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Vertical Flow Pond Layout Feasibility Study

Nenthead Caplecleugh Adit

The Coal Authority

Project number: 60596575

15th June 2020

Quality information

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		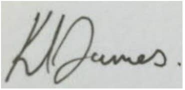	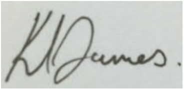
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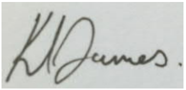
Revision History

Revision	Revision date	Details	Authorized	Name	Position
Draft	15/06/2020	Draft		Kirsty James	Technical Director

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1. Introduction

Overview

The Coal Authority (referred to herein as TCA) is proposing to submit a planning application to Cumbria County Council's Mineral Planning Authority (MPA) for a Mine Water Treatment Scheme for the Nenthead Mine Caplecleugh Adit.

The Mine Water Treatment Scheme (referred to herein as the 'Development') would be located on a site 0.9 km to the south east of Nenthead, at OS National Grid Reference 378591E 543232N (refer to Figure 1.1).

AECOM Infrastructure & Environment UK Ltd has been commissioned by TCA to prepare a Feasibility Study for the layout and treatment pond configuration for the Proposed Development.

Need for the Development

The EU Water Framework Directive (WFD) sets out a legislative framework for the analysis, planning and management of water bodies. It is delivered through River Basin Management Plans (RBMPs), which describe baseline waterbody conditions and objectives for their improvement. The Northumbria River Basin Management Plan sets out legally binding objectives for each quality element within every water body.

The Nent catchment fails to reach good status or good potential under the Northumbria River Basin Management Plan due to high concentrations of some metals, in particular zinc, cadmium and lead. The sources of these metals are former mine workings and associated mine water discharges located at the top of the catchment. For the River Nent water body, objectives include reducing metal concentrations to improve the quality in this water body towards good status by implementing measures to limit the input of metal to the river and to manage metal-contaminated sediments already in the river.

Drainage from abandoned metal mines is an acute and pervasive form of aquatic pollution. Based on assessment by the Environment Agency, these discharges of metals including cadmium, lead and zinc pollute up to 1,500 kilometres (km) of rivers in England. Consequently, there is a need to tackle these issues in pursuance of improved national water quality and of meeting the objectives of the WFD.

The Nenthead site has been identified as a significant source of metals within the River Nent catchment. The Proposed Development has potential for significant environmental benefits through improving the quality of water discharging from Nenthead to the River Nent through the removal of metals (notably zinc, lead and cadmium), which would contribute to the waterbody meeting the River Basin Management Plan objective of Good Potential by 2027.

The Department for Environment, Food and Rural Affairs (Defra) and the North East Local Enterprise Partnership have allocated funding for TCA and the Environment Agency to implement a programme of measures to minimise pollution from abandoned metal mines (the Water and Abandoned Metal Mines programme (WAMM). The Proposed Development forms part of this programme.

2. Development Description

Site Location and Environmental Context

The Proposed Development site is located approximately 0.9 km to the south-east of Nenthead village (refer to the Figure 1.1 - Site Location Plan).

The Caplecleugh adit is located at the Nent Mines car park adjacent to the Nenthead Mines Heritage Centre. The main treatment site is to be located to the south-east of the adit, upstream of the current mine water discharge location and is bounded to the north by the A689 and to the south by a quarry track. The western edge of the Proposed Development site steeply slopes down to the mine museum and to the east is open countryside. Part of the main treatment site is within the Scheduled Monument (SM), list entry number 10158582 “Lead mines, ore works and smeltmill at Nenthead”. The Smallcleugh Mine SSSI is located adjacent to the southern boundary of the main treatment site.

The wider area is rural in character and dominated by farmland / pasture. A number of farm properties, including residential buildings are located within 500 m of the site including Mill Cottage, Hilltop Cottages, Nenthead House, Eastern House, Thornleigh and Granary Cottage.

Key environmental constraints were summarised in the EIA Scoping report prepared by AECOM and have been extracted and are shown in Figure 2.1 – Environmental Constraints Plan. Statutory designated sites present within 2 km of the Proposed Development boundary are listed in Table 2.1 below.

Table 2-1: Statutory Designated Sites Within 2 Km

Designation	Site Name	Distance from Site Boundary (km)	Direction from Site Boundary
Area of Outstanding Natural Beauty	North Pennines AONB	0	
Special Area of Conservation (SAC)	Tyne and Nent SAC	0.7	W/SW
	North Pennine Moors SAC	1.1	NE
Special Protection Area (SPA)	North Pennine Moors SPA	1.1	NE
Site of Special Scientific Interest	Smallcleugh Mine SSSI	0	S/SW
	Haggs Bank SSSI	2	NW
	Allendale Moors SSSI	1.1	NE
	Whitesike Mine and Flinty Fell SSSI	0.7	W/SW
	Coalcleugh lead rake	1.3	NE
	Lead mines, ore works and smeltmill at Nenthead	0	
	Perry’s Dam	1.2	S

Designation	Site Name	Distance from Site Boundary (km)	Direction from Site Boundary
	Lead rake workings on Flinty Fell, 800m north west of Flinty Quarry	1.5	SW
Scheduled Monuments	Lead mines, ore works and smeltmill at Nenthead (List entry no. 1015858)	0	
	Lead rake workings on Flinty Fell, 800m north west of Flinty Quarry (List entry no. 1017448)	1.5 and 2km	SW
	Perry's Dam (List entry no. 1015859)	1.4	S
	Coalcleugh lead rake (List entry no. 1015833)	1.4	NE
Listed Building (Grade II)	Milestone to North east of Hilltop	0.05	NE
	Ivy House	0.15	N
	Dene Terrace	0.1	W
	Former powder magazine 150m south west of Chapel Houses	0.3	N
	Reading room, adjoining west end of ivy house	0.15	N
	3rd house from west end of road	0.2	N
	Memorial pump and canopy	0.15	N
	Milepost about 100m east of Killhope head Bridge	2	E
	Milestone to north of Woodbrae	1	NW
	Killhope cross	0.9	E
	Boundary stone c2000 yards south east of Nenthead in field on north side of road	1.6	SW

Designation	Site Name	Distance from Site Boundary (km)	Direction from Site Boundary
	Forecourt walls, gate piers and central gate to front of Ivy House	0.15	N
	Boundary stone C1600 yards south west of Nenthead in field on south side of road	1.3	SW
	The Beeches	0.8	NW
	Nenthead Methodist Church	0.15	N

The Proposals

The Proposed Development is a water treatment scheme which would improve the quality of water discharging from the Caplecleugh adit to the River Nent through the removal of metals (notably zinc, lead and cadmium), which contribute to heavy metal pollution of the River Nent and the downstream South Tyne catchment.

The Proposed Development site was selected by TCA as the preferred treatment site following a site selection process undertaken by TCA which resulted in a shortlist of three potential treatment sites that were presented to the public in 2017. The preferred site was subsequently selected as it had a number of distinct advantages including: fewer nearby receptors, good accessibility, shorter pipeline routes away from public highways, reasonable topography, availability of space, potential for a partnership with Nenthead Mines Conservation Society[1]. Whilst the site has a number of constraints, including archaeology and visual impacts, a meeting held between TCA and Historic England concluded with there being broad agreement that a scheme could be built whilst being sensitive to the historic features and landscape.

A description of the initial design for the Proposed Development is set out below. The purpose of this report is to review the impact on cost and performance of reducing the total area of ponds by increasing the depth and therefore volume of the compost medium. These would be subject to detailed design and any requirements for mitigation identified through the environmental impact assessment process.

The initial design for the site was based on the design principles used in the design of Nent Haggs treatment site and comprised: three compost based treatment ponds (CBTPs) of 1,000m^3 volume each (3,000m^3 for the three ponds in total), one balancing pond, one wetland, a single storey, pitched roof, stone clad building housing plant for chemical dosing and welfare facilities, access and maintenance tracks. The Proposed Development also included a mine water capture structure, pumping station, transfer pipelines to and from the main treatment site and a new outfall to the River Nent. The Proposed Development will be accessed from the A689 by an existing track.

Water discharging from the Caplecleugh adit will be intercepted by a capture structure at the Caplecleugh adit, which will collect the untreated mine water before it enters the river. Captured mine water will be transferred across the river via an above water level pipeline to a pumping station from where a pumped rising main will transfer the water flows to the treatment site. On entering the treatment site, the mine water flow will be split into three and will flow through the CBTPs before draining via gravity to a “polishing” wetland comprising shallow reed beds. The treated water will then be returned back to the river via a gravity pipeline. It is intended that the treated mine water will be discharged back into the River Nent via a new outfall at a location close to the existing discharge point. The treatment scheme will be designed to treat a maximum flow rate of 10l/s.

Odour dosing plant will also be provided as part of the Proposed Development to allow for management and treatment of any excess hydrogen sulphide which may be generated by the treatment process and which has

[1] Coal Authority, 2018. Nenthead (Caplecleugh) Mine Water Treatment Scheme Sites 23, 100 and 101 Feasibility

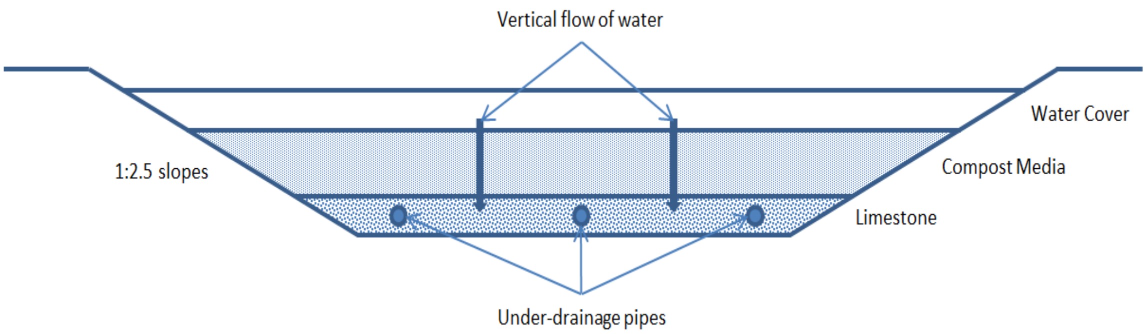
potential to give rise to malodours if not managed. The odour dosing plant will be housed in a single-storey, pitched, stone-clad building. The same building wold also house essential welfare facilities for maintenance staff when visiting the operational site.

The proposed treatment scheme is based on the same technology as the Nent Haggs mine water treatment scheme which Cumbria County Council has recommended is granted planning consent, subject to a Section 106 legal agreement and planning conditions (planning application 3/18/9001). This technology relies upon the chemical reduction of sulphate (SO_4^{2-}), which is typically found in elevated concentrations in mine water, to sulphide (S^{2-}). The sulphide that is generated then reacts with the dissolved metals in the mine water to precipitate low solubility metal sulphides. The precipitated solid metal sulphides are retained within the compost-based treatment media, thus removing the metal pollutants from the mine water.

The reduction of sulphate is facilitated by the action of sulphate-reducing bacteria, a process referred to as Bacterial Sulphate Reduction. In the reactions taking place during metal sulphide precipitation the molar ratio of SO_4^{2-} to divalent metal (e.g. zinc (Zn^{2+}), lead (Pb^{2+})) is 1:1 (i.e. for every one 'part' (mole) Zn^{2+} removed 1 'part' (mole) SO_4^{2-} (or S^{2-}) is removed).

Plate 2.1 below shows the generalised form of a CBTP. Mine water is piped into the pond at the upper water surface; whilst treated water is removed from the base of the pond through a limestone under-drainage blanket. A network of under-drainage pipes establishes a downwards vertical water flow through the reactive compost media which forms the treatment cell. The pond water cover is typically 400 mm deep, which allows an even flow of water across the surface of the pond and an even distribution of the vertical flows through the compost bioreactor layer.

Plate 2.1: General CBTP Composition



The type of treatment system that will be used in the Scheme has successfully removed heavy metals from mine water at a pilot unit located in the grounds of the Nenthead Mines Heritage Centre and in full scale application at Force Crag mine in Cumbria. Odour monitoring and engineering control and dosing trials undertaken on-site at Force Crag mine in 2017 were used to inform the design of the Nent-Haggs Mine Water Treatment Scheme and will be used to inform the design of the Proposed Development.

Purpose of this Report

AECOM understand that TCA wish to explore the impacts of reducing the overall pond footprint on both cost and performance of the treatment ponds. The options we have been asked to consider are increasing the currently proposed depth of the compost layer from 400mm to both 800mm and 1200mm to increase the volume of the layer by two and three times respectively. It is understood from discussions with TCA and Dr Adam Jarvis (Newcastle University) that performance of the compost layer will not be adversely affected by the increase in depth.

