

National Trust

Castlefield Viaduct Phase 2

Flood Risk Assessment

Reference: CVI-ARUP-ZZ-ZZ-RP-C-000001

| 09 August 2024

Flood Risk Assessment and Drainage Strategy



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Job number 282210-42

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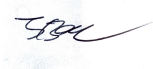
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Abbreviations List

Abbreviation	Meaning
AOD	Above Ordnance Datum
BGS	British Geological Survey
EA	Environment Agency
FRA	Flood Risk Assessment
NPPF	National Policy Planning Framework
CIRIA	Construction Industry Research and Information Association
PPS25	Planning Policy Statement 25

1. Introduction

This Flood Risk Assessment (FRA) has been prepared by Ove Arup and Partners Ltd. (Arup) on behalf of The National Trust. It has been prepared for the proposed redevelopment known as Castlefield Viaduct. This FRA supports the Planning Application for the Proposed Development of Phase 2, the permanent urban park and travel hub scheme. This will include a proposed elevated walkway and access steps connecting the viaduct with the canal towpath below.

The proposed development to Castlefield Viaduct will include the park extension to the other side of the A57, Mancunian Way. The existing structure will allow access for visitors walking through to the new section of the park. The plan involves transforming the current viaduct into an urban park, providing local access to green spaces, a new community amenity area, and an elevated walkway. All of this aligns with Manchester's broader strategic goals while preserving the heritage of the Grade II Listed structure and its surroundings.

This document includes a review of detailed flood risk data available for the site, which has been obtained from the Environment Agency. Consideration is also given to the National Planning Policy Framework (2019) (NPPF1)[1], Manchester City Council's Strategic Flood Risk Assessment (2011) (SFRA)[2], and the Environment Agency's Climate Change Allowance (2022) (CCA)[3] guidance. The Climate Change Allowance guidance sets out the Environment Agency's recommended climate change allowances for development, when considering flood risk and coastal change for planning purposes.

A previous FRA was conducted by Royal HaskoningDHV in March 2021 during the design phase of Phase 1. Phase 1, shown in Figure 1. The pilot 'micro park' scheme which covers half the viaduct was launched in July 2022.



Figure 1 - Phase 1 Urban Park (Source: Dezeen, 2022)

¹ Ministry of Housing, Communities & Local Government. "National Planning Policy Framework." Last updated 20 December 2023. <https://www.gov.uk/government/publications/national-planning-policy-framework-2> (accessed 30 July 2024).

² Manchester City Council. "Strategic Flood Risk Assessment." Last updated 1 March 2011. https://www.manchester.gov.uk/downloads/download/3871/strategic_flood_risk_assessment_sfra (accessed 29 July 2024).

³ Environment Agency. "Flood Risk Assessments: Climate Change Allowances." Last updated 27 May 2022. <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances> (accessed 26 July 2024).

2. Existing Conditions

2.1 Site Description

The Site is in the North-West of England, within the Manchester City Council's authority area within Greater Manchester. The Site is a 330-metre-long, Grade II listed structure situated within the Castlefield Conservation Area shown in Figure 3. It is approximately 1km from Junction 3 of the M602 Motorway, which provides access to and from east and west bound carriageways.

The site covers approximately 0.2 hectares and is centred on National Grid Reference SJ82746 97482. It is currently a disused railway viaduct transformed into an urban park in Phase 1, featuring a variety of plants, seating areas and a visitors' centre. The Site is an elevated walkway elevated with an approximate height of 15m above ordnance datum (AOD) which will be accessed via proposed access steps near the canal tow path beneath the viaduct by Egerton Street.

The study area for this FRA has been defined as encompassing all surface water, groundwater and flood risk receptors located within the site boundary of the Proposed Development. The development site is located within Flood Zone 2 on the Environment Agency Flood Maps (Table 1). Flood Zone 2 indicates a medium probability of flooding.



Figure 2 - Phase 2 Site Location

2.2 Site Topography

To the west, the River Irwell is situated, while to the south are the Bridgewater Canal, the River Medlock, and the Rochdale Canal. Situated in an urban setting, the Castlefield Viaduct area is elevated and predominantly flat. Historically, Castlefield formed part of the Manchester basin, fed by the River Medlock.

2.3 Existing Surface Water Features

The following local water features are in close proximity the proposed development site area and can also be depicted in Figure 3

- River Irwell: The River Irwell flows to the west of the viaduct, approximately 230 metres away⁴. It is a tributary of the River Mersey and is not tidally influenced in its upper reaches. The river rises at Irwell Springs on Deerplay Moor and flows southwards for 63 kilometres (39 miles) to meet the

⁴ "Distance between Full UK Postcodes." 2024. Wwww.freemaptools.com. <https://www.freemaptools.com/distance-between-uk-postcodes.htm>.

Mersey near Irlam. The Irwell marks the boundary between Manchester and Salford, and its lower reaches have been canalised to form part of the Manchester Ship Canal. The river joins the River Mersey and plays a crucial role in the region's drainage and flood management systems.

- River Medlock: This river flows to the east of the viaduct, about 300 metres away. It is not tidally influenced and discharges into the River Irwell in Manchester city centre. The River Medlock plays a significant role in the local drainage system and flood management.
- Bridgewater canal: Located directly south of the viaduct, the Bridgewater Canal is approximately 100 metres away. The River Medlock merges with the Bridgewater Canal at a point approximately 250 metres west of the site. It is not tidally influenced and primarily serves as a navigable waterway for boats. The canal connects to the Manchester Ship Canal via a lock at Cornbrook and also links with the Rochdale Canal, the Trent and Mersey Canal, and the Leeds and Liverpool Canal.

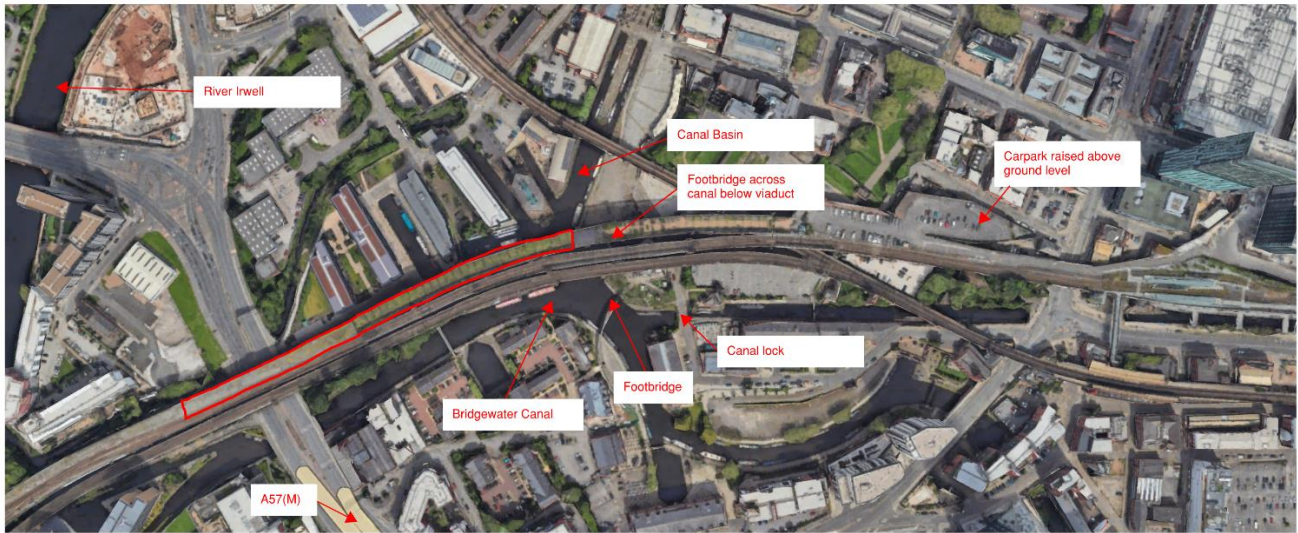


Figure 3 - Phase 2 Site Location and Surrounding Features

3. Flood Risk Policy

3.1 National Planning Policy Framework (NPPF)

The National Planning Policy Framework (NPPF) revised in December 2023 sets out the government's planning policies for England and how these are expected to be applied.

It states that inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk. Where development is necessary, it must be made safe without increasing flood risk elsewhere.

The NPPF states that Local Plans should be supported by Strategic Flood Risk Assessments (SFRA) and policies developed in order to manage flood risk from all sources.

The NPPF requires that the 'Sequential Test', and if necessary, the Exception Test is applied during the planning process. The Sequential Test aims to ensure that preference for developable land is given to land that has the lowest risk of flooding, based on the data available. The starting point for the Sequential Test is the system of 'Flood Zoning'. This system assesses the risk posed by rivers and, in coastal areas, estuaries and the sea. This information is collected and made available by the EA and the LPA.

