Environment Agency

Isles of Scilly Source Protection Zone Delineation

Project ENVRESW001361

December 2016

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Environment Agency
Horizon House, Deanery Road,
Bristol BS1 5AH
Email: enquiries@environment-agency.gov.uk
www.gov.uk/environment-agency

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Executive summary

The Environment Agency delineates Source Protection Zones (SPZs) to protect groundwater in the catchments of potable groundwater abstractions from pollution by potentially contaminative activities. SPZ 1 represents the 50 day groundwater travel time to a source (or is a 'default' 50 m radius), SPZ 2 represents the 400 day travel time (or is a default 250 m radius), and SPZ 3 represents the total catchment to the source.

Prior to 2010, the Isles of Scilly were exempt from UK environmental legislation. This situation was ended in 2010, with the introduction of the Environmental Permitting Regulations (EPR). Due to the extension of EPR to the islands, the Environment Agency has produced SPZs there.

The Isles of Scilly are formed of fractured granite, with overlying blown sand and alluvium in some areas. The surface of the granite has been very highly weathered. Groundwater flow through the fractured granite is very rapid.

The Isles of Scilly are dependent upon groundwater for water supply. Source Protection Zones have been delineated for the groundwater abstractions operated by the Council of the Isles of Scilly, the Duchy of Cornwall and Tresco Estate. These sources supply a large proportion of the population.

The zones were delineated using available information about the sources, the geology, hydrogeology and topography of the islands, groundwater velocity estimates, and a simple model. Due to the rapid groundwater flow, separate SPZ3s were not drawn. SPZ 2 was taken to extend to entire catchments.

The zones are shown in the Figures section of this report.

Contents

1. Background

The Isles of Scilly comprise 5 inhabited islands, and a large number of uninhabited islands. St Mary's is the main inhabited island. The other inhabited islands are St Martin's, St Agnes, Tresco and Bryher.

The Isles of Scilly are dependent upon groundwater for water supply. There are few surface water courses on the islands, and these are not abstracted from. The Council of the Isles of Scilly provides a water supply on St Mary's, which comes from groundwater and a desalination plant. The Council also supplies Bryher, from groundwater abstraction. The Duchy of Cornwall operate some groundwater abstractions on St Martin's and St Agnes. On Tresco, all water supply is provided from groundwater by Tresco Estate. A great number of private abstractions also exist across the islands, supplying individual households or groups of households.

Prior to 2010, the Isles of Scilly were exempt from UK environmental legislation. This situation was ended in 2010, with the introduction of the Environmental Permitting Regulations. The Environment Agency uses Source Protection Zones (SPZs) in its risk assessment of permit applications and in response to pollution incidents. With the introduction of permitting to the islands, SPZs are needed.

SPZ 1 represents the 50 day groundwater travel time to a source (or is a 50 m default radius), and SPZ 2 represents the 400 day groundwater travel time (or is a default 250 m radius). SPZ 3 represents the total groundwater catchment draining towards a source.

This report describes the delineation of SPZs for the groundwater sources operated by the Council of the Isles of Scilly, the Duchy of Cornwall and Tresco Estate. These sources were chosen for this initial SPZ delineation as they supply the largest number of people.

2. Description of sources

The Council of the Isles of Scilly operates the following sources:

Table 1

Source name	NGR	information
St Mary's Carss	SV 92237 10973	Well Located in Higher Moors Average daily abstraction rate 2012 – 2015: 21 m3/d Average water level 2010 – 2015: 1.3 mbgl
St Mary's Holes	SV 92139 11040	Borehole Located in Higher Moors Average daily abstraction rate 2012 – 2015: 115.9 m3/d Average water level 2010 – 2015: 4.1 mbgl
St Mary's Venns	SV 92200 11099	Well Located in Higher Moors Average daily abstraction rate 2012 – 2015: 105.8 m3/d Average water level 2010 – 2015: 3.1 mbgl

St Mary's Joaneys	SV 91353 10736	Well Located in Lower Moors Average daily abstraction rate 2012 – 2015: 58.6 m3/d Average water level 2010 – 2015: 1.8 mbgl Borehole depth: 5.49 m
St Mary's Rocky Hill	SV 91107 11077	Borehole Located in Lower Moors. Average daily abstraction rate 2012 – 2015: 84.3 m3/d Average water level 2010 – 2015: 3mbgl Borehole depth: 10.36 m
Bryher Well	SV 87685 15138	Constructed 1980 Well depth:6 m Water level 02/12/15: 3 mbgl Average daily abstraction rate 2011 – 2015: 14.5 m3/d
Bryher BH2	SV 87803 15038	Constructed 2011 Borehole depth: 32 m Water level 02/12/15: 8.3 mbgl Average daily abstraction rate 2011 – 2015: 4.5 m3/d
Bryher BH4	SV 87773 15372	Constructed 2011 Borehole depth: 40 m Water level 02/12/15: 9.3 mbgl Average daily abstraction rate 2011 – 2015: 0.7 m3/d
Bryher BH1	SV 87[illegible]79 15167	Constructed 1992 Borehole depth: 32 m Water level 02/12/15: 11.5 mbgl Average daily abstraction rate 2011 – 2015: 9.5 m3/d
Bryher BH3	SV 87894 14694	Only used in summer months when demand at its peak Average daily abstraction rate 2011 – 2015: 4.2 m3/d

The Duchy of Cornwall operates the following sources:

Table 2

Source name	NGR	information
St Martin's Higher Town Borehole 1 North	SV 92919 15608	Combined Higher Town boreholes average daily abstraction rate 2008 – 2015: 1.5 m3/d.
St Martin's Higher Town Borehole 1 South	SV 92907 15588	Combined Higher Town boreholes average daily abstraction rate 2008 – 2015: 1.5 m3/d. Borehole depth approximately 40m Water level 11/11/15: 10.7 mbgl
St Martin's Lower Town Borehole 3a	SV 91706 16284	Combined Lower Town boreholes average daily abstraction rate 2008 – 2015: 1.3 m3/d.
St Martin's Lower Town Borehole 3b	SV 91872 16456	Combined Lower Town boreholes average daily abstraction rate 2008 – 2015: 1.3 m3/d.
St Martin's Middle Town Borehole 2a	SV 91948 16347	Combined Middle Town boreholes average daily abstraction rate 2008 – 2015: 7.9 m3/d.
St Martin's Middle Town Borehole 2b	SV 92038 1625[illegible]	Combined Middle Town boreholes average daily abstraction rate 2008 – 2015: 7.9 m3/d.
St Agnes Coveon Borehole (Higher Town) 29	SV 8830[illegible] 08169	Data supplied by the Duchy for 2013 – 2016 shows average daily abstraction rates for the 4 St Agnes boreholes combined of 6.3 m3/d.
St Agnes Johans Field Borehole 33	SV 87916 08233	Data supplied by the Duchy for 2013 – 2016 shows average daily abstraction rates for the 4 St Agnes boreholes combined of 6.3 m3/d.
St Agnes Plump Borehole 2[illegible] (Higher Town)	SV 88259 08243	Supplies half of St Agnes Borehole depth 29.6 m Water level 11.9 mbgl Data supplied by the Duchy for 2013 – 2016 shows average daily abstraction rates for the 4 St Agnes boreholes combined of 6.3 m3/d.
St Agnes Tommys Barn Borehole 31	SV 88075 08141	Data supplied by the Duchy for 2013 – 2016 shows average daily abstraction rates for the 4 St Agnes boreholes combined of 6.3 m3/d.

