Ground Investigation Report

Worsborough Reservoir, Barnsley

Reference : 20119-R-001-V02
Date : 01 February 2022

SOIL AND STRUCTURES

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Report Author and Authoriser

Author	Signature
Russell Bowman Director BSc (Hons) MSc CEng CWEM MCIWEM	 01 February 2022

Non-Technical Summary

Additional intrusive investigation has been completed across a section of Worsborough Reservoir's northern shore where failure of an existing retaining wall had occurred.

Alongside this, a review of existing ground-related reporting has been undertaken.

This investigation has revealed that failure of the retaining wall is likely due to erosional processes resulting in localised loss of support at the base of the wall.

These erosional processes likely driven by the action of burrowing Signal Crayfish, a non-native invasive species, that have been reported within the reservoir waters.

Other mechanisms, e.g. wave action or preferentially weaker/more weathered supporting soils, may be contributing to the instability but are considered secondary to the main erosional action of burrowing Signal Crayfish.

This investigation also confirmed that large-scale instability of the embankment immediately north of the retaining wall is unlikely. The report does however identify that localised instability may occur around areas of the embankment where steep cut-faces have been formed.

Further investigation of the potential for Signal Crayfish to be present is recommended as this will inform the design of remedial solutions.

In advance of this further investigation, outline recommendations are presented for various remedial options for the retaining wall and lower footpath.

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- **Drawings:** Exploratory Hole Location Plans (ref. 20119-D-001-V01 and 20119-D-001-V01)
- **Exploratory Hole Logs:** HP101 to HP103 and WS101 to WS103
- **Existing Reports:** Abbeydale Building Environment Consultants report 'Phase 1 Desk Study Report' dated November 2019 ref. 151092DS that appends various other ground-related reports referenced herein.

Appointment

Soil and Structures Ltd were instructed by Barnsley Council (the Client) in November 2021 to prepare a Ground Investigation Report (this Report) to support an assessment of ground conditions and slope stability along a section of the northern shore of Worsborough Reservoir, Barnsley (the Site) where an existing retaining wall along the edge of the reservoir wall was failing.

Scope and Context

Align Property Partners Ltd conducted non-intrusive investigations of the retaining wall and adjoining land that included a variably angled embankment above the retaining wall. The findings of these investigations were reported in a 'Structural and Civil Report' dated 03 August 2021 (ref. BC2135-APP-WR-XX-RP-S-0100-S1). This report included the recommendation for intrusive investigation of the retaining wall and the embankment (including the upper level footpath).

Soil and Structures were subsequently commissioned to undertake an intrusive ground investigation, comment on the stability of the embankment and offer outline advice on possible remedial solutions.

Reliance on the advice presented herein rests solely with the Client.

References

The Ground Investigation Report has been written with reference to various sources of information. These are either appended or referenced throughout this Report as footnotes.

Existing ground investigation reporting has been made available for review.

1.0 Introduction

1.1 The Site and the Scenario

Location: The Site comprises an approximately 100 m long section of Worsborough Reservoir's northern shore. The Site includes the reservoir base itself, a short masonry retaining wall that has failed (Photo 1) that supports a lower level footpath and an embankment that rises to an upper level footpath.

Access: The Site is accessed on foot via the access footpath to the north-east that itself is accessed via an access track 100 m north of the Site.

Topography: The topography of the Site is characterised by a near-level lower footpath resting around 60.00 mAOD from which an embankment slopes up at variable angles to an upper footpath that ascends from east to west from around 60.75 to 63.75 mAOD.

Scenario: The short masonry retaining wall that borders the reservoir has been subject to rotational 'down-and-out' failure that has resulted in the appearance of a tension crack along the length of the lower footpath.

With the stability of this lower footpath having been compromised, it has been closed to the public from an unknown date.

This tension crack rests at the base of an embankment the stability of which was questions within Align Property Partners' Structural and Civil Report.

Over the course of the works it became apparent that existing intrusive investigations had been conducted across the Site that was subsequently made available for review.



Photo 1: Rotational 'down-and-out' failure of retaining wall

> *Looking west.*
> *View of eastern end of masonry retaining wall.*



Photo 2: Presentation of the northern shore retaining wall

> *Looking east.*
> *View of western end of masonry retaining wall.*



Photo 3: Presentation of the northern shore retaining wall

> *Looking west.*
> *View of central section of masonry retaining wall.*

2.0 Background to this Report

This section summarises, in chronological order, the background to this Ground Investigation Report including existing ground-related reporting. Commentary, in italics, is offered against each of these respective reports.

This ground investigation information does not appear to have been made available to Align Property Partners in the preparation of their Structural and Civil Report.

July 2018 (or July 2019) – JNP Group Ground Investigation Report ref. S10732-JNP-XX-XX-RP-C-1003-S2)

> The report is written in the context of the retaining wall failure and includes intrusive investigation data obtained from windowless sample boreholes (3) completed at the crest and base of the embankment and hand excavated trial pits (2) completed on the lower level footpath. Key findings include:

- The presence of 'firm to stiff' clay deposits across the Site underlain by coal measures (bedrock) including coal *(Barnsley Coal Seam)*.
- The anecdotal presence of 'ash' at the base of the retaining wall when constructed.
- The report concludes that the damage to the retaining wall is likely to be resulting from bearing failure of the coal *that the wall partially bears* onto being 'undercut and eroded' by the action of either reservoir water or water flowing in underground workings. The report excludes an assessment of slops stability and notes that large scale global failure (*presumably relating to the slope*) is unlikely to the cause.
- The report recommends that the wall is reconstructed with foundations formed below the base of the coal seam.

> *The report contributes a valuable ground model that is developed from the findings of the intrusive investigation (Figure 1) as well as in-situ and laboratory geotechnical testing data relating to the main materials encountered on Site. Whilst coal is a degradable material, the potential for water-softening or erosion of co-deposited mudstones and clay layers is equally likely to occur with the likelihood of a near consistent level of movement across the entire length of the retaining wall unlikely to arise from this mechanism.*

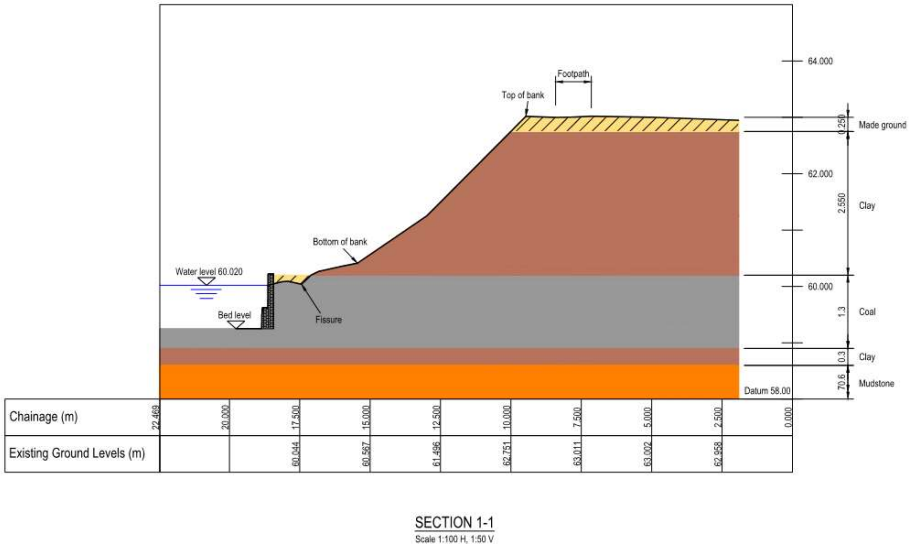


Figure 1: Ground model extract from JNP Group report

> *Key coal mining features noted along with 'embankment'*

29 October 2019 – South Yorkshire Mining Advisory Service report on 'Worsborough Reservoir Bank Failure' ref. M953/1.

> The report is written in the context of the retaining wall failure and key findings include:

- The recorded presence of shallow mine workings (coal) immediately north of the Site that are associated within the Barnsley Coal Seam that is recorded outcropping immediately south of the northern shore (Figure 2).
- The 'embankment feature' north of the retaining wall likely comprising a sandstone escarpment relating to the Barnsley Rock Sandstone (that overlies the Barnsley Coal Seam) (Figure 2 and 3).
- The report concludes that the damage to the retaining wall is unlikely to be coal mining related however, it does note that water ingress into the Barnsley Coal Seam (unmined) may be resulting in the foundations being 'undercut and eroded'.

> *The report establishes the mining setting of the Site assessing mining related subsidence to unlikely be the cause of the retaining wall failure. Whilst not referencing the JNP Group report, the report comes to the same conclusion that erosion of coal is likely the cause of the ground movement beneath the retaining wall. Again, based on the presentation of the retaining wall and near complete failure along its length, this failure mechanism is considered unlikely.*

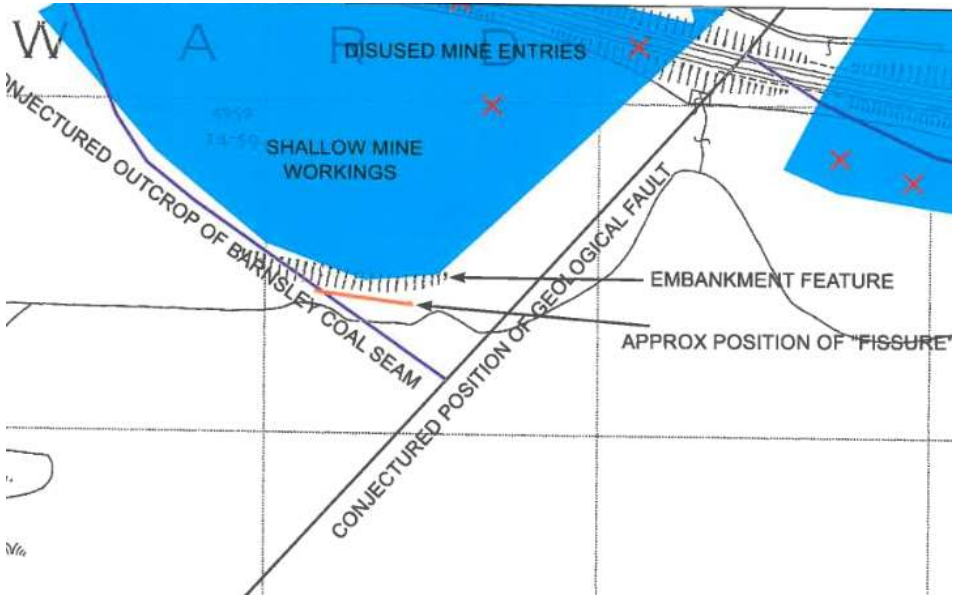


Figure 2: Extract from SYMAS report

> *Key coal mining features noted along with 'embankment'*

November 2019 – Abbeydale Building Environment Consultants report 'Phase 1 Desk Study Report' ref. 151092DS

> The report is written in the context of the retaining wall failure. The report: i) presents a detailed summary of the Site's historical and geological setting, ii) references (and appends) the two earlier reports prepared by SYMAS and JNP Group; and, iii) offers outline recommendations on various remedial options for the retaining wall.

> Reference to this existing report (appended) is recommended for more detailed descriptions of the Site setting (history, geology, hydrology and hydrogeology). In summary, key findings include:

- An assessment of coal risk that supersedes that presented within the SYMAS report indicating there to be a very high 'risk' (*likelihood*) of unrecorded mine entries and mine workings to be present beneath the Site (in and around the retaining wall).
- A low 'risk' (*likelihood*) of quarrying activities having taken place on the Site.
- Commentary on the prevailing wind directions being towards the retaining wall including overtopping of the retaining wall by reservoir waters during storm events.
- The recommendation of various options to remediate the unstable retaining wall with at least 600 mm 'freeboard' to mitigate against wave action.

> *The report offers broad based advice on potential remedial solutions however omits to qualify how these measures may be potentially impacted by the 'very high' risk associated with shallow coal mine workings and mine entries.*

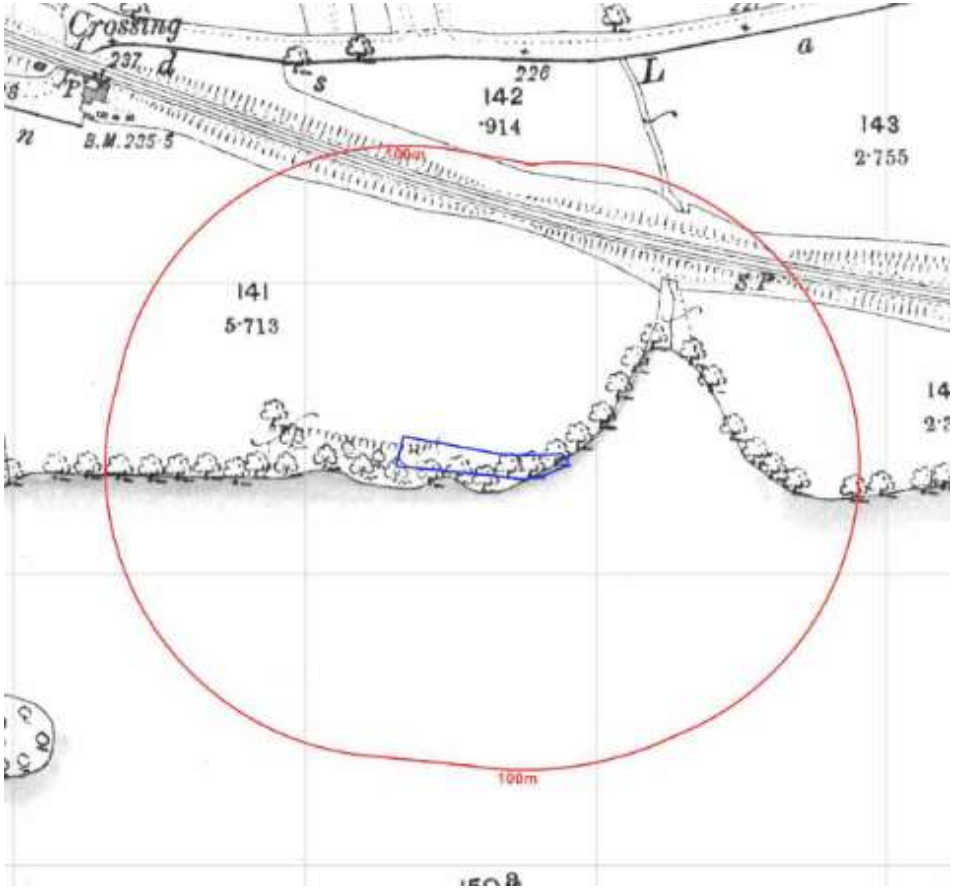


Figure 3: 1892 OS mapping for the Site

> *Embankment feature partially masked by trees*

August 2021 - Align Property Partners publish their 'Structural and Civil Report' (ref. BC2135-APP-WR-XX-RP-S-0100-S1).

- The report is written in the context of the retaining wall failure. The report contributes additional detail relating the reservoir's construction that is not available in earlier reporting and concludes by assessing either bearing failure and/or slope instability are likely resulting in the failure of the retaining wall.
- The report makes recommendations for remediating the retaining wall and either re-profiling the existing embankment or else, offering additional support through the inclusion of additional retaining walls at the base and top of the embankment.
- Recommended works includes an intrusive ground investigation (this Report) and an ecological survey.
- *The report offers wide-ranging advice on potential remedial solutions with a focus on mitigating potential slope instability. Whilst local evidence of slope instability is present, there is a greater weight of evidence that failure of the retaining wall is due to undercutting; a localised failure rather than wider-scale slope induced failure.*

2.1 Summary of Existing Reporting

Existing ground related reports have been prepared for the Site; all in the context of the retaining wall failure.

Two main mechanisms for failure of the wall are suggested: i) loss of support at the base of the wall arising from wash-out or erosion of coal deposits (or supporting material); and, ii) excessive active pressure induced by slope instability across the embankment.

Various remedial options are proposed including: i) remodelling of the embankment to make the slope more favourable (in light of possible slope instability); ii) installation of a new retaining wall (middle and top retaining walls are proposed by Align Property Partners in light of the possible slope instability) of various materials/constructions; iii) installation of 'rip-rap' protection to the front face of the wall; and, iv) reconditioning the existing wall.

3.0 Ground Investigation Fieldworks

3.1 Visual Inspection

In advance of the intrusive investigation fieldworks visual inspection of the full length of the retaining wall and embankment was completed.

This inspection was undertaken whilst the reservoir levels were depressed permitting access along the base of the retaining wall.

Key findings (including residual hazards ⚠) of the inspection include:

> ⚠ The presence of a tension crack along almost the entire length of the retaining wall that is located at varying distances from the top of the retaining wall but typically within 750 mm and of widths consistent with a rotational movement 'down-and-out' from its original position. The tension crack is symptomatic of the vertical movement of the wall largely being completed (it is mostly bearing onto the base of the reservoir) however rotational movement and potential collapse, particularly under load, may occur should access be permitted.

> ⚠ The presence of sections of the wall (western end) that are undercut by up to 300 mm depth resulting in a potential collapse hazard should access be permitted.

> ⚠ The presence of variable slope angles (including up to vertical) across the embankment face that include localised areas of disturbed or spalled soils suggestive of ground movement. Whilst the stability of the embankment is generally considered to be 'good' or stable, these localised areas of instability may give rise to small landslides or slumps during or following unfavourable conditions, e.g. heavy rainfall.

> The existing retaining wall was found to be very shallowly founded (on the surface of the reservoir base) and either undercut or collapse along its entire length.

> The lack of evidence of coal deposits along the base of the retaining wall.

> The lack of evidence of mass instability across the embankment, e.g. tension cracks or marked changes in level towards the crest of the slope indicative of rotational failure planes / blocks.

> The presence of drainage pathways along the upper footpath that, on initial inspection, were considered potential tension cracks but found to be erosional features that linked into the natural drainage pathways across the upper footpath.

> The presence of a surface water erosion pathway leading from the upper footpath to the lower footpath resulting in more localised damage to the retaining wall.

> The presence of informal steel bar restraints along the length of the wall that are assumed to have been installed to arrest movement when it first became apparent.

> The presence of numerous alder (?) saplings within or immediately adjacent to the retaining wall's construction.

> The presence of frequent rootlets and silt/clay soils below the base of the undercut wall (western end) and rounded small cobbles and large to medium gravel below the base of the collapsed wall (remainder of its length).



Photo 4: Presentation of the eastern end of retaining wall

- *Looking north-east.*
- *View of access to lower footpath with upper level footpath seen rising to left hand side of image.*
- *Tension crack along retaining wall top visible on right hand side of image.*



Photo 5: Condition of upper footpath

- *Looking south-east.*
- *View of access to upper footpath small surface water erosional channel visible in centre of image.*
- *Crest of embankment found to be generally set at higher level relative to footpath.*



Photo 6: Surface water erosion channel

> *Looking north.*
> *View up surface water erosion channel where water from the upper footpath appears to be channelled down the slope and is resulting in increased damage to the retaining wall on the northern shore.*



Photo 7: Typical presentation of tension crack

> *Looking north.*
> *300 mm crack width on lower footpath with whitish yellow limestone gravel and sandstone cobbles/boulder sub-base exposed within side-wall of the crack.*



Photo 8: Undercut western end of retaining wall.

> *Looking north-east.*
> *View of undercut base with sandy gravelly silt/clay with frequent rootlets present along base of the wall.*



Photo 9: Undercut western end of retaining wall.

> *Maximum recorded depth of undercut – 300 mm – wall is being held in tension but the retained soils to its rear.*

3.2 Intrusive Investigation

An outline scope of works for the intrusive investigation was provided verbally by Align Property Partners that included characterisation of ground conditions and foundation details from the base of the retaining wall all the way up the embankment slope.

The intrusive investigation employed a variety of portable drilling and excavation techniques to enable wider scale characterisation of the ground conditions below the embankment and retaining wall. These include hand held window sampling, rotary auger sampling, hand excavation and hand augering. All these techniques are highly disruptive to the soil but rapidly deployable and permit characterisation of soils and rocks that is often sufficient to enable modelling of ground conditions.

Table 1: Scope and Rationale of the Intrusive Investigation

Activity	Rationale
8 No. window sample boreholes (WS101a/b/c, WS102a/b/c and WS103a/b) *Appended Exploratory Hole Location Plan illustrates positions*	To investigate shallow ground conditions across the lower footpath and embankment.
3 No. hand excavated trial pits (HP101 to HP103) *Appended Exploratory Hole Location Plan illustrates positions*	To investigate shallow ground conditions below the retaining wall.

No geotechnical or environmental samples were obtained as part of this investigation.

The intrusive investigation was completed in advance of the existing ground investigation reporting being made available.

Copies of the exploratory hole location plans and logs are appended. In summary, the key findings included:

> The presence of a shallow bedrock profile along the base of the retaining wall characterised by completely weathered to very weathered sandstone, mudstone and coal deposits. As expected, these deposits became more intact and less weathered with depth with progression of augered and percussive boreholes beyond 1.5 m below the base of the wall not permissible ('bouncing' on suspected sandstone).

> The presence of a layer of up to around 1.0 m of less dense / softer consistency material across the embankment face that rapidly becomes denser / stiffer with depth (residual bedrock).

> The presence of groundwater at depths consistent with the reservoir water level indicating hydraulic continuity between the reservoir and soils/ground behind (supported by) the retaining wall.

> The presence of a shallow seam of coal within the embankment slope and below the base of the retaining wall.

> The presence and predominance of sandstone deposits within the embankment slope and below the retaining wall.

> The localised presence of a deeper topsoil/silt profile towards the western end of the embankment slope below the canopy of the established trees.

These findings were generally consistent with the recorded geology and findings of the previous ground investigation completed by JNP Group in 2019.

It is however noted that JNP recorded the predominance of mudstone deposits within the embankment slope (this investigation typically encountering a more varied ground model typically comprising completely to highly weathered sandstone deposits) and the presence of a locally deeper intact/engineering bedrock profile below the retaining wall.

These variations are consistent with the expected ground conditions and natural variance in weathering profiles.

3.3 Aural Testimonies

Over the course of the fieldworks, discussions with the current bailiff (angling), former bailiff and manager of the visitor centre took place. These discussions were instructive, key findings of which included:

> Manager of visitor centre noted: A 'small crack' appeared within the lower footpath around 2017 with the worsening condition of the retaining wall on Site linked to the formation of the wave break boardwalk present to the east of the Site.

  It was suggested, and both plausible and likely, that inclusion of the wave break boardwalk (installed to limit erosion further east along the northern shore) was resulting in wave-refraction towards the retaining wall. The northern shore was noted to face the prevailing south-westerly wind direction.

  This would result in a change of wave pattern (varied frequency and potentially higher energy) that in turn could be leading to increased erosion of support from the base of the shallowly founded retaining wall.

  A similar pattern of damage / ground movement was noted along the southern shore of the reservoir.

> Current bailiff noted: The completion of a previous intrusive ground investigation 'recently' using a 'tracked drilling rig' - likely the JNP Group ground investigation.

> Former bailiff noted: The presence of Signal Crayfish being noted within the reservoir waters around 5 years ago (~2016) with evidence of burrowing along the entire length of the reservoir shore noted subsequently.

  The formation of the retaining wall in the 1980s with no signs of movement noted until recently (~ 5 years ago).

  The presence of 'Swan Muscles' within the reservoir concern over which was expressed due to the dropping of water levels likely leading to die-back of these molluscs and associated fouling (reduced quality) of the reservoir waters.

4.0 Ground Model

Anticipated ground conditions: The existing ground investigation data together with available mapping information offered a good impression of ground conditions across the Site.

The ground model presented in the JNP Group reporting (reproduced in Figure 1) is considered to offer a good impression of the ground conditions and, together with the additional intrusive investigation data presented herein, carried forward within the ground models presented in Figure 4 and Figure 5 hereafter.

Revealed ground conditions: The additional intrusive investigation undertaken on Site as part of this Report confirmed the anticipated conditions.

This additional information further supports an appraisal of the embankment's overall stability (potential for local instability) as well as the likely mechanisms leading to the retaining wall's failure.

These assessments are detailed within the conclusion (Section 5.0) and should be read in conjunction with the annotated ground model (profile) presented in Figure 4 and Figure 5 hereafter

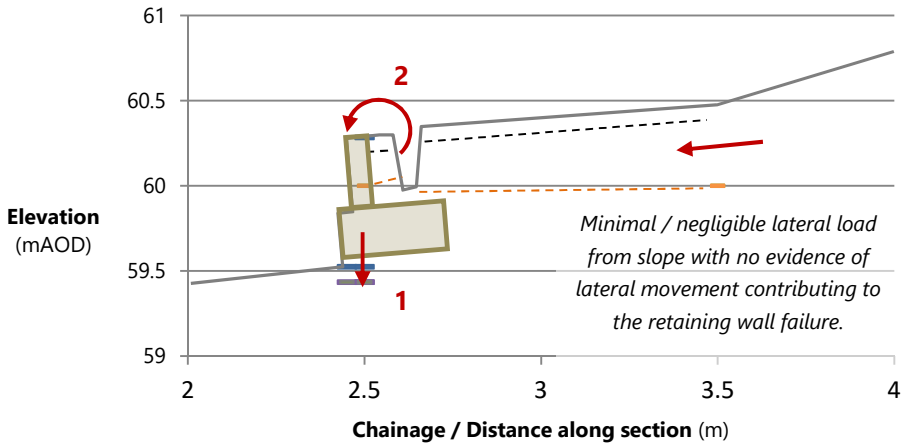


Figure 4: Ground model (profile) – retaining wall section only

- *Illustrative only – do not scale – to be read in conjunction with drawing ref. 20119-D-001-V01*
- *Red arrows illustrate pattern and sequence of likely movement: 1) loss of support at the base of the wall followed by; 2) rotational 'down-and-out' tilting of the wall with both vertical and lateral displacement from original level.*
- *Pattern of movement and tension crack is indicative of localised movement across the full length of the retaining wall with residual movement still possible along sections of undercut wall. The majority of the wall alignment has 'settled' into a new equilibrium on the reservoir base however, the tilt across the wall will likely give rise to further self-weight movement occurring. If and where further erosion and loss of support at the base takes place, a possibility, then collapse of the wall into the reservoir is likely.*

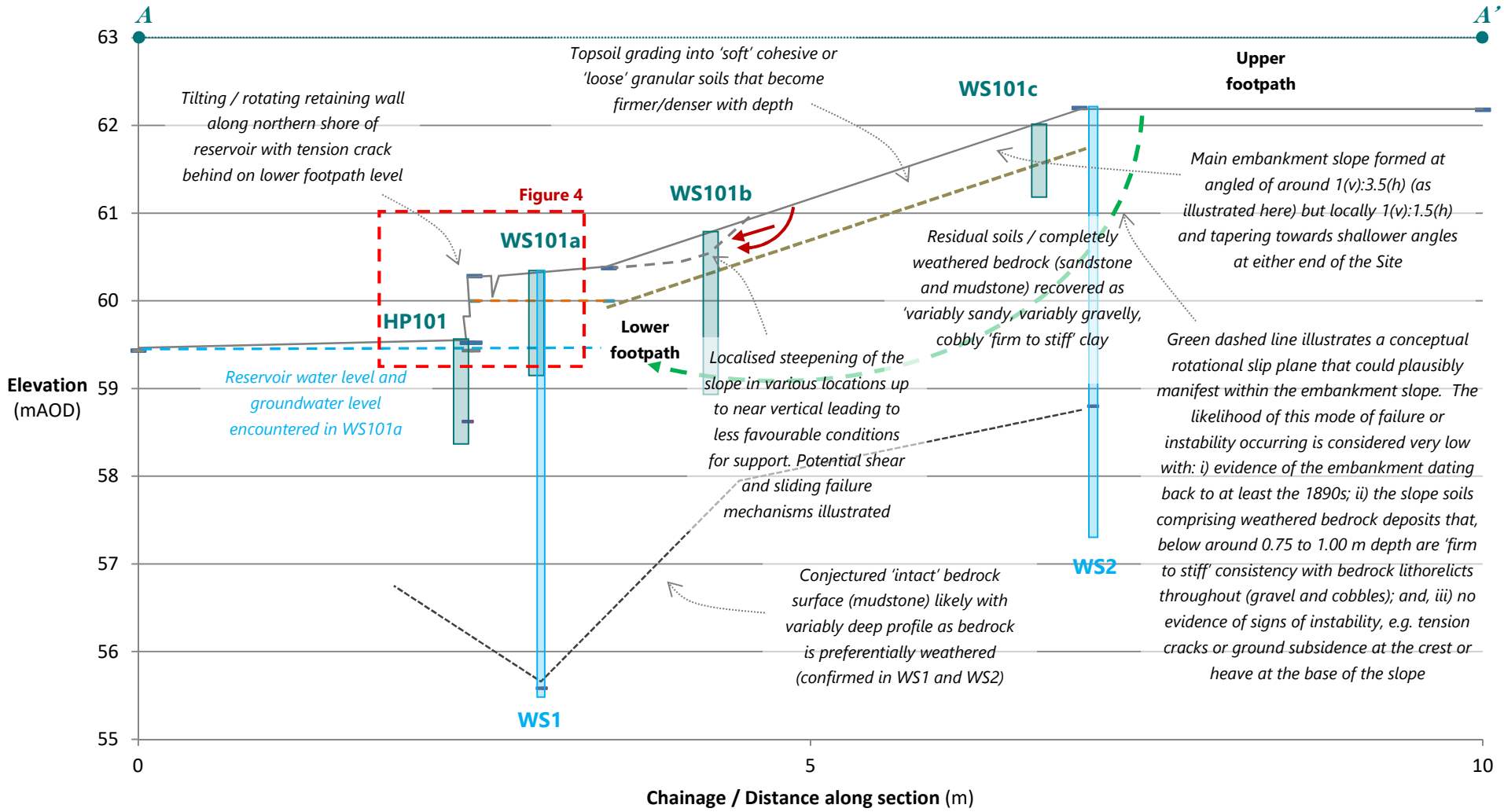


Figure 5: Ground model (profile)

> *Illustrative only – do not scale – to be read in conjunction with drawing ref. 20119-D-001-V01*

5.0 Conclusions and Recommendations

Retaining wall failure: This investigation has revealed that failure of the retaining wall is likely due to erosional processes resulting in loss of support at the base of the wall.

These erosional processes likely driven by the action of burrowing Signal Crayfish, a non-native invasive species, that have been reported within the reservoir waters.

The main line of evidence for Signal Crayfish burrowing being the primary cause of instability is the reservoir-wide presentation with the reported date of instability consistent with the first reported cases of Signal Crayfish being noted within the waters. Whilst this Report relates to the northern retaining wall, the instability is understood to be manifest along the majority of exposed banking and retaining walls.

Other mechanisms, e.g. wave action or preferentially weaker/more weathered supporting soils, may be contributing to the instability but are considered secondary to the main erosional action of burrowing Signal Crayfish.

Further information on potential instability issues brought about by Signal Crayfish is available at:

> Canal and River Trust Briefing
> Sanders H. et al (2021)
> Mason J. and Sanders H. (2021) – extract below
> Magazine Article (good broad based commentary)

> *"Semi-quantitative field observations in the UK (Faller et al., 2016) and the Iberian Peninsula (Arce & Diéguez-Uribeondo, 2015; Barbaresi et al., 2004) have suggested that the presence of animal burrowing can increase the probability of riverbank collapse.* ***Faller et al. (2016) estimated that signal crayfish add approximately 3 t km^{-1} of sediment in burrowed sections of the Thames catchment, UK, but burrowing was patchy and occurred at only 10% of banks surveyed****. Sanders et al. (2021) provide the first long term (22-month) empirical field evidence of a relationship between burrows and accelerated bank retreat and collapse. By destabilizing river banks, signal crayfish may supply more than 49 times as much sediment to river systems than burrowing alone, with accelerated retreat supplying 25.4 t km a^{-1} of additional sediment to a UK lowland river, contributing 12% of total sediment supply from riverbanks at the reach scale (Sanders et al., 2021)…."* (Extract from Mason J. and Sanders H. (2021).

Management of Signal Crayfish populations is understood to remain an area requiring further research. For example, trapping is likely to only result in a small proportion of the population being removed, even when widely employed. It is therefore recommended that mitigation is employed through the remedial option design, i.e. ensuring sufficient embedment of any new retaining structures to limit the potential for burrowing.

