Land at Bankside (Phase 2)

Banbury

Flood Risk Assessment

Hallam Land Management

Brookbanks

Document Control Sheet

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Contents

1 Introduction

1.1 Brookbanks Consulting Limited is appointed by Hallam Land Management Ltd to complete a Flood Risk Assessment for a proposed residential development on land at Bankside (Phase 2) in Banbury, Oxfordshire.

1.2 The objective of the study is to demonstrate the development proposals are acceptable from a flooding risk and drainage viewpoint.

1.3 This report summarises the findings of the study and specifically addresses the following issues in the context of the current legislative regime:

- Flooding risk
- Surface water drainage
- Foul water drainage

1.4 Plans showing the existing and proposed development are contained within the appendices.

2 Background Information

Location & Details

2.1 The proposed development lies to the south of the urban extent of Banbury and to the east of Bodicote village. The site is bound to the west by College Park House, Bodicote Park (Rugby Grounds) and to the south-west by the A4260 Oxford Road. The remaining boundaries of the site are bound by agricultural fields that extend to the surrounding areas. Several farm properties are shown within proximity of the site.

2.2 The land is currently undeveloped and is not thought to have been historically subject to any significant built development. The site location and boundary are shown indicatively on Figure 2a, below:

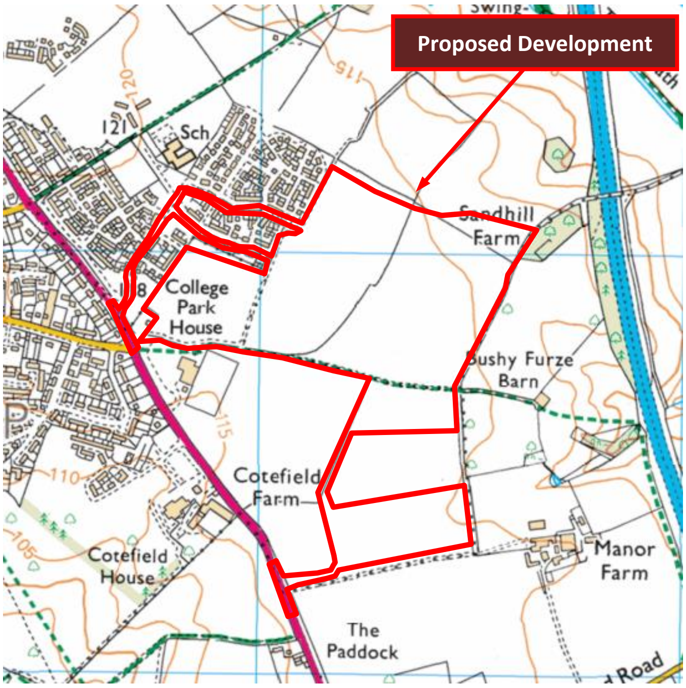

Figure 2a: Site Location

Development Criteria

2.3 It is proposed to develop up to 850 residential units and an area designated for allotments and green space.

Sources of Information

2.4 The following bodies have been consulted while completing the study:

- Thames Water - Foul water drainage
- Thames Water - Storm water drainage
- Environment Agency - Flood risk and storm drainage

2.5 The following additional information has been available while completing the study:

- Mastermap Data - Ordnance Survey
- Published Geology - British Geological Survey
- Preliminary Flood Risk Assessment - Oxfordshire County Council, June 2011
- Regional Flood Risk Appraisal (RFRA) for South East England - Halcrow on behalf of the South East England Regional Assembly, October 2008
  RFRA Summary - November 2008
- Level 1 Strategic Flood Risk Assessment - Cherwell District Council & West Oxfordshire District Council, April 2009
- Thames Catchment Flood Management Plan - Environment Agency, December 2009 – Summary Report

Topography & Site Survey

2.6 The site is situated on a localised high point. The topography across the site is characterised by shallow gradients falling in an easterly direction towards the River Cherwell and a westerly direction towards Sor Brook. Ground levels on site range from approximately 118m AOD in the north-west to lower levels of 110m AOD in the north-east and 115m AOD in the south-west.

Ground Conditions

Geology & Hydrogeology

2.7 With reference to the British Geological Survey map, the majority of the site is shown to be underlain by ferruginous limestone and ironstone belonging to the Marlstone Rock Formation. A small area in the north of the site is shown to be underlain by mudstone belonging to the Whitby Mudstone Formation.

2.8 The BGS website does not identify any superficial deposits on the proposed development, however Alluvium - Clay, Silt, Sand And Gravel deposits have been identified in the adjacent field.

2.9 The published site geology is illustrated on Figure 2b.

2.10 The underlying geology comprising limestone, ironstone and mudstone forms a Minor Aquifer, with soils of Intermediate Leaching Potential.

2.11 Minor Aquifers are fractured or potentially fractured rocks, which do not have a high primary permeability, or other formations of variable permeability including unconsolidated deposits. Although not producing large quantities of water for abstraction, they are important for local supplies and in supplying base flow to rivers.

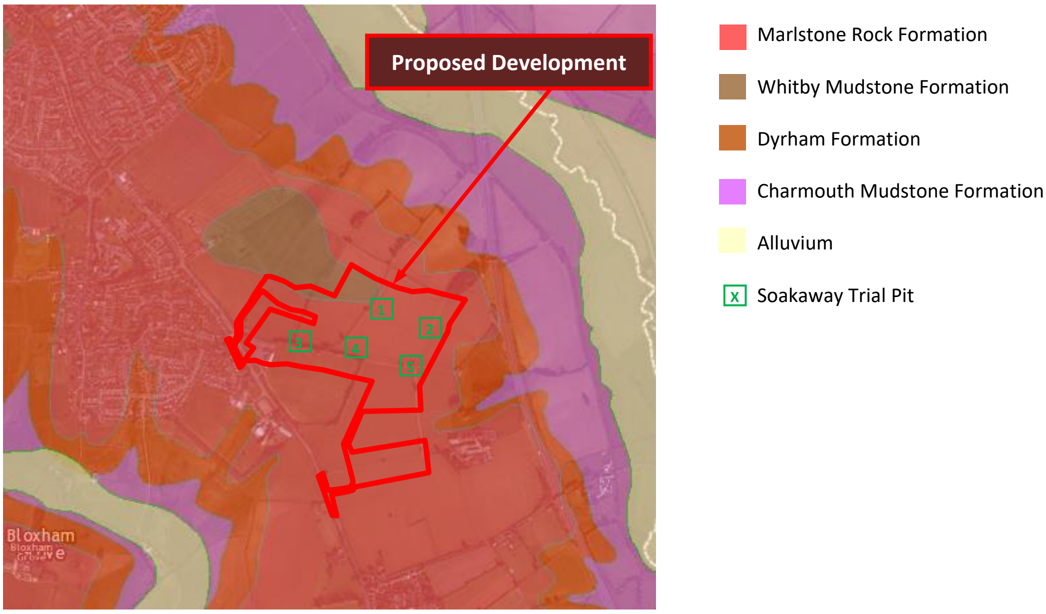

Figure 2b: BGS Published Geology

2.11 Eight soakaway trial pits were excavated on site as part of the ground investigations carried out by Geo Environmental Group Ltd. Three soakaway tests were undertaken per pit to assess the viability of infiltration type drainage and to confirm the underlying geology at the site, as detailed below in Figure 2c.

Depth	Strata	Description
0.00 - 0.40m BGL	Topsoil	Soft, friable brown CLAY
0.40 - 1.40m BGL	Weathered Marlstone Rock Formation	Soft to stiff, friable brown, slightly sandy CLAY with occasional sub-angular to sub-rounded ferruginous limestone lithorelicts.
1.40 - 1.80m BGL	Marlstone Rock Formation	Very weak, orange brown and dark brown ferruginous LIMESTONE.
1.80 - 2.10m BGL	Weathered Marlstone Rock Formation	Firm, yellow brown CLAY with some gravel-sized sub-angular to sub-rounded ferruginous limestone lithorelicts.

Figure 2c: Geological Strata

2.12 The location of the trial pits is illustrated in Figure 2b.

2.13 The average infiltration rates within each trial pit are presented below in Figure 2d.

Location	Groundwater Encountered	Average Infiltration Rate (m/s)
TP01	Nil	N/A
TP02	Nil	9.06×10^{-5}
TP03	Occasional damp pockets from 1.20 - 1.60m BGL	1.50×10^{-4}
TP04	Occasional damp pockets from 1.80m BGL	N/A
TP05	Nil	6.77×10^{-5}
TP06	Nil	2.59×10^{-4}
TP07	Nil	1.26×10^{-4}
TP08	Nil	7.34×10^{-5}

Figure 2d: Average Infiltration Rates

2.14 Occasional damp pockets of groundwater were only encountered in trial pits 3 and 4.

2.15 The full site investigation report completed by Geo Environmental Group Ltd is contained in the Appendix, however the above results confirm the site is relatively permeable and the underlying geology is as per the published records.

Watercourse Systems & Drainage

On-Site

2.16 There are no natural or man-made watercourses / drains located within the site boundary.

Off-Site

2.17 The nearest surface water feature to the site is a pond located to the north of Manor Farm, approximately 210m to the east of the site boundary. The Upper Oxford Canal is shown approximately 375m north-east of the site's boundary.

2.18 The following watercourses are situated within 1km of the site boundary: The River Cherwell approximately 550m east of the site and Sor Brook approximately 760m south of the site. The Flood Zone mapping identifies flooding on both the river and the brook, with flows seen to come out of bank during the 1 in 100 (1% AEP) and 1 in 1,000 year (0.1% AEP) events.

2.19 With reference to the Flood Estimation Handbook CD dataset V3 the site is shown to lie within the catchment of an ordinary watercourse tributary of the River Cherwell, a tributary of the River Thames. Having an URBEXT2000 value of 0.0215 the catchment can be described as *"essentially rural".* The FEH catchment is shown in Figure 2e.

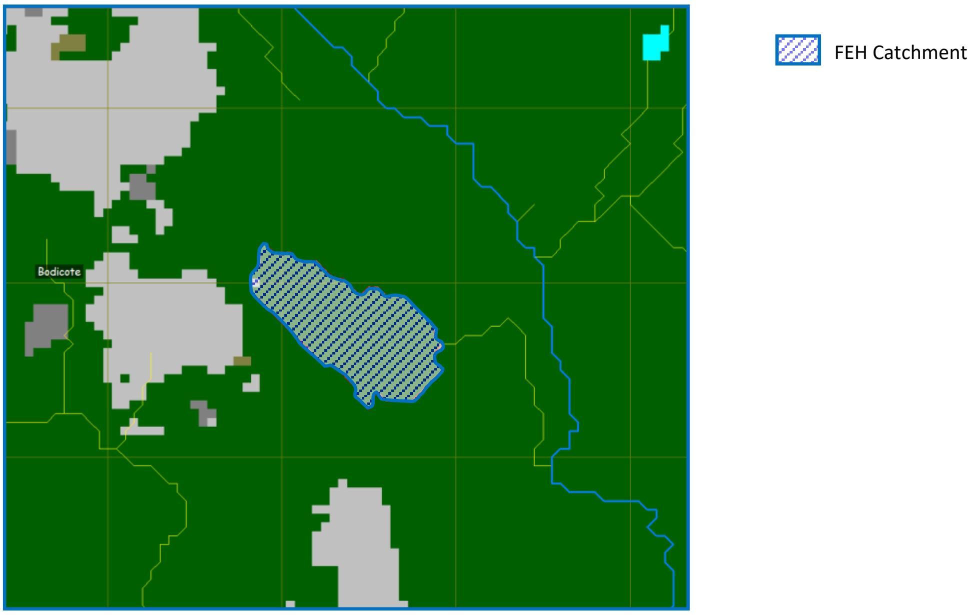

Figure 2e: FEH Reported Catchment

2.20 Site investigations demonstrate that the ground and underlying geology conditions are relatively permeable and as such, a moderate degree of storm water infiltration is likely to take place. Water is likely to be conveyed through the relatively permeable sub strata in a south eastern direction towards the River Cherwell and associated tributaries to the south of the site boundary.

3 Flooding Risk

National Planning Context

3.1 The National Planning Policy Framework (NPPF) was introduced in March 2012 and updated in February 2019, with the aim at rationalising and simplifying planning guidance. The Policy is supported by a Technical Guide, which provides advice in relation to Flood Risk and Drainage matters at Paragraphs 2 to 9. This element of the Technical Guide largely follows the principles set out in the earlier adopted planning guidance on flood risk and drainage, being PPS25.

3.2 Allocation and planning of development must be considered against a risk based search sequence, as provided by the NPPF guidance. In terms of fluvial flooding, the guidance categorises flood zones in three principal levels of risk, as follows:

Flood Zone	Annual Probability of Flooding
Zone 1: Low probability	< 0.1 %
Zone 2: Medium probability	0.1 – 1.0 %
Zone 3a / 3b: High probability	> 1.0 %

Figure 3a: NPPF Flood Risk Parameters

3.3 The Guidance states that Planning Authorities should *"apply a sequential, risk-based approach to the location of development to avoid where possible flood risk to people and property and manage any residual risk, taking account of the impacts of climate change."*

3.4 According to the NPPF guidance, residential development at the proposed site, being designated as "More Vulnerable" classifications, should lie outside the envelope of the predicted 1 in 100 year (1%) flood, with preference given to sites lying outside the 1 in 1,000 (0.1%) year event and within Flood Zone 1.

3.5 Sites with the potential to flood during a 1 in 100 (1%) year flood event (Flood Zone 3a) are not normally considered appropriate for proposed residential development unless on application of the "Sequential Test", the site is demonstrated to be the most appropriate for development and satisfactory flood mitigation can be provided. Additionally, proposed residential developments within Flood Zone 3a are required to pass the "Exception Test", the test being that:

- The development is to provide wider sustainability benefits
- The development will be safe, not increase flood risk and where possible reduce flood risk.

Regional & Local Policy

3.6 Banbury lies within Oxfordshire, in which Oxfordshire County Council (OCC) is the Lead Local Flood Authority (LLFA). A **Preliminary Flood Risk Assessment** (PFRA) was produced in 2011 by OCC according to the guidance and information provided by DEFRA. The PFRA identifies flood risk from local flood sources and extreme events occurrence.

3.7 **Regional Flood Risk Assessment (RFRA)**: identifies at a regional level the general locations of flood risk and flooding issues which are to be considered by local planning authorities within their Strategic Flood Risk Assessments. The South of England RFRA was prepared in October 2008 by Halcrow, on behalf of the South East England Regional Assembly.

3.8 The RFRA includes the Oxfordshire region which lies within the Thames Catchment and includes the River Cherwell. It is reported that the Thames Valley is subject to groundwater flooding caused by gravel deposits underlying the river floodplain. Surface water flooding in West Oxfordshire was reported after extensive flooding in 2007.

3.9 The following recommendations are given for locating development where there may be groundwater and/or surface water flood risk:

"Where it is necessary to locate new development in areas of groundwater flood risk such developments should be focussed within areas where:

- *A permanent dry access route is provided (as groundwater flooding can last),*
- *The effect of development and permanent dry access do not adversely affect groundwater, which could result in increased flood risk elsewhere,*
- *The development and in particular its foundations are designed as flood resistant against long periods of groundwater flooding,*
- *The habitable ground floor levels are set above the highest groundwater level recorded.*

Where it is necessary to locate new development in Flood Zone 1 & 2 but there is a risk from surface water flooding, it is recommended that development should be focussed within areas where:

- *It is possible to divert the surface water risk to open areas within the new development (carparks, wetlands, ponds) provided that the diverted flood risk hazard is acceptable,*
- *It is viable to reduce the risk to an acceptable level, by adopting SuDS measures,*
- *Adequate drainage infrastructure is provided (with contribution from the developers) to reduce the existing risk to an acceptable level, while allowing for additional runoff from the new development. An effective Surface Water Management Plan could ensure in particular that the cumulative effects of incremental development are not overlooked."*

3.10 **Strategic Flood Risk Assessment:** To support local planning policy, NPPF guidance recommends that local planning authorities produce a Strategic Flood Risk Assessment (SFRA). The SFRA should be used to help define the Local Plan and associated policies; considering potential development zones in the context of the sequential test defined in the guidance.

3.11 Cherwell District Council & West Oxfordshire District Council published a Level 1 Strategic Flood Risk Assessment in April 2009. The document outlines the results of a review of available flood risk related policy and data across the region and sets out recommendations and guidance in terms of flood risk and drainage policy that generally underpin national guidance.

3.12 The document makes no specific reference to the site however assess the risk of flooding in Banbury, which forms one of three major urban centres in the district of Cherwell. The following sources will be discussed further in this document:

- Fluvial Flooding
- Sewer Flooding
- Pluvial Flooding
- Groundwater Flooding
- Artificial Sources

3.13 Following on from this, in May 2017 Cherwell District Council produced a Level 2 Strategic Flood Risk Assessment.

3.14 Oxfordshire County Council published the **Local Flood Risk Management Strategy** (LFRMS) which offers Guiding Principals in managing flood risk and a structure of managing strategy, in addition to that provided in the SFRA.

3.15 **Catchment Flood Management Plans:** A Catchment Flood Management Plan (CFMP) is a high-level strategic plan through which the Environment Agency seeks to work with other key-decision makers within a river catchment to identify and agree long-term policies for sustainable flood risk management.

3.16 The Thames Catchment Flood Management Plan (December 2009), outlines that the Thames River Basin District has been divided into 9 sub-catchments. The Site is shown to be situated within Sub-area 1 Towns and villages in open floodplain (north and west) which is covered by the following policy:

"**Policy 6: Areas of low to moderate flood risk where we will take action with others to store water or manage run-off in locations that provide overall flood risk reduction or environmental benefits.**

This policy will tend to be applied where there may be opportunities in some locations to reduce flood risk locally or more widely in a catchment by storing water or managing run-off. The policy has been applied to an area (where the potential to apply the policy exists) but would only be implemented in specific locations within the area, after more detailed appraisal and consultation."

3.17 **Development Flood Risk Assessment:** At a local site by site level, the NPPF guidance and supporting documents advocate the preparation of a Flood Risk Assessment (FRA). The NPPF requires that developments covering an area of greater than one hectare prepare an FRA in accordance with the guidance. The FRA is required to be proportionate to the risk and appropriate to the scale, nature and location of the development.

3.18 This document forms a Flood Risk Assessment (FRA), to accord with current guidance and addresses national, regional and local policy requirements in demonstrating that the proposed development lies within the acceptable flood risk parameters.

Flood Mechanisms

3.19 Having completed a site hydrological desk study and walk over inspection, the possible flooding mechanisms at the site are identified as follows:

Mechanisms	Potential?	Comment
Fluvial	N	No major watercourses lie within an influencing distance of the proposed development. The River Cherwell, Sor Brook and Oxford Canal are all situated within 1km of the site boundary.
Coastal & Tidal	N	No tidal watercourses lie within an influencing distance of the proposed development.
Overland flow	N	Small areas of surface water flooding are shown within the site boundary, corresponding with the site topography. The overall risk is considered to be very low.
Ground water	N	Limestone and mudstone geology underlying the site potentially has a high permeability. However, no groundwater flooding was identified within the SFRA and therefore the risk is considered low.
Sewers	N	A Thames Water foul rising main runs from the north of the site to the south-west. There are no reported problems in their adjacent network.
Reservoirs, Canals etc.	Y	The Oxford Canal is situated approximately 375m north-east of the site boundary, a residual flooding risk is considered to be low.