Tresco Estate operates the following sources

Table 3

Source name	NGR	information
Borehole by Lake	SV 89113 14952	This source is only used in summer, and yields around 30 m3/d. Well depth: 25.4 m Water level 23/11/15: 4.65 mbgl
Ox's Well	SV 89195 15521	Water level ranges seasonally between around 0.5 and 3.8 mbgl. Well depth: 5.84 m Water level 23/11/15: 2.7 mbgl
Bridge Field Well	SV 89639 14590	Very wide diameter well. Tresco Estate excavated it 20 years ago. Concrete ring construction. Water level ranges seasonally between around 1.5 mbgl and 3.8 mbgl. Well depth: 4.9 m Water level 23/11/15: 3.1 mbgl
Wellfield Well	SV 89300 15350	Well was constructed by the Navy in World War One. In summer, water level reaches pump cut out. Water level ranges seasonally between around 2.5 mbgl and 6 mbgl. Well depth 6.6 m Water level 23/11/15: 4.6 mbgl

Information provided by Tresco Estate shows an average daily water usage for the island of 81 m3/d in 2013 - 2014.

3. Geological and hydrogeological conceptual understanding

3.1. General

The Isles of Scilly are located 45km to the west of Land's End. These granite islands are part of the Cornubian batholith (a line of igneous intrusions), which begins at Dartmoor in Devon, and extends through Cornwall.

Barrow (1906) states that, 'the material formed by the denudation of the granite is an important component of some of the islands. This granite waste takes two forms, angular head and blown sand. The latter is by far the more important so far as bulk is concerned'.

Barrow states further that, 'considering the small size of the area above water, the amount of blown sand in the Scilly Isles is remarkable', and that, 'the blown sand has had the effect of joining different granite patches or small islands together so as to form a continuous land-surface or one island'.

Watkins (1999) expands on the hydrogeological aspects of, this stating that, 'the upper surface of the granite has been very highly weathered, by glacial processes, into a permeable sandy material or head, known locally as Ram'. Over some lower-lying parts of the islands, the granite head is overlain by blown sand, which is also very highly permeable.

The islands are characterised by a general absence of streams (except within the Higher and Lower Moors SSSIs). This indicates that there is minimal runoff and that residual rainfall (after evapotranspiration) infiltrates the drift or bedrock (ESI, 2012). The high bedrock permeability is due to the highly fractured nature of the granite. Groundwater flow through the fractures is likely to be rapid. Fracturing is most highly developed in the upper parts of the granite. The majority of groundwater flow is therefore fairly shallow. Groundwater flow paths are likely to be short and to follow the topography, from the higher land towards the centre of the islands towards the sea, where discharge occurs.

It must be noted that, in contrast to the understanding presented above, South West Water (1982), states that, 'pumping tests have shown that the area of influence of each borehole source rarely exceeds 40 m radial distance because the permeability of the granite is very low'. This relates to private sources, however.

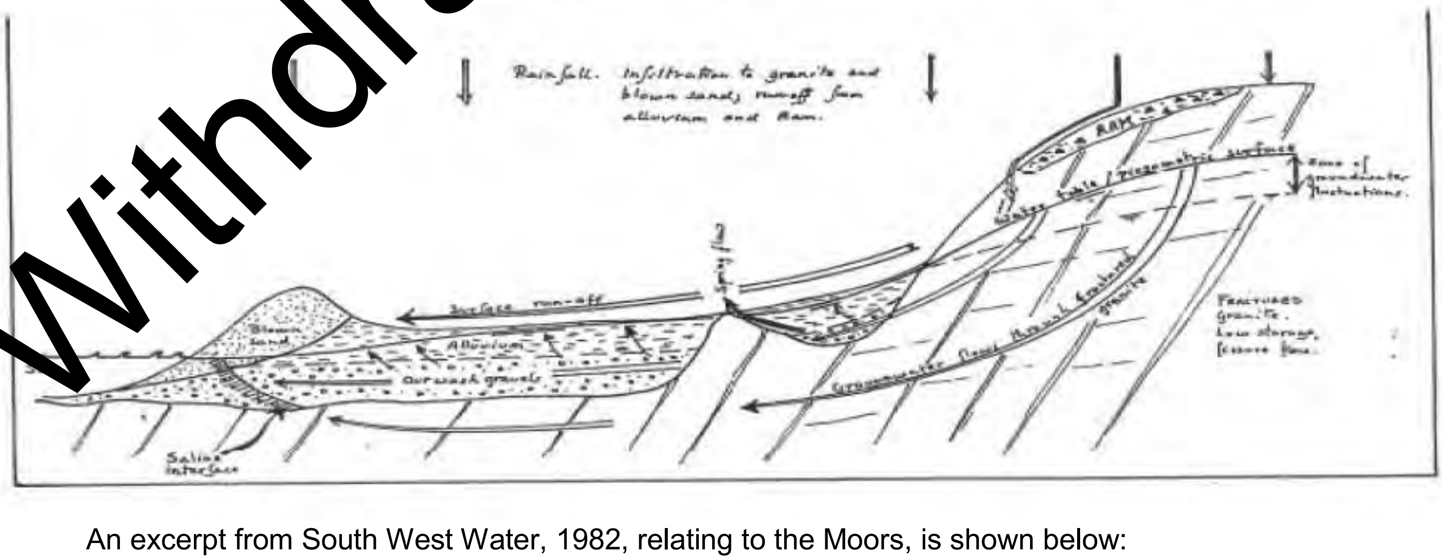
3.2. St Mary's

The Council of the Isles of Scilly abstraction boreholes are located in the Higher Moors and Lower Moors areas of St Mary's.

According to ESI (2012), the alluvial aquifers of the Lower and Higher Moors form the major groundwater catchments on St Mary's. In the Higher Moors, the drift infills a valley running from Holy Vale to Porth Hellick, and in the Lower Moors, drift covers the area bounded by Old Town Beach in the south and Porth Mellon in the west, with a tongue stretching to Porthloo. The drift infilling the granite hollows is made up of lower granitic 'head', locally known as ram, and the weathered granite layer, also known as re-worked ram, underlying a confining layer of alluvium. In the Higher Moors, sandy units of the drift deposits are considered to act as 'drainage blankets', collecting water from the underlying granite and discharging it seawards.

A diagram reproduced in ESI's report indicates groundwater flowing through the granite of the Higher Moors, from the higher land to the north towards the sea. Groundwater is also indicated flowing through outwash gravels between the alluvium and granite. Groundwater is shown flowing beneath the drift infill, and then through it at the saline interface. The diagram is shown below:

Illustration 4-1: Schematic Hydrogeological Section, St Mary's (WRc 1983)



An excerpt from South West Water, 1982, relating to the Moors, is shown below:

3.2.1. Thankfully, a significant proportion of groundwater within the granite also drains to the low-lying ground at Higher Moors and at Lower Moors, where, in following its natural flow path towards the sea, it must pass through the permeable alluvial*sands and silts which infill glacially-cut depressions in the granite bedrock(see figure 6).

