STOCKHOLM TREEPITS

GUIDE TO DESIGNING TREE PITS WITH STONE-BASED STRUCTURAL SOILS

Version 2.0

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STOCKHOLM TREEPITS

1. An introduction to growing urban trees in stone-based structural soils

Big trees provide valuable ecosystem services and they are a key component of green infrastructure. The benefits of larger trees greatly outweigh those that smaller trees are able to offer. With the right conditions mature trees will grow to their full size and provide benefits for many decades.

Urban tree planting can be expensive, so it is important that landscape designers provide suitable environments for trees to live long enough for them to deliver returns on the investment of planting and maintaining them in their early years.

Essentially urban trees need engineered tree pits to flourish. This guide concentrates on building tree pits with structural soils in the UK, although there are alternative methods. In this document 'structural soil' refers to a stone-based structural soil containing biochar for use in the UK; sand-based structural soils and other types of stone-based structural soil are available but their use is not covered in this document.

Structural soils are an aggregate based growing medium that can support pedestrian and vehicular traffic, and so their use allows tree pits to be extended beneath hard surfacing. This enables designers to provide enough soil for a tree to be healthy and reach maturity.

When designing tree pits with structural soils, rainwater that has been collected from roofs, roads and paved surfaces is diverted into the tree pit. Trees grow extremely well in tree pits constructed in this way and the approach also offers valuable benefits for sustainable drainage systems (SuDS).

Stockholm Tree Pits is able to supply a range of products that can be used with this system.

Figure 1:
These trees are growing in a structural soil beneath a pavement. The long shoot extension and uniform growth of the avenue shows that all of these trees are very healthy.

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2. Tree pits beneath hard surfacing

Just as a potted plant can grow too large for the volume of soil in the pot, so too can an urban tree reach a size where its growth becomes limited by the available root space. When the root system cannot increase in size because the rooting space is filled to capacity, crown growth will slow and the tree will develop a stunted appearance. Water stress becomes more frequent and severe, which makes it more susceptible to secondary disease and insect problems. When stress becomes severe, decline will begin. This is why it is common to see urban trees in poor health, and trees planted in hard landscaping often die young.

The typical street tree is situated in a narrow strip between the road and adjacent buildings and has to compete for underground space with a variety of utilities. Under these circumstances trees rarely have enough soil to allow them to grow to a size where they provide significant benefits. To solve this problem, there is a need to construct **subterranean tree pits** that extend beneath areas that are used by pedestrians and cars. Specially engineered tree pits are required to create a functional rooting environment beneath a hard surface *(see Figure 2)*.

The benefits of using structural soils include the following:

+ ***Allow tree pits to be extended beneath hard surfacing***

Tree pits can be made larger so that street trees are provided with enough soil to live long and healthy lives

+ ***Uses rainwater to irrigate the urban trees***

Water is diverted from aboveground into the tree pit where it can be taken up by tree roots

+ ***The approach allows oxygen to reach the soil***

Roots need oxygen to respire, structural soils provide pathways for gaseous exchange between the soil and the aboveground atmosphere

+ ***A healthy soil ecosystem***

Structural soils provide a soil structure suitable for supporting a range of soil biota and a functioning soil ecosystem

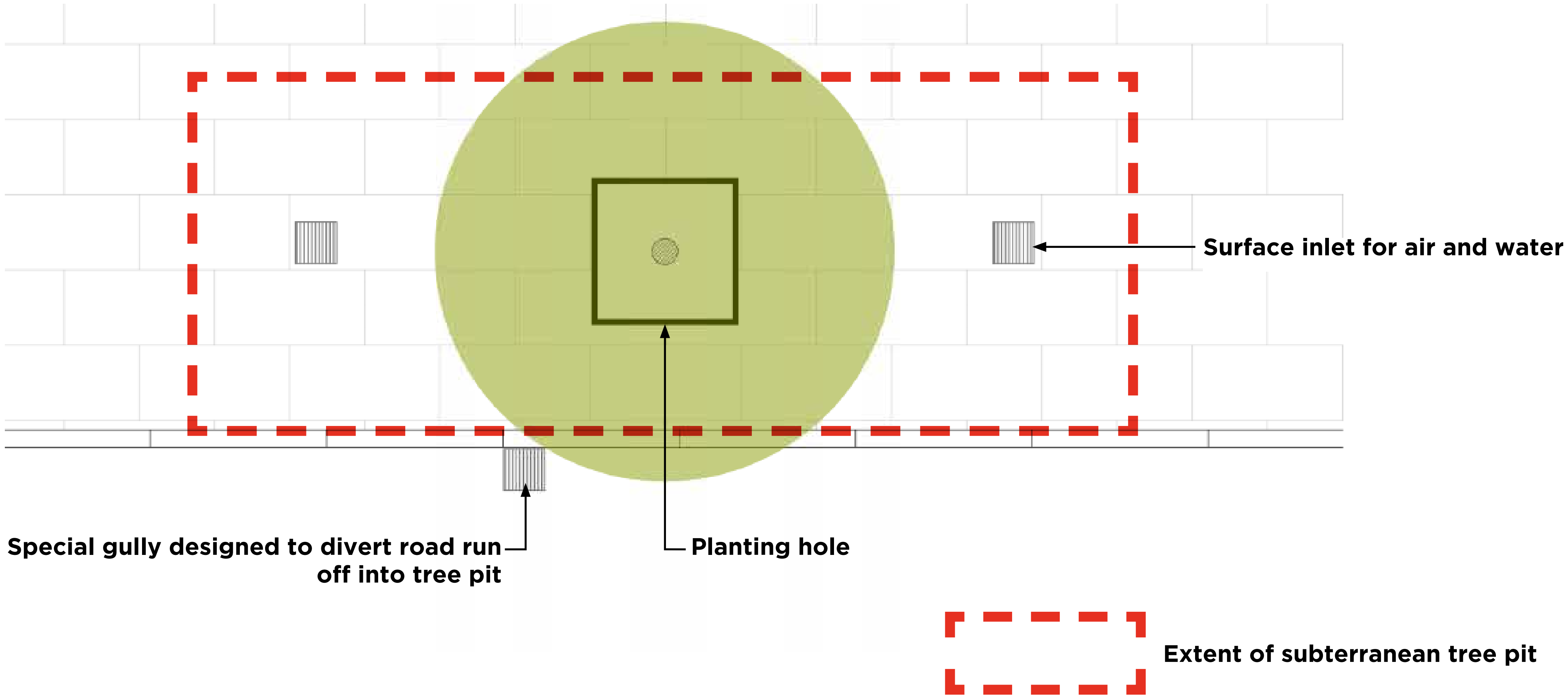

Figure 2:
The key elements of a subterranean tree pit.

3. What are structural soils?

A durable road or pavement needs a solid base. The traditional method of constructing a reliable surface is to dig down and install a deep sub-base with aggregate ranging in particle size from around 100mm down to dust. These aggregates are highly compacted to meet load-bearing requirements and engineering standards. This often acts as a barrier to the spread of tree roots, causing them to be contained within a very small useable volume of soil without adequate water, nutrients or oxygen. A typical tree used for street planting needs a root volume of at least $20m^3$ (and preferably a lot more) at maturity (say 50 years) but often the hole dug in the pavement to form a tree pit less than $2m^3$. Trees planted this way will suffer from ill health and won't make it to maturity. Furthermore, because the roots are unable to penetrate the hard-packed base they often grow into the thin layer of sand beneath the surface and cause trip hazards by lifting the pavement.

An alternative approach, which has been evolving in Europe and the USA for several decades, is now commonly being used in the UK. It involves the creation of a stone-based **'structural soil'** that can be compacted to provide a solid base for surfacing while allowing large voids to remain for water movement, air diffusion and tree root growth. Structural soils can meet engineering standards for supporting pedestrian and vehicular traffic whilst at the same time providing enough soil for a tree to be healthy and reach maturity.

The design encourages roots to grow deep underground to avoid lifting the pavement. The tree planting programme carried out by the City of Stockholm has demonstrated that exceptionally healthy trees can be cultivated when using structural soils.

When installing structural soils around existing services structural soils should be treated as any other sub-base material, and so delicate pipework or infrastructure can be protected with pipe bed aggregate as it is under normal circumstances.

A key benefit of using structural soils is that they can easily be dug up and re-instated if necessary, which allows easy access to repair or install underground services once the tree is established.

Structural soils are a versatile technology, combining drainage and hard surfaces for a wide range of applications, including areas that are trafficked by HGVs, on all types of projects, whether new or retrofit. While structural soils are popular as part of a management train comprising various SuDS techniques they can equally be used in isolation as a stand-alone technique to improve conventional drainage systems.

Additional benefits of using structural soils include:

+ ***Provides a solid foundation***

The compacted stone that makes up the structural soil meets the necessary engineering requirements to support a load-bearing surface

+ ***Prevents surface rooting***

The design ensures root growth happens deep below the surface and so footpath disturbance is avoided, and future surface maintenance requirements are minimised

+ ***Easy to install***

The components of structural soils are easily available and can be installed using standard construction machinery

+ ***Tried and tested***

Structural soils have been proven to be a cost-effective way to provide for the needs of both engineers and trees

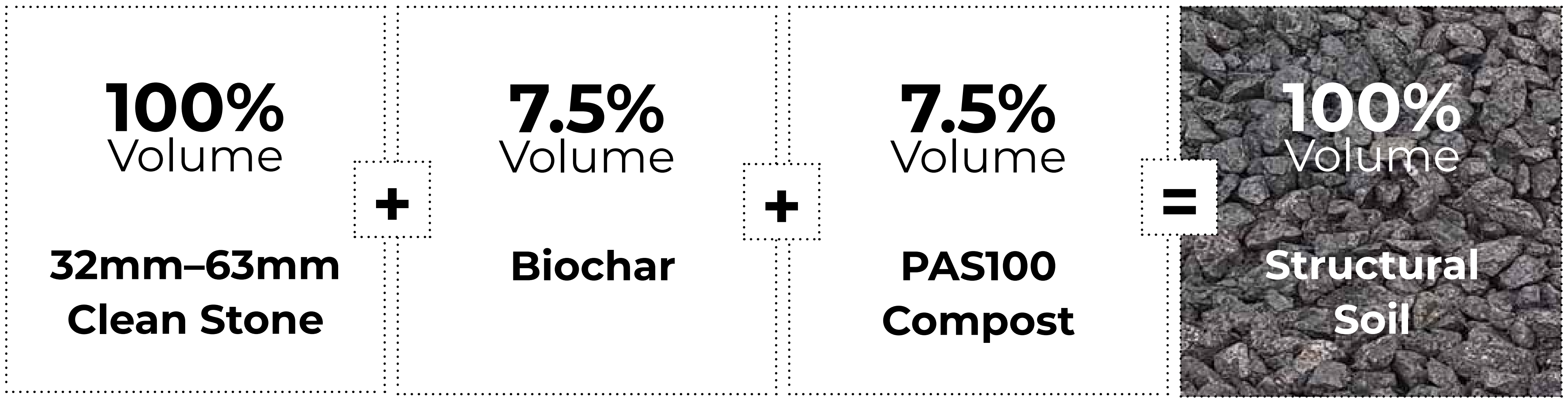

Figure 3:
Most of a structural soil is made up of crushed rock. After the rock has been compacted, and a soil mix added, there remains a network of interconnected voids between the stones. These void spaces provide opportunities for root growth, air diffusion, and water movement.

