3 and Table 6-4. It should be noted that it was not possible to show that sampling could be stopped at any site altogether and therefore this would be savings in laboratory sampling alone. As shown by the tables, based on the statistical analysis and taking account of risk, the annual cost savings by reducing sampling and/or individual analyses were negligible. **Table 6-3 - Annual sampling saving for Conwy**

| Parameter | Average laboratory cost per sample per determinand (£) | | |
|---|---|---|---|
| Determinand | Ammonium | Hydrogen ion (pH) (Indicator) | Conductivity |
| Type | Part 2 Indicator parameter | Part 2 Indicator parameter | Part 2 Indicator parameter |
| Cost per sample (£) | 3.95 | 2.03 | 1.94 |
| Annual Savings (£) | 7.90 | 2.03 | 1.94 |

**Table 6-4 - Annual sampling saving for West Dorset**

| Parameter | Average laboratory cost per sample per determinand (£) | | | | | |
|---|---|---|---|---|---|---|
| Determinand | Hydrogen ion (pH) (Indicator) | Conductivity | Copper | Nickel | Cadmium | Selenium |
| Type | Part 2 Indicator parameter | Part 2 Indicator parameter | Part 1 Table B | Part 1 Table B | Part 1 Table B | Part 1 Table B |
| Cost per sample (£) | 2.03 | 1.94 | 2.17 | 2.28 | 2.23 | 3.96 |
| Annual Savings (£) | 4.06 | 1.94 | 2.17 | 2.28 | 2.23 | 7.92 |

# 7. Conclusions and recommendations

## 7.1. Conclusions

### 7.1.1. Overall project objective

The overall objective of this project was to investigate whether it is feasible to group together PrWS to reduce monitoring by sampling from a source which is representative of the water quality across a defined area. It was important to identify any limitations and risks with the proposed approach in addition to estimating the potential cost savings. This section summarises the conclusions from the four main tasks that were carried out to achieve the project objective.

### 7.1.2. Identify criteria to group PrWS and apply these to trial LAs

The first step in this task was to identify two trial LA areas. Using GIS it was possible to combine the PrWS water quality dataset for England and Wales with open-source data and to compare and assess the distribution and quality of data across all LAs. Outputs from this screening provide a useful overview of the PrWS water quality data across England and Wales. The screening process identified a short list of trial areas that contained enough data for investigation without being so complex and densely analysed that they were not representative of the majority of LAs in England and Wales. From this short list two trial LAs were selected for the project: West Dorset and Conwy.

The criteria used to delineate conceptual zones for groundwater PrWS related to geology and aquifer properties. River catchments were used for grouping surface water supplies. For the groundwater PrWS, there are a range of different open-source geological and aquifer related datasets that could be used for conceptual zoning. Two approaches were developed for defining groundwater zones and each was taken forward for further evaluation:

- a detailed method resulting in many small catchments utilising the BGS 625k Bedrock Geology dataset, WFD operational groundwater catchments and BGS Groundwater Vulnerability mapping); and
- a simpler method resulting in fewer larger catchments utilising the WFD operational groundwater catchments dataset).

The delineation of conceptual areas was based on datasets that are readily available to LAs and focuses on the receptor and pathway components of a source-pathway-receptor risk assessment approach. Consideration of impacts from contamination sources is only included in the detailed groundwater catchments by the inclusion of bedrock vulnerability boundaries. The inclusion of additional source-risk data (for example land-use data) would have created too many conceptual zones.

### 7.1.3. Investigate if historical water quality data can be used to validate the PrwS conceptual zones

A number of methods were used to investigate the validity of using the conceptual zones to characterise water quality spatial trends. Of the summary statistics, the most useful were the maximum values recorded as these could be used with a risk-based approach. However, this measure does not give a sense of the homogeneity of the sample points within the conceptual zones which is key in validating the conceptual zones.

Having considered a range of techniques for assessing the homogeneity of the sample points across the conceptual zones the Kruskal-Wallis was identified as the most appropriate. This test does not assume a specific distribution of data and can give useful results for relatively low subgroup counts (greater than five results). This test was applied to the PrWS data by using a conceptual zone as the main group and sample points as the sub-groups to be tested for differences.

Microbiological determinands had more data and therefore could return results for more conceptual zones than physico-chemical determinands but were considered less useful for verifying the conceptual zoning approach, due to role of local factors in determining microbiology for PrWS, hence physico-chemical determinands were focused on.

By excluding sample points with less than five results for a specific determinand there was often a low count of PrWS sample points within a conceptual zone. This hindered the effectiveness of the test in validating conceptual zones.

There were not enough data to complete the test for at least 50% of the zones, for any determinand. This meant there were not enough data to validate the conceptual zones using the historical water quality data. The tests did however show that for a limited set of determinands and conceptual zones there were enough data to show evidence of homogeneity. These results were taken forward to develop a method of reducing sampling for these conceptual zones and determinands.

Overall, although there are a lot of analytical data in total in some LAs, when it comes to individual locations, at present the number of determinands and number of analyses are often small. This limits the potential for identifying zones of PrWS with statistically similar water quality. Further explanation is provided in the section below.

### 7.1.4. Appraise and report on the limitations and any potential risks which could be attributed to this approach

There are a number of limitations and risks for defining PrWS zones which have been identified. In particular, the nature of the historical water quality dataset limited the validation of the conceptual zones for the following reasons:

- The dataset is only available for a relatively short time period (2010-2017 inclusive) and the frequency of sampling for some of the PrWS means that there can be as few as only one or two sample results per determinand.
- There is uncertainty over the source of some of the PrWS e.g. where productive superficial deposits overly productive bedrock, so these have been excluded from the data set analysed, reducing the dataset further.
- Quality assurance checks e.g. grid references locating PrWS outside LA area, multiple site IDs etc, further reduced the dataset.
- For PrWS with 50% or more results below the limit of detection for a specific determinand, the data were excluded from the analysis.
- While for conceptual zones there was often a reasonable amount data per determinand, the count of data per determinand for PrWS sample points is much lower, often less than five results per determinand. To ensure the Kruskal-Wallis test result were valid, only sample points/determinands with five or more results were included (as required for the Kruskal-Wallis test). It should be noted that five results per sub-group is still a relatively low number of results to perform this kind of test.

In general terms, it was concluded that there were no additional ‘benefits’ from applying the detailed conceptual zoning approach and in the absence of this, it was judged that the simple approach was also more likely to be practical for LAs to apply.

The statistical approach applied in this project to attempt to verify the conceptual zones using the available water quality data is necessarily complex due to the nature of the source data; this report sets out the steps taken that showed the increasingly complex analyses used to understand the data. However, even using a complex and statistically sensitive method it was not possible to detect enough structure in the data of the trial LAs to advise a reduction of monitoring based on conceptual zoning. Had a clear data structure been discovered by this method this report would have further investigated whether it would be possible to simplify the method and still identify potential reductions in monitoring.

If the current method were to be adopted for use by LAs then it would be useful to develop a methodology and a tool to aid a standardised application of this approach. However, a number of potential sources for error would remain. In particular: the quality of the input data has to be assured; there are a number of intermediate stages which require some interpretation to understand the full meaning of the results; and the relatively low number of results per PrWS per determinand means that there is a need for further visual inspection of box and whisker plots to determine whether the results are valid.

### 7.1.5. Scope potential cost savings which could be made from grouping PrWS

For a limited number of conceptual zones and determinands evidence of homogeneity was found using the Kruskal-Wallis test. These zones and determinands were taken forward to assess whether sampling rates could be reduced. If all the results for a conceptual zone and determinands were below 60% of the PCV then the number of sample points and the annual sampling rate was analysed. Where sample results were below 60% of the PCV there were a limited number sample points. Based on this statistical approach, and taking account of risk, the annual cost savings by reducing sampling and/or individual analyses were found to be are negligible. Results indicated that savings would only be achieved in the laboratory as the sample points would still need to be visited to collect samples for other determinands.

While it would be possible to either modify the existing method to increase potential savings or even to develop a different method, it is unlikely that a statistically robust method could be developed that will make substantial savings across the two trial LAs.

## 7.2. Recommendations

A review of this work should be undertaken in four or five years' time when more water quality data are available. During this period, in addition to data continuing to be collected at the frequency historically seen, the 2017/2018 amendments to the Private Water Supply Regulations[3] stipulate additional recent monitoring for Regulation 9 supplies[4].

LAs with very high densities of PrWS were not chosen as trial areas because they would not have been representative of the majority of LAs. It is possible that applying the method described in this report to LAs with more data might yield more results to prove or disprove the approach of conceptual zoning as there would likely be more sample points per conceptual zone. It should be noted that this may result in the conceptual zoning being disproved if the higher number of sample points shows greater diversity in results and therefore it cannot be guaranteed this will result in greater cost savings for those LAs. However, if this method was to be tested further, or alternative approaches explored, this should focus on LAs with high densities of PrWS.

The method applied here excludes some of the historical water quality data for a number of reasons including: QA issues (e.g. grid references locating PrWS outside LA area, multiple site IDs etc); and uncertainty over the source of the water (e.g. where productive superficial deposits overly productive bedrock). Undertaking some further work in liaison with the LA could resolve some of these issues. Compiling further information on the source of some of the groundwater PrWS (for example writing a short letter questionnaire to the PrWS owner asking the depth of their borehole or well) would allow more data to be used in the assessment.

Consideration could also be given to alternative methods for PrWS zone definition; in particular,

[3] Under the Private Water Supplies (England) Regulations 2016, the Private Water Supplies (England) (Amendment) Regulations 2018 and the Private Water Supplies (Wales) Regulations 2017

[4] DWI guidance note on Regulation 7 Monitoring private water supplies (accessed 24/10/2018): http://www.dwi.gov.uk/private-water-supply/regs-guidance/Guidance/info-notes/england/reg-7.pdf

data-driven approaches as opposed to the conceptually driven approach that was the brief for this project.

# 8. References


DWI (2017a) Drinking water 2016, Private water supplies in England, A report by the Chief Inspector of Drinking Water, July 2017

DWI (2017b) Drinking water 2016, Private water supplies in Wales, A report by the Chief Inspector of Drinking Water, July 2017

European Commission (2017) Drinking Water: Review of the Directive http://ec.europa.eu/environment/water/water-drink/review_en.html accessed 31/08/2017

# Appendices

# Appendix A. Trial area selection – technical methodology

# Technical Note

| | | | |
|---|---|---|---|
| Project: | The Provision of the Private Water Supply Zones Feasibility Project | | |
| Subject: | Selection of Trial Local Authority Areas - Technical Note | | |
| Author: | Matt Shipton; Chris Rowell | Atkins No.: | 5162737 |
| Date: | 11/04/2018 | Quality assurance | Originated - MS & CR<br>Checked - HS<br>Reviewed - DR<br>Authorised - DR |
| Distribution: | Richard Phillips | Representing: | Defra |

# 1. Objective

## 1.1. Project objective

The objective of this project is to investigate whether it is feasible to group private water supplies together to reduce monitoring by sampling from a source which is representative of the water quality across a defined area. In doing this the project will identify any limitations and risks with the proposed approach in addition to estimating the potential cost savings.

## 1.2. Task objective

The purpose of this technical note is to explain how Atkins has identified six Local Authorities (LAs) from which Defra will select two to be used as trial areas for this project. Using the conceptual setting and historical private water abstraction sample water quality data from the two selected LAs, Atkins will then develop criteria to group private water supplies into broadly representative supply zones in terms of water quality. The data processing that has been carried out to identify candidate trial areas will be a valuable foundation for subsequent phases of the project.

# 2. Method

## 2.1. Data

The method described herein uses a partial copy (to preserve data confidentiality) of private water supply sampling water quality results reported by England and Wales LAs between 2010 and 2016 (PWS_Records for Atkins v2.xlsx). Atkins received the data from Defra on 08/02/2018. The data contains 858,667 analyses results of 260 unique parameters at 19,558 sites located in 262 different LAs. A more thorough summary of the data is provided below.

### 2.1.1. Private water supply sites

Individual sites were identified based on unique site references listed in the data. The LA the site was listed in was also utilised in this process, since on occasions different LAs were found to use the same site referencing convention. A total of 19,558 sites were identified. Sites were plotted in GIS using coordinates from the sample data of the most recent date the site was visited. Just under half of the sites, 8,707 (44%), were only sampled once (i.e. visited on one day) between 2010 and 2016. Of the remainder:

- 10,514 (54%) were sampled between 2 and 15 times;
- 313 (2%) were sampled between 15 and 50 times; and
- 24 sites (<1%) were sampled more than 50 times in this period.

### 2.1.2. Private water supply source types

The source type of each private water supply in the incoming data was identified based on the detailed categories shown in Table 2-1. For the purpose of trial LA selection, these detailed categories have been grouped into summary categories. As can be seen from Table 2-1 and Figure 2-1, private water supply across England and Wales is dominated by groundwater and spring supplies (88%). Only 4% of private water supplies are exploiting surface water sources.

| Detailed source type category | Summary source type category | Private water supplies | |
|---|---|---|---|
| | | Number | % |
| Borehole | Groundwater (GW) | 11,008 | 56 |
| Well | | | |
| Spring | Spring (SP) | 6,210 | 32 |
| Surface water | Surface water (SW) | 867 | 4 |
| Multiple sources - borehole and spring | Other (OTH) | 1,473 | 8 |
| Borehole influenced by surface water | | | |

| | | | |
|---|---|---|---|
| Estuarine/brackish water | | | |
| Unknown | | | |

**Table 2-1 Private water supply source type – detailed and summary categories**

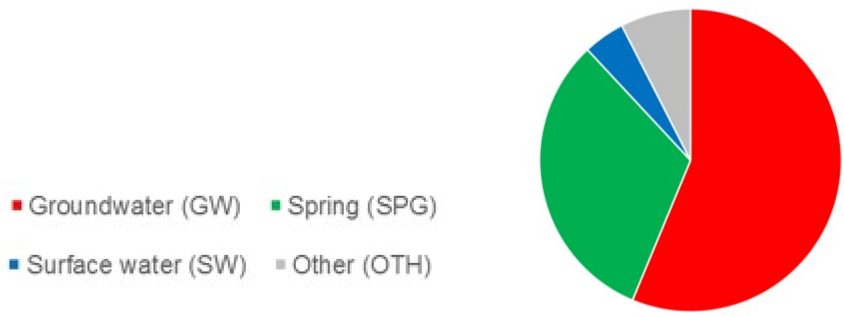



**Figure 2-1 Private water supply source type – summary categories**

### 2.1.3. Private water supply parameters tested

Although 260 unique parameters were tested, the 20 most tested parameters were analysed 706,072 times making up 82% of all analyses (858,667).

The 2017 private water supply reports for both England and Wales identify parameters most likely to fail due to the quality of water in the catchment (see Appendix A). These parameters make up 26% of all the analyses.

The only parameters with a fail rate greater than 10% were: Escherichia coli (E.coli), Hydrogen ion (pH) (Indicator), Enterococci, Nitrate, Odour, Nitrite - Consumer's Taps, and Nitrite/Nitrate formula. These were all included in the 20 most tested parameters.

On average seven parameters were tested at each site per year.

## 2.2. Quality assessment

A number of data processing tasks have been undertaken to assess the quality of the private water supply sampling dataset. A number of these concerned the location data associated with each analysis – that is the Easting and Northing coordinates as well as the name of the LA in which the analysis was listed. The process by which this was done is explained below.

### 2.2.1. Location data

Quality assurance of the location data in the private water supply sampling dataset excluded 112 LAs from being selected as trial areas. The process by which this was done is set out in Figure 2-2 and Table 2-2. All excluded LAs are shown in grey in Figure 2-2. The assessment left 236 LAs remaining, i.e. those with reasonably accurate location data from which the trial areas would be selected.

**Table 2-2 Location inconsistencies**

| Reason for exclusion of LA | Count of LAs |
|---|---|
| >5 of the analyses listed in LA have incomplete or missing coordinates* or coordinates that plot outside of England and Wales | 12 |
| >5 of the analyses listed in LA have coordinates that plot in another LA | 5 |
| >5 of the analyses with coordinates plotting in LA are listed as being in another LA | 8 |
| LAs in which no analyses are listed | 87 |

** 1,191 analyses were found to have either incomplete or missing coordinates*

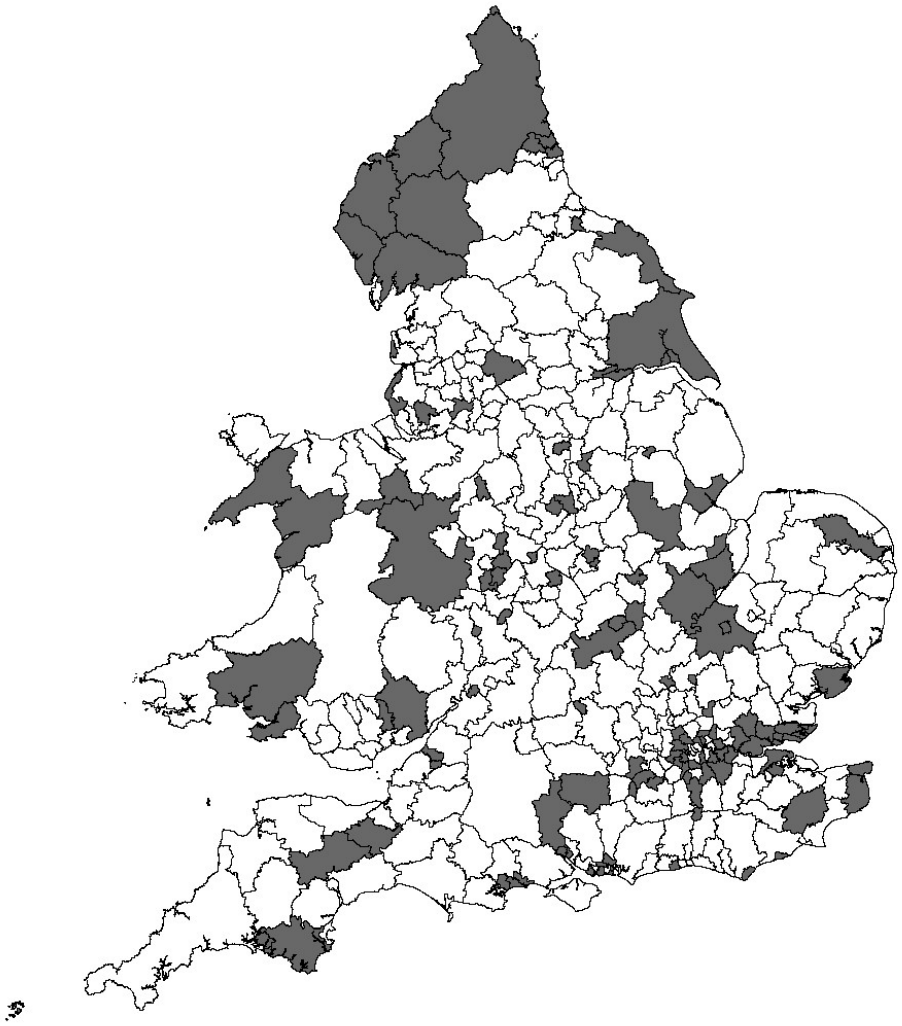


**Figure 2-2 LAs with poor quality location data**

## 2.3. Process

### 2.3.1. Data filtering – long-list

Following the high-level quality checks, the private water supply data, the list of LAs from which the trial areas would be selected was further reduced by applying the following five criteria:

1. LA excluded if it contained less than 100 sample sites or more than 500;
2. LA excluded if the average number of parameters analysed per visit was < $50^{th}$ percentile;
3. LA excluded if the site density was < $50^{th}$ percentile;
4. LA excluded if, on average, sites were sampled on less than two days between 2010 and 2016;
5. LA excluded if more than 10% of the analyses were attributed with a site type of other[5] were excluded.

[5] Other sources are those that are not exclusively groundwater, spring water or surface water. The category is made up of sites with: multiple sources, boreholes influenced by surface water, estuarine/brackish water or sites of an unknown type.

Applying these criteria ensured that the proposed trial areas would contain enough data for the next stage without being so complex and densely analysed that they were not representative of the majority of LAs in England and Wales. It also ensured the selected LAs would have a history of repeated water quality sampling of a range of parameters at established sites, had a reasonable mixture of known site types (i.e. sources) and that the sites were not so sparsely located that zoning would be unfeasible. The 331 LAs that were excluded by the above criteria were removed from further consideration as trial areas and are shown in grey in Table 2-3. This left 17 LAs, five of which were previously excluded based on the quality of their location data (see Table 2-2), resulting in a long-list of 12 potential trial LAs.

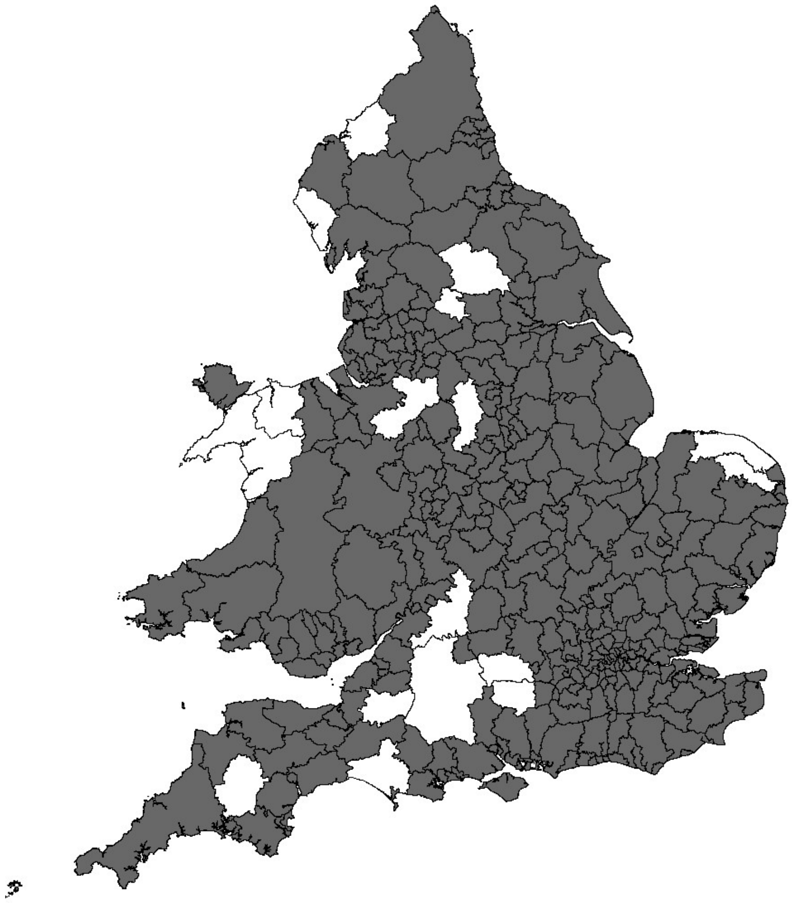


**Figure 2-3 LAs with private water supply data outside of preferred range**

### 2.3.2. Conceptual characterisation – short-list

The 12 potential trial LAs on the long-list are shown in Figure 2-4. These represent the LAs with reasonably well-located analyses and with preferable ranges of data as set out in sections 2.2.1 and 2.3.1 respectively. It is important to note at this stage that there is only one LA (Conwy) on the longlist that contains significant numbers of surface water supplies (greater than 10). This reflects the broader picture of private water supply in England and Wales that is dominated by groundwater and spring supplies (see section 2.1.2).

This long-list has been reduced to a short-list of six based the conceptual characteristics of each LA. Since most of the private water supplies across England and Wales are dominated by groundwater and spring supplies, most weight has been placed on the hydrogeological setting of each LA. Table 2-3 summarises key hydrogeological information for each LA – aquifer types, bedrock geology and superficial geology found within the LA area. Summary comments based on this hydrogeological information and the spatial distribution of groundwater, spring and surface water supplies in the LA, have been recorded in Table 2-3 and used to inform the short-list selection which is presented in the last column of Table 2-3. Note, different aquifer types can apply to different outcrops of the same undifferentiated bedrock unit.