The Flood Zoning system adopted in England is described in Table 1 found within the online guidance.

Table 1: Fluvial Flood Risk Zoning System

Flood Zone	Definition
Zone 1 Low Probability	Land having a less than 1 in 1,000 (0.1%) annual probability of river or sea flooding. (Shown as 'clear' on the Flood Map – all land outside Zones 2 and 3).
Zone 2 Medium Probability	Land having between a 1 in 100 (1%) and 1 in 1,000 (0.1%) annual probability of river flooding; or land having between a 1 in 200 and 1 in 1,000 annual probability of sea flooding. (Land shown in light blue on the Flood Map).
Zone 3a High Probability	Land having a 1 in 100 (1%) or greater annual probability of river flooding; or Land having a 1 in 200 or greater annual probability of sea flooding. (Land shown in dark blue on the Flood Map).
Zone 3b Functional Floodplain	This zone comprises land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. (Not separately distinguished from Zone 3a on the Flood Map).

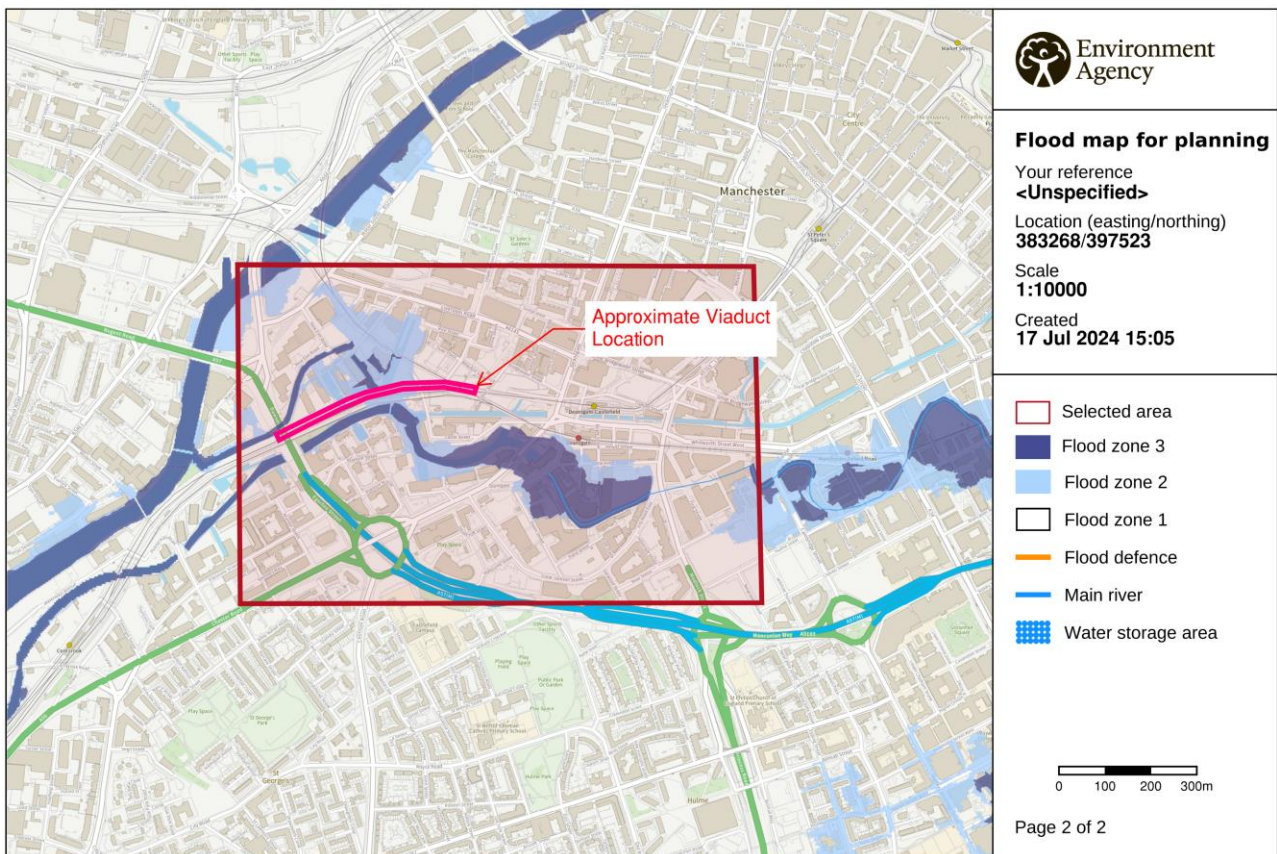


Figure 4 – Flood Map for Pluvial Flooding (Source: Environment Agency)

As per the Environment Agency’s Pluvial Flood Risk Map for Planning in Figure 4, the location of the site falls predominantly within Flood Zone 1 and partially in Flood Zone 2. However, the flood zone classification is based on data representing ground levels beneath the existing viaduct and the walkway is elevated 15m above ground. As such, the viaduct is not directly located within the flood extent, and flood risk is considered for the proposed access steps by Egerton Street, which falls in Flood Zone 2.

The NPPF also encourages consideration to the flood vulnerability of the proposed development to the impact of flooding. The compatibility of development in terms of its vulnerability and Flood Zoning is described in Table 2, which is based on Table 2 within the Flood Risk and Coastal Change Planning Practice Guidance (PPG)[5]. This is relevant for considering what type of development is appropriate for a site (based on its Flood Zone) and how a development site should be laid out if there are different Flood Zones encountered within a site.

⁵ Ministry of Housing, Communities & Local Government. “Flood Risk and Coastal Change.” Last updated 25 August 2022. <https://www.gov.uk/guidance/flood-risk-and-coastal-change#table2>. (Accessed 1 August 2024)

Table 2: Flood Risk Vulnerability and Compatibility

Flood Zone	Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood 1	✓	✓	✓	✓	✓
Flood Zone 2	✓	✓	Exception Test	✓	✓
Flood Zone 3a	Exception Test	✓	✗	Exception Test	✓
Flood Zone 3b “Functional Floodplain”	Exception Test	✓	✗	✗	✗

Key:

✓ Development is appropriate

✗ Development should not be permitted, “Exception Test” will be required.

3.1.1 Vulnerability classification

For Phase 2 of the development, it is intended to introduce some uses that will likely that would be classified as ‘Less Vulnerable’ development under the NPPF and the Flood Risk and Coastal Change PPG. The proposed Egerton Street access steps on the Westernmost side of the viaduct are classified as ‘Amenity Open Space’ and are therefore ‘Water Compatible Development’.

As noted above, the walkway is elevated 15m above the watercourses and is considered at low risk of fluvial flooding and thus passes the sequential test.

The proposed access steps are in Flood Zone 2 and to be considered under the Sequential test, and if required the Exception test.

3.1.2 Sequential test

Under the NPPF, the Sequential test is a requirement for all new planning applications. The Sequential Test requires that development should only be considered within Flood Zone 2 if there are no appropriate development sites in Flood Zone 1. Development in Flood Zone 3 should only be considered if development is not possible in Flood Zone 2, assuming development in Flood Zone 1 has also been ruled out.

The sequential test follows a flow diagram to establish the next steps, shown below;

As the site is existing, and the access steps cannot be allocated in a different flood zone, so the sequential test progresses to the exception test.

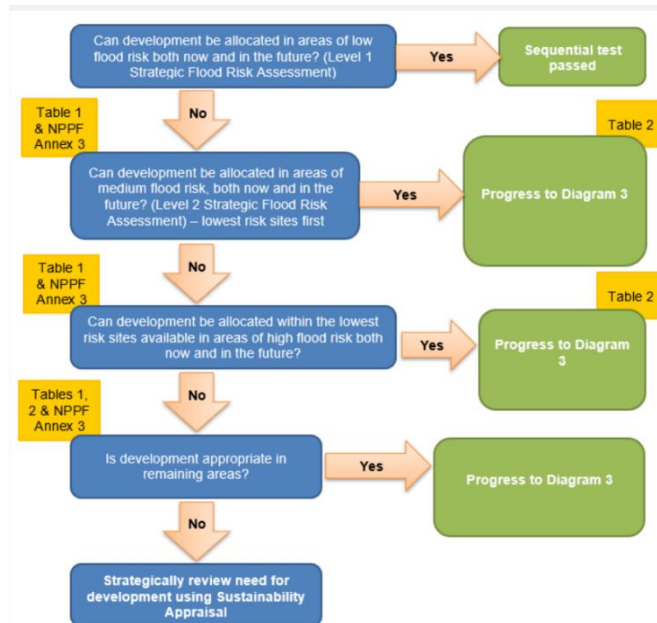


Figure 5 - Sequential Test Flow Chart (Source - <https://www.gov.uk/guidance/national-planning-policy-framework/14-meeting-the-challenge-of-climate-change-flooding-and-coastal-change>)

3.1.3 Exception Test

The location of the proposed access steps falls within Flood Zone 2, where an exception test is mandated solely for developments deemed ‘highly vulnerable’ as per the specifications of Table 2. In alignment with Annex 3 of the NPPF, the proposed access steps is presently designated for ‘Water Compatible’ open space amenity⁶, thereby exempting it from the requirement of an exception test.