Figure 3b: Flooding mechanisms

3.20 Where potential risks are identified in Figure 3b, above, more detailed assessments have been completed and are outlined within the following paragraphs, along with further background information.

Fluvial Flooding

3.21 The Environment Agency's (EA) National Generalised Modelling (NGM) Flood Zones Plan indicates predicted flood envelopes of Main Rivers across the UK. In many circumstances, the NGM is based on basic catchment characteristic data and modelling techniques. Where appropriate, more accurate Section 105 / SFRM models are produced using more robust analysis techniques.

3.22 The following watercourses are within proximity of the site: The River Cherwell is situated approximately 550m east of the site and Sor Brook is located approximately 700m south of the site. The Flood Zone mapping identifies flooding on both the river and the brook, with flows seen to come out of bank during the 1 in 100 (1% AEP) and 1 in 1,000 year (0.1% AEP) events.

3.23 The mapping shows that the entire site lies within Flood Zone 1; being an area of Low Probability of flooding, outside both the 1 in 100 (1% AEP) and 1 in 1,000 (0.1% AEP) year flood events. The EA Flood Zone plan is reprinted as Figure 3c.

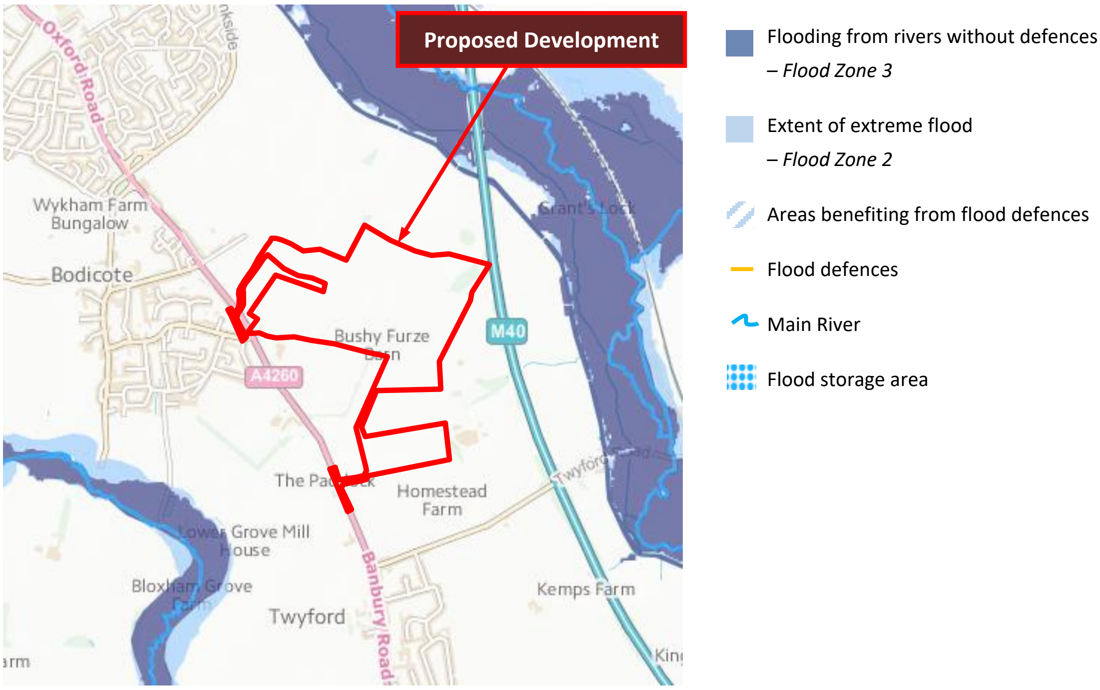

Figure 3c: EA Flood Zone Plan showing 1 in 100 & 1 in 1,000 year floodplain

Coastal Flooding

3.24 The site lies a significant distance from the nearest tidal watercourse and the coast. As such there is no risk of tidal or coastal flooding at this location.

Overland Flow (Pluvial Flooding)

3.25 Overland flow mechanisms result from the inability of unpaved ground to infiltrate rainfall or due to inadequacies of drainage systems in paved areas to accommodate flow directed to gullies, drainage downpipes or similar. In minor cases, local ponding may occur. In more extreme events, flows accumulate and may be conveyed across land following the topography.

3.26 The Environment Agency has recently produced a series of surface water flood maps for many parts of the UK. The plan containing the proposed site is reprinted as Figure 3d.

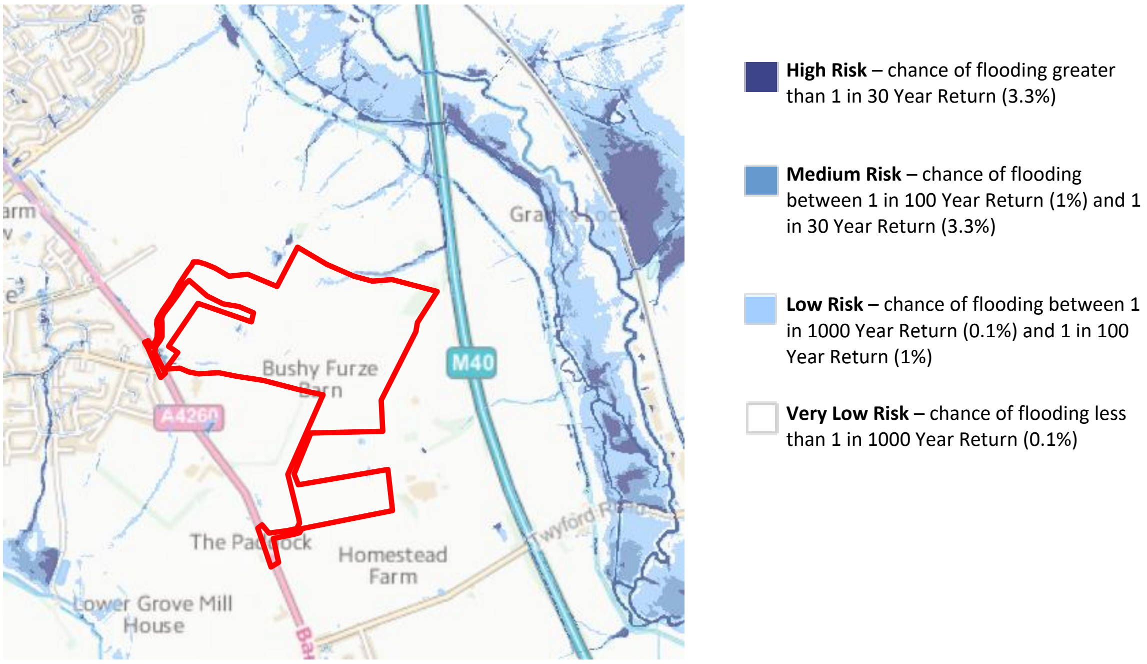

Figure 3d: Environment Agency Risk of Surface Water Flooding Mapping

3.27 The mapping provided by the EA identifies relatively small areas of surface water flooding within the site boundary. These areas correspond with the site topography, with pooling directed to the lower regions of the site. The proposed development will have a very low risk of flooding from surface water.

3.28 Given the available evidence and site characteristics, the proposed development land is considered to have a low probability of overland flow flooding risk.

3.29 Recognising the risk of overland flow mechanisms, published guidance in the form of Sewers for Adoption 7th Edition and the Environment Agency document *Improving the Flood Performance of New Buildings: Flood Resilient Construction et al* advocate the design of developments that implement infrastructure routes through the development that will safely convey flood waters resulting from sewer flooding or overland flows away from buildings and along defined corridors. Further to protect the proposed development, current good practice measures defined by guidance will be incorporated.

3.30 Given the baseline site characteristics and further mitigating measures to be implemented residual flood risk from an overland flow mechanism is considered to be a low probability.

Ground Water

3.31 Groundwater flooding is characterised by low-lying areas often associated with shallow unconsolidated sedimentary aquifers which overly non-aquifers. These aquifers are reported to be susceptible to flooding, especially during the winter months, due to limited storage capacity.

3.32 Groundwater related flooding is fortunately quite rare, although where flooding is present, persistent issues can arise that are problematic to resolve. Such mechanisms often develop due to construction activities that may have an unforeseen effect on the local geology or hydrogeology.

3.33 Whilst no site-specific investigations have been completed, information from the Level 1 SFRA has not identified any incidents of groundwater flooding within the site boundary. Reported groundwater issues are however highlighted at the base of Crouch Hill approximately 3.25km to the north-west of the site boundary.

3.34 Positive drainage systems incorporated into the proposed development will further reduce the risk as a result of permeable pipe bedding materials and filter drains incorporated within elements of the built development.

3.35 Given the baseline site characteristics (Minor Aquifer with an Intermediate Leaching Potential) and further mitigating measures to be implemented, residual flood risk from a ground water mechanism is considered to be a low probability.

Sewerage Systems

3.36 Flooding related to sewerage systems is a result of there being insufficient capacity within an existing sewerage system (combined and surface water sewers) or from there being a blockage within the system.

3.37 Investigations with Thames Water provide no evidence of present or historic sewer flooding at the site.

3.38 The SFRA reports: "Developments within Cherwell have historically been piped to watercourses due to the local geology. Discharges from older (generally preceding 1970) development are often unattenuated exacerbating the flashy responsiveness of the Districts fluvial systems to rainfall".

3.39 Positive drainage measures incorporated on site, coupled with sustainable drainage systems (SuDS) will ensure that no increase in surface water will result from the site. Flood risk associated with sewer flooding is therefore considered to be a low probability.

Artificial Water Bodies - Reservoirs & Canals

Upper Oxford Canal

3.40 The Upper Oxford Canal runs parallel to the River Cherwell, approximately 375m north-east of the site's boundary. The canal merges with the river at two points within the district and includes a series of locks and weirs which direct any excess flows from the canal into the river.

3.41 A residual risk associated with the canal lies with the potential for flooding to occur due to breaching or overtopping of the canal. However, the prevailing slope would ensure that flooding from the canal is to the northeast, away from the site. The canal lies an estimated 10m below the lowest point of the site.

Banbury Flood Alleviation Scheme

3.42 The Banbury Flood Alleviation Scheme was completed in 2012 following heavy rainfall events which occurred in 2007 (when the River Cherwell burst its banks) and in 2008. These relatively severe fluvial flooding events caused disruption and damage to many properties and services.

3.43 The scheme consists of the following: a flood storage reservoir upstream of Banbury, raising the A361 road, localised storage defences downstream of the reservoir, a pumping station at Moorfield Brook and the creation of a Biodiversity Action Plan (BAP) Habitat. It is reported that the flood defence work carried out provides 'an increased standard of protection of 1 in 200 years for 437 residential properties'.

3.44 Following the completion of the above defence works, it may be concluded that there is a low risk of flooding associated with artificial water bodies at the proposed development.

Reservoirs

3.45 There are two reservoirs (Clattercote and Grimsbury) within the Cherwell District. However, EA mapping illustrate that they do not pose a flooding risk to the proposed development site.

Residual Flood Risk

3.46 An FRA should consider the Residual Flood Risk once development activities are complete, ensuring that appropriate mitigation is proposed to ensure risks are not increased as a result of the activities. This FRA promotes, within the main body of the text, a series of proposals that will be employed to ensure post development situation is acceptable and that residual flood risk is managed. The following list summarises the main proposals that will adequately control residual flood risk:

- All development is to lie within Flood Zone 1.
- Compliance with guidance in terms of flood routing and resilience for new developments.
- Provision of a multi-tier storm water SuDS management system (see Section 4).
- Connection to a point of adequacy on the foul water drainage network with completion of necessary downstream reinforcements to ensure adequate conveyance and treatment capacity (see Section 5).
- Provision of ongoing maintenance for SuDS features.
- Adoption and associated ongoing maintenance of development storm and foul drainage system.

Summary

3.47 In terms of fluvial and tidal flood risk, the proposed development can be seen to lie within Flood Zone 1, and hence has a low probability of flooding from this mechanism.

3.48 Assessment of other potential flooding mechanisms shows the land to have a low probability of flooding from overland flow, ground water and sewer flooding.

3.49 Accordingly, the proposed development land is in a preferable location for residential development when appraised in accordance with the NPPF Sequential Test and local policy. The site should be considered preferable to other potential developments that may lie wholly within Flood Zone 2 or Flood Zone 3.

Objectives

3.50 The key development objectives that are recommended in relation to flooding are:

- Compliance with SFA 7th Edition and EA guidance in relation to flood routing through the proposed development in the event of sewer blockages.
- Implementation of a 150mm slab freeboard above the level of the proposed flood routes, to protect buildings in the event of a localised blockage.

4 Storm Drainage

Background

4.1 To understand the baseline provision for storm drainage in the area, a copy of the Thames Water sewerage network records has been obtained (Anglian Water do not have any assets within proximity of the site). The nearest public storm water sewers present are situated within the residential areas along East Street approximately 500m east of the site boundary.

4.2 The site is presently not serviced by a positive storm water drainage network. It is believed that storm water currently discharges to the underlying strata via infiltration.

Drainage Options

4.3 The following paragraphs in this section outline the proposed drainage strategy to meet national and local design requirements and guidance.

4.4 Current guidance[1] requires that new developments implement means of storm water control, known as SuDS (Sustainable Drainage Systems), to maintain flow rates discharged to the surface water receptor at the pre-development 'baseline conditions' and improve the quality of water discharged from the land.

4.5 It is proposed to implement a SuDS scheme consistent with local and national policy at the proposed development.

4.6 The Cherwell & West Oxfordshire SFRA accords with national guidance on the provision of storm water drainage, encouraging the use of sustainable means of drainage at new developments.

4.7 When appraising suitable storm water discharge options for a development site, Part H of the Building Regulations 2002 (and associated guidance) provides the following search sequence for identification of the most appropriate drainage methodology.

"Rainwater from a system provided pursuant to sub-paragraphs (1) or (2) shall discharge to one of the following, listed in order of priority -

(a) an adequate soakaway or some other adequate infiltration system; or where that is not reasonably practicable,
(b) a watercourse; or where that is not reasonably practicable,
(c) a sewer. "

4.8 Dealing with the search order in sequence:

(a) Source control systems treat water close to the point of collection, in features such as soakaways, porous pavements, infiltration trenches and basins. The use of some can have the benefit of discharging surface water back to ground rather than just temporarily attenuating peak flows before discharging it to a receiving watercourse or sewer.

As source control measures generally rely upon the infiltration of surface water to ground, it is a prerequisite that the ground conditions are appropriate for such. Site ground investigations specific to flood risk have been completed which confirm the underlying geology is relatively permeable and as such, drainage via infiltration is a possibility at the site.

(b) Next in the search sequence, defined by Part H, is discharge to a watercourse or suitable receiving water body. Where coupled with appropriate upstream attenuation measures, this means of discharge can provide a sustainable drainage scheme that ensures that peak discharges and flood risk in the receiving water body are not increased.

Site inspections confirm on the presence of minor field drains within the site boundary along the routes of existing hedgerows.

(c) Last in the search sequence is discharge to a sewer. In the context of SuDS this is the least preferable scheme as it relies on 'engineered' methods to convey large volumes of water from development areas, has a higher likelihood of flooding due to blockage and provides less intrinsic treatment to the water.

The nearest storm water sewer identified in the Thames Water records is located along East Street, approximately 500m east of the site boundary.

[1] NPPF, CIRIA C522, C609, C697 et al.

4.9 The search sequence outlined above indicates that discharge to the underlying geology via infiltration is the most appropriate receptor for stormwater discharges from the proposed development. A means to discharge surface water has been established via the use of infiltration basin.

4.10 Accordingly, a plan showing the conceptual drainage masterplan for the site is contained within the Appendix as drawing 10327-DR-05 E.

4.11 Coupled with the storm water control benefits, the use of SuDS can also provide betterment on water quality. National guidance in the form of CIRIA 609 outlines that by implementing SuDS, storm water from the site can be polished to an improved standard thus ensuring the development proposals have no adverse affects on the wider hydrology.

4.12 The following paragraphs outline the potential SuDS features appropriate for use on-site.

Primary Drainage Systems (source control)

4.13 At the head of the drainage network, across the site, source control measures could be implemented to reduce the amount of run-off being conveyed directly to piped drainage systems.

4.14 The common aims of a Primary Drainage System are:

- Reduction in peak discharges to the agreed site wide run-off rate from the development areas.
- Provide water quality treatment where appropriate

4.15 Through work on other similar strategically sized projects, BCL has shown that peak discharges of circa 35% in residential areas can readily be achieved using source control measures without unacceptable impacts on net developable land or prohibitive financial implications.

4.16 Through consultations at outline planning stage, it has been agreed that the nature of source control measures to be implemented will need to remain flexible, providing a ‘toolkit’ of options to reach an agreed target for peak discharge reduction and water treatment. The following paragraphs describe a few options available.

Permeable Paving

4.17 Permeable Paving (Figure 4a) can act as a receptor for surface water run-off from nearby commercial buildings and house roofs. However, the system is perhaps best suited to manage parking areas and shared surfaces where block paving is typically used as the surface treatment and ongoing maintenance can be ensured by way of a management company or the like.

4.18 There is little need for underground pipes or gullies, and the attenuation afforded within the sub-base layer helps to reduce the volume of storage required elsewhere.

Figure 4a: Permeable paving

Filter Strips

4.19 Filter strips have been used in the drainage of highways for many years. The absence of traditional pipe work in such a system frees the drainage design to employ shallow gradients on both channels and drains, which in turn also act as a means of passive treatment to improve water quality.

4.20 Highways within the development could potentially incorporate filter drains. Alternatively, filter strips can be used to collect flows from areas such as a group of houses.

4.21 Figure 4b below shows an example of a filter strip in a road corridor.

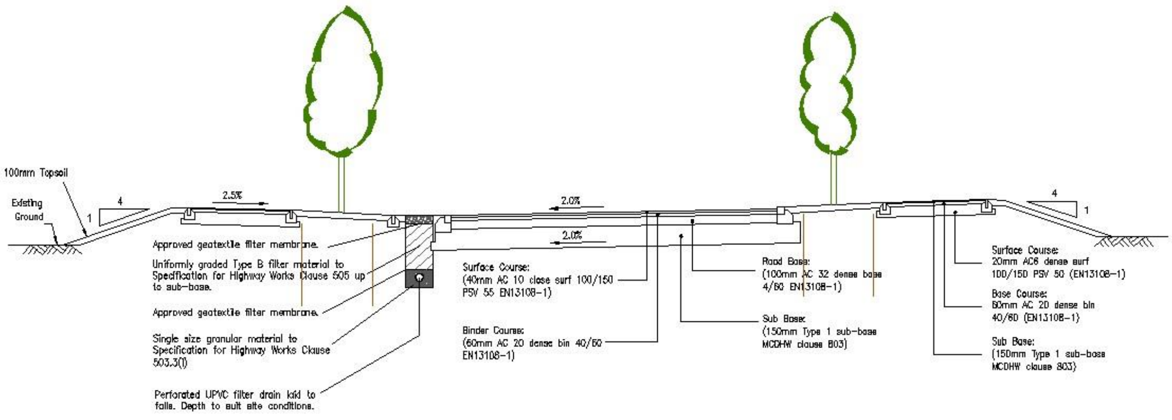

Figure 4b: Filter Strip along highway

Ditches

4.22 Ditches may be used along highways and in common areas to infiltrate, attenuate and convey flows from hard surfaces across the development before being discharged into the secondary system. Linear features, such as ditches and filter strips provide an efficient means of improving water quality.

