HIGHGATE CEMETERY

LONDON

LANDSCAPE SOIL MANAGEMENT STRATEGY REPORT

Prepared on behalf of:

GUSTAFSON PORTER + BOWMAN

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Prepared by:

Tim O'Hare Associates LLP
Howbery Park, Wallingford
Oxfordshire, OX10 8BA,
United Kingdom
Web: www.toha.co.uk

TIM O'HARE ASSOCIATES

SOIL & LANDSCAPE CONSULTANCY

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1.0 INTRODUCTION

Tim O'Hare Associates LLP was commissioned by Gustafson Porter + Bowman (GP+B) to produce a Landscape Soil Management Strategy Report to inform the soft landscape scheme design for the Highgate Cemetery project, London.

Highgate Cemetery is considered one of the world's most iconic cemeteries, with a long history dating back to the late 1830's. The Cemetery is split between the Eastern and Western Cemeteries, which are divided by Swain's Lane.

Historically the cemetery comprised managed and maintained gardens, however over time, the landscape was allowed to develop a natural 'wilderness', with a dense monoculture of Ash trees across the site. Environmental factors including climate-change and the prevalence of Chalara Ash Dieback within the cemetery has resulted in the need for intervention to preserve the monuments and graves and protect users within the park.

The removal of a large number of the existing Ash trees provides an opportunity to develop a new landscape scheme that looks to both the history of the site as well as the future. The design is intended to take inspiration from the historical landscape and character of the cemetery whilst introducing more environmental resilience and ecological diversity. The works will also enhance the visitor experience, allow for better interconnectivity between the two sides of the cemetery and provide a more easily managed landscape.

The project is currently at RIBA Stage 3 and the landscape proposals have progressed to a level of detail where it is possible to determine the main soil requirements. The design incorporates a diverse range of planting environments and soils of variable composition and function are therefore likely to be required. Due to the site constraints and its historical value, it will be necessary to minimise disturbance to the existing soils and re-use as much of the resource (topsoil and subsoil) as possible for the new landscape.

Investigations relating to existing ground conditions have previously been undertaken, the findings of which have been reviewed and utilised to ascertain the soil requirements of the scheme.

2.0 SCOPE OF WORKS

A technical review has been undertaken of the various elements of the project's design that will influence, or be influenced by, soils. This includes the following information:

- current landscape design (layouts and planting types, soil depths / types, selected species, etc.);
- existing soil resources on site to identify their nature and variability;
- topography, formation and finished levels;
- ecological targets;
- irrigation, water and drainage strategies;
- environmental requirements.

The purpose of this review is to determine the soil requirements for the various landscape habitats to be established and to identify the opportunities and constraints presented by the existing site soil resources. The study has also sought to ascertain the need for provision of imported soils, soil ameliorants and drainage as necessary.

2.1 Document Review

The following documents have been reviewed:

- Gustafson, Porter + Bowman – *Highgate Cemetery Landscape Masterplan – Stage 2 Report* – dated 15/06/2023
- Jo Thompson Garden Design / Gustafson, Porter + Bowman – *Highgate – Stage 3* – dated June 2023
- Gustafson, Porter + Bowman – Draft Soft Details (WIP) – issued to TOHA for review on 28/06/2024
- Gustafson, Porter + Bowman – 240713_GPB_Highgate base diagrams_Stage 3_Irrigation2-01 - issued to TOHA for information on 15/07/2024
- Max Fordham – *J7048 Highgate Cemetery Landscape - Stage 2 Report* – dated 12/06/2023
- Ashgrove Ecology Ltd – *Highgate Cemetery – Ecological Baseline Report* – version 3, dated September 2022
- Ashgrove Ecology Ltd – *Highgate Cemetery – Ground Level Tree Assessment (Phase 1)* – version 1, dated October 2023
- Bartlett Tree Experts Ltd – Priority Tree Removals West Cemetery – Drawing Ref. *JPL/220484/R - Highgate Cemetery 1 of 2* – dated 31/08/2022
- Bartlett Tree Experts Ltd – Priority Tree Removals East Cemetery – Drawing Ref. *JPL/220484/R - Highgate Cemetery 2 of 2* – dated 31/08/2022
- Bartlett Tree Experts Ltd – Priority Tree Removals West Cemetery – Drawing Ref. *JPL/220484/R - Highgate Cemetery 1 of 2* – dated 31/08/2022
- Bartlett Tree Experts Ltd – *Stage 2 – Highgate Cemetery Woodland Ash Dieback & Canker Survey* – Report Ref. *JPL/220284/R* – East Cemetery and West Cemetery
- The Morton Partnership
- Mayer Environmental – *Highgate Cemetery – Soil Resource Survey Report* – Report Ref. R129-1880, Dated September 2022
- Albury S.I. Ltd – *Highgate Cemetery – Phase 1 Desk Study and Phase 2 Site Investigation Report* – Report Ref. 21/12141/GO – Dated July 2021
- Tim O'Hare Associates – *Technical Note – Soil Resource Survey Review* – Ref. *TOHA/24/8209/MH/TN1*, dated 7th March 2024
- Sub-Surface Soil Infiltration Test Report Ref. SE1801, dated 21/05/2024

In addition workshops have been attended to discuss the current proposals.

3.0 PROJECT PROPOSALS

3.1 Landscape Proposals

The landscape proposals are to take inspiration from the historic planting of the cemetery whilst creating more diverse landscape habitats that re-establish historic views within the cemetery and into London. The landscape proposals for Western and Eastern Cemeteries from the Stage 3 design are summarised in Table 1 below.

The proposals will include retaining selected trees and habitats based on their wider significance to the landscape and environment. A new network of paths is to traverse the cemetery. Sustainable Urban Drainage System (SuDS) features are proposed on one or both sides of main pathways.

Varying planting typologies are to be included, as discussed in Section 3.2 below.

3.1.1 Proposed Typologies

The proposed planting mixes identified within Stage 3 information are summarised in Table 1 below. Species mixes have been varied according to light levels and anticipated soil type.

Table 1: Proposed landscape typologies

Planting Typology	Summary of Planting Types
YW1 Yew Woodland	90% seeded 10% planting (9% herbaceous, 1% shrubs) 8-10 bulbs per sqm
BW1 Broadleaved Woodland with shade on light soils	
BW2 Broadleaved Woodland with sun on light soils	
BW3 Broadleaved Woodland with hade on medium to heavy soils	
BW4 Broadleaved Woodland with sun on medium to heavy soils	
BW5 Broadleaved Woodland with shade on heavy soils	
BW6 Broadleaved Woodland with sun on heavy soils	
WW1 Wet Woodland with shade on heavy soils	
WW2 Wet Woodland with sun on heavy soils	
SA1 Stream with sun on heavy soils	10% planting (9% herbaceous, 1% shrubs) 8 bulbs per sqm Majority of planting to be retained
HP1 High profile areas – edge of paths (sunny and shaded areas)	100% planting (90% herbaceous, 10% shrubs) 10 bulbs per sqm
EM1 Embankments / Slopes (sunny and shaded areas)	100% planting (80% herbaceous, 20% shrubs) 10 bulbs per sqm

Planting Typology	Summary of Planting Types
GD1 Dry Grassland / meadow with sun on medium to heavy soils	100% seeded
GW1 Wet Grassland /Meadow with sun on heavy soils	100% seeded
GG1 Grassland / Meadow with sun on heavy soils	100% seeded
SP1 Species-rich Lawn with sun on heavy soils	100% seeded
SU1 SuDS	100% planting (95% herbaceous, 5% shrubs) 10 bulbs per sqm
HR1 Hedgerows	100% planting

3.2 Planting Stock Types

The current landscape design comprises a number of new habitats and planting typologies to be created across the two cemeteries as summarised above. At this stage, the planting stock types are anticipated to comprise:

- New tree planting (whips, half standard, light standard (6-8cm girth), select standard (10-12cm girth) or semi-mature (20-25cm girth));
- Ornamental shrub and herbaceous perennials (P9, 1L and 3L pots);
- Containerised hedge plants;
- Bulbs;
- Wet and dry species-rich meadow grassland (seeded).

In addition, a proportion of existing vegetation is to be retained across both cemeteries.

All trees are to be planted within soft landscape. The current proposals do not include any trees to be planted in hard surfacing.

3.3 Current Ground Conditions

Mayer Environmental Soil Resource Survey

The existing in-situ soil resources have been assessed by Mayer Environmental Ltd through desk study review and on-site investigation, the findings of which are presented in the *Highgate Cemetery Soil Survey Report*. A review of the findings this assessment are summarised in the *TOHA Technical Note* (Ref. TOHA/24/8209/MH/TN1) and a summary is presented Table 2 below.