3.2 Local Flood Risk Policy

Manchester City Council issued a Strategic Flood Risk Assessment (SFRA) in 2018 ⁷, outlining their plan for developments in the Greater Manchester area to manage flood risk and to aid sustainable building. There are 5 key policies for developers in this document:

Avoiding Development in Flood-Prone Areas:

- Developers should avoid building in locations with existing flood risk. This policy emphasises the need to protect vulnerable areas and prevent further exposure to flooding.

Evidence-Based Decision-Making:

- Developers must base their decisions on robust flood risk evidence. This requires understanding historical flood patterns, assessment of future risk, and considering cumulative flooding sources and cross-boundary impacts.

Collaborative Working:

- The framework encourages collaboration among stakeholders, including local authorities, developers, and environmental agencies. By working together, we can create more resilient communities and minimise flood risk.

Natural Flood Management (NFM):

⁶ <https://www.gov.uk/guidance/national-planning-policy-framework/annex-3-flood-risk-vulnerability-classification>

⁷ “Greater Manchester Strategic Flood Risk Management Framework Final Report.” 2018. <https://www.greatermanchester-ca.gov.uk/media/1726/gmca-final-strategic-sfra-framework-january-2019.pdf>.

- Developers should explore NFM approaches, such as sustainable drainage systems (SuDS) and green infrastructure. These nature-based solutions can help manage surface water and reduce flood risk.

Integration with Local Plans:

- Developers should align their proposals with local development plans. The GMSF complements existing policies and activities implemented by Greater Manchester local authorities.

The policies in the SFRA reinforce that the NPPF guidance should be followed to ensure that flood risk zones and vulnerabilities are identified, and lower risk options can be considered. The SFRA complements Planning Policy Statement 25 (PPS25) Development and Flood Risk Practice Guide [8] which emphasises on an approach to assess flood risk by a new development through the hierarchy of ‘*assess-avoid-substitute-control-mitigate*’. As well as this, the importance of SuDS and natural flood management are emphasised to improve the sustainability of the region’s developments.

4. Flood Risk Appraisal

4.1 Flood Risk from Surface Water (Pluvial Risk)

The Environment Agency defines surface water flooding scenarios as follows:

- High risk: Land with a greater than 3.3% annual probability of flooding from surface water (indicative of the 1 in 30-year return period).
- Medium risk: Land with a 3.3% to 1% annual probability of flooding from surface water (indicative of the 1 in 100-year return period).
- Low risk: Land with a 1% to 0.1% annual probability of flooding from surface water (indicative of the 1 in 1,000-year return period).
- Very Low risk: Land with less than a 0.1% annual probability of flooding from surface water. The viaduct stands approximately 15 meters above the watercourse below, rendering it less vulnerable to surface water flooding from overland flow beneath its structure.

The Environment Agency’s Flood Risk from Pluvial sources map (Figure 4) indicates that most of the site falls within a ‘**Very Low**’ risk category for flooding from surface water and as noted in Section 3.1, the viaduct is 15m above the ground level. However, the proposed access steps by Egerton Street are oversailing a Flood Zone 2 area, and thus are categorised as ‘**Medium Risk**’.

4.2 Flood Risk from Rivers and Sea (Fluvial Risk)

Flooding from rivers, streams, and other natural inland watercourses typically occurs due to prolonged or intense rainfall. This heavy rain generates high rates of surface water runoff either locally to the site or higher in the catchment, and is subsequently conveyed towards the site through the fluvial system. Therefore, the capacity of the system is exceeded, resulting in overflow into any adjacent floodplain storage and low-lying areas.

The majority of the Castlefield viaduct site is located within a ‘**Very Low Risk**’ flood zone and indicates a low probability of flooding overall according to EA, shown in figure 6. However, as noted in Section 3.1, the flood zone classification is based on data representing ground levels and the walkway is elevated 15m above

⁸ “Planning Policy Statement 25: Development and Flood Risk Practice Guide.” 2009.
<https://assets.publishing.service.gov.uk/media/5a7955d4ed915d042206789f/pps25guideupdate.pdf>.

ground. As such, the viaduct is not directly located within the flood extent. This is with the exception of the Egerton Street Staircase access to the site at ground level, which is shown to be at **‘Medium Risk’** of flooding from fluvial sources at the foot of the walkway in a 1 in 100 year and 1 in 30-year return period river flooding event.

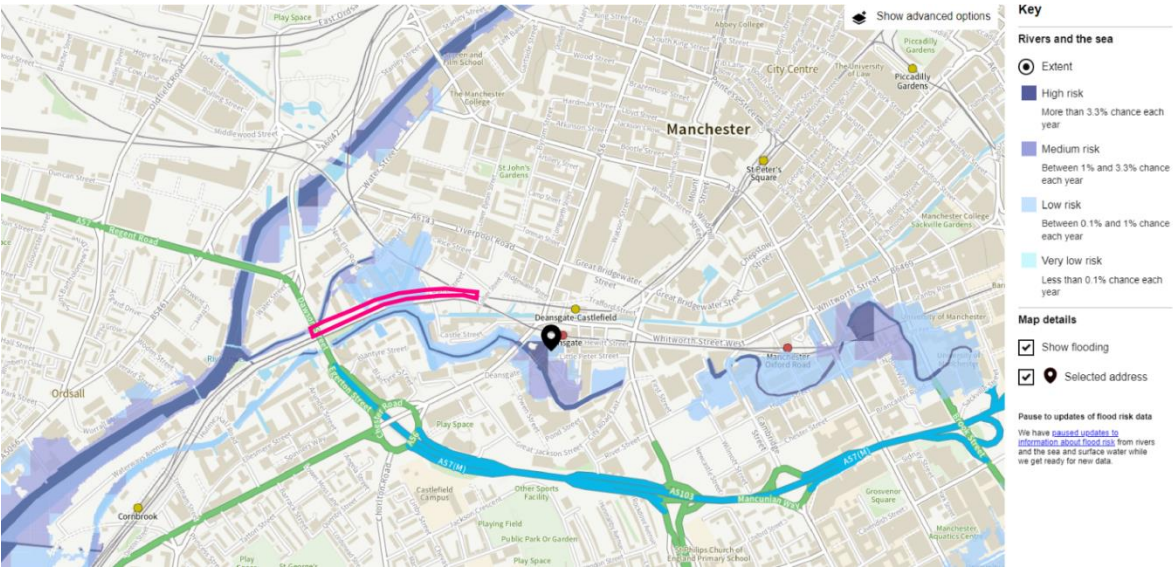


Figure 6 - Flood Risk from Rivers and Sea (Source Environment Agency)

4.3 Existing Flood Risk from Groundwater

According to the British Geological Survey (BGS), the underlying bedrock at the site is the Chester Formation (Figure 7), primarily composed of sandstone. The BGS classifies this as a ‘Principal’ bedrock aquifer—a rock layer with high intergranular permeability, capable of significant water storage. Such aquifers can support water supply and river baseflow on a strategic scale.

The BGS Geology of Britain Viewer does not identify any superficial deposits beneath the site. Additionally, the site is not situated within an Environment Agency Groundwater Source Protection Zone. From the Manchester City Council SFRA Flooding from Groundwater map (Figure 8), the east section of the viaduct falls in an area at risk of Groundwater Flooding.

However, as the viaduct slated for redevelopment stands approximately 15 meters above ground level, the risk of groundwater flooding is considered ‘**Low**’.



Figure 7 - BGS Combination of Bedrock and Geology



Figure 8 - Groundwater Flood Risk (Source: Manchester City Council [9])

4.4 Flood Risk from Reservoirs

The Environment Agency's Risk from Reservoir Flooding Map indicates that the site lies beyond the flood extent in the event of reservoir flooding as shown in Figure 9. To the north of the viaduct, there is a risk of flood depths ranging from 0.3 meters to 2 meters during a reservoir failure event. However, given that the viaduct (along with the existing access via Deansgate-Castlefield car park) stands approximately 15 meters above the surrounding ground level, the risk of flooding following reservoir failure is considered **very low**.

As with river flooding, the Egerton Street access steps have some presence at ground level, and as a result they must be considered separately. In this case, the stairs fall in an area only vulnerable to reservoir flooding when there is also river flooding, as a result they can be considered being at **low** risk.

