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CSO Discharge Designers Risk Assessment Permanent Case – Albert Embankment Foreshore

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Bazalgette Tunnel Limited

Tideway 15 January 2024



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CSO Discharge Designers Risk Assessment Permanent Case – Albert Embankment Foreshore

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1. Executive summary

- 1.1 This designers risk assessment has been produced to assess the hazards of swamping, capsizing, grounding and collision created by the ALBEF CSO discharge flows to vessels on the Thames at the Albert Embankment Foreshore (ALBEF) site.
- 1.2 It has been undertaken for the permanent phase when the existing CSO is diverted to the new CSO outfall that is situated further into the river Thames in the new ALBEF structure.
- 1.3 This designers risk assessment has assessed the risk to all types of vessels that undertake passages past the location through bridge Arches 4 and 3.
- 1.4 A most probable worst-case scenario of a 1 in 15-year event at MLWN with an instantaneous peak discharge modelled +/- 50 minutes from slack water has been analysed to assess the impacts to vessels in the bridge Arches.
- 1.5 All discharges should be considered as the most probable worst case where it is not possible to establish the magnitude of the discharge at the time of discharge. Consideration should be made to the magnitude of the discharge rate and the minimum period of 2 minutes and 30 seconds from the start of the discharge to a significant rate of discharge.
- 1.6 With the tunnel in permanent operation the discharges are likely to occur approximately 1 to 3 times per year reducing from the current predictions of 114 times per year when the tunnel is not in operation.
- 1.7 It has been concluded that the impact of the discharge to Arch 3 occurs for 50 minutes, starting 25 minutes before MLWN and concluding 25 minutes after, this period of impact should be applied for all low tides.
- 1.8 It has been concluded that the impact of the discharge to Arch 4 occurs from mid-ebb to midflood.
- 1.9 The assessment has concluded that the discharges cannot be predicted within 30m of the CSO outfall and all vessels should avoid that close proximity to the discharge at any state of the tide.
- 1.10 It is assumed that the same effects from the CSO discharges would be present when a Thames barrier closure is in operation and the river is in a permanent state of slack water.
- 1.11 Due to the limitations of the HRW modelling of the discharges, a more conservative approach to assessing the most probable worst case tidal window to arch 3 could be to make an allowance for the variabilities potentially caused by environmental and climatic conditions, a suggested tidal window is LW Slack +/- 45 minutes
- 1.12 It has been concluded that the overall residual risk is low for powered vessels when an effective warning system is used to warn vessel operators during a CSO discharge event at low water subject to confirmation in the NRA, detailed design and operational plan.
- 1.13 It has been concluded that the risk to the worst effected unpowered and low powered vessels in Arch 4 reduces from moderate to low when an effective warning system is used to warn vessel operators during a CSO discharge event that occurs between mid-ebb to mid-flood, subject to confirmation in the NRA, detailed design and operational plan.

- 1.14 The main works contractor, FLO, will undertake a navigational risk assessment to consider the residual risks and confirm their mitigations, in consultation with the Port of London Authority, required to be in place during the phase that is covered by this DRA.
- 1.15 The main works contractor FLO will need to consider the detailed design and the NRA to develop an operational plan, in consultation with the PLA, outlining how they will manage a CSO discharge event with the use of a warning system in line with Tideways "Technical Memorandum on CSO warning performance specification and strategy"
- 1.16 The permanent case has been risk assessed incorporating the findings of the ship simulations and will be subject to a navigational risk assessment by the Main Works Contractor to determine, in agreement with the Port of London Authority, any permanent mitigations that may be required. The Technical Memorandum on CSO warning performance specification and strategy should be considered to confirm the mitigations.