Table 2: Summary of Existing Soil Conditions (Mayer Environmental Ltd Soil Resource Survey)

Western Cemetery	
Topsoil	**Subsoil**
• Average depth: 0.31m (0.10 – 0.5m) (depth not proven at 4 No. locations). • Light soil texture (*sandy loam*) in northeastern and central zone. • Medium soil texture (*sandy clay loam* to *medium clay loam*) in southern and western zone. • Low to moderate (occasionally high) stone content. • Strongly acid to strongly alkaline (pH 5.3 to pH 8.3). • Low salinity. • Moderate reserves of organic matter, total nitrogen and magnesium. • Low to moderate (occasionally high) reserves of extractable phosphorus and potassium. • Topsoil Carbon Stock ranged between 89 – 170t/ha, comprising predominantly *Organic* Carbon (SOC). • High total bacteria and low to good active bacteria, very low to low total fungi and low to good active fungi. • Low numbers of flagellates (except *WC14*), very low levels of amoebae and Nematodes, high numbers of ciliates (except *WC14*). • Low levels of potential contaminants, exceedance of Benzo(a)pyrene and Dibenzo(ah)anthracene at *WC01*.	• Light soil texture (*loamy sand* to *sandy loam*) in northern portion of the site. • Medium soil texture (*sandy clay loam* to *clay loam*) in southern half. • Low stone content. • Strongly acid to slightly alkaline (pH 5.3 – pH 7.3). • Low salinity. • Low to moderate levels of organic matter (1.3% – 2.9%). • Low total nitrogen and extractable potassium. • Low to moderate extractable phosphorus and magnesium. • Subsoil Carbon Stock of 12 t/ha, comprising predominantly *Organic* Carbon (SOC).

Eastern Cemetery	
Topsoil	**Subsoil**
• Average depth: 0.29m (0.20 – 0.45m) (depth not proven at 5 No. locations). • Variable soil texture: light to heavy (*loamy sand*, *sandy loam* and *heavy clay loam*) in northern third. • Generally heavy soil texture (*sandy clay loam*, *heavy clay loam*, *silty clay* and *clay*) in southern two thirds of the site. • Low to moderate stone content. • Slightly acid to alkaline (pH 6.3 to pH 7.9). • Low salinity. • Moderate to high reserves of organic matter, total nitrogen and magnesium. • Low to moderate reserves of extractable phosphorus and potassium. • Topsoil Carbon Stock ranged between 105 – 344t/ha, comprising predominantly *Organic* Carbon (SOC). • High total bacteria and low to good active bacteria, very low to low total fungi and low to high active fungi. • High numbers of flagellates, very low levels of amoebae and Nematodes, very high numbers of ciliates. • Low levels of potential contaminants, exceedance of Benzo(a)pyrene and Dibenzo(ah)anthracene at *EC03* and *EC08* and Benzo(b)fluoranthene at *EC08*.	• Predominantly heavy soil texture (*sandy clay loam*, *heavy clay loam*, *sandy clay*, *silty clay* and *clay* (*loamy sand* at *EC01*)). • Low to high stone content. • Slightly acid to alkaline (pH 6.9 – pH 7.8). • Low salinity. • Moderate levels of organic matter (3.6% – 5.7%). • Low to moderate total nitrogen and extractable potassium. • Generally, very low to low extractable phosphorus (except EC16). • High to very high extractable magnesium.

Based on the findings of the Soil Resource Survey, the existing soils were considered to have potential for landscape re-use. However, a number of horticultural soil properties are likely to impact on their re-use potential. A summary of the main factors is provided below and further discussion on the suitability of the existing soils for the current landscape design is given in Section 4.5.

Soil Texture

The soils in the Western Cemetery were *light* to *medium* in texture. Soils such as these are usually considered suitable for most general landscape purposes provided the soil's physical condition is satisfactory. The medium textured soils would be more susceptible to physical degradation and compaction during handling, and especially when plastic in consistency.

The Eastern Cemetery soils were predominantly *heavy* in texture. Such soils usually have good water and nutrient retention capacities, but they tend to be slow-draining, moisture-retentive and can suffer from seasonal waterlogging following periods of prolonged or heavy rainfall. They are also prone to structural degradation and compaction during handling, and especially when plastic in consistency.

Heavy textured soils may be considered suitable for more robust landscape applications, including hardy trees and shrubs and amenity grass (low foot traffic only), provided the physical condition of the soil is satisfactory and provided species tolerant of moisture retentive, heavy soil are selected. The soil would not be suited to more demanding planting environments or plant species that require or prefer light or free-draining soil. In addition, smaller plant stock, such as whips and transplants, would be more suited than containerised or rootballed stock, as they tend to be more tolerant of adverse soil conditions.

Soil Chemistry

The soil pH levels across both the Eastern and Western Cemetery were variable.

The Western Cemetery topsoil was strongly acid to strongly alkaline whilst the subsoil was strongly acid to slightly alkaline in reaction. The topsoil and subsoil in the Eastern Cemetery were both slightly acid to alkaline in reaction.

Soil Organic Matter and Fertility

Topsoil

The topsoil's organic matter and nitrogen content across both sides of the cemetery were at levels which would be considered suitable for general landscape uses.

The levels of extractable magnesium were moderate to high. Although this should not significantly limit the re-use potential of the topsoil, there is an increased risk that the high levels observed could interfere with trace element availability within the topsoil.

The levels of extractable potassium and extractable phosphorus were generally low to moderate.

For planting typologies that require higher soil fertility, the nutrient levels may need to be supplemented by suitable ameliorants. This may include conventional inorganic fertilisers; however, use of organic ameliorants (e.g. compost) could be preferable from a sustainability perspective.

Subsoil

The organic matter content of the existing subsoil was often higher than would be considered ideal for subsoil. This may be indicative of past disturbance of the soil profile and intermixing of soil layers during excavation for instance. Furthermore, the presence of combusted material such as ash or clinker can lead to analytical error and may not be entirely representative of humified organic matter should the soil contain these inclusions.

The presence of higher levels of organic matter within subsoil could promote increased microbial activity. The microbial growth will exert an oxygen demand on the soil and if this oxygen demand is not met, this can lead to the formation of anaerobic conditions. Anaerobism will subject plants to significant stress and may ultimately lead to plant failure.

In this instance, no anaeorobism was recorded in the Mayer Environmental report and the risk is reduced where the soils are left in-situ and undisturbed. However, if the subsoil is disturbed / physically degraded, it will be important to ensure that its condition is repaired to a well-structured and aerated state. Subsoil with higher organic matter content would also not be considered suitable for more demanding landscape types (e.g. large rootballed trees and ornamental shrubs).

The nutrient content of the subsoil was low or moderate for most parameters recorded, with high magnesium levels within the Eastern Cemetery samples.

Topsoil Depths

The topsoil depths recorded (where proven) were noted to be reasonably consistent in the Eastern Cemetery, with thicknesses considered generally acceptable for a number of landscape types.

In the Western Cemetery the topsoil depths were noted to be more variable, with shallower topsoil noted in the central zone and deeper topsoil thickness in the peripheral areas. These topsoil depths will need to be considered within the landscape design.

Potential Contaminants

A range of samples were submitted for testing of potential contaminants. Of the phytotoxic contaminants tested (copper, nickel and zinc), none were found at levels detrimental to plant growth.

With regard to human health contaminants, the majority of those tested were found at levels that did not exceed the screening values used, except for:

- Benzo(a)pyrene (samples *WC01, EC01* and *EC08*)
- Dibenzo(ah)anthracene (samples *WC01, EC01* and *EC08*)
- Benzo(b)fluoranthene (sample *EC08*)

The significance of these exceedances will need to be assessed by the project team.

Ground Investigation Report (Albury S.I. Ltd)

This information is based on review of the site investigation report prepared by Albury S.I. Ltd. The Phase 2 intrusive investigation was undertaken in the entrance area of the Western Cemetery only.

The stratum summarised within the report are as follows in Table 3 below.

Table 3: Ground Conditions Encountered – Albury S.I. Ltd Report

Stratum	Description	Depth to top (m bgl)	Thickness (m)
Made Ground *TP1, TP8 and TP10*	Dark brown, brown and orange brown silty SAND, sandy CLAY and clayey SAND with roots, brick and sandstone fragments and flint gravel.	0.0	0.4 to 1.1
Made Ground (below Macadam / cobbles) *BH1 - BH2* *TP2 – TP7 and TP9*	Macadam or cobbles over dark brown to brown, SAND, clayey SAND, sandy CLAY and silty CLAY with gravel of flint and brick. Layers of brick rubble and large stone masonry noted as well as clinker, charcoal and ash.	0.0	0.2 to 2.25
Claygate Member	Soft, brown to grey, sandy CLAY. Lenses of silt and fine sand. Some rounded flint gravel.	0.2 to 4.1	1.1 to 3.9
London Clay Formation	Firm to very stiff, brownish grey to grey, silty CLAY.	1.9 to 5.0	Unproven

From the description, the majority of the ground in this area comprised *Made Ground* below hardstanding (macadam / cobbles and concrete). The *Made Ground* at locations *TP1*, *TP8* and *TP10* may be more of a 'topsoil' type medium, supporting plant growth in these areas.

Contaminants

The report summarises that the potential risk related to presence of contaminants with respect to human health contaminants is deemed to be low, with a single exceedance of benzo(a)pyrene noted at *TP2*. This exceedance was considered to be of low significance.

