



Remediation Strategy and Verification Plan

Project Name: Penygarnddu Industrial Estate

Location: Merthyr Tydfil, Wales, CF 48 2TA

Client: Glanville Consultants Ltd.

Project ID: V0996

Report Date: 5th June 2026

Report Issue: 2

SUMMARY

The site, which extends to maximum of approximately 70m by 40m, comprises a roughly rectangular parcel of disused land within the Penygarnddu Industrial Estate. At the time of the intrusive site investigation (August 2025), the site was largely covered in hardstanding, with an earth bund approximately 3-4m high in the south-west and north-west part of the site. It is proposed to construct a new McDonald's building with associated car parking, soft landscaping and drive-thru.

The site has a history of quarrying/ ground working and industrial use. From the 1980s it was annotated as a works, including cement and aggregate related operations, with subsequent clearance and later temporary reuse for ready mix concrete operations before the site was cleared to the concrete slab.

A Phase I Desk Study and Coal Mining Risk Assessment, followed by a Phase II Site Investigation and Risk Assessment, were carried out.

Relevant pollutant linkages were identified in respect of PAH and TPH in Made Ground and potential direct contact/permeation effects on new water supply pipes. The Phase II investigation did not identify significant contamination in terms of the proposed commercial development, and the ground gas regime was assessed as Characteristic Situation 1 (CS1).

A Remediation Strategy comprising the provision of a minimum 300mm certified clean topsoil layer over a geotextile membrane within soft landscaped/planting areas, consultation with service providers regarding appropriate materials for new services, and decommissioning of monitoring wells is proposed, subject to approval by regulatory authorities.

A Verification Plan and Discovery Strategy are also included.

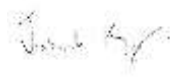
The contamination screening values used are valid at the time of writing but may be subject to change and any such changes will have implications for the assessments based upon them. Their validity should be confirmed at the time of site development.

The recommendations contained in this report are made in respect of the particular development proposals as described in the report and may not be appropriate to alternative development schemes.

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The findings and opinions conveyed via this report are based on information obtained from a variety of sources as detailed within this report, and which Southern Testing Laboratories Limited believes are reliable. Nevertheless, Southern Testing Laboratories Limited cannot and does not guarantee the authenticity or reliability of the information it has obtained from others.

This report should be considered in its entirety and Southern Testing Laboratories Ltd. accepts no responsibility for and excludes liability in respect of any omission or alteration made by others, and any use of the report for any purpose other than that for which it was produced.

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For and on behalf of Southern Testing Laboratories Limited

DOCUMENT HISTORY AND STATUS

Issue No	Date	Purpose or Status	Author	Check / Review
01	05/06/26	Remediation Strategy and Verification Plan	AB	JK
02	03/07/26	Updated following comments from NRW	AB	JK

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A INTRODUCTION

1 Authority

Our authority for carrying out this work is contained in an email from Mr J Cross of Glanville Consultants Ltd., dated 28th May 2026.

2 Location

The site located on the southern side of the Penygarnddu Industrial Estate to the north-east of Merthyr Tydfil in Wales. The approximate National Grid Reference of the site is SO 07802 08695. The site location is indicated on Figure 1 within Appendix A.

3 Proposed Construction

It is proposed to construct a new McDonald's building on the site with associated car parking, soft landscaping, and drive-thru.

For the purposes of the contamination risk assessment, the proposed development land use is classified as Commercial/Industrial CLEA Model Ref [1] / C4SL Report Ref [2].

The gas sensitivity of the proposed development is rated as Low CIRIA C665 Ref [3].

4 Scope

This report presents our Remediation Options Appraisal, Remediation Strategy, and Verification Plan for the proposed remedial works at the site.

As with any site there may be differences in soil conditions between exploratory hole positions.

The findings and opinions conveyed via this investigation report are based on information obtained from a variety of sources as detailed within this report, and which Southern Testing Laboratories Limited believes are reliable. Nevertheless, Southern Testing Laboratories Limited cannot and does not guarantee the authenticity or reliability of the information it has obtained from others.

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B BACKGROUND INFORMATION

5 Site Investigation Works

The site has been the subject of a series of site investigation reports, as listed below.

Ref	Date	Author	Title / Ref No	Subject
1	December 2024	Southern Testing Laboratories Ltd.	J15809	Phase I Desk Study & Coal Mining Risk Assessment Report

Ref	Date	Author	Title / Ref No	Subject
2	August 2025	Southern Testing Laboratories Ltd.	J15809	Site Investigation & Risk Assessment Report

These reports provided good coverage and characterisation of the site and information derived from these reports is discussed below. The reader is referred to the original reports for supporting detail if needed. These reports are referred to below by the number given in the left hand column of the above table.

6 Site History

The earliest map from 1876 (from the desk study, detailed in [1] above) showed the site to have been already worked out; it remained rough and undulating as heathland for grazing. Undulations and reconfiguration infers additional fill movements in the 1960's and 1980's. By 1980 a batching / aggregate works operation was established on the site which remained until at least 2006. Aerial images showed the site cleared in 2008, with efforts made to remove on-site infrastructure.

Ready mix concrete operations temporarily resumed around 2016 to 2021; during this time stockpiling and frequent vehicle movement is noted. By 2021 all plant and equipment was removed leaving only the concrete slab. The site remained this way until the site investigation in 2025.

The site is located in a coal mining area. More detail is provided below.

7 Summary of Findings

7.1 Phase I Desk Study & Coal Mining Risk Assessment Report, STL – December 2024

The desk study [1] identified the site as a roughly rectangular parcel of disused land within the Penygarnddu Industrial Estate, extending to a maximum of approximately 70m by 40m. The site was covered in hardstanding, with an earth bund approximately 3-4m high in the south-west/north-west, standing water in the south-western section, a disused welfare cabin, and some fly tipped material between the rear of the bund and the retaining wall to the adjacent car park.

The published geology was recorded as Made Ground over Till over the South Wales Lower Coal Measures Formation. Historical mapping indicated that the site had been worked/quarried and subsequently used as a works, with a hopper/conveyor and earth bund shown from the 1980s. Potential on-site sources identified included Made Ground, fly tipped material, historic infilled quarry/worked ground, former railway land and concrete manufacturing related industrial uses.

The desk study identified potential ground gas sources including four nearby landfills, infilled quarried area, coal mining activity and Made Ground. The coal mining risk assessment identified the site as being within a Coal Mining Development High Risk Area, with the potential for worked coal and ironstone seams beneath the site. Further intrusive investigation and ground gas monitoring were recommended.