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Acronyms and abbreviations

Abbreviation	Abbreviation Description
ALARP	As Low As is Reasonably Practicable
ALBEF	Albert Embankment Foreshore
CFD	Computational Fluid Dynamics
CS0	Combined Sewer Overflow
DRA	Designers Risk Assessment
FLO	Ferrovial Laing O'Rourke – Tideway Central Main Works Contractor
НАТ	Highest Astronomical tide
LAT	Lowest Astronomical Tide
LRT	Lowest Recorded Tide
LTT	London Tideway Tunnel
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
NRA	Navigational Risk Assessment
PLA	Port of London Authority
SUP	Stand Up Paddleboard
UWWTD	Urban Waste Water Treatment Directive

2. Introduction

2.1 Introduction

- 2.1.1 As part of the Thames Tideway Tunnel project a new foreshore structure called Albert Embankment Foreshore (ALBEF) to intercept both Clapham and Brixton Combined Sewer Overflow (CSO) has been planned and constructed.
- 2.1.2 The site comprises an area of foreshore parallel to Albert Embankment between Tintagel House and St George Wharf. The site is divided into two halves with the northern section, in front of Camelford House containing the drop shaft and the southern section, either side of Vauxhall bridge, containing the interception structures.
- 2.1.3 The new CSO outfall for ALBEF is located in the interception structure on the northern side of Vauxhall bridge combining both the Clapham and Brixton CSO discharges.
- 2.1.4 Jacobs, as the designer for the reference design, has the duty under the CDM regulations to eliminate risks as far as reasonably practicable, where the risks cannot be eliminated the risks need to be reduced as far as reasonably practicable and information provided on residual risk.
- 2.1.5 Under the CDM regulations the Principal Designer, Jacobs, has a responsibility to plan, manage, monitor and coordinate the health and safety in the pre-construction phase of the project.
- 2.1.6 During the development of the design a designers risk assessment was undertaken to identify risks through design whilst also identifying any residual risks that would need to be considered.
- 2.1.7 As part of Designers Risk Assessment Albert Embankment PLH2X the impact of the new structure was considered under risk reference CDM-ALBEF-024, as presented below in Table 2-1.

Risk ref.	Title / description	Phase	Activity	Potential hazards	Effect summary inc person at risk.	Severity	Probability	First Risk Rating	Design measures to eliminate hazards	Design measures to reduce risk and/or design assumptions	Severity	Probability	Risk Rating after E & R	Residual risk (if significant, etc.)	How is it communicate d and / or documented?
CDM- ALBEF- 024	River Traffic	Operation	Normal Operation of Traffic	Projection of permanent works into the river	Vessels can collide with permanent works, putting river users, public and maintenance operatives at risk	3	2	Medium	Unable to eliminate hazard further	Drop shaft designed to resist ship impact as required Other mitigation measures will depend on the outcome of navigation risk assessment carried out as part of detailed design	3	2	Medium	Vessels collide with permanent works, putting river users, public and maintenance operatives at risk.	Preliminary navigational risk report included in site information/Se ction 0 of ITT

 Table 2-1 Extract from Designers Risk Assessment Albert Embankment PLH2X

2.1.8 Whilst CDM-ALBEF-24 recognises that there is a risk to vessels in the river due to the structures it does not consider the impact of a discharge on passing vessels.

- 2.1.9 To ensure that all the relevant risks and mitigations are covered through a Designers Risk Assessment this document is an addendum which will consider a detailed risk assessment of the ALBEF CSO discharges impacting the vessels on the river.
- 2.1.10 This DRA designer's risk assessment (DRA) considers: -
 - (a) The permanent case with the new foreshore structure in place and the flows able to be intercepted and diverted to the main tunnel.
 - (b) When the tunnel is out of operation for maintenance and inspection works.
- 2.1.11 The DRA makes the assessment based on the information that has been produced by the contractor, HR Wallingford document 4410-FLOJV-ALBEF-520-VZ-RG-100004_CSO discharge modelling for permanent works Albert Embankment Foreshore_P04 and documents produced by Jacobs, Interim DRA 665397CH-ALBEF-DRA-Interim-REV.06 and the updated rainfall information compiled by Tideway.
- 2.1.12 The DRA should be read in conjunction with HR Wallingford document 4410-FLOJV-ALBEF-520-VZ-RG-100004_CSO discharge modelling for permanent works Albert Embankment Foreshore_P04. Within the HR Wallingford report the discharges are modelled with a mean absolute error of 6% for neaps and 7% for springs when compared to the peak flow.
- 2.1.13 The HR Wallingford document 4410-FLOJV-ALBEF-520-VZ-RG-100004_CSO discharge modelling for permanent works Albert Embankment Foreshore_P04 only considers a steady state where the variability of environmental and climatic conditions such as, but not limited to, wind, rain and surge are not considered due to the infinite, possible scenarios.
- 2.1.14 In addition, it considers additional information; -
 - (a) LL1658-R-01 Navigational Risk Assessment Review Port of London Authority, which was undertaken by Rendel Limited with Waves Group,
 - (b) The latest discharge modelling data and vessel impact modelling undertaken by Jacobs (and HR Wallingford Physical Model).
 - (c) The outputs of the HR Wallingford Ship Simulation centre; and
 - (d) The CCTV river traffic survey report produced by Nash Maritime.