4.23 The following SuDS guidance is provided for Banbury within the Level 1 SFRA:

"In preparing Local Development Documents and the determination of planning application, local authorities should require the incorporation SuDS and other attenuation measures and take account of increased surface water drainage and sewerage effluent flows on fluvial flood risk."

Preliminary Drainage Proposals

4.24 Preliminary assessment of the requirements for storm drainage have been based on the following criteria:

Application Site Area:	39.23ha
Developed Area:	23.00 ha
Landscaped Area:	16.23 ha
Impermeability – Residential:	0.60
Impermeability – Roads:	1.00
Sewer design return period (2)	1 in 1 years
Sewer flood protection (2)	1 in 30 years
Fluvial / Development flood protection (1)	1 in 100 years
M5-60(3)	19.80 mm
Ratio r (2)	0.411
Minimum cover to sewers (1)	1.2 m
Minimum velocity (1)	1.0 m/sec
Pipe ks value (1)	0.6 mm
Allowance for climate change (4)	40%

4.25 The storm water management system has been developed having a series of drainage cells, each contributing to local infiltration systems. The proposed system has been developed close to source, in accordance with guidance, thereby avoiding reliance on a regional treatment system.

4.26 Drawing 10327-DR-05 E contained in the Appendix highlights the contributing areas utilised when appraising the storm drainage proposals using the WinDES Source Control module along with the approximate location for the SuDS feature.

4.27 Figure 4d, below, indicates the infiltration storage requirements for the site.

Site Use	Developable Area (ha)	Impermeable Area (ha)	Urban Creep (10%)	Infiltration Rate (m/s)	Infiltration Storage (m^3)	Plan Area Required (m^2)
Residential	23.00	13.92	15.28	9.06×10^{-5}	7,415	7,266

Figure 4d: Infiltration storage volumes for development cells

4.28 The above feature has been designed to accommodate a 1 in 100 (+40%) year event storm across the site with the WinDES output calculations contained within the Appendix.

[2] Sewers for Adoption 7th Edition
[3] Wallingford Report
[4] NPPF requirements for residential development

4.29 The Sustainable Drainage Systems (SuDS), being an above ground naturally landscaped features, will be designed to enhance the biodiversity and landscape character of the site, while also acting as functional features to control storm discharges from the site and improve water quality. However, the use of infiltration basins restricts having permanent water within the basin and therefore, can only be used a short term storage basin.

4.30 The storm water management system will provide features that are designed to provide extended detention of storm water collected from within the development.

4.31 The proposed strategic drainage masterplan is shown illustratively on drawing 10327-DR-05 E contained in the Appendix.

4.32 Being an outline planning application, without the benefit of a detailed layout, it is not possible to provide a final drainage layout. However, the development framework plan coupled with the criteria set out in this report will form the framework of the final design at reserved matters stage.

Water Quality

4.33 Impermeable surfaces collect pollutants from a wide variety of sources including cleaning activities, wear from car tyres, vehicle oil and exhaust leaks and general atmospheric deposition (source: CIRIA C609). The implementation of SuDS in development drainage provides a significant benefit in removal of pollutant from development run-off.

4.34 The SuDS Manual C753 describes a 'Simple Index Approach' for assessing the pollution risk of surface run-off to the receiving environment using indices for likely pollution levels for different land uses and SuDS performance capabilities.

4.35 CIRIA document C753 Table 26.2, as shown in Figure 4e below, indicates the minimum treatment indices appropriate for contributing pollution hazards for different land use classifications. To deliver adequate treatment, the selected SuDS components should have a total pollution mitigation index (for each contaminant type) that equals or exceeds the pollution hazard index.

Land Use	Pollution Hazard Level	Total suspended solids (TSS)	Metals	Hydrocarbons
Residential roofs	Very Low	0.2	0.2	0.05
Individual property driveways, residential car parks, low traffic roads (e.g. cul-de-sacs, home zones and general access roads) and non-residential car parking with infrequent change (e.g. schools, offices) i.e. < 300 traffic movements/day	Low	0.5	0.4	0.4
Other roofs (typically commercial/ industrial roofs)	Low	0.3	0.2 (up to 0.8 where there is potential for metals to leach from the roof)	0.05
Commercial yard and delivery areas, non-residential car parking with frequent change (e.g. hospitals, retail) all roads except low traffic roads and trunk roads/motorways.	Medium	0.7	0.6	0.7

Figure 4e: CIRIA 753 Table 26.2 Pollution Hazard Indices

4.36 For a residential type development, roof water requires a very low treatment of 0.2 for total suspended solids, 0.2 for heavy metals and 0.05 for hydrocarbons, and run-off from low traffic roads such as cul-de-sacs and individual property driveways requires low treatment of 0.5 for total suspended solids, 0.4 for heavy metals and 0.4 for hydrocarbons.

4.37 To provide the correct level of treatment, an assessment needs to be made of the mitigation provided by each SuDS feature. Tables 26.3 and 26.4 of The SuDS Manual CIRIA document C753 shown as Figure 4f and 4g for discharges to surface waters and groundwater respectively indicate the treatment mitigation indices provided by each SuDS feature.

Type of SuDS component	Total suspended solids (TSS)	Metals	Hydrocarbons
Filter Strip	0.4	0.4	0.5
Filter Drain	0.4	0.4	0.4
Swale	0.5	0.6	0.6
Permeable pavement	0.7	0.6	0.7
Detention basin	0.5	0.5	0.6
Proprietary treatment systems	These must demonstrate that they can address each of the contaminant types to acceptable levels for frequent events up to approximately the 1 in 1 year return period event, for inflow concentrations relevant to the contributing drainage area.		

Figure 4f: CIRIA 753 Table 26.3 SuDS Mitigation Indices for discharges to surface waters.

Characteristics of the material overlying the proposed infiltration surface, through which the runoff percolates	Total suspended solids (TSS)	Metals	Hydrocarbons
A layer of dense vegetation underlain by a soil with good contaminant attenuation potential of at least 300 mm in depth	0.6	0.5	0.6
A soil with good contaminant attenuation potential of at least 300 mm in depth	0.4	0.3	0.3
Infiltration trench (where a suitable depth of filtration material is included that provides treatment, i.e. graded gravel with sufficient smaller particles but no single size coarse aggregate such as 20mm gravel) underlain by a soil with good contaminant attenuation potential of at least 300 mm in depth	0.4	0.4	0.4
Constructed permeable pavement (where a suitable filtration layer is included that provides treatment, and including a geotextile at the base separating the foundation from the subgrade) underlain by a soil with good contaminant attenuation potential of at least 300 mm in depth	0.7	0.6	0.7
Bioretention underlain by a soil with good contaminant attenuation potential of at least 300 mm in depth	0.8	0.8	0.8
Proprietary treatment systems	These must demonstrate that they can address each of the contaminant types to acceptable levels for frequent events up to approximately the 1 in 1 year return period event, for inflow concentrations relevant to the contributing drainage area.		

Figure 4g: CIRIA 753 Table 26.4 SuDS Mitigation Indices for discharges to groundwater

4.38 Where more than one mitigation feature is to be used, CIRIA guidance states that the total mitigation index shall be calculated as follows:

Total SuDS mitigation index = Mitigation Index 1 + 0.5 x Mitigation Index 2

4.39 At present, the site and surrounding area does not benefit from any additional measures of stormwater treatment.

4.40 Due to the need to provide wider sustainability benefits and view the development at a strategic level, SuDS will be implemented to passively treat run off from the development to have a positive impact on the surrounding natural environment.

4.41 The site will employ SuDS features, such as porous paving, and infiltration basins. These are widely accepted to be of high pollutant removal efficiency (CIRIA 609). This provides for one stage of treatment onsite. Coupled with this however, the local watercourse should also be seen as an additional stage of treatment as the sedimentation process is not limited to artificial drainage systems but is taken from the natural processes observed within the water cycle. This gives 2-3 stages of treatment, providing an extensive system by which to effectively decrease pollutant load within stormwater run-off.

4.42 As the site is not presently served by any means of storm water treatment mechanisms, by providing the afore mentioned SuDS within the proposed development it will be possible to maintain present water quality in the area and thus the development can be seen to be having no significant environmental impact in relation to water.

Implementation Proposals

4.43 The conceptual drainage proposals have been developed in a manner that will allow the site wide system to be designed to encourage passive treatment of discharged flows and to improve the water quality by removing the low-level silts, oils which could be attributed to track/parking area run off of this nature. Final design will provide for appropriate geometry and planting to maximise this benefit.

4.44 The storm water management features will be constructed and operational prior to the first use of the site, derived on a phase-by-phase requirement.

4.45 It has previously been the case that the functionality of the storm water management system would be ensured by ongoing maintenance, completed by the Local Authority, Drainage Authority, or a private maintenance company as appropriate. It is proposed that, for this development, a private maintenance company will be appointed to carry out the maintenance regime below in Figure 4h.

4.46 It is usual for the following maintenance regime to be implemented:

REGULAR MAINTENANCE		
1	LITTER MANAGEMENT	
1.1	Pick up all litter in SUDS and Landscape areas and remove from site.	Monthly
2	LANDSCAPE MAINTENANCE	
2.1	Mow all grass verges at 35-50mm with 75mm max and remove from site.	As required or monthly
2.2	Mow all SUDS basins and margins to low flow channels at 100mm with 150mm max.	4-8 visits as required Annually
2.3	Weeding and invasive plant control.	As required or 1 visit annually
2.4	Tree and shrub maintenance.	As required or once every 2 years
2.5	Aquatic and shoreline vegetation management	As required or 1 visit annually
3	INLET AND OUTLET STRUCTURES	
3.1	Inspect monthly, remove silt from slab aprons and debris. Strim 1m round for access.	Monthly and after every named storm or storm with designated return period.
4	PROPRIETARY SYSTEMS	
4.1	Inspect and clean flow control.	
OCCASIONAL MAINTENANCE		
5	INSPECTION	
5.1	Annual inspection, remove silt and check free flow.	1 visit annually
5.2	Inspection and removal of debris	Post major storm events
6	SILT MANAGEMENT	
6.1	Inspect basin annually for silt accumulation.	1 visit annually
6.2	Excavate silt, stack and dry, spread, rake and over-seed.	As required
7	VEGETATION MANAGEMENT	
7.1	Major vegetation maintenance and watercourse channel works.	Once every 15-20 years
REMEDIAL MAINTENANCE		
8	INSPECTION	
8.1	Structure rehabilitation/repair	As required after annual inspection

Figure 4h: Framework maintenance of detention / retention system

4.47 The conceptual drainage masterplan proposals outlined in this report will be used for final drainage design and detailing. The storm water management system will be constructed and operational in full prior to first use of the relevant phase of development.

Summary

4.48 A strategy for storm drainage at the site has been developed to meet both national and local policy. The above options outline the viability of the site to employ means of drainage to comply with NPPF guidance, together with the Cherwell District Council & West Oxfordshire District Council SFRA and other national and local guidance.

4.49 The development drainage system will manage storm water by way of a SuDS management train and ensure peak discharges from the developed land are reduced to the appraised baseline rates. The system will also provide improvements to the quality of water discharged from the development.

Objectives

4.50 The key objectives for the site drainage will be:

- Implementation of a sustainable drainage scheme in accordance with current national and local policy together with principles of good practice design.
- Control of peak discharges from the site to baseline conditions, during all storm events.
- Development of storm water management proposals that improve water quality and biodiversity of the site.
- Implementation of the storm water management system prior to first occupation of dwellings.

5 Foul Drainage

Background

5.1 In 2015 a copy of the Thames Water (TW) sewerage network records were obtained to confirm the presence of adopted foul sewers within the vicinity of the site. Adopted foul sewers service the existing residential development areas to the north and west of the site.

5.2 A 500mm foul rising main intersects the site from the north to the south eastern corner of the site. Should the pipeline not be diverted, a 3m easement either side of the existing sewer will likely be required, to ensure access for any future repair and maintenance of the pipe. Discussions are ongoing with Thames Water to obtain approval for this.

Design Criteria / Network Requirements

5.3 Peak design discharges have been calculated based on the current development criteria as described in Section 2 of this report and for the following:

Domestic peak = 4,000 litres / dwelling / day (peak) [5]

5.4 Assessed in accordance with SFA 7th Edition requirements, the development will have a design peak discharge of approximately 38.19 l/s.

Network Requirements / Options

5.5 A pre-development enquiry is currently being undertaken by TW to assess and confirm the capacity within the existing sewer network and the nearest point of contact (anticipated to be a 300mm sewer approximately 600m to the south west of the site).

5.6 In addition to this, TW will need to confirm capacity within the Banbury Sewage Treatment Works to accept the flows and thus, would accept a requisition from the site directly to the works.

Treatment Requirements

5.7 Discussions with Thames Water have outlined that the existing foul water network conveys flows towards the Banbury Sewage Treatment Works, approximately 3km from the site boundary.

5.8 Water companies have a statutory obligation through the Water Industry Act 1991, 2003 *et al*, to provide capital investment in strategic treatment infrastructure to meet development growth. This investment planning is managed and regulated by OFWAT through the Asset Management Plan (AMP) process. The five yearly cyclical process requires that water companies allocate finances to a range of strategic projects to meet their statutory obligations.

5.9 Where development programming requirements necessitate the reinforcement of facilities ahead of allocation in an AMP period, mechanisms are available to ensure the infrastructure can be delivered in a timely fashion, to the meet the development programme.

[5] Sewers for Adoption 7th Edition

Implementation Proposals

5.10 The proposed drainage network across the site will be designed to current Sewers for Adoption 7th Edition Standards, employing a point of connection agreed with Thames Water. The system will be offered for the adoption of Thames Water under S104 of the Water Industry Act 1991.

5.11 In the absence of a finalised point of connection, due to the site topography, it is likely that an on-site pumping station will be required.

Summary

5.12 A site drainage strategy has been developed that meets with current regulatory requirements by discharging drainage to a sewerage network with capacity to accommodate the flows.

5.13 Once development is complete, the network conveying flows from the site will be adopted by Thames Water and be maintained as part of their statutory duties.

Objectives

5.14 The key development objectives required for the site drainage scheme are:

- Implementation of a drainage scheme to convey water to the local Thames Water network which is designed and maintained to an appropriate standard.

6 Summary

6.1 This FRA has identified no prohibitive engineering constraints in developing the site for the proposed residential usage.

6.2 Assessment of fluvial flood risk shows the land to lie in Flood Zone 1 and hence be a preferable location for residential development when considered in the context of the NPPF Sequential Test. Assessment of other potential flooding mechanisms shows the land to have a low probability of flooding from overland flow, ground water and sewer flooding.

6.3 Means to discharge storm and foul water drainage have been established that comply with current guidance and requirements of Thames Water.

6.4 Storm water discharged from the development will be directed to the underlying geology. Foul water will discharge to the existing Thames Water network.

6.5 Should the pipeline not be diverted, a 3m easement has been issued by Thames Water either side of the existing foul sewer which crosses the development site, to ensure access for any future repair and maintenance of the pipe. Any proposed development within this zone will require approval from Thames Water.

6.6 The site is fully able to comply with NPPF guidance together with associated local and national policy guidance.

7 Limitations

7.1 The conclusions and recommendations contained herein are limited to those given the general availability of background information and the planned usage of the site.

7.2 Third party information has been used in the preparation of this report, which Brookbanks Consulting Ltd, by necessity assumes is correct at the time of writing. While all reasonable checks have been made on data sources and the accuracy of data, Brookbanks Consulting Ltd accepts no liability for same.

7.3 The benefits of this report are provided solely to Hallam Land Management Ltd for the proposed development land at Banbury only.

7.4 The FRA can be relied upon by the relevant authority and its consultees within the planning process.

7.5 Brookbanks Consulting Ltd excludes third party rights for the information contained in the report.

Appendix A

10327-SV-02

NOTES:

1. Do not scale from this drawing.
2. All dimensions in metres unless otherwise stated.
3. This drawing has been produced using survey data provided by a Third Party. Brookbanks Consulting Ltd cannot be held responsible for the accuracy of this data. All discrepancies are to be reported to the Engineer immediately, ahead of work commencing.
4. The existing services shown are not necessarily complete nor is their location with regard to position and depth precise. It is the Contractor's responsibility to liaise with all relevant services companies to ensure that all services are accurately located, marked out and adequately protected during all site works.

KEY:

Site Boundary

Rev.	Revision Details	Drawn	Checked	Approved	Date
B	Site boundary updated	AM	DS		Jun 17
A	Site boundary updated	SO			SEP 16

Issue Status	Approved	Date
PRELIMINARY		10.11.14

Drawn AA | Checked DW | Date NOV 14

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Hallam Land Management

Land at Bankside
Banbury, Phase II

Site Survey

Scale at A1	Drawing No.	Rev.
1:2,000	10327-SV-02	B

Original Drawing Size A1

Appendix B

Original Drawing Size A1

Construction Design and Management (CDM)
Key Residual Risks

Contractors entering the site should gain permission from the relevant land owners and/or principle contractor working on site at the time of entry. Contractors shall be responsible for carrying out their own risk assessments and for liaising with the relevant services companies and authorities. Listed below are Site Specific key risks associated with the project.

1) Overhead and underground services
2) Street Lighting Cables
3) Working adjacent to water courses and flood plain
4) Soft ground conditions
5) Working adjacent to live highways and railway line
6) Unchartered services
7) Existing buildings with potential asbestos hazards

NOTES:

1. Do not scale from this drawing
2. All dimensions are in metres unless otherwise stated.
3. Brookbanks Consulting Ltd has prepared this drawing for the sole use of the client. The drawing may not be relied upon by any other party without the express agreement of the client and Brookbanks Consulting Ltd. Where any data supplied by the client or from other sources has been used, it has been assumed that the information is correct. No responsibility can be accepted by Brookbanks Consulting Ltd for inaccuracies in the data supplied by any other party. The drawing has been produced based on the assumption that all relevant information has been supplied by those bodies from whom it was requested.
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KEY:

- Red Line
- Catchment Boundary
- Flow Direction
- Infiltration Basin and Maintance Strip
- Potential Conveyance Channel Locations
- Indicative Internal Storm Water Sewers

E	Updated Storm Sewers	KM	DS	DS	10.01.20
D	Updated Parameters Plan and Basin	KM	DS	DS	02.01.20
C	Updated Basin and Conveyance Systems	KM	DS	DS	24.10.19
B	Updated Basin and Conveyance Swales	KM	DS	DS	14.10.19
A	Updated Masterplan and Basins	KM	SO	LW	07.05.19
-	First Issue	KM	SO	LW	21.01.19

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Hallam Land Management

Land South of Bankside, Banbury

Illustrative Surface Water Drainage Strategy

Status		Status Date
Draft		JAN 2020
Drawn	**Checked**	**Date**
KM	LW	21.01.19
Scale	**Number**	**Rev**
1:2500	10327-DR-05	E

0 50 100 150 200 250
METRES

UNTIL TECHNICAL APPROVAL HAS BEEN OBTAINED FROM THE RELEVANT LOCAL AUTHORITIES, IT SHOULD BE UNDERSTOOD THAT ALL DRAWINGS ARE ISSUED AS PRELIMINARY AND NOT FOR CONSTRUCTION. SHOULD THE CONTRACTOR COMMENCE SITE WORK PRIOR TO APPROVAL BEING GIVEN, IT IS ENTIRELY AT HIS OWN RISK.

