

Bristol City Council

Bristol Avon Flood Strategy - Cumberland Road Defences

Geotechnical Feasibility Study

Reference: 285982-ARP-ZZ-RP-GEO-003 Cumberland Road Feasibility Study

Issue | 26 January 2024



National Library of Scotland, 2023. Ordnance Survey Six inch, 1888-1913 [1]

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Job number 285982-00

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1. Introduction

1.1 Scope of works

Bristol City Council is working with the Environment Agency and other partners to create a vital long-term strategy for managing the flood threat from the River Avon, supported by The Capital Strategic Partner (consisting of Arcadis, Arup and Mott Macdonald). The strategy will outline action to be taken in phases to reduce the chance and impact of flooding from the River Avon, and how each phase will be funded. The Strategic Outline Case (SOC) for the Bristol Avon Flood Strategy was consulted on in 2020 prior to adoption by Bristol City Council and adoption by the Environment Agency.

The engineering design presented for the strategy involved a required a review of the engineering logic and costing approach proposed by Aecom (2017) [2] for an earlier SOC. This took into account the revised hydraulic modelling and increased project extents, as well as the feasibility of the original approach. The preferred option for the Strategy comprises raised defences along the River Avon including new tidal stop gates for the Floating Harbour. The standard of protection (SoP) provided by this strategy considers two epochs – 2069 and 2130. To develop the costing of the defences, the strategy assumes an adaptive approach to defences which means:

- an initial phase of construction (Phase 1) assumed for the 2020s
- a subsequent phase of constructing additional defences and raising defences in the 2060s (Phase 2).

The preferred option specifies the construction of defences to the National Planning Policy Framework (NPPF) SoP for 2065 in the 2020s. In the 2060s, defences will be raised as necessary to the higher of the 200-year FCERM or NPPF SoP for 2130.

Works at the Cumberland Road are part of the initial phase of construction (Phase 1) and within this phase is the part of the second build stage (Build Stage 2). As part of these works it is proposed to construct a flood wall along and to the south of Cumberland Road (tied into the Reach 1 works at Western Harbour – See 285982-ARP-XX-RP-GEO-001). In addition, a flood gate will be installed at the eastern extremity of this flood wall across the heritage railway. The proposed works are considered to provide significant flood benefits for relatively low costs.

The Cumberland Road flood wall area is referred to in the overall strategy as Reach 2, the eastern flood gate is referred to as Reach 3. The present understanding is that Reach 2 is 850m long and runs along the north banks of the Avon River. The subject site of this report is entirely within Reaches 2 and 3. The baseline engineering report 285982-ARP-XX-RP-CIV-001 provides more detail. It should be noted that significant placemaking opportunities have been identified for the area, as well as the possibility of integrating with the ongoing Western Harbour and Harbour Hopes visions and development, which may result in significantly changed works.

The baseline engineering report [14] conducted for the Bristol Avon Flood Strategy identified several ground related risks and opportunities associated with the works in Reaches 2 and 3, these are outlined in Appendix C, Table 6.

It is noted that a major collapse of Cumberland Road occurred in January 2020 and construction works are ongoing to repair it. The works to address this will also have an impact on the detailed design of proposals in this area as follows:

- The type and size of foundations will govern the size of construction plant required and therefore impact the stability of the slope/bank during construction. The impact of construction surcharge on the bank stability and the design needs to be carefully evaluated at later designs stages.
- The defences are proposed across the alignment of the former River Avon natural channel. Costs could vary significantly due to lack of ground investigation information for the foundations of the defences. The adjacent Chocolate Path Remedial Works pile design was affected by aggressive ground conditions in the tidal flat deposits. The harbour railway drainage has failed in places, due to

sedimentation. This increases the risk of bank slippage/instability, particularly at times of tidal surge and with the harbour railway retaining structure in front of the highway retaining structure.

- Costs could vary significantly due to lack of ground investigation. There is a significant risk of poor ground conditions near the historic riverbed and peat has been identified from existing ground investigation information which has been allowed for in the design but if not realised may lead to a cost saving. Information gathered in the ongoing repair works could be used.
- Using the existing historic foundations wherever possible could reduce the costs, but the condition and exact size and ground conditions would need to be clearly understood.

The study aims to provide additional information and insights to the above risks and opportunities that will contribute to the development of a comprehensive outline business case.

2. Background Information

2.1 The Site

The site is located in the west of Bristol city and centred approximately at National Grid Reference ST 57783 72164. The site location and layout are shown in Figure 1. The site covers Reach 2 and 3 and is approximately 850m in length from west to east, see Figure 2.

The area of the proposed works lies directly to the south of Cumberland Road, north of the River Avon which at this location is located in an artificially excavated channel termed the Avon New Cut. This channel was excavated between 1804 and 1809 [2] in order to re-direct the River Avon south and allow the impounding of Bristol's Floating Harbour which assumes the approximate former river channel at the time.

Beyond Cumberland Road to the south is a low retaining wall (0.5-0.6m high) and railings which separates the road from an historic railway which is now used as a heritage railway. To the south of the railway, separated from it by a fence line, a pedestrian path is present termed the "Chocolate Path" so named as it is finished with precast blocks that resemble chocolate bars, to the south of the path lies the Avon New Cut. To the north of Cumberland Road in the west are areas of ship and boat building while over the remainder of the stretch are a caravan park, as well as residential and commercial premises.

The site is sits at approximately 7-10m Above Ordnance Datum (AOD) with a general rise from approximately 7m AOD in the west to 10m AOD in the east.

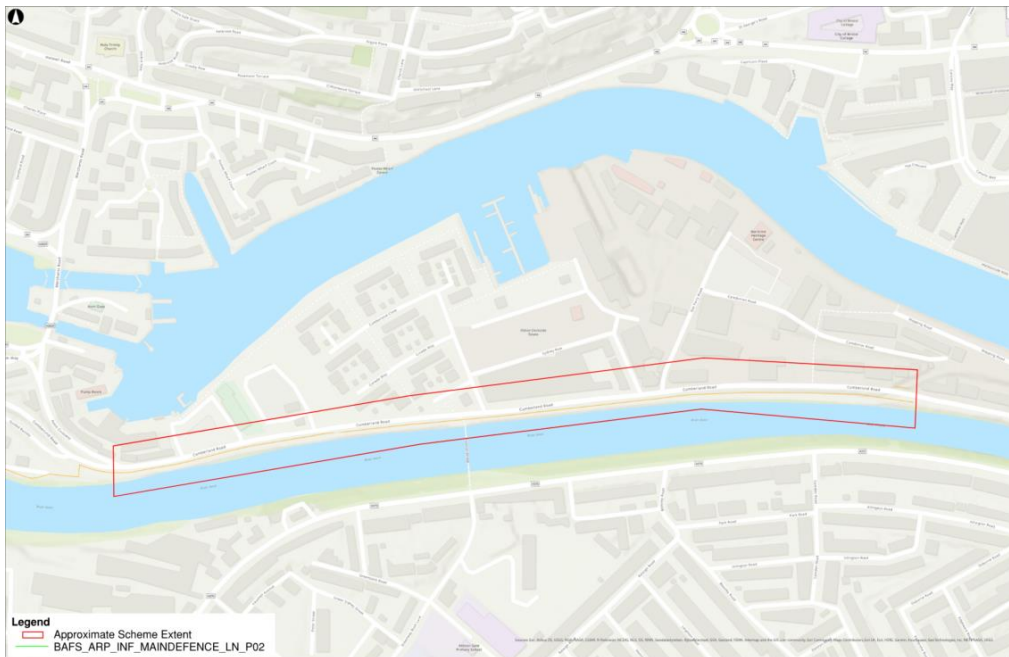


Figure 1 – Site Location Plan

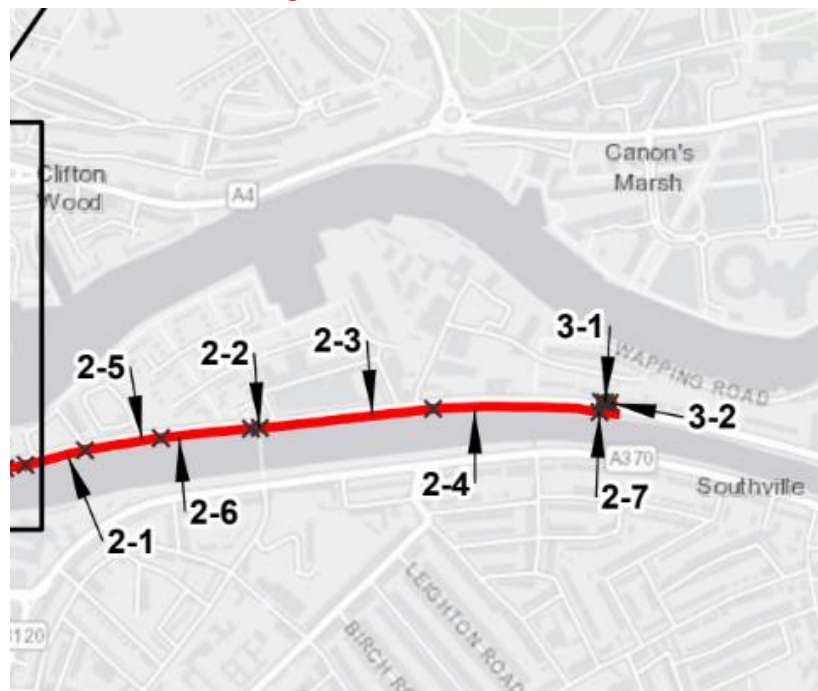


Figure 2 - Reaches 2 and 3 (with sub-reaches)

2.2 Proposed Development

The works proposed for costing at SOC stage comprise an 850m long concrete flood wall with piled foundations (Reach 2) and a flood gate (Reach 3). As detailed in the baseline report (285982-ARP-XX-RP-CIV-001) a review of ongoing Chocolate Path Remedial Works (Project Ref. 673846.CV.73.01) information was undertaken and it was concluded that the works in this section would provide sufficient foundations for the proposed flood wall and on this basis this 113m long section was excluded from the cost build up. An option was explored along the remaining section of Reach 2 to increase the height of the existing Metrobus wall to the required flood height. This was not considered feasible and as such a new piled foundation concrete wall will be required along the remainder of Reach 2. The extent of flood defences in Reach 2 is included in Figure 3, a typical cross section through the area of Chocolate Path Remedial Works is included as **Error! Reference source not found..**

For Reach 3 a flood gate is proposed across the railway underneath Cumberland Road bridge, this will have a flood wall of 2m in height on the downstream end and ramps on the upstream end. The flood gate will tie directly into the Reach 2 defences. The location of the flood gate is shown on Figure 5.

Significant design work is still to be carried out, including integration with the Western Harbour and Harbour Hopes developments, and realising of placemaking opportunities related to the Western Harbour character area. A key objective of this study is to highlight risks and constraints which will further inform the design of the flood defence structures.

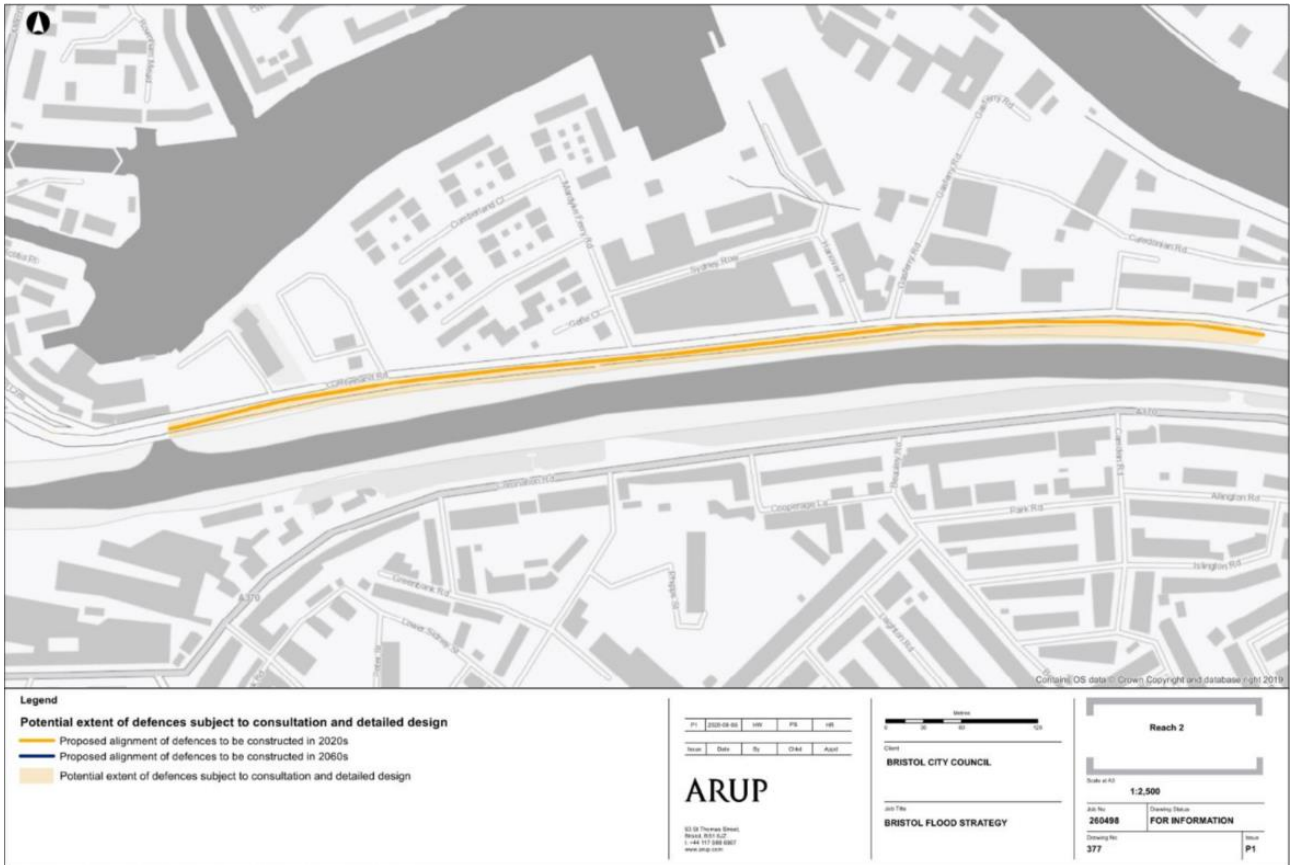


Figure 3 - Extent of flood defences in Reach 2

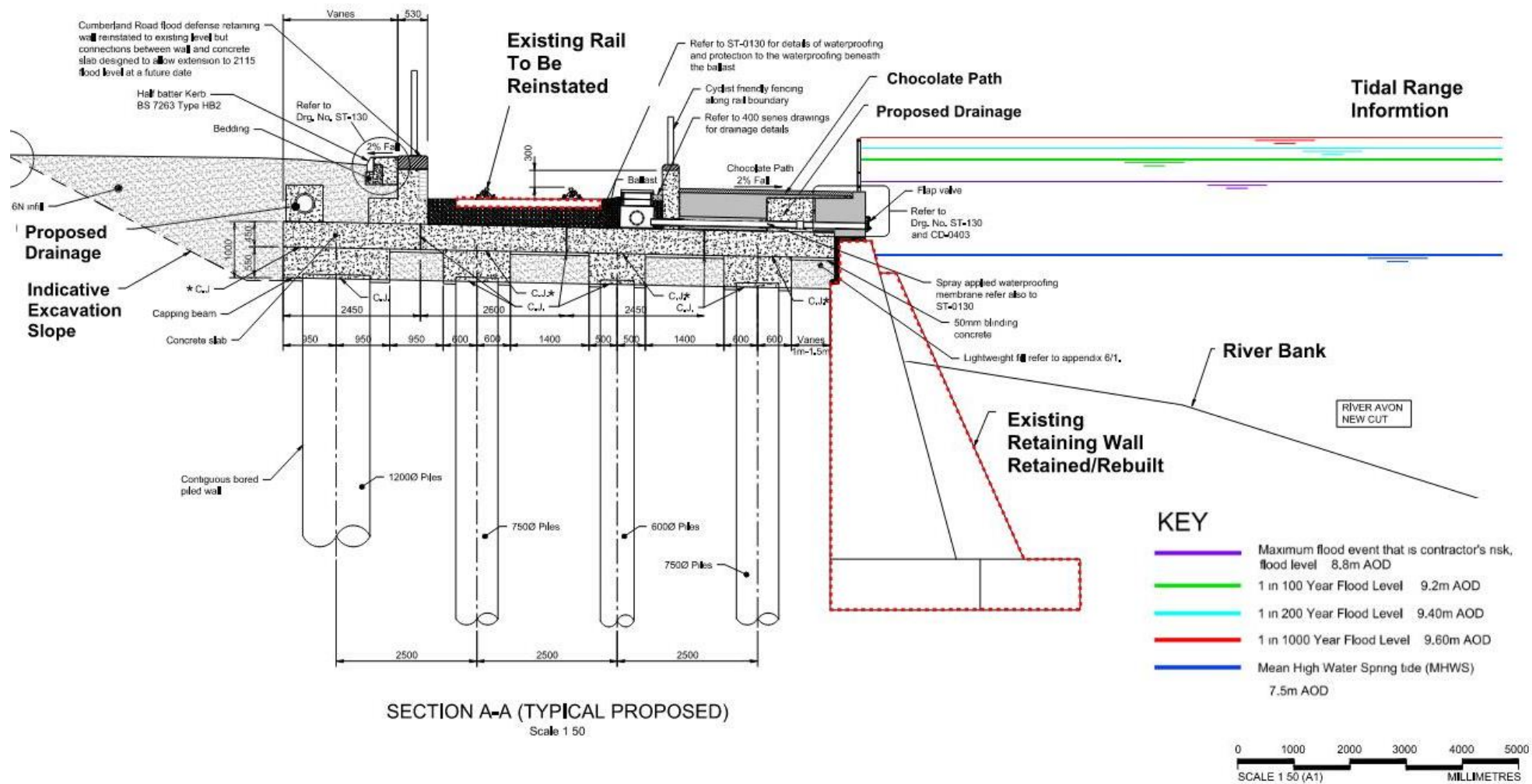


Figure 4 - Proposed flood defence tied into existing remedial works



Figure 5 - Extent of flood defences in Reach 3

3. Data Acquisition

A number of information sources have been consulted in order to inform site conditions and constraints in relation to the development of the site. The sources are summarised below. A summary of the findings from the review of these sources are summarised in section 4 and headline risk and opportunities presented in Section 5.

- **Geological information** – A review of the British Geological Survey (BGS) GeoIndex, BGS 1:50,000 England and Wales Sheet 264 map of Bristol, the BGS 1:10,630 ST57 SE map and nearby BGS borehole records has been undertaken to develop a ground model for the site to feed into design development [3]. In addition the BGS 1:625,000 Hydrogeological map has been used to assess the aquifer designations on site and determine their sensitivity to the proposed works.
- **Previous Site Investigation Data** – Where available, a review of the results from previous intrusive investigation has been undertaken to provide ground truthing of published geological data and additional detail from site specific assessment and testing. This information can then be used to inform preliminary design of flood defences.
- **Coal Mining** - Assessment of the Coal Authority Interactive Viewer [4] has been undertaken alongside review of relevant geological extracts including the BGS sheet information to assess the risk from past coal mining on the proposed works.
- **Risk from Unexploded Ordnance (UXO)** – A review from the risk of unexploded ordnance has been undertaken using free publicly available information to provide an assessment of the risk and provide indication on the likely mitigation required as part of the proposed works [5].
- **Historic Development** – A review of relevant Ordnance Survey mapping for the area has been undertaken using extracts from historic OS maps to build up a picture of the sites historic development. This has been used to assess potential risks from contaminative past uses and possible other impacts such as obstructions from buried foundations [6] [1].
- **Environmental Setting** - Multi-Agency Geographic Information for the Countryside (MAGIC) maps have [7] been used to assess the site and its surroundings in relation to sensitive receptors that may be impacted by the proposed development. In addition publicly available information from the Environment Agency and Bristol City Council [8] has also been reviewed to feed into the understanding of the sites environmental setting.
- **Historic Aerial Imagery** – A review of historic aerial photographs [9] [10] has been undertaken into order to assess the historic development of the site. This feeds into the understanding of the historic and existing built environment along with information on past land uses that can impact on ground conditions and contaminated land.
- **Bristol City and the Harbour Office Archives** – A search of relevant records from both resources has been undertaken to identify pertinent information on historic and existing structures on site. This information has been sourced to assess potential interfaces with these structures as part of the proposed works.

4. Site Conditions

4.1 Geology and Hydrogeology

The online BGS sources indicate that the site is underlain by made ground along its length until approximately the boundary between sub-reach 2-3 and 2-4, beyond this point eastward made ground is noted as absent. It is considered likely given the historic development of the area east of the 2-3/2-4 sub-reach boundary that a thin veneer of made ground will be present.

In the west of the site and up to the approximate sub-reach 2-2 (locale of Vauxhall Bridge) the made ground is shown to be underlain by Alluvium/Tidal Flat Deposits. These are which typically described as ‘soft to firm, brown and grey, silty clay with layers of gavel and sand’. Notation on the 1:10,560 scale mapping indicates that these deposits comprise approximately 7.6m of clay and sand with a 1m layer of peat directly east of the Underfall Yard sluices. Further west (outside of Reach 2) at the location of the B Bond Building further notation indicates the Alluvium/Tidal Flat Deposits are up to 18m in thickness and as such it is assumed that these deposits thin eastwards and “pinch out” to the east of sub-reach 2-2 (locale of Vauxhall Bridge).

Below the made ground and Alluvium/Tidal Flat Deposits the bedrock geology is shown as the Redcliffe Sandstone Member within the Mercia Mudstone Group. The BGS lexicon describes this deposit as “sandstone, distinctive fine to medium grained deep red, calcareous and ferruginous, commonly decalcified at shallow depths below the surface, giving rise to an uncemented sand”. Notation on the 1:10,000 and 1:10,560 mapping of exposures in the Avon New Cut and in the cutting for the Heritage Railway (beneath Cumberland Road Bridge) suggest that in this area of Bristol the Redcliffe Sandstone Member is interbedded with marl beds. The tendency of this unit to decalcify near the surface and weather to a sand may cause instability to shallow excavations and cuttings. The base of the Redcliffe Sandstone Member lies unconformably over the Lower Coal Measures Formation in this area of Bristol, this is indicated on the 1,10,000 and 1,50,000 scale mapping by the sub-crop of the Ashton Great Coal and Ashton Little Coal seams below the site, the latter indicated at the approximate Reach 2 western extremity and the former indicated immediately east of the Underfall Yard sluices. The closest record of the upper surface of the Lower Coal Measures is from a well present on Greenway Bush Lane approximately 250m to the south of Reach 2 which indicates the upper surface at a depth of 45m below ground level.

In addition to the review of BGS mapping, several BGS borehole records have been reviewed as part of the study. A summary of the findings from these is included below:

Table 1 – Summary of findings from BGS Boreholes

Borehole Reference	Location	Ground Conditions	Comments
ST57SE129	Drilled for the Bristol Barrage, River Avon (New Cut), located in the middle of River Avon to the southwest of Reach 2.	Circa 5.5m thick of alluvial deposit of soft clay with basal gravel, underlain by weathered marl and then coarse-grained sandstone.	Drilled from river bed at -2.24m AOD.
ST57SE131	Drilled for the Bristol Barrage, River Avon (New Cut), located at the northern bank of River Avon, to the west of western end of Reach 2 (outside Reach 2).	Circa 14.5m thick of Alluvium/Tidal Flat Deposits, which comprises 7m thick of soft to firm silty clay with some stone at the top, followed by 5m thick of slightly clayey sand and 2.5m thick of clay, sand, gravel and rock fragment of sandstone. Underlying the superficial deposits are the hard red marl, sandstone with carbonate and quartzite to the depth of at least 26m below ground level (BGL). Groundwater level was recorded at circa 5m BGL (circa 3m AOD) during drilling.	-

Borehole Reference	Location	Ground Conditions	Comments
ST57SE134	Drilled for the Bristol Barrage, River Avon (New Cut), located circa 50m north of sub-reach 2-1.	<p>Circa 0.4m thick of made ground, followed by 15m thick of Alluvium/Tidal Flat Deposits, which comprises 13.5m thick of soft to firm silty clay with some stone at the top, followed by 1.5m thick of dense fine to coarse gravel. Underlying the superficial deposits are 6m marl which was recorded as firm and becoming harder with depth, followed by 8.5m of sandstone, breccia conglomerate and quartzite.</p> <p>Groundwater level was recorded at circa 9-10m BGL (circa 0-1m AOD) during drilling.</p>	-
ST57SE135	Drilled for the Bristol Barrage, River Avon (New Cut), located circa 20m north of sub-reach 2-1.	<p>Circa 0.5m thick of made ground, followed by 17.5m thick of Alluvium/Tidal Flat Deposits, which comprises 15.5m thick of soft to firm silty clay with some stone, followed by 2m thick of fine gravel. Underlying the superficial deposits are 6.5m hard marl, followed by 3m of sandstone, breccia conglomerate and quartzite.</p> <p>Groundwater level was recorded at circa 6-7m BGL (circa 2-3m AOD) during drilling.</p>	-
ST57SE136	Drilled for the Bristol Barrage, River Avon (New Cut), located south of sub-reach 2-1.	<p>Circa 14m thick of Alluvium/Tidal Flat Deposits, which comprises 13m thick of soft to firm silt clay with a layer of 2m thick peat, followed by 1m thick of gravel. Underlying the superficial deposits are 3m marl and 10m of sandstone, breccia conglomerate and quartzite.</p> <p>Groundwater level was recorded at circa 2.5m BGL (circa 4m AOD) during drilling.</p>	-
ST57SE328	Located circa 160m the west of Reach 3.	1.1m thick of Made Ground, followed by 1.6m thick of weathered sandstone of clayey sand, and then moderately strong coarse-grained sandstone to 2.8m BGL.	No information on ground elevation
ST57SE329	Located circa 160m the west of Reach 3.	1.21m thick of Made Ground, followed by 1.13m thick of weathered sandstone of clayey sand, and then moderately strong coarse-grained sandstone to 3.3m BGL.	No information on ground elevation

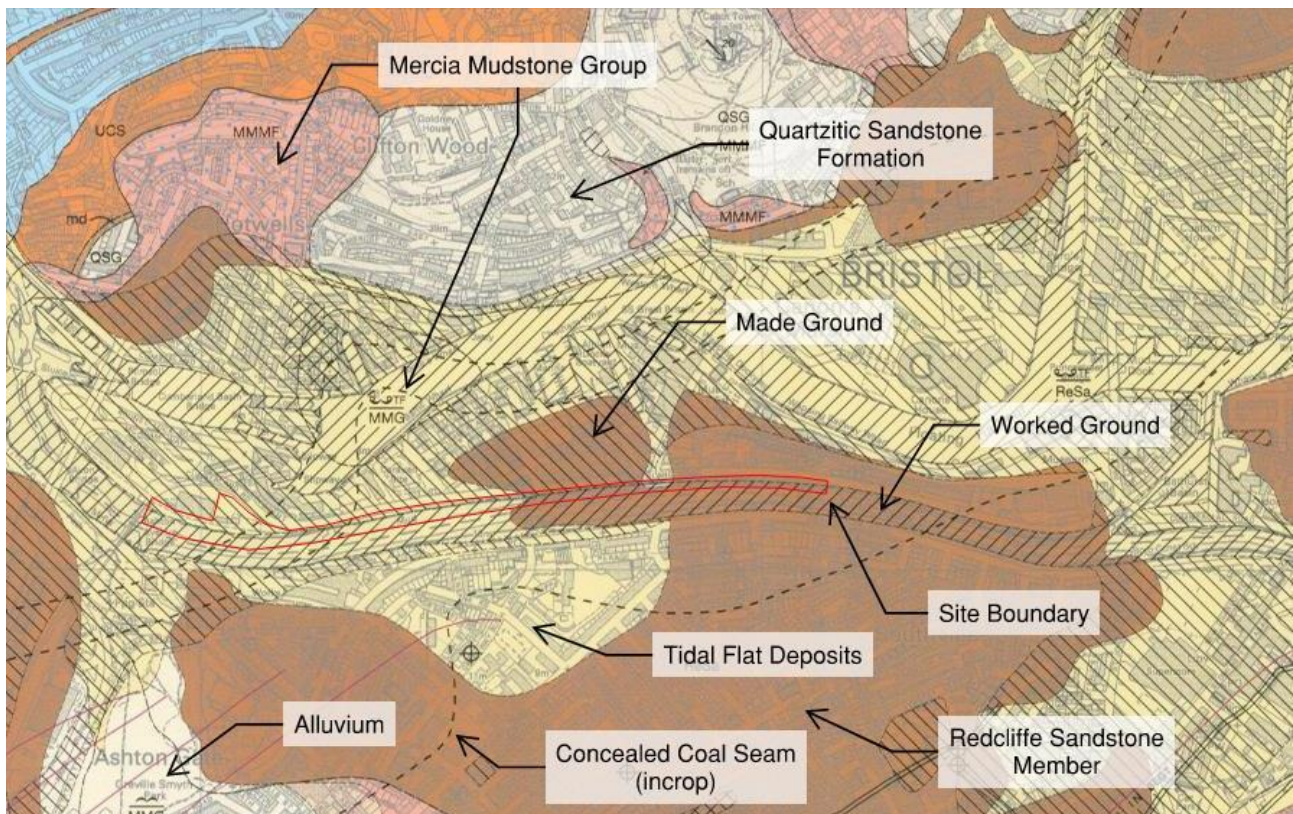


Figure 6 - Site Geological Map

The BGS Hydrogeological 1:625,000 map classifies the majority of the site as Triassic rocks (undifferentiated) and a moderately productive aquifer summarised as a locally important aquifer generally producing hard groundwater from solution enhanced joints.