3.2.2. Even though these two deposits are only a few metres thick, they form the only major aquifers on St. Mary's. The permeability of the alluvial aquifer at Higher Moors has been estimated to be in the range 5 to 20 m/d, between 10 and 50 times greater than that of the granite. Existing large diameter wells yield between 0.13 and 0.27 Ml/d (30,000 to 60,000 gpd), though it must be emphasised that these yields are not obtained by simple drainage* (dewatering) of the alluvium. Groundwater is also drawn in from the surrounding and underlying granite as pumping progressively draws down*the groundwater level in the alluvium. Alluvial sources can therefore act as a 'sink' for the major part of the granite catchments which drain to the coast through the Moors areas.

3.2.3. Within the alluvium the slope of the water table and the rate of flow are both notably different to those found in the granite because of the marked difference in their permeability. In the granite, the hydraulic gradients are generally steep though groundwater flow rates are low. In the alluvium the hydraulic gradients are extremely small but rates of flow are much faster.

Joaney's Well geological log (Appendix 4) shows that this source is 5.49 m deep and that only the final 15 cm is 'hard fissured granite'. 'Fine china clay and gravel' forms the largest thickness (2.44 m). 'Coarse gravel' and 'mixed coarse gravel and decomposed granite' together form 1.83 m of the borehole. Information included with the geological log shows a yield of up to 90 m3/d 'during sinking operations'. It states that 'immediately pumping ceased, the well commenced to fill and rose to a point [0.3 m] below normal rest level in one hour'. The pumped water level was 2.74 mbgl. 'steady pumping [up to 163 m3/d] failed to lower the water table below [2.74 mbgl]'. The information states that the borehole is supplied by granite fissures at depth [-3 mbgl]. Taken together, this information indicates that the well is supplied by very permeable strata, and that groundwater flow rates will be rapid.

Rocky Hill's geological log (Appendix 4) shows subsoil and sand from the surface to 3.81 mbgl, and decomposed granite below that, to the base of the borehole, at 10.36 mbgl.

3.3. St Martin's

ESI (2012) states that hydrogeologically St Martin's can be described in terms of two main aquifers, the granite and the blown sand, generally comprising the higher and lower lying ground respectively. Typical permeability is 0.04 m/d in the granite, and 4 m/d in the blown sand. Steep hydraulic gradients within the granite and shallow gradients in the blown sand suggest that the sand (and possibly the ram) may act as a subsurface drain. Regular dipping by Camborne School of Mines showed rest water levels in some wells fluctuating by up to 10 m between summer and winter.

3.4. Bryher

ESI (2012) state that no information has been seen on aquifer characteristics for Bryher, but that it is likely that these are very similar to the other islands.

3.5. Tresco

Barrow (1906) states that blown sand is exceptionally abundant on the island of Tresco, and that within the main sand bar on the southern part of the island is 'a depressed area containing a large fresh-water lake, the surface of which is distinctly below high-water mark, yet the sea water does not seem to filter through'.

Aquatic Water Services, 2005, states that the wells on Tresco are relatively shallow and that the blown sand is the main aquifer. Aquatic Water Services carried out pumping tests in 2004 and 2005 and state that the hydraulic conductivities calculated for Ox's Well, Wellfield Well and Bridge Field Well are moderate to high, which is representative of blown sand deposits. The report shows hydraulic conductivities ranging between 7 m/d and 13 m/d.

3.6. St Agnes

ESI (2012) report that hydrogeological conditions on St Agnes are very similar to on St Martin's. They state, however, that some studies have commented that the granite of St Agnes seems to be less permeable than that of St Martin's. ESI report a seasonal fluctuation of groundwater levels of 2 – 3 m.

4. Delineation of Source Protection Zones

4.1. General

SPZ 1 represents the 50 day groundwater travel time to a source, and SPZ 2 the 400 day groundwater travel time. SPZ 3 represents the total groundwater catchment draining towards a source.

All potable groundwater sources in England automatically have 'default' 50 m radius SPZ 1s and 250 m radius SPZ 2s. For most larger sources, 'bespoke' SPZs have been produced, using more detailed information. As a starting point for the Isles of Scilly delineation, circles of 50 m and 250 m radii were produced about the abstraction points. They were then modified, using information on the geological, hydrogeological and topographical setting. Groundwater velocities were estimated using available aquifer parameters. For the larger sources, on St Mary's, the US Environmental Protection Agency's 'WhAEM' (Wellhead Analytical Element Model) model 'simple WHPA' (Well Head Protection Area) option was used to give some additional estimates of zone size. This model is one of the standard methods used by the Environment Agency in SPZ delineation. Its use in the Isles of Scilly SPZ work is described in Appendix 1.

Due to assumed fast groundwater flow travel times (as described earlier for the islands' fissured granite, decomposed granite, gravel, alluvium and blown sand), separate SPZ 3s were not produced. The 400 day travel time zone (SPZ 2) is set equal to the total catchment zone (SPZ 3).

This report describes the delineation of SPZs for the larger groundwater abstractions on the islands, which can be seen as equivalent to public water supplies. Although SPZs for smaller, private supplies have not been drawn in this exercise, all potable abstractions do automatically have the default 50 m radius SPZ 1 and 250 m radius SPZ 2s.

The SPZs for each island are shown in Figures 1, 3, 5 and 7. Their construction is shown in Figures 2, 4, 6 and 8.

4.2. St Mary's

See Figures 1 and 2. The sources on St Mary's fall into a Higher Moors group and a lower Moors Group.

For the Higher Moors group (Carss, Hales and Venns), a combined SPZ 1 was produced for all 3 sources, and a combined SPZ 2 was produced for all 3 sources. For the Lower Moors group (Joaneys and Rocky Hill), individual zones were produced.

The SPZ 2s of the 2 groups adjoin each other. These were drawn following the topography (on the assumption that the groundwater table is a subdued version of the topography, and groundwater divides roughly follow topographic ridges), and taking the default 250 m SPZ 2 buffer as a starting point. The SPZ 2s extend to the topographic high point approximately 800 m to the north of the sources. The boundary extends through Mount Todden and Pelistry, between Maypole and Borough, and south of Porthloo. The SPZ 2s of the two groups are divided by the topographic ridge running from Rocky Hill to Maypole. The SPZ 2 area is very similar to the Source Protection Zone catchment area proposed by ESI in their 2012 study. ESI's proposed zones are reproduced in Figure 9.

It is assumed that the alluvium-infilled valley running from Holy Vale to Porth Hellick, in which the Higher Moors group of abstractions are located, forms a preferential flow path for groundwater flowing through the granite and very permeable alluvium and gravels, and discharging to the sea. To produce the SPZ 1s, aquifer properties reported from investigations on the sources were taken from ESI's 2012 study, input into a calculation to estimate groundwater flow velocity and distance travelled over 50 days, and also input into the WhAEM model. The output from WhAEM is shown in Figure 2. The values input into WhAEM are shown in Appendix 2. The length of the 50 day travel time zone obtained from the velocity calculation was 158 m. The calculation and results are shown in Appendix 3.