2.2 Report Structure

- 2.2.1 The Structure of this report is as follows:
 - a. Section 3 Outline methodology for producing the risk assessment
 - b. Section 4 Site discharge activity
 - c. Section 5 Assessment of discharges
 - d. Section 6 Ship simulation comparison
 - e. Section 7 Risk assessment
 - f. Section 8 Mitigations
 - g. Section 9 Summary

2.3 The site and CSO discharge location

- 2.3.1 The original Clapham and Brixton CSO's are located on the southern bank of the Thames either side of Vauxhall Bridge, as shown on Figure 2-1.
- 2.3.2 Both outfall structures extended beyond the line of the river wall into the Thames and were marked by wooden dolphins, as can be seen in Figure 2-2 and Figure 2-3.

Figure 2-1 Plan of historic Clapham and Brixton CSO Locations.



Figure 2-2 Original Clapham CSO.



Figure 2-3 Original Brixton CSO.



- 2.3.3 Brixton is the dominant overflow with approximately 92 discharges in a typical year, compared with approximately 11 from the Clapham CSO.
- 2.3.4 The new ALBEF interception structure, shown in Figure 2-4, combines both the Clapham and Brixton CSOs and diverts them to the new Tideway Tunnel. There is a single new outfall which will discharge when the tunnel is full or unavailable. Although in the vicinity of the original Brixton CSO, the new CSO discharge point is approximately 12m closer to the navigation channel.

Figure 2-4 New ALBEF foreshore structure and CSO outfall location.



3. Outline Methodology

- 3.1 To analyse the impact of CSO discharges from the site to the river, identify the risks to vessels on the river, identify the impacted vessels, propose mitigations and present the residual risks the following has been undertaken:
- 3.1.1 Confirm site discharge activity by:
 - i) Reviewing historical rain and discharge data
 - ii) Reviewing resilience to climate change
 - iii) Confirm tidal windows of potential impact to vessels
 - iv) Review and analyse the impact of discharges on the river from HR Wallingford document 4410-FLOJV-ALBEF-520-VZ-RG-100004_CSO discharge modelling for permanent works Albert Embankment Foreshore_P04.
- 3.1.2 Review impact of most probable worst-case discharge on vessels on the river by:
 - i) Confirming areas of the river
 - ii) Confirming vessels that use the river in this area
 - iii) Confirming predicted drift angle of vessels caused by a ALBEF CSO discharge
 - iv) Summarise impacted vessels on the river
- 3.1.3 Risk assessment
 - i) Hazards
 - ii) Receptors Using the CCTV river traffic survey data
 - iii) Severity of harm
 - iv) Likelihood of harm
- 3.1.4 ERIC approach to review mitigation
 - i) Eliminate
 - ii) Reduce
 - iii) Inform
 - iv) Control
- 3.1.5 Summary

4. Site discharge activity

4.1 Consideration of rainfall events

- 4.1.1 CSO discharges were produced for a range of return period storms using an InfoWorks network model of the upstream sewer catchment.
- 4.1.2 Synthetic storms were generated by the software based on the Flood Estimation Handbook (FEH).
- 4.1.3 The critical storm duration for the system (i.e., that which produces the highest flows at the outfall) was found to be 120 minutes.
- 4.1.4 Normally, when generating synthetic storm events, rainfall intensities are reduced as the footprint of a storm increases. However, in this instance, the storm event was applied over the entire catchment without applying an areal reduction factor.
- 4.1.5 With an approximate catchment area of 550km², the corresponding reduction factor for the Tideway catchment would have been 0.76 the rainfall intensities are therefore overestimated by approximately 32%.
- 4.1.6 In addition, the model assumes that all rainfall landing on a catchment freely enters the sewer system. In practise, for higher rainfall intensities, this cannot happen as the gullies and upstream collection pipework act as a restriction, resulting in flooding and ponding on the surface. For this reason, the modelled 100-year storm flows are considered theoretical and unlikely to ever be realised. It is the upstream sewer system that limits the peak CSO discharge rate, not the size of the CSO opening itself.
- 4.1.7 The InfoWorks model was run with free discharge (i.e., low tide) as a worst-case scenario and the discharge rates included in the projects works information (WI 7706). These WI flows are shown in Table 4-1.
- 4.1.8 Periodic updates are made to the model depending on the results of surveys/inspections. Discharge rates using the updated model are also given in Table 4-1.
- 4.1.9 At higher tides the CSO becomes submerged and there is a corresponding decrease in discharge rates, also included in Table 4-1.