It is however important to note that where mitigation measures are included for new retaining walls, if and where Signal Crayfish remain in the reservoir waters, they will likely seek out other areas to form burrows. This may lead to accelerated erosion across other portions of the reservoir edge.

Confirmation of the presence of Signal Crayfish is beyond the scope of this Report with the evidence for their presence confirmed indirectly through the presentation of the instability. It is therefore recommended that a suitably qualified and experienced ecologist is employed to undertake an aquatic survey with the specific aim of confirming/disproving the presence of Signal Crayfish.

In the event that no Signal Crayfish are recorded, it is nonetheless recommended that remedial options employ the same principles with the potential for Signal Crayfish infestations remaining a potential threat in the UK. Similarly, there is compelling evidence that biological erosion is occurring (reservoir wide impact with onset around a similar date) any design considerations would offer complementary protection against most forms of erosion, biological or otherwise.

Figure 6 illustrates the outline recommendations for remedial works across the northern shore retaining wall. The principles of these recommendations include:

> A deep or piled retaining wall solution offering:
  - Protection against future burrowing from Signal Crayfish or other basal erosional processes;
  - Rapidly deployable 'dry' construction not necessarily requiring the use of 'wet' concrete near an aquatic environment;
  - The ability for the temporary and permanent works to be sequenced with the design loads of any construction plant likely to exceed that of any proposed loads;
  - The minimal loss of reservoir capacity with the wall being formed immediately out-bound of the existing retaining wall.
  - The facility to design for the retention/abandonment of the existing wall structure behind the retaining wall limiting the amount of material needing to be excavated as part of the works.
  - Attention would need to be given to: i) access restrictions likely limiting plant sizes or requiring alternative access arrangements – barges or air-dripped; ii) low-pressure plant to offer the potential for a reservoir level working platform; iii) the presence of a variable weathered profile within the bedrock deposits
  - For design purposes, the embedment of the retaining wall may be modelled on the basis of a 'stiff' clay soil with a typical undrained shear strength of 75 kN/m^2. Reference to the testing data presented within the JNP Group report can be made for further details. The presence of the shallow coal is also flagged with piles likely embedded within weathered coal deposits encountered at shallow depths along the length of the retaining wall. If and where modelled on a 'stiff' clay, the coal is considered likely to offer comparable, if not greater levels of relative support. Piles would likely be designed based on a minimum embedment length with premature termination possible but a low likelihood in the ground conditions revealed on Site (employing a suitably sized and powered pile-driver).

> The adoption of alternative remedial solutions may be considered at the discretion of the Engineer with attention given to the general principles outlined above.

It is understood that gabion baskets may be considered as a form of edge protection and support. The flexible nature of these structures would likely enable any potential undermining/burrowing to be readily compromised by controlled collapse of the baskets.

Further research would be prudent to determine if and where gabions are suitable in this scenario. If undermined, this would likely result in an uneven surface rather than the structural integrity being compromised like the existing 'brittle' retaining walls.

Earlier reporting prepared for the Site (Abbeydale Phase 1 Desk Study Report) identified a very high 'risk' (likelihood) of shallow coal mine workings and mine entries being present across the Site (the embankment and retaining wall area).

Whilst the potential for unrecorded mine entries cannot be discounted, given the very shallow depth at which the coal is encountered, if and where historic mining had taken place, surface instability is considered likely to have already manifest. Similarly, preferential erosion of the shallow coal deposits beneath the retaining wall is assessed as unlikely to be resulting in the instability.

It is further noted that recorded mine workings are present to the north of the Site within the same coal seam with the southern extent recorded terminating north of the Site. This extent is likely due to the fact the coal seam was tending towards becoming an outcrop and mine roof material becoming less stable (soil-like not rock).

As noted, the potential for unrecorded mine entries to be present within the Site, e.g. adits or shafts, cannot be discounted however, it is recommended for inclusion as a residual hazard with a low probability of occurrence. If and where any ground movement is noted during the works, it is recommended that the advice of a suitably qualified engineering geologist is sought. Where the feature is clearly identified as a void, contact with the Coal Authority's 24 hr hazard reporting line 0800 288 4242.

Attention should be given to the potential for collapse of the existing retaining wall where undercut or if loaded at the top or already tilted sections.

Embankment stability: This investigation also confirmed that large-scale instability of the embankment immediately north of the retaining wall is unlikely. In general, this is due to the slope being formed at angles below or close to the inherent angle of internal friction for the slope's soils. The report does however identify that localised instability may occur around areas of the embankment where steep cut-faces have been formed.

Across these localised areas of the embankment slope where angles of greater than 1(v):2(h) are present (small cuttings into the base of the slope generally), it is recommended that engineering fill (Class 2 {cohesive} General Fill) is placed in benched terraces of no greater than 300 mm thickness and compacted to a 'firm' consistency to match the in-situ strength characteristics of the slope and offer increased basal support.

It is also recommended that consideration is given to the planting of hardy shrubs or trees along the embankment slope. Whilst specific guidance is available on the selection of species and planting arrangements, a general spread of shrubs and/or trees could be planted and offer support-in-principle. This vegetation could be planted with minimal disruption to the existing vegetation cover that, across the main part of the embankment, is brambles.

In its current condition the full length of the embankment is likely to be 'stable' and, if and where, localised treatment works are undertaken (as recommended), then the condition of the slope local to the works may be taken closer to the point of instability (local). In general, the placement of additional material at the toe of the embankment within the select few areas where the slope angle is greater than 1(v):2(h) will result in more favourable conditions however, any temporary excavation/cut works may induce instability. The appointed contractor should include an assessment of risk for undertaking this work, e.g. under a watching brief, outside of inclement weather.

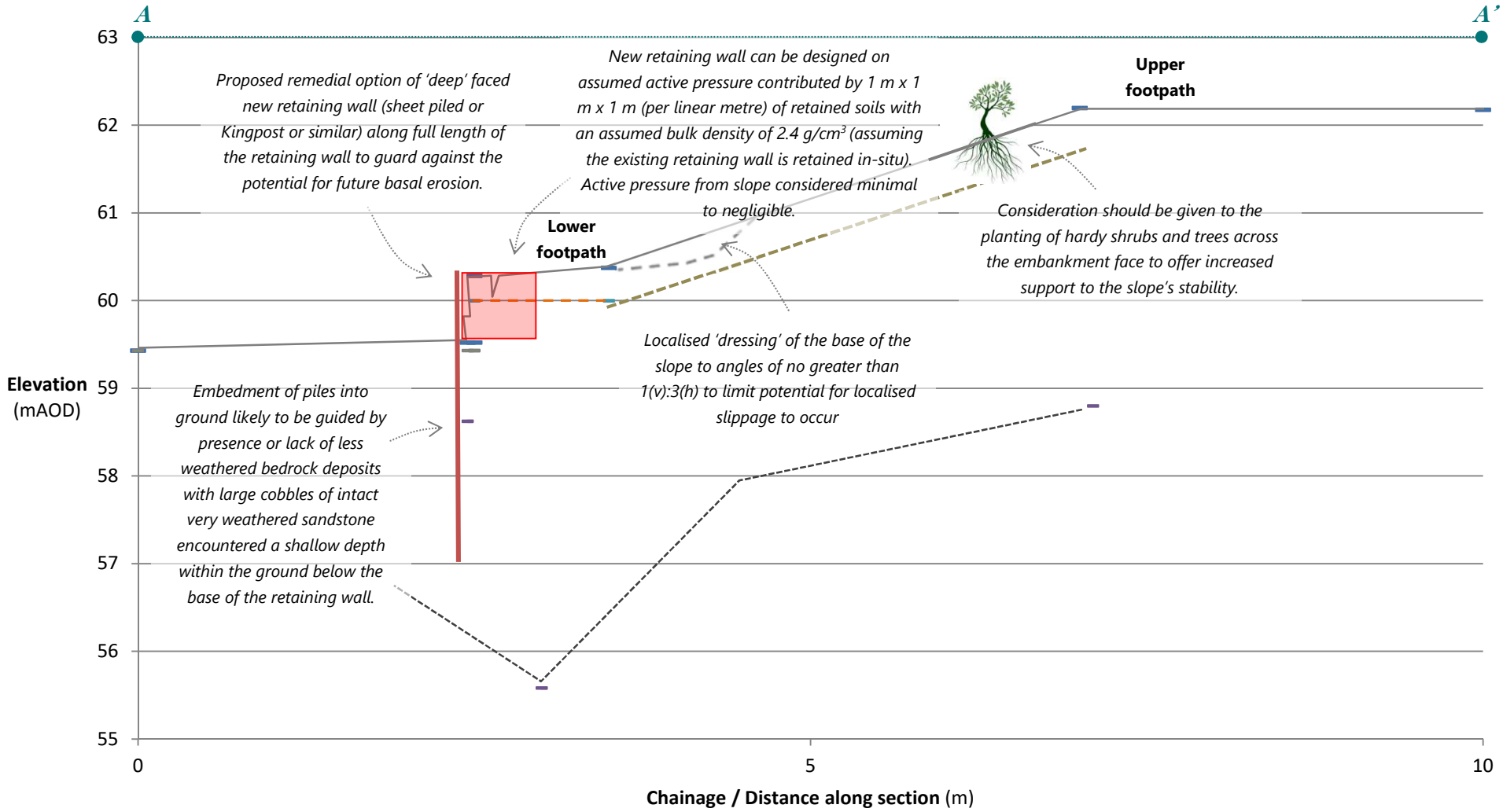


Figure 6: Conceptual model of recommended remedial works

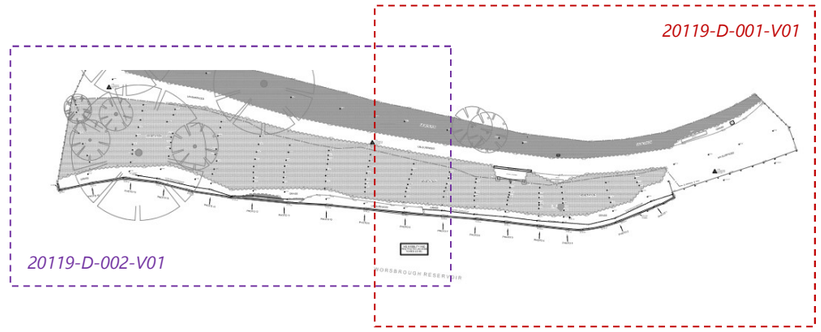
> *Illustrative only – do not scale – to be read in conjunction with Figure 4 and 5 and drawing ref. 20119-D-001-V01*

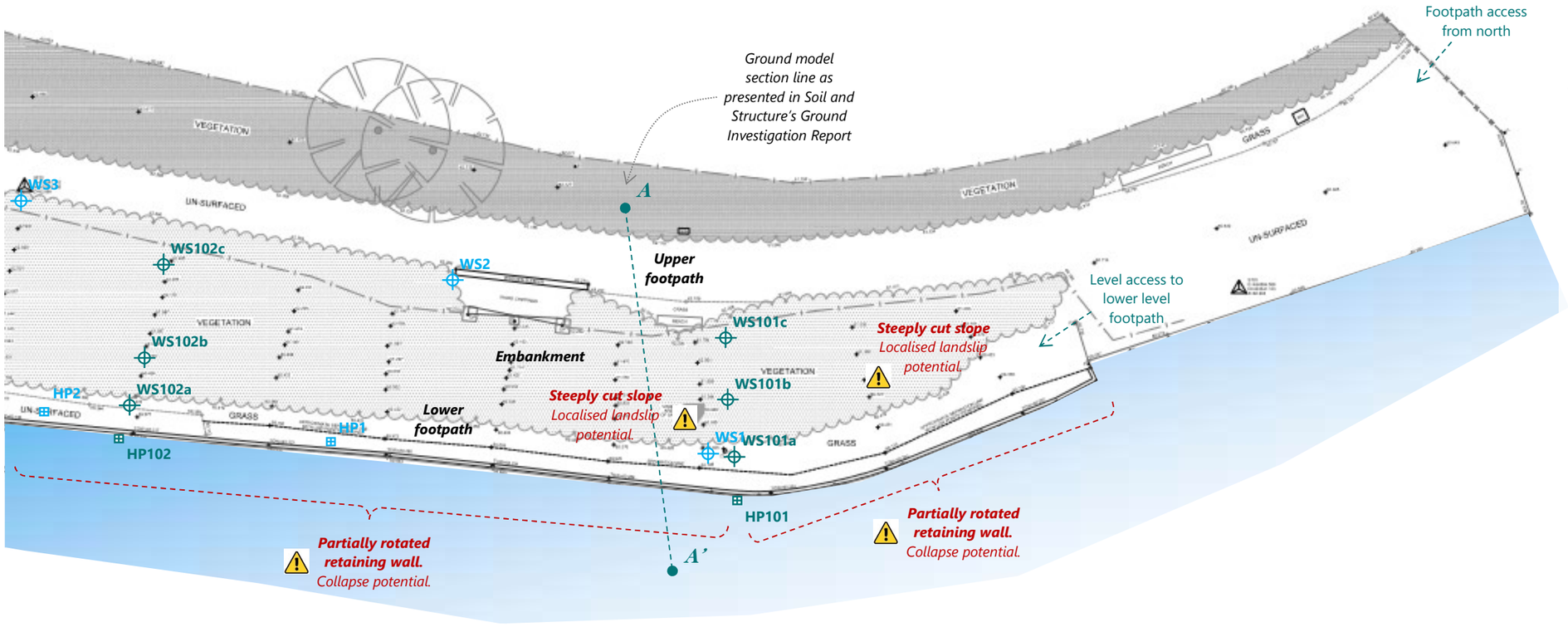
Wider reservoir area: It is understood that the instability evidenced across the Site area (northern shore retaining wall) is present across the southern and eastern shores of the reservoir. Treatment of these area is also understood to be planned.

Whilst additional ground investigation in advance of this work would be considered prudent, available geological mapping information and historical testimonies presented within the Align Property Partners Structural and Civil Report; *"All the glacial deposits have been eroded away and the area now freed of boulder clay",* indicate that similar ground conditions to those evidenced across the northern shore will likely be present in these areas.

Exploratory Hole Location Plan

Worsborough Reservoir, Barnsley





Exploratory Hole Key

JNP Group Investigation – July 2019

- Windowless sample borehole
- Hand excavated trial pit

Soil and Structures Investigation - November 2021

- Window sample borehole
- Hand excavated trial pit

Hazard Key

⚠ Observed hazards identified by yellow warning triangle. Non-exhaustive. Any contractor undertaking works on Site should satisfy themselves that a review of all potential hazards is completed in advance of works commencing.

V01 –	Issue for information

SOIL AND STRUCTURES

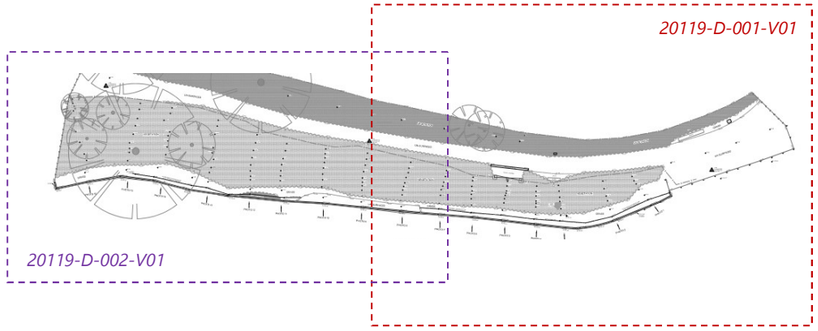
office@soilandstructures.co.uk

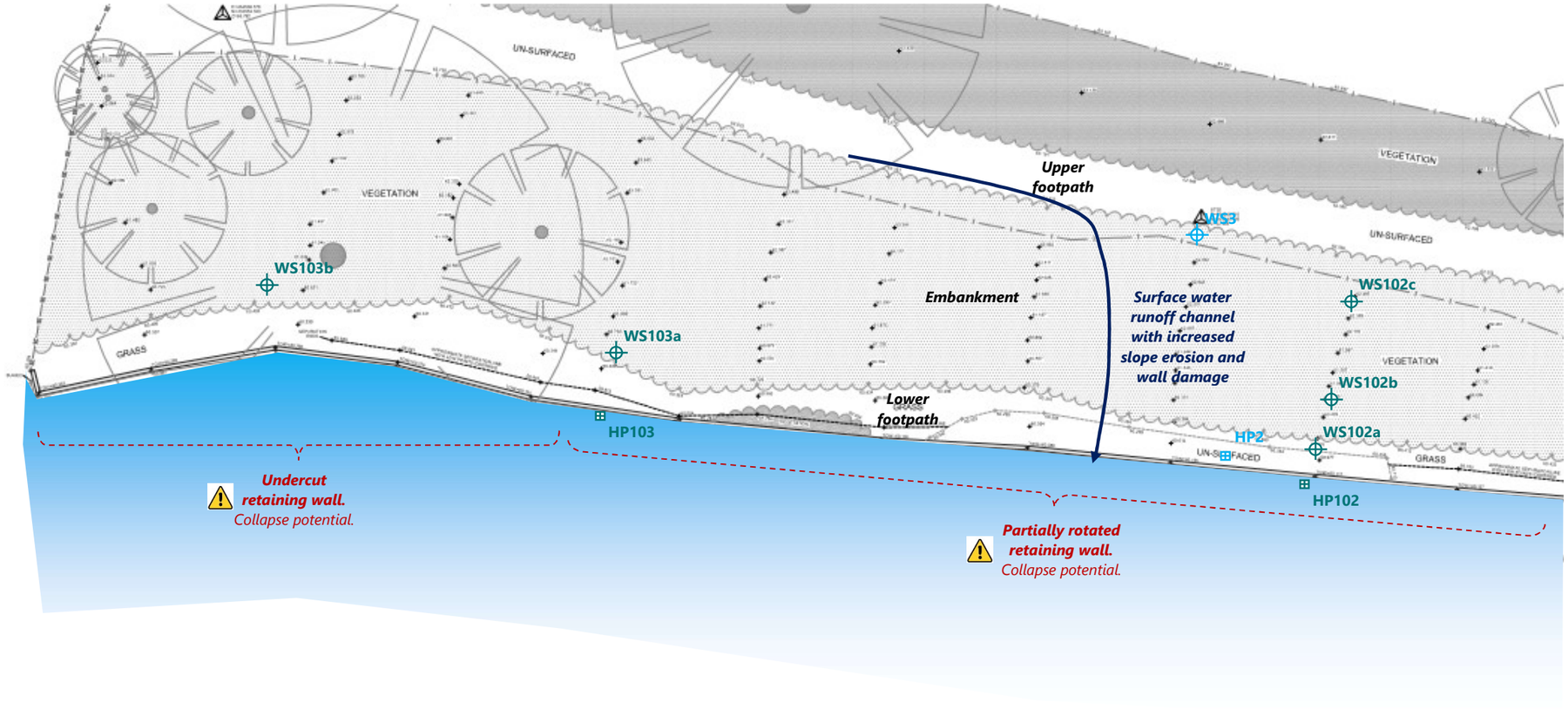
07500 346 541

Drawn by:	RGB	**Drawing ref:**	> **Do not scale from this drawing**
Date:	25.11.2021	20119-D-001-V01_EHLP	> **Dimensions in metres unless stated otherwise**
Scale:	NTS		> **Drawing copyrighted to Soil and Structures Ltd**
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Exploratory Hole Location Plan

Worsborough Reservoir, Barnsley





Exploratory Hole Key

JNP Group Investigation – July 2019

- Windowless sample borehole
- Hand excavated trial pit

Soil and Structures Investigation - November 2021

- Window sample borehole
- Hand excavated trial pit

Hazard Key

⚠ Observed hazards identified by yellow warning triangle. Non-exhaustive. Any contractor undertaking works on Site should satisfy themselves that a review of all potential hazards is completed in advance of works commencing.

V01 –	Issue for information

SOIL AND STRUCTURES

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Scale:	NTS		> **Reproduction subject to permission**

Exploratory Hole Log

HP101

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand tools
Logger	RB

Engineer's Log

Depth mbgl	Depth mAOD	Water	Material	Description	Samples	In-Situ Testing
0.00	59.46 (Topo)			Brown with orange mottling very clayey silty fine to coarse SAND. [POSSIBLE REWORKED NATURAL SOILS]		
0.50	58.96	20		Firm becoming stiff light grey and orange mottled sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is fine to coarse rouded to sub-rounded sandstone. [RESIDUAL BEDROCK] .... From 0.70 m becoming very stiff and very sandy. Scraping/chiselling base.		
0.90	58.56					

Purpose: *Investigation of retaining wall footing formation.*

Exploratory Hole Dimesions

Width	0.40	m
Length	0.40	m
Diameter	-	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	Seepage at 0.85 m depth. Standing at 0.85 m at 20 mins
Termination	Refused in base of pit
In-Situ Testing	None

Material Key

Topsoil, Granular, Bedrock, Made Ground, Cohesive, Void

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Exploratory Hole Log

HP101

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

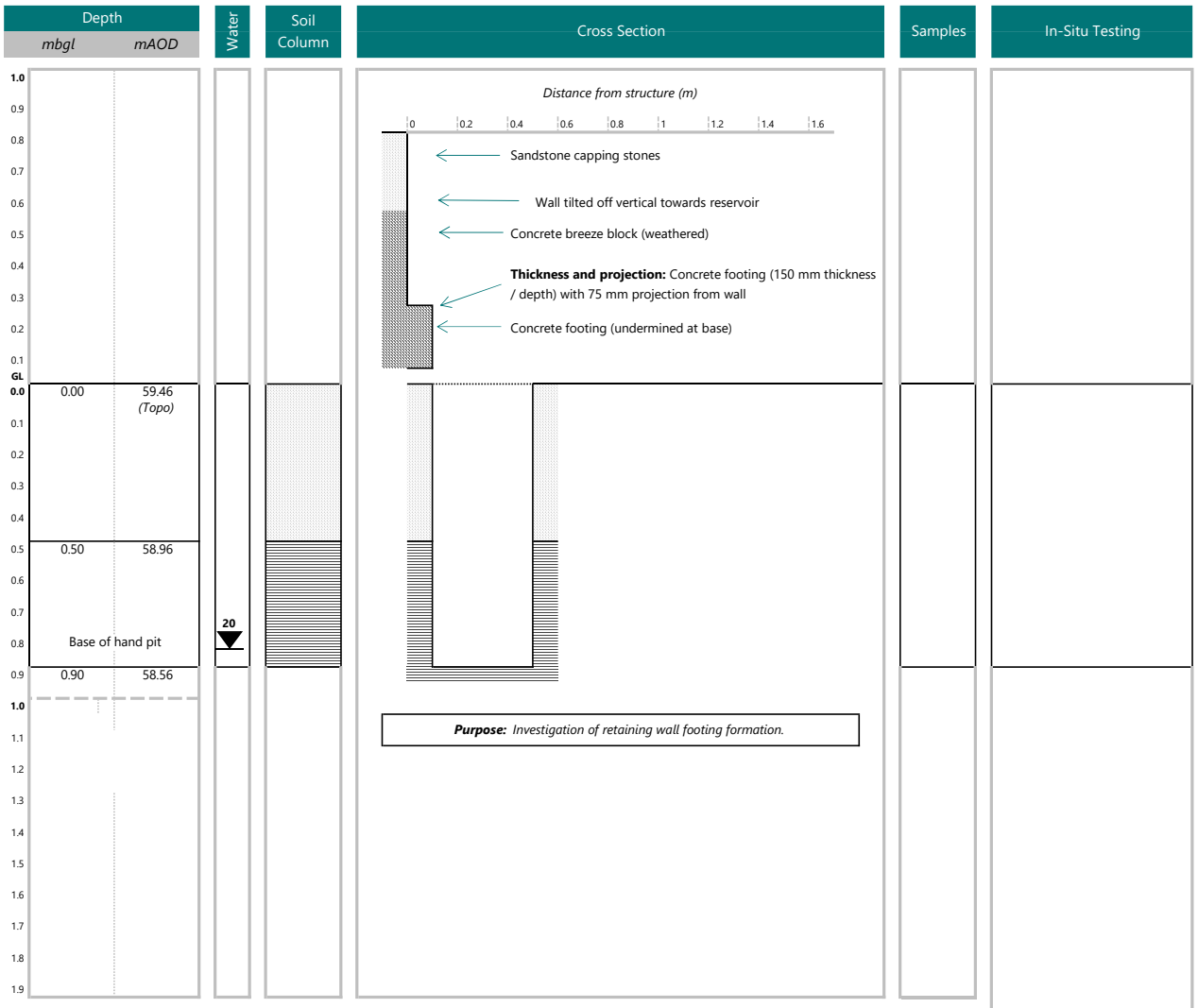
Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand tools
Logger	RB

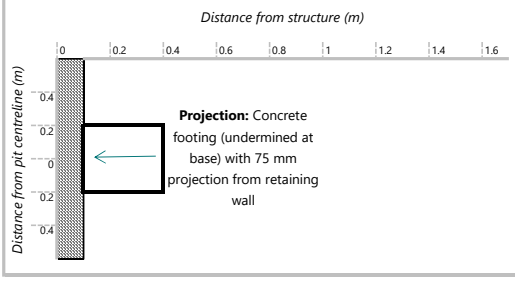
Cross Section



Photo



Plan



Exploratory Hole Dimesions

Width	0.40	m
Length	0.40	m
Diameter	-	m
Backfill	Arisings	

Notes

Stability	Stable.
Groundwater	None encountered in hand pit.
Termination	Target depth achieved - underside of footing.
In-Situ Testing	Mackintosh Probe in advance of borehole drilling.

Material Key

Topsoil
Granular
Bedrock
Made Ground
Cohesive
Void

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Exploratory Hole Log

HP102

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand tools
Logger	RB

Engineer's Log

Depth mbgl	Depth mAOD	Water	Material	Description	Samples	In-Situ Testing
0.00	59.36 (Topo)			Soft dark brown mottled light grey very sandy gravelly SILT. Sand is fine to coarse. Gravel is rounded to sub-angular fine to medium sandstone. [POSSIBLE REWORKED NATURAL SOILS]		
0.10	59.26			Soft locally very soft or firm light grey, dark grey, black and grey mottled organic slightly sandy slightly gravelly CLAY. [POSSIBLE REWORKED NATURAL SOILS]		
0.50	58.86			Firm to stiff light grey light grey, dark grey, black and grey mottled organic slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is fine to coarse sub-angular sandston. [RESIDUAL BEDROCK]		
0.70	58.66			Black completely weathered COAL. Recovered as silty fine to medium angular gravel. [RESIDUAL BEDROCK]		
0.80	58.46			Firm to stiff light grey, dark grey, black and grey mottled organic sandy very gravelly CLAY with high cobble content and boulders. Sand is fine to coarse. Gravel is fine to coarse sub-angular sandston. Cobbles are small to large tabular sub-angular sandstone. Boulders are up to 450 mm and sub-angular sandstone. [RESIDUAL BEDROCK]		
1.60	56.86			1.3 m ... becoming very sandy and cobbly - auger scraping sides - suspected weathered sandstone		

Purpose: *Investigation of retaining wall footing formation.*

Exploratory Hole Dimesions

Width	0.40	m
Length	0.40	m
Diameter	-	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	Minor, moderate rate seepage at 0.70 m depth
Termination	Refused in base of pit
In-Situ Testing	None

Material Key

Topsoil, Granular, Bedrock, Made Ground, Cohesive, Void

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Exploratory Hole Log

HP102

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

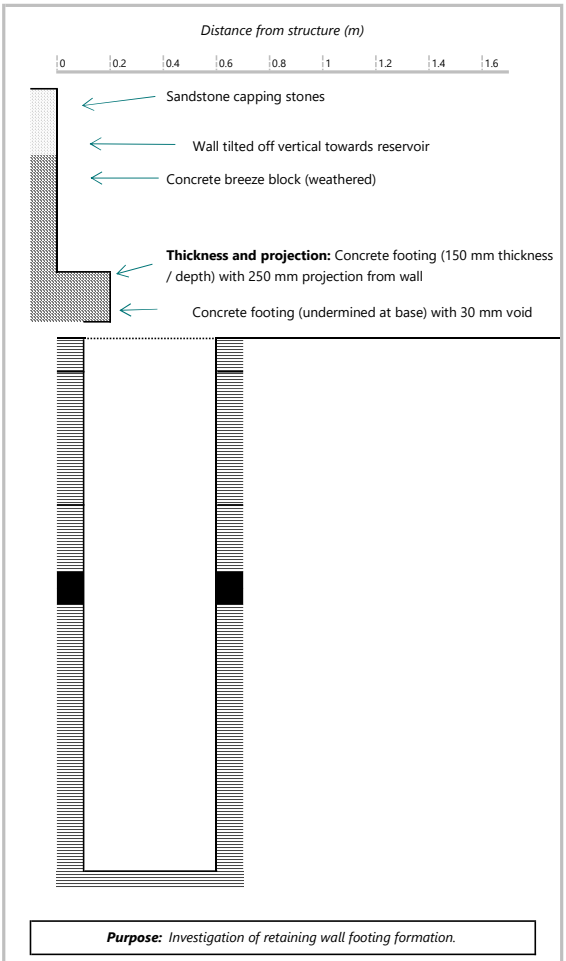
Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand tools
Logger	RB

Cross Section

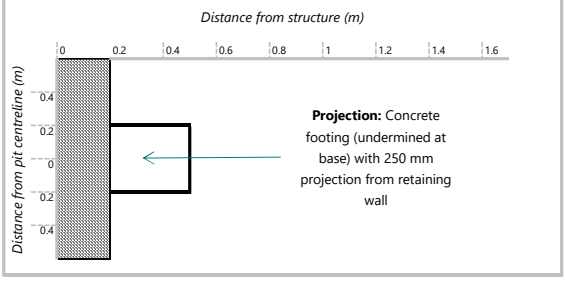
Depth mbgl	Depth mAOD	Soil Column
GL 0.0	59.36 (Topo)	
0.10	59.26	
0.50	58.86	
0.70	58.66	
0.80	58.46	
1.60	56.86	



Photo



Plan



Exploratory Hole Dimesions

Width	0.45	m
Length	0.60	m
Diameter	-	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	None encountered
Termination	Refused in base of pit
In-Situ Testing	None

Material Key

Topsoil
Granular
Bedrock
Made Ground
Cohesive
Void

(C) Soil and Structures Ltd

01/02/2022

Exploratory Hole Log

HP103

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand tools
Logger	RB

Engineer's Log

Depth mbgl	Depth mAOD	Water	Material	Description	Samples	In-Situ Testing
0.00	59.36 (Topo)			Soft dark brown mottled light grey very sandy gravelly SILT. Sand is fine to coarse. Gravel is rounded to sub-angular fine to medium sandstone. [POSSIBLE REWORKED NATURAL SOILS]		
0.10	59.26			Soft locally very soft or firm light grey, dark grey, black and grey mottled organic slightly sandy slightly gravelly CLAY. [POSSIBLE REWORKED NATURAL SOILS]		
0.30	59.06			Black completely weathered COAL. Recovered as silty fine to medium angular gravel. [RESIDUAL BEDROCK]		
0.40	58.96			Firm to stiff light grey, dark grey, black and grey mottled organic very sandy very gravelly CLAY with high cobble content and boulders. Sand is fine to coarse. Gravel is fine to coarse sub-angular sandston. Cobbles are small to large tabular sub-angular sandstone. Boulders are up to 450 mm and sub-angular sandstone. [RESIDUAL BEDROCK] ... becoming more cobbly and harder to excavate with depth. Locally organic.		
1.00	58.36			Weak yellowish light brown SANDSTONE with orange staining. Recovered as slightly clayey, very sandy, very gravelly sub-angular cobbles of sandstone. [PENNINE MIDDLE COAL MEASURES]		

Purpose: *Investigation of retaining wall footing formation.*

Exploratory Hole Dimesions

Width	0.45	m
Length	0.60	m
Diameter	-	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	None encountered
Termination	Refused in base of pit
In-Situ Testing	None