4. The SuDS benefits of structural soils

It is difficult to grow healthy, large trees in urban areas because the environmental conditions are often harsh and the soils inhospitable. To thrive, trees need a continual supply of water, so drought stress is a main contributor to the premature death of urban trees.

In most built-up areas rainwater is diverted away from the trees into storm attenuation systems, but this is a waste of an important resource because the local street trees would benefit from receiving that water. The Stockholm system collects rainwater from roofs, roads and paved surfaces and diverts it into the tree pit. This type of tree pit design serves the soil's need for oxygen by incorporating large inlets that provide pathways for gaseous exchange and water ingress. The inlets are deliberately designed to be at the low point of hard surfaced areas so that they receive as much rainwater as possible. Runoff from the roads can also be diverted into the tree pits using roadside drains (see fig. 2). Therefore, trees planted in this way contribute to SuDS.

Many existing urban drainage systems can cause problems of flooding, pollution or damage to the environment and are not proving to be sustainable in the context of wider challenges from climate change and urbanisation. SuDS designs seek to optimise natural water losses before it reaches traditional drainage networks like sewers and watercourses. Urban trees provide all the functions associated with SuDS, including the interception and storage of rainfall at source, the filtration of pollutants, the provision of amenity, and supporting local wildlife. Studies have found that access to stormwater increases the growth rates of street trees during the establishment period compared to traditional street tree planting techniques. This is why stormwater management and urban tree establishment are best when they are part of one integrated design.

The overarching aim of SuDS is to manage surface water for maximum benefit, both immediately and in the future. The larger and healthier a tree is, the more effectively it can intercept and conserve water. So, using rainwater to irrigate urban trees brings multiple SuDS benefits, as well as enhancing their survival.

From a SuDS perspective, a major benefit of urban tree pits is their ability to function as a source control for pollutants. Trees can degrade xenobiotic contaminants in the soil of their rhizosphere by exuding enzymes that catalyse the breakdown of the compounds – or by stimulating microorganisms to do so. These compounds may be immobilised and sequestered in the soil, or absorbed by the tree where they might remain intact or be further degraded. Through these processes, passing runoff through tree pits can stabilise contaminants and reduce their movement into the wider environment. The biochar in a structural soil mix also has excellent filtration properties which remove waterborne contaminants.

Each element should be considered as part of a treatment train to ensure that the appropriate levels of water quality are achieved when discharging to surface water drainage systems. Refer to the CIRIA SuDS Manual for further guidance.

Figure 4:
Mature street trees in structural soil (Stockholm).

Figure 5:
Trees growing in soils amended with biochar have healthy foliage, this foliage helps intercept rainfall and particulates.

5. The use of biochar as a soil amendment

Biochar is the residue of organic material combusted under low oxygen conditions, which results in a low-density and carbon-rich material. When added to soil, it is considered a form of humus because it has a high affinity for nutrients, is highly porous and has a large surface area. Biochar is not a single chemical entity; individual particles of biochar vary in both structure and chemical composition. It differs from charcoal because it is manufactured to give it properties that make it of value as a soil amendment or for broader environmental management. Therefore, a product cannot be called biochar if it contains harmful levels of heavy metals or organic contaminants.

A growing body of research supports the use of biochar to increase soil quality and plant growth. The main purposes of using biochar as a soil supplement include increasing soil carbon content, fostering soil biota, increasing water holding capacity, improving nutrient retention and bioavailability, enhancing soil structure, and promoting plant growth.

Biochar can be improved as a soil amendment if it is co-composted, i.e. mixed with organic materials in the process of becoming compost. Co-composting is a simple form of enrichment; it produces a growing medium combining the ability of biochar to slowly release essential plant nutrients like nitrate and phosphate with the fertilisation potential of compost (easily broken-down organic matter rich in mineralisable nutrients). The process of co-composting appears to produce a synergistic effect; it promotes plant growth beyond the combination of raw biochar with either mineral fertiliser or mature non biochar-amended compost.

The incorporation of compost and biochar in urban tree soils reduces drought stress in trees during periods of water scarcity. Crucially the mix creates ideal conditions for mycorrhizae and soil microbes that are beneficial for tree root growth. Furthermore, using biochar and compost together reduces the leaching of nutrients into waterways and groundwater, and conserves nutrients in the compost in forms that can help promote soil health and plant vigour. Adding biochar to the soil also provides additional benefits that are less obvious, the most notable of which is an increased resilience to diseases and environmental stressors such as defoliating insects.

With the right pyrolysis methodology, a tonne of biochar used in an urban soil equates to almost 3 tonnes of carbon dioxide removal (CDR). The Intergovernmental Panel on Climate Change recognises biochar as one of five land-based carbon dioxide removal (CDR) techniques (IPCC, 2022). Therefore, by sequestering carbon, the use of biochar as a soil amendment in green infrastructure has the potential to contribute to the mitigation of climate change.

All biochar used as a soil amendment should meet the requirements of the International Biochar Initiative (IBI) Biochar Standards and/or the European Biochar Certificate (EBC) guidelines.

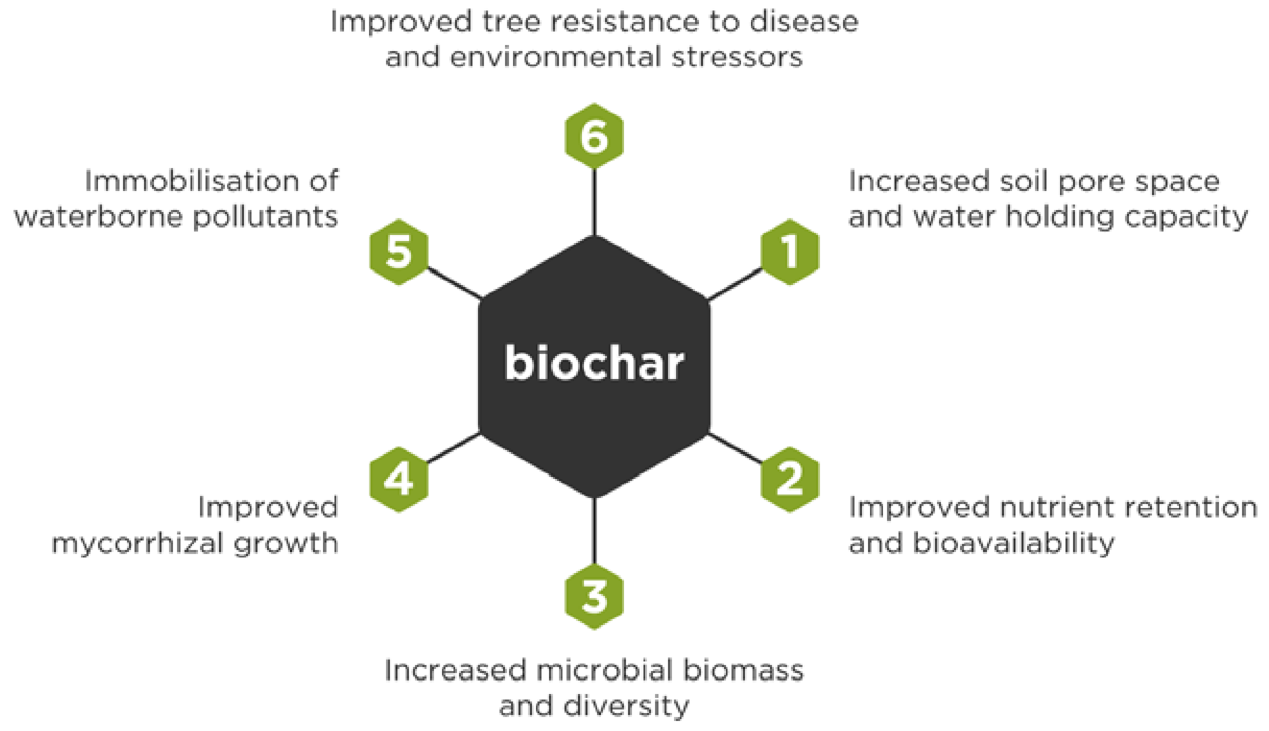

Figure 6:
The benefits of adding biochar to urban tree soils.

IPCC, (2022). Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, et al. (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA.

Structural Soil Tree Pit Design

Planting hole dimensions at surface: 1.2m x 1.2m.

Recommended depth min. 0.8m - max. 1.5m.

All crushed clean stone aggregate to be either basalt or granite unless specified otherwise.

Sustainable drainage principles and water quality
A suitably qualified engineer should advise on the below:

- Infiltration potential and lining of pits to be determined by a drainage engineer based on ground investigation results, including any risk to groundwater. Any liner that forms a root barrier to be avoided where possible to allow for future rooting area beyond the tree pit.
- In addition to the above, this design should be considered as part of a treatment train to ensure that the appropriate levels of water quality are achieved when discharging to surface water drainage systems. Refer to CIRIA SuDS Manual for further guidance.