The Environment Agency classifies the superficial deposits as unproductive strata, the Redcliffe Sandstone Member as a Secondary A aquifer. Secondary A aquifers are defined as permeable strata capable of supporting water supplies at a local rather than strategic scale and in some cases forming an important source of base flow to rivers. The bedrock beneath the site is classified as High Vulnerability.

Review of the BGS boreholes record indicated that groundwater levels of the site are between 0m and +4m OAD. It is anticipated that groundwater will be encountered during excavations as part of the proposed scheme and that this groundwater is likely to fluctuate with the water level of the River Avon which is tidally influenced at this point. The groundwater may also artificially be impacted by the water level of the floating harbour located to the north of the site.

4.2 Previous Site Investigation Data

A site investigation was undertaken in 2013 by Structural Soils Ltd on behalf of Bristol City Council for the Ashton Vale to Temple Meads metrobus scheme. The investigation comprised three boreholes excavated on the Cumberland Road within Reach 2. The borehole records have been reviewed and a summary of the findings from this is included below:

Table 2 – Summary of Borehole undertaken by Structural Soil Ltd in 2013

Borehole Reference	Location	Ground Conditions	Comments
BH545	On the southern edge of Cumberland Road near sub-reach 2-1.	1.2m thick of Made Ground, underlain by 17m thick of Alluvium/Tidal Flat Deposits. Underlying is Mercia Mudstone Group of clay and to a depth of circa 23.4m BGL.	-
BH545D	On the southern edge of Cumberland Road near sub-reach 2-5.	1.2m thick of Made Ground, underlain by 13m thick of Alluvium/Tidal Flat Deposits.	Terminated before reaching Mercia Mudstone Group.
BH545E	On the southern edge of Cumberland Road approximately 10m west of the Vauxhall footbridge near sub-reach 2-2.	1.8m thick of Made Ground, followed by 4m thick of Alluvium/Tidal Flat Deposits. Underlying is Mercia Mudstone Group of clay and to a depth of circa 10.4m BGL.	-

Following the review of the available boreholes on the site Table 3 gives the summary of the expected geological strata across Reach 2 and 3.

Table 3 – Expected Geological Strata

Strata	Anticipated thickness (m)	Anticipated layer top depth (mAOD)	Comments on occurrence
Made Ground [MG]	Between 1m (beneath Cumberland Road) and 3m (beneath Harbour Railway and Chocolate Path).	+9.2mAOD on Cumberland Road. +8.5mAOD on the Chocolate Path and Harbour Railway. [Topography survey taken in 2009, CH2M report, 2018].	Variable depth and composition across the site: Dark brownish grey to black subangular fine to coarse very sandy GRAVEL of limestone and sandstone with rare brick fragments [MG]. (Possible Made Ground) Dark mottled grey reddish brown sandy slightly gravelly CLAY [Possible MG].
Alluvium / Tidal Flat Deposits [TFD] NB: These are often interchangeable terms	From 15m on Cumberland Road (SSL 2013 BH545) to 6m in the New Cut (BGS ST57SE129).	Directly beneath Made Ground across the site, between 1m and 3m depth.	Soft low strength (becoming firmer and higher strength) greyish brown slightly sandy slightly gravelly CLAY [ALLUVIUM]. Very dense dark greyish brown sandy GRAVEL of low cobble content rounded to subangular sandstone and limestone [TFD].
Redcliffe Sandstone Member [RSM] (Mercia Mudstone Group [MMG])	From 3.5m to 15m when base encountered.	-11mAOD at Tobacco Warehouse B (BGS 133). +0mAOD at Vauxhall Bridge. Presumed gradual incline dipping to the west, and	Encountered at varying depth across the site, reducing towards Vauxhall Bridge and towards the New Cut riverbank. Reddish brown mottled grey slightly sandy silty CLAY [MMG].

Strata	Anticipated thickness (m)	Anticipated layer top depth (mAOD)	Comments on occurrence
		influenced by the route of the New Cut.	Extremely weak reddish brown medium bedded silty MUDSTONE with greenish grey pockets.[MMG] Very weak locally extremely weak reddish brown fine to medium SANDSTONE with rare lenticular pockets (<10mm) of greenish grey fine to coarse sandstone. [RSM] Very weak thinly to medium bedded reddish-brown SILTSTONE with very weak occasional lenticular irregular pockets (<10mm) of greenish grey siltstone.
Coal measures	Not encountered.	Would only be present at the base of Triassic Mercia Mudstone Group bedrock; anticipated deeper than 30m depth.	Not applicable to proposed developments.

4.3 Geological Cross Sections

Figure 9 and Figure 10 present geological cross sections for the current proposals along Reach 2, divided into the western end where the Tidal Flat deposits are anticipated to be present and then towards the eastern end where they are anticipated to be absent. It is noted that both sections present the concept design only and that further detailed design will be required to confirm the approach.

Given that the failure of drainage was a contributing factor to the failure of the preexisting structure, any proposed design should also include enhanced/repaid drainage solutions. It should be noted that the slip failure followed several years of movement and subsequent monitoring by the council. A picture of the 2019 slip is shown in Figure 7, and from a historic slip in 1981 in Figure 8.



Figure 7: Showing the historic 2019 slip on Cumberland Road



Figure 8: Showing historic slippage from 1981 on Cumberland Road

The 2019 proposed Cumberland Road stabilisation works typical cross section drawing in Appendix D shows proposed drainage locations.

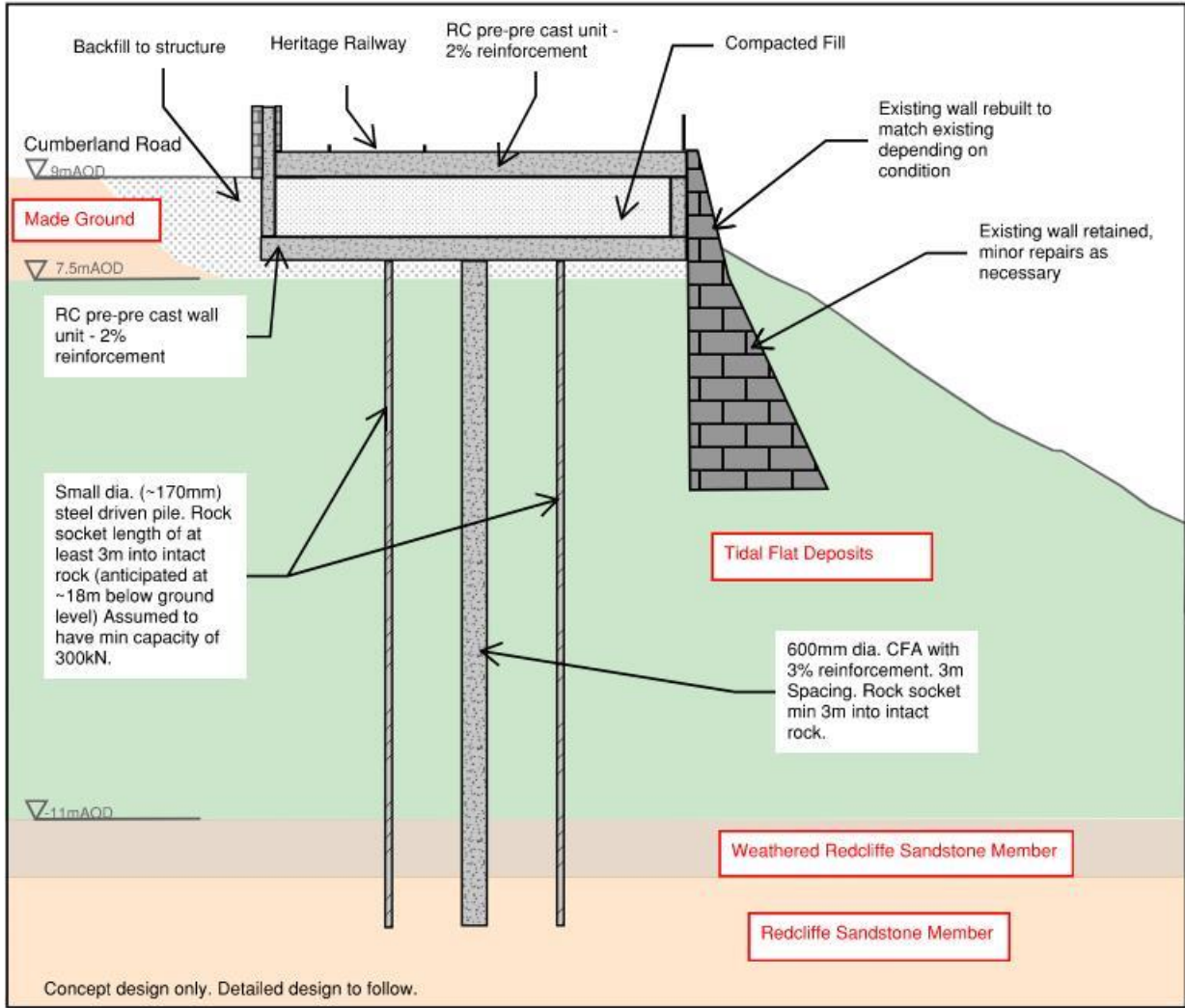


Figure 9 - Western Reach 2 Cross Section

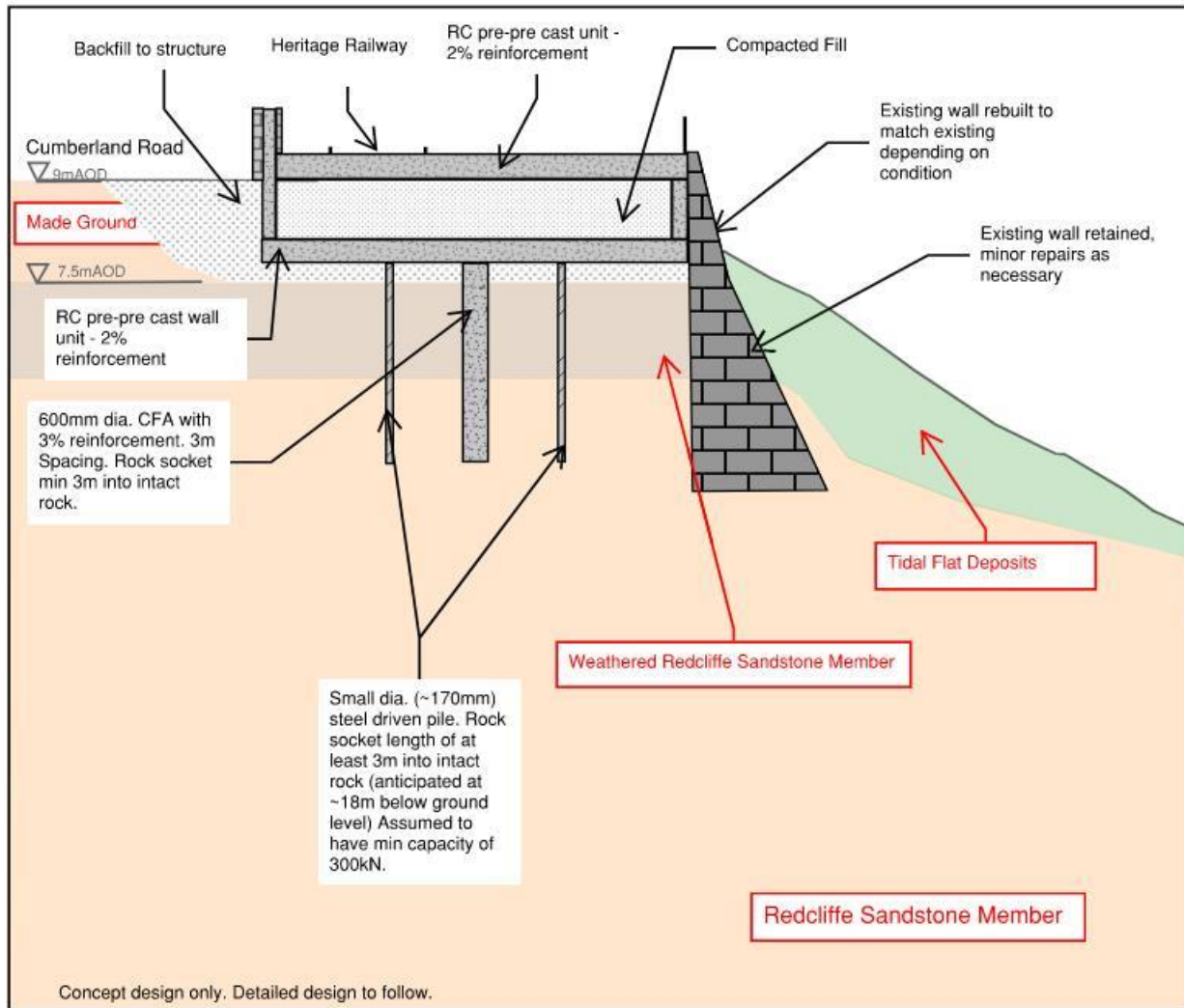


Figure 10 - Eastern Reach 2 Cross Section

4.4 Coal Mining

The Coal Authority Interactive Viewer [4] has been reviewed to assess the risk from past coal mining on the proposed works. Both Reaches 2 and 3 fall within the Coal Mining Reporting Area and a section of the western extent of Reach 2 is within an area designated in the Abandoned Mines Catalogue (No. SWR3435), shown in Figure 11. The Ashton Little Coal seam and the Ashton Great Coal seam are shown on BGS maps to run parallel to each other beneath the western extent of Reach 2 continuing to the north of Spike Island. These are the area defined as Development High Risk Area and Probable Shallow Coal Mine Working in the Coal Authority Interactive Online Map (Figure 11). There are no mine entries recorded in proximity to Reaches 2 and 3. The closest mine entry record is circa 300m south of sub-reach 2-6 (Figure 11). Despite the area being within a Development High Risk Area and in Probable Shallow Coal Mining risk areas the coal seams driving this assessment actually sub-crops at the base of the Mercia Mudstone Group which lie unconformably over the erosional surface of the Carboniferous Coal Measures. As such it is expected that any workings would be at a depth below this contact.

On the basis of the above records, it is considered that the proposed works are not within an area that could be affected by past coal mining at or close to the surface and the risk associated with the past coal mining is negligible.

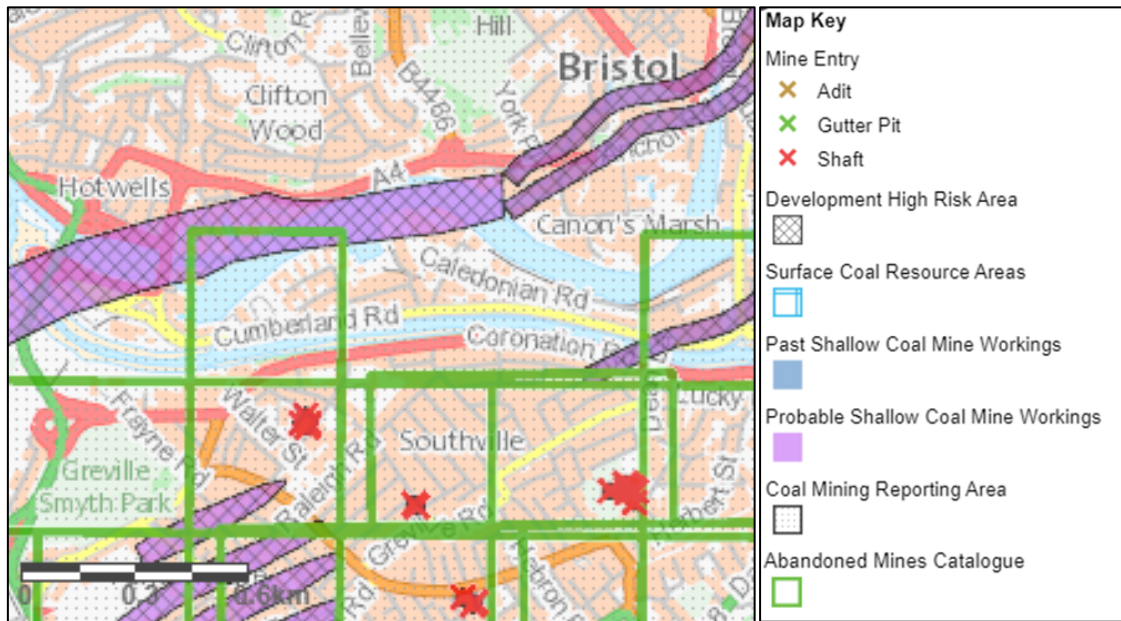


Figure 11 – Coal Authority Interactive Map [4] Risk from Unexploded Ordnance (UXO)

4.5 Unexploded Ordnance

A review from the risk of unexploded ordnance has been undertaken using Zetica UXO [5].

Based on the Unexploded Bomb Risk Map by Zetica UXO, both Reaches 2 and 3 fall within the high bomb risk area, which is indicated as having bombing density of 50 bombs per 1000 acre or higher. This is probably due to its locality to the Bristol Harbour area which is known to have been targeted in World War II. There were various Luftwaffe targets around the entrance to the floating harbour and along Spike Island. There have been several confirmed UXO items found to the east of the reach around the M-Shed and the Arnolfini museum. It is considered that the UXO risk remains. Therefore, it is recommended that a UXO desk study and risk assessment of the site be completed prior to an intrusive investigation and as the design is progressed to detailed design stage.

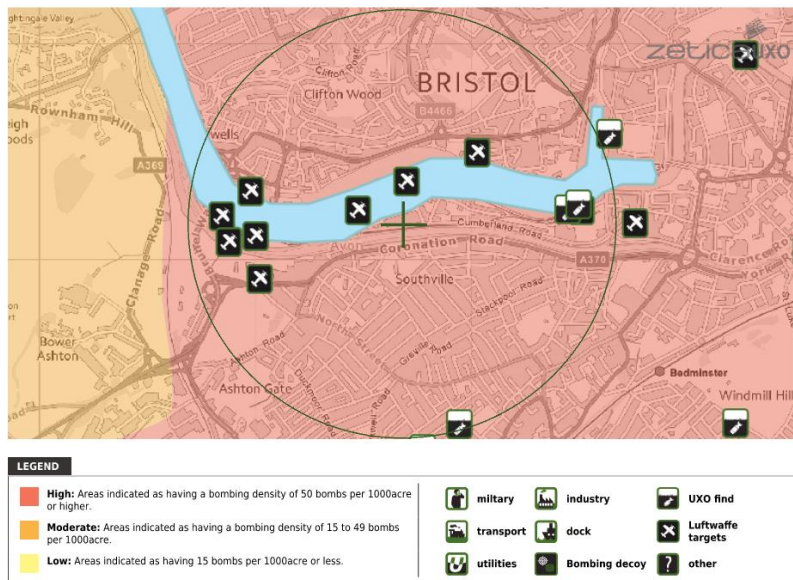


Figure 12 – Unexploded Bomb Risk Map [5]

4.6 Historic Development

A review of the historical maps and historic aerial photographs using Know Your Place [6], historic OS maps [1], Britain From Above [9] and Historic England [10] has been undertaken in order to assess the historic development of the site. This feeds into the understanding of the historic and existing built environment along with information on past land uses that can impact on ground conditions and contaminated land. The following presents a summary of the pertinent aspects of this historic review.

The site was predominantly undeveloped pasture and agricultural land prior to 1828. By 1828, the Avon New Cut, Cumberland Basin, and Floating Harbour had been constructed and the overfall dam on the west side of the site was built. The Cumberland Road was also built during this time. By the 1880s, timber yards and saw mills were located to the north of Cumberland Road bounded by Mardyke Ferry Road to the east. To the east of Mardyke Ferry Road, the site was developed into residential houses and warehouses. In the 1960s, an engineering works and asphalt works were noted near the east of the site near Gasferry Road, which were likely associated with the Wapping Railway Wharf to the north. By the 1990s, the site was developed into the residential and recreational land use, similar to its current state.

Following the construction of the Avon New Cut, several key structures are noted along or in the vicinity of the northern side of the Avon New Cut which will potentially impact the proposed flood defences. These include:

- Between 1879 and 1894 the Wapping Railway is constructed immediately south of Cumberland Road and north of the Avon New Cut. OS mapping indicates that the land prior to the railway formed a bank/slope down to the mean high water mark, possibly with some masonry lining at its upper most section. It appears from the mapping that the railway was constructed by removal of this bank at the eastern end where it passes under the Cumberland Road. At the same time it appears that the existing masonry retaining walls along the northern bank were formed along with Chocolate Path. At some sections there may be a partial cut of the river bank with fill in a wedge behind the retaining wall to extend the land south into the channel. This is most obvious at the section of the railway that passes over the sluices at Underfall Yard.
- Between 1879 and 1894 at the western end of the site land reclamation has taken place in the areas to the south of the B Bond Warehouse. This included the creation of the existing access way and a small wharf area. At the same time the Ashton Swing Bridge was also constructed.

In 1981, a major deep-seated slip occurred on the northern bank of the River Avon at the western end of Cumberland Road, south of the Avon Crescent. The landslide included an area of Cumberland Road and the ground between the road and the Avon New Cut .

In 2019, the Chocolate Path stabilisation works were carried out following the ground failure of the road due to excessive deformation. This slip failure occurred following several years of of movement and monitoring of the ground underlying the Chocolate Path.

4.7 Environmental Setting

Multi-Agency Geographic Information for the Countryside (MAGIC) maps [7] have been used to assess the site and its surroundings in relation to sensitive receptors that may be impacted by the proposed development. In addition, publicly available information from the Environment Agency and Bristol City Council [8] has also been reviewed to feed into the understanding of the sites environmental setting. The environmental constraints have been summarised in Table 4.

Table 4 – Summary of Designated Sites

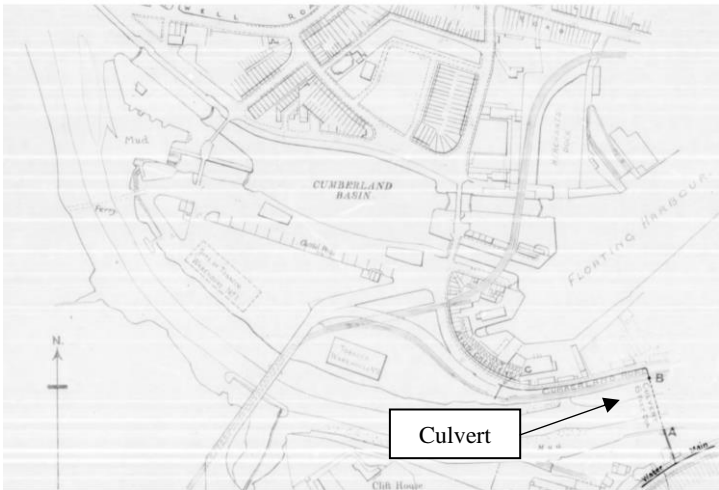
Designated Sites	Description
National Natural Reserves (NNR), Local Natural	There is a Local Natural Reserves (LNR) of Avon New Cut covering the river extent immediately to the south of the proposed works.

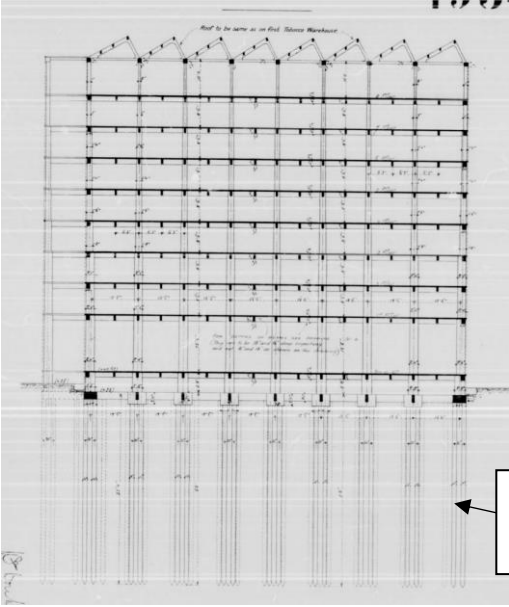
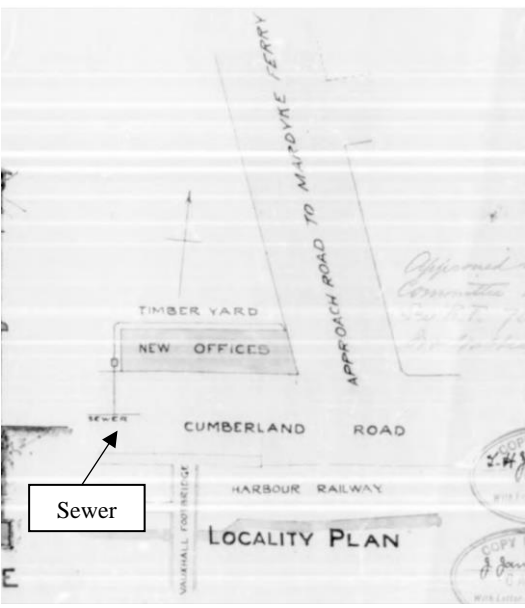
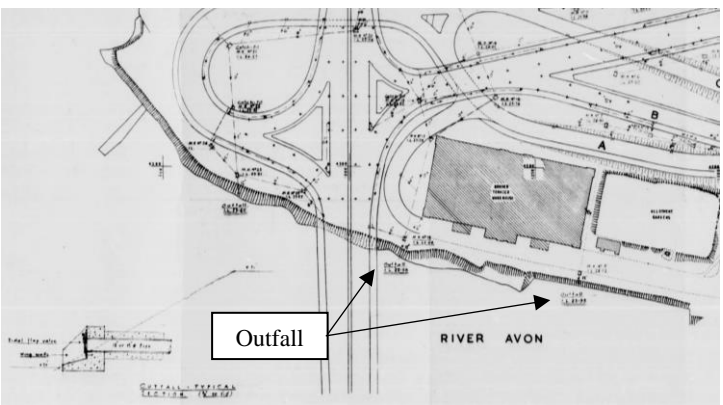
Reserves (LNR), Ancient Woodland	
Historic Environment	“Underfall Yard, Bristol Docks” is a Scheduled Monument and is located near the western end of Reach 2.
Habitats	The banks of the River Avon are classed as Mudflats by the Environment Agency, which are protected as a priority habitat. The Avon New Cut is designated as a Local Nature Reserve.
Protected Species / Invasive Species	There are no records of Protected Species / Invasive Species within or in close proximity of the proposed works.
Landfills	There is a designated area of historic landfill called “Clift House Tannery” on the south bank of the River Avon at approximately ST 57112 71982. The licence was active between 1977 and 1993 involving inert materials. It is approximately 1 acre in area. It is anticipated that this may be associated with land raising rather than a landfill given the location and proximity to the Avon New Cut. Given it is present to the south of the Avon New Cut it is not considered a potential risk to the proposed works.