Summary of Results for 100 year Return Period (+40%)

Half Drain Time : 185 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
15 min Summer	0.616	0.616	313.0	3596.8	O K
30 min Summer	0.773	0.773	330.0	4582.4	O K
60 min Summer	0.894	0.894	343.2	5361.8	O K
120 min Summer	0.943	0.943	348.7	5685.0	O K
180 min Summer	0.926	0.926	346.7	5567.9	O K
240 min Summer	0.897	0.897	343.6	5380.9	O K
360 min Summer	0.839	0.839	337.2	5005.1	O K
480 min Summer	0.787	0.787	331.5	4672.3	O K
600 min Summer	0.738	0.738	326.1	4357.1	O K
720 min Summer	0.690	0.690	320.9	4056.0	O K
960 min Summer	0.600	0.600	311.2	3495.5	O K
1440 min Summer	0.442	0.442	294.4	2537.0	O K
2160 min Summer	0.261	0.261	275.5	1471.0	O K
2880 min Summer	0.139	0.139	262.9	775.9	O K
4320 min Summer	0.047	0.047	239.7	261.7	O K
5760 min Summer	0.038	0.038	191.1	206.9	O K
7200 min Summer	0.031	0.031	158.0	172.7	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
15 min Summer	137.942	0.0	25
30 min Summer	90.166	0.0	38
60 min Summer	56.129	0.0	66
120 min Summer	33.767	0.0	120
180 min Summer	24.758	0.0	152
240 min Summer	19.753	0.0	184
360 min Summer	14.306	0.0	252
480 min Summer	11.383	0.0	320
600 min Summer	9.527	0.0	388
720 min Summer	8.233	0.0	456
960 min Summer	6.536	0.0	588
1440 min Summer	4.713	0.0	842
2160 min Summer	3.394	0.0	1196
2880 min Summer	2.685	0.0	1536
4320 min Summer	1.928	0.0	2204
5760 min Summer	1.523	0.0	2896
7200 min Summer	1.268	0.0	3672

Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
8640 min Summer	0.027	0.027	137.7	148.9	O K
10080 min Summer	0.024	0.024	119.9	129.8	O K
15 min Winter	0.760	0.760	328.6	4501.1	O K
30 min Winter	0.955	0.955	349.9	5760.7	O K
60 min Winter	1.113	1.113	367.6	6819.5	O K
120 min Winter	1.200	1.200	377.4	7410.4	O K
180 min Winter	1.192	1.192	376.6	7359.1	O K
240 min Winter	1.157	1.157	372.5	7117.4	O K
360 min Winter	1.081	1.081	364.0	6603.5	O K
480 min Winter	1.007	1.007	355.8	6107.9	O K
600 min Winter	0.934	0.934	347.7	5624.9	O K
720 min Winter	0.863	0.863	339.8	5158.9	O K
960 min Winter	0.727	0.727	325.0	4292.4	O K
1440 min Winter	0.491	0.491	299.6	2833.4	O K
2160 min Winter	0.224	0.224	271.6	1257.1	O K
2880 min Winter	0.064	0.064	255.2	355.5	O K
4320 min Winter	0.038	0.038	191.1	208.1	O K
5760 min Winter	0.030	0.030	152.9	165.5	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
8640 min Summer	1.091	0.0	4328
10080 min Summer	0.961	0.0	4992
15 min Winter	137.942	0.0	25
30 min Winter	90.166	0.0	38
60 min Winter	56.129	0.0	66
120 min Winter	33.767	0.0	120
180 min Winter	24.758	0.0	174
240 min Winter	19.753	0.0	198
360 min Winter	14.306	0.0	274
480 min Winter	11.383	0.0	350
600 min Winter	9.527	0.0	426
720 min Winter	8.233	0.0	498
960 min Winter	6.536	0.0	636
1440 min Winter	4.713	0.0	900
2160 min Winter	3.394	0.0	1256
2880 min Winter	2.685	0.0	1532
4320 min Winter	1.928	0.0	2204
5760 min Winter	1.523	0.0	2896

Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
7200 min Winter	0.025	0.025	127.5	137.9	O K
8640 min Winter	0.022	0.022	109.8	118.6	O K
10080 min Winter	0.019	0.019	97.1	104.8	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
7200 min Winter	1.268	0.0	3592
8640 min Winter	1.091	0.0	4408
10080 min Winter	0.961	0.0	5072

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.925
M5-60 (mm)	19.800	Shortest Storm (mins)	15
Ratio R	0.411	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 15.280

Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)	Time From:	(mins) To:	Area (ha)
0	4	5.093	4	8	5.093	8	12	5.093

Model Details

Storage is Online Cover Level (m) 1.500

Infiltration Basin Structure

Invert Level (m) 0.000 Safety Factor 2.0
Infiltration Coefficient Base (m/hr) 0.32616 Porosity 1.00
Infiltration Coefficient Side (m/hr) 0.32616

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	5489.8	0.400	5939.3	0.800	6406.4	1.200	6891.2
0.100	5600.5	0.500	6054.4	0.900	6526.0	1.300	7015.2
0.200	5712.3	0.600	6170.6	1.000	6646.6	1.400	7140.3
0.300	5825.2	0.700	6288.0	1.100	6768.4	1.500	7266.4

Appendix C

Appendix D
Infiltration Tests
Bankside, Banbury
TP01 Test 1

Time (min)	Depth from Surface (cm)	% Effective Depth
0	52	100%
1	54	98%
10	57	95%
46	60	92%
81	60	92%
112	61	91%
175	63	89%
216	63	89%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP02 Test 1

Time (min)	Depth from Surface (cm)	% Effective Depth
0	47	100%
1	59	88%
2	62	85%
3	68	79%
4	73	74%
5	77	70%
25	119	27%
51	140	6%
End of Test		

Note: Trial pit collapsed to 1.40m

Appendix D
Infiltration Tests
Bankside, Banbury
TP02 Test 2

Time (min)	Depth from Surface (cm)	% Effective Depth
0	54	100%
1	58	95%
6	72	79%
21	99	48%
43	119	24%
47	122	21%
51	124	19%
57	127	15%
61	130	12%
64	134	7%
End of Test		

Note: Trial pit collapsed to 1.40m

Appendix D
Infiltration Tests
Bankside, Banbury
TP02 Test 3

Time (min)	Depth from Surface (cm)	% Effective Depth
0	49	100%
1	54	95%
3	58	90%
8	70	77%
12	77	69%
15	83	63%
32	105	38%
50	117	25%
56	120	22%
End of Test		

Note: Trial pit collapsed to 1.40m

Appendix D
Infiltration Tests
Bankside, Banbury
TP03 Test 1

Time (min)	Depth from Surface (cm)	% Effective Depth
0	65	100%
1	77	87%
2	90	74%
3	94	69%
4	108	55%
5	113	49%
12	132	29%
24	147	14%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP03 Test 2

Time (min)	Depth from Surface (cm)	% Effective Depth
0	60	100%
1	80	80%
2	90	70%
3	98	62%
4	105	55%
5	109	51%
21	135	25%
23	137	23%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP03 Test 3

Time (min)	Depth from Surface (cm)	% Effective Depth
0	60	100%
2	79	81%
7	108	52%
20	129	31%
22	132	28%
45	157	3%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP04 Test 1

Time (min)	Depth from Surface (cm)	% Effective Depth
0	97	100%
1	98	99%
5	104	93%
17	109	88%
58	118	79%
88	122	75%
125	125	72%
189	129	68%
231	131	66%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP05 Test 1

Time (min)	Depth from Surface (cm)	% Effective Depth
0	72	100%
1	84	88%
2	88	84%
3	93	79%
4	99	73%
5	103	69%
6	107	65%
7	110	62%
8	113	59%
9	116	56%
10	119	53%
13	124	48%
18	135	37%
23	143	29%
33	156	16%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP05 Test 2

Time (min)	Depth from Surface (cm)	% Effective Depth
0	72	100%
6	86	86%
13	98	74%
22	111	61%
36	128	44%
56	145	27%
66	154	18%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP05 Test 3

Time (min)	Depth from Surface (cm)	% Effective Depth
0	104	100%
15	119	78%
23	126	68%
29	133	57%
37	136	53%
48	145	40%
56	149	34%
75	155	25%
	End of Test	

**Last Point Extrapolated*

Appendix D
Infiltration Tests
Bankside, Banbury
TP06 Test 1

Time (min)	Depth from Surface (cm)	% Effective Depth
0	66	100%
1	83	83%
2	95	71%
3	105	61%
4	120	46%
8	137	29%
9	139	27%
10	141	25%
11	143	23%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP06 Test 2

Time (min)	Depth from Surface (cm)	% Effective Depth
0	66	100%
7	125	41%
16	146	20%
23	155	11%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP06 Test 3

Time (min)	Depth from Surface (cm)	% Effective Depth
0	66	100%
6	123	43%
12	138	28%
18	147	19%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP07 Test 1

Time (min)	Depth from Surface (cm)	% Effective Depth
0	82	100%
1	93	89%
2	101	81%
3	109	73%
4	117	65%
5	122	60%
6	127	55%
7	130	52%
8	135	47%
9	138	44%
10	140	42%
12	145	37%
14	149	33%
20	159	23%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP07 Test 2

Time (min)	Depth from Surface (cm)	% Effective Depth
0	82	100%
7	121	61%
13	139	43%
19	149	33%
26	156	26%
30	159	23%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP07 Test 3

Time (min)	Depth from Surface (cm)	% Effective Depth
0	82	100%
14	140	42%
19	150	32%
31	158	24%
End of Test		

Appendix D
Infiltration Tests
Bankside, Banbury
TP08 Test 1

Time (min)	Depth from Surface (cm)	% Effective Depth
0	61	100%
1	74	87%
2	78	83%
4	87	74%
6	95	66%
9	105	56%
14	116	45%
22	129	32%
28	132	29%
34	139	22%
End of Test		

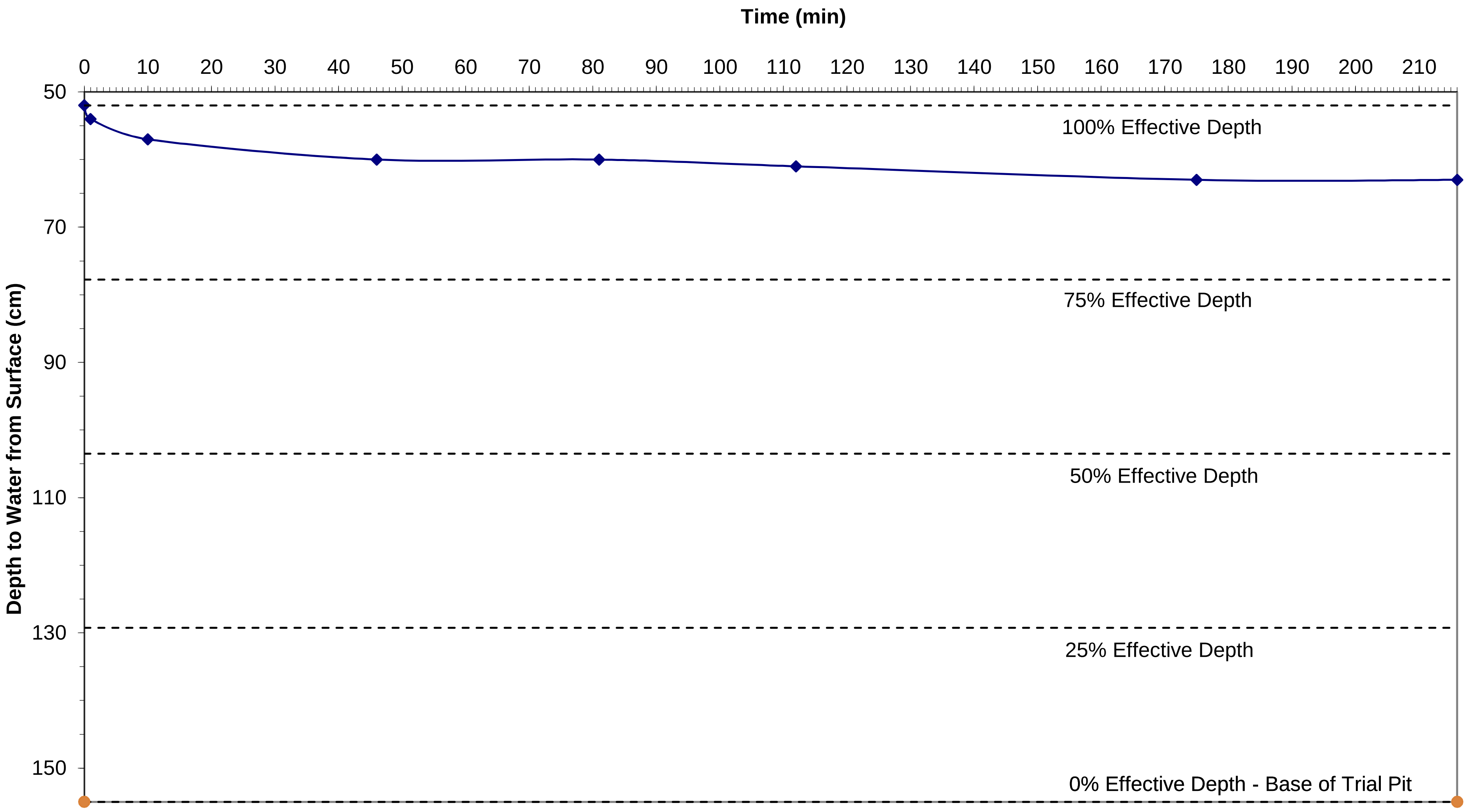
Appendix D
Infiltration Tests
Bankside, Banbury
TP08 Test 2

Time (min)	Depth from Surface (cm)	% Effective Depth
0	61	100%
1	67	94%
8	94	67%
15	109	52%
21	118	43%
28	125	36%
39	134	27%
48	139	22%
End of Test		

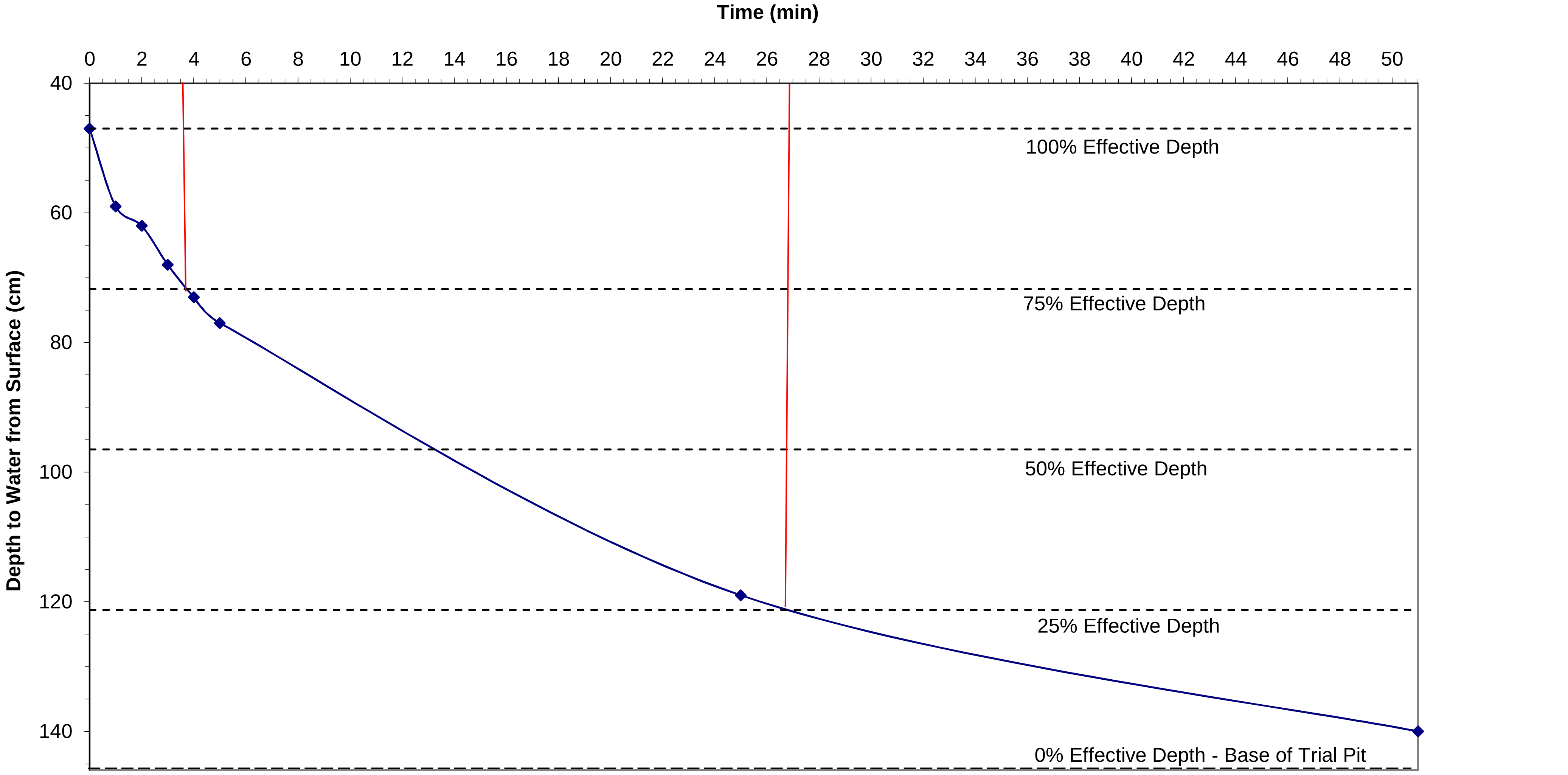
Appendix D
Infiltration Tests
Bankside, Banbury
TP08 Test 3

Time (min)	Depth from Surface (cm)	% Effective Depth
0	61	100%
8	91	70%
14	104	57%
26	119	42%
32	123	38%
44	131	30%
55	135	26%
60	137	24%
End of Test		