Material Key

Topsoil, Granular, Bedrock, Made Ground, Cohesive, Void

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01/02/2022

Exploratory Hole Log
HP103

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

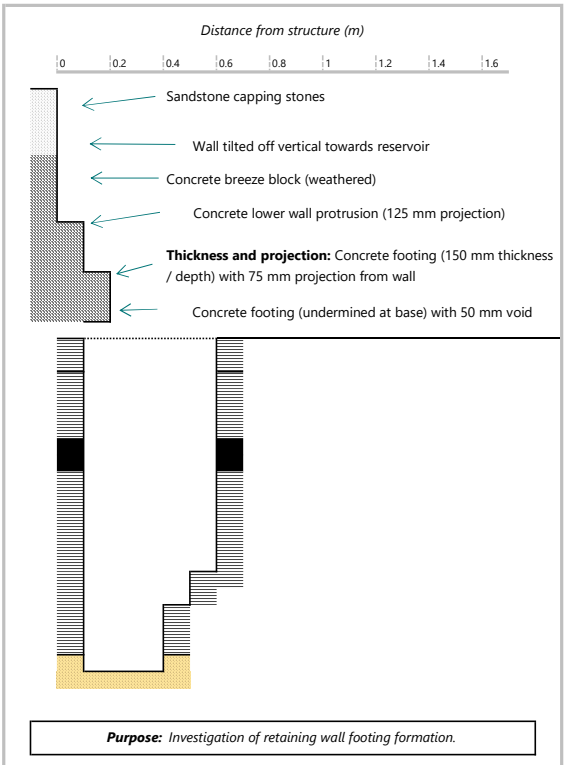
Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand tools
Logger	RB

Cross Section

Depth mbgl	Depth mAOD	Soil Column
GL		
0.0	59.36 (Topo)	
0.10	59.26	
0.30	59.06	
0.40	58.96	
1.00	58.36	

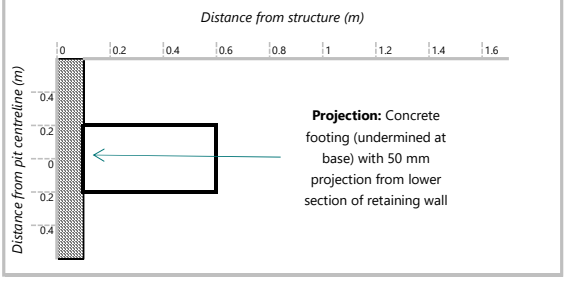


Purpose: *Investigation of retaining wall footing formation.*

Photo



Plan



Exploratory Hole Dimesions

Width	0.45	m
Length	0.60	m
Diameter	-	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	None encountered
Termination	Refused in base of pit
In-Situ Testing	None

Material Key

Topsoil
Granular
Bedrock
Made Ground
Cohesive
Void

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01/02/2022

Exploratory Hole Log

WS101a

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand augers
Logger	RB

Engineer's Log

Depth (mbgl)	Depth (mAOD)	Water	Material	Description	Samples	In-Situ Testing
0.00	60.38 (Topo)			Brown slightly silty gravelly slightly organic SAND. Gravel is fine to medium sandstone and quartz. [TOPSOIL]		
0.10	60.28			MADE GROUND: Cream sandy gravel of limestone. Sand is medium to coarse. Gravel is sub-angular.		
0.30	60.08			Soft to firm brown sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is fine to coarse rouded to sub-rounded sandstone. [PROBABLE REWORKED NATURAL SOILS]		
0.70	59.68			Firm to stiff becoming very stiff light grey, dark grey, black and grey mottled sandy very gravelly CLAY with probable cobbles. Sand is fine to coarse. Gravel is fine to coarse sub-angular sandstone. [RESIDUAL BEDROCK]		
1.70	58.68					

Exploratory Hole Dimesions

Diameter	0.10	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	None encountered
Termination	Refusal
In-Situ Testing	None

Material Key

Topsoil, Granular, Bedrock, Made Ground, Cohesive, Void

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01/02/2022

Exploratory Hole Log

WS101b

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand augers
Logger	RB

Engineer's Log

Depth (mbgl)	Depth (mAOD)	Material	Description	Samples	In-Situ Testing
0.00	61.50 (Topo)		Brown very silty slightly gravelly slightly organic fine to medium SAND. Gravel is fine to medium sub-angular sandstone and occasional sub-angular mudstone. [TOPSOIL]		
0.60	60.90		Firm to stiff becoming very stiff light grey, dark grey and grey mottled sandy gravelly CLAY. Sand is fine to coarse. Gravel is fine to coarse sub-angular sandstone. [RESIDUAL BEDROCK]		
0.80	60.70		Light grey, dark grey and grey mottled very clayey very gravelly fine to coarse SAND with probable cobbles. Gravel is fine to medium sub-angular sandstone and coal. [RESIDUAL BEDROCK]		
			Fine to medium sand (loose)		
			... scraping base		
1.90	59.60				

Exploratory Hole Dimesions

Diameter	0.10	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	None encountered
Termination	Refusal
In-Situ Testing	None

Material Key

Topsoil, Granular, Bedrock, Made Ground, Cohesive, Void

(C) Soil and Structures Ltd

01/02/2022

Exploratory Hole Log

WS101c

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand augers
Logger	RB

Engineer's Log

Depth (mbgl)	Depth (mAOD)	Water	Material	Description	Samples	In-Situ Testing
0.00	62.20 (Topo)			Brown slightly clayey slightly gravelly slightly organic fine to medium SAND. Gravel is fine to medium sub-angular sandstone and occasional sub-angular mudstone. [TOPSOIL]		
0.60	61.60			Stiff brown sandy gravelly CLAY possibly dessicated/highly friable. Sand is fine to coarse. Gravel is fine to coarse sub-angular sandstone. [RESIDUAL BEDROCK]		
0.60	61.60					

Exploratory Hole Dimesions

Diameter	0.10	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	None encountered
Termination	Refusal
In-Situ Testing	None

Material Key

Topsoil, Granular, Bedrock, Made Ground, Cohesive, Void

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01/02/2022

Exploratory Hole Log

WS102a

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand augers
Logger	RB

Engineer's Log

Depth (mbgl)	Depth (mAOD)	Water	Material	Description	Samples	In-Situ Testing
0.00	60.35 (Topo)			Brown slightly silty gravelly slightly organic SAND. Gravel is fine to medium sandstone and quartz. [TOPSOIL]		
0.05						
0.15	60.20			MADE GROUND: Cream sandy gravel of limestone. Sand is medium to coarse. Gravel is sub-angular. Sandstone boulder (angular and tabular) at base.		

Exploratory Hole Dimesions

Diameter	0.10	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	None encountered
Termination	Refusal
In-Situ Testing	None

Material Key

Topsoil, Granular, Bedrock, Made Ground, Cohesive, Void

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01/02/2022

Exploratory Hole Log

WS102b

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand augers
Logger	RB

Engineer's Log

Depth (mbgl)	Depth (mAOD)	Water	Material	Description	Samples	In-Situ Testing
0.00	61.00 (Topo)			Soft brown very silty sandy gravelly CLAY. Sand is fine to coarse. Gravel is fine to medium sub-angular sandstone occasional sub-angular mudstone and rare coal. [TOPSOIL]		
0.70	60.30			Soft to firm mottled grey and orange slightly sandy CLAY. Sand is fine to coarse. [POSSIBLE REWORKED NATURAL SOILS]		
0.90	60.10			Firm orange brown sandy organic SILT. Organic matter is relic plant matter. [RESIDUAL SOIL]		
1.10	59.90			Light grey, dark grey and grey mottled very clayey very gravelly fine to coarse SAND with probable cobbles. Gravel is fine to medium sub-angular sandstone and coal. [RESIDUAL BEDROCK]		
1.90	59.10			Black highly weathered bitumenous COAL. Recovered as silty fine to medium angular gravel. [RESIDUAL BEDROCK]		
2.00	59.00			Light grey and brown mottled clayey very gravelly fine to coarse SAND with cobbles. Gravel is fine to medium sub-angular sandstone. [RESIDUAL BEDROCK]		
2.00	59.00					

Exploratory Hole Dimesions

Diameter	0.10	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	None encountered
Termination	Refusal
In-Situ Testing	None

Material Key

Topsoil, Granular, Bedrock, Made Ground, Cohesive, Void

(C) Soil and Structures Ltd

01/02/2022

Exploratory Hole Log

WS102c

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand augers
Logger	RB

Engineer's Log

Depth mbgl	Depth mAOD	Water	Material	Description	Samples	In-Situ Testing
0.00	62.45 (Topo)			Light brown slightly very sandy slightly gravelly slightly organic SILT. Sand is fine to medium. Gravel is fine to medium sub-angular sandstone. [TOPSOIL]		
0.30	62.15			Firm light grey, dark grey and grey mottled sandy gravelly CLAY. Sand is fine to coarse. Gravel is fine to medium sub-angular sandstone and coal. [RESIDUAL BEDROCK]		
0.50	61.95			Stiff brown sandy gravelly CLAY possibly dessicated/highly friable. Sand is fine to coarse. Gravel is fine to coarse sub-angular sandstone. [RESIDUAL BEDROCK] ... becoming very sandy with depth ... possible cobble in base - irregular scraping		
1.00	61.45					

Exploratory Hole Dimesions

Diameter	0.10	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	None encountered
Termination	Refusal
In-Situ Testing	None

Material Key

Topsoil, Granular, Bedrock, Made Ground, Cohesive, Void

(C) Soil and Structures Ltd

01/02/2022

Exploratory Hole Log

WS103a

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand augers
Logger	RB

Engineer's Log

Depth (mbgl)	Depth (mAOD)	Water	Material	Description	Samples	In-Situ Testing
0.00	60.50 (Topo)			Soft to firm brown sandy gravelly SILT. Sand is fine to medium. Gravel is fine to coarse sub-angular sandstone and coal. [TOPSOIL GRADUATING INTO RESIDUAL BEDROCK]		
				... bcomeing stiff		
1.00	59.50			possible cobble in base - irregular scraping		

Exploratory Hole Dimesions

Diameter	0.10	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	None encountered
Termination	Refusal
In-Situ Testing	None

Material Key

Topsoil, Granular, Bedrock, Made Ground, Cohesive, Void

(C) Soil and Structures Ltd

01/02/2022

Exploratory Hole Log

WS103b

SOIL AND STRUCTURES

Project Details

Name	Worsborough Reservoir
Reference	20119

Dates & Weather

Start	10.11.2021
End	10.11.2021
Weather	Sunny and 10 to 15oC

Operations

Contractor	Soil and Structures
Plant	Hand augers
Logger	RB

Engineer's Log

Depth (mbgl)	Depth (mAOD)	Water	Material	Description	Samples	In-Situ Testing
0.00	60.60 (Topo)			Soft to firm brown and light brown sandy gravelly organic SILT. Sand is fine to medium. Gravel is fine to coarse sub-angular sandstone. [TOPSOIL]		
0.90	59.70			Stiff light grey, dark grey and grey mottled very sandy gravelly CLAY with occasional rootlets. Sand is fine to coarse. Gravel is fine sub-angular sandstone. [RESIDUAL BEDROCK]		
1.1	59.50			Black highly weathered bitumenous COAL. Recovered as silty fine to medium angular gravel. [RESIDUAL BEDROCK]		
1.40	59.20			Light grey firm CLAY. [RESIDUAL BEDROCK / SEATEARTH]		
1.50	59.10			Stiff light grey, dark grey and orange mottled very sandy very gravelly CLAY. Sand is fine to coarse. Gravel is fine sub-angular sandstone. [RESIDUAL BEDROCK]		
1.70	58.90					

Exploratory Hole Dimesions

Diameter	0.10	m
Backfill	Arisings	

Notes

Stability	Stable
Groundwater	Dampness towards base of pit. No rise in 20 mins.
Termination	Refusal
In-Situ Testing	None

Material Key

Topsoil, Granular, Bedrock, Made Ground, Cohesive, Void

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01/02/2022

Abbeydale
Building Environment Consultants

PHASE 1 DESK STUDY REPORT

Worsbrough Reservoir, Worsbrough Mill & County Park, Barnsley, South Yorkshire

Report: 151092DS

Date: November 2019

Client:
Barnsley Metropolitan Borough Council
Regeneration and Culture
Place Directorate
PO Box 634
Barnsley
S70 9GG

Abbeydale Building Environment Consultants Ltd, 4 Neville Street, Wakefield, WF1 5EF,
Tel: 01924 376622 | E-mail: info@abbeydalebec.com | www.abbeydalebec.com
Director: P J Lloyd BSc MSc CGeol FGS | Company Registation No. 06707508 | VAT: 600 2099 91

PHASE 1 DESK STUDY REPORT

Worsbrough Reservoir, Worsbrough Mill & County Park, Barnsley

DOCUMENT VERIFICATION SHEET

	Prepared By:	Checked By:
Name:	Peter J Lloyd	Richard Saville
Qualifications:	BSc MSc CGeol FGS	BSc (hons) CGeol FGS
Position:	Managing Director	Senior Consultant
Signature:		R. Saville

SUMMARY

Site Grid Ref:	434566, 403534	**Site Level (m AOD):**	60	**Site Length (m):**	60

	Issue:	Fissuring and subsidence of footway at toe of embankment, immediately north of reservoir wall.
	Historical Setting:	Reservoir constructed pre 1850.
	Made Ground:	Small amount of made ground / topsoil anticipated to superficial depth.
	Natural Soils:	Residual soils weathered down from parent bedrock.
Ground Conditions	**Bedrock:**	Undifferentiated Middle Coal Measures; likely mudstone and siltstone with bands of sandstone.
	Groundwater:	Shallow groundwater recorded in monitoring wells.
	Shallow mining:	Barnsley Coal conjectured to outcrop through site; shallow workings recorded to north of reservoir.
	Environmental Assessment:	Construction workers to take standard precautions.
	Drainage:	Stop water ponding behind reservoir wall.
	Geotechnical Considerations:	No information available regarding reservoir walls.
	Remedial Options:	Outline options include installation of sheet piles and/ or raising of reservoir wall to stop ingress of water behind wall.

PHASE 1 DESK STUDY REPORT

Worsbrough Reservoir, Worsbrough Mill & County Park, Barnsley

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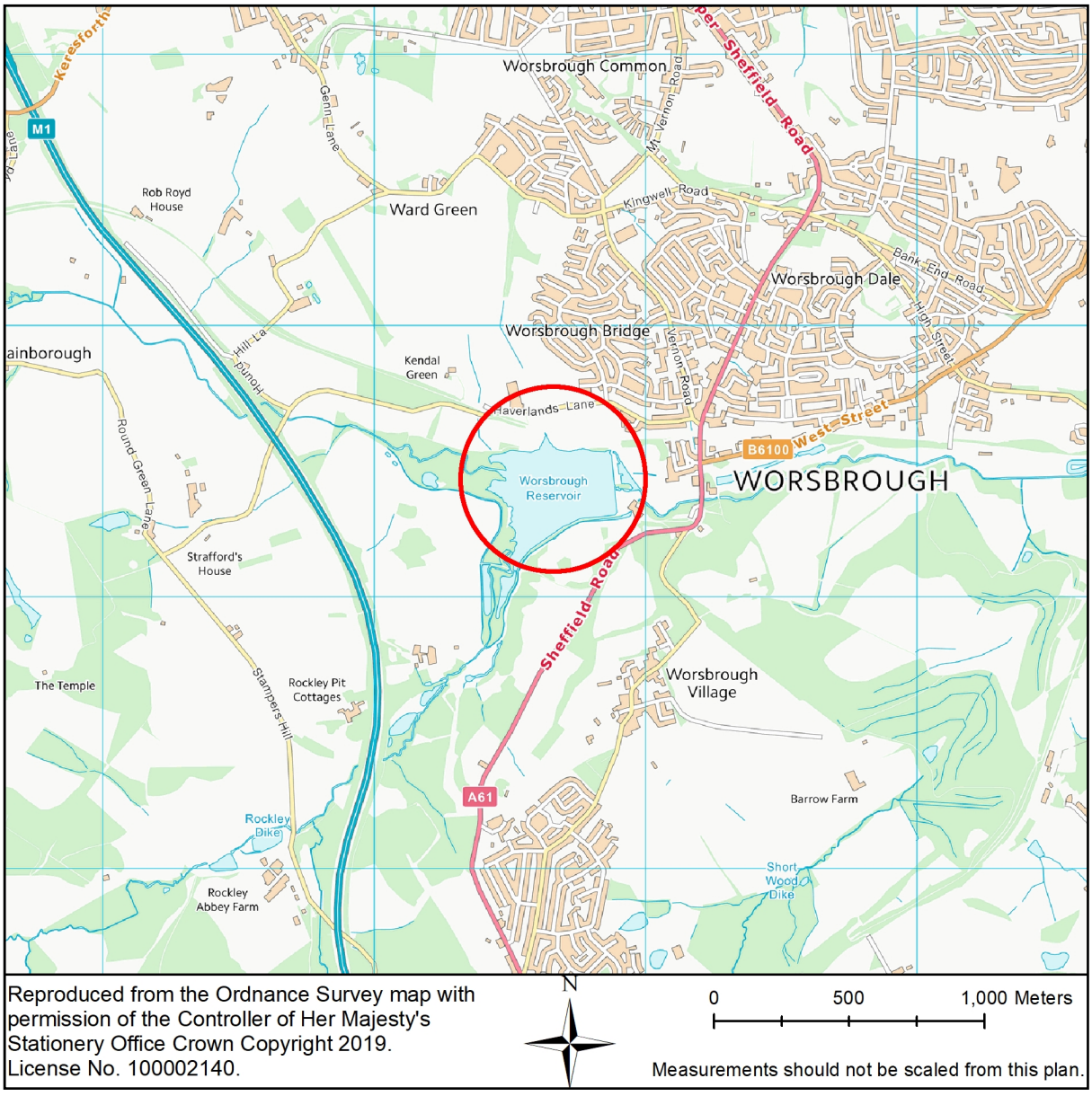
APPENDIX C - JNP GROUP GROUND INVESTIGATION REPORT C

PHASE 1 DESK STUDY REPORT

Worsbrough Reservoir, Worsbrough Mill & County Park, Barnsley

1. INTRODUCTION

On the instruction of Barnsley Metropolitan Borough Council (Barnsley MBC), a Desk Study was carried out by Abbeydale Building Environment Consultants Ltd (Abbeydale BEC) on a section of the northern wall of Worsbrough Reservoir, situated off Park Road in Worsbrough, to the south-west of Barnsley, South Yorkshire. The section of the reservoir wall in question is around 60m in length, centred on National Grid Reference 434566, 403534. See Figure 1 below.



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FIGURE 1 - KEY PLAN

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The comments and recommendations presented in this Desk Study report are based on the findings of a review of available information. There may be other conditions prevailing on the site which have not been recorded by the available information and therefore have not been taken into account by this report. Responsibility cannot be accepted for unrecorded information.

When writing this report the proposed development was remediation measures to the northern bank of Worsbrough Reservoir. If there are changes to these proposals then some modification to the comments and recommendations given may be required.

2. OBJECTIVES

This report has been undertaken to evaluate current condition of the northern shore of Worsbrough Mill Country Park reservoir and determine why it is in the degraded state observed. To undertake this study previous investigations made available by Barnsley MBC have been assessed and report on, together with information held in Abbeydale BEC archives. Having assessed the information available the potential cause(s) of the collapse of the northern wall are evaluated and possible remedial options considered.

3. THE SITE

As part of the Desk Study assessment, a site walkover was undertaken on 15 October 2019, to visually assess the area of recorded ground movement and the wider reservoir site for any potential causes for the ground fissuring previously observed.

The main area of concern is a 60m stretch of the reservoir banking on the reservoirs north side centred on a Bird Watchers Cabin (BWC), seen located on a raised embankment 2-3m above the reservoirs water level. A contour plan and section of this section of banking is shown in the jnpgroup report Drawing P1. This drawing records the water level at ~60m AOD which we understand was at a time when water was flowing over the dams spillway, with typical variation in level being no more than 100-200mm. Further areas of similar collapse were seen at the eastern end of north side of the reservoir banking close to the earthen embankment dam. The dam was full when observed holding back the waters from Brough Green Brook and Rocky Dyke before descending to ~52m AOD into the River Dove, which in turn flows into the River Dearne south of Darfield. See Key Plan Fig 1 and annotated site plan Figure 2.

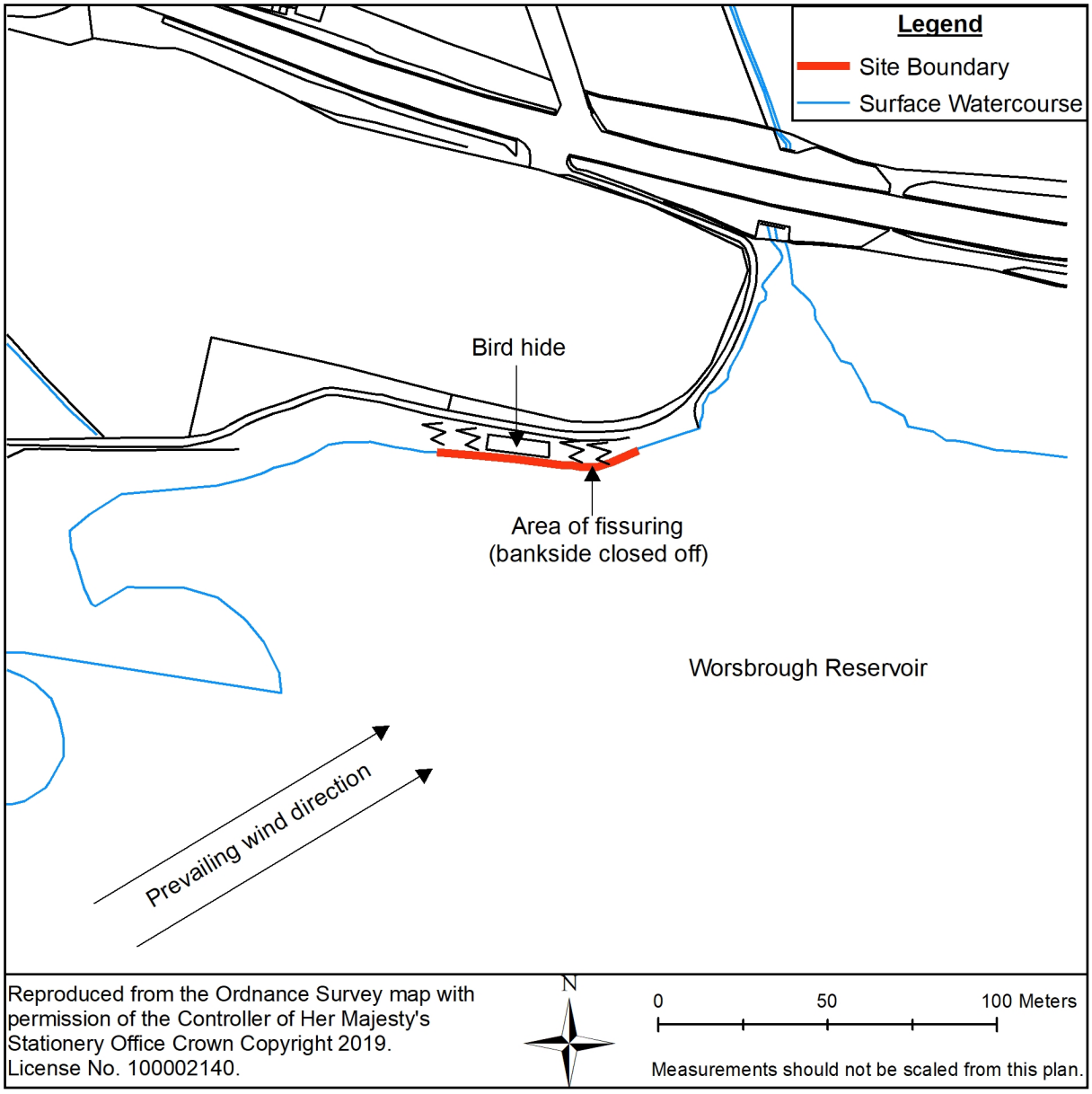


FIGURE 2 - SITE PLAN

4. HISTORY

The historic Ordnance Survey (OS) maps of the site and surrounding area have been obtained from GroundSure, dated 31 October 2019; included in Appendix A. All measurements stated are approximate distances from the site boundaries to the recorded features.

4.1. The Site

The site is shown as an unoccupied strip of land along the shore of Worsbrough reservoir. Little is shown to change through to the present day.

4.2. Surrounding Area

The dam was completed in 1804 to supply water to the Worsbrough branch of the Dearne and Dove Canal. It was enlarged in 1826 creating 20 acres of surface water and two new spillways were installed in 1984 to comply with the Reservoir Act. The earliest OS map of 1850-1855 depicts and area marked Prince Albert Colliery 550m to the north west of site. Worsbrough reservoir is depicted along it current outline, but extending further upstream into the west and south west inlets. The next OS map of 1890-1891 depicts Worsbrough reservoir Colliery 300m south west of the site. Prince Albert colliery is no longer depicted. By 1906 is no longer depict Worsbrough reservoir Colliery however an area marked "shaft" is still depicted. The Old Silkstone Branch railway is shown on the higher ground to the north of the reservoir from the earliest maps of 1850 to its closure after 1977, and has subsequently become a national cycleway. Also in the early 1970's the M1 Motorway was built across the valley on embankment 600m to the west. Worsbrough Mill Country Park covering over 240 acres encompasses the reservoir from the 1993 OS map.

5. GEOLOGY

The geological survey maps of the area, Sheet SE30SW, BGS Sheet 87 and Yorkshire County Series Sheet 274 SE have been examined. The site is shown to be underlain by undifferentiated mudstones siltstone and sandstone of the Pennine Middle Coal measures and the Barnsley Rock sandstone; dipping to the north east at 5° from an assessment of outcrop patterns and dip indicators on the geological maps.

The nearest geological fault is conjectured directly beneath the area of failure on the site, trending north-east to south-west and downthrowing strata to the north west.

Superficial alluvial deposits are shown over the solid geology across the area of failure. Areas of recorded made ground are present 100m north east and 400m west of the site. Likely associated with the Barnsley Coal. However, made ground to superficial depths would be anticipated across the site associated with past historic uses.

6. MINING RISK ASSESSMENT & QUARRYING

The presence of rock and mineral seams, including coal, which may have been mined or quarried in the area has been determined by published geological maps and memoirs of the area, and the appended SYMAS report dated 29th October 2019, included in Appendix B.

The Barnsley Coal seam of around 2.5m thickness is conjectured to outcrop within the reservoir, immediately to the south of the bank, dipping under the higher ground to the north west and is likely to be present at shallow depth.

The appended SYMAS report states that shallow historic coal mining is recorded in the Barnsley seam to the north. The exact date of the workings is unknown, but likely to be between mid 1800's to early 1900's. To the north the Coal Authority record large scale working of the Barnsley seam in the 1920's and 1930's. Earlier unrecorded workings beneath the bank area cannot be ruled out.

The SYMAS report also states that deep mining operations have taken place beneath this area in various coal seams in the distant past. Whilst undermining the dam structure may have been avoided, working under the reservoir areas was not uncommon provided an impermeable roof rock was found. All subsidence movement from these workings will be long complete and in this area of Barnsley most mines have become flooded as groundwater has rebounded.

No shafts are highlighted on, or within 20m of the site. However with the Barnsley seam being so heavily worked in the area it would be surprising if adit workings into the hillside to the north west had not taken place prior to the construction of the reservoir. The risk of unrecorded mine adits in the area of the banking is therefore **very high**.

Based on the above information the risk of shallow mine workings beneath the site is deemed to be **very high**. Depending on the depth and thickness of any underlying shallow mine workings there is the potential for the workings to adversely affect the surface stability of the site, should collapse of any shallow coal workings occur.

As no quarrying has been identified locally the resultant risk of unrecorded quarrying having affected the site is considered to be **low**.

7. PREVIOUS INVESTIGATION INFORMATION

The anticipated ground conditions have been interpreted from the geological maps and available archive information as being mainly Coal Measures mudstone with the Barnsley Coal outcropping along the northern edge of the reservoir. A factual ground investigation report prepared by jnpgroup presented in Appendix C, which records the ground conditions at the top and bottom of the embankment around the area of the Bird Watchers Cabin.

At 300mm above water level(WL) WS1 records a layer of limestone hardcore over a "*soft to firm grey/brown mottled orange CLAY",* which is typical of the weathered bedrock found in this area. Below 2.7m SPT strengths are shown to increase until slightly weathered mudstone is recorded at 4.7m bgl (-4.4m WL). Two Hand Pits HP1 and HP2, excavated around the sandstone reservoir wall extends 200-400mm above the water level of the reservoir. At both locations the wall was stepped and widened down to about 200mm below water level and the front and back the wall widened to 600-700mm width. The front of the wall was measured down to 600mm below water level without the reservoir bed level being found. This would suggest that the wall has been reconstructed at various times in the past. We have anecdotal evidence that in 2008 when the dam was partly drained down the base of the wall was exposed and seen, in parts, to have been undercut.

Two further exploration holes WS2 and WS3 were bored at the top of the embankment at the level of the Bird Watchers Cabin. Both record similar ground as reported in WS1, a *"Firm becoming stiff orange/brown mottled light grey slightly sandy slightly gravelly CLAY"*. In WS2 very stiff light grey MUDSTONE was identified from 3.4m (-1.2m WL) to the holes base at 5m bgl. Further west in WS3 a 1.3m thickness of *"very weak black COAL"* was recorded at 2.8m bgl extending down to 4.1m bgl (+0.4m to -0.9m WL).

Whilst no groundwater was encountered during drilling, when inspected in October 2019 standing water levels of 0.25m bgl (+0.05m WL) and 2.2m bgl (0.00mm WL) were recorded in WS1 and WS2 respectively. These indicating the ground water level is in continuity with the reservoir levels and are similar to the jnpgroup reading in July 2019 given in Table 6.4.

Geotechnical testing of the samples collected from the Window Sample holes found medium plasticity clay typical of the weathered mudstone found in the area. Index testing range between plastic limits of 20-31% and liquid limits of 38-49%, resulting in plasticity index values of 16-19% Moistures however, were generally below the PL% indicating the clays remain in a solid state.

8. GEOTECHNICAL CONSIDERATIONS

8.1. General

To evaluate options as to how to remediate the lengths of collapsing north reservoir wall the evidence available has been examined and several possible approaches have been considered in Section 8.4.

8.2. Overview of Ground Conditions

Having been built in two stages in the early half of the 1800's Worsbrough dam will have been constructed prior to the majority of coal mining in this area. However, it is not unreasonable to suspect that crop and adit working of the Barnsley Coal took place prior to this date, so modifying the ground slope in the areas of concern. Whilst there would have been a later reluctance to undermine the dam structure the reservoir areas were commonly undermined for coal, provided the overlying rock remained impermeable. The result will have been to deepen the reservoir and potentially cause the lake sides to extend beyond their original line as the ground above workings subsided. Where walling was already in place the walls would have had to be raised or allowed to overtop. The evidence indicates that the reservoir side walls have been raised and strengthened on a piecemeal basis in the past and that wall tops were left with limited freeboard along the reservoirs northern side.

The evidence offed by WS3 is that the Barnsley Coal was only partly worked in the area being considered, however, old adits into the seam may still be present which have subsequently been flooded or covered over.

The result is the slopes above the reservoir have been overstepped and the reservoir wall as well as forming the reservoir side is also functioning as a retaining structure.

8.3. Other Factors

Evidence gained during a drawdown of the lake in 2008 would suggest that the banking wall base had been undermined at several locations, allowing sections of the wall to slide forward of topple forward. There was also evidence that the wall had cracked along its length allowing water ingress and sediment loss from the ground behind.

The standing water levels monitored during our visit would suggest that the ground behind is heavily fractured and the groundwater is in continuity with the lake. Therefore during fluctuations in lake level flow through the wall and side slopes would be anticipated.

A further consideration is the influence of the prevailing south westerly winds on the lake sides. With nearly a 400m fetch across the lake the wave height can cause waves to exceed the freeboard of the current wall. The result is the water forming the tops of the waves will flow onto the unbound ground behind the wall before draining back into the lake. With time this has resulted in a channel forming behind the wall, with outfalls occurring where movement fractures in the face of the wall have previously occurred.

8.4. Remedial Options

Rather than offering a single solution to remediate the reservoir wall a number of potential options have been considered in light of the ground conditions identified. We would recommend any wall built needs to have a freeboard of at least 600mm to counter the wave action currently been observed.

Option 1. Reconstruct the wall.

As recommended within the jnpgroup report the existing retaining wall could be replaced. The wall requiring footing extending into the underlying [stiff] clay or mudstone below the coal seam. Whilst the basic criteria for such a wall is given, its relationship with the existing wall and the extent of works is left undetermined. Presumably jnpgroup consider this is for the design Structural Engineer to decide.