The overall pond depth will increase to accommodate the increase in depth of the compost layer. AECOM will aim to identify the overall impact of this on the proposed earthworks for the scheme, and therefore the impact on cost.

We will review the GI information to assess whether a cut fill balance could be achieved for each of the options. We will aim to identify any differences in ongoing maintenance that might become apparent between the options, and where possible assess the cost implications of these.

3. Development of the Options

Premise

The overall objective of this report is to assess the impact that increasing the depth of the pond compost layer has on the feasibility of the project. Three options were developed to assess this impact. Varying the depth of the compost layer also meant that the number of ponds could be reduced, which in turn reduces plan area of the ponds. The impact of reducing the number of ponds was also assessed in this report.

Option 1 has a compost layer that consists of a 400mm deep, woodchip layer and is based upon the "tried and tested" Nent Haggs design. For Option 2, the depth of the compost layer was increased to 800mm and the woodchips were replaced with a limestone-based compost layer. The number of ponds for Option 2 was reduced to two. For Option 3 the depth of the compost layer was further increased to 1200mm and the number of ponds was reduced to one. Option 3 also replaced the woodchip compost with the limestone-based material.

To accommodate the increased volume of compost per pond, the overall depth of the ponds will increase but all other factors will remain the same (i.e. freeboard, depth of access track, construction build up etc.).

Ground Conditions

AECOM reviewed the Phase 2 Ground Investigation Report that was produced in February 2020 to gain an understanding of the ground conditions that are present on site. The results of the report reveal that elevated levels of lead and zinc have been identified on site (see **Appendix B** for details). Under WM3 waste classification guidance, these contaminants can be classified as carcinogenic (HP7), toxic for reproduction (HP10) and ecotoxic (HP14). Therefore, if material containing these contaminants is to be sent to landfill, Waste Acceptance Criteria (WAC) will be required to determine the appropriate receiving landfill classification. In light of this information, it has been assumed that any soil from the site that is to be sent to landfill will be considered as containing hazardous materials for the purposes of this report.

The report also contained the findings of the ground investigation surveys that had previously been carried out. It was concluded that there were no particular issues relating to the ground conditions that are likely to prevent the construction of the scheme. However, several issues were highlighted that must be considered and they include;

- Overbreak during construction of Mine capture chamber, could result in undermining the existing car park surface;
- Shallow groundwater and permeable strata at mine water treatment site requiring special consideration during construction of the pump well and excavation for the pipeline;
- Potential for settlement within the proposed central settlement pond in relation to the void identified in BH105;
- Potential for shallow rock within excavation for the proposed settlement ponds and reed bed within mine water treatment site;
- Excavated material unsuitable for reworking and not able to be designed to the required slope at the settlement ponds in its current condition. It is recommended that the excavated material is improved by lime stabilisation or another suitable method of improvement;
- Shallow groundwater and potential marginal slope stability in the settlement pond area. Uplift of the wetland liner due to groundwater pressure. If any part of the liner is to be taken to below groundwater level, then adequate topsoil and/or other cover material must be placed to prevent uplift;
- Prior to pavement construction for the access roads, 1m of suitable capping material or lesser thickness of capping with a geogrid should be placed prior to pavement construction.

One of the key concerns for the purposes of this study is the depth of the bedrock beneath the ground surface and the ground investigation surveys revealed that the bedrock depth varied significantly across the site. The approach taken to overcome this issue is discussed further in the Modelling section of the report.

For more details regarding the ground conditions, the Phase 2 Ground Investigation Report will be made available upon request.

Modelling

Using Autodesk Civil 3D software, AECOM have completed three high-level 3D models for the options to assess the required earthworks for each. The pond profiles modelled as part of this study were based on the ponds that were developed for Nent Haggs.

The models include the ponds profiles, surrounding access track and the required earthwork embankments. An access track (4.35m wide) surrounds each pond, with a crossfall of 2.5% falling away from the ponds to prevent surface water runoff flowing into the ponds. For options that have more than one pond, access tracks of adjacent ponds are connected.

Features that are common to all three options developed have not been incorporated into the models (i.e. welfare and dosing buildings). This approach was adopted as common features will have the same impact regardless which option is pursued. Therefore, these features are not required in order to compare the options outlined at this stage but will be considered during detailed design.

Each pond consists of the following layers:

- 200mm Pond Liner
- 400mm drainage layer
- Compost layer (400mm, 800mm or 1200mm)
- 400mm operating water depth
- 300mm freeboard

A cut/fill report was produced for each option based upon the models created using Autodesk Civil 3D software (see **Appendix** I for details). The results of the cut/fill reports have been reviewed to inform the cost analysis contained within this study. The corresponding volumes of cut or fill were determined by comparing the existing surface (generated from the existing topography survey) to the proposed dimensions of the ponds. By calculating the difference, the software could determine the volume of cut and fill that would be required.

Calculations

For the purpose of this report the porosity of the compost has been assumed to be 0.35 and the residence time of the mine water in the pond was assumed to be an average of 15 hours, both of which are based upon the Nent Haggs treatment site. Using this information, the required volume of compost to accommodate a design flowrate of 10 l/s was calculated based on these parameters taken from the previous study. The required compost surface area could then be determined as the slope of the sides of the ponds and the depth of the compost layers were known. The overall ponds were then sizes based upon the required compost layer surface area. The results of these calculations are presented in Table 3-1 (see **Appendix J** for full calculations).

$$Design\ Flow = \frac{Compost\ Volume\ \times Porostiy}{Residence\ Time}$$

Table 3-1: Compost Volumes Required

Reference	Compost Layer Depth (mm)	Compost Volume per Pond (m^3)	Compost Layer Surface Area per Pond (m^2)
Option 1 (3 Ponds)	400	514.29	1286.71
Option 2 (2 Ponds)	800	771.43	967.29
Option 3 (1 Pond)	1200	1542.86	1290.71

The results presented above show that to accommodate a design flowrate of 10l/s, approximately **1543**m^3 of compost is required.

Design Considerations

It was anticipated that the cost associated with the estimated volume of earthworks required would be one of the most significant contributing factors to the overall cost. Therefore, minimising the earthworks was deemed to be a key design focus. However, the combination of a steep topography and presence of shallow bedrock made this challenging.

As previously discussed, three options were developed as part of this study to assess the impact that increasing the depth of the compost layer would have. The required volume of compost remains constant as the treatment capability of the compost is linked to the volume rather than the surface area. In theory, by building up rather than out, the surface area of the ponds can remain the same whilst providing increased treatment capacity. However, due to the site topography, increasing depth of the compost layer also increases the required volume of earthworks needed to construct the ponds.

It was determined that long, narrow ponds were more efficient as they could be orientated to follow the contours of the existing site and minimise the earthworks required. For options with multiple ponds, the levels were set to be uniform to maintain a surface level across the pond and access track surface.

To mitigate the challenges posed by the bedrock, the maximum cut depth beneath ground level was set to 500mm. Whilst the micro-siting of the ponds can be further explored during outline and detailed design stages, a very broad but consistent approach was adopted for the study at this feasibility stage. The impact this has had on each of the models will be explained in further detail in **Section 0**, however, the general impact is that the required earthwork cut throughout the site is minimal, whilst the required fill to construct the front edge bund and ponds is significant.

The positioning of the ponds for each option was determined by considering the constraints that were present at the existing site. Several features to be avoided were identified by reviewing the topography survey of the existing site, these include;

- an earthworks scar that is understood to indicate the approximate location of buried surface water drainage pipe;
- a small watercourse that feeds into the existing reservoir;
- depressions potentially due to collapsed mine shafts;
- existing reservoir;
- existing drystone wall to the east of the reservoir.

An overview of the existing topography revealed that the site was more constrained to the south (by collapsed mines and the earthworks scar) so it was determined that it was more suitable to locate the rising main distribution chamber and odour dosing building to the north of the ponds. The impact of this can be seen in Option 2 & Option 3 with the ponds being positioned towards the north.

Option 1 – Three Pond TCA Feasibility Layout

The first option is the three pond layout with 400mm, woodchip compost layer which was utilised for Nent Haggs. This option comprises three ponds, with a compost layer depth of 400mm. The overall plan area for the proposal is approximately 14520m^2. This pond arrangement provides an approximate volume of 514.3m^3 of compost per pond which provides capacity for 3.33l/s per pond, totalling the required 10l/s for the development.

This option was originally proposed using the Nent Haggs layout as a template, a tried and tested method. Due to the constraints on the Nenthead site however, it is likely that the three pond option will be unacceptable due to the constraints of the site. The ponds in this option are slightly wider than the other options as reducing the width meant increasing the pond length. Longer ponds would have encroached onto the constraints to the north and south of the site.

The southernmost pond is located directly above the surface water drainage pipe from an upstream reservoir. This pipe feeds the hydroelectricity station located near the Nenthead Mines Conservation Society buildings. There are also two historic mine shaft entrances/collapses west of the dry stone wall on the southern extent of the site. Fitting the third pond between these constraints was very difficult and the final position of the third pond for this study partly covers the surface water sewer. Further consultation with the owner of the utility is required to explore whether the extra cover over the pipe would be acceptable.

This option will require a flow control chamber with three outlets which can be controlled independently to allow for maintenance without entirely halting through flow. Each pond will also require infrastructure to provide odour dosing.

Plate 3-1: Option 1 Proposed Layout

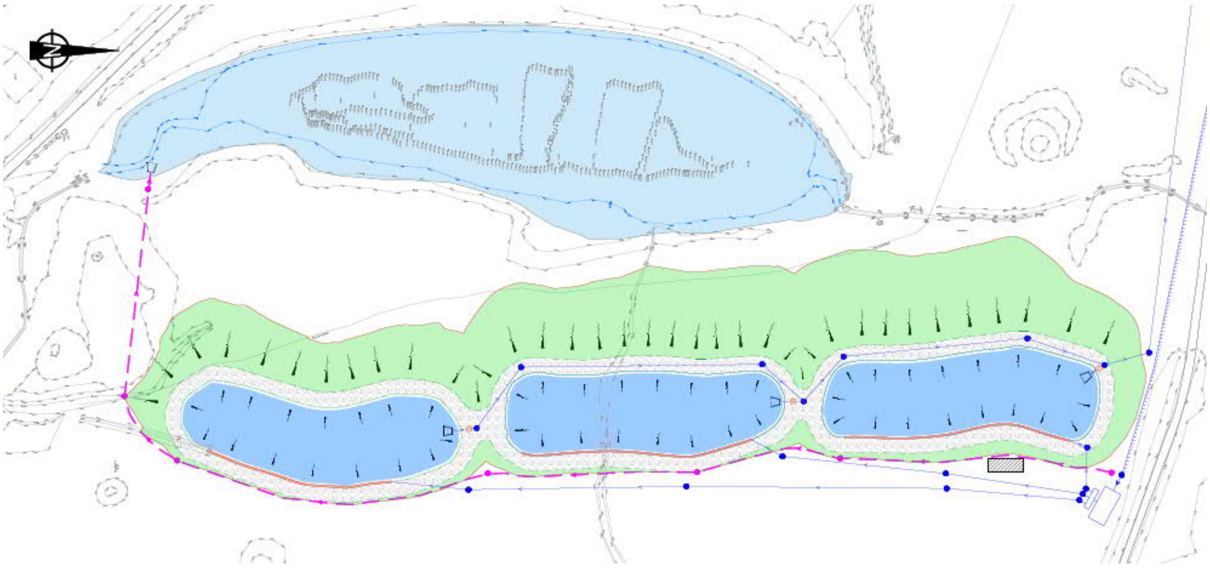


Plate 3-1 shows the proposed layout for Option 1 (refer to Appendix C for more details).

Option 2 – Two pond layout with 800mm compost layer

For Option 2, the required volume of compost was split evenly between two ponds and the depth of the compost layer in the ponds was increased to 800mm. This arrangement meant that each pond contained approximately 774.4m^3 of compost material and is capable of treating a flowrate of 5l/s. The overall plan area for the proposal is approximately 8787m^2. By increasing the compost volume per pond, the number of ponds that are required can be reduced, reducing the overall surface area of the proposal.

The proposed location of the ponds in Option 2 is also similar to Option 1 but with the southernmost pond removed. This reduces the impact of the development on the site constraints, as a result, there is no longer a need to interface with either the surface water drainage pipe or the two mine shaft entrances/collapses near the southern boundary. However, the on-site constraints still present some challenges.

The proposed location of Pond 2 (the southern pond) sits on top of the existing watercourse that drains into the existing reservoir. A series of alternative layouts were discussed to determine whether this could be avoided but it was determined that it could not. Increasing the pond widths to reduce the pond lengths would significantly increase the cost due to an increased fill volume required and may even encroach on other constraints to the east and west of the ponds. It was determined that surface water runoff could be collected by a filter drain and conveyed to the nearby disused reservoir.