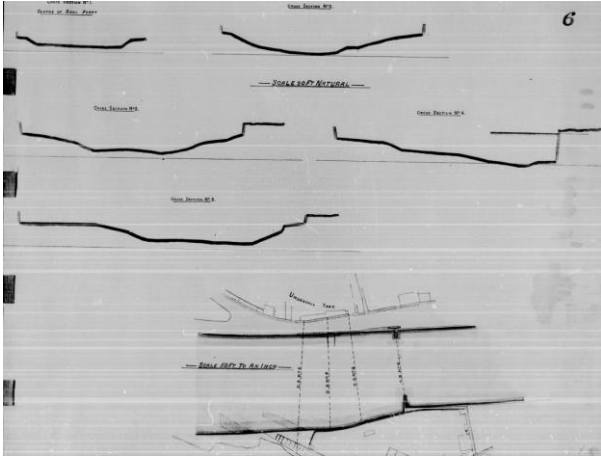
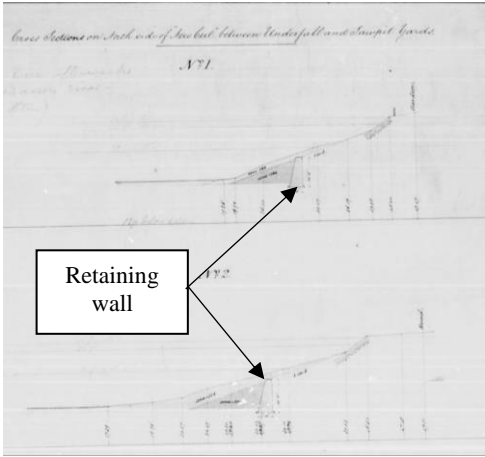
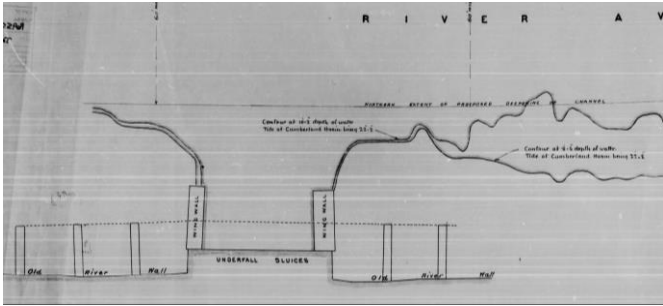
4.8 Bristol City and the Harbour Office Archives

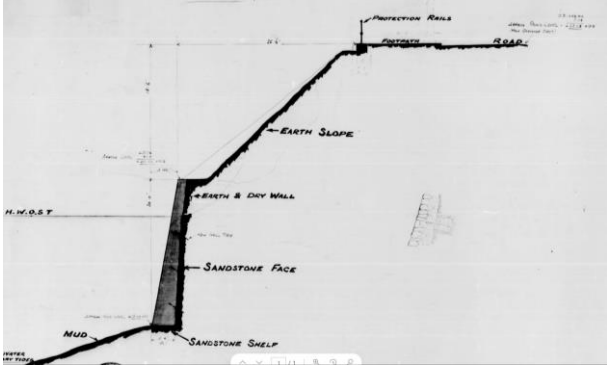
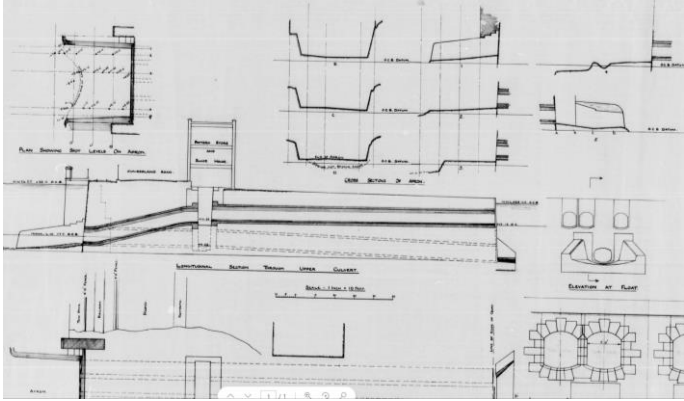
Bristol City and the Harbour Office Archives documents were used to acquire information from records detailing the original engineering works at Cumberland Road. Relevant extracts from documents have been included in Table 5. These have allowed for an informed interpretation of the site.

Table 5 – Snippets of Relevant Archives Documents

Snippets of Relevant Archives Documents	Description
 <p data-bbox="165 1509 887 1568">Archive reference: CD-03881_38402-000384_Proposed Work on Culvert Water Main around Cumberland Basin_14-12-1983</p>	<p data-bbox="919 1003 1388 1196">As shown on the historic drawing on “Proposed Work on Culvert Water Main Around Cumberland Basin_14-12-1983”, there is a culvert water main recorded on the east of Avon crescent between Cumberland Road and Coronation Road. The culvert is of 6ft (circa 1.8m) dia. as indicated in the drawing.</p>

Snippets of Relevant Archives Documents	Description
 <p>Possibly the driven timber piles</p> <p>Archive reference: CD-02097_4790_Transfer Section Drg No 2_24-08-1905</p>	<p>To the west of Reach 2, there were Tobacco warehouse buildings located on Cumberland Basin on either side of the Ashton Ave bridge. From the historic drawing, the buildings were supported by piles, which appears to be driven timber pile, of 15in (circa 0.4m) dia. and 51ft 4in (circa 13m) long. The impact of this foundation to the proposed works is considered negligible due to its distance from Reach 2. The foundation depth is indicative of bedrock depth to at least 13m depth in the area near the west of Reach 2.</p>
 <p>Sewer</p> <p>Archive reference: CD-03892_38402-000397_Offices Cumberland Road_14-12-1983</p>	<p>There was a sewer drain beneath the Cumberland Road opposite to Vauxhall bridge and adjacent to Mardyke Ferry Road, as indicated on the drawing dated c.1983. This implies potential underground utilities near the proposed works.</p>
 <p>Outfall</p> <p>RIVER AVON</p>	<p>There are two no. of outfalls on the west of Reach 2 on the front of Tobacco Warehouse Building along with the existing watermain and manhole, as indicated on the drawing date c.1984</p>

Snippets of Relevant Archives Documents	Description
<p>Archive reference: CD-05471_38402-001233_Cumberland Road Junction Drainage and Services_21-02-1984</p>  <p>Archive reference: CD-06002_38402-002394_Sections Across New Cut_06-10-1989</p>	<p>There are sections across the New Cut besides the outfall sluice, showing the river profiles, as indicated in the drawing date c.1989.</p>
 <p>Archive reference: CD-06199_38402-001431_Cross Sections on South Side of New Cut Between Underfall and Sawpit Yards</p>	<p>There are records on retaining walls of circa. 10ft 6in – 16ft (3.2 – 4.9m) in height on the north side of Avon New Cut between Underfall and Sawpit yards. Above the retaining wall were the 1 in 3 slope till the brick-facing slope beneath the road.</p>
 <p>Archive reference: CD-06135_38402-002497_Underfall Sluices_12-10-1989</p>	<p>Plan view of the Underfall sluice showing the arrangement of wing wall for the Underfall sluice and the old river wall.</p>

Snippets of Relevant Archives Documents	Description
 <p>Archive reference: CD-07700_38401-000001_Slip of Wall in New Cut Gaol Ferry_24-11-1982</p>	<p>As shown on the drawing, titled “Slip of wall in New Cut Gaol Ferry” dated 24/11/1982, there was a 20ft (6.1m) high retaining wall recorded at the river bank, probably as part of the stabilization works. The retaining wall is shown sitting on mud at 15ft (4.6m) AOD with sandstone wall facing.</p>
 <p>Archive reference: CD-07773_38401-000010_Underfall Sluices_08-11-1989</p>	<p>Plan view of the Underfall Sluice, elevation and the longitudinal section of its culvert, as shown on the drawing dated 22/9/1944.</p>

5. Headliner Risk Assessment

A number of information sources have been consulted to inform site conditions, constraints, and likely risks to be encountered during development of the site. These items are summarised below, together with a prediction of their risk to the works, and description of any findings.

Risk item	Description	Source of Information
Loose ground	<p>BGS maps illustrate the course of the River Avon as Worked (excavated) Ground, referring to its diversion along the ‘New Cut’ (completed in 1809) for the establishment of Bristol Floating Harbour. Both riverbanks are delineated as Made (artificially raised) Ground. BGS boreholes have recorded a minimum thickness of 1.2m of Made Ground across Spike Island.</p> <p>This Worked and Made Ground likely consists of loose material, as evidenced by historical failures along the River Avon’s banks. Failures within the site boundaries include:</p> <ol style="list-style-type: none"> 1. The area currently under construction due to failure of the historic retaining structure in 2019. 2. A section of the historic retaining structure (ST 57141 72070) which failed in 1981. 3. A region along the eastern extent of the reach, where recent support structures and soil pins have been attached to the historic retaining structure. <p>Proposed works must take into account the tidal nature of the River Avon, considering its fluctuating water levels. The cyclic flow rates of the river will influence erosion and sediment deposition rates along the riverbank.</p>	<ul style="list-style-type: none"> • BGS maps • Drawing “Opportunities and constraints plan – Cumberland Road” (Ref: 285982-ARP-XX-DR-CIV-101) • Google Maps • RA001-RA037 Combined Photos from Bristol Heritage Railway (BHR)
Soft ground	The extent of superficial deposits are shown in Figure 6. Across the site, these are classified as Tidal Flat Deposits comprising silts and clays with peat layer.	BGS map 1: 50,000 sheet 264 (2004)
Bedrock level	<p>Bedrock beneath the entirety of the reach is known to be of the Mercia Mudstone Group and Redcliffe Sandstone Formation. Rockhead is expected at increasingly shallow depths towards the east of the reach, and nearby to ground level from around the location of Vauxhall Bridge.</p> <p>In a previous investigation, cobbles were encountered at the base of superficial deposits on the riverbank beside the Underfall sluice.</p>	<ul style="list-style-type: none"> • BGS map 1: 50,000 sheet 264 (2004) • Geotechnical Constraints Map (Ref. AVTM-X-PR-DRG-001), by Halcrow & West of England, 2013.
Groundwater / Hydrogeology	<p>The BGS Hydrogeological 1:625,000 map classifies the majority of the site as Triassic rocks (undifferentiated) and a moderately productive aquifer summarised as a locally important aquifer generally producing hard groundwater from solution enhanced joints.</p> <p>Groundwater is expected to fluctuate with the water level of the River Avon, as well being impacted by the water level of the floating harbour located to the north of the site.</p>	BGS Hydrogeological Maps
Hydrology	There is an artificially excavated channel, Avon New Cut, located to the south of the reaches running westwards. To the north of the Spike Island that the reaches to be built on is the Floating Harbour, which is approximately 50m to 200m to the north of the reaches.	Google Map

Risk item	Description	Source of Information
Coal measures / mining	<p>According to Coal Authority Interactive Online Map, the entirety of the reach is within the Coal Mining Reporting Area, and a section of the western extent of the reach is within an area designated in the Abandoned Mines Catalogue (No. SWR3435).</p> <p>The Ashton Little Coal seam and the Ashton Great Coal seam are shown on BGS maps to run parallel to each other beneath the western extent of the reach continuing to the north of Spike Island. These are the areas defined as Development High Risk Area and Probable Shallow Coal Mine Working. Any coal seams beneath the site are unlikely to be encountered above 30m depth.</p>	<ul style="list-style-type: none"> • Coal Authority Interactive Viewer • BGS map
Obstructions / Archaeology	<p>There is potential risk of obstruction associated with the Underfall sluice and its associated structures, which are located to the west of Reach 2 (centred approximately at National Grid Reference ST 57231 72077) and are visibly in disrepair.</p> <p>Another potential source of obstruction is the Albion Dockyard Outfall pipeline, which is located on the riverbank to the east of Vauxhall Bridge (centred approximately at National Grid Reference ST 57774 72147).</p> <p>It is also worth noting that the nearby Underfall Yard is a Scheduled Ancient Monument.</p>	Historic drawings
Services / Utilities	A previous investigation gained service and utility plans for the length of the reach. These show various underground electric cables, water mains, gas mains, foul water sewers and road drains running along the northern pavement and vehicle lane of Cumberland Road.	Illustrative Corridor Utilities Plan (Ref. AVTM-UT-DRG-010 to 014) by Halcrow & West of England, 2013
UXO	A Zetica report download shows that the entire reach is within a zone at high risk of unexploded ordnance. This is defined as being an area with a bombing density of '50 bombs per 1000 acre or higher'. There are various Luftwaffe targets around the entrance to the floating harbour and along Spike Island. There have been several confirmed UXO items found to the east of the reach around the M Shed and the Arnolfini museum.	Zetica UXO
Soil disposal / waste	Contamination may present within the site, such as Made Ground, given the nearby railway infrastructure. Any potential offsite disposal requirements should be considered and soil classification will be required for offsite disposal, where necessary.	Historic drawings
Environmental	The banks of the River Avon are classed as Mudflats by the Environment Agency, which are protected as a priority habitat.	Environment Agency WMS service
Landfills	There is a designated area of historic landfill called "Clift House Tannery" on the south bank of the River Avon at approximately ST 57112 71982. The licence was active between 1977 and 1993 involving inert materials. It is approximately 1 acre in area. It is expected that this may be associated with land raising, and since it is located south of the Avon New Cut and outside of the proposed works it is unlikely to impact the proposed works.	Environment Agency WMS service
Contaminated land / ground gas	<p>In a previous investigation, methane was encountered in superficial deposits around the A Bond Tobacco Warehouse building. This will need to be included as a risk for construction workers but is unlikely to have an impact post development.</p> <p>The site history, in particular its use as a railway and associated made ground used in the construction of the railway and backfill to the river wall, are considered potential on site sources of contamination. This material may contain heavy metals, asbestos and organic contaminants. These would present a potential risk to construction workers involved in the scheme. Risks to end site users post site development would likely be mitigated by the development itself. There is a potential risk of impact to surface waters albeit this is considered to be relatively low post development. Further intrusive works including chemical analysis of the site soils is considered necessary to confirm the risks.</p>	Geotechnical Constraints Map (Ref. AVTM-X-PR-DRG-001), by Halcrow & West of England, 2013

Risk item	Description	Source of Information
Solution features	Review of the BGS geological map and existing ground investigation records on the site solid geology indicates that the potential for ground dissolution stability hazards is low for the site.	<ul style="list-style-type: none"> • BGS geological map • Existing ground investigation records
Flood Risk	The Environment Agency flood maps indicate the risk of flooding due to rivers or sea is very high. The risk of flooding from surface water is very low.	Environment Agency Flood Maps

6. References

- [1] National Library of Scotland, “Map Finder Georeferenced Maps Side by Side,” National Library of Scotland, 2023. [Online]. Available: <https://maps.nls.uk/geo/explore/side-by-side>.
- [2] “<https://www.bristolfloatingharbour.org.uk/harbour-trails/heritage-trails/the-new-cut/>,” [bristolfloatingharbour.org](https://www.bristolfloatingharbour.org), 2009. [Online].
- [3] British Geological Survey, “BGS Maps Portal,” British Geological Survey, 2023. [Online]. Available: <https://www.bgs.ac.uk/information-hub/bgs-maps-portal/>.
- [4] The Coal Authority, “Interactive Map,” The Coal Authority, 2023. [Online]. Available: <https://mapapps2.bgs.ac.uk/coalauthority/home.html>.
- [5] Zeica UXO, “Risk Maps,” XIST2, 2023. [Online]. Available: <https://zeticaxo.com/downloads-and-resources/risk-maps/>.
- [6] Bristol Council, “Know Your Place Bristol,” 2023. [Online]. Available: <https://maps.bristol.gov.uk/kyp/?edition=>.
- [7] Natural England & Landmark, “MAGIC MAP,” Landmark, 2023. [Online]. Available: <https://magic.defra.gov.uk/MagicMap.aspx>.
- [8] Environment Agency, “Historic Landfill Sites,” Environment Agency, [Online]. Available: <https://www.arcgis.com/apps/mapviewer/index.html?layers=23387a5a77514de59929dd67a97abd5a>. [Accessed 2023].
- [9] Historic Environment Scotland, “Britain From Above,” Historic Environment Scotland, 2023. [Online]. Available: <https://www.britainfromabove.org.uk/en>.
- [10] Historic England, “<https://historicengland.org.uk/images-books/archive/collections/aerial-photos/>,” Historic England, 2023. [Online]. Available: <https://historicengland.org.uk/images-books/archive/collections/aerial-photos/>.

Appendix A

BGS Borehole Records

DEPTH OF BOREHOLE

ST 57 SE / 131

3b

TYPE OF RIG	CORE BARREL & BIT DESIGN	ORIENTATION	SITE Bristol Barrage, P. Avon (New Cut).	SHEET No 2 of 2
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DRILLING & CASING PROGRESS	WATER RECOVERY AM LEVEL	R.O.D.	CORE RECOVERY & SIZE	DESCRIPTION OF STRATA	FOOTNOTES	U.D. LEVEL	SYMBOLIC LOG
				Red sandy mud and grey quartzite			
fractured "gash veins"				Grey quartzite with red brecciated "gash veins"			
				Grey impure quartzite with carbonaceous reaction			
				Grey quartzite sandstone with slight carbonate reaction.			
				Grey quartzite			
				Quartzitic sandstone with carbonate reaction quartzite with vertical "gash veins" base of 34'			

REMARKS

CLIENT

Sir Alexander Gibb & Partners,
Tottenham Street,
LONDON SW1.

Shell and auger to
21.50m.
Rotary core drilling
to base.

8.75m.O.D.
DEPTH OF BOREHOLE
30.00m.

S1575E/134
ST 57:87215
1st 264

7

TYPE OF RIG

CORE BARREL
& BIT DESIGN
Diamond
NX Bit.

ORIENTATION

Vertical

SITE

Bristol Barrage,
N. Avon (New Cut).

SHEET No.

1 of 2

DRLING & CASING PROGRESS	WATER RECOVERY & A.M. LEVEL	R.O.D.	CORE RECOVERY & SIZE	DESCRIPTION OF STRATA	FOOTNOTES	O.D. LEVEL	SYNTHETIC LOG
				Fill, ash and soil			
				Soft to firm, brown and grey silty clay with some stones.			
				Soft, brown and grey, silty clay, slightly sandy.			
				Soft to firm, brown and grey, silty clay, slightly sandy in places.			
				Dense, medium to large gravel.			
				Medium, dense, fine gravel.			
				Red and grey silt, fine becoming harder with depth.			

log ends
21/7/75
15.30m
22/7/75
7.00m
22/7/75
08.30m
22/7/75

REMARKS

Log based on Driller's Daily Report.

CLIENT Sir Alexander Gibb & Partners,
Tophill Street,
LONDON SW1A.

Shell and auger to
24.30m.
Rotary core drilling
to base.

3.10m. O.D.,
DEPTH OF BOREHOLE
27.60m.

ST 57297211

1st 264

8

TYPE OF RIG

CORE BARREL
& BIT DESIGN
Diamond
NX Bit

ORIENTATION

Vertical

SITE

Bristol Barrage,
R. Avon (New Cut).

SHEET No.

1 of 2

DRILLING & LOGGING F.O.C.D. RECORDS F.O.C.D. RECORDS F.O.C.D. RECORDS	CORE BARREL & BIT DESIGN	ORIENTATION	SITE	DESCRIPTION OF STRATA	FOOTNOTES	O.D. LEVEL	SYMBOLIC LOG
				Fill rubble, ash and soil.			
				Fine, brown and grey clay.			
				Soft to firm, brown and grey clay with some stones.			
				Soft, grey, peaty clay with some stones.			
				Peat, with grey clay and some stones.			
				Soft to firm, grey, silty clay and some stones.			
				Fine brown clay with streaks of grey clay.			
				Soft to firm, brown and grey, silty clay with sand layers.			
				Medium dense fine gravel.			
				Hard red and grey marl.			

REMARKS

1 Log based on Driller's Daily Report.

SHEET Sir Alexander Gibb & Partners,
Tophill Street,
LONDON SW1.

DRILLING METHOD

GROUND LEVEL

SS DISTANCES

DEPTH OF BOREHOLE

ST 75E/135

8

TYPE OF RIG

CORE BARREL
& BIT DESIGN

ORIENTATION

SITE

Bristol Barrage,
R. Avon (New Cut).

SHEET No.

2 of 2

DRILLING &
LOGGING
PROGRESS20 WHITE
45 REDDISH
50 A.M. LEVEL30 R.Q.D.
30
3030 CORE
FE SIZE
30

DESCRIPTION OF STRATA

FOOTNOTES

O.D. LEVEL

SYMBOLIC
LOG

Hard, red and grey sand.

Fine gravel.

Hard red and grey sand.

Red sandstone with some brachiopodiferous
layers.Grey quartzite with grey breccias, some of
which with limestone fragments.

Grey quartzite.

BASE OF B.H.

REMARKS

1 log based on Driller's Daily Report.

CLIENT

Sir Alexander Gibb & Partners,
Tothill Street,
LONDON SW1.

Shell and auger to
14.38m.
Rotary core drilling
to base.

6.48m. O.D.
DEPTH OF BOREHOLE
27.50m.

SF 57525/136
ST 57397208
1" 264

9

TYPE OF RIG	CORE BARREL & BIT DESIGN Diamond MX Bit.	ORIENTATION Vertical	SITE Bristol Barrage, R. Avon (New Cut).	SHEET No. 1 of 2
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DRILLING & LOGGING PROGRESS	CORE RECOVERY % (M. & S. & S. & S.)	R.C.D.	DESCRIPTION OF STRATA	FOOTNOTES	C.D. LEVEL	SAMPLES
			Brown, soft clay.			
			Soft, grey silty clay			
			Soft, grey brown silty clay			
			Soft, grey silty clay with organic matter			
			Firm brown peat			
			Gray soft silty clay			
			Firm to stiff red brown, grey very silty clay.			
			Red brown grey silty clay			
			Coarse and medium size gravel.			
			Hard red sand.			
			Buff red silty sand			
			Buff red silty sand			
			Buff red, sandy, fine grained sandstone with tan green lenses.			
			Buff red, sandy, fine grained sandstone with red green lenses.			

17.00m
5/6/73
17.30m
7/5/73
20.30m
7/5/73
20.50m
7/5/73

REMARKS
1 Rockhead.
2 Log based on Driller's Daily Reports

CLIENT Sir Alexander Gibb & Partners,
Tothill Street,
LONDON SW1.

TRIAL PIT THREE

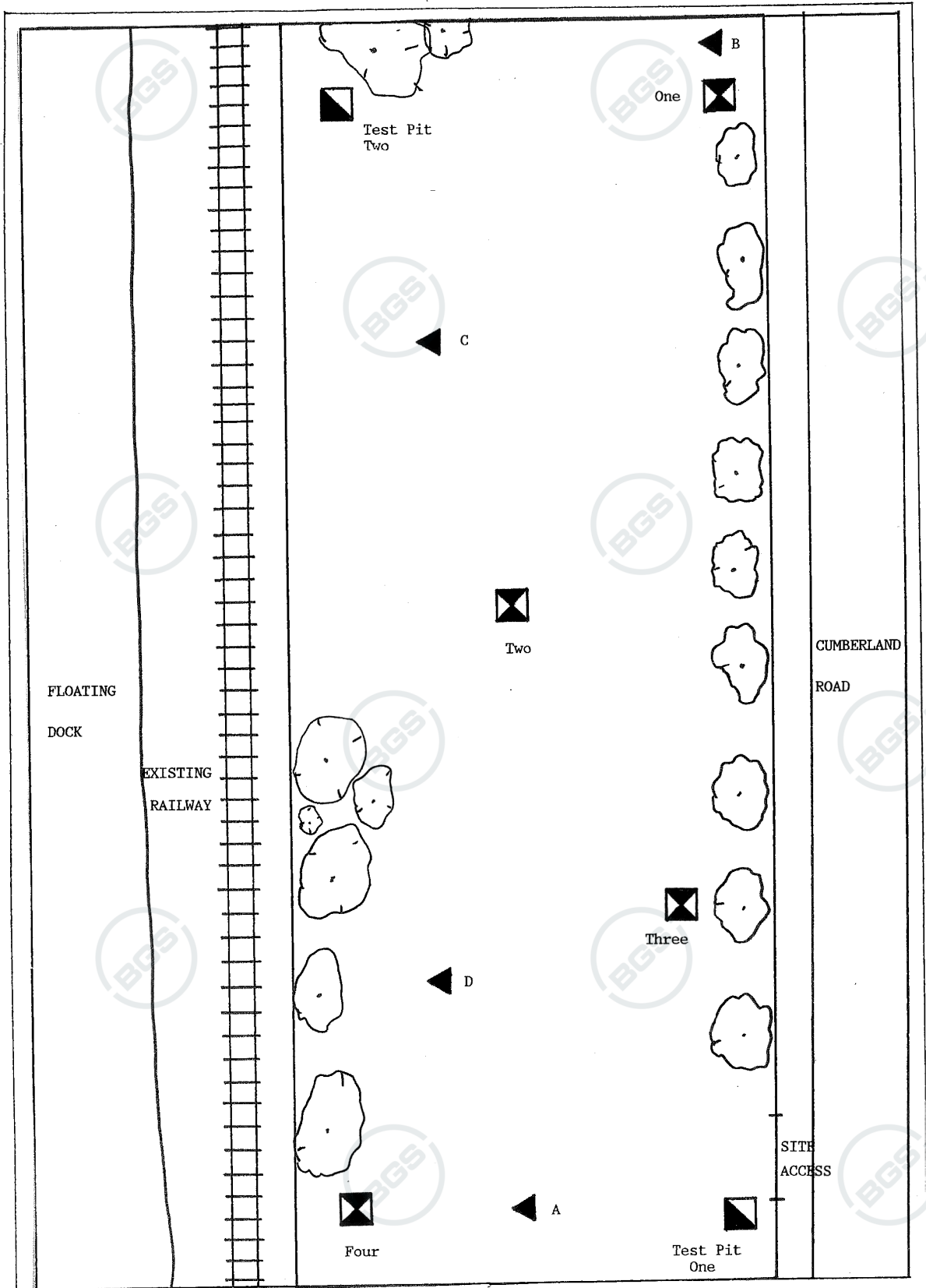
Depth -m	Strata Description
	MADE GROUND
Ground level - 1.10	Red brick, concrete tile, glass and limestone rubble.
	WEATHERED ZONE
1.10 - 2.70	Medium to coarse red brown clayey SAND, clay content increasing with depth.
	REDCLIFFE SANDSTONE
2.70 - 2.80	Buff pink coarse grained rubbly, becoming massive with depth, moderately strong calcareous SANDSTONE.

Remarks

1. Trial pit excavated by mechanical excavator on 4.06.1987.
2. Trial pit dimensions 1.10 x 2.20 x 2.80m deep.
3. No groundwater encountered.
4. Dynamic penetration test undertaken in the base of the trial pit shows a 'N' value equivalent of 14 for a penetration of 210mm at 2.80m.

Date June, 1987	TRIAL PIT LOG	Report No. S.888
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TYRONE



Trial Pit Location



Penetration Probe Location

Approximate scale 1 : 265

<p>Date June, 1987</p>	<p>TRIAL PIT / PENETRATION PROBE LOCATION PLAN</p> <p>TYRONE</p>	<p>Report No. S.888</p>
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TRIAL PIT FOUR

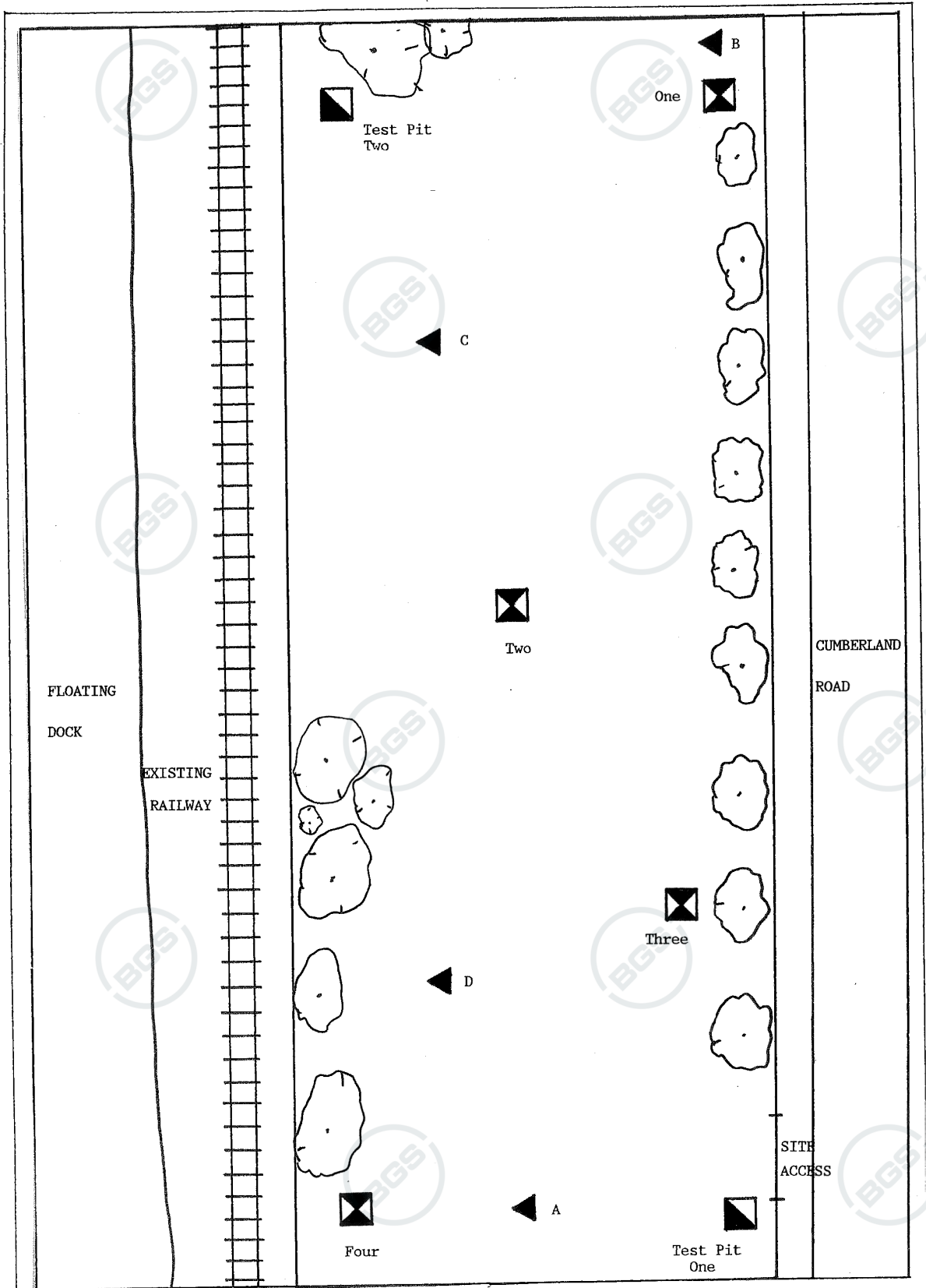
Depth -m	Strata Description
	MADE GROUND
Ground level - 1.10	Loose buff grey sandstone chippings.
0.10 - 1.10	Red brick, bottles and concrete set in a dark brown silty matrix with occasional marl layers.
1.10 - 1.21	Black cinder layer.
	WEATHERED ZONE
1.21 - 2.34	Medium to coarse dark red brown slightly clayey SAND with small fragments of weathered buff SANDSTONE.
	REDCLIFFE SANDSTONE
2.34 - 3.30	Buff red brown coarse grained rubbly, becoming massive with depth fresh moderately strong calcareous SANDSTONE.