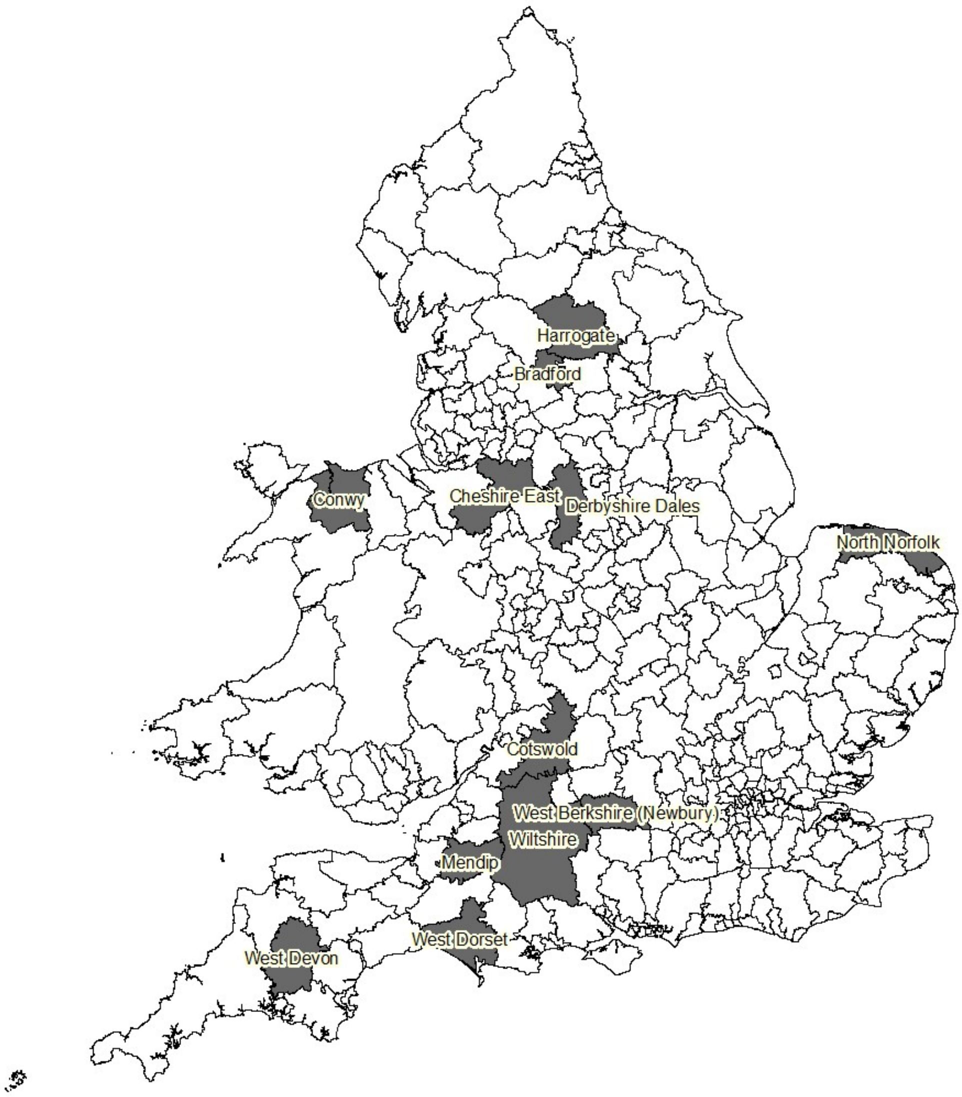



**Figure 2-4 Long-list of potential trial LAs**

Table 2-3 Long-list of potential trial LAs – conceptual characterisation

| LA | Number of private water supplies[1] | | | | Geology / hydrogeology | | | Summary comments | Shortlist |
|---|---|---|---|---|---|---|---|---|---|
| | Total | GW | SP | SW | Aquifer types[2] found in LA | Main bedrock rock units[3] found in LA | Main superficial deposits[4] found in LA | | |
| **Bradford** | 169 | 104 | 57 | 3 | Moderately productive (F) | Millstone Grit Group<br>Pennine Lower Coal Measures Formation | *Moderate coverage:*<br>• Till<br>• Peat<br>• Alluvium | GW and SP supplies spread evenly across Millstone Grit;<br>Few supplies associated with Coal Measures Millstone Grit;<br>Some GW and SP supplies potentially exploiting superficial deposits (till); Adjacent to Harrogate. | No – insufficient variation to bedrock underlying GW/SP supplies. |
| **Cheshire East** | 127 | 73 | 43 | 8 | Low productivity (F) | Triassic Rocks (undiff.) | *Extensive coverage:*<br>• Till<br>• Sands and gravels | Distribution of GW and SP supplies is very uneven across the LA;<br>GW and SP supplies are mainly located on the Millstone Grit;<br>Some GW and SP supplies potentially exploiting superficial deposits (till);<br>Near to Derbyshire Dales. | No – insufficient variation to bedrock geology underlying GW/SP supplies. |
| | | | | | Moderately productive (F) | Millstone Grit Group<br>Pennine Lower Coal Measures Formation | | | |
| | | | | | Highly productive (IG) | Triassic Rocks (undiff.) | | | |
| **Conwy** | 140 | 34 | 43 | 50 | Low productivity (F) | Ludlow Rocks (undiff.)<br>Wenlock Rocks (undiff.)<br>Caradoc Rocks (undiff.) | *Moderate coverage:*<br>• Till<br>• Alluvium | Considerable number of SW supplies;<br>Even split between GW, SP and SW supplies; GW and SP supplies associated with low productivity aquifer or superficial deposits. | Yes – considerable number of SW supplies. Good bedrock variability including low productivity. |
| | | | | | Moderately productive (F) | Warwickshire Group<br>Dinantian Rocks (undiff.) | | | |
| | | | | | Highly productive (IG) | Permian Rocks (undiff.) | | | |
| **Cotswold** | 167 | 103 | 58 | 3 | Highly productive (F) | Inferior Oolite Group<br>Great Oolite Group | *Minor coverage:*<br>• Alluvium<br>• Till<br>• River terrace deposits | GW supplies mainly located on the Great Oolite;<br>Significant numbers of springs associated with Bridport Sands and Inferior Oolite;<br>Few supplies associated with superficial deposits;<br>Adjacent to Wiltshire. | Yes – GW and SP supplies associated with a variety of bedrock. |
| | | | | | Rocks with essentially no GW | Lias Group<br>Kellaways Formation | | | |
| | | | | | Moderately productive (IG) | Bridport Sand Formation | | | |
| **Derbyshire Dales** | 124 | 25 | 86 | 8 | Moderately productive (F) | Bowland High and Craven Groups (undiff.)<br>Dinantian Rocks (undiff.)<br>Millstone Grit Group | *Moderate coverage:*<br>• Till<br>• Sands and gravels<br>• Alluvium | Not many GW supplies, mainly SP;<br>SP largely location on the Millstone Grit;<br>Distribution of supplies over the rest of the LA is sparse;<br>Water quality summary is good (<5% of top 20 and catchment affected parameters fail); Near to Cheshire East. | No – insufficient GW supplies. |
| | | | | | Low productivity (F) | Triassic Rocks (undiff.) | | | |
| | | | | | Highly productive (IG) | Triassic Rocks (undiff.) | | | |
| **Harrogate** | 420 | 211 | 183 | 3 | Moderately productive (F) | Millstone Grit Group<br>Pennine Lower Coal Measures Formation<br>Bowland High and Craven Groups (undiff.) | *Moderate coverage:*<br>• Sands and gravels<br>• Alluvium<br>• Peat<br>• Lacustrine deposits (clay)<br>• River terrace deposits | Good distribution of GW and SP sources across the LA;<br>GW sources located across varied bedrock geology; SP sources largely associated with the Millstone Grit and superficial deposits;<br>Likely that significant numbers of GW and SP supplies are exploiting superficial deposits; Adjacent to Bradford. | Yes – GW and SP supplies associated with a variety of bedrock and superficial deposits. |
| | | | | | Highly productive (IG) | Triassic Rocks (undiff.) | | | |
| | | | | | Highly productive (F) | Zechstein Group | | | |
| | | | | | Rocks with essentially no GW | Permian Rocks (undiff.) | | | |
| **Mendip** | 105 | 58 | 46 | 0 | Rocks with essentially no GW | Lias Group<br>Kellaways Formation | *Moderate coverage:*<br>• River terrace deposits<br>• Alluvium<br>• Peat | GW supplies mainly located on the Great Oolite and Triassic;<br>Few GW and SP supplies associated with superficial deposits. | No – total number of sources is at the bottom end of the specified range. |
| | | | | | Moderately productive (F) | Great Oolite Group<br>Dinantian Rocks (undiff.) | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Low productivity (F) | Triassic Rocks (undiff.) | | Adjacent to Wiltshire. | |
| | | | | | Highly productive (F) | Inferior Oolite Group | | | |



| **LA** | **Number of private water supplies[1]** | | | | **Geology / hydrogeology** | | | **Summary comments** | **Shortlist** |
|---|---|---|---|---|---|---|---|---|---|
| | **Total** | **GW** | **SP** | **SW** | **Aquifer types[2] found in LA** | **Main bedrock rock units[3] found in LA** | **Main superficial deposits[4] found in LA** | | |
| | | | | | Moderately productive (IG) | Bridport Sand Formation | | | |
| **North Norfolk** | 207 | 140 | 64 | 1 | Moderately productive (IG) | Neogene to Quaternary Rocks (undiff.) | *Complete coverage:*<br>• Till<br>• Sands and gravels<br>• Alluvium | Even distribution of GW supplies across the LA;<br>SP supplies are only located where there is Chalk bedrock;<br>Likely that some GW and SP supplies potentially exploiting superficial deposits. | No – insufficient variation in bedrock. |
| | | | | | Highly productive (F) | White Chalk Subgroup | | | |
| **West Berkshire** | 130 | 127 | 2 | 0 | Highly productive (F) | White Chalk Subgroup | *Extensive coverage:*<br>• Alluvium<br>• Clay with Flints<br>• River terrace deposits | Very few SP supplies;<br>GW supplies located across the whole LA;<br>Probable some GW supplies are exploiting superficial deposits;<br>Water quality summary is good (<5% of top 20 and catchment affected parameters fail); Adjacent to Wiltshire. | Yes – GW supplies associated with a variety of bedrock and superficial deposits. |
| | | | | | Rocks with essentially no GW | Thames Group | | | |
| | | | | | Low productivity (IG) | Lambeth Group | | | |
| **West Devon** | 365 | 188 | 158 | 9 | Low productivity (F) | Holsworthy Group<br>Teign Valley Group<br>Upper Devonian Rocks (undiff.)<br>Unnamed igneous intrusion<br>Unnamed extrusive rocks | *Minor coverage:*<br>• River terrace deposits<br>• Alluvium<br>• Peat | GW and SP supplies mainly located on low productivity bedrock;<br>GW and SP supplies located across varied bedrock;<br>Few supplies associated with superficial deposits. | Yes – GW and SP supplies associated with a variety of bedrock. |
| | | | | | Moderately productive (IG) | Permian Rocks (undiff.) | | | |
| **West Dorset** | 255 | 169 | 82 | 2 | Highly productive (F) | White and Grey Chalk Subgroups<br>Inferior Oolite Group | *Minor coverage:*<br>• River terrace deposits<br>• Alluvium<br>• Clay with Flints<br>• Landslip deposits | GW and SP supplies located across varied bedrock, including some principal aquifers;<br>Possible some GW and SP supplies are exploiting superficial deposits. | Yes – GW and SP supplies associated with a variety of bedrock and superficial deposits. |
| | | | | | Moderately productive (F) | Great Oolite Group<br>Corralian Group<br>Purbeck Limestone | | | |
| | | | | | Rocks with essentially no GW | Lias Group<br>Kellaways Formation<br>Thames Group<br>West Walton/Ampthill Clay/Kinmeridge Clay Formations | | | |
| | | | | | Moderately productive (IG) | Upper Greensand Formation<br>Bracklesham and Barton Groups | | | |
| **Wiltshire** | 463 | 414 | 27 | 6 | Highly productive (F) | White and Grey Chalk Subgroups<br>Inferior Oolite Group<br>Great Oolite Group | *Minor coverage:*<br>• River terrace deposits | GW supplies largely located across Chalk;<br>Fewer SP sources, mainly located on geological boundaries; | No – GW supplies dominated by Chalk bedrock. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Rocks with essentially no GW | Kellaways Formation<br>West Walton/Ampthill Clay/Kinmeridge Clay Formations<br>Thames Group<br>Gault Formation | • Alluvium<br>• Clay with Flints | Possible some GW supplies are exploiting superficial deposits (river terrace deposits and alluvium);<br>Adjacent to Mendip, Cotswolds, West Berkshire. | |
| | | | | Moderately productive (IG) | Upper Greensand Formation | | | |
| | | | | Moderately productive (F) | Corralian Group<br>Portland Group<br>Purbeck Limestone | | | |
| | | | | Highly productive (IG) | Lower Greensand Formation | | | |

**Notes**

[1] Supplies grouped according to the source type designation provided with the incoming private water supply dataset provided by Defra:



GW = groundwater supply (borehole or well)
SP = spring supply
SW = surface water supply

[2] Aquifer types are based on the classification used in the BGS 625k hydrogeology dataset. Aquifers types have been ordered within each LA by proportion (aquifer type with the largest coverage listed first). Different aquifer types can apply to different outcrops of the same undifferentiated bedrock unit e,g, Triassic Rocks (undiff.). F = aquifers in which flow is virtually all through fractures and other discontinuities
IG = aquifers with significant intergranular flow

[3] Bedrock units are based on the classification used in the BGS 625k hydrogeology dataset (undiff. = undifferentiated). Summary hydrogeological descriptions for these bedrock units provided with the dataset are included in Appendix B. [4] Superficial deposits are based on the classification used in the BGS 625k superficial geology dataset. Approximate qualitative coverage assessments for each LA have been made based on the following scale:

Minor – < 25% coverage
Moderate – approximately between 25 and 75% coverage
Extensive – > 75% coverage
Complete – 100% coverage

# 3. Result

## 3.1. Short-list of potential trial LAs

The short-list of potential trial LAs is shown in Table 3-1 and on Figure 3-1. From this list, two LAs are to be selected by Defra as trial LAs. To assist Defra with this selection process, a conceptual figure has been produced for each short-listed LA that displays relevant hydrogeological and hydrological information. These figures are provided in Appendix C. Each of these figures contains four maps, each of which overlays private water supply locations on top of a different data layer as detailed below:

1. Aquifer type (based on BGS Hydrogeology 625k dataset)
2. Bedrock geology (based on BGS Hydrogeology 625k dataset)
3. Superficial geology (based on BGS Superficial Geology 625k dataset)
4. Main rivers (EA/NRW Main Rivers 10k dataset)

**Table 3-1 Short-list of potential trial LAs**

| LA | Number of private water supplies | | | | Conceptual figure |
|---|---|---|---|---|---|
| | Total | GW | SP | SW | Appendix |
| **Conwy*** | **140** | **34** | **43** | **50** | **C.1** |
| Cotswold | 167 | 103 | 58 | 3 | C.2 |
| Harrogate | 420 | 211 | 183 | 3 | C.3 |
| West Berkshire | 130 | 127 | 2 | 0 | C.4 |
| West Devon | 365 | 188 | 158 | 9 | C.5 |
| **West Dorset*** | **255** | **169** | **82** | **2** | **C.6** |

** Recommended trial LAs highlighted in bold (see Section 3.2)*

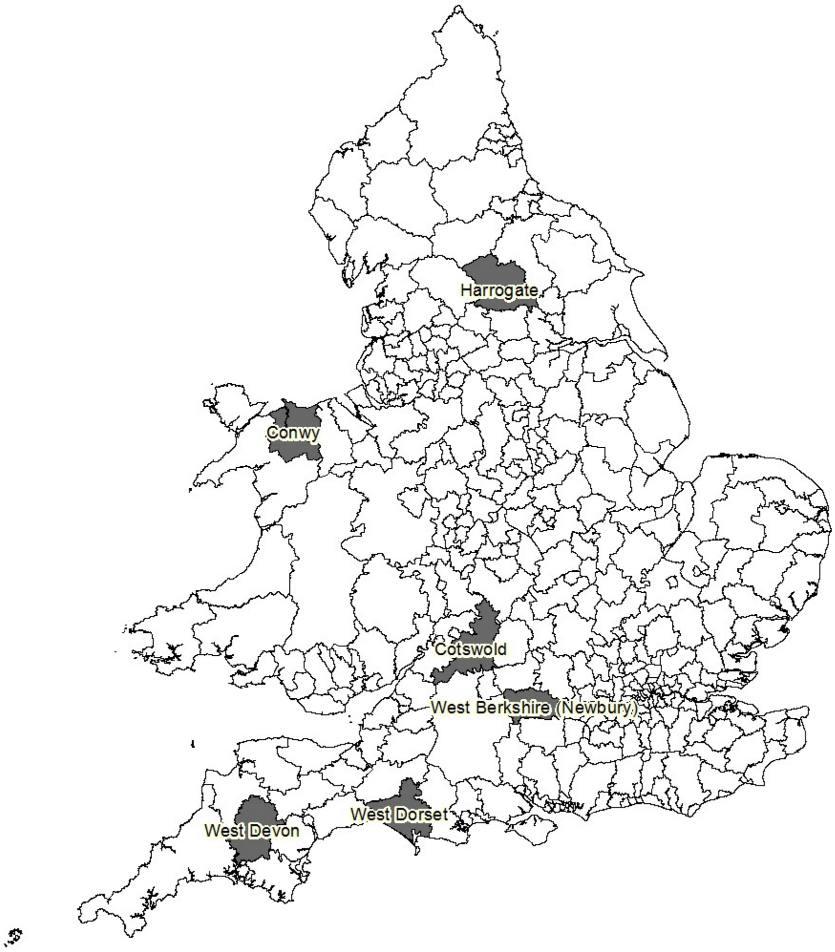



**Figure 3-1 Short-list of potential trial LAs**



## 3.2. Recommendation

The selection of two LAs to be taken forward and used as trial areas in the next stage of work is at Defra's discretion. To assist with this decision, we have selected two LAs on this short-list that we believe are most suitable to be used as trial areas in the feasibility study.

### 3.2.1. Recommendation 1 (surface water focused LA) – Conwy

As mentioned in section 2.3.2, Conwy is the only LA on the short-list with significant numbers of surface water supplies (50). Although private water supply in England and Wales is dominated by groundwater and spring supplies, some LAs do exploit surface water resources for private supply. These LAs tend to be located in rural upland areas such as north-west Wales and parts of north-west England. For these LAs, it is important that the feasibility of grouping surface water supplies to reduce the amount of water quality monitoring is investigated. This requires at least one of the trial areas to have significant numbers of surface water supplies.

As well as surface water, Conwy also contains groundwater (34) and spring (43) supplies. These exploit at least three different bedrock units (Caradoc, Wenlock and Ludlow Rocks) which are classified as low productivity aquifers (fracture flow) and possibly some superficial deposits. Therefore, if selected as a trial area, Conwy will provide the opportunity to test the zoning methodology on secondary aquifers where fracture flow dominates.

### 3.2.2. Recommendation 2 (groundwater and spring focused LA) – West Dorset

West Dorset only has two surface water supplies (2), however it has significant numbers of groundwater (169) and spring (82) supplies and has a very different geological setting to Conwy, located in the south-west of England where the bedrock geology is dominated by Jurassic and Cretaceous sediments. The groundwater and spring sources are well distributed across the LA and are associated with some of the principal aquifers of the UK – the Chalk and the Great Oolite Group. Supplies are also located on less productive secondary aquifers such as the parts of the Lias Group. This variety of bedrock geology will provide the opportunity to delineate multiple groundwater/spring catchments, within which supplies can potentially be grouped.

Although the coverage of superficial deposits in this LA is minor, there is potentially some scope for developing small groupings of supplies associated with superficial deposits.



# Appendices

# Appendix A. Parameters most likely to arise due to quality of water in the catchment

## A.1. 2017 private water supply report for England

**Table 13: Parameters most likely to arise due to quality of water in the catchment**

| Parameter | Current standard or specified concentration | Total number of tests | Number of tests not meeting the standard or specification | Percentage of tests not meeting the standard |
|---|---|---|---|---|
| **EU parameters** | | | | |
| Nitrate | 50µg/l | 5,524 | 573 | 10.4 |
| Fluoride | 1.5mg/l | 1,134 | 74 | 6.5 |
| Arsenic | 10µg/l | 1,774 | 50 | 2.8 |
| Pesticides (individual)* | 0.1ug/l | 60,100 | 1,569 | 2.6 |
| Trichloroethene and Tetrachloroethene | 10µg/l | 313 | 6 | 1.9 |
| Boron | 1mg/l | 775 | 10 | 1.3 |
| Selenium | 10µg/l | 830 | 10 | 1.2 |
| Pesticides (total by calculation) | 0.5µg/l | 210 | 1 | 0.5 |
| Benzene | 1µg/l | 707 | 1 | 0.1 |
| Cyanide | 50µg/l | 508 | 0 | 0.0 |
| 1,2-Dichloroethane | 3µg/l | 629 | 0 | 0.0 |
| **National parameters** | | | | |
| Manganese | 50µg/l | 5,784 | 395 | 6.8 |
| Tetrachloromethane | 3µg/l | 601 | 16 | 2.7 |
| Colour | 20mg/l Pt/Co | 5,634 | 91 | 1.6 |
| **Indicator parameters** | | | | |
| Hydrogen ion (pH) | 6.5 – 9.5 | 8,520 | 678 | 8.0 |
| Radioactivity – Gross Alpha | 0.1 Bq/l | 194 | 15 | 7.7 |
| Sulphate | 250mg/l | 761 | 26 | 3.4 |
| Chloride | 250mg/l | 795 | 17 | 2.1 |
| Ammonium | 0.5mg/l | 5,994 | 118 | 2.0 |
| Conductivity | 2500µS/cm | 8,369 | 6 | 0.1 |
| Total Organic Carbon | No abnormal change | 376 | 0 | 0.0 |
| Radioactivity – Gross β | 1.0 Bq/l | 190 | 0 | 0.0 |
| Tritium | 50µg/l | 94 | 0 | 0.0 |
| Indicative dose | 0.10 mSv/year | 39 | 0 | 0.0 |
| Radon | 100 Bq/l | 3 | 0 | 0.0 |

Source: DWI (2017) Drinking Water 2016 Private Water Supplies in England, dated July 2017.

## A.2. 2017 private water supply report for Wales

**Table 13: Parameters generally arising due to quality of water in the catchment**

| Parameter | Current standard or specified concentration | Total number of tests | Number of tests not meeting the standard or specification | Percentage of tests not meeting the standard |
|---|---|---|---|---|
| **EU parameters** | | | | |
| Arsenic | 10µg/l | 161 | 5 | 3.1 |
| Nitrate | 50µg/l | 361 | 7 | 1.9 |
| Selenium | 10µg/l | 85 | 1 | 1.2 |
| Pesticides (individual)* | 0.1ug/l | 343 | 0 | 0 |
| Fluoride | 1.5mg/l | 183 | 0 | 0.0 |
| Boron | 1mg/l | 24 | 0 | 0.0 |
| Benzene | 1µg/l | 14 | 0 | 0.0 |
| Cyanide | 50µg/l | 13 | 0 | 0.0 |
| 1,2-Dichloroethane | 3µg/l | 13 | 0 | 0.0 |
| Pesticides (total by calculation) | 0.5µg/l | 4 | 0 | 0.0 |
| Trichloroethene and Tetrachloroethene | 10µg/l | 1 | 0 | 0.0 |
| **National parameters** | | | | |
| Manganese | 50µg/l | 1,152 | 86 | 7.5 |
| Colour | 20mg/l Pt/Co | 1,116 | 22 | 2.0 |
| Tetrachloromethane | 3µg/l | 13 | 0 | 0.0 |
| **Indicator parameters** | | | | |
| Hydrogen ion (pH) | 6.5 – 9.5 | 1,286 | 272 | 21.2 |
| Ammonium | 0.5mg/l | 1,072 | 14 | 1.3 |
| Conductivity | 2500µS/cm | 1,337 | 0 | 0.0 |
| Sulphate | 250mg/l | 112 | 0 | 0.0 |
| Chloride | 250mg/l | 45 | 0 | 0.0 |
| Total organic carbon | No abnormal change | 8 | 0 | 0.0 |
| Radioactivity – gross α | 0.1Bq/l | 8 | 0 | 0.0 |
| Radioactivity – gross β | 1.0Bq/l | 8 | 0 | 0.0 |
| Radon | 100Bq/l | 3 | 0 | 0.0 |
| Tritium | 50µg/l | 0 | 0 | 0.0 |
| Indicative dose | 0.10 mSv/year | 0 | 0 | 0.0 |

Source: DWI (2017) Drinking Water 2016 Private Water Supplies in Wales, dated July 2017.

# Appendix B. Hydrogeological descriptions

The table below contains the hydrogeological descriptions for bedrock units in the BGS 625k hydrogeology dataset, used in Table 2-3.

| Rock unit | Hydrogeological summary |
|---|---|

| | |
|---|---|
| Bowland High Group and Craven Group (undifferentiated) – Derbyshire Dales, Harrogate | Highly indurated rocks with limited groundwater. |
| Bowland High Group and Craven Group (undifferentiated) – Harrogate | Indurated multi-layered aquifer with small local yields. |
| Bracklesham Group and Barton Group (undifferentiated) | Variable multi-layered aquifer locally important. |
| Bridport Sand Formation | Local sand and silt aquifer often in hydraulic continuity with overlying Inferior Oolite Group. Yields up to 40 L/s around Yeovil from combined aquifer, lower elsewhere. Springs at base. |
| Caradoc Rocks (undifferentiated) | Mudstone, siltstone and sandstone with limited yields. |
| Corallian Group | Locally an important aquifer with yields up to 15 L/s in Yorkshire, 5-10 L/s in Oxfordshire, 10L/s in Dorset. |
| Dinantian Rocks (undifferentiated) | Massive karstic limestone aquifer with rapid response to rainfall. Yields highly variable from dry to 40 L/s. |
| Gault Formation | Low permeability clays up to 100 m thick separating Chalk and Upper Greensand aquifer from underlying Lower Greensand aquifer. |
| Great Oolite Group | Significant limestone aquifer producing large yields. |
| Grey Chalk Subgroup | Marly Chalk aquifer that can yield up to 5 L/s from wells with headings. |
| Holsworthy Group | Indurated mudstones, siltstones and sandstones containing only small amounts of groundwater. |
| Inferior Oolite Group | Limestone aquifer producing large yields where confined. Copious springs at outcrop; brackish at depth. |
| Kellaways Formation and Oxford Clay Formation (undifferentiated) | Largely clays confining underlying aquifers. Kellaways Sand near base yields small quantities, often brackish. |
| Lambeth Group | Variable sequence of clays, shell beds, fine sands, silts and pebble beds giving low yields. Sometimes in hydraulic continuity with underlying Chalk aquifer. |
| Lias Group | Largely mudstone sequence with limestone and Marlstone Rock forming local aquifers yielding small supplies. |
| Lower Greensand Formation | Sandstone, commonly glauconitic, aquifer yielding up to 50 L/s. Quality usually soft, except where limestone present, and can be ferruginous. |
| Ludlow Rocks (undifferentiated) | Highly indurated argillaceous rocks with limited groundwater. |
| Millstone Grit Group | Regionally significant multi-layered aquifer up to 900 m thick with yields of 5-10 L/s, rarely 50 L/s, with many springs. |

| Rock unit | Hydrogeological summary |
|---|---|
| Neogene To Quaternary Rocks (undifferentiated) | Fine-grained, largely unconsolidated sands and silts aquifer up to 80 m thick. Yields of up to 40 L/s can be obtained but water is hard and ferruginous. |
| Pennine Lower Coal Measures Formation and South Wales Lower Coal Measures Formation (undifferentiated) | Regional, cyclic multi-layered aquifer with moderate yields from sandstones and many springs. Mine water quality poor but elsewhere reasonable. |
| Permian Rocks (undifferentiated) – Conwy | Sandstone, with some conglomerates, aquifer yielding up to 25 L/s in Eden and Clwyd valleys. |
| Permian Rocks (undifferentiated) – West Devon | Sandstone, with some conglomerates and mudstones, aquifer yielding up to 12 L/s in south-west England. |
| Permian Rocks (undifferentiated) | Sandstone, with some conglomerates, aquifer yielding up to 25 L/s in Eden and Clwyd valleys. |
| Portland Group | Locally important aquifer. |
| Purbeck Limestone Group | Generally low permeability limestone, mudstone and evaporites. |
| Teign Valley Group | Indurated mudstones, siltstones and sandstones containing little groundwater. |
| Thames Group | Predominantly clayey sequence up to 140 m thick confining underlying aquifers. Occasional springs at base have very hard water. |
| Triassic Rocks (undifferentiated) – Cheshire East, Derbyshire Dales, Mendip | Largely argillaceous sequence with occasional sandstones yielding less than 0.5 L/s of water that can be highly mineralised. Confines the underlying Sherwood Sandstone aquifer. |
| Triassic Rocks (undifferentiated) – Mendip | Locally important aquifer generally producing hard groundwater from solution enhanced joints. Where overlies Dinantian Limestone the two formations are in hydraulic continuity. |
| Triassic Rocks (undifferentiated) – Cheshire East, Derbyshire Dales | Principal sandstone aquifer up to 600 m thick and yielding up to 125 L/s. Quality good but hard and becomes saline beneath confining Mercia Mudstone. |
| Unnamed Extrusive Rocks, Carboniferous | Small amounts of groundwater in near surface weathered zone and secondary fractures. Up to 2 L/s from rare springs. |
| Unnamed Igneous Intrusion, Carboniferous To Permian | Local aquifer in south-west England yielding up to 1 L/s from near surface weathered zone and secondary fractures. |
| Upper Devonian Rocks (undifferentiated) | Indurated multi-layered aquifer with small local yields from secondary fractures. |
| Upper Greensand Formation | Glauconitic sands yielding up to 25 L/s and often in hydraulic continuity with overlying Chalk. |

| | |
|---|---|
| Warwickshire Group | Regional, cyclic multi-layered aquifer with moderate to large yields from sandstones. |
| Wenlock Rocks (undifferentiated) | Highly indurated, largely argillaceous rocks with limited groundwater. |
| West Walton Formation, Ampthill Clay Formation and Kimmeridge Clay Formation (undifferentiated) | Low permeability clays that can confine underlying aquifers. |
| Rock unit | Hydrogeological summary |
| White Chalk Subgroup | Principal aquifer in UK up to 450 m thick and yielding 50 to 100 L/s from large diameter boreholes and up to 300 L/s from adited systems. Hard to very hard, good quality water. |
| Zechstein Group | Significant regional dolomitised limestone aquifer up to 300 m thick near Durham. Locally yielding up to 50 L/s of very hard water. |

**Notes:**

Bedrock rock units and associated hydrogeological descriptions are taken from the BGS 625k hydrogeology dataset.