Source		LT 1- Year Storm	LT 2- year storm	LT 5- year storm	LT 10- year storm	LT 15- year storm	LT 30- year storm	LT 50- year storm	LT 100- year storm
Latest DA Model	Instantaneous Peak Low water (m ³ /Sec)	-	12.4	17.9	20.8	21.9	23.8	24.6	25.1
Latest DA Model	Rolling Hourly Average Low water (m ³ /Sec)	-	10.0	15.6	18.8	20.3	22.4	23.6	24.6
Latest DA Model	Instantaneous Peak High water (m ³ /Sec)	-	6.9	9.4	12.4	14.2	16.9	18.4	20.3
WI 7706	Instantaneous Peak Flow	11.6	13.0	18.1	20.9	22.0	24.0	-	-

Table 4-1 Comparison of Instantaneous peak discharge rates from WI 7706 and the updated model

- 4.1.10 It should be noted that occasionally TWUL can make minor diversions to the sewer network upstream to facilitate maintenance access. However, these are generally local in nature and don't have a significant impact on CSO discharges.
- 4.1.11 The developed nature of the upstream catchment means it is not possible to make substantial changes to the network connectivity that could significantly affect peak CSO discharges. Ultimately there is a fixed amount of rainfall falling on a fixed area, served by a sewer system of fixed and limited capacity.
- 4.1.12 Only when the works are complete will there be planned works that significantly impact CSO discharges. Every 10 years it is planned to close the tunnel for inspections, under these conditions all flow is diverted to the CSO. Whilst the exact duration of the closure is yet to be finalised, it is expected to be of the order of two weeks.
- 4.1.13 Given the conservative nature of the rainfall generation, the theoretical nature of the network modelling, the limited scope to significantly alter the upstream sewer network and the range of possible tide levels, the 1 in15 year storm scenario at a discharge flow rate of 22m³/s is considered a maximum realistic CSO discharge rate.
- 4.1.14 Figure 4-1 shows the discharge hydrograph for the 15-year storm at low tide (peak flow 22m3/s). The hydrograph represents the 'Tunnel Closed' scenario. In this instance the storm started at 07:00 it took approximately 60 minutes for the CSO to start discharging and approximately another 30 minutes for the peak discharge to be realised.

Figure 4-1 CSO Discharge Hydrograph for the 15-year storm, tunnel closed



4.1.15 Figure 4-2 shows the same storm event but with the 'Tunnel Operational' scenario. It can be seen that the tunnel storage delays the onset of the CSO discharge by approximately 15 minutes but the duration between the start of discharge and reaching peak discharge is reduced to 15 minutes.



Figure 4-2 CSO Discharge Hydrograph for the 15-year storm, Tunnel Operational

- 4.1.16 At the design phase of the project, 40 years of recorded rainfall data was available, spanning 1970-2010. Following inspection of this data set it was determined that the most representative (typical) year was October 1979 to September 1980. A further review of the data up to 2020 has confirmed that this remains the case.
- 4.1.17 Table 4-2 summarises the peak CSO discharges at ALBEF during the typical year (1979/80).