To make a decision on the depth of footing and the extent of the wall we would recommend further ground investigation and a structural survey of the existing wall are undertaken. Suitable founding strata would need to be determined along the full length of wall to be replaced, including establishing whether the coal recorded in WS3 dips under the ground exposed in WS1 and WS2 or the coal has been faulted out. Depending on the positioning of the wall it might also be necessary to gain ground

information in front of the existing wall where conditions might be significantly different.

The reconstruction of the wall would also require the groundwater regime to be better understood requiring a series of groundwater measurements in existing and any additional holes undertaken.

Finally construction would have to be undertaken in the dry, presumably during a period when lake levels are reduced to below to the levels of the footing.

Option 2. **Driven Piled Wall**

To limit the amount of further investigation required and the need to drain the lake, a driven piles option could be considered. Whilst a large number of pile types could be considered the use of sheet piles are commonly used to front areas of erosion or collapse along many canals. A pile cap of concrete or timber could then be used to face the top of the wall and the ground between the existing wall and piles infilled with stone.

The piles could be located directly in front of the existing wall and designed to cantilever into the underlying strata. The piling method and length of piles could be adapted more easily to changes in ground conditions found during construction so the existing investigation may be sufficient. However, if design finds piles need to extend below the level of the existing holes then consideration needs to be given to additional investigation holes to confirm ground conditions beyond the depth of the proposed piles.

Option 3. **Recondition Existing Wall**

Whilst not all sections of the existing reservoir wall will be suitable for long term reconditioning there were section where the raising of the existing wall could be beneficial. The two hand pit sections jnpgroup provide show that the back of wall may have been extensively widened in the past at a level of 200mm below lake level. With a further structural assessment and survey of the rear of the wall consideration might be given to raising the rear of the wall by at least 200mm, to a level at least 600mm above reservoir water level. The ground level behind would not necessarily need to be raised above its current level, but weep holes to drain surface water would need to be considered.

Option 4. **Rip-Rap Protection**

Consideration could be given to semi-randomly placed stone blocks being placed in front of the existing wall. Before installing any stones a geofabric should be place in front of the existing

wall and say at least 1m across the bed in front to limit further sediment loss. Sandstone would most suit the Worsbrough area, but needs to be sufficiently strong and resistant to wave action to limit erosion. The stone should have a 10% fines value of at least 50kN (Los Angles coefficient of 50 or less). The stone would need to be placed (rather than tipped) onto the floor of the reservoir in front of the wall and built up against the existing wall with a maximum 40 degree front face. To limit the effects of wave action the top stones should have a freeboard of at least 600mm above water level and also at least 0.5m wide. Where this approach has previously used changing bed levels and modified profiles can be easily adapted to provide changing ecological conditions along its length. The approach can also be undertaken in stages.

Option 5. **Take no immediate action**

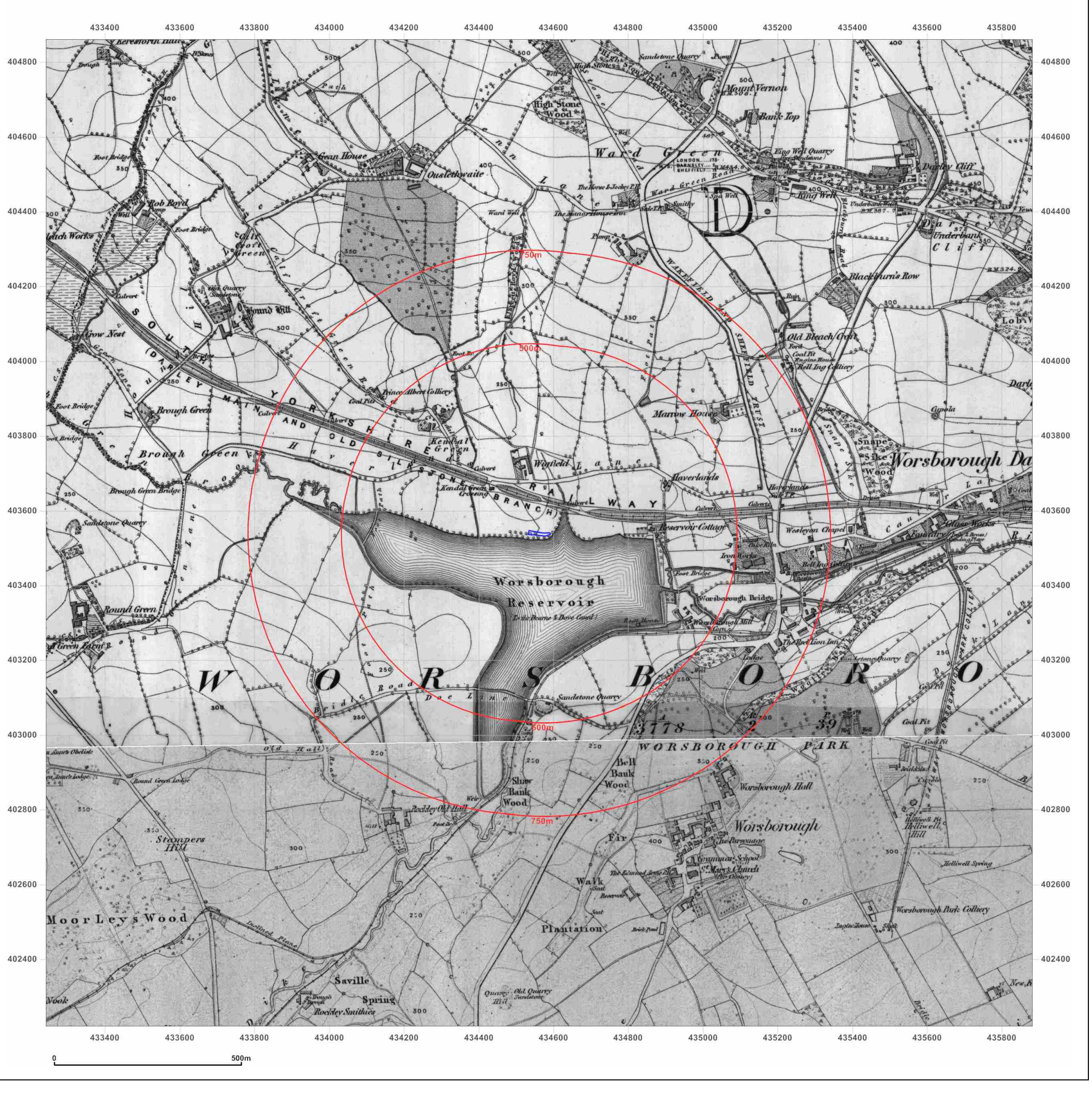
The consequent of no action will be that the existing reservoir wall will deteriorate and water ingress into the ground behind will increase. Issues related to H&S would also need to be considered. Consideration could be given to increasing the existing walls freeboard to at least +600mm WL using cement-bags and filling the gaps in the wall with the same, but this should only be considered as a temporary measure until finance for a more robust option is available.

9. FURTHER INVESTIGATION

The information obtained during the jnp group intrusive ground investigation would suggest that there will be strata changes along the two sections of wall that are of concern. The amount of further investigation necessary will depend on the option(s) being considered. If the reconstructed wall option is to be used we would recommend that the ground conditions behind and in front of the wall are better understood before a final design or construction are agreed. In contrast, for a Rip-Rap option sufficient information has been gained which would allow this more flexible option to be used.

Report 151092DS / PJL/ November 2019

APPENDIX A - HISTORICAL MAPS



Groundsure INSIGHTS

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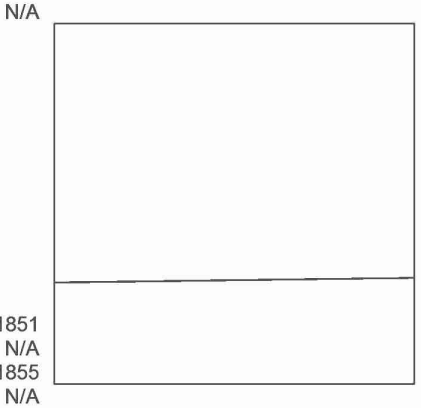
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Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: County Series
Map date: **1850-1855**
Scale: 1:10,560
Printed at: 1:10,560

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Surveyed 1851
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Edition 1850
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Levelled N/A



Surveyed 1851
Revised N/A
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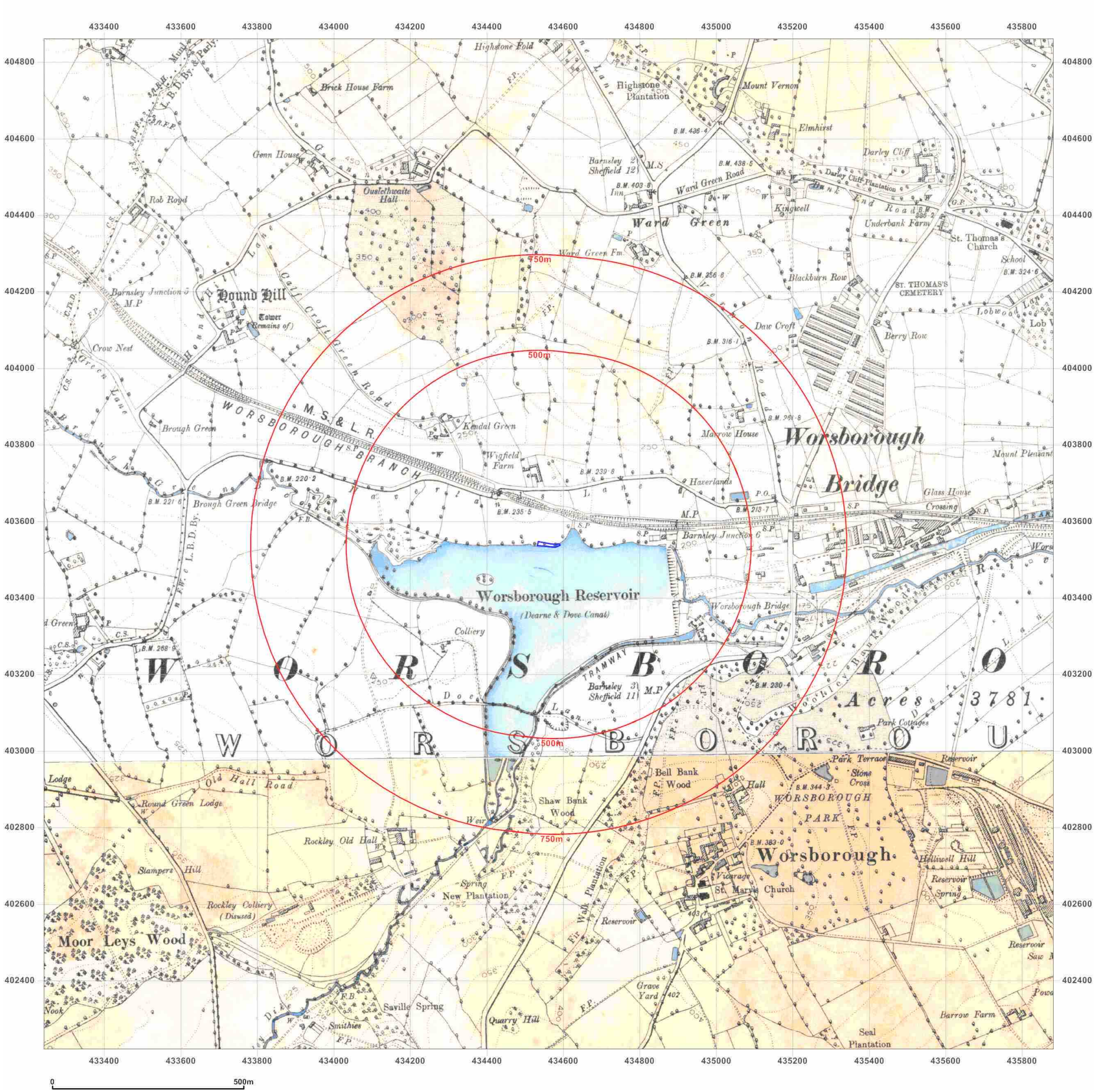
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Groundsure INSIGHTS

Site Details:

WORSBROUGH MILL, PARK ROAD, WORSBROUGH, BARNSLEY, S70 5LJ

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Report Ref: GS-6433075
Grid Ref: 434561, 403540

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Printed at: 1:10,560

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Surveyed 1890
Revised 1890
Edition 1890
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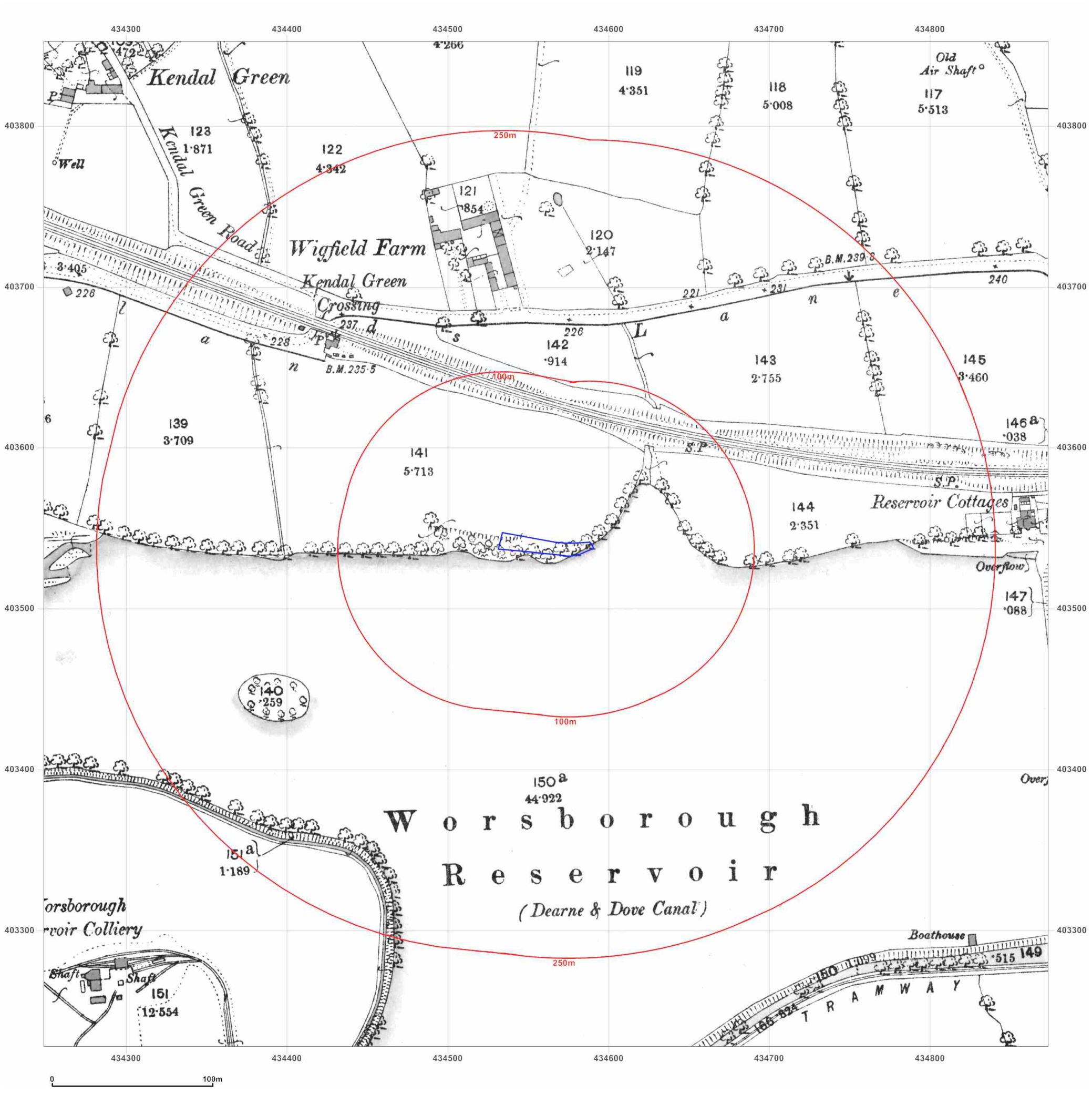
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Client Ref: 151092-3507
Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: County Series

Map date: **1892**

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Surveyed 1892
Revised 1892
Edition N/A
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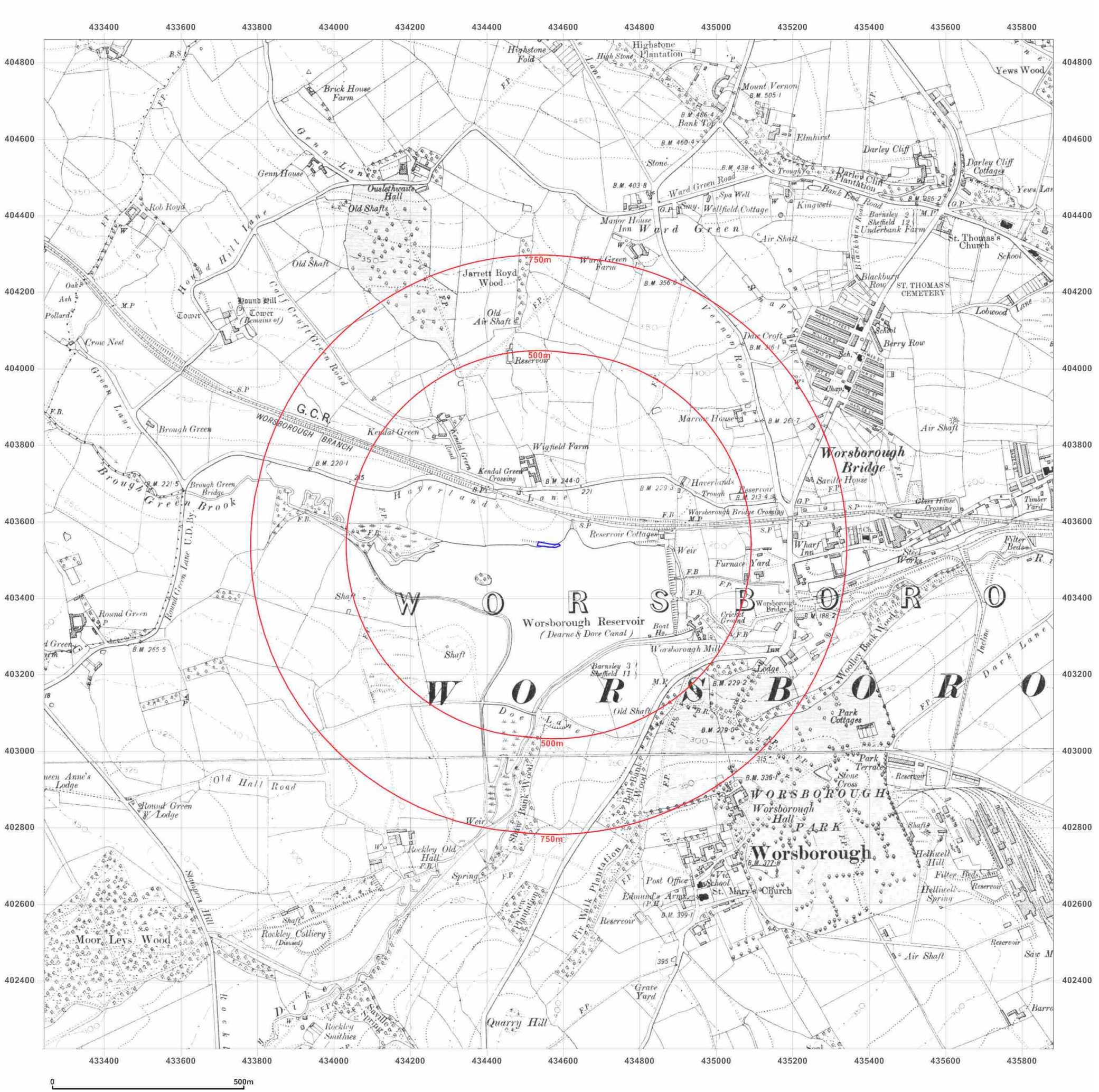
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Grid Ref: 434561, 403540

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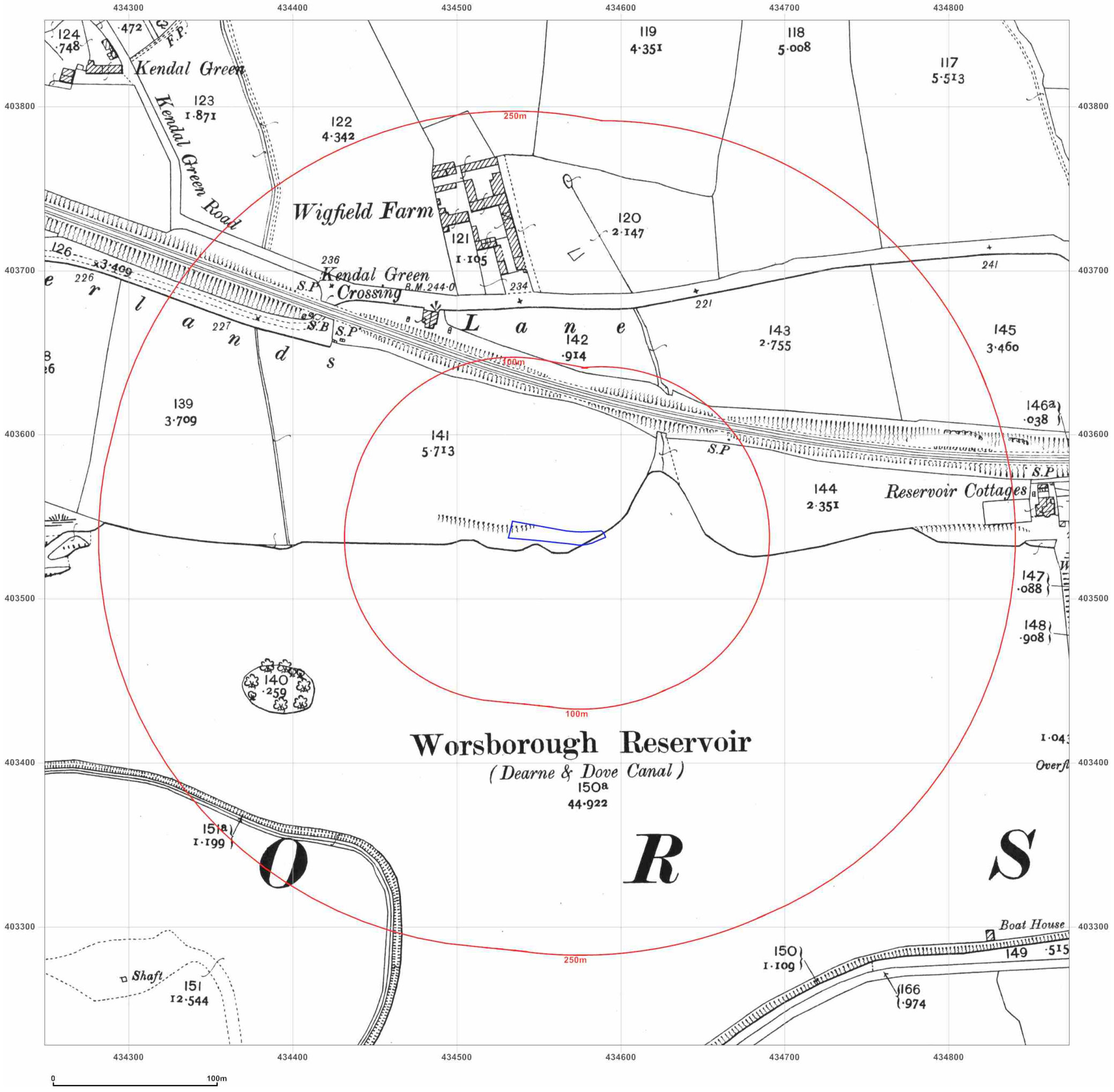
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Site Details:

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Grid Ref: 434561, 403540

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Surveyed 1906
Revised 1906
Edition N/A
Copyright N/A
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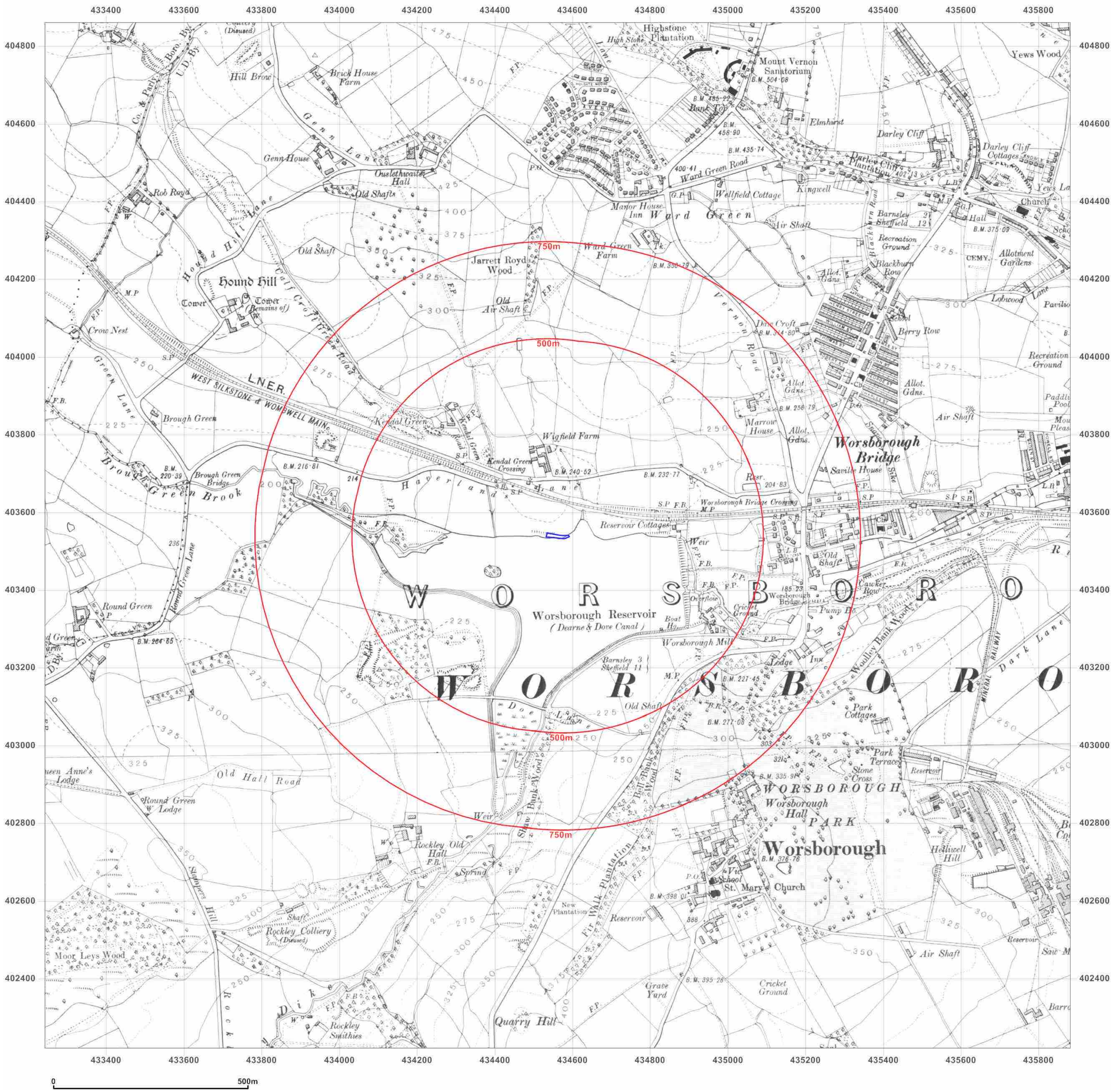
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Site Details:

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Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: County Series

Map date: **1929**

Scale: 1:10,560

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Edition 1929
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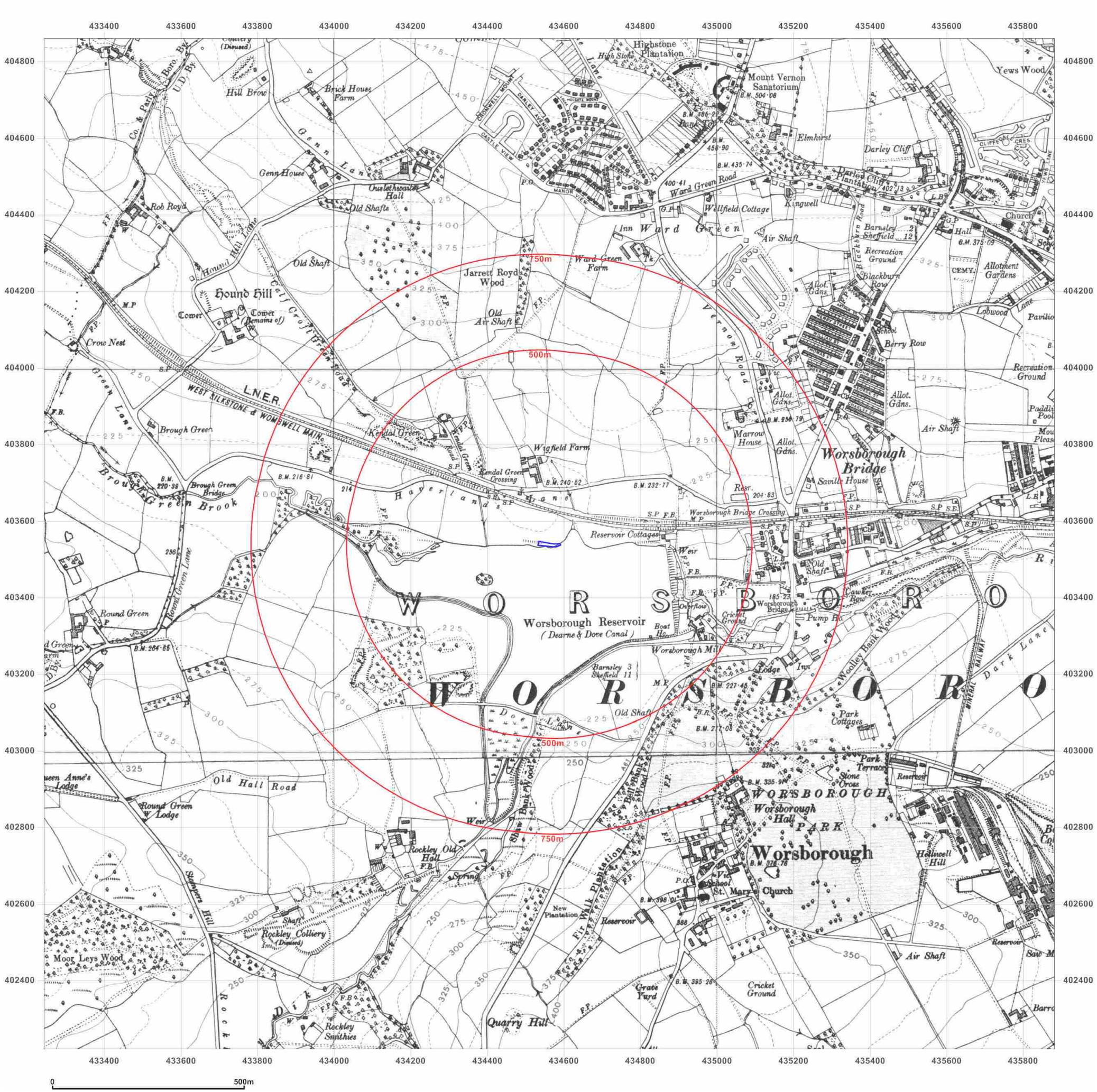
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Client Ref: 151092-3507
Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: County Series

Map date: **1938**

Scale: 1:10,560

Printed at: 1:10,560

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Revised 1938
Edition 1938
Copyright N/A
Levelled 1929