⁹ "Strategic Flood Risk Assessment (SFRA) Maps Groundwater Flooding," n.d.
https://www.manchester.gov.uk/download/downloads/id/26466/map_-_mst_groundwater_flooding_gw_21.pdf. [Accessed 30/7/2024]

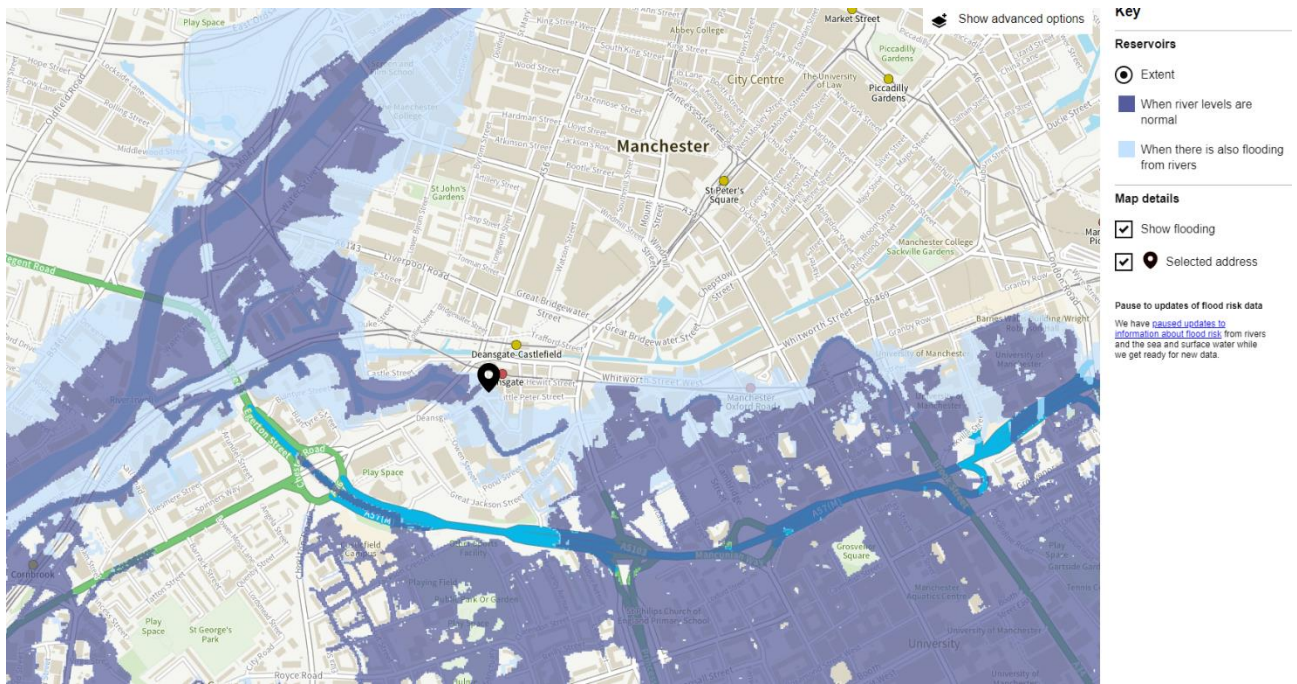


Figure 9 - Flood Risk from Reservoir Failure Map

4.5 Existing Drainage

The area of the development is currently drained via the existing network, consisting of a series of surface gullies collecting surface water and conveying it to a below-deck gutter system, which ultimately outfalls via downpipes to either the Bridgewater canal or directly onto the ground. An example is shown in Figure 10 below, a gutter connects to the downpipe on the column and runs to an outfall to the canal.



Figure 10 – Castlefield Viaduct Existing Drainage

4.6 Flood Risk Summary

The majority of the proposed development is considered to be at low risk of flooding from fluvial, pluvial and groundwater sources. In accordance with NPPF Chapter 14: Summary of policy requirements, a Low Vulnerability Development in Flood Zone 2 is 'acceptable with no constraints' and the sequential test and exception test is not applicable.

With the exception of the access steps by Egerton Street which are classified by the Environment Agency as medium risk from surface water, river and sea flooding. However, the NPPF guidance advises that stair accesses of this kind are 'Water Compatible' and thus, as above, are 'acceptable with no constraints' and the sequential test and exception test are not applicable.

5. Proposed Drainage Strategy

5.1 Surface Water Management

5.1.1 Surface Water Runoff

A drainage strategy is proposed to manage surface water and mitigate the risk of flooding on the viaduct. It is also proposed that surface water is used as irrigation for vegetation within the proposed 'WaterAid' garden section of the viaduct.

For the purposes of this drainage strategy, only 'The Garden' area will be considered, as these are proposed to be permanent with a design life of 50 years. The 'Broadwalk Area' is considered temporary and will not be included in the drainage strategy, this delineation is shown in Figure 11 below.

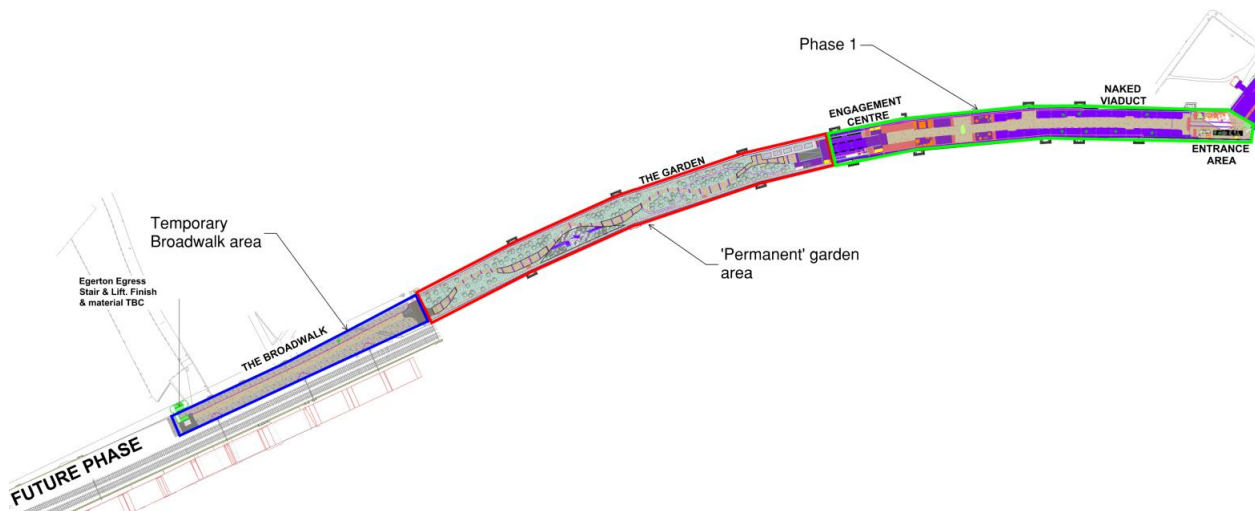


Figure 11 - Existing and Proposed Viaduct areas

Section C of the Construction and Design Guidance for the Sewerage Sector [10] requires that new developments have the capacity within the on-site drainage network to store the runoff from a 1 in 30-year rainfall event, accounting for the effects of climate change over the design life. The guidance also requires that the runoff from a 1 in 100-year rainfall event is able to be stored on the site and will not pass on flooding to an adjacent area.

It is assumed that this site is to be considered as 'permanent', thus the effects of climate change need to be considered. The Environment Agency have estimated that developments with design lives of 30 years must account for a 35% CC increase in rainfall in the Irwell Catchment. This results in the existing runoff rate increasing from 38.1 l/s to 51.4 l/s, see Appendix A for calculations.

The historical flooding data, in Appendix B, shows the viaduct does not have a record of flooding on the site, as a result, it is assumed that maintaining the existing rainwater runoff of the viaduct is acceptable, thus the drainage network must be able to store and attenuate the additional rainfall resulting from climate change.

¹⁰ "Design and Construction Guidance for Foul and Surface Water Sewers Offered for Adoption under the Code for Adoption Agreements for Water and Sewerage Companies Operating Wholly or Mainly in England ('the Code') Approved Version 2.1." 2021. <https://www.water.org.uk/wp-content/uploads/2021/07/SSG-App-C-Des-Con-Guide.pdf>.

The storage capacity needed to meet this requirement has been calculated as approximately 12m³ using the HR Wallingford Modified Rational Method [11], these calculations are shown in Appendix C.

5.1.2 Assumptions

- The development is to be considered permanent
- The existing brownfield runoff rate is acceptable to be maintained
- Decking structure has a loading capacity of 7.6kPa
- Critical Rainstorm is of 15-minute duration

5.2 Attenuation

As it assumed that the existing rainwater runoff is acceptable to be maintained, any additional discharge must be restricted and stored on site. Therefore, the discharge will be restricted to 38.1l/s, see Appendix C for calculations. Restriction will be achieved via flow control measures at the points of outfall.