Remarks

1. Trial pit excavated by mechanical excavator on 4.06.1987.
2. Trial pit dimensions 1.10 x 2.00 x 3.30m deep.
3. No groundwater encountered.
4. Dynamic penetration test undertaken in the base of the trial pit shows a 'N' value equivalent of 15 for a penetration of 15mm at 3.90m.

Date. June, 1987	TRIAL PIT LOG	Report No. S.888
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TYRONE



Trial Pit Location



Penetration Probe Location

Approximate scale 1 : 265

<p>Date June, 1987</p>	<p>TRIAL PIT / PENETRATION PROBE LOCATION PLAN</p> <p>TYRONE</p>	<p>Report No. S.888</p>
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Appendix B

Existing Site Investigation Records



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545		
Contract Ref: 727305		Start: 21.06.13	End: 24.06.13	Ground Level (m AOD): 8.97	National Grid Co-ordinate: E:357291.2 N:172096.3		Sheet: 1 of 10	

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
0.50 0.50	1 2	ES B								MADE GROUND: Dark brownish grey very sandy, fine to coarse subangular to angular GRAVEL of limestone and sandstone with rare brick fragments. (MADE GROUND)	7.97	1.00	[Cross-hatch pattern]
1.00 1.00	3 4	ES B								MADE GROUND: Dark mottled grey reddish brown sandy slightly gravelly CLAY. Gravel is fine to coarse, subangular to angular of sandstone and limestone. With rare coal and brick fragments. (MADE GROUND)	7.77	1.20	[Cross-hatch pattern]
1.20	5	U _(UT100)	7 blows							Soft low strength greyish brown slightly sandy slightly gravelly CLAY. Gravel is fine to medium subangular to subrounded of sandstone and limestone. (ALLUVIUM)			[Horizontal line pattern]
1.80 1.80	6	D HP	c _u =25								6.97	2.00	[Horizontal line pattern]
2.00-2.45 2.00-2.50	7 8	SPT B	1/1,1 N=2							Soft to firm high strength greyish brown slightly sandy slightly gravelly CLAY. Gravel is fine to medium subangular to subrounded of sandstone and limestone. (ALLUVIUM) ... with rare fragments of coal at 2.00m.			[Horizontal line pattern with circles]

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Boring Progress and Water Observations						Chiselling / Slow Progress			General Remarks			
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	From	To	Duration (hh:mm)				
21/06/13		15.00	15.00	150	15.00							
24/06/13	13:20	18.00	17.70	121	16.10							
All dimensions in metres								Scale: 1:14				
Method Used:	Cable Percussion + Rotary Cored		Plant Used:	Dando 3000 + Comacchio MC300		Drilled By:	DS + LH		Logged By:	BSaimen + JShallcross + CReader	Checked By:	

1. Location CAT scanned prior to drilling and hand dug inspection pit from ground level to 1.20m depth.
2. Cable percussion boring from 1.20m to 18.00m depth.
3. Rotary coring from 18.00m to 23.40m depth.
4. Water flush used.



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545		
Contract Ref: 727305		Start: 21.06.13	Ground Level (m AOD): 8.97	National Grid Co-ordinate: E:357291.2 N:172096.3		Sheet: 2 of 10		
End: 24.06.13								

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
3.00	9	U _(UT100)	12 blows									(1.60)	
3.60 3.60	10	D HP	c _u =60							Firm medium strength light greyish brown slightly sandy slightly gravelly CLAY. Gravel is fine to medium subangular of sandstone and limestone. (ALLUVIUM)	5.37	3.60	(0.40)
4.00-4.45	11	SPT	/1,1							Very soft becoming soft medium strength bluish grey mottled brown slightly sandy CLAY. (ALLUVIUM)	4.97	4.00	
4.00-4.50	12	B	N=2										

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Boring Progress and Water Observations						Chiselling / Slow Progress			General Remarks				
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	From	To	Duration (hh:mm)					
									5. SPT hammer RD01-2012 (E _r = 71.40%) used.				
All dimensions in metres									Scale: 1:14				
Method Used:	Cable Percussion + Rotary Cored		Plant Used:	Dando 3000 + Comacchio MC300			Drilled By:	DS + LH		Logged By:	BSaimen + JShallcross + CReader	Checked By:	



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads		Client: Bristol City Council		Borehole: BH545	
Contract Ref: 727305		Start: 21.06.13 End: 24.06.13	Ground Level (m AOD): 8.97	National Grid Co-ordinate: E:357291.2 N:172096.3	
				Sheet: 3 of 10	

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
5.00	13	U _(UT100)	12 blows										
5.60 5.60	14	D HP	c _u =35							... below 5.60m clay becomes soft.			
6.00-6.45	15	SPT	1/1,2,1,2 N=6									(4.10)	
6.00-6.50	16	B											

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Boring Progress and Water Observations						Chiselling / Slow Progress			General Remarks			
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	From	To	Duration (hh:mm)				
All dimensions in metres								Scale: 1:14				
Method Used:	Cable Percussion + Rotary Cored		Plant Used:	Dando 3000 + Comacchio MC300		Drilled By:	DS + LH		Logged By:	BSaimen + JSHallcross + CReader	Checked By:	



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545		
Contract Ref: 727305		Start: 21.06.13 End: 24.06.13	Ground Level (m AOD): 8.97		National Grid Co-ordinate: E:357291.2 N:172096.3		Sheet: 5 of 10	

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
10.50	21	U _(UT100)	13 blows										
11.10 11.10	22	D HP	c _u =100							... with rare calcareous concretions at 11.10m.			
12.00-12.45	23	SPT	1,2/3,3,2,3 N=11										
12.00-12.50	24	B										(5.50)	

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Boring Progress and Water Observations						Chiselling / Slow Progress			General Remarks			
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	From	To	Duration (hh:mm)				
All dimensions in metres								Scale: 1:14				
Method Used:	Cable Percussion + Rotary Cored		Plant Used:	Dando 3000 + Comacchio MC300		Drilled By:	DS + LH		Logged By:	BSaimen + JShallcross + CReader	Checked By:	



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545		
Contract Ref: 727305		Start: 21.06.13 End: 24.06.13	Ground Level (m AOD): 8.97		National Grid Co-ordinate: E:357291.2 N:172096.3		Sheet: 6 of 10	

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
13.50	25	U _(UT100)	14 blows										
14.10	26	D											
											-6.03	15.00	

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Boring Progress and Water Observations						Chiselling / Slow Progress			General Remarks								
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	From	To	Duration (hh:mm)									
Method Used: Cable Percussion + Rotary Cored								Plant Used: Dando 3000 + Comacchio MC300		Drilled By: DS + LH		Logged By: BSaimen + JSHallcross + CReader		Checked By:			
All dimensions in metres										Scale: 1:14							



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545		
Contract Ref: 727305		Start: 21.06.13	Ground Level (m AOD): 8.97	National Grid Co-ordinate: E:357291.2 N:172096.3		Sheet: 7 of 10		
			End: 24.06.13					

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
15.00-15.44	27	SPT	5,11/16,14,11,9 for 65mm N=52*							Very dense dark greyish brown sandy GRAVEL with a low cobble content. Gravel is rounded to subangular of sandstone and limestone. Cobbles are subangular of sandstone. (TIDAL FLAT DEPOSITS)			
15.00-15.50	28	B										(1.50)	
16.50-16.88	29	SPT	6,8/11,18,18,3 for 0mm N=67*							Very dense light greyish brown slightly clayey sandy GRAVEL with a low cobble content. Gravel is rounded to subangular of sandstone and mudstone. Cobbles are subangular of sandstone. (TIDAL FLAT DEPOSITS)			
16.50-17.00	30	B										(0.50)	
17.00	31	D								Reddish brown mottled grey slightly sandy silty CLAY. (MERCIA MUDSTONE GROUP Zone IVb)	-8.03	17.00	
												(1.00)	

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Boring Progress and Water Observations						Chiselling / Slow Progress			General Remarks				
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	From	To	Duration (hh:mm)					
All dimensions in metres													
Scale: 1:14													
Method Used:	Cable Percussion + Rotary Cored		Plant Used:	Dando 3000 + Comacchio MC300			Drilled By:	DS + LH		Logged By:	BSaimen + JShallcross + CReader	Checked By:	



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545		
Contract Ref: 727305		Start: 21.06.13 End: 24.06.13	Ground Level (m AOD): 8.97		National Grid Co-ordinate: E:357291.2 N:172096.3		Sheet: 8 of 10	

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
18.00-18.90											-9.03	18.00	
18.00	32	D											
18.00-18.39	33	SPT	8,9/14,14,18,4 for 15mm N=62*										
18.00													
18.00	33	D HP	c _u => 250										
18.55-18.80				100	100	100							
	27	CS											
18.90-20.40													
							150 300 800						
19.70-19.90				100	100	100						(2.90)	
	28	CS											

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Boring Progress and Water Observations						Chiselling / Slow Progress			General Remarks	
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	From	To	Duration (hh:mm)		
Method Used: Cable Percussion + Rotary Cored						Plant Used: Dando 3000 + Comacchio MC300			Drilled By: DS + LH	
All dimensions in metres						Scale: 1:14			Logged By: BSaimen + JSHallcross + CRader Checked By:	



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545		
Contract Ref: 727305		Start: 21.06.13	End: 24.06.13	Ground Level (m AOD): 8.97	National Grid Co-ordinate: E:357291.2 N:172096.3		Sheet: 9 of 10	

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
20.40-21.90				100	100	100	150 300 800			rough infilled with red clay upto 3mm.			
21.40-21.53	29	CS		93	93	89	150 200 400			Very weak locally extremely weak reddish brown fine to medium SANDSTONE with rare lenticular pockets (<10mm) of greenish grey fine to coarse sandstone. Bedding fracture are 5 to 10° closely to medium spaced undulating rough infilled with red clay/smears of red clay. Joints are 30 to 80° fine to medium spaced partly open with red clay upto 2mm. (REDCLIFF SANDSTONE FORMATION Zone I) ... between 21.00 and 21.20m depth extremely closely spaced lenticular pockets of greenish grey extremely weak siltstone/fine sandstone. ... between 21.07 and 21.25m depth joint is 80° planar rough. ... at 21.35m depth purple fine to medium grained strong sandstone/quartzite layers up to 40mm. ... at 21.54m depth joint is 30° undulating rough with orange brown discolouration on surface.	-11.93	20.90	(0.90)
21.90-23.40				100	100	96	50 110 290			... at 21.54m depth joint is 30° undulating rough with orange brown discolouration on surface. ... between 21.70 and 21.80m depth joint is 60° planar infilled with red clay upto 2mm. Weak very thinly to medium bedded reddish brown SILTSTONE with very weak to extremely weak occasional lenticular irregular pockets (<10mm) of greenish grey siltstone. Bedding fractures are 5 to 15° very closely to medium spaced undulating rough infilled with red sandy clay. (MERCIA MUDSTONE GROUP Zone I) <i>Description on next sheet</i>	-12.83	21.80	

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Boring Progress and Water Observations						Chiselling / Slow Progress			General Remarks			
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	From	To	Duration (hh:mm)				
All dimensions in metres								Scale: 1:14				
Method Used:	Cable Percussion + Rotary Cored		Plant Used:	Dando 3000 + Comacchio MC300		Drilled By:	DS + LH		Logged By:	BSaimen + JSHallcross + CRader	Checked By:	



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545D		
Contract Ref: 727305		Start: 17.06.13	Ground Level (m AOD): 9.26	National Grid Co-ordinate: E:357373.9 N:172113.5		Sheet: 1 of 6		
End: 18.06.13								

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
0.50	1	ES								MADE GROUND: Black ASPHALT. (MADE GROUND)	8.96	(0.30)	
0.50	2	B								MADE GROUND: Greyish brown very sandy subangular fine to coarse GRAVEL of limestone (sub-base). (MADE GROUND)	8.76	(0.20)	
										MADE GROUND: Dark brown very sandy subangular to very angular fine to coarse GRAVEL of brick, limestone and clinker. (MADE GROUND)	8.46	(0.30)	
1.00	3	ES								POSSIBLE MADE GROUND: Very soft to soft grey occasional mottled brown silty CLAY. Organic odour. (MADE GROUND)	8.06	(0.40)	
1.00	4	B											
1.20-1.65	1	SPT	1/1,1,1							Soft medium strength greyish brown mottled orange slightly sandy CLAY with occasional brown organic matter/pseudo fibrous peaty matter. (ALLUVIUM) ... between 1.40 and 1.60m depth firm.			
1.20-1.70	5	B	N=3										
1.40		HP	$c_u=50/60$										
1.60		HP	$c_u=30/30/35$										
1.70-2.00	6	U _(ws)									7.26	2.00	
2.00-2.30	7	B								Soft becoming firm low to medium strength brown slightly sandy CLAY with occasional black mottling and pseudo fibrous material. (ALLUVIUM) ... between 2.00 and 2.20m depth occasional black mottling of organic material. ... between 2.20 and 2.30m depth occasional pseudo fibrous black peat with an odour of organic material.			
2.00		HP	$c_u=35/25/35$										
2.20-2.65	2	SPT	1,1/1,2,3,2										
2.20		HP	$c_u=25/35$										
2.30-2.50	8	B											
2.35		HP	$c_u=60/62$										

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Boring Progress and Water Observations						General Remarks	
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth		
17/06/13	13:09	3.90	None	121	3.90	1. Location CAT scanned prior to drilling and hand dug inspection pit to 1.20m depth. 2. Dynamic sampling from 1.20m to 12.00m depth. 3. Rotary coring from 12.00m to 13.00m depth. 4. Water strike at 3.90m depth. 5. Water flush used. 6. SPT hammer EQU250-2013 ($E_t = 65.94\%$) used.	
17/06/13	13:29	3.90	None	121	3.40		
18/06/13	08:00	10.20	None	121	1.80		
All dimensions in metres						Scale:	1:14
Method Used:	Dynamic sampling + Rotary Cored		Plant Used:	Comacchio MC300		Drilled By:	JG
						Logged By:	AVenn + BSaimen
						Checked By:	AGS



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545D		
Contract Ref: 727305		Start: 17.06.13	Ground Level (m AOD): 9.26	National Grid Co-ordinate: E:357373.9 N:172113.5		Sheet: 2 of 6		
End: 18.06.13								

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend	
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)							
2.52-2.68	9	U _(WS)												
2.70	10	HP	$c_u=65/62$								6.56	2.70		
2.75-3.08		U _(WS)												
3.08-3.20	11	D	$c_u=65/60$ 18 blows 100% recovery											
3.10		HP												
3.20-3.90		U _(UT100)												
3.90-4.25	12	B										(2.30)		
4.25-4.50	13	D												
4.40		HP	$c_u=65/62$											
4.50-4.85	14	U _(WS)												
4.85-5.00	15	D												
4.90		HP	$c_u=50/55$								4.26	5.00		

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Boring Progress and Water Observations						General Remarks
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	
All dimensions in metres						Scale: 1:14
Method Used: Dynamic sampling + Rotary Cored	Plant Used: Comacchio MC300			Drilled By: JG	Logged By: AVenn + BSaimen	Checked By:



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545D		
Contract Ref: 727305		Start: 17.06.13	Ground Level (m AOD): 9.26	National Grid Co-ordinate: E:357373.9 N:172113.5		Sheet: 3 of 6		
End: 18.06.13								

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend	
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)							
5.00-5.45	3	SPT	2,1/1,1,2,2 N=6							Soft low strength bluish grey mottled brown slightly sandy CLAY with occasional brown mottling of organic material. (ALLUVIUM)				
5.50-6.00 5.50	16	B HP	$c_u=25/30$											
6.50-7.20		$U_{(UT100)}$	19 blows 100% recovery											
7.20-8.70 7.20	17	B HP	$c_u=0/0/0$							Very soft extremely low strength bluish grey locally mottled brown silty CLAY with occasional brown pseudo fibrous peat remains. (ALLUVIUM) ... between 7.20 and 8.70m depth	2.06	7.20		

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Boring Progress and Water Observations						General Remarks	
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth		
All dimensions in metres						Scale:	1:14
Method Used:	Dynamic sampling + Rotary Cored		Plant Used:	Comacchio MC300		Drilled By:	JG
						Logged By:	AVenn + BSaimen
						Checked By:	AGS



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545D		
Contract Ref: 727305		Start: 17.06.13	End: 18.06.13	Ground Level (m AOD): 9.26		National Grid Co-ordinate: E:357373.9 N:172113.5		Sheet: 4 of 6

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend	
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)							
8.70-9.15	4	SPT	2,1/1,2,1,3 N=7							recovery only 15% probably due to the compression of clay.		(2.40)		
9.15-9.60	18	B								... between 8.60 to 8.65 and 8.70 and 8.85m depth band of brown plastic clayey amorphous peat.				
9.40		HP	c _u =0/0/0								-0.34	9.60		
9.60-10.00	19	B								Very soft very low strength greyish blue slightly sandy peaty CLAY with occasional bands of brown plastic clayey amorphous peat. (ALLUVIUM)		(0.40)		
9.90		HP	c _u =20/20/20							... between 9.90 and 10.00m depth clay becomes soft and bluish grey.		-0.74	10.00	

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Boring Progress and Water Observations						General Remarks	
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth		
All dimensions in metres						Scale:	1:14
Method Used:	Dynamic sampling + Rotary Cored		Plant Used:	Comacchio MC300		Drilled By:	JG
						Logged By:	AVenn + BSaimen
						Checked By:	AGS



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads		Client: Bristol City Council		Borehole: BH545D	
Contract Ref: 727305		Start: 17.06.13 End: 18.06.13	Ground Level (m AOD): 9.26	National Grid Co-ordinate: E:357373.9 N:172113.5	
Sheet: 5 of 6					

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
10.00-10.20	20	B								Very soft bluish grey slightly sandy CLAY with closely spaced very thin beds of bluish clayey gravelly fine to coarse sand and occasional brown pseudo fibrous peat. (ALLUVIUM) ... between 10.04 and 10.07 and 10.15 and 10.20m depth bluish grey very thin bed of clayey sand. ... at 10.10m depth brown fibrous peaty material. ... between 10.20 and 10.90m UT100 sample.			
10.08		HP	$c_u=0/0/0$										
10.20-10.90		$U_{(UT100)}$	100% recovery										(0.90)
10.90-11.40	21	B								Very soft extremely low strength bluish grey and brown slightly gravelly slightly sandy CLAY with occasional pockets (3mm) of brown pseudo fibrous peat. Gravel is subrounded to rounded fine to coarse of sandstone. (ALLUVIUM) ... between 10.90 and 11.40m depth clay is very soft and the recovery is 50%. ... at 11.10m depth occasional fine to coarse subrounded to rounded gravel of fine to coarse sandstone.	-1.64	10.90	
10.90		HP	$c_u=0/0/0$										(0.50)
11.40-11.65	22	B								Grey very clayey gravelly fine to coarse SAND. Gravel is subrounded to rounded fine to coarse of white sandstone and siltstone. (TIDAL FLAT DEPOSITS) ... at 11.35m depth fine to coarse subrounded gravel of sandstone.	-2.14	11.40	
11.65-12.00	23	B											(0.25)
12.00-13.00	5	SPT(c)	20,5/31,19 for 50mm N=120*	↑	↑	↑				Grey and brown very clayey very sandy fine to coarse GRAVEL. Gravel is subrounded to rounded fine to coarse of white siltstone and sandstone. (TIDAL FLAT DEPOSITS) ... below 11.65m depth sand grades into clayey gravel.	-2.39	11.65	
12.00-12.24													
				25	0	0				Brown and greyish very clayey very sandy GRAVEL and COBBLES. Gravel is angular to subrounded fine to coarse of brown and green sandstone, quartzite and white siltstone. (TIDAL FLAT DEPOSITS) ... between 12.00 and 13.00m depth recovery is 20%.	-2.74	12.00	
												(1.00)	

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Boring Progress and Water Observations						General Remarks
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	
All dimensions in metres						Scale: 1:14
Method Used:	Dynamic sampling + Rotary Cored		Plant Used:	Comacchio MC300		Drilled By: JG
						Logged By: AVenn + BSaimen
						Checked By: AGS



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads		Client: Bristol City Council		Borehole: BH545D	
Contract Ref: 727305		Start: 17.06.13 End: 18.06.13	Ground Level (m AOD): 9.26	National Grid Co-ordinate: E:357373.9 N:172113.5	
Sheet: 6 of 6					

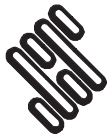
Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
				25	0	0					-3.74	13.00	
Borehole terminated at 13.00m depth.													

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Boring Progress and Water Observations						General Remarks
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	

All dimensions in metres Scale: **1:14**

Method Used: Dynamic sampling + Rotary Cored	Plant Used: Comacchio MC300	Drilled By: JG	Logged By: AVenn + BSaimen	Checked By:	
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Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545E		
Contract Ref: 727305		Start: 17.06.13 End: 18.06.13	Ground Level (m AOD): 9.21		National Grid Co-ordinate: E:357550.6 N:172134.3		Sheet: 1 of 5	

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
0.50	1	ES								MADE GROUND: Black ASPHALT. (MADE GROUND)	9.11	0.10	[Cross-hatch pattern]
0.50	2	B								MADE GROUND: Greyish brown very sandy subangular fine to coarse GRAVEL of concrete, brick and limestone. Cobbles are subangular to angular of concrete. Occasional cobble size clay pockets. (MADE GROUND)		(0.70)	[Cross-hatch pattern]
1.00	3	ES								POSSIBLE MADE GROUND: Firm pale greyish brown silty sandy CLAY with some gravel. (MADE GROUND)	8.41	0.80	[Cross-hatch pattern]
1.00	4	B											
1.20-1.65	1	U _(UT100)	16 blows 90% recovery									(1.00)	[Cross-hatch pattern]
1.65-2.10	1	SPT	1,1/1,1,2,2 N=6										
1.80	6	U _(WS) LB								Stiff high strength brown mottled grey and bluish grey mottled brown slightly sandy CLAY with occasional brown mottling of organic matter. (ALLUVIUM) ... between 1.80 and 2.40m depth clay is brown mottled grey and becomes bluish grey mottled brown.	7.41	1.80	[Horizontal line pattern]
1.80-2.40													
2.00		HP	c _u =80/87/80										
2.40-2.80	7	B											

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Boring Progress and Water Observations						General Remarks					
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth						
17/06/13	16:30	4.70	5.30	121	0.00	1. Location CAT scanned prior to drilling and hand dug inspection pit to 1.20m depth. 2. Dynamic sampling from 1.20m to 6.60m depth. 3. Rotary coring from 6.60m to 10.40m depth. 4. Water flush used. 5. SPT hammer EQU083-2013 (E _r = 67.68%) used.					
18/06/13	09:00	5.30	5.30	121	0.00						
All dimensions in metres						Scale:	1:14				
Method Used:	Dynamic sampling + Rotary Cored		Plant Used:	Comacchio MC300		Drilled By:	LH	Logged By:	AVenn + BSaimen	Checked By:	

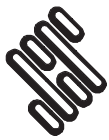


Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545E		
Contract Ref: 727305		Start: 17.06.13	End: 18.06.13	Ground Level (m AOD): 9.21	National Grid Co-ordinate: E:357550.6 N:172134.3		Sheet: 2 of 5	

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
2.80-3.25 2.80	2	U _(UT100) HP	50 blows 100% recovery c _u =95/95									(2.30)	
3.25-3.70	2	SPT	2,2/2,2,3,3 N=10										
3.40 3.40-4.00	8	U B											
3.75		HP	c _u =95/95/97										
4.10-4.40 4.10	9	D HP	c _u =100/95							... between 4.00 and 4.10m depth bed of reddish brown gravelly fine to coarse sand and firm reddish brown mottled black silty clay. Stiff extremely high strength reddish brown slightly sandy CLAY with occasional lenticular pockets (<10mm) of greenish grey fine to coarse sand. (MERCIA MUDSTONE GROUP Zone IVb) ... at 4.30m depth lenticular beds of fine greenish grey siltstone/sandstone.	5.11	4.10	
4.40-4.85	3	U _(UT100)	60 blows 50% recovery										
4.70		U _(WS)											
4.85-5.30	3	SPT	2,4/8,8,12,14 N=42										

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Boring Progress and Water Observations						General Remarks
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	
All dimensions in metres						Scale: 1:14
Method Used: Dynamic sampling + Rotary Cored	Plant Used: Comacchio MC300		Drilled By: LH	Logged By: AVenn + BSaimen	Checked By:	



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545E		
Contract Ref: 727305		Start: 17.06.13	End: 18.06.13	Ground Level (m AOD): 9.21	National Grid Co-ordinate: E:357550.6 N:172134.3		Sheet: 3 of 5	

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
5.30-5.72	4	SPT	4,7/10,12,15,13 for 40mm N=57*									(2.00)	
6.00-6.30	10	D									3.11	6.10	
										Very stiff reddish brown slightly sandy CLAY with occasional lenticular pockets (<10mm) of greenish grey fine to coarse sand. (MERCIA MUDSTONE GROUP Zone IVb)	2.81	6.40	
6.60-8.10										Extremely weak reddish brown thinly to medium bedded SILTSTONE with occasional thin laminations of greenish grey extremely weak siltstone. Bedding fracture is horizontal. (MERCIA MUDSTONE GROUP Zone I)			
7.02-7.40	10	CS		100	100	100	150 200 600			... at 6.90m depth joint is 65° planar partly open.			

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Boring Progress and Water Observations						General Remarks	
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth		
All dimensions in metres						Scale:	1:14
Method Used:	Dynamic sampling + Rotary Cored		Plant Used:	Comacchio MC300		Drilled By:	LH
						Logged By:	AVenn + BSaimen
						Checked By:	AGS



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads			Client: Bristol City Council			Borehole: BH545E		
Contract Ref: 727305		Start: 17.06.13	End: 18.06.13	Ground Level (m AOD): 9.21	National Grid Co-ordinate: E:357550.6 N:172134.3		Sheet: 4 of 5	

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
8.10-9.60				100	100	100		150 200 600		... at 7.45 and 7.60m depth joints are 55° planar partly open.		(2.40)	XXXXXX
8.95-9.25	11	CS		90	90	90				... between 8.40 and 8.55m depth occasional lenticular laminations of extremely weak greenish grey sandstone. ... between 8.64 and 8.82m depth greenish grey extremely weak fine to coarse sandstone with some thin reddish brown laminations of reddish brown completely weathered mudstone. Weak brown thinly bedded fine to coarse SANDSTONE with occasional cavities upto 10mm formed by the dissolution of calcite crystals. Bedding is 5°. (REDCLIFF SANDSTONE FORMATION Zone I) ... at 8.95m depth pockets of calcite up to 20mm.	0.41	8.80	XXXXXX
9.60-10.40				100	81	81		120 180 440		Very weak thinly to medium bedded greenish grey fine to coarse SANDSTONE interbedded with very weak to weak medium bedded reddish brown fine to medium siltstone. Bedding fractures are 5 to 10° closely to medium spaced undulating rough infilled with sandy clay. (REDCLIFF SANDSTONE FORMATION Zone I) ... between 9.40 and 9.60m depth mudstone is very weak. ... occasional lenticular mudstone pockets with greenish grey fine to coarse sandstone. ... between 9.60 and 9.72 and 10.16 and 10.40m depth mudstone are weak.	0.21	9.00	XXXXXX

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Boring Progress and Water Observations						General Remarks
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	
All dimensions in metres						Scale: 1:14
Method Used: Dynamic sampling + Rotary Cored	Plant Used: Comacchio MC300		Drilled By: LH	Logged By: AVenn + BSaimen	Checked By:	



Contract: Bristol Rapid Transit Ashton Vale to Temple Meads		Client: Bristol City Council		Borehole: BH545E	
Contract Ref: 727305		Start: 17.06.13 End: 18.06.13	Ground Level (m AOD): 9.21	National Grid Co-ordinate: E:357550.6 N:172134.3	
Sheet: 5 of 5					

Depth (m)	Samples & Testing			Mechanical Log				Backfill & Instrumentation	Water	Description of Strata	Reduced Level	Depth (Thickness)	Material Graphic Legend
	No	Type	Results	TCR (%)	SCR (%)	RQD (%)	If (mm)						
				100	81	81	120 180 440				-1.19	10.40	
Borehole terminated at 10.40m depth.													