Surveyed 1851
Revised 1938
Edition 1938
Copyright N/A
Levelled 1929

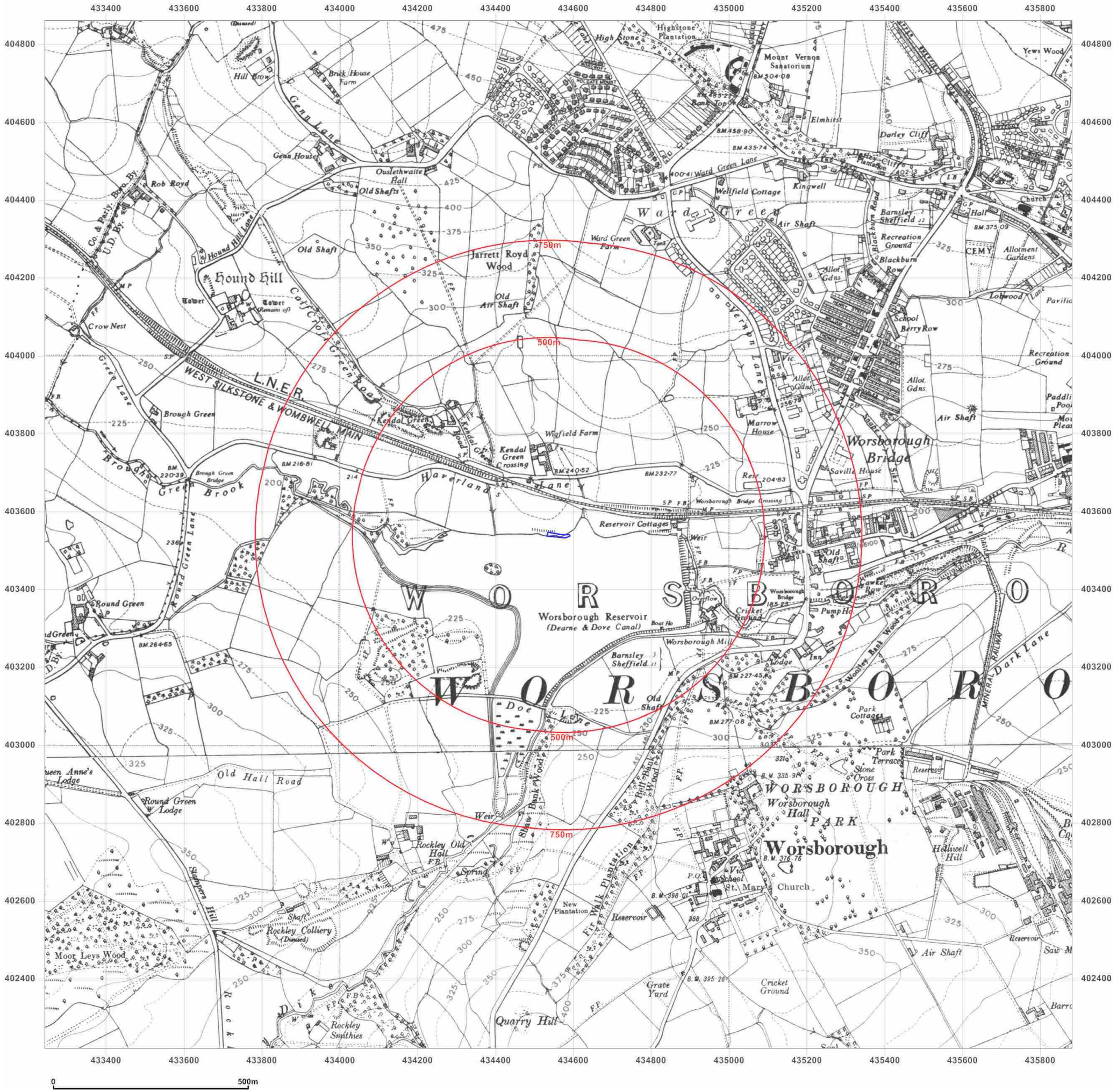
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Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: County Series

Map date: **1948**

Scale: 1:10,560

Printed at: 1:10,560

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Surveyed 1851
Revised 1948
Edition 1948
Copyright N/A
Levelled 1929

Surveyed 1851
Revised 1948
Edition 1948
Copyright N/A
Levelled 1929

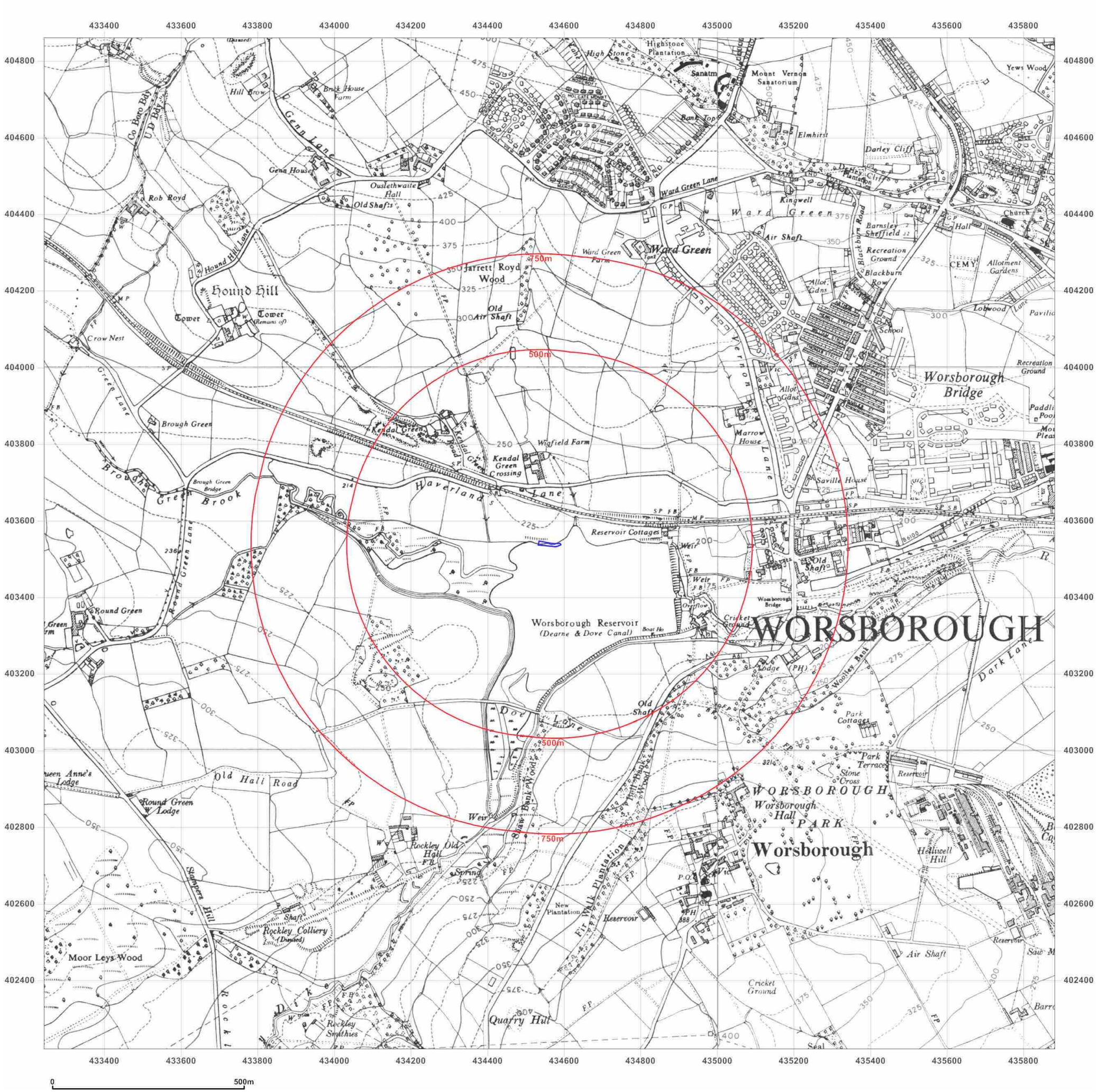
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Client Ref: 151092-3507
Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: Provisional
Map date: **1951-1956**
Scale: 1:10,560
Printed at: 1:10,560

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Surveyed N/A
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Edition N/A
Copyright 1956
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Surveyed 1951
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Copyright 1951
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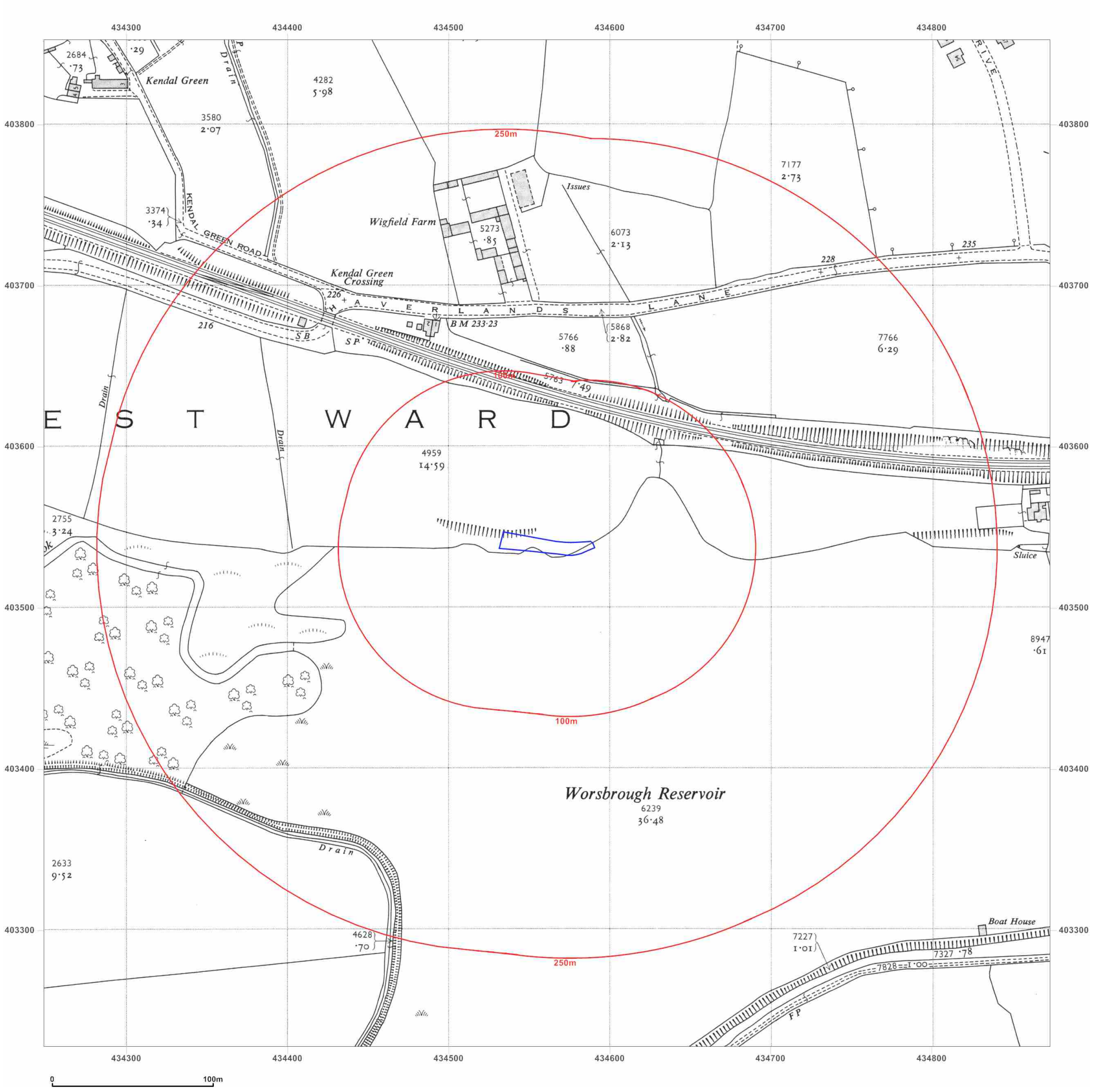
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Client Ref: 151092-3507
Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: National Grid

Map date: **1960**

Scale: 1:2,500

Printed at: 1:2,500

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Surveyed 1959
Revised 1960
Edition N/A
Copyright 1961
Levelled 1959

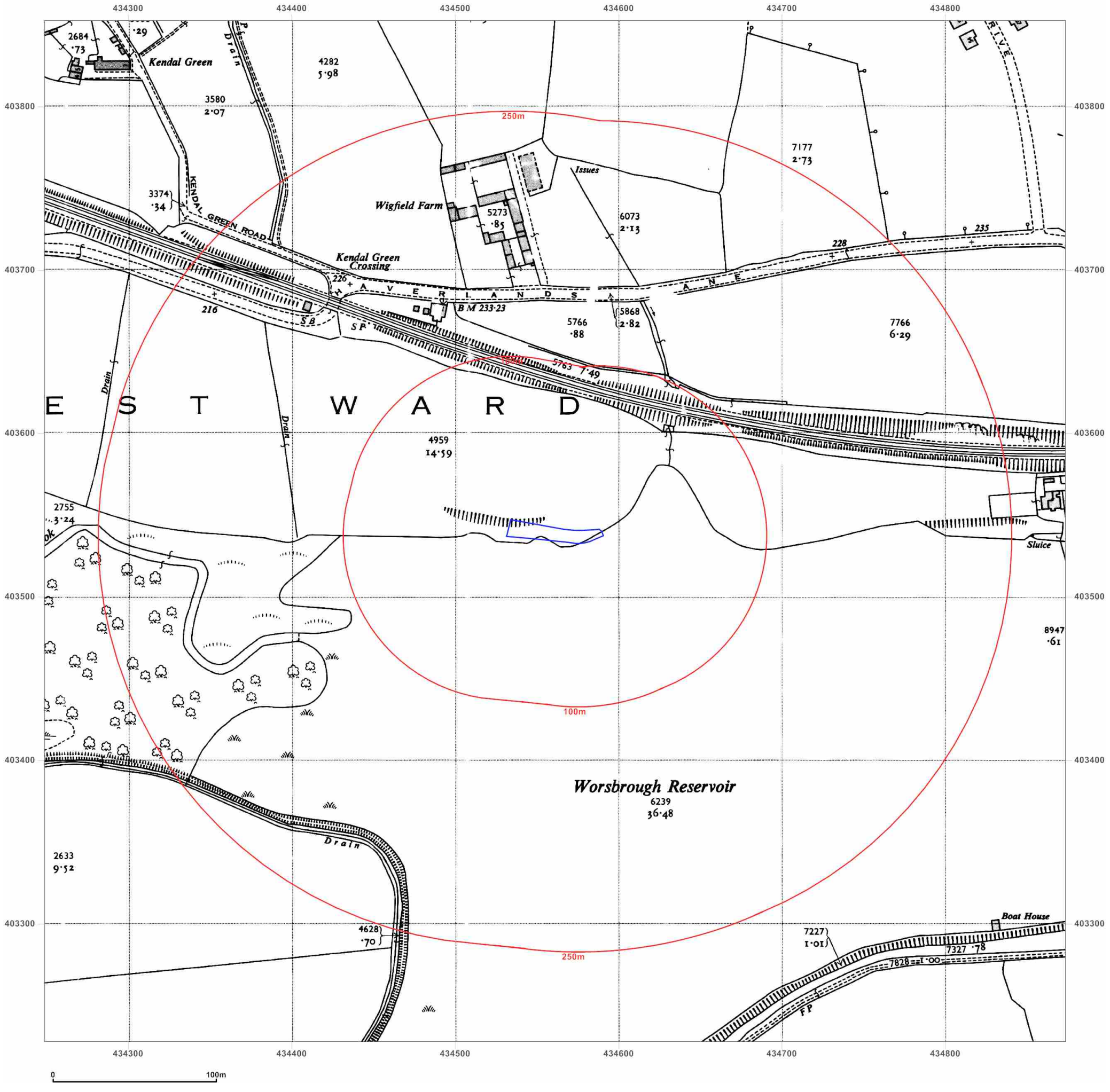
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Client Ref: 151092-3507
Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: National Grid

Map date: **1965**

Scale: 1:2,500

Printed at: 1:2,500

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Surveyed N/A
Revised N/A
Edition N/A
Copyright N/A
Levelled N/A

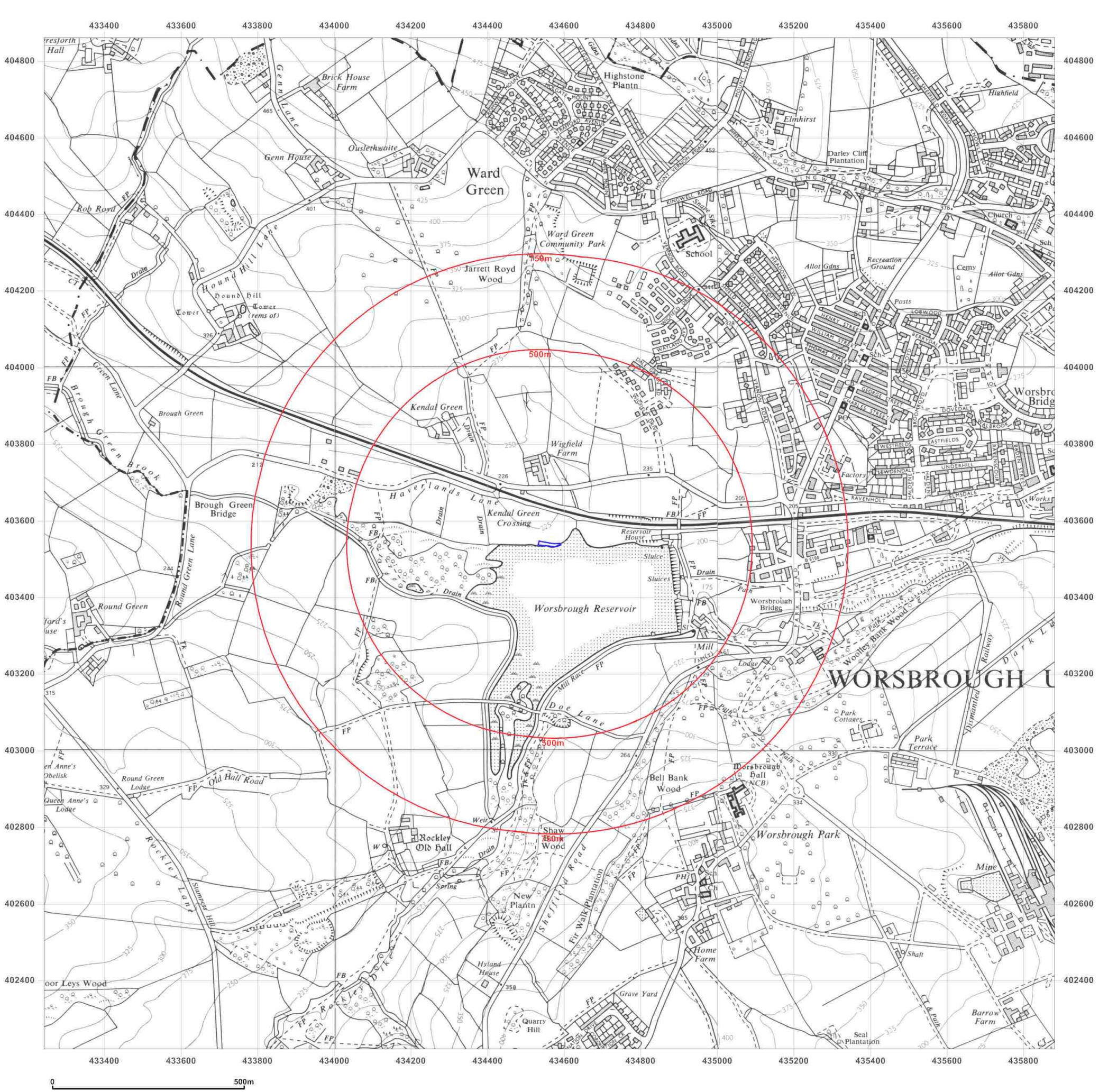
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Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: Provisional

Map date: **1965-1966**

Scale: 1:10,560

Printed at: 1:10,560

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Surveyed 1965	Surveyed 1966
Revised 1965	Revised 1966
Edition N/A	Edition N/A
Copyright N/A	Copyright 1966
Levelled N/A	Levelled N/A

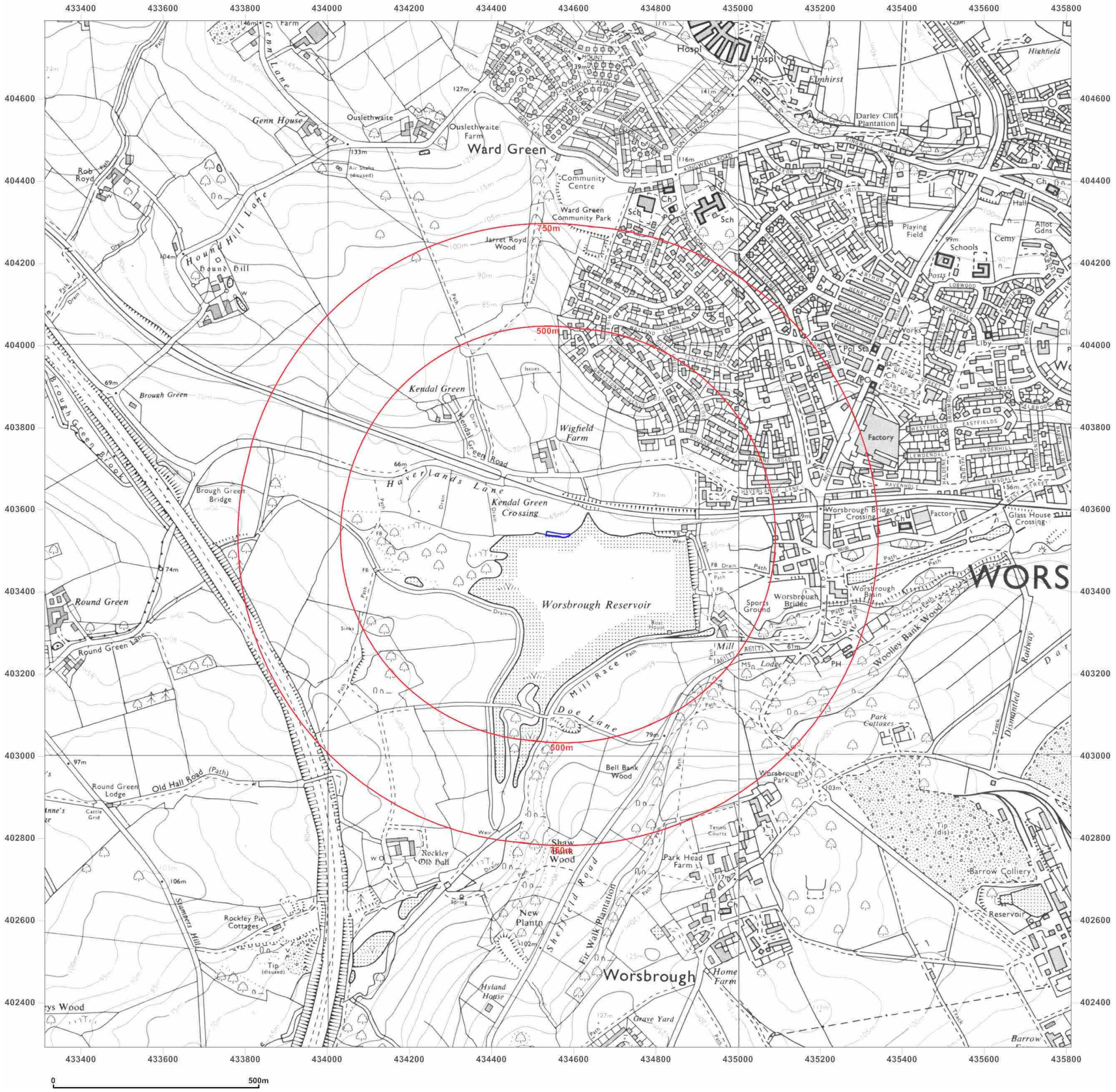
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Client Ref: 151092-3507
Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: National Grid
Map date: **1977**
Scale: 1:10,000
Printed at: 1:10,000

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Surveyed 1973	Surveyed 1976
Revised 1977	Revised 1977
Edition N/A	Edition N/A
Copyright N/A	Copyright 1978
Levelled N/A	Levelled 1978

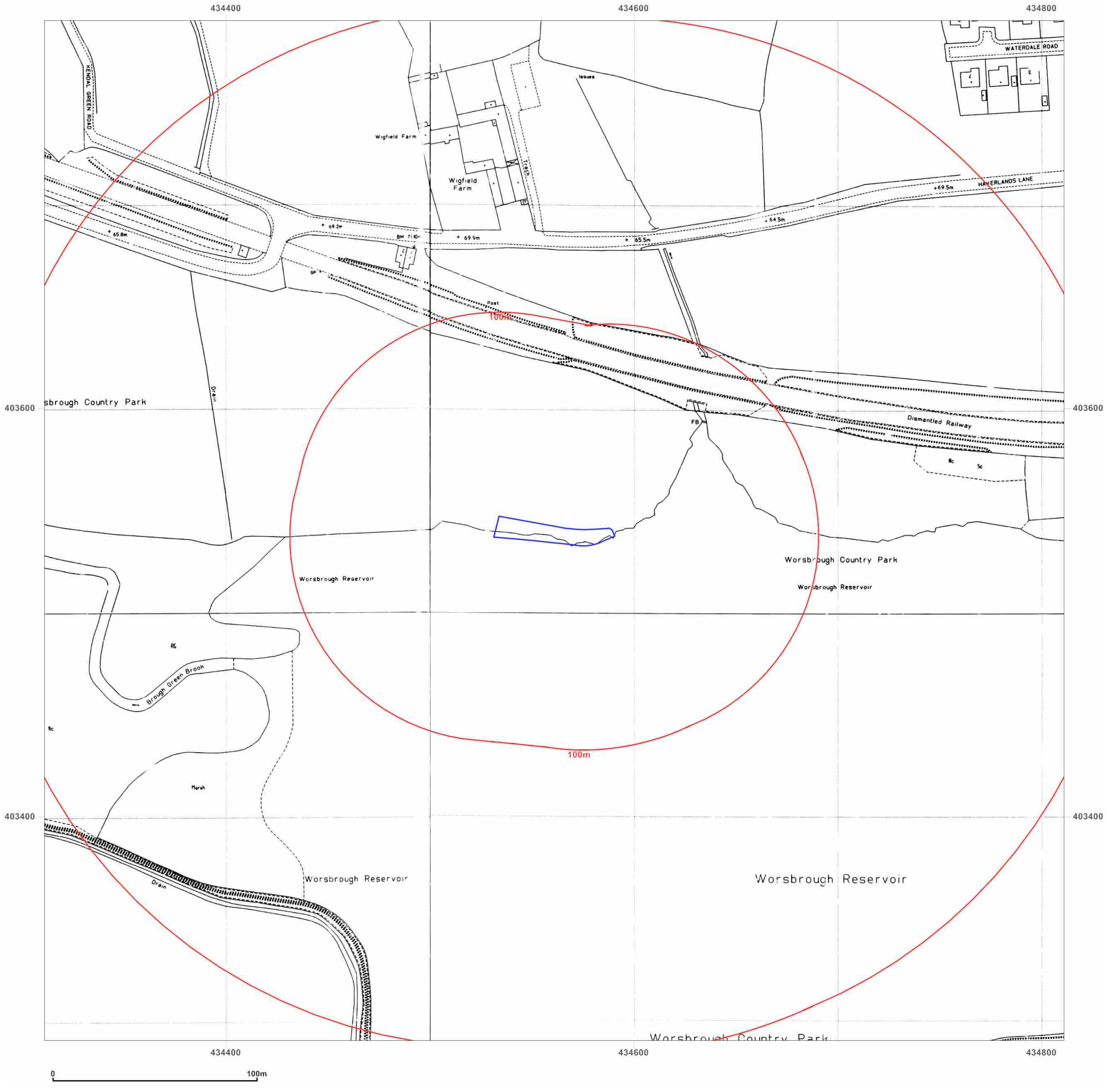
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Client Ref: 151092-3507
Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: National Grid

Map date: **1993**

Scale: 1:1,250

Printed at: 1:2,000

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Surveyed N/A
Revised N/A
Edition N/A
Copyright 1993
Levelled N/A

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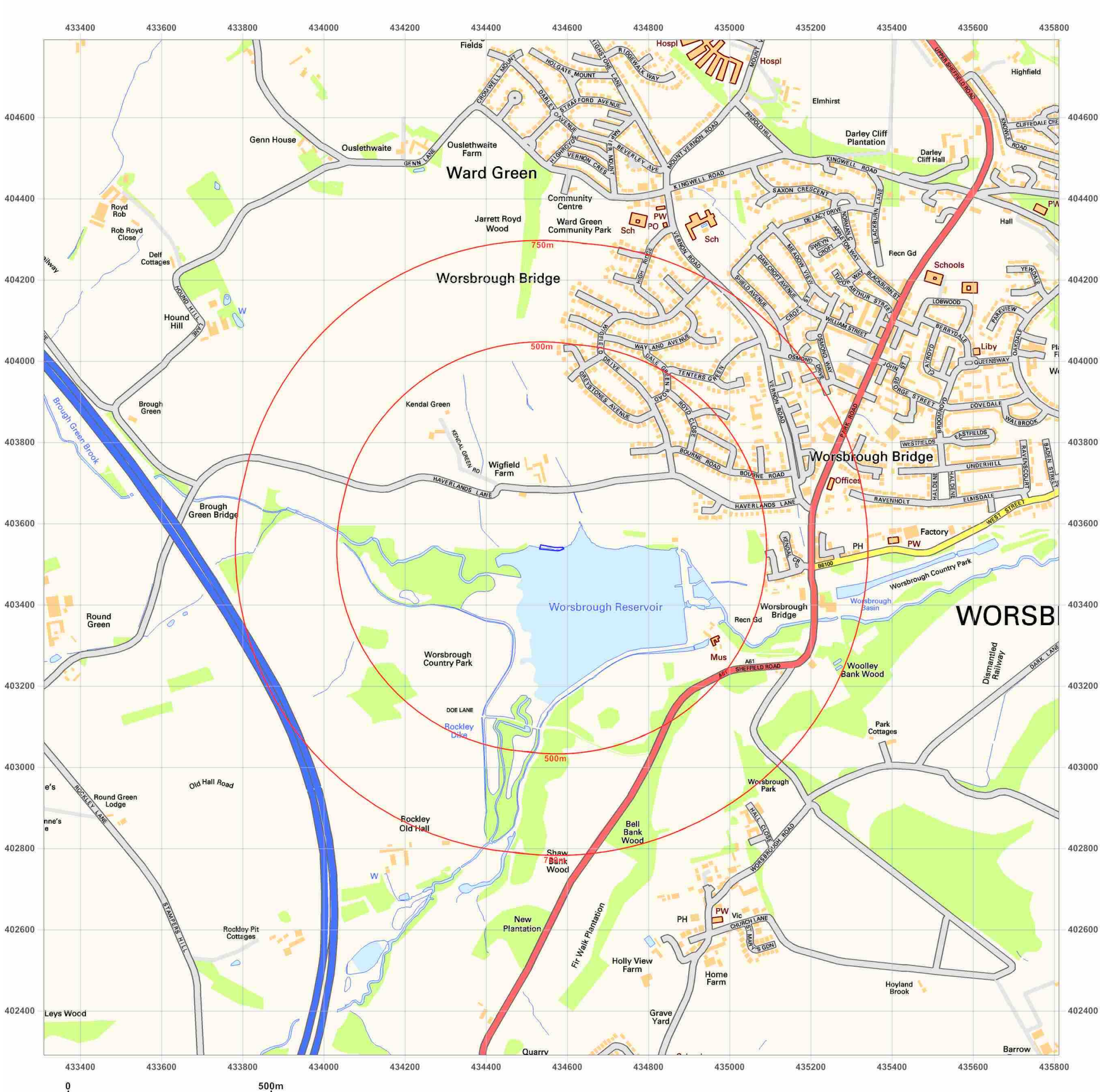
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Client Ref: 151092-3507
Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: National Grid
Map date: 2001
Scale: 1:10,000
Printed at: 1:10,000

