

Caulmert Limited

Engineering, Environmental & Planning
Consultancy Services

Wasperton Farm Quarry

Smiths Concrete Limited

Environmental Permit Application

Hydrogeological Risk Assessment

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Hydrogeological Risk Assessment**TABLE OF CONTENTS**

1.0	INTRODUCTION	1
1.1	Background	1
1.2	Site Location and Surrounding Land Use	1
1.3	Site History and Proposed Development.....	2
2.0	HYDROGEOLOGICAL CONCEPTUAL MODEL	3
2.1	Overview	3
2.2	Source	3
2.3	Pathways.....	3
2.4	Receptor.....	6
3.0	HYDROGEOLOGICAL RISK ASSESSMENT	3
3.1	The nature of the hydrogeological risk assessment	3
3.2	Water Balance for the site	3
3.3	Proposed Attenuation Layer	4
3.4	Proposed Assessment Scenarios.....	5
3.5	Model Parameterisation	6
3.6	Model Results	8
3.7	Sensitivity Analysis.....	9
3.8	Review of Technical Precautions	10
4.0	REQUISITE SURVILLANCE	11
4.1	Leachate Monitoring.....	11
4.2	Groundwater Monitoring	11
4.3	Surface water Monitoring.....	12
5.0	CONCLUSIONS AND DISCUSSION	13
5.1	Conclusions	13

DRAWINGS

LD135-WSP-005d	Final Restoration Phases 1-12 Restored
JER8879-SI-002	Groundwater Monitoring Locations
5526-CAU-XX-XX-DR-V-1802	Sidewall Attenuation Detail

APPENDICES

Appendix 1	Hydrogeological Impact Assessment (HIA)
Appendix 2	Geological Logs
Appendix 3	HRA Models and Results
Appendix 4	Groundwater Monitoring Borehole Logs

1.0 INTRODUCTION

1.1 Background

- 1.1.1 Caulmert Limited have been appointed by Smiths Concrete Limited ('the Operator') to prepare a new bespoke environmental permit application for a waste recovery operation at Wasperton Farm Quarry ('the Site'), located within an agricultural area in the vicinity of Holloway Farm and Wasperton Farm, close to the town of Barford, Warwickshire.
- 1.1.2 This Hydrogeological Risk Assessment (HRA) has been undertaken in line with the current guidance 'Groundwater risk assessment for your environmental permit' (last updated April 2018) and guidance for deposits for recovery¹.

1.2 Site Location and Surrounding Land Use

- 1.2.1 Wasperton Farm is located between Barford and Wellesbourne, to the east of the A429. To the north of the Site is Wasperton Lane, with Barford village centre being further north of Wasperton Lane. To the east, the land rises to Wasperton Hill. To the south the land is generally flat farmland falling very gently to the Thelsford Brook. The western boundary is formed by the A429 Wellesbourne Road, with Wasperton village sitting to the west of the road between the A429 and the River Avon. The site location is presented in Figure 1 below.

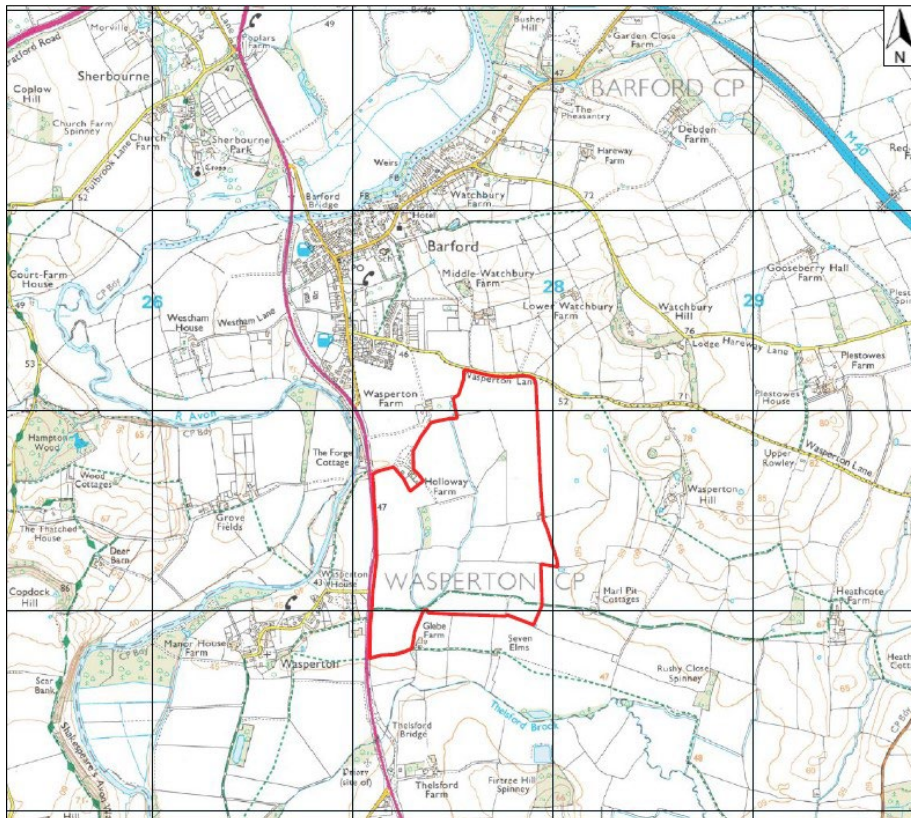


Figure 1 – Site Location (planning boundary in red)

¹ <https://www.gov.uk/government/publications/deposit-for-recovery-operators-environmental-permits/waste-recovery-plans-and-deposit-for-recovery-permits#risk-assessment-for-bespoke-deposit-for-recovery-activities>

- 1.2.2 The site is set within predominantly agricultural land. The Site is currently used for arable farming with a mix of crops being grown. Also within the Site are a number of small tree blocks, which are a mix of natural and planted areas.
- 1.2.3 The site is located within an area of relatively level topography to the east of the River Avon. Ground levels rise generally eastwards, from approximately 45mAOD in the west to 47mAOD in the east of the site.

1.3 Site History and Proposed Development

- 1.3.1 The Wasperton Farm Site is predominantly rural comprising two farmhouses and a range of assorted aged farm buildings. Wasperton Farmhouse is Grade II listed. The Site area has been in continual agricultural use since at least 1995 (according to Google Earth imagery).
- 1.3.2 The proposed development consists of the extraction of sand and gravel, with the importation of up to 200,000 tonnes per annum of inert wastes to the Site as a recovery operation in order to achieve the required restoration levels stipulated within the planning application.
- 1.3.3 It is proposed to extract the full thickness of sand and gravel and process the mineral on-site. The quarry will be worked in a phased manner (a total of 12 phases), with phase 1 being worked and the resultant void sub-divided to be used as a silt settlement lagoon and freshwater lagoons.
- 1.3.4 Clay rich overburden present on the site will be stripped and temporarily stored on-site and will be used to construct an attenuation layer on the sides of the quarry void, along with use for restoration materials.
- 1.3.5 The proposed restoration scheme and phases are shown on attached drawing LD135-WSP-005d. Restoration will be concurrent with mineral extraction and imported inert material will be used to backfill the quarry void, with stripped overburden and topsoils from the site used to create the final landform. The lagoons constructed in phase 1 will not be backfilled and the waterbodies allowed to vegetate naturally. After completion of restoration, the land will be returned to agricultural use.

2.0 HYDROGEOLOGICAL CONCEPTUAL MODEL

2.1 Overview

- 2.1.1 The full conceptual model for the site, including the source, pathway and receptor linkages are presented within the Environmental Site Setting and Design (ESSD) report included with this permit application (Report Ref: 5526-CAU-XX-XX-RP-V-0303). The hydrogeological conceptual site model is summarised below.
- 2.1.2 A hydrogeological impact assessment (HIA) was previously undertaken by Hafren Water (report ref: 3242/HIA) as part of the planning application. This presented the hydrogeological conceptual model and assessed the impacts of the quarrying operations and restoration on the surrounding groundwater environment. The full report is included in Appendix 1.
- 2.1.3 This HRA report will assess the risks of the placement and potential contaminating components from the proposed inert restoration materials to be imported and used at the site.

2.2 Source

- 2.2.1 The proposed operation is to be the importation of inert restoration materials only, as detailed in the ESSD report.
- 2.2.2 The potential source of contamination at the site is taken to be the imported inert restoration materials. Infiltrating water from rainfall will pass out the sides of the side. As water flushes through the restoration material, the source term concentrations will decline at a rate governed by the infiltration flux. A water balance for the site is included in Section 3.2 of this HRA.
- 2.2.3 Permitted wastes to be accepted at the site into the proposed operation will be strictly inert and the potential impact from the placement of restoration soils within the Site is considered to be minor.

2.3 Pathways

- 2.3.1 In order to understand the pathways at the site, an investigation into the geology and hydrogeology has been undertaken, using available online data and site-specific data.

Geology

Regional Geology

- 2.3.2 The superficial deposits in the region are associated predominantly with the River Avon and situated on lower elevations. The superficial deposits comprise Alluvium, River Terrace 1 and River Terrace 2 deposits. The Alluvium generally comprises a mixture of clay, silt, sand and gravel. The River Terrace deposits comprise sand and gravel and local lenses of silt, clay or

peat. The site is indicated to be entirely underlain by the River Terrace 2 deposits, which comprises the mineral (sand and gravel) to be extracted.

- 2.3.3 The bedrock geology comprises marls and mudstones of the Mercia Mudstone Group. The thickness of this unit in the area is indicated to be up to 100m.

Local Geology

- 2.3.4 A total of 68 mineral investigation boreholes have been drilled at the site, geological logs and cross sections are included in appendix 2. Topsoil and overburden were encountered down to between 0.6 metres below ground level (mbgl) (44.18 mAOD) and 3.6 mbgl (42.41 mAOD) comprising clay, sandy clay, sandy silt or clayey silt.
- 2.3.5 Sand and gravel was encountered between 40.6 mAOD and 42.74 mAOD, with an average thickness of 2.3m. The upper units of the mineral deposit comprise sand with varying contents of silt, clay and gravel. Towards the base, the strata predominately comprises of sand and gravel.
- 2.3.6 Sand and gravel was absent within seven of the mineral investigation boreholes drilled in the northeast of the site. This site-specific data differs from the boundary defined on BGS mapping, indicating that the lateral limit of the sand and gravel deposit occurs within the site boundary.
- 2.3.7 Bedrock was encountered directly beneath the sand and gravel and was recorded as either a mudstone or firm to stiff clay.

Hydrogeology

- 2.3.8 The superficial deposits (sand and gravel) are designated by the Environment Agency as a Secondary A Aquifer. These are layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.
- 2.3.9 The bedrock underlying the site, the Mercia Mudstone, is designated a Secondary B aquifer. These are defined as mainly lower permeability layers that may store and yield limited amounts of groundwater through characteristics like thin cracks (called fissures) and openings or eroded layers.
- 2.3.10 The site is not located within a groundwater Source Protection Zone (SPZ), the nearest located 570m south of the site.

Groundwater Levels

- 2.3.11 Water strikes were recorded in 55 of the 68 mineral investigation boreholes. Generally, two water strikes were encountered, the first representing perched water within the overburden and the second within the sand and gravel deposits. The water strikes were at or close to the top of the sand and gravel strata and ranged between 1.4 mbgl and 2.3 mbgl.

2.3.12 Monitoring standpipes were installed within four of the mineral investigation boreholes drilled in 2019, with an additional five monitoring locations installed in 2020. Hydrographs are available for water level records from 2019 to 2023 (Figure 2 below). The data indicates that groundwater levels show a similar pattern in all monitoring locations, with some seasonal change evident, with lower levels reported in the summer months, and increasing in winter months following higher amounts of rainfall.

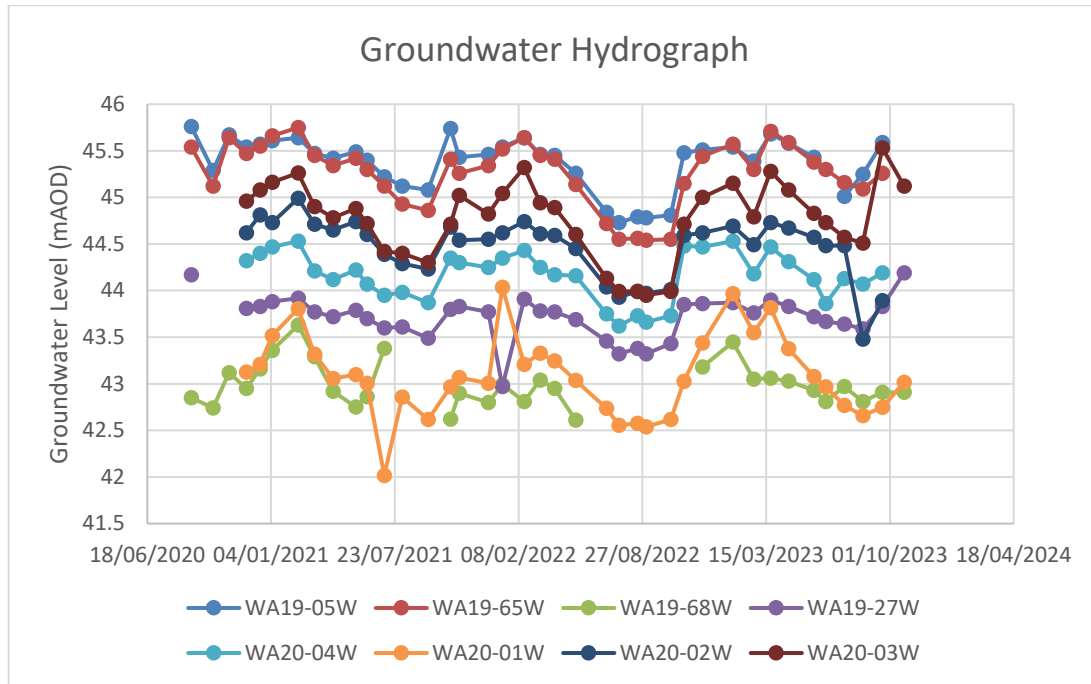
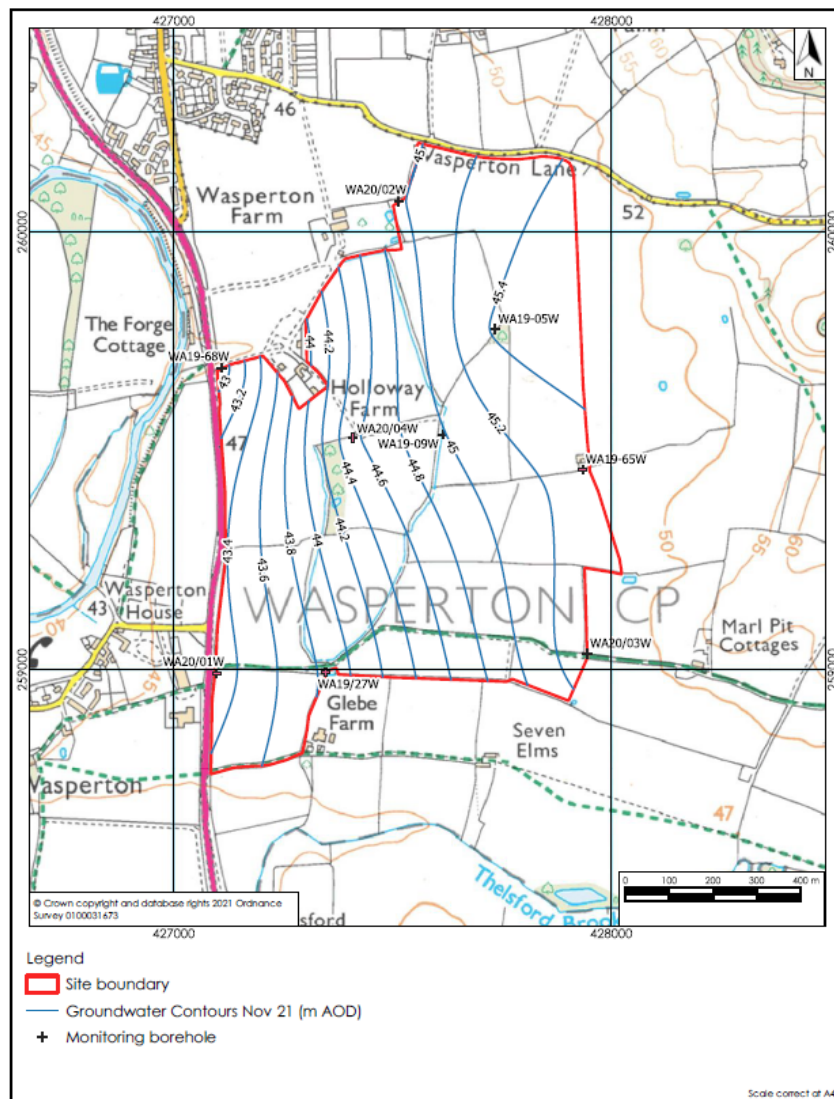


Figure 2 - Groundwater Hydrograph

2.3.13 The data indicates that groundwater flow is westwards, towards the River Avon. Groundwater contours are shown in Figure 3 below:

Figure 3 - Groundwater contours.

2.3.14 Due to the lateral extent of the sand and gravel within the site boundary, it is considered there is no pathway/receptor towards the east/north east.

2.4 Receptor

Groundwater

2.4.1 The groundwater receptors considered within this assessment consists of the sand and gravel Secondary A Aquifer adjacent to the site.

2.4.2 The nearest groundwater abstractions are not considered receptors due to their distance from the site and that they are hydraulically isolated from the site due to their location on a different aquifer to the site.

Surface Water

2.4.3 A number of surface water features are present within the area and are described in the hydrogeological impact assessment included in Appendix 1 and included on the drawing extract below (Figure 4). The following surface water features are considered potential receptors:

- The nearest named watercourse is the River Avon which is located approximately 100m west of the site at its closest point.
- A tributary to the River Avon, Thelsford Brook passes 170m to the south of the site, flowing westwards towards the River Avon.
- A number of small ponds (W1-6) with associated drainage ditches are present across the site. Levels recorded within these indicate these are all in continuity with groundwater elevations and therefore likely to be in hydraulic continuity with the groundwater.
- A number of surface water abstractions are also present within 2km of the site boundary (shown on Figure 4 below). The closest is located approximately 100m west of the site boundary, abstracting from the River Avon.

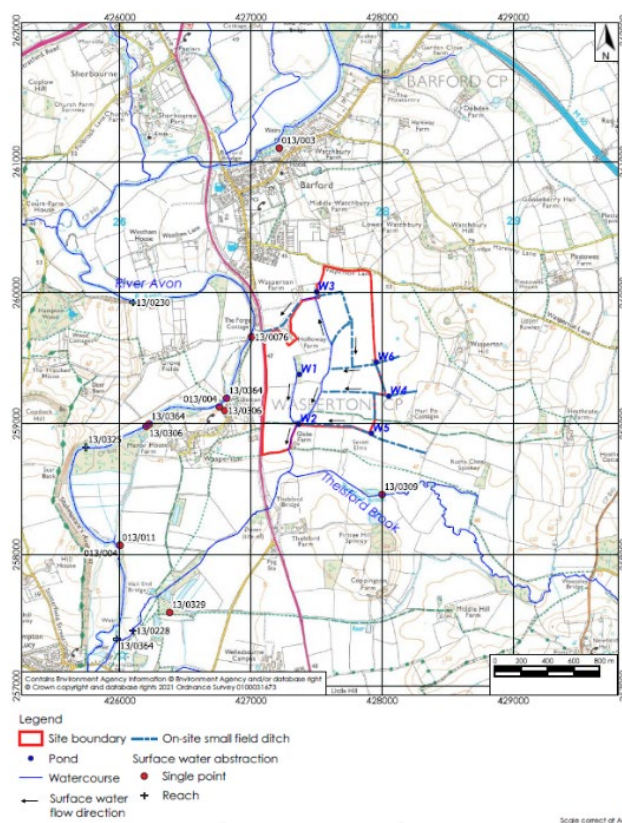


Figure 4. Surface water features and abstractions surrounding the site

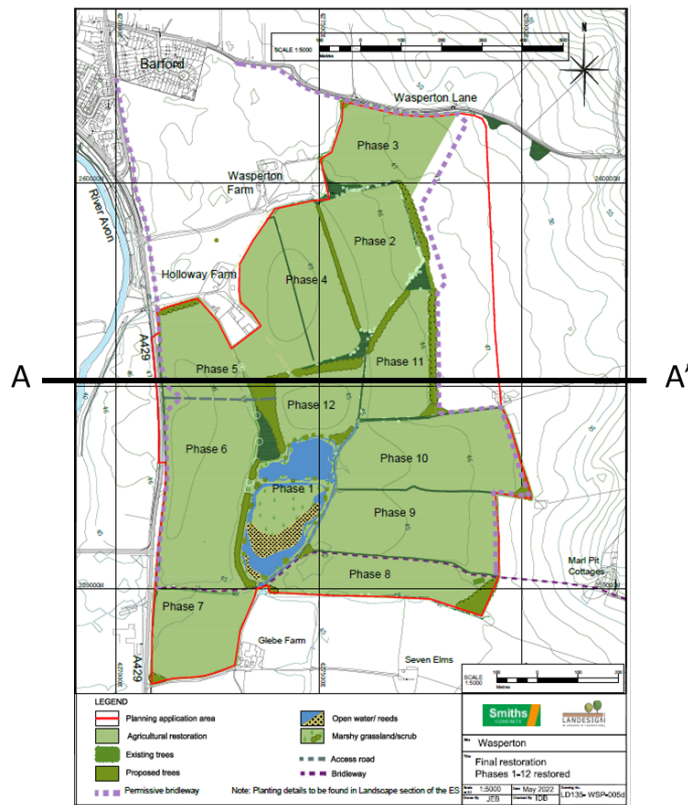
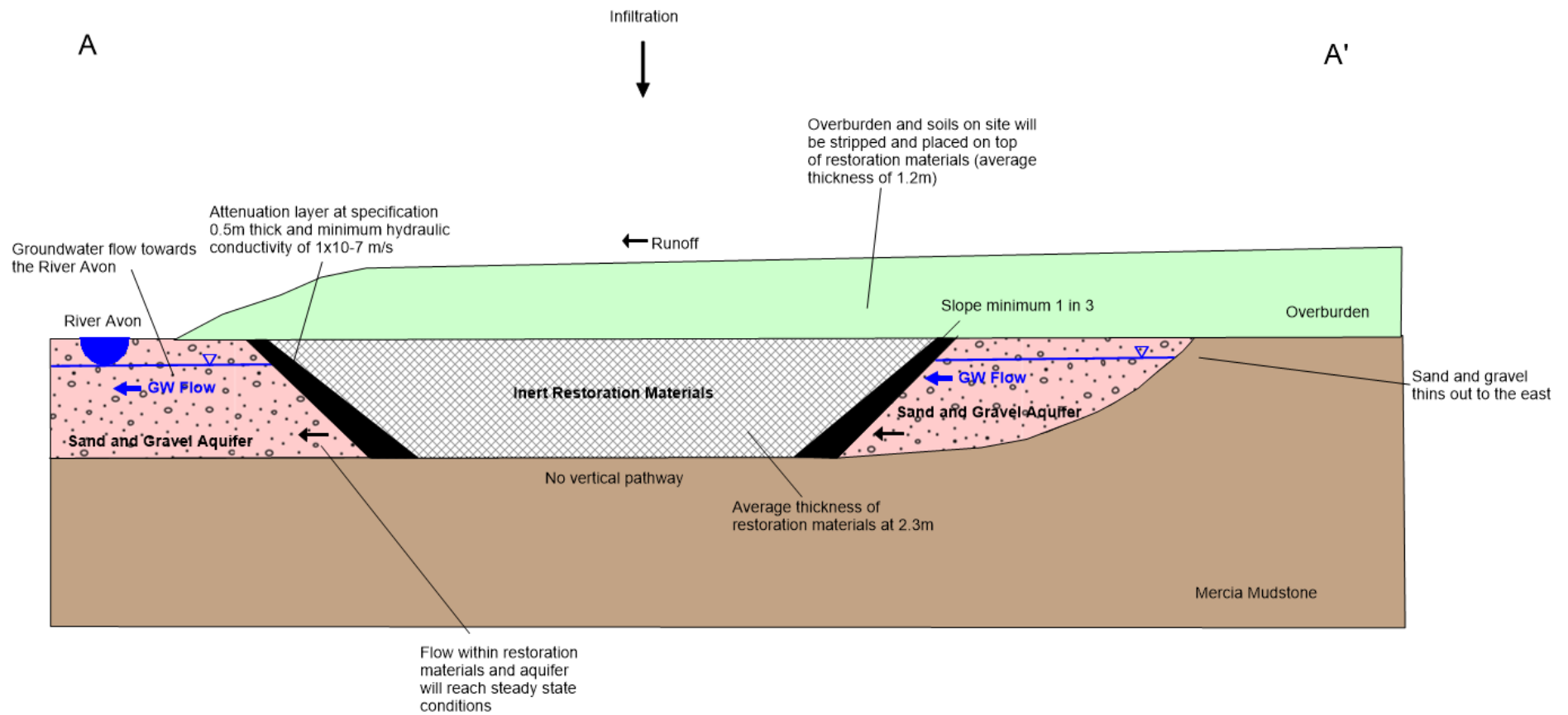
**Figure 5. Cross Section Line**