Similar to Option 1, this option requires a flow control chamber but with two outlets instead of three. Similarly, these outlets require the ability to be controlled individually to allow for maintenance activities and to adjust flows if needed. Both ponds will also require odour dosing infrastructure.

Plate 3-2: Option 2 Proposed Layout

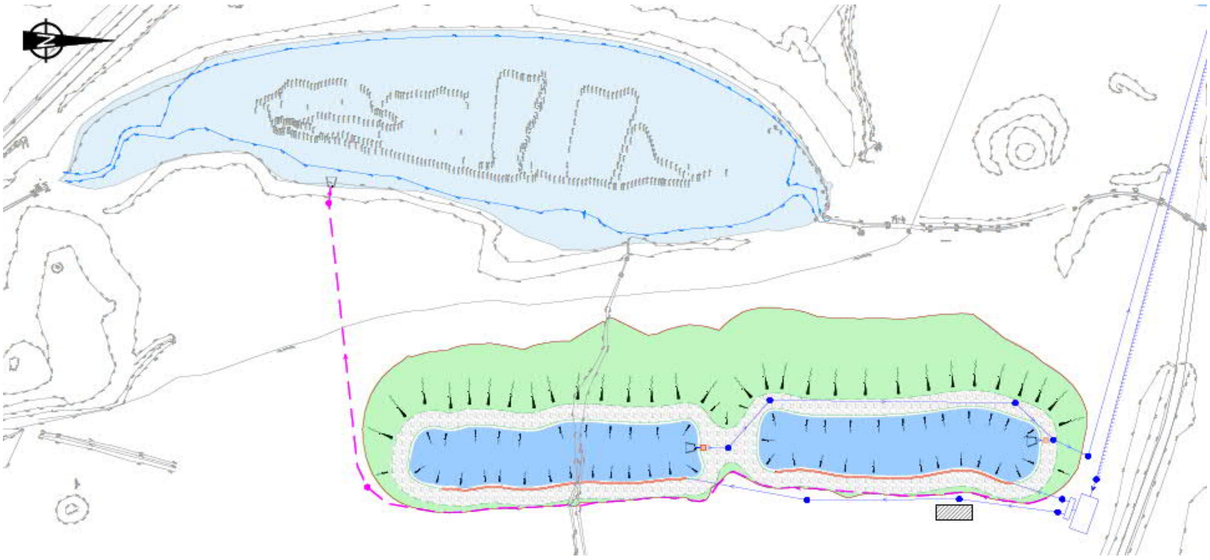


Plate 3-2 shows the proposed layout for Option 2 (refer to Appendix E for more details).

Option 3 – One pond layout with 1200mm compost layer

For Option 3, the depth of the compost layer was increased to 1200mm. The volume of the compost provided is approximately 1542.9m^3 and has a design flow rate capacity of 10 l/s. The overall plan area for the proposal is approximately 6289m^2. By increasing the volume of compost provided by a single pond, the total number of ponds required could be reduced to one.

As previously discussed, this pond was positioned in the northern portion of the site as it was less confined, and the shape of the pond was developed to avoid the constraints that do exist at this location. As the height and width of the ponds increase to accommodate the increased compost layer depth, it becomes more challenging to avoid the constraints due to the increased volume of fill required to construct the larger side slopes of the pond. Although a longer, narrower pond may have required potentially less fill volume, such a pond could not be built without encroaching on the watercourse that drains into the reservoir.

This option would not require a distribution chamber to split the incoming flow. Odour dosing facilities would still be required.

Plate 3-3: Option 3 Proposed Layout

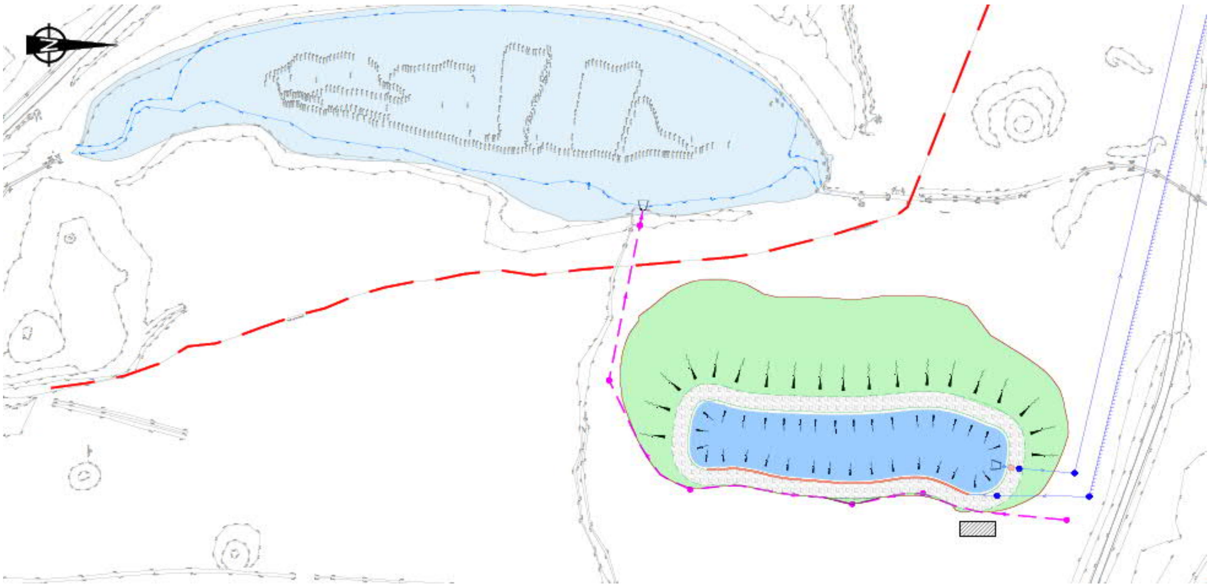


Plate 3-3 shows the proposed layout for Option 3 (refer to Appendix G for more details).

4. Results

Cut / Fill Reports

The results of the cut / fill analysis for each option is presented below (see **Appendix** I for details).

Table 4-1 shows that the cut volumes for each option are minimal in comparison to the required fill volumes. This is as expected as the minimum allowable depth for cutting was set to 500mm to avoid cutting into bedrock.

Table 4-1 – Civil 3D Cut / Fill Volumes

Option	Pond Footprint Area (m^2)	Cut Volume (m^3)	Fill Volume (m^3)	Net (m^3)
Option 1 (3 Ponds)	14519	32	37173	37141 (Fill)
Option 2 (2 Ponds)	8786	15	19603	19588 (Fill)
Option 3 (1 Pond)	6288	13	16871	16857 (Fill)

The results reveal that Option 3 requires the least imported fill, followed by Option 2 and with Option 1 requiring the most. Comparing these figures shows that the fill required to construction Option 1 is significantly higher than the alternative options and is over twice the fill required for Option 3. Comparison of Options 2 & 3 also reveal that there is a relatively small difference in footprint area and required earthworks between the two options.

Cost Analysis

All costs rates have been collected from SPONS 2019 unless otherwise stated. Each rate has been referenced within Appendix J.

Using the models that were developed, a high-level cost estimate for each option was calculated (refer to **Appendix J** to see the full calculations). In order to simplify the assessment process, cost items that remain constant across all of the options were excluded. An example of an item that was not included is the pumping apparatus required to deliver the design flow of 10 l/s, as it has been assumed these costs would not change depending on the option. This methodology was adopted to focus on the variables that will affect the overall cost of the project. It should be noted that this estimated cost only serves to provide an indication of which option appears to offer the most economical solution. It should also be noted that the impact on site contraints for each option has been partially considered, with drainage costs for diverting the small watercourse into the reservoir accounted for but any diversion costs for the surface water drainage pipe that is impacted in Option 1 are excluded. The assumption is that the pipe could be left in situ, but a risk remains that this may require a diversion.

A summary of the estimated costs are presented below.

Table 4-2: Summary of Cost Estimates

Item Description	Cost		
	Option 3	**Option 2**	**Option 1**
Site Clearance	£158,250	£220,630	£365,490
Pond Construction	£475,800	£567,930	£1,116,710
Access Track Construction	£39,650	£73,000	£111,640
Drainage Items	£5,970	£11,200	£16,680

Other Costs	£0.00	£9,290	£13,130
Total	**£679,670**	**£882,050**	**£1,623,650**

Note: "Other costs" include items such as the distribution chamber, penstocks and hydrobrakes which are required to split the design flow between ponds.

Table 4-2 shows that Option 1 is the most expensive solution and Option 3 is the least expensive. Table 4-3 shows that each cost item held roughly the same share of the overall cost when compared to the other options. The results show that constructing the pond accounted for the majority of the estimated costs, with a share ranging between 64.4 – 70% of the total cost, where an average of 88% of this cost is associated with the cost of acquiring the required volume of fill. Following pond construction, site clearance accounted for the second largest share, with between 22.5 – 25 % of the costs.

Table 4-3: Cost per Item

Item Description	Proportion of Total Cost (%)		
	1 Pond	**2 Ponds**	**3 Ponds**
Site Clearance	23.3%	25.0%	22.5%
Pond Construction	**70.00%**	**64.4%**	**68.8%**
Access Track Construction	5.8%	8.3%	6.9%
Drainage	0.9%	1.3%	1.0%
Other Costs	0.00%	1.1%	0.8%
Total	100.00%	100.00%	100.00%

To further analyse the results, a cost comparison conducted to investigate the cost difference for each item compared to the alternative options proposed, the results of which are presented within Table 4-4 below. As Option 3 (1 Pond) was estimated to have the lowest cost, it was selected as the "baseline" option to compare the others to. The results show that Option 2 costs approximately 29% more than Option 3, and Option 1 cost approximately 137% more than Option 3. By taking a closer look at the figures in Table 4-4, it can be seen that some of the costs increase proportionally with the number of ponds required and some do not.

For site clearance, the cost depends on the pond footprint area whereas, pond construction depends on the footprint and the height. When it comes to drainage and track construction, the overall length of the ponds is the key variable to consider, which is closely linked to the number of ponds for the proposed options.

Table 4-4: Cost Comparison

Item Description	Cost Percentage Increase on Baseline Option		
	Baseline: Option 3 (1 Pond)	**Option 2 (2 Ponds)**	**Option 1 (3 Ponds)**
Site Clearance	-	39%	131%
Pond Construction	-	19%	135%
Access Track Construction	-	84%	182%
Drainage	-	78%	159%
Other Costs	-	N/A	N/A

Total	**-**	**29%**	**137%**

Note: Values contained within

To further analyse the results, a cost comparison conducted to investigate the cost difference for each item compared to the alternative options proposed, the results of which are presented within Table 4-4 below. As Option 3 (1 Pond) was estimated to have the lowest cost, it was selected as the "baseline" option to compare the others to. The results show that Option 2 costs approximately 29% more than Option 3, and Option 1 cost approximately 137% more than Option 3. By taking a closer look at the figures in Table 4-4, it can be seen that some of the costs increase proportionally with the number of ponds required and some do not.

For site clearance, the cost depends on the pond footprint area whereas, pond construction depends on the footprint and the height. When it comes to drainage and track construction, the overall length of the ponds is the key variable to consider, which is closely linked to the number of ponds for the proposed options.

Table 4-4 **show the percentage increase in costs for Options 1 (3 Ponds) and Option 2 (2 Ponds) in comparison to Option 3 (1 Pond).**

5. Maintenance Implications

The differences between the three options will have implications on the maintenance requirements and costs. AECOM have undertaken a high level qualitative assessment of the differences in maintenance between the options and have not undertaken any cost assessment of these.

Option 1

Option 1 is the most flexible of the three options, similar to Nent Haggs the three ponds allows one to be shut down for maintenance whilst the other two remain in operation. The overall reduction of throughput is therefore only 33%, and if the two live ponds have the capacity to operate above their design capacity, they need to increase throughput by 50% each in order to maintain the overall throughput.

The depth of the compost layer is the smallest of the three options, so it is possible the plant required to undertake any required maintenance could be smaller than the other options.

Option 2

Option 2 maintains some of the operational flexibility of Option 1, however if one pond were closed for maintenance then overall throughput is reduced by 50%. To maintain a constant level of throughput, the remaining live pond would need to increase throughput by 100% in order to achieve this.

The depth of the compost layer is the median of the three options, so it is possible the plant required to undertake any required maintenance could be smaller than Option 3, but larger than Option 1.

Option 3

Option 3 as shown within this report has the least operational flexibility as the single pond construction would require all operations to cease for maintenance. A solution to this that has not been considered as part of this report but could be explored during design would be to bund the pond in one or two locations, effectively creating 2 or three pools within the single pond structure. This could be achieved with earth bunding, or with a manufactured solution such as sheet piling. It is likely the more natural earth bunding would be more appropriate given the requirements of the site being located within an Area of Outstanding Natural Beauty, though earth bunds would necessitate extra space and a larger overall dig for the construction of the ponds.