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Boring Progress and Water Observations						General Remarks
Date	Time	Borehole Depth	Casing Depth	Borehole Diameter (mm)	Water Depth	

All dimensions in metres Scale: **1:14**

Method Used: Dynamic sampling + Rotary Cored	Plant Used: Comacchio MC300	Drilled By: LH	Logged By: AVenn + BSaimen	Checked By: AGS
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Appendix C

Risks and Opportunities

Table 6 - Risks and Opportunities

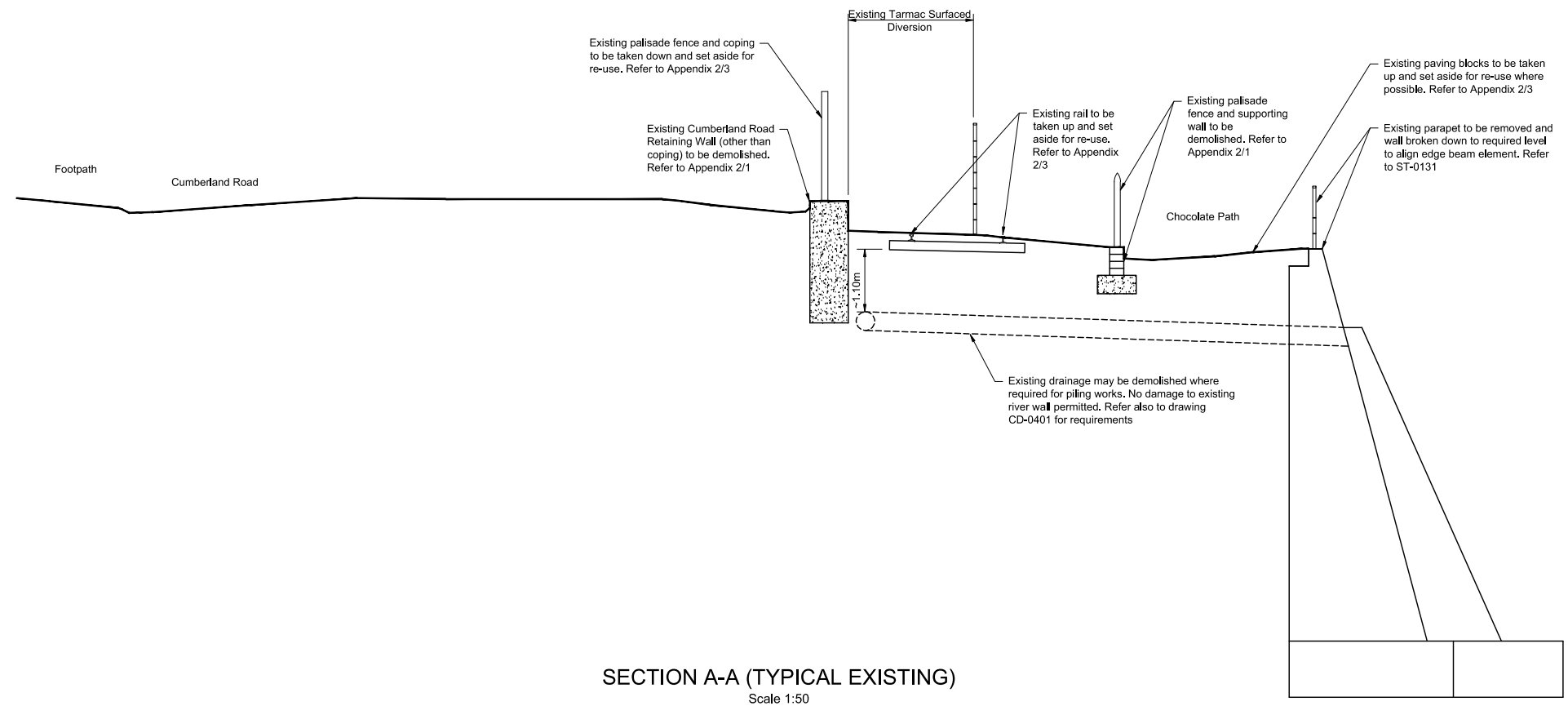
Reach	Risks	Opportunities
Reach 2 – Cumberland Road	<ul style="list-style-type: none"> It is noted that a major collapse of Cumberland Road occurred in January 2020 and construction works are ongoing to repair it. The works to address this will also have an impact on the detailed design of proposals in this area. From the asset inspection in January 2020, a bridge supporting the chocolate path (NCN03a) is suffering from severe corrosion with significant weaknesses along the main girder at the bearing and stiffener locations. The bridge is adjacent to Cumberland Road and just upstream of Ashton Avenue Bridge. A full structural survey has been recommended as part of the condition survey before the bridge is confirmed suitable for vehicles. As this bridge is directly supporting a section of the Chocolate Path, flood defence works in this area are likely to impact the bridge. Therefore, construction works cannot be commenced until the bridge has been structurally assessed and repaired or replaced. The type and size of foundations will govern the size of construction plant required and therefore impact the stability of the slope/bank during construction. The impact of construction surcharge on the bank stability and the design needs to be carefully evaluated at later designs stages. Temporary and permanent construction including piling onto the riverbank may have negative environmental and ecological impacts and are anticipated to require road closures. Road raising on the landside of the new wall to reduce the visual impact may be required. Construction details of the existing retaining riparian wall are unknown, with unrecorded buttresses encountered during the adjacent Chocolate Path Remedial Works. Existing sluice gates and culverts need to be located and incorporated into the design. This area is a conservation area, has landscape sensitivities and is the gateway to the city bringing complexities that may vary costs. The defences are proposed across the alignment of the former River Avon natural channel. Costs could vary significantly due to lack of ground investigation information for the foundations of the defences. The adjacent Chocolate Path Remedial Works pile design was affected by aggressive ground conditions in the tidal flat deposits. The harbour railway drainage has failed in places, due to sedimentation. This increases the risk of bank slippage/instability, particularly at times of tidal surge and with the harbour railway retaining structure in front of the highway retaining structure. 	<ul style="list-style-type: none"> Bring this work forward as the interfaces are relatively simple and known. Re-arranging cycling and walking paths on the river side has been considered in line with the ‘Western Corridor’ character area intervention typology as set out in the Placemaking Opportunities Report. Costs could vary significantly due to lack of ground investigation. There is a significant risk of poor ground conditions near the historic riverbed and peat has been identified from existing ground investigation information which has been allowed for in the design but if not realised may lead to a cost saving. Information gathered in the ongoing repair works could be used. Engagement with contractors to ensure temporary and permanent works are addressed to reduce the whole life costs. Using the existing historic foundations wherever possible could reduce the costs, but the condition and exact size and ground conditions would need to be clearly understood. Maximise the historic asset of the chocolate path Improve biodiversity and encourage a green corridor Incorporate long term service plans into the back of the flood defence (future proofing) Improve access links to and from the cut river crossings.

Reach	Risks	Opportunities
	<ul style="list-style-type: none"> • The Cumberland Road flood wall (constructed between the highway and the railway) is a flood defence. Temporary works will need to ensure no reduction in flood defence during the construction phase. • The path is on the riverside of the flood defence. A combination of ramps and possibly gates will be required to provide suitable access from Cumberland Road. 	
Reach 3 – Cumberland Road East Defence	<ul style="list-style-type: none"> • The structures review in April 2018 [8] found there was insignificant risk of potential variation, although interactions with the heritage railway may cause cost variations. • Approvals by Office of Rail and Road (ORR). • This area is a conservation area and has landscape sensitivities bringing complexities that may vary costs. 	<ul style="list-style-type: none"> • No major opportunities have been identified.

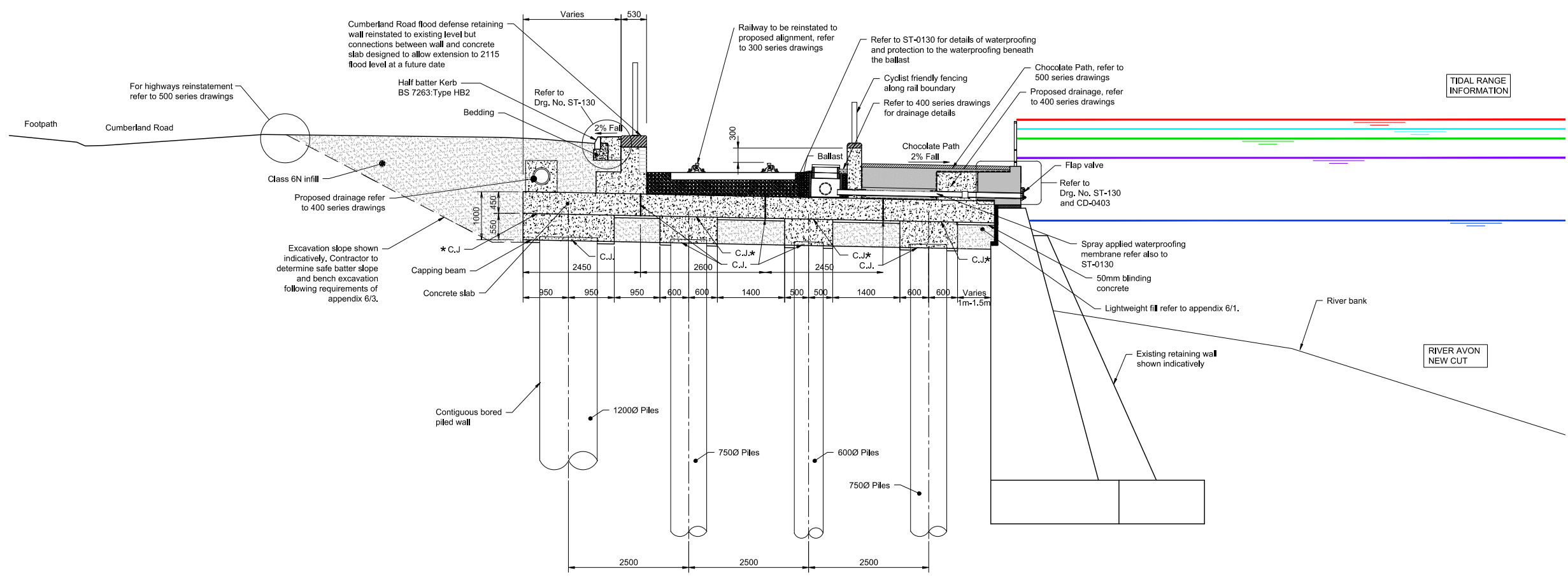
Appendix D

Cumberland Road Stabilisation Works Typical Cross Section

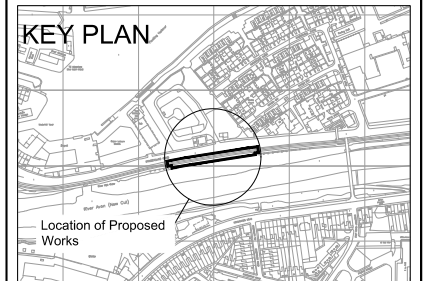
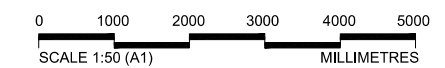
Cumberland road Stabilisation Works Typical Cross Section



SECTION A-A (TYPICAL EXISTING)
Scale 1:50



SECTION A-A (TYPICAL PROPOSED)
Scale 1:50



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- Refer to Drg No.673846-CH2-SGN-CHP-DR-ST-0101 for general notes.
- Flood levels are taken from the River Avon Flood Strategy January 2019.
- Refer to Appendix 6/1 for details of lightweight fill (Leica or similar approved). Contractor may propose foam concrete as an alternative for project manager acceptance. Requirements for foam concrete are given in 1770AR.
- C.J = Construction Joint.
- *C.J = Construction joint may be omitted if preferable for the contractors method of works.

KEY

	Maximum flood event that is contractor's risk, flood level = 8.8m AOD
	1 in 100 Year Flood Level = 9.2m AOD
	1 in 200 Year Flood Level = 9.40m AOD
	1 in 1000 Year Flood Level = 9.60m AOD
	Mean High Water Spring tide (MHWS) = 7.5m AOD

RESIDUAL HSE RISKS

In addition to the risks associated with construction which would be expected by a competent Contractor, consideration should be given to the following residual site risks:

- Construction:**
- Working near water.
 - Potential risk for flooding.
 - Ground instability.
 - Working near live traffic.
- Operation:**
- Working near water.
 - Potential risk for flooding.
 - Working near live traffic including rail.
- Decommissioning:**
- Working near water.
 - Potential risk for flooding.
 - Ground Instability.
 - Working near live traffic.

Rev	By	Chkd	Apprvd	Date	Description
P5	DaC	RRR	JPM	15/11/2019	ISSUED FOR TENDER
P4	FG	RRR	JPM	07/11/2019	ISSUED TO CAT II CHECKER
P3	FG	RRR	JPM	15/10/2019	ISSUED TO CAT II CHECKER
P2	FG	RRR	JPM	04/10/2019	ISSUED TO CAT II CHECKER
P1	DaC	RRR	JPM	19/07/2019	ISSUED TO CAT 2 CHECKER



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Project
CUMBERLAND ROAD STABILISATION WORKS

STABILISATION WORKS TYPICAL CROSS SECTIONS

Drawn by: DaC	Date: 19/07/2019
Checked by: RRR	Date: 19/07/2019
Approved by: JM	Date: 19/07/2019
Drawing No. 673846-CH2-SGN-CHP-DR-ST-0104	Doc. Sult. Revision
D2	P5

Drawing Scale: AS SHOWN AT A1

Bristol City Council

Bristol Avon Flood Strategy - St Philip's Defences

Geotechnical Feasibility Study

Reference: 285982-ARP-ZZ-RP-GEO-009 St Philip's Feasibility Study

P02 | 30 January 2024

This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 285982-00

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United Kingdom
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1. Introduction

1.1 Scope of works

Bristol City Council is working with the Environment Agency and other partners to create a vital long-term strategy for managing the flood threat from the River Avon, supported by The Capital Strategic Partner (consisting of Arcadis, Arup and Mott Macdonald). The strategy will outline action to be taken in phases to reduce the chance and impact of flooding from the River Avon, and how each phase will be funded. The Strategic Outline Case (SOC) for the Bristol Avon Flood Strategy was consulted on in 2020 prior to adoption by Bristol City Council and adoption by the Environment Agency.

The engineering design presented for the strategy involved a review of the engineering logic and costing approach proposed by Aecom (2017) [1] for an earlier SOC. This accounted for the revised hydraulic modelling and increased project extents, as well as the feasibility of the original approach. The preferred option for the Strategy comprises raised defences along the River Avon including new tidal stop gates for the Floating Harbour. The standard of protection (SoP) provided by this strategy considers two epochs – 2069 and 2130. To develop the costing of the defences, the strategy assumes an adaptive approach to defences which means:

- An initial phase of construction (Phase 1) assumed for the 2020s
- A subsequent phase of constructing additional defences and raising defences in the 2060s (Phase 2).

The preferred option specifies the construction of defences to the National Planning Policy Framework (NPPF) SoP for 2069 in the 2020s. In the 2060s, defences will be raised as necessary to the higher of the 200-year FCERM or NPPF SoP for 2130.

A baseline report [2] summarising all current project proposals has been prepared. Where necessary information has been carried into this desk study review.

1.1.1 Project Proposals

Works within the St Philip's area are split into Reach 7, Reach 13 and Reach 14 as summarised in Table 1. A more detailed summary of the proposed development is provided in Section 2.2.

Table 1: Summary of St Philip's defences

Reach	Construction Phase/Build Stage	Proposals
7 - Bristol Temple Quarter/St Philip's Marsh	Phase 1/Build Stage 2	1488m - Concrete wall on angled mini-piles, flood gate, ramps, embankment.
13 – Totterdown South	Phase 2	440m – Concrete wall on mini-piles.
14 – Feeder Road	Phase 1/Build Stage 2	880m – Piled flood wall.

Reach 13 falls under construction Phase 2 (2060s) and therefore does not form part of the imminent works. It is anticipated that any development in this area between now and the second phase will provide defences to the 2130 SoP [2].

1.1.2 Risks and Opportunities

The baseline engineering report [2] conducted for the Bristol Avon Flood Strategy identified the following ground related risks and opportunities associated with the works in Reaches 7, 13 and 14. These are summarised in Appendix A. The study aims to provide additional information and insights to the above risks and opportunities that will contribute to the development of a comprehensive outline business case.

2. Background Information

2.1 The Site

The site is located in St Philip's Marsh, approximately 1.5km southeast of Bristol City centre, (National Grid Reference of St Philip's Marsh: ST 60521 72092). The proposed Reaches (summarised in Section 2.2) surround St Philip's Marsh on the western, southern and northern extent as bounded by the River Avon and Feeder Canal. Temple Meads is located approximately 300m northwest of the centre of the site.

St Philip's Marsh comprises light industrial land use with several large warehouses, railway sidings and supporting road infrastructure. As discussed in Section 4.1, the area was raised in the mid-1800s and has been subject to industrial development to the present day.

The site topography is generally flat with ground level at approximately 10 mOD. This is consistent with the historical development, including previous ground raising creating a level platform. Approximately 300m south of the River Avon in Totterdown and Arnos Vale ground level rises to approximately 47m OD and 23m OD respectively. Ground level continues to rise to 80m OD in Knowle 600m further south.

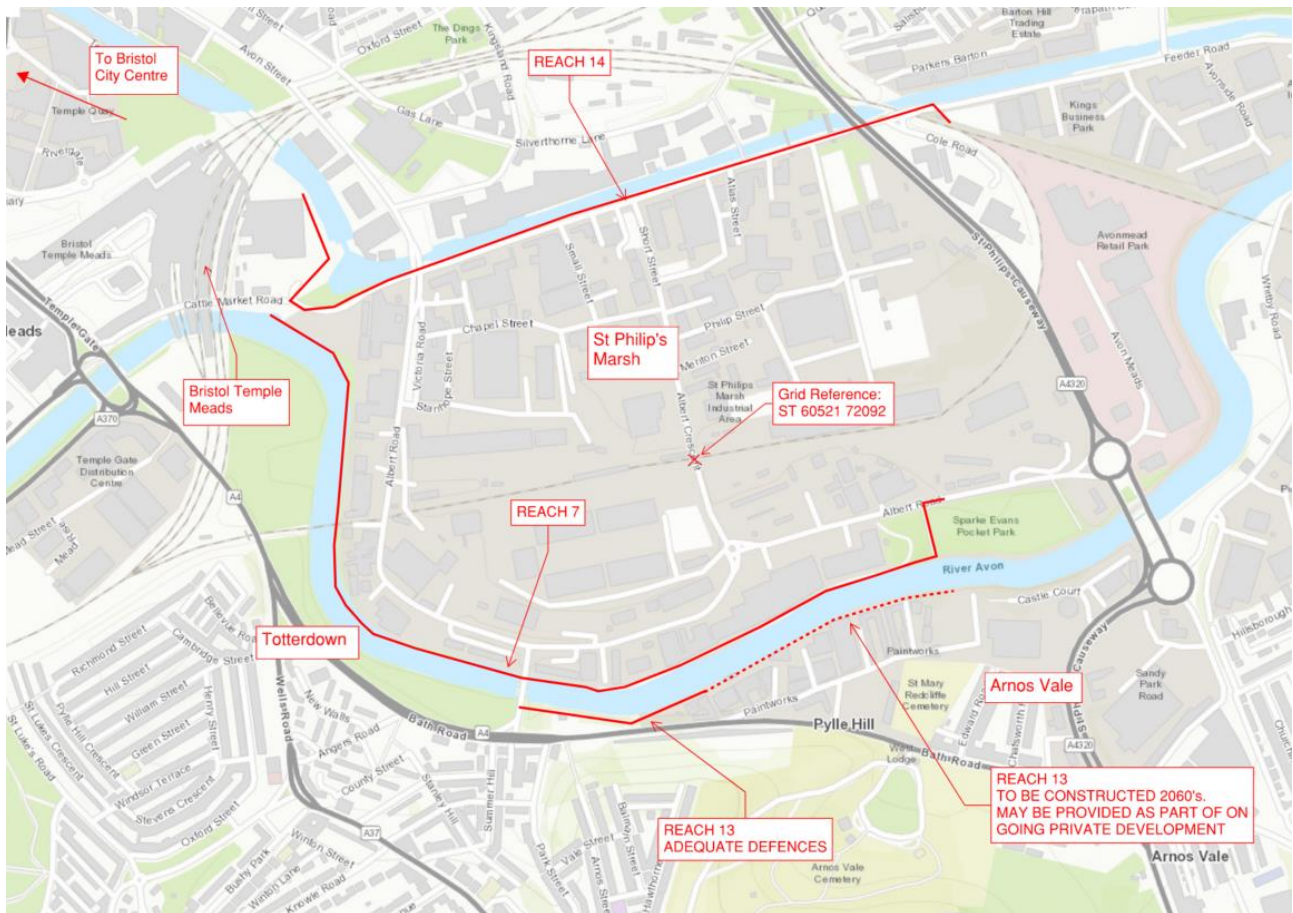


Figure 1: Site Location Plan

2.2 Proposed development

2.2.1 Reach 7

A 1488m long concrete flood wall is proposed on angled mini piles. An embankment will be required in the eastern extent to raise the ground level by 1.5m before constructing the concrete piled wall to a flood defence level of 10.81m AOD to meet the 2130 SoP.

The proposal ties into Reach 6 at Bristol Arena Road bridge and Sparke Evans Park at the downstream and upstream end respectively. In addition to the tie ins with wider scheme proposals, the defences interface with the existing Brock's Bridge, Great Western Railway Bridge (avoiding line) and Totterdown Bridge as well as the St Philip's footbridge. The footbridge is 4m wide and constrains access for construction plant when working adjacent to existing structures in St Philip's Marsh [3]. A cross section of the proposals and interpreted geology is presented in Figure 8.

However, this area is included under the Temple Quarter masterplan. Therefore, the surrounding area is likely to change significantly from the current arrangements, leading to a change in the required flood defences. Any changes to the surrounding area including a widening of the river corridor is a significant opportunity for the scheme and would likely lead to better overall outcomes as the space constraints are likely to be less severe.

The current proposal for Reach 7, as outlined in this report, describes a viable option for development should the Temple Quarter masterplan either not be progressed, or not be delivered in time.

2.2.2 Reach 13

The western extent of Reach 13 has been concluded to meet the 2065 SoP as presented in Figure 1. The eastern extent is proposed to be constructed in the 2060s and is likely to involve raising the existing retaining wall. However, on-going development along the Reach is likely to provide raised defences. At this point in time, detailed cross sections for proposals have not been prepared.

2.2.3 Reach 14

The proposed works for Reach 14 comprise of an 880m long reinforced concrete contiguous piled wall to achieve a flood defence level of 8.75m AOD (2065 SoP). 2130 SoP will be achieved by raising the defences with a glass flood wall. The proposed defences interface with trees along Feeder Canal, the Floating Harbour/Feeder Canal Lock, Avon St Bridge, a footbridge north of Feeder Road, three pipe trestles, Philip's Causeway bridge and Great Western Railway Bridge (avoiding line) as annotated in Figure 3. A cross section of the proposals and interpreted geology is presented in Figure 9.

3. Data acquisition

Several information sources have been consulted in order to inform site conditions and constraints in relation to the development of the site. The sources are summarised below. A summary of the findings from the review of these sources can be found in Section 4.

- **Historic Aerial Imagery** – A review of historic aerial photographs [4] has been undertaken into order to assess the historic development of the site. This feeds into the understanding of the historic and existing built environment along with information on past land uses that can impact on ground conditions and contaminated land.
- **Historic Development** – A review of relevant Ordnance Survey mapping for the area has been undertaken using extracts from historic OS maps to build up a picture of the historic development on site. This has been used to assess potential risks from contaminative past uses and possible other impacts such as obstructions from buried foundations [5] [6] [7].
- **Bristol City and the Harbour Office Archives** – A search of relevant records [8] from both resources has been undertaken to identify pertinent information on historic and existing structures on site. This information has been sourced to assess potential interfaces with these structures as part of the proposed works shown in Appendix B.
- **Geological information** – A review of the British Geological Survey (BGS) GeoIndex [9], BGS 1:50,000 England and Wales Sheet 264 map of Bristol, the BGS 1:10,630 ST57 SE map and nearby BGS borehole records has been undertaken to develop a ground model for the site to feed into design development [5]. In addition, the BGS 1:625,000 Hydrogeological map and DEFRA Multi-Agency

Geographic Information for the Countryside (MAGIC) maps [10] has been used to assess groundwater levels, aquifer designations on site and determine their sensitivity to the proposed works.

- **Coal Mining** - Assessment of the Coal Authority Interactive Viewer [11] has been undertaken alongside review of relevant geological extracts including the BGS sheet information to assess the risk from past coal mining on the proposed works.
- **Risk from Unexploded Ordnance (UXO)** – A review from the risk of unexploded ordnance has been undertaken using free publicly available information to provide an assessment of the risk and provide indication on the likely mitigation required as part of the proposed works [12].
- **Environmental Setting** - Multi-Agency Geographic Information for the Countryside (MAGIC) maps have [10] been used to assess the site and its surroundings in relation to sensitive receptors that may be impacted by the proposed development. In addition, publicly available information from the Environment Agency and Bristol City Council [13] has also been reviewed to feed into the understanding of the site’s environmental setting.

4. Site conditions

4.1 Historical development

A review of the historical maps and aerial photographs using Know Your Place [7], National Library of Scotland [6] and aerial imaging from Google Earth Pro [4] has been undertaken. The findings pertinent to Reaches 7 and 13 and Reach 14 are summarised in Table 2 and Table 3 respectively. Features and constraints identified during the review are also presented in Figure 2 and Figure 3.

Table 2: Summary of historical development Reach 7 and 13

Information source	Summary of pertinent features
1828 Ashmead Scale: Not provided	<ul style="list-style-type: none"> • Western extent of St Philip’s Marsh mapped. Isolated buildings present in otherwise undeveloped land. • Rest of St Philip’s area mapped as marsh land.
1840-1890 OS Map, 1:500	<ul style="list-style-type: none"> • Industrial land use: 3 iron works (Albert Road), chemical, manure and varnish works (Southern end of Victoria Street immediately north of the River Avon). • Residential development in the northern area of St Philip’s Marsh. • Strip of land circa 80m wide immediately north of the River Avon mapped as marshland indicating that ground raising has occurred in northern and central extent of St Philip’s. • Residential development south and southwest of the River Avon. • Railway station: Joint Station (currently known as Bristol Temple Meads).
1855 Ashmead Scale: Not provided	<ul style="list-style-type: none"> • Additional industrial land use: oil works (Albert Road).
185-1990 OS One Inch	<ul style="list-style-type: none"> • Great Western Railway (avoiding line) Bridge.
1892-1914 OS 25 Inch	<ul style="list-style-type: none"> • Additional industrial land use: Acid works and manure works (Albert Road). • Totterdown Bridge constructed.
1898-1939	<ul style="list-style-type: none"> • Linoleum works on Albert Road and warehouse replaces manure works on Albert Road.
1937-1961 OS 1:125000	<ul style="list-style-type: none"> • Expansion of Bristol Temple Meads train station including bridge. • Sparke Evans Footbridge constructed. • Development in south of St Philips, no marshland mapped.
1947-1965 OS National Grid 1:2500	<ul style="list-style-type: none"> • Additional industrial land use: paint factory (between the River Avon and Bath Road), petrol depot (northeast of Totterdown Bridge), iron works and acid works no longer present.
1949 BGS Gloucestershire 76NW 1:10 560	<ul style="list-style-type: none"> • Floor of buried channel thought to lie at around –15mOD, cuts through the River Avon (drawn onto historical map with pen).
1999 Google Earth Pro Scale: not Provided	<ul style="list-style-type: none"> • No significant changes.