Figure 6. Schematic Hydrogeological Conceptual Site Model

Note. Not to scale and vertically exaggerated

3.0 HYDROGEOLOGICAL RISK ASSESSMENT

3.1 The nature of the hydrogeological risk assessment

3.1.1 The hydrogeological conceptual model presented in section 2 above indicates the following:

- The sand and gravel is the main groundwater bearing unit and is designated a Secondary A aquifer.
- The sand and gravel is underlain by the Mercia Mudstone, which has a low hydraulic conductivity and therefore it is considered there will be no vertical pathway beneath the base of the site.
- Groundwater flow is to the west, towards the River Avon, indicating that groundwater within the sand and gravel aquifer and the river are in hydraulic continuity.
- The sand and gravel aquifer is laterally confined by the topography to the east and by the River Avon to the north and west.
- The sand and gravel will be worked 'dry' at the site, which will require dewatering due to the presence of groundwater within the mineral deposits. The Site will then be restored progressively to agricultural land using imported inert fill and site-derived overburden, deposited into the dewatered voids. No materials will be deposited into water.
- Following completion of restoration, groundwater levels will be allowed to rebound and flow within the inert materials will reach steady state conditions.
- The placement of clay-rich site-won overburden on top of the inert restoration materials will be integrated into the final landform and therefore the amount of runoff and infiltration is unlikely to significantly change following completion of restoration.

3.1.2 Although the quarry will be worked dry, based on the natural surrounding groundwater levels, the inert restoration materials will be sub water table, following the rebound of groundwater levels at the site. Therefore, a detailed quantitative risk assessment has been undertaken, using standard hydrogeological equations using excel add in, probabilistic modelling tool Crystal Ball.

3.1.3 It is proposed as part of the site operation to install an attenuation layer on the sides of the quarry void adjacent to the surrounding sand and gravel aquifer. As there is no vertical pathway, it is considered no attenuation layer is required on the base. The attenuation layer will be constructed using clay rich overburden materials present on-site and suitable imported inert materials where required. The requirements for the imported inert materials is discussed in section 3.3 below. As a conservative approach the attenuation layer has been modelled using a 0.5m thickness, with a minimum hydraulic conductivity of 1×10^{-7} m/s.

3.2 Water Balance for the site

3.2.1 The HIA (see Appendix 1) completed as part of the planning application looked at the potential impact on groundwater flows and quality surrounding the site. The water balance at the site indicates the following:

- Rainfall will fall onto the ground surface, where a proportion will infiltrate the restoration soils and the remaining will run-off the site surface. Infiltration to the restoration soils will be subject to evapo-transpiration. Any water running off the site surface is considered to infiltrate the aquifer at the site perimeter.
- The inert restoration material is likely to be less permeable than the surrounding sand and gravel aquifer. As low permeability Mercia Mudstone lies beneath the site, it is likely a 'leachate head' may be present within the inert materials due to recharge at the site, which will have the potential to discharge from the sides of the site through the attenuation layer.
- Following rebound of the surrounding groundwater levels, it is considered steady state conditions will be achieved where the generation of 'leachate' within the restoration materials is limited to the amount of infiltration through the surface of the materials.
- During mineral extraction dewatering is considered likely to only impact the water features internally and immediately adjacent to the site. However, as these features are both groundwater and run-off supported, the impacts are likely to be minor.
- Following restoration, any decrease in groundwater recharge is anticipated to be balanced by increased run-off. As the ditches will be retained, they are connected with the waterbodies, and ultimately convey water to the same watercourse that the groundwater discharges to, the overall impact to the surrounding water balance will be minor.

3.3 Proposed Attenuation Layer

- 3.3.1 It is proposed to install an attenuation layer on the sides of the quarry void adjacent to the surrounding sand and gravel aquifer. The attenuation layer will be constructed using clay-rich overburden materials present on site and suitable imported inert materials where required. The applicant does not currently have access to the site and so are unable to undertake minerals testing on the overburden to confirm suitability and therefore, this will be undertaken prior to operations commencing at the site and will be presented as evidence supporting the CQA plan.
- 3.3.2 The site investigation into the mineral at the site indicated there will be sufficient overburden present on site to undertake the required side wall engineering, however as the operation will be undertaken in strict phases there is the possibility that there may be a shortage of material for some phases and therefore the option of suitable imported materials may be required. If imported materials are required for the attenuation layer, these will not be used prior to approval from the Environment Agency on the physical and geochemical suitability for use. Waste Acceptance Criteria for imported soils will be based on the geochemistry of the geology of the site (soils overburden) and the justification of the proposed WAC will be submitted as part of a pre-operational condition, to the EA prior to acceptance of any soils used for the attenuation layer.

- 3.3.3 The underlying Mercia mudstone is considered an unproductive aquifer (non-aquifer) and effectively impermeable.² It is therefore considered that due to the low permeability nature, leakage rates from the proposed restoration materials within the underlying Mercia Mudstone would be insignificant and therefore there is no identified vertical pathway beneath the site. It is therefore considered no attenuation layer is required on the base. The sidewall attenuation layer will be engineered with an anchor trench keyed into the underlying Mercia mudstone to cut off any preferential pathways (see drawing 5526-CAU-XX-XX-DR-V1802) for engineering details).
- 3.3.4 As a conservative approach the attenuation layer has been modelled using a 0.5m thickness, with a minimum hydraulic conductivity of 1×10^{-7} m/s.

3.4 Proposed Assessment Scenarios

Lifecycle Phases

- 3.4.1 There will be no active leachate management at the site, as it is considered that no significant amount of leachate will be generated within the site. Therefore, no active management phase will be considered within the assessment.
- 3.4.2 During the operational phase whilst groundwater is being pumped from the surrounding aquifer, it is considered limited leachate will be generated during this phase and any recharge through the sidewalls/attenuation layer will be pumped via the groundwater pumping system.
- 3.4.3 There will be no cap or artificial sealing liner installed at the site, as such there is no consideration of deterioration of these components included within the model. Clay-rich soils and overburden will be stripped from the site and will be placed on top of the inert restoration materials as part of the final restoration profile.
- 3.4.4 There will be no difference in the water balance or transport mechanisms and processes between the operational and post-restoration phases. Therefore, a single lifecycle phase is considered within the model.
- 3.4.5 Sensitivity analysis has been undertaken within the model to assess the impact of the hydraulic conductivity of the proposed attenuation layer and from the potential of rogue loads accepted onto site.

Model Assumptions

- 3.4.6 The model has been undertaken with the following assumptions:
- The entire waste mass is present within the model. As the site is progressively filled, the source term will gradually decline as the site is continuously filled over a number of years.

² The Physical Properties of Minor Aquifers in England and Wales (2000). *British Geological Survey Technical Report*, WD/00/4.

- Concentrations of all parameters are present at the C_0 values. It is unlikely that all source term parameters will be present at the maximum leachability concentrations and therefore this is considered a conservative approach.
- Leakage rates from the recovery materials are equal to the effective rainfall due to model steady-state conditions following groundwater level recovery.

3.5 Model Parameterisation

Site Characteristics

3.5.1 The site will consist of 12 phases which will be progressively extracted and restored to agricultural farmland. For simplicity, the site is considered to be one single phase within the model, in which all restoration materials are present within the model.

Table 1. Site Characteristic Parameters

Parameter	Value	Derivation
Perimeter of Site (length of sidewalls following completion)	2,388m	Measured from site plans
Thickness of recovery materials	2.3m	Average thickness based on current site surveys
Infiltration	275mm/yr (4.79m ³ /sec)	Effective rainfall (rainfall minus evapo-transpiration)

Source Term

3.5.2 Strict waste acceptance procedures in place at the site will ensure only suitable inert materials will be accepted as per the permit. An attenuation layer will be constructed on the sides of the site, using suitable inert restoration materials.

3.5.3 A source term which represents modern inert restoration materials has been selected and based on the C_0 values provided in Section 2.1.2.1 of European Council Decision 2003/33/EC.

Table 2. Source Term Parameters

Parameter	Value	Derivation
Ammoniacal Nitrogen	1 mg/l	Degradable material is not permitted at inert sites. Ammoniacal nitrogen has been included in case of small amounts of topsoil or other degradable material are accidentally accepted.
Chloride	460 mg/l	C_0 value from Section 2.1.2.1 of 2003/33/EC
Sulphate	1,500 mg/l	C_0 value from Section 2.1.2.1 of 2003/33/EC
Nickel	0.12 mg/l	C_0 value from Section 2.1.2.1 of 2003/33/EC

Parameter	Value	Derivation
Zinc	1.2 mg/l	C ₀ value from Section 2.1.2.1 of 2003/33/EC
Lead	0.15 mg/l	C ₀ value from Section 2.1.2.1 of 2003/33/EC
Naphthalene	1 mg/l	Assumed value for a contaminated soil. Included within the assessment to represent diesel-range organics.

Attenuation Layer Properties

- 3.5.4 It is proposed that the attenuation layer will be placed on the sides of the quarry prior to the placement of the restoration materials. This will consist of overburden material present on site and suitable imported inert materials where required. The proposed attenuation layer will be a minimum thickness of 0.5m and have a minimum hydraulic conductivity of 1×10^{-7} m/s.
- 3.5.5 Attenuation of modelled parameters has been included within the assessment, which are shown in Table 3 below.

Table 3. Attenuation Layer Properties

Parameter	Value	Derivation
Nominal head of Leachate	1m	Assumed head between 'leachate' and groundwater
Thickness of attenuation layer	0.5m	Proposed design
Hydraulic Conductivity	1×10^{-7} m/s	Proposed minimum hydraulic conductivity for the attenuation layer on sidewalls of quarry void
Retardation coefficient ammoniacal nitrogen (Kd)	0.5 to 2 ml/g Uniform distribution	LandSim default values
Retardation coefficient chloride (Kd)	0 ml/g	No retardation, conservative parameter
Retardation coefficient sulphate (Kd)	0 ml/g	No retardation, conservative parameter
Retardation coefficient nickel (Kd)	20 to 800 ml/g Uniform distribution	LandSim default values
Retardation coefficient zinc (Kd)	1 to 600 ml/g Uniform distribution	LandSim default values
Retardation coefficient lead (Kd)	27 to 2.7×10^5 ml/g Uniform distribution	LandSim default values
Retardation coefficient naphthalene (Koc)	1288 ml/g	ConSim default value
Fraction of organic carbon	0.001 to 0.05 Uniform distribution	Estimate for overburden

Aquifer Properties

3.5.6 As presented in the conceptual model above, the pathway is the surrounding sand and gravel aquifer. Aquifer properties input into the model as shown in Table 4 below.

3.5.7 The model assumes that there is no unsaturated zone present at the site once the groundwater rebound has occurred.

Table 4. Aquifer properties

Parameter	Value	Derivation
Hydraulic Conductivity	7×10^{-7} to 3×10^{-2} m/s Uniform Distribution	Average values for a sand and gravel aquifer (LandSim default values)
Regional Gradient	0.002	Calculated from groundwater levels across the site
Aquifer depth in contact with perimeter	Min: 1m, Avg: 2.3m, Max: 3.4m Triangular distribution	Thickness of sand and gravel from site investigations
Length of sidewall	2,388m	Total perimeter of site boundary

3.6 Model Results

3.6.1 The models indicate that the predicted leakage from the waste mass with a nominal 1m 'leachate' head within the restoration materials cannot be sustained by the recharge through the waste mass. Consequently, the modelled leakage has been limited to the effective rainfall. It is noted no account for runoff has been included within the model.

3.6.2 As a conservative approach, modelling has been completed using dilution within the immediate surrounding aquifer. No dispersion or attenuation has been included within the model.

3.6.3 Results have been compared to the environmental assessment limits and presented in Table 5 below. The results indicate that there would be no significant impact on the groundwater quality from the placement of inert restoration materials at the inert Waste Acceptance Criteria (WAC) values.

3.6.4 Results have been compared against the EQS values for freshwater, due to the surrounding groundwater flow towards the River Avon, downgradient of the site boundary.

Table 5. Model results and environmental assessment limits

Parameter	50 th percentile (mg/l)	95 th percentile (mg/l)	EQS (AA) (mg/l)
Ammoniacal Nitrogen	3.31×10^{-4}	3.13×10^{-3}	0.39
Chloride	0.15	1.44	250
Sulphate	4.96×10^{-4}	4.96×10^{-3}	400
Nickel	3.97×10^{-7}	3.75×10^{-6}	0.004 (bioavailable)

Parameter	50 th percentile (mg/l)	95 th percentile (mg/l)	EQS (AA) (mg/l)
Zinc	3.97x10 ⁻⁵	3.75x10 ⁻⁴	0.0109 (bioavailable)
Lead	4.96x10 ⁻⁸	4.69x10 ⁻⁷	1.2 (bioavailable)
Naphthalene	3.31x10 ⁻⁷	3.13x10 ⁻⁶	0.002

- 3.6.5 The models assume a constant source term which is highly conservative and therefore the concentrations above represent a very conservative estimate of the risks.
- 3.6.6 The retarded travel times were calculated for each parameter using the unretarded travel time multiplied by a calculated retardation coefficient. Parameters chloride and sulphate are conservative parameters and therefore show no retardation. Table 6 below shows the travel time results, with the 5th percentile indicating a 'worst case' scenario. It is considered the travel times across the attenuation layer are sufficient.

Table 6. Travel times model results

Parameter	5 th percentile (days)	50 th percentile (days)	95 th percentile (days)
Unretarded Travel Time	-	11.57	-
Ammoniacal Nitrogen RTT	117	243	432
Nickel RTT	11,570 (31 years)	77,612 (212 years)	163,395 (448 years)
Zinc RTT	4,092 (11.2 years)	52,594 (144 years)	118,937 (326 years)
Lead RTT	2,378,924 (6517 years)	24,312,850 (66610 years)	54,530,313 (149398 years)
Naphthalene RTT	1,062 (2.9 years)	6,010 (16.4 years)	12,970 (35 years)

3.7 Sensitivity Analysis

- 3.7.1 Sensitivity analysis has been undertaken on the model, with respect to the hydraulic conductivity of the attenuation layer and the potential for rogue loads.
- 3.7.2 Due to the clay-rich nature of the overburden on site, the hydraulic conductivity of the material used for the attenuation layer may be lower in areas, which would likely increase the travel times through the attenuation layer. Re-running the model using a hydraulic conductivity of the attenuation layer set at 1x10⁻⁹ m/s, the unretarded travel time would be 1,157 days.

Accidents and their consequences

- 3.7.3 Due to the low-risk inert nature of the restoration materials and the management procedures that will be in place at the site, it is considered that significant accidents are unlikely to occur.
- 3.7.1 Although it is unlikely that concentrations of all parameters will be present at the inert C₀ values, it is feasible that rogue loads of non-inert materials may be accidentally placed if the stringent site management procedures failed. Sensitivity analysis on the model has been undertaken to determine the effects of possible rogue loads, by increasing the source concentrations by a factor of 3 (see Table 7 below).

Table 7. Sensitivity analysis (rogue loads)

Parameter	Input Concentration (mg/l)	50 th percentile (mg/l)	95 th percentile (mg/l)
Ammoniacal Nitrogen	3	0.001	0.010
Chloride	1,380	0.45	4.49
Sulphate	4,500	1.45×10^{-3}	0.0146
Nickel	0.36	1.16×10^{-6}	1.17×10^{-5}
Zinc	3.6	1.16×10^{-4}	1.17×10^{-3}
Lead	0.45	1.45×10^{-7}	1.46×10^{-6}
Naphthalene	3	9.69×10^{-7}	9.76×10^{-6}

- 3.7.2 The results in Table 7 indicate that there would be no significant impact from rogue loads on the surrounding groundwater. It is also noted that the presence of a rogue load of non-inert materials would only comprise a small proportion of the overall material placed at the site, and therefore contaminants present would be subject to attenuation and dilution within the surrounding soils. It is considered that the probability of rogue loads causing a discernible impact on groundwater quality is extremely unlikely.

3.8 Review of Technical Precautions

Waste Acceptance

- 3.8.1 There will be strict waste acceptance procedures in place at the site to ensure that only inert restoration materials are placed. The waste acceptance criteria will be inert WAC values, as presented in the risk assessment above.

Basal and Sidewall Attenuation Layer

- 3.8.2 The proposed attenuation layer will be placed on the quarry sidewalls and constructed using clay-rich overburden materials present on site and suitable imported inert materials where required. The attenuation layer will have a minimum thickness of 0.5m, and a minimum hydraulic conductivity of 1×10^{-7} m/s.

Groundwater Management

- 3.8.3 The quarry will be worked dry and therefore, groundwater will be required to be pumped from the quarry during extraction and restoration. There will be no direct placement of inert restoration materials into the groundwater.

4.0 REQUISITE SURVILLANCE

4.1 Leachate Monitoring

- 4.1.1 The site will have no leachate management system. It is assumed no leachate will be generated during the operational and post-operational phases following restoration. Therefore, no leachate management is proposed.

4.2 Groundwater Monitoring

- 4.2.1 A number of monitoring boreholes have been installed at the site in 2019 and 2020 in order to monitor the groundwater levels, the locations of these are shown on drawing JER8879-SI-002. Boreholes located on the perimeter of the site are considered to be appropriate for monitoring the groundwater quality in the surrounding sand and gravel aquifer. Borehole logs for these boreholes are included in appendix 4.
- 4.2.2 It is proposed that an additional downgradient monitoring borehole will be installed on the downgradient boundary, to the west of the site, adjacent to the River Avon.
- 4.2.3 Baseline monitoring will be undertaken in boreholes for a minimum of 12 months prior to restoration materials being placed at the site. Groundwater will continue to be monitored within the boreholes during the lifetime of the site and in the aftercare phase to ensure any impact from the recovery soils are monitored.
- 4.2.4 For the groundwater monitoring boreholes installed at the site, the following groundwater monitoring regime is proposed for prior and during the operational phase of the recovery activity.

Table 8. Proposed groundwater monitoring regime

Monitoring Point	Parameter	Monitoring Frequency	Monitoring standard or method
WA19-27W, WA19-65W, WA19-68W, WA20-01W, WA20-02W, WA20-03W, Additional downgradient GW point*	Groundwater level Ammoniacal nitrogen Chloride Sulphate pH Electrical conductivity	Monthly	As specified in Environment Agency Guidance TGN02 'Monitoring of Landfill Leachate, Groundwater and Surface Water' (February 2003), risk assessments for your environmental permit (www.gov.uk), or such other subsequent guidance as may be agreed in writing with the Environment Agency. Monitoring of PAH in accordance with BS ISO 285540 or as otherwise agreed in writing with the Environment Agency.
	Cadmium Chromium Copper Nickel Lead Zinc Mercury	Quarterly*	
	PAHs Total Petroleum Hydrocarbons	Quarterly*	

*Quarterly for a minimum of 1 year and then annually or as otherwise agreed in writing with the Environment Agency

4.3 Surface water Monitoring

- 4.3.1 No surface water monitoring is considered to be required at the site during the operational phases. Surface water will be directed towards a silt lagoon for settling out suspended solids, prior to being stored in several other 'clean lagoons' for reuse on site as dust suppression.
- 4.3.2 The final design of the site is such that ground levels will be restored to assist with drainage and rainwater will run-off to the proposed wetland area in Phase 1 and eventually discharge to nearby field drains and tributaries of the River Avon.
- 4.3.3 It is proposed to undertake surface water monitoring as part of the aftercare phase, due to the sensitivity of the nearby River Avon and associated tributaries designated a Local Wildlife Site. Access to the site is currently unavailable to determine appropriate locations for surface water monitoring, however surface water locations within the nearby tributaries and ponds will be investigated prior to completion of the site to determine the appropriate locations to undertake surface water monitoring to ensure the recovery soils are not impacting on the surface water quality. The following monitoring suite is proposed on surface water locations during the aftercare phase:

Table 9. Proposed surface water monitoring regime

Monitoring Point	Parameter	Monitoring Frequency	Monitoring standard or method
Surface water monitoring Locations	Ammoniacal nitrogen Chloride Sulphate pH Electrical conductivity Suspended Solids Visual oil and grease	Monthly	As specified in Environment Agency Guidance TGN02 'Monitoring of Landfill Leachate, Groundwater and Surface Water' (February 2003), risk assessments for your environmental permit (www.gov.uk), or such other subsequent guidance as may be agreed in writing with the Environment Agency.