7.2 Site Investigation & Risk Assessment Report, STL – August 2025

The Phase II investigation [2] comprised 3 No. windowless sampler boreholes to a maximum depth of 5.0m bgl, 4 No. trial pits to a maximum depth of 3.0m bgl, 1 No. cable percussive borehole with rotary cored follow-on to 30.0m bgl, 2 No. down-the-hole-hammer boreholes with rotary cored follow-on to a maximum depth of 36.4m bgl, and 2 No. hand auger boreholes to 1.5m bgl. Gas and groundwater monitoring wells were installed in WLS01, WLS02, BH01 and BH02.

Ground conditions comprised concrete and/or sub-base over Made Ground over Till over the South Wales Lower Coal Measures Formation. Made Ground was encountered in all exploratory holes and proven to between 4.5m and 11.0m bgl in the deeper boreholes. It generally comprised greyish brown to dark grey gravelly clay with brick, mudstone, siltstone, limestone and coal fragments, with occasional limestone cobbles. A void was encountered in BH03 between 29.90m and 30.60m bgl, interpreted as possible mine workings.

Organic odours were noted in WLS01 between 3.8m and 5.0m bgl and in TP03 between 0.4m and 1.2m bgl. General contamination testing of Made Ground recorded contaminant concentrations below the corresponding Tier 1 assessment criteria for commercial/industrial developments. No asbestos containing materials were detected in the samples analysed and none were observed in the exploratory holes. Petroleum hydrocarbon concentrations were below the Tier 1 assessment criteria and Hazard Index values were well below 1.0. A low risk was confirmed to the contractors, staff customers and controlled waters.

Six ground gas monitoring visits were undertaken over a two month period. The maximum methane concentration recorded was 0.1% and the maximum carbon dioxide concentration was 1.8%, with negligible flow rates. The site was assessed as Characteristic Situation 1 (CS1), Very Low Risk, and gas protection measures were not required.

The only possible relevant pollutant linkage identified by the Phase II report was in respect of new water supply pipes and the minor organic contamination identified. The report also recommended that approximately 300mm of certified clean, suitable topsoil be provided within proposed new soft landscaping areas, with geotextile separation from Made Ground if necessary, and that existing monitoring wells should be decommissioned

8 Relevant Pollutant Linkages

The various site investigations and risk assessments carried out identified the following Relevant Pollutant Linkages for the site:

Contaminant / Source	Pathways	Receptor
PAHs/TPH in Made Ground	Direct contact	Water supply pipes

C REMEDIAL OBJECTIVES AND OPTIONS

9 Remedial Objectives

The site is to be developed for commercial end-use comprising a new McDonald's building with associated car parking, drive-thru and soft landscaping. On the basis of the Phase II investigation, measured contaminant concentrations fall below the relevant Tier 1 screening values for the proposed development and the gas regime has been assessed as Characteristic Situation 1 (CS1). The principal objectives of the remediation are therefore to manage the possible pollutant linkage to new water supply pipes. Additional objectives are to achieve the remediation goal in a cost effective and timely manner, whilst minimising impact from associated traffic movements, landfill and resource consumption.

10 Options Appraisal

TPH and PAH in the Made Ground and Buried Services

The Phase II report identified the only possible relevant pollutant linkage as relating to new water supply pipes and the minor organic contamination identified. Organic contaminants present in soils, particularly PAHs and petroleum hydrocarbons, could affect plastic underground service pipes used by water and gas supply companies.

Consultation with the relevant utility provider is required to confirm the most appropriate materials for new services. Use of upgraded barrier pipework, or other provider approved specification. This approach is commonly adopted on brownfield sites and avoids unnecessary bulk excavation where soils are otherwise suitable to remain on site.

Excavation and off-site disposal of soils along proposed service routes could also reduce risk, but would generate additional waste and traffic movements and is not considered necessary on the basis of the Phase II assessment unless specifically required by the service provider or if unforeseen contamination is encountered.

The preferred option is therefore to manage the receptor/pathway by specifying appropriate service pipe materials in consultation with the service provider, with the discovery strategy adopted for any unforeseen contamination encountered during service trench excavations.

D REMEDIATION STRATEGY

11 Remediation Methods

The Remediation Strategy will comprise the following:

Location	Details
Soft landscaped areas and areas of planting	To provide a growing medium and mitigate the minor contamination risk identified in the investigations by others, a minimum of 300mm certified clean topsoil is recommended, placed above an alert membrane to separate the imported soil from the underlying Made Ground. Some removal of the Made Ground may be required depending upon finished levels. Please note, the depth quoted above is considered a minimum. The landscaping contractor may wish for a greater depth of topsoil in some areas depending on the specific planting. This should be confirmed with the specialist contractor.
Buried Services	Consultation with the services providers is required to confirm the most appropriate materials for new services.
Monitoring Wells	The monitoring wells will be decommissioned in line with industry guidance, following the additional monitoring. This is relevant to the wells installed during the Phase II investigation by STL and any others encountered during works (see Appendix C)

12 Assessment Criteria

The following assessment criteria values will be used in the verification process:

Imported soils shall be free from deleterious materials, weeds and contamination. The material to be used will be tested in accordance with the appropriate BS Specifications for Topsoil (BS 3882:2015) and Subsoil (BS 8601:2013) and the analysis shall also comply with the most conservative values given for commercial/ industrial land use in the table in Appendix B. These values are valid at the time of writing but may be subject to change and any such changes will have implications for the assessments based on them. Their validity should be confirmed at the time of site development.

Certificates for imported soils must include details of the source, description of the material, and dates of sampling and analysis, as well as the test results for potential contaminants. The date of sampling and analysis must relate to the material imported. Associated consignment notes must clearly identify the source material, and must correspond to the certified material.

E VERIFICATION PLAN

13 Data Collection

Location	Data	Responsible Party
Soft landscaped areas and areas of planting	Reducing levels and laying membrane Post placement check of thickness Post placement soil samples Consignment Notes	Groundworker Southern Testing Southern Testing Groundworker
Buried Services	Written confirmation from relevant service providers of the pipe specification required for the site. Installation records/ drawings confirming location and material specification of new services. Photographs to confirm installation (if relevant)	Developer / Groundworker

Location	Data	Responsible Party
Monitoring Wells	Decommissioning record/report for existing monitoring wells (see Appendix C)	Southern Testing / Specialist Contractor

14 Analytical Framework

Although no specific remediation is necessary in terms of the risk to human health, there will be areas of soft landscaping and planting on site. As there is no suitable source of topsoil on site, certified clean topsoil will need to be imported for these areas. This exercise will need to be validated and documented.

Any soils that are imported shall be free from deleterious materials, weeds and contamination. Chemical analyses of soil should comply with the **most conservative screening criteria** i.e. that of a proposed residential end use with the potential for the consumption of home-grown produce, as per the recommendations of the local authority. The screening values for this end use are presented within the table within Appendix B. These contamination screening values are valid at the time of writing but may be subject to change and any such changes will have implications for the assessments based on them. Their validity should be confirmed at the time of site development.