The depth of the compost layer in Option 1 is the largest of the three options, so it is likely to require the largest plant for maintenance activities.

6. Summary

The results of the cost analysis revealed that the required volume of imported fill accounts for the majority of the estimated costs and was the most significant factor when it came do differentiating the cost-effectiveness of each option. Table 6-1 outlines the potential advantages and disadvantages of each of the options developed. Constructing multiple ponds has the advantage of being a more resilient solution as if treatment within one pond has to stop, the system can continue to operate through the other ponds. However, based on the results of the cost analysis, these benefits come at a greater cost.

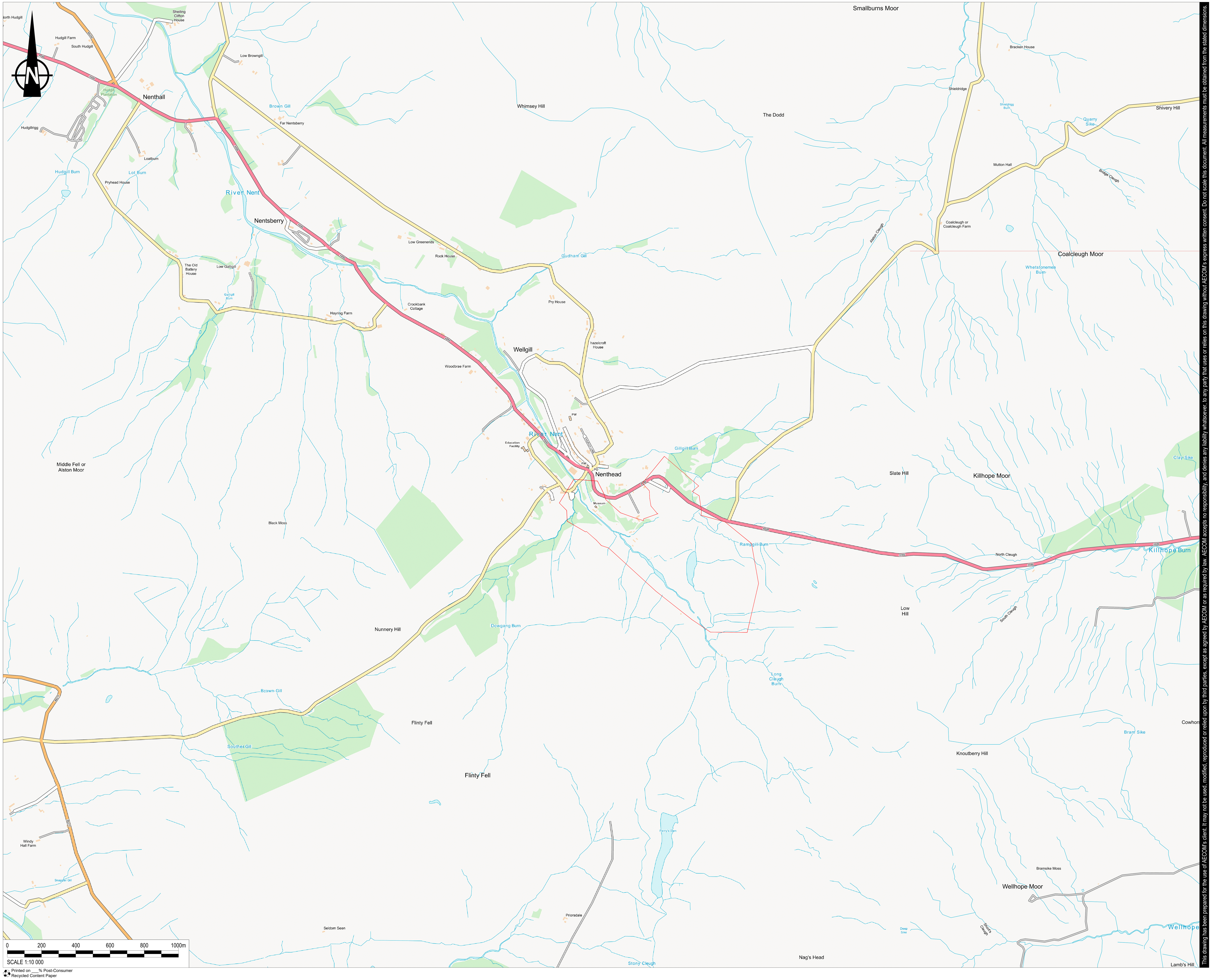
It is clear that Option 1 performs poorly in relation to costs and it proved difficult to avoid the on-site constraints, particularly towards the south. Whereas for Option 2, the cost was significantly lower, and the constraints were mostly avoided. Whilst Option 3 was the cheapest, if the pond was to fail, treatment will have to cease until a repair can be carried out. An alternative solution to develop resilience within Option 3 could involve creating segments within the single pond using bunds, effectively creating multiple ponds that can be operated independently, within the single pond.

Table 6-1: Option Summary

Option Reference	Advantages	Disadvantages
Option 1 (3 Ponds)	• Resiliency – if one pond fails the two remaining ponds can continue to provide treatment (33% loss of throughput) • Smallest depth and volume of compost per pond could mean maintenance cost will be lower	• Large footprint area required • Largest capital expenditure • Southernmost pond encroaches on several constraints • Requires watercourse diversion • Flow distribution chamber and infrastructure required • Three odour dosing chambers required • Potential for surface water drainage pipe diversion
Option 2 (2 Ponds)	• Resiliency – if one pond fails one pond can continue to provide treatment (50% loss of throughput) • Relatively small increase in cost compared to low-cost option	• Requires drainage channel diversion • Flow distribution chamber and infrastructure required
Option 3 (1 Pond)	• Smallest capital expenditure. • No flow distribution chamber and infrastructure required • Only one odour dosing chamber required • No watercourse diversion required • Least visually intrusive	• No redundancy – no backup if pond fails (total loss of throughput)[1] • Largest depth and volume of compost per pond could mean maintenance cost will be higher[1]

[1]This could potentially be offset if a bunded pond solution is adopted

Appendix A – Site Location Plan



ISO A1 594mm x 841mm Approved: KJ Checked: KJ Designer: AL Project Management Initials:

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KEY:

RED LINE BOUNDARY

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I/R	DATE	DESCRIPTION
01	15.06.2020	FIRST ISSUE

Proj Mgr : KJ	Status :
Date Created : 01.03.2019	Scale : 1:10 000

PROJECT NUMBER

60596575

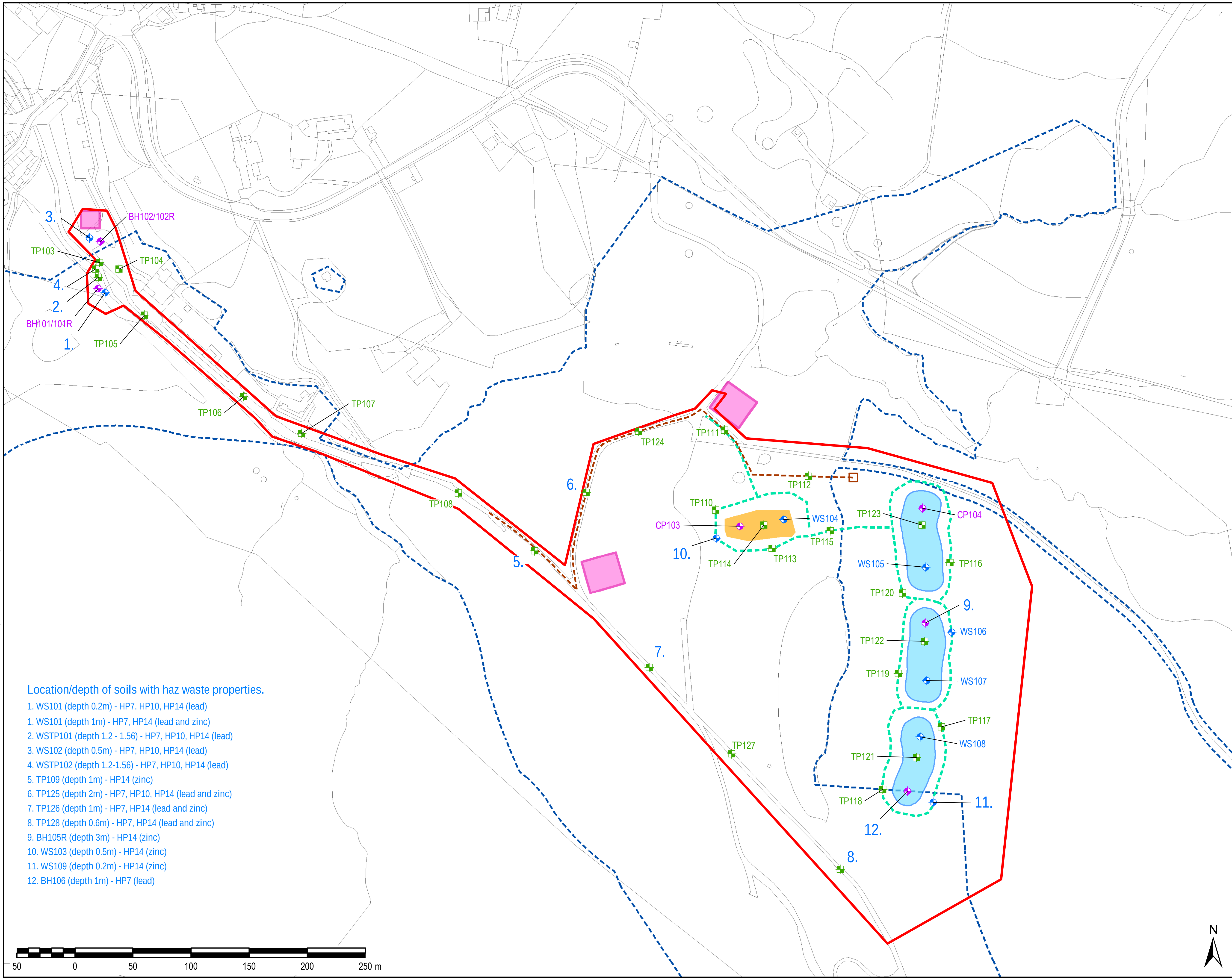
SHEET TITLE

SITE LOCATION PLAN

SHEET NUMBER

MWTS-AEC-NC-XX-DR-C-2001

Appendix B – Locations of Soils with Hazwaste Properties



Location/depth of soils with haz waste properties.

1. WS101 (depth 0.2m) - HP7. HP10, HP14 (lead)
1. WS101 (depth 1m) - HP7, HP14 (lead and zinc)
2. WSTP101 (depth 1.2 - 1.56) - HP7, HP10, HP14 (lead)
3. WS102 (depth 0.5m) - HP7, HP10, HP14 (lead)
4. WSTP102 (depth 1.2-1.56) - HP7, HP10, HP14 (lead)
5. TP109 (depth 1m) - HP14 (zinc)
6. TP125 (depth 2m) - HP7, HP10, HP14 (lead and zinc)
7. TP126 (depth 1m) - HP7, HP14 (lead and zinc)
8. TP128 (depth 0.6m) - HP7, HP14 (lead and zinc)
9. BH105R (depth 3m) - HP14 (zinc)
10. WS103 (depth 0.5m) - HP14 (zinc)
11. WS109 (depth 0.2m) - HP14 (zinc)
12. BH106 (depth 1m) - HP7 (lead)

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LEGEND

- Site Boundary
- Scheduled Monument Boundary
- Proposed Trial Pit
- Proposed Window Sample Borehole
- Proposed Borehole
- Suggested Route of Rising Main and Outfall Chamber
- Proposed Access Track
- Proposed Contractor Compound
- Proposed Reed Bed
- Proposed Mine Water Treatment Pond