5.0 CONCLUSIONS AND DISCUSSION

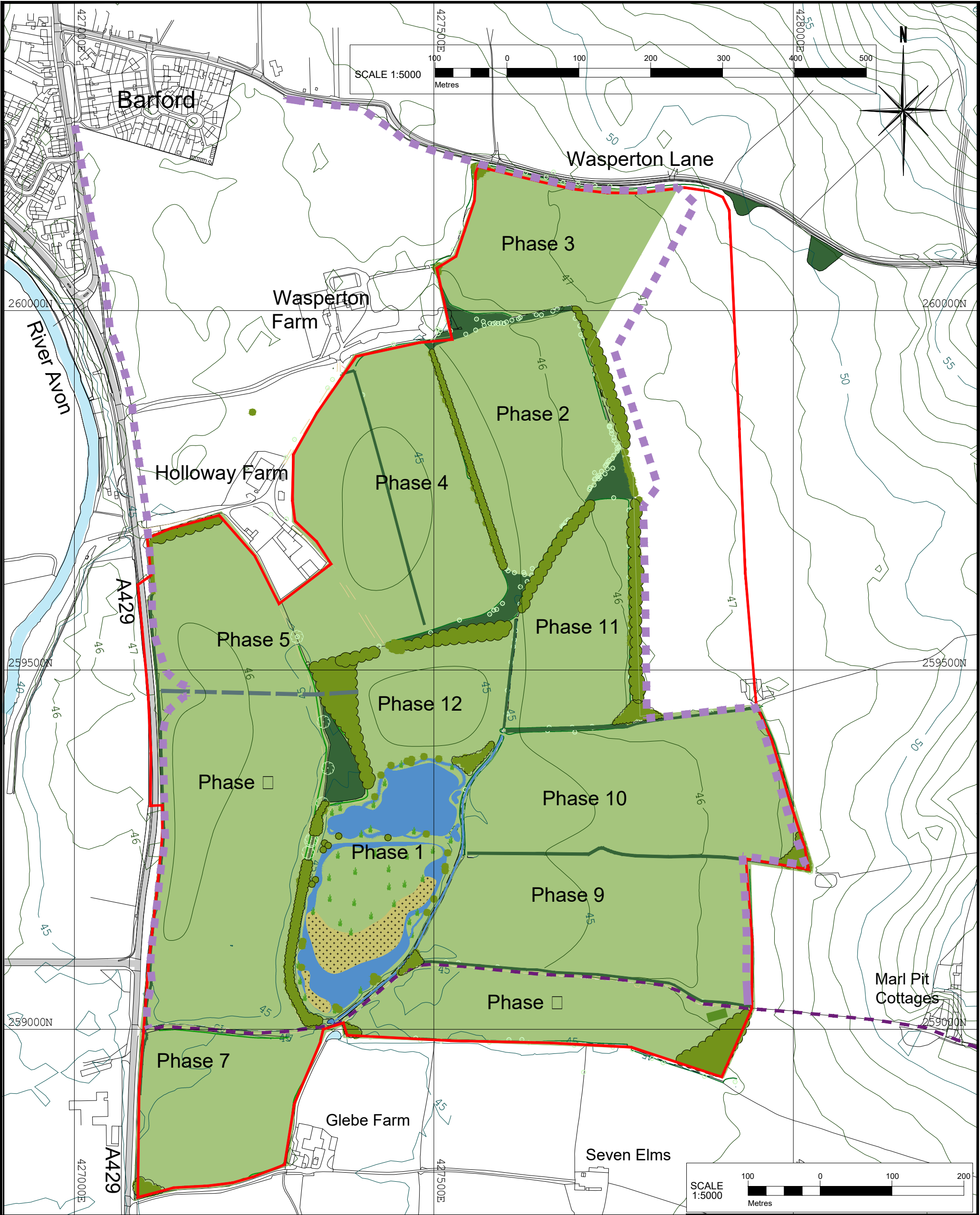
5.1 Conclusions

- 5.1.1 This hydrogeological risk assessment (HRA) has been undertaken in line with the Environment Agency guidance 'Groundwater risk assessment for your environmental permit' (last updated April 2018) and guidance for deposits for recovery¹.
- 5.1.2 The conceptual hydrogeological model has been developed, showing the relationship of the groundwater within the surrounding sand and gravel aquifer to the proposed restoration material deposits. Based on this conceptual model a detailed quantitative risk assessment has been undertaken using standard hydrogeological equations using probabilistic modelling tool Crystal Ball.
- 5.1.3 An attenuation layer is proposed to be constructed on the sides of the quarry for additional protection to the groundwater environment and adjacent Secondary A Aquifer within the sands and gravels external to the quarry. The proposed attenuation layer will be constructed using overburden material present on-site, with suitable imported inert materials where required. It will consist of a minimum thickness of 0.5m, and a minimum hydraulic conductivity of 1×10^{-7} m/s. No attenuation layer is required on the base of the quarry due to the underlying unproductive strata (Mercia Mudstone) and lack of vertical pathway.
- 5.1.4 Strict waste acceptance procedures will be in place at the site to ensure only inert material is accepted in the recovery operations. Acceptance criteria is based on those for inert WAC, in which the waste has been modelled using the C_0 values provided in Section 2.1.2.1 of European Council Decision 2003/33/EC. These are considered most likely to represent the initial peak concentrations of contaminants in 'leachate' and ensure a conservative approach.
- 5.1.5 Modelling results indicate there will be no discernible impact on the surrounding groundwater from the proposed restoration materials. Sensitivity analysis was undertaken on the model, with the potential for rogue loads of non-inert material being accepted into the operation, which indicated that there would also be no significant impact on the groundwater should this occur.
- 5.1.6 Monitoring of groundwater will be undertaken in the boreholes surrounding the site. Baseline monitoring data will be collected for a minimum of 12 months prior to restoration materials being placed at the site.

DRAWINGS

LD135-WSP-005d Final Restoration Phases 1-12 Restored

JER8879-SI-002 Groundwater Monitoring Locations



LEGEND

- Planning application area
- Agricultural restoration
- Existing trees
- Proposed trees
- Permissive brideway

- Open water/ reeds
- Marshy grassland/scrub
- Access road
- Bridleway

Note: Planting details to be found in Landscape section of the ES



Site	Wasperton		
Title	Final restoration Phases 1-12 restored		
Scale at A3	1:5000	Date	May 2022
Drawn By	JEB	Checked By	IDB
		Drawing No.	LD135- WSP-005d

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- Legend**
- Monitoring well locations
 - Parking locations
 - Driving Route
 - Walking Route

Rev	Description	By	CB	Date



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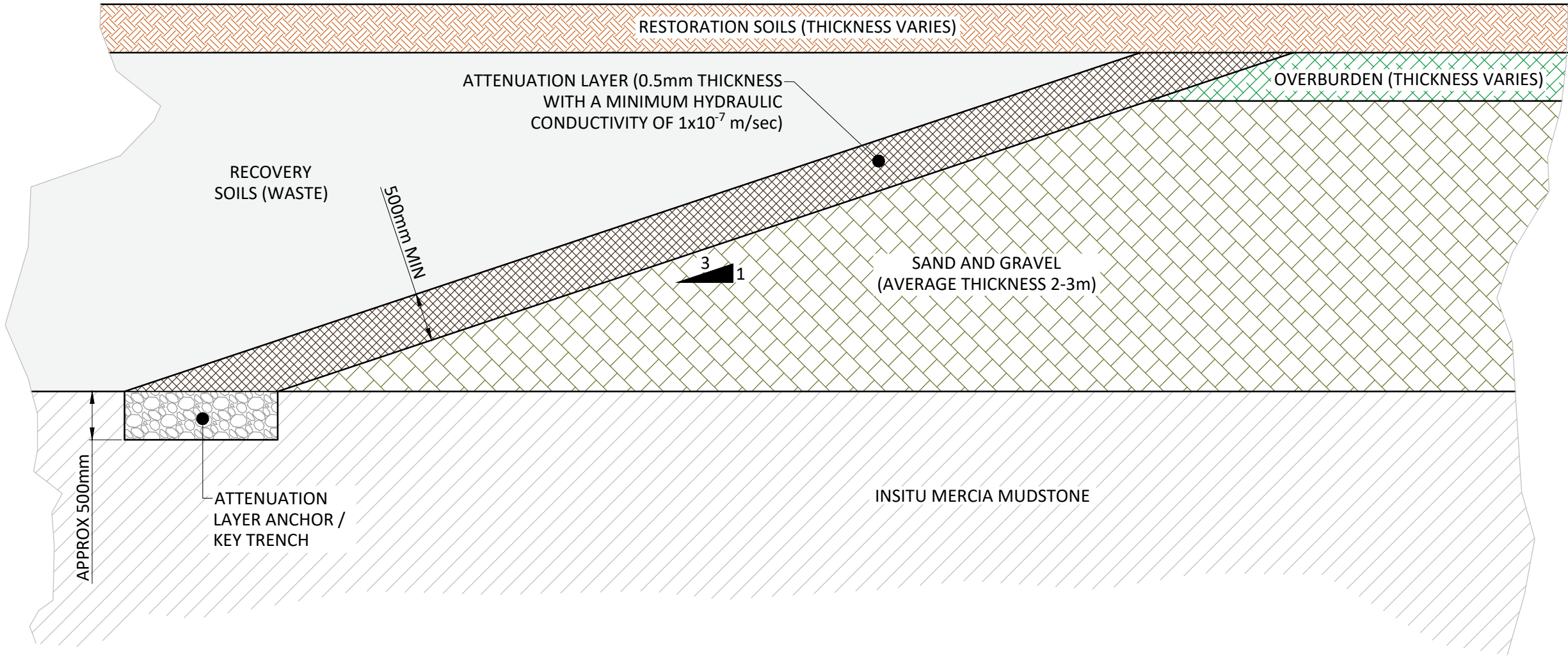
Project **Wasperton**

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APPENDIX 1

Hydrogeological Impact Assessment (HIA)

**HYDROGEOLOGICAL AND
HYDROLOGICAL ASSESSMENT FOR A
PROPOSED SAND AND GRAVEL QUARRY
AT WASPERTON, WARWICKSHIRE**

**Report Reference: 3242/HIA
Version F2
October 2022**

Report prepared for:

Smiths Concrete Ltd
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GENERAL NOTES

Title of report: Hydrogeological Impact Assessment

Site: Wasperton

Report ref: 3242/HIA

Date: October 2022

Version	Date	Issued to
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Final F1	March 2022	Ian Briggs, Landesign
Final F2	October 2022	Ian Briggs, Landesign

Author: Dylan Ingman MEng MSc FGS

Reviewer: Chris Leake BSc MSc FGS

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[https://hafrenw.sharepoint.com/sites/HafrenWater/Shared Documents/General/Projects/Wasperton/3242 HIA & FRA/Reports/HIA/Draft/3242_HIA F2 \(Oct 22\).docx](https://hafrenw.sharepoint.com/sites/HafrenWater/Shared Documents/General/Projects/Wasperton/3242 HIA & FRA/Reports/HIA/Draft/3242_HIA F2 (Oct 22).docx)

CONTENTS

1	INTRODUCTION	1
1.1	Background	1
1.2	Location	1
1.3	Scope of assessment	1
1.4	Data sources	1
1.5	Methodology	2
2	BASELINE CONDITIONS	3
2.1	Introduction	3
2.2	Site description	3
2.3	Hydrology	3
2.3.1	Rainfall	3
2.3.2	Watercourses	4
2.3.3	Waterbodies	4
2.3.4	Springs	5
2.3.5	Surface water abstractions	5
2.3.6	Flooding	5
2.4	Sites of ecological and conservation interest	5
2.5	Landfills	6
2.6	Geology	6
2.6.1	Regional	6
2.6.2	Local	6
2.7	Hydrogeology	7
2.7.1	Aquifer status and regional context	7
2.7.2	Local hydrogeology	7
2.7.3	Groundwater abstractions	8
2.7.4	Conceptual hydrogeology	9
3	PROPOSED DEVELOPMENT	10
3.1	Mineral extraction	10
3.2	Restoration	10
3.3	Water management	10
3.3.1	During mineral extraction	10
3.3.2	Post-restoration	11
3.3.3	Water inflow rates	11
3.3.4	Licensing	11
4	ASSESSMENT OF IMPACTS	13
4.1	Methodology	13
4.2	Baseline sensitivity	13
4.3	Radius of influence	14
4.4	Potential impacts during mineral extraction	15
4.4.1	Groundwater flow and elevations	15
4.4.2	Water quality	16
4.5	Potential impacts following restoration	17
4.5.1	Groundwater flow and elevation	17
4.5.2	Water quality	18
5	MITIGATION MEASURES AND RESIDUAL IMPACTS	19

5.1	During mineral extraction	19
5.1.1	Water quality	19
5.2	Post-restoration.....	19
5.2.1	Water quality	19
6	CUMULATIVE IMPACTS	20
7	SUMMARY AND CONCLUSIONS.....	21

TABLES

3242/HIA/T1:	Rainfall data from the Wellesbourne rain gauge	3
3242/HIA/T2:	Private groundwater abstractions	8
3242/HIA/T3:	Receptor sensitivity	13
3242/HIA/T4:	Water level impacts during development.....	16
3242/HIA/T5:	Water quality impacts during development	17
3242/HIA/T6:	Water level impacts following restoration.....	18
3242/HIA/T7:	Water quality impacts following restoration	18

DRAWINGS

3242/HIA/01	Site location
3242/HIA/02	Water features
3242/HIA/03	Ecological sites
3242/HIA/04	Landfill sites
3242/HIA/05	Geology
3242/HIA/06	Groundwater hydrographs
3242/HIA/07	Groundwater contours
3242/HIA/08	Extraction Plan LD135-WSP-004
3242/HIA/09	Restoration Plan LD135-WSP-005

APPENDICES

3242/HIA/A1	Assessment methodology
3242/HIA/A2	Groundwater inflow and radius of influence calculations

1 INTRODUCTION

1.1 Background

The proposed mineral extraction site at Wasperton, Warwickshire ('the site') comprises agricultural land extending to approximately 89 hectares (ha). It is located adjacent to the River Avon. It is proposed to extract sand and gravel down to bedrock, which will yield approximately 1 million tonnes of mineral. The restoration of the site will involve the importation of inert material to enable the return of the area to agricultural use.

Hafren Water has been commissioned to undertake an assessment of the extant water environment, including the potential for impact of the proposed development.

1.2 Location

The site is located approximately 5.5 km south of Warwick, centred on National Grid Reference (NGR) SP 27558 59426. The village of Wasperton is located 400 m west of the site and Barford is approximately 970 m to its north-northwest. The site location is shown on *Drawing 3242/HIA/01*.

1.3 Scope of assessment

The objectives of the investigation are as below:

- Determination of baseline conditions of the water environment at the site and its environs
- Identification of potential impacts of the proposed mineral extraction and restoration
- Assessment of the magnitude and significance of potential impacts of mineral extraction and the proposed subsequent restoration
- Derivation of appropriate mitigation measures for any identified potential impacts

1.4 Data sources

The characteristics of the water environment have been investigated with the use of existing published data and reports, assessment of site data, and experience of other sites in broadly similar settings. The data sources used in the investigation are:

Ordnance Survey (OS) mapping

- 1:25,000 scale

Greenfield Environmental

- A Geological Investigation & Mineral Reserves Assessment of Land at Holloway & Wasperton Farms, Nr Barford, Warwickshire, January 2020

Environment Agency

- Licensed surface water and groundwater abstractions

Warwick District Council

- Private surface water abstractions

British Geological Survey (BGS)

- Geological map, 1:50,000 (England & Wales), Sheet 184, Warwick, Bedrock and Superficial Edition
- GeolIndex (www.bgs.ac.uk/geoindex/)

1.5 Methodology

Baseline conditions of the water environment have been defined by the collation and analysis of existing data and field observations. The potential effects of the proposed development upon the extant water environment have been assessed by reference to the baseline data and a series of matrices (*Appendix 3242/HIA/A1*). The latter were applied to ensure a rigorous and consistent approach to the assessment of potential impacts. Mitigation measures have been proposed, where appropriate.

2 BASELINE CONDITIONS

2.1 Introduction

A review of the data sources presented in on-line databases and previous reports has been used to define the baseline conditions, which are described below.

2.2 Site description

The site predominantly comprises agricultural land divided by vegetated field boundaries. Three small, wooded areas exist within the site. Wasperton Farm and Holloway Farm lie on the northwestern boundary, with Glebe Farm and a residential property (Seven Elms) located on the southern.

The western boundary of the site is defined by the A429 and to the south and east by agricultural land. The northern boundary is marked by a minor road leading east from Barford Village.

The site is located within an area of relatively level topography to the east of the River Avon. Ground levels rise generally eastwards, from approximately 45 m in the west to c47 m in the east. To the east of the site, ground levels rise to 85 metres Above Ordnance Datum (mAOD) at Watchbury Hill (c710 m northeast) and 83 mAOD at Wasperton Hill (1 km east).

2.3 Hydrology

2.3.1 Rainfall

Rainfall data were obtained from the Environment Agency for the Wellesbourne rain gauge, which is located c2.5 km to the southwest of the site (NGR SP 27095 56470). Data from between 14th July 1981 and 15th February 2021 were available. The average monthly rainfall in the recording period is shown in *Table 3242/HIA/T1*.

3242/HIA/T1: Rainfall data from the Wellesbourne rain gauge												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	50.8	37.3	38.5	43.1	52.0	50.9	53.9	53.5	45.2	58.9	54.5	52.5

During the same period the total annual rainfall varied between 486 mm (2005) and 881 mm (2008), with a mean of 543 mm.

2.3.2 Watercourses

The nearest named watercourse to the site is the River Avon, which is located c100 m west of the site at its closest approach. The river flows generally south to southwestwards.

A tributary of the River Avon, Thelsford Brook, passes 170 m to the south of the site, flowing westwards towards the River Avon.

Two field ditches originate in the north of the site near Holloway Farm and Wasperton Farm, respectively. A surface water drainage divide exists close to the southern extent of the proposed Phase 2 extraction. North of the divide the ditches flow northwards, towards Wasperton Farm, and then west past Holloway Farm to the River Avon. To the south the ditches flow southwards and coalesce at a waterbody (W2, Section 2.3.3) approximately 130 m north of Glebe Farm. From this point the water flows southwards joining Thelsford Brook 170 m south of the site. At the time of the site walkover (16th February 2022) the water level within these ditches was approximately 0.1 m to 0.2 m deep and at a similar elevation to groundwater. The flow rate within these ditches was generally so slow as to be indeterminable.

Field ditches are present along most of the field boundaries and convey run-off towards the larger ditches. Where waterbodies are located near field boundaries, water is conveyed into and out of the waterbodies by the perimeter ditches (Section 2.3.3). Monitoring of groundwater elevations within nearby boreholes (Section 2.7.2) indicates that the elevation of the water within the ditches is similar to groundwater.

The watercourses are shown on *Drawing 3242/HIA/02*.

2.3.3 Waterbodies

A small pond is located within the wooded area to the south of Holloway Farm (W1 on *Drawing 3242/HIA/02*). Comparison of groundwater levels and LiDAR data indicates that this is a groundwater-supported waterbody. During the site walkover the water level within this waterbody was similar to the adjacent field ditch.

A small pond (W2) is located north of Glebe Farm, which discharges water southwards off-site via a ditch. Water is conveyed to this waterbody via the two larger ditches and a smaller boundary ditch. Water elevations in a nearby monitoring borehole indicate that this pond is in hydraulic continuity with groundwater.

Ordnance Survey mapping indicates the presence of two waterbodies at Wasperton Farm (W3). The southern waterbody is incorporated into the drainage system.

A further two ponds located to the east (W4) and southeast (W5) of the site boundary are considered likely to have originally been surface water-fed due to their location on bedrock (low permeability Mercia Mudstone, Section 2.6.2). However field ditches pass through these waterbodies, creating a connection to groundwater (Section 2.3.2).

A waterbody which is not shown on OS mapping (W6) is located on the eastern site boundary. This waterbody has also been connected to the adjacent field ditches.

2.3.4 Springs

No springs are present on OS mapping within the same surface water catchment as the site.

2.3.5 Surface water abstractions

Records of nearby licensed water abstractions were requested from the Environment Agency. Fourteen licensed surface water abstractions are located within 2 km of the site boundary. Ten of these abstractions are made from the River Avon and four from the Thelsford Brook.

The closest abstraction is located approximately 100 m west of the site boundary (Licence N^o 18/54/13/076). It is used for direct spray irrigation at Wasperton Hill Farm between 1st March and 31st October. The licence permits 140,000 m³/a, and 2,000 m³/d. The next nearest abstractions are located c300 m west of the site boundary, from the River Avon, near the village of Wasperton. These abstractions are also for spray irrigation.

The locations of the abstractions are shown on *Drawing 3242/HIA/02*.

2.3.6 Flooding

The majority of the site is located within Flood Zone 1, however southern parts are within Flood Zones 2 and 3 associated with Thelsford Brook. The flood risk associated with development of the site is discussed further in the Flood Risk Assessment (Ref 3242/FRA/F1, March 2022).

2.4 Sites of ecological and conservation interest

The MAGIC website (www.magic.gov.uk) indicates that the site is not located within 2 km of a Special Area of Conservation (SAC), Site of Special Scientific Interest (SSSI) or Special Protection Area (SPA).

A Local Wildlife Site (LWS) is designated along the ditch adjacent to Holloway Farm and Wasperton Farm, and includes the waterbody W3 (Section 2.3.3). The location of the LWS is shown on *Drawing 3242/HIA/03*.

2.5 Landfills

There are no licensed landfill facilities within a 2 km radius of the site.

Six historic landfills are located within 2 km of the site boundary, all of which are between 1.6 km and 1.9 km north of the site. These sites received inert, industrial, commercial and household waste. The locations are shown on *Drawing 3242/HIA/04*.

2.6 Geology

2.6.1 Regional

The superficial deposits in the region are associated predominantly with the River Avon and situated on lower elevations. The superficial deposits comprise Alluvium, River Terrace 1 and River Terrace 2 deposits. The Alluvium generally comprises a mixture of clay, silt, sand and gravel. The River Terrace deposits comprise sand and gravel with local lenses of silt, clay or peat. The site is indicated to be entirely underlain by the River Terrace 2 deposits, which comprises the economic mineral. Isolated glacial deposits are located on some of the high points within the area.

The geology is shown on *Drawing 3242/HIA/05*, taken from the 1:50,000-scale BGS geological map for Warwick.

The regional bedrock geology comprises marls and mudstones of the Mercia Mudstone Group (MMG). The thickness of this unit in the area is indicated to be up to 100 m. The MMG outcrops on the higher ground of Wasperton Hill and Watchbury Hill to the east of the site, where a number of 'skerries' have been mapped by the BGS.

2.6.2 Local

Sixty-eight mineral investigation boreholes have been drilled at the site. Topsoil and overburden were encountered down to between 0.6 metres below ground level (mbgl) (44.18 mAOD) and 3.6 mbgl (42.41 mAOD) comprising clay, sandy clay, sandy silt or clayey silt.