Our understanding is that the capping layer will comprise 300mm of imported topsoil over an alert membrane. On this basis the requested imported topsoil shall be tested, depending on the source, as table below.

Soil Origin	Testing Frequency	Chemical Testing Suite
Greenfield / Manufactured Soils	Minimum 3 or 1 per 250m ³ (whichever is greater)	Standard metals/metalloids (should include as a minimum As, Cd, Cr, CrVI, Cu, Hg, Ni, Pb, Se, Zn); PAH (16 USEPA speciation); TPH (Aliphatic / Aromatic Split) and Asbestos.
Brownfield / Site won Soils	Minimum 6 or 1 per 100m ³ (whichever is greater)	

15 Reporting

At the end of the remediation, a verification report will be produced by Southern Testing Laboratories Limited. The remediation and validation process at McDonald's sites is well established. The contractor is provided with a copy of the various phases of report, and this Remediation Method Statement, so is aware of the data that is required. Discussions will also be held with the groundworker to confirm this.

Photographs of the barrier pipes, if required, in service trenches, are taken by the groundworker for inclusion in the report. The groundworker or Southern Testing will also supply pictures confirming the decommissioning of the gas monitoring wells. The areas of planting will need to be validated in terms of the depth and quality of topsoil imported. Tickets for the exportation and importation of material will also be supplied for inclusion in the report.

16 Discovery Strategy

As with any site, areas of contamination not identified during site investigation works may come to light in the course of redevelopment. Accordingly, a discovery strategy will be adopted to ensure that any hitherto unknown contamination is identified and dealt with in an appropriate manner, as follows:

- A close watch will be maintained during all demolition and excavation works.
- In the event that unexpected or malodorous soils or liquids are encountered, excavation work shall cease in the affected area.
- The affected area shall be made safe and fenced off to prevent unauthorised access.
- The Site Manager shall notify Southern Testing Laboratories Limited of the discovery, who will attend site to inspect the suspect materials, provide advice and take samples as necessary. Within Southern Testing Laboratories Limited the Project Engineer shall be the first point of contact.
- The Site Manager shall notify Merthyr Tydfil County Borough Council of the discovery. Within the Council the contaminated land officer shall be the first point of contact.

Any suspect excavated soil will be stockpiled separately on polythene sheeting, covered, and tested before being removed.

17 General Guidance

In general terms, the workforce and general public should be protected from contact with contaminated material. There is a range of relevant documents published by the Health and Safety Executive, and organisations such as CIRIA, and the BRE.

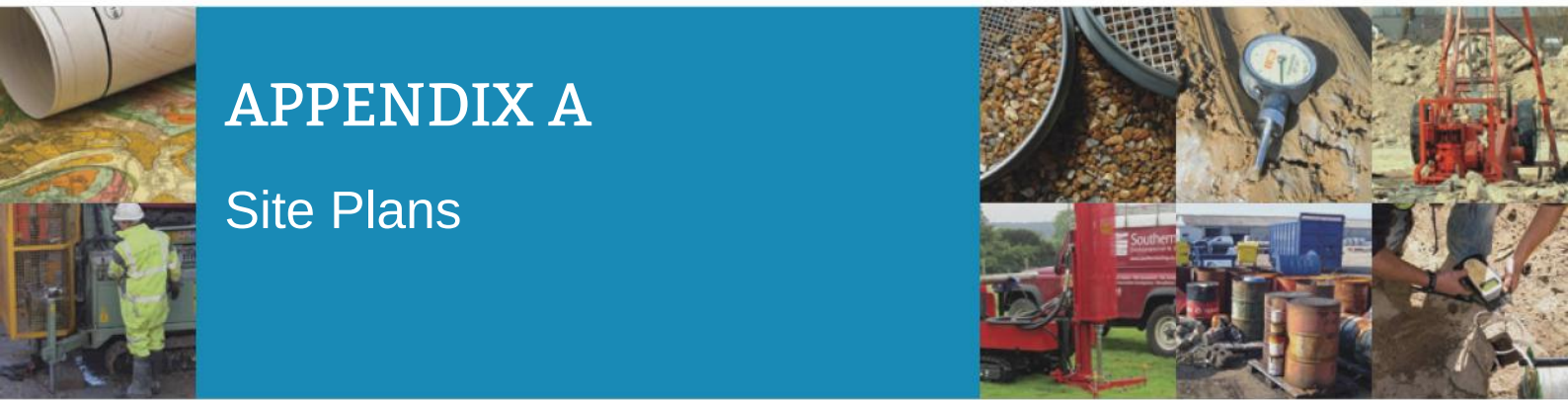
Some soils will require removal from site and disposal to suitably licensed landfills. Different guidelines and charges will apply to different waste classifications. As waste producers, the Developer holds responsibilities under the various governing regulations, including:-

- Ensuring that waste is characterised in accordance with current Technical Guidance.
- Ensuring that waste is disposed of at a facility appropriately licensed to receive the waste as classified.
- Keeping accurate records of all waste classification, transfer and a disposal log including information such as:
 - Date, Waste Classification, Carrier's Registration Number, Transfer Note Number, Ultimate Destination.
- Submitting full copies of those records for inclusion in validation/closure reports.

Maintaining those records for potential future regulatory inspection.