Of the phytotoxic contaminants determined (copper, nickel and zinc), a single exceedance of zinc was noted at 0.5m in *TP4*.

3.4 Earthworks Proposals

The earthworks proposals for the site are minimal, with the only works currently proposed being associated with the construction / renovation of buildings within the site, new and refurbished footpaths across the cemeteries, associated SuDS features in certain locations and tree pit excavation.

As such, minimal earthworks operations are anticipated, with a degree of surplus soils from these excavation works expected. At this stage it is intended to re-use the site-won soils for the landscape scheme where possible and feasible for the proposed planting types. Imported soils will be required for the SuDS planting.

3.5 Proposed Soil Types

The current proposals intend use of the existing soils for the majority of the planting typologies. Limited use of imported soils is anticipated for tree pits and SuDS planting areas.

3.6 Water Management

The current drainage proposals for the site are, at present, to utilise repaired existing drainage networks as well as new SuDS features along the footpath networks to manage water across the two cemetery areas. The topographical low points of both areas are located at their southern extent and, as such, the landscape proposals make considerations for these as wetter areas.

The following is currently proposed for the footpath network:

- *Primary and Secondary Paths*: elevated surface level, self-binding gravel or concrete with exposed aggregate over sub-base. Where existing drainage is present and operating effectively, this will be utilised. Where no drainage is present or functioning, SuDS features, including rain gardens, along the footpaths will be utilised. These rain gardens will act as a conduit to gravel attenuation bodies (to 1m depth) below the footpath.

  The SuDS features are currently specified to be backfilled with a 'free-draining growing medium'.

- *Tertiary Paths*: these are proposed to be constructed using permeable materials through which water will pass through into a French drain sub-base that will convey the water to a Primary or Secondary Path.

In the pathways, the drainage / attenuation layers will be constructed as weirs to account for the site topography. Where the ground is level, flat-trench soakaways will be installed.

In the southern extent of the Eastern Cemetery, pumped soakaways may be utilised to store and discharge excess water to the drainage system.

Infiltration Tests

Review of Soil Infiltration Test Results recorded within the supplied Sub-Surface Report Ref. SE1801, dated 21/05/2024, indicated results ranging from 3.98×10^{-5} m/sec down to 7.01×10^{-7} m/sec, with no soakage recorded at a number of locations. The results, when reviewed with reference to guidelines in the CIRIA SuDS Manual (2015), indicate generally poor to very poor (occasionally good) infiltration rates at the locations tested. Based on these results, drainage intervention is likely to be required.

Further discussion on drainage requirements and materials is given below in Section 5.0.

3.7 Irrigation Proposals

Watering points are to be installed as part of the works, as well as retention of existing points.

Allowance for watering is intended following planting / sowing and indicated at between 4 – 7 litres per day for planting (depending on mix type) and 8 – 25 litres per day for trees (according to size).

4.0 SOIL REQUIREMENTS

This section of the report considers the requirements for soils in order to support the new landscape design, including considerations for management and re-use of existing soils, together with recommendations for imported soil types.

4.1 Landscape Soil Profile

Natural soil profiles typically consist of an organic topsoil layer of varying thickness, underlain by an inorganic subsoil layer. The topsoil layer will need to provide

- a source of major and minor plant nutrients;
- a sustainable microbe population;
- sufficient aeration and drainage to maintain optimum root function;
- structural stability to withstand the pressures from constant and excessive trafficking.

The principal functions of the subsoil layer are:

- to provide a stable rooting environment and anchorage for the trees;
- to act as a reservoir of water for plant uptake (particularly the trees) and for water attenuation purposes;
- to ensure that the water can percolate freely from the overlying topsoil layer.

4.2 Planting Requirements

Different planting environments require certain soil properties in order to meet their inherent cultural requirements, and to minimise the stress caused during transplanting and the establishment phase of a new landscape scheme. Discussion on the general requirements for various planting types is given below in Section 4.5 for the selected typologies in context of re-using existing soils.

4.3 Species Selection

A review has been carried out of the developing species selection proposals to provide information on the likely soil requirements for the scheme.

Due to the variability of pH recorded across the Cemetery as well as the likelihood of variability due to the heterogeneous nature of the existing soils, it is recommended that plant species selected have a broad pH tolerance.

The drainage preferences of species will need to be considered when selecting plants. The existing soils in the Western Cemetery are light to medium in texture and, as such, would allow for a broader selection of species. The existing soils in the Eastern Cemetery are medium to heavy in texture (particularly the subsoil). As such, species selected should be tolerant of heavier, moisture retentive soils. These soils would not be well suited to plant species which specifically require light, free-draining soils.

Plant species within the southern extents of the two cemeteries as well as within the SuDS features should be selected based on the anticipated moisture regimes of these areas.

Comments

The selected species mixes have been varied according to light levels and anticipated soil type. Review of the anticipated species indicates that the majority of the envisaged species have a reasonably broad soil pH range (typically ranging from slightly acid and non-calcareous to alkaline or calcareous). Furthermore, most of the species (except many of those in the Wet Woodland and Stream habitats) typically prefer *well-drained* or *moist but well-drained* conditions.

Certain species are considered to be particularly intolerant of moisture-retentive, poorly draining soils and so specifically require free-draining, light-textured soils. This includes *Taxus baccata*, which is especially prone to soil-borne pathogens such as *phytophthora* which thrive in persistently moist soils. Given the existing soil conditions, it is recommended that planting pits for this species are backfilled with light textured, imported soils.

Lime free (non-calcareous) soils are considered preferred by some of the indicated species, including *Liquidambar styraciflua, Asarum europaeum, Epimedium pubigerum, Aster divaricatus, Gillenia trifoliata, Matteuccia struthiopteris, Iris pseudacorus, Juncus effusus* and *Liriope muscari*. The pH range of the site soils varies significantly from strongly acid to slightly alkaline; however, the available soil survey information does not indicate whether the soils recorded as being alkaline are significantly calcareous (lime-rich) or not. Furthermore, there does not appear to be a discernible pattern in the spatial distribution of the pH range recorded. In the instance, the response of these species to the existing soil conditions could be variable.

Some species are considered to prefer neutral to alkaline soils, including *Nyssa sylvatica, Helleborus orientalis, Seslaria autumnalis, Campanula persicifolia, Iris unguicularis, Knautia arvensis, Dianthus carthusianorum, Hyotelephium spp., Galium verum* and *Iris latifolia*.

4.4 Soil Types

The intention is that the new soft landscaping will be established within the existing soils wherever possible. Significant reserves of soil are present across both sites. Aspirations for the Western Cemetery include more woodland and ornamental planting whereas the Eastern Cemetery comprises significant areas of species-rich grassland. The demands of new landscape scheme will need to be supported effectively by the soil profile. The re-use potential of the existing soils therefore requires careful consideration in order to identify the measures that need to be taken to maximise their quality and function.

Use of imported soils may be required for certain elements of the scheme for which the site soils are not suitable. Discussion on potential imported soil sources and types appropriate for this project is given below in Sections 4.8 and 4.9.

4.5 Site-Won Soils

The obvious advantage of re-using site-won soils is reduced cost and improved sustainability within the procurement process. However, the existing soils do present some constraints in relation to the proposed scheme, with regards to texture and drainage capability.

The re-use potential of the site soils for the anticipated planting typologies within the cemetery is summarised in Table 4 (Topsoil) and Table 5 (Subsoil). Further discussion on re-use considerations is given below the tables.

The re-use of the site soils is on the proviso that they are in good physical condition, with adequate soil structure, and suitable plant species are selected (see 'Species Selection' in Section 4.3 above).

Table 4: Suitability of Existing Topsoils for Proposed Planting Typologies

Typology		Western Cemetery Topsoil Suitability	Eastern Cemetery Topsoil Suitability
Rootballed Tree Planting	Larger Trees (20-25cm girth)	O	O
	Small Trees (light standards, half standards and 10-12cm girth))	✓	✓
	Taxus baccata (Yew)	O	X
Bareroot stock (including tree whips)		✓	✓
Containerised stock	Ornamental Shrubs & Herbaceous Perennials	✓	O
	Hedging	✓	O
Bulb Planting		✓	✓
Species rich Wildflower Meadows	Dry grassland	✓#	✓#
	Wet grassland	✓#	✓#
SuDS Planting – *assuming requirement for free draining soils*		X	X
Marginal & Aquatic Planting		✓^	✓^

✓ = Soil suited to this landscape type provided it is adequately structured, aerated and drained and suitable species are selected.

O = Soil only suitable for this landscape type provided it is in its optimum physical condition, plant species are tolerant of the soil conditions and consideration is made for improved drainage.

X = Soil not suited to this landscape type.

= Provided soil fertility levels and anticipated floral diversity levels are acceptable.