Sand and gravel was encountered to between 40.60 m and 42.74 mAOD, with an average thickness of 2.3 m. The upper units of the mineral deposit comprise sand with varying

contents of silt, clay and gravel. Towards the base the strata predominantly comprise sand and gravel.

Sand and gravel was absent within seven mineral evaluation boreholes drilled in the northeast of the site. This site-specific data differs from the boundary defined on BGS mapping, indicating that the lateral limit of the sand and gravel deposit occurs within the site boundary.

Bedrock was encountered directly beneath the sand and gravel and was recorded as either a mudstone or firm to stiff clay.

2.7 Hydrogeology

2.7.1 Aquifer status and regional context

The superficial deposits at the site are classified by the Environment Agency as a Secondary A Aquifer. These are layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

The bedrock beneath the site, the Mercia Mudstone, is designated as a Secondary B Aquifer. These are defined as layers that may store and yield limited amounts of groundwater within fissures and cracks.

The site is not located within a groundwater Source Protection Zone (SPZ), the nearest being located 530 m south of the site.

2.7.2 Local hydrogeology

Water strikes were recorded in fifty-five of the sixty-eight mineral investigation boreholes. Generally, two water strikes were encountered; the first representing perched water within the overburden and the second within the sands, and sand and gravel deposits. The water strikes were at or close to the top of the sand and gravel strata and ranged between 1.4 m and 3.6 mbgl. For the boreholes where water strikes were not recorded, there was either no sand and gravel present (in the east of the site) or the boreholes were located in the west of the site, adjacent to Holloway Farm.

Monitoring standpipes were installed within four of the mineral investigation boreholes drilled in 2019 with a further five monitoring locations installed in 2020. One borehole has been damaged. Fifteen water monitoring records exist between November 2019 and November 2021. Hydrographs of the monitoring data are presented on *Drawing 3242/HIA/06*. The data

indicates that groundwater flow is westwards, towards the River Avon. A groundwater contour plot is shown on *Drawing 3242/HIA/07* using data from November 2021.

2.7.3 Groundwater abstractions

Licensed abstractions

A freedom of information request was submitted to the Environment Agency to identify the currently licensed abstractions.

One licensed groundwater abstraction is present within a 2 km radius of the site boundary. It is situated at Thelsford Corner, 800 m to its south. This licence (Nº 18/54/13/283) is held by Severn Trent Water for public water supply and allows the abstraction of 1,168,322 m³/y and 4,000 m³/d. However, it is noted that this volume also includes abstraction from two other boreholes located 4.2 km to the south, at Wellesbourne. Comparison with BGS borehole records indicates that both the Thelsford Corner borehole and Wellesbourne boreholes abstract from the Mercia Mudstone Group. A small source protection zone (500 m diameter) is associated with these boreholes.

The location of the abstraction is shown on *Drawing 3242/HIA/05*.

Unlicensed abstractions

Unlicensed abstractions are those with a volume of less than 20 m³/d. Data provided by Warwick District Council indicates three private water supplies within a 2 km radius of the site boundary. These were cross-referenced with data available from BGS mapping. No BGS borehole records were available for these abstractions. Anecdotal evidence indicates that a water abstraction for a livery exists at Green Barn, located approximately 380 m northeast of the site boundary. Details of the abstractions are summarised in *Table 3242/HIA/T2* and their locations are shown on *Drawing 3242/HIA/05*.

3242/HIA/T2: Private groundwater abstractions					
Location	NGR	Distance & direction	Purpose	Type	Source
Brook Cottage	428042 261603	1.4 km N	Domestic	Well	River Terrace Deposits
Lower Watchbury Farm	428048 260573	410 m N	Domestic	Well	Mercia Mudstone
Watchbury Hill	428373 260386	520 m NE	Domestic	Well	Baginton Sand & Gravel Formation
Green Barn	428265 260301	380m NE	Livestock	Unknown	Mercia Mudstone

2.7.4 Conceptual hydrogeology

Based on the background information, a hydrogeological conceptual model for the site has been constructed to be used as a basis for the risk assessment in Section 4. The conceptual model is summarised below.

The site is underlain by clayey overburden, River Terrace sand and gravel deposits, and the Mercia Mudstone Group.

The sand and gravel is the main groundwater bearing unit and the underlying low hydraulic conductivity Mercia Mudstone is considered to act as the base of the aquifer, restricting downward flow of groundwater. The sand and gravel aquifer is laterally confined by the topography in the east, and by the River Avon in the north and west. Groundwater within the Mercia Mudstone is expected to be confined to sandstone interbeds.

A shallow layer of clay, and locally silt, is present across the majority of the site and is likely to locally impede recharge from rainfall. Monitoring indicates that groundwater is at a depth of between 1.0 m and 3.3 mbgl, with a range of approximately 1 m throughout the year and an average depth of 1.6 mbgl. The watertable is therefore generally located close to the base of the overburden. The overall groundwater flow direction is towards the River Avon, indicating that groundwater and the river are in hydraulic continuity. However, comparison of ground elevations and groundwater level data indicate that a seepage face exists on the river bank, during normal flow condition.

Due to the shallow depth of groundwater, the waterbodies at the site are anticipated to be groundwater supported.

Ditches within the site are in hydraulic continuity with groundwater and receive run-off from the fields. A surface water drainage divide exists at the site, and as such the ditches convey water both southwards towards Thelsford Brook and westwards towards the River Avon. The network of ditches intersects the majority of waterbodies within the site, resulting in hydraulic continuity between the groundwater, ditches and waterbodies.

Groundwater abstractions are sourced both from the superficial sand and gravel deposits and subordinate sandstone beds within the Mercia Mudstone Group. The nearby unlicensed water abstractions target shallow strata and are hydraulically isolated from the site due to their location on a different aquifer to the site.

3 PROPOSED DEVELOPMENT

3.1 Mineral extraction

It is proposed to extract the full thickness of sand and gravel and process the mineral on-site.

The plant site area containing the mineral processing plant, weighbridge, wheel wash and site offices will be constructed first, in approximately the centre of the site. Concurrently, Phase 1 of mineral extraction, to the south of the plant area, will be worked and the resultant void sub-divided to be subsequently used as silt settlement lagoon and freshwater lagoons.

Subsequent phases of mineral extraction will then be undertaken in an anticlockwise direction, starting in the north, with the mineral beneath the plant area being extracted during the final phase, Phase 12. Overburden stripped from the site will be temporarily stored on-site and used to progressively restore completed phases.

Due to the elevation of the groundwater, dewatering will be required in all phases to allow complete and safe mineral extraction and restoration.

The phasing plan is shown on *Drawing 3242/HIA/08*.

3.2 Restoration

Restoration will be concurrent with mineral extraction. Imported inert material will be used to backfill the majority of the quarry void. Site-won overburden stripped from the site during the extraction phases will be used to create the final landform. After the completion of restoration the land will be returned to agricultural use.

The lagoons constructed in Phase 1 will not be backfilled and the waterbodies would be allowed to revegetate naturally.

The proposed restoration scheme is presented on *Drawing 3242/HIA/09*.

3.3 Water management

3.3.1 During mineral extraction

A freshwater and silt lagoon system will be constructed in Phase 1 for mineral processing, an additional unlined lagoon will be constructed adjacent to Phase 1 and will be included in the recirculation of water. Part of the mineral deposit is situated below the watertable, therefore it is proposed to dewater to allow complete and safe mineral extraction. Each phase will be dewatered individually and pumping will continue until backfilling is completed to above the watertable. Hence, up to three phases may be being dewatered at one time.

Water in the quarry void will be directed to a sump and pumped to the lagoons in Phase 1. Depending on demand, water will be directed to the freshwater lagoon for top-up, or into an outfall lagoon which will discharge to the adjacent ditch via a gravity overflow.

3.3.2 Post-restoration

Upon completion of infilling of the quarry void dewatering will cease and groundwater levels will be allowed to return to their pre-extraction state. No active water management will take place following the completion of restoration.

The lagoons constructed within Phase 1 will create additional long-term storage of surface water on the site and the field boundary ditches will be retained.

3.3.3 Water inflow rates

Water inflow volumes have been calculated using the Dupuit-Forcheimer equation and long-term rainfall rates. Based on groundwater monitoring data, it has been assumed that a drawdown of 2 m will be necessary to fully dewater the sand and gravel. As up to three phases will be dewatered at once, the largest three consecutive phases (Phases 9, 10 and 11) have been used to determine the working area, as this will represent the largest groundwater inflow. A groundwater inflow rate of 6.2 l/s (538.5 m³/day) has been calculated, including rainfall incident to these phases gives an annual average inflow rate of 9.9 l/s (855.4 m³/day). It should be noted that the aquifer is of limited extent and the majority of water will be derived from aquifer storage, therefore inflow rates are likely to decrease following commencement of dewatering.

3.3.4 Licensing

The ability to abstract water for use and to allow dewatering at the proposed quarry has been investigated. Abstraction of water at the site would be regulated by the Environment Agency under the conditions detailed within the Warwickshire Abstraction Licensing Strategy (ALS) document.

There are no designated Principal Aquifers, with specific water availability assessments, in the vicinity of the site. Groundwater availability in the Secondary Aquifers would be determined by surface water resource availability. Therefore, groundwater is available for licensing, however restrictions apply. A Hands Off Flow (HOF) restriction applies to all new consumptive or partially consumptive abstractions in the catchment when flow at the Evesham gauging station on the River Avon drops below 409 Ml/day or below 1800 Ml/day at Deerhurst on the River Severn. Abstraction may be available for 318 days per annum, and 32.6 Ml/day is available for abstraction within the catchment. New licences will be time limited to 31st

March 2025, however, when an application is made within 6 years of a common end date (CED) the licence is generally granted with the following CED. Time limited licences will be renewed provided that the abstraction is sustainable, is an efficient use of water and there is a continued justification for the need.

The type of abstraction licence required depends on the use, duration, and volume of water abstracted. As it is intended to use water from dewatering in mineral processing a full licence would be required.

4 ASSESSMENT OF IMPACTS

4.1 Methodology

An assessment has been undertaken to determine the potential effects of the proposed mineral extraction and subsequent restoration on the water environment within and surrounding the site.

Potential impacts to the baseline and current conditions have been assessed for the short-term (operational) and long-term (post-restoration) phases of site development. The potential for unplanned incidents, such as spillage of hazardous substances, have also been taken into account. The following factors were considered:

- Magnitude of the impact
- Spatial extent of the impact
- Frequency of the impacts
- Timescale over which the impact may occur
- Cumulative impacts
- Sensitivity of the receiving environment

Mitigation measures and residual impacts have been considered as part of the assessment. The method of assessment is detailed in *Appendix 3242/HIA/A1* together with the matrices used to provide a robust method of assessment. Mitigation measures and residual impacts are discussed in Section 5.

4.2 Baseline sensitivity

The characteristics of the baseline water environment have been used to form a basis for the impact assessment. Details of how the baseline catchment sensitivity is assessed are provided in *Table 3242/HIA/A1.1* of *Appendix 3242/HIA/A1*.

Baseline sensitivities for various features surrounding the site are given in *Table 3242/HIA/T3*.

3242/HIA/T3: Receptor sensitivity		
Receptor	Sensitivity	Reasons
SURFACE WATER		
On-site ditches	Low	The ditches are artificial and exist to convey run-off. There are no abstractions from the features. A local wildlife site is designated along part of one of the ditches.

3242/HIA/T3: Receptor sensitivity		
Receptor	Sensitivity	Reasons
River Avon & Thelsford Brook	Medium	Both watercourses are sources for water abstractions. Water is designated as being available for licensing. No water supported statutory sites are located downstream of the site. The River Avon is designated as a Local Wildlife Site.
Waterbodies within and surrounding the site	Low	Small waterbodies which do not act as a supply of water. Waterbodies are both groundwater and run-off supported.
GROUNDWATER		
Superficial Aquifer	Medium	The superficial deposits contribute to the baseflow of the River Avon and Thelsford Brook which support several water abstractions. Unlicensed abstractions in the area target the superficial deposits, however these are hydraulically isolated from the site.
Bedrock Aquifer	Medium	Public water supplies abstract from the bedrock at distance from the site. Abstractions target sandstone bands within bedrock. Vertical hydraulic conductivity is expected to be low.

4.3 Radius of influence

The proposed dewatering will induce groundwater level lowering beyond the curtilage of the site. The lateral limit of such lowering is termed the 'radius of influence' and it can be estimated using empirical formulae. The estimated radius can then be used to identify the receptors that may be impacted by dewatering activities.

It should be noted that the degree of watertable lowering reduces exponentially from the centre of dewatering.

The saturated thickness of the sand and gravel has been determined from the borehole logs and monitoring data for the site and is assumed to be 2 m in all phases. The calculation assumes that all phases will be dewatered at once, therefore giving a worst-case estimate of the extent of drawdown. Due to the lack of site-specific data generic hydraulic conductivity values have been used, based on the presence of clay bands and the clay content of the sand and gravel.

The Sichardt equation was used to obtain an estimate for the radius of influence, giving a value of 64.5 m. Details of the calculations are given in *Appendix 3242/HIA/A2*.

4.4 Potential impacts during mineral extraction

4.4.1 Groundwater flow and elevations

Dewatering will be required for all phases of mineral extraction, however only two or three phases (or the equivalent area) will be open at any one time due, to the progressive restoration. The effects of dewatering would therefore be time limited. Calculations indicate that the groundwater drawdown due to dewatering would be limited to the immediate vicinity of the site, with the adjacent waterbodies being the only water-supported features within this radius.

The waterbodies and ditches will be retained throughout the extraction period. As these receive both groundwater and run-off, the impact from dewatering is expected to be minimal. W1 is the only waterbody within, or close to, the site which is not directly linked to the field ditches and is groundwater supported. It is therefore considered likely that this waterbody may be temporarily impacted by dewatering of the nearby phases.

The nearby unlicensed water supply boreholes are hydraulically isolated from the site as superficial deposits are absent between the extraction phases and the locations of the boreholes, additionally, two of the boreholes abstract from the bedrock. Dewatering at the site would therefore not impact the water levels at the unlicensed abstractions.

The site is adjacent to the River Avon, which is in hydraulic continuity with the sand and gravel deposits. At its closest approach the river is within 140 m of where dewatering will take place (Phase 5). Thelsford Brook is located c180 m from the closest extraction phase (Phase 7). Neither of these watercourses is likely to be impacted by dewatering due to their distance from the site.

The bedrock underlying the site comprises low permeability Mercia Mudstone, with subordinate sandstone beds. The bedrock dips shallowly, and the mineral investigation boreholes did not identify sandstone directly beneath the superficial deposits. The potential hydraulic connectivity between the superficial deposits and bedrock is therefore low. Consequently dewatering would have no discernible impact on the water-bearing horizons within the bedrock.

3242/HIA/T4: Water level impacts during development			
Receptor	Sensitivity	Magnitude	Significance
SURFACE WATER			
On-site watercourses/ ditches	Low	Low	Minor
River Avon & Thelsford Brook	Medium	Negligible	Minor
Waterbodies within and surrounding the site	Low	Low	Minor
GROUNDWATER			
Superficial Aquifer	Medium	Low	Minor
Bedrock Aquifer	Medium	Negligible	Minor

4.4.2 Water quality

As with all quarries, mineral extraction operations can pose a contaminant risk to the water environment through the accidental release of hydrocarbons (or other contaminants) from mobile and fixed plant, or the release off-site of water with high suspended solid content.

Spill prevention measures and emergency spill procedures will be in place during operation to minimise the likelihood of contaminants being released into the environment. Further details are given in Section 5.

During the operational phase, dewatering would induce groundwater flow towards the quarry void, thereby preventing any potential contamination from migrating off-site. In the unlikely event that contaminated water entered the water management system, water would be prevented from leaving the site and the contamination dealt with in accordance with best practice. The vertical migration of contaminants would be impeded by the low permeability of the bedrock.

Any fines generated during dewatering will settle out within the sump to be created in the floor of the quarry void. Water would then be pumped to the settlement lagoons which would promote further settlement. Suspended solids will be produced during mineral washing. The silt-laden effluent water from the plant will be recirculated to the silt lagoons and allowed to settle. The silt settlement lagoon system will be self-contained therefore, there is no route for suspended solids to be discharged off the site to the external water environment.

Water quality impacts associated with imported inert fill are discussed in Section 4.5.2 below.

3242/HIA/T5: Water quality impacts during development			
Receptor	Sensitivity	Magnitude	Significance
SURFACE WATER			
On-site watercourses/ditches	Low	Low	Minor
River Avon & Thelsford Brook	Medium	Low	Minor
Waterbodies within and surrounding the site	Low	Low	Minor
GROUNDWATER			
Superficial Aquifer	Medium	Low	Minor
Bedrock Aquifer	Medium	Negligible	Minor

4.5 Potential impacts following restoration

4.5.1 Groundwater flow and elevation

Restoration of the site will be achieved by the importation of inert material. The fill is expected to predominantly comprise soils and clays that will likely possess a lower bulk hydraulic conductivity than the pre-existing superficial deposits.

As groundwater flow within the superficial deposits is westwards, and the eastern boundary of the site effectively represents the margin of the superficial aquifer, there would not be a rise in groundwater level up-gradient of the site.

Shallow, low permeability overburden is present across most of the site which results in poor drainage. This overburden will be used in the shallow restoration of the site, therefore the near-surface drainage characteristics are likely to remain the same. Retention of the existing surface water features and the silt and freshwater lagoons within Phase 1 will increase the surface water storage capacity at the site.

Groundwater currently discharges to the River Avon to the west of the site. Replacing the sand and gravel with less permeable inert fill would result in less groundwater recharge and more surface water run-off. The run-off would be captured by the ditches and be conveyed to the River Avon via the Thelsford Brook.

Similarly, the reduction in groundwater flow to the waterbodies and watercourse, due to the placement of lower permeability material, will be balanced by additional run-off to these features, therefore impacts will be minimal.

3242/HIA/T6: Water level impacts following restoration			
Receptor	Sensitivity	Magnitude	Significance
SURFACE WATER			
On-site watercourses/ditches	Low	Low	Minor
River Avon & Thelsford Brook	Medium	Negligible	Minor
Waterbodies within and surrounding the site	Low	Low	Minor
GROUNDWATER			
Superficial Aquifer	Medium	Low	Minor
Bedrock Aquifer	Medium	Negligible	Minor

4.5.2 Water quality

The backfilling of completed phases will be concurrent with mineral extraction and be undertaken using imported inert material for which an Environmental Permit will be required. The base of the extraction will comprise the low permeability Mercia Mudstone Group, which will restrict the downward movement of water.

The properties of the imported fill material will be controlled by strict Waste Acceptance Criteria (WAC) and procedures. This process will prevent any chemically unsuitable waste being placed at the site. The risk assessment which will be undertaken as part of the permitting process will fully assess the risk posed in the unlikely event that material exceeding the WAC limits is deposited at the site. Therefore, the potential for receiving non-compliant waste and resultant contamination will be prevented by the permitting process.

3242/HIA/T7: Water quality impacts following restoration			
Receptor	Sensitivity	Magnitude	Significance
SURFACE WATER			
On-site watercourses/ditches	Low	Low	Minor
River Avon & Thelsford Brook	Medium	Low	Minor
Waterbodies within and surrounding the site	Low	Low	Minor
GROUNDWATER			
Superficial Aquifer	Medium	Low	Minor
Bedrock Aquifer	Medium	Negligible	Minor

5 MITIGATION MEASURES AND RESIDUAL IMPACTS

5.1 During mineral extraction

5.1.1 Water quality

Hydrocarbons

Impacts due to the accidental spillage of contaminants from fixed or mobile plant will be mitigated by adopting the following measures:

- i) All refuelling of mobile plant will take place on hardstanding in the plant area, thereby minimising the risk of spillages reaching the sand and gravel aquifer.
- ii) Fuel will be stored in a double skinned and/or bunded tank.
- iii) All plant will be maintained in accordance with best practice and manufacturer's specification. Where possible, all maintenance will be carried out off-site or on areas of hardstanding.
- iv) Written procedures will be in place for responding to an accidental spillage
- v) Spill kits will be available for use on-site in the unlikely event of such an occurrence.

By following the above measures, the risk posed to receptors during the site operation will be reduced as far as reasonably practicable and no further mitigation measures are considered necessary.

5.2 Post-restoration

5.2.1 Water quality

The risk of degrading water quality by importing inert material will be mitigated by the implementation of strict Waste Acceptance Criteria, as well as other conditions that could be imposed by the Environmental Permit. No further mitigation measures are considered necessary.

6 CUMULATIVE IMPACTS

There are no other mineral extraction or waste facilities in close proximity to the site, therefore cumulative effects are not envisaged.

7 SUMMARY AND CONCLUSIONS

Smiths Concrete are seeking Planning Permission for sand and gravel extraction at a greenfield site near Wasperton, Warwickshire. It is proposed to work the sand and gravel 'dry', which will require dewatering due to the presence of groundwater within the deposit. The site will be restored progressively to agricultural land using imported inert fill and site derived overburden.

The site is located on the eastern bank of the River Avon. The River Thelsford, a tributary of the Avon, passes to the south of the site. A network of interconnected ditches conveys water southwards through the site into the Thelsford Brook. Several natural waterbodies are incorporated into the drainage network.

The proposed development is situated on River Terrace deposits, comprising sands and gravels, which comprise the economic mineral. Mineral evaluation boreholes indicate that the sand and gravel is underlain by the Mercia Mudstone Group.

The sand and gravel is classed by the Environment Agency as a Secondary A Aquifer, however nearby groundwater abstractions target sandstone bands within the underlying Mercia Mudstone, a Secondary B Aquifer. The three nearby private abstractions are hydraulically isolated from the site.

There are no statutory sites of ecological interest within a 2 km radius of the site boundary. Part of the ditch along the northern boundary of the site and to the south of Wasperton Farm is designated as a Local Wildlife Site.

The groundwater flow direction in the sand and gravel is westwards, towards the River Avon, with which it is in hydraulic conductivity.

Dewatering at the site will require licensing and will be governed by the Warwickshire Abstraction Licence Strategy. Water is indicated as being available for licensing, however the catchment is subject to Hands Off Flow (HOF) conditions, with abstraction being available on average 318 days per year.