Excess rainwater held back by flow restrictions will be stored within the viaduct drainage system. Storage is proposed to be provided by a series of permavoid tanks with gullies and channels to collect rainwater from the viaduct deck. These tanks will then flow into the existing outfalls on the viaduct.

The Greater Manchester SFRA sets out that SuDS are to be integrated into the drainage networks for new developments. Using Construction Industry Research and Information Association (CIRIA) SuDS Manual guidance C753, the SuDS hierarchy recommends that best practice is to store rainwater as close as possible to its source point, this being the viaduct surface. The proposed permavoid tanks meet this recommendation.

Figure 12 shows a plan of the proposed permavoid at different locations across the viaduct. Two configurations of the permavoid are proposed.

Permavoid proposed at A1, A2, A3 and A4 will attenuate rainwater to restrict the discharge. It is proposed that surface water will be conveyed to the permavoid using a series of channels and gullies on the pavement surface. This will consist of 150mm deep permavoid layers (see Figure 13) connected to an outlet draining into the existing outfalls. The locations of the permavoid have been chosen according to the structural strength of the viaducts and the existing outfall locations, so these can be effectively reused.

The permavoid layers in areas A1, A2, A3, A4 can store an approximate combined total of 31m³. This is sufficient to store the runoff in both the 1 in 30-year rainfall event and the 1 in 100-year rainfall event. The storage provided by B1 is not considered as it has no outlet and may not have capacity to store runoff at all times. This fulfils the requirement of the Sewer Sector Guidance.

¹¹ "The Modified Rational Method" volume 4 https://eprints.hrwallingford.com/37/2/Volume4_Modified_Rational_Method.pdf

Area B1 is the WaterAid Garden area, where it is proposed that the permavoid is used for rainwater harvesting, instead of attenuation. This configuration of permavoid will include a pump and capillaries to provide for irrigation to the vegetated areas of the WaterAid garden. This will consist of a 150mm depth of permavoid (see Figure 14) across its area, providing a maximum of approximately 21m³ of rainwater storage for irrigation of the garden.

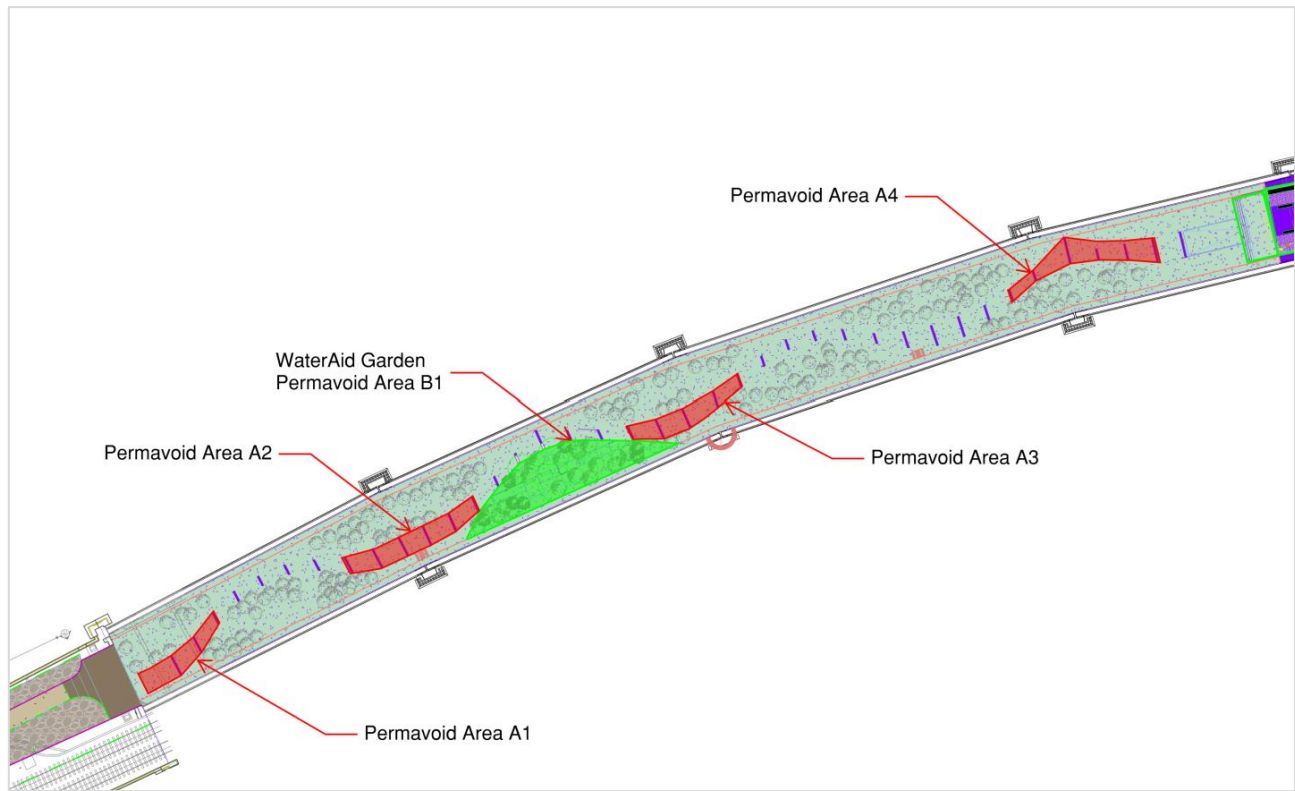


Figure 12- Proposed Permavoid Locations

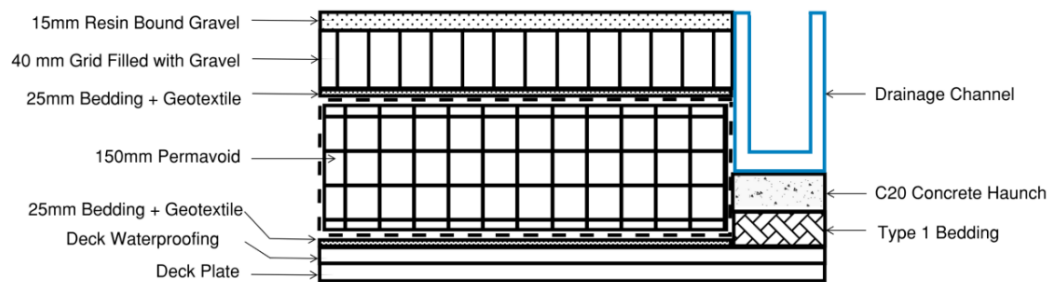


Figure 13 Type A permavoid configuration

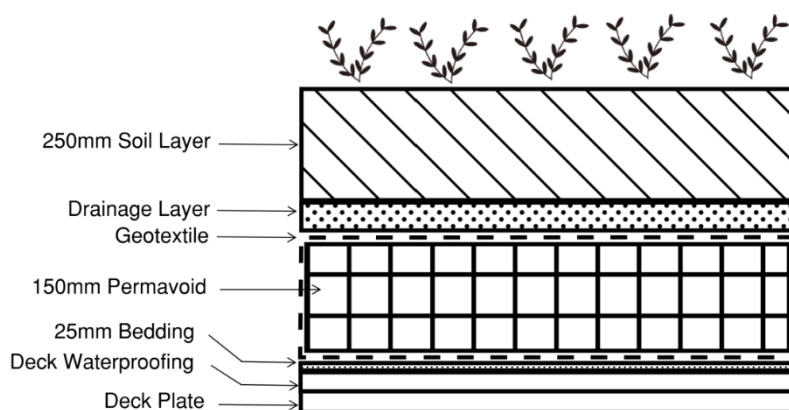


Figure 14 Type B permavoid configuration

5.3 Proposed Outfall

The viaduct currently drains to ultimate outfall via surface gullies connecting to gutters below the viaduct deck, which drain into downpipes. These downpipes carry the water to either outfall into the Bridgewater Canal, or directly onto the ground below it, the locations of these are shown in Figure 15

The gutters and downpipes will be reused for Phase 2, to provide the same discharging points as existing. The permavoid tanks proposed to be used for discharge, shown in Figure 15 will connect to these, using an orifice to restrict their discharge.

It is recommended that remediation works are undertaken on the gutters and outfall pipes to ensure that they are fit for purpose.