^ = Provided soil fertility levels and soil texture are acceptable (seek advice from aquatic specialist)

Table 5: Suitability of Existing Subsoil for Proposed Planting Typologies

Typology		Western Cemetery Subsoil Suitability	Eastern Cemetery Subsoil Suitability
Rootballed Tree Planting	Large Trees (20-25cm girth)	O*	X
	Small Trees (light standards, half standards and 10-12cm girth)	✓*	O
	Taxus baccata (Yew)	X	X
Bareroot stock (including tree whips and hedging)		✓	✓
Containerised stock	Ornamental Shrubs & Herbaceous Perennials	✓	O
	Hedging	✓	O
Bulb Planting		✓	✓
Species rich Wildflower Meadows	Dry grassland	✓	✓
	Wet grassland	✓	✓
SuDS Planting – *assuming requirement for free draining soils*		X	X
Marginal & Aquatic Planting		✓^	✓^

✓ = Soil suited to this landscape type provided it is adequately structured, aerated and drained and suitable species are selected.

O = Soil only suitable for this landscape type provided it is in its optimum physical condition, plant species are tolerant of the soil conditions and consideration is made for improved drainage.

X = Soil not suited to this landscape type.

* = Placement of min. 150mm imported sandy subsoil recommended to support rootball for standard and light standard trees. Min. 300mm of imported subsoil for large trees.

^ = Provided soil texture is acceptable (seek advice from aquatic specialist)

Rootballed Tree Planting

Trees that are supplied with a rootball are usually the most demanding planting type. Good aeration and drainage around and below the rootball, as well as moderate to high fertility status, are critical at planting and during the establishment period. Without these properties, trees can very quickly suffer and possibly die during their first few growing seasons after planting. Given their demanding nature, all rootballed/air-pot trees should be planted with well-aerated and free-draining soils to the full rooting depth (normally considered to be 1.0m).

The topsoil in both areas may be suitable for planting medium to large rootballed specimens, provided the soil is in its optimum physical condition and suitable species selected. In contrast, the subsoil (particularly that in the Eastern Cemetery) is not well suited to trees of this size. The subsoil will be susceptible to compaction under the weight of the rootball and reduced drainage performance. This combined with the generally high organic matter levels recorded in the subsoil means there is an additional risk of anaerobism within the subsoil profile.

As such, use of imported subsoil is recommended for backfilling planting pits for medium to large rootballed trees (e.g. 10-12cm and 20-25cm girth) in the Eastern Cemetery, and potentially the southern half of the Western Cemetery. Use of imported topsoil and subsoil is advised for all tree pits for such specimens if the site soils are not in an adequate physical condition or the depths of topsoil or subsoil in the proposed location is not sufficient (see Section 4.6 below).

For small to medium rootballed trees (e.g. up to heavy standard), the site soils in the Western Cemetery would be considered suitable. The Eastern Cemetery topsoil would also be considered suitable; however, the placement of an imported sandy subsoil material would be beneficial beneath the rootball of standard trees.

Consideration for additional drainage assistance would also be recommended for larger rootballed trees (see Section 5.0 below).

Tree Planting – Wet Woodland

Rootballed trees planted within areas of wet woodland will still require suitably aerated soil, much like those established in drier areas. However, species adapted to this environment can normally tolerate periods of intermittent waterlogging so long as the water does not stagnate and can still drain away. Options such as mounding up trees (see Section 5.3 below) could be considered here to keep the rootball aerated, whilst water can be channelled between.

Ornamental Shrubs, Hedges and Herbaceous Perennials (Containerised / Ornamental Stock)

Containerised / ornamental plants (including shrubs, hedges and perennials) require less soil to root into than trees, however, there is still a requirement for optimum drainage and aeration, as well as higher levels of fertility. Plant nutrients should predominantly be in a slow-release form with not too much nitrogen to encourage slow, steady growth of the root system as well as top growth.

Perennial flowering plants require higher inputs of readily available, soluble nutrients (especially nitrogen and potassium) during the summer months to optimise flowering intensity and colour.

Based on the findings of the *Soil Resource Survey*, the overall composition of the existing soils within the Western Cemetery does not present any particular concerns for shrub and herbaceous planting, provided plant species are tolerant of the soil type (broad pH and don't specifically require free-draining soils, particularly in the southern part of the cemetery). The soils in the Eastern Cemetery may also be suitable for such planting; however, the plant species should be tolerant of moisture-retentive soils and a wide pH tolerance. This is on the proviso that the physical condition of the soil is maintained to facilitate drainage and aeration.

Species that specifically require free-draining, light textured soils would not be considered appropriate for planting into the majority of the site soils, with the possible exception of the northern extent of the Western Cemetery (see Section 4.3 above).

The site topsoils have good reserves of organic matter, nitrogen and magnesium but were deficient in phosphorus and potassium in some instances. Nutrient levels can be supplemented using conventional inorganic fertilisers; however, use of organic ameliorants would be preferable from a sustainability perspective. Whilst the topsoil's organic matter content is generally sufficient, appropriate use of green compost for instance could provide additional nutrient supply for more demanding shrub planting if required.

Tree Whips (Bare-Root Native Stock)

Bare root whips are less demanding than containerised or rootballed or containerised stock. As such, a broader range of soil types can be used for these, provided the species selected do not require any specific growing conditions.

The soils across both the Eastern and Western Cemeteries would be considered suitable for such planting, provided plant species are tolerant of the soil conditions and anticipated moisture regime.

Bulb Planting

Bulbs typically require reasonably well drained and well aerated soil as they will be vulnerable to attack from soil-borne pathogens that thrive in moisture retentive soils. In addition, bulbs will usually require reasonably nutrient-rich soils that will warm up quickly at the beginning of the growing season to encourage growth.

The soils across both the Eastern and Western Cemeteries would be considered suitable for bulbs, provided the species are tolerant of the soil conditions. Given the heavy texture of the soil in the Eastern Cemetery, the soil will need to be in good physical condition to maintain aeration and reduce risk of the bulbs rotting.

Species-rich Wildflower Meadow

Species-rich wildflower meadow habitats typically require low soil fertility, and in particular low phosphorus levels (ideally less than 10 mg/l and on average less than 16mg/l), in order to promote species diversity and to prevent domination of the sward by grasses and aggressive weeds such broad-leaved dock (*Rumex obtusifolius*) and stinging nettle (*Urtica dioica*). The soil should ideally also contain moderate to high levels of soil organic matter and total nitrogen to aid in sward establishment and display high levels of soil microbial activity. Other environmental 'stressors' such as hydrology will also influence establishment of these typologies.

The levels of extractable phosphorus observed within the Western Cemetery topsoil were variable, ranging from what would be considered as *'low-fertility'* to '*high-fertility'*. The topsoil in the Eastern Cemetery was, on average, of a reduced fertility level, ranging from '*low-fertility'* to *'intermediate fertility'*.

On account of this variability, the suitability of the topsoil for re-use in low-fertility habitats will be dependent on the aspirations for the swards and acceptable levels of species diversity. Where fertility levels are higher, the sward produced may not achieve a high level of plant biodiversity in the long term. Appropriate management of the sward will be necessary in most instances to encourage diversity (e.g. mowing regime, etc).

Alternatively, where opportunity arises, use of the subsoil as 'topsoil' for species-rich habitat creation may be considered as the subsoils generally possessed lower fertility levels and have the added advantage of having a lower weed seed bank to compete with the new sward. However, establishment is likely to be slower on this material and significant disturbance to the soil profile is likely to be undesirable in many locations.

In any instance, the seed mix proposed should have a wide pH tolerance and be suited to the anticipated moisture regime. Variations in soil and environmental factors are likely to create differing plant stresses which could help produce a 'mosaic' habitat.

There are only limited areas of species-rich meadow habitats proposed in the Western Cemetery, with a large proportion of these areas currently comprising hardstanding. It is however noted that the *Soil Resource Survey* did not specifically target the areas proposed for such habitats. In the Eastern Cemetery, much larger areas of low fertility habitats are proposed. Due to the limited fertility data and variability of the soil fertility results, it may be beneficial to undertake further assessment of nutrient levels within the areas proposed for low-fertility habitats.

SuDS Planting

Shrubs and herbaceous planting as well as bulbs are proposed within the SuDS features along the Primary and Secondary paths. Based on the soil build-up details for these features the SuDS planting areas are to be backfilled with a 'free draining growing media' and are to be positively drained in parts, or act as attenuation body where drainage is not feasible. As such, it is assumed that the soils within these features are expected facilitate rapid dispersal of surface water input.

The generally cohesive and variable nature of the site soils is not suited to re-use within free-draining soil profiles such as these and imported, sand-based soil will likely be required. Information on the expected soakage performance of the soil profile would be required to refine the compositional requirements for the soil backfill for the SuDS features.

Marginal & Aquatic Planting

Marginal plant species are normally suited to intermittent/prolonged periods of waterlogging. They are not typically tolerant of drought/ or periods during which the soils dry out. Given their close association with water bodies, highly fertile soils are normally not used for marginal planting. Cohesive soils are usually best suited to these requirements.

The substrate type for aquatic planting can vary according to the water quality requirements and may include cohesive or granular types.