Table 4-2 Peak CSO) discharges during	typical year (1979/80)
--------------------	---------------------	------------------------

	Spill Duration	Peak Flow	Spill Volume
Start of Spill	(mins)	(m3/s)	(m3)
09/10/1979 07:00	245	11.76	35,224
25/10/1979 14:25	272	7.08	27,276
02/11/1979 00:56	89	0.07	145
06/11/1979 00:55	115	0.35	751
26/11/1979 14:00	282	1.76	11,347
09/12/1979 01:50	173	0.09	223
13/12/1979 04:30	149	2.53	5,103
27/12/1979 01:35	657	2.34	28,165
03/01/1980 22:30	205	3.42	11,582
20/01/1980 17:15	185	0.34	968
03/02/1980 15:20	171	1.21	2,988
04/02/1980 14:50	106	0.16	357
22/02/1980 10:55	153	0.56	1,930
06/03/1980 10:00	216	1.46	5,934

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	-		
17/03/1980 07:40	328	1.94	11,907
31/03/1980 10:25	124	0.51	1,140
01/04/1980 11:46	143	0.68	1,634
30/05/1980 10:10	108	0.29	595
31/05/1980 13:56	291	0.72	2,506
12/06/1980 15:40	127	1.84	2,990
13/06/1980 03:40	303	7.77	18,141
17/06/1980 17:25	161	2.62	6,043
22/06/1980 10:20	223	7.43	20,680
24/06/1980 09:25	200	2.98	6,660
27/06/1980 00:42	82	0.04	76
30/06/1980 19:45	281	2.75	12,386
03/07/1980 23:05	112	0.30	620
07/07/1980 14:05	167	3.92	8,674
18/07/1980 09:30	110	0.30	598
25/07/1980 23:40	285	10.74	35,560
12/08/1980 21:35	188	4.40	9,679
14/08/1980 18:55	231	3.02	13,912
16/09/1980 08:45	213	0.49	1,551
21/09/1980 11:20	117	0.45	914

4.1.18 Figure 4-3 below shows the combined peak flows from the Clapham and Brixton CSO outfalls using the full set of actual rainfall data for 1970-2020. Over that period, peak flows have exceeded the 1 in 5-year rates but not the 1 in 15-year rates.





4.2 Discharge frequency and magnitude

4.2.1 The ALBEF structure will be in intercepting both the Brixton CSO and Clapham CSO whose flows will be diverted to the main tunnel, however there will be periods when the tunnel will be taken out of operation for inspection and maintenance. During these periods the tunnel will be isolated, and the intercepted flows will discharge through the new CSO. Whilst these works will be planned to be undertaken during periods of low flow there may be storms and there the magnitude of these discharges and the potential frequency needs to be understood.

Magnitude

4.2.2 The 2020 CSO peak discharge flows have been analysed and presented in Figure 4-4, this includes the two storms from July 2021 which were noted for their intensity.

Figure 4-4 Modelled combined Clapham and Brixton CSO discharge peak rates with actual rain data for 2020, including storms from July 2021



- 4.2.3 From the information presented in Figures 4-3 and 4-4 the average instantaneous peak discharge rate during 2020 was 1.4m³/s with a maximum combined instantaneous peak of 11.5m³/s which is in line with the typical year return period event peak discharge velocity of 11.6m³/s. During the 2021 summer storm the modelled combined CSO discharge rate was 15 m³/s.
- 4.2.4 After analysing data relating to the 50-year data model outputs, the 2020 output and the July 21 storm outputs, it can be confirmed that there has been 5 occurrences that marginally exceeded the works information 1:5-year return period discharge rate. This confirms that using the 1:15 return period discharge rate is highly conservative.

Frequency

4.2.5 In 2019 an event duration monitor (EDM) was installed into the Clapham and Brixton Storm Relief Sewers to enable TWUL to deliver against the regulatory requirement to report CSO discharges capturing the number of discharges and their duration. The records from the Brixton and Clapham Storm Sewer EDM's started being reported from 2020 and since installation the EDM has recorded between 81 and 152 discharges per year with a long-term average of 114.25 discharges per year.

Climate change

- 4.2.6 During the development of the scheme and in support of the application for Development Consent, Tideway produced document 7.23 Resilience to Change. This document was developed to assess whether the scheme would continue to meet the Urban Waste Water Treatment Directive (UWWTD) requirements in the future whilst taking into consideration climate change and population increase.
- 4.2.7 The baseline data for the frequency and volume of CSO discharges was developed from the 1979/80 typical year of 588mm of rainfall depth which when modelled indicated a discharge of circa 39 million m³ of sewage into the Thames.
- 4.2.8 Table 6.3 from document 7.23 presents the typical year CSO spill volumes and event count comparisons for the current climate and medium emission modelled scenarios from the UKCPO9 government data on climate change. Table 4-3 below is the extract from that table for the modelled ALBEF CSO discharges.