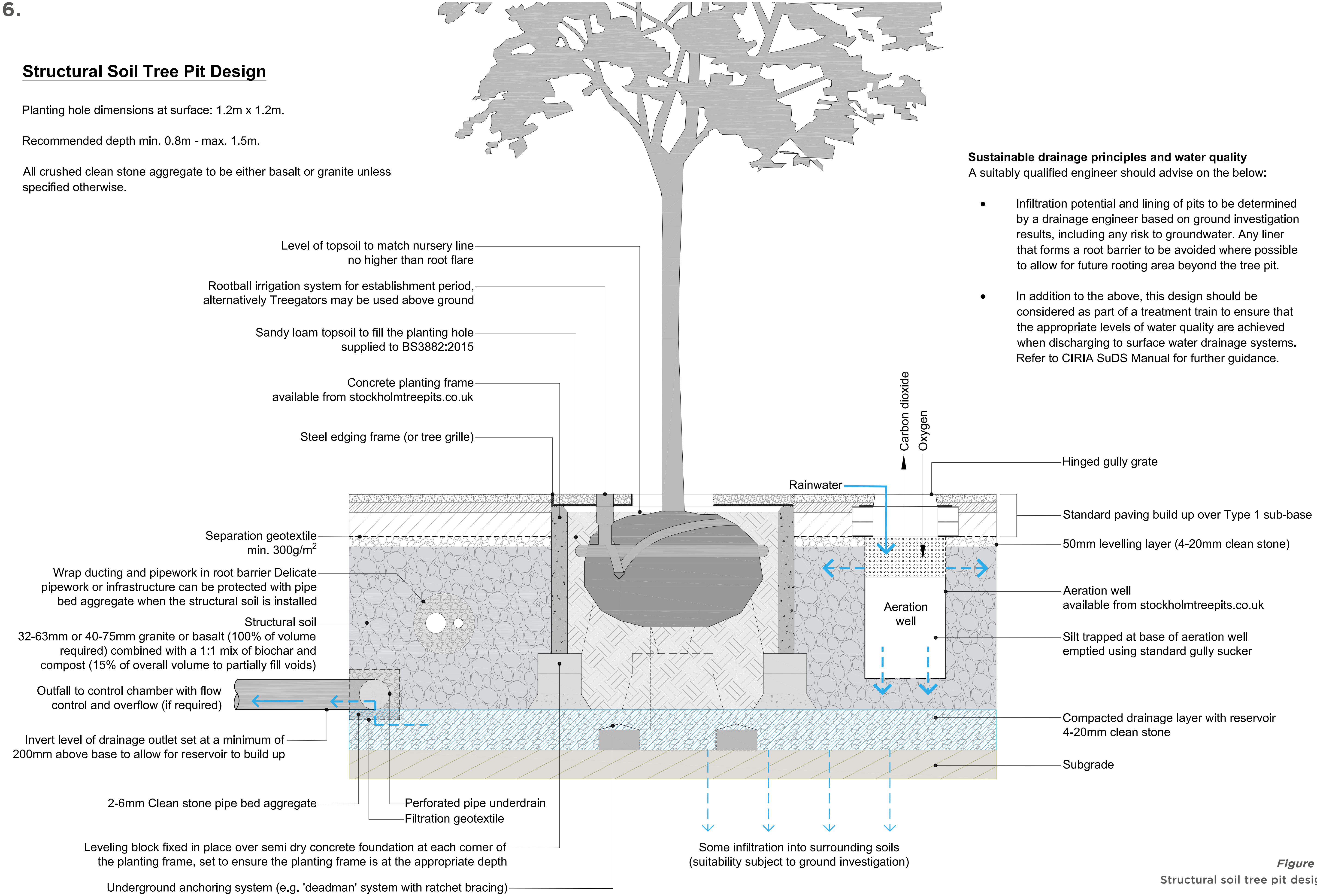

Figure 7:
Structural soil tree pit design

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7. Bioretention & raingarden tree pits

Tree pits that use the Stockholm system are bioretention features because they are designed to hold water at the base of the tree pit that acts as a reservoir to support the tree during times of drought. An example of a structural soil tree pit design is provided in Figure 7.

A separation geotextile is required immediately above the structural soil to prevent base-layer material beneath the paving from migrating downwards and impairing the functioning of the structural soil. Geotextiles may also be required on the sides and the bottom of the tree pit in some situations.

Stormwater is harvested above ground and directed to bioretention tree pits via aeration wells or permeable pavements. This water may be used by the tree, but the design also allows water to be attenuated within the tree pit.

The sump in a bioretention tree pit is a layer of compacted clean stone which provides pathways that water and air can flow through. These voids give the material a porosity of 30-40%, allowing storage of up to 400 litres of water per cubic metre of the drainage layer. This creates the possibility of controlling water flow within the system and discharging it to the conventional sewer system in a controlled manner (Edge, 2023). Apart from temporarily retaining water in the water retention zone, the system allows stormwater to be kept as a reservoir at the base of the tree pit for use by the tree during periods of low rainfall.

Bioretention tree pits may be designed and dimensioned differently depending on the volume of stormwater expected to be handled and the expected length of the drought periods, but the principle of water retention zones is based on the traditional water reservoir. The control of the system is flexible: they may be designed to cope with a light rain or extreme downpours. Tree roots require oxygen to respire and so the part of the tree pit designed to accommodate tree roots should not be inundated with water for any longer than 24 hours.

Figure 8:
Raingarden tree pit.

Figure 9:
Bioretention zone tree pit in paving.

Email us at enquiries@stockholmtreepits.co.uk to get a quote for your project.

References:
Edge, (2023). Liveable Streets – A Handbook for Bluegreengrey Systems.
Edge, Malmö: www.edges.se

Embrén, B. (2022). Planting Beds in the City of Stockholm, A Handbook version 4.5. City of Stockholm.

Raingarden Tree Pit Section

Recommended depth min. 0.8m - max. 1.5m.

All crushed stone aggregate to be either basalt or granite unless specified otherwise.

Sustainable drainage principles and water quality
A suitably qualified engineer should advise on the below:

- Infiltration potential and lining of pits to be determined by a drainage engineer based on ground investigation results, including any risk to groundwater. Any liner that forms a root barrier to be avoided where possible to allow for future rooting area beyond the tree pit.
- In addition to the above, this design should be considered as part of a treatment train to ensure that the appropriate levels of water quality are achieved when discharging to surface water drainage systems. Refer to CIRIA SuDS Manual for further guidance.

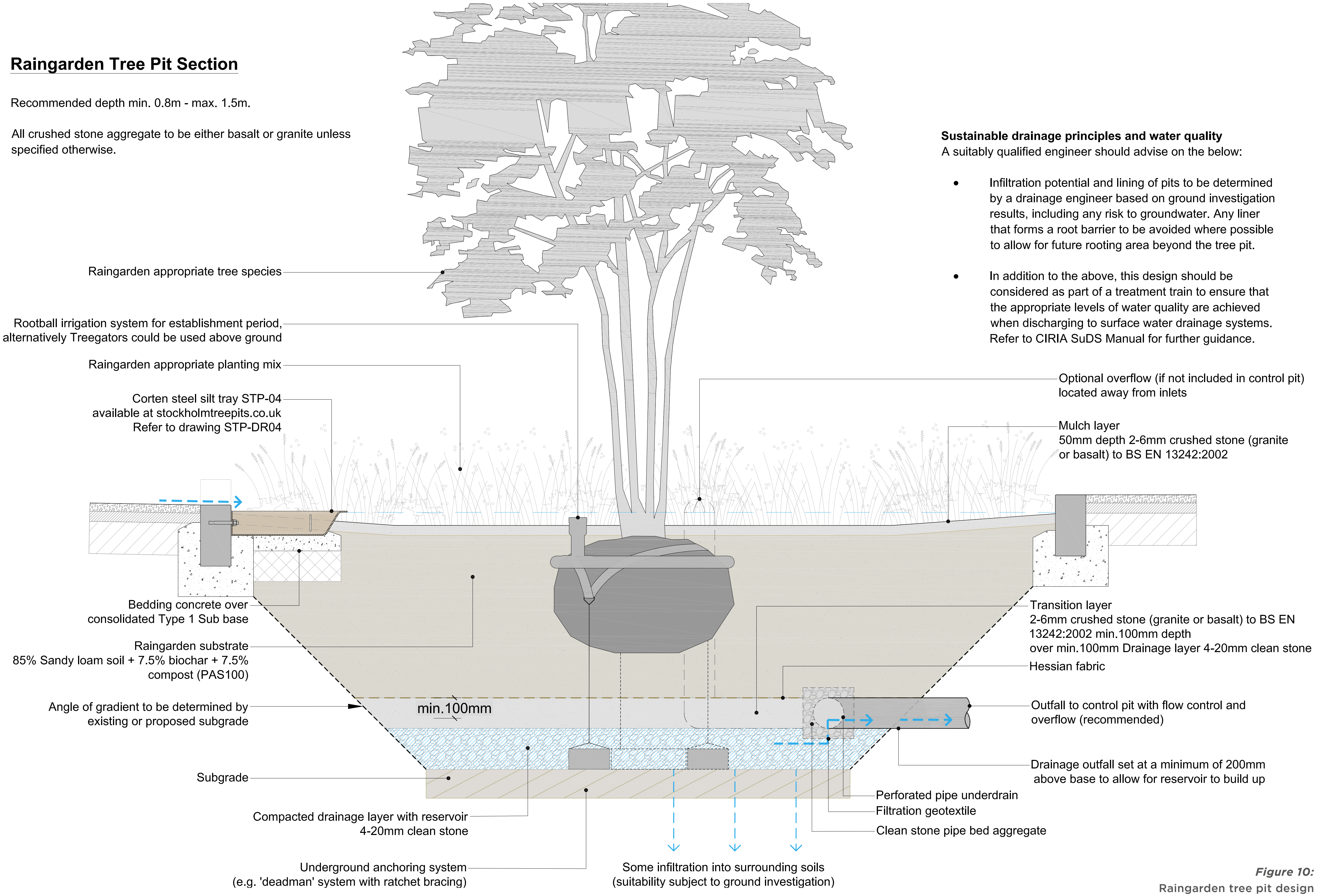

Figure 10:
Raingarden tree pit design

8. Extending raingardens with structural soils

Raingardens are planted depressions designed to take all, or as much as possible, of the excess rainwater run-off from a building and its associated landscape. They are designed to be at a lower level than the surrounding surfacing so that they can receive and retain water at the surface. They typically have soils with high porosity so that water can rapidly infiltrate the soil.

Raingardens are a space-efficient form of source control used to manage surface water and they bring a wide range of SuDS benefits. Engineered soils can improve their performance. Biochar is a particularly good amendment for soils used in raingardens because the structure helps retain water, it provides habitats for micro-organisms, and it immobilises potential pollutants.

Trees are often planted in raingardens and the size of trees within the raingardens can greatly increase the biomass that they support as well as the habitats and amenity that they provide. The trees' foliage intercepts rainfall and the trees themselves collect and store runoff, and they provide water treatment via filtration and phytoremediation.

Small raingardens are often unable to support large-growing tree species however structural soils beneath hard surfacing adjacent to the raingarden can be used to increase the rootable volume available to trees growing within a raingarden (see fig. 12). This approach allows larger-growing tree species to be planted in raingardens that would otherwise have small soil volumes.