The combined SPZ 1 for the Higher Moors group was produced by drawing a polygon to encompass the 50 m radius default circles and WhAEM zones for each source. The lengths of the zones produced by WhAEM were around 50 m longer than those produced by the velocity calculation. SPZ 1 was then extended up-gradient around the boundary of the alluvium as the available information indicates that groundwater flow in the alluvium and underlying gravel is rapid.

Separate SPZ 2s were produced for Joaneys Well and Rocky Hill. The dividing line is a topographic ridge.

Joaneys Well SPZ 1 was produced by extending the 50 m radius circle up the valley above the source to the distance suggested by the WhAEM model output. The bedrock in valleys is generally more fractured and transmissive than on interfluves, and groundwater converges towards valleys. They therefore form preferential groundwater flow paths. The WhAEM model output is a long, thin zone, due to the high hydraulic conductivity and hydraulic gradient and low porosity values input into it.

For Rocky Hill, the SPZ 1 was drawn by extending the default 50 m radius SPZ 1 circle up to the SPZ 2 catchment divide. The WhAEM output suggested a longer distance than this, but there is insufficient additional evidence for extension of the zone beyond the topographic divide. Note that the groundwater flow direction is a specified, single input parameter to the model. The output will therefore be a straight line, and will not bend with the curve of e.g. a valley.

4.3. St Martin's

See Figures 3 and 4. The 6 Duchy of Cornwall sources on St Martin's are located on or close to the top of the ridge which runs the length of the island. Assuming that the groundwater catchments are roughly equivalent to the topographic catchments, this means that the up-gradient catchment areas will be small.

The 2 Higher Town boreholes are close together (approximately 23 m apart). They are located on the top of a fairly flat area of the topographic ridge, and their average abstraction rates (1.5 m3/d combined 2008 – 2015) are low. Their catchments are likely to be small. SPZ 1 was delineated by merging the 50 m radius circles about each borehole. SPZ 2 was delineated by merging the 250 m radius circles about each borehole, and adding a small area of higher ground to the north of the sources.

A combined SPZ 2 was produced for the Lower Town and Middle Town boreholes. The 50 m radius circles were extended the short distances to the topographic divide in the up-gradient direction. One of the Middle Town boreholes is directly up-gradient of the other, and the SPZ 1s for these 2 sources were combined.

4.4. Tresco

The 250 m default SPZ 2 radii extended to close to the topographic divides up-gradient of the sources. Where the circles did not reach a divide, the SPZ was extended to it.

Results from the groundwater velocity equation were used to assist in drawing SPZ 1s. The same parameters were used as were used for the St Mary's sources, except that a hydraulic conductivity of 0.47, reported by ESI, 2012 for St Martin's was taken, and hydraulic gradients were estimated for the area close to each source. The results showed 50 day travel time distances beyond the topographic divides for all sources but Ox's Well. SPZ 1 was drawn to the topographic divides for all sources but Ox's Well.

Ox's Well is located in an area of mapped blown sand. The permeability of the blown sand is reported to be high. SPZ 1 was drawn by extending the 50 m radius default circle in the up-gradient direction as far as the edge of the outcrop of the mapped blown sand.

4.5. Bryher

Since the island is small, the 250 m SPZ 2 default radii extended beyond any catchment divides. The groundwater velocity equation was applied as described in the section on Tresco above. It gave distances beyond topographic divides, so the SPZ 1s were drawn to the topographic divides.

4.6. St Agnes

A single SPZ 2 was drawn for the 4 Duchy of Cornwall sources on this small island. SPZ 1s were drawn by extending the default 50 m radius circles the short distances to groundwater divides.

5. Confidence in Source Protection Zone boundaries, and potential for further work

Topographic catchment boundaries were the main means of delineating the SPZ total catchment zones. However, it is possible for groundwater catchments to differ from and extend beyond topographic catchments. There is potential for this to happen in the granite due to fractures forming preferential groundwater pathways. The British Geological Survey (BGS) geological memoir (Barrow, 1906), mentions, 'a series of cracks or fissure lines trending slightly west of north'. Barrow states that 'they have an important bearing on the configuration of the islands, and on the production of the water-ways into the interior sea'. There was not sufficient information on the fractures for this piece of information to have a bearing on the delineation of the SPZs, however.

The most recent geological mapping of the Isles of Scilly was carried out by the BGS in 1906. In response to an enquiry on the potential for re-mapping, the BGS stated that they could provide more detail on joint (fracture) patterns, and could more accurately delineate the extent of the superficial deposits and weathered granite. Re-mapping would contribute to an improved understanding of groundwater flow patterns. This would aid in any future update of the SPZs, and also in the Environment Agency's permitting and incident response roles.

This report describes the delineation of Source Protection Zones for the Isles of Scilly's larger groundwater sources, which can be seen as equivalent to public water supplies on the mainland. This work could be extended in future to include drawing SPZs for smaller, private potable abstractions. Due to the large concentrations of private abstractions on the islands, the mapped SPZs would cover a large land area. Although the Environment Agency has not drawn SPZs for the Isles of Scilly's private supplies through the exercise described in this report, the 50 m radius default SPZ 1 and 250 m radius default SPZ 2 do automatically exist for all private supplies there.

6. Figures

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Figure 1: St Mary's Source Protection Zones