REFERENCES

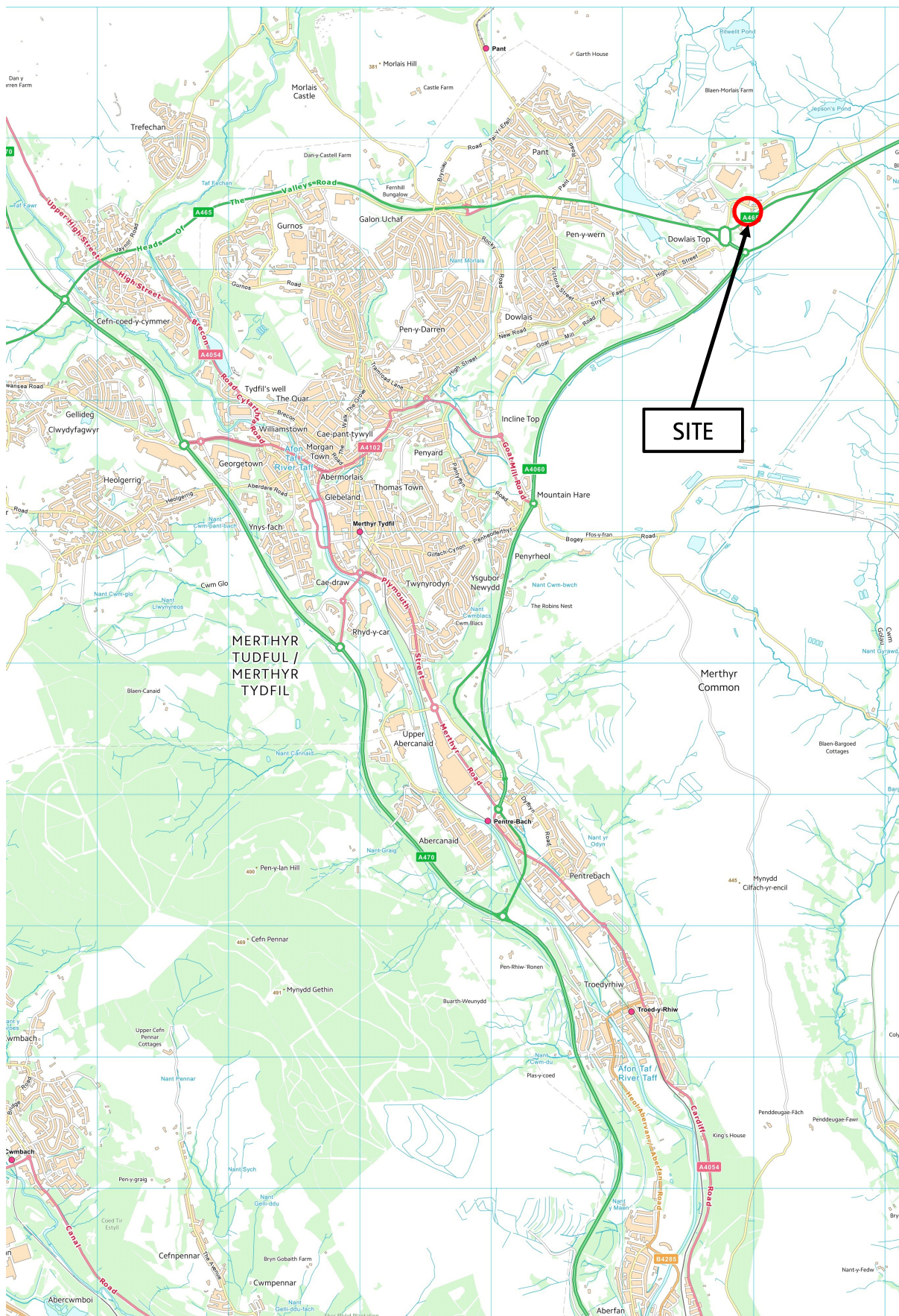
- [1] Environment Agency, “Updated technical background to the CLEA model,” 2009.
- [2] Contaminated Land: Applications in Real Environments (CL:AIRE), “Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination,” 2014.
- [3] CIRIA, “C665 Assessing risks posed by hazardous ground gases to buildings,” 2007.



APPENDIX A

Site Plans





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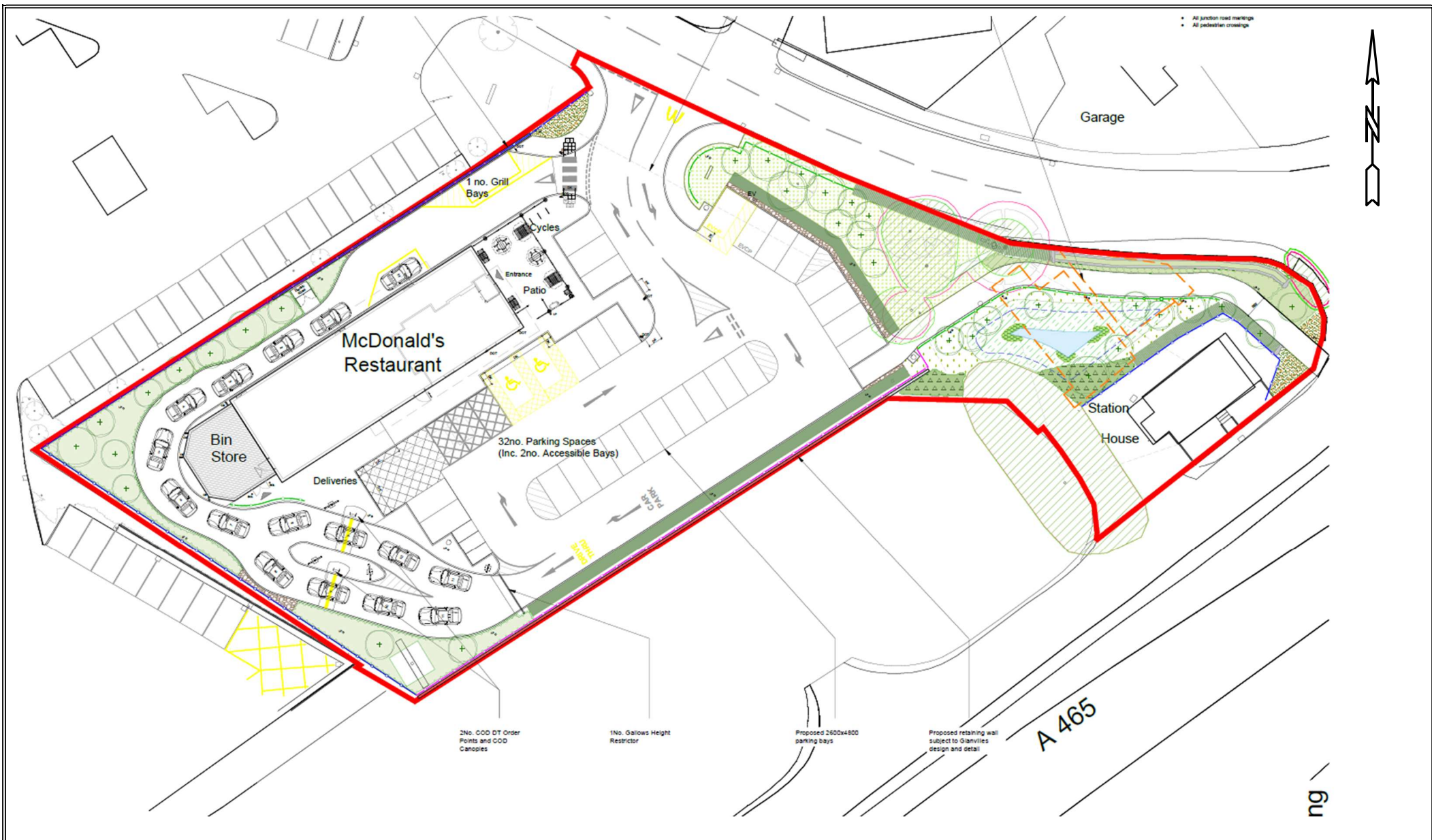
Site: Penygarnddu Industrial Estate, Merthyr Tydfil, CF48 2TA

STL: V0996

Fig No: 1

Date: 5th June 2026

Site location plan.