The site topsoils contain moderate levels of organic matter and total nitrogen and so could be a source of soluble nitrates, as well as other nutrients that could impact on water quality. The site subsoil, with its lower organic matter content could be a better alternative in this instance, and the cohesive nature of that within the Eastern Cemetery in particular would be suited to marginal planting.

Retained Vegetation

Existing trees, hedges and shrubs are well established and will therefore have an extensive root network. The protection of roots (including correct pruning and management of soils surrounding them) will be paramount to their health and longevity. Therefore, minimising their disturbance and the correct handling of site soils to prevent compaction and anaerobism during new planting is vital.

4.6 Soil Depths

Sufficient soil depth is necessary for plants to provide rooting volume for sourcing of nutrients and moisture, as well as anchorage. In natural soil environments topsoil depths normally range from between around approximately 150mm to 400mm and this should generally be repeated when new landscape soil profiles are constructed. In this instance, a significant proportion of the new planting will be established within existing soil profiles.

Further discussion on existing topsoil thickness and requirements for newly constructed soil profiles is given below.

Existing Topsoil Thickness

With reference to the *Soil Resource Survey* report, the topsoil depths in the Eastern Cemetery were, on average, at a thickness that would be considered acceptable for the majority of the landscape types proposed. A few localised incidences of increased topsoil depth (>400mm thickness) were noted.

In the Western Cemetery the topsoil depths were more variable, with a number of shallow topsoil depths (<200mm thickness) noted particularly in the central area of the Western Cemetery. In peripheral areas, increased topsoil depths (>400mm thickness) were also noted, which is likely to be indicative of past disturbance to the soil profile.

Where shrub, herbaceous, hedging or whip planting is to be established within in-situ soil profiles without excavation of a dedicated planting pit (as in the case for rootballed trees), some considerations for increasing topsoil depths will need to be made where the present thickness is shallow.

Shallow Topsoil Thickness

Where the topsoil depths are too shallow for the landscape type (see recommended target thicknesses in Table 6 below), there are 2 No. potential options available to increase the topsoil thickness:

1. The topsoil thickness could be increased to an appropriate depth by importing and spreading an appropriate source of good quality, fertile, free-draining topsoil.
2. Cultivate the topsoil and underlying subsoil and incorporate an appropriate source of bulky organic matter such as green compost. If this is done mechanically the maximum depth of incorporation will be limited to around 200mm. Alternatively the traditional method of 'double digging' could be used to incorporate the organic material to 300mm depth.

Deep Topsoil Thickness

Where topsoil depths are deeper than ideal, there is a risk of anaerobism (oxygen depletion) developing in the profile. However, no observations of anaerobism were noted in the *Soil Resource Survey*. As such, in its undisturbed state, the topsoil is sufficiently structured and aerated. Therefore, if the soil remains in this condition, the increased topsoil thickness may be acceptable for less demanding landscape types (e.g. native bareroot stock and grassland areas). For more demanding planting (e.g. large rootballed trees or specimen shrubs), it is recommended that the topsoil (and subsoil if required) is excavated to the appropriate depth and backfilled with topsoil and subsoil to suitable depths

Newly Constructed Soil Profiles

Where soil profiles are to be reconstructed, e.g. within areas excavated for pathway installation or building works, or within tree pits for instance, it is not advisable to place topsoil too deep (greater than 400mm) as it is prone to anaerobism (oxygen depletion). This is because the oxygen requirement (Biochemical Oxygen Demand) for the microbes in topsoil exceeds the supply of oxygen to this depth, thereby resulting in a net deficiency. Anaerobic conditions, if they persist, impede basic root function and subject plants to significant stress and even complete failure.

The lower portion of the soil profile should be made up with a suitable inert 'subsoil' material (see Section 4.8 for further discussion on subsoil types). Note the subsoil layer could be formed of either newly placed soil and / or also retained, prepared in-situ subsoil. In the case of tree pits, the upper part of the subsoil layer could be formed of imported subsoil, with the lower section prepared site won subsoil.

Table 6 below summarises the recommended soil depths for each of the proposed planting typologies, where new soil profiles are constructed. Note this refers to soil layer thickness only and not to specific soil types.

Due to the textural properties of the site topsoils, it is recommended that, once excavated and replaced, they are not spread thicker than 300mm. Imported topsoil may potentially be placed to greater depth (e.g. up to 400mm in some instances, depending on composition); however, this is not usually necessary.

Depending on the drainage strategy for the soft landscape areas, a layer of gravel may be required beneath the subsoil layer in certain planting situations. The depth of this gravel layer will be dependent on the proposed outfall strategy (e.g. see discussion on 'Drainage' in Section 5.0 below).

Table 6. Recommended Soil Depths – New Soil Profiles

Planting Type		**Topsoil Layer Depth (mm)**	**Subsoil Layer Depth (mm)**
Rootballed Tree Planting	Larger Trees (up to 20-25cm girth)	300*	600
	10-12cm girth	300	500
	Light standards, half standards	300	300
Bareroot tree whips and hedging		300	300#
Containerised Stock (e.g. shrubs, herbaceous perennials, hedging)		300	300#
Bulb Planting		300	300#
Species rich Wildflower Meadows	Dry grassland	Minimum 150	150#
	Wet grassland		
SuDS Planting		See Note Below	
Marginal Planting		300	300#
Aquatic Planting		Dependant on design requirements	

* Where soils are heavy in texture (e.g. Eastern Cemetery), use of imported soils are recommended for larger trees, unless plant species are specifically tolerant of heavy, moisture retentive soils.

Minimum subsoil thickness provided for relevant planting typology. This could be formed of prepared subsoil material remaining at formation level or placement of additional subsoil (site won or imported) as required.

Soil Depth for SuDS Planting

From a planting perspective, the soil depth within SuDS area should suit the nature of the planting proposed, which in this case is predominantly herbaceous, together with shrubs. As such, a minimum depth of 600mm soil would be advised, formed of layers comprising 300mm each of suitable, free-draining subsoil and topsoil (see SuDS Soils in Section 4.9 below). The need for any additional soil depth in these areas (e.g. for attenuation volume) would need to be confirmed with the project drainage engineer.

4.7 Soil Preparation

Soil Decompaction and Cultivation

Earthworks and landscape construction activities are likely to cause some degree of compaction to the soils. Soils require adequate structure in order to retain porosity which is necessary to facilitate moisture infiltration and enable root extension. In addition, a suitably fine tilth needs to be achieved prior to planting and seeding (usually <30mm ped size for planting and <10mm for seeding).

As the soils are anticipated to remain in-situ and receive minimal disturbance, there may just be a requirement for cultivating the surface (e.g. by forking / raking over or using a pedestrian operated power harrow for instance). A variety of cultivation methods and equipment could be employed on this site to alleviate any potential surface compaction. If any, more significant compaction of the soils is caused by operations (e.g. footpath and building construction / renovation areas), a more intensive decompaction exercise may be required (e.g. using equipment such as that indicated in Plates 3 and 4 below).

Images of a selection of cultivation and decompaction equipment are given below. These examples are not exhaustive, and the suitability of any equipment will vary in their application, depending on space available, depth of treatment required and degree of cultivation necessary.

Plate 1: Pedestrian power harrow

Plate 2: Spiking soil surface with hand fork

Plate 3: Landscape rake attachment

Plate 4: Ripper tine attachment

Stone Removal

The topsoil currently contains a low to moderate proportion of stone. Coarse fragments of anthropogenic material (concrete and sandstone etc.) were also recorded in the topsoil layer.

It may be prudent to consider reducing the proportion of larger stones and any foreign matter in some instances, particularly for seeded areas. Any large stones brought to surface during soil preparation works will also need to be removed by appropriate means.

The removal of a large number of Ash trees and other vegetation is likely to leave a proportion of vegetation / woody matter. It would be prudent to as much of this material as possible rather than incorporating it into the topsoil. This is because presence of lignin-rich material in particular can cause nutrient imbalances and increases risk of anaerobism.

Soil Ameliorant Applications

If the site topsoil is used for planting typologies that require a higher soil nutrient status (e.g. trees, shrub planting etc.), the nutrient deficiencies recorded could be addressed by incorporation of a bulky organic ameliorant (e.g. PAS100 green compost). The incorporation of compost will also provide benefits to the soil microbiology by inoculating the soils with beneficial microbes, which in turn support soil health for plant growth.

No compost or fertiliser applications are recommended for areas of species-rich grassland seeding.

Construction Works

Any existing soils present within construction zones for new buildings and features across the cemetery will need to be managed appropriately, where intended for re-use. This may include appropriate protection measures and treatment post works, or, where feasible, preliminary excavation and storage of the soils before construction commences to prevent unnecessary physical degradation or cross-contamination during the operations. The soft landscape specification information will need to include requirements for management of these soils; together with detailed method statements produced by the appointed contractor to confirm the equipment and sequencing to be used for these works.

4.8 Imported Soil Sources

On this site, there are currently large reserves of existing topsoil and subsoil, which are to remain in-situ and be utilised as far as practically possible. However, as discussed above, there are certain landscape types for which these soils would not be suitable. Therefore, limited use of appropriate imported soils will be necessary within the scheme (see Section 4.9 below for recommended types).