Trees and large shrubs are beneficial in raingardens as they:

+ ***Intercept precipitation and allow water to evaporate from leaf surfaces***
+ ***Dissipate rainfall-runoff energy***
+ ***Facilitate infiltration and groundwater recharge, because of their more extensive root systems***
+ ***Provide shade and can reduce runoff temperatures***
+ ***Provide visual amenity and biodiversity benefits***

Raingarden substrates:

- **In the UK, raingarden substrates tend to be specified utilising sandy loam soils as the predominant soil medium.**
- **In Stockholm and elsewhere in mainland Europe crushed rock based soils are often favoured.**

Reference:

Woods Ballard, B., Wilson, S., Udale, C. H., Illman, S., Scott, T., Ashley, R. & Kellagher, R. (2015). The SuDS manual. London: CIRIA.

Figure 11:
Raingarden tree pit with extended open stone build up spanning the width of the road.

Raingarden Tree Pit with Underbuild Section

Recommended depth:
min. 0.8m - max. 1.5m.

All crushed stone aggregate to be either basalt or granite unless specified otherwise.

Sustainable drainage principles and water quality
A suitably qualified engineer should advise on the below:

- Infiltration potential and lining of pits to be determined by a drainage engineer based on ground investigation results, including any risk to groundwater. Any liner that forms a root barrier to be avoided where possible to allow for future rooting area beyond the tree pit.
- In addition to the above, this design should be considered as part of a treatment train to ensure that the appropriate levels of water quality are achieved when discharging to surface water drainage systems. Refer to CIRIA SuDS Manual for further guidance.

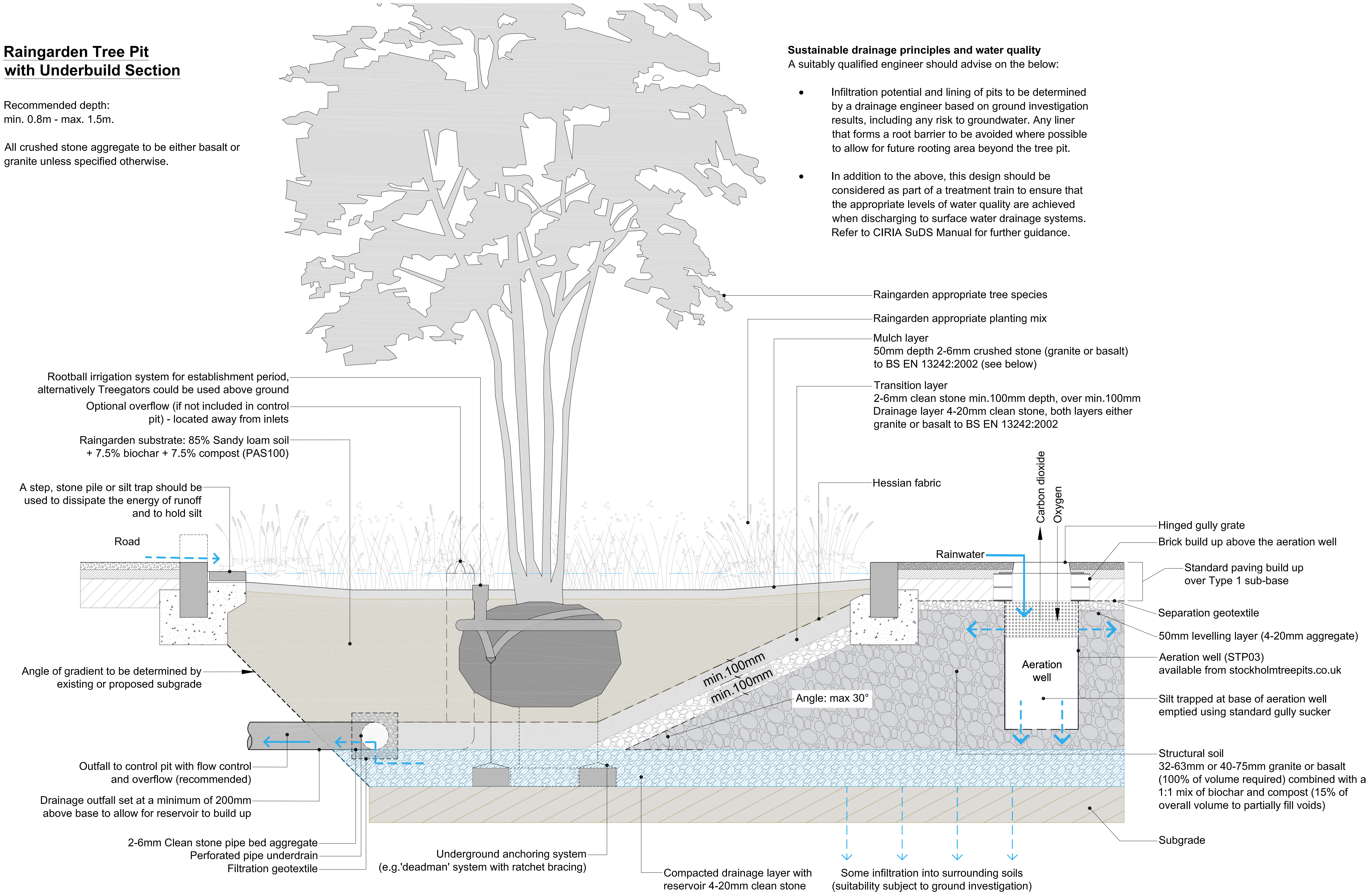

Figure 12:
Raingarden tree pit with underbuild design

9. Specifying tree pits with structural soils

The structural soil is installed in layers and once the material has been laid it is effectively a macadam sub-base. The best results are being achieved by using crushed rock combined with a 1:1 mix of biochar and compost (15% volume). Specifiers should be aware that the stone fraction of the soil mix fills the tree pit and that the biochar/ compost mix adds nothing to the overall volume of the soil because it fits into the void spaces between the stones.

The load bearing capacity of a structural soil will depend on the strength of the stone aggregate used in the design. Standard paving stones have been tested with a heavy vehicle simulator, and it was shown that the build-up can handle repeated loading from a vehicle with 10 tonnes standard axle without any cracked paving stones (Hellman et al, 2012). Field tests have also shown that structural soils with asphalt have a rutting depth development that corresponds to the standard construction (Hellman et al, 2012). Therefore, structural soils can be used beneath footpaths, cycle paths and car parking areas; it is even possible to use structural soils beneath trafficked streets if they are designed and constructed properly.

Structural soils are designed to be load bearing and they are unsuitable for use beneath areas of soft landscaping (except raingardens). **Topsoil should not be placed above a structural soil** (even if a separation geotextile is used) because the discontinuity between the two materials significantly inhibits water transfer. Water can move sideways between topsoil and a structural soil and so, as an alternative solution for larger planting beds, topsoil can be used for the whole of the planting area and connected to structural soils laid beneath paved surfacing beyond the planting bed (as shown in fig. 12).

Standard machinery found on most building sites can be used to install structural soils. Also, the low-tech approach means that the surface can be dug up after the pavement has been laid if any future ground works are required, and shallow underground services can be installed in the gap between the pavement and the tree roots below.

Further guidance on specifiying tree pits with structural soils is provided in:

BS8640:2025 Structural and supported soils for trees in hard landscapes - Guide.

Machinery required to install structural soils:

- **1 x excavator (6-13 tonnes)**
- **1 x dumper (3-6 tonnes)**
- **1 x vibrating plate compactor (400kg+)**

Reference:
Hellman, F. et al. (2012). Draining hard packed surfaces in a city environment – breakdown tests with HVS equipment at VTI. Statens Väg-och transportforskningsinstitut (VTI), Sweden.

Figure 13:
A structural soil tree pit in the process of construction. In this instance larger aggregate is being used so that the final surface will be able to support heavy traffic.

[Image courtesy of Björn Embrén]

9. Specifying tree pits with structural soils

The load bearing element of the structural soil needs to be a hard rock such as crushed granite or basalt. For most installations 32–63mm crushed rock is used but 40–75mm is also suitable (see Table 1). It is recommended that the rock is mixed with the biochar/compost mix before being installed.

Larger stones (90–150mm) are used for roads because they are able to support heavier loads. This method is well established and evaluated in Stockholm and the build up has been tested by the Swedish National Road and Transport Research Institute (VTI) and has been shown to have such good load bearing capacity that it can be used under paved surfaces for carriageways and parking areas.

The 90/150mm aggregate should be laid in layers that are 200mm deep and each layer compacted. When the larger stones are used the biochar/compost mix should be hosed into the void spaces after the stones have been compacted. Flushing soil down into the structural layer is time-consuming. To optimize the process, the soil is laid out in thin 200mm layers and washed down with a pressure hose. Further guidance is provided in Appendix A of Planting Beds in the City of Stockholm (Embrén, 2022).

Compaction, specified by engineers for earthworks, is usually (not always) between 90–95% maximum dry density (MDD). In order to create even stability, the structural soil should be laid in lifts of 100–125mm and spread with the excavator bucket, and each lift must be thoroughly compacted before the next layer is laid out. Adequate compaction of each layer can normally be achieved by at least 8 passes with a vibrating plate compactor (min. 400kg in size) or at least 10 passes with a roller with a line load of over 25kN/m. A static load test (or equivalent) can be carried out to ensure that the desired load capacity level has been achieved. Alternatively, some compaction equipment can be programmed to alert the operator when the desired level of compaction has been achieved.

A pre-cast concrete planting frame is used for the planting hole to house the rootball. This also functions as a root deflector by ensuring that roots can only grow deep beneath the surface. The concrete planting frame has rigidity which allows stone to be introduced and compacted around the planting hole during the construction of the tree pit.

Excavate in stages and backfill promptly to limit moisture change and weathering. Backfill within 48 hours of opening unless otherwise agreed. Do not place aggregate in standing water and suspend placement during heavy rain. If the excavation softens or pumps under foot, trim and proof roll, then over excavate to firm ground and replace with compacted stone.

Aggregate sizes for stone based systems

Dimensions in millimetres

Layer	Aggregate sizes
Surface layer	Paving with standard sub-base
Levelling layer	4/10, 2/14, 4/20, 20/40
Structural soil	20/50, 30/50, 32/63, 30/70, 40/75, 22/90, 90/150
Drainage layer	4/20, 16/90, 20/40, 32/63, 40/75, 32/90

Table 1:
Aggregate sizes recommended for tree pit designs that use crushed rock (reference: Table 5 of BS8640:2025 Structural and supported soils for trees in hard landscapes - Guide).

Figure 14:
The structural soil is compacted in layers during installation.