Site: Penygarnddu Industrial Estate, Merthyr Tydfil, CF48 2TA

Date: 5th June 2026

STL: V0996

Fig No: 2

Site plan showing proposed development.

A collage of six images related to geotechnical testing. Top left: A large white pipe. Top middle: A sieve containing brown soil particles. Top right: A penetrometer being used on a soil sample. Middle left: A worker in a high-visibility yellow suit operating a piece of machinery. Middle right: A red truck with 'Southern' written on its side, parked next to several large metal drums. Bottom right: A person's hands using a tool to work with soil in a container.

APPENDIX B

Verification Criteria

B

Contaminant Screening Values for Imported Soils

Contaminant	Units	Proposed Land Use					
		Residential with home grown produce consumption	Residential without home grown produce consumption	Open Space * (Residential)	Open Space * (Park)	Allotments	Commercial / Industrial
Arsenic (As) [2]	mg/kg	37	40	79	170	43	640
Cadmium (Cd) [2]	mg/kg	11	85	120	555	1.9	190
Trivalent Chromium (CrIII) [2]	mg/kg	910	910	1,500	33,000	18,000	8600
Hexavalent Chromium (CrVI) [2]	mg/kg	6	6	7.7	220	1.8	33
Lead (Pb) [3]	mg/kg	200	310	630	1300	80	2330
Mercury (Hg) [1,2,7]	mg/kg	7.6-11	9.2-15	40	68-71	6.0	29-320
Selenium (Se) [2]	mg/kg	250	430	1,100	1,800	88	12,000
Nickel (Ni) [2,4]	mg/kg			pH <6.0 pH 6.0 – 7.0 pH >7.0	60 75 110		
Copper (Cu) [2,4]	mg/kg			pH <6.0 pH 6.0 – 7.0 pH >7.0	100 135 200		
Zinc (Zn) [2,4]	mg/kg			pH <6.0 pH 6.0 – 7.0 pH >7.0	200 200 300		
Phenol [1,2]	mg/kg	120-380	440-1200	440-1300	440-1300	23-83	440-1300
Benzo[a]pyrene [1,5]	mg/kg	1.7-2.4	2.6	4.9	10	0.67-2.7	36
Naphthalene [1,2]	mg/kg	2.3-13	2.3-13	77-430*	77-430*	4.1-24	77-430*
Total Cyanide (CN) [6]	mg/kg	/	/	/	/	/	/
Free Cyanide [6]	mg/kg	/	/	/	/	/	/
Complex Cyanides [6]	mg/kg	/	/	/	/	/	/
Thiocyanate [6]	mg/kg	/	/	/	/	/	/

Notes:

* Open Space levels calculated on the basis of the exposure modelling developed in the C4SL research.

+ Screening values constrained to saturation limit. Higher values may be acceptable on a site specific basis.

[1] Where ranges of values are given for organic contaminants the screening value is dependent on the Soil +Organic Matter.

[2] LQM/CIEH S4UL (2014). Copyright Land Quality Management Ltd. reproduced with permission; Publication Number S4UL 3116. All rights reserved.

[3] C4SL (DEFRA 2014).

[4] Copper, Zinc and Nickel may have phototoxic effects at the given concentrations. Alternative criteria should be adopted for importation of Topsoil or other soils for cultivation. BS3882:2015 and BS8601:2013 suggest values of 200 to 300mg/kg for Zn, 100 to 200mg/kg for Cu, and 60 to 110mg/kg for Ni, for topsoil and subsoil, depending on pH.

[5] Based on the Surrogate Marker approach and modelled using the modified exposure parameters of C4SL but retaining 'minimal risk' HCV.

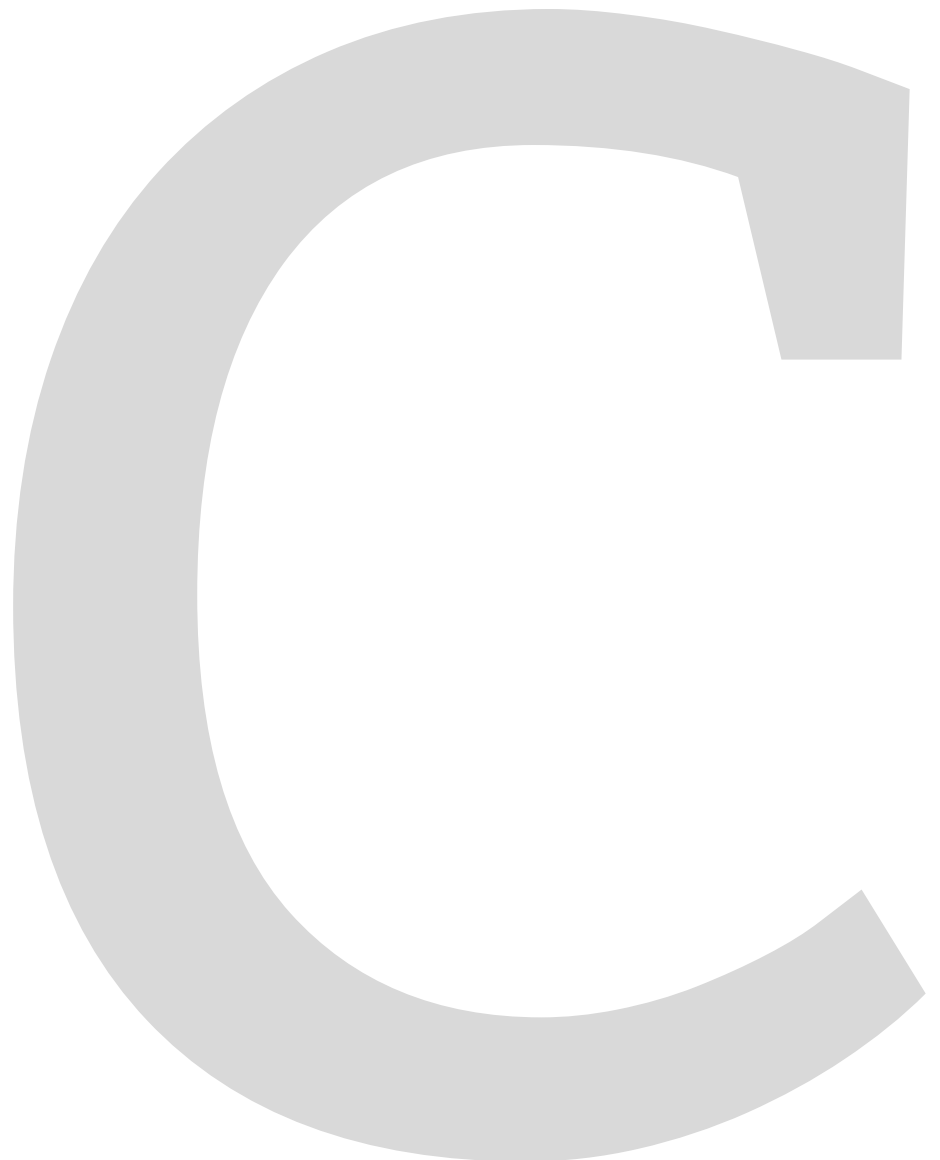
[6] Screening criteria derived on a site specific basis if test results indicate.