# Appendix C. Conceptual figures

## C.1. Conwy

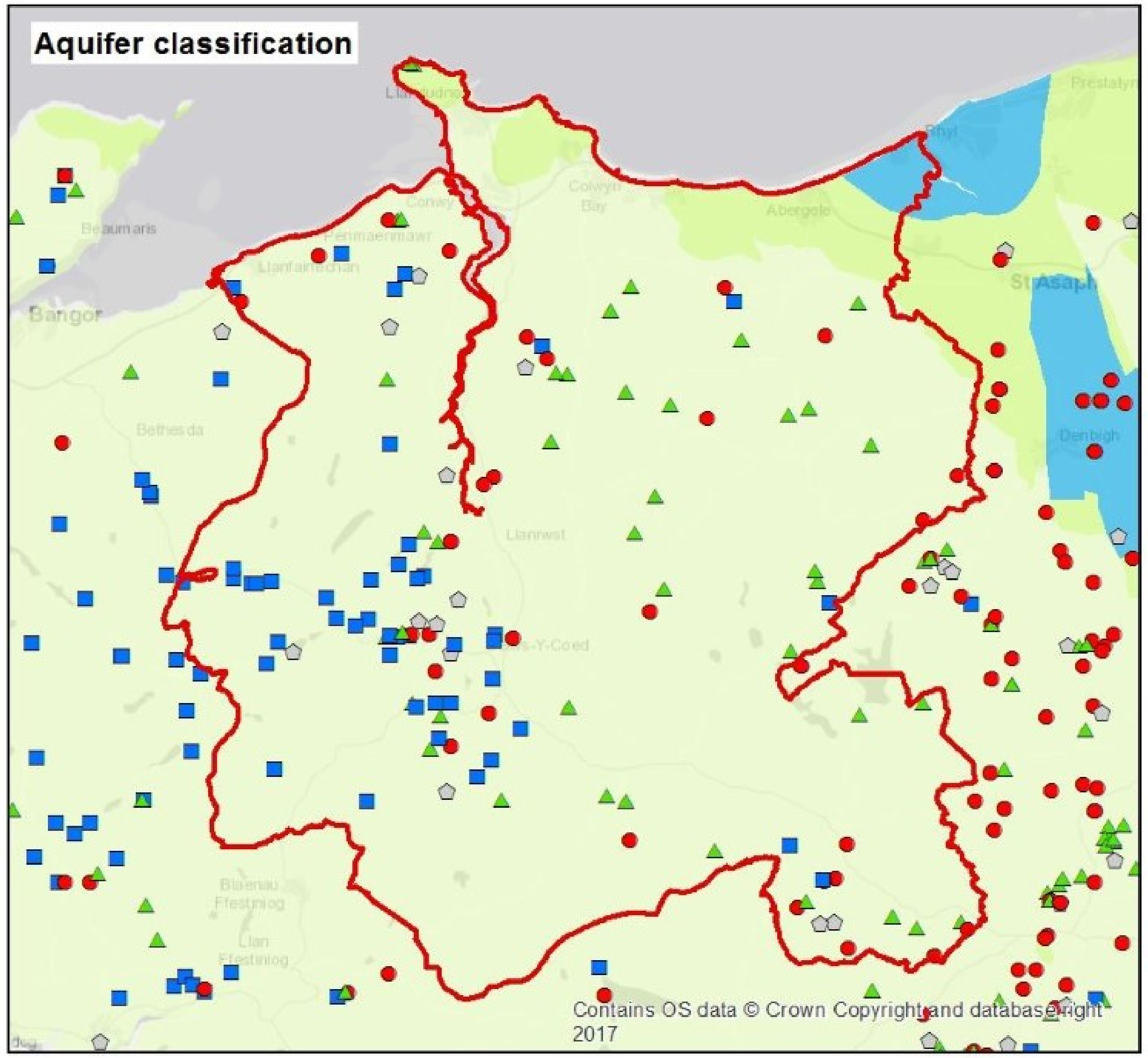
## C.2. Cotswold

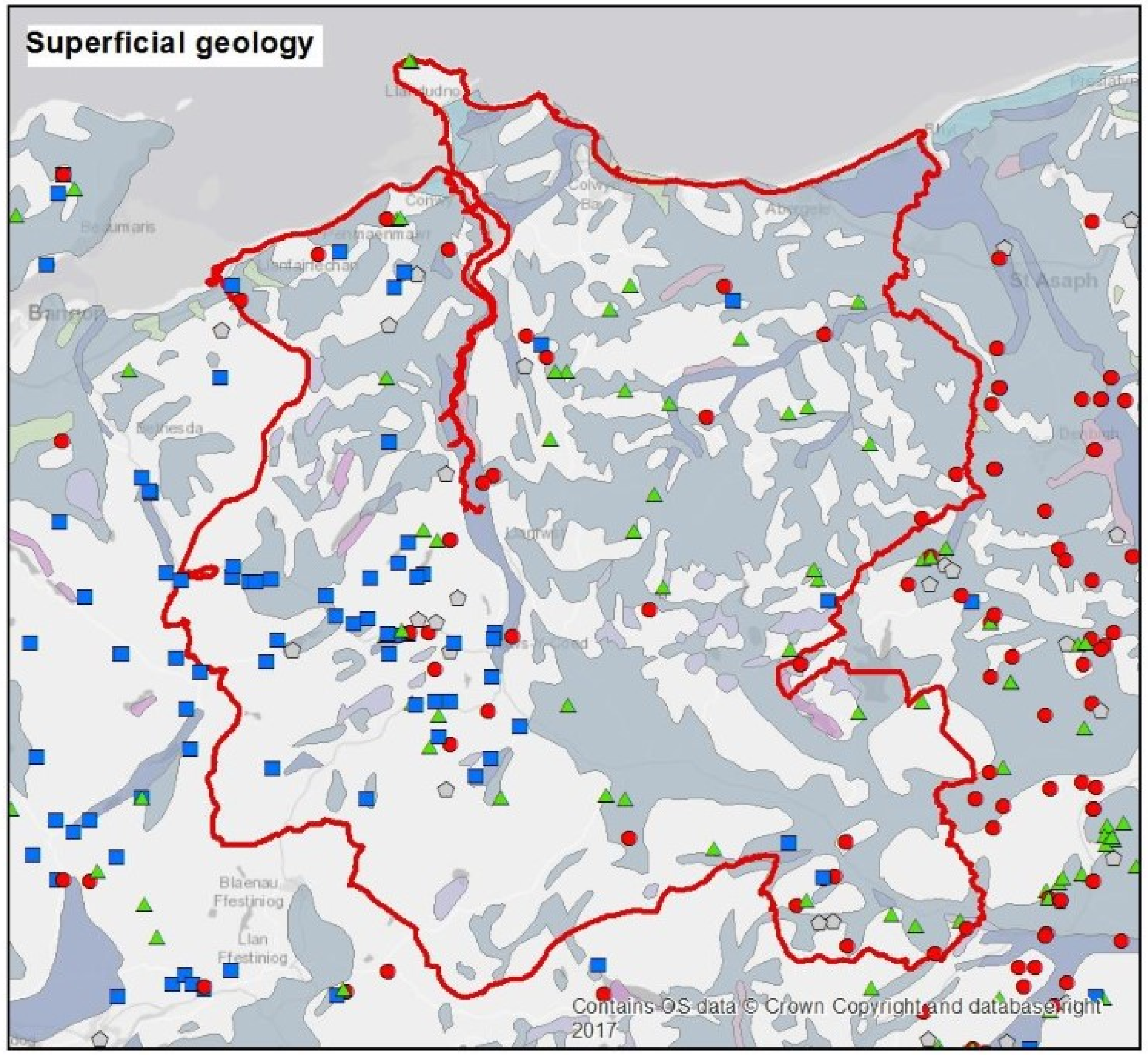
## C.3. Harrogate

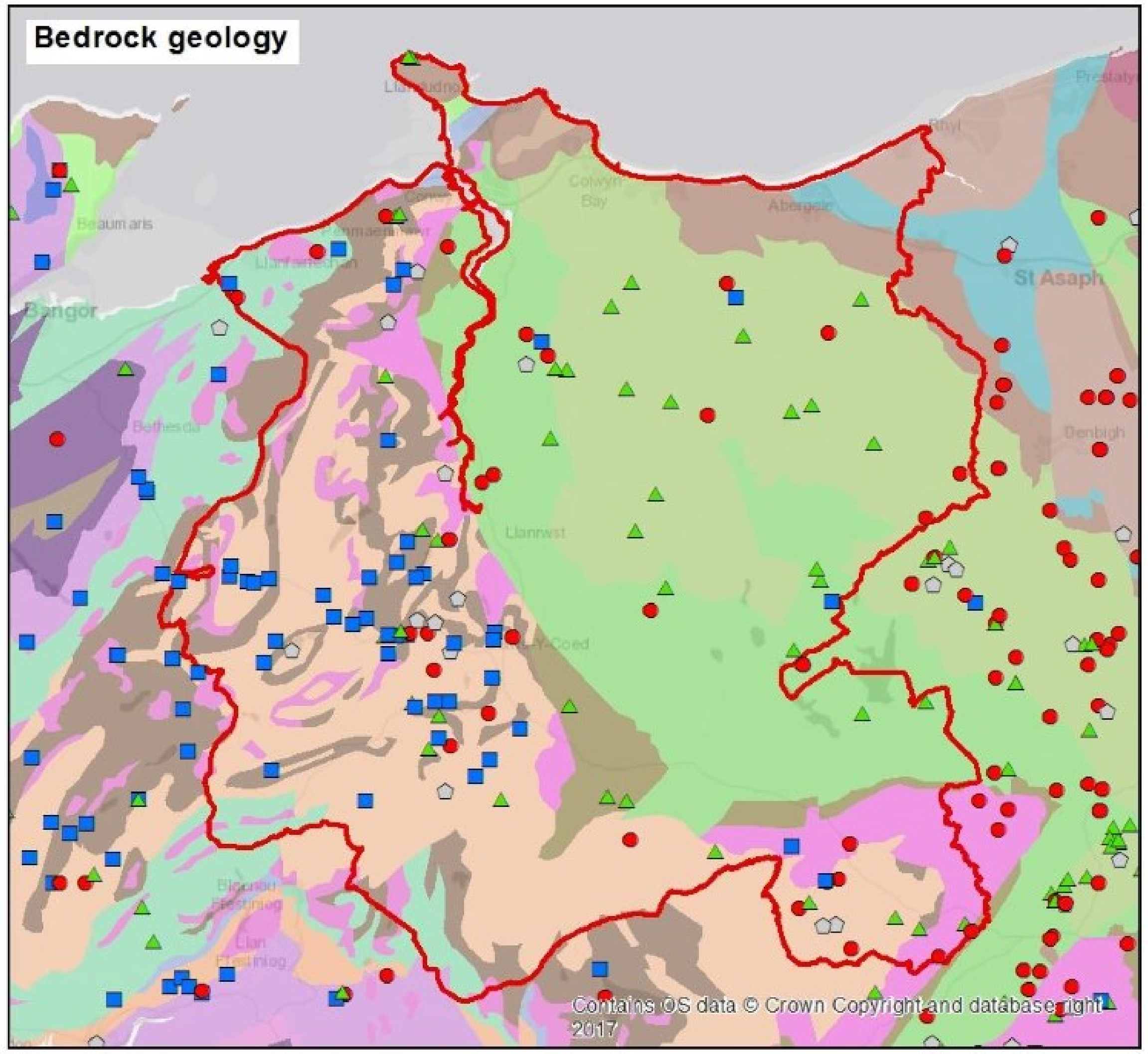
## C.4. West Berkshire

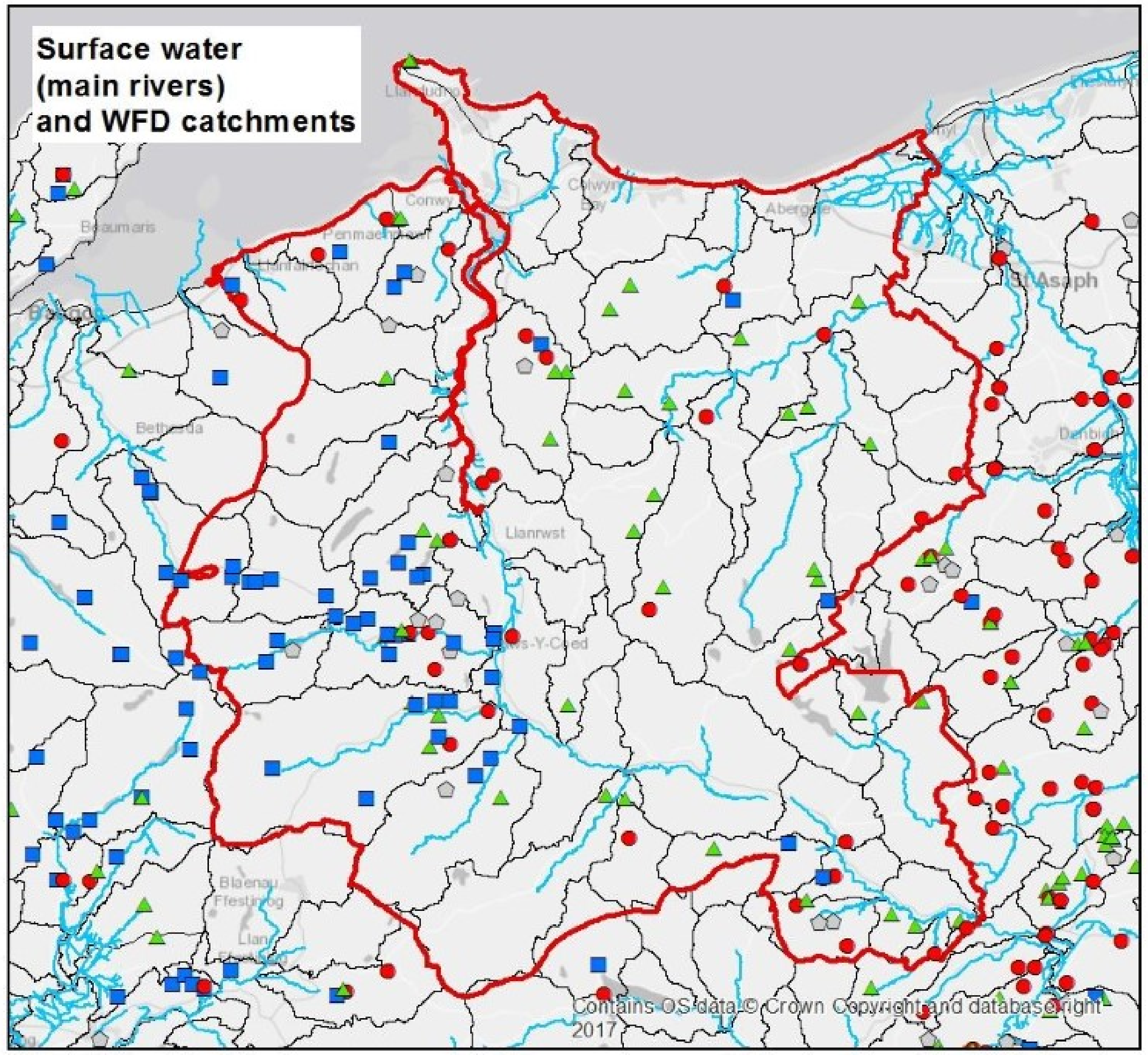
## C.5. West Devon

## C.6. West Dorset




# The Provision of the Private Water Supply Zones Feasibility Project

## Potential trial area - Conwy

N

Local authority boundary

**Private water supply source type**

- Groundwater
- Spring
- Surface water
- Other

**Aquifer classification**

- Highly productive (intergranular flow)
- Moderately productive aquifer (fractures)
- Low productivity aquifer (fractures)

Main rivers

WFD river waterbody catchments

**Superficial geology**

- ALLUVIUM
- BLOWN SAND
- DRIFT GEOLOGY NOT MAPPED
- GLACIAL SAND AND GRAVEL
- PEAT
- RIVER TERRACE DEPOSITS (UNDIFF)
- TILL

**Bedrock geology**

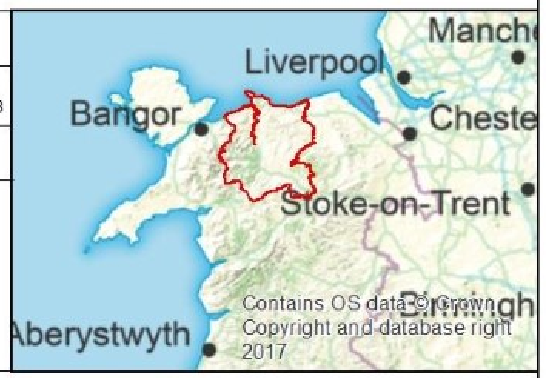
- ARENIG ROCKS (UNDIFFERENTIATED)
- ASHGILL ROCKS (UNDIFFERENTIATED)
- BOWLAND HIGH GROUP AND CRAVEN GROUP (UNDIFFERENTIATED)
- CARADOC ROCKS (UNDIFFERENTIATED)
- DINANTIAN ROCKS (UNDIFFERENTIATED)
- LLANDOVERY ROCKS (UNDIFFERENTIATED)
- LLANVIRN ROCKS (UNDIFFERENTIATED)
- LOWER CAMBRIAN ROCKS (UNDIFFERENTIATED)
- LUDLOW ROCKS (UNDIFFERENTIATED)
- MIDDLE CAMBRIAN
- MILLSTONE GRIT GROUP
- ORDOVICIAN ROCKS (UNDIFFERENTIATED)
- PENNINE LOWER COAL MEASURES FORMATION AND SOUTH WALES LOWER COAL MEASURES FORMATION (UNDIFFERENTIATED)
- PERMIAN ROCKS (UNDIFFERENTIATED)
- TREMADOC ROCKS (UNDIFFERENTIATED)
- UNNAMED EXTRUSIVE ROCKS, CAMBRIAN
- UNNAMED EXTRUSIVE ROCKS, NEOPROTEROZOIC
- UNNAMED EXTRUSIVE ROCKS, ORDOVICIAN
- UNNAMED IGNEOUS INTRUSION, ORDOVICIAN TO SILURIAN
- UNNAMED METAMORPHIC ROCKS, NEOPROTEROZOIC
- UPPER CAMBRIAN, INCLUDING TREMADOC
- WARWICKSHIRE GROUP
- WENLOCK ROCKS (UNDIFFERENTIATED)

Drawn: ED 06/04/2018

Checked: MS CR HS 09/04/2018

Authorised: DR 10/04/2018

Reference: 5162737 - 001






0 2 4 8 12 16 20 24 Km

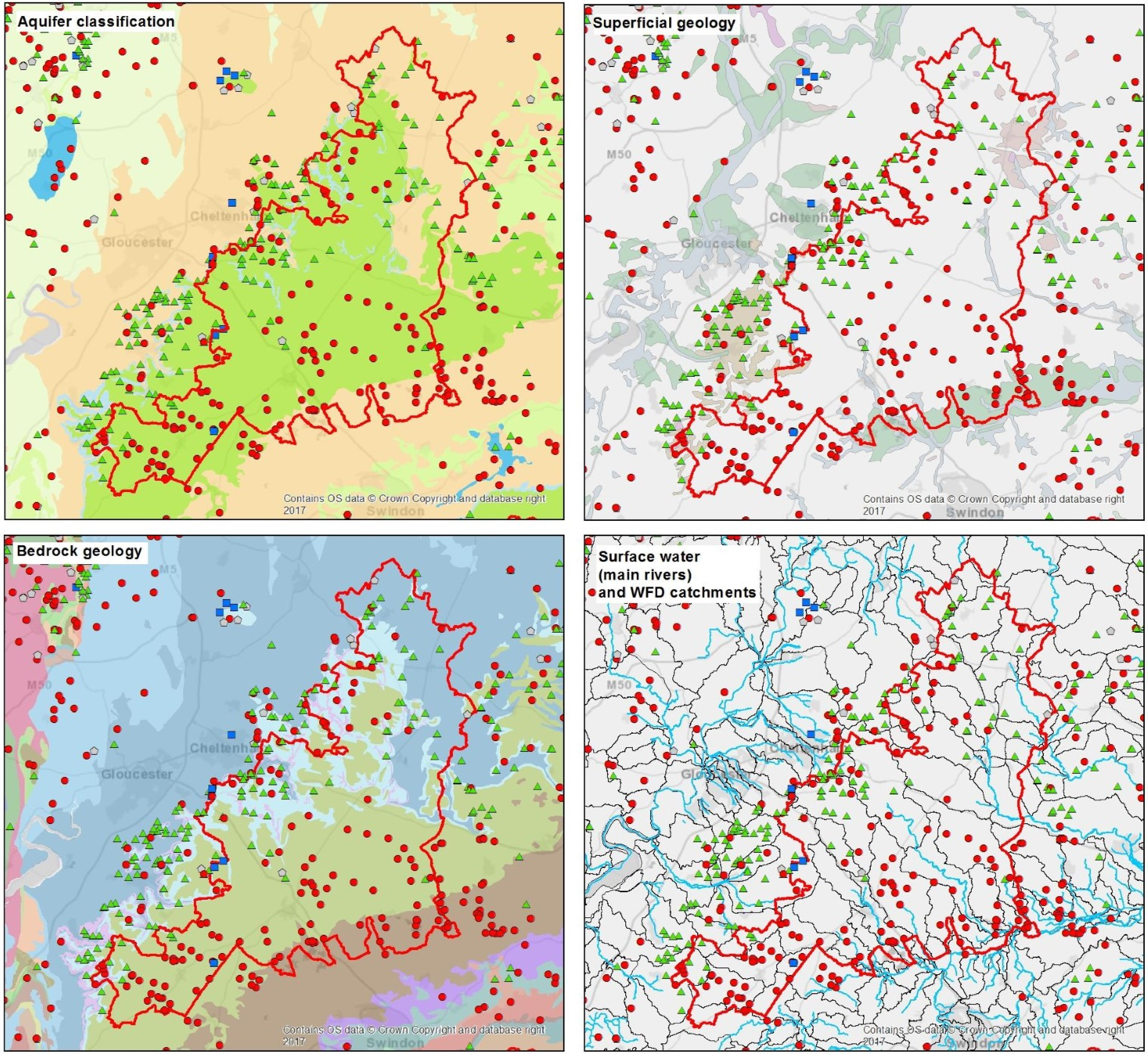
Scale (at A3): 1:350,000

defra Department for Environment Food and Rural Affairs

ATKINS Member of the SNC-Lavalin Group

Project: P:\GBEMC\WGE\Projects\Water\20171633 Private Water Supply Zones\7 WIP\7.0 GIS\MXD\Shortlist figures Conwy.mxd

Atkins, Epsom Gateway, 2 Ashley Avenue, Epsom, Surrey, KT18 5AL




# The Provision of the Private Water Supply Zones Feasibility Project

## Potential trial area - Cotswold

N

Local authority boundary

**Private water supply source type**

- Groundwater
- Spring
- Surface water
- Other

Main rivers

WFD river waterbody catchments

**Aquifer classification**

- Highly productive aquifer (intergranular flow)
- Moderately productive aquifer (intergranular flow)
- Highly productive aquifer (fractures)
- Moderately productive aquifer (fractures)
- Low productivity aquifer (fractures)
- Rocks with essentially no groundwater

**Superficial geology**

- ALLUVIUM
- GLACIAL SAND AND GRAVEL
- LANDSLIP
- RIVER TERRACE DEPOSITS (UNDIFF)
- TILL

**Bedrock geology**

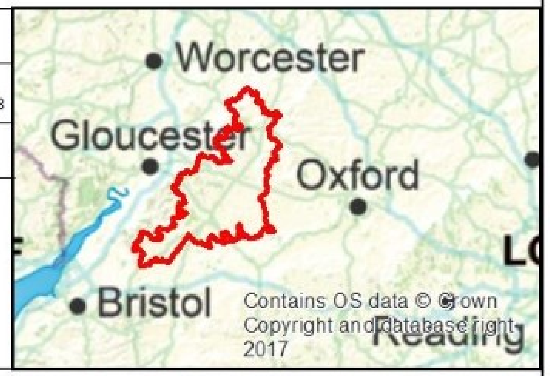
- BRIDPORT SAND FORMATION
- CORALLIAN GROUP
- GAULT FORMATION
- GREAT OOLITE GROUP
- GREY CHALK SUBGROUP
- INFERIOR OOLITE GROUP
- KELLAWAYS FORMATION AND OXFORD CLAY FORMATION (UNDIFFERENTIATED)
- LIAS GROUP
- LLANDOVERY ROCKS (UNDIFFERENTIATED)
- LOWER GREENSAND GROUP
- PORTLAND GROUP
- SILURIAN ROCKS (UNDIFFERENTIATED)
- TRIASSIC ROCKS (UNDIFFERENTIATED)
- UNNAMED EXTRUSIVE ROCKS, NEOPROTEROZOIC
- UNNAMED IGNEOUS INTRUSION, NEOPROTEROZOIC
- UPPER GREENSAND FORMATION
- WENLOCK ROCKS (UNDIFFERENTIATED)
- WEST WALTON FORMATION, AMPTHILL CLAY FORMATION AND KIMMERIDGE CLAY FORMATION (UNDIFFERENTIATED)
- WHITE CHALK SUBGROUP