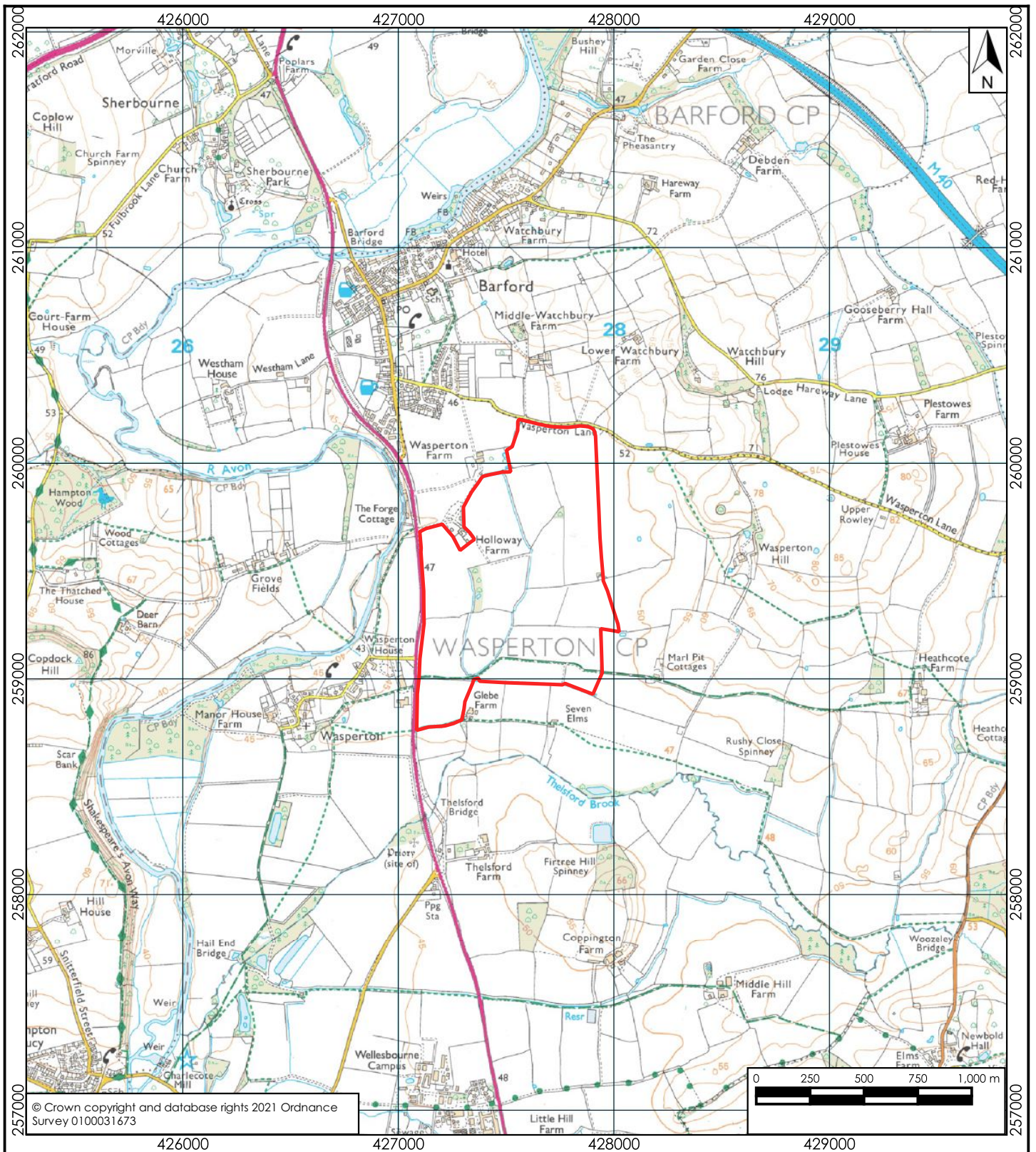
An assessment of the impacts associated with operations at the proposed site has been made with consideration of groundwater and surface water flows and quality, proximity to local areas of ecological interest and water abstractions. The potential impacts of the proposed operation and restoration have been assessed against the extant, greenfield conditions.

During mineral extraction dewatering is considered likely to only impact the water features internal and immediately adjacent to the site. However, as these features are both groundwater and run-off supported the impacts are likely to be minor.

Following restoration, decreased groundwater recharge is anticipated to be balanced by increased run-off. As the ditches will be retained, are connected with the waterbodies, and ultimately convey water to the same watercourse that the groundwater discharges to, the overall impact will be minor. The potential of imported restoration material to degrade water quality is considered to be minor due to the strict adherence to Waste Acceptance Criteria (WAC) to regulate the waste placed at the site. Any further mitigation measures would be identified during the permitting process.

It is considered that there will be no cumulative impacts associated with the proposed development of the site due to the absence of other quarries in the vicinity.

DRAWINGS



Legend

Site boundary

Scale correct at A4

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Client **Smiths Concrete Ltd**
Southam Road
Banbury
Oxfordshire
OX16 2RR

Title **Site Location**

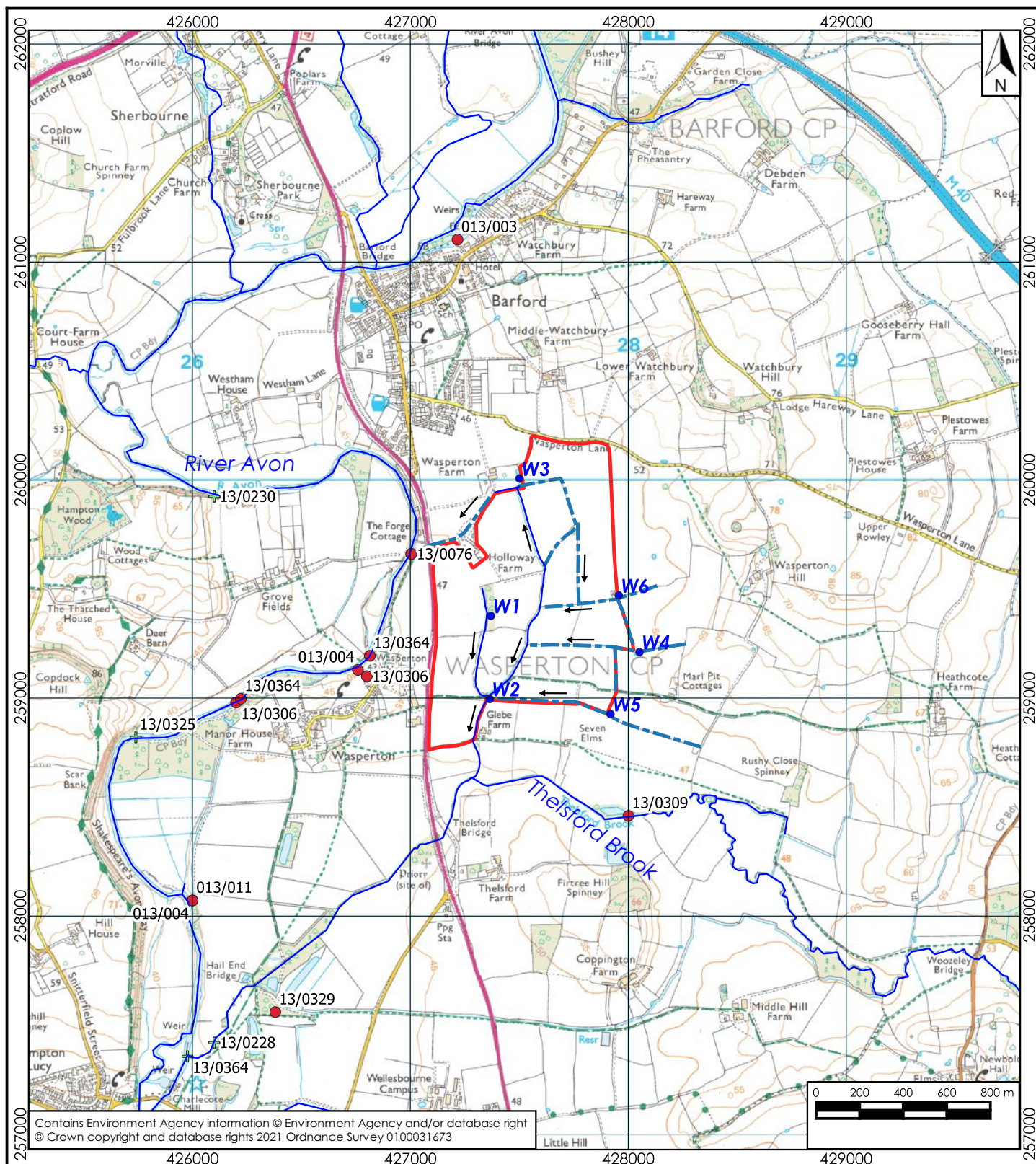
Project **Wasperton**

Drawing **3242/HIA/01**

Date **Mar 22**

Version **1**

Scale **1:25,000**



Legend

- Site boundary
- On-site small field ditch
- Pond
- Surface water abstraction
- Watercourse
- Single point
- Surface water flow direction
- + Reach

Scale correct at A4

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Client
Smiths Concrete Ltd
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OX16 2RR

Title
Surface water features

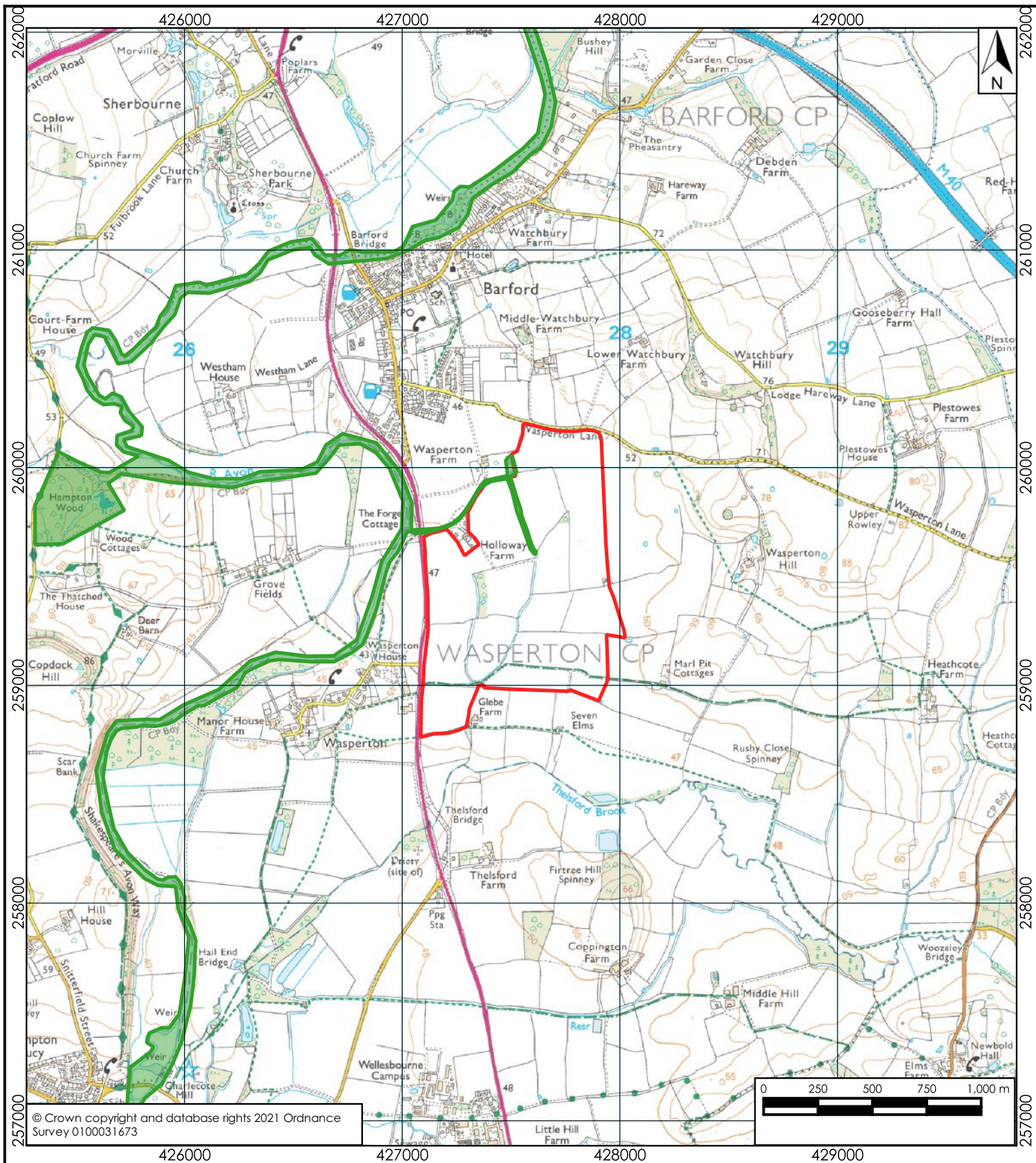
Project
Wasperton

Drawing
3242/HIA/02

Version
1

Date
Mar 22

Scale
1:25,000



Legend

- Site boundary
- Local Wildlife Site

Scale correct at A4

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Client **Smiths Concrete Ltd**
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Title **Ecological Sites**

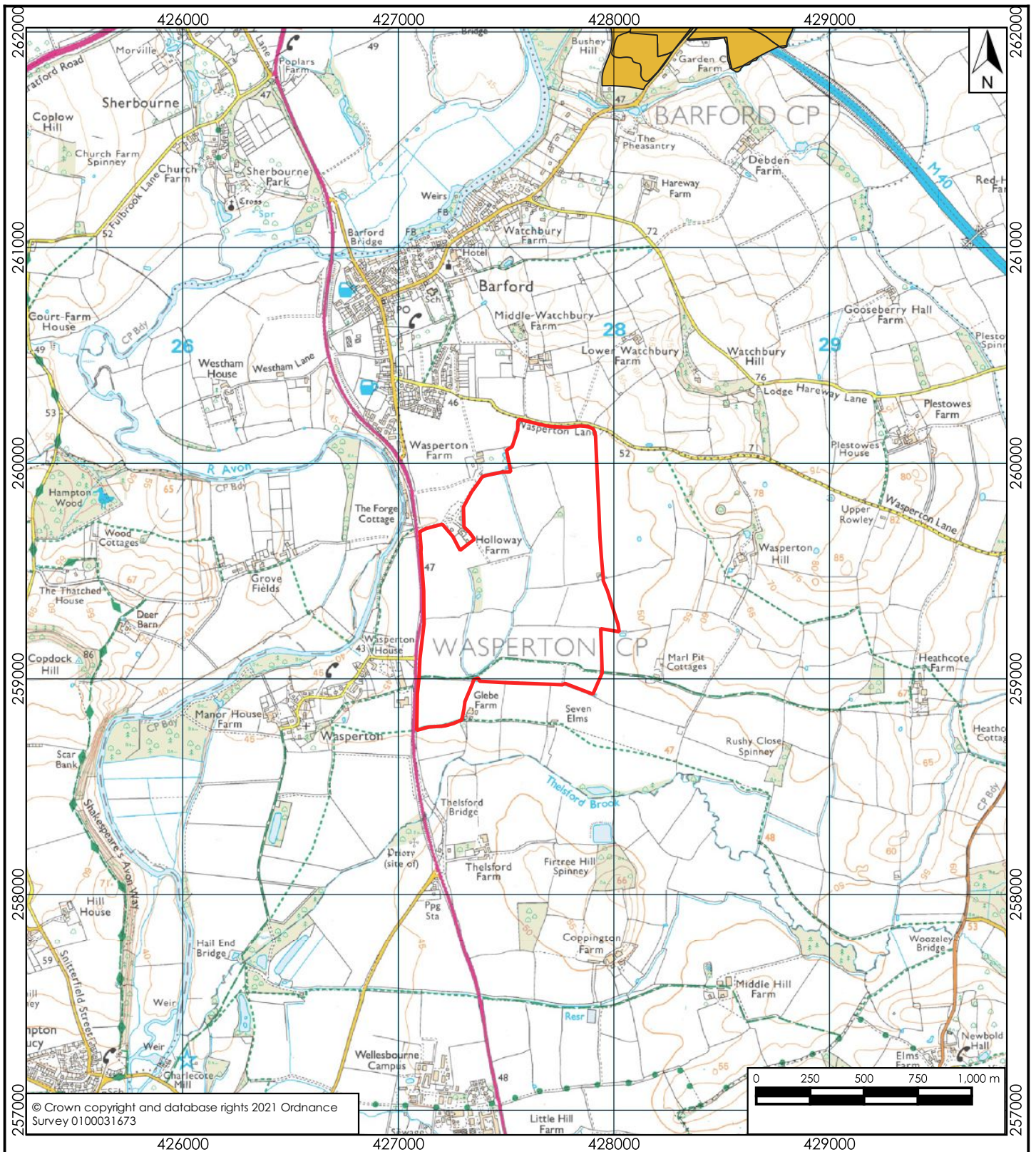
Project **Wasperton**

Drawing **3242/HIA/03**

Version **1**

Date **Mar 22**

Scale **1:25,000**



Legend

- Site boundary
- Historic Landfill

Scale correct at A4

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Client **Smiths Concrete Ltd**
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OX16 2RR

Title **Landfill Sites**

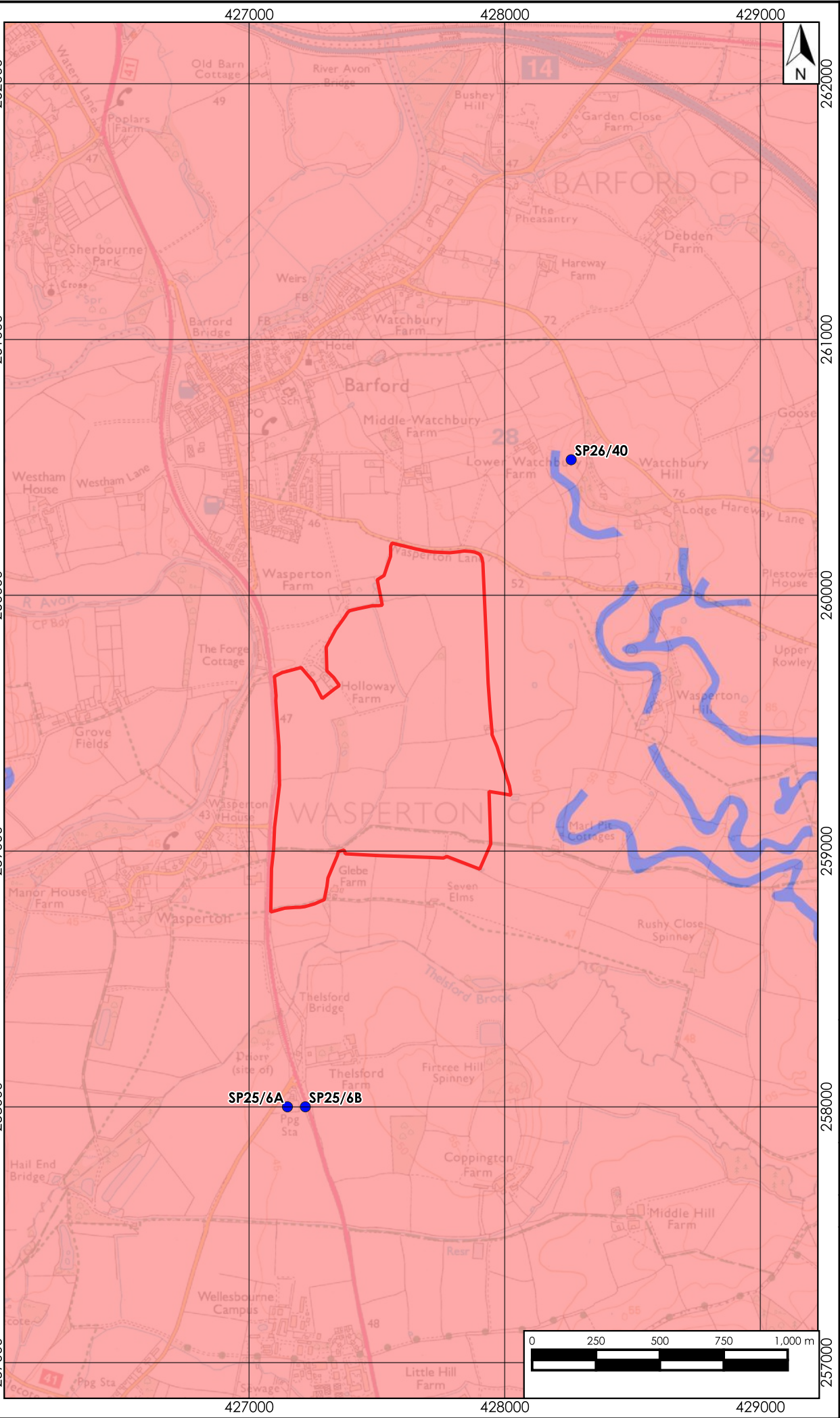
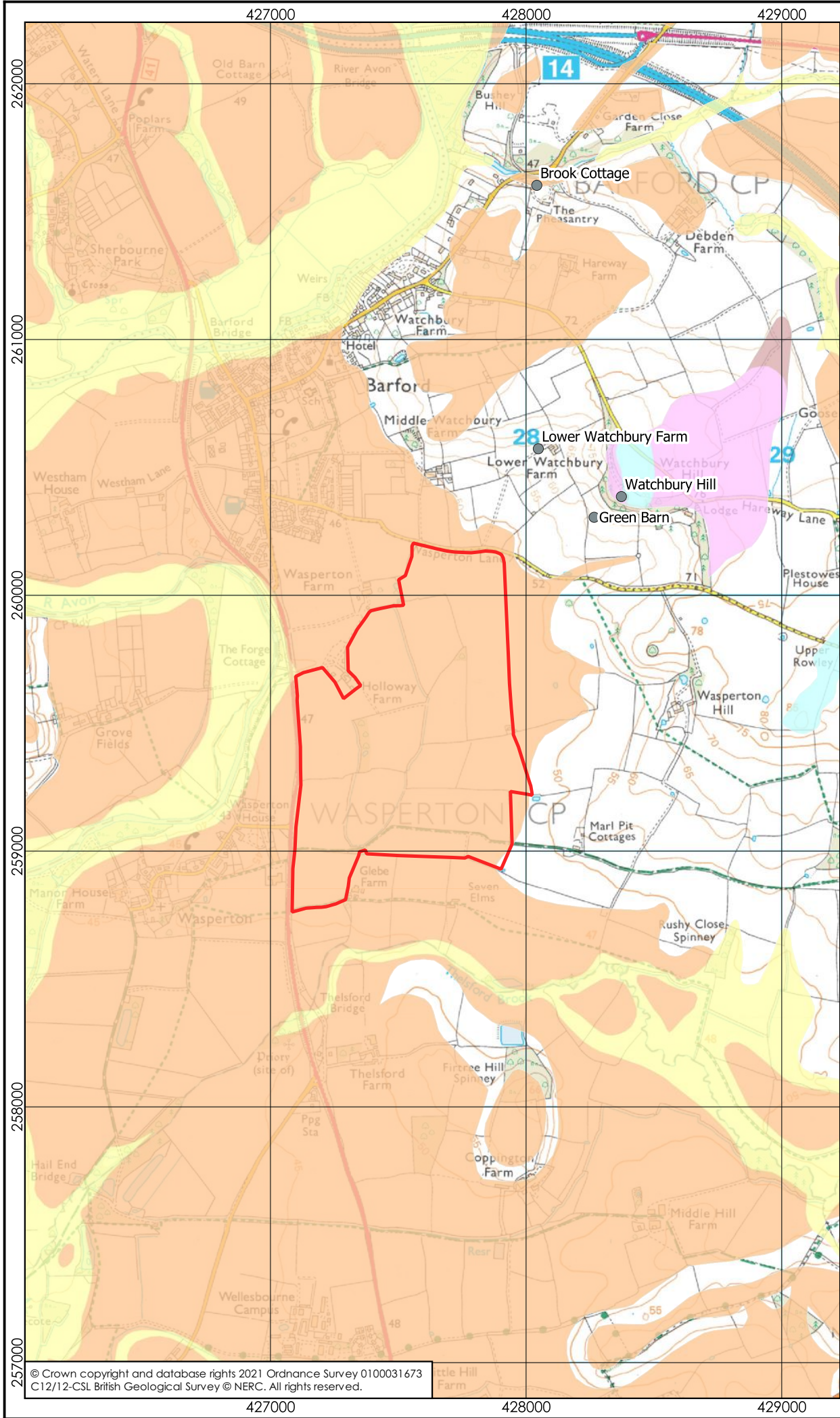
Project **Wasperton**