2019 BCC Q2 basemap Scale: Not provided	<ul style="list-style-type: none"> • Brock's Bridge constructed east of Bristol Temple Meads station. • St Philip's Marsh is industrial only (no longer residential).
2020 Google Earth Pro Scale: Not provided	<ul style="list-style-type: none"> • St Philip's Footbridge appears on maps north of Great Western Railway Bridge (avoiding line) on the River Avon.
2023 Google Earth Pro Scale: not provided	<ul style="list-style-type: none"> • All previous works have been removed and replaced with light industrial use.

Table 3: Summary of historical development Reach 14

Information source	Summary of pertinent features
1828 Ashmead Scale: Not provided	<ul style="list-style-type: none"> • Feeder Canal and adjacent road infrastructure in the same alignment as present day. • Industrial land use north of Feeder Canal comprises: gas works (Gas Ln), iron works (immediately north of Feeder Canal), vitriol works (north of Avon St Bridge).
1840-1890 OS Map, 1:500	<ul style="list-style-type: none"> • Residential development immediately south of Feeder Canal. • Additional industrial land use south of Feeder Canal: manure works (Small Street and 100m southeast of site), Marsh Oil Mill (Victoria Road), pottery and glass works (Atlas Street), timber yard (Small Street), glue works (Atlas Terrace) and clay pit. • Additional industrial land use immediately north of Feeder Canal: Extension to iron works and timber yard. • Feeder Float Lock present. • Great Western Railway Bridge (avoiding line) present.
1855 Ashmead Scale: Not provided	<ul style="list-style-type: none"> • Alkali works north of Avon St Bridge. • Great Western Colliery approx. 150m south of Great Western Railway (avoiding line) Bridge.
1874 Ashmead Scale: Not provided	<ul style="list-style-type: none"> • Gas works replace alkali works north of Avon St Bridge. • Dock constructed northwest of Great Western Railway Bridge (avoiding line).
1887-1902 Goad Insurance Plans Scale: Not provided	<ul style="list-style-type: none"> • Vitriol works last annotated. • Gasworks that replaced alkali works no longer mapped.
1894-1903 OS 2nd Ed 25 Inch	<ul style="list-style-type: none"> • Great Western Colliery disused. • Clay pit no longer present.
1898-1939 OS 3rd Ed 25 Inch	<ul style="list-style-type: none"> • Previously mentioned dock backfilled - west of Great Western Railway Bridge (avoiding line), (backfill material unknown), and pipe trestles constructed in the same location.
1947-1965 OS National Grid 1:2500	<ul style="list-style-type: none"> • Timber yard immediately north of Feeder Canal replaced by tar works • Paint and glue works immediately south of Feeder Canal replaced by varnish works.
1949 BGS Gloucestershire 76NW 1: 10560	<ul style="list-style-type: none"> • Floor of buried channel thought to lie at around -15m, mapped to cross the western extent of Feeder Canal (drawn onto historical map with pen).
1949-1972 OS 1:10,000	<ul style="list-style-type: none"> • Iron works immediately (north of Feeder Road) last annotated.
2012 Aerial Scale: Not Provided	<ul style="list-style-type: none"> • A4320 Philip's Causeway present.
2019 BCC Q2 base map Scale: Not provided	<ul style="list-style-type: none"> • One additional footbridge constructed west of Great Western Railway Bridge (avoiding line).
2021 Google Earth Pro Scale: Not provided	<ul style="list-style-type: none"> • Gas works (on Gas Ln) no longer present.
2023 Google Earth Pro Scale: Not provided	<ul style="list-style-type: none"> • All previous works have been removed and replaced with light industrial use.

4.1.1 Summary of historical development

The St Philip's Marsh area has been subject to ground raising in the 1800s and subsequent residential and commercial land-use development to the present day. The nature of the fill used for the ground raising is unknown and may have been placed with poor engineering control. Furthermore, the fill may contain contaminants, considering the previous industrial land-use.

The proposals along Reach 7, 13 and 14 generally comprise installation of piles into the manmade embankments. This highlights the risk of encountering contaminated arisings and the impact to construction operatives and of contaminant migration to the watercourses. Furthermore, there is risk of instability of large construction plant due to the poorly defined ground conditions.

Figure 2 and Figure 3 present the key features and constraints identified through the review of the historical information. Of note is the industrial land use and the existing structural foundations.

No additional culverts or buried channels were identified during this preliminary review. It is recommended that a full set of historical OS and utility maps are procured and reviewed ahead of scoping any targeted ground investigation to better inform this risk.

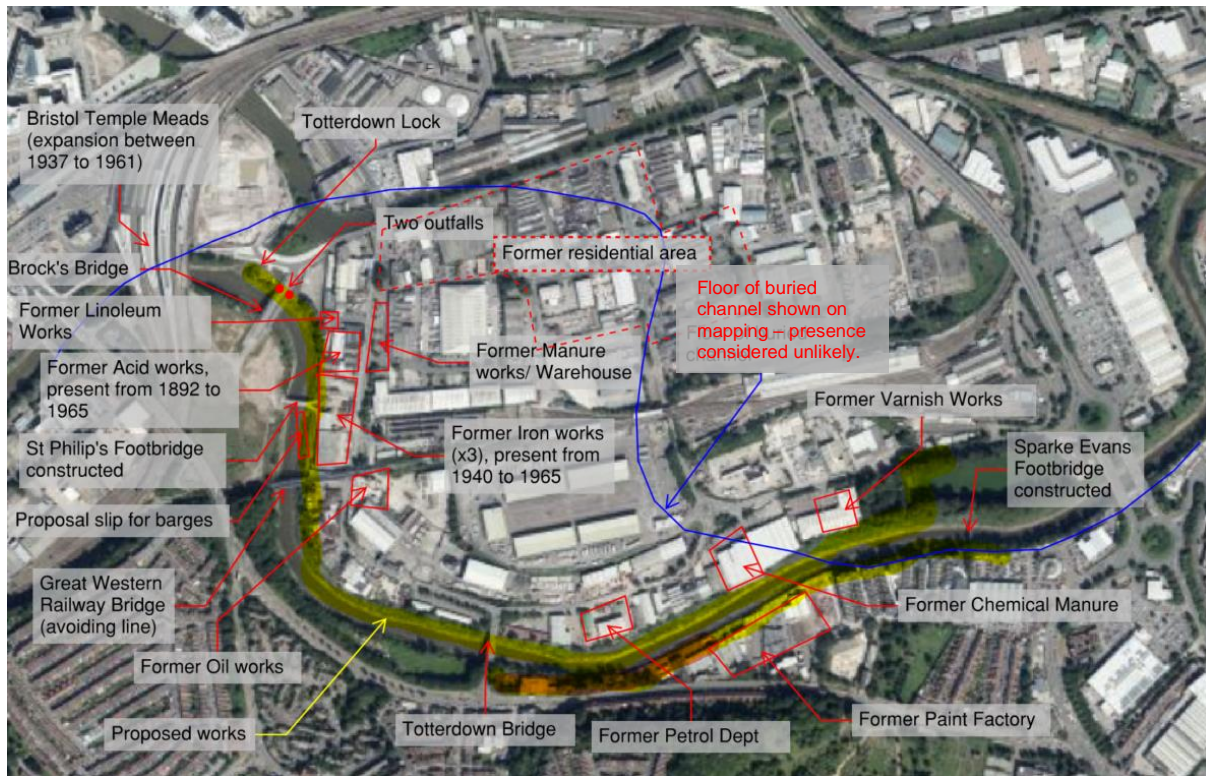


Figure 2: Reach 7 and 13 features and constraints

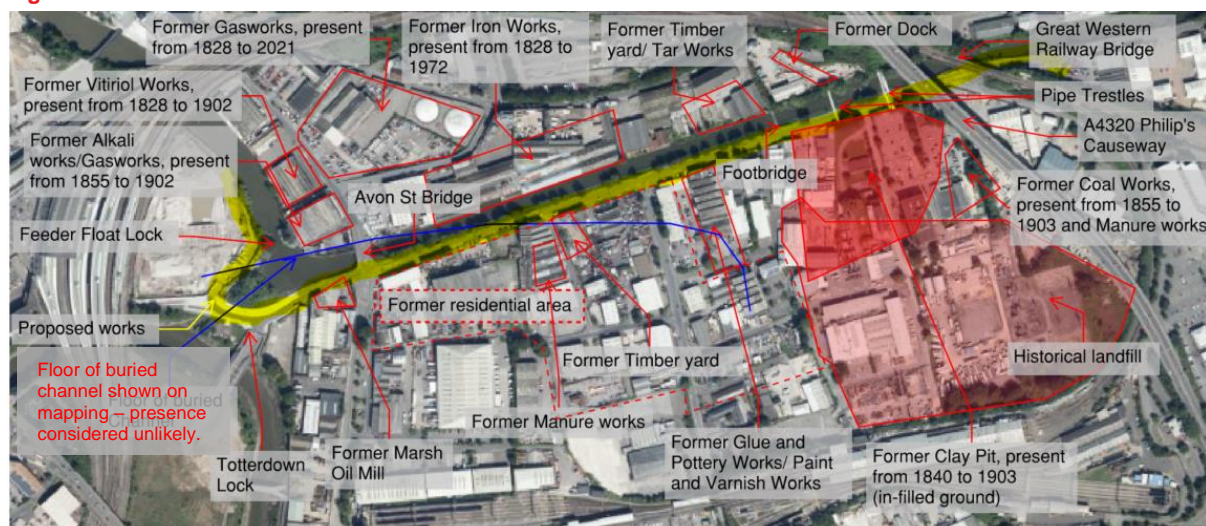


Figure 3: Reach 14 features and constraints.

4.1.2 Listed buildings

The listed structures within the vicinity of the scheme are presented in Figure 4 (as recorded by the Historic England dataset [14] on Know your Place [7]). There are 6 listed buildings to the north and northwest of the

St Philip's Marsh area that should be considered when developing proposals for Reaches 7 and 14. St Vincent's Works includes 4 separate listed structures. There are also 3 listed buildings within 200m south of the proposed works.

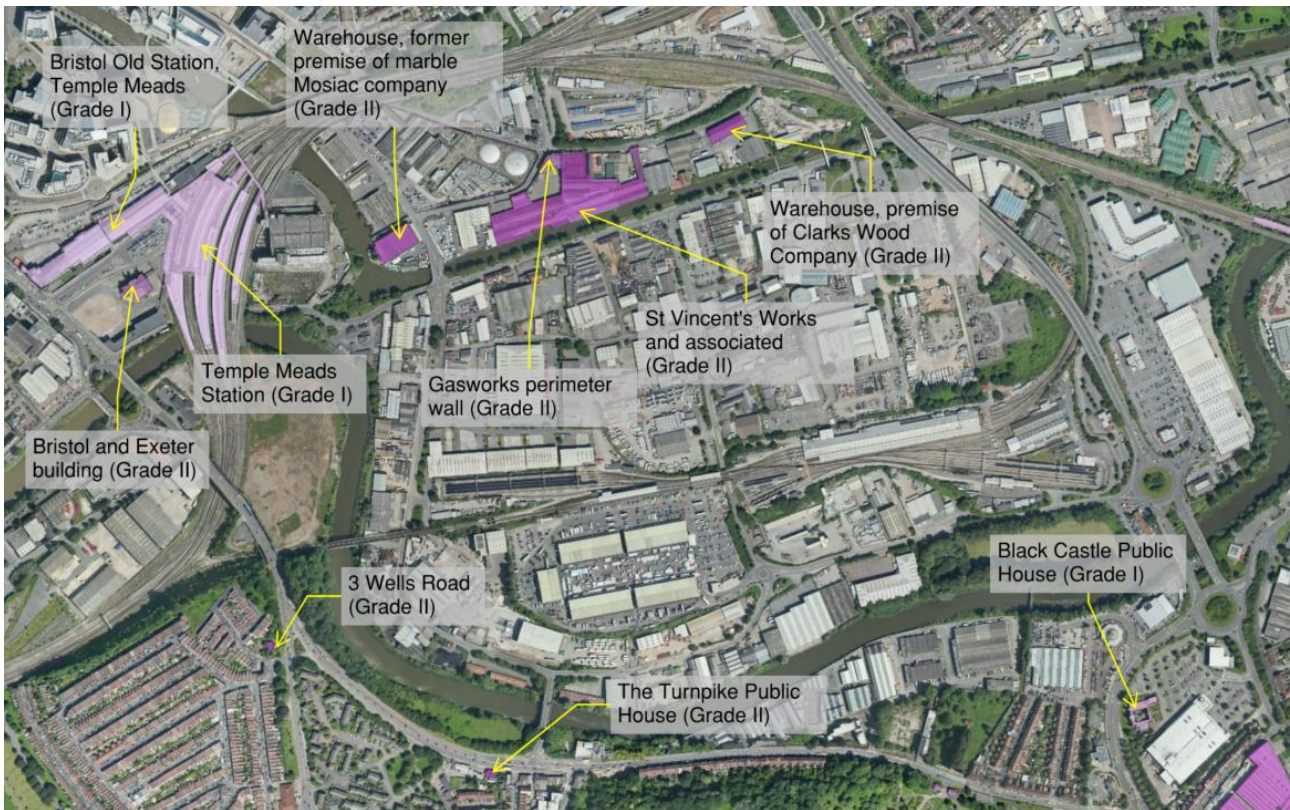


Figure 4: Summary of listed structures (extracts from Know Your Place)

4.1.3 Bristol City Archives

A search of relevant records [8] has been undertaken to supplement the review of historical information with a focus on identifying structures which may impact the proposed works, the records are shown in Appendix B. The following observations were made:

- Two outfalls (St George Sewer and Old Bristol Sewer) towards Reach 7, with indicated locations near the western side of Feeder Canal, shown on the feature and constraints map (Figure 2).
- Location of GWR (avoiding line) Viaduct foundations and proposed site of slip for barges on the riverbank of Reach 7.
- Outfalls and drains along the River Avon north of Bath Road.
- Totterdown Lock junction widening.
- Widening of Feeder Float Lock junction.
- Collapse of N. Bank of New Cut between wing wall of Temple Meads Bridge and bridge over Totterdown lock.
- Feeder Canal locks and bridges cross-section.
- Position of moorings around Floating Harbour from Bristol Bridge to Totterdown Lock.
- Proposed weir and lock at Totterdown.

4.2 Site geology

A review of the published geology beneath the site has been undertaken using the British Geological Survey (BGS) GeoIndex [9] and BGS Map Sheet 264 1:50,000 [5], a summary of the findings are in Figure 5 and Table 4.

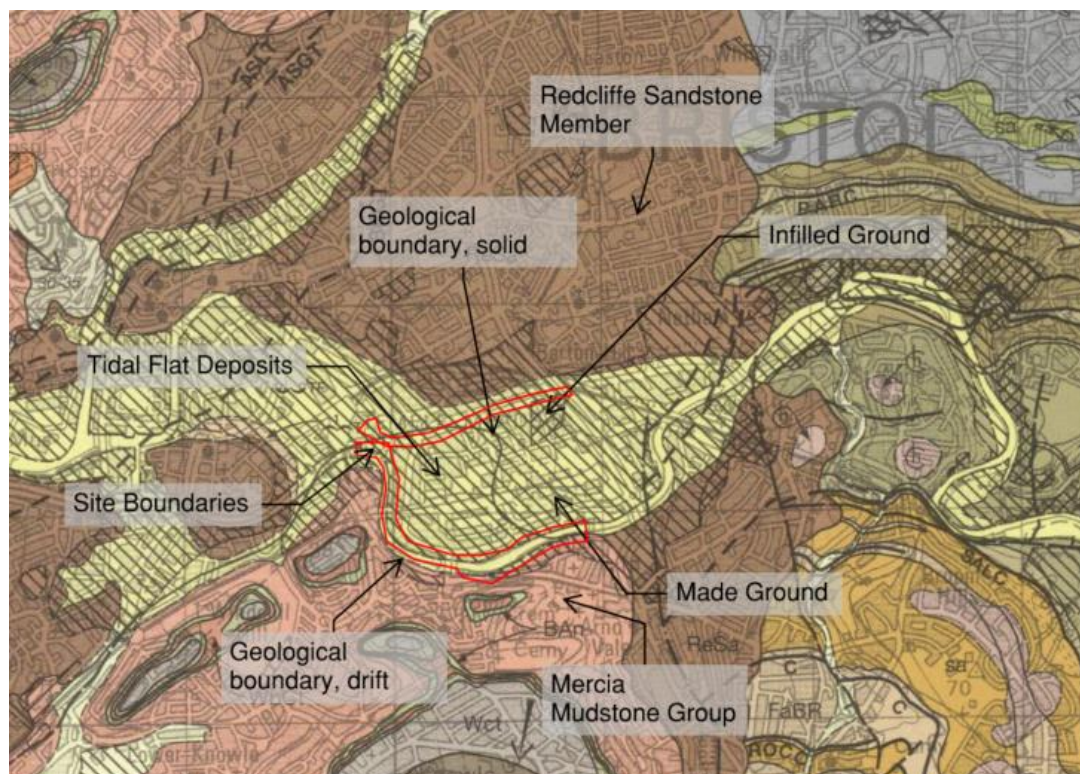


Figure 5: BSG Map Sheet 264 (extracts from 2004 1:50,000 version)

Table 4: Available Published Geology.

Stratum	Description
Made Ground	<p>Artificial raised ground is mapped to be present beneath the entire extent of St Phillip’s Marsh [9]. This is consistent with the historical map review which identified ground raising and on-going development within the area.</p> <p>There is also an area of infilled ground assumed to be associated with the historical clay pit and/or coal works, south of Great Western Railway Bridge (avoiding line) and Feeder Canal.</p> <p>The nature of the made ground across the extent of St Philip’s Marsh is unknown. It is possible that material associated with industrial land use and by-products may have been deposited, highlighting the risk of contamination. Furthermore, the geotechnical properties of the embankment fill are unknown.</p>
Superficial Deposits	<p>Geological mapping indicates the entire site to be underlain by tidal flat deposits [9]. These are typically described as soft clays and silts. Tidal flat deposits are also known to comprise significant thicknesses of peat within the wider southwest England and south Wales region.</p>
Bedrock	<p>1:50 000 scale BGS geological mapping [9] indicated the site to be underlain by the Redcliffe Sandstone Member (RSM) with a typical description of “Sandstone, distinctive fine- to medium-grained, deep red, calcareous and ferruginous. Commonly decalcified at shallow depths below the surface, giving rise to an uncemented sand”.</p> <p>The Mercia Mudstone Group (MMG) is also mapped to be at surface immediately south of St Philip’s Marsh with a typical description of “Dominantly red, less commonly green-grey, mudstones and subordinate siltstones with thick halite-bearing units in some basinal areas. Thin beds of gypsum/anhydrite are widespread; thin sandstones are also present. Mid Triassic (Anisian) to latest Triassic (Rhaetian)”. The formation is mapped to overlie the Redcliffe Sandstone member.</p> <p>It is possible that both formations underlie the tidal flat deposits when considering the depositional environment associated with the Mercia Mudstone Group.</p> <p>Immediately south of the River Avon is a geological boundary labelled drift. The BGS mapping [9] show no fault lines on site.</p>

The Historical BGS map exert shown in Figure 6 has an annotation indicating the presence of a buried channel running through site and indicated by the dotted line. However, a review of other geological maps, including the GeoIndex Interactive map [9] does not indicate the presence of a buried channel at the position indicated in Figure 6.

According to Geindex mapping, the superficial deposits underlying the site include tidal flat deposits of clay and silt, and river terrace deposits of sand and gravel. However, this does not indicate that the River Avon previously ran along the path indicated by the dotted line. Meandering of the River Avon throughout the Quaternary Period in addition to flooding is the most likely cause of the superficial deposits mapped below the site.

Furthermore, a review of the underlying bedrock geology, as shown in Figure 7, indicates that interface between the Redcliffe Sandstone Member and Mercia Mudstone Group geological formations lies in the same position as the dotted line in Figure 6 which may have been mistaken for a buried channel feature.

In light of the information given above, the risk of encountering a buried channel underlying the site is considered minimal.



BGS Gloucestershire 76 NW 1949

Figure 6: BGS Gloucestershire Map (1949) with Buried Chanel Annotation

4.2.1 Historical exploratory hole logs

A review of the available historical boreholes on the BGS GeoIndex, as shown in Figure 7, was undertaken and is summarised in Table 5 and Table 6.

Table 5: BGS Boreholes relevant to Reach 7 & 13

Exploratory holes	Stratum	Typical Description	Top of Stratum (m OD)	Thickness (m)
ST67SW58 ST67SW294 ST67SW298	Made ground	Reddish brown, dark grey, sometimes black sandy gravel and silty clay with inclusions of	7.65m- 10.57mAOD	2.9-5.9m

ST67SW299 ST67SW300 ST67SW293 ST67SW292 Commencement level ranges from 7.65m OD to 10.57m OD.		glass, brick, concrete, metals, rare metals, pottery, slag and ash. ST67SW292 encountered paint traces and very strong chemical odour at 2m bgl.		
	Alluvium	Very soft to soft grey clay and silt, shell fragments and organic inclusions, brown sand, grey brown gravel, dark grey black silt. ST67SW292 encountered slight chemical odour in clay and some firm to stiff clay directly below the Made Ground.	2.9m-5.9m bgl 3m-4.5mAOD Typically 4mAOD	4m-8.7m Typically 4.5m
	Bedrock	<u>Mercia Mudstone Group</u> Red, redbrown sandstone, red brown and green siltstone. <u>Redcliffe Sandstone Member</u> East part of the Reach is underlain by Redcliffe sandstone.	Typically 10m bgl -4.55mOD to -0.58mOD	Unproven

Table 6: BGS boreholes relevant to Reach 14

Exploratory holes	Stratum	Typical Description	Top of Stratum (m OD)	Thickness (m)
ST67SW57 ST67SW295 ST67SW108 (BH3) ST67SW233 ST67SW234 ST67SW238 ST67SW239 Commencement level ranges from 7.2m OD to 8.8m OD.	Made ground	Reddish brown sand and blackish brown ash with inclusions of gravel, brick, stone, wood, glass, metal and coal waste.	7.2mAOD-8.8mAOD	0m-4.4m Typically 3.5m
	Alluvium	Soft grey and brownish grey silty sandy clay. Black grey sandy silt and orange yellow sand. Typically the TFD are underlain by grey and yellowish brown silty fine, medium and coarse sand with fine, medium and coarse gravel. Fibrous peat of variable thickness (typically 2m) at top levels of 3.2mAOD-5.45mAOD).	3.91mAOD-7.2mAOD	3.5m-10.7m Typically 8m
	Bedrock	<u>Redcliffe sandstone member</u> (southwest of Reach underlain by mercia mudstone) Predominantly red and reddish brown standstone, siltstone and mudstone. ST67SW234 encountered a coal seam at 29.27m bgl (1m in thickness).	-4.5mOD to 0.7mAOD	Unproven

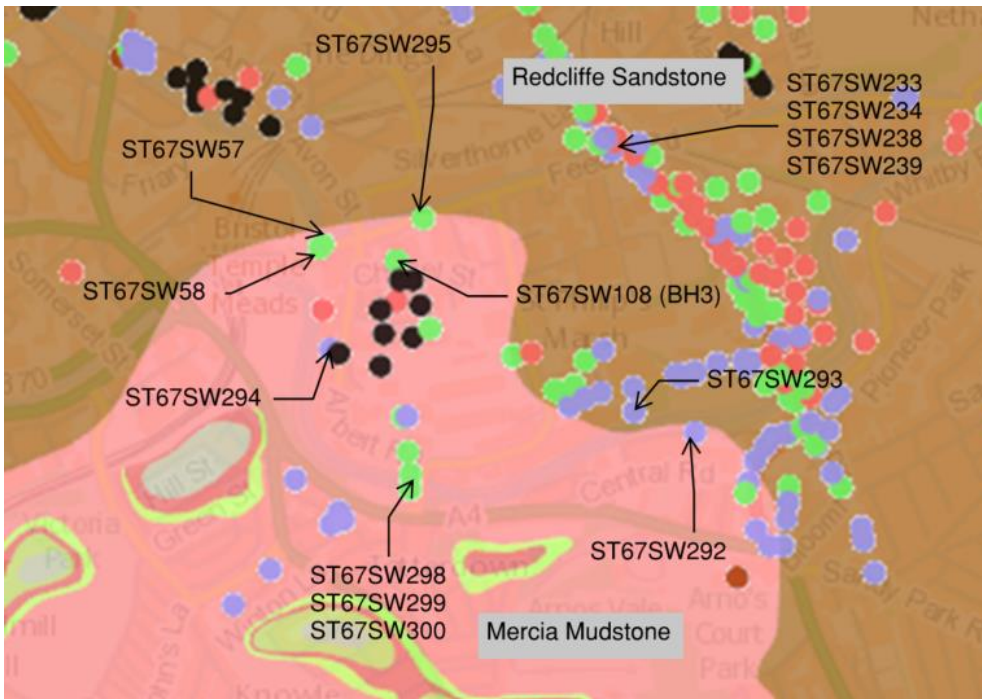


Figure 7: BGS Boreholes summarised in Table 5 and Table 6.

4.2.2 Geological cross sections

Figure 8 and Figure 9 present geological cross sections for the proposals along Reach 7 and 14, using geological data collated in Section 4.2.1 above.

Figure 8, extracted from the baseline report [2], shows the proposed concrete retaining wall on mini piles alongside the interpreted geology. The design of the mini piles will need to consider the risk of extending into the underlying bedrock. This could create piles which are in the order of 12m in length.

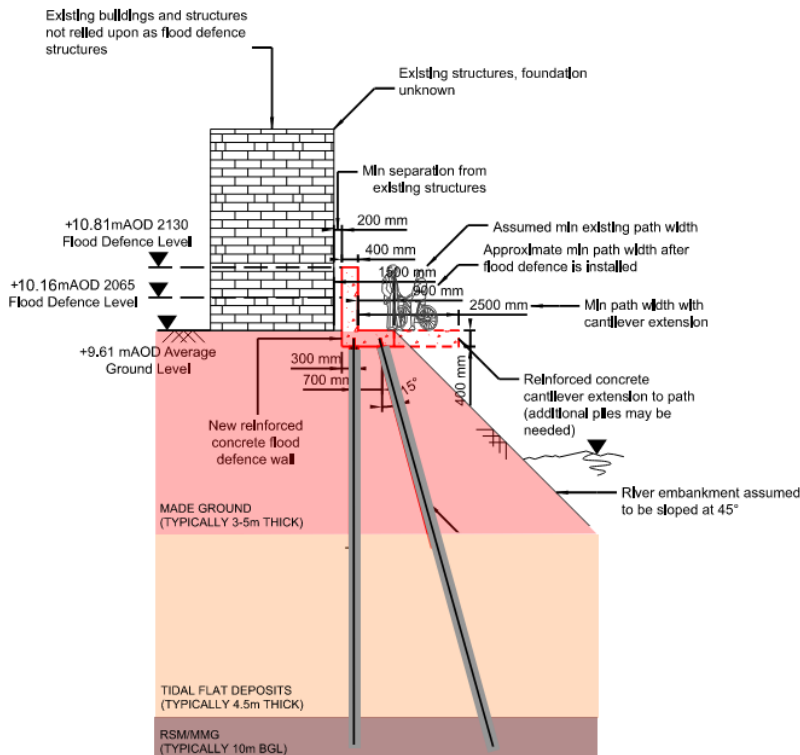


Figure 8: Reach 7 proposals (extract from Baseline Report)

Figure 9 presents the proposed concrete piled wall, in relation to the interpreted geology along Reach 14. Due to the high variation in ground conditions, a pile length of approximately 12m-15m may be required to provide a nominal rock socket. The pile diameter and lengths will be dependent on ground investigation results and design development.