Drawn: ED 06/04/2018

Checked: MS CR HS 09/04/2018

Authorised: DR 10/04/2018

Reference: 5162737 - 002






0 2.5 5 10 15 20 25 30 35 40 Km

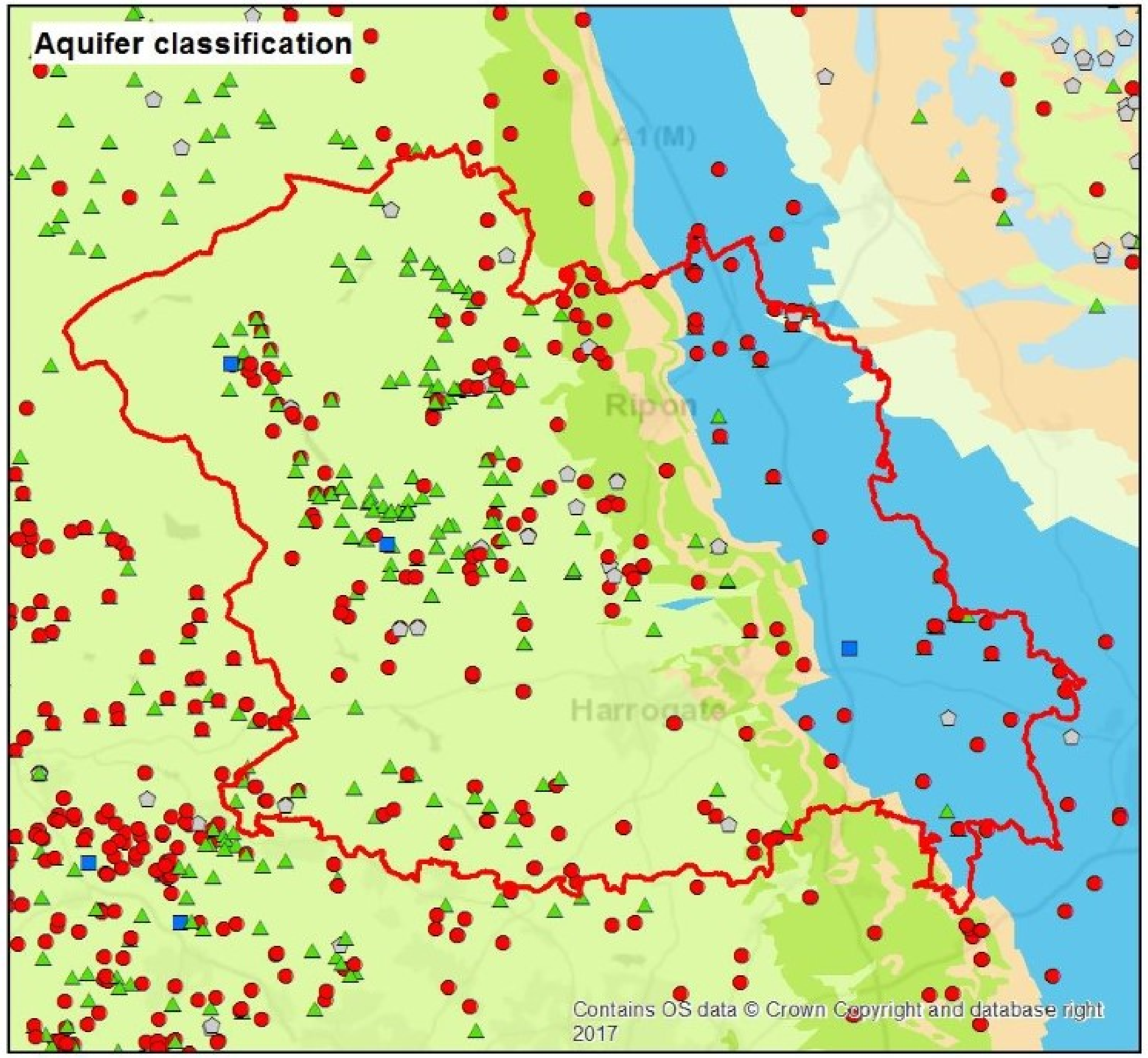
Scale (at A3): 1:470,000

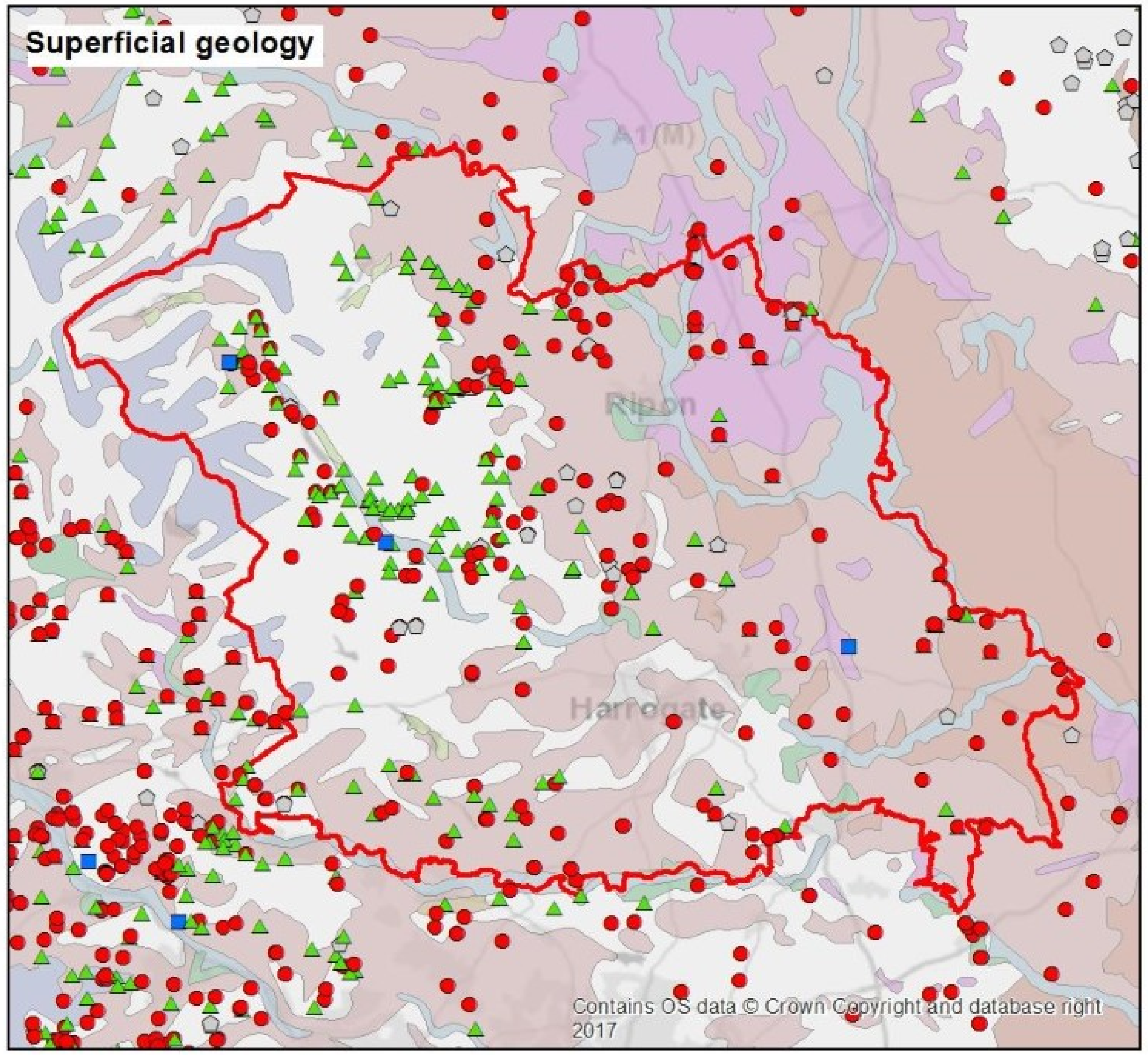
defra Department for Environment Food and Rural Affairs

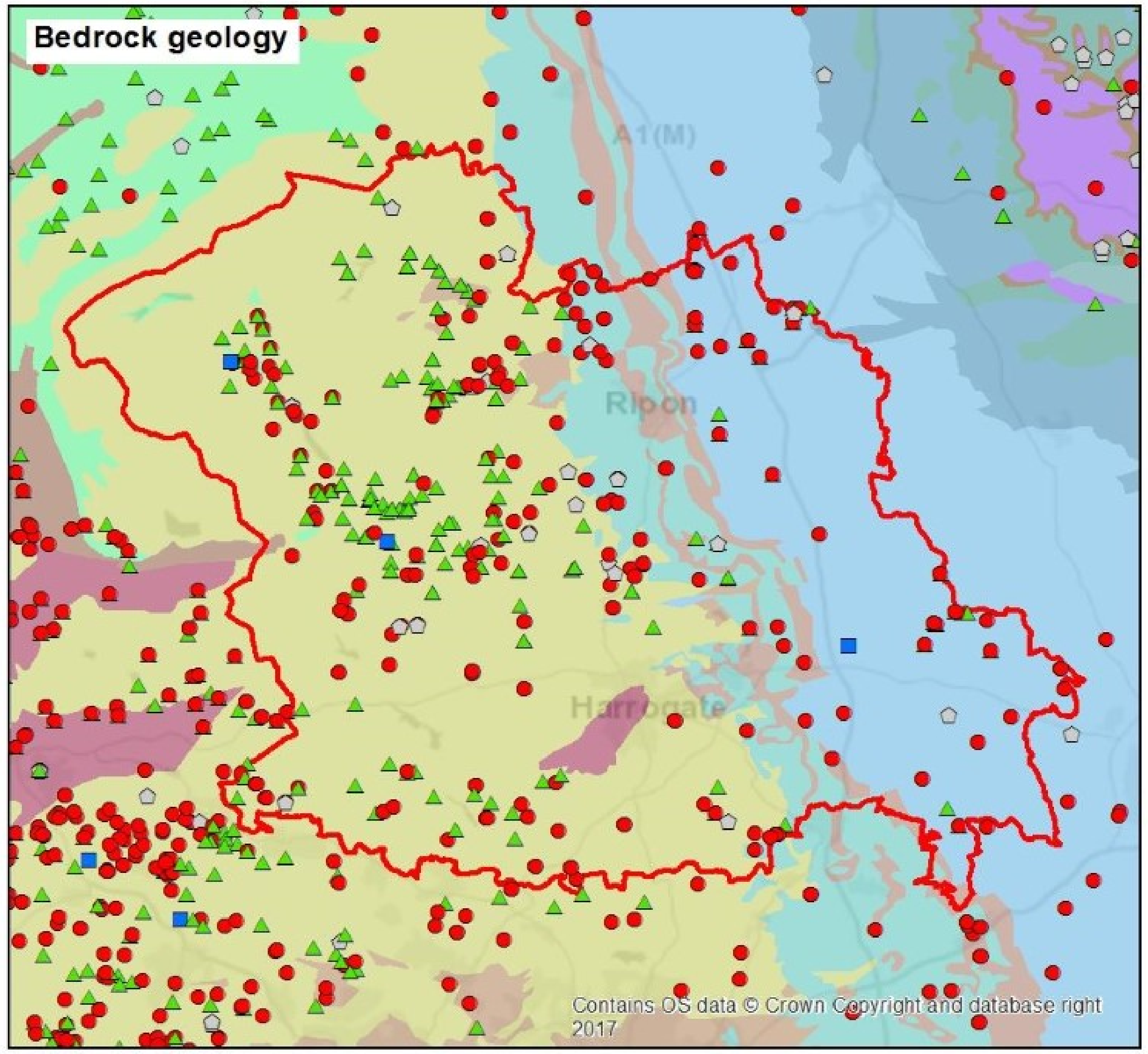
ATKINS Member of the SNC Lavalin Group

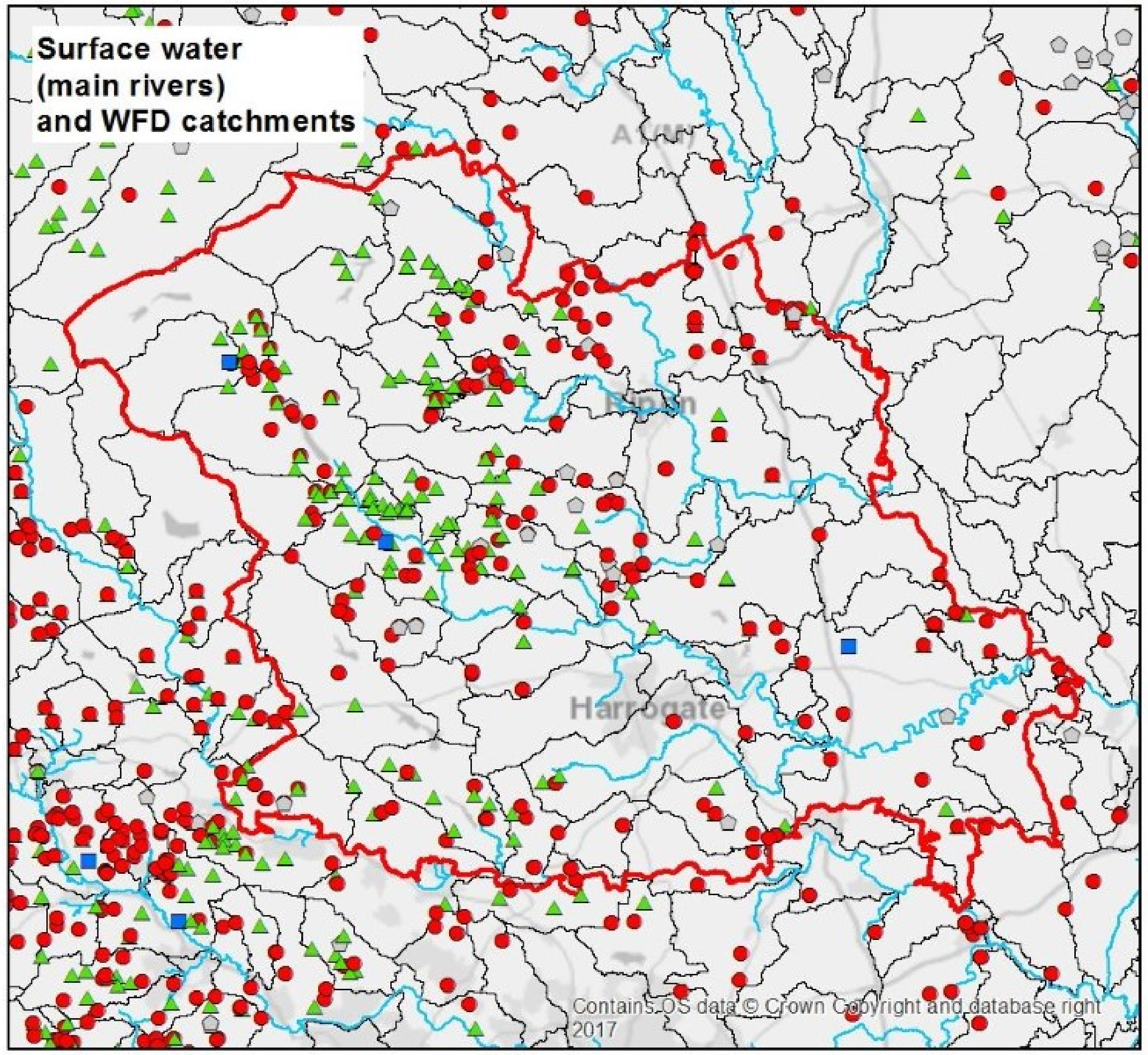
Project: P:\GBEMC\WGE\Projects\Water\20171633 Private Water Supply Zones\7 WIP\7.0 GIS\MXD\Shortlist figures Cotswold.mxd

Atkins, Epsom Gateway, 2 Ashley Avenue, Epsom, Surrey, KT18 5AL




# The Provision of the Private Water Supply Zones Feasibility Project

## Potential trial area - Harrogate

N

Local authority boundary

**Private water supply source type**

- Groundwater
- Spring
- Surface water
- Other

Main rivers

WFD river waterbody catchments

**Aquifer classification**

- Highly productive aquifer (intergranular flow)
- Moderately productive aquifer (intergranular flow)
- Highly productive aquifer (fractures)
- Moderately productive aquifer (fractures)
- Low productivity aquifer (fractures)
- Rocks with essentially no groundwater

**Superficial geology**

- ALLUVIUM
- DRIFT GEOLOGY NOT MAPPED
- GLACIAL SAND AND GRAVEL
- LACUSTRINE DEPOSITS (UNDIFF)
- LANDSLIP
- PEAT
- RIVER TERRACE DEPOSITS (UNDIFF)
- TILL

**Bedrock geology**

- BOWLAND HIGH GROUP AND CRAVEN GROUP (UNDIFFERENTIATED)
- CORALLIAN GROUP
- DINANTIAN ROCKS (UNDIFFERENTIATED)
- KELLAWAYS FORMATION AND OXFORD CLAY FORMATION (UNDIFFERENTIATED)
- LIAS GROUP
- MILLSTONE GRIT GROUP
- PENNINE LOWER COAL MEASURES FORMATION AND SOUTH WALES LOWER COAL MEASURES FORMATION (UNDIFFERENTIATED)
- PERMIAN ROCKS (UNDIFFERENTIATED)
- RAVENSCAR GROUP
- TRIASSIC ROCKS (UNDIFFERENTIATED)
- WEST WALTON FORMATION, AMPTHILL CLAY FORMATION AND KIMMERIDGE CLAY FORMATION (UNDIFFERENTIATED)
- YOREDALE GROUP
- ZECHSTEIN GROUP

Drawn: ED 06/04/2018

Checked: MS CR HS 09/04/2018

Authorised: DR 10/04/2018

Reference: 5162737 - 002




0 2 4 8 12 16 20 24 Km

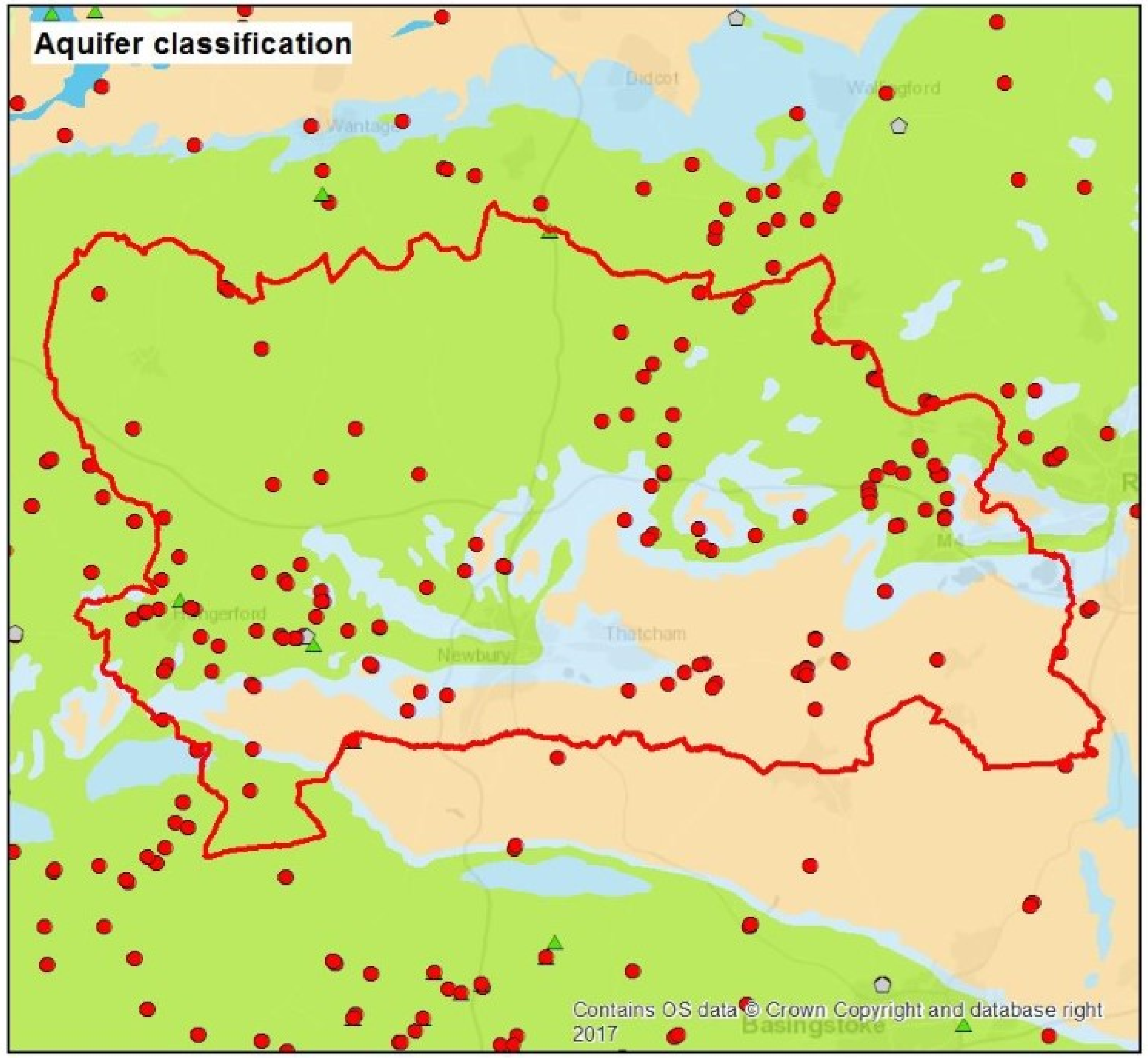
Scale (at A3): 1:400,000

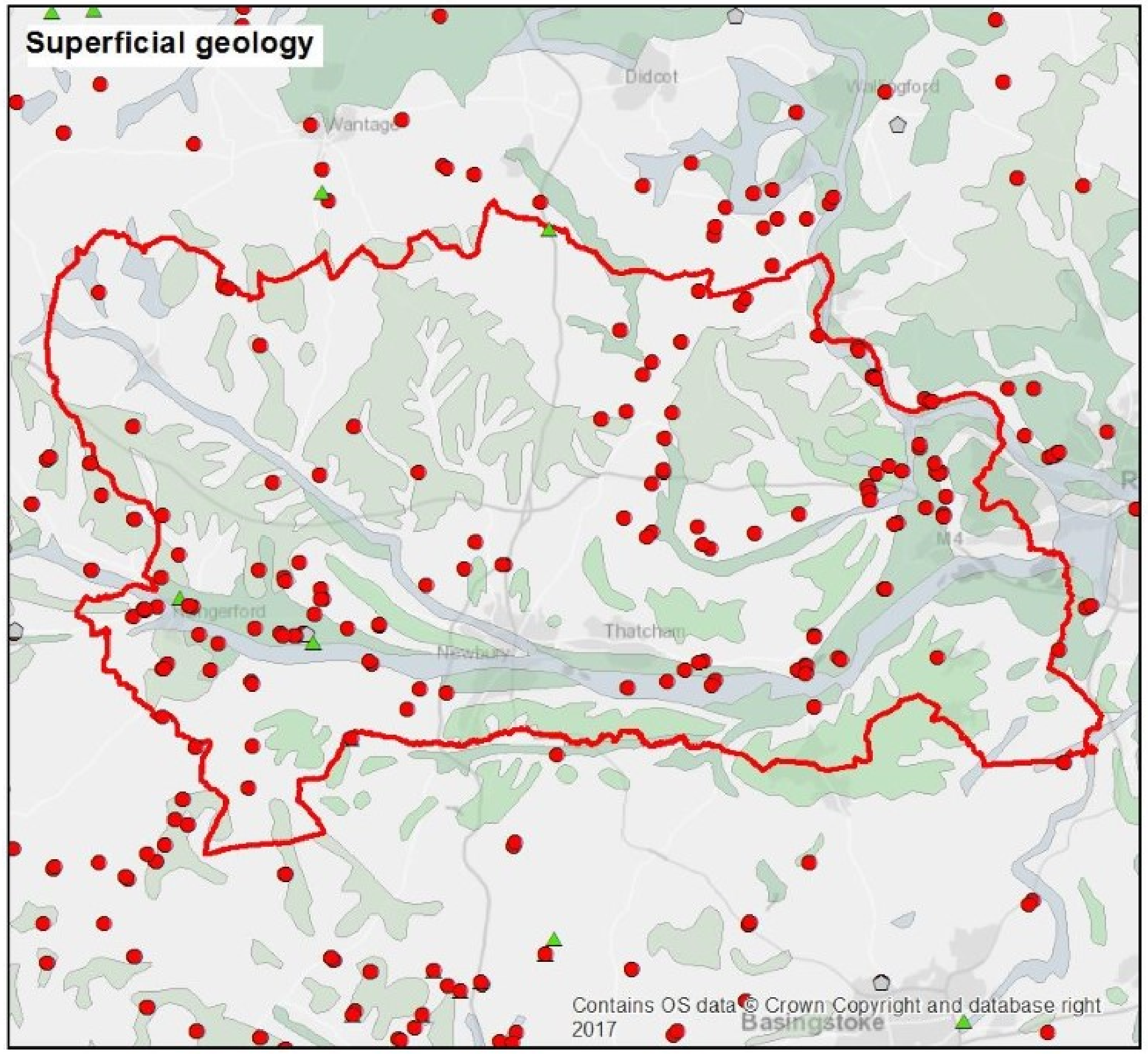
defra Department for Environment Food and Rural Affairs

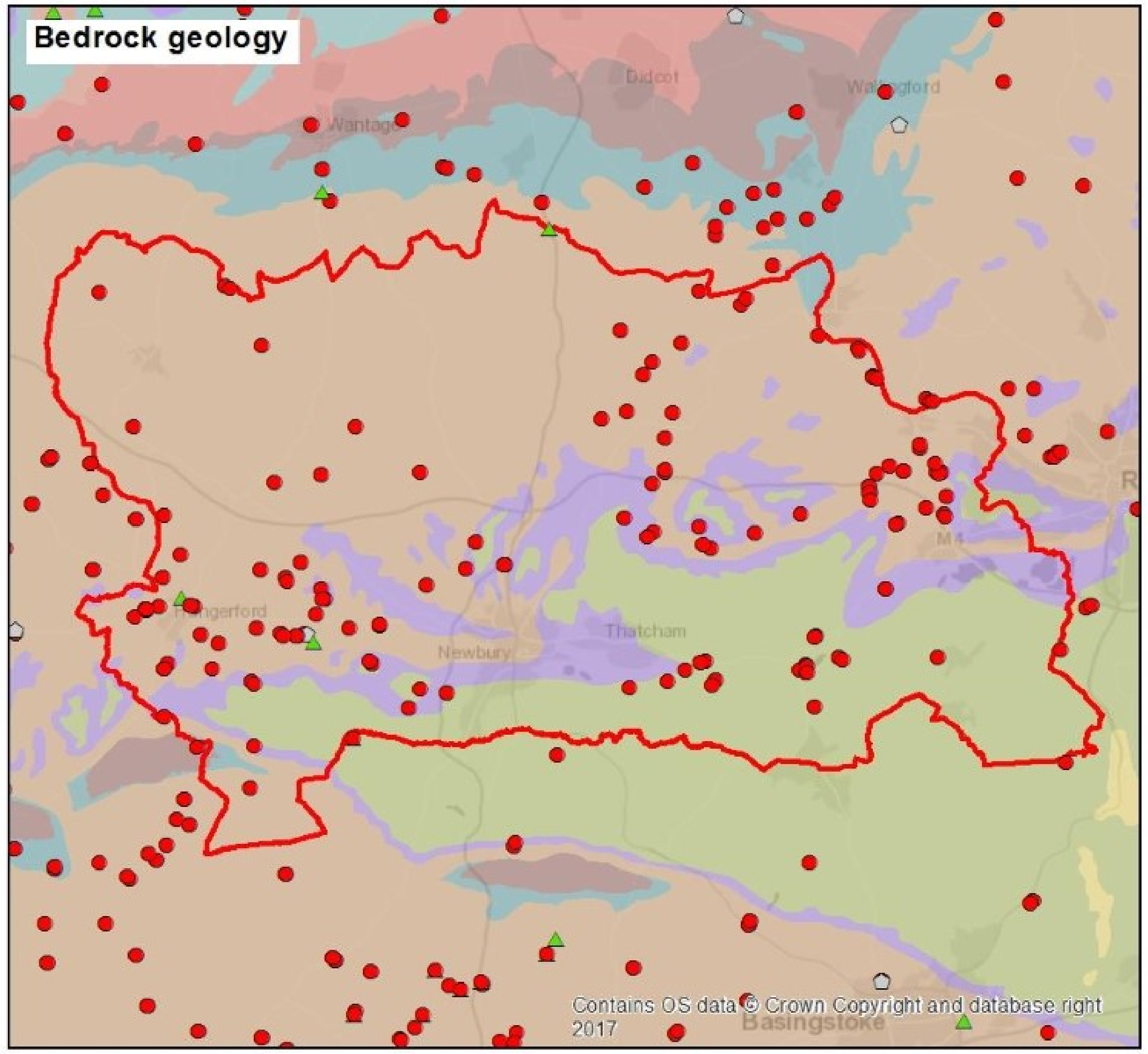
ATKINS Member of the SNC-Lavalin Group

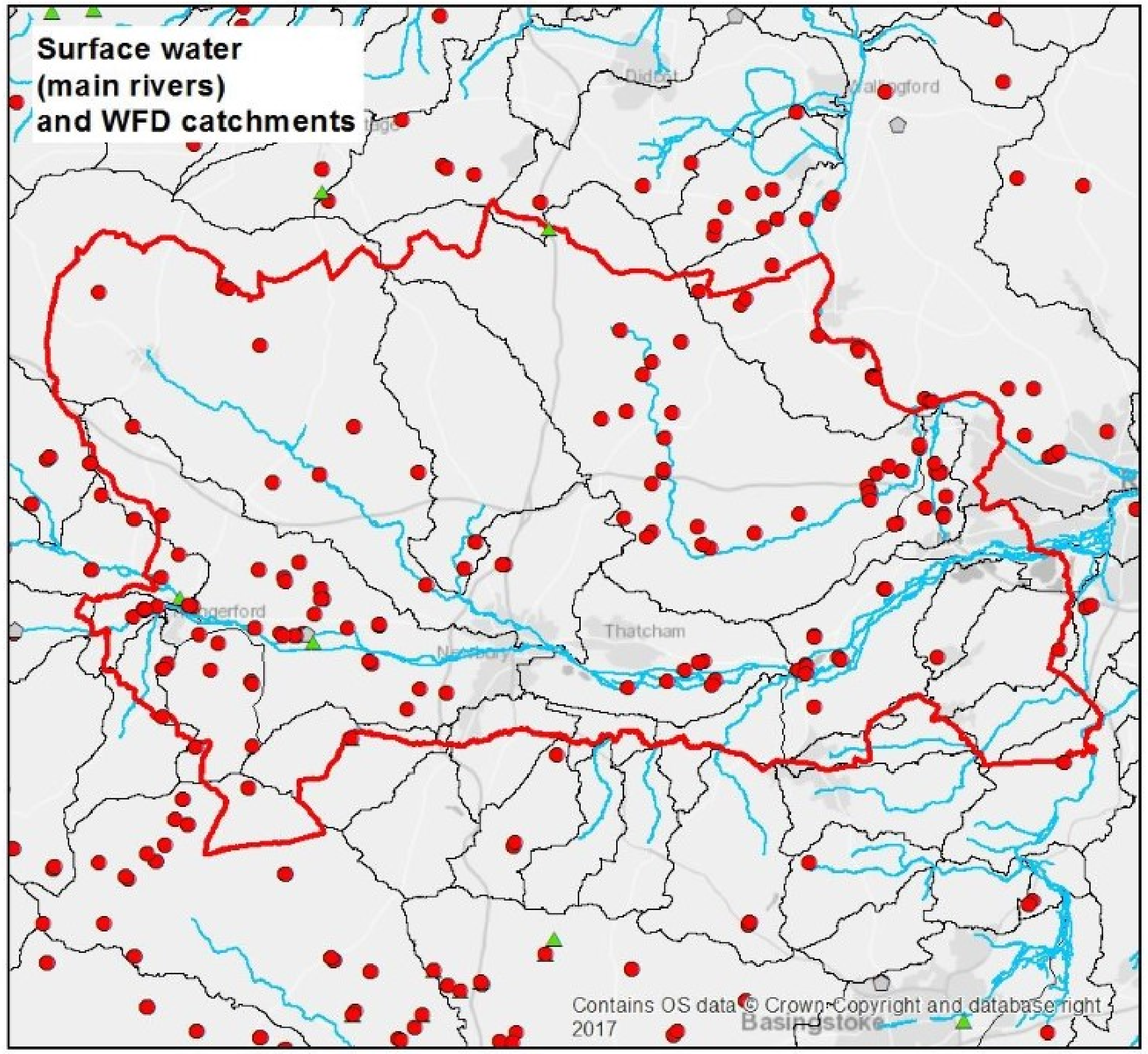
Project: P:\GBEMC\WGE\Projects\Water\20171633 Private Water Supply Zones\7 WIP\7.0 GIS\MXD\Shortlist figures Harrogate.mxd