Drawing **3242/HIA/04**

Date **Mar 22**

Version **1**

Scale **1:25,000**

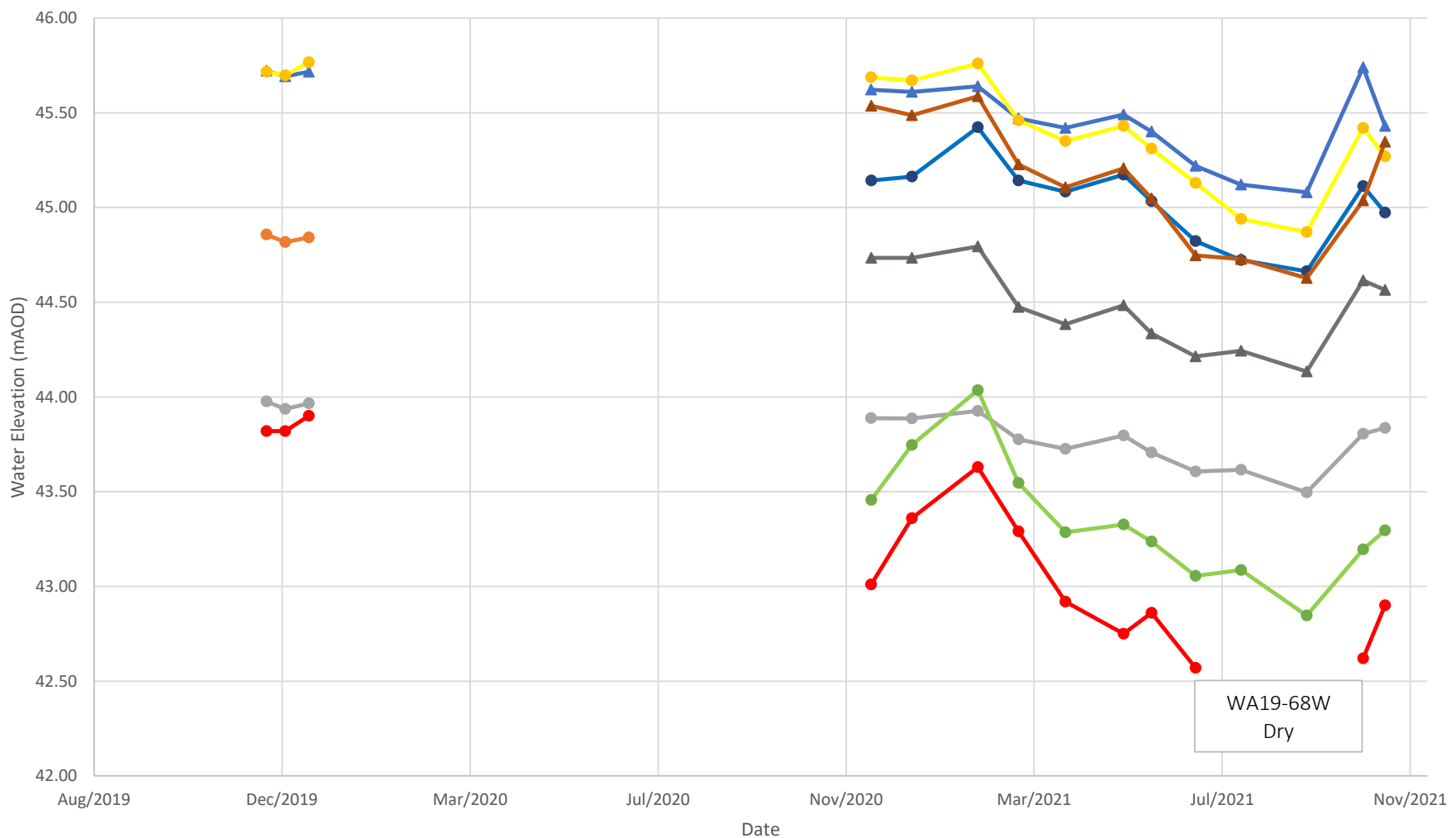


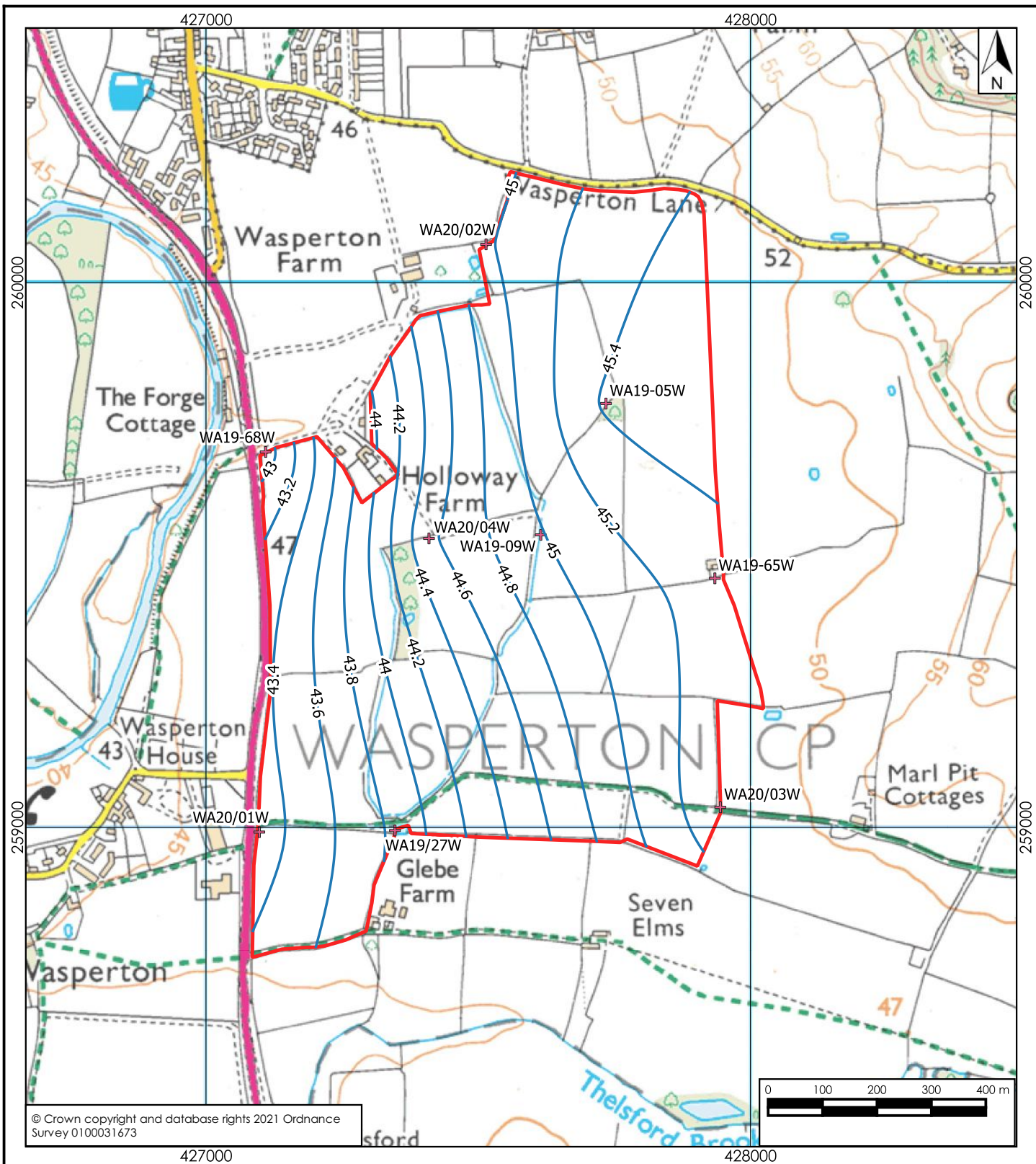
- Legend
- Site boundary
 - Licenced Borehole Abstraction
 - Private Water Abstraction
- Bedrock Geology
- Mercia Mudstone Group
 - Mercia Mudstone Group (Dolomitic Siltstone)
- Superficial Bedrock
- Alluvium
 - River Terrace Deposits
 - Head
 - Thrussington Member
 - Baginton Sand and Gravel Formation

Scale correct at A3

Client	Smiths Concrete Ltd Southam Road Banbury Oxfordshire OX16 2RR		
Title	Superficial & Bedrock Geology		
Project	Wasperton		
Drawing	3242/HIA/05	Version	1
Date	Mar 22	Scale	1:20,000

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Legend

- Site boundary
- Groundwater Contours Nov 21 (m AOD)
- + Monitoring borehole

Scale correct at A4

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Title Groundwater Contours

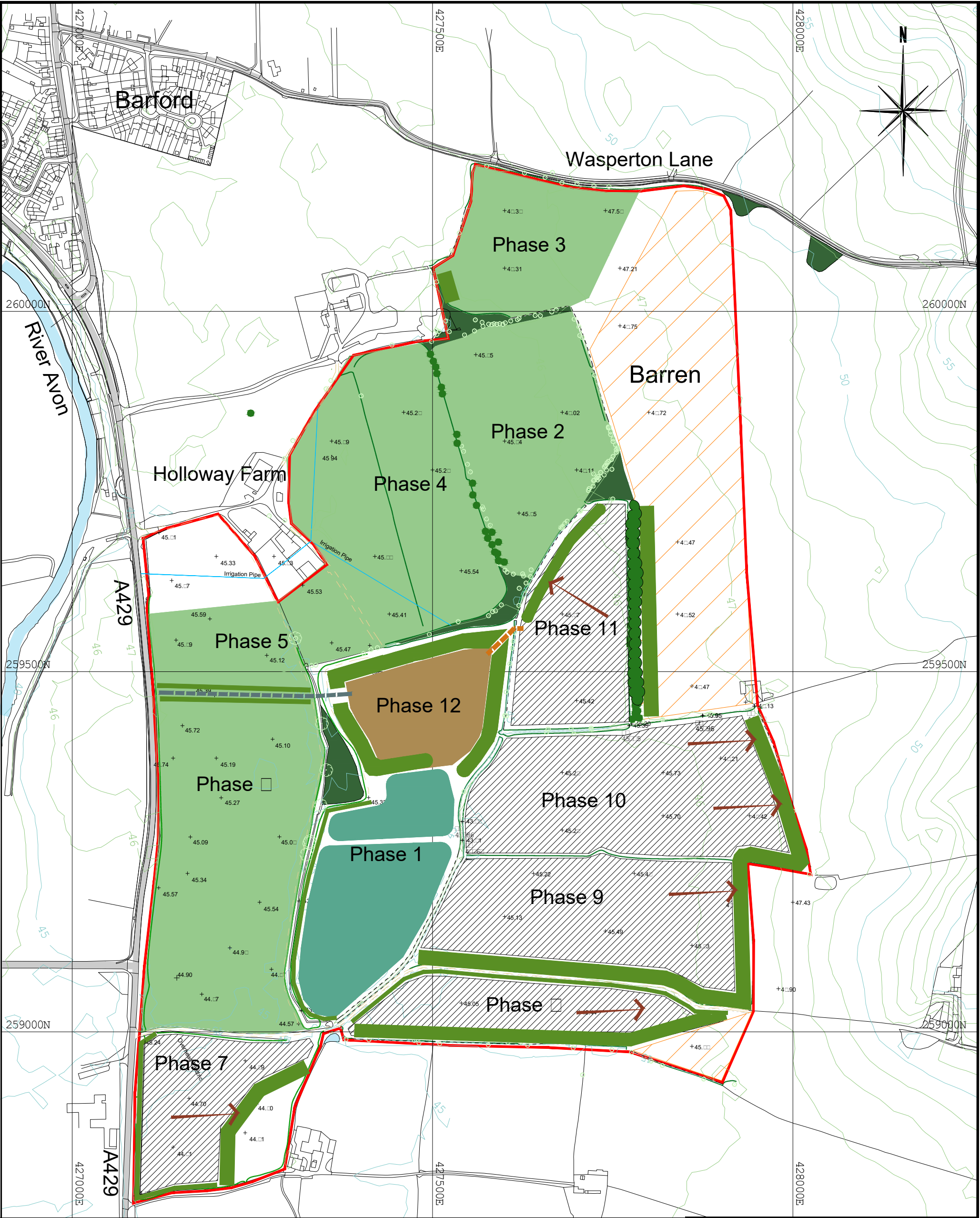
Project Wasperton

Drawing 3242/HIA/07

Version 1

Date Mar 22

Scale 1:10,000



LEGEND

- | | | | |
|--|----------------------|--|------------|
| | Working phase | | Water |
| | Screen/storage bunds | | Grass |
| | Existing trees | | Haul route |
| | Proposed trees | | |



Site	Wasperton		
Title	Working plan 2 Phases 7-12		
Scale at A3	1:5000	Date	Feb 2021
Drawn By	JEB	Checked By	IDB
		Drawing No.	LD135- WSP-004

APPENDIX 3242/HIA/A1

Assessment methodology

Method of assessment

The method of assessment of hydrological and aquatic effects has involved:

- Characterisation of the baseline environment
- Determination of the sensitivity of key catchments and watercourses
- Evaluation of the significance of predicted effects taking account of the magnitude of effects (before and after mitigation)
- Evaluation of the sensitivity of the baseline environment affected

A rigorous and consistent approach to the assessment has been adopted using matrices to help classify sensitivity of the resource and determine the scale and significance of effects.

Baseline sensitivity

The characterisation of the baseline water environment has involved the review of data and identification of sensitivities. The characterisation of catchment sensitivities has been guided by the matrix presented in *Table 3242/HIA/A1.1* which lists indicative criteria.

The criteria for sensitivity are based approximately on hierarchy of factors relating to the quality of the aquatic environment. The criteria have been used to guide the analysis of the sensitivity of the baseline hydrological, hydrogeological and water quality environment.

Table 3242/HIA/A1.1: Catchment sensitivity classification		
Sensitivity category	Sensitivity criteria	
	Adjacent to Application Area	Downstream/in catchment
High sensitivity	SSSI or Aquatic Natura 2000 site Wetland/watercourse habitat of particular ecological importance Highly vulnerable groundwater Significant peat deposits on sloping ground	Aquatic Natura 2000 site or SSSI immediately downstream/ adjacent to site
Medium sensitivity	Wetland watercourse habitat of particular ecological importance Moderately vulnerable groundwater Significant peat deposits	Aquatic Natura 2000 site or SSSI further downstream of the catchment. Sensitive locally designated site of ecological interest
Low sensitivity	Low vulnerability groundwater Superficial peat deposits	
Not sensitive	No aquatic habitats or watercourses present No significant groundwater present	

Impact prediction and evaluation

The prediction and assessment of effects on hydrology, hydrogeology and other aquatic resources has been undertaken using a series of tables to document the various potential impacts from aspects of the proposed project. Impacts have been predicted for the proposed development based on the guideline criteria for impact magnitudes set out in *Table 3242/HIA/A1.2*.

Table 3242/HIA/A1.2: Impact magnitude	
Impact magnitude	Guideline criteria
High	Total loss of, or alteration to, key features of the baseline resource such that post-development characteristics or quality would be fundamentally and irreversibly changed, eg watercourse realignment
Medium	Total loss of, or alteration to, key features of the baseline resource such that post-development characteristics or quality would be partially changed, eg in-stream permanent bridge works
Low	Small changes to the baseline resource which are detectable but the underlying characteristics or quality of the baseline situation would be similar to pre-development conditions, eg culverting of very small watercourses
Negligible	A very slight change from baseline conditions, which is barely distinguishable and approximates to the 'no change' situation, eg short-term compaction from plant movements

Using these criteria a series of generic impacts have been predicted for the proposed development. Residual effects have been predicted taking into account site-specific mitigation.

The significance of the predicted effects has been assessed in relation to the sensitivities of the baseline resource. A matrix of significance was developed to provide a consistent framework for evaluation and is presented in *Table 3242/HIA/A1.3*. Guideline criteria for the various categories of effect are included in *Table 3242/HIA/A1.4*.

Table 3242/HIA/A1.3: Significance matrix				
Magnitude	Sensitivity			
	High	Medium	Low	Negligible
High	Major	Major	Moderate	Minor
Medium	Major	Moderate	Minor	Minor
Low	Moderate	Minor	Minor	None
Negligible	Minor	Minor	None	None

Table 3242/HIA/A2.4: Significance of effects categories		
Significance	Definition	Guideline criteria
None	No detectable change to the environment	No effects on drainage patterns, surface and groundwater quality or aquatic habitat
Minor	A small but detectable change to the environment	Localised changes in drainage patterns or groundwater flows, or changes resulting in minor and reversible effects on surface and groundwater quality or aquatic habitats
Moderate	A larger, but non-fundamental change to the environment	Changes in water quality or quantity affecting part of a catchment or groundwaters of moderate vulnerability, or changes resulting in loss of conservation value to aquatic habitats or designated areas
Major	A fundamental change to the environment	Changes in water quality or quantity affecting widespread catchments or groundwater reserves of strategic significance, or changes resulting in substantial loss of conservation value to aquatic habitats and designations

In the above classification, fundamental changes are those which are permanent, detrimental and would result in widespread change to the baseline environment.

The matrices used to guide the assessment have been applied with a degree of flexibility since the evaluation of effects would always be subject to particular location-specific characteristics which need to be taken into account. For this reason, the evaluation of impact significance, in particular, would not always correlate exactly with the cells in the relevant matrix where professional judgement and knowledge of local conditions may result in a slightly different interpretation of the impact concerned. Cumulative effects have been taken into account through prediction and evaluation of effects at a catchment-wide level.

APPENDIX 3242/HIA/A2

Groundwater inflow and radius of influence calculations

Calc sheet by:
Version number:
Date:

DI
1
19/04/2021



Hydraulic parameters

	<i>min</i>	<i>most likely</i>	<i>max</i>
Hydraulic conductivity, K (m/day)	1	10	15

Dupuit-Forcheimer formula for inflows

Initial saturated thickness, h_0 (m)	2		
Seepage face, h_s (m)	0.25		
Drawdown, Δh (m)	2		
Saturated thickness, h_w (m)	0.25		
Radius of working area choice	Circular	← select result from box 1	
Radius of working area, r_w (m)	249.9		
	<i>min</i>	<i>most likely</i>	<i>max</i>
Groundwater inflow, Q (m ³ /day)	157.6	538.5	675.1
Groundwater inflow, Q (L/s)	1.82	6.23	7.81

Box 1: CIRIA formula for effective radius of working area

Length (m)	443	
Width (m)	443	
	<i>Circular</i>	<i>Rectangular</i>
Effective radius (m)	249.9	282.0

Box 2: Sichardt formula for radius of influence

Sichardt factor, Cs	3000	(3000 for radial flow, 1500-2000 for linear flow)	
Drawdown (m)	2		
	<i>min</i>	<i>most likely</i>	<i>max</i>
Radius of influence, R_0 (m)	20.4	64.5	79.1

Total ingress (groundwater + rainfall)

Groundwater inflow choice	most likely	← select result from Theim calcs	
Groundwater inflow (m ³ /day)	538.5		
Runoff catchment (m ²)	196000		
	<i>min</i>	<i>most likely</i>	<i>max</i>
Fraction of rainfall forming runoff	60%	80%	100%
Fraction of rainfall choice	max	← select proportion from table above	

	Avg. rainfall per month (mm)	Runoff rate (m ³ /day)	Runoff rate (L/s)	Runoff + GW inflow (m ³ /day)	Runoff + GW inflow (L/s)
January	50.80	321.2	3.72	859.6	9.95
February	37.30	261.1	3.02	799.6	9.25
March	38.50	243.4	2.82	781.9	9.05
April	43.10	281.6	3.26	820.0	9.49
May	52.00	328.8	3.81	867.2	10.04
June	50.90	332.5	3.85	871.0	10.08
July	53.90	340.8	3.94	879.2	10.18
August	53.50	338.3	3.92	876.7	10.15
September	45.20	295.3	3.42	833.8	9.65
October	58.90	372.4	4.31	910.9	10.54
November	54.50	356.1	4.12	894.5	10.35
December	52.50	331.9	3.84	870.4	10.07
Annual average		316.9	3.7	855.4	9.9
Annual maximum		372.4	4.3	910.9	10.5

EXPLANATION OF CELL COLOURS

Yellow	Data entry
Green	Formulae
Blue	Select from list

EXPLANATION OF DUPUIT-FORCHEIMER FORMULA

Dupuit-Forcheimer is valid for unconfined flow (i.e. variable saturated thickness) CIRIA 2000: Eq 6.7.