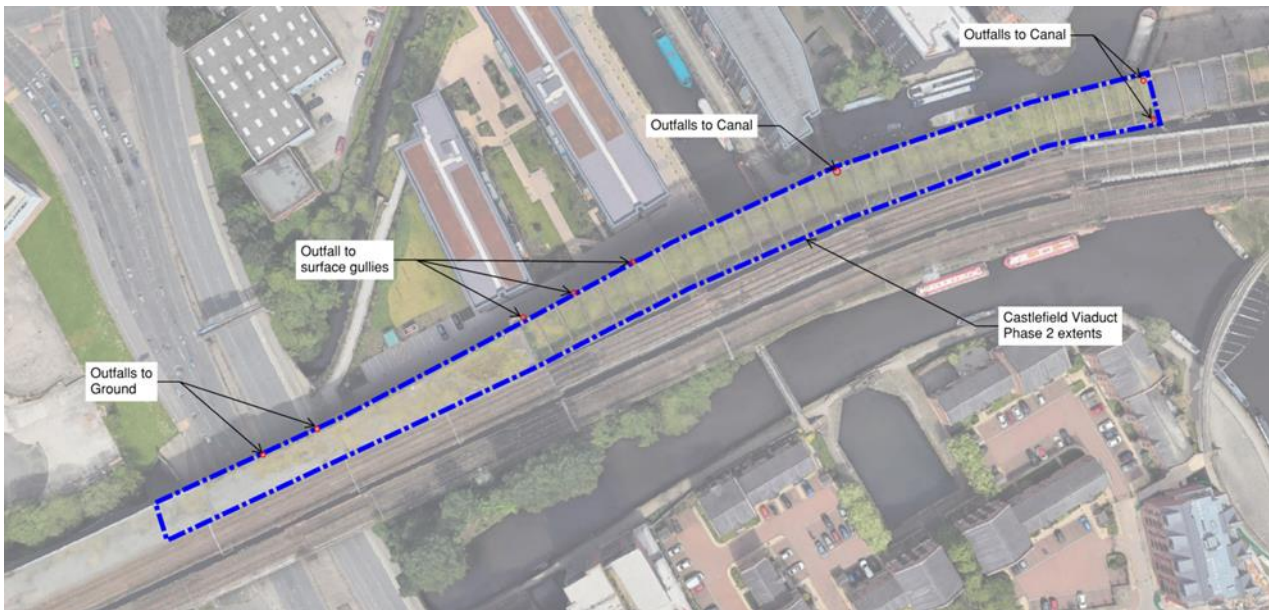


Figure 15 - Existing Outfall Locations to be Reused

5.4 Maintenance

Effective maintenance is essential for ensuring the function and performance of a permavoid sub-surface surface water drainage system. Regular inspections are recommended to identify signs of wear, blockages, or sediment buildup. Frequent clearing debris from inlets, outlets, and permeable surfaces is required, in compliance with manufacturer's guidelines to ensure sediment does not build up in the system and impair function. Vegetation on the WaterAid Garden section should be maintained to ensure planting does not interfere with the drainage system.

Responsibility for maintenance sits with the National Trust as site operators.

5.5 Proposed Foul Drainage

According to United Utilities records, there is an existing public foul water sewer culvert, 300mm x 400mm in size, in Duke Street near the viaduct. It is proposed that the toilets provided on the viaduct connect to this directly, via a 110mm downpipe from the viaduct to a 150mm diameter subsurface pipe connection, shown in Figure 16. it is assumed that the existing network has capacity for this connection.

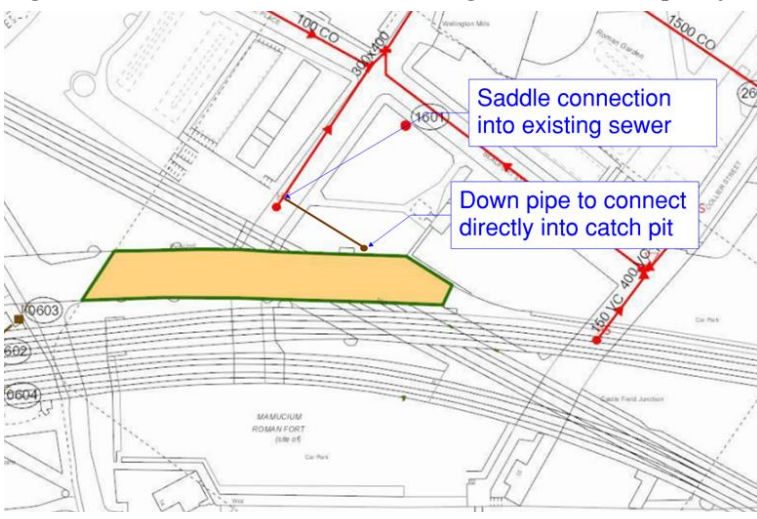


Figure 16 - Proposed Sewer Connection

6. Summary and Next Steps

6.1 Summary

Due to the viaduct's location and height above the ground, its risk from flooding from any source is considered to be low. A drainage network is proposed in order to manage surface water on the viaduct deck through attenuating the flow of rainwater at its source point. This accounts for increases in rainfall due to climate change, and maintains the runoff from the viaduct as the existing state.

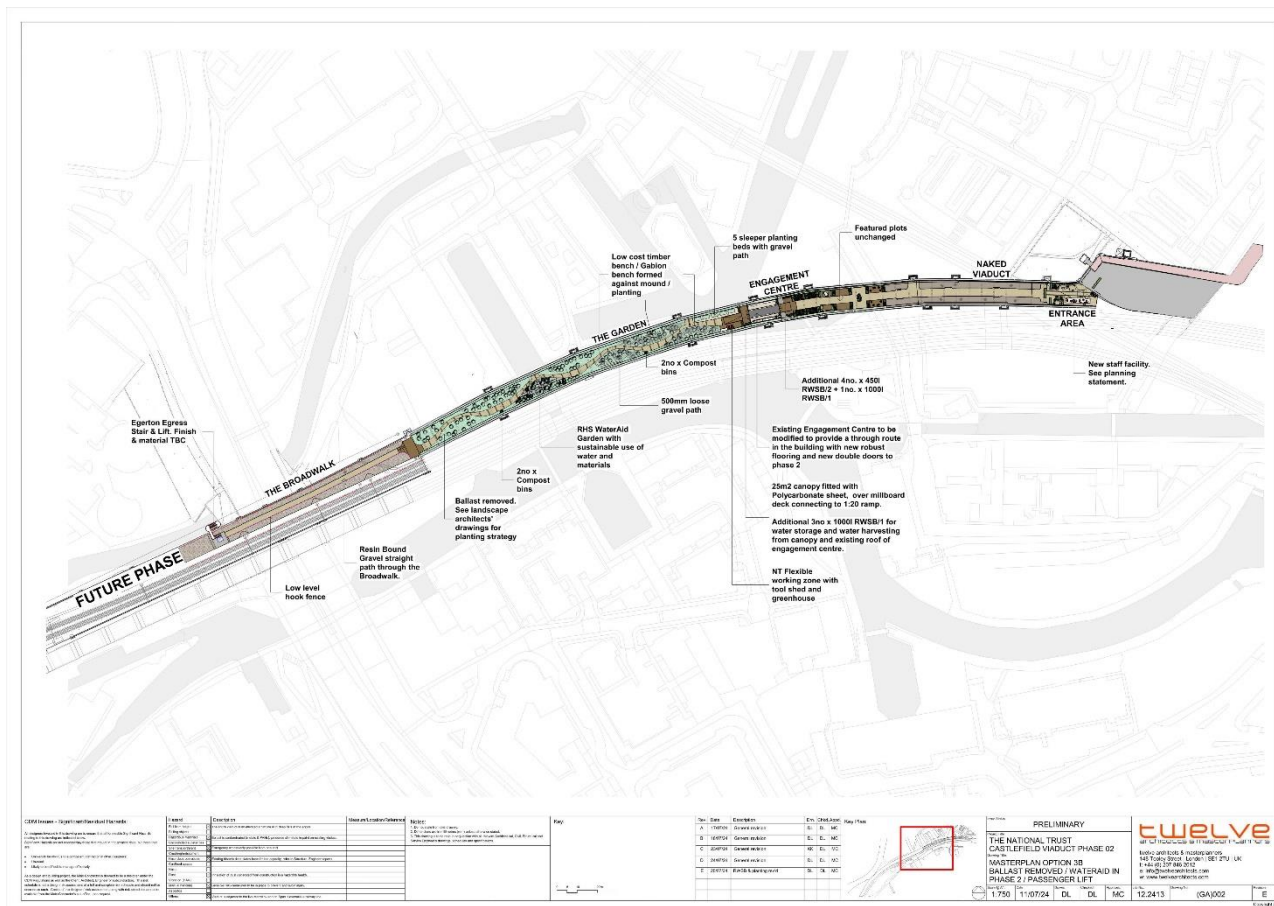
6.2 Next Steps

From site observations, the existing drainage network is in a poor condition. If it is to be reused, remediation works are recommended in order to ensure its function for the Phase 2 scheme. A detailed design of the permavoid proposal should also be undertaken to establish dimensions and outfall detail.