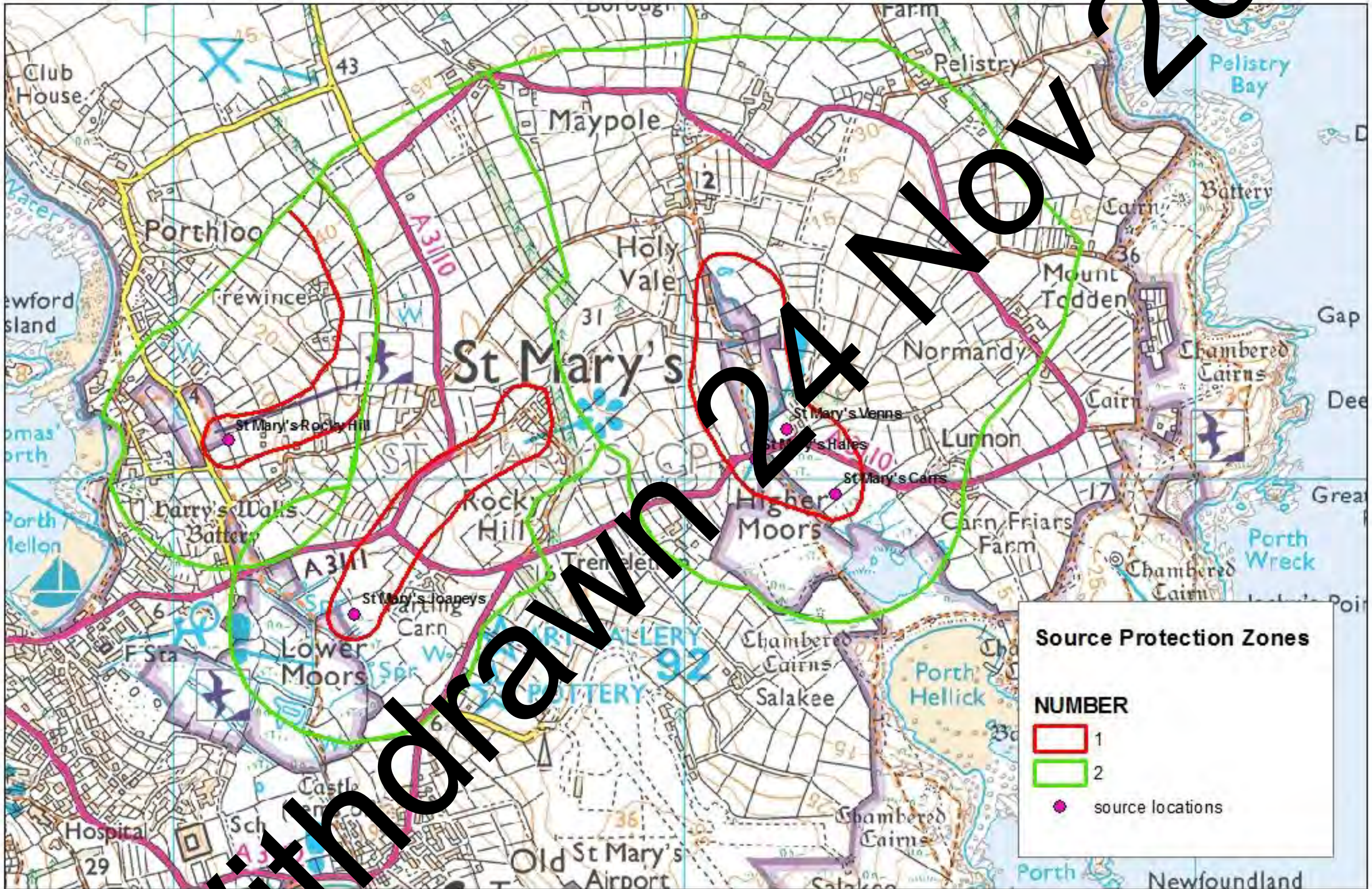


Figure 2: St Mary's Source Protection Zone construction

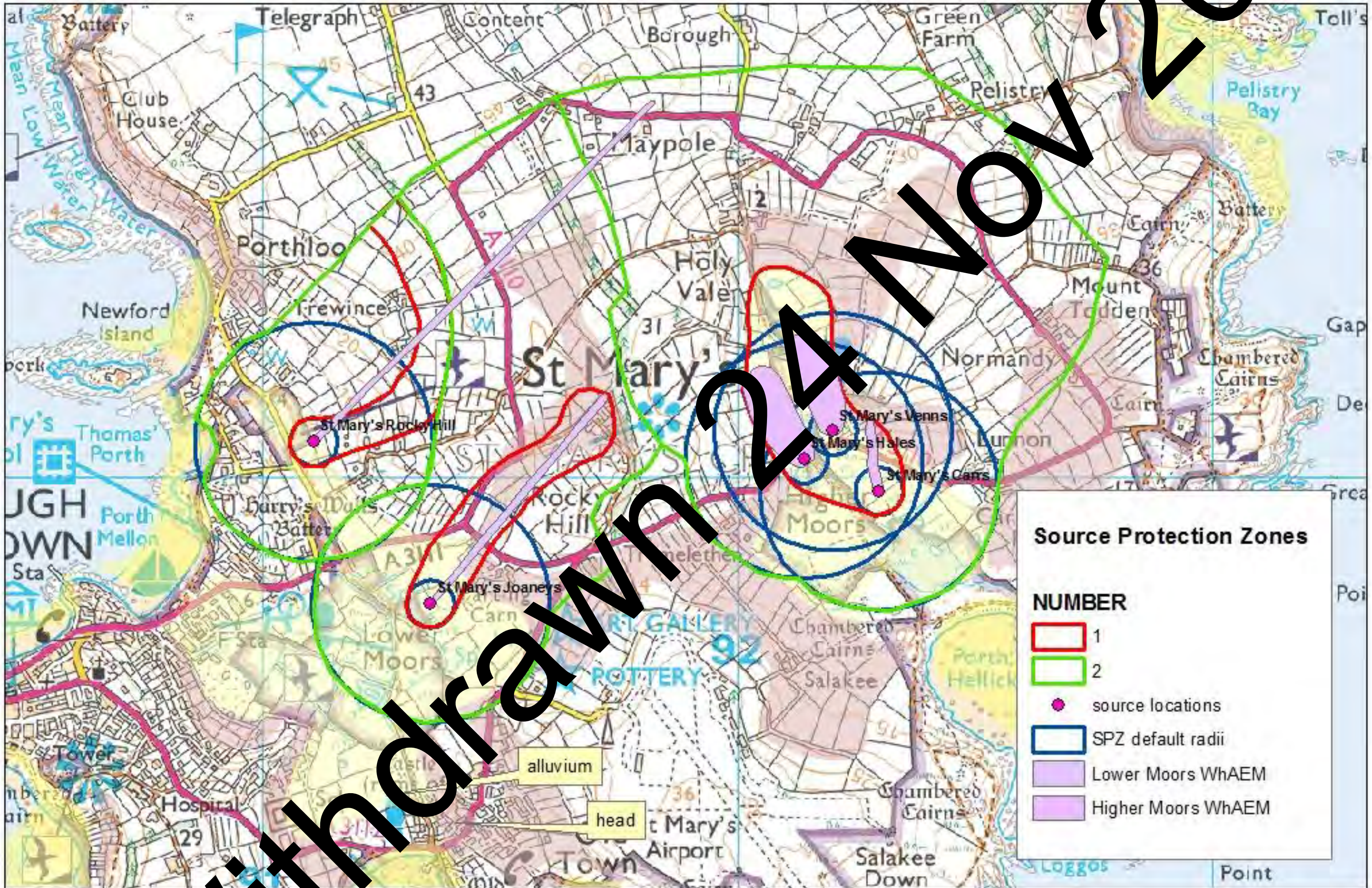