Atkins, Epsom Gateway, 2 Ashley Avenue, Epsom, Surrey, KT18 5AL




## The Provision of the Private Water Supply Zones Feasibility Project

### Potential trial area - West Berkshire

N

Local authority boundary

**Private water supply source type**

- Groundwater
- Spring
- Surface water
- Other

Main rivers

WFD river waterbody catchments

**Aquifer classification**

- Highly productive aquifer (intergranular flow)
- Moderately productive aquifer (intergranular flow)
- Low productivity aquifer (intergranular flow)
- Highly productive aquifer (fractures)
- Moderately productive aquifer (fractures)
- Rocks with essentially no groundwater

**Superficial geology**

- ALLUVIUM
- CLAY-WITH-FLINTS
- RIVER TERRACE DEPOSITS (UNDIFF)
- SAND AND GRAVEL

**Bedrock geology**

- BRACKLESHAM GROUP AND BARTON GROUP (UNDIFFERENTIATED)
- CORALLIAN GROUP
- GAULT FORMATION
- GREY CHALK SUBGROUP
- LAMBETH GROUP
- LOWER GREENSAND GROUP
- THAMES GROUP
- UPPER GREENSAND FORMATION
- WEST WALTON FORMATION, AMPTHILL CLAY FORMATION AND KIMMERIDGE CLAY FORMATION (UNDIFFERENTIATED)
- WHITE CHALK SUBGROUP

Drawn:
ED 06/04/2018

Checked:
MS CR HS 09/04/2018

Authorised:
DR 10/04/2018

Reference:
5162737 - 002




0 1.5 3 6 9 12 15 18 21 24 Km

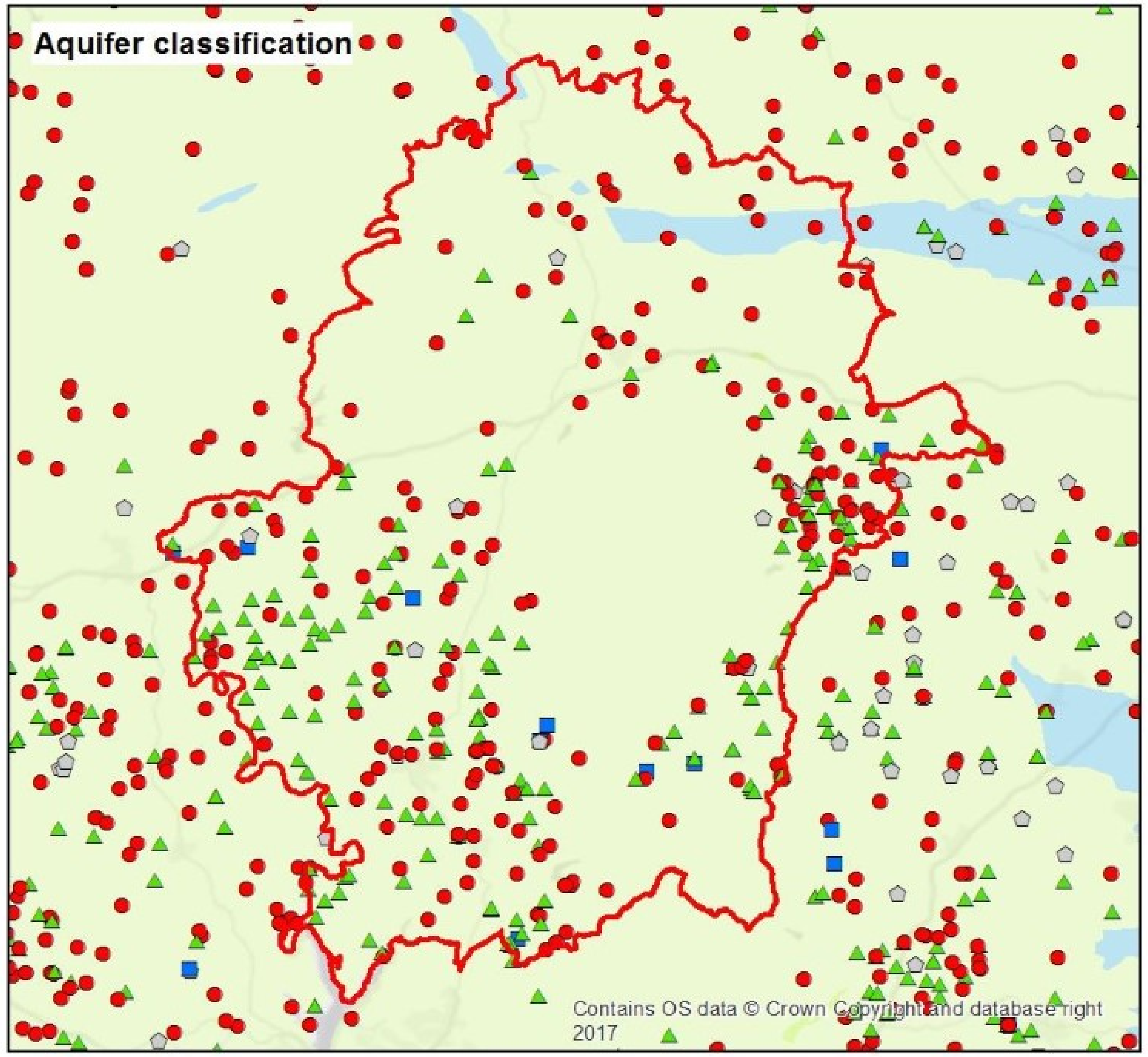
Scale (at A3): 1:300,000

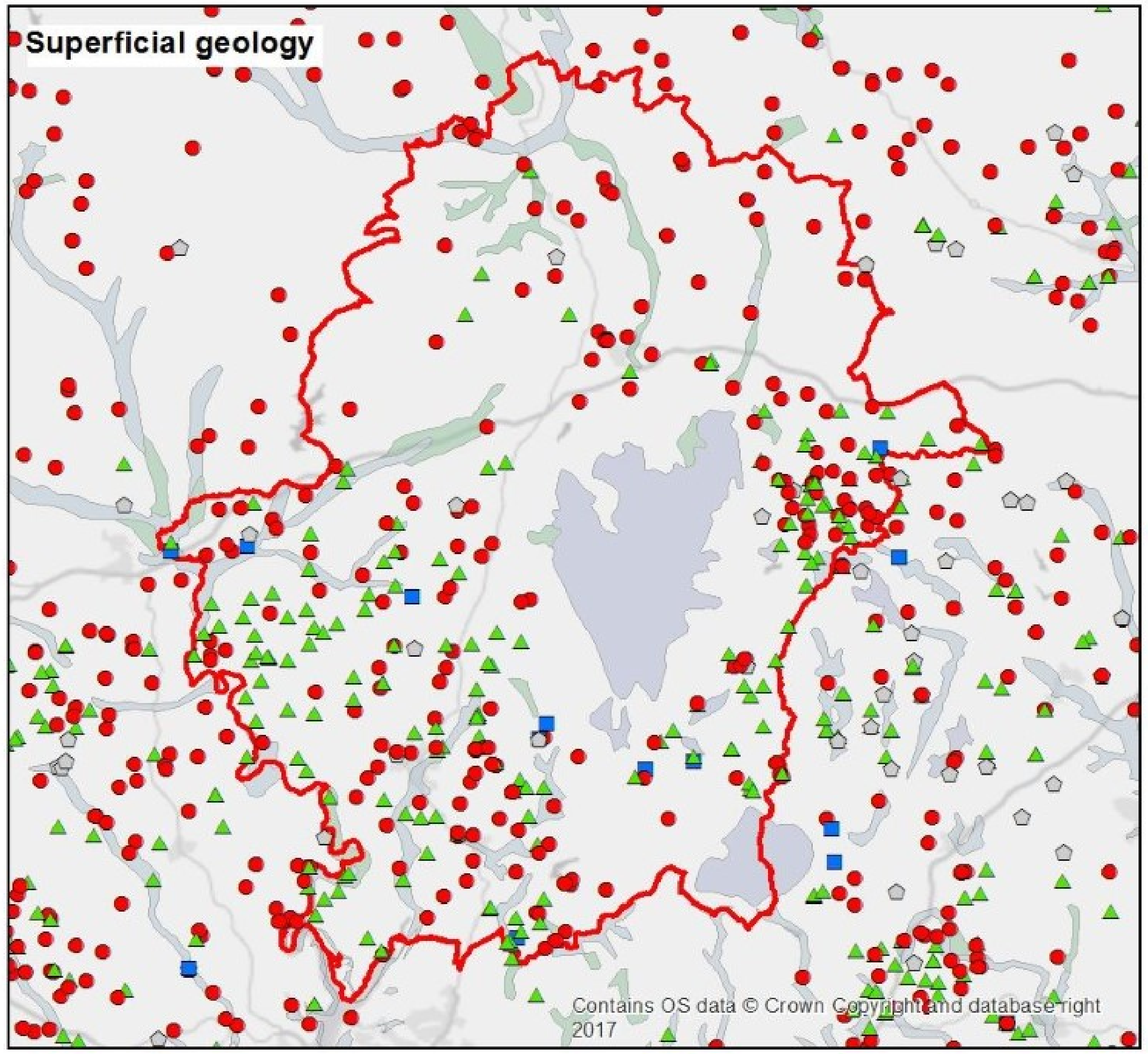
defra Department for Environment Food and Rural Affairs

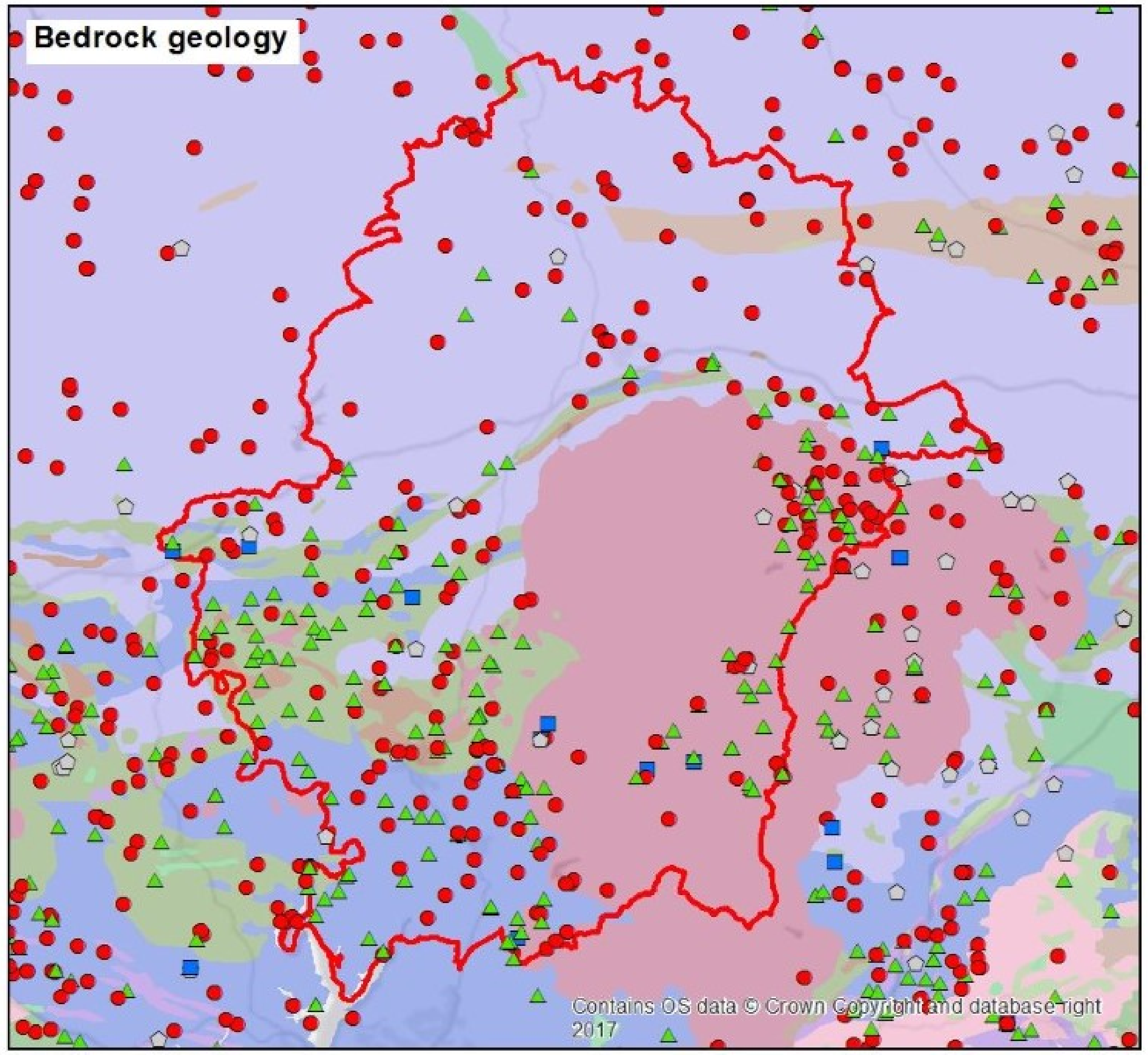
ATKINS Member of the SNC-Lavalin Group

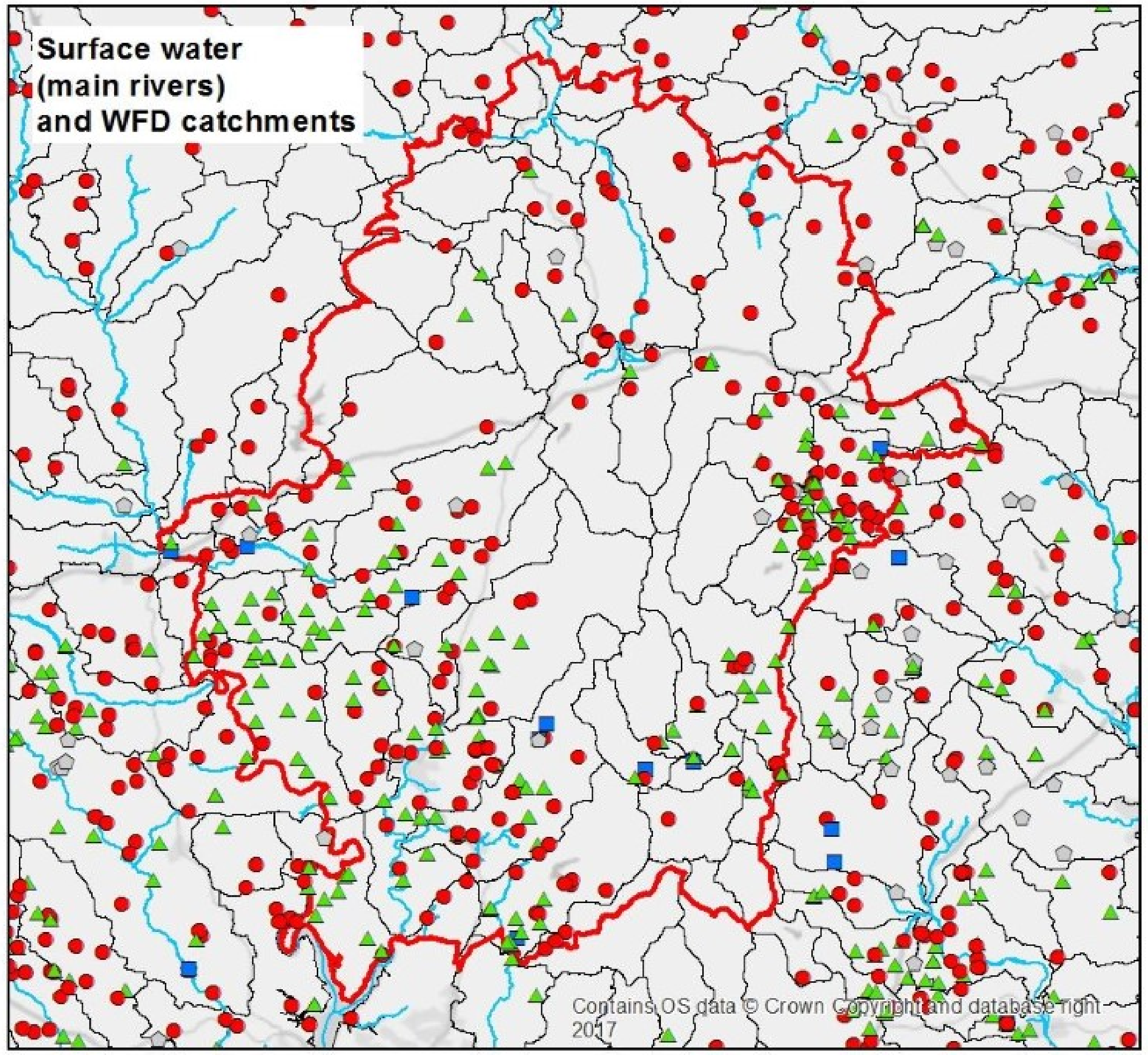
Project: P:\GBEMC\WGE\Projects\Water\20171633 Private Water Supply Zones\7 WIP\7.0 GIS\MXD\Shortlist figures west berkshire.mxd

Atkins, Epsom Gateway, 2 Ashley Avenue, Epsom, Surrey, KT18 5AL




# The Provision of the Private Water Supply Zones Feasibility Project

## Potential trial area - West Devon

N

Local authority boundary

**Private water supply source type**

- Groundwater
- Spring
- Surface water
- Other

Main rivers

WFD river waterbody catchments

**Aquifer classification**

- Moderately productive aquifer (intergranular flow)
- Moderately productive aquifer (fractures)
- Low productivity aquifer (fractures)

**Superficial geology**

- ALLUVIUM
- BRICKEARTH
- PEAT
- RIVER TERRACE DEPOSITS (UNDIFF)

**Bedrock geology**

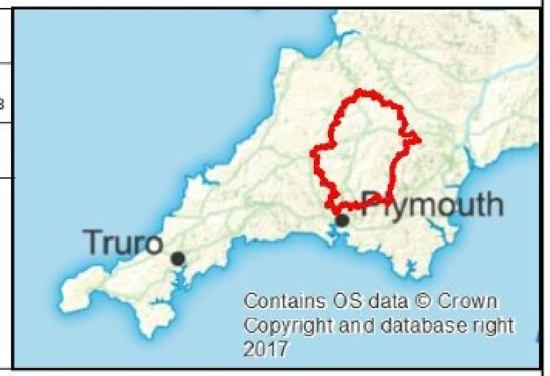
- BRACKLESHAM GROUP AND BARTON GROUP (UNDIFFERENTIATED)
- DEVONIAN ROCKS (UNDIFFERENTIATED)
- DINANTIAN ROCKS (UNDIFFERENTIATED)
- EOCENE TO MIOCENE ROCKS (UNDIFFERENTIATED)
- HOLSWORTHY GROUP
- LOWER DEVONIAN ROCKS (UNDIFFERENTIATED)
- MIDDLE DEVONIAN (UNDIFFERENTIATED)
- PERMIAN ROCKS (UNDIFFERENTIATED)
- TEIGN VALLEY GROUP
- UNNAMED EXTRUSIVE ROCKS, CARBONIFEROUS
- UNNAMED EXTRUSIVE ROCKS, DEVONIAN
- UNNAMED EXTRUSIVE ROCKS, PERMIAN
- UNNAMED IGNEOUS INTRUSION, CARBONIFEROUS TO PERMIAN
- UNNAMED IGNEOUS INTRUSION, DEVONIAN
- UPPER DEVONIAN ROCKS (UNDIFFERENTIATED)
- UPPER GREENSAND FORMATION