9. Specifying tree pits with structural soils

The starting point for constructing the tree pit should be identifying its precise location and installing the deadman anchors. Once these are in place the feet of the concrete planting frame should be installed on a solid base; this is best done by sitting the feet onto stone slabs or concrete blocks that are bedded onto semi dry concrete. When compacting structural soil around the planting frame some of the stones should be allowed to fall through the side apertures because this will improve stability and provide a more gradual interface between the topsoil in the planting pit and the structural soil that surrounds it.

Aeration wells should be sited at a low point of the surface and where they are likely to serve a large proportion of the tree pit. A critical requirement is that the perforations in the walls of the aeration well marry up with open-textured aggregate so that pathways for air to reach the whole of the tree pit. It is also advised that the aeration well is positioned away from the drainage pipe to allow water to pass through the tree pit rather than directly from the inlet to the outlet, and ideally 1.5m away from the concrete planting frame.

Impermeable tarmac or any sort of paving can be laid on top of tree pits constructed using the Stockholm system. A geotextile is laid over the entire tree pit followed by a base material for the pavement and the surface layer for the specific paving of the road, pavement, or cycle path to be installed.

The most common error when constructing tree pits with structural soils is when the separation geotextile is installed between the wrong layers. The geotextile is required to prevent the surface base course from mixing with the levelling layer. The levelling layer prevents the geotextile from being torn by the large angular stones in the aeration layer. Therefore, the geotextile must be placed on top of the levelling layer (see fig. 15).

The geotextile and the levelling layer together ensure that root growth is well below the final surface and so problems caused by roots lifting pavements are avoided.

Structural soils can be placed around underground services. The services can be protected from root ingress by wrapping them in a suitable geotextile or by installing them inside plastic ducting. Fragile pipes or infrastructure can be protected in the standard way by surrounding them with a pipe-bed gravel mix (4–10mm crushed rock) or by using sand as protection.

When concrete is used for embedding curbs, a small amount will run into the open sub-base layer before the material has hardened. In order to prevent that volume from being taken away from the system and to minimize material costs, a dry set concrete should be used. Geotextile or other fabrics should not be used in this situation.

The final surface is likely to be much more durable if the interfaces between the different sub-bases are considered in the design. Therefore, it's usually sensible to use structural growing media for the full width of a surface rather than just part of it. This homogeneity would ensure uniform engineering characteristics below the pavement, particularly with regards to frost heaving and drainage. This design requirement can help achieve rooting volumes that are larger than the minimum required.

After planting it normally takes any urban tree two to three years to become established. During this period consistent and regular watering of the rootball will be required in the summer months to prevent the tree from suffering drought stress.

Once the trees have been planted the tree pits should be periodically inspected to ensure that they are functioning effectively. It is important that arrangements are made to empty the aeration wells at least once a year.

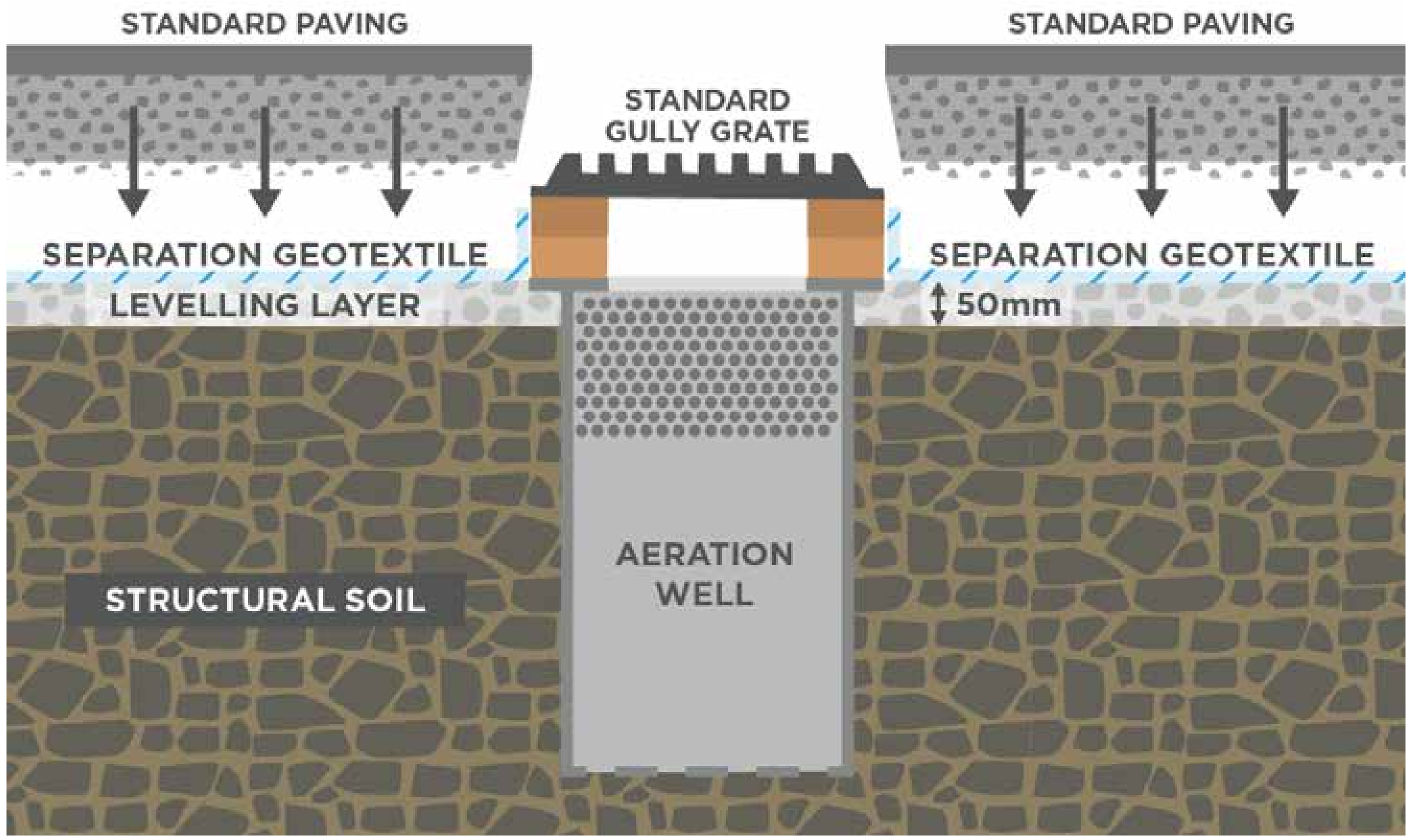

Figure 15:
Example build up of structural soil, aeration layer and standard surface paving over a separation geotextile.

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9. Specifying tree pits with structural soils

Transition layers for raingardens

In a raingarden (bioretention) profile, the transition layer sits between the filter media (the raingarden soil water percolates through) and the coarse drainage/storage layer below. Its role is purely hydraulic and mechanical: preventing fines from migrating into and clogging the aggregate layer, while still allowing water to pass freely.

Current best practice increasingly avoids placing a woven or non-woven geotextile directly on the aggregate at this interface, for several reasons:

- Concentrated clogging: fines that would normally disperse through a graded aggregate profile instead cake onto a single geotextile plane.
- Biofouling and root intrusion: synthetic fabric interfaces attract root mats and microbial biofilms.
- Poor maintainability: a clogged geotextile at depth can't be jetted, swept, or replaced without excavation, whereas a graded granular filter degrades gradually rather than failing outright.
- Longevity mismatch: geotextiles often have a shorter design life than the SuDS asset's intended 25–50+ years, especially under freeze-thaw or root pressure.

CIRIA's SuDS Manual (C753) and most current UK bioretention guidance now favour a graded granular filter over fabric at this interface for these reasons.

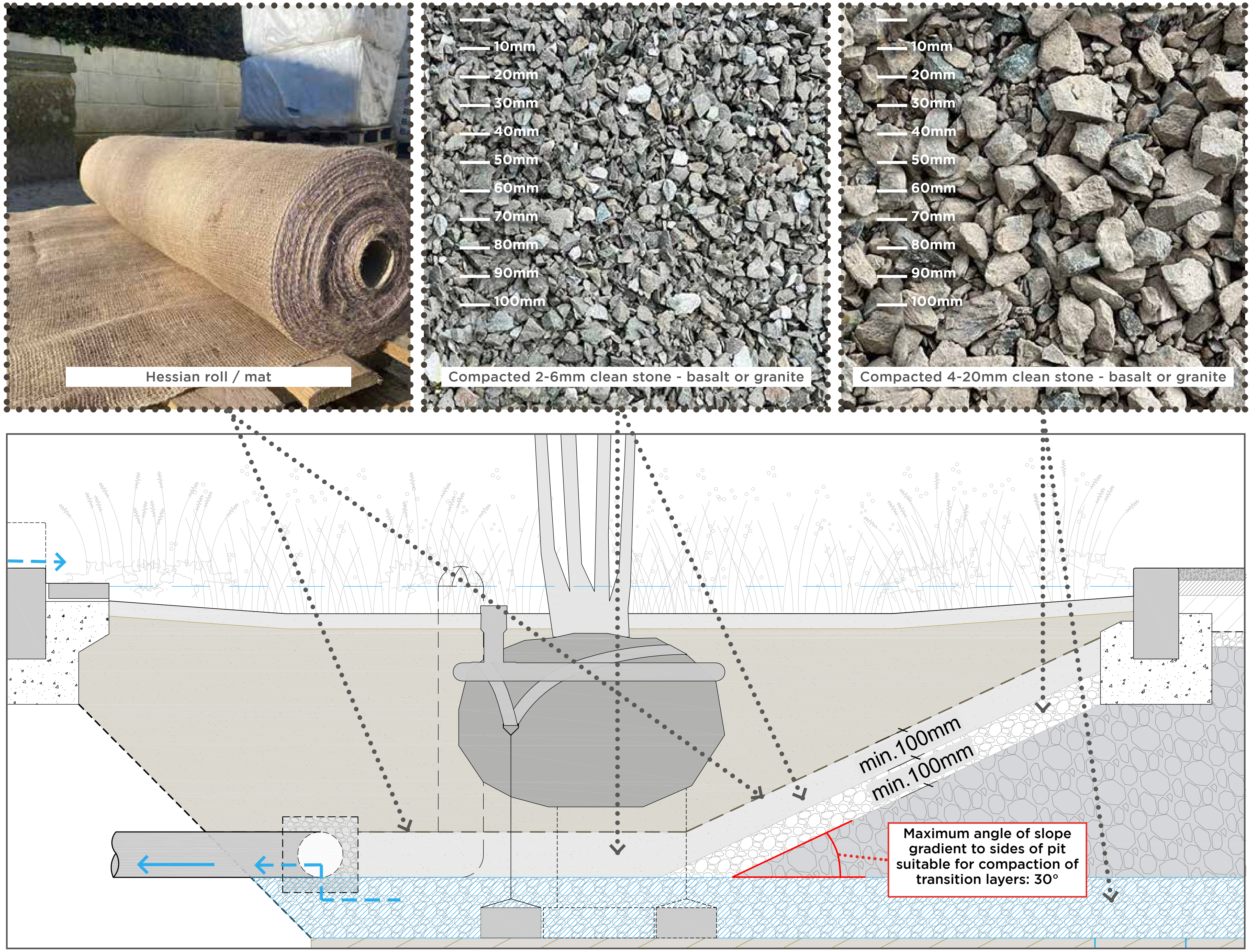

Figure 16:
Material specification and locations of transition layers when interfacing with structural soil

Tree Pit Gully Pot Inlet Design

Precast gully pots are supplied by Marshalls CPM. All materials readily available from most construction suppliers. Standard construction equipment can be used for handling and compacting the structural soil.