In this instance, the preferred source of any imported topsoil would be 'Manufactured Topsoil', produced by blending various mineral and organic substrates into a growing medium that will function as a topsoil. Imported subsoil or sand should be derived from suitable quarried deposits. Further discussion on these and materials to avoid is given below.

Manufactured Topsoil

A manufactured topsoil is essentially a soil that is formed when two or more components (mineral and organic) are intimately mixed to form a rooting medium that will provide all the necessary physical, chemical and biological components to support plant life in a landscape environment.

In many instances, manufactured topsoils can provide a better alternative to natural topsoil for certain demanding planting types, especially if the site-won topsoil is heavy textured (such as on this site). Their attributes include a consistent composition, a greater availability, the ability to control and modify the product to suit the end-use, and they are free from weeds, disease and contamination, provided suitable substrates have been selected for the mix.

Manufactured Topsoil is the preferred option for imported topsoil for this project where the site-won topsoil is unsuitable (see suitability Table 4 above).

Imported Subsoil Sources

For planting types for which the site-won subsoil is unsuitable (see suitability Table 5 above), a sand-based imported subsoil should be selected. Quarry 'overburden' or quarried washed sand are recommended for this project below for differentiation between types for various planting environments). Recycled Skip Waste should not be used (see comments below).

Quarry Overburden

Quarry Overburden generally represents the materials that are deemed to be uneconomical primary mineral deposits at quarrying sites, or the by-products of secondary processes at mineral extraction operations e.g. washing plants. Overburden materials that are often suitable for use in landscaping include as-dug sands and gravels, rock sand, China Clay waste spoil and crushed stone fines.

As the materials are derived from natural geological deposits, the risk of contamination is low. Likewise, the presence of weed seeds, sharps and other undesirable components is highly unlikely.

Washed Sands

Quarried and washed sands are primary mineral deposits from quarrying sites. These can be graded according to different particle size specifications to meet the necessary requirements for the end-product (for example glass production, cements, building sands, etc etc). Selection of well-graded sand has benefits for use in landscaping as it will retain porosity, even when subject to compaction.

Skip Waste Soils

Skip waste soil is the result of screening materials derived from site clearances, building and demolition operations and the 'muck away' market. The coarse fraction is removed and used as recycled aggregates whilst the fines (soil fraction) are stockpiled for re-sale as 'subsoil' or even 'topsoil'.

The skip waste soil usually consists of a mixture of topsoil, subsoil, clay and fragments of building waste materials – brick, concrete, mortar, ash, clinker, and to a lesser extent glass, metal, wood and plastic. In terms of its physical and chemical soil properties, the material is usually extremely alkaline with a pH range of 8.0-10.0, saline, low in organic matter and plant nutrients, can often have elevated levels of zootoxic and phytotoxic contaminants and contain 'sharps' e.g. glass and metal.

The material is therefore at the fringe of the requirements for a landscaping soil. It would not be considered suitable for this landscape scheme, where design contains quality trees and ornamental planting.

4.9 Recommended Imported Soil Types

Where the site-won soils are not suitable or there is a shortfall in appropriate material, imported soils will be required. The recommended types and relevant planting environments are given in Table 7, with further discussion on these types below.

Other imported soil types not included within this table may also be considered for certain elements of the scheme. These are discussed below under "Additional Imported Soil Types".

Table 7: Imported Soil Types for Selected Planting Environments

Soil Type	Planting Environment
General Purpose Topsoil	Tree pits and general planting where existing topsoils are not suitable, or volumes are not sufficient. *Note not suited to species-rich grassland*
Landscape Subsoil	Tree pits and general planting where existing subsoils are not suitable, or volumes are not sufficient.
SuDS Topsoil	Topsoil within the upper portion of SuDS features.
SuDS Subsoil	Subsoil within the lower portion of SuDS features.

General Purpose Topsoil

General Purpose Topsoil would be a growing medium suited to high fertility planting environments (e.g. tree and shrub planting), for use where the site soils are not suitable or where volumes are not sufficient to make up levels. A more free-draining topsoil type is likely to be necessary for the SuDS features, depending on drainage strategy (see "SuDS Soils" below).

The soil properties and characteristics will need to be suitable for the selected plant species and environment categories, whilst meeting the drainage requirements of the project. Localised adjustments to composition and fertility can be made using various soil ameliorants (composts, fertilisers, lime, sand) to suit specific requirements of certain species.

A moderate drainage rate and porosity is normally targeted to provide a balance between good 'available water-holding capacity' for plant uptake and sufficient drainage potential to remove surplus water and avoid stagnation and anaerobism. The overall fertility status should be high to start with to help landscape establishment and reduce the need for regular nutrient inputs. The majority of nutrients should be in a slow-release, organic form.

Organic matter is recognized as a means to help achieve good water-holding properties and improving nutrient retention. It is also likely to be the main source of plant nutrients and trace elements, and to supply essential soil microbes (e.g. fungi, bacteria) that are required for nutrient synthesis.

To summarise, the *General Purpose Topsoil* specification could be expected to require the following properties for this soil type:

- *sandy loam* or *loamy sand* texture class
- moderate drainage rate
- moderate to high organic matter content and fertility status
- no chemical or physical contamination

A *manufactured topsoil* or lighter textured *as dug topsoil* would likely be appropriate to achieve these requirements.

Landscape Subsoil

For tree planting where imported subsoil is required, a sandy material with a moderate to high drainage rate would be appropriate to compliment the overlying topsoils, and to compensate for the reduced permeability of underlying cohesive soils. This will also provide an attenuation function to support the development's water management strategy.

Engineering fill materials containing recycled soils and aggregates are often not suitable for use as *Landscape Subsoil* on account of the typically high pH value associated with such material. The high pH levels are usually due to the presence of concrete, brick, mortar and lime-stabilised material. Soil pH has a direct effect on important chemical aspects of the soil and root function. As such, the pH of a soil is a key parameter for the assessment of soils to be re-used for plant growth.

The organic matter content of the Landscape Subsoil should be low (i.e. <2%) in order to reduce the risk of anaerobism (oxygen depletion). The presence of organic matter exerts an oxygen demand as the organic matter decomposes. As subsoil is placed at greater depth beneath a topsoil layer, this oxygen demand may not be met, which may lead to the formation of anaerobic conditions if the organic matter content is too high.

To summarise, the *Imported Landscape* specification could be expected to require the following properties for this soil type:

- *loamy sand* or *sand* texture class (narrow particle size distribution)
- moderate to high drainage rate
- low organic matter content
- no chemical or physical contamination

A quarried, unprocessed sand or an overburden material from a sand and gravel quarry will be an ideal imported subsoil material. For high-value stock such as rootballed trees and instant hedging, use of recycled soils and aggregates are unlikely to be considered suitable.

SuDS Soils

The necessary water attenuation and infiltration capacity needed, presence of ancillary features such as underdrains or overflow points, and whether the feature is required to perform other specialist functions (e.g. treatment of pollution in surface draining water), will all influence the performance criteria for the soil used in within the proposed SuDS system.

In this instance, further information will be required from the drainage engineer on expected permeability (e.g. in mm/hr) and porosity (%) for the soil used for backfilling SuDS planting beds. For reference, 'normal' landscaping topsoil may be expected to be 'slowly permeable', with permeability rates of around 4-35 mm/hr. In contrast, specialist, high permeability rootzones could be expected to achieve a permeability rate of at least 100 mm/hr, if not greater. This material will have a high sand content and narrow overall particle size distribution in order to enable the system to receive moisture but not remain waterlogged and stagnant.

The topsoil or rootzone will need to be complemented by a sufficiently free-draining subsoil layer to convey water to the drainage layer below. Well graded, quarried and processed, washed sand with a narrow overall particle size distribution would likely be an appropriate subsoil material within this system type. Recycled sands, marine dredgings or crushed aggregates are unlikely to be suitable.

Additional Imported Soil Types

Grassland Topsoil

The site contains significant reserves of topsoil that is deemed appropriate for establishment of species-rich wildflower swards, provided these are maintained appropriately to encourage long-term species diversity. As such, it is not anticipated that any imported topsoil will be necessary for this typology. However, should the need arise, topsoil with a reduced fertility status, especially a low phosphorus content would be specified in this instance.

Washed Sand

Well-graded, quarried and washed sand is usually recommended for use in the base of the tree pits of particularly large trees (e.g. greater than 35cm girth). At present, trees of this size are not anticipated within the design; however, if these are to be included within the final design, washed and will be recommended as subsoil backfill in the tree pits to provide a compaction resistant and highly porous layer below the rootball.

Granular Aquatic Soil

The requirements for the soil type used below the permanent water line will need to be identified by an aquatic specialist. If cohesive soil is required, then the site won soils may be appropriate, depending on the suitability of their texture and fertility status. If, however, a granular 'mulch' is required (e.g. to reduce sediment clouding and encourage invertebrates), then a separate granular substrate may be necessary.