NOTE:
PROPOSED CONTRACTOR COMPOUNDS NOT TO SCALE

Purpose of Issue
FOR INFORMATION

Client
THE COAL AUTHORITY

Project Title
NENTHEAD MWTS

Drawing Title
Locations of Soils with Hazwaste Properties

Drawn	Checked	Approved	Date
AG	LC	JS	06/01/2020

AECOM Internal Project No. 60596575
Scale @ A3 1:3,000

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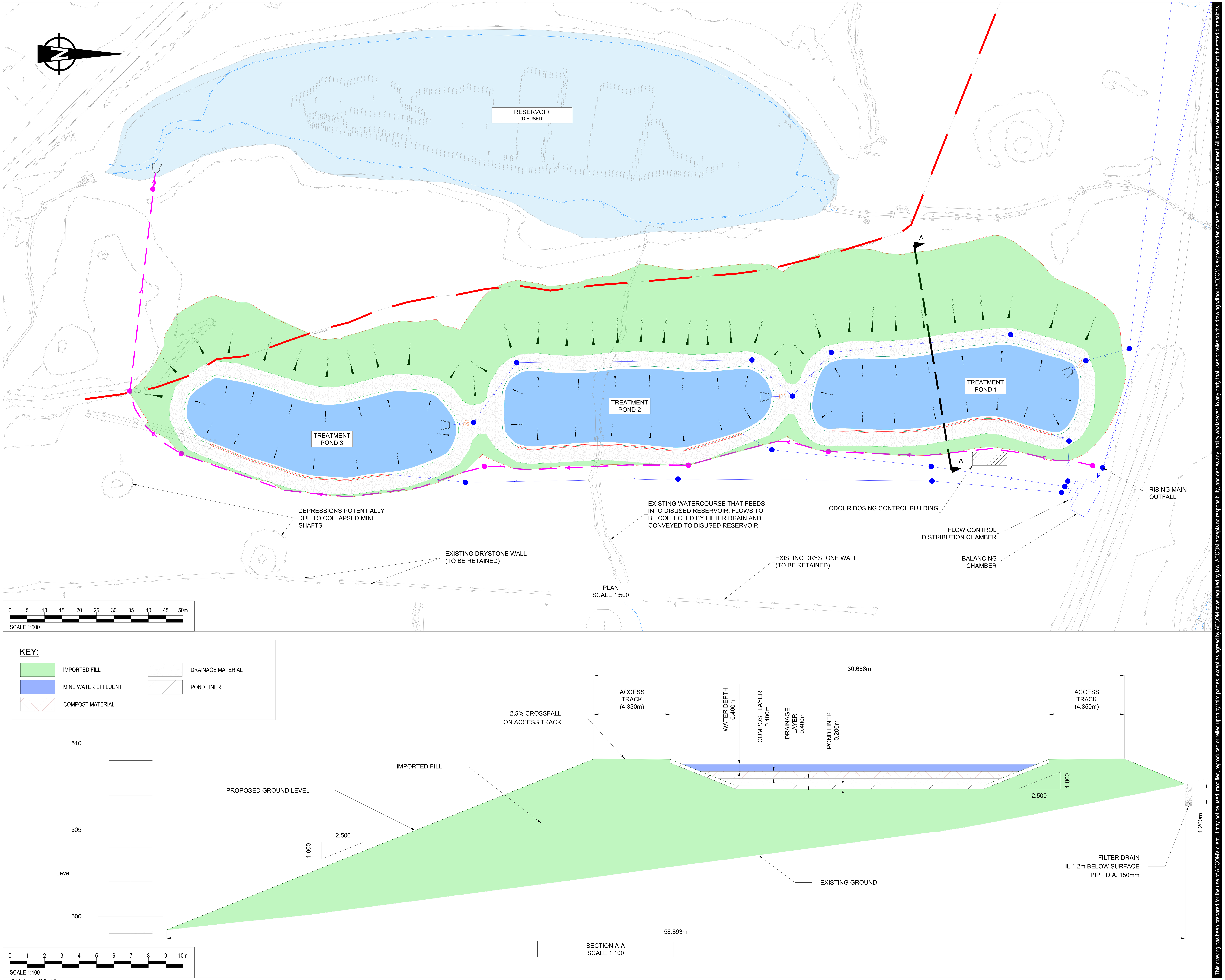
Drawing Number
FIGURE 6
Rev
0

File Name:\\eu.aecomnet.com\emea\UK\UKLDS2\Jobs\PR-389512_Nenthead_Outline_Des\900_CAD_GIS\912_GIS\02 Maps\Heritage\Proposed Ground Investigation_AG.mxd

Appendix C - Option 1 GA (3 Ponds)

Project Management Initials: Designer: JC Checked: AL Approved: KJ

Filename: \\EU.AECOMNET.COM\EMIA\UK\UKLDS2\JOBS\PR-389512_NENTHEAD_OUTLINE_DES\900_CAD_GIS\910_CAD\CE\WORKING DRAWINGS\MWTS-AEC-NC-XX-DR-C-2020 - FIGURE 3.1 - TREATMENT AREA POND GA (OPTION 1) REV 01.DWG Last saved by: JAMIE.CARROLL Last Plotted: 2020-06-12



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- SURFACE WATER RISING MAIN
- SURFACE WATER MANHOLE
- HEADWALL
- POND EXTENTS
- WATER LEVEL
- ACCESS TRACK
- ODOUR DOSING CONTROL BUILDING
- ODOUR DOSING CHAMBER
- MINE WATER DISTRIBUTION CHANNEL
- SURFACE RUNOFF FILTER DRAIN
- SURFACE RUNOFF FILTER DRAIN MANHOLE
- EARTHWORKS SCAR (SUSPECTED BURIED SURFACE WATER DRAINAGE PIPE)
- ACCESS TRACK
- ENGINEERED SLOPE
- POND WATER SURFACE

ISSUE/REVISION

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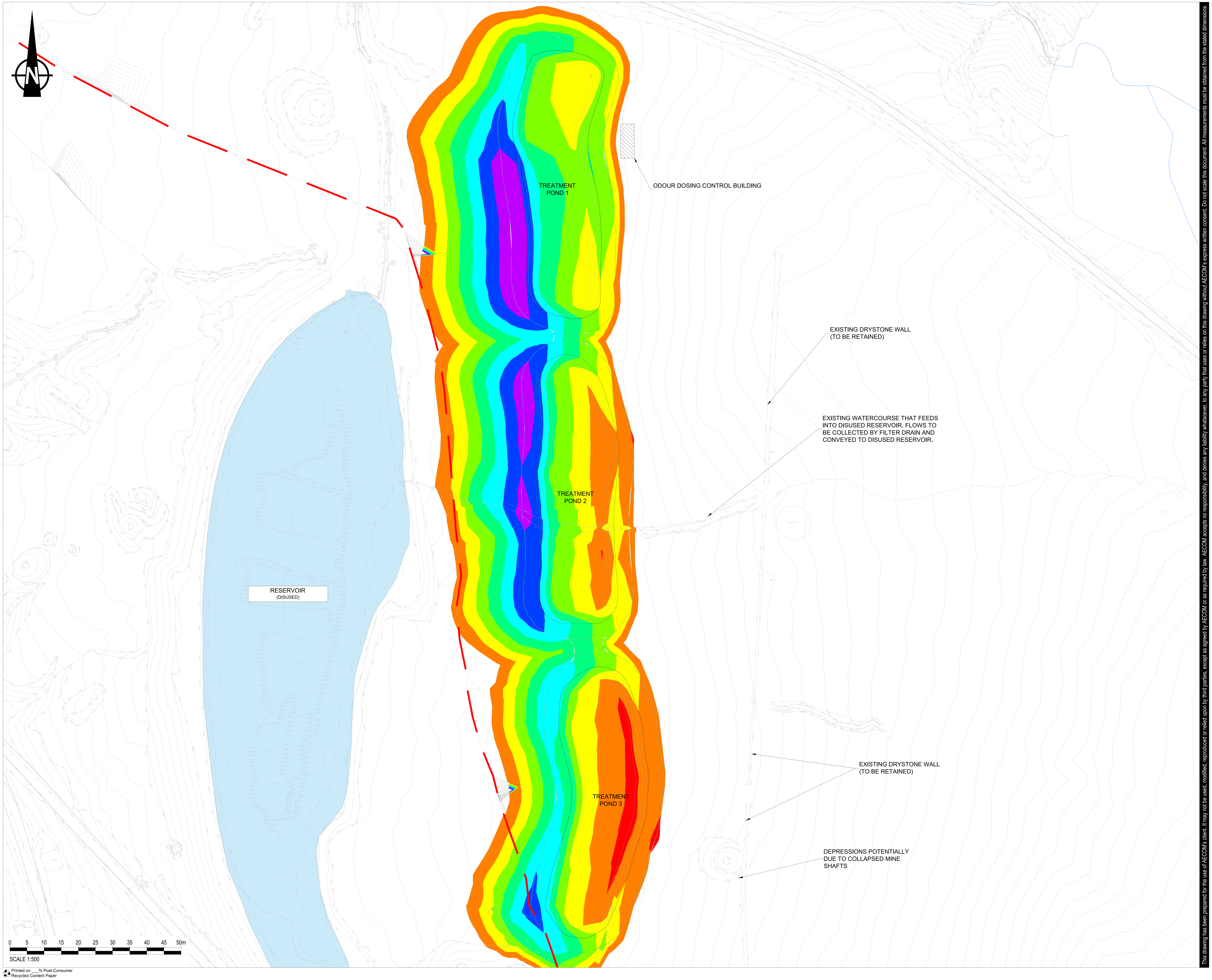
SHEET TITLE

FIGURE 3.1 - TREATMENT AREA POND GENERAL ARRANGEMENT (OPTION 1 - 3 PONDS)

SHEET NUMBER

MWTS-AEC-NC-XX-DR-C-2020

Appendix D – Option 1 Heatmap GA



ISO A1 594mm x 841mm

Approved: KJ

Checked: AL

Designer: JC

Project Management Initials:

Filename: \\EU.AECOMNET.COM\EMEA\UKLDS2\JOBS\PR-389512_NENTHEAD_OUTLINE_DES\900_CAD_GIS\910_CAD\CE\WORKING DRAWINGS\MWTS-AEC-NC-XX-DR-C-2023 - FIGURE 4.1 - TREATMENT AREA POND HEAT MAP (OPTION 1).DWG Last saved by: JAMIE.CARROLL Last Plotted: 2020-06-15

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SURFACE LEVEL DATA

NUMBER	MIN. LEVEL	MAX. LEVEL	COLOUR
1	-0.50	0.00	red
2	0.00	1.00	orange
3	1.00	2.00	yellow
4	2.00	3.00	light green
5	3.00	4.00	green
6	4.00	5.00	cyan
7	5.00	6.00	blue
8	6.00	7.00	purple

KEY:

EARTHWORKS SCAR (SUSPECTED BURIED SURFACE WATER DRAINAGE PIPE)

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SHEET TITLE

FIGURE 4.1 - TREATMENT AREA POND HEAT MAP (OPTION 1 - 3 PONDS)