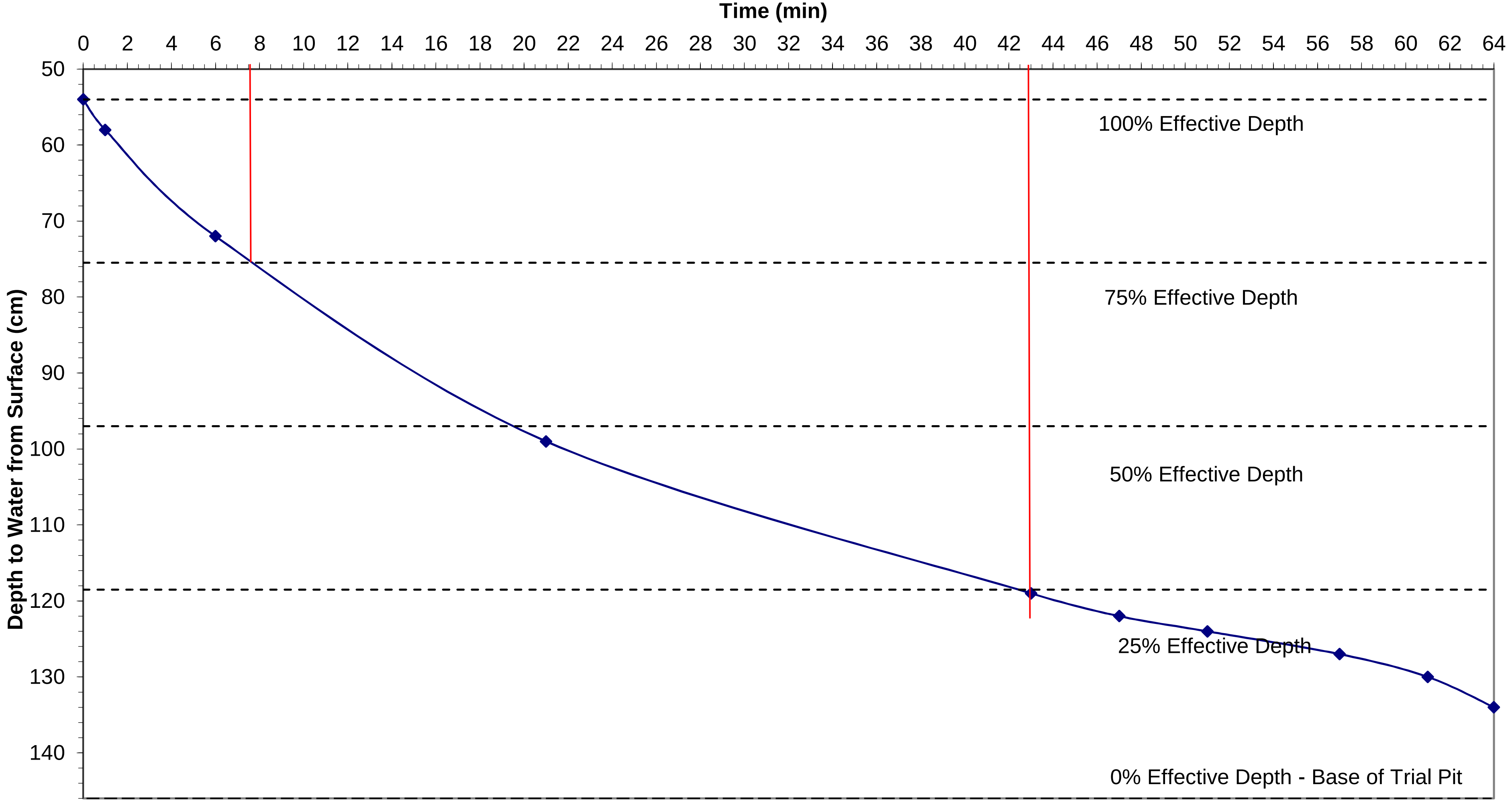
GEG-14-358 Bankside, Banbury. Figure D-1. Infiltration Test Results - TP01 Test 1



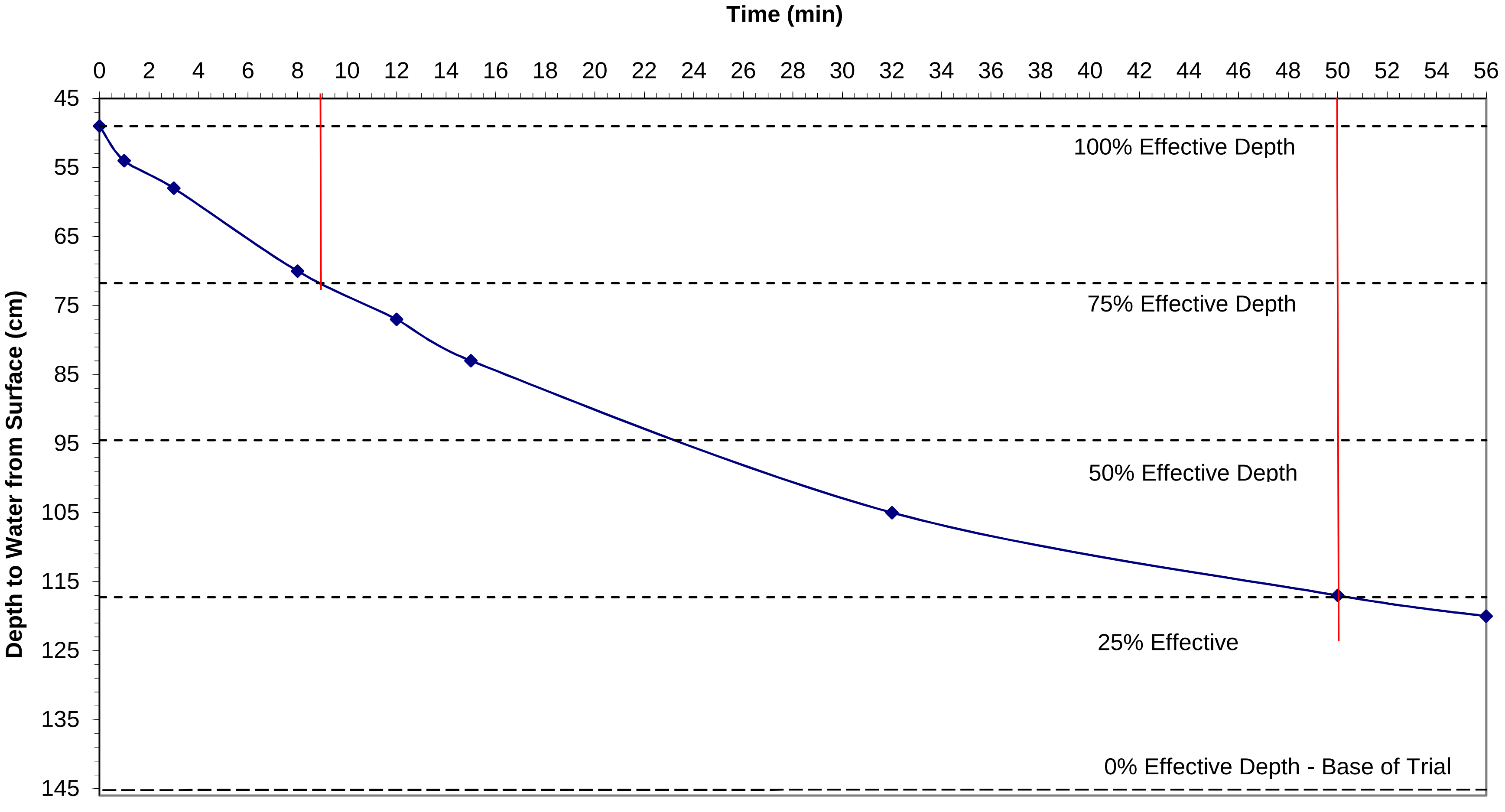
GEG-14-358 Bankside, Banbury. Figure D-2. Infiltration Test Results - TP02 Test 1

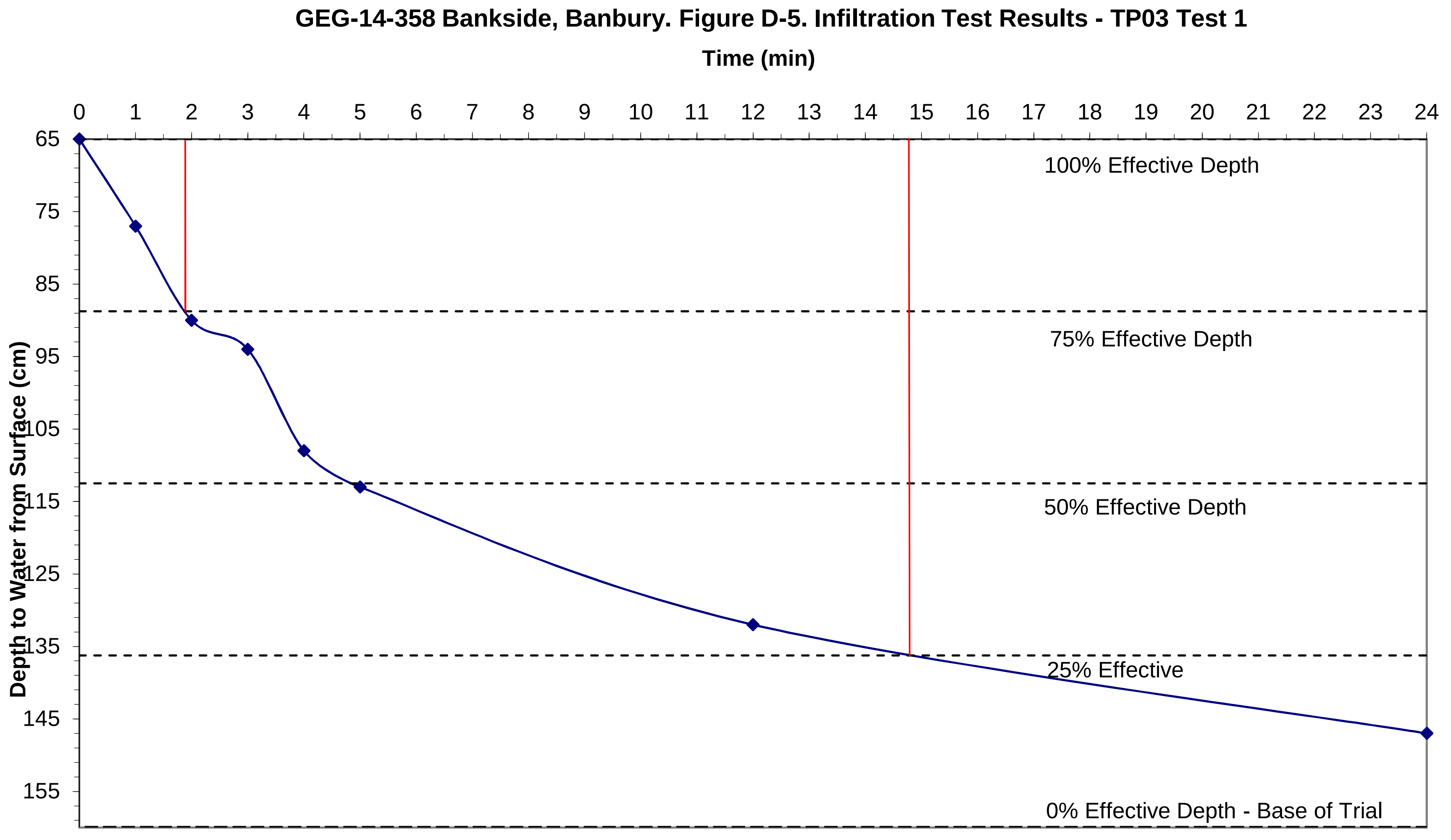


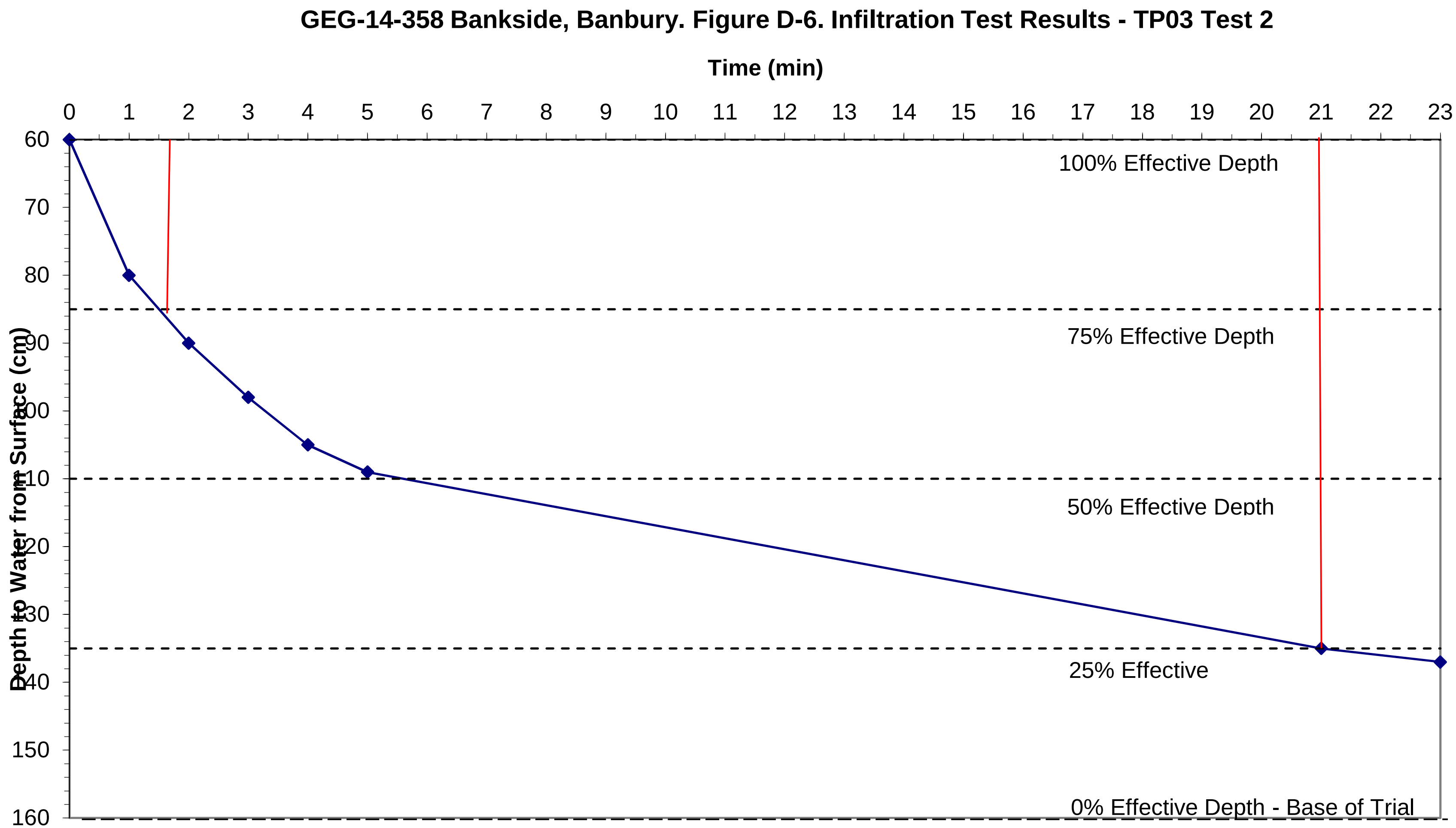
GEG-14-358 Bankside, Banbury. Figure D-3. Infiltration Test Results - TP02 Test 2



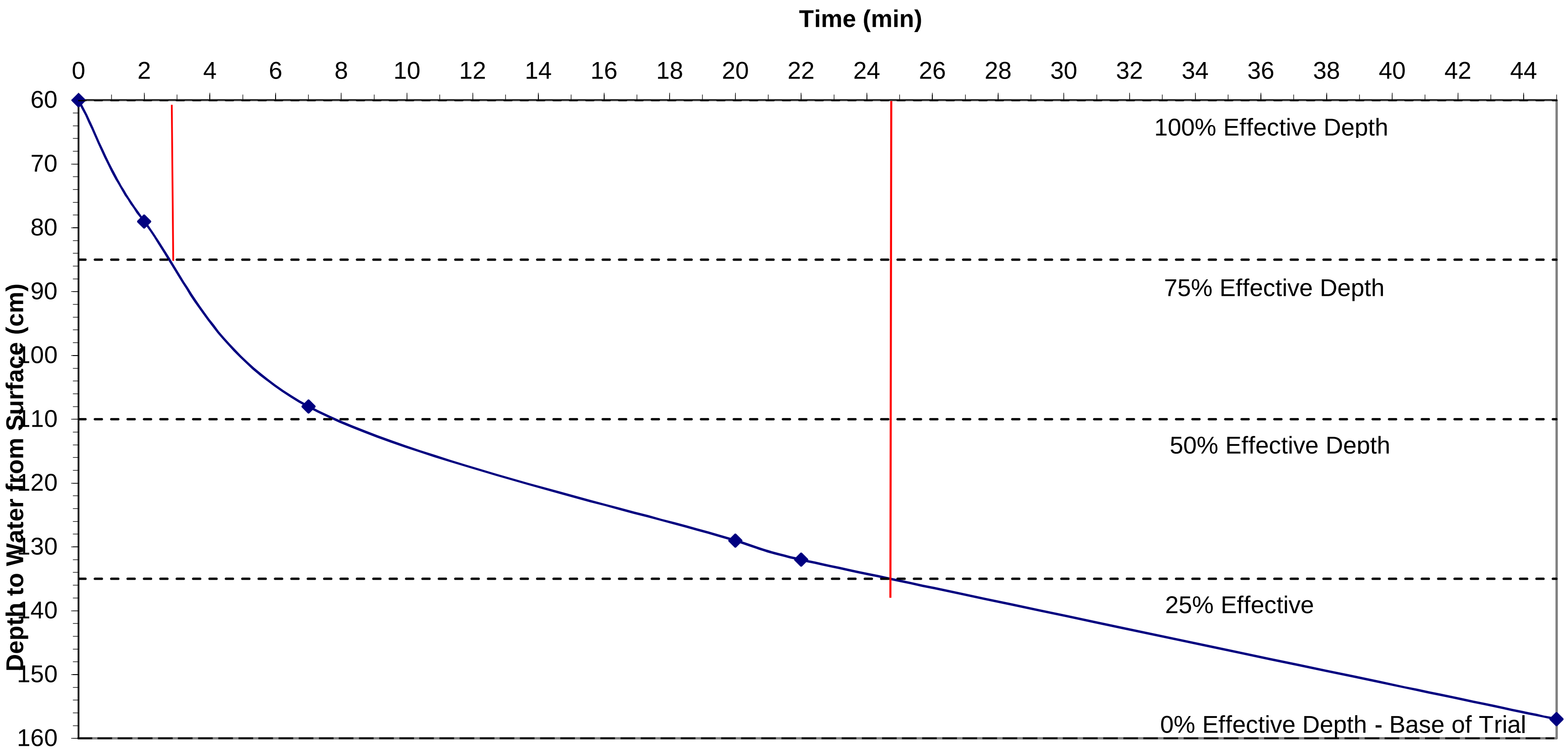
GEG-14-358 Bankside, Banbury. Figure D-4. Infiltration Test Results - TP02 Test 3