4.10 Soil Specification and Soil Management

There will be a need to develop specifications for the topsoils and landscape subsoil for the purpose of sourcing appropriate soils.

It will also be important to provide detailed soil management information to ensure the soils are handled, ameliorated and prepared correctly.

4.11 Potential Contaminants

It is assumed at this stage that imported soils will need to be compliant with criteria for potential contaminants (e.g. heavy metals, hydrocarbons, asbestos, etc), with appropriate certification provided. Reference shall therefore need to be made to appropriate criteria within subsequent soil specifications.

Unless site-specific assessment criteria (SSAC) are provided, published Generic Assessment Criteria (GAC) will need to be derived for use in the specification document for imported soils. The suitability of any GAC selected will need to be confirmed by the project environmental consultant / Local Authority Contaminated Land Officer, as applicable.

Soil specification information for the procurement stage should outline the contaminant testing requirements for landscape soils prior to import of the soils to site. The requirements for any *verification* testing carried out subsequent to import of the soils should be as per the project environmental consultant's specified protocol.

4.12 Other Considerations

Existing Vegetation Removal

Methods for any vegetation removal should be selected to minimise disturbance to existing soils (where they are to remain), avoid damage to roots of retained vegetation and avoid excessive vehicle / foot trafficking.

Geotextiles

For any locations where a permeable geotextile is to be used anywhere within the landscape soil profile, it is advised that an open weave geotextile is selected. Narrow gauge geotextiles often become blocked up with soil 'fines', thereby reducing permeability over time and adversely affecting the function of the landscape soil profile above.

Use of suitable sand as a 'blinding layer' could be considered as a robust alternative for permeable textiles in certain applications.

Maintenance

Appropriate ongoing maintenance operations will be required to retain a satisfactory soil profile for the landscape scheme, e.g. decompaction / aeration treatments and amelioration requirements (e.g. compost / fertiliser) as necessary.

Mulch

Organic mulch should not be placed too thick as this can restrict oxygen supply within the underlying rooting zone. A maximum thickness of 50mm would normally be advised; however, in some instances, a greater thickness (e.g. up to 100mm) could be beneficial for planting in existing woodland. Where a greater thickness of mulch is used, there is increased risk of reduced aeration to the soil below and as such, it will important to ensure that the mulch is only placed when the soil surface is sufficiently dry. Furthermore, the soil surface should not be in a compacted state.

Selection of organic mulch with minimal 'fines' is advised. This also applies to mineral mulches, and these should also be resistant to physical weathering.

Where green compost is used to supplement organic matter and nutrient reserves in the soil, this should be dug into the soil surface to incorporate it, prior to application of any surface mulch material.

It is understood that a broadly graded mulch is intended for steeply sloping areas (depth up to 100mm) in order to avoid slippage.

Root Barriers

It is understood that the architects have confirmed that no root barriers will be necessary for the current planting proposals. However, should this change, the following considerations should be noted.

If root barriers are used, their specified locations should allow maximum soil volume availability for the planting. Ideally these would not be wrapped around all sides of tree pits for instance.

5.0 DRAINAGE

5.1 General Considerations

The drainage performance of the soil profile is important to facilitate successful establishment of the scheme. Any reduction in soakage potential can have a severe impact on the landscape and the overall function of the site for end-users. This includes:

- Waterlogged and anaerobic topsoil
- Surface water ponding and runoff on to hardstanding
- Plant and lawn failures
- Access restrictions due to wet, muddy ground

Based on the *Soil Resource Survey*, the soils within Western Cemetery appear to be better drained in their current state compared to the soils in the Eastern Cemetery.

In the Western Cemetery, given that most of the soils are to remain in-situ, inclusion of additional drainage assistance is unlikely to be required for most planting typologies in this zone. This is provided that any excavation works for planting result in minimal disturbance to the soils in order to preserve their existing soil structure, and the base of excavations must not be left compacted. Large rootballed trees would, however, benefit from inclusion of drainage assistance (see Section 5.3 below).

In the Eastern Cemetery, the heavier textured soils are likely to have a reduced drainage performance. As such, drainage provision should be considered within the design, particularly for rootballed trees and sensitive planting types. Localised solutions such as mounding could also be considered for rootballed trees.

The details relating to landscape drainage will be dependent on the findings of the drainage and soakage assessments being undertaken as part of the project.

5.2 Soil Preparation & Groundworks

The handling and preparation of the soils in all soft landscape areas should aim to maximise water infiltration and percolation through the soil profile to increase the soil's water attenuation capacity and minimise the risks of flooding, erosion, waterlogging and plant failure. This includes protecting the surface from foot / vehicle traffic during all works and will also influence the location of the site compound and welfare facilities. Working sequences will need to be carefully planned to avoid tracking over areas to be landscaped. Soil preparation works within soft landscape zones will include decompacting and cultivating soils prior to planting.

5.3 Drainage – Tree Pits

Given the anticipated poor drainage characteristics of the existing ground, particularly in the Eastern Cemetery, there is a risk of new tree pits acting as sumps for surface and sub-surface draining water. Waterlogged tree pits are one of the most common causes of plant failure, where the compacted or heavy nature of the ground beneath and adjacent to the pit/bed offers little, if any, soakage potential. This results in the tree pit acting as a 'sump' for surface and sub-surfacing draining water and can cause a rapid decline and even failure of the trees. Larger, semi-mature trees are particularly vulnerable, as are species that are intolerant of persistently moist soil conditions.

The options for drainage intervention include positive (piped) drainage and use of granular attenuation layers. Given the constraints of this site, it is unlikely that positive drainage provision will be feasible; however, the principles of both options are outlined below.

Granular Attenuation Layer

On this site where positive drainage is unlikely to be feasible in many instances, an adequate depth of suitable gravel ('drainage layer') could be considered for placement at the base of the tree planting pits to initially attenuate surplus water. This layer will have the dual function of providing additional water reserves (through capillary rise) during the main growing season when the rate of water uptake by trees increases considerably. The gravel layer will need to be placed to a suitable depth to provide enough void space to attenuate sufficient volumes of water. In this situation, the gravel layer will therefore need to be at the very least 300mm (ideally 400-600mm) for trees (150-200mm is insufficient).

The gravel layer should also ideally be accompanied by a vertical monitoring/extraction pipe installed down into the gravel layer to check water levels in the pit and to enable extraction of stagnant water if necessary. Monitoring of the water level within the vertical pipes is usually required for at least the first 3 years (establishment phase) and should be carried out on a quarterly basis and particularly at the end of the winter period and well before the start of the growing season to enable any waterlogged pits to be de-watered.

Figure 1 below demonstrates the arrangement of an attenuation layer and water monitoring pipe within a tree pit.

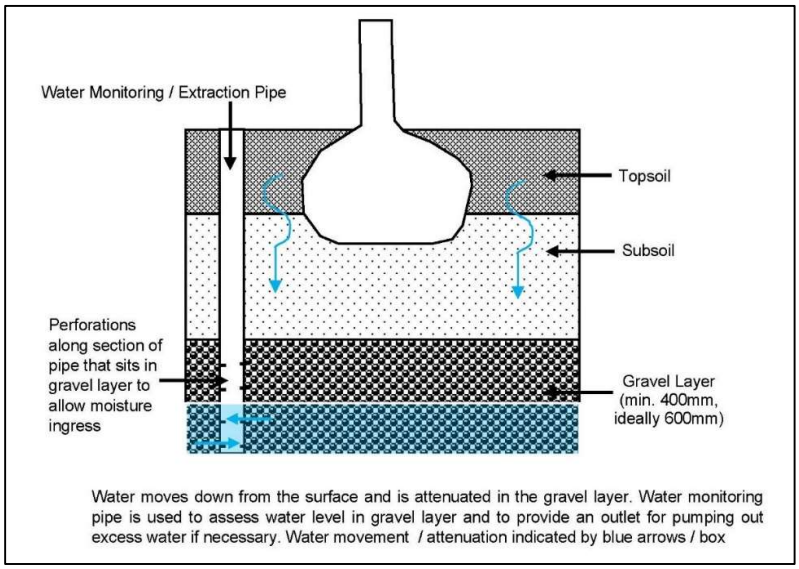

Figure 1. Tree Pit with Attenuation Layer and Water Monitoring Pipe

Positive Drainage

Positive drainage would comprise a piped land drain running from each pit / group of trees or planting bed / hedge trench to remove surplus water. The pipework would need to be connected to an appropriate outfall point, which will need to be coordinated with project drainage engineer. Figure 2 below demonstrates the arrangement of positive drainage within a tree pit.

As noted above, given the constraints of this site, it is unlikely that positive drainage provision will be feasible.