Figure 3: St Martin's Source Protection Zones

Figure 4: St Martin's SPZ construction

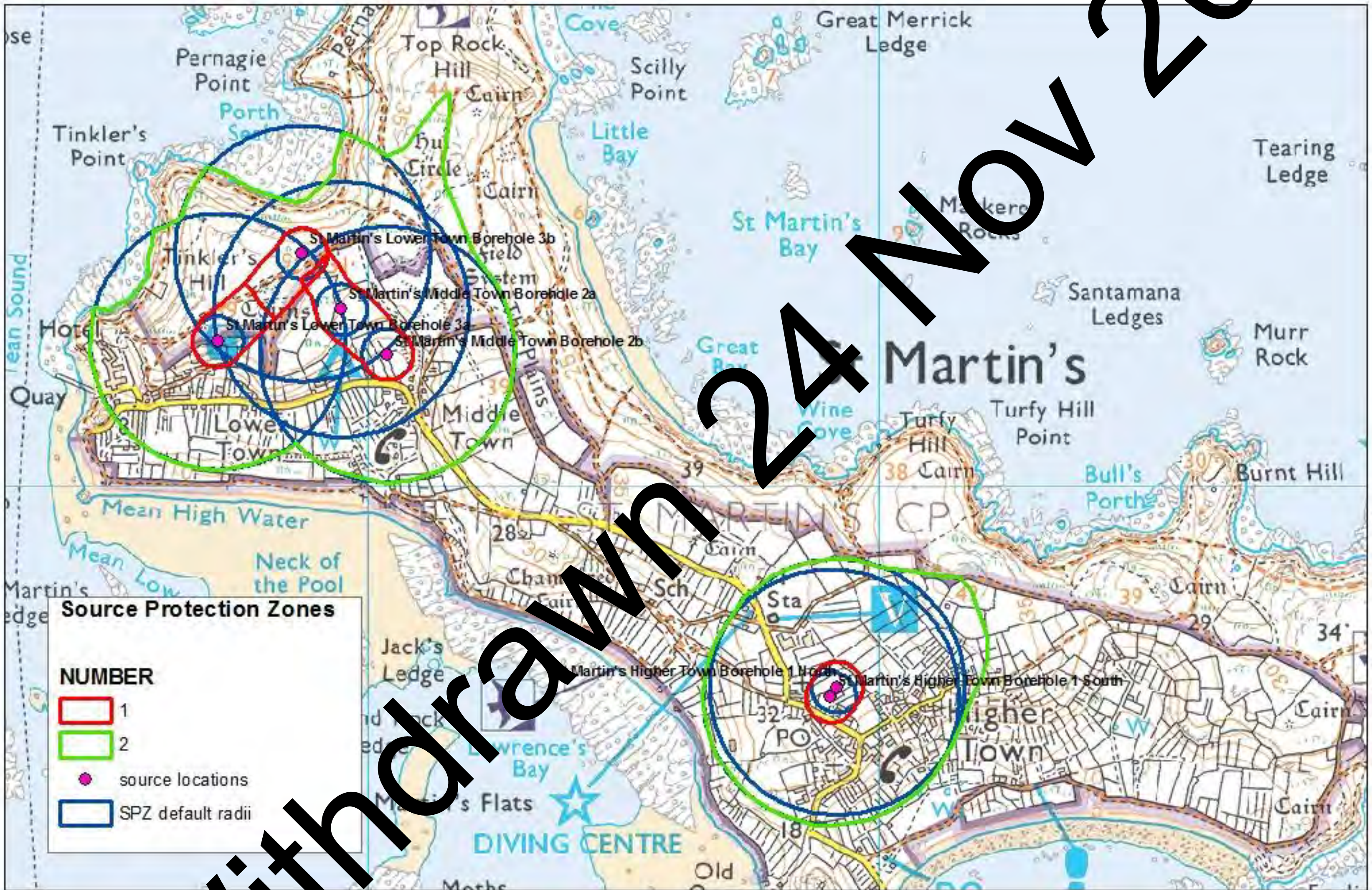


Figure 5: Tresco and Bryher Source Protection Zones