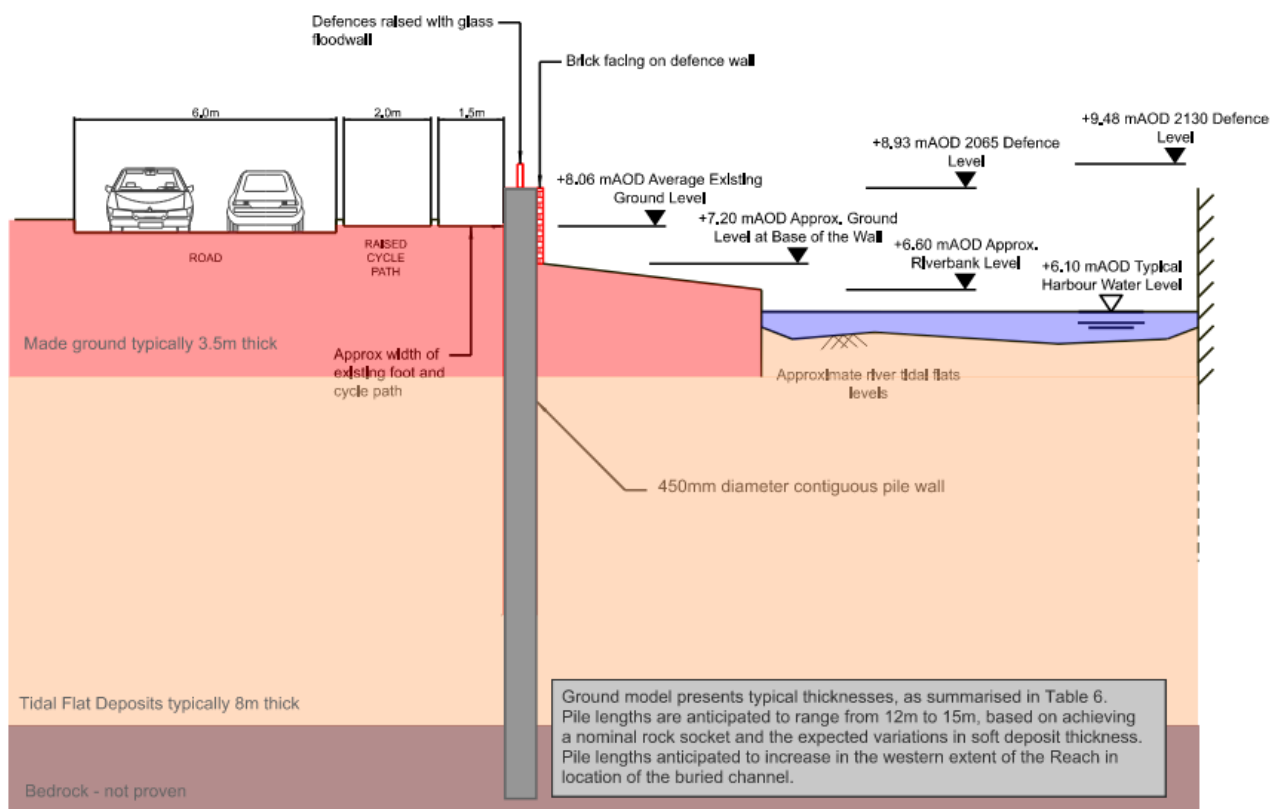


Figure 9: Proposal of Reach 14 with indicative ground model (extracts from 285982-ARP-XX-DR-CIV-216)

4.3 Hydrogeology

A review of the DEFRA online mapping [10] with 1:25 000 scale, reveals that the bedrock present beneath the site is a designated Secondary A aquifer in the north area of the site associated with the Redcliffe Sandstone Member and a Secondary B aquifer in the south area of the site associated with the Mercia Mudstone Formation.

A Secondary A aquifer has the following definition: ‘Secondary A aquifers comprise permeable layer that can support local water supplies and may form an important source of base flow to rivers.’

A Secondary B aquifer is defined as ‘mainly lower permeability layers that may store and yield limited amounts of groundwater through characteristics like thin cracks (called fissures) and openings or eroded layers.’

The superficial deposits of Alluvium are designated as an unproductive aquifer.

The groundwater vulnerability of the site is shown to be medium, however there is high risk vulnerability groundwater directly south and north of the site. Generally, the BGS historical borehole logs [5] show that groundwater was observed to strike at around 4mbgl and 9mbgl (approximately 4.5mAOD and -0.5mAOD) and was seen to rise to a final level of 3mbgl and 6mbgl (approximately 6mAOD and 2.5mAOD), respectively.

4.4 Coal mining

Bristol falls within the Coal Authority (CA) Consultation area and has been subject to extensive coal mining in its recent history. A review of the CA Interactive Viewer [11] was conducted to identify risks associated with mining legacy along the Reaches. Figure 10 summarises the available mining related data.

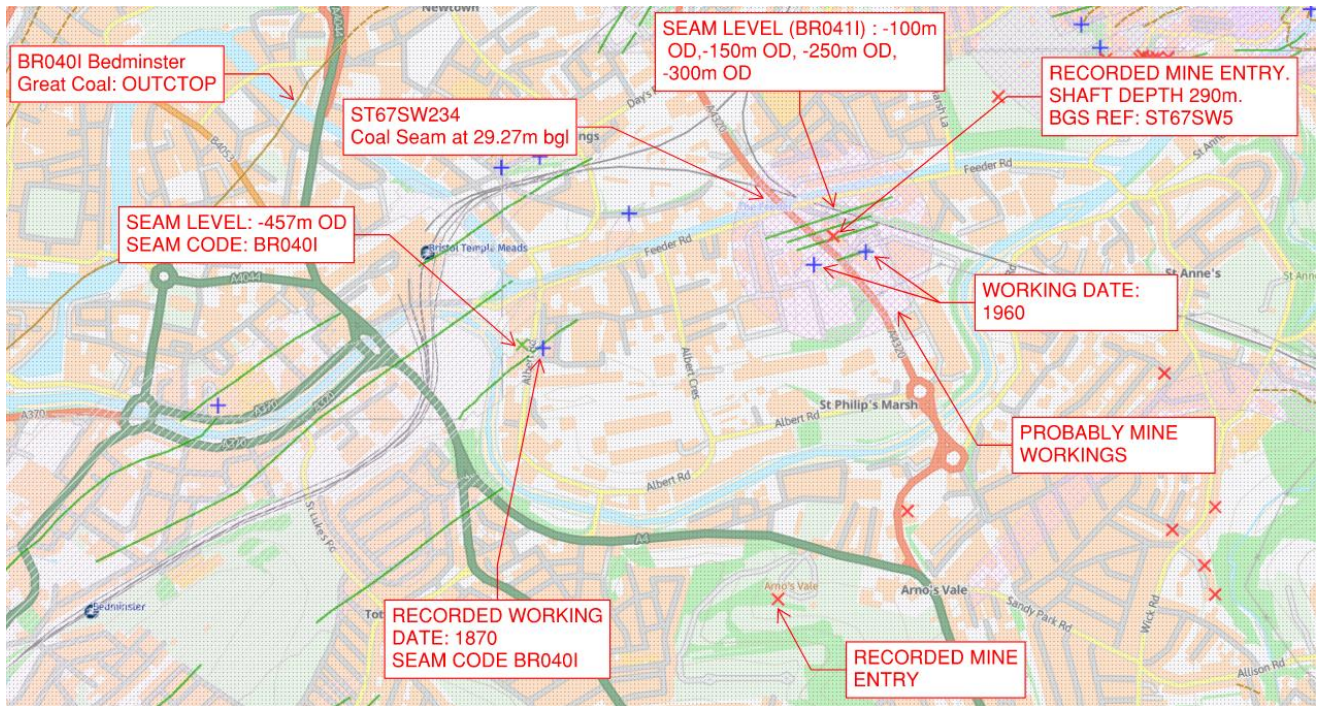


Figure 10: CA Interactive webviewer extracts

4.4.1 Recorded mine workings

Recorded mine workings are mapped within the northern extent of Reach 7. A mine entry and seam level record relating to Seam BR040I (Bedminster Great Coal) is mapped approximately 100m east of the Reach, adjacent to Victoria Road. The workings were undertaken in 1870. Records indicate the coal seam to be -457m OD. Subsidence risks associated with collapse of worked seams are negligible due to their depth.

Probable mine workings and a mine entry are mapped approximately 150m southeast of where St Philip's Causeway Bridge spans Feeder Canal, relating to the eastern extent of Reach 14. This coincides with the area of "worked ground" identified within geological mapping [11]. Four seam levels are mapped as -100m OD, -150m OD, -250m OD and -300m OD relating to BR040I (Bedminster Great Coal). The seams were encountered shallower than anticipated when considering the plan distance to the outcrop (1.2km northwest) and the mapped dip angle of 30-35 degrees, indicating that the formation has been subject to folding. A record for the mineshaft was available on the BGS Geotindex ST67SW5 [9]. The shaft encountered a coal seam at 97m bgl (1.2m in thickness) and 120m bgl (1m in thickness), which broadly agrees with the CA dataset depths. Risks associated with collapse of worked seams in this area are negligible due to the depth and thickness of the seams. Furthermore, the location of the mine shaft is very unlikely to affect proposals along Reach 14.

4.4.2 Unrecorded mine workings

A review of BGS historical exploratory holes identified a coal seam in ST67SW234 at 29.27m bgl (1m in thickness) immediately north of Feeder Canal. This was the only record of shallow coal identified. Furthermore, there was no evidence of shallow workings within the logs reviewed. It is considered unlikely that shallow coal was worked within the vicinity of Feeder Canal due to the colliery being present on mapping (first mapped as present and dis-used in 1894-1903 OS 25" OS mapping) after the construction of Causeway Bridge and there being no evidence of Feeder Road being re-aligned. However, it is likely that shallow coal was worked south of Feeder Road associated with the infilled ground in Figure 3.

4.4.3 Conclusions and recommendations

Based on the information reviewed, it is considered very unlikely that collapse associated with mining legacy will have an impact on the proposed works. In addition, no mine entries were identified within proximity of the Reaches. It is however recommended that a coal mining risk assessment is undertaken to better inform the risk of possible shallow mine workings within the eastern extent of Reach 14.

It is possible that spoil from mine working may be encountered which may be contaminated. Uncontrolled filling with arisings may also have taken place which could lead to settlement and stability issues.

4.5 Unexploded ordnance (UXO)

A review of the risk of unexploded ordnance has been undertaken using Zetica UXO [12], shown in Figure 11 with map centre given as 360201, 171827. Based on the Unexploded Bomb Risk Map, Reach 7, 13 and 14 fall within the high bomb risk area, which are areas indicated as having a bombing density of 50 bombs per 1000acre or higher. This is likely connected to the proximity of the site to the Bristol harbour area which is known to have been targeted in World War II. There are seven Luftwaffe targets within the area concerning Reaches 7, 13 and 14 and three confirmed UXO finds approximately 1.1km west and one other confirmed UXO find approximately 1km southwest of St Philip’s Marsh area.

Considering the geology of the site there is potential for soft ground (Alluvium superficial deposits) to be present across the site which may have allowed UXO to remain undetonated and thus pose a risk to any works on site. Therefore, it is recommended that a UXO desk study and risk assessment of the site be completed prior to an intrusive investigation.

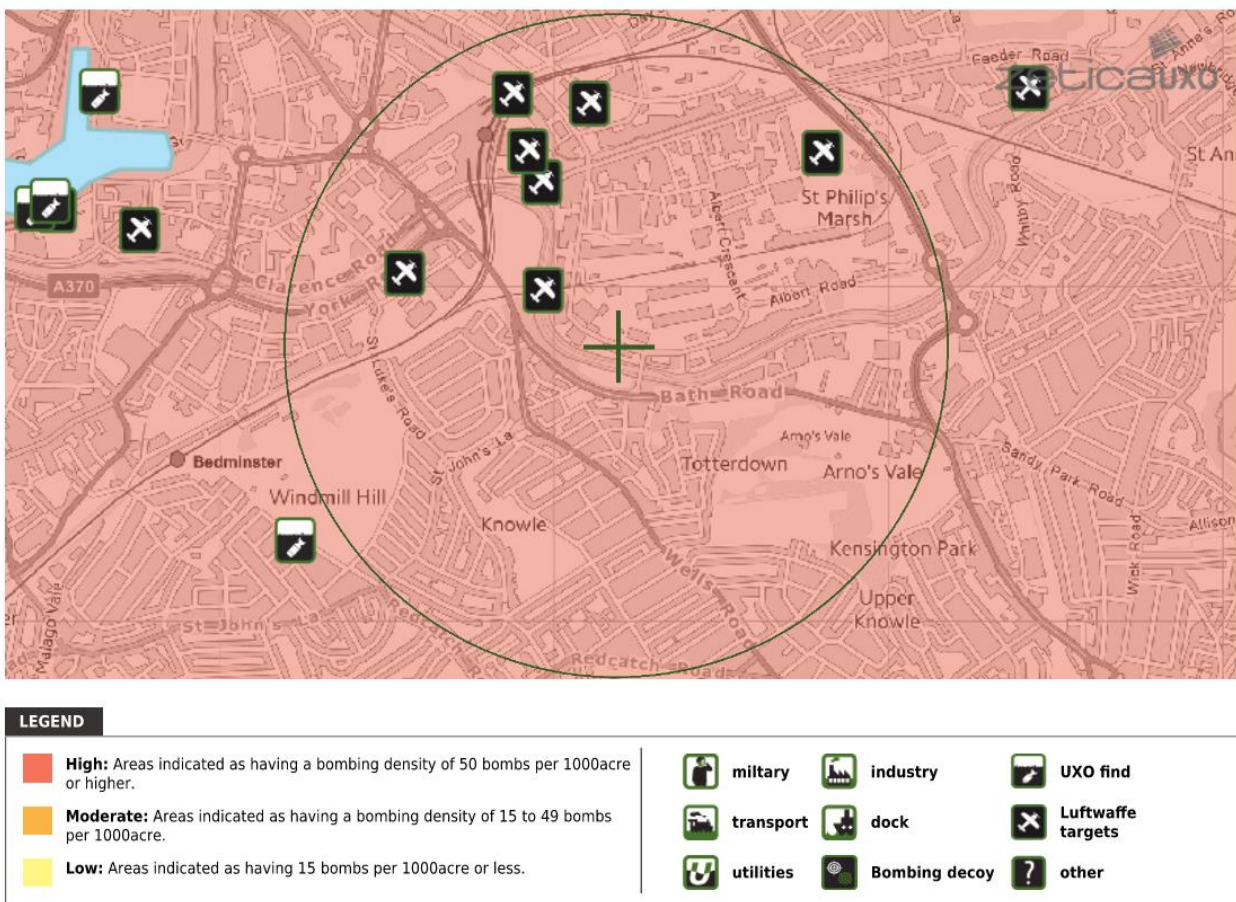


Figure 11: Extract of Zetica UXO risk map

4.6 Environmental setting

Multi Agency Geographic Information for the Countryside (MAGIC) maps [10], available information from the Environment Agency and Bristol City Council [13] and BGS GeoIndex [9] have been used to assess the site and surrounding areas in relation to receptors sensitive to the proposed works.

Table 7: Environmental setting

Environmental constraint	Description
National Natural Reserves (NNR), Local Natural	Priority Habitat Inventory – Deciduous woodlands, north and south of Bath Road on the opposite riverbank to Reach 7 and is unlikely to be affected by the works.

Environmental constraint	Description
Reserves (LNR), NNR, LNR, Local Wildlife Site, Ancient Woodland, Habitats	A Local Nature Reserve (LNR) is immediately downstream of Reach 7 and 13 to the west of the proposed sites. As the Reaches are upstream from the LNR, contamination could be introduced to the site through the river. Also downstream are Ashton Court (SSI), Avon Gorge Woodlands (SAC), Leigh Woods (NNR), ancient and semi-natural woodland, ancient replanted woodland and priority habitat inventory – Deciduous woodland that could become receptors to any contamination present on site.
Historic Environment	There are no Scheduled Monuments in the St Philip's Marsh area.
Protected Species / Invasive Species	Approximately 500m southwest of the St Philip's Marsh area is an area with the European protected species of bats.
Landfills	There is a designated area of historical landfill in the St Philip's Marsh area south of Feeder Road at approximately ST 60758 72278.

5. Headline risk assessment

Following a review of the sources stated in Section 3, there are a number of risks to the proposed development which are summarised in Table 8. This includes a prediction of the proposed risk and a description of any findings.

Table 8: Headliner Risk Assessment

Risk item	Description	Source of information
Made Ground	<p>The St Philip's Marsh area is underlain by Made Ground associated with ground raising and on-going development within the area. There is also an area of infilled ground northeast of the St Philip's Marsh area that may be linked to the clay pit and/or the coal works.</p> <ul style="list-style-type: none"> Reach 7 and 13: Typical thickness of 2.9m – 5.9m Reach 14: Typical thickness of 3.5m <p>The chemical nature of the made ground and geotechnical properties are unknown. Reach 7 & 13 description: sandy gravel and silty clay with inclusions of glass, brick, concrete, metals, rare metals, pottery, slag and ash. Reach 14 description: ash with inclusions of gravel, brick, stone, wood, glass, metal and coal.</p>	British Geological Survey (BGS) GeoIndex [9] and BGS Map Sheet 264 1:50,000 [5]
Loose/Soft Ground	<p>BGS mapping shows that the site is underlain by Tidal Flat Deposits which is comprised of soft clays and silts.</p> <ul style="list-style-type: none"> Reach 7 and 13: Typical thickness of 4.5m Reach 14: Typical thickness of 8m (2m of peat) <p>Risk of instability of construction plant. Risk of pile lengths increasing should they need to create a nominal rock socket.</p>	British Geological Survey (BGS) GeoIndex [9] and BGS Map Sheet 264 1:50,000 [5]
Bedrock	<p>The majority of the St Philip's area is underlain by Mercia Mudstone Group, however, further east of Reach 7 and 13 and further northeast of Reach 14 are underlain by Redcliffe Sandstone Member. The bedrock is recorded to lie at between -0.5mOD and -4.5mOD in historical borehole logs.</p> <p>Buried Channel (see Section 4.1.1 and Figure 2) mapped in BGS mapping as solid boundary and on BGS Map Sheet 264 (1920 edition) in pen as a channel feature. Unconfirmed depth of soft deposits.</p> <p>Risk of encountering hard sandstone bands which may influence pile design and construction methodology. Risk of early refusal within areas of hard rock.</p>	British Geological Survey (BGS) GeoIndex [9] and BGS Map Sheet 264 1:50,000 [5]
Slope Instability	<p>Due to the nature of the proposed works, a slope stability assessment for both the temporary and permanent case of the embankment will be required for the Reaches. This is due to the additional loading of the proposed structures and the construction plant required.</p>	-
Obstructions	<p>Obstructions that may cause early refusal to the piling work:</p> <ul style="list-style-type: none"> Risk of encountering hard bands of sandstone bedrock. Culverts/outfalls western extent of Reach 7. All three Reaches interface with many existing buildings, bridges and locks. 	British Geological Survey (BGS) GeoIndex [9], Google Earth Pro [4] and BGS Map Sheet 264 1:50,000 [5]

Risk item	Description	Source of information
Archaeology	Although the St Philip's Marsh area has been redeveloped post WWII, there is still a possibility of encountering archaeological remains within the site boundaries. Therefore, an archaeological watching brief is recommended.	Know Your Place [7], National Library of Scotland [6] and aerial imaging from Google Earth Pro [4]
Hydrogeology	<ul style="list-style-type: none"> • Redcliffe Sandstone member (north of site) – Secondary A aquifer. • Mercia Mudstone Group (south of the site) – Secondary B aquifer. • Superficial deposits – unproductive aquifer. • Groundwater vulnerability – medium. • Groundwater strike at 4mbgl and 9mbgl and seen to rise to a final level of 3mbgl and 6mbgl, respectively. 	DEFRA online mapping [10] and BGS historical borehole logs [5]
Coal Mining	Low risk of historical mine workings affecting the proposals. An area of infilled ground is present within the eastern extent of Reach 14. It is recommended that a coal mining risk assessment is undertaken.	Coal Authority Interactive Viewer [11]
UXO	Based on the Zetica UXO risk map the entire St Philip's Marsh area falls within a high bomb risk area. There are seven Luftwaffe targets within the area concerning Reaches 7, 13 and 14 and three confirmed UXO find approximately 1.1km west and one other confirmed UXO find approximately 1km southwest of St Philip's Marsh area. A detailed UXO risk assessment is recommended.	Zetica UXO [12]
Utilities	A previous investigation gained service and utility plans for the length of the Reach. These show various underground electric cables, gas mains, rail infrastructure, foul water sewers and road drains running through or in close proximity to the site. Further searches will be required to determine the exact location and nature of services underlying the site.	Utilities Plans [15] [16] [17] [18] [19]
Environmental Setting	There are Priority Habitat Inventory – Deciduous woodlands, north and south of Bath Road on the opposite riverbank to Reach 7 and is unlikely to be affected by the proposed works. Approximately 500m southwest of the St Philip's Marsh area is an area with the European protected species of bats.	Multi Agency Geographic Information for the Countryside (MAGIC) maps [10] and BGS GeoIndex [9]
Landfill	There is 1No. designated area of historical landfill in the St Philip's Marsh area south of Feeder Road at approximately ST 60758 72278.	Environment Agency and Bristol City Council [13]
Contaminated Land	Based on the historical development of the St Philip's Marsh area (Section 4.1), there is a risk of contaminated land due to the ground raising as well as the industrial uses of the land. Ground investigations are recommended to better inform the risk to construction workers and for materials management.	Know Your Place [7], National Library of Scotland [6] and aerial imaging from Google Earth Pro [4]
Access/Egress	Access along Reach 7 is likely to be restricted due to the presence of neighbouring buildings. Construction phasing and planning for access/egress is required.	

6. Recommendations

It is recommended that the following is undertaken:

- An intrusive ground investigation to gather information on the ground conditions beneath the Reaches. This would include groundwater and ground gas monitoring as well as geotechnical and geoenvironmental testing.
- A coal mining risk assessment supplemented by the results of the ground investigation.
- A detailed UXO risk assessment.
- Further searches for utilities and services within footpaths and their interfaces with project proposals.
- Foundation works risk assessment, pending results from the ground investigation.
- An archaeological evaluation survey/investigation.
- A slope stability assessment pertaining to both temporary and permanent works.

7. References

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- [2] ARUP, “285982-ARP-XX-RP-CIV-001 (Baseline Engineering Report),” 2022.
- [3] Knight Architects, “St. Philips Footbridge,” [Online]. Available: <https://www.knightarchitects.co.uk/bridges/st-philips-footbridge>.
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- [15] Western Power Distribution, “Utilities Plan- 25263073_WPD-South West (Feeder Road),” Bristol, 2022.
- [16] Wales and West Utilities, “Feeder Road- WWU Utilities Plan (25263073_WWU),” Bristol, 2022.
- [17] Western Power Distribution, “Reach 7 Utilities Plan-(25261122_WPD - South West),” Bristol, 2022.
- [18] Wales&West Utilities, “Reach 7 - WWU Utilities Plan (25261122_WWU),” Bristol, 2022.
- [19] Last Mile Asset Management Limited 25261122_LastMile) BFS7, “Reach 7 - Utilities Plan (,” Bristol, 2022.

Appendix A: Extracted Risk and Opportunities

Below is the extracted risk and opportunities from the baseline report [2].

Table 9: Extracted risk and opportunities.

Reach	Risks	Opportunities
7 - Bristol Temple Quarter/St Philip’s Marsh	<ul style="list-style-type: none"> • Access to the St. Philips Marsh River path is restricted with approximately 30% of the footpath with a path width of less than the Sustrans Design Guidance minimum recommendation of 2.5m, going down to 1.5m in some sections. This limits the construction plants and piling rigs that can be used for construction which will limit the size and type of foundations that can be installed. • Riverbank stability needs to be maintained in the temporary and permanent stages. There is a risk that further design may result in bigger piles that may not be able to be built from landside due to restrictions on allowable construction surcharge. • There are numerous existing structures on the landward side of the footpath, details of which are unknown. The existing structures and foundations may be constraints to the new wall as the risk of any damage or disturbance to these structures could result in higher project costs related to additional temporary works. • The floodwall may require temporary and permanent construction including piling onto the riverbank which may have negative environmental and ecological impacts. • A large section of this reach is privately owned, as shown on the Bristol New Cut Land Ownership maps. We recommend consultation with the landowners at the next stage as this will influence the design of the defences and costs. • The cantilevered path is on the riverside of the flood defence. A combination of ramps and possibly gates will be required to provide suitable access from the hinterland. • A low series of bunds/walls were installed in 1981 to reduce the chance of flooding. The condition of these structures and ability to maintain them is poor. The proposals will need to address this. 	<ul style="list-style-type: none"> • This reach forms part of the Eastern Corridor character area and has been identified with placemaking opportunities. • There is a significant opportunity to incorporate flood defences into existing developments. • There is no reliance on existing structures for flood defence in this reach. It could be that parts of the wall are not required should these existing properties be proven to provide sufficient flood defence.
13 – Totterdown South	<ul style="list-style-type: none"> • The structural integrity and residual life of the existing gabion walls at the Paintworks development are unknown and will need to be investigated further as they may not be structurally sound to be used as defences for the 2125 SoP. There may be additional costs associated with strengthening the gabion wall. 	<ul style="list-style-type: none"> • The road (A4) behind the 150m downstream end of this reach is at a higher level than the flood defence levels, therefore there is an opportunity to review the protection required for this section

	<p>The structural form assumed may require updating to suit public realm requirements with cost implications.</p> <ul style="list-style-type: none"> • It was noted on the harbour condition survey that there is some damage to the existing wall. As this wall is to be relied upon for this strategy, survey and / or repair work should be carried out. • From the asset inspection in January 2020, deformed blockwork was noticed on the top of the capping beam (asset NCS41) at the upstream end of the central trading estate. This is causing cracking in the blockwork at the end of these sections. The existing wall is likely to be utilised as part of the strategy, and it may require raising in the 2060s to account for sea level rise. An assessment and suitable repairs to the wall are therefore required to ensure they operate effectively. • There are existing private defences in place along this reach, with unusual riverfront flood gates for visual connectivity. 	<p>along with future developments in this area.</p> <ul style="list-style-type: none"> • Some of the properties are from recent development; they are designed with flood risk resilience measures such as flood tolerant ground floors and/or raised thresholds to current standards.
14 – Feeder Road	<ul style="list-style-type: none"> • Interface with Bristol University Campus developments. • At the downstream (southern) end of Feeder Road, there are existing historic structures which may be impacted by the works. • There are three service bridges and the St Philips causeway bridge along Feeder Road and the interfaces of the new wall and piling activities with these existing structures will need to be considered at a future stage. • The riverbank at Feeder Road is used by the public and therefore public engagement may alter the scheme, adding costs. • It was noted on the harbour condition survey that there is some damage to the existing retaining wall. • The construction details of the existing wall are unknown. 	<ul style="list-style-type: none"> • The reach is also within and interfaces with the Bristol Temple Quarter, an area identified as strategic growth and regeneration area in the Bristol Local Plan Review 2018. A Development • Framework for the area is under preparation. There is an opportunity for future development to integrate the flood defence proposals. • The toe level required is highly dependent on the thickness of the alluvium/TFD layer. A thorough GI may show a varying thickness of this weaker layer, in which case the pile length could be shortened

Appendix B: Bristol City Archives

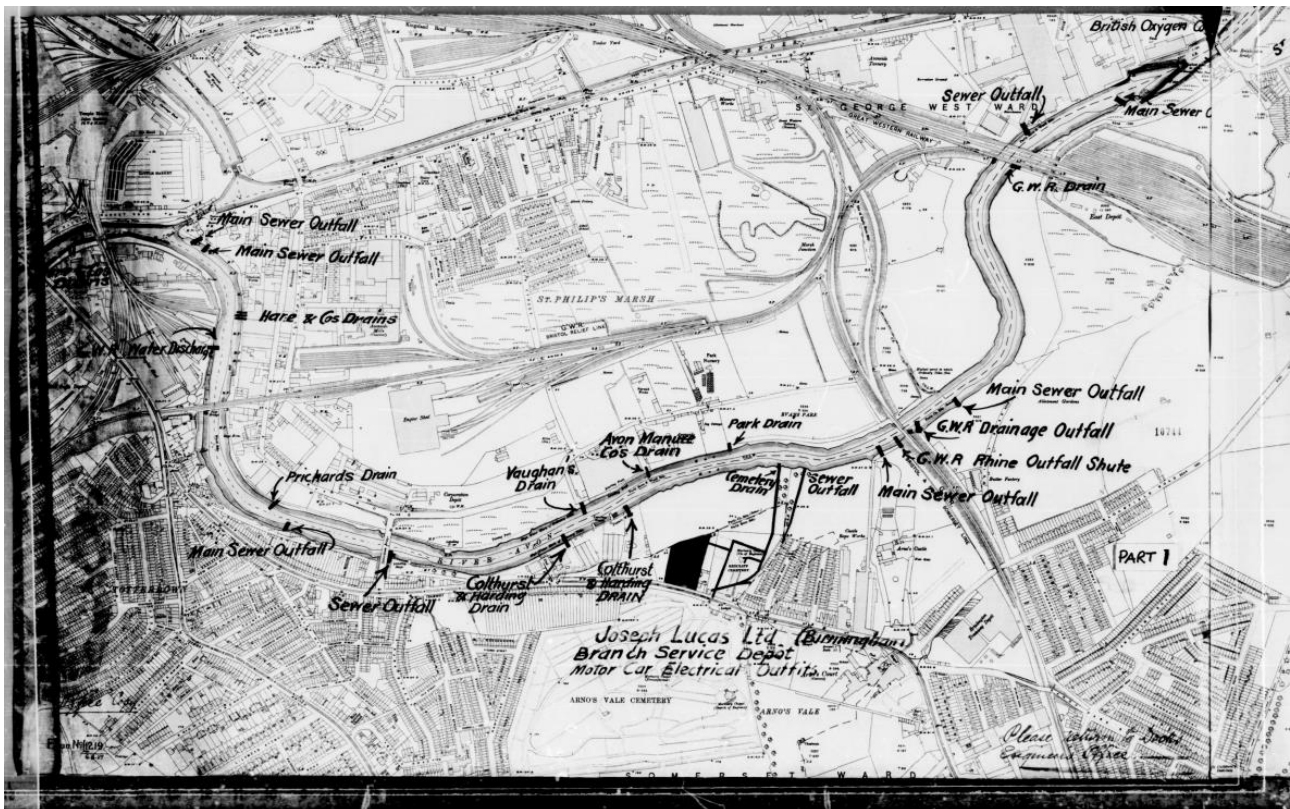
The Bristol City and Harbour Office Archives [8] have been reviewed and the relevant information in summarised below. The documents have been collated and are available for more detailed review in future project stages.