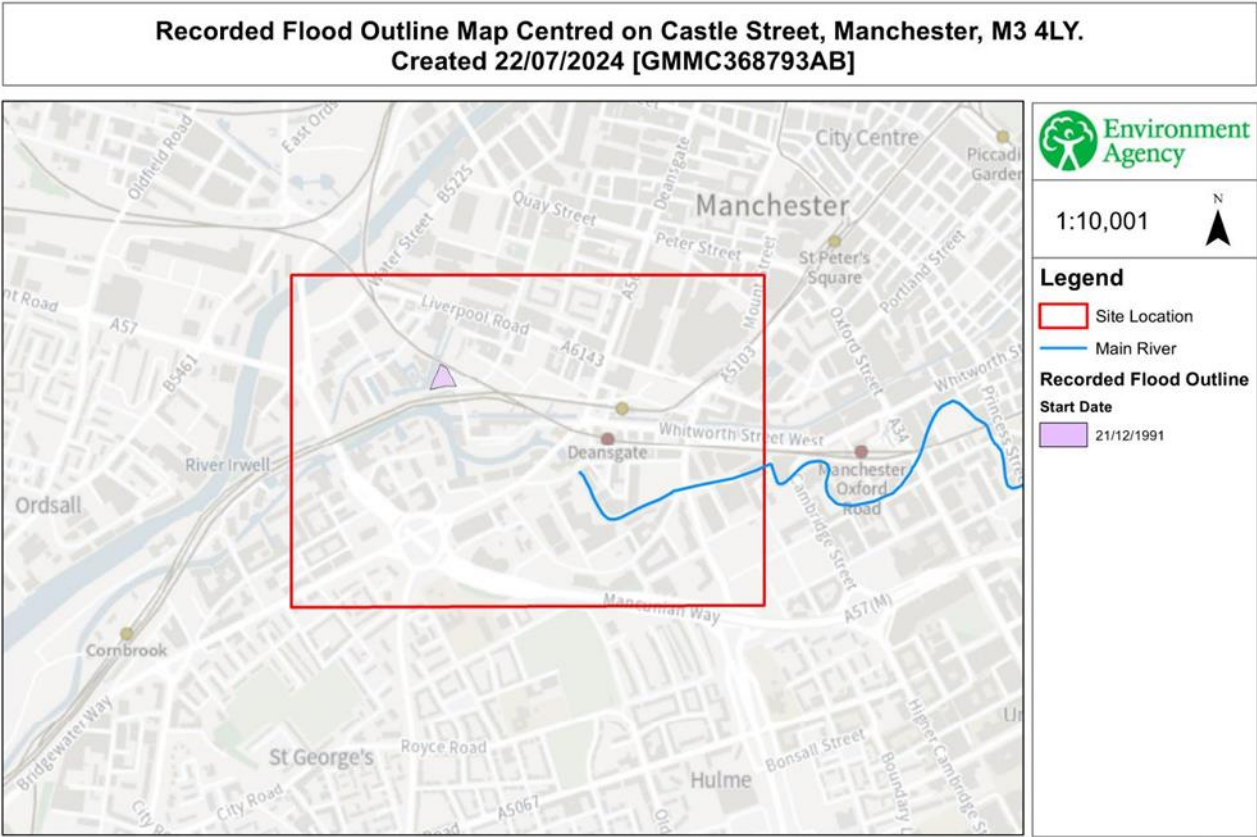
A CCTV survey of the adjacent foul network should be undertaken in order to understand its depth and location to assess feasibility of a connection.

Further detailed design will need to be considered for the access steps flood resilience, impacts on flows and surfacing around them, taking into consideration the identified flood risk in the area that they are proposed.

Appendix A – Layout Masterplan



Appendix B- Historical Flooding Data



Appendix C – Runoff Calculations

Rainwater Storage Hand Calculations – HR Wallingford Method

Existing Runoff Rate:

30-year return period – 15 minute storm

Z_1 (Figure A3a HRW): 0.61

$M5 - D$: 10.98

Z_2 : 1.5

$M30 - D$: 16.47

To calculate the 15-minute intensity, I_{15} :

$$I_{15} = \frac{M_{30-D}}{\frac{15}{60}} = \frac{16.47}{\frac{15}{60}} = 65.88 \text{ mm/hr} =$$

Given:

$$I_{15} = 65.88 \frac{\text{mm}}{\text{hr}}$$

$$C_v = 0.8$$

$$C_T = 1.3$$

$$A = 0.2 \text{ ha (assumed)}$$

To calculate the runoff rate, Q_{30}

$$Q_{30} = 2.78 \times A \times C_v \times C_T \times I_{15}$$

Substituting the values:

$$Q_{30} = 2.78 \times 0.2 \times 0.8 \times 1.3 \times 65.88 = 38.1 \text{ l/s}$$

Including a 35% allowance for climate change:

$$Q_{30+cc} = 51.41 \text{ l/s}$$

Additional runoff to be attenuated:

$$51.41 - 38.1 = 13.31 \text{ l/s}$$

For a 15-minute storm (900s):

$$900 \times 13.3 = 11.97 \text{ m}^3$$

Storage requirement: 12 m³

Rainwater Storage Hand Calculations – HR Wallingford Method

Existing Runoff Rate:

100-year return period – 15 minute storm

Z_1 (Figure A3a HRW): 0.61

$M5 - D$: 10.98

Z_2 : 1.5

$M100 - D$: 21.3

To calculate the 15-minute intensity, I_{15} :

$$I_{15} = \frac{M_{100-D}}{\frac{15}{60}} = \frac{21.3}{\frac{15}{60}} = 85.2 \text{ mm/hr} =$$

Given:

$$I_{15} = 85.20 \frac{\text{mm}}{\text{hr}}$$

$$C_v = 0.8$$

$$C_T = 1.3$$

$$A = 0.2 \text{ ha (assumed)}$$

To calculate the runoff rate, Q_{100}

$$Q_{100} = 2.78 \times A \times C_v \times C_T \times I_{15}$$

Substituting the values:

$$Q_{100} = 2.78 \times 0.2 \times 0.8 \times 1.3 \times 85.2 = 49.3 \text{ l/s}$$

Including a 45% allowance for climate change:

$$Q_{100+cc} = 71.5 \text{ l/s}$$

Additional runoff to be attenuated:

$$71.5 - 38.1 = 33.4 \text{ l/s}$$

For a 15-minute storm (900s):

$$900 \times 33.4 = 30.06 \text{ m}^3$$

Storage requirement: 30.1 m³

Rainwater Storage – Modelled InfoDrainage data

30-year return period:

Input

Input Type

User Input

Area (ha)

0.20

Volumetric Runoff Coefficient

1.000

Discharge Rate (L/s)

38.0

Infiltration Rate (m/hr)

0.0

Safety Factor

1.0

Quick

Calculate

Create New

From Library

All

FSR

Method

FSR

Number of Storms

76

Max. Run Time (mins)

20160

Label

FSR

Parameters

Return Periods

Storm Durations

Parameters

Region

England And Wales

MS-60 (mm)

18.0

Ratio R

0.360

Storm Profile

Summer

Winter

Map

Select from the following

Label

FSR

Parameters

Return Periods

Storm Durations

Return Periods

Use	Return Period (years)	Increase Rainfall (%)
☒	30	35
☐	100	45

Add

Delete

Clear All

Deselect All

Select All

Results

Quick Storage Estimate variables require approximate storage of between 12m³ - 39m³.

These values are estimates only and should not be used for final design purposes.

100-year return period :

Input

Input Type

User Input

Area (ha)

0.20

Volumetric Runoff Coefficient

1.000

Discharge Rate (L/s)

38.0

Infiltration Rate (m/hr)

0.0

Safety Factor

1.0

Quick

Calculate

Create New

From Library

All

FSR

Method

FSR

Number of Storms

76

Max. Run Time (mins)

20160

Label

FSR

Parameters

Return Periods

Storm Durations

Parameters

Region

England And Wales

M5-60 (mm)

18.0

Ratio R

0.360

Storm Profile

Summer

Winter

Map

Parameters

Return Periods

Storm Durations

Return Periods

Use	Return Period (years)	Increase Rainfall (%)
☐	30	35
☒	100	45

Add

Delete

Clear All

Deselect All

Select All

Results

Quick Storage Estimate variables require approximate storage of between 28m³ - 65m³.

These values are estimates only and should not be used for final design purposes.