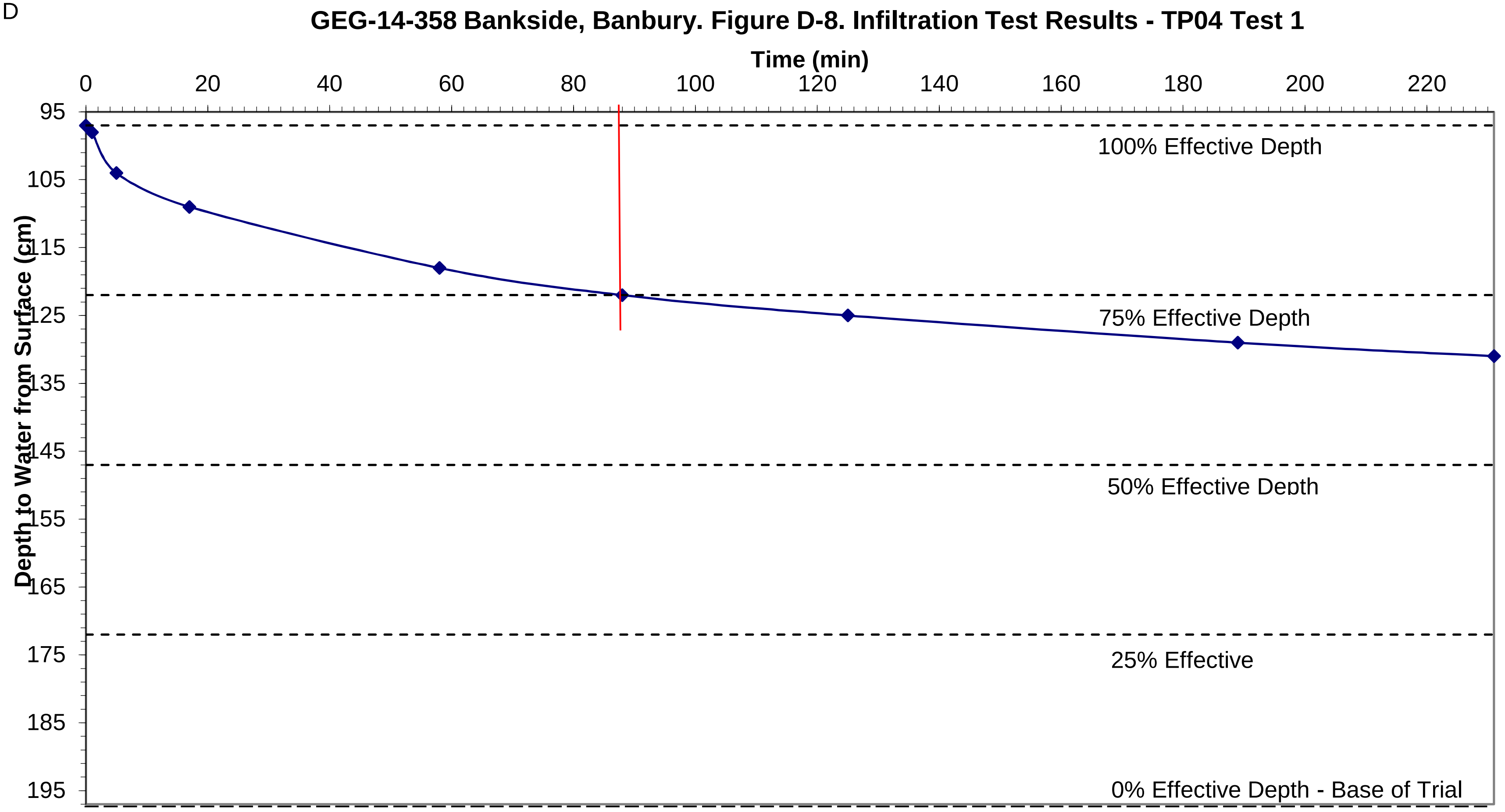

GEG-14-358 Bankside, Banbury. Figure D-5. Infiltration Test Results - TP03 Test 1
Time (min)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Depth to Water from Surface (cm)
65
75
85
95
105
115
125
135
145
155
100% Effective Depth
75% Effective Depth
50% Effective Depth
25% Effective
0% Effective Depth - Base of Trial


GEG-14-358 Bankside, Banbury. Figure D-6. Infiltration Test Results - TP03 Test 2
Time (min)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Depth to Water from Surface (cm)
60
70
80
90
100
110
120
130
140
150
160
100% Effective Depth
75% Effective Depth
50% Effective Depth
25% Effective
0% Effective Depth - Base of Trial

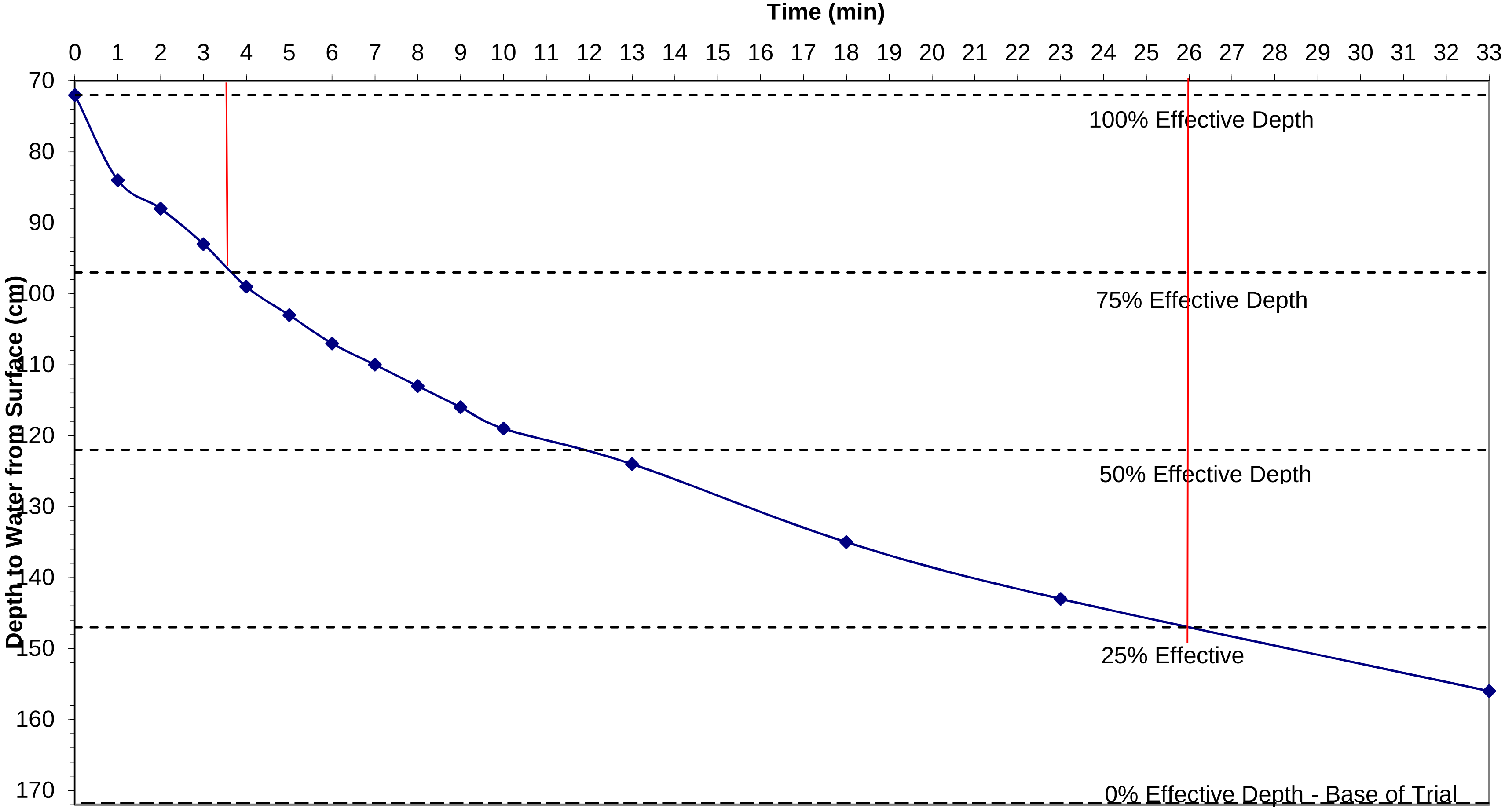
GEG-14-358 Bankside, Banbury. Figure D-7. Infiltration Test Results - TP03 Test 3



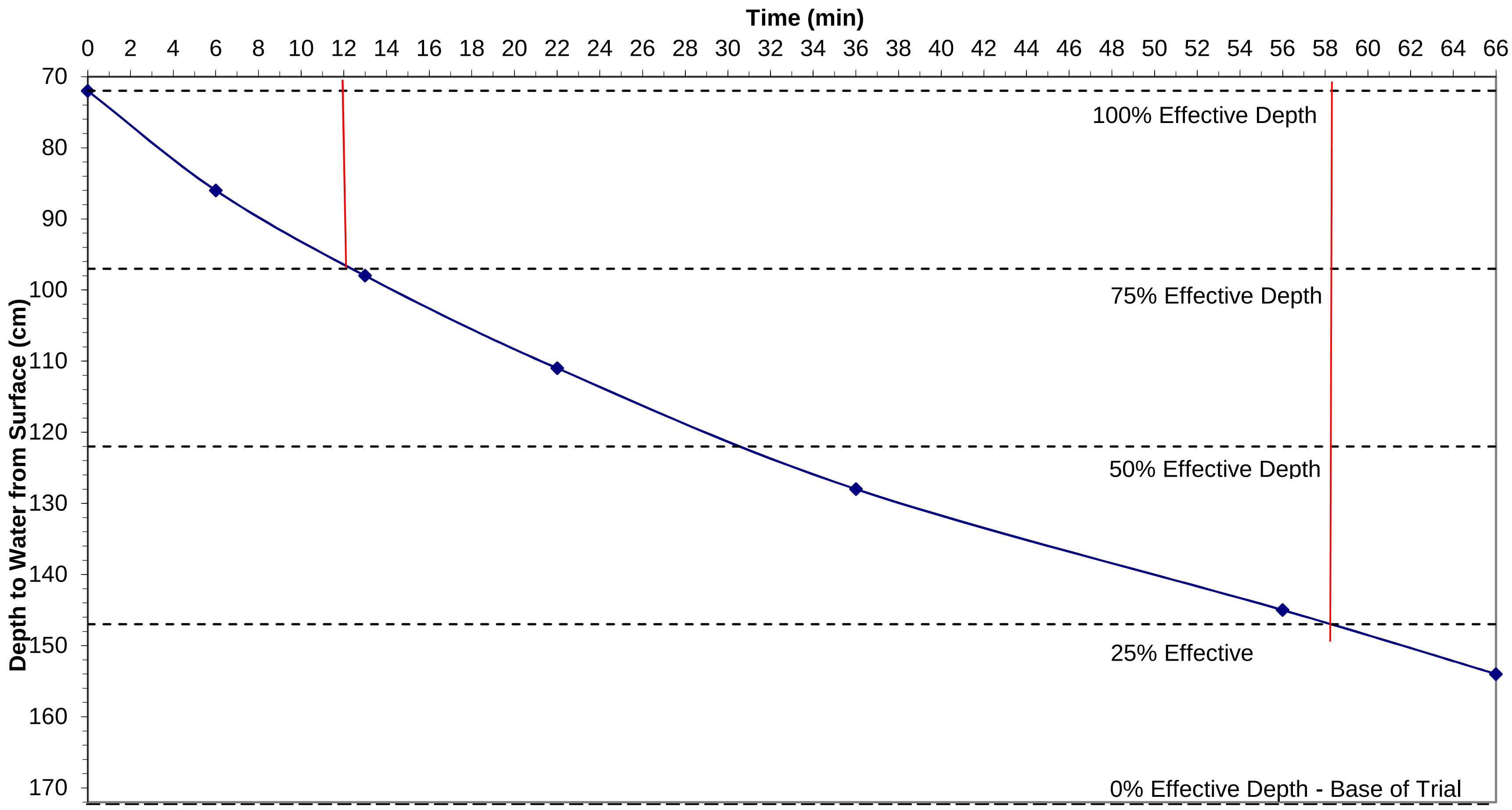
D

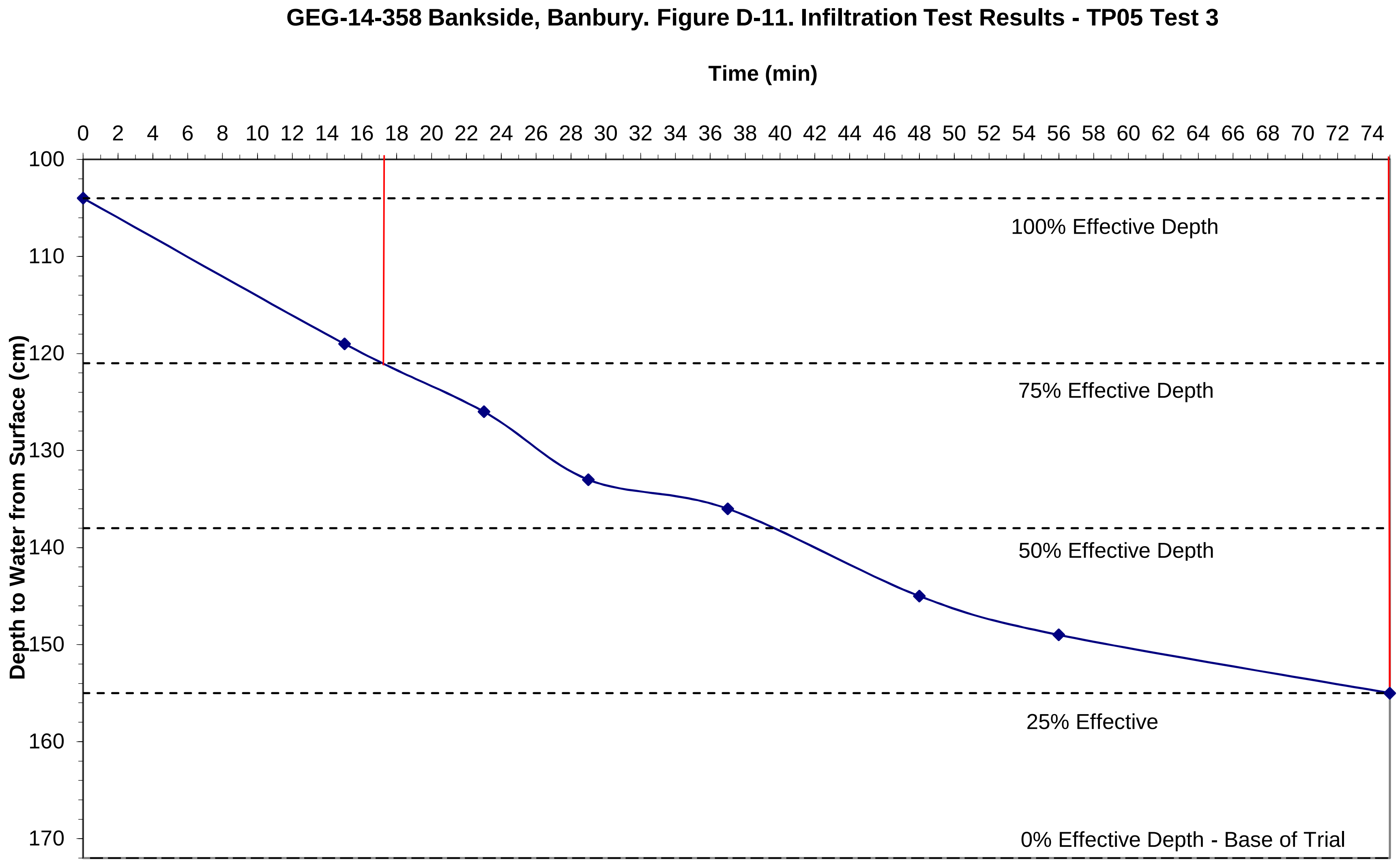

GEG-14-358 Bankside, Banbury. Figure D-8. Infiltration Test Results - TP04 Test 1
Time (min)
0
20
40
60
80
100
120
140
160
180
200
220
Depth to Water from Surface (cm)
95
105
115
125
135
145
155
165
175
185
195
100% Effective Depth
75% Effective Depth
50% Effective Depth
25% Effective
0% Effective Depth - Base of Trial

GEG-14-358 Bankside, Banbury. Figure D-9. Infiltration Test Results - TP05 Test 1