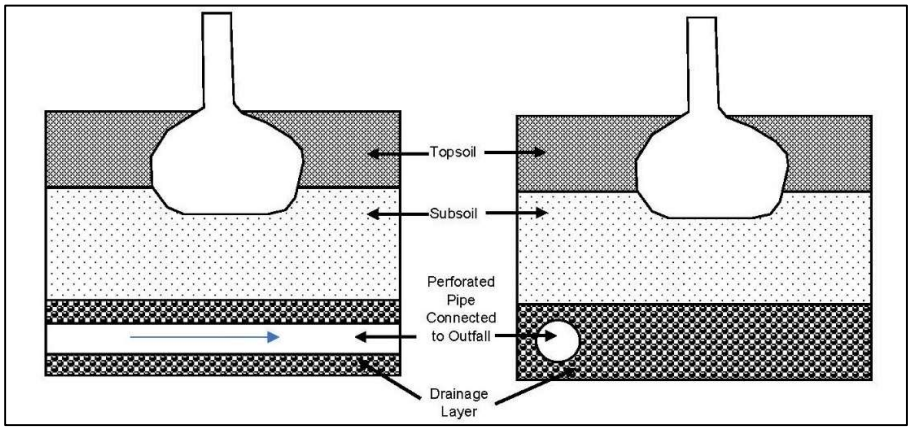

Figure 2. Tree Pit with Positive Drainage

Other Options

Mounding around trees or groups of trees and planting could also be considered, particularly for vulnerable species. This effectively 'lifts' the plants and reduces the risk of harm from waterlogging and improves aeration within the rooting zone. This approach can be extremely cost effective and is not reliant on an outfall. 'Linear' mounds or 'ridge and furrow' arrangement with channels in between could also be considered for groups of trees and may be useful in wet woodland areas for instance.

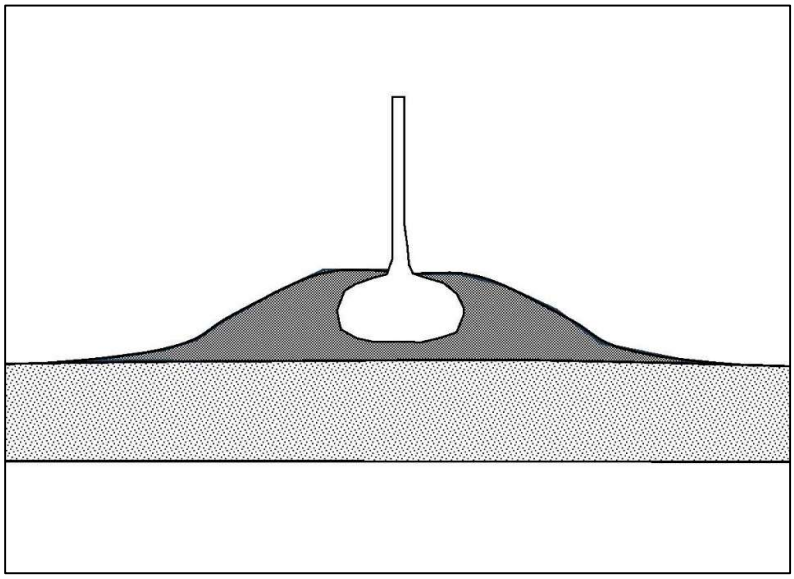

Figure 3. Tree Planted within Mound

Where trees are located on slopes, drainage pipes could be constructed to run from the gravel layer in the tree pit, out towards the slope surface. Connection to the drainage network is not required as the water will outfall to the slope. Any moisture that doesn't infiltrate the soil would run-off the surface to the toe of the slope where it can be picked up by pathway drainage, SuDS features or wetland zones.

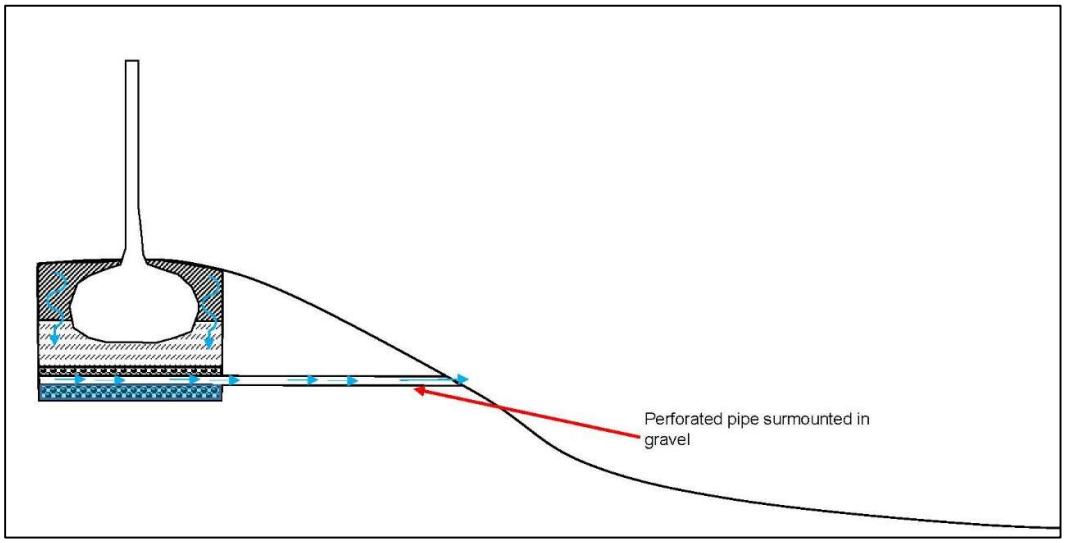

Figure 4. Tree on Slope with Pipe Option

Other Considerations

Consideration may also need to be given to drainage assistance for any new hedge trenches and formal planting beds that do not contain trees, depending on the topography in these locations, together with the drainage preferences of selected plant species. In any case, the formation layer should ideally be profiled towards a collection point and loosened to encourage soakage.

5.4 Drainage Media

The selection of an appropriately graded drainage media is important to enable hydraulic continuity from the soil layer above. Hydraulic continuity is the ease with which water can move through pore spaces in the soil. This process requires a gradual change in pore size, otherwise water will be held within the small pores by pressure caused by air within the larger pores. If the gravel aggregates are too coarse the increase in pore size compared to the soil above will be too large and hydraulic continuity will be lost, leading to retention of water within the soil rather than drainage into the gravel. In this instance, use of pea shingle with aggregate size no greater than 10mm would be advised for any drainage layers that interface with soils, including tree pits / shrub beds, SuDS features, etc.

6.0 SURPLUS SOILS

Options are being sought to maximise retention of surplus topsoil on site. However, it is anticipated that some degree of surplus soil will remain that cannot be re-used within the scheme. As such, appropriate disposal of this material could be necessary.

The least sustainable means of managing surplus soils will be disposal to landfill. If the material is to be sent as waste to landfill, it will be subject to appropriate Waste Acceptance Criteria testing (The Landfill (England and Wales) Regulations 2002) as amended by further legislation, including the Environmental Permitting (England and Wales) Regulations 2010.

A more sustainable approach to managing surplus soils would be to re-use off-site or to recycle via a licenced processor. In these instances reference should be made to the *CL:AIRE Definition of Waste: Development Industry Code of Practice* for guidance on requirements for soils transferred to other sites.

The process of recycling soils usually involves the collection of soils from various sources at a central processing facility. The soils are then screened and ameliorated to produce a final soil product for re-sale.

Topsoil and subsoil that is traded is normally tested for compliance with the relevant British Standard (*BS3882:2015* for topsoil and *BS8601:2013* for subsoil) to help confirm its re-use potential and demonstrate its quality. If third parties are considering taking the soils, it is recommended that they commission their own testing to determine if it satisfies their requirements.

If the site soils are to be considered for re-use, review of the specific scheme requirements and the suitability of the soils should always be made on a site-by-site basis.

7.0 FURTHER WORK

7.1 Design and Specification

This report does not constitute a specification and is issued as a guide to indicate the principles to be considered within the detailed landscape soils design. This information will need to be reviewed and refined during the subsequent RIBA Design Stage 4 to confirm the soil management and amelioration methods for all soils (site-won and imported) and compositional requirements for imported materials, together with necessary quality schedules.

7.2 Additional Surveys

The Soil Resource Survey undertaken by Mayer Environmental was largely limited to locations close to pathways and did not specifically focus on assessment for particular habitat types. Due to the limited fertility data and variability of the soil fertility results, it may be beneficial to undertake further assessment of chemistry and nutrient levels within the soils, particularly those areas proposed for low-fertility habitats.

We would like to thank Gustafson Porter + Bowman for entrusting our practice with this commission. We trust this report meets with your approval and provides the necessary information. Please do not hesitate to contact the undersigned if we can be of further assistance.

Ceri Spears
BSc MSc MISoilSci
Senior Associate

For & on behalf of Tim O'Hare Associates LLP

Report Qualifications

This report outlines the design considerations for soft landscape construction for the Highgate Cemetery project, London. It should not therefore be relied on for alternative end-uses or for other schemes. This report has been prepared solely for the benefit of our client Gustafson Porter + Bowman. No warranty is provided to any third party and no responsibility or liability will be accepted for any loss or damage in the event that this report is relied upon by a third party or is used in circumstances for which it was not originally intended.