SHEET NUMBER

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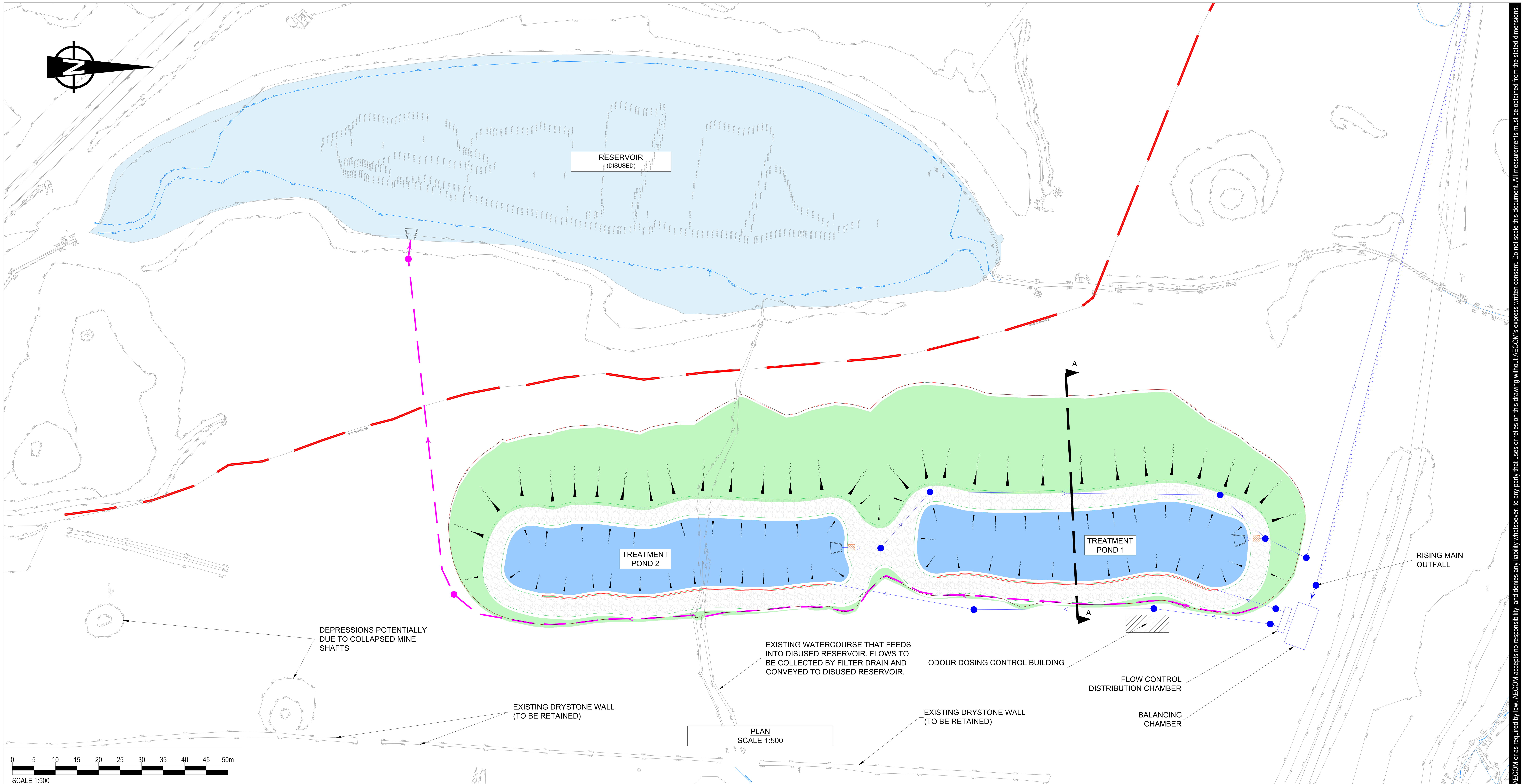
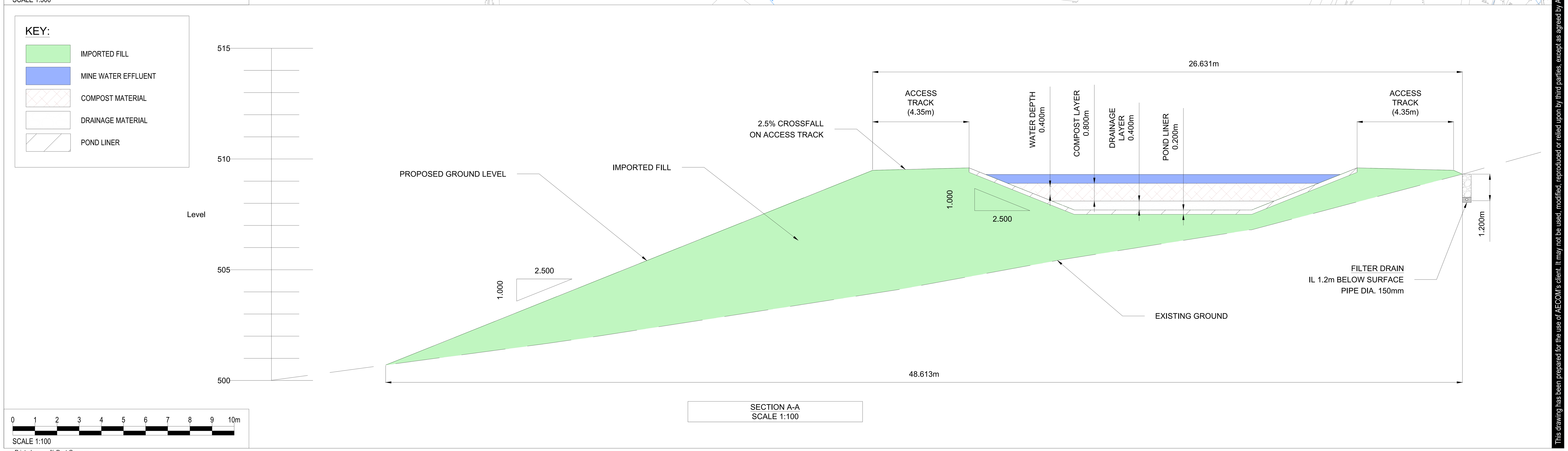
Appendix E - Option 2 GA (2 Ponds)





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- SURFACE WATER RISING MAIN
- SURFACE WATER MANHOLE
- HEADWALL
- POND EXTENTS
- WATER LEVEL
- ACCESS TRACK
- ODOUR DOSING CONTROL BUILDING
- ODOUR DOSING CHAMBER
- MINE WATER DISTRIBUTION CHANNEL
- SURFACE RUNOFF FILTER DRAIN
- SURFACE RUNOFF FILTER DRAIN MANHOLE
- EARTHWORKS SCAR (SUSPECTED BURIED SURFACE WATER DRAINAGE PIPE)
- ACCESS TRACK
- ENGINEERED SLOPE
- POND WATER SURFACE

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FIGURE 3.2 - TREATMENT AREA POND GENERAL ARRANGEMENT (OPTION 2 - 2 PONDS)

SHEET NUMBER

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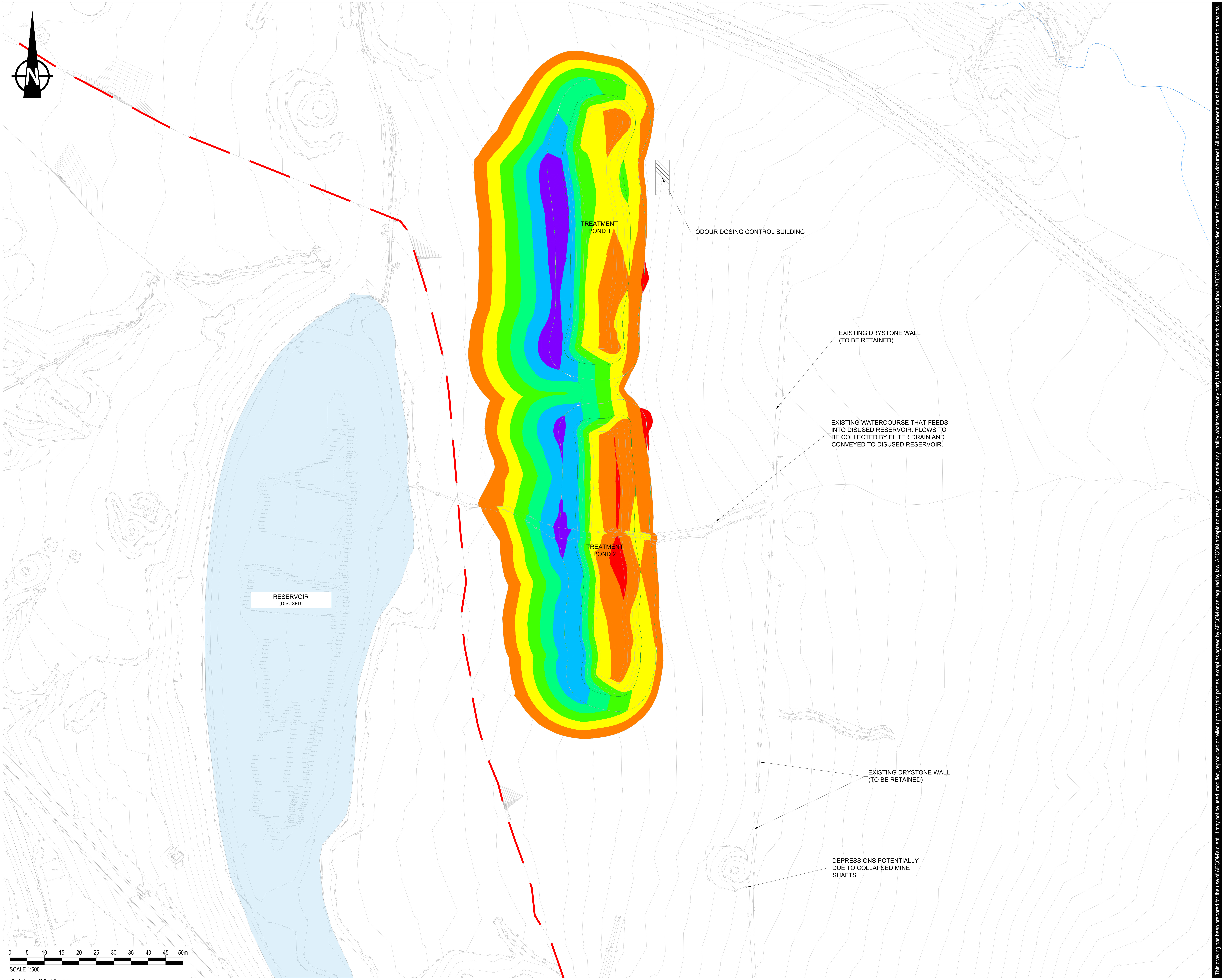
Appendix F – Option 2 Heatmap GA



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SURFACE LEVEL DATA

NUMBER	MIN. LEVEL	MAX. LEVEL	COLOUR
1	-0.50	0.00	
2	0.00	1.00	
3	1.00	2.00	
4	2.00	3.00	
5	3.00	4.00	
6	4.00	5.00	
7	5.00	5.75	

KEY:

EARTHWORKS SCAR (SUSPECTED BURIED SURFACE WATER DRAINAGE PIPE)

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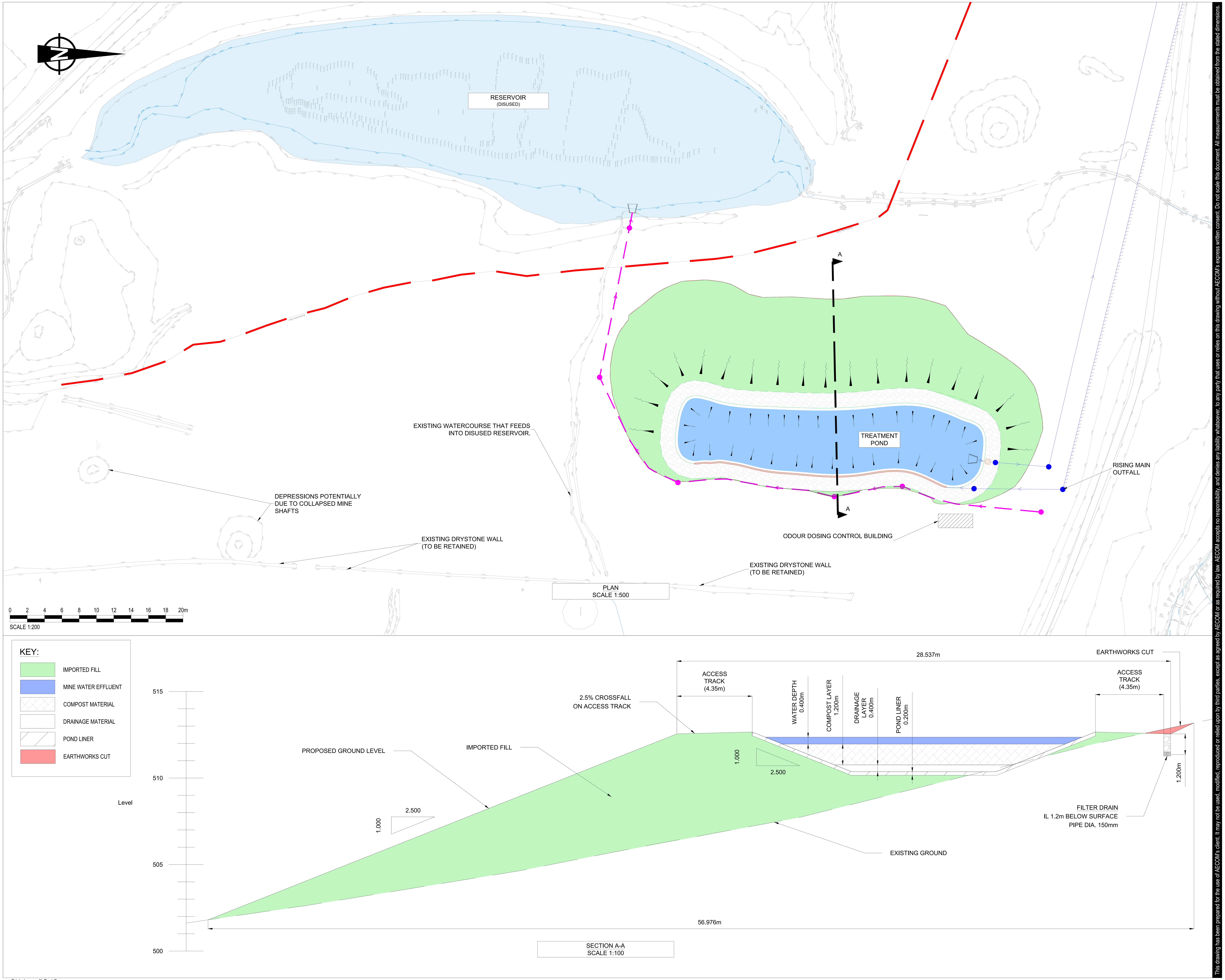
SHEET TITLE

FIGURE 4.2 - TREATMENT AREA POND HEAT MAP (OPTION 2 - 2 PONDS)

SHEET NUMBER

MWTS-AEC-NC-XX-DR-C-2024

Appendix G - Option 3 GA (1 Pond)