The gully pot inlet should be installed in conjunction with an aeration well (STP-03) installed in the paved surface over the tree pit that has pathways for air to reach the structural soil.

To be read in conjunction with STP-DR-01 Structural soil tree pit section.

Amphibians and small mammals can become trapped in gully pots, measures to mitigate against this are strongly recommended:
ACO Wildlife Kerb (www.aco.co.uk/products/wildlife-kerb)
Amphibean Gully Pot Ladder as recommended and supplied by the British Herpetological Society (www.thebhs.org/shop)

Sustainable drainage principles and water quality
A suitably qualified engineer should advise on the below:

- Infiltration potential and lining of pits to be determined by a drainage engineer based on ground investigation results, including any risk to groundwater. Any liner that forms a root barrier to be avoided where possible to allow for future rooting area beyond the tree pit.
- In addition to the above, this design should be considered as part of a treatment train to ensure that the appropriate levels of water quality are achieved when discharging to surface water drainage systems. Refer to CIRIA SuDS Manual for further guidance.

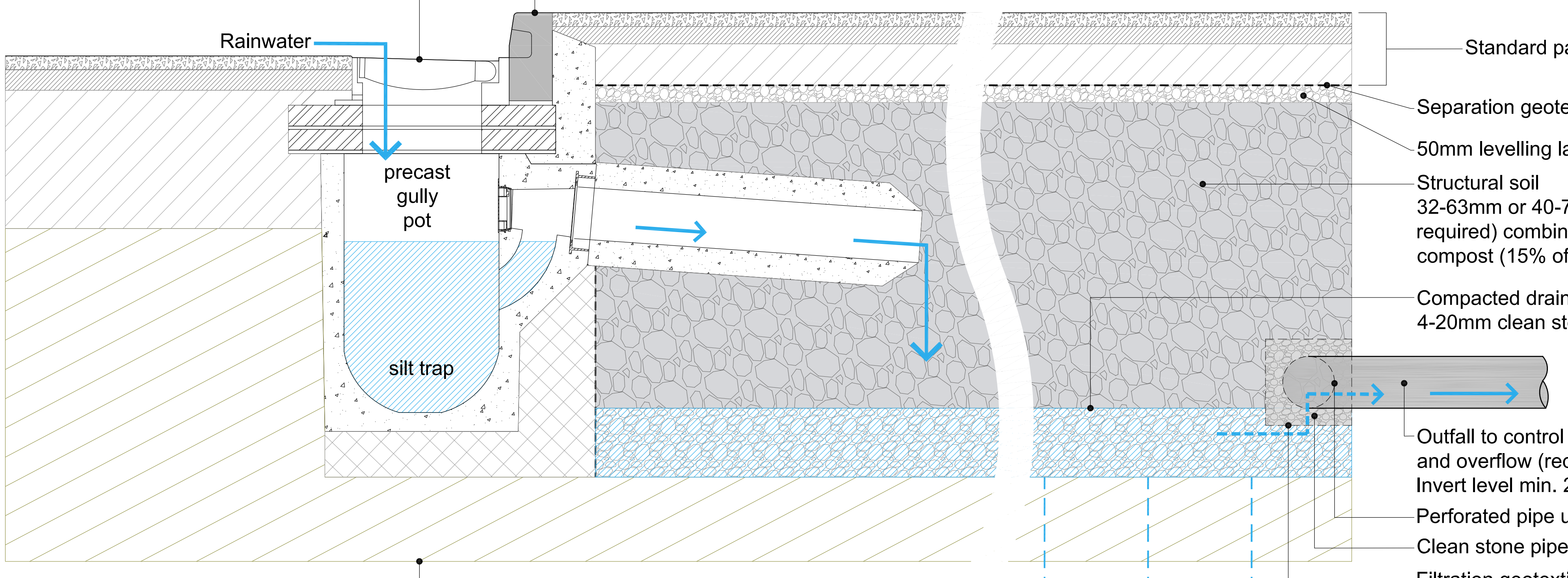

Figure 16:
Tree Pit Gully Pot Inlet Design

10. Specifying soil volumes

The soil provides many tree resources, primary among them being water, oxygen, nutrients and a volume to allow stabilizing root growth. When soil volume is limited, tree growth suffers because the top growth of the tree is dependent on what the roots can provide.

Trees bring significant benefits to the urban environment, in, for example, cooling through shade and evapotranspiration, the reduction of air-borne particulates and the sequestration of carbon. In order to fully benefit from these effects when designing urban spaces, it is therefore necessary to check that both the quality and volume of the soil are sufficient for the tree to be healthy through to maturity.

In the past the lack of understanding of the tree's requirements has led to them being planted with inadequate soil volumes. Recommended volumes for tree pits that use structural soils with biochar and compost are provided in Table 2.

Adequate root space can be difficult to achieve on most urban and sub-urban sites, especially in the UK where space is at a premium and there is a high demand for new housing. In this context, trees situated in hard landscaping often need suitable growing conditions to be extended beneath the hard surfacing, this can be done by constructing engineered tree pits. Adjacent trees can share soil because root systems can overlap (as any woodland stand demonstrates). In design terms, this means that the volume of soil/rooting medium required by each tree can be reduced.

One of the first steps taken by a specifier should be to calculating the volume of soil available in a planting position. This will identify what tree species can be supported in that location. Specifiers should also be aware that factors such as air temperature, wind speed, relative humidity, and light help determine how quickly water is lost from the leaves, so trees planted in exposed locations need larger soil volumes than standard specifications.

Soil volume guidance for tree pits is provided in BS8640:2025 (BSI 2025). Table 2 shows the recommended volume of structural soils required by trees that grow to different sizes at maturity.

Where possible tree pits should be linked to other viable soils in the vicinity of the tree pit. This maximises opportunities for tree root growth and can reduce the volume of structural soil required in the tree pit.

Mature tree sizes are listed in Tree species selection for green infrastructure – a guide for specifiers (TDAG, 2018).

	Very Small (<5m)	**Small** (5–10m)	**Medium** (10–15m)	**Large** (15-25m)	**Massive** (>25m)
Recommended minimum volume of stone-based structural soil	**$12m^3$** ($10m^3$ if shared)	**$24m^3$** ($19m^3$ if shared)	**$40m^3$** ($32m^3$ if shared)	**$56m^3$** ($48m^3$ if shared)	**$72m^3$** ($60m^3$ if shared)
Recommended number of air/water inlets	**1** (0.5 if shared)	**1** (0.5 if shared)	**1**	**2** (1.5 if shared)	**2**

Table 2:
Recommendations for tree pit volume specifications (reference: BS8640:2025 Structural and supported soils for trees in hard landscapes - Guide).

References:
BS8640:2025 Structural and supported soils for trees in hard landscapes - Guide.

TDAG (2018). Tree Species Selection for Green Infrastructure: A Guide for Specifiers. Trees and Design Action Group. London.

11. Drainage

Once the tree species have been selected and the required soil volume identified, the drainage engineer should become involved in the design of the tree pit because effective drainage is essential to maintain soil conditions suitable for tree root systems. Water harvesting for the tree pit and subsequent drainage should be included in the drainage layout.

Designers need to ensure that tree pits have adequate pathways for water ingress and to allow gaseous exchange between the soil and the above-ground atmosphere. This could be provided by installing a permeable surface over the whole of the tree pit or by using a non-permeable surface with specially designed inlets (such as aeration wells). Permeable surfacing allows rainwater and air to reach the soil directly from above but supplementary inlets to help them reach the lower levels of the tree pit are recommended. Suitable inlets would be substantially larger than an irrigation tube and service the whole of the tree pit. The surface should be designed to have inlets at local low points so that the tree pits receive as much rainwater as possible, the planting hole can sometimes be used to collect surface water if it is designed to be highly permeable and lower than the surrounding surfacing.

Engineered tree pits need under-drainage included as part of the design to prevent the tree pit from becoming waterlogged (unless there is good drainage in the surrounding soil). The tree pit drainage should be designed in such a way that the rainwater passes through the soil before it is drained out of the tree pit. Sites that have level ground are the most suitable for tree pits that use structural soils because this allows efficient temporary storage of flows for treatment. For sloping sites where the subgrade gradient exceeds 5%, check dams or underground terracing are likely to be required.

For the tree pit to provide water storage the flow of water out of it must be restricted using a flow control device.

When the flow is restricted at the outlet water backs up into the permeable construction where it is stored temporarily. The water should be controlled to leave the soil at a gradual pace however it is advised that the tree pit is not inundated for periods longer than 24 hours. A site-specific flow control device will normally be required for most projects.

As with any drainage system, flood conveyance routes to cater for extreme events should be planned within the overall project layout. Design of tree pits with structural soils must also take into account the overland flow routes of water when the design capacity is exceeded. Although exceedance will result in flooding of some areas, the flows should be routed to prevent flooding of buildings for events that are well in excess of the capacity of the system. Further guidance is provided in CIRIA Report C635 (Balmforth et al., 2006).

Reference:

Balmforth, D., Digman, C, Kellagher, R and Butler, D (2006). Designing for exceedance in urban drainage - good practice (C635). London: CIRIA.

Figure 17:
Raingarden tree pits can be designed to receive road run off.
Image credit: Rasmus Elleby

12. Maintenance

Irrigation of newly planted trees

During the tree's establishment phase, adequate watering during the growing season is critical if the tree is to survive. Bare root trees, rootballed trees and container-grown trees all require regular and consistent watering until their root systems grow large enough to support their crowns.