Drawn:
ED 06/04/2018

Checked:
MS CR HS 09/04/2018

Authorised:
DR 10/04/2018

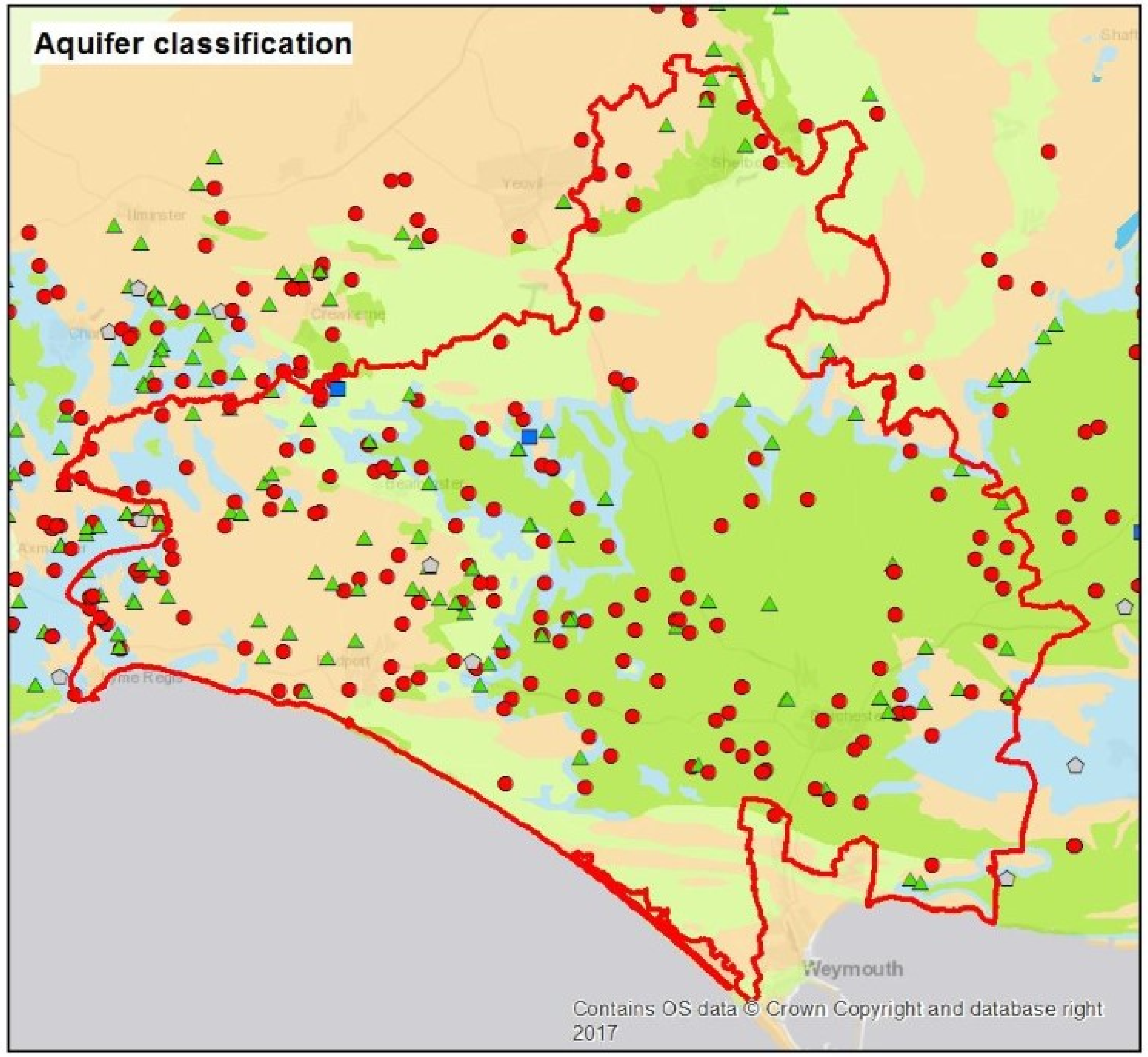
Reference:
5162737 - 002

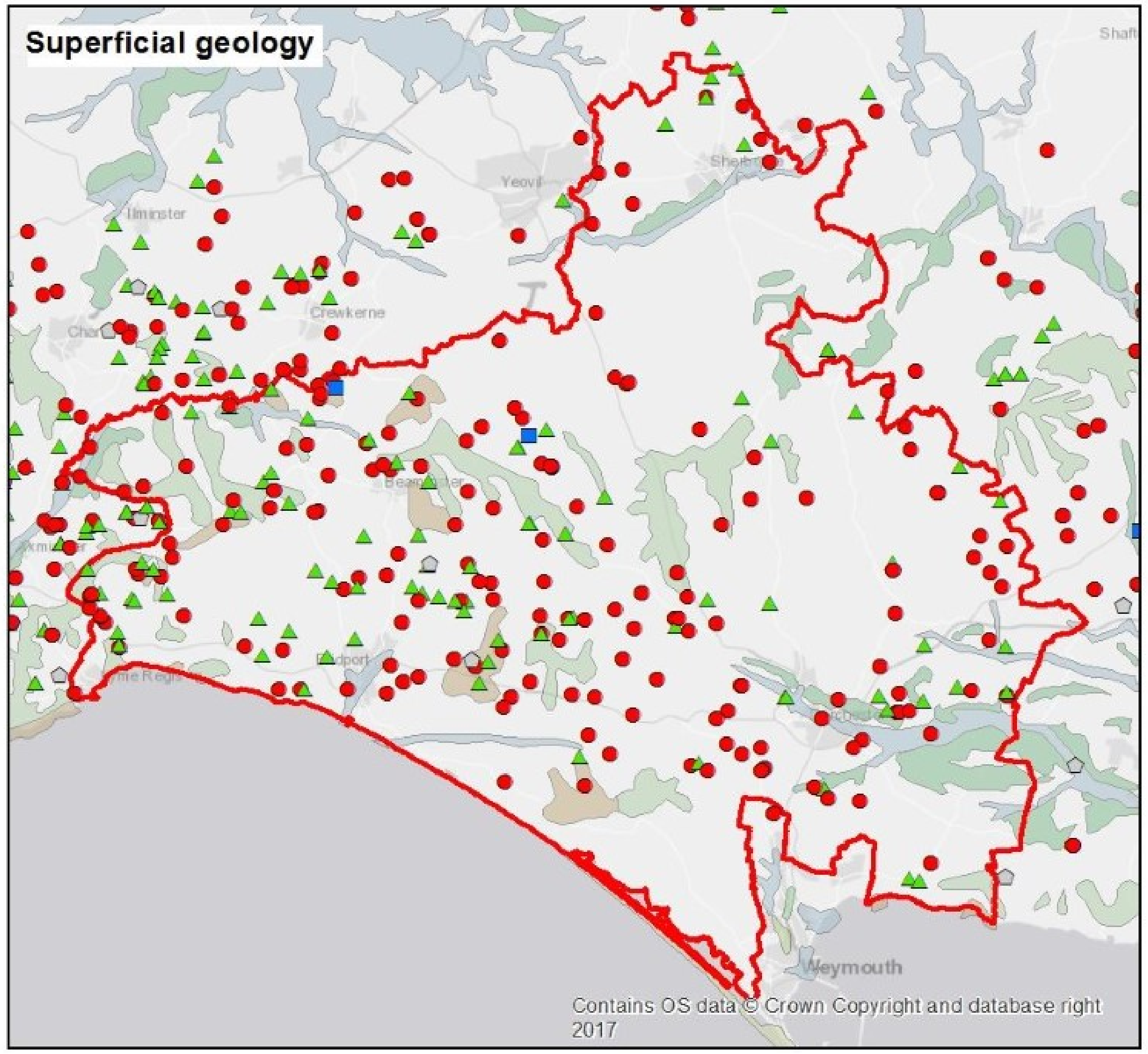


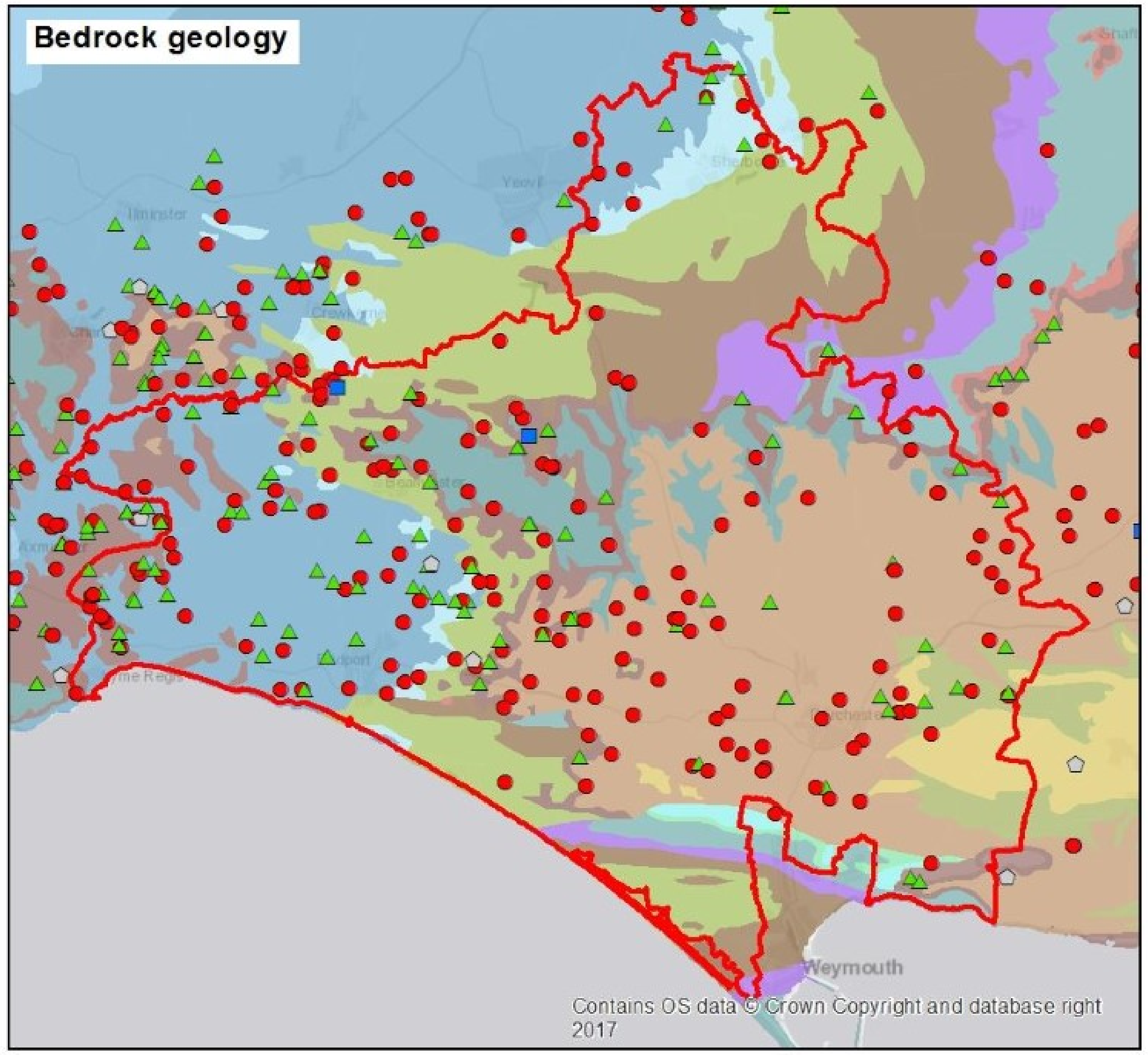

- Contains OS data © Crown copyright and database right (2018)
- Reproduced with the permission of the British Geological Survey ©NERC. All rights Reserved.
- Contains public sector information licensed under the Open Government Licence v3.0.
- Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.
- Contains information derived from private water supply sampling data collected from 2010 to 2016. Supplied by Defra, 2018.

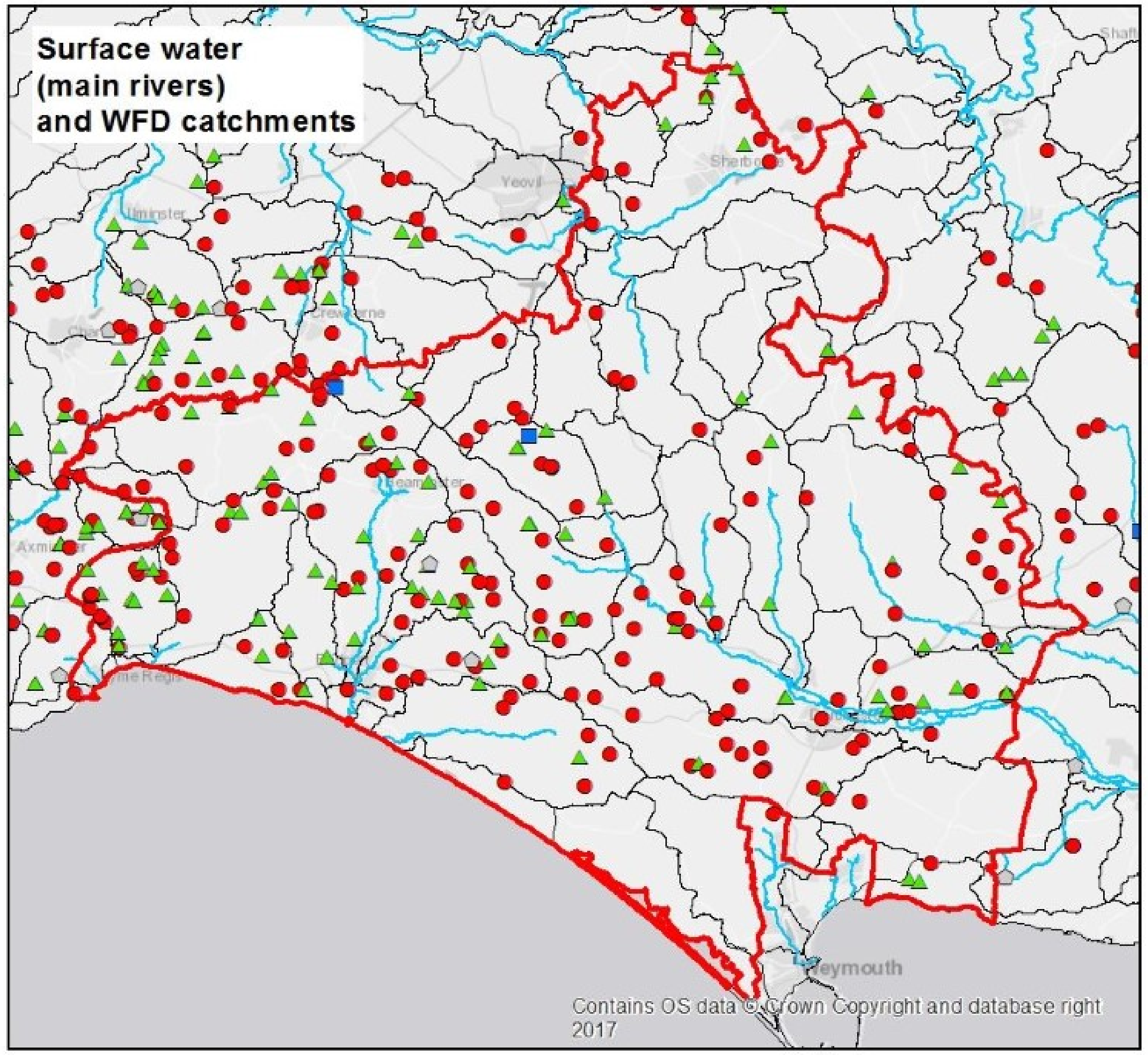
0 2 4 8 12 16 20 24 28 32 Km

Scale (at A3): 1:385,000




# The Provision of the Private Water Supply Zones Feasibility Project

## Potential trial area - West Dorset

N

Local authority boundary

**Private water supply source type**
- Groundwater
- Spring
- Surface water
- Other

Main rivers

WFD river waterbody catchments

**Aquifer classification**
- Highly productive aquifer (intergranular flow)
- Moderately productive aquifer (intergranular flow)
- Highly productive aquifer (fractures)
- Moderately productive aquifer (fractures)
- Low productivity aquifer (fractures)
- Rocks with essentially no groundwater

**Superficial geology**
- ALLUVIUM
- CLAY-WITH-FLINTS
- DRIFT GEOLOGY NOT MAPPED
- LANDSLIP
- RAISED MARINE DEPOSITS (UNDIFF)
- RIVER TERRACE DEPOSITS (UNDIFF)
- SAND AND GRAVEL

**Bedrock geology**
- BRACKLESHAM GROUP AND BARTON GROUP (UNDIFFERENTIATED)
- BRIDPORT SAND FORMATION
- CORALLIAN GROUP
- GAULT FORMATION
- GREAT OOLITE GROUP
- GREY CHALK SUBGROUP
- INFERIOR OOLITE GROUP
- KELLAWAYS FORMATION AND OXFORD CLAY FORMATION (UNDIFFERENTIATED)
- LIAS GROUP
- LOWER GREENSAND GROUP
- PORTLAND GROUP
- PURBECK LIMESTONE GROUP
- THAMES GROUP
- TRIASSIC ROCKS (UNDIFFERENTIATED)
- UPPER GREENSAND FORMATION
- WEALDEN GROUP
- WEST WALTON FORMATION, AMPTHILL CLAY FORMATION AND KIMMERIDGE CLAY FORMATION (UNDIFFERENTIATED)
- WHITE CHALK SUBGROUP

Drawn: ED 06/04/2018

Checked: MS CR HS 09/04/2018

Authorised: DR 10/04/2018

Reference: 5162737 - 002




0 2 4 8 12 16 20 24 Km

Scale (at A3): 1:360,000

defra Department for Environment Food and Rural Affairs

ATKINS Member of the SNC-Lavalin Group

# Appendix B. Defining conceptual areas – technical methodology

SNC·LAVALIN

ATKINS

Member of the SNC-Lavalin Group

# Feasibility of Private Water Supply Zones

## Defining Conceptual Areas

Department for Environment Food & Rural Affairs

# Document History

| | | | |
|---|---|---|---|
| **Project:** | **The Provision of Private Water Supply Zones - Feasibility Project** | | |
| **Subject:** | Proposed method to delineate conceptual areas for grouping private water supplies (rev1) | | |
| **Author:** | Matt Shipton; Chris Rowell | **Atkins No.:** | 5162737 |
| **Date:** | 22/05/2018 | **Quality assurance** | Originated - MS & CR<br>Checked - HS<br>Reviewed - DR<br>Authorised - DR |
| **Distribution:** | Richard Phillips | **Representing:** | Defra |

SNC·LAVALIN ATKINS Member of the SNC-Lavalin Group

# Objective

This slide deck outlines our method to delineate initial conceptual areas (groundwater and surface water) for grouping private water supplies (PrWS).

This method will be used to identify conceptual areas for the two trial Local Authority (LA) areas.

The next stage will consider verifying these initial conceptual areas using the available water quality data.

Note, the methodology presented is:

- Based on widely available datasets
- Largely concerned with the receptor and pathway components of a source-pathway-receptor risk assessment approach. Consideration of contamination sources with be included in subsequent stages of this project.

SNC·LAVALIN

ATKINS
Member of the SNC-Lavalin Group

Department for Environment Food & Rural Affairs

This table schematically defines different types of groundwater conceptual area.

We propose using 3 of these areas (green) in the conceptual grouping:

- 2 x bedrock conceptual areas (BED1
- 1 x superficial conceptual area (SUP1)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| SUPERFICIALS | | | ▲● | ▲● | | | | NO SUPERFICIALS | | |
| BEDROCK | | Shallow (outcrop) | | ▲● | △● | | | | | ▲● |
| | | Deep | | | | | ○ | ○ | | |
| GROUNDWATER CONCEPTUAL AREA | Likely to contain | Springs ▲ | Y | Y | Y superficial / bedrock contacts | N | N | N | N | Y |
| | | BHs/wells? ● | Y | Y | Y | N | ? – PrWS BHs unlikely to be deep due to drilling costs | | N | Y |
| | | Code | SUP1 | | BED1 | | | | | BED2 |
| | | Description | Productive superficials Unproductive bedrock | Productive superficials and bedrock | Unproductive superficials Productive bedrock | Unproductive superficials and bedrock | Unproductive superficials and shallow bedrock Productive deep bedrock | No superficials Unproductive shallow bedrock Productive deep bedrock | No superficials Unproductive bedrock | No superficials Productive bedrock |
| | | Assumptions | PrWS exploit superficials | PrWS exploit superficials and bedrock | PrWS exploit bedrock | No PrWS | | | | PrWS exploit bedrock |
| | | Included in conceptual grouping | YES | NO – uncertain source | YES | NO – no PrWS | | | | YES |

| | |
|---|---|
| | Productive bedrock or superficial deposits |
| | Unproductive bedrock or superficial deposits |
| ● | Boreholes or wells (solid – BHs/wells likely; open – BHs/wells possible) |
| ▲ | Springs (solid - springs likely; open - springs possible) |

Groundwater

# Conceptual Areas

and BED2)

# Conceptual Areas for Bedrock Geology

Our preferred method for delineating groundwater conceptual areas (BED1and BED2) for bedrock geology is summarised below and worked through over the following slides.

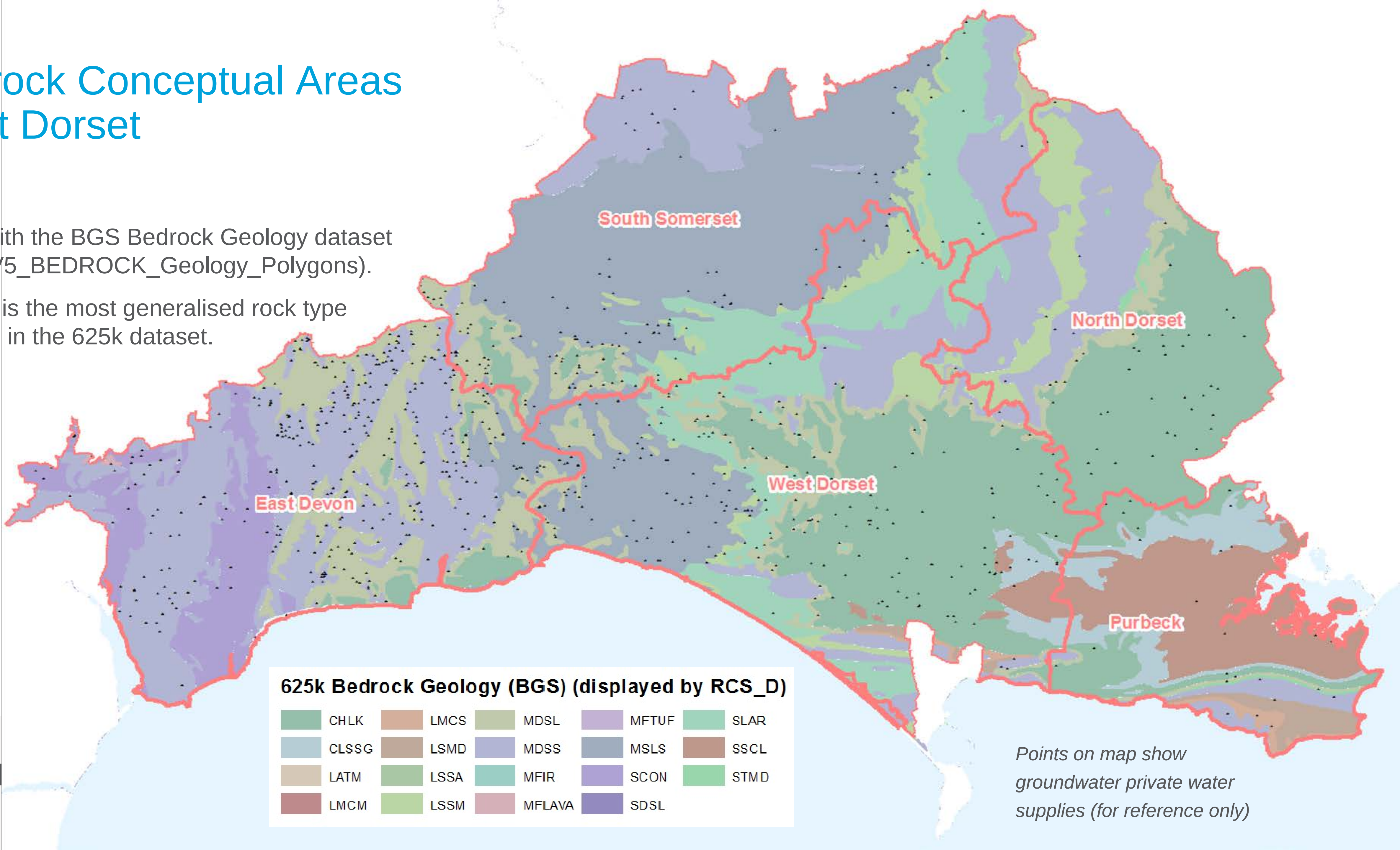
- Step 1 - Begin with the BGS 625k Bedrock Geology dataset – displayed by broad rock type attribute (RCS_D)
- Step 2 - Divide the BGS Bedrock Geology dataset up using WFD Groundwater Operational Catchments
- Step 3 - Identify areas of medium and low bedrock vulnerability in each of these areas
- Step 4 - Clip out areas where superficial geology is productive (principal / secondary) or where productivity unknown
- Step 5 – Review and 'sense check' conceptual areas

*Note – 3 different methods for delineating groundwater conceptual areas have been considered (see slides 23-25 – this preferred approach is method 3).*

# Bedrock Conceptual Areas
# West Dorset

Begin with the BGS Bedrock Geology dataset (625k_V5_BEDROCK_Geology_Polygons).

RCS_D is the most generalised rock type attribute in the 625k dataset.




*Points on map show groundwater private water supplies (for reference only)*

**Step 1**

RCS_D identifies broad bedrock types which might be expected to have similar groundwater chemistry.

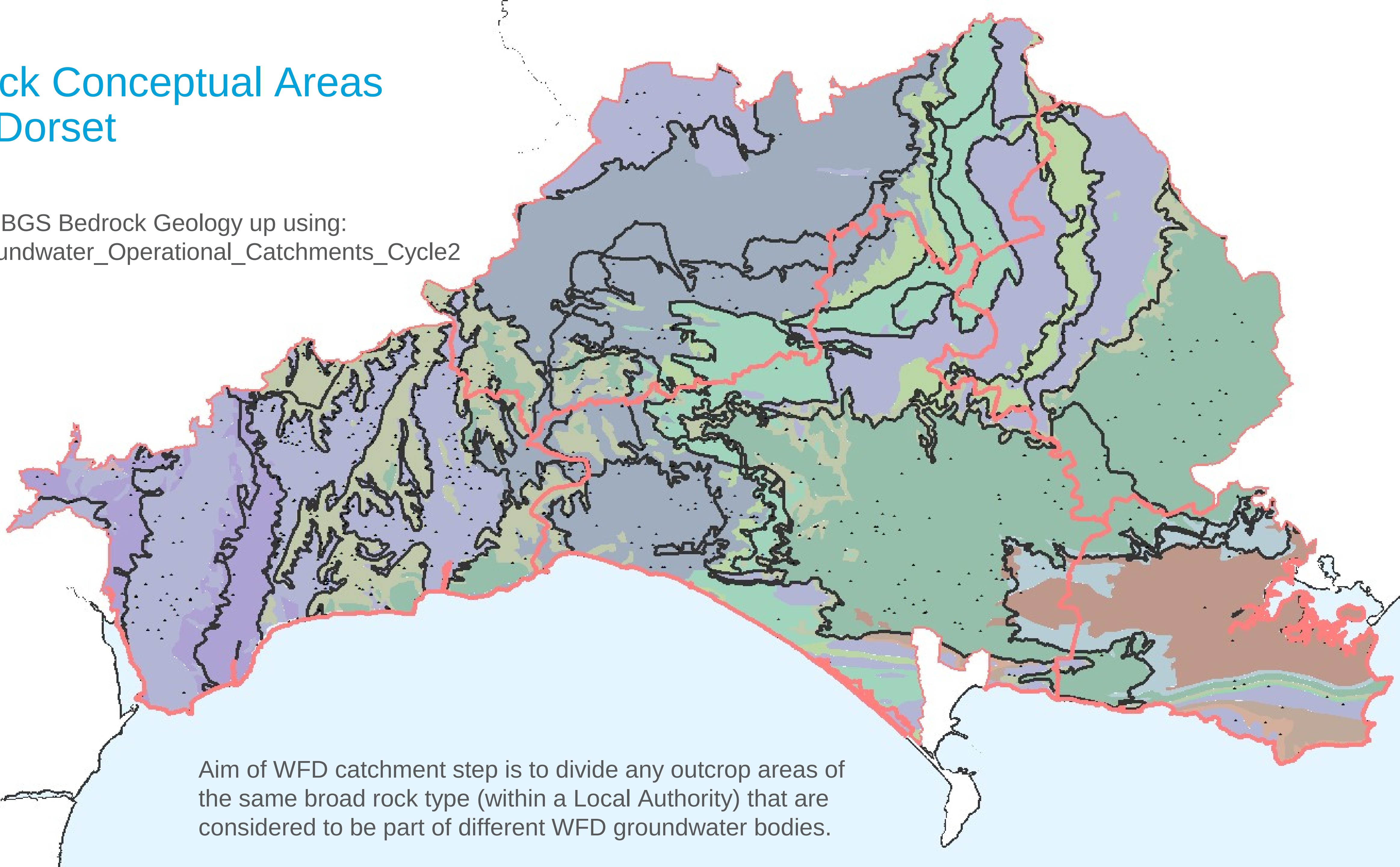
SNC·LAVALIN

ATKINS

Member of the SNC-Lavalin Group

# Bedrock Conceptual Areas
# West Dorset

Divide the BGS Bedrock Geology up using:
WFD_Groundwater_Operational_Catchments_Cycle2

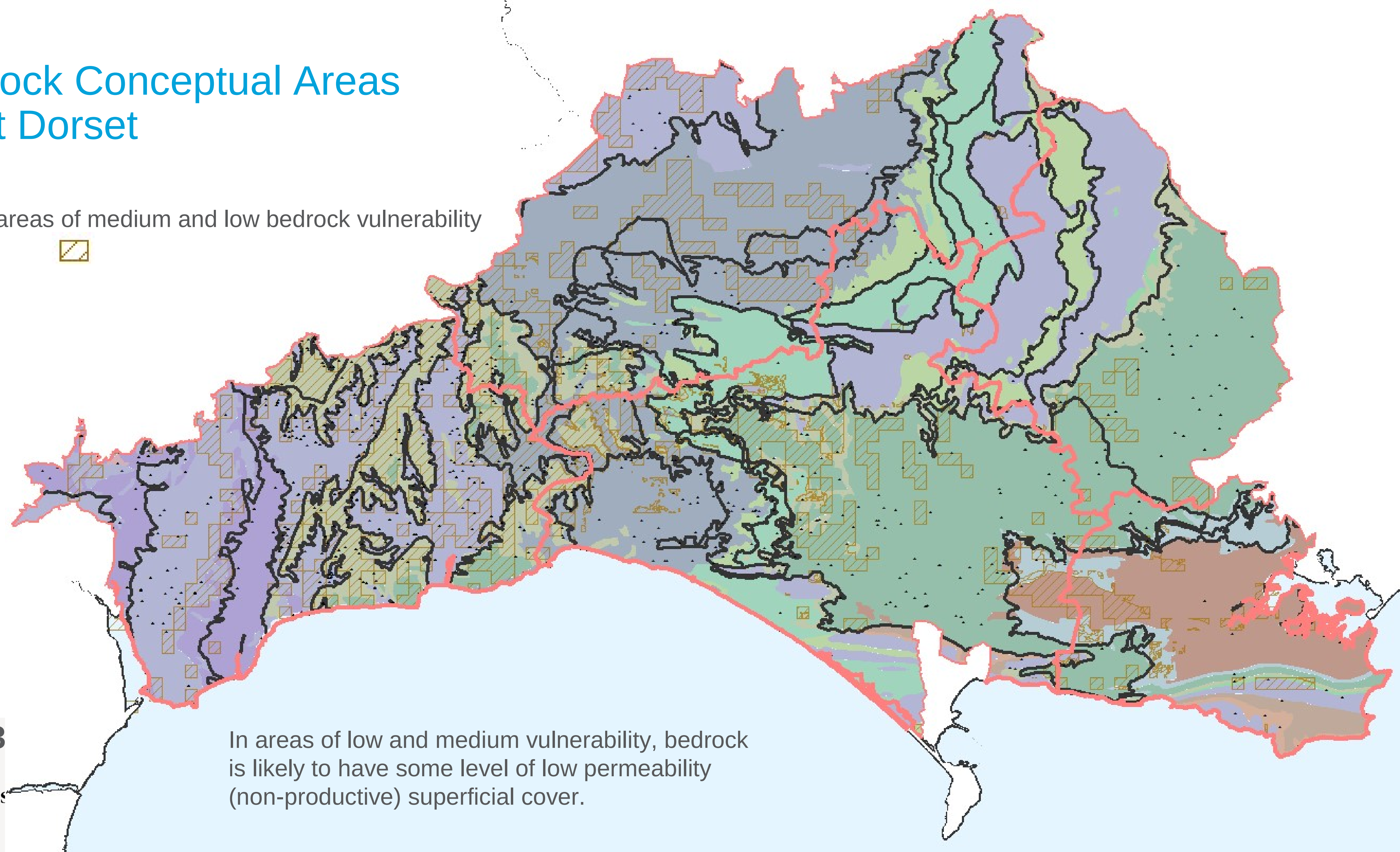


## Step 2

Aim of WFD catchment step is to divide any outcrop areas of the same broad rock type (within a Local Authority) that are considered to be part of different WFD groundwater bodies.