[7] S4UL for Methyl Mercury, higher concentrations may be tolerable if inorganic mercury is the only species present. Lower concentrations apply for elemental Mercury.



APPENDIX C

Monitoring Well Decommissioning Guidance



Good practice for decommissioning redundant boreholes and wells

October 2012

What's the purpose of this guidance?

Redundant boreholes and wells must be dealt with appropriately to make them safe and secure, and also to ensure they don't cause groundwater pollution or loss of water supplies. This guidance focuses on groundwater protection aspects but there are many other important factors owners and developers need to consider when designing and carrying out decommissioning works. These will be site specific, depending on the situation and intended afteruse. For example, boreholes near landfills or other sources of soil gas may require an opening to the air to prevent the build-up of noxious, explosive or flammable gas. Therefore, you should seek expert site-specific advice.

Legal framework

The Environment Agency (EA) has a duty to promote the sustainable use of water and to ensure it is protected from pollution. The Environmental Permitting (England and Wales) Regulations 2010 require the EA to take all necessary measures to prevent input of so called hazardous substances (for example pesticides) and limit the input of other non-hazardous pollutants (such as nitrate) into groundwater*, including for example contaminated run-off directly entering groundwater via an uncapped borehole.

**Groundwater is defined as water that is below the surface of the ground in the saturated zone and is in direct contact with the ground or subsoil.*

Why is it important to decommission properly?

Boreholes and wells are constructed for a variety of purposes including water supply, de-watering excavations, collecting geological information, investigating or sampling soils and groundwater and, increasingly, for ground source heating and cooling and geothermal (non-carbon) energy production. Many old water wells and boreholes are redundant as most properties are now connected to a mains water supply.

Improperly abandoned boreholes and wells can provide preferential pathways for groundwater or contaminant movement. This may result in the contamination of groundwater, the mixing of groundwaters of variable quality from different aquifers, or contribute to the loss of aquifer yield and water pressure (referred to as the potentiometric or piezometric head) as groundwater flows out of the system. This can threaten the availability and quality of groundwater resources for other users and potentially have an impacts on wetlands. Abandoned boreholes and wells can also present a physical hazard to people and property.

Artesian boreholes (where groundwater at depth in a 'confined aquifer' is at sufficient pressure to cause water to discharge either at the ground surface or into another overlying aquifer without any pumping) can be particularly problematic. They require special attention to prevent uncontrolled discharge of groundwater or cross-contamination of different aquifer units.

Therefore, site owners need to ensure that redundant boreholes and wells are made both safe and structurally stable, and also backfilled or sealed to prevent groundwater pollution and flow of water

between different aquifer units. This is particularly important where other potable groundwater supplies are at risk.

However, in certain circumstances they may be adapted for use as a groundwater monitoring facility.

You must not use wells or boreholes as soakaways for foul or surface water drainage because they provide a direct discharge route into groundwater and, as such, pose a risk of groundwater pollution.

This is prohibited by the Environmental Permitting (England & Wales) Regulations 2010.

Firstly, what are the construction details?

When considering how best to backfill and seal a borehole or well, or whether it could be adapted for monitoring purposes – you should first obtain information on the geological strata encountered by the borehole and how it was constructed (including depth, diameter and casing details). These can usually be obtained from site records or the original driller's log; the British Geological Survey holds the national water well archive and other borehole databases.

Is the site suitable for groundwater monitoring?

There are many good reasons for collecting groundwater samples or measuring groundwater levels; the information can, for example, help to validate the success of any remedial works being undertaken on a contaminated land site. Therefore, before decommissioning a borehole you should consider whether you wish to retain it as a monitoring facility. If it is to fulfil part of a planning condition or other legal monitoring requirement you may wish to discuss the details of how you do this with the Environment Agency.

If not, it is still worth contacting us via our National Customer Contact Centre (NCCC) to check whether we would be interested in incorporating it into our strategic groundwater level or quality monitoring networks.

If the borehole is not going to be converted then it should be abandoned using the guidelines below and the British Geological Survey should be informed.

Decommissioning

Each situation is different in terms of its location, geological setting, borehole construction, dimensions, hazards and, very importantly, intended site afteruse. Therefore the most appropriate abandonment procedure will vary from site to site. It is strongly recommended that you engage the services of a proficient well contractor with a good knowledge of the local geology and well abandonment procedures. For large boreholes and wells you may need to seek engineering advice. **(Note that structural aspects are outside the scope of this guidance.)**