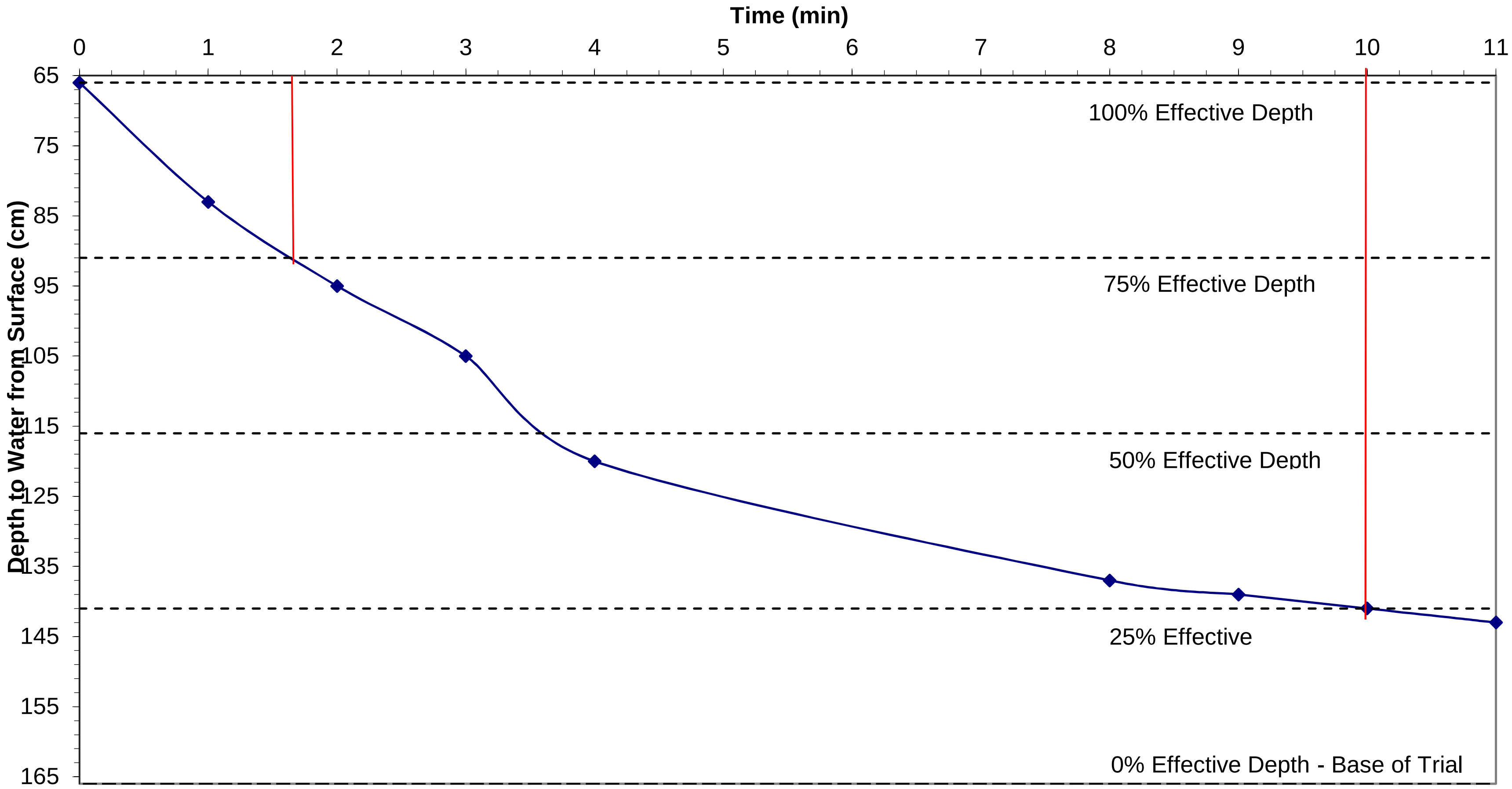


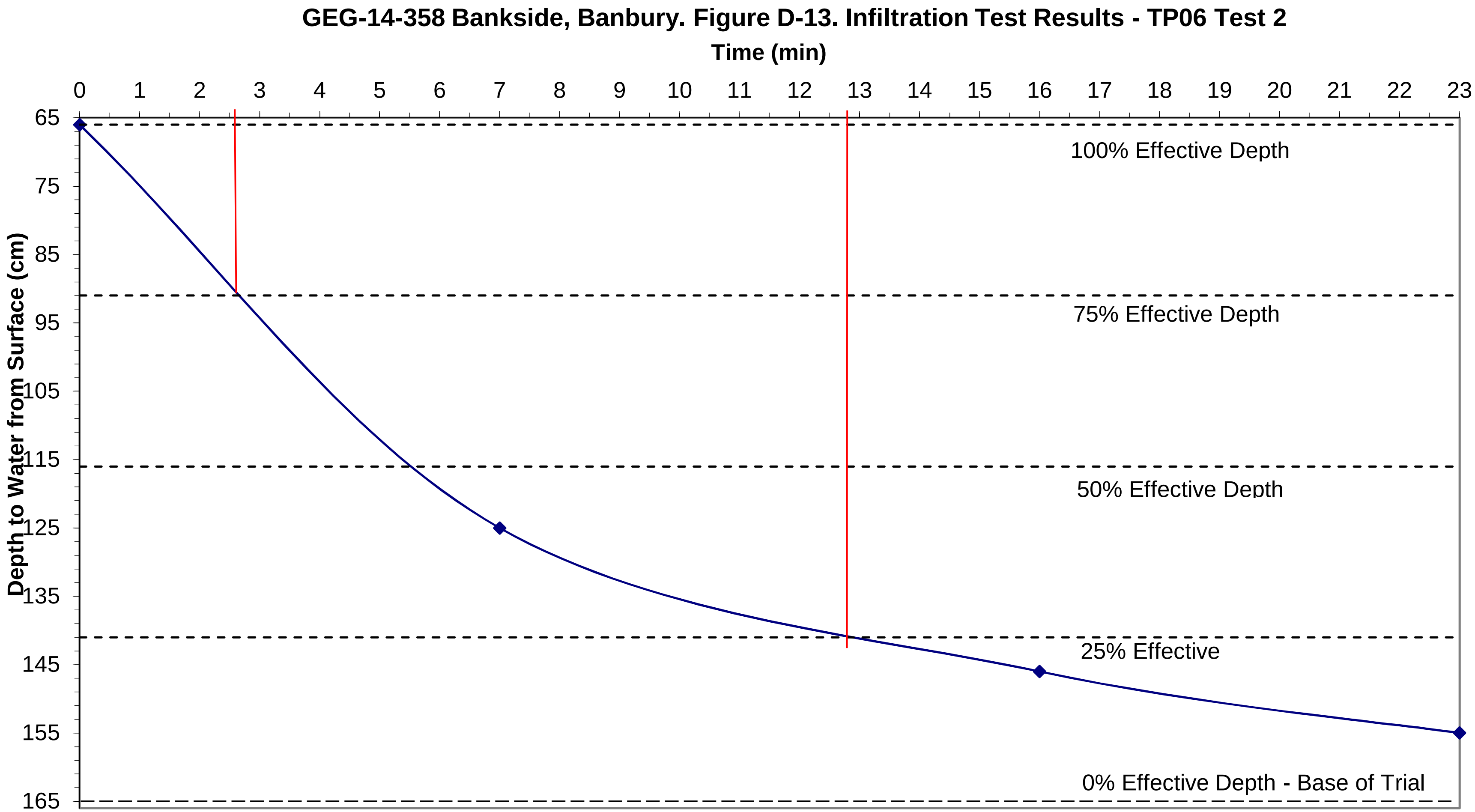
GEG-14-358 Bankside, Banbury. Figure D-10. Infiltration Test Results - TP05 Test 2



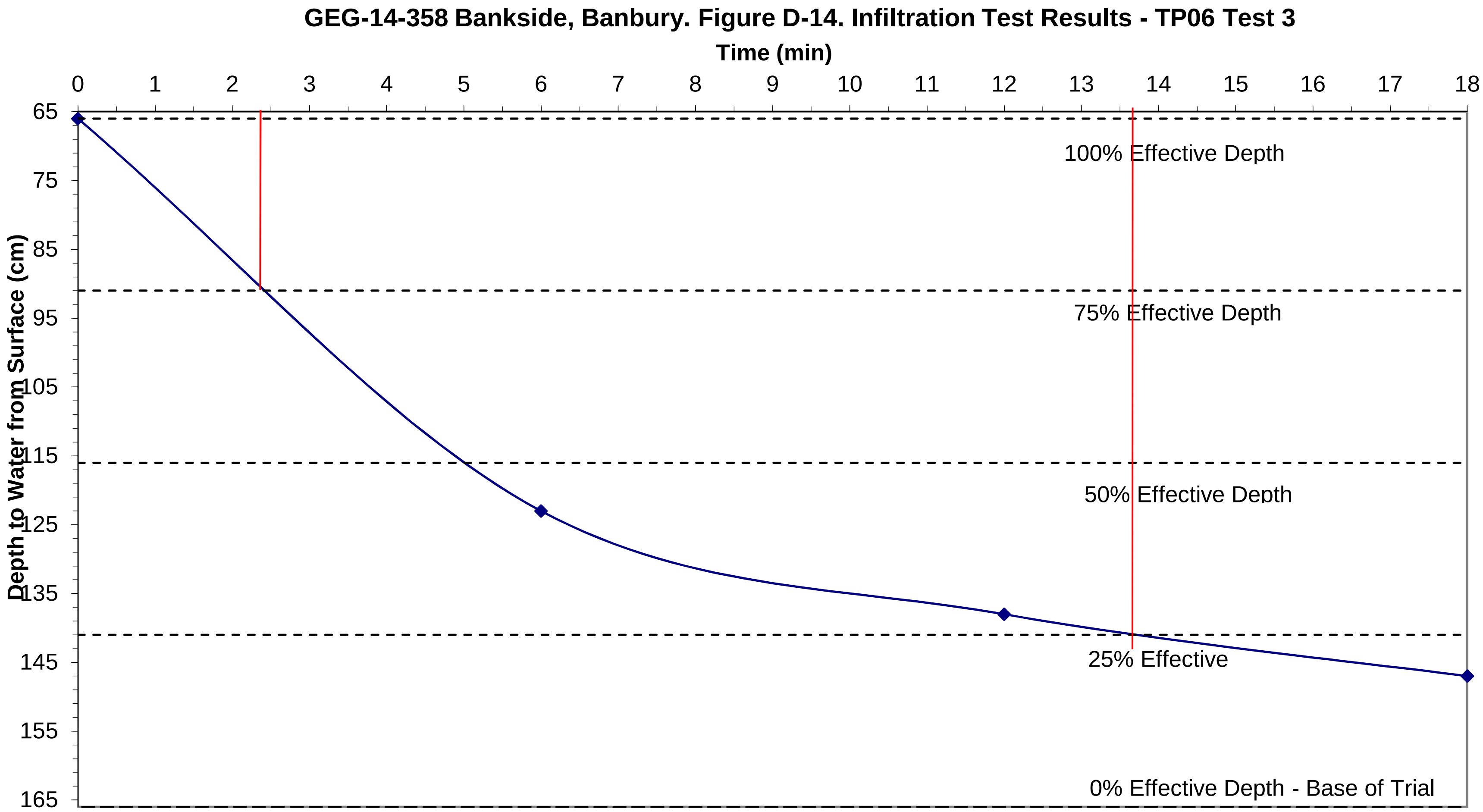

GEG-14-358 Bankside, Banbury. Figure D-11. Infiltration Test Results - TP05 Test 3
Time (min)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74
Depth to Water from Surface (cm)
100 110 120 130 140 150 160 170
100% Effective Depth
75% Effective Depth
50% Effective Depth
25% Effective
0% Effective Depth - Base of Trial

GEG-14-358 Bankside, Banbury. Figure D-12. Infiltration Test Results - TP06 Test 1

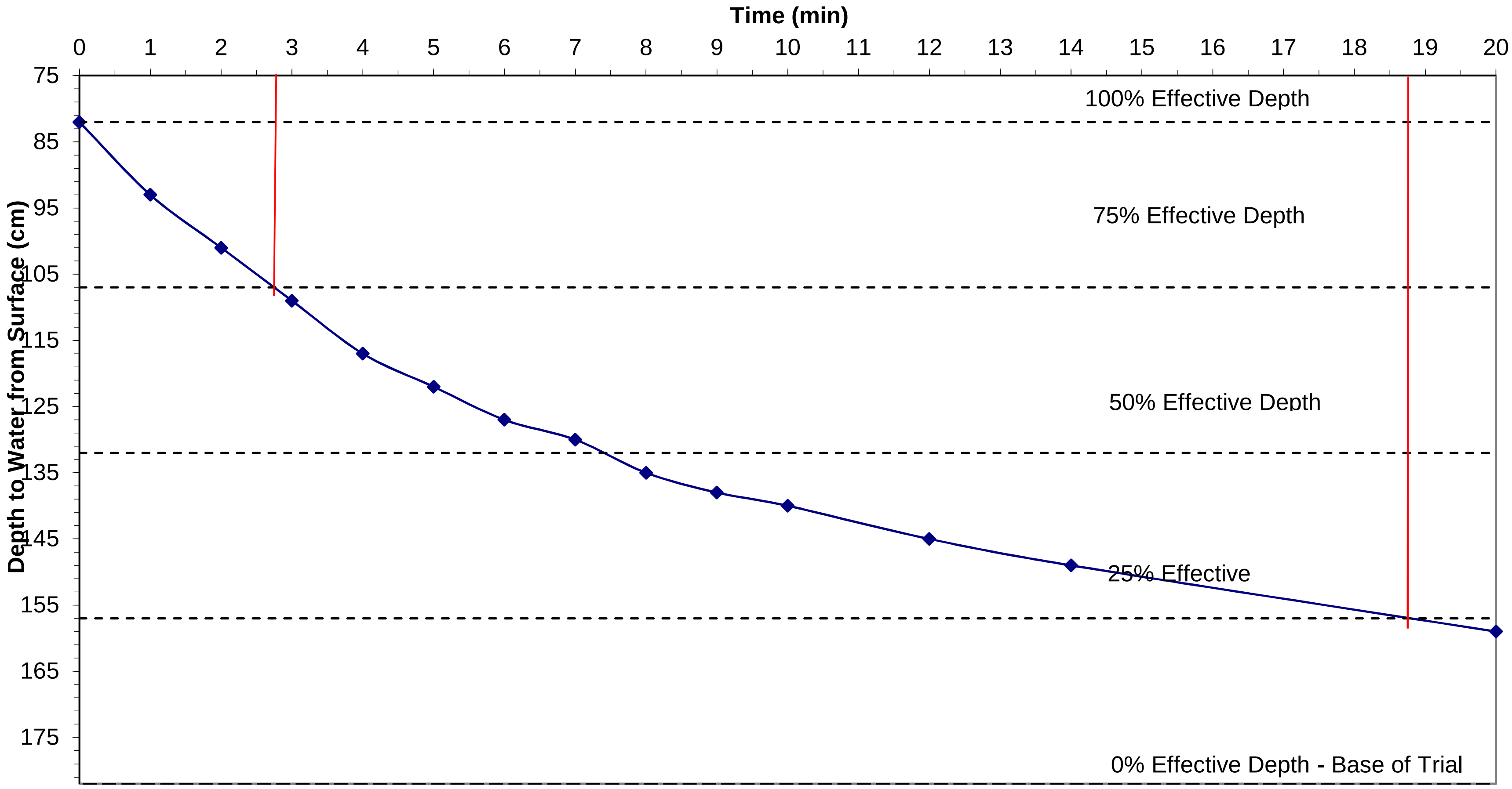


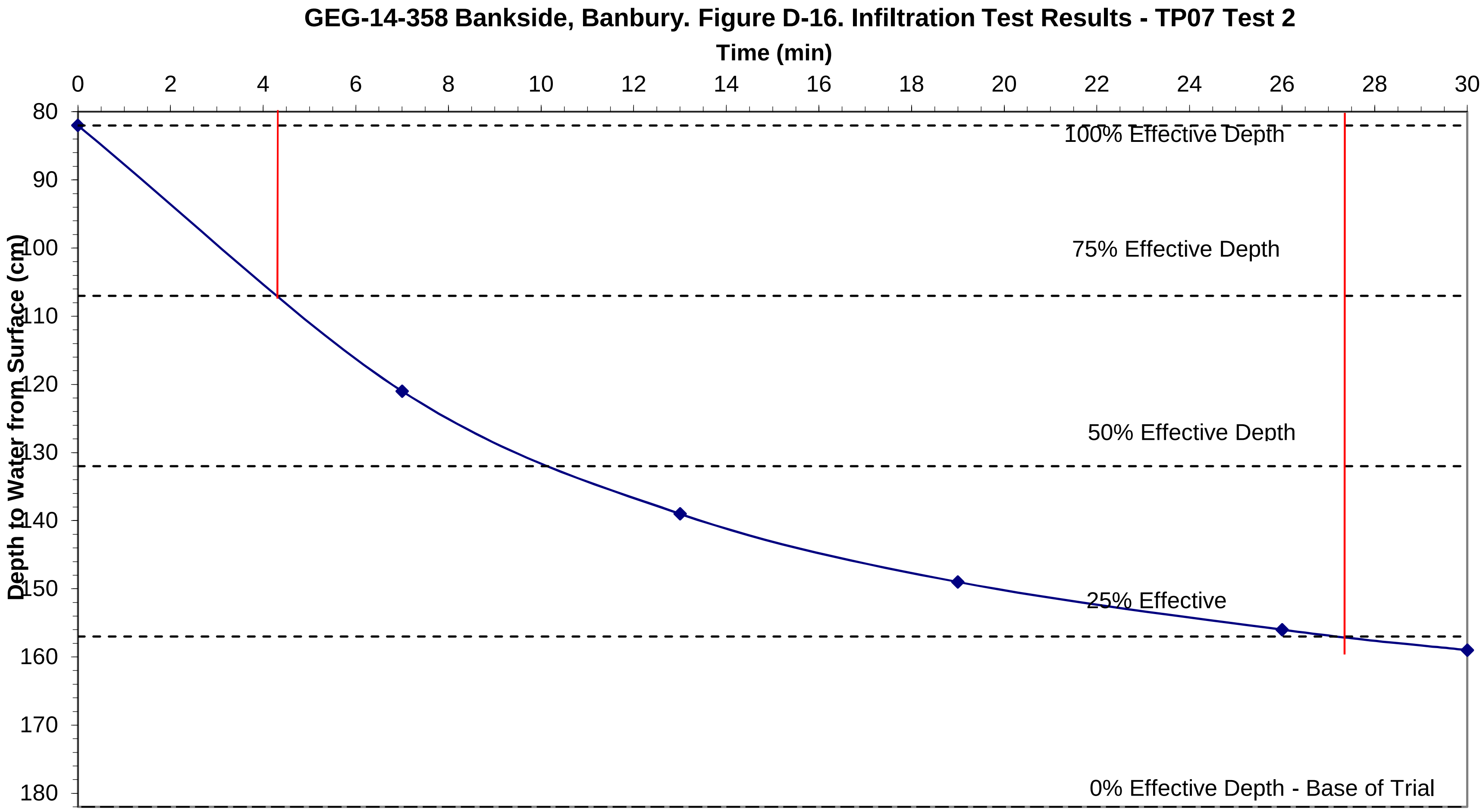


GEG-14-358 Bankside, Banbury. Figure D-13. Infiltration Test Results - TP06 Test 2
Time (min)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Depth to Water from Surface (cm)
65 75 85 95 105 115 125 135 145 155 165
100% Effective Depth
75% Effective Depth
50% Effective Depth
25% Effective
0% Effective Depth - Base of Trial