Insufficient watering in the initial years after planting is the main cause of poor tree establishment. Landscape managers will naturally want to economise on the costs of watering but even one period of drought can significantly impact the momentum of a tree's development and so regular irrigation should be considered essential.

Watering a newly planted tree should begin at the time of bud burst in the spring and continue throughout the spring and summer until the leaves have fallen in autumn (for deciduous trees). The first watering of the season could be as late as May or as early as March, depending on site conditions and weather. Generally, it is better for the tree if watering is done more often rather than less often, even if more water is applied. Trees planted in exposed locations will also require more water than normal.

Small trees grow faster and will establish more quickly than larger planting stock because their roots come into balance with their shoots sooner. However, small trees are prone to vandalism and so it is often sensible to plant larger trees in urban areas because they are sturdier. **When planting large or semi-mature trees, specifiers should be aware that they will need more water than smaller trees and that using larger planting material will prolong the establishment period.** The minimum establishment irrigation period for newly planted trees should be:

- Two growing seasons for trees up to 20 cm girth.
- Three growing seasons for trees between 20 cm and 30 cm girth.
- Three to five growing seasons for trees greater than 30 cm girth or where site conditions are particularly challenging.

For trees planted in areas of hard landscaping it is recommended that sub-surface irrigation is provided via a horizontal perforated pipe installed around the shoulder of the root system, to approximately a third of its depth. Alternatively, tree watering bags installed above ground may be used.

In the first year after planting, trees should be watered at least once per week in dry weather from May to September, and in subsequent years this can be reduced to once every two weeks.
The volume of water recommended for different sized planting stock is provided in Table 3.

During periods of prolonged dry weather (more than seven consecutive days where temperatures exceed 25°C without significant rainfall, or five consecutive sunny days where temperatures on some of those days exceed 30°C), watering frequency for all trees planted within the establishment irrigation period should increase to twice per week.

Size Category	Girth of tree at 1m (cm)	Diameter of tree at 1m (cm)	Volume of water required at each irrigation event (L)
A	<20	<6	75
B	20-30	6-10	120
C	30-60	10-20	150

Table 3:
Recommended volumes for the irrigation of newly planted trees in dry weather during the growing season.

Figure 18:
A filled watering bag around a newly planted tree

12. Maintenance

Tree pit maintenance

An initial check should make sure that the tree is planted at the right depth and that the stem is upright. After this, the trees will be inspected by the management authority or maintenance contractor in accordance with the agreed schedule. Each inspection will look for signs of disease or damage to the foliage, shoots, and stem. Pruning may be required to encourage a good form and to remove dead, diseased or damaged branches, and any basal shoots.

For Stockholm style tree pits keeping the inlets clear is the single most critical maintenance task. Any surface debris or litter needs to be manually removed from gully grates and surface channels. At least once a year the gully grate above the aeration well should be opened and a gully sucker used to extract accumulated fine sediment and organic matter from the bottom of the chamber.

Every year the surface above the tree pit should be checked to ensure that it is stable. Check the hard surface paving edges around the concrete planting frame. Look for any cracking, sinking, or shifting in the adjacent asphalt or paving slabs. If settling happens, it usually indicates that the geotextile separation layer has failed or the base course is migrating into the structural stones. Such situations would require immediate civil engineering assessment

Raingarden maintenance

Monthly maintenance checks of raingardens are required throughout the year. Additional inspections and maintenance may be required following severe storm events, prolonged drought, or other exceptional circumstances.

Raingarden inlets must be kept clear to ensure that surface runoff doesn't bypass the pit. The free passage of runoff into and through the raingarden shall be maintained at all times.

All inlets, kerb openings, channels, pipe connections, and overflow structures shall be kept free of sediment, vegetation, litter, and other debris. Accumulated sediment shall be removed manually where practical. Any damaged or displaced components shall be repaired or replaced promptly.

Planting shall be maintained to achieve complete and healthy vegetation cover. Any dead or dying plants should be removed. Any planting losses exceeding 10% of the original design quantity shall be replaced. Plant species shall be replaced on a like-for-like basis unless otherwise agreed by the management authority.

For open tree pits and raingardens weeds will need to be controlled monthly during growing season. Manually remove weeds and deep-rooted invasive plants from the open surface of the tree pit. **Do not use chemical herbicides.**

Activity	Description	Frequency	Responsibility
Inspection	Check inlets, outlets, sediment build-up, vegetation condition	Monthly-quarterly	Maintenance Contractor
Debris removal	Remove litter, leaves, organic material	Monthly	Maintenance Contractor
Inlet clearance	Remove blockages and localised sediment at inlets	Quarterly / as needed	Maintenance Contractor
Surface maintenance	Light raking, mulch top-up, minor sediment removal	1–2 times/year	Maintenance Contractor
Sediment removal	Remove accumulated silt (50–100 mm typical) and reinstate media	Annually / as required	Maintenance Contractor
Vegetation reinstatement	Replace damaged or buried planting	As required	Maintenance Contractor
Corrective works	Media replacement, drainage repairs, desilting of system	As required	Specialist Contractor
Sediment disposal	Reuse or dispose in accordance with regulations	As required	Contractor

Table 4:
Outline raingarden maintenance schedule

The surface mulch layer of the raingarden must be maintained at a depth of 50-75mm to suppress weeds and retain moisture.

Mulch must be kept clear of tree stems to prevent decay and pest damage.

Persistent ponding beyond 48 hours should trigger further investigation into possible blockage, compaction, or media failure.

13. Products for planting trees using structural soils

Stockholm Tree Pits produce concrete planting frames that are either 1m², 1.2m² or 1.5m² which means that a standard tree grille can be fitted above. We also supply aeration wells and silt trays for raingardens.

We can help with designing tree pits by reviewing drawings and providing advice on SuDS schemes that include tree pits. Using this approach, the project team is better able to recognize potential problems and address them before the designs are fixed.

In addition, Stockholm Tree Pits offers a monitoring service in which we oversee the installation of tree pits. This entails carrying out site visits during construction to check on the quality of materials used and provide guidance on how to install them correctly. These quality checks will ensure that the tree pits are functionally effective and compliant with the required standards. Ultimately our aim is to help create an environment that allows urban trees to thrive and live to old age.

BOSKY TREES

Institute of Chartered Foresters Registered Consultant

AA Registered CONSULTANT trees.org.uk

Logika CONSULTANTS

The authors would like to thank Björn Embrén and Britt-Marie Alvem of the City of Stockholm, and Kent Fridell of Edge in Malmö, along with our wider network of European colleagues for sharing their knowledge so generously. Without their help this guide would not have been possible.

About the authors

Ben Rose is the principal arboricultural consultant at Bosky Trees and a researcher into urban tree pit design. He is the founder of Stockholm Tree Pits and is dedicated to improving the success rate of urban tree planting schemes by sharing his findings through consultancy and industry training.

Jim Hallybone is a chartered landscape architect and technical director at Logika Consultants, specialising in nature-based solutions. He believes that well-designed natural environments can work hard - increasing climate resilience, managing water naturally, enhancing biodiversity, and improving wellbeing.

Both Jim and Ben are members of a network of European colleagues focussed on advancing the development of integrated urban green blue infrastructure, an initiative instigated by the City of Stockholm and the Swedish University of Agricultural Sciences.

All of the tree pit designs that we recommend and the technical specifications of our products can be downloaded as CAD files from

www.stockholmtreepits.co.uk

If you are interested in purchasing our products and would like to speak to someone in our sales team, please call us on 07872 609 633.

Alternatively send an email to enquiries@stockholmtreepits.co.uk

13. Case study: Structural soil - Kings Square, Gloucester


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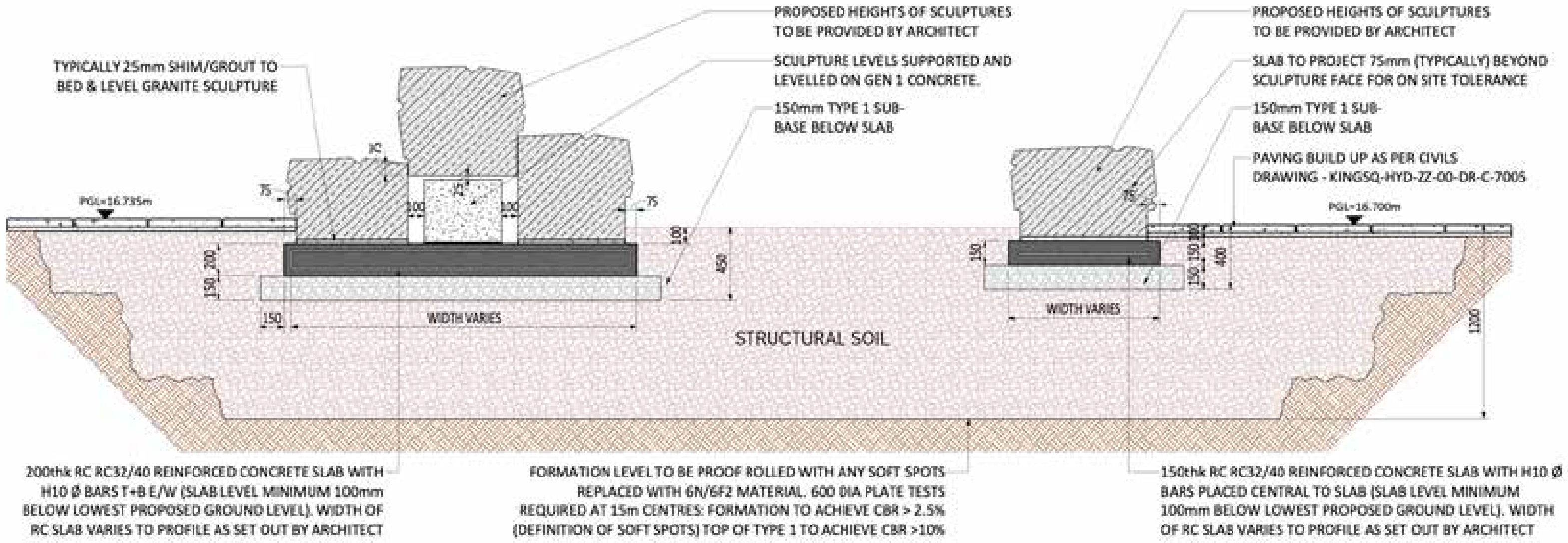
Image credits: Ginkgo Projects (1+4)
George King Architects (2+3)

Gloucester's most significant public open space, Kings Square, was built around 1928 and has gone through several phases as the city has developed over the past eighty years. Gloucester City Council recognised that in recent years it had become run down and required an extensive refurbishment in order to establish a modern and distinctive focal point for businesses, residents, and visitors.