National Trust
| 09 August 2024 | Ove Arup & Partners Limited

Castlefield Viaduct Phase 2
Flood Risk Assessment

Page 6

Appendix D – Permavoid Specifications

PERMAVOID 150

Permavoid 150 is a modular interlocking polypropylene geocellular unit. It is designed as a high strength, lightweight and shallow subbase replacement system. The system is characterized by its exceptionally high compressive strength and bending resistance. The units are connected with PermaTies to create a rigid horizontal structural

'raft', ideal for multifunctional subbase applications. In combination with the Permavoid Capillary Cylinders the system can be used in water sensitive urban design, enabling stormwater attenuation, conveyance and natural capillary plant irrigation without the use of energy, pumps or in-building water storage tanks.

Applications

- Parkings
- Roads
- Bicycle paths
- Blue-Green roofs
- Podium Decks
- Sports
- Equestrian
- Urban Trees
- Landscaped SUDS
- Hardscaped SUDS and lightweight rigid subbase replacement

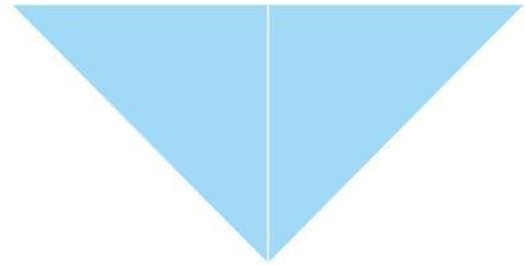
GENERAL

Brand	Permavoid
Product name	Permavoid 150
Item nr.	3550005
Color	Black
Material	Polypropylene (CoPo)
Material description	Frost and resistant, hydrofoob, inert, acid and hydrocarbon resistant, impervious to bacterial and fungal growth
Recycled/Virgin	Recycled material
Lifespan	> 50 years



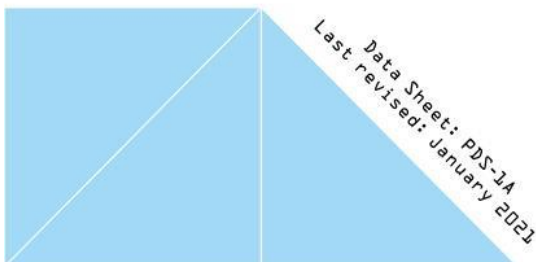
For capillary irrigation PDS-1B will be added.

Data Sheet: PDS-1A
Last revised: January 2021



PERMAVOID 150

SIZE		PACKAGING	
Size	708 x 354 x 150 mm (l x b x h), approx. 0.25 m ² , +/- 1%	Packaging	Single units on a pallet. Foil wrapped
Weight	approx. 3 kg	Pallet size	1.200 x 1.100 x 2.300 mm (l x w x h)
Color	Black	Pallet capacity	72 pieces, 18m ²
Coefficient of Linear Thermal Expansion	0,0004 - 0,0008 m/m K	Pallet total weight	217 kg
Volumetric void ratio	> 95%	Storage instruction	Prevent exposure to direct sunlight during long term storage
Perforated surface ratio	> 59%	HS Code	39269097
Compressive strength (safe design strength)	715 kN/m ²	Notes Permavoid Ltd. will not be held liable if our products are used in a manner inconsistent with our requirements, standards or the purposes indicated in the standards. Standards can be obtained at www.permavoid.com . This document is not contractual. With our constant concern for improvements, the information this document contains and the products presented may be modified without notice. The latest version of this document can be obtained at www.permavoid.com . Please get in touch with us if you require any further documentation or information.	
Short-term vertical deflection	126 kN/m ² /mm		
Necessary ancillaries (included)	PermaTies: each unit is tied to the next with 5 x 2 (bottom and top) conical PermaTies to create a stable raft. Removable, reusable.		
Optional Ancillaries	Capillary Irrigation Cylinders (3520005 and 3520006 form one complete cylinder). Shear Connector (3510004)		



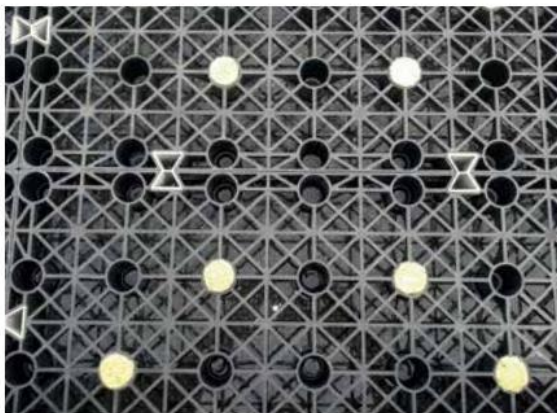
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Kattenburgerstraat 5
1018 JA | Amsterdam | The Netherlands
www.permavoid.com | info@permavoid.co.uk
Permavoid Ltd. is part of the Polypipe Group.

Permavoid System: **Passive Irrigation**

Passive irrigation uses an inert porous medium to transport water and oxygen to the roots and surrounding soil, which boosts the amount of water held in the soil in dry periods and promotes the use of water as a valuable resource.

The Permavoid system can use passive irrigation to effectively replenish soil moisture content at shallow depths. The 92% void ratio of the Permavoid Capillary cells allows a high volume of stormwater to be stored within the system, before being moved up through the cell via capillary action. This is achieved by filling the hollow structural columns within the Permavoid geocellular units with absorbent Capillary Cones, which draw up the stormwater that has collected within the unit.

The system helps to maintain a consistent nutrient content for longer, and allows engineers to design load-bearing systems in urban settings that not only mimic nature, but can also be incorporated into a sustainable stormwater management system.



Applications:

- Green Roofs
- Brown Roofs
- Landscaped Areas
- Sports Pitches
- Amenity Areas
- Bioretention Systems



Strong Interlocking Raft



Beneath porous & non-porous surfaces



Source Control



Treatment



Retention



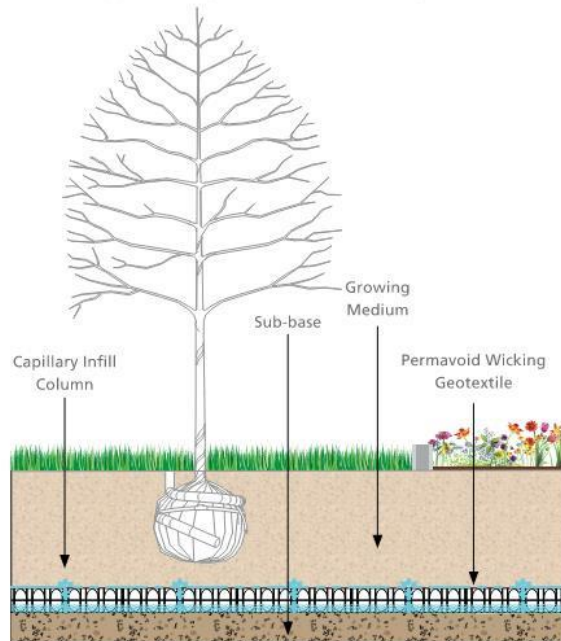
Attenuation



Infiltration

 **Polypipe**

Typical section through Permavoid capillary irrigation system showing Infilled Permavoid Capillary Cones



For smaller areas or individual landscaped areas it is possible to provide on-demand irrigation using Permafoam units. Permafoam is an open celled, highly absorbent and water retentive phenolic foam that is incorporated into a Permavoid geocellular unit. It can store 3l/unit (125l/m²) and has water permeability up to 0.452 l/s/m. Permafoam has the same unique structural properties of the Permavoid cell and can be incorporated as part of a structural raft used for attenuation/retention.



Benefits of Permavoid Capillary Cones

- Provides a consistent, high strength raft to support the rooftop garden surface loading and associated maintenance traffic.
- 92% void ratio of the Permavoid Capillary cells allows for the collection of a reservoir of stormwater within the system.
- Passive irrigation replenishes soil moisture content, and enables plants with medium water demands to be installed on rooftops with slender soil cover. This reduces the loading on roofs associated with deeper soil cover, and minimises evaporation and over-spraying losses associated with over ground irrigation systems.
- Passive irrigation maintains the soil moisture content at between 15% and 45% by volume, ensuring plants have the correct amount of soil moisture to promote growth and prevent wilting.
- The hydrophilic geotextile, installed above the irrigation system, allows the wicked stormwater to spread across a large surface area.
- Provides an undersoil drainage system that can be incorporated into a sustainable stormwater management system.
- Provides rainwater interception at source
- Air reservoir provides oxygen to root system
- Evaporative cooling mitigates the heat island effect by reducing urban air temperatures.
- A zero energy irrigation system, Capillary irrigation potentially replaces the need for a pumped irrigation system. This produces a system with a low carbon footprint and low maintenance requirement, reducing the carbon footprint for the development and maximising BREEAM points.



Contact Us

to find out about our Technical Workshop

Look out for our Permavoid Technical Manual, available to download from our website

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