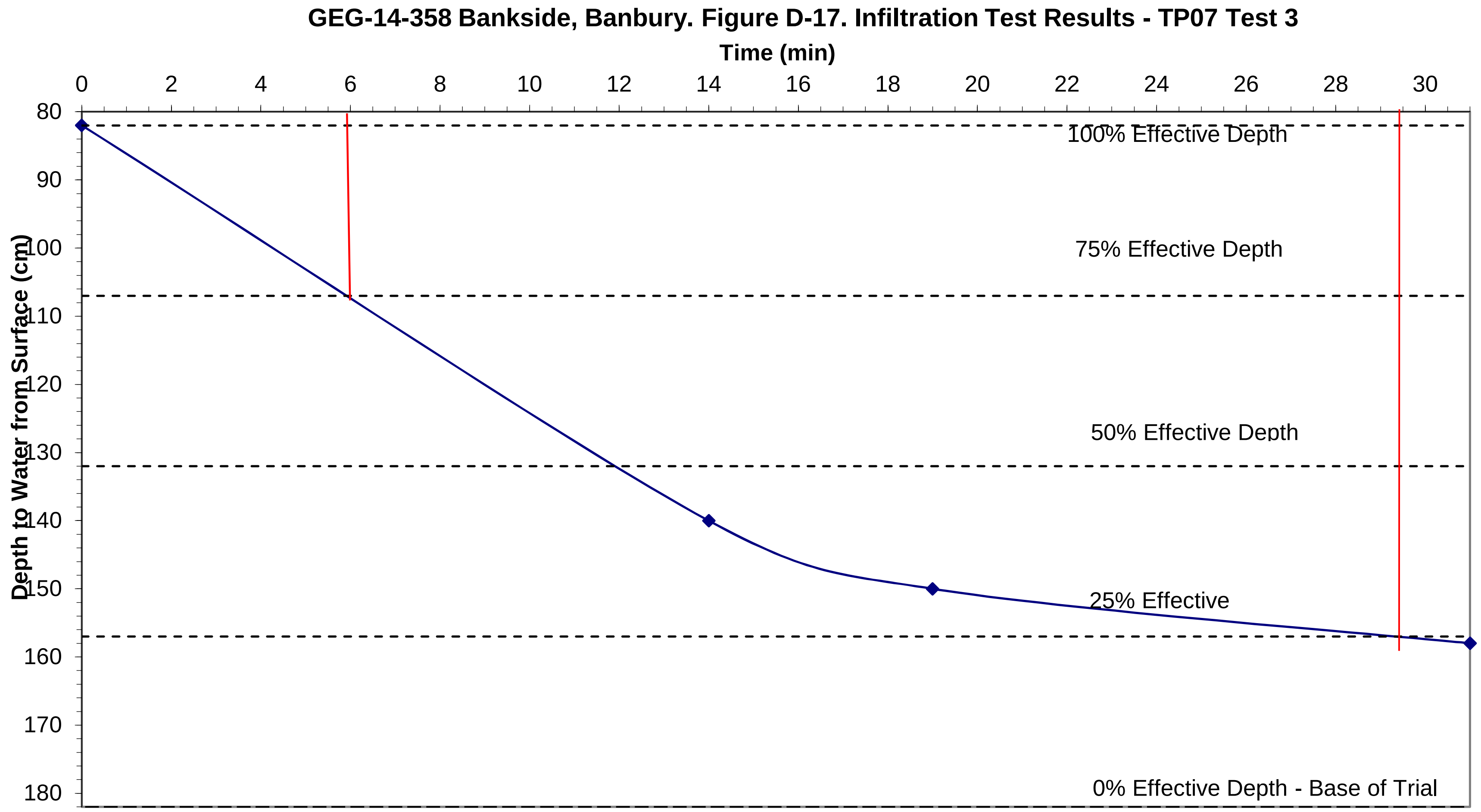

GEG-14-358 Bankside, Banbury. Figure D-14. Infiltration Test Results - TP06 Test 3
Time (min)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Depth to Water from Surface (cm)
65
75
85
95
105
115
125
135
145
155
165
100% Effective Depth
75% Effective Depth
50% Effective Depth
25% Effective
0% Effective Depth - Base of Trial

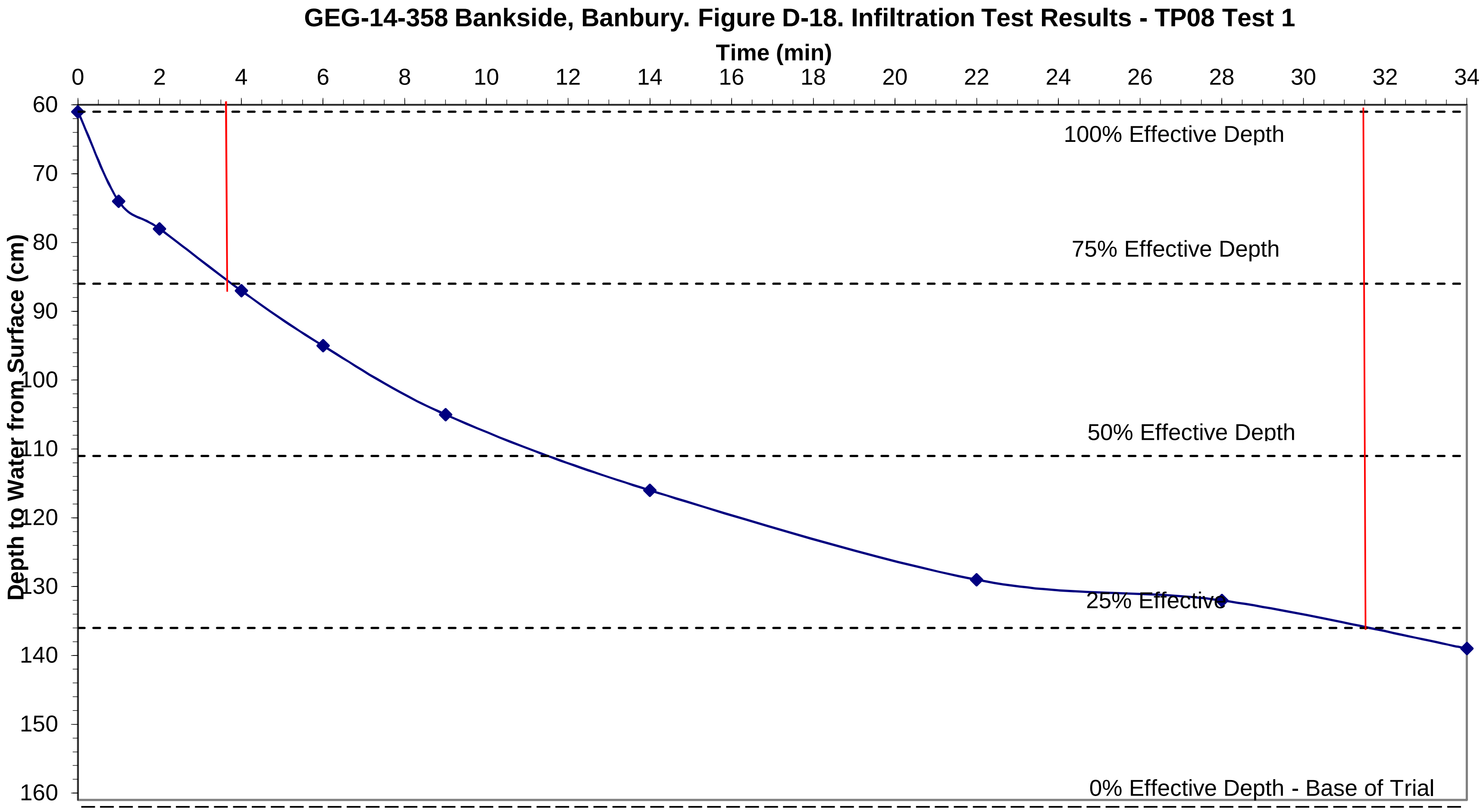
GEG-14-358 Bankside, Banbury. Figure D-15. Infiltration Test Results - TP07 Test 1



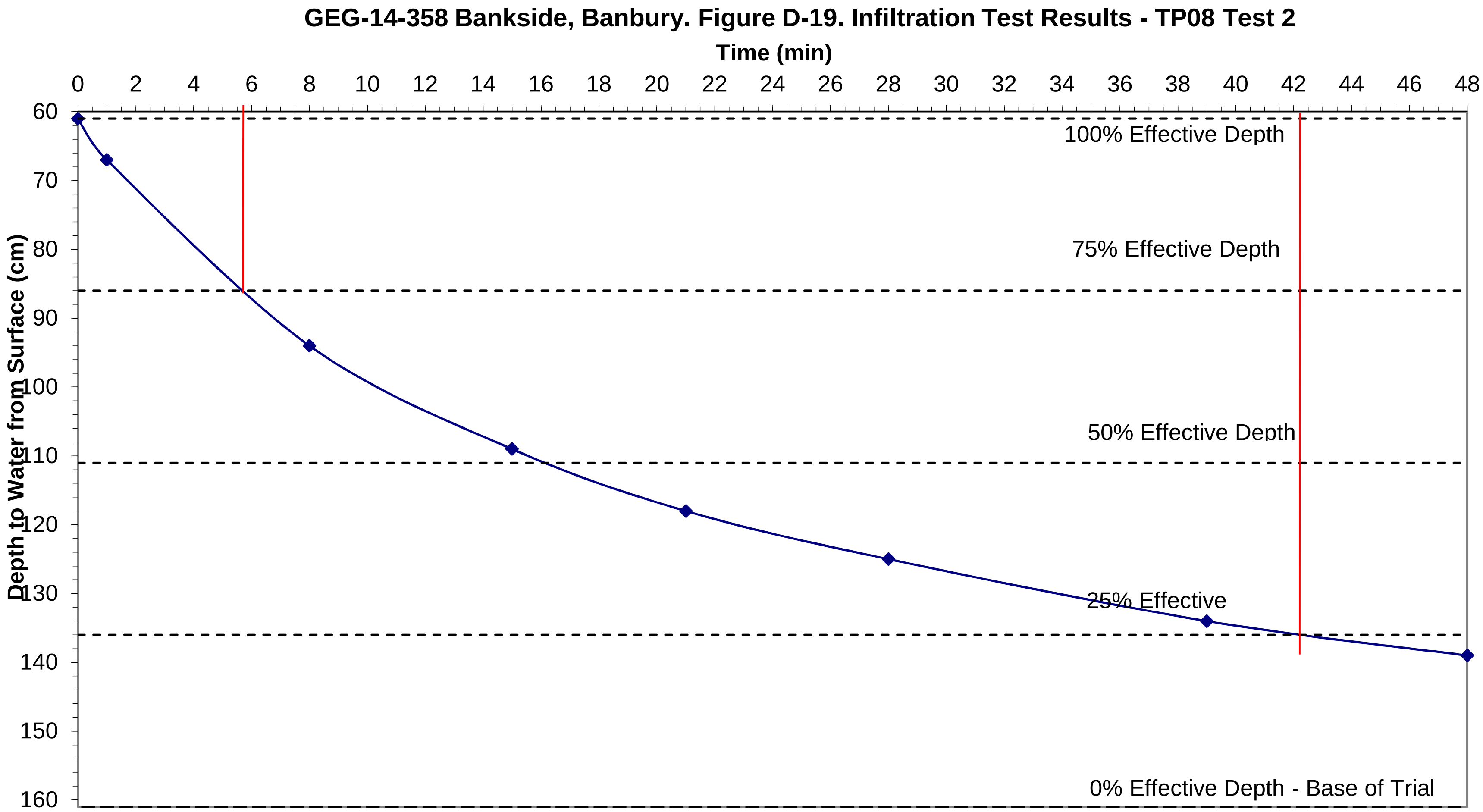


GEG-14-358 Bankside, Banbury. Figure D-16. Infiltration Test Results - TP07 Test 2
Time (min)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Depth to Water from Surface (cm)
80
90
100
110
120
130
140
150
160
170
180
100% Effective Depth
75% Effective Depth
50% Effective Depth
25% Effective
0% Effective Depth - Base of Trial

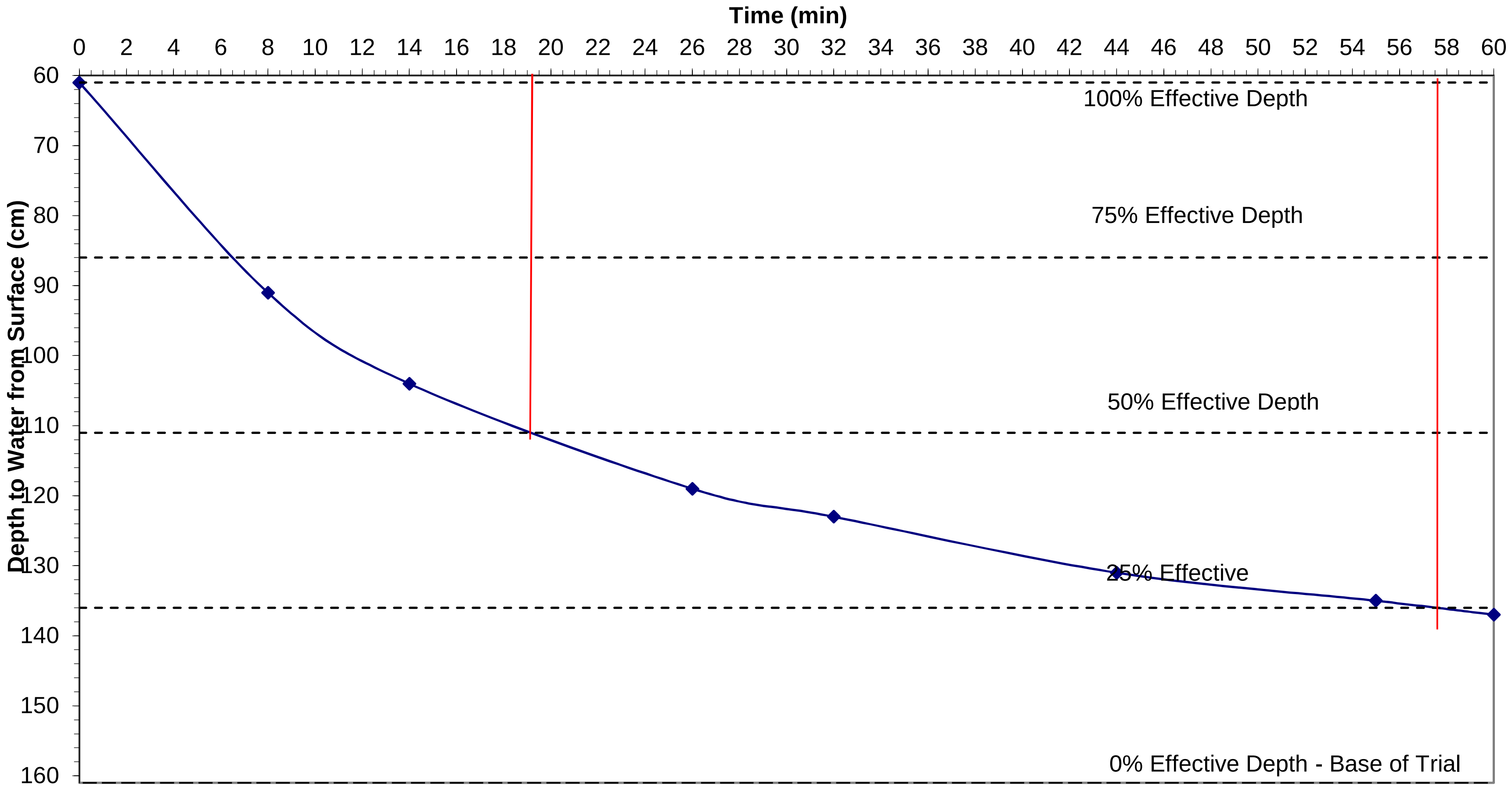

GEG-14-358 Bankside, Banbury. Figure D-17. Infiltration Test Results - TP07 Test 3
Time (min)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Depth to Water from Surface (cm)
80
90
100
110
120
130
140
150
160
170
180
100% Effective Depth
75% Effective Depth
50% Effective Depth
25% Effective
0% Effective Depth - Base of Trial



GEG-14-358 Bankside, Banbury. Figure D-18. Infiltration Test Results - TP08 Test 1
Time (min)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
Depth to Water from Surface (cm)
60
70
80
90
100
110
120
130
140
150
160
100% Effective Depth
75% Effective Depth
50% Effective Depth
25% Effective
0% Effective Depth - Base of Trial


GEG-14-358 Bankside, Banbury. Figure D-19. Infiltration Test Results - TP08 Test 2
Time (min)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Depth to Water from Surface (cm)
60
70
80
90
100
110
120
130
140
150
160
100% Effective Depth
75% Effective Depth
50% Effective Depth
25% Effective
0% Effective Depth - Base of Trial

GEG-14-358 Bankside, Banbury. Figure D-20. Infiltration Test Results - TP08 Test 3



Appendix D
Infiltration Rate Calculations
Bankside, Banbury

Parameter	Symbol	Calculation	Units	**TP01 Test 1**	**TP02 Test 1**	**TP02 Test 2**	**TP02 Test 3**	**TP03 Test 1**	**TP03 Test 2**	**TP03 Test 3**	**TP04 Test 1**	**TP05 Test 1**	**TP05 Test 2**
Effective Depth of Trial Pit	d_p		m	1.03	0.99	0.86	0.91	0.95	1.00	1.00	1.00	1.00	1.00
Width of Trial Pit	w		m	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Length of Trial Pit	l		m	1.90	1.60	1.60	1.60	1.90	1.90	1.90	2.00	1.50	1.50
Volume of Trial Pit	V	$= d_p \times w \times l$	m^3	1.17	0.95	0.83	0.87	1.08	1.14	1.14	1.20	0.90	0.90
Volume of Trial Pit at 50% Effective Depth	$V_{50\%}$	$= V \times 0.5$	m^3	0.59	0.48	0.41	0.44	0.54	0.57	0.57	0.60	0.45	0.45
Internal Surface Area of Trial Pit to 50% Effective Depth (including base)	$a_{p50\%}$	$= l \times w + d_p \times (w + l)$	m^2	3.72	3.138	2.85	2.962	3.52	3.64	3.64	3.8	3.00	3.00
Time to reach 75% Effective Depth	$T_{p75\%}$		min	NA	3.5	7.5	9	1.75	1.5	2.5	88	3.5	12.2
Time to reach 25% Effective Depth	$T_{p25\%}$		min	NA	21	43	50	14.75	21	24.75	NA	26	58.2
Time 75% - 25%	$T_{p75\%-25\%}$	$= T_{p25\%} - T_{p75\%}$	min	NA	17.5	35.5	41	13	19.5	22.25	NA	22.5	46
Infiltration Rate	f	$= V_{50\%} / a_{p50\%} \times (T_{p75\%-25\%})$	m/s	**NA**	**1.44E-04**	**6.80E-05**	**5.99E-05**	**1.98E-04**	**1.34E-04**	**1.17E-04**	**NA**	**1.11E-04**	**5.43E-05**

Parameter	Symbol	Calculation	Units	**TP05 Test 3**	**TP06 Test 1**	**TP06 Test 2**	**TP06 Test 3**	**TP07 Test 1**	**TP07 Test 2**	**TP07 Test 3**	**TP08 Test 1**	**TP08 Test 2**	**TP08 Test 3**
Effective Depth of Trial Pit	d_p		m	0.68	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Width of Trial Pit	w		m	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Length of Trial Pit	l		m	1.50	1.60	1.60	1.60	1.60	1.60	1.60	1.40	1.40	1.40
Volume of Trial Pit	V	$= d_p \times w \times l$	m^3	0.61	0.96	0.96	0.96	0.96	0.96	0.96	0.84	0.84	0.84
Volume of Trial Pit at 50% Effective Depth	$V_{50\%}$	$= V \times 0.5$	m^3	0.31	0.48	0.48	0.48	0.48	0.48	0.48	0.42	0.42	0.42
Internal Surface Area of Trial Pit to 50% Effective Depth (including base)	$a_{p50\%}$	$= l \times w + d_p \times (w + l)$	m^2	2.33	3.16	3.16	3.16	3.16	3.16	3.16	2.84	2.84	2.84
Time to reach 75% Effective Depth	$T_{p75\%}$		min	17.2	1.7	2.6	2.4	2.75	4.75	6	3.6	5.75	19.1
Time to reach 25% Effective Depth	$T_{p25\%}$		min	75	10	12.8	13.7	18.75	27.4	29.5	31.5	42.1	57.5
Time 75% - 25%	$T_{p75\%-25\%}$	$= T_{p25\%} - T_{p75\%}$	min	57.8	8.3	10.2	11.3	16	22.65	23.5	27.9	36.35	38.4
Infiltration Rate	f	$= V_{50\%} / a_{p50\%} \times (T_{p75\%-25\%})$	m/s	**3.79E-05**	**3.05E-04**	**2.48E-04**	**2.24E-04**	**1.58E-04**	**1.12E-04**	**1.08E-04**	**8.83E-05**	**6.78E-05**	**6.42E-05**