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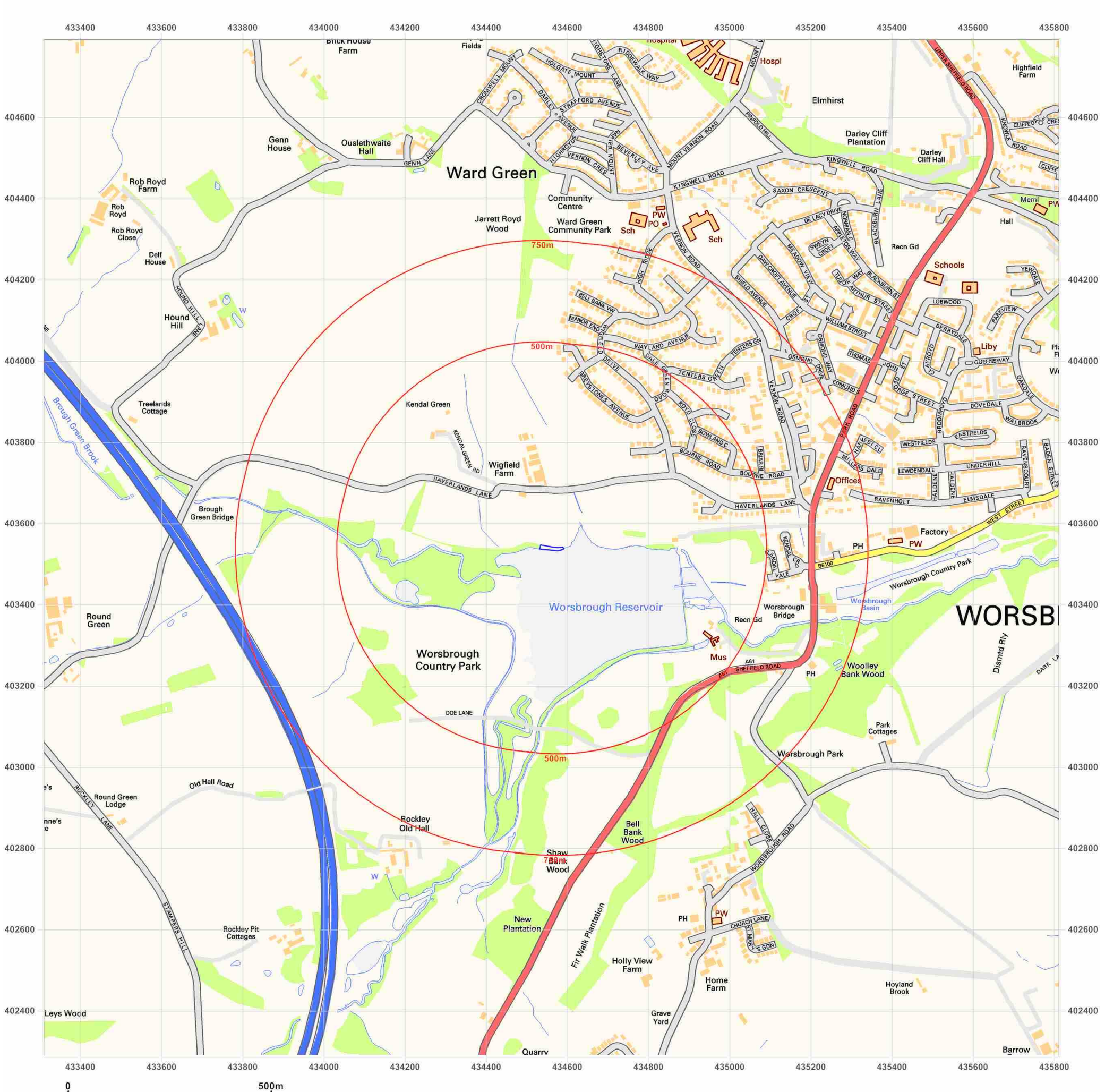
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Report Ref: GS-6433075
Grid Ref: 434561, 403540

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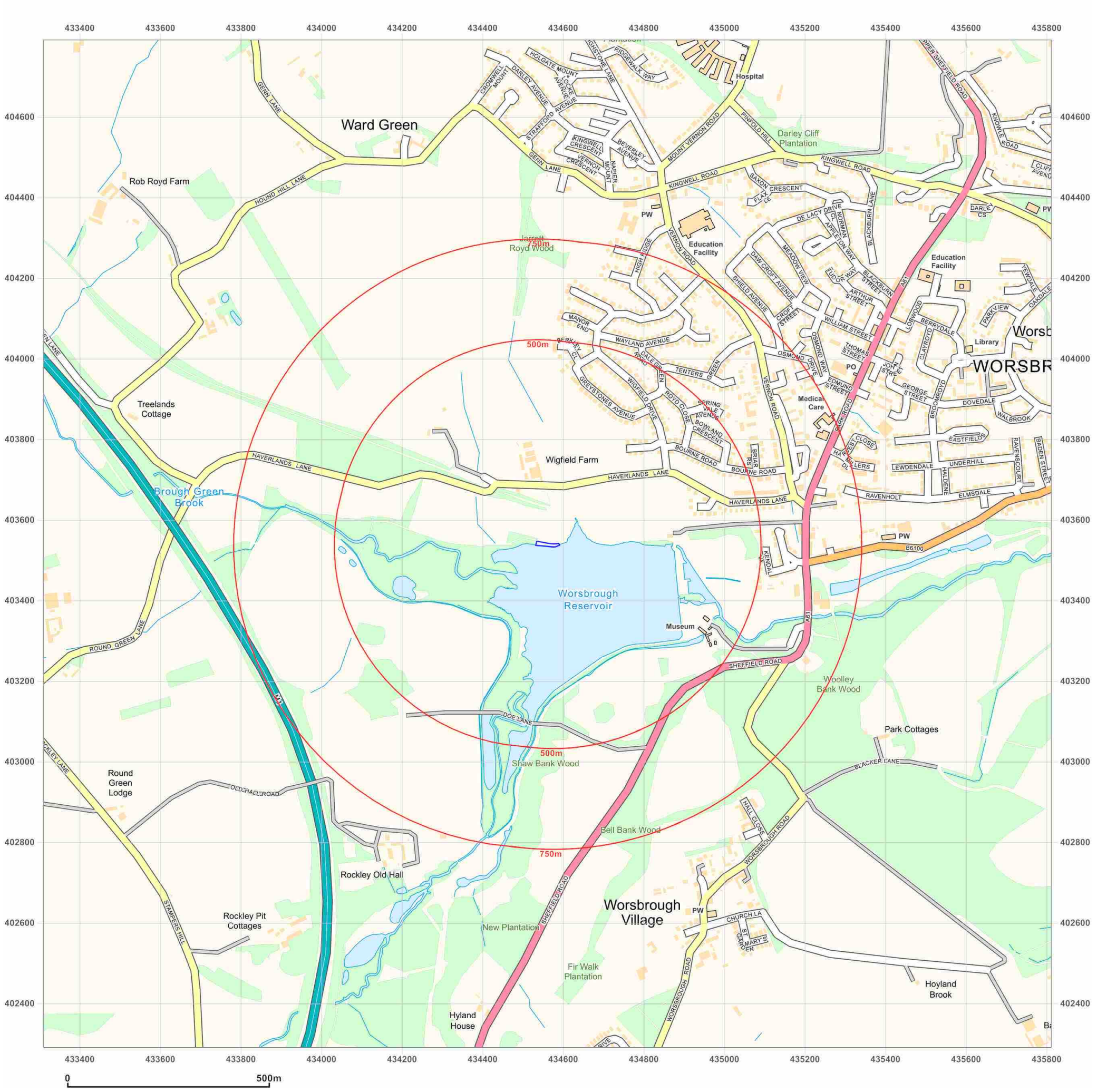
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Site Details:

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Client Ref: 151092-3507
Report Ref: GS-6433075
Grid Ref: 434561, 403540

Map Name: National Grid
Map date: **2019**
Scale: 1:10,000
Printed at: 1:10,000

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APPENDIX B - SYMAS REPORT

PLACE DIRECTORATE
South Yorkshire Mining Advisory Service

BARNSLEY
Metropolitan Borough Council

To:	NPS		**FAO:**	Dan Goulding	
My Ref:	M953/1		**Your Ref:**	Worsbrough Res	
Date:	29th Oct 2019	**Enquiries to:**	Mr. P. James	**Ext:**	2690
Subject:	WORSBROUGH RESERVOIR BANK FAILURE.				

SITUATION

A mining report has been requested for land along the bank of Worsbrough Reservoir which has recently suffered from damage in the form of a linear crack or fissure. The location of the damage is illustrated on the attached drawing M953-1A. The bank is faced by a stone wall of unknown height. The wall is of single stone construction and is leaning forward/has partially subsided into the water hence the development of a shallow fissure to its rear.
This report provides an overview of the mining and geological history of the site and an assessment for the potential of mining legacy issues being related to the damage.

GEOLOGICAL INFORMATION

Geological records indicate that the land is underlain by Mudstones, Siltstones and Sandstone of the Middle Coal Measures. The Barnsley coal seam, of around 2.5m in thickness is conjectured to outcrop immediately to the south of the bank and is likely to be present at a shallow depth beneath it. The Barnsley rock sandstone is present above the seam and will form the bedrock of the land to the north.

A geological fault is conjectured to pass the site some 20m away to the south-east, trending in a SW to NE (south-west to north-east) direction.

MINING

Shallow Mining

Shallow historic coal mining is recorded in the Barnsley seam to the north as illustrated on the attached drawing M953-1A. The exact date of the workings is unknown but likely to be mid 1800's to early 1900's. Further unrecorded workings beneath the bank area cannot be ruled out.

Deep Mining

Deep mining operations have taken place beneath this area in various coal seams in the distance past. All subsidence movement from these workings will be long complete.

Mine Entries

There are no known mine entries in close proximity to the site.

HISTORICAL ORDNANCE SURVEY

According to historical ordnance survey maps an area of steep ground/embankment is/was located immediately north of the bank as illustrated on drawing M953/1B which reproduces the 1961 ordnance survey map. The steep ground/embankment feature is present on historical maps dating from 1892 to 1961.

FUGITIVE GAS

There are no records of any fugitive mine gas issues at this location. However, considering the proximity of recorded shallow mine workings, the presence of fugitive mine gases cannot be ruled out. It would be prudent to employ precautions and monitoring procedures where any site personnel are required to work in deep or confined excavations.

CONCLUSIONS

1. The Barnsley coal seam is likely to be present beneath the wall at a shallow depth. Although the presence of shallow unrecorded mine workings cannot be ruled out, the damage observed is not consistent with crown hole development due to the collapse of shallow mine workings.

   The crack/fissure runs parallel to the reservoir bank and to the rear of a stone facing wall. The most probable cause of the fissure is the failure of the wall foundations due to undercutting. This has caused the wall to subside and lean forward hence the development of a shallow fissure behind it. It is possible that water may be naturally entering the Barnsley coal seam beneath the wall foundations. Overtime this has probably undercut and eroded the foundations.

2. Deep coal mining beneath this land is now long complete, the site will be stable from the deep coal mining subsidence aspect for the foreseeable future.

3. An area of steep ground/embankment is present immediately to the north. This is most likely a sandstone escarpment associated with the Barnsley Rock Sandstone and is not thought to be relevant to the damage.

4. A coal mining subsidence damage claim cannot be substantiated. Options to repair/re-profile or manage the section of bank should now be explored.

5. SYMAS has no records of any fugitive mine gas emissions in this area. However due to the proximity of recorded mine workings it would be prudent to employ safety precautions/monitoring procedures if/where site personnel are required to work in deep or confined excavations.

THIS REPORT IS BASED ON AND LIMITED TO THE RECORDS IN THE POSSESSION OF SYMAS AT THE TIME THE ENQUIRY IS ANSWERED.

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Report prepared by P James 29th October, 2019.

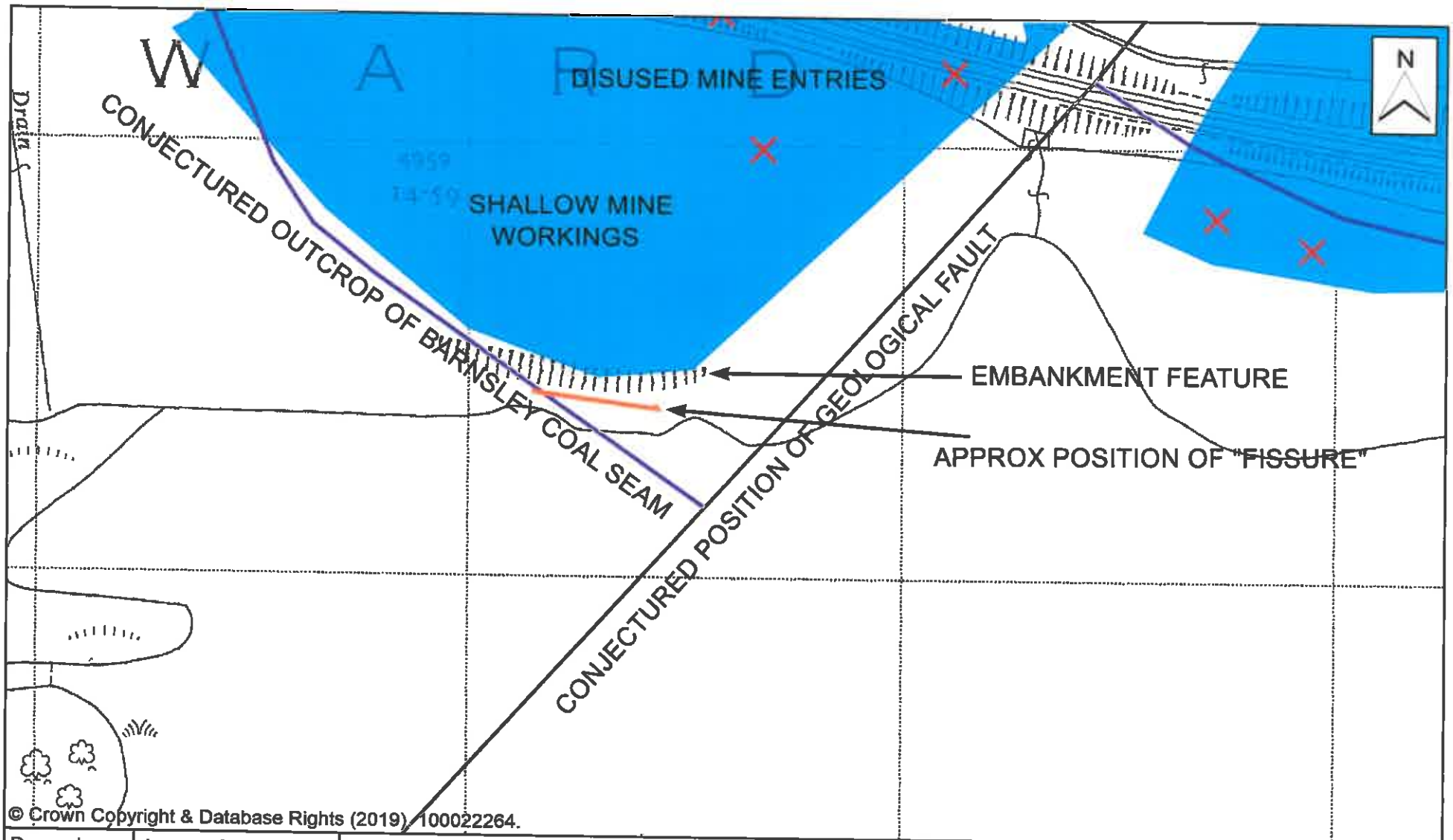
P. James,
Principal Mining Engineer.



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Drawn by:	James , Paul	**Title:**	WORSBROUGH RESERVOIR BANK "FISSURE"
Date:	29 October 2019		
Drawing No:	M953-1A		
Scale:	1:1250		

BARNSLEY
Metropolitan Borough Council

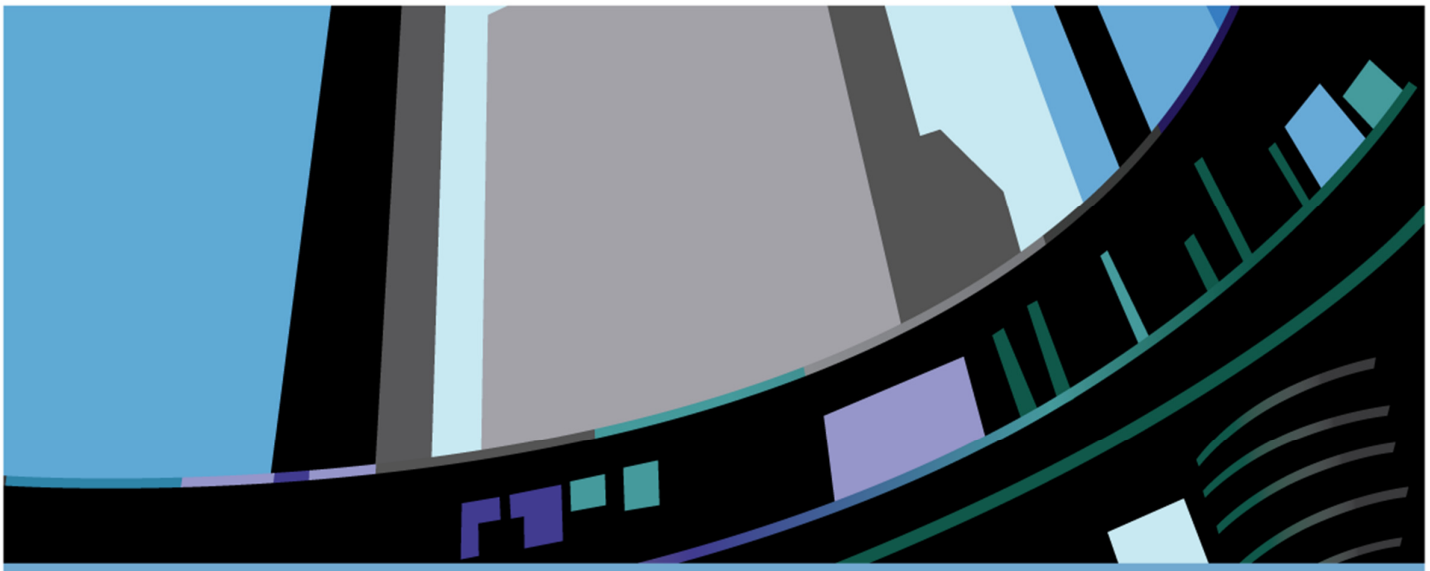


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Drawn by:	James , Paul	**Title:**	1960 Ordnance survey showing embankment feature
Date:	29 October 2019		
Drawing No:	M953-1B		
Scale:	1:1250		

BARNSLEY
Metropolitan Borough Council

APPENDIX C - JNP GROUP GROUND INVESTIGATION REPORT



john newton & partners
jnpgroup
Consulting Engineers

www.jnpgroup.co.uk

Ground Investigation

Project: Worsbrough Mill Country Park

Client: NPS Group (NPS Barnsley)

Reference: S10732-JNP-XX-XX-RP-C-1003-S2

Date: July 2018

Sheffield

telephone
0114 2443 500

email
sheffield@jnpgroup.co.uk

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DOCUMENT CONTROL SHEET

Worsbrough Mill Country Park - Ground Investigation Report



Prepared by……
Philip Taylor BSc (Hons) MA CGeol FGS
Principal Engineer



Approved by……
Daniel Sykes BSc (Hons) MSc CGeol FGS
Office Lead

FOR AND ON BEHALF OF JNP GROUP

Date: 30 July 2019

Document Issue Record

Rev	Date	Description	Prepared	Checked	Approved
~	30/07/19	First Issue	PT	DRS	DRS

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Figure 2	*SPT N Value / Depth Plot*
Figure 3	*Foundation Pit Sketches*
S10732-JNP-XX-XX-DR-C-2001-P1	*Exploratory Hole Location Plan and Cross Section*

List of Appendices

Appendix A	*Limitations*
Appendix B	*Exploratory Hole Records*
Appendix C	*Geotechnical Laboratory Test Results*
Appendix D	*Chemical Laboratory Test Results*

1 INTRODUCTION

1.1.1 jnpgroup was instructed by NPS Group (NPS Barnsley), herein referred to as 'the client', to undertake a ground investigation of a site known at Worsbrough Mill Country Park (hereinafter referred to as 'the site'). This report is subject to the limitations presented in Appendix A.

1.1.2 It is understood that an area of the existing northern reservoir wall described as a retaining wall, and the land immediately to the rear of the wall is showing signs of distress and as such a ground investigation is required in order to inform a design of a repair to the wall.

1.1.3 Any comments given are based on the understanding that the proposed works will be as detailed above.

1.2 Objectives

1.2.1 The purpose of the investigation was to determine the ground conditions immediately adjacent to an area of failed retaining wall for the purpose of designing possible remedial options. The scope of work comprised limited intrusive investigation works along with laboratory testing, and groundwater level monitoring. This report contains details of the site, the work and laboratory testing undertaken, strata encountered, geotechnical and chemical laboratory test results, and provides an interpretative assessment of the ground conditions with regard to the failing retaining wall.

2 SITE DESCRIPTION

2.1.1 The site is located on the northern edge of Worsbrough Mill Reservoir which is situated on the south western edge of Worsbrough. (see Figure 1 Key Plan). The centre of the site is located at approximate National Grid Reference SE 346035.

2.1.2 At the time of the site works the top of a stone retaining wall was visible to a height of 0.20m above the reservoir level. Behind the retaining wall a flat grassed area approximately 1.0m wide was present to the base of an embankment which sloped upwards to the north. The embankment was heavily vegetated, and a gravel footpath was present along the top with farmers' fields present beyond.

2.1.3 The flat area immediately behind the retaining wall was showing signs of distress with large longitudinal cracks visible. In addition, the retaining wall appears to have subsided locally and was in places below the reservoir water level as shown in photograph 1 below.



Photograph 1 – Showing cracking and settlement of retaining wall

3 GEOLOGY, HYDROLOGY AND HYDROGEOLOGY

3.1 Geology

3.1.1 The geology of the site has been determined by reference to the 1:50,000 scale British Geological Survey (BGS) online Geoindex Tool (http://mapapps2.bgs.ac.uk/geoindex/home.html).

3.1.2 No artificial or Made Ground is indicated to be present underlying the site, however mapped artificial ground believed to be associated with historic mine waste are shown in the vicinity of the site.

3.1.3 The superficial geology of the site is indicated to be Alluvium, which is described by the BGS as "*Normally soft to firm, consolidated, compressible silty clay, but can contain layers of silt, sand, peat and basal gravel. A stronger, desiccated surface zone may be present*".

3.1.4 The underlying geology is indicated to be the Pennine Middle Coal Measures Formation, which is described by the BGS as '*Interbedded grey mudstone, siltstone, pale grey sandstone and commonly coal seams, with a bed of mudstone containing marine fossils at the base, and several such marine fossil-bearing mudstones in the upper half of the unit.'.*

3.1.5 The Coal Authority viewer indicates that are a number of mine entries within close proximity of the site. The site is shown to be in a development high risk zone and is shown to be underlain by an area of both known and probable shallow workings. A coal outcrop is shown to cut across the site orientated from the north west to the south east.

4 FIELDWORK AND MONITORING

4.1.1 The intrusive fieldwork was undertaken by jnpgroup on 20th June 2019 and comprised three Dynamic Sample boreholes, and two hand excavated trial pits. Two return groundwater level monitoring visits were undertaken on the 02nd and 15th of July 2019. All site work was completed under the instruction and supervision of jnpgroup, with the ground investigation procedures and sample descriptions based on BS 5930 (2015) 'Code of Practice for Site Investigations' and BS 10175 (2001+A1:2013) "Investigation of potentially contaminated sites - code of practice". The locations of the exploratory holes are shown on jnpgroup Drawing No S10732-JNP-XX-XX-C-2001-P1. The exploratory hole records are presented in Appendix B. The full details of the fieldwork undertaken are summarised in the following sections.

4.2 Dynamic Sample Boreholes

4.2.1 Three Dynamic Sample boreholes, designated WS1 to WS3 (inclusive) were sunk on 20th June, to depths of 5 m below ground level (bgl) at various locations across the site.

4.2.2 The dynamic sampling technique uses a lightweight tracked rig to advance a borehole by 1 m intervals using 1 m long steel sampler tubes, at diameters of 100 mm, reducing to 70 mm. The soils are then recovered from each sample tube as continuous core samples, which are logged and sub-sampled on site. In situ Standard Penetration Tests (SPTs) were undertaken in accordance with BS1377 (1990) Part 9 at 1 m intervals in the sample holes in order to provide strength parameters for geotechnical design.

4.2.3 All exploratory boreholes were hand excavated to 1.2 m bgl to avoid existing services.

4.2.4 Two boreholes (WS1 and WS2) were installed with 50 mm gas monitoring standpipes, with flush fitting steel covers set in concrete at ground level. The remaining sample boreholes were backfilled with arisings and the ground surface left in a safe and tidy manner.

4.2.5 For full details of the depth of each Dynamic Sample borehole, strata encountered, samples taken, information on groundwater encountered, results of in-situ testing, and any other relevant information, reference should be made to the logs presented in Appendix B.

4.3 Hand Excavated Pits

4.3.1 jnpgroup undertook two hand excavated pits to the rear of the retaining wall in order to attempt to expose the existing foundations. Details of the foundations exposed are enclosed in Appendix C. The locations of the hand excavated pits are shown on jnpgroup Drawing S10732-JNP-XX-XX-C-2001-P1.

4.4 Monitoring

4.4.1 Monitoring was undertaken on two occasions on the 02nd and 15th July 2019 after the completion of the fieldwork.

4.4.2 Monitoring involved the measurement of the depth to groundwater within the standpipe. It should be noted that long-term groundwater levels may vary from those reported due to seasonal fluctuation or weather events, such as droughts, significant rainfall, or recent flooding.

5 LABORATORY TESTING

5.1 Geotechnical

5.1.1 A programme of laboratory testing was scheduled by jnpgroup to determine the geotechnical properties of selected soil samples obtained from the investigation. The details of the geotechnical testing are summarised below:

Table 11.1: Scheduled Geotechnical Laboratory Tests

Test Description	Number of Tests
Water soluble sulphate and pH	2
Atterberg limits including moisture content	4

5.1.2 Tests were undertaken in accordance with BS1377 (1990) "Methods of test for Soils for Civil Engineering purposes". The results of the geotechnical testing are presented in Appendix C.

6 GROUND AND GROUNDWATER CONDITIONS

6.1 Strata Encountered

6.1.1 The ground conditions encountered during the intrusive investigation were generally consistent with the published geological map. A limited thickness of made ground was encountered in WS1 only. A firm to stiff grey and orange brown mottled clay was encountered in all exploratory holes to depths between 2.8m to 4.7m. Weathered coal was encountered in WS3 from 2.8m to 4.1m with mudstone encountered at depth in all boreholes.

6.1.2 A summary of the strata encountered in the window samples during the investigation is presented in Table 6.1 and described in the following sections, but for full details and descriptions, reference should be made to the exploratory hole records presented in Appendix B.

Table 6.1: Strata Encountered

Stratum	Depth to Top (m bgl)	Depth to Base (m bgl)	Thickness (m)
Made Ground WS1 and WS3	Ground level	0.25 - 0.40	0.25 - 0.40
Clay All locations	Ground Level – 0.40	2.80 – 4.70	2.80 – 4.70
Coal WS3 only	2.80	4.10	1.30
Mudstone All locations	3.40 – 4.70	Not proven >5m	>5m

6.2 Made Ground

6.2.1 Window sample WS1 was drilled at the base of the slope behind the retaining wall and encountered a light cream hardcore to a depth of 0.40m. The two hand pits excavated immediately behind the retaining wall also encountered hardcore which was proven to a depth of 0.63m. Hardcore was also encountered underlying the turf in WS03 to a depth of 0.25m.

6.3 Pennine Middle Coal Measures

6.3.1 Weathered coal measures strata recovered as a firm to stiff grey orange and brown mottled clay was encountered in all window sample holes. In WS1 and WS3 the clay became a weathered mudstone recovered as a gravel from 3.4m to 4.7m.

6.3.2 In WS2 a weathered seam of black coal was encountered between 2.80 and 4.10m this was in turn underlain by a thin layer of clay to 4.40m and then onto weathered mudstone as per the other exploratory holes.

Table 6.2: Pennine Middle Coal Measures – Geotechnical Laboratory Test Results Summary

Property	Number of Tests	Range	Mean	Assessment
Natural Moisture Content	4	18 - 33	24	Low volume potential
% passing 425 sieve	4	85 - 100	94	
Liquid Limit %	4	38 - 49	43	
Plastic Limit %	4	20 - 31	25	
Plasticity Index %	4	16 - 19	18	
Modified Plasticity Index %	4	16 - 17	17	
c_u = 4.5 x SPT 'N' Value (kN/m^2)	15	36- 225*	105	Low to high strength (medium strength)
Hand Shear Vane (kN/m^2)	14	20 - 78	52	

*When refusal blows removed range is 36-153kN/m²

6.3.3 The SPT N value / depth profile is presented as Figure 2.

6.4 Groundwater

6.4.1 The levels of groundwater recorded during the fieldwork period, and subsequently during the monitoring visits, are summarised in the following table:

Table 6.4: Summary of groundwater observations

Window Sample	Groundwater 02nd July	Groundwater 15th July
WS1	0.30m	0.31m
WS2	2.31m	2.29m

7 GEOTECHNICAL ENGINEERING ASSESSMENT

7.1 Summary

7.1.1 The ground investigation works have confirmed that the ground conditions present beneath the site is predominantly a firm to stiff clay underlain by mudstone of coal measures strata. The exception to this was in WS3 where a coal seam was encountered which is projected to outcrop at foundation level for the reservoir retaining wall. A cross section across the embankment and existing wall is shown on drawing S10732-JNP-XX-XX-DR-C-2001-P1.

7.1.2 During the supervision of the ground investigation a visual inspection of the embankment was undertaken by the geotechnical engineer and no evidence of ground movement was noted within the embankment. A full assessment of the stability of the embankment has not been undertaken at this stage.

7.1.3 The Coal Authority online viewer indicates that a coal seam outcrops across the site orientated north west to south east. The top of this seam was encountered in WS3 at a depth of 2.8m and whilst the angle of dip is unknown, based on a shallow dip to the south west the coal seam is anticipated to intercept the foundation level of the retaining wall in the area where the wall has sunk beneath the water level.

7.1.4 The viewer also indicates that shallow workings have taken place beneath the site.

7.1.5 Anecdotally during the site works a number of local residents stated that the wall showing signs of distress was constructed on ash, this ash may in fact have been the coal seam encountered in the adjacent borehole.

7.1.6 Given the above, we believe at this stage that the existing reservoir retaining wall was likely constructed within the coal seam. As such it is possible that the most likely cause of the failure to the wall is that the coal on which the wall is founded is being eroded away causing the failure of the retaining wall. This may be as a result of the water action in the reservoir or due to water flowing from the reservoir through to the underground shallow workings.

7.1.7 Given the level of investigation and the findings of the said investigation it is jnpgroup's view that this settlement / bearing failure is more of a likely failure mechanism rather than large scale global failure although it is stressed that a full slope stability assessment is beyond the scope of this report.

7.1.8 Notwithstanding the above, it would also appear that the wall has not been fully maintained and whatever the failure mechanism, once water seepages have occurred through the wall this will have resulted in wash out to the rear and freeze thaw action during winter months exacerbating the issue.

7.2 Recommendations

7.2.1 Based on the above it is recommended that the retaining wall is reconstructed with a foundation taken through the coal seam to found on the underlying clay or mudstone.

7.2.2 The replacement retaining wall will need to be suitably designed utilising appropriate design codes by a structural engineer taking into account; the findings of this investigation, the retaining requirements and the environment the structure is within.