# Bedrock Conceptual Areas West Dorset

Identify areas of medium and low bedrock vulnerability



**Step 3**

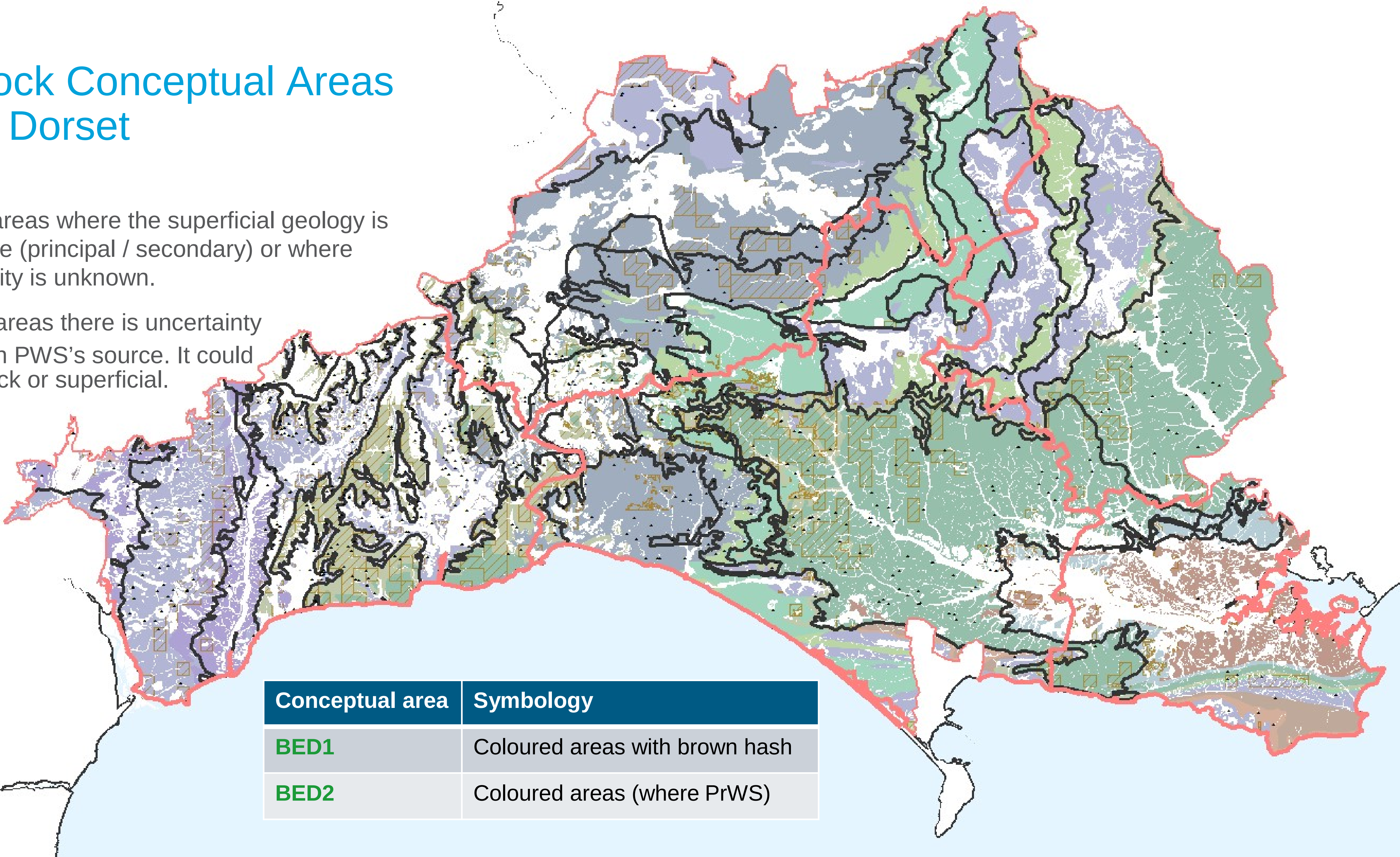
In areas of low and medium vulnerability, bedrock is likely to have some level of low permeability (non-productive) superficial cover.

(GWV_BGS)

# Bedrock Conceptual Areas West Dorset

Clip out areas where the superficial geology is productive (principal / secondary) or where productivity is unknown.

In these areas there is uncertainty over each PWS's source. It could be bedrock or superficial.

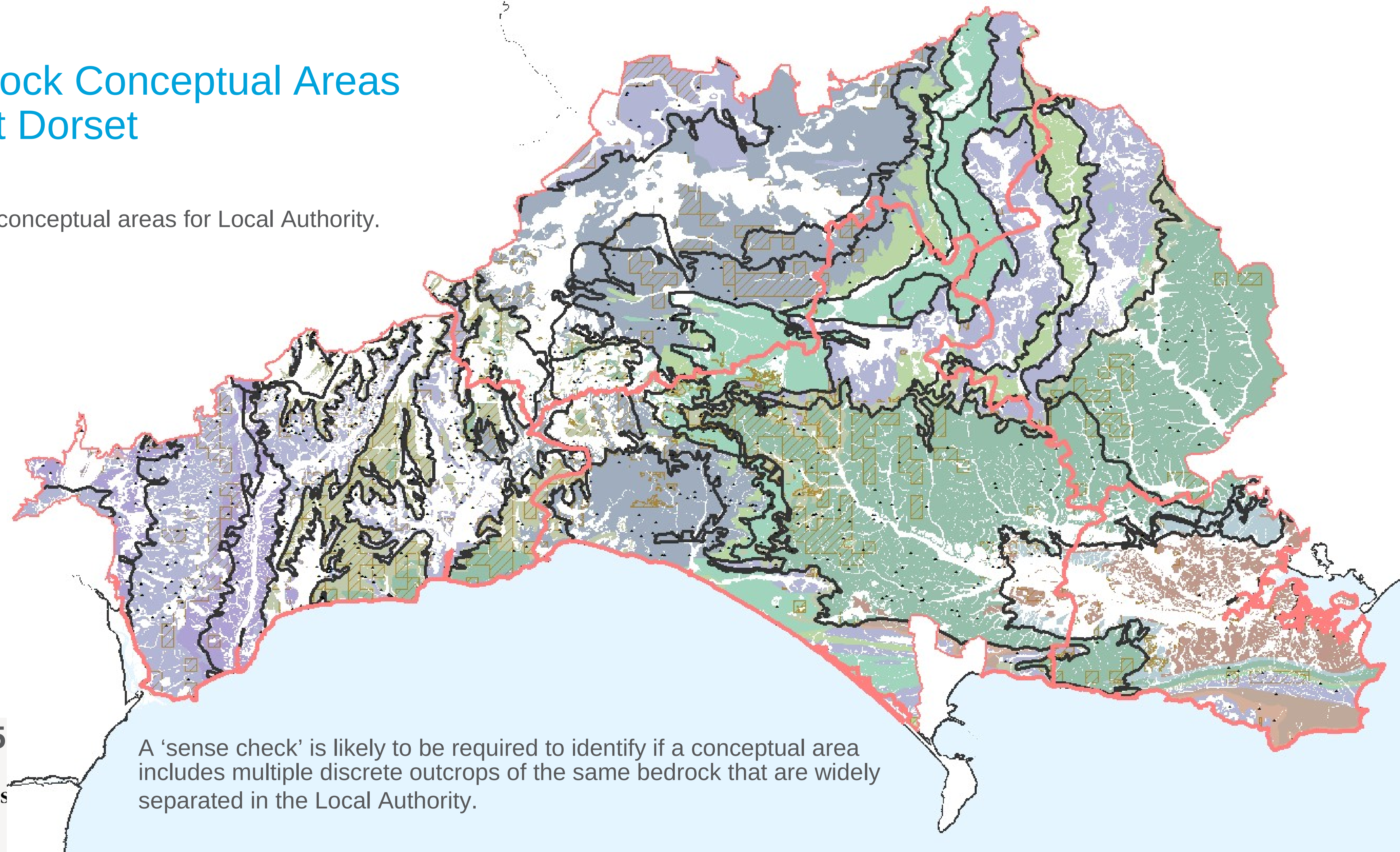


| Conceptual area | Symbology |
|---|---|
| BED1 | Coloured areas with brown hash |
| BED2 | Coloured areas (where PrWS) |

Step 4

# Bedrock Conceptual Areas West Dorset

Review conceptual areas for Local Authority.



**Step 5**

A ‘sense check’ is likely to be required to identify if a conceptual area includes multiple discrete outcrops of the same bedrock that are widely separated in the Local Authority.

# Bedrock Conceptual Areas
# West Dorset

The table below shows the results of applying this method to West Dorset LA (contains 169 borehole/well sources and 82 springs).

There are 10 bedrock types and 11 WFD Groundwater bodies within West Dorset LA.

| Item | Number of Conceptual Areas | | |
|---|---|---|---|
| | Total | Containing >0 PrWS | Containing >10 PrWS |
| Unique bedrock, WFD | 55 | 30 | 7 |

| | | | |
|---|---|---|---|
| Unique bedrock, WFD, vulnerability | 103 | 39 | 5 |

# Bedrock Conceptual Areas
# West Dorset

The table below lists the groundwater conceptual areas for West Dorset LA with > 10 PrWS:

| WFD Groundwater Catchment | Bedrock Rock Type | Bedrock Vulnerability | Number PrWS | Conceptual Area Type |
|---|---|---|---|---|
| Bridport Sands (West Alliton) | Mudstone, siltstone, limestone and sandstone (MSLS) | High vulnerability | 15 | BED2 |
| West Dorset Stream Groundwater Body | Mudstone, siltstone, limestone and sandstone (MSLS) | High vulnerability | 28 | BED2 |

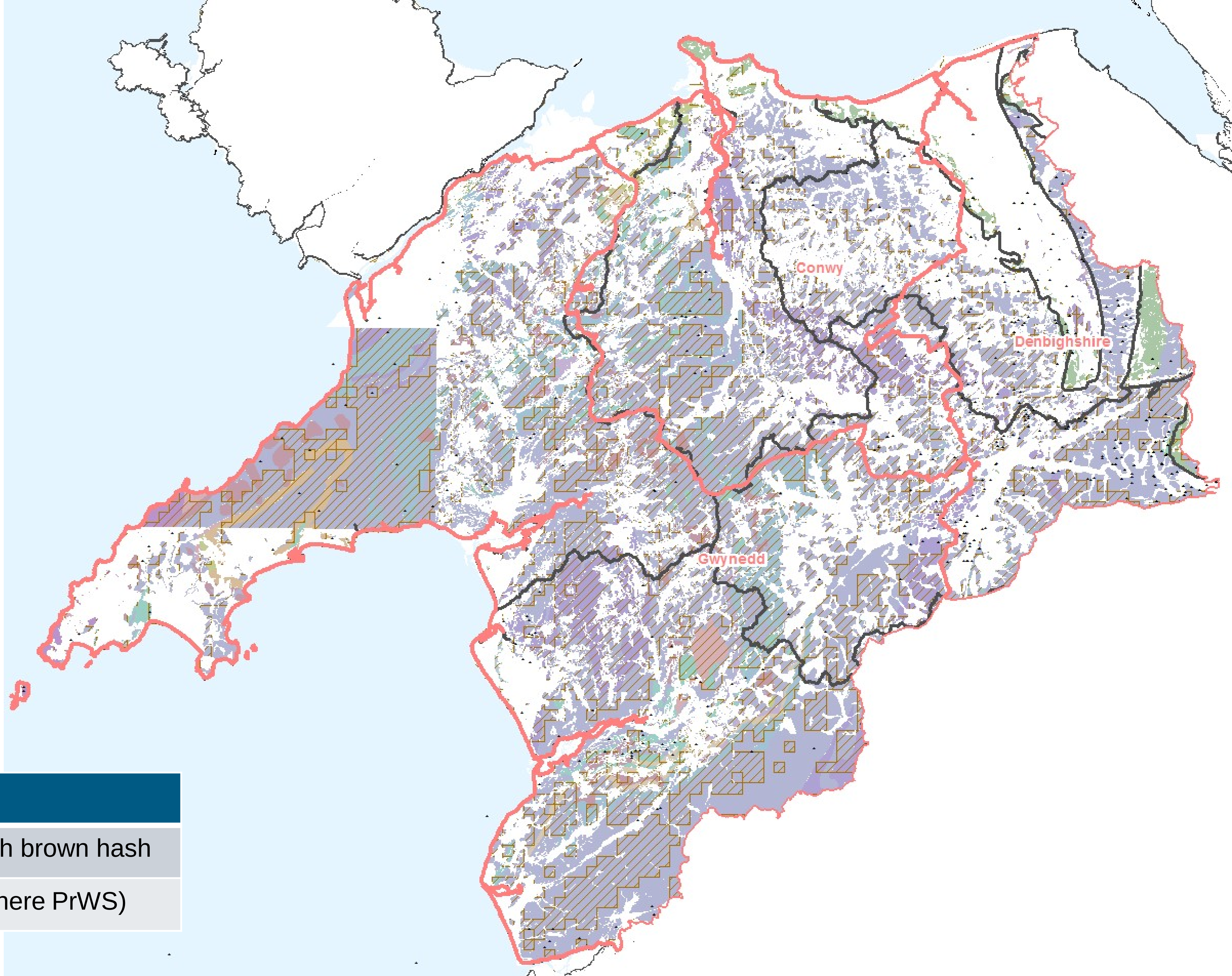
SNC·LAVALIN

ATKINS
Member of the SNC-Lavalin Group

| | | | | |
|---|---|---|---|---|
| Upper Frome and Piddle | Chalk (CHLK) | High vulnerability | 32 | BED2 |
| Upper Frome and Piddle | Mudstone, sandstone and limestone (MDSL) | High vulnerability | 12 | BED2 |
| None | Mudstone, sandstone and limestone (MDSL) | High vulnerability | 11 | BED2 |

# Bedrock Conceptual Areas Conwy

The bedrock conceptual areas for Conwy and its adjacent LAs are shown opposite.




| Conceptual area | Symbology |
|---|---|
| BED1 | Coloured areas with brown hash |
| BED2 | Coloured areas (where PrWS) |

# Conceptual Areas for Superficial Geology

Our preferred method for delineating groundwater conceptual areas (SUP1) for superficial geology is summarised below and worked through over the following slides.

- Step 1 - Identify unproductive bedrock
- Step 2 - Identify productive superficial geology (principal / secondary)
- Step 3 - Calculate areas where there is productive superficial geology over unproductive bedrock

- *An additional step may be required to divide up areas resulting from steps 1-3 into conceptual areas of similar superficial deposit type e.g. use the broad deposit (ROCK_D) in the BGS 625k superficial geology.*

- Step 5 – Review and ‘sense check’ conceptual areas

# Superficial Conceptual Areas West Dorset

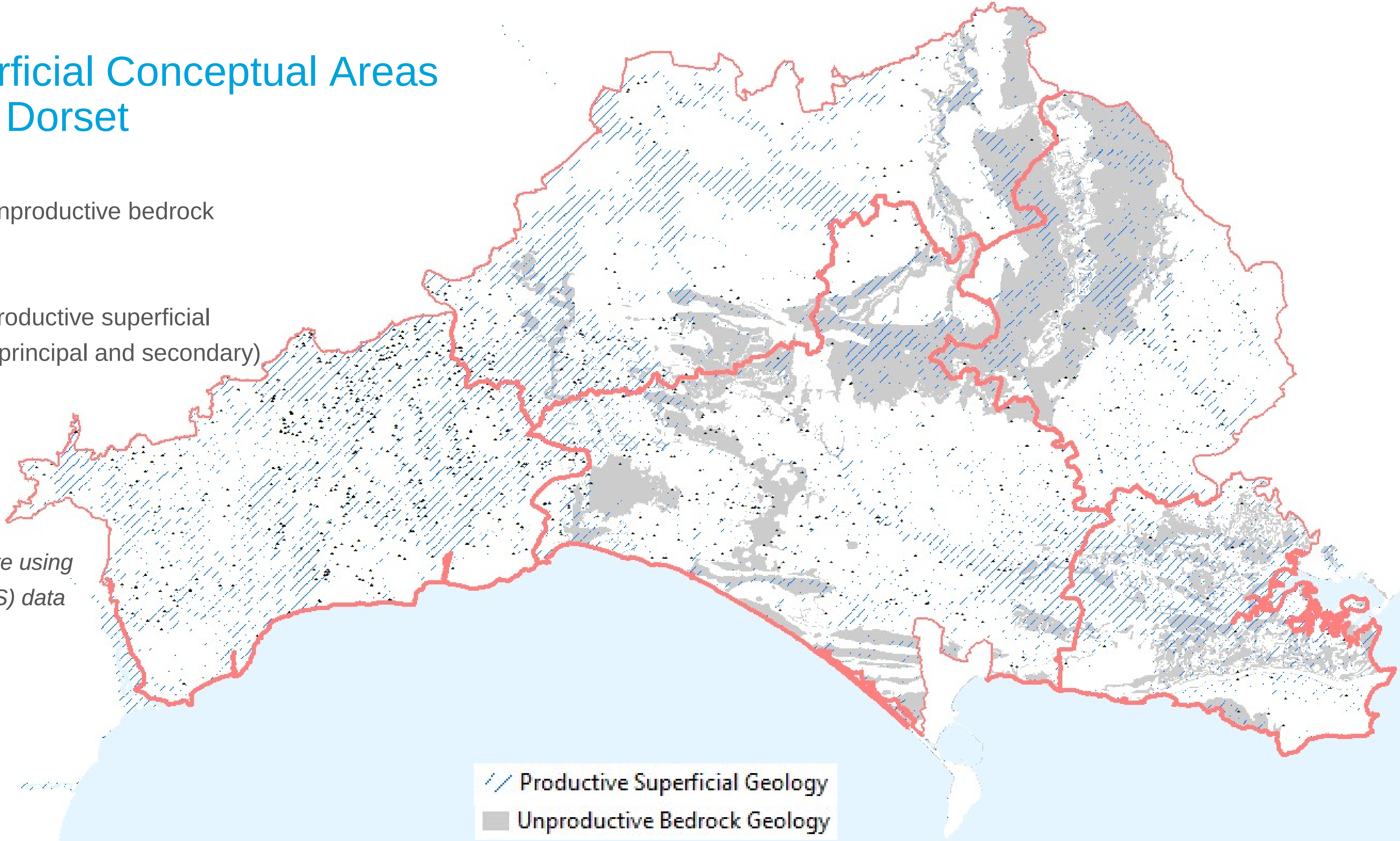
## Step 1

Identify unproductive bedrock

## Step 2

Identify productive superficial geology (principal and secondary)

*Both above using GVV (BGS) data*

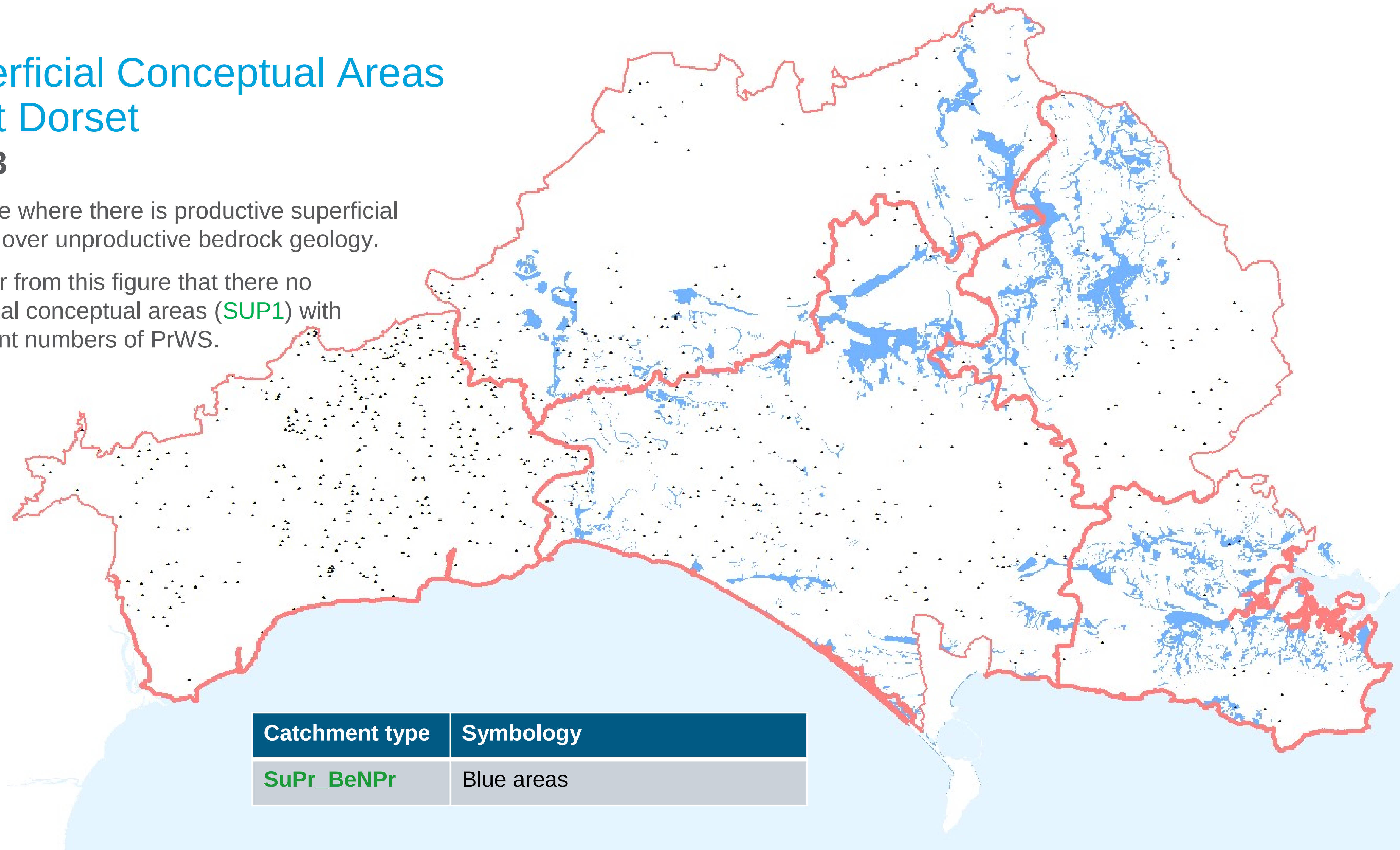


# Superficial Conceptual Areas West Dorset

## Step 3

Calculate where there is productive superficial geology over unproductive bedrock geology.

It is clear from this figure that there no superficial conceptual areas (SUP1) with significant numbers of PrWS.



| Catchment type | Symbology |
|---|---|
| **SuPr_BeNPr** | Blue areas |

# Groundwater Conceptual Areas – Questions

The initial methodology for delineating groundwater conceptual areas will be tested further in the next phase of the project.

This will allow further consideration of the following questions:

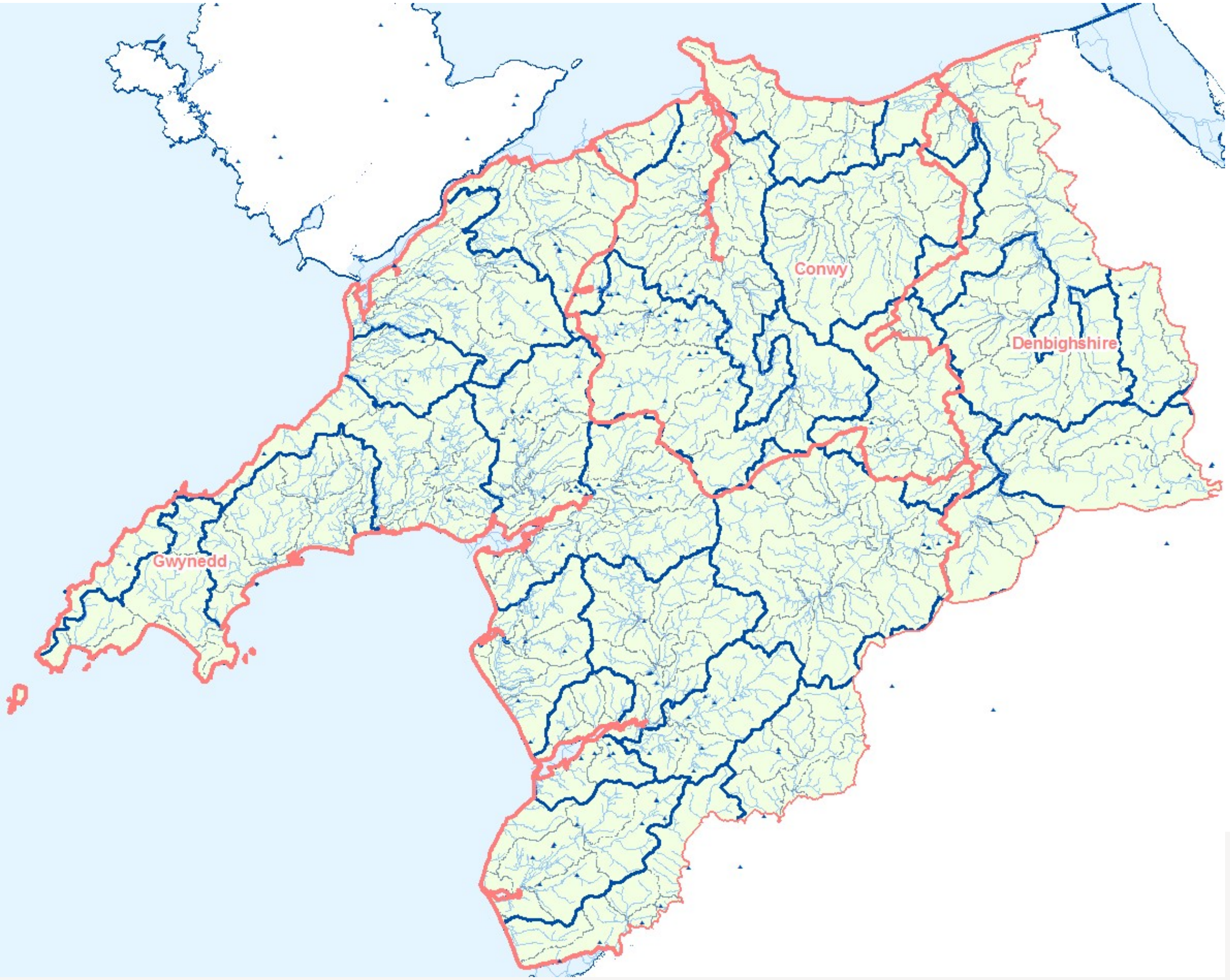
- Does the RCS_D attribute provide the right level of bedrock resolution for our conceptual areas?
- WFD Groundwater Catchments are not always limited to aquifer outcrop boundaries e.g. where aquifer is confined under unproductive bedrock – does this matter?
- Is it appropriate to group medium and low bedrock vulnerability together in step 3?
- What level of technical input is required for the review step?
- Is it necessary to sub-divide superficial catchments (based on deposit type)?