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- POND EXTENTS
- WATER LEVEL
- ACCESS TRACK
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- ODOUR DOSING CHAMBER
- MINE WATER DISTRIBUTION CHANNEL
- SURFACE RUNOFF FILTER DRAIN
- SURFACE RUNOFF FILTER DRAIN MANHOLE
- EARTHWORKS SCAR (SUSPECTED BURIED SURFACE WATER DRAINAGE PIPE)
- ACCESS TRACK
- ENGINEERED SLOPE
- POND WATER SURFACE

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SHEET TITLE
FIGURE 3.3 - TREATMENT AREA POND GENERAL ARRANGEMENT (OPTION 3 - 1 POND)

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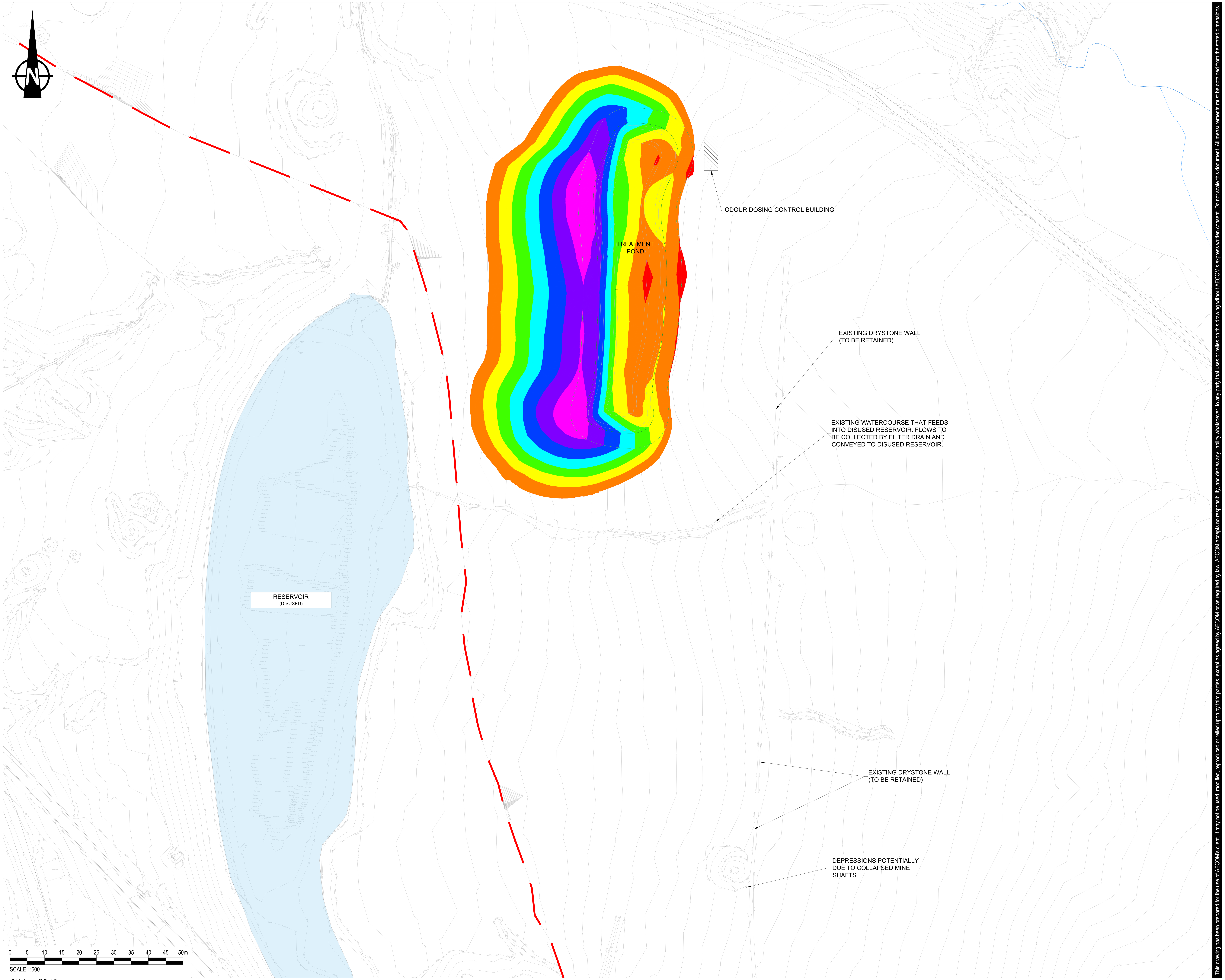
Appendix H – Option 3 Heatmap GA



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SURFACE LEVEL DATA

NUMBER	MIN. LEVEL	MAX. LEVEL	COLOUR
1	-0.50	0.00	Red
2	0.00	1.00	Orange
3	1.00	2.00	Yellow
4	2.00	3.00	Green
5	3.00	4.00	Cyan
6	4.00	5.00	Blue
7	5.00	6.00	Purple
8	6.00	6.97	Magenta

KEY:

EARTHWORKS SCAR (SUSPECTED BURIED SURFACE WATER DRAINAGE PIPE)

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SHEET TITLE

FIGURE 4.3 - TREATMENT AREA POND HEAT MAP (OPTION 3 - 1 POND)

SHEET NUMBER

MWTS-AEC-NC-XX-DR-C-2025

Appendix I - Autodesk Civil 3D Cut/Fill

Cut/Fill Report

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By user: jamie.carroll

Drawing: \\eu.aecomnet.com\emia\UKI\UKLDS2\Jobs\PR-389512_Nenthead_Outline_Des\900_CAD_GIS\910_CAD\CE\Working Drawings\Civil 3D\\\eu.aecomnet.com\emia\UKI\UKLDS2\Jobs\PR-389512_Nenthead_Outline_Des\900_CAD_GIS\910_CAD\CE\Working Drawings\Civil 3D\General Arrangement - 3 Pond Layout V3.2.dwg

Volume Summary

Name	Type	Cut Factor	Fill Factor	2d Area (sq.m)	Cut (Cu. M.)	Fill (Cu. M.)	Net (Cu. M.)
Final Design (3D)	full	1.000	1.000	14519.446	31.937	37173.339	37141.402<Fill>

Totals

	2d Area (sq.m)	Cut (Cu. M.)	Fill (Cu. M.)	Net (Cu. M.)
Total	14519.446	31.937	37173.339	37141.402<Fill>

* Value adjusted by cut or fill factor other than 1.0

Cut/Fill Report

Generated: 2020-05-19 10:29:33

By user: jamie.carroll

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Volume Summary

Name	Type	Cut Factor	Fill Factor	2d Area (sq.m)	Cut (Cu. M.)	Fill (Cu. M.)	Net (Cu. M.)
Final Design (3D)	full	1.000	1.000	8786.347	14.960	19602.820	19587.860<Fill>

Totals

	2d Area (sq.m)	Cut (Cu. M.)	Fill (Cu. M.)	Net (Cu. M.)
Total	8786.347	14.960	19602.820	19587.860<Fill>

* Value adjusted by cut or fill factor other than 1.0

Cut/Fill Report

Generated: 2020-05-19 10:28:25

By user: jamie.carroll

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Volume Summary

Name	Type	Cut Factor	Fill Factor	2d Area (sq.m)	Cut (Cu. M.)	Fill (Cu. M.)	Net (Cu. M.)
Final Design (3D)	full	1.000	1.000	6288.446	13.494	16870.630	16857.136<Fill>

Totals

	2d Area (sq.m)	Cut (Cu. M.)	Fill (Cu. M.)	Net (Cu. M.)
Total	6288.446	13.494	16870.630	16857.136<Fill>

* Value adjusted by cut or fill factor other than 1.0

Appendix J – AECOM Calculations

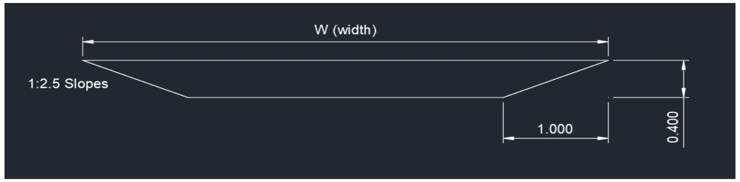
Nenthead, Cumbria

3 Pond Layout Calculations

Date:	15.06.2020
Calculations:	JC
Checked:	AL
Approved:	KJ

Design Parameters	
Pond Side Slopes (1:2.5)	0.40
Design Flowrate (l/s)	10
Residence Time (hr)	15
Porosity	0.35
Total Compost Volume Required (m3)	1542.86
Pond Excavation Depth (m)	0.5
Pond Construction Depth (m)	2.1

Pond Cross-Section



Calculation Results

Pond	Design Flowrate (l/s)	Pond Design Depth (m)	Compost Layer Depth (m)	Compost Volume Required (m^3)	Top Surface Area (m2)
P1	3.33	2.100	0.400	514.29	1286.71
P2	3.33	2.100	0.400	514.29	1285.71
P3	3.33	2.100	0.400	514.29	1285.71
Total	10	6.300	1.200	1542.86	3858.14

Compost Volume (m^3) = 514.286 = 2*0.5*HL + (W-1*2)HL
W = compost surface layer width, L = length of pond, H = depth of compost layer (0.4m)
SA = WL = (514.286+0.4)/H ; SA = 1286.715m
Compost based on nominal fill time of 19.5 hours.
At nenthead actual residence time was 15 hours.

Pond	Pond Level Elevations (mAOD)								
	Surface Level Reference (m)	Pond Base (m)	Top Level of Lining Layer (m)	Top Level of Drainage Layer (m)	Top Level of Compost Layer (m)	Top Level of Operating Water Level (m)	Freeboard Level (m)	Access Track Level - Inner Edge (m)	Access Track Level - Outer Edge (2.5% Crossfall) (m)
P1	508.000	507.500	507.700	508.100	508.500	508.900	509.200	509.200	509.091
P2	508.000	507.500	507.700	508.100	508.500	508.900	509.200	509.200	509.091
P3	508.000	507.500	507.700	508.100	508.500	508.900	509.200	509.200	509.091

Assumptions:
Ponds design at total 1.7m depth
Pond minimum depth: 500mm below ground surface
Access Track 4.35m wide
400mm compost
400mm stone drainage
400mm normal operating water
200mm thick pond liner beneath pond
300mm freeboard
2.5% Crossfall from inner to outer edge of path

Three Pond Layout (From Model)

Pond	Approx. Width; excluding slopes (m)	Approx. Length; excluding slopes (m)	Model Footprint Area; including slopes (m2)	Pond Compost Surface Area (m^2)	Drainage Layer Surface Area (m^2)	Stone Volume; 400mm depth (m^3)
P1	30.500	86.500	-	1,349.66	1,174.79	436.36
P2	30.000	87.000	-	1,348.87	1,177.60	438.05
P3	30.500	93.600	-	1,351.48	1,179.85	438.97
Total	-	-	14577.955	4,050.01	2,352.39	1,313.37

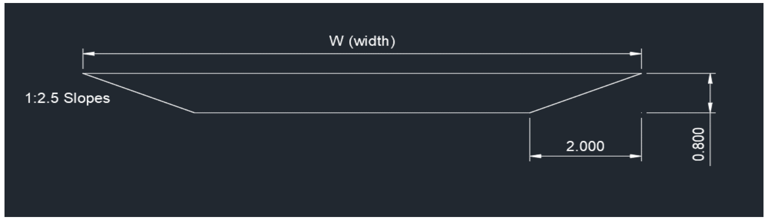
Cut/Fill Summary	Cut Volume (m3)	Fill Volume (m3)	Net Cut/Fill Volume (m3)	Cut: Fill Ratio
Total	31.94	37173.34	37141.40	0.001

Nenthead, Cumbria

2 Pond Layout Calculations

Date:	15.06.2020
Calculations:	JC
Checked:	AL
Approved:	KJ

Pond Cross-Section



Design Parameters	
Pond Side Slopes (1:2.5)	0.40
Design Flowrate (l/s)	10
Residence Time (hr)	15
Porosity	0.35
Total Compost Volume Required (m3)	1542.86
Pond Excavation Depth (m)	0.5
Pond Construction Depth (m)	2.1

Calculation Results

Pond	Design Flowrate (l/s)	Pond Design Depth (m)	Compost Layer Depth (m)	Compost Volume Required (m³)	Top Surface Area (m2)
P1	5	2.100	0.800	771.43	967.29
P2	5	2.100	0.800	771.43	967.29
Total	10	-	1.600	1542.86	1934.57

Compost Volume (m^3) = 771.429 = 2*0.5*HL + (W-2*2)HL
W = compost surface layer width, L = length of pond, H = depth of compost layer (0.8m)
SA = WL = (771.429 + 2.4) / H ; SA = 967.286m^2
Compost based on nominal fill time of 19.5 hours.
At nenthead actual residence time was 15 hours.