Figures / Drawings



Figure 1

Site Location Plan

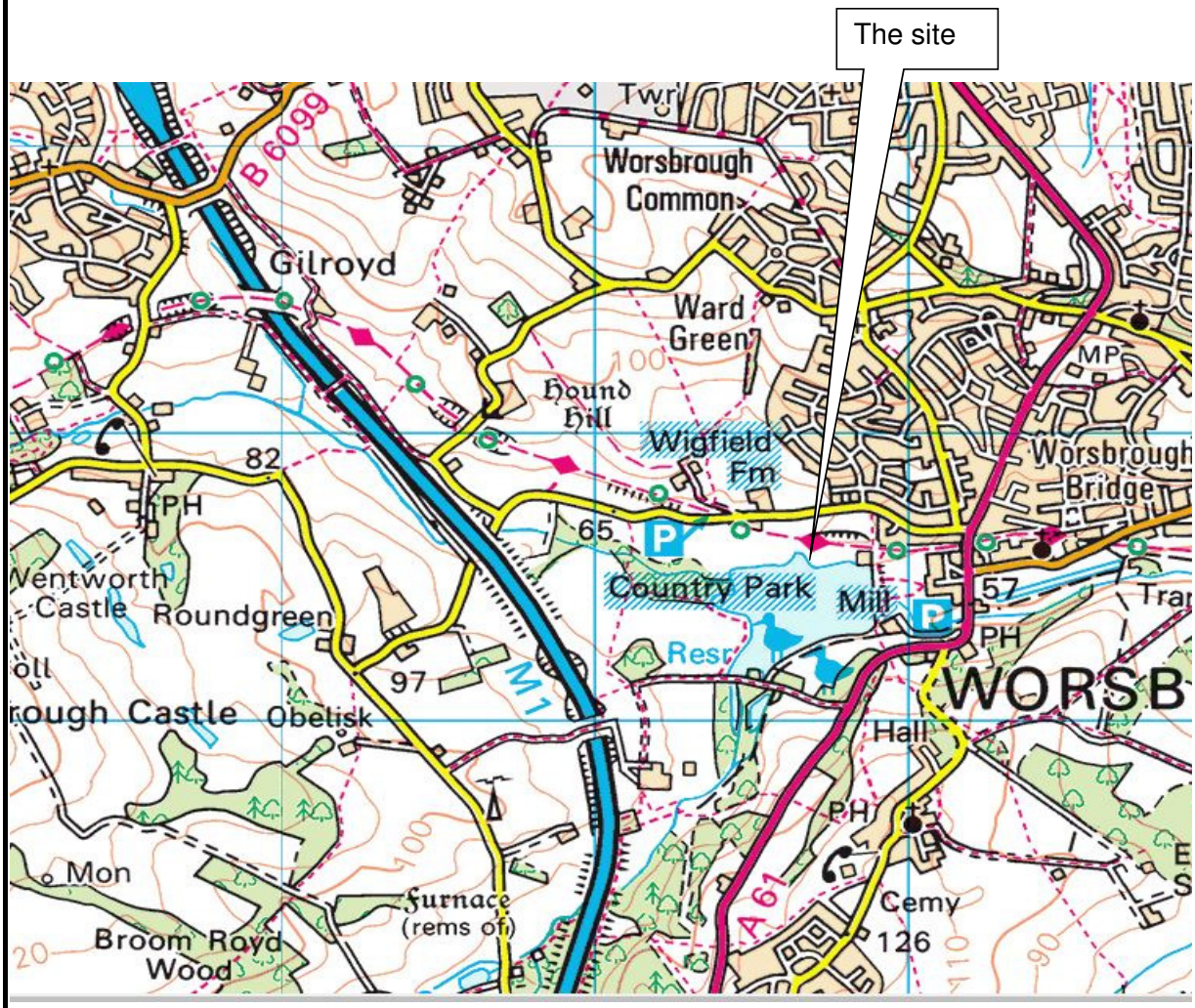
john newton & partners jnpgroup Consulting Engineers

Project:

Worsborough Mill Country Park

Project No:

S10732



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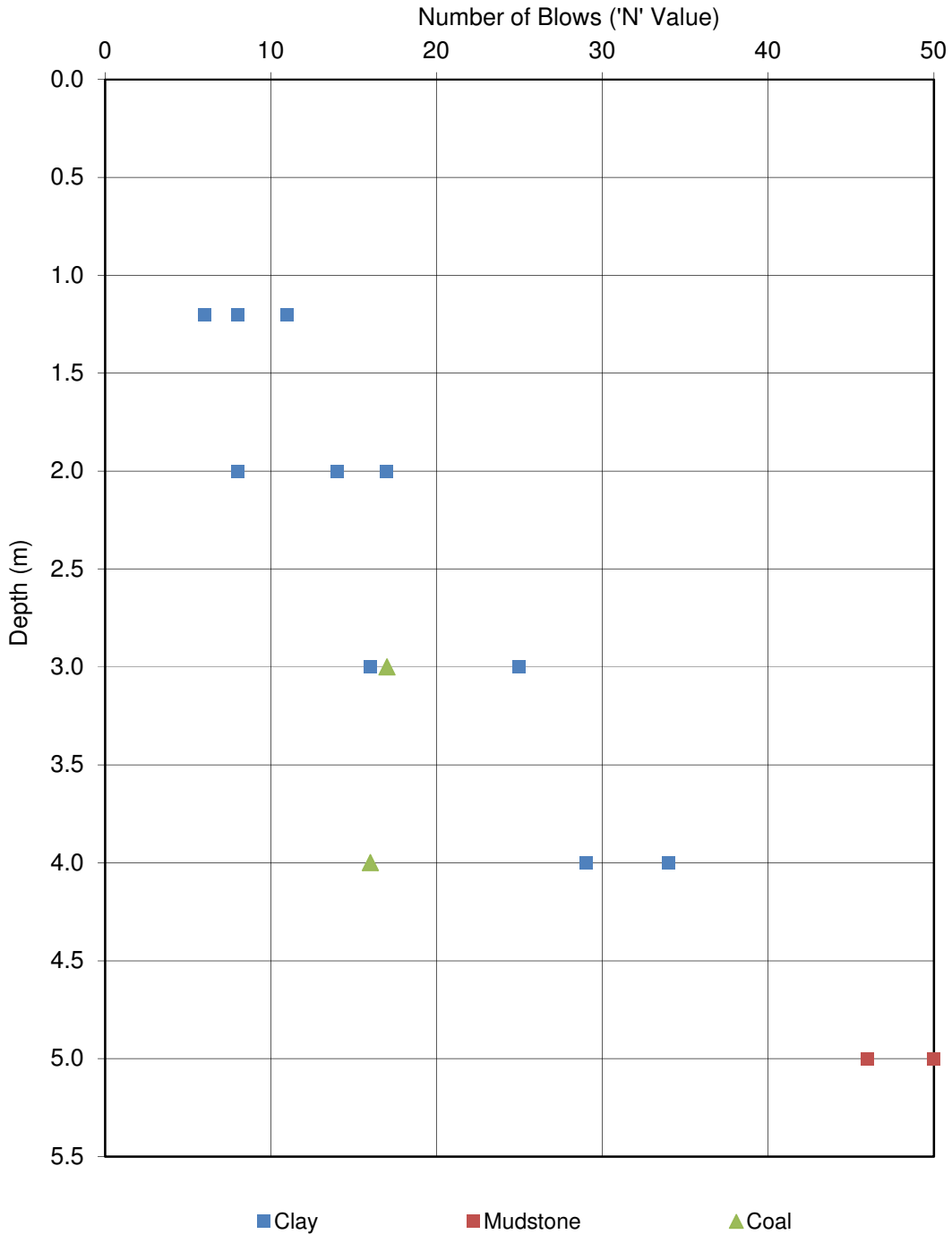
Figure 2

SPT / Depth Relationship

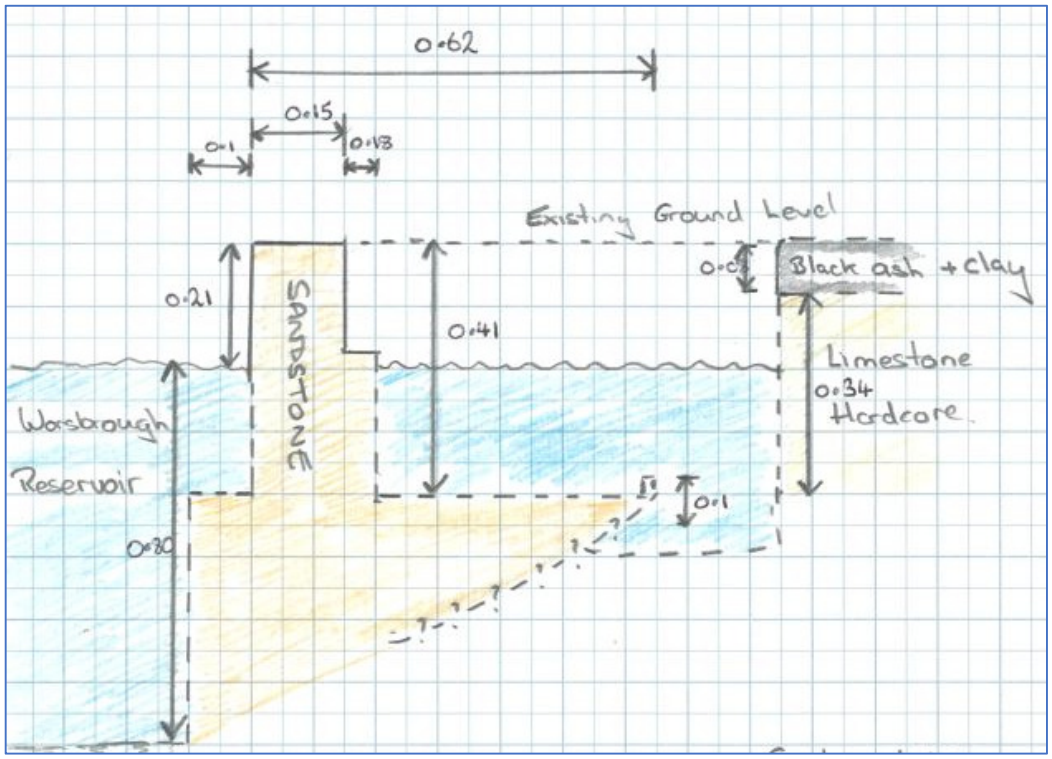
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Project:
Worsborough Mill Country Park

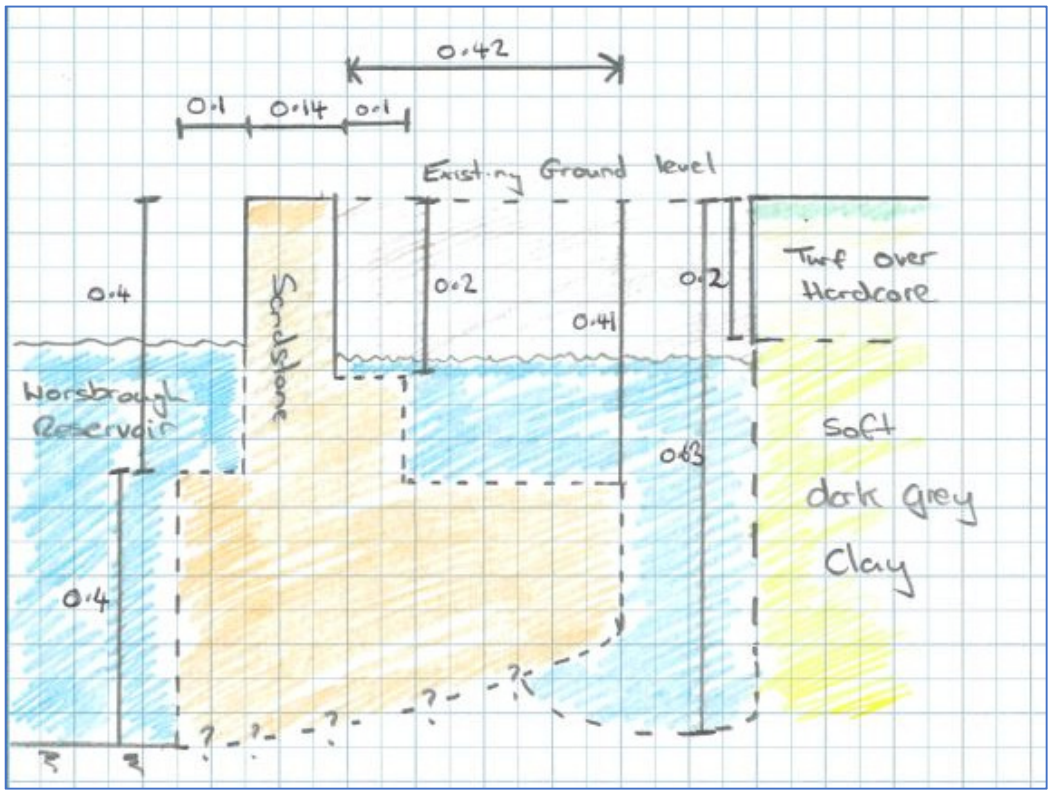
Project No:
S10732

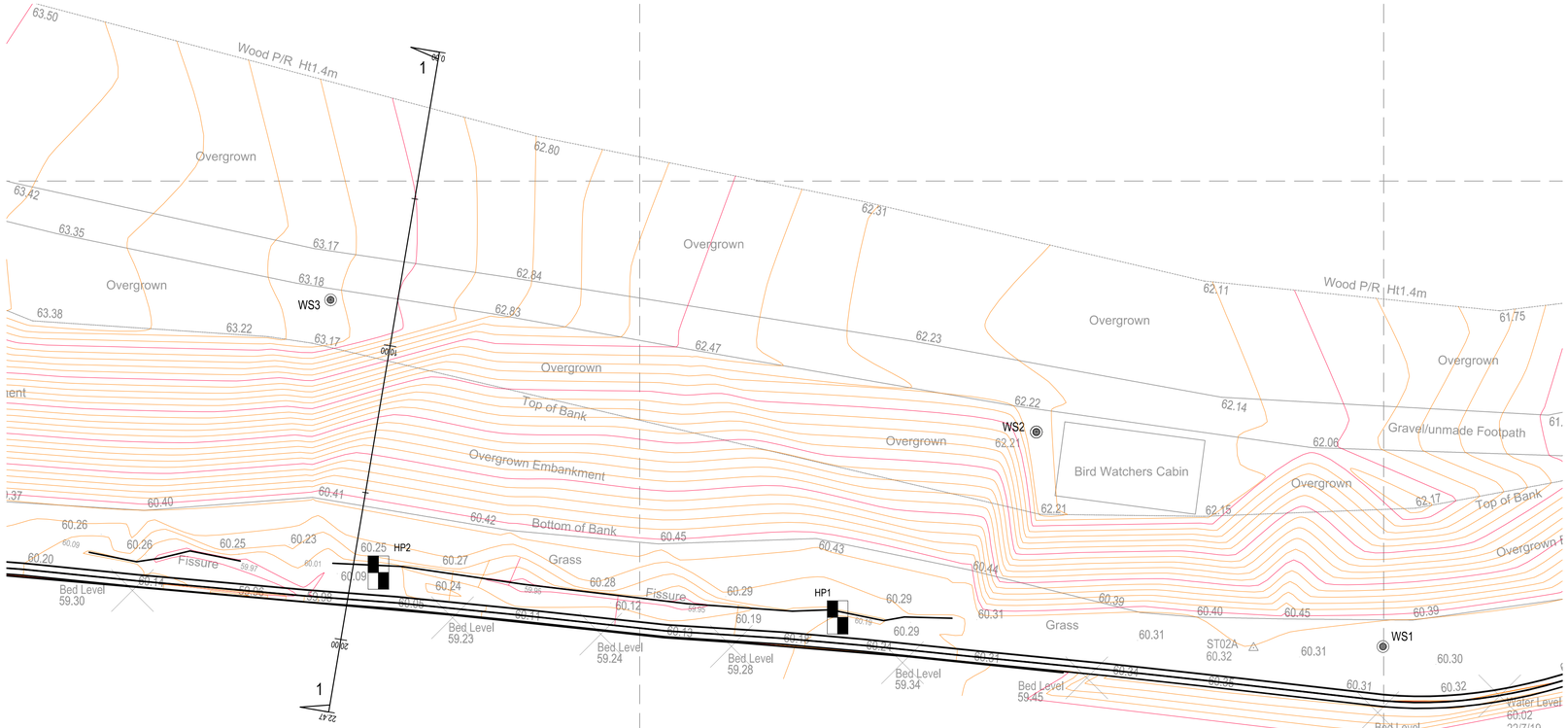


Hand Pit 1

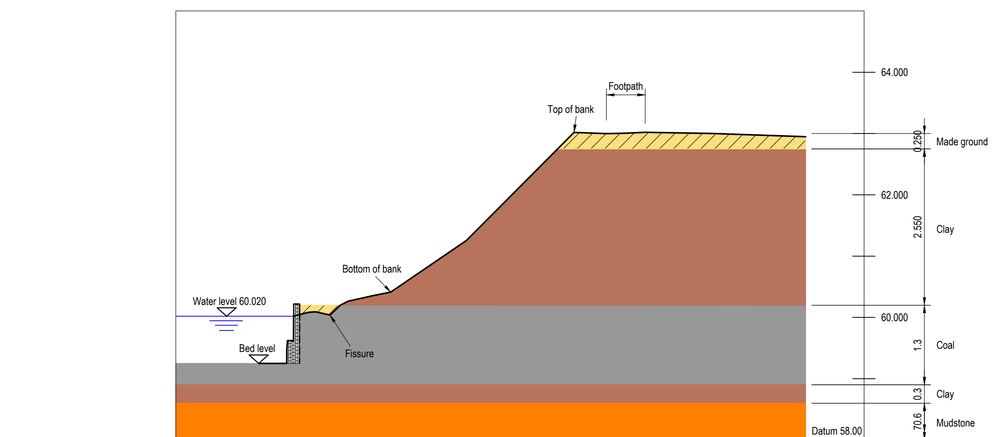


Hand Pit 2





PLAN
Scale 1:100



Chainage (m)	22.469	20.000	17.500	15.000	12.500	10.000	7.500	5.000	2.500	0.000
Existing Ground Levels (m)			60.044	60.567	61.496	62.751	63.011	63.002	62.958	

SECTION 1-1
Scale 1:100 H, 1:50 V

General Notes

1. Where this drawing has been issued in electronic .dwg format it has been done so in good faith. jnpgroup do not take any responsibility for any inaccuracies in the electronic data, which should be checked against the paper (or .pdf) drawing issue. Any apparent discrepancies should be immediately reported to jnpgroup. The electronic .dwg file should not be assumed to be to scale and should not be used for 'overlaying', setting out or checking of any third party information. All dimensions should be taken from the paper (or .pdf) version of the drawing. Electronic drawings may contain third party information. jnpgroup take no responsibility for this information, which should be checked against the originators paper drawing(s).
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3. Do not scale.
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7. This drawing should be read in conjunction with Report number S10732-JNP-XX-XX-RP-C-1003-S2

Health & Safety Note

The details on this drawing have been prepared on the assumption that a competent contractor will be carrying out the works. If the contractor(s) considers that there is insufficient Health and Safety information on this drawing, this should immediately be brought to the attention of the designer.

HAZARD IDENTIFICATION BOX

This table is provided to assist the Principal Contractor to fulfil their obligations under the CDM Regulations 2015

Hazard Ref	Hazard Type (Construction/Maintenance/Cleaning/Demolition/Adaptation)	Hazard Description	Mitigation Measures/ Residual Risk
1			

KEY

- Window sample borehole
- Hand dug trial pit

Rev.	Date	Description	Drn / Chk'd / Appr'd
P1	25/07/2019	First Issue	RAC/PT/PT

Suitability:
S0 - Work In Progress

john newton & partners
jnpgroup
Consulting Engineers
www.jnpgroup.co.uk
Chesham ● Brighouse ● Hartlepool ● Leamington Spa ● Sheffield
Website www.jnpgroup.co.uk

Client:
NPS Group (NPS Barnsley)

Job:
Worsborough Mill Country Park

Title:
Exploratory Hole Location Plan and Cross Section

Classification:	Scale @ A1:	Date Issued:	Drawn / Eng. Chk / Tech. Chk
FI_60_20	As Shown	25/07/19	RAC / PT / PT

Supplier No: 000024

Project - Originator - Volume/System - Level/Location - Type - Discipline - Number: S10732-JNP-XX-XX-DR-C-2001 (Document/Drawing Number) | Revision: P1

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JNP Group Internal Project Number: S10732

Complies to ISO9001:2008 - JNP QA Ref: QD019 Rev E

Appendix A

Limitations

Introduction

This report is confidential and has been prepared solely for the benefit of the client and those parties with whom a warranty agreement has been executed, or with whom an assignment has been agreed. Should any third party wish to use or rely upon the contents of the report, written approval must be sought from jnpgroup; a charge may be levied against such approval. jnpgroup accepts no responsibility or liability for the consequences of this document being used for any purpose or project other than for which it was commissioned, and: this document to any third party with whom and agreement has not been executed.

Any comments given within this report are based on the understanding that the proposed works to be undertaken will be as described in the introduction and the information referred to and provided by others and will be assumed to be correct and will not have been checked by jnpgroup and jnpgroup will not accept any liability or responsibility for any inaccuracy in such information.

Any deviation from the recommendations or conclusions contained in this report should be referred to jnpgroup in writing for comment and jnpgroup reserve the right to reconsider their recommendations and conclusions contained within. jnpgroup will not accept any liability or responsibility for any changes or deviations from the recommendations noted in this report without prior consultation and our full approval.

The details contained within this report reflect the site conditions prevailing at the time of investigation. jnpgroup warrants the accuracy of this report up to and including that date. Additional information, improved practice or changes in legislation may necessitate this report having to be reviewed in whole or in part after that date. If necessary, this report should be referred back to jnpgroup for re-assessment and, if necessary, re-appraisal.
This report is only valid when used in its entirety. Any information or advice included in the report should not be relied upon until considered in the context of the whole report. Whilst this report and the opinion made herein are correct to the best of jnpgroups' belief, jnpgroup cannot guarantee the accuracy or completeness of any information provided by third parties.

The report represents the finding and opinions of experience geotechnical and geo-environmental engineers. jnpgroup does not provide legal advice and the advice of lawyers may also be required.

jnpgroup has provided advice and made recommendations based on the findings of the work undertaken, however this is subject to the approval / acceptance by the relevant Regulatory Authorities.

Objectives

The work undertaken to provide the basis of this report comprised a study of available documented information from a variety of sources (including the Client), together with (where appropriate) a brief walk over inspection of the site. The opinions given in this report have been dictated by the finite data on which they are based and are relevant only to the purpose for which the report was commissioned. The information reviewed should not be considered exhaustive and has been accepted in good faith as providing true and representative data pertaining to site conditions. Should additional information become available which may affect the opinions expressed in this report, jnpgroup reserves the right to review such information and, if warranted, to modify the opinions accordingly. It should be noted that any risks identified in this report are perceived risks based on the information reviewed; actual risks can only be assessed following a physical investigation of the site.

Phase II Intrusive Investigations

Where intrusive investigations have been undertaken they have been designed to provide a reasonable level of assurance on the conditions. Given the discrete nature sampling, no investigation technique is capable of identifying

all conditions present in all areas. The number of sampling points and the methods of sampling and testing do not preclude the existence of localised "hotspots" of contamination where concentrations may be significantly higher than those actually encountered. The risk assessment and opinions provided, inter alia, take into consideration currently available guidance relating to acceptable contamination concentrations; no liability can be accepted for the retrospective effects of any future changes or amendments to these values.
Groundwater levels may vary from those reported due to seasonal, or other effects.

Whilst this report and the opinion made herein are correct to the best of jnpgroups' belief, jnpgroup cannot guarantee the accuracy or completeness of any information provided by third parties.

Appendix B

Exploratory Hole Records

john newton & partners jnpgroup Consulting Engineers

Borehole Log

Borehole No. **WS1**

Sheet 1 of 1

Project Name: Worsbrough Mill Country Park	Project No. S10732	Co-ords: -	Hole Type WLS
Location: S70 5JL		Level:	Scale 1:50
Client: NPS Group (NPS Barnsley)		Dates: 20/06/2019 - 20/06/2019	Logged By PT

Well	Water Strikes	Samples and In Situ Testing: Depth (m)	Type	Results	Depth (m)	Level (m)	Legend	Stratum Description
		0.20	D		0.05			Turf.
		0.20	ES		0.40			Light cream to dark brown/black gravelly sand. Gravel is of limestone hardcore. MADE GROUND
		1.20	D					Soft to firm grey/brown mottled orange CLAY. Firm becoming stiff below 1.50m. WEATHERED PENNINE MIDDLE COAL MEASURES
		1.20	ES					
		1.20		N=8 (2,1/1,2,2,3) HVP=20 HVP=22 HVP=24 HVP=42 HVP=48 HVP=54				
		2.00		N=17 (2,2/4,3,4,6)	2.70			
		2.90	D					Firm to stiff light grey mottled orange/brown CLAY. WEATHERED PENNINE MIDDLE COAL MEASURES
		3.00		N=25 (3,4/4,5,7,9) HVP=76 HVP=78				
		4.00		N=34 (5,5/8,7,8,11)				
		4.60	ES		4.70			Very weak thinly laminated grey MUDSTONE. WEATHERED PENNINE MIDDLE COAL MEASURES
		5.00		HVP=76 HVP=78 HVP=78 N=50 (7,8/50 for 275mm)	5.00			End of borehole at 5.00 m

Remarks
Terminated at 5.0m bgl.
Monitoring standpipe installed to 5.0m bgl.
No groundwater encountered.

AGS

john newton & partners jnpgroup Consulting Engineers

Borehole Log

Borehole No. **WS2**

Sheet 1 of 1

Project Name: Worsbrough Mill Country Park	Project No. S10732	Co-ords: -	Hole Type WLS
Location: S70 5JL		Level:	Scale 1:50
Client: NPS Group (NPS Barnsley)		Dates: 20/06/2019 - 20/06/2019	Logged By PT

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
		0.10	D		0.25			Firm friable dark brown to dark grey CLAY. TOPSOIL
		0.10	ES					
		0.90	D		1.30			Firm orange/brown mottled grey slightly gravelly CLAY. Gravel is of angular sandstone. WEATHERED PENNINE MIDDLE COAL MEASURES
		0.90	ES					
		1.20		N=8 (2,2/2,2,2,2)				
		1.80	D		2.70			Firm to stiff brown CLAY with occasional flecks of black coal and rare red sandstone gravel. WEATHERED PENNINE MIDDLE COAL MEASURES
		1.80	ES					
		2.00		N=8 (0,0/2,2,2,2)				
				HVP=38				
				HVP=48				
				HVP=52				
		2.90	D		3.40			Stiff to very stiff orange/brown mottled light grey slightly sandy slightly gravelly CLAY. WEATHERED PENNINE MIDDLE COAL MEASURES
		2.90	ES					
		3.00		N=16 (6,4/4,3,4,5)				
		3.85	D		5.00			Very stiff light grey MUDSTONE with occasional iron staining. Becoming thinly laminated at 4.00m. (Weathered mudstone at base). WEATHERED PENNINE MIDDLE COAL MEASURES
		4.00		N=29 (4,4/6,5,8,10)				
		5.00		N=46 (10,7/9,11,12,14)				End of borehole at 5.00 m

Remarks
Terminated at 5.0m bgl.
Monitoring standpipe installed to 5.0m bgl.
Sample damp at 2.50m bgl.

AGS

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Borehole Log

Borehole No. **WS3**

Sheet 1 of 1

Project Name: Worsbrough Mill Country Park	Project No. S10732	Co-ords: -	Hole Type WLS
Location: S70 5JL		Level:	Scale 1:50
Client: NPS Group (NPS Barnsley)		Dates: 20/06/2019 - 20/06/2019	Logged By PT

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
		0.10	D		0.25			Turf over firm friable dark brown to black clay topsoil with pale yellow hardcore gravel. MADE GROUND
		0.10	ES					
		0.80	D		1.30			Firm friable pale yellow and brown mottled grey CLAY. WEATHERED PENNINE MIDDLE COAL MEASURES
		0.80	ES					
		1.20		N=11 (3,2/3,2,3,3)				
		1.50	D		2.10			Firm to stiff dark brown slightly gravelly CLAY. Gravel is of red angular sandstone and black flecks of coal. WEATHERED PENNINE MIDDLE COAL MEASURES
		2.00		N=14 (4,3/4,3,3,4)				
		2.50	D		2.80			Stiff to very stiff orange/brown mottled grey CLAY with occasional orange staining. WEATHERED PENNINE MIDDLE COAL MEASURES
		3.00		N=17 (3,2/3,4,4,6)				Very weak black COAL recovered as a sandy gravel. WEATHERED PENNINE MIDDLE COAL MEASURES
		4.00		N=16 (2,1/2,2,4,8)	4.10			
					4.40			Very stiff light grey thinly laminated CLAY. WEATHERED PENNINE MIDDLE COAL MEASURES
		5.00		N=50 (7,10/50 for 255mm)	5.00			Very stiff dark yellow and grey thinly laminated clay with pockets of iron staining. Recovered as very weak MUDSTONE gravel towards the base. WEATHERED PENNINE MIDDLE COAL MEASURES
								End of borehole at 5.00 m

Remarks
Terminated at 5.0m bgl.
No groundwater encountered.

AGS

john newton & partners
jnpgroup
Consulting Engineers

Appendix C

Geotechnical Test Results

TEST CERTIFICATE

Liquid and Plastic Limits

i2 Analytical Ltd
7 Woodshots Meadow
Croxley Green Business Park
Watford Herts WD18 8YS

4041

Tested in Accordance with: BS 1377-2: 1990: Clause 4.4 and 5

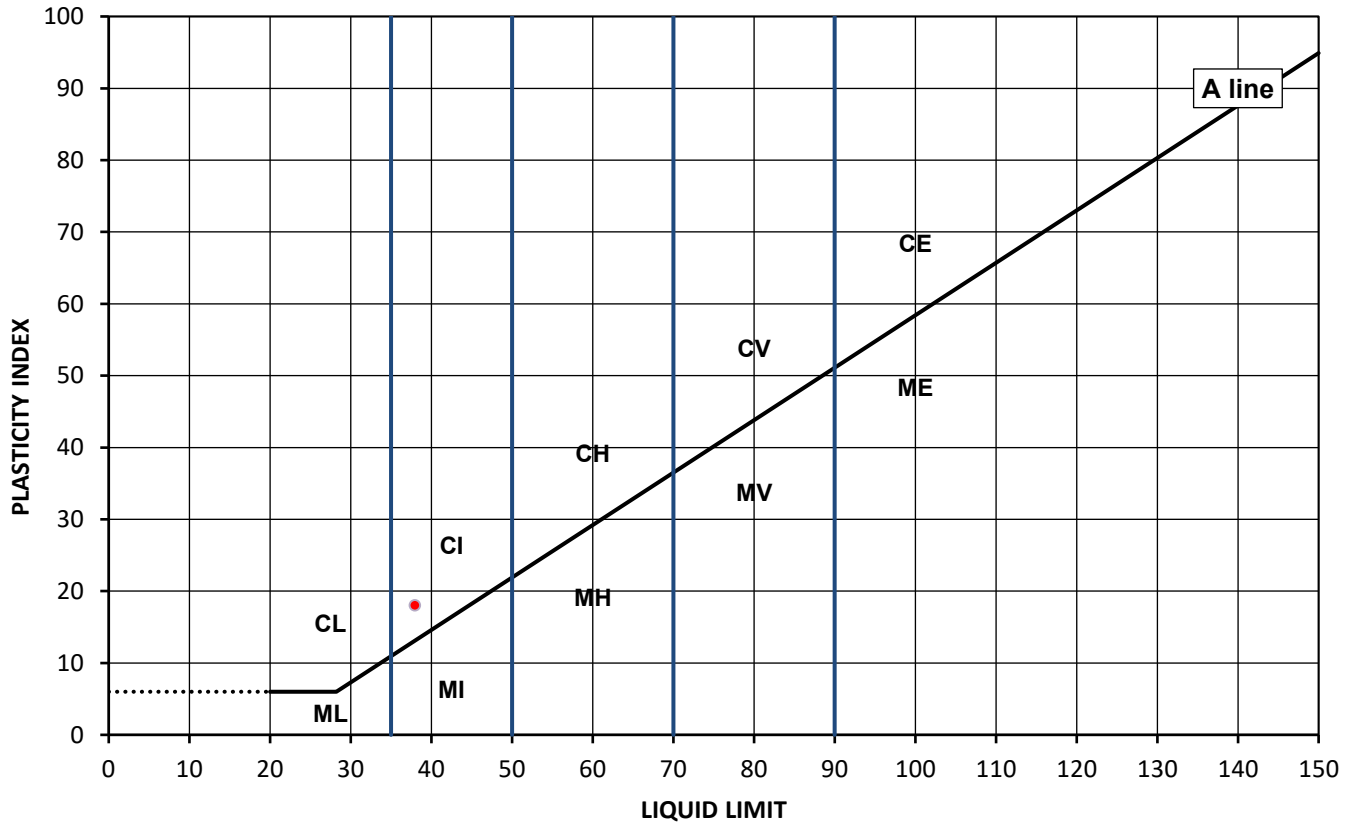
Client:	JNP Midlands LLP	Client Reference:	S10732
Client Address:	No.1 Meadowhall, Riverside, Sheffield	Job Number:	19-46878
		Date Sampled:	Not Given
		Date Received:	24/06/2019
Contact:	Philip Taylor	Date Tested:	27/06/2019
Site Name:	Worsbrough Mill	Sampled By:	Not Given
Site Address:	Not Given		

Test Results:

Laboratory Reference:	1251895	Depth Top [m]:	1.20
Hole No.:	WS1	Depth Base [m]:	1.20
Sample Reference:	Not Given	Sample Type:	D
Soil Description:	Mottled brown slightly gravelly sandy CLAY		

Sample Preparation: Tested after washing to remove >425um

As Received Moisture Content [%]	Liquid Limit [%]	Plastic Limit [%]	Plasticity Index [%]	% Passing 425µm BS Test Sieve
25	38	20	18	93



Legend, based on BS 5930:2015 Code of practice for site investigations

		Plasticity		Liquid Limit
C	Clay	L	Low	below 35
M	Silt	I	Medium	35 to 50
		H	High	50 to 70
		V	Very high	70 to 90
		E	Extremely high	exceeding 90
	Organic	O	append to classification for organic material (eg CHO)	

Note: Moisture Content by BS 1377-2: 1990: Clause 3.2

Remarks:

Approved: Dariusz Piotrowski
PL Geotechnical Laboratory Manager
Date Reported: 08/07/2019

Signed: Darren Berrill
Geotechnical General Manager
for and on behalf of i2 Analytical Ltd **GF 232.5**

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This report may not be reproduced other than in full without the prior written approval of the issuing laboratory.
The results included within the report are representative of the samples submitted for analysis.
The analysis was carried out at i2 Analytical Limited, ul. Pionierow 39, 41-711 Ruda Slaska, Poland."