George King Architects created a series of sculptural stone wave patterns that frame the square, drawing inspiration from the tidal bore of the River Severn.

In order to provide advice on trees, tree pit design and specification, Ben Rose of Stockholm Tree Pits (Bosky Trees) was hired as arboricultural consultant for the project.

13. Case study: Structural soil - Kings Square, Gloucester



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The use of structural soils with biochar as a crucial component of the sustainable drainage system (SuDS) for this renovated public square was a pioneering innovation in this project.

Runoff from the nearby paving is diverted into planting areas and aeration chambers. Around the square's edges, substantial amounts of structural soil were employed, enabling the gigantic stone wave forms to be built directly on top. This not only created an underground space that functions as a sponge for runoff, but it also guarantees that the tree planting would have enough room for root systems, aeration, and moisture.

Image credits: Hydrock (1)
E.G.Carter (2)

13. Case study: Structural soil - Kings Square, Gloucester





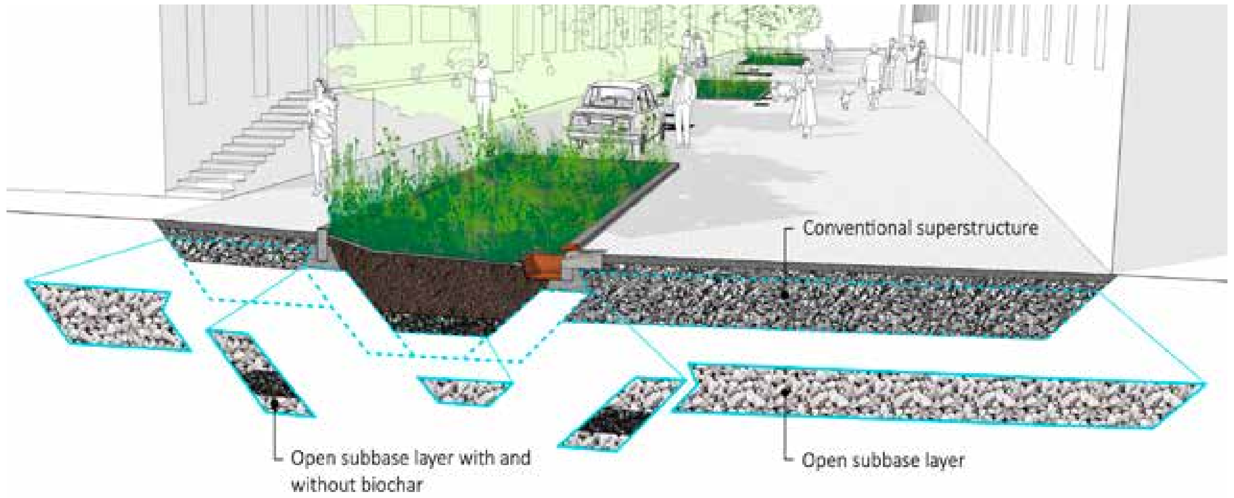

Two years on and the square has been embraced by the Gloucester community and is well used by both locals and visitors.

The tree planting is also flourishing, despite two years of drought conditions. Extension growth on both species of trees is impressive. As one of the first large scale public realm projects to utilise a structural soil system in the UK, it has been a resounding success.

STOCKHOLM TREEPITS

14. Case study: Raingardens + Structural soil - Rosendal, Uppsala, Sweden

Amanuensgatan in Rosendal with an open subbase layer across the width of the street space with raingardens capturing runoff



Above image + design credits: Kent Fridell / Edge (edges.se)

Uppsala municipality plans to manage rainwater on a district wide scale. The new development of Rosendal is located within the city's drinking water source protection zone, which lays tight obligations on stormwater management. The district has adopted the 'Blue Green Grey' system (pioneered by Edge) for this development zone.

Blue Green Grey (BGG) is a concept that aims to integrate functions encompassing stormwater management (the blue), vegetation (the green), and hard surfaces (the grey). A system for urban environments in which blue, green, and grey functions coexist in the same location and space. Designed as a solution for traffic loads, stormwater flows, pollution, biodiversity and climate change resilience. With this strategy, the minimum surface area can offer multiple benefits at a lower cost than addressing the same functions separately.

14. Case study: Raingardens - Rosendal, Uppsala, Sweden

An open subbase layer can replace conventional subbase layers allowing for void space to be created underneath street spaces

Control well with overflow

Images + design credits: Kent Fridell / Edge (edges.se)

The open subbase layer in a BGG system is comprised of clean 'open stone' aggregate which has had fines removed leaving void space of 30-40%. This void space allows storage of up to 400 litres of water per cubic metre. Because of this high porosity, BGG systems have high hydraulic conductivity for water and gas exchange with the potential to hold rainwater run off and stormwater flow within the system before discharging it to the conventional sewer system in a controlled manner. An 'urban sponge'.

Alongside retaining water in the open subbase layer, the system can be designed with integral bioretention (raingarden) areas and tree pits in which run off can be retained and absorbed. By allowing the roots of trees and vegetation to develop into the open subbase layer, higher biological activity is encouraged, promoting more effective purification. Trees and vegetation also benefit from increased space to develop a root system and find moisture and nutrients.

14. Case study: Raingardens - Rosendal, Uppsala, Sweden

Sand / silt trap at raingarden inlet

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The raingarden is equipped with a sand / silt trap where larger particles can be separated from the rainwater before it flows into the substrate. In a significant rain event the raingarden is able overflow into to the open subbase layer via a control well. Roof water is judged to be sufficiently clean, so can be fed directly into to the open subbase layer where it is delayed and purified before it, together with any stormwater is released to the mains. If the open subbase layer is overloaded or the flow regulator in the control well becomes clogged, there is a in-built overflow which allows for water to pass the flow regulator. The system is estimated to be able to remove between 70-80% of heavy metals and pollutants.

Image credits (1+2): Kent Fridell / Edge (edges.se)

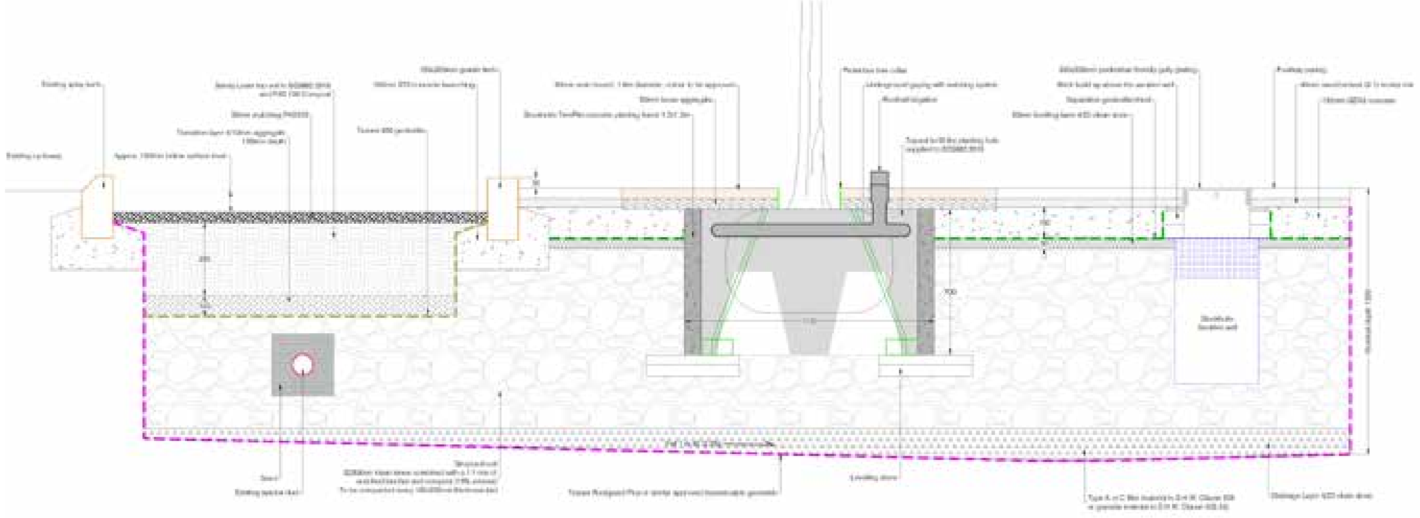
15. Case study: Raingardens + Structural soil - Markhouse Corner, Walthamstow, London

Image credits: Meristem Design

Improvements to the public realm around the 'Markhouse Corner' crossroads. The aim of the project was improve the look and feel of the spaces around Markhouse Corner in Lea Bridge by introducing more plants, attracting and encouraging biodiversity, creating more flood-resilient spots and to make the area more visually appealing for the local community.

The London Borough of Waltham Forest were keen to use a SuDS design for the new tree planting. Three trees were planted using the Stockholm system and compacted soil around an established street tree was replaced.

15. Case study: Raingardens + Structural soil - Markhouse Corner, Walthamstow, London



The initial design was produced by the architect (Matter Architecture), the landscape architect (Churchman Thornhill Finch) and the client (The London Borough of Waltham Forest). Stockholm Tree Pits were employed as a design angel to work on a detailed design for the tree pits and the adjacent raingarden.

The Stockholm system uses a structural soil and captures rainwater to irrigate the trees. A structural soil is a growing medium that can be compacted to load-bearing criteria and installation requirements while still permitting healthy root growth.

Surface water was collected from an existing roadside gully and directed into the tree pit. Aeration wells were also installed to help air and water reach the soil in the tree pit.

After the hole had been excavated a water infiltration test was carried out to test the natural drainage at the bottom of the tree pit. This informed us that the natural drainage at the base of the tree pit was adequate, and that additional drainage infrastructure was unnecessary.

15. Case study: Raingardens + Structural soil - Markhouse Corner, Walthamstow, London

Image credits (above): Meristem Design

Lots of underground services were uncovered when the hole for the shared tree pit was excavated including a capped gas main, clay water pipes, and a high voltage electricity cable. The gas main and the water pipes were protected with sand before the structural soil was introduced (see above).

A pre-mixed structural soil was used in this project. It was delivered to site on 8-wheel lorries and tipped immediately adjacent to the excavated tree pit.

Stockholm Tree Pits were employed to supervise construction works in order to assist the groundwork contractors and help ensure that the tree pits were properly installed.

Once the tree pits had been constructed Meristem Design were employed to plant the trees and the raingarden at Markhouse Corner.

The final result is a multi-functional space with trees growing within an area of hard surfacing. There is also a raingarden that helps local water infiltration and delivers water to the underground tree pit.