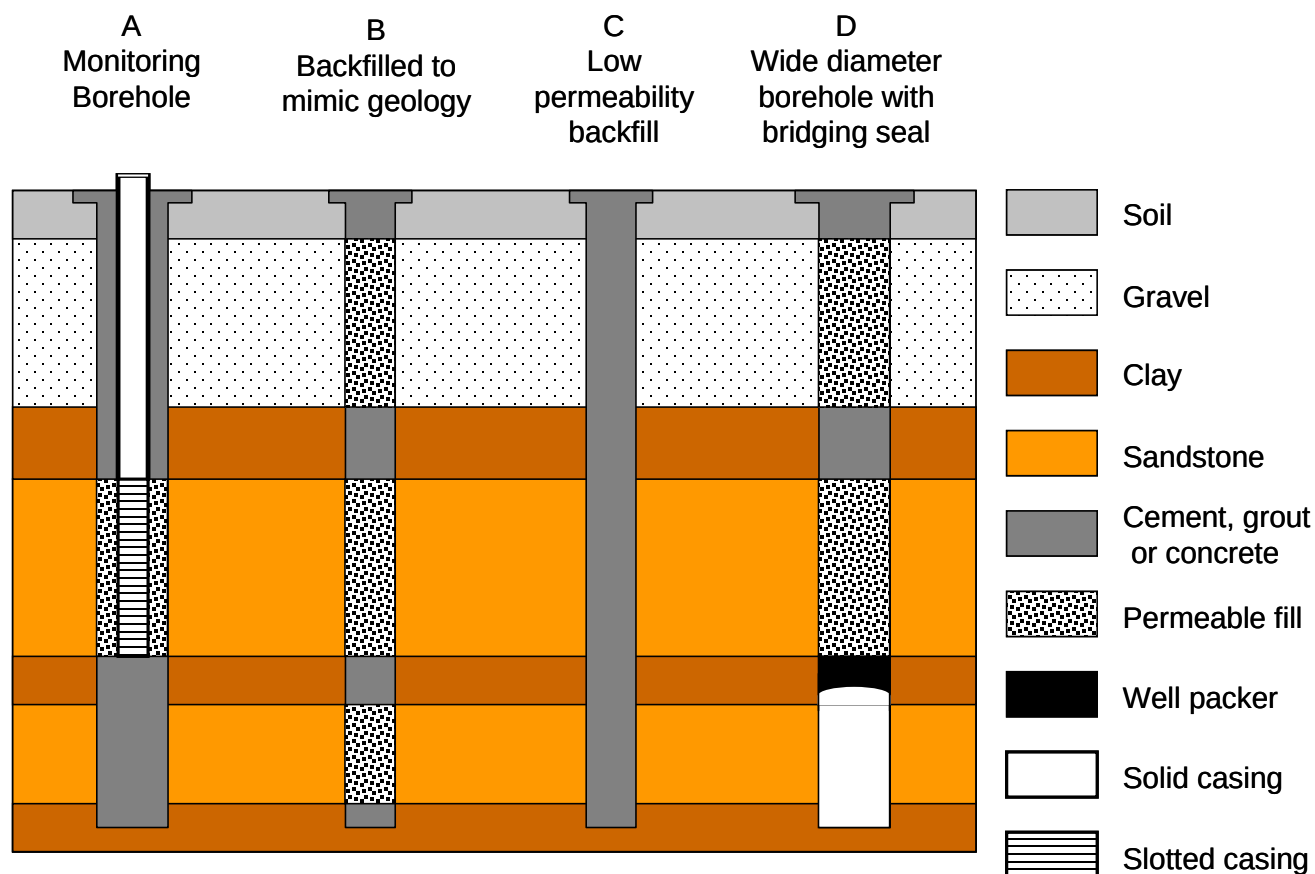


Figure 1: Schematic options (B–D) for decommissioning wells and boreholes

Step 1 - Defining the objectives

When planning the decommissioning works, in addition to any site specific afteruse considerations, the method should address the following objectives:

- Remove the hazard of an open hole (safety issues).
- Prevent the borehole acting as a conduit for contamination of groundwater.
- Prevent the mixing of contaminated and uncontaminated groundwater from different aquifers.
- Prevent the flow of groundwater from one geological horizon to another.
- Prevent the wastage of groundwater from the overflow of artesian boreholes.

Step 2 - Removing headworks and casing

It is crucial to ensure that the borehole or well is free from all obstructions that may interfere with the sealing of the hole. In particular, the pump and pipework should be removed, together with any other infrastructure (dip tubes etc).

The condition of any borehole casing and grout must be examined to ascertain whether its retention in the hole would prejudice any of the objectives of the abandonment. For many holes, examination of the casing from the ground surface will be adequate. However, deep boreholes may require the use of closed-circuit television (CCTV) to examine the casing at depth.

Where the casing has corroded or broken, or the grouting has failed, depending on the setting it may be necessary to remove those materials to prevent any flow of groundwater around the outside of the borehole. However, this is not without its own risks since removal of the well casing can result in collapse of the borehole walls (particularly in unconsolidated materials) and possible subsidence at ground level. If the well casing needs to be removed, a specialist well contractor can advise on appropriate techniques and associated risks.

Step 3 - Backfilling

General considerations

For most purposes the ground should be restored as closely as possible to its pre-drilled condition. The borehole or well should be backfilled with clean (washed), uncontaminated materials so that the permeability of the selected materials are similar to the properties of the geological strata against which they are placed. The backfilled borehole will then mimic the surrounding natural strata and groundwater flow and quality will be protected.

Restoration will require a variety of materials to be used so that permeable aggregates (for example pea gravel and sand) are positioned adjacent to aquifer horizons, whilst low permeability materials (usually clay, bentonite cement grout, or concrete) are positioned adjacent to low permeability horizons (see Fig. 1(B)). Alternatively, the entire borehole or well can be backfilled with low permeability

materials that will prevent significant vertical or horizontal movement of groundwater through or along the borehole (see Fig. 1(C)).

The backfill materials must be clean, inert and non-polluting. Suitable materials include pea gravel, sand, shingle, concrete, bentonite, cement grout and uncontaminated rock. There are also a range of recycled products, like crushed glass, on the market that are designed for use in boreholes

IMPORTANT - Never use backfill materials that can cause pollution.

You should also consider the geochemical environment into which these materials will be placed, as the behaviour of materials may change under different environmental conditions (for example, iron-rich sands may contaminate the aquifer; phenol contamination may prevent bentonite grouts curing).

Aggregates (pea gravel, shingle, sand etc) should be selected such that they have a grain size that allows easy delivery into the borehole and should be introduced in a controlled manner to ensure that accidental 'bridging' does not occur within the borehole. Concrete and grouts that are introduced in a liquid form should be introduced through an appropriate delivery pipe (e.g. tremie pipe), to ensure that voids do not form. **Note:** It is good practice to monitor the volume of backfill material that is being emplaced, compared to that calculated at the design stage, to check if bridging within the borehole, or loss to the formation is occurring.

Boreholes that penetrate highly fissured aquifers, such as some limestones and gypsum bearing units, present additional problems. Liquid grouts (particularly those injected under pressure), or fine-grained aggregates (e.g. sand) may be transported out of the borehole into the body of the aquifer through fissures. Careful monitoring of the process is required if these techniques are used, and in these cases it may be more appropriate to use coarser aggregates such as gravel as a backfill.

Deep and large diameter boreholes/wells

When dealing with very deep or large diameter boreholes and wells (note, this does not apply to mine shafts), the volume of the hole may be considerable. In such circumstances it may be appropriate to adopt an alternative approach to completely backfilling the void, as long as this will not prejudice any of the design objectives.

Provided that the long-term structural stability of the borehole can be demonstrated, it may be possible to place a permanent bridging seal within the borehole and then to infill above this level using the approach summarised above (see Fig. 1(D)). The bridging seal should ideally be positioned below the lowest aquifer horizon. However, where this is not possible, it is important that the open borehole beneath the bridging seal penetrates no more than a single aquifer unit, thereby preventing the flow of groundwater between different aquifers.