Pond	Pond Level Elevations (mAOD)								
	Surface Level Reference (m)	Pond Base (m)	Top Level of Lining Layer (m)	Top Level of Drainage Layer (m)	Top Level of Compost Layer (m)	Top Level of Operating Water Level (m)	Freeboard Level (m)	Access Track Level - Inner Edge (m)	Access Track Level - Outer Edge (2.5% Crossfall) (m)
P1	508.000	507.500	507.700	508.100	508.900	509.300	509.600	509.600	509.491
P2	508.000	507.500	507.700	508.100	508.900	509.300	509.600	509.600	509.491

Assumptions:
Ponds design at total 2.1m depth
Pond minimum depth: 500mm below ground surface
Access Track 4.35m wide
400mm compost
400mm stone drainage
400mm normal operating water
200mm thick pond liner beneath pond
300mm freeboard
max water operating level 400mm above average water level
2.5% Crossfall from inner to outer edge of path

Two Pond Layout (From Model)

Pond	Approx. Width; excluding slopes (m)	Approx. Length; excluding slopes (m)	Model Surface Area; including slopes (m2)	Pond Compost Surface Area (m²)	Drainage Layer Surface Area (m²)	Stone Volume; 400mm depth (m³)
P1	26.000	87.300	-	1,010.22	679.62	240.69
P2	25.750	89.200	-	1,010.30	671.59	236.91
Total	-	-	8786.347	2,020.52	1,351.21	477.59

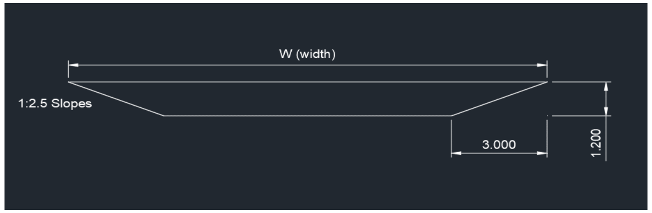
Cut/Fill Summary	Cut Volume (m3)	Fill Volume (m3)	Net Cut/Fill Volume (m3)	Cut: Fill Ratio
Total	14.96	19602.82	19587.86	0.00

Nenthead, Cumbria

1 Pond Layout Calculations

Date:	15.06.2020
Calculations:	JC
Checked:	AL
Approved:	KJ

Pond Cross-Section



Design Parameters	
Pond Side Slopes (1:2.5)	0.40
Design Flowrate (l/s)	10
Residence Time (hr)	15
Porosity	0.35
Total Compost Volume Required (m3)	1542.86
Pond Excavation Depth (m)	0.5
Pond Construction Depth (m)	2.5

Calculation Results

Pond	Design Flowrate (l/s)	Pond Design Depth (m)	Compost Layer Depth (m)	Compost Volume Required (m^3)	Top Surface Area (m2)
P1	10	2.500	1.200	1542.86	1290.71

Compost Volume (m^3) = 1542.857 = 2*0.5*HL + (W-3*2)HL
W = compost surface layer width, L = length of pond, H = depth of compost layer (1.2m)
SA = WL = (1542.857 + 6) / H ; SA = 1290.714 m2
Compost based on nominal fill time of 19.5 hours.
At nenthead actual residence time was 15 hours.

Pond	Pond Level Elevations (mAOD)								
	Surface Level Reference (m)	Bottom of Pond (m)	Top Level of Lining Layer (m)	Top Level of Drainage Layer (m)	Top Level of Compost Layer (m)	Top Level of Operating Water Level (m)	Freeboard Level (m)	Access Track Level - Inner Edge (m)	Access Track Level - Outer Edge (2.5% Crossfall) (m)
P1	510.000	509.500	509.700	510.100	511.300	511.700	512.000	512.000	511.891

Assumptions:
Ponds design at total 2.5m depth
Pond minimum depth: 500mm below ground surface
Access Track 4.35m wide
400mm compost
400mm stone drainage
400mm normal operating water
200mm thick pond liner beneath pond
300mm freeboard
max water operating level 400mm above average water level
2.5% Crossfall from inner to outer edge of path

One Pond Layout (From Model)

Pond	Approx. Width; excluding slopes (m)	Approx. Length; excluding slopes (m)	Model Surface Area; including slopes (m2)	Pond Compost Surface Area (m^2)	Drainage Layer Surface Area (m^2)	Stone Volume; 400mm depth (m^3)
P1	27.750	100.000	6288.45	1,347.38	778.88	276.40

Cut/Fill Summary	Cut Volume (m3)	Fill Volume (m3)	Net Cut/Fill Volume (m3)	Cut: Fill Ratio
P1	13.49	16870.63	16857.14	0.00

Nenthead, Cumbria

Cost Comparison

Date:	15.06.2020
Calculations:	JC
Checked:	AL
Approved:	KJ

1. Introduction

The following cost analysis seeks to offer a comparison of the potential costs of the three options outlined. For the purposes of this comparison, all features that are common to all three options have not been considered. An example of this would be site mobilisation, as it is fair to assume that this cost would be similar for each option. By excluding common costs, the analysis can focus on the aspects that separate the options outlined and highlight the advantages and disadvantages of each.

Unless otherwise stated, all costs have been sourced from Spon's Civil Engineering and Highway Works Price Book 2019. The source page of each rate has been referenced.

Option 1 contains 3 ponds; Option 2 contains 2 ponds and Option 3 contains 1 pond.

Assumptions:

a) Topsoil present on site will require clearance and a depth of 200mm has been assumed

b) Removed topsoil assumed to provide suitable material for bedding layer & paver fill for access track construction

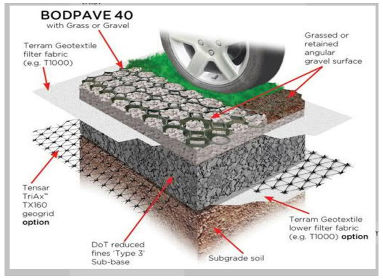
c) The number of ponds only affects operational costs in relation to odour control (i.e. setup costs are consistent between options)

d) The following costs have been assumed to be consistent;

- On-site buildings (i.e. Welfare & Odour building costs)
- Aeration Cascade
- Pumping Arrangements
- Compost material
- Drainage connection costs
- Site establishment & demobilisation
- Location cost factors
- Associated fees (i.e. designers, contractors, contingency etc.)
- Polishing pond for each option

Model Output Parameters	Unit	Option 3	Option 2	Option 1
Footprint Area of Proposal	m^2	6288.45	8786.35	14519.45
Cut Volume	m^3	13.49	14.96	31.94
Fill Volume	m^3	16870.63	19602.82	37173.34
Access Track Surface Area	m^2	968.66	1783.60	2727.67

Site Clearance	Unit	Quantity			Unit Rate	Cost Reference	Cost		
		Option 3	Option 2	Option 1			Option 3	Option 2	Option 1
Excavation of topsoil (200mm) Cost provided covers maximum depth ne 0.25m	m^3	1257.69	1757.27	2903.89	£3.52	Page 183	£4,427.07	£6,185.59	£10,221.69
Excavate material other than topsoil, rock or artificial hard material; 0.25-0.5m depth	m^3	13.49	14.96	31.94	£3.52	Page 183	£47.50	£52.66	£112.42
Disposal of Excavated Topsoil (200mm); Removal 15km distance	m^3	1257.69	1757.27	2903.89	£26.81	Page 186	£33,718.65	£47,112.39	£77,853.27
Disposal of excavated earth other than rock or artificial hard material; removal; 15km distance; using 20 t tipper	m^3	13.49	14.96	31.94	£28.08	Page 186	£378.91	£420.08	£896.79
Landfill tax; applies to all waste Standard rate	m^3	1271.18	1772.23	2935.83	£94.15	HMRC Guidance: Landfill Tax rates	£119,681.90	£166,855.40	£276,408.04
						Total	£158,254.02	£220,626.11	£365,492.21
						Percentage Increase on low-cost Option	-	39.41%	130.95%



Pond Construction	Unit	Quantity			Unit Rate	Cost Reference	Cost		
		Option 3	Option 2	Option 1			Option 3	Option 2	Option 1
Pond Liner	m^2	1700.43	2647.45	4997.63	£9.62	AECOM Past Project	£16,358.15	£25,468.44	£48,077.20
Imported Fill Volume; Cohesive material DfT Class 2 A/B/C/D (1.8 t/m3); using tractor loader. Imported acceptable material in embankments and other areas of fill.	m^3	15874.18	18532.66	36507.72	£26.64	Page 410	£422,888.18	£493,710.08	£972,565.74
Drainage Layer; (400mm depth) imported well graded granular material (1.90 t/m³); (bedding/free draining materials under shore protection) using tractor loader; Imported acceptable material in embankments and other areas of fill	m^3	276.40	477.59	1313.37	£33.39	Page 411	£9,229.13	£15,946.85	£43,853.51
Seeding for slopes	m^2	3898.21	4679.15	7448.03	£7.01	Page 495	£27,326.44	£32,800.87	£52,210.68
						Total	£475,801.90	£567,926.24	£1,116,707.12
						Percentage Increase on low-cost Option	-	19.36%	134.70%

Access Track Construction	Unit	Quantity			Unit Rate	Cost Reference	Cost		
		Option 3	Option 2	Option 1			Option 3	Option 2	Option 1
Track Surface Area	m^2	968.66	1783.60	2727.67	-	-	-	-	-
BODPAVE 40 (40mm deep paving grid)	m^2	968.66	1783.60	2727.67	£16.50	Supplier Price (Green-tech)	£15,982.89	£29,429.38	£45,006.51
Geogrid & Geotextiles; stabilization applications for reinforcement of granular subbases, capping layers and railway ballast placed over weak and variable soils. Geotextiles; stabilization applications for reinforcement of granular subbases, capping layers and railway ballast placed over weak and variable soil. For use over weak soils with moderate traffic intensities, e.g. car parks, light access roads; Tensar SS20 Polypropylene Geogrid Note: 3 Layers required for BODPAVE build up.	m^2	968.66	1783.60	2727.67	£3.66	Spons: Page 191	£10,635.89	£19,583.92	£29,949.78
Sub-Base (100mm thick): Type 3 (open grade) unbound mixtures Subbase; spread and graded; 60-100mm thick	m^3	96.87	178.36	272.77	£134.48	Spons: 297	£13,026.54	£23,985.84	£36,681.67
						Total	£39,645.32	£72,999.14	£111,637.95
						Percentage Increase on low-cost Option	-	84.13%	181.59%

Drainage	Unit	Quantity			Unit Rate	Cost Reference	Cost		
		Option 3	Option 2	Option 1			Option 3	Option 2	Option 1
Filter drains installed uphill of ponds (m) POLYVINYL CHLORIDE PIPES – 150mm Dia, in trenches, depth not exceeding 1.5m. Ultrarib unplasticized PVC pipes; ring seal joints; excavation and supports, backfilling (up to 1.5m deep)	m	105.00	195.00	290.00	£49.20	Page 240	£5,166.00	£9,594.00	£14,268.00
Catchpits: Polypropylene inspection chambers 475mm dia. PPIC inspection chamber including all excavations; earthwork support; cart away surplus spoil; concrete bed and surround; lightweight cover and frame	m	2.00	4.00	6.00	£402.50	Page 145	£805.00	£1,610.00	£2,415.00
						Total	£5,971.00	£11,204.00	£16,683.00
						Percentage Increase on low-cost Option	-	87.64%	179.40%

Other Costs	Unit	Quantity			Unit Rate	Cost Reference	Cost		
		Option 3	Option 2	Option 1			Option 3	Option 2	Option 1
Manhole : 1350 × 700 chamber 2500 depth to invert; excavation, support, backfilling and disposal; concrete base; brickwork chamber and access shaft (700 × 700); concrete reducing slab; concrete cover slab; concrete benching, main and branch channels; step irons; access cover and frame	No.	1.00	0.00	0.00	£3,217.44	Page 246	£3,217.44	£0.00	£0.00
Distribution Chamber (2m x 1m); 1m deep WATER AND TREATMENT FACILITIES - Reinforced concrete tanks; excavation, fill, structural work, valves, penstocks, pipework	m^3	0.00	1.00	1.00	£815.00	Page 148	£0.00	£1,630.00	£1,630.00
Hydrobrakes	No.	0.00	2.00	3.00	£3,000.00	Assumed Cost	£0.00	£6,000.00	£9,000.00
Penstocks; cast iron; wall mounted; hand operated; 350mm	No.	0.00	2.00	3.00	£831.91	Spons 241	£0.00	£1,663.82	£2,495.73
						Total	£0.00	£9,293.82	£13,125.73
						Percentage Increase on low-cost Option	-	N/A	N/A

	Option 3	Option 2	Option 1
TOTALS	£679,672.23	£882,049.31	£1,623,646.01
Percentage Increase on low-cost Option	-	29.78%	138.89%

Typical Construction Profile