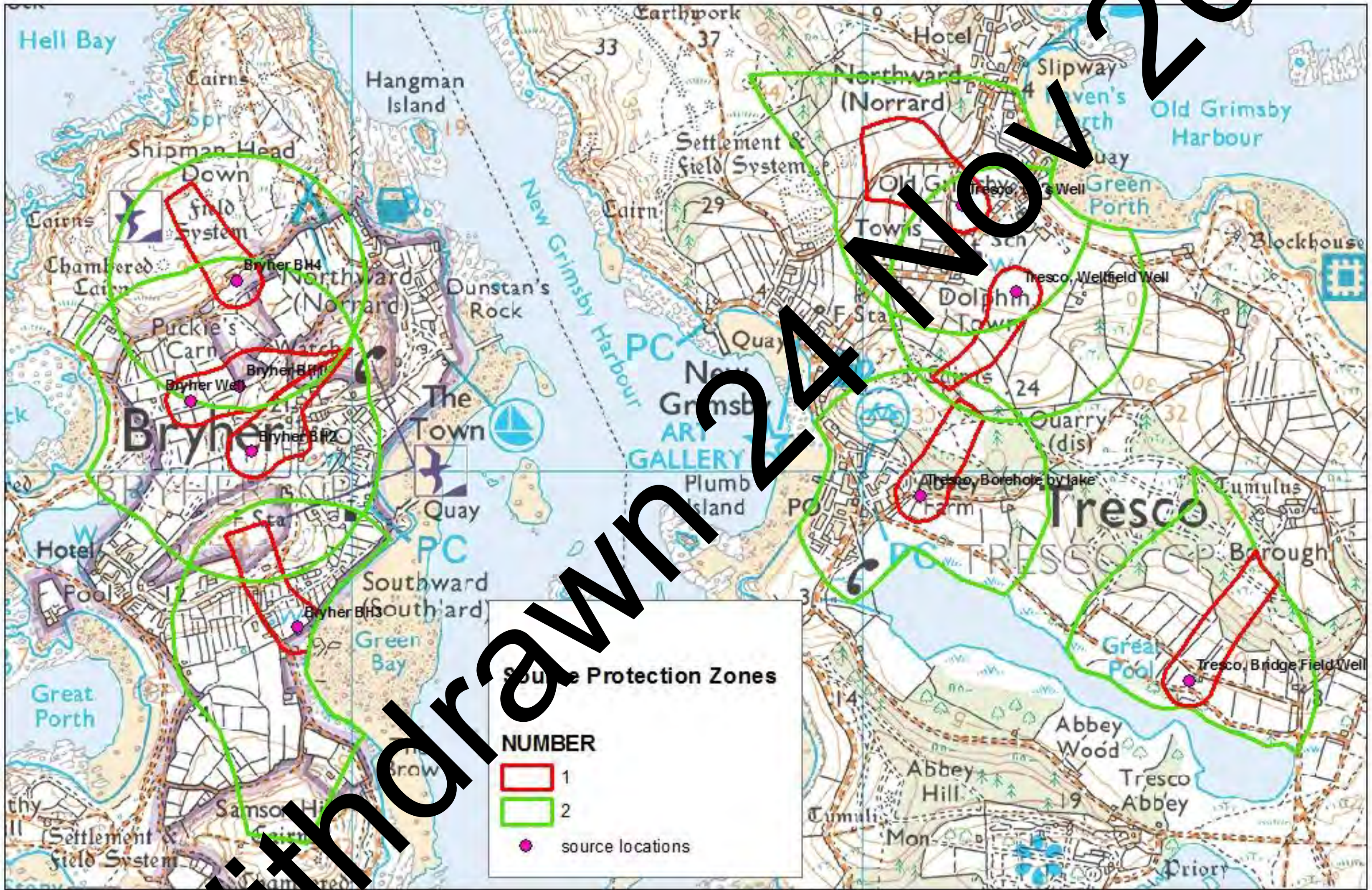


Figure 6: Tresco and Bryher SPZ construction

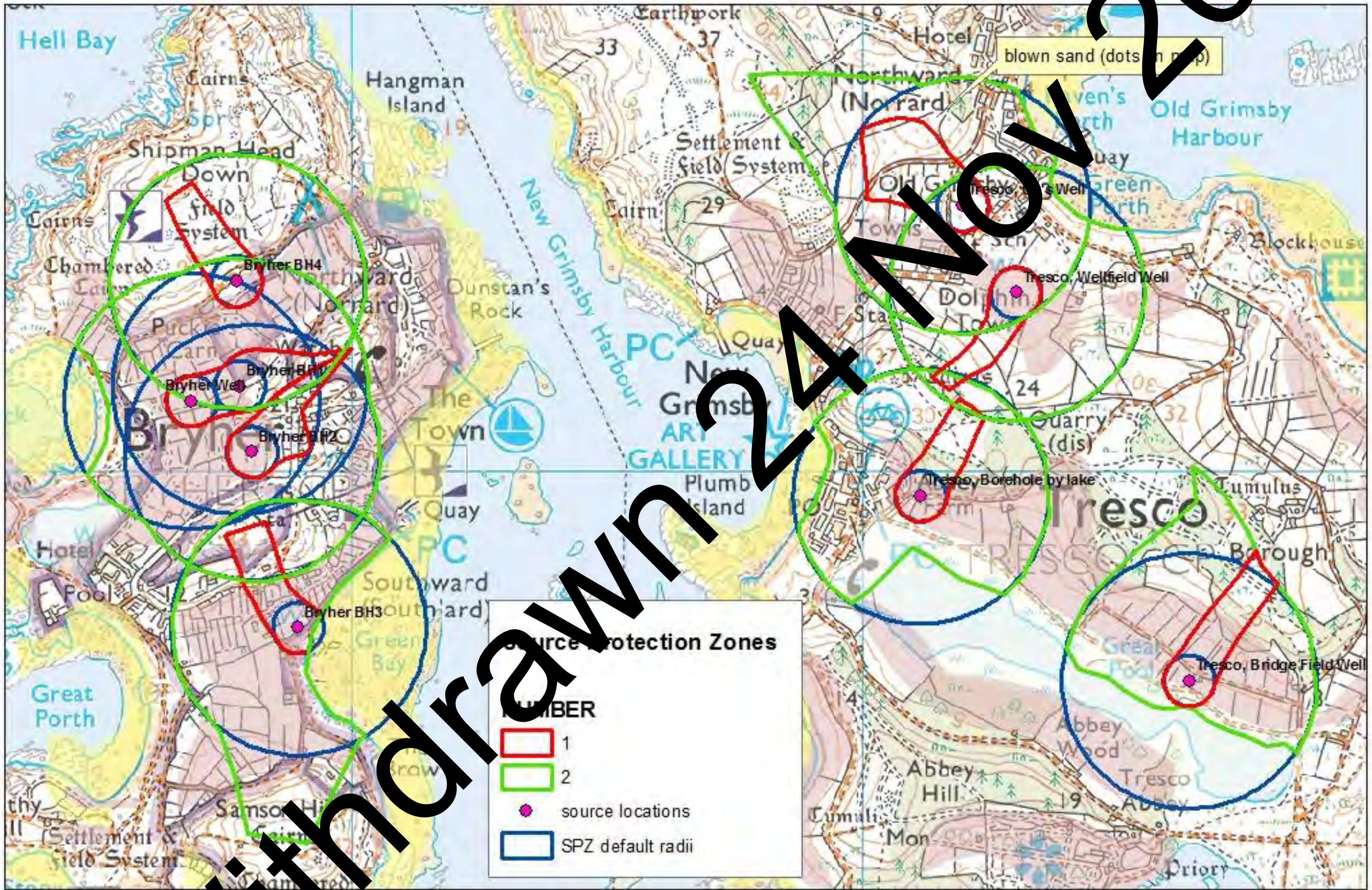
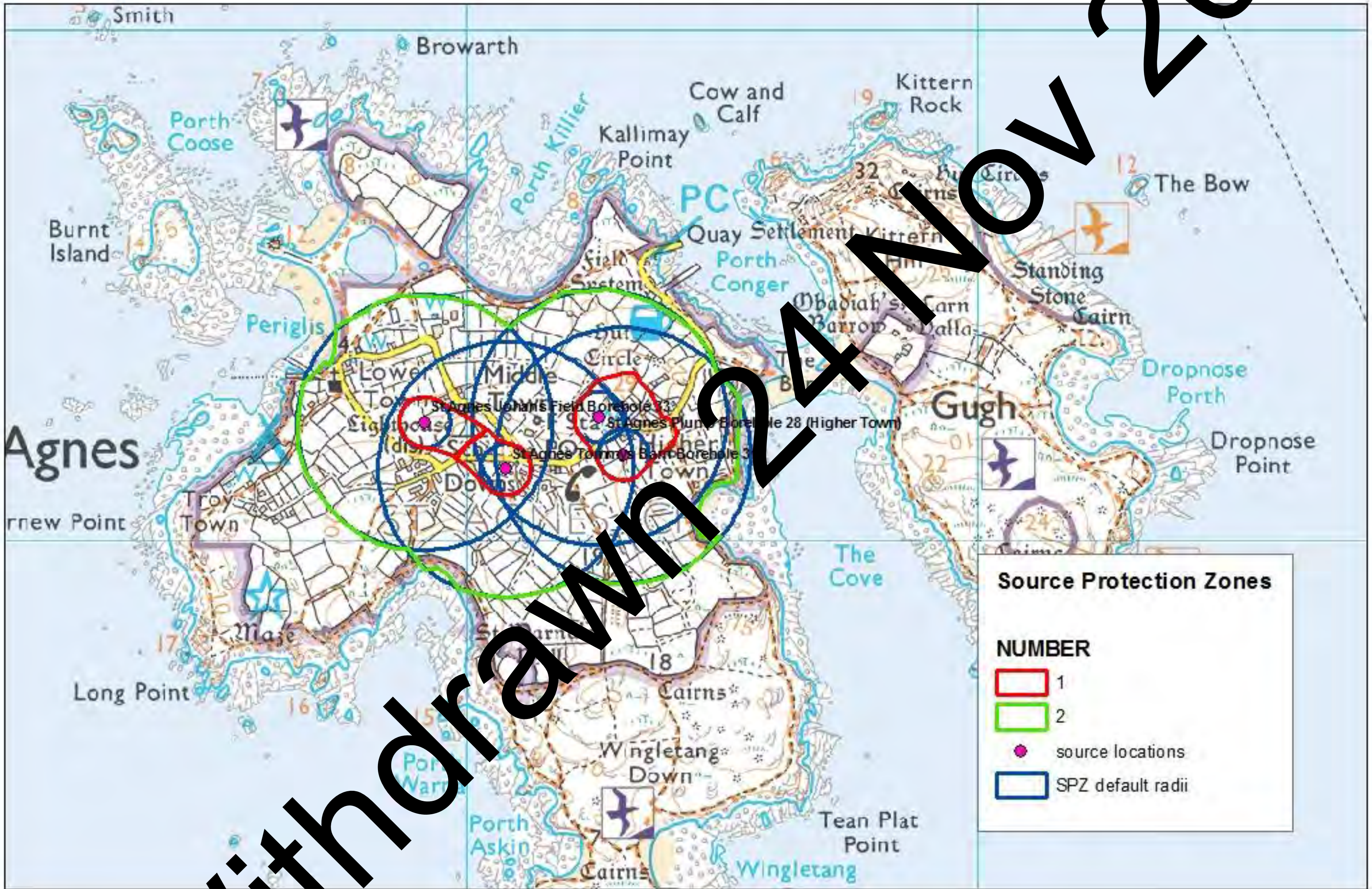