This is called the Theim-Dupuit equation by the Environment Agency 2007: box 3.2.

$$Q = \pi k \left[\frac{h_o^2 - h_w^2}{\ln(r_o / r_w)} \right]$$

Where

- Q = groundwater ingress rate (m³/d)
- k = hydraulic conductivity (m/d)
- h_o = sat'd thickness before drawdown (m)
- h_s = height of seepage face in workings (m)
- h_w = sat'd aquifer thickness after drawdown + h_s (m)
- r_w = radius of working area (m)
- r_o = r_w + radius of influence (m)

Effective radius of the working area estimate is based on CIRIA 2000: equation 6.5

EXPLANATION OF SICHARDT FORMULA

Cited as equation 6.8 in CIRIA 2000, and equation 3.4 by Cashman and Preene 2001.

$$r = Ch \sqrt{k}$$

Where

- r = radius of influence (m)
- C = constant
- h = drawdown (m)
- k = hydraulic conductivity (m/s)
- r_w = radius of working area (m)

REFERENCES

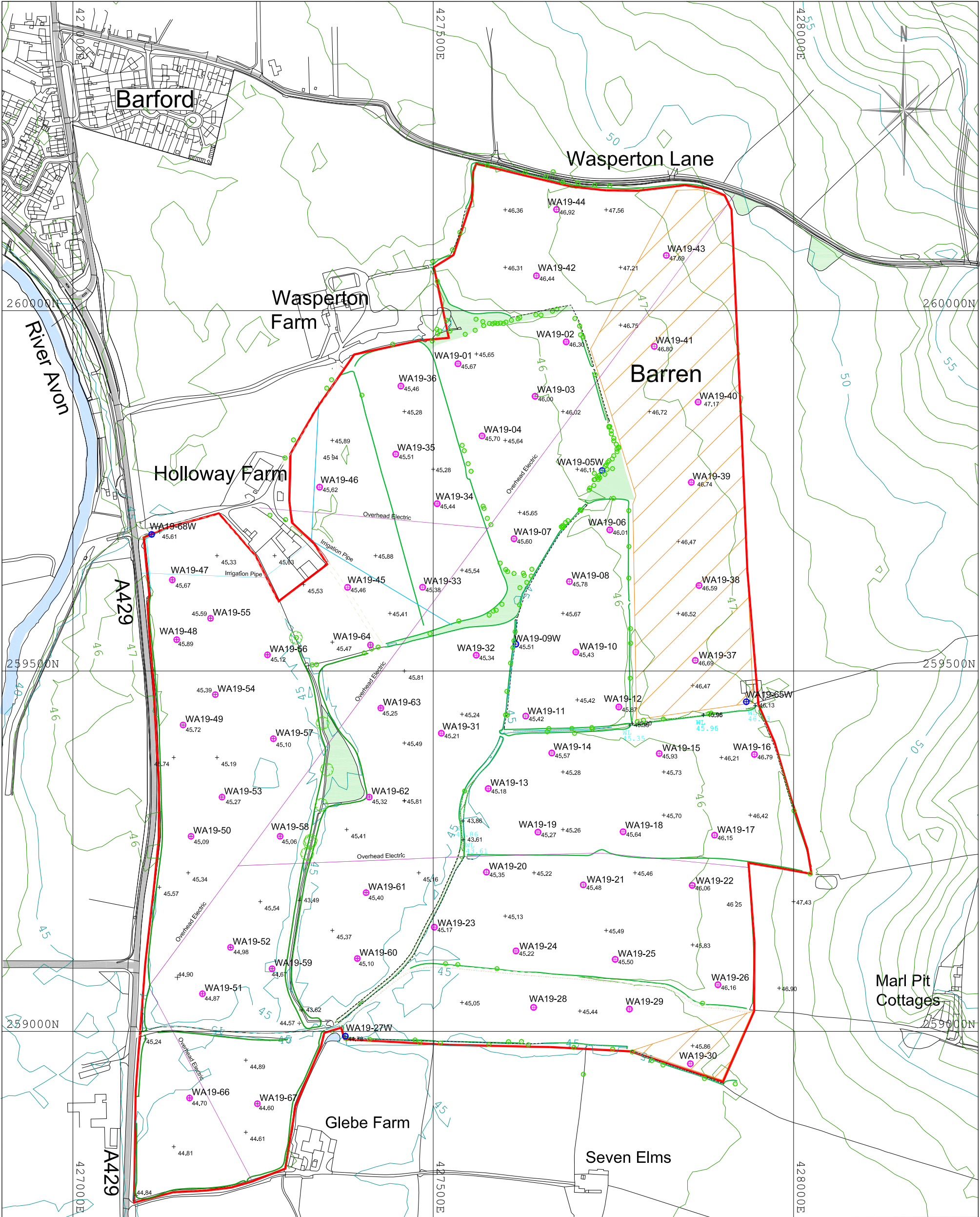
Cashman and Preene, 2001. Groundwater Lowering in Construction: A Practical Guide. Spon Press. (Superseded by Cashman and Preene, 2020. Groundwater Lowering in Construction: A Practical Guide to Dewatering (3rd edition). CRC Press)

CIRIA, 2000. Groundwater control - design and practice. Report C515 (Superseded by CIRIA, 2007. Groundwater control - design and practice (second edition). Report C750.)

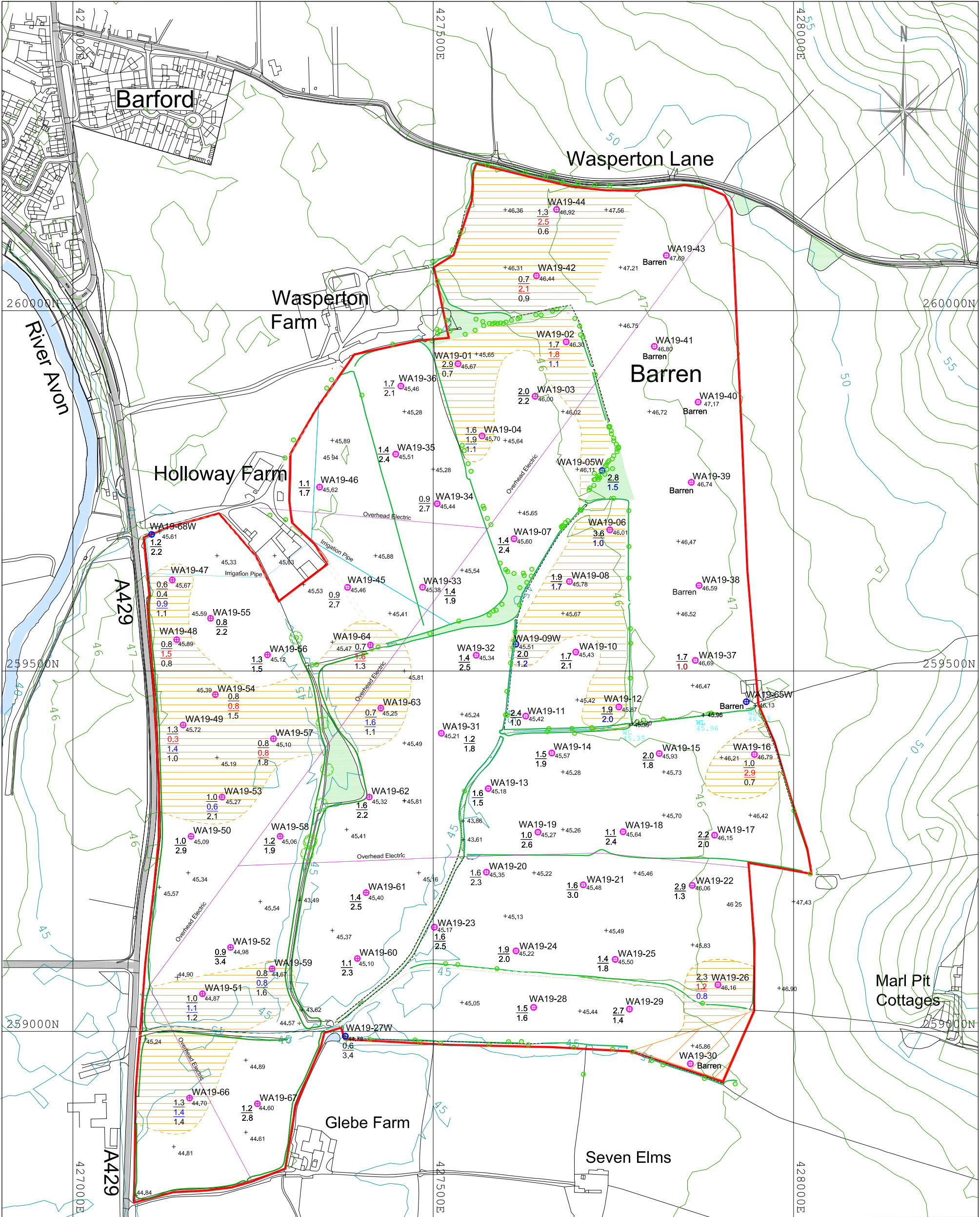
Environment Agency, 2007. Hydrogeological impact appraisal for dewatering abstractions. Science Report SC040020/SR1

APPENDIX 2

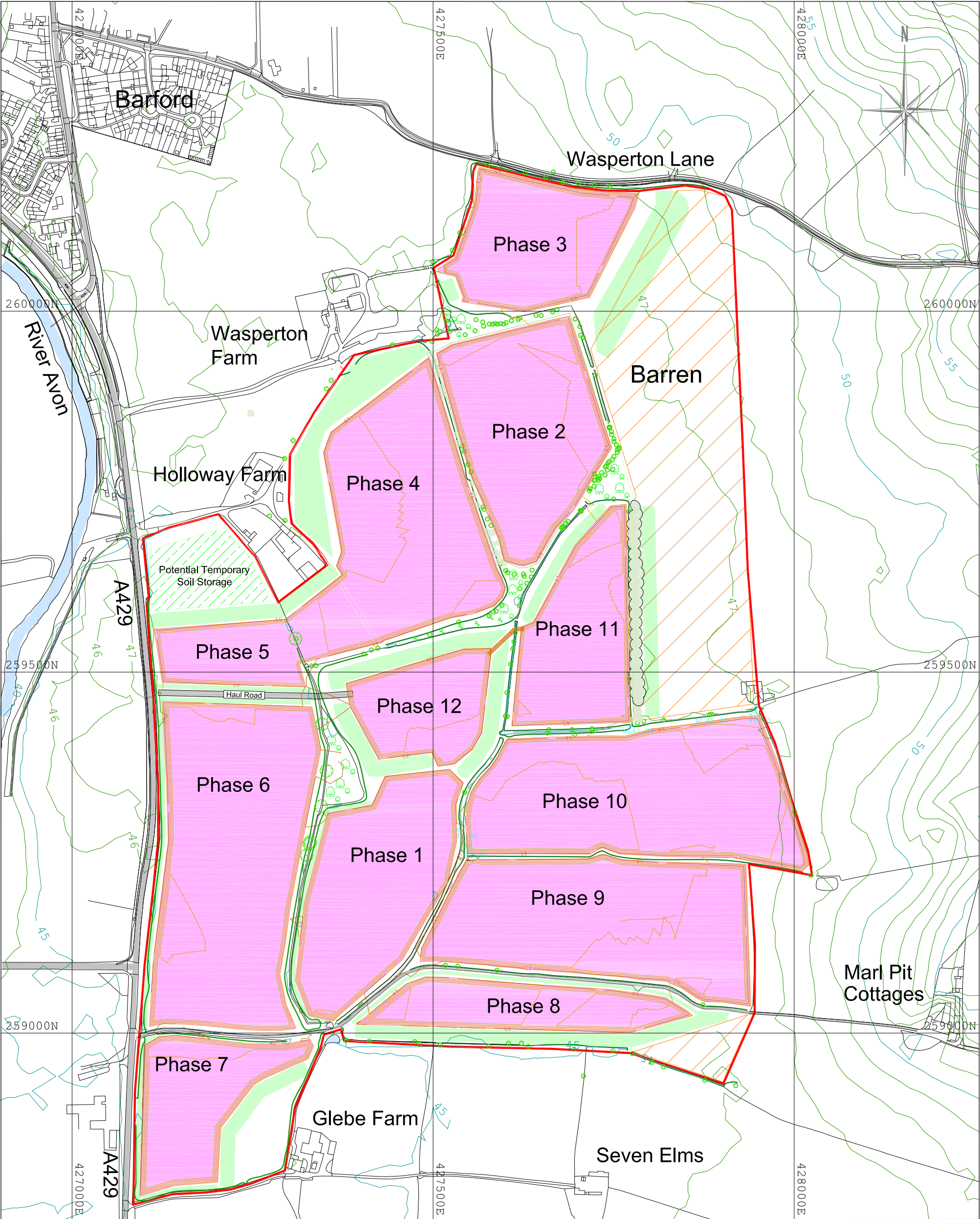
Geological Logs



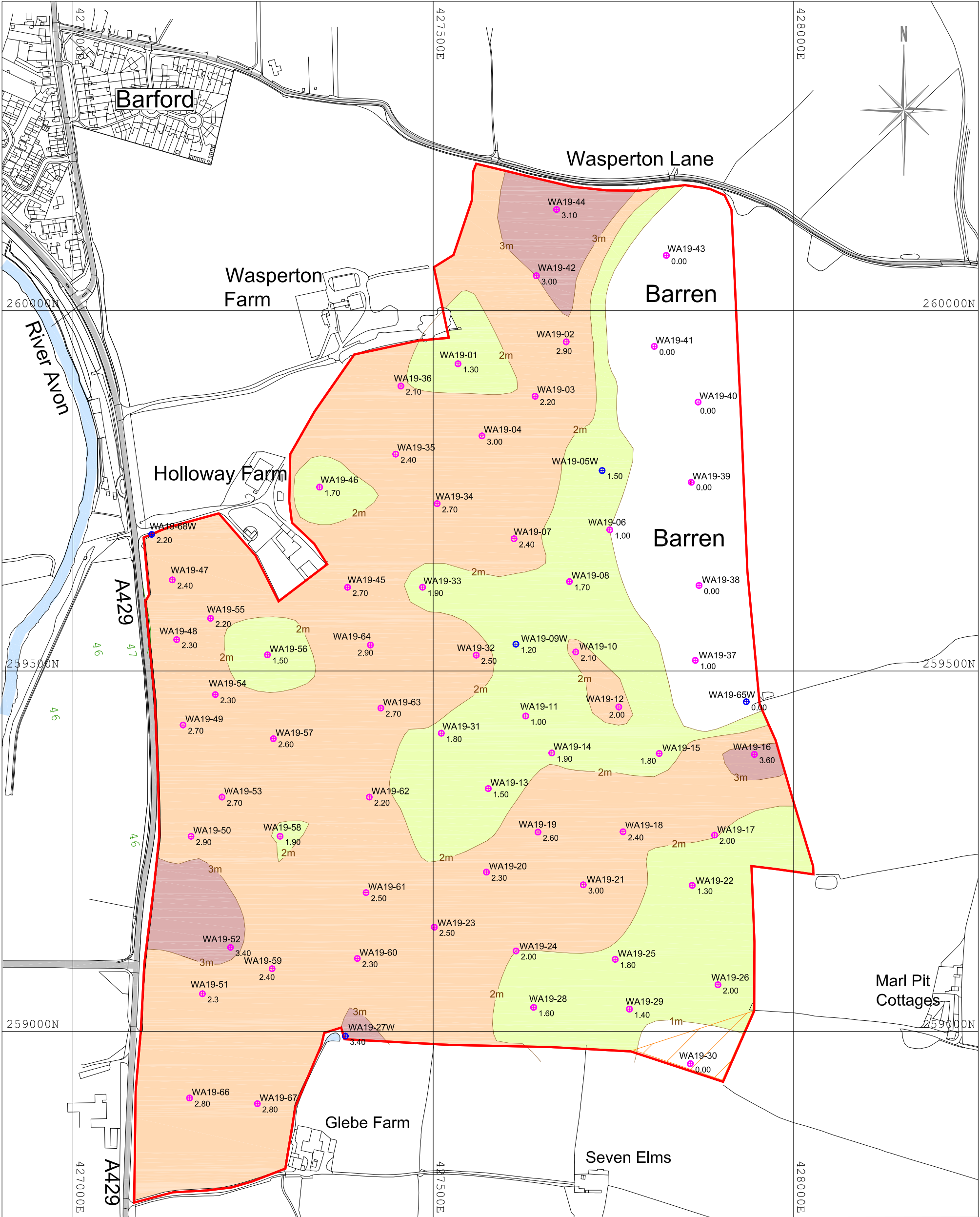
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		Site surveyed by Greenfield Environmental October 2019 Based upon 2013 Ordnance Survey 1:2500 digital base with the permission of The Controller of Her Majesty's Stationary Office. © Crown Copyright. Licence No. 100020505 The copyright of this drawing and its contents are the sole property of Greenfield Environmental and must not be copied or shown to third parties without prior consent of the Company or its clients.	



Site Wasperton Project Geological Investigation Plan WSP 22-2 BH Summary	Key WA19-28 1.5 1.1 1.2 1.6 Overburden Thickness (m) Silty Sand Thickness (m) (where proven) Pebbly Sand Thickness (m) (where proven) Sand & Gravel Thickness (m) Contours Area of investigation Woodland Silty Sand / Pebbly Sand Units Scale 0m 100m 200m	Scale: 1:5000@A3, 1:3500@A2 Date: 23/06/2022 Project No: SC/WSP/100 File: WSP BH Summary V3.dwg Drawn by: ISC	Smiths CONCRETE
		Site surveyed by Greenfield Environmental October 2019 Based upon 2013 Ordnance Survey 1:2500 digital base with the permission of The Controller of Her Majesty's Stationary Office. © Crown Copyright. Licence No. 100020505 The copyright of this drawing and its contents are the sole property of Greenfield Environmental and must not be copied or shown to third parties without prior consent of the Company or its clients. G Greenfield enviro	



Site Wasperton Project Geological Investigation Plan WSP 22-3 Extraction Design	Key Quarry Contours Topo Contours Area of investigation Barren Area Bunds Extraction Areas Scale 0m 100m 200m	Scale: 1:5000@A3, 1:3500@A2 Date: 23/06/2022 Project No: SC/WSP/100 File: WSP 2022 Extraction Design v2.dwg Drawn by: ISC	Smiths CONCRETE
		Site surveyed by Greenfield Environmental October 2019 Based upon 2013 Ordnance Survey 1:2500 digital base with the permission of The Controller of Her Majesty's Stationary Office. © Crown Copyright. Licence No. 100020505 The copyright of this drawing and its contents are the sole property of Greenfield Environmental and must not be copied or shown to third parties without prior consent of the Company or its clients. G Greenfield enviro	



Site Wasperton Project Geological Investigation Plan WSP22-4 Mineral Thickness Contours	Key WA19-28 Borehole Location Area of investigation
--	---

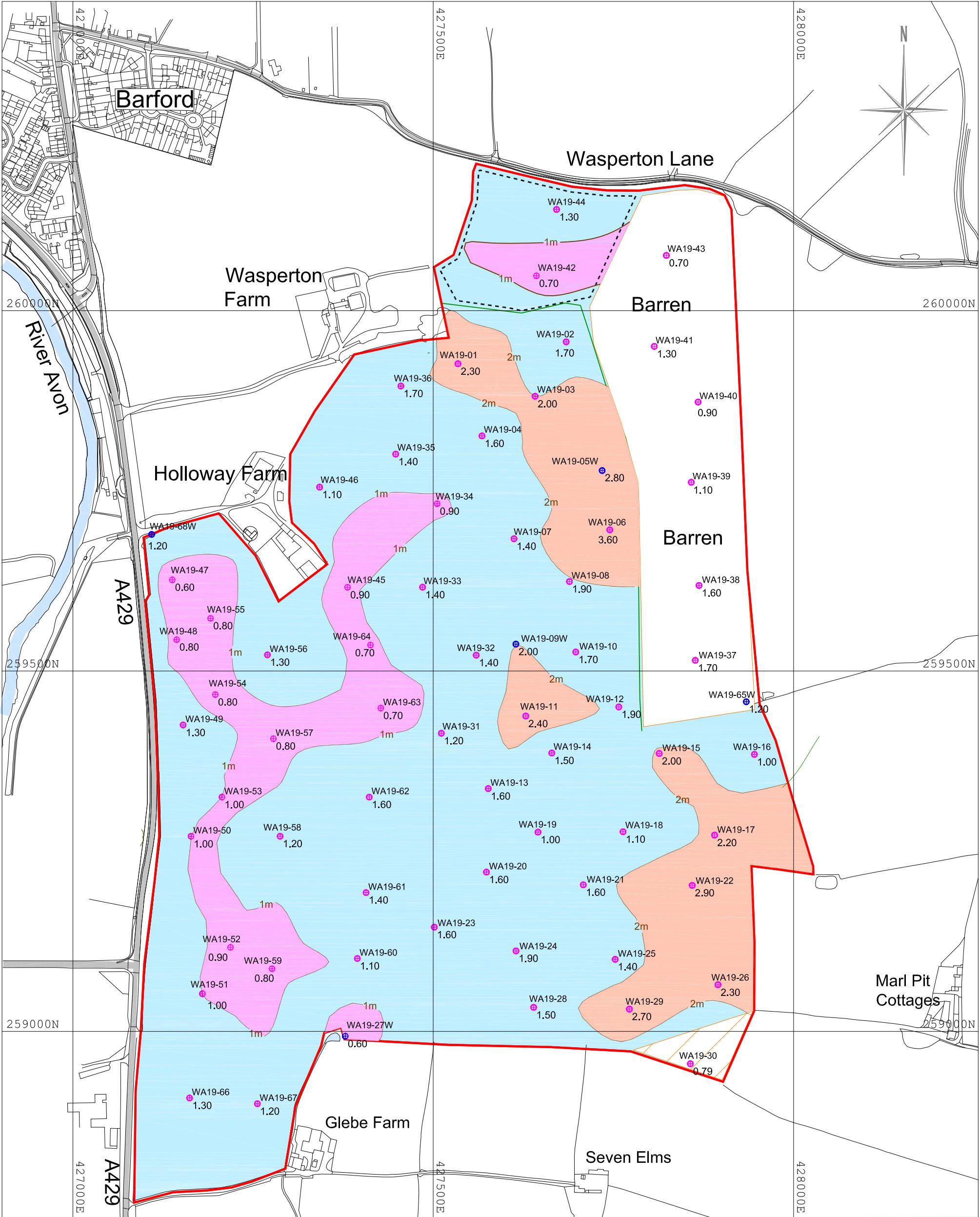
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Mineral Thickness Contours

1 - 2m

2 - 3m

>3m



Site Wasperton Project Geological Investigation Plan WSP22-5 Overburden Thickness Contours	Key WA19-28 Borehole Location Area of investigation
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—1m—