"Any assessment of compliance with specifications based the analytical results in a report take in to account no contribution from uncertainty of measurement. Application of uncertainty of measurement would provide a range within which the true result lies. An estimate of measurement uncertainty can be provided on request."

TEST CERTIFICATE

Liquid and Plastic Limits

i2 Analytical Ltd
7 Woodshots Meadow
Croxley Green Business Park
Watford Herts WD18 8YS

4041

Tested in Accordance with: BS 1377-2: 1990: Clause 4.4 and 5

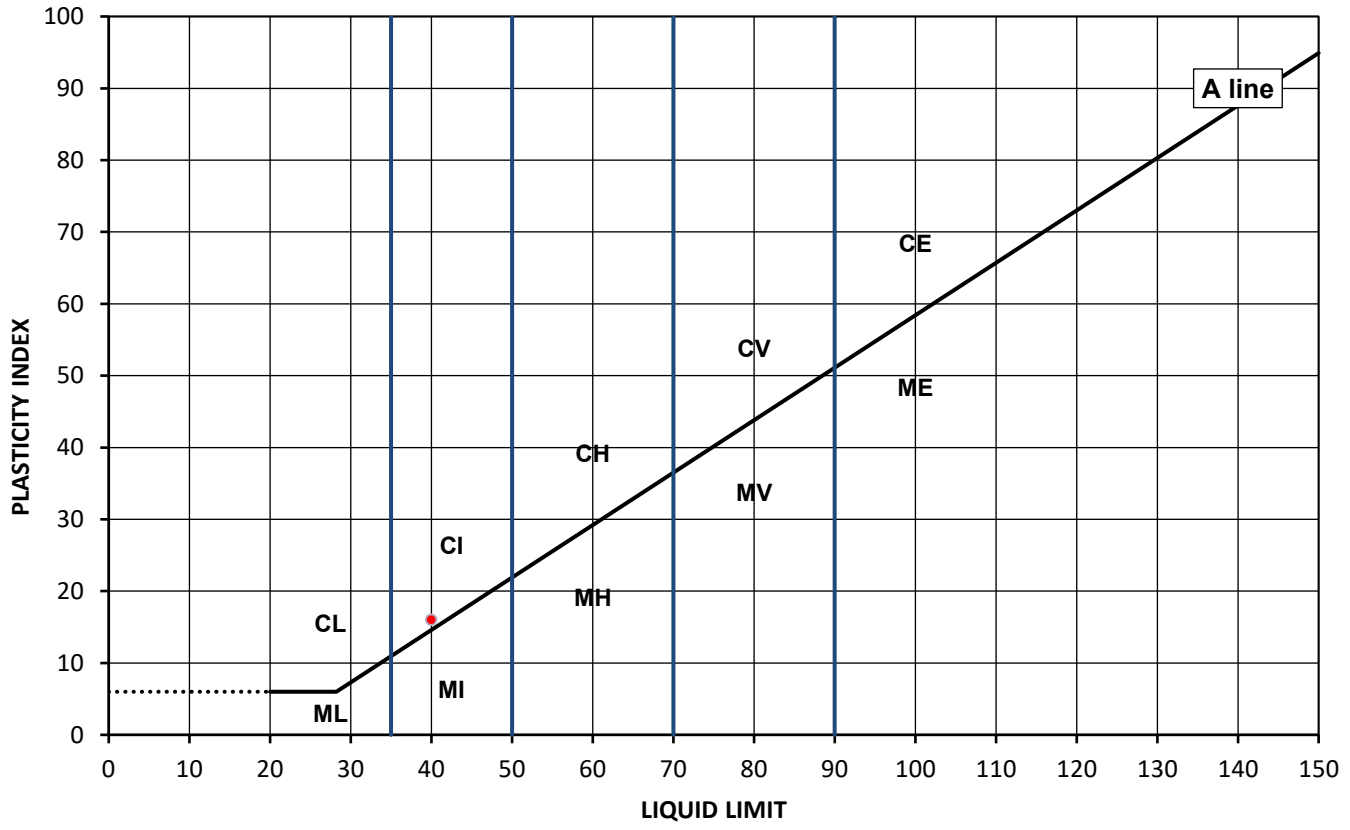
Client:	JNP Midlands LLP	Client Reference:	S10732
Client Address:	No.1 Meadowhall, Riverside, Sheffield	Job Number:	19-46878
		Date Sampled:	Not Given
		Date Received:	24/06/2019
Contact:	Philip Taylor	Date Tested:	27/06/2019
Site Name:	Worsbrough Mill	Sampled By:	Not Given
Site Address:	Not Given		

Test Results:

Laboratory Reference:	1251896	Depth Top [m]:	2.90
Hole No.:	WS1	Depth Base [m]:	2.90
Sample Reference:	Not Given	Sample Type:	D
Soil Description:	Brownish grey sandy CLAY		

Sample Preparation: Tested in natural condition

As Received Moisture Content [%]	Liquid Limit [%]	Plastic Limit [%]	Plasticity Index [%]	% Passing 425µm BS Test Sieve
18	40	24	16	100



Legend, based on BS 5930:2015 Code of practice for site investigations

		Plasticity		Liquid Limit
C	Clay	L	Low	below 35
M	Silt	I	Medium	35 to 50
		H	High	50 to 70
		V	Very high	70 to 90
		E	Extremely high	exceeding 90
	Organic	O	append to classification for organic material (eg CHO)	

Note: Moisture Content by BS 1377-2: 1990: Clause 3.2

Remarks:

Approved: Dariusz Piotrowski
PL Geotechnical Laboratory Manager
Date Reported: 08/07/2019

Signed: Darren Berrill
Geotechnical General Manager
for and on behalf of i2 Analytical Ltd **GF 232.5**

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The analysis was carried out at i2 Analytical Limited, ul. Pionierow 39, 41-711 Ruda Slaska, Poland."

"Any assessment of compliance with specifications based the analytical results in a report take in to account no contribution from uncertainty of measurement. Application of uncertainty of measurement would provide a range within which the true result lies. An estimate of measurement uncertainty can be provided on request."

TEST CERTIFICATE

Liquid and Plastic Limits

i2 Analytical Ltd
7 Woodshots Meadow
Croxley Green Business Park
Watford Herts WD18 8YS

UKAS TESTING 4041

Tested in Accordance with: BS 1377-2: 1990: Clause 4.4 and 5

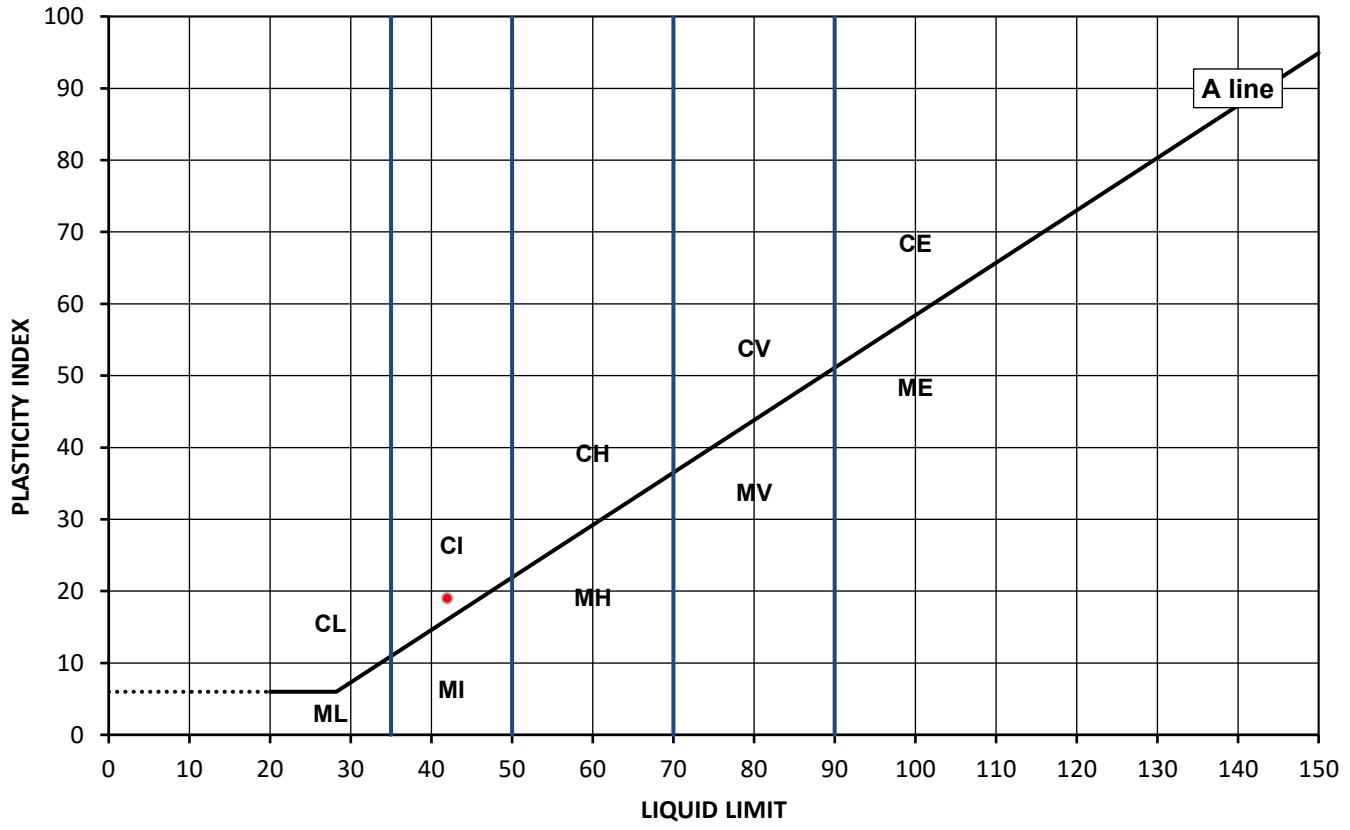
Client:	JNP Midlands LLP	Client Reference:	S10732
Client Address:	No.1 Meadowhall, Riverside, Sheffield	Job Number:	19-46878
		Date Sampled:	Not Given
		Date Received:	24/06/2019
Contact:	Philip Taylor	Date Tested:	27/06/2019
Site Name:	Worsbrough Mill	Sampled By:	Not Given
Site Address:	Not Given		

Test Results:

Laboratory Reference:	1251897	Depth Top [m]:	0.90
Hole No.:	WS2	Depth Base [m]:	0.90
Sample Reference:	Not Given	Sample Type:	D
Soil Description:	Mottled brown slightly gravelly sandy CLAY		

Sample Preparation: Tested after washing to remove >425um

As Received Moisture Content [%]	Liquid Limit [%]	Plastic Limit [%]	Plasticity Index [%]	% Passing 425µm BS Test Sieve
19	42	23	19	85



Legend, based on BS 5930:2015 Code of practice for site investigations

		Plasticity		Liquid Limit
C	Clay	L	Low	below 35
M	Silt	I	Medium	35 to 50
		H	High	50 to 70
		V	Very high	70 to 90
		E	Extremely high	exceeding 90
	Organic	O	append to classification for organic material (eg CHO)	

Note: Moisture Content by BS 1377-2: 1990: Clause 3.2

Remarks:

Approved: Dariusz Piotrowski
PL Geotechnical Laboratory Manager
Date Reported: 08/07/2019

Signed: Darren Berrill
Geotechnical General Manager
for and on behalf of i2 Analytical Ltd **GF 232.5**

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TEST CERTIFICATE

Liquid and Plastic Limits

i2 Analytical Ltd
7 Woodshots Meadow
Croxley Green Business Park
Watford Herts WD18 8YS

UKAS TESTING 4041

Tested in Accordance with: BS 1377-2: 1990: Clause 4.4 and 5

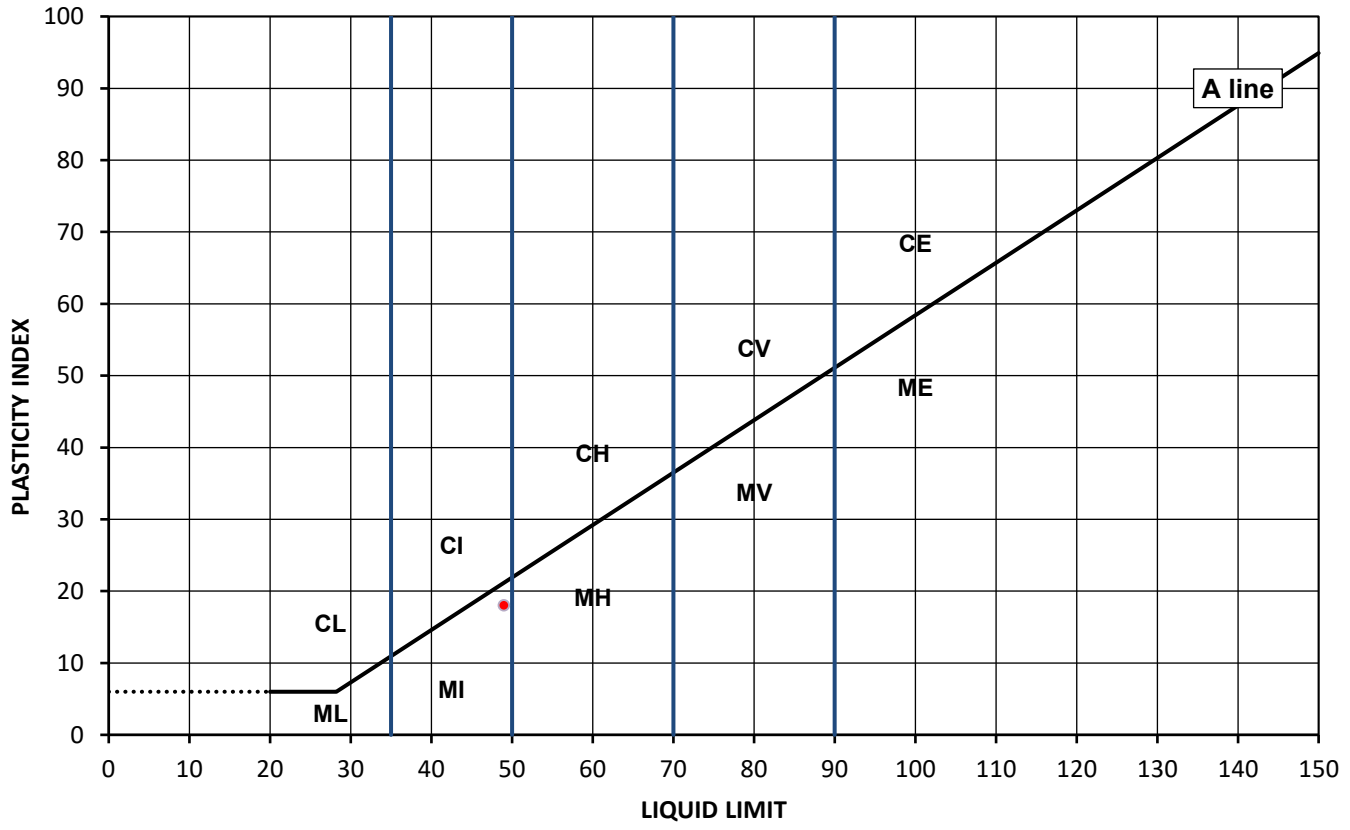
Client:	JNP Midlands LLP	Client Reference:	S10732
Client Address:	No.1 Meadowhall, Riverside, Sheffield	Job Number:	19-46878
		Date Sampled:	Not Given
		Date Received:	24/06/2019
Contact:	Philip Taylor	Date Tested:	27/06/2019
Site Name:	Worsbrough Mill	Sampled By:	Not Given
Site Address:	Not Given		

Test Results:

Laboratory Reference:	1251898	Depth Top [m]:	1.80
Hole No.:	WS2	Depth Base [m]:	1.80
Sample Reference:	Not Given	Sample Type:	D
Soil Description:	Brown slightly gravelly slightly sandy CLAY		

Sample Preparation: Tested after >425um removed by hand

As Received Moisture Content [%]	Liquid Limit [%]	Plastic Limit [%]	Plasticity Index [%]	% Passing 425µm BS Test Sieve
33	49	31	18	95



Legend, based on BS 5930:2015 Code of practice for site investigations

		Plasticity		Liquid Limit
C	Clay	L	Low	below 35
M	Silt	I	Medium	35 to 50
		H	High	50 to 70
		V	Very high	70 to 90
		E	Extremely high	exceeding 90
	Organic	O	append to classification for organic material (eg CHO)	

Note: Moisture Content by BS 1377-2: 1990: Clause 3.2

Remarks:

Approved: Dariusz Piotrowski
PL Geotechnical Laboratory Manager
Date Reported: 08/07/2019

Signed: Darren Berrill
Geotechnical General Manager
for and on behalf of i2 Analytical Ltd GF 232.5

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SUMMARY REPORT

Summary of Classification Test Results

i2 Analytical Ltd
7 Woodshots Meadow
Croxley Green Business Park
Watford Herts WD18 8YS

UKAS TESTING 4041

Environmental Science

Tested in Accordance with:

MC by BS 1377-2: 1990: Clause 3.2; WC by BS EN 17892-1: 2014; Atterberg by BS 1377-2: 1990: Clause 4.3, Clause 4.4 and 5; PD by BS 1377-2: 1990: Clause 8.2

Client: JNP Midlands LLP

Client Address: No.1 Meadowhall, Riverside, Sheffield

Contact: Philip Taylor

Site Name: Worsbrough Mill

Site Address: Not Given

Client Reference: S10732

Job Number: 19-46878

Date Sampled: Not Given

Date Received: 24/06/2019

Date Tested: 27/06/2019

Sampled By: Not Given

Test results

Laboratory Reference	Hole No.	Sample				Description	Remarks	MC	WC	Atterberg				Density			Total Porosity#		
		Reference	Depth Top	Depth Base	Type					% Passing 425um	LL	PL	PI	bulk	dry	PD			
			m	m				%	%	%	%	%	%	Mg/m3	Mg/m3	Mg/m3	%		
1251895	WS1	Not Given	1.20	1.20	D	Mottled brown slightly gravelly sandy CLAY	Atterberg 1 Point	25		93	38	20	18						
1251896	WS1	Not Given	2.90	2.90	D	Brownish grey sandy CLAY	Atterberg 1 Point	18		100	40	24	16						
1251897	WS2	Not Given	0.90	0.90	D	Mottled brown slightly gravelly sandy CLAY	Atterberg 1 Point	19		85	42	23	19						
1251898	WS2	Not Given	1.80	1.80	D	Brown slightly gravelly slightly sandy CLAY	Atterberg 1 Point	33		95	49	31	18						

Note: # Non accredited; NP - Non plastic

Comments:

Approved: Dariusz Piotrowski
PL Geotechnical Laboratory Manager
Date Reported: 08/07/2019

Signed: Darren Berrill
Geotechnical General Manager
for and on behalf of i2 Analytical Ltd **GF 234.7**

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The analysis was carried out at i2 Analytical Limited, ul. Pionierow 39, 41-711 Ruda Slaska, Poland."

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Appendix D

Chemical Test Results

Philip Taylor
JNP Midlands LLP
No.1 Meadowhall
Riverside
Sheffield

e: Philip.Taylor@jnpgroup.co.uk

i2 Analytical Ltd.
7 Woodshots Meadow,
Croxley Green
Business Park,
Watford,
Herts,
WD18 8YS

t: 01923 225404
f: 01923 237404
e: reception@i2analytical.com

Analytical Report Number : 19-46887

Project / Site name:	Worsbrough Mill	**Samples received on:**	24/06/2019
Your job number:	S10732	**Samples instructed on:**	24/06/2019
Your order number:	G174	**Analysis completed by:**	04/07/2019
Report Issue Number:	1	**Report issued on:**	04/07/2019
Samples Analysed:	2 soil samples		

Signed: K. Lewicka

Katarzyna Lewicka
Head of Reporting Section
For & on behalf of i2 Analytical Ltd.

Standard Geotechnical, Asbestos and Chemical Testing Laboratory located at: ul. Pionierów 39, 41 -711 Ruda Śląska, Poland.

Accredited tests are defined within the report, opinions and interpretations expressed herein are outside the scope of accreditation.

Standard sample disposal times, unless otherwise agreed with the laboratory, are :

soils	- 4 weeks from reporting
leachates	- 2 weeks from reporting
waters	- 2 weeks from reporting
asbestos	- 6 months from reporting

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Any assessments of compliance with specifications are based on actual analytical results with no contribution from uncertainty of measurement. Application of uncertainty of measurement would provide a range within which the true result lies. An estimate of measurement uncertainty can be provided on request.

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The results included within the report are representative of the samples submitted for analysis.

Analytical Report Number: 19-46887

Project / Site name: Worsbrough Mill

Your Order No: G174

Lab Sample Number				1251916	1251917			
Sample Reference				WS1	WS2			
Sample Number				None Supplied	None Supplied			
Depth (m)				0.20-0.20	2.90-2.90			
Date Sampled				Deviating	Deviating			
Time Taken				None Supplied	None Supplied			
Analytical Parameter (Soil Analysis)	**Units**	**Limit of detection**	**Accreditation Status**					
Stone Content	%	0.1	NONE	< 0.1	< 0.1			
Moisture Content	%	N/A	NONE	12	12			
Total mass of sample received	kg	0.001	NONE	0.65	0.70			
General Inorganics								
pH - Automated	pH Units	N/A	MCERTS	9.9	8.8			
Total Sulphate as SO_4	%	0.005	MCERTS	0.061	0.020			
Water Soluble SO4 16hr extraction (2:1 Leachate Equivalent)	g/l	0.00125	MCERTS	0.045	0.057			
Water Soluble Chloride (2:1) (leachate equivalent)	mg/l	0.5	MCERTS	11	5.2			
Total Sulphur	%	0.005	MCERTS	0.034	0.011			
Water Soluble Nitrate (2:1) as N (leachate equivalent)	mg/l	2	NONE	< 2.0	< 2.0			
Heavy Metals / Metalloids								
Magnesium (water soluble)	mg/kg	5	NONE	6.0	6.1			
Magnesium (leachate equivalent)	mg/l	2.5	NONE	3.0	3.0			

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The results included within the report are representative of the samples submitted for analysis.

Analytical Report Number : 19-46887

Project / Site name: Worsbrough Mill

* These descriptions are only intended to act as a cross check if sample identities are questioned. The major constituent of the sample is intended to act with respect to MCERTS validation. The laboratory is accredited for sand, clay and loam (MCERTS) soil types. Data for unaccredited types of solid should be interpreted with care.

Stone content of a sample is calculated as the % weight of the stones not passing a 10 mm sieve. Results are not corrected for stone content.

Lab Sample Number	Sample Reference	Sample Number	Depth (m)	Sample Description *
1251916	WS1	None Supplied	0.20-0.20	Light brown clay and sand with gravel.
1251917	WS2	None Supplied	2.90-2.90	Brown clay and sand.

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Analytical Report Number : 19-46887

Project / Site name: Worsbrough Mill

Water matrix abbreviations: Surface Water (SW) Potable Water (PW) Ground Water (GW) Process Water (PrW)

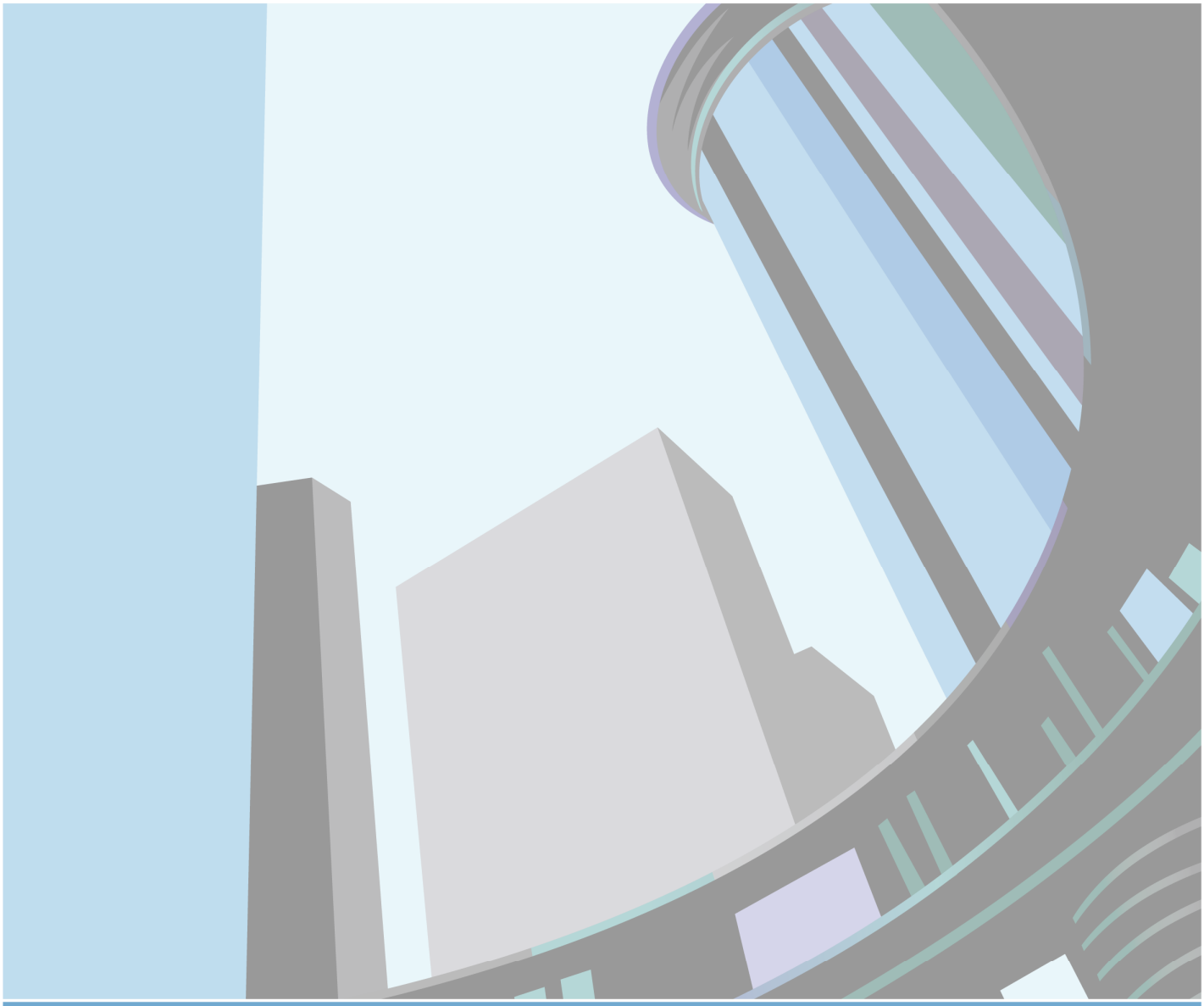
Analytical Test Name	Analytical Method Description	Analytical Method Reference	Method number	Wet / Dry Analysis	Accreditation Status
Chloride, water soluble, in soil	Determination of Chloride colorimetrically by discrete analyser.	In-house method based on BS1377 Part 3, 1990, Chemical and Electrochemical Tests. 2:1 extraction.	L082-PL	D	MCERTS
Magnesium, water soluble, in soil	Determination of water soluble magnesium by extraction with water followed by ICP-OES.	In-house method based on TRL 447	L038-PL	D	NONE
Moisture Content	Moisture content, determined gravimetrically.	In-house method based on BS1377 Part 2, 1990, Chemical and Electrochemical Tests	L019-UK/PL	W	NONE
pH in soil (automated)	Determination of pH in soil by addition of water followed by automated electrometric measurement.	In-house method based on BS1377 Part 3, 1990, Chemical and Electrochemical Tests	L099-PL	D	MCERTS
Stones content of soil	Standard preparation for all samples unless otherwise detailed. Gravimetric determination of stone > 10 mm as % dry weight.	In-house method based on British Standard Methods and MCERTS requirements.	L019-UK/PL	D	NONE
Sulphate, water soluble, in soil (16hr extraction)	Determination of water soluble sulphate by ICP-OES. Results reported directly (leachate equivalent) and corrected for extraction ratio (soil equivalent).	In-house method based on BS1377 Part 3, 1990, Chemical and Electrochemical Tests, 2:1 water:soil extraction, analysis by ICP-OES.	L038-PL	D	MCERTS
Total Sulphate in soil as %	Determination of total sulphate in soil by extraction with 10% HCl followed by ICP-OES.	In-house method based on BS1377 Part 3, 1990, Chemical and Electrochemical Tests""	L038-PL	D	MCERTS
Total Sulphur in soil as %	Determination of total sulphur in soil by extraction with aqua-regia, potassium bromide/bromate followed by ICP-OES.	In-house method based on BS1377 Part 3, 1990, and MEWAM 2006 Methods for the Determination of Metals in Soil	L038-PL	D	MCERTS
Water Soluble Nitrate (2:1) as N in soil	Determination of nitrate by reaction with sodium salicylate and colorimetry.	In-house method based on Examination of Water and Wastewatern & Polish Standard Method PN-82/C-04579.08, 2:1 extraction.	L078-PL	W	NONE

For method numbers ending in 'UK' analysis have been carried out in our laboratory in the United Kingdom.
For method numbers ending in 'PL' analysis have been carried out in our laboratory in Poland.
Soil analytical results are expressed on a dry weight basis. Where analysis is carried out on as-received the results obtained are multiplied by a moisture correction factor that is determined gravimetrically using the moisture content which is carried out at a maximum of 30oC.

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The results included within the report are representative of the samples submitted for analysis.

Sample ID	Other_ID	Sample Type	Job	Sample Number	Sample Deviation Code	test_name	test_ref	Test Deviation code
WS1		S	19-46887	1251916	a			
WS2		S	19-46887	1251917	a			

Key: a - No sampling date b - Incorrect container
c - Holding time d - Headspace e - Temperature



john newton & partners
jnpgroup
Consulting Engineers

www.jnpgroup.co.uk

Brighouse
Woodvale House
Woodvale Road
Brighouse
West Yorkshire
HD6 4AB

telephone
01484 400691

email
brighouse@jnpgroup.co.uk

Chesham (HQ)
Link House
St Mary's Way
Chesham
Buckinghamshire
HP5 1HR

telephone
01494 771221

email
chesham@jnpgroup.co.uk

Hartlepool
The Innovation Centre
Venture Court
Queens Meadow Business Park
Hartlepool
TS25 5TG

telephone
01429 239539

email
hartlepool@jnpgroup.co.uk

Leamington Spa
Marlborough House
48 Holly Walk
Leamington Spa
Warwickshire
CV32 4XP

telephone
01926 889955

email
leamingtonspa@jnpgroup.co.uk

Sheffield
No.1 Meadowhall Riverside
Meadowhall Road
Sheffield
South Yorkshire
S9 1BW

telephone
0114 244 3500

email
sheffield@jnpgroup.co.uk