The material commonly used as a bridging seal is cement, although a combination of a mechanical plug (packer) and cement can be used. Cement seals must be allowed to set (cure) in place before backfilling is continued and completed.

Again, this is a specialist area of work that requires high standards of design and workmanship to ensure an effective permanent seal is achieved.

Artesian boreholes

For artesian boreholes, the decommissioning process should aim to confine the groundwater to the aquifer from which it came – in order to prevent loss of confining pressure and the loss of water resources to the surface or other formations.

The first step is to control the artesian flow. There are a number of ways to accomplish this depending, in part, on the water pressure in the confined aquifer and the depth to which the water level must be lowered. These include:

- Pumping the borehole to produce the necessary drawdown.
- Pumping nearby boreholes.
- Extending the casing above ground level beyond the elevation to which water will rise in the borehole. (the potentiometric or piezometric surface).
- Introducing dense, non-polluting fluids into the borehole.
- Introducing a pre-cast plug at an appropriate level within the hole.
- Using an inflatable packer and pressure grouting the void space below it.

In aquifers that have large seasonal fluctuations in water level, decommissioning artesian boreholes is likely to be easiest in late summer, when groundwater levels and artesian flows are at their lowest.

The importance of the potential pathways in and around the casing should also be considered.

Decommissioning artesian boreholes is a specialist job and requires expert advice.

Step 4 - Sealing the top of the borehole

The backfilled borehole/well should be completed with an impermeable plug and cap to prevent entry of potentially contaminated surface run-off or other liquids. The top two metres should be filled with cement, concrete or bentonite grout. A concrete cap of suitable strength, with a diameter at least one metre greater than the width of the backfilled borehole (see Fig. 2), should then be installed. The exact finished depth of this cap will depend on the setting and planned afteruse of the site. It should be at least 2 metres below plough depth in agricultural areas and at least 1 metre below formation level for sites proposed for redevelopment. Never build structures directly onto well caps or linings.

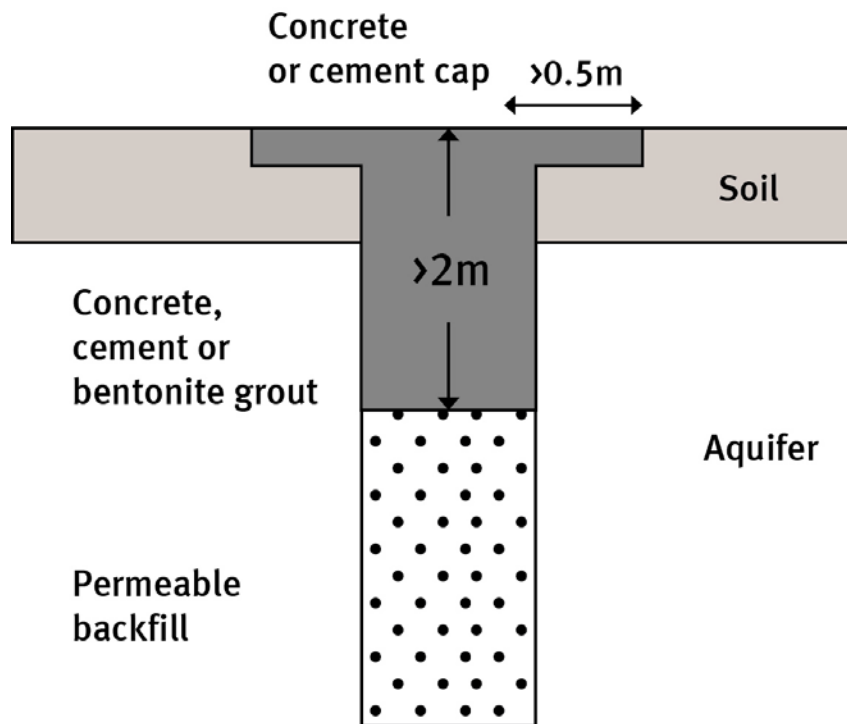


Figure 2: Schematic diagram for borehole seal and cap

Step 5 - Recording details and informing others

You should keep an accurate record of the abandonment details for future reference, including:

- The reasons for abandonment (for example water quality problems).
- Measurement of groundwater level prior to backfilling.
- The depth and position of each layer of backfilling and sealing materials.
- The type and quantity of backfilling and sealing materials used.
- Any changes made to the borehole/well during the abandonment (for example casing removal).
- Any problems encountered during the abandonment procedure.

The location of abandoned borehole and wells should be clearly marked on site records. This is essential where any part of the well has not been filled.

It is also very good practice to mark or deeply inscribe well caps with the word "WELL". Even if done crudely it can avoid considerable risk, delay or uncertainty in the event of the structure being discovered during excavation by others in the future, who may not otherwise know what the feature is.

Always notify the Environment Agency and British Geological Survey of the abandoned well location and structure.

Conversion to soakaways

Wells and boreholes should not be converted to soakaways, as these allow the direct discharge of pollutants into groundwater without any potential for attenuation, and will often result in groundwater pollution. The direct discharge of hazardous substances to groundwater, via a borehole, is effectively prohibited by the Environmental Permitting (England & Wales) Regulations 2010, and the pollution risk from any direct discharge of non-hazardous pollutants, such as sewage effluent, is so great as to make it highly unlikely to be acceptable.

Further advice and guidance

It is recommended that the advice of a specialist well contractor should always be sought, Details can be obtained from:

- **The British Drilling Association.** Wayside, London End, Upper Boddington, Daventry, Northamptonshire, NN11 6DP. Tel: 01327 264 622, email: office@britishdrillingassociation.co.uk

The Environment Agency cannot provide an advisory service on decommissioning individual boreholes and wells but your local Groundwater & Contaminated Land team may have some generic advice to help you; and would appreciate a copy of your abandonment details. They can be contacted via our National Customer Contact Centre (NCCC)

- **Environment Agency NCCC** Tel: 03708 506 506

The British Geological Survey are the national custodian of water well records in addition to other borehole records and geological information. They may have a record of the borehole or well you are dealing with, and will be interested in the abandonment details

- **British Geological Survey. National Geosciences Data Centre (NGDC)**, Keyworth, Nottingham, NG12 5GG. Tel: 0115 936 3143.

Useful references

- Environment Agency GP3 (Groundwater Protection Principles and Practice)
<http://www.environment-agency.gov.uk/research/library/publications/40741.aspx>
- American Society for Test and Materials (ASTM) D5299 - 99(2005) Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities
- Driscoll, F.G., 1986. Groundwater and Wells. Second Edition, Johnson Division.

Note: *This guidance supersedes the document ' Good practice for decommissioning redundant boreholes and wells' produced by our former National Groundwater and Contaminated Land Centre*

Product Code: LIT 6478 / 657_12

Updated October 2012

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