B.1 Outfalls

Table 10: Archived documents of outfalls and drains

Aperture Card Title	Card Reference
BRISTOL DOCKS BRISTOL ST PHILIPS MARSH	CD-10388
BRISTOL DOCKS BRISTOL ST PHILIPS MARSH	CD-10389
PORT OF BRISTOL AUTHORITY SEWER OUTFALL	CD-10744

Figure 12: CD-10744_PORT OF BRISTOL AUTHORITY SEWER OUTFALL (1980s)

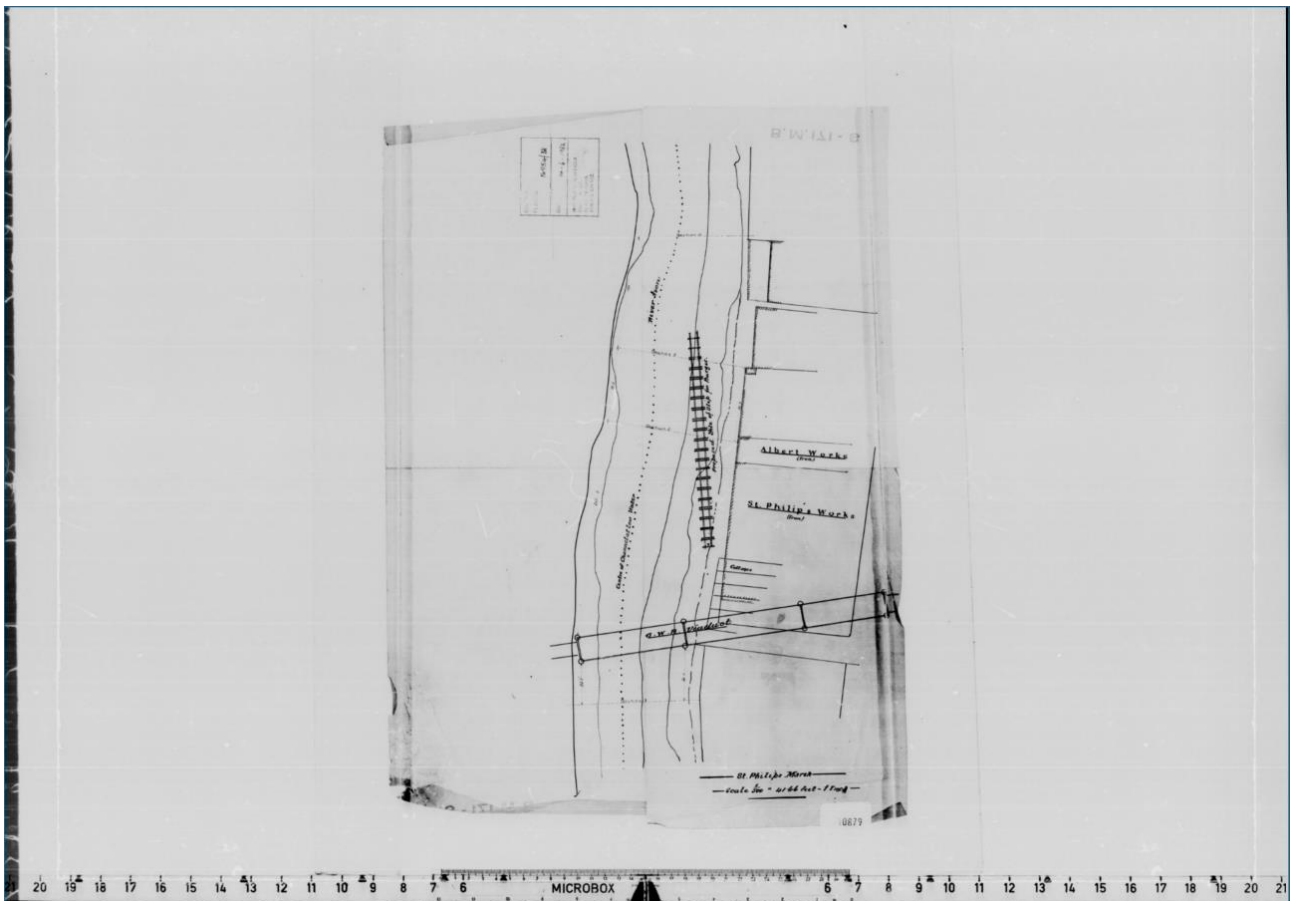


B.2 GWR (avoiding line) Viaduct & Slip

Table 11: Archived documents of GWR (avoiding line) Viaduct and slip

Aperture Card Title	Card Reference
ST PHILIPS MARSH PLAN NO 16954-38	CD-10879

Figure 13: CD-10879_ST PHILIPS MARSH PLAN NO 16954-38



B.3 Totterdown Lock

Table 12: Archived documents of Totterdown Lock

Aperture Card Title	Card Reference
SECTION OF FEEDER LOCK BRIDGE	CD-00004_72
TOTTERDOWN BRIDGE DETAILS OF LOCK AND LOCK GATES NEW JUNCTION_02-06-1989	CD-01010_31387
BARS NO 2 60FT SURVEY BEDMINSTER BRIDGE TO TOTTERDOWN LOCK TO ABOVE MARSH BRIDGE_31-05-1989	CD-01920_31231
TOTTERDOWN LOCK BRIDGE_02-06-1989	CD-02234_31388
FOR THE BARGE LOCK AT TOTTERDOWN FOR THE FEEDER LOCKS_02-06-1989	CD-02235_31389
BRIDGE OVER TOTTERDOWN LOCK_02-06-1989	CD-02236_31390
DETAILS OF SKEW BRIDGE OVER TOTTERDOWN LOCK_02-06-1989	CD-02239_31393
DESIGN FOR WIDENING BRIDGE OVER TOTTERDOWN LOCK_02-06-1989	CD-02241_31395
LOCATION PLAN TOTTERDOWN LOCK_21-08-1989	CD-03771_38402-001904
LAMPS AT TOTTERDOWN LOCK_21-08-1989	CD-03812_38402-001921
CAR PARK AT TOTTERDOWN LOCK_12-12-1983	CD-03847_38402-000371
PROPOSED WHARF WALL NEAR TOTTERDOWN LOCK_12-12-1983	CD-03862_38402-000378
BRISTOL DOCKS PROPOSED WALL NEAR TOTTERDOWN LOCK PLAN AND SECTIONS SURVEY MADE FOR SAME 27-06-1912_12-12-1983	CD-03863_38402-000377

COLLAPSE OF NORTH BANK OF NEW CUT BETWEEN WING WALL AT TEMPLE MEADS BRIDGE AND TOTTERDOWN LOCK_31-08-1989	CD-04259_38402-003069
TOTTERDOWN LOCK_15-11-1989	CD-08074_38401-000754
PLAN REFFERRED TOTTERDOWN LOCK AREA_21-11-1983	CD-08075_38401-000077
PLAN OF AREA SE OF TOTTERDOWN LOCK BRISTOL_21-11-1983	CD-08076_38401-000076
PLAN OF AREA SE OF TOTTERDOWN LOCK BRISTOL_15-11-1989	CD-08077_38401-000755
PROPOSED WEIR AND LOCK AT TOTTERDOWN_21-11-1983	CD-08078_38401-000075

Figure 14: CD-04259_38402-003069 COLLAPSE OF NORTH BANK OF NEW CUT BETWEEN WING WALL AT TEMPLE MEADS BRIDGE AND TOTTERDOWN LOCK_31-08-1989

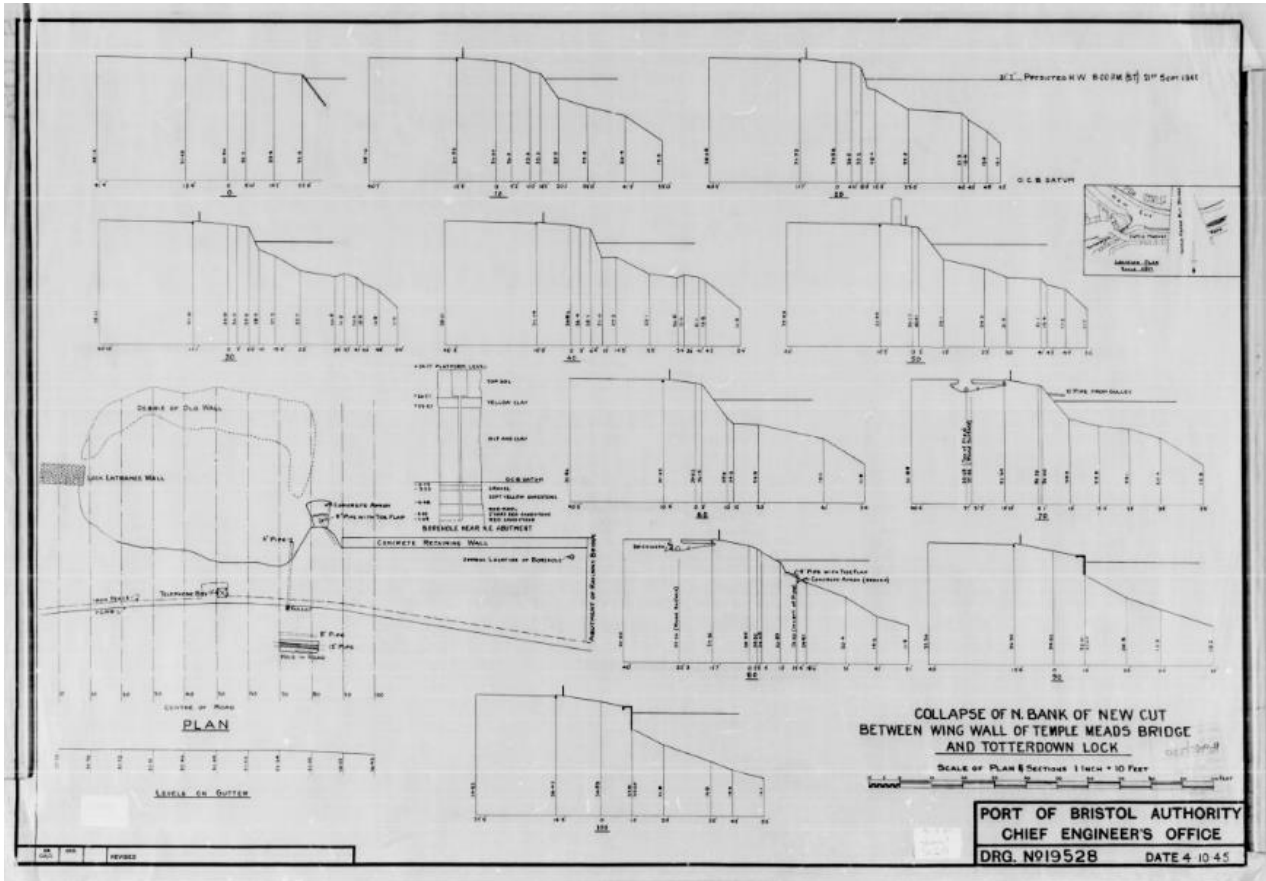


Figure 15: CD-03863_38402-000377_BRISTOL DOCKS PROPOSED WALL NEAR TOTTERDOWN LOCK PLAN AND SECTIONS SURVEY MADE FOR SAME 27-06-1912_12-12-1983

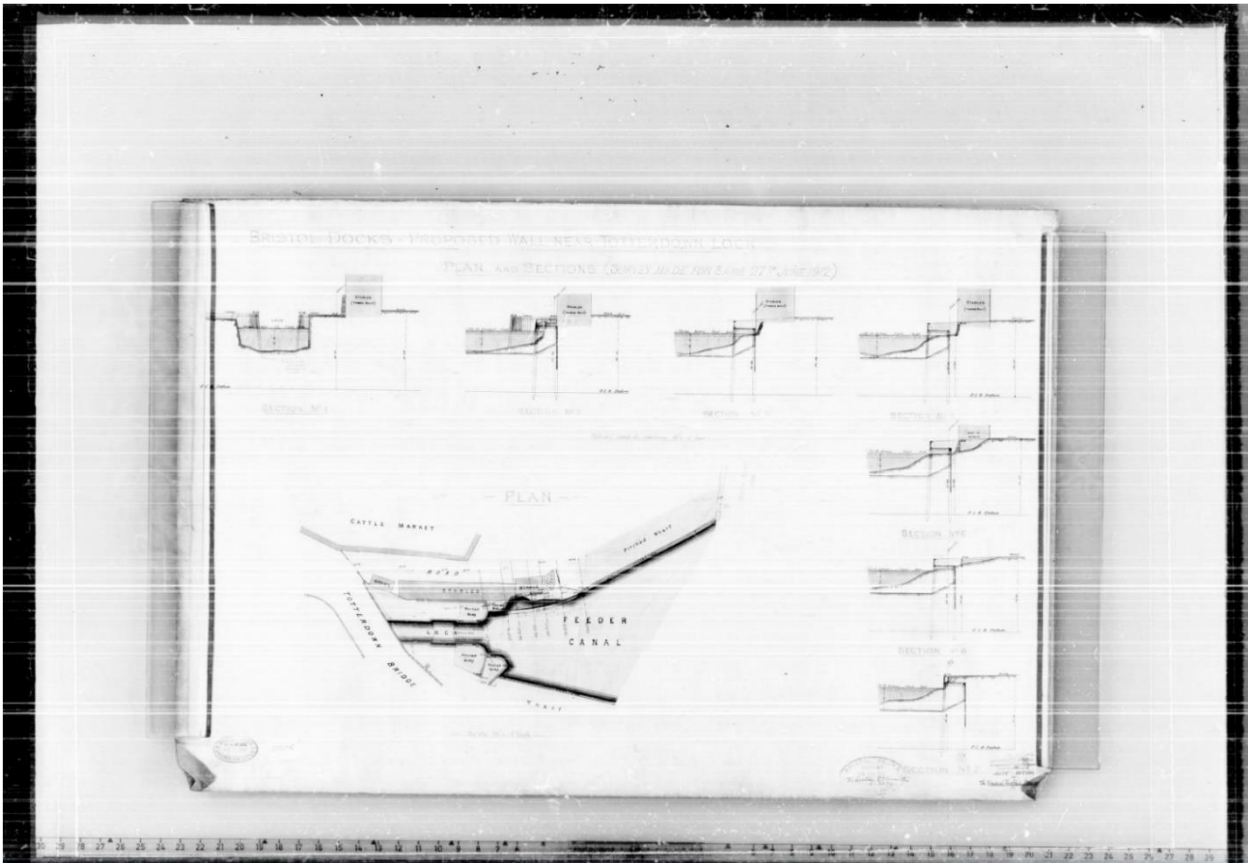
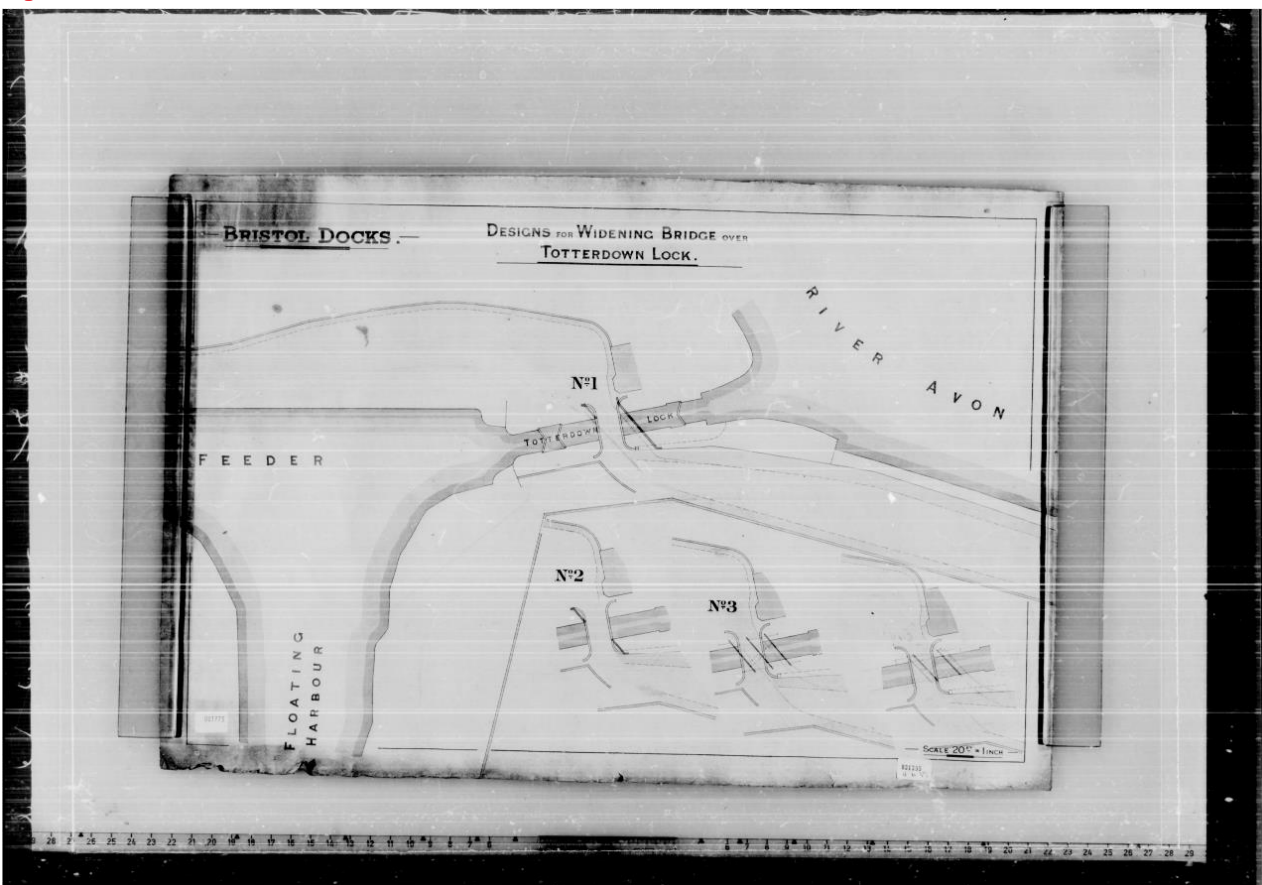


Figure 16: CD-02241_31395_DESIGN FOR WIDENING BRIDGE OVER TOTTERDOWN LOCK_02-06-1989



B.4 Feeder Float Lock & Feeder Canal

Table 13: Archived documents of Feeder Float Lock and Feeder Canal

Aperture Card Title	Card Reference
PBA WIDENING OF FEEDER FLOAT JUNCTION LOCK NEAR TOTTERDOWN LOCK_17-08-1989	CD-03763_38402-001899
PBA WIDENING OF FEEDER FLOAT JUNCTION LOCK NEAR TOTTERDOWN LOCK_05-12-1989	CD-03764_38402-000329
LOCATION PLAN TOTTERDOWN LOCK_17-08-1983	CD-03767_38402-001902
WIDENING OF TOTTERDOWN JUNCTION LOCK_05-12-1983	CD-03768_38402-000330
WIDENING OF TOTTERDOWN JUNCTION LOCK_05-12-1983	CD-03769_38402-000331
WIDENING OF THE FEEDER FLOAT JUNCTION LOCK NEAR TOTTERDOWN LOCK_05-12-1983	CD-03775_38402-000332
FEEDER CANAL LOCKS AND BRIDGES CROSS SECTION_19-09-1989	CD-05023_38402-002238
FEEDER CANAL LOCKS AND BRIDGES CROSS SECTION_13-02-1984	CD-05024_38402-000942

Figure 17: CD-05023_38402-002238_FEEDER CANAL LOCKS AND BRIDGES CROSS SECTION_19-09-1989

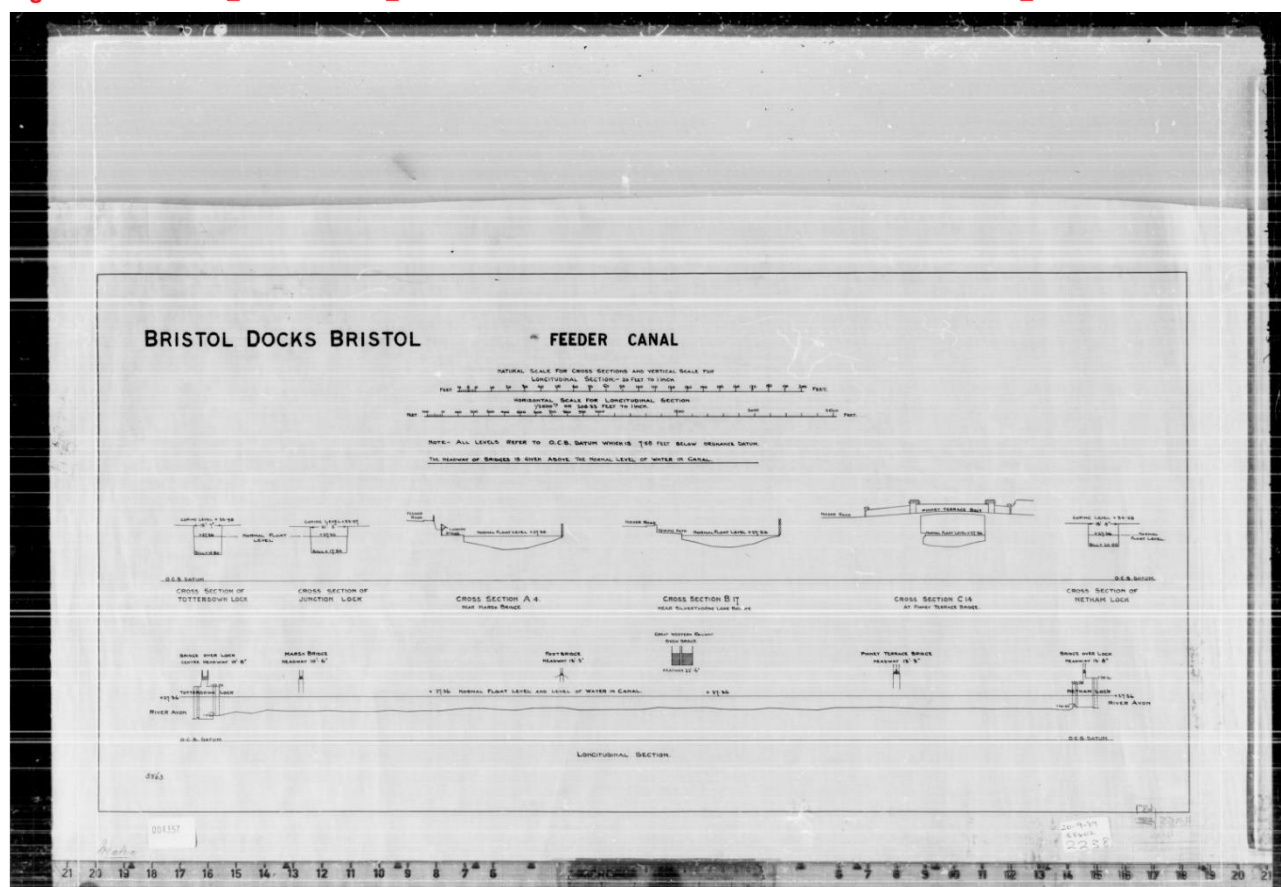
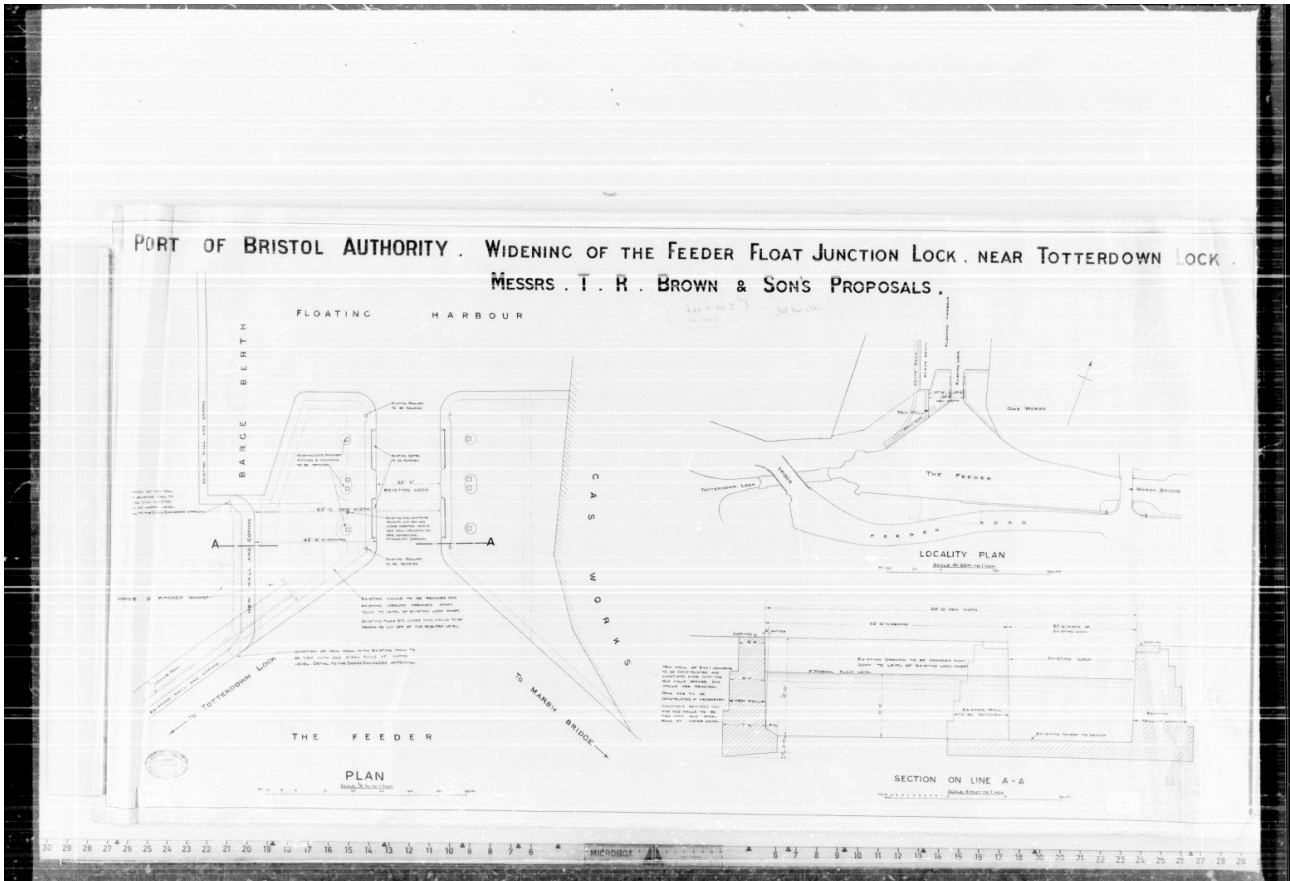


Figure 18: CD-03763_38402-001899_PBA WIDENING OF FEEDER FLOAT JUNCTION LOCK NEAR TOTTERDOWN LOCK_17-08-1989



B.5 Positions of Moorings (Floating Harbour)

Table 14: Archived documents of positions of moorings

Aperture Card Title	Card Reference
POSITION OF MOORINGS AROUND FLOATING HARBOUR FROM BRISTOL BRIDGE TO TOTTERDOWN LOCK_17-11-1989	CD-08263_38401-000832

B.6 St Philip's Marsh Wider Area

Table 15: Archived documents of St Philip's Marsh wider area

Aperture Card Title	Card Reference
LOCATION PLAN OF BRIDGES AND LOCKS FEEDER CANAL_13-02-1984	CD-05022_38402-000943
PLAN OF RIVER FROM TOTTERDOWN LOCK TO NETHAM DAM_16-02-1984	CD-05216_38402-001074
BRISTOL DOCKS BRISTOL ST PHILIPS MARSH	CD-10390
BRISTOL DOCKS BRISTOL ST PHILIPS MARSH	CD-10391
BRISTOL DOCKS BRISTOL ST PHILIPS MARSH	CD-10392
BRISTOL DOCKS BRISTOL ST PHILIPS MARSH	CD-10393

Figure 19: CD-10391_BRISTOL DOCKS BRISTOL ST PHILIPS MARSH