Overburden Thickness Contours

0 - 1m

1 - 2m

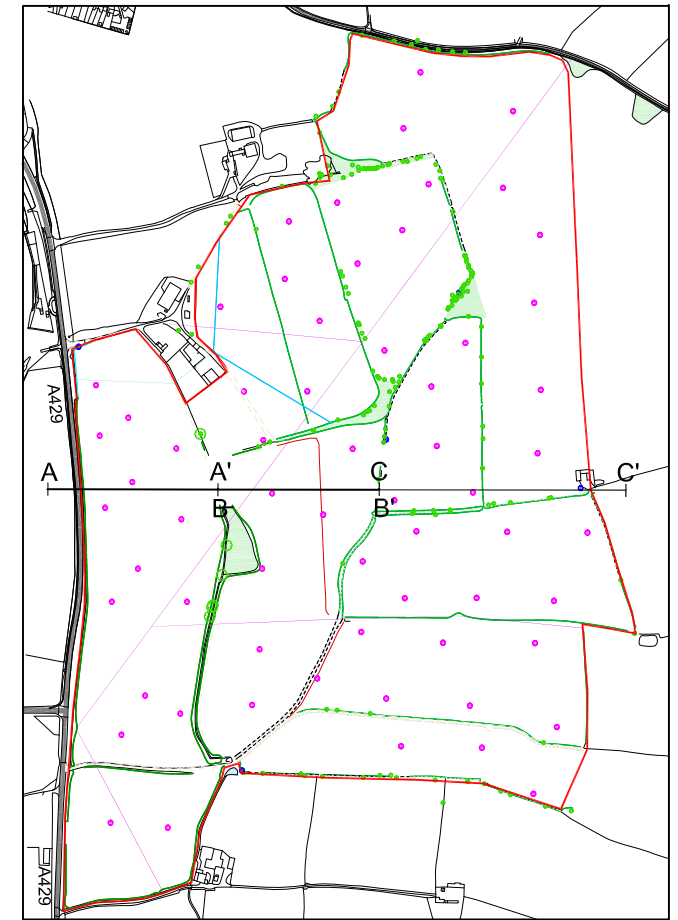
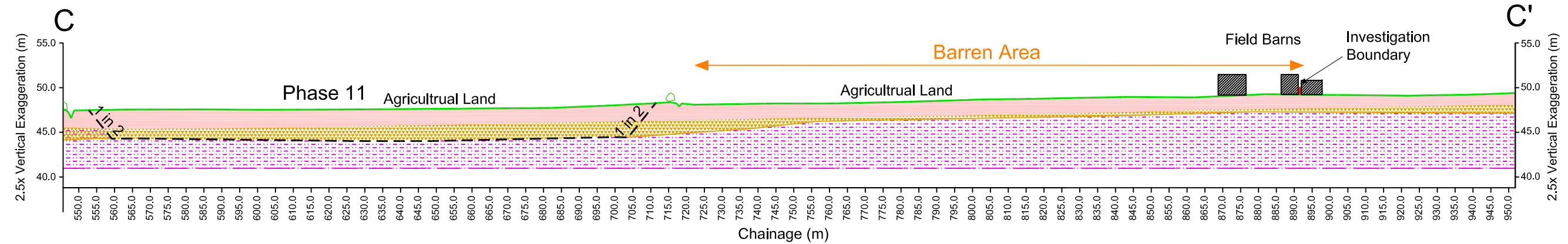
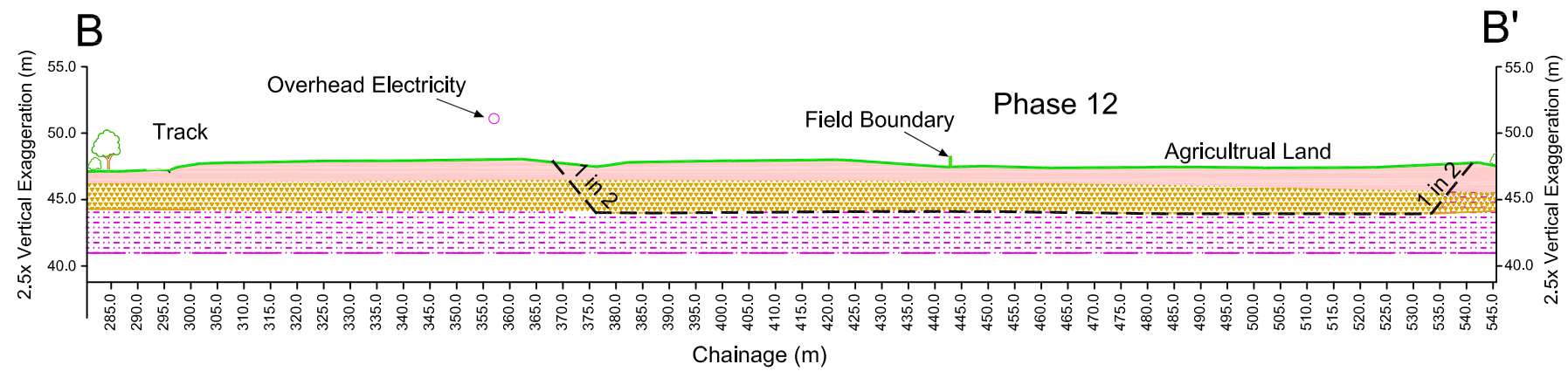
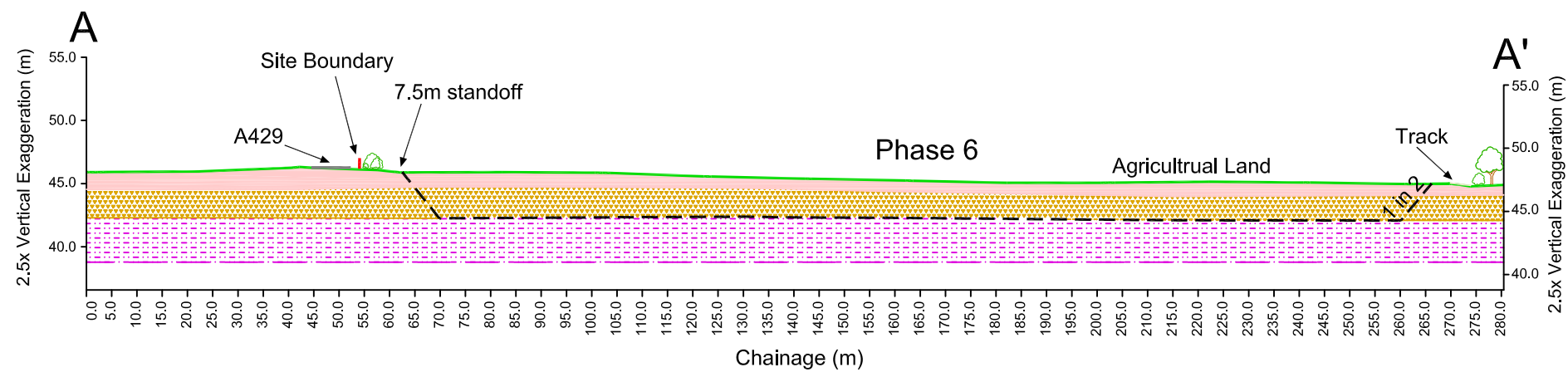
2 - 3m

Scale

0m

100m

200m



Site
Wasperton

Project
Geological Investigation

Plan
WSP 22-6 Cross Sections

Key

- Current Topography
- Overburden
- Mineral
- Mudstone/Clay Bedrock
- Investigation Boundary
- - - Proposed Extraction Design
- Building

Scale

0m 50m

Scale: 1:1250@A3
 Date: 23/06/2022
 Project No: SC/WSP/100
 File: WSP Cross Sections.dwg
 Drawn by: ISC

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APPENDIX 3

HRA Models and Results

APPENDIX 4

Groundwater Monitoring Borehole Logs

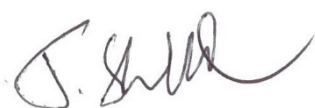
Wasperton, near Barford, Warwickshire
Borehole Installation Drilling – November 2020

1. Introduction

- 1.1. At the request of Hanson UK (on behalf of Smiths Concrete), Greenfield Environmental were commissioned to undertake the installation of five groundwater monitoring boreholes at Wasperton, near Barford, Warwickshire.
- 1.2. The purpose of the proposed installations was to replace damaged boreholes and improve the coverage of monitoring points across the site (See Figure 1 below).

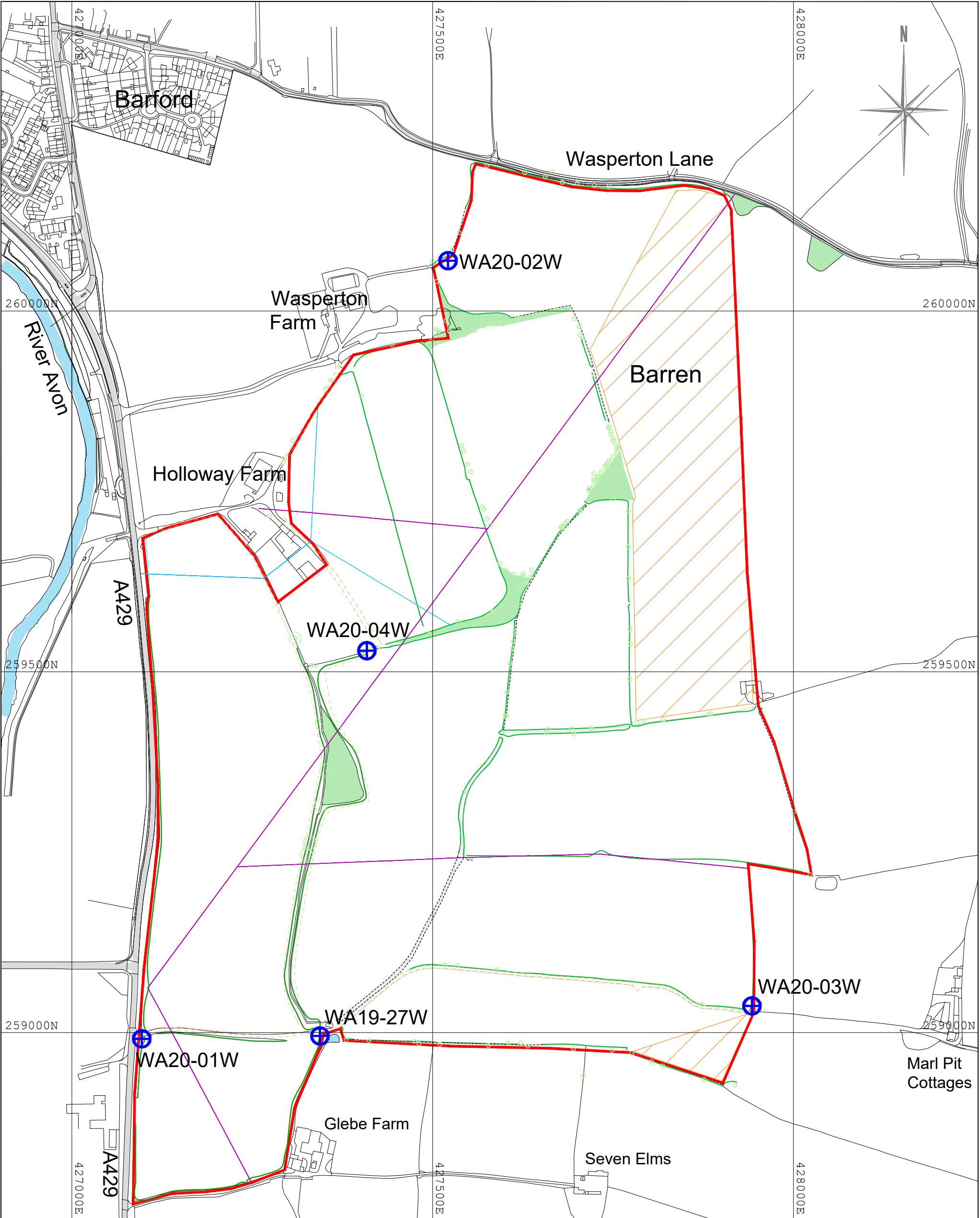
2. Borehole Drilling & Installation

- 2.1. Five cable percussion boreholes were drilled by Metcalfe Bros Ltd between 16th and 18th November 2020. Bulk samples were collected at regular intervals and logged by Greenfield Environmental on site. See borehole logs attached below.
- 2.2. The overburden varied from 1.0m to 2.4m thick and was generally a stiff grey/brown mottled clay with overlying topsoil. The proven mineral ranged from 1.2m to 2.8m and was generally silty fine to coarse and gravel, with clayey silty sand in WA20/02W. WA20/03W in the east of the site was barren, correlating with the results of the previous investigation.
- 2.3. After drilling each borehole was installed with 50mm HDPE pipework, which was secured with an end-cap. The slotted pipework was wrapped in geo-wrap to limit fines ingress to the borehole. The length of plain to slotted was determined by the water strikes and lithologies within each borehole (see borehole logs for detail).
- 2.4. Each borehole annulus was then backfilled with clean pea gravel to 0.8m below ground level, whereupon it was sealed with bentonite pellets to 0.3m below ground level.
- 2.5. Steel headworks were cemented in to secure the top and labelled with the borehole reference. Wooden marker posts were then secured round each of the installations to aid in identifying the location of each borehole (see attached photo plates).



Tom Shellard B.Sc., FGS

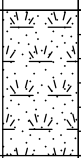
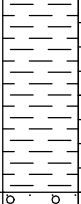
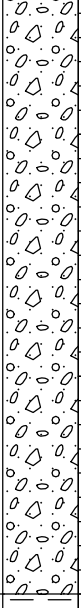
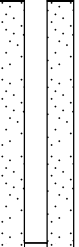
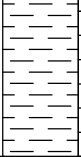
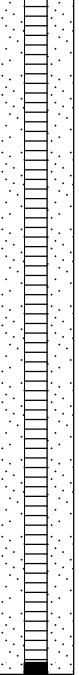
for Greenfield Environmental



Site Wasperton Project Installation Drilling - Nov 2020 Plan Figure 1 Monitoring Borehole Locations	Key Area of investigation Woodland ⊕ 2020 Water Monitoring Borehole Locations Scale	Scale: 1:5000@A3, 1:3500@A2 Date: 03.12.2020 Project No: SC/WSP/100 File: WSP WM BH Locations 2020.dwg Drawn by: TJS	
		Site surveyed by Greenfield Environmental November 2020 Based upon 2013 Ordnance Survey 1:2500 digital base with the permission of The Controller of Her Majesty's Stationary Office. © Crown Copyright. Licence No. 100020505 The copyright of this drawing and its contents are the sole property of Greenfield Environmental and must not be copied or shown to third parties without prior consent of the Company or its clients.	

BOREHOLE LOG

Project Wasperton Installation Boreholes 2020			BOREHOLE No WA19/27W	
Job No SC/WSP/101	Dates start 18-11-20 finish 18-11-20	Ground Level (m) 44.827		
Client Smiths Concrete		Co-Ordinates () E 427346.883 N 258994.61	Sheet 1 of 1	

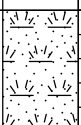
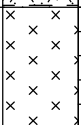
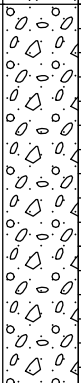
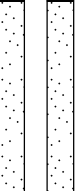
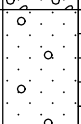
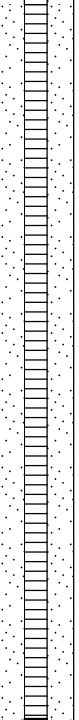
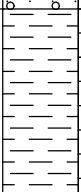
STRATA				INSTALLATION			SAMPLES & TESTS		
Depth	Legend	(Thickness) Reduced Level	Description	Description	Legend	Water	Depth	Type No	Test Result
0.60		(0.60) 44.23	TOPSOIL Stiff dark clayey soil	Cemented headworks, pipework extends 0.2m agl					
1.40		(0.80) 43.43	CLAY Firm brown and grey mottled gravelly CLAY	Bentonite pellets					
3.90		(2.50) 40.93	SILTY SAND & GRAVEL Brown silty fine to coarse SAND and fine to medium rounded to sub-angular quartzite and flint gravel GRAVEL with occasional cobbles	50mm HDPE plain pipework with pea gravel backfill			1.40	B1	
4.60		(0.70) 40.23	CLAY Firm to stiff red marl CLAY	50mm HDPE slotted pipework with geowrap			2.90	B2	
				End cap					

Water Observations				Remarks/Chiselling/Water Added etc.					
Date	Water Depth	Level mOD	Remarks						

All dimensions in metres Scale 1:31.25	Contractor Metcalf Bros	Method/ Plant Used Dando 1500	Logged By L Collins
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BOREHOLE LOG

Project Wasperton Installation Boreholes 2020			BOREHOLE No WA20/01W	
Job No SC/WSP/101	Dates start 17-11-20 finish 17-11-20	Ground Level (m) 45.357		
Client Smiths Concrete		Co-Ordinates () E 427097.762 N 258991.757		Sheet 1 of 1

STRATA				INSTALLATION			SAMPLES & TESTS		
Depth	Legend	(Thickness) Reduced Level	Description	Description	Legend	Water	Depth	Type No	Test Result
0.50		(0.50) 44.86	TOPSOIL	Cemented headworks, pipework extends 0.2m agl					
1.00		(0.50) 44.36	SILT Soft brown sandy SILT	Bentonite pellets			0.50	H1	
2.60		(1.60) 42.76	SAND & GRAVEL Brown slightly silty fine to coarse SAND and fine to coarse rounded to sub-angular quartz quartzite and flint GRAVEL ...very clayey in the top 0.3m	50mm HDPE plain pipework with pea gravel backfill			1.30	B2	
3.10		(0.50) 42.26	PEBBLY SAND Light brown slightly silty fine to medium SAND with some fine to medium sub-round to sub-angular quartzite gravel	50mm HDPE slotted pipework with geowrap			2.60	B3	
3.80		(0.70) 41.56	SAND & GRAVEL Brown fine to coarse SAND and fine to coarse rounded to sub-angular quartz quartzite and flint GRAVEL				3.10	B4	
4.60		(0.80) 40.76	CLAY Stiff red marl CLAY						
				End cap					

Water Observations				Remarks/Chiselling/Water Added etc.	
Date	Water Depth	Level mOD	Remarks		

BOREHOLE LOG

Project Wasperton Installation Boreholes 2020			BOREHOLE No WA20/02W	
Job No SC/WSP/101	Dates start 16-11-20 finish 16-11-20	Ground Level (m) 45.931		
Client Smiths Concrete		Co-Ordinates () E 427514.198 N 260070.682		Sheet 1 of 1

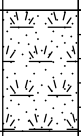
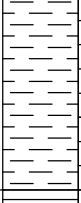
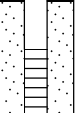
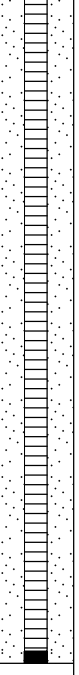
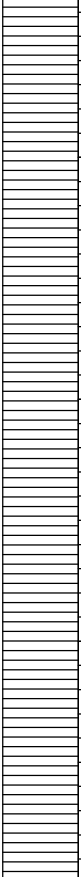
STRATA				INSTALLATION			SAMPLES & TESTS		
Depth	Legend	(Thickness) Reduced Level	Description	Description	Legend	Water	Depth	Type No	Test Result
0.20		(0.20) 45.73	TOPSOIL	Cemented headworks, pipework extends 0.2m agl			0.20	H1	
			Stiff dark clayey soil CLAY	Bentonite pellets					
			Stiff to very stiff grey/brown mottled CLAY with occasional snady pockets	50mm HDPE plain pipework with pea gravel backfill					
		(2.20)							
2.40		43.53	CLAYEY SAND				2.40	B2	
			Brown clayey silty SAND with occaisonl fine to emdium sub-angulr to roudned flint and quartite gravel	50mm HDPE slotted pipework with geowrap					
		(1.20)							
3.60		42.33	CLAY				3.60	H3	
			Firm to stiff red marl CLAY						
		(1.00)							
4.60		41.33		End cap					
									

Water Observations				Remarks/Chiselling/Water Added etc.	
Date	Water Depth	Level mOD	Remarks		

All dimensions in metres Scale 1:31.25	Contractor Metcalfe Bros	Method/ Plant Used Dando 1500	Logged By L Collins
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BOREHOLE LOG

Project Wasperton Installation Boreholes 2020			BOREHOLE No WA20/03W	
Job No SC/WSP/101	Dates start 18-11-20 finish 18-11-20	Ground Level (m) 46.731		
Client Smiths Concrete		Co-Ordinates () E 427944.64 N 259037.238	Sheet 1 of 1	

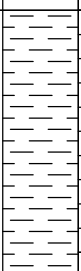
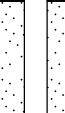
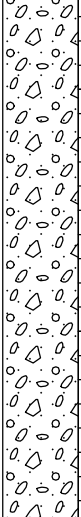
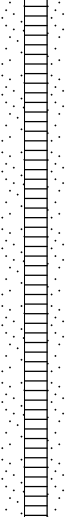
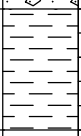
STRATA				INSTALLATION			SAMPLES & TESTS		
Depth	Legend	(Thickness) Reduced Level	Description	Description	Legend	Water	Depth	Type No	Test Result
0.50		(0.50) 46.23	TOPSOIL Firm dark clayey soil	Cemented headworks, pipework extends 0.2m agl					
1.30		(0.80) 45.43	CLAY Firm to stiff red/grey/brown mottled CLAY with occasional coarse sand and fine gravel and rootlets	Bentonite pellets			0.50	H1	
				50mm HDPE plain pipework with pea gravel backfill					
				50mm HDPE slotted pipework with geowrap			1.30	H2	
5.00		(3.70) 41.73	MUDSTONE Stiff to very stiff red with greenish grey mottling CLAY/weathered MUDSTONE	End cap					

Water Observations				Remarks/Chiselling/Water Added etc.					
Date	Water Depth	Level mOD	Remarks						

All dimensions in metres Scale 1:31.25	Contractor Metcalf Bros	Method/ Plant Used Dando 1500	Logged By L Collins
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BOREHOLE LOG

Project Wasperton Installation Boreholes 2020			BOREHOLE No WA20/04W	
Job No SC/WSP/101	Dates start 17-11-20 finish 17-11-20	Ground Level (m) 45.308		
Client Smiths Concrete		Co-Ordinates () E 427409.373 N 259530.772	Sheet 1 of 1	

STRATA				INSTALLATION			SAMPLES & TESTS		
Depth	Legend	(Thickness) Reduced Level	Description	Description	Legend	Water	Depth	Type No	Test Result
1.10		(1.10) 44.21	CLAY Firm brown gravelly CLAY	Cemented headworks, pipework extends 0.3m agl					
				Bentonite pellets					
				50mm HDPE plain pipework with pea gravel backfill			1.10	H1	
1.60		(0.50) 43.71	CLAYEY SAND Brown clayey silty fine to medium SAND with some fine to medium sub-angular to rounded quartzite gravel				1.60	B2	
3.80		(2.20) 41.51	SAND & GRAVEL Brown slightly silty fine to coarse SAND and fine to coarse rounded to sub-angular quartz flint and quartzite GRAVEL	50mm HDPE slotted pipework with geowrap			3.10	B3	
4.30		(0.50) 41.01	CLAY Firm to stiff red marl CLAY	End cap					

Water Observations				Remarks/Chiselling/Water Added etc.	
Date	Water Depth	Level mOD	Remarks		

All dimensions in metres Scale 1:31.25	Contractor Metcalfe Bros	Method/ Plant Used Dando 1500	Logged By L Collins
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Wasperton Borehole Installation Drilling - November 2020



Plate 1: Covering slotted pipework with geowrap



Plate 2: Inserting plain and slotted pipework to borehole annulus and cutting down to length

Wasperton Borehole Installation Drilling - November 2020



Plate 3: Backfilling with pea gravel and hydrated bentonite pellets



Plate 4: Cementing steel headworks in place

Wasperton Borehole Installation Drilling - November 2020



Plate 5: Installing wooden marker posts and labelling headworks with borehole reference

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