# Surface water

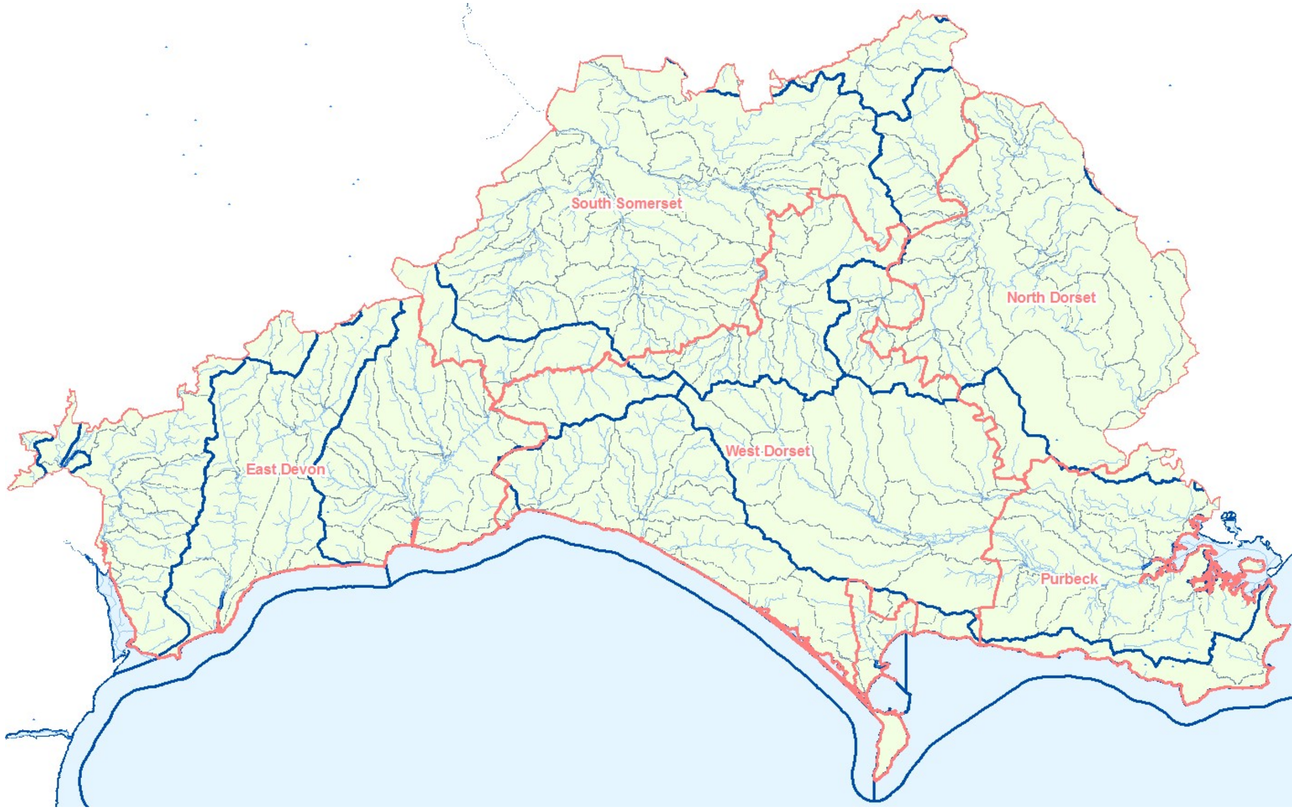
# Surface Water Conceptual Areas

The assessment of surface water conceptual areas will use existing WFD surface water operational catchments (cycle 2).

## Conwy




## West Dorset




*River lines and WFD waterbody catchments (sub-catchments) are shown for reference only*

SNC·LAVALIN

ATKINS
Member of the SNC-Lavalin Group

# Surface Water Conceptual Areas

# Conceptual Areas for Bedrock Geology
# Further Info

The aim of delineating bedrock groundwater catchments, is to identify areas of bedrock that would be expected to have similar groundwater chemistry.

Table outlines possible data layer attributes that could be used:

| Layer | Attribute | Categorisation | Comment |
| --- | --- | --- | --- |
| HydrogeologyUK/ GW vulnerability | Aquifer type | Principal, secondary, unproductive | Not enough detail<br>e.g. does not distinguish between principal chalk and sandstone aquifers which would be expected to have different groundwater chemistry |
| WFD Groundwater bodies | | | Some uncertainty as to how these have been delineated<br>Do not always readily map to bedrock outcrop areas |

SNC·LAVALIN

ATKINS
Member of the SNC-Lavalin Group

| | | | |
|---|---|---|---|
| BGS 625k | Formation | Individual geological formations | Too much detail – likely to result in catchments that are too small to deliver monitoring efficiencies |
| BGS 625k | RCS_D | Broad lithological rock types | Appropriate level of detail |

# Conceptual Areas for Bedrock Geology Further Info

By combining BGS 625k bedrock geology layer with other geological layers, 3 methods for delineating groundwater catchments (BED1 and BED2) are possible.

| | Method 1* | Method 2** | Method 3 |
|---|---|---|---|
| Superficial geology data | BGS 625k superficials (ROCK_D) | BGS groundwater vulnerability (superficial aquifer type) | BGS groundwater vulnerability (superficial aquifer type) |

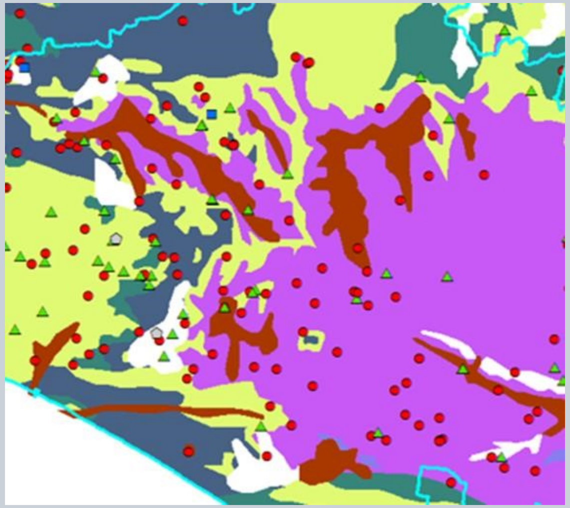
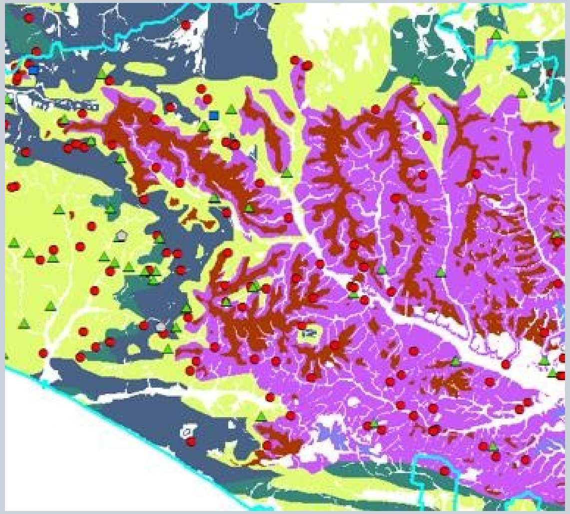
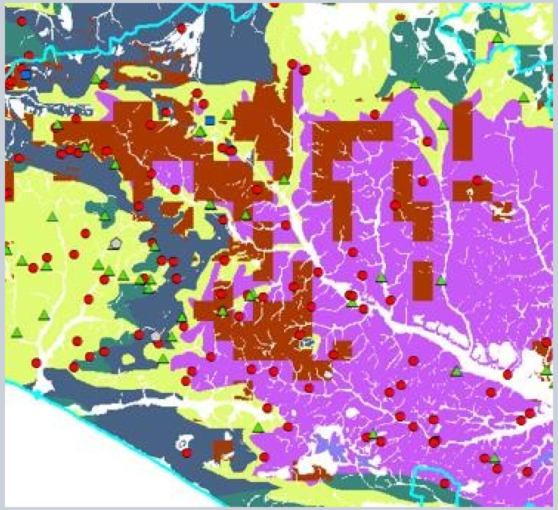
| | | | |
|---|---|---|---|
| Bedrock geology data | BGS 625k bedrock (RCS_D) | BGS 625k bedrock (RCS_D) | BGS 625k bedrock (RCS_D)<br>BGS groundwater vulnerability (bedrock vulnerability) |
| Delineation BED1 | Impermeable superficials over bedrock | Unproductive superficials over bedrock | Protected (less vulnerable) bedrock |
| Delineation BED2 | No superficials over bedrock | No superficials over bedrock | No superficials over bedrock |

* Method 1 uses assumed permeability of superficial deposits as a ‘proxy’ for bedrock vulnerability.

* Method 2 uses productivity of superficial deposits as a ‘proxy’ for bedrock vulnerability.

SNC·LAVALIN

ATKINS
Member of the SNC-Lavalin Group

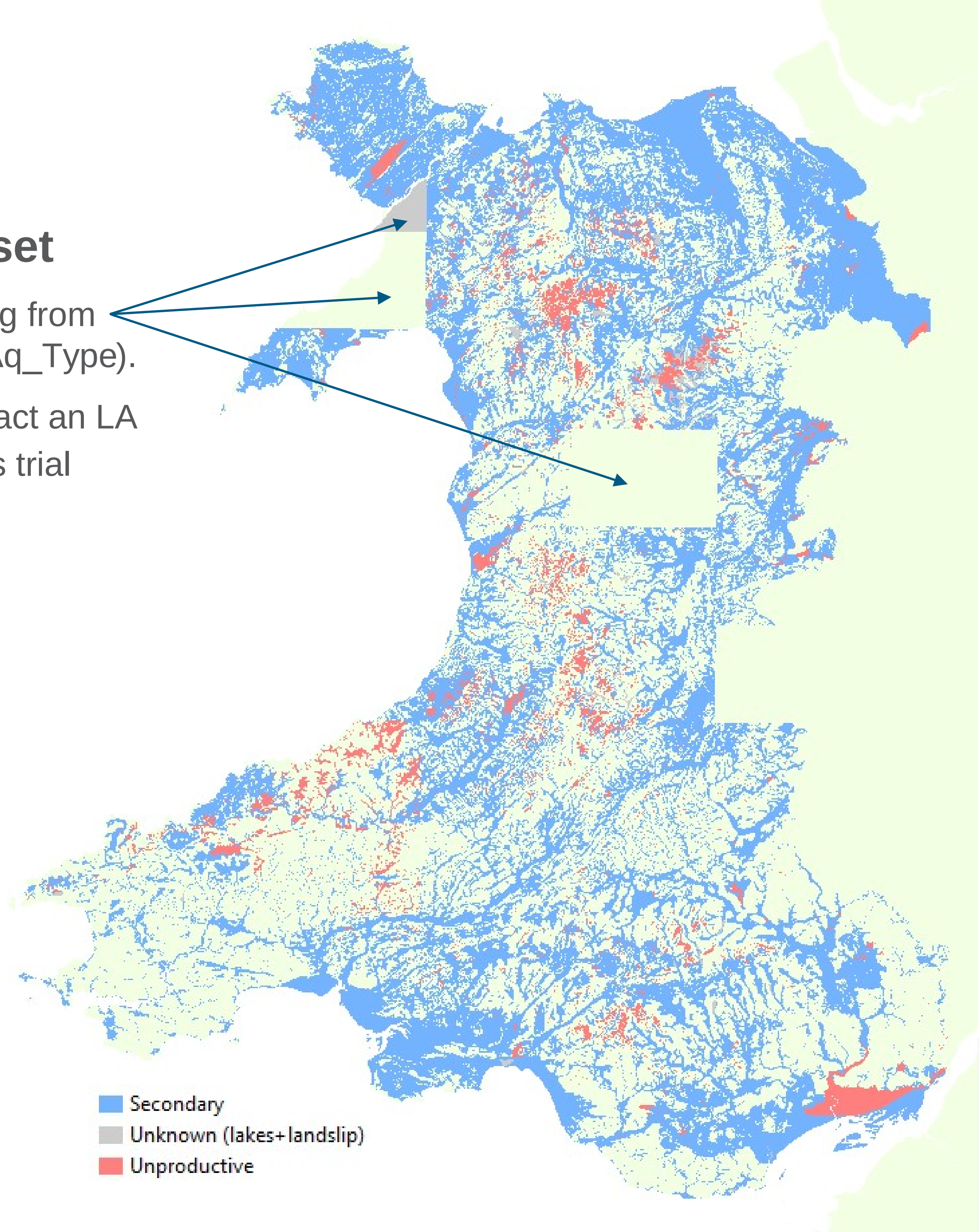
| | Method 1 | Method 2 | Method 3 |
|---|---|---|---|
| Example |  |  |  |
| Pros | • Superficials mapping very simple | | • Distinguishes between bedrock catchments on basis of bedrock vulnerability |
| Cons | • Superficials mapping too generalised<br>• Distinguishes between bedrock catchments on basis of permeability of superficials<br>• Subjective assessment of permeability based on broad deposit type | • Most detailed mapping<br>• Maps visually more complex to interpret for potential audience | • Maps visually more complex to interpret for potential audience |

# Input Data Quality

## Superficial GWV BGS dataset

There appears to be some data missing from the Welsh version of this dataset (Sf_Aq_Type).

Not a widespread issues but does impact an LA adjacent to Conwy (one of the project’s trial LAs).



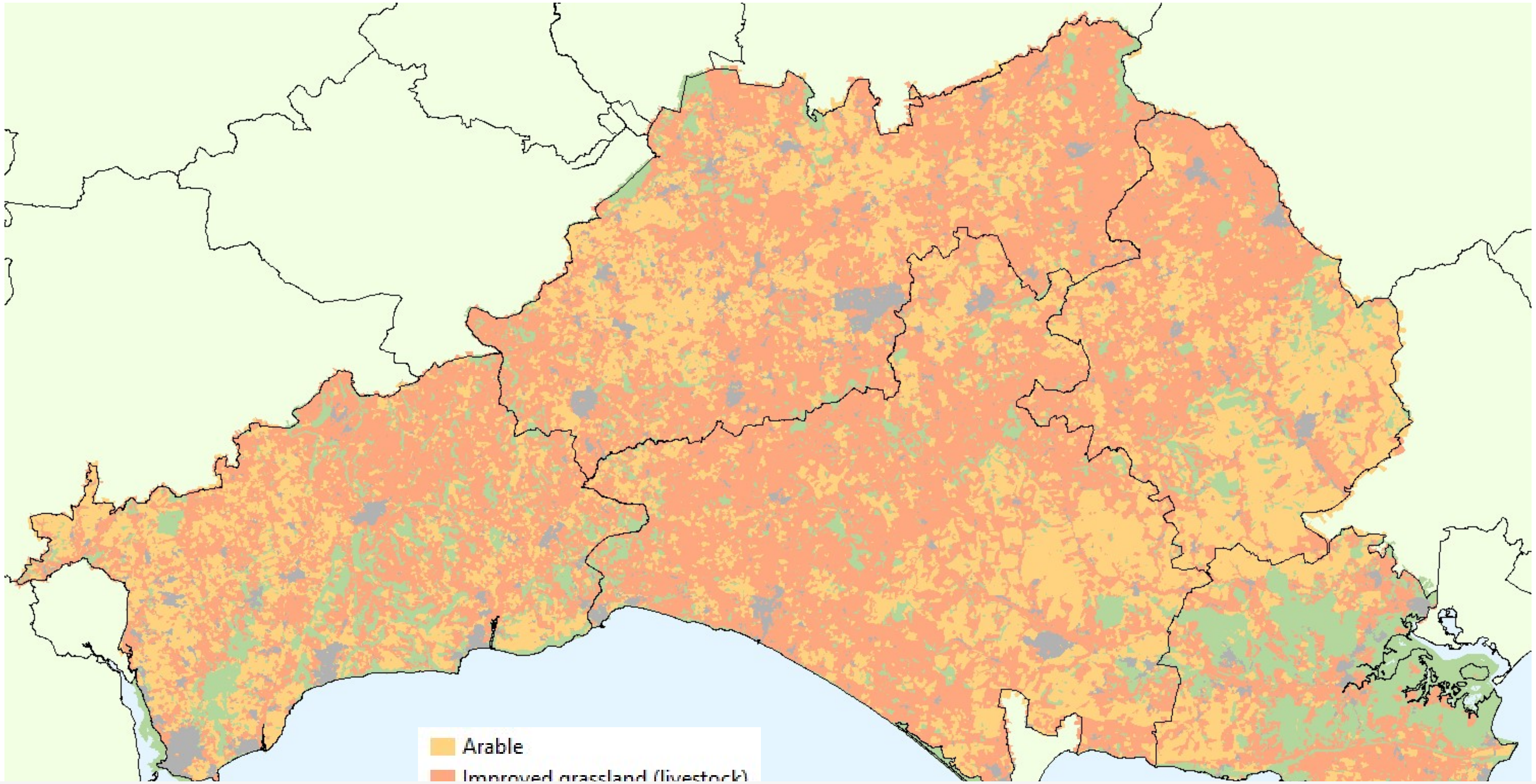
# Land Use Data

## Simplified LCM

Simplified land use data has not been used to help define conceptual areas at this stage

The extent of the ‘natural’ land use type is limited (in the trial LAs).

Consideration of land use will be included the next phase of the work.



# Appendix C. Summary of cost estimates for laboratory water quality analysis

| Type | Parameter | Average cost |
| --- | --- | --- |
| Microbiological parameters | Coliform bacteria | £4.37 |
| | Colony Counts 22oC | £2.79 |
| | Colony Counts 37oC | £2.73 |
| | E. coli | £4.48 |
| | Enterococci | £6.50 |
| | Pseudomonas aeruginosa | £8.57 |
| Chemical and organic | 1,2-dichloroethane | £17.11 |
| | Acrylamide | £65.11 |
| | Aluminium | £1.82 |
| | Antimony | £2.13 |
| | Arsenic | £2.13 |
| | Benzene | £17.11 |
| | Benzo(a)pyrene | £26.46 |
| | Boron | £3.70 |
| | Bromate | £24.81 |
| | Cadmium | £2.23 |
| | Chromium | £2.13 |
| | Colour | £2.43 |
| | Copper | £2.17 |
| | Cyanide | £9.17 |
| | Epichlorohydrin | £98.50 |
| | Fluoride | £4.53 |
| | Iron | £1.82 |
| | Lead | £2.28 |
| | Manganese | £1.82 |
| | Mercury | £6.72 |
| | Nickel | £2.28 |
| | Nitrate | £3.13 |
| | Nitrite | £3.31 |
| | Odour | £5.98 |

| Type | Parameter | Average cost |
|---|---|---|
| | Polycyclic aromatic hydrocarbons | £14.69 |
| | Selenium | £3.96 |
| | Sodium | £3.05 |
| | Tetrachloroethene/Trichloroethene | £11.57 |
| | Tetrachloromethane | £11.57 |
| | Turbidity | £2.05 |
| | Vinyl chloride | £59.14 |
| Pesticides | Aldrin | £7.89 |
| | Dieldrin | £7.89 |
| | Heptachlor | £7.89 |
| | Heptachlor epoxide | £7.89 |
| | Other pesticides | £48.15 |
| | Pesticides total | £7.95 |
| | Pesticide suite | £33.54 |
| Indicator parameter | Ammonium | £3.95 |
| | Chloride | £2.91 |
| | Clostridium perfringens | £11.60 |
| | Conductivity | £1.94 |
| | Hydrogen ion concentration | £2.03 |
| | Radon | £61.48 |
| | Sulphate | £3.58 |
| | Taste | £2.83 |
| | Total Organic Carbon | £9.79 |
| Radioactivity | Alpha and beta radioactivity | £61.04 |
| | Speciation | £878.66 |
| | Tritium | £60.15 |

*Note - Average sampling price calculated from quotes provided by four separate labs in 2016.*

# Appendix D. List of water quality determinands

| Determinand | Result Count | |
|---|---|---|
| | Conwy | West Dorset |
| Iron | 310 | 810 |
| Odour | 164 | 339 |
| Escherichia coli (E.coli) | 616 | 991 |
| Clostridium perfringens | 481 | 638 |
| Colour | 257 | 218 |
| Aluminium | 252 | 690 |
| Ammonium | 224 | 656 |
| Turbidity | 328 | 263 |
| Hydrogen ion (pH) (Indicator) | 260 | 771 |
| Conductivity | 306 | 771 |
| Taste | 14 | 255 |
| Colony Counts After 3 Days At 22°c | 491 | 677 |
| Colony Counts After 48 Hours At 37°c | 116 | 684 |
| Manganese | 290 | 810 |
| Coliform bacteria (Indicator) | 520 | 990 |
| Nitrite - Consumer's Taps | 8 | 695 |
| Nitrate | 73 | 695 |
| Lead (Total – 25) | 51 | 86 |
| Copper | 79 | 689 |
| Nitrite - Treatment Works | 57 | 0 |
| Antimony | 38 | 299 |
| Nickel | 58 | 620 |
| Fluoride | 54 | 1 |
| Arsenic | 73 | 300 |
| Sulphate | 35 | 92 |
| Enterococci | 440 | 906 |
| Chromium | 56 | 300 |
| Cadmium | 61 | 499 |
| Chloride | 42 | 121 |

| | | |
|---|---|---|
| Total Organic Carbon | 34 | 1 |
| Bottles or Containers: Hydrogen ion (pH) | 0 | 1 |
| Bottles or containers: Enterococci | 0 | 1 |
| Selenium | 37 | 142 |
| Boron | 45 | 296 |
| Sodium | 15 | 62 |

| Determinand | Result Count | |
|---|---|---|
| | Conwy | West Dorset |
| Trihalomethanes (Total by Calculation) | 40 | 40 |
| Heptachlor | 21 | 30 |
| 1 2-Dichloroethane | 44 | 44 |
| Tritium | 6 | 0 |
| Cyanide | 6 | 5 |
| Dieldrin | 22 | 38 |
| Heptachlor Epoxide | 22 | 38 |
| Aldrin | 24 | 30 |
| Benzene | 45 | 33 |
| Mercury | 6 | 141 |
| Benzo(a)pyrene | 4 | 0 |
| Tetrachloromethane | 22 | 36 |
| Bromate | 21 | 33 |
| Polycyclic Aromatic Hydrocarbons (Total by Calculation) | 2 | 2 |
| Trichloroethene & Tetrachloroethene - Sum Of 2 Substances (Total by Calculation) | 43 | 52 |
| Total Indicative dose (radioactivity) | 0 | 0 |
| Pesticides (Total by Calculation) | 25 | 58 |
| other Pesticides | 1 | 0 |
| Nitrite/Nitrate formula | 20 | 0 |
| Turbidity – Indicator | 9 | 508 |
| Bottles or Containers: Colony Counts After 48 Hours at 37°c | 0 | 0 |
| Pesticide - Terbutryn | 0 | 40 |

| | | |
|---|---|---|
| Pesticide - Quintozene | 0 | 29 |
| Pesticide - 2 4-DB (Total) | 6 | 54 |
| Pesticide - Trietazine | 0 | 40 |
| Pesticide - Chlorothalonil | 0 | 24 |
| Pesticide - Gamma-HCH (Lindane) | 0 | 35 |
| Pesticide - Atrazine (Total) | 6 | 37 |
| Pesticide - MCPB (Total) | 6 | 54 |
| Pesticide - Chloridazon | 0 | 37 |
| Pesticide - Chlortoluron (Total) | 6 | 33 |
| Pesticide - Metribuzin | 0 | 40 |
| Pesticide - Metamitron | 0 | 37 |
| Pesticide - 2 4-D (Total) | 6 | 54 |
| Pesticide - Metazachlor | 6 | 39 |

| Determinand | Result Count | |
|---|---|---|
| | Conwy | West Dorset |
| Pesticide - Isoproturon (Total) | 6 | 37 |
| Pesticide - Methabenzthiazuron | 0 | 40 |
| Pesticide - Fluroxypyr | 6 | 54 |
| Pesticide - Dicamba (Total) | 6 | 54 |
| Pesticide - Monolinuron | 0 | 40 |
| Pesticide - Diuron (Total) | 6 | 37 |
| Pesticide - Alpha-HCH | 0 | 37 |
| Pesticide - Clopyralid (Total) | 6 | 54 |
| Pesticide - Cyanazine | 0 | 37 |
| Pesticide - Picloram (Total) | 0 | 54 |
| Pesticide - Bentazone (Total) | 6 | 54 |
| Pesticide - MCPA (Total) 4-chloro-o-tolyloxyacetic acid | 6 | 54 |
| Pesticide - 1,1,1-trichloro-2,2-ethane pp'-DDT | 0 | 41 |
| Pesticide - Propazine | 0 | 37 |
| Pesticide - Triclopyr (Total) | 6 | 54 |
| Pesticide - Desethylatrazine | 0 | 37 |

| Determinand | Result Count | |
|---|---|---|
| | Conwy | West Dorset |
| Pesticide - Napropamide | 0 | 39 |
| Pesticide - Dichlobenil (Total) | 0 | 38 |
| Pesticide - MCPP(Mecoprop) (Total) | 6 | 54 |
| Pesticide - Hexachlorobutadiene | 0 | 30 |
| Pesticide - Prometryne | 0 | 43 |
| Pesticide - Simazine (Total) | 6 | 40 |
| Pesticide - Tri-allate (Total) | 0 | 29 |
| Pesticide - Monuron | 0 | 40 |
| Pesticide - Linuron (Total) | 6 | 40 |
| Pesticide - Terbuthylazine | 0 | 40 |
| Pseudomonas aeruginosa | 2 | 1 |
| Radioactivity - Gross Alpha | 5 | 0 |
| Radioactivity - Gross Beta | 5 | 0 |
| Lead (10 - will apply 25/12/2013) | 206 | 415 |
| Radon | 0 | 0 |
| Pesticide - Pentachlorobenzene | 0 | 9 |
| Pesticide - Azoxystrobin (Total) | 0 | 22 |
| Pesticide - Trichlorobenzene | 0 | 6 |
| Pesticide - Hexachlorobenzene | 0 | 8 |
| Pesticide - Hexachlorocyclohexane (HCH) | 0 | 3 |
| Pesticide - Bromoxynil (Total) | 6 | 0 |
| Pesticide - Benazolin (Total) | 6 | 0 |
| Pesticide - Fenoprop | 6 | 0 |
| Pesticide - Asulam | 6 | 0 |
| Pesticide - Glyphosate | 6 | 0 |
| Pesticide - 2,4,5-T | 6 | 0 |
| Pesticide - Pentachlorophenol (Total) | 6 | 0 |
| Pesticide - Metaldehyde | 6 | 0 |
| Pesticide - Imazapyr | 6 | 0 |

| | | |
|---|---|---|
| Pesticide - Ioxynil (Total) | 6 | 0 |
| Pesticide - 2,3,6-Tba | 6 | 0 |
| Pesticide - Dichlorprop (Total) | 6 | 0 |

Helen Stockham
**Atkins Limited**
Western House (Block C)
Peterborough Business Park
Lynch Wood
Peterborough
PE2 6FZ

**Tel: +44 (0)1733 366900**
**Helen.stockham@atkinsglobal.com**