Figure 7: St Agnes Source Protection Zones

Figure 8: St Agnes SPZ construction



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8. Appendices

Appendix 1 – WhAEM model

The US Environmental Protection Agency's 'Wellhead Analytical Element Model' (WhAEM) 'simple WHPA' (Well Head Protection Area) option was used to assist in producing SPZ 1s for the sources on St Mary's. This option implements Jacob and Bear's (1965) solution for finding the down-gradient stagnation point and the width of the area from which groundwater is drawn towards a well. It is able to solve the equation in such a way as to give travel time zones, and hence also gives up-gradient capture zone extents.

Appendix 2 - values input into WhAEM:

The values input for the Higher Moors group are listed below:

Aquifer parameter	value	Source of information
Hydraulic gradient (i)	0.019	estimated from topographic contours shown on 1:25k scale OS map
Porosity	0.006	ESI, 2012
Ambient flow	0.95 m/d	k*h*I (k*h = transmissivity, which was given as 50 m2/d in ESI, 2012). i was estimated from topographic contours to be 0.019.
Aquifer thickness (h)	50 m	estimated

The same values were used for the Lower Moors abstractions, except that ambient flow was calculated using a transmissivity of 112 m2/d (ESI, 2012), an i of 0.03 was used for Jo[illegible]eys and 0.05 for Rocky Hill.

Appendix 3

A groundwater velocity equation was used to assist in producing the SPZ 1s.

The equation: SPZ 1 length = 50ki/ne was used, where:

K = hydraulic conductivity

i = hydraulic gradient

ne = porosity

The values used in, and calculated by the equation for the Higher Moors group are shown in the table below:

aquifer parameter	value	notes
K (m/d)	1.00	a transmissivity of 50 m3/d (ESI, 2012), divided by an estimated aquifer thickness of 50m
i (dimensionless)	0.019	estimated from topographic contours shown on 1:25k scale OS map
ne (dimensionless)	0.006	ESI, 2012
time (d)	50.00	
Velocity (m/d)	3.17	Calculated by equation
Distance (m)	158	Calculated by equation

Appendix 4 – geological and construction logs

Joaneys Well

From M/H File 657/9819 –

IOS/5 SV91/1?

To be furnished in Triplicate

"Barneys Well"

20 ft. east of well named as "Aunt Joaney's well" on 6" Cornwall 87 SE/W

WELLS AND BOREHOLES

Information to be supplied to the Ministry of Health

SV 9138 1076

Name of District	St. Mary's Isle Scilly.
If the District is a Rural District, name of Contributory Place concerned	–
Level of surface of ground above Ordnance Datum	10.? ?.
Depth and diameter of shaft or boring, or of each	6'0" internal di
Depth or depths at which water was found	at ?.80 O.D.
Estimated Quantity of Water required in Gallons per day	?esent about 15, G.p. 24 hours. Ultimately - esti 40,000 gals.per
Yield of water in gallons per diem, as ascertained by continuous pumping during days or otherwise	
Level of water above Ordnance Datum at commencement of pumping	6.80 O.D.
Level of water above Ordnance Datum at cessation of pumping	- 0.50 O.D.
Time taken for water to return to original rest level after pumping ceased	Pumping continued ?ced town(see tab ted statement).
A tabulated Statement should be sent showing the quantity of water pumped in each 24 hours during the duration of the test together with the level of the water above Ordnance Datum at the end of each day. If there should be any stoppage, the reason and duration should be stated.	Note: Test pumping took place after 300,000 gals.had pumped to waste du well sinking.
Limit of deviation from vertical as specified in inches per 100 feet	Nil.
Deviation as ascertained by measurement.	Nil.
Distances of the well or borehole from any other known wells or boreholes in the neighbourhood	120 yds.
Quality. (Copies of chemical and bacteriological analyses should be annexed. Information as to the mineral constituents of the water is desirable)	attached.
A 6" to the mile Ordnance map showing (in red) the precise situation of the well or borehole	See plan, not attached.
Date of Completion of well or borehole	8/9/1944
Well or borehole sunk by	St. Just Engineering

Signed J. H. Wright.

Date 23rd Dec. 1944

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A description of the Strata pierced should be given as follows:-

	Thickness of each Stratum		Total depths from the surface	
	Feet	Inches	Feet	Inches
Meat Earth		6		6
Mixed China Clay	1	6	2	0
Fine China Clay and gravel.	8	0	10	0
Coarse Gravel	3	6	13	6
Mixed Coarse Gravel	2	6	16	0
and decomposed granite	1	6	17	6
Hard fissured granite.		6	18	0

RECORD OF WELL (SHAFT OR BORE)

(attach copy of analysis if available)

For Survey use only

No. SV91/22

IOS

EXACT SITE OF WELL

At ROCKYHILL

SV 9114 1111

Town or Village ST. MARYS

County ISLES OF SCILLY Six-inch quarter sheet 87 SE/W

For Mr. J HOYLE

State whether owner, tenant, builder, contractor, consultant, etc. :—

Address (if different from above)

Level of ground surface above sea-level (O.D.) ft.

If well-top is not at ground level, state how far {above; below;

SHAFT ft.; diameter ft.; Details of headings

BORE 34 ft.; diameter of bore: at top 8 ins.; at bottom 8 ins.

Details of permanent lining tubes 12ft 6ins from top

Water struck at depths of 25ft ft. below well-top

TEST CONDITIONS

Rest-level of water 4 ft. ~~above~~ below well-top. Suction at ft. Yield on hours' days'

pumping at 200 galls. per hr. with depression to 6 ft. below well-top.

Recovery to rest-level in 1 mins. ~~hours~~ Capacity of pump 200 g.p.h. Date of measurements

Description of permanent pumping equipment:

NORMAL CONDITIONS

Make and/or type Motive power

Capacity gallons per hour. Suction at ft.

Amount pumped galls. per day. Estimated consumption galls. per

Well made by Vivian & Sons Ltd Date of well 1950

Information from

ADDITIONAL NOTES

S.Ileston Cornwall 87 SE/W.

30.5.50. A.W.

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(For Survey use only) Geological Classification	Nature of Strata If measurements start below ground surface, state how far ...	Thickness Feet ...	Thickness Inches ...	Depth Feet	Depth Inches
	Subsoil & Sand from				
	surface to	12	6		
	Decomposed Granite from	12	6		
	to —	34	0		

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