P														
			Typical Year - 2020 population and current climate			Typical year - 2080 population and medium emission scenario, 10 percentile			Typical year - 2080 population and medium emission scenario, 50 percentile			Typical year - 2080 population and medium emission scenario, 90 percentile		
LTT ID	EA Category	CSO Name	Total Volume (m³)	No. of Spills	Spill Duration (Hrs)	Total Volume (m³)	No. of Spills	Spill Duration (Hrs)	Total Volume (m³)	No. of Spills	Spill Duration (Hrs)	Total Volume (m³)	No. of Spills	Spill Duration (Hrs)
CS19X	CAT 1	Clapham Storm Relief	7,900	1	5	12,500	1	6	16,400	1	8	22,700	3	16
CS20X	CAT 1	Brixton Storm Relief	5,700	1	4	9,300	1	5	12,800	1	5	17,500	3	12

Table 4-3 Extract of table 6.3 from document 7.23 - typical year CSO spill volumes and event count comparisons for the current climate and medium emission modelled scenarios

- 4.2.9 Table 4-3 demonstrates that the predicted CSO discharge frequency at ALBEF is not expected to increase significantly.
- 4.2.10 The UK government updated the climate scenarios and presented them as UKCP18. Tideway reviewed the information to confirm that the scheme would still meet its UWWTD requirements in the future. The review confirmed there had not been significant change in the outcomes and the resilience of the scheme as described in document 7.23 still held true.
- 4.2.11 Table 4-4 summarises the peak rainfall climate change allowances in England up to 2125, extracted from the DEFRA website.
- Table 4-4 Peak rainfall climate change allowances up to 2125

	Storm Return Period		
	30 year	100 year	
Central Range (50th %ile)	20%	25%	
Upper Range (95th %ile)	35%	40%	

- 4.2.12 These allowances are of the same order of magnitude as the overestimation of the synthetic rainfall intensities explained in paragraph 4.1.5 (32%). It can therefore be considered that climate change has been adequately allowed for.
- 4.2.13 Notwithstanding the above, any future increase in rainfall intensities will not have a significant impact on the 1:100-year ALBEF CSO discharge rates for the reasons set out in paragraph 4.1.6.

4.3 Tidal Considerations

- 4.3.1 This section is to consider the HR Wallingford report 4410-FLOJV-ALBEF-520-VZ-RG-100004_CSO discharge modelling for permanent works Albert Embankment Foreshore_P04 to confirm the worst-case scenario and the impact of a CSO discharge across the tidal range.
- 4.3.2 The 1:15-year return HR Wallingford plumes will be used to assess the zone of impact of the lateral flow on the river with its associated tidal window, for the reasons established in section 4.1.13, it is the most probable worst-case return period event that could occur without warning during a maintenance period or when a return storm occurs and the penstocks are closed.
- 4.3.3 The HR Wallingford document was commissioned to provide 2-d depth averaged velocity discharge plumes using the instantaneous peak velocities for a typical year (1:1) and 1:15 -year events at the following tide states shown in Table 4-5. Depth average velocity is the average velocity at any location within the footprint of the discharge plume and typically occurs at 60% of the depth, measured from the top.
- 4.3.4 The report states that in considering the results it should be remembered that the model is 2D depth-averaged and hence will not model the detail of 3D aspects of the jet, especially within the distance taken for the expanding jet to mix fully with the receiving waters. Therefore, care should be taken in assessing the results close to the discharge point. Beyond 20 to 30 m of the discharge point the jet would be expected to be mixed with the receiving waters and the general modelled flow patterns are reliable. It has therefore been concluded that any effects within that zone are unpredictable and therefore the impacts within that zone cannot be established and will be considered as worst case.

Tidal condition	Tidal States								
Spring tide	Low water slack	Mid-ebb flow	Mid-flood flow	High water slack					
Neap tide	Low water slack	Mid-ebb flow	Mid-flood flow	High water slack					

Table 4-5 HR Wallingford modelling tidal discharge cases.

- 4.3.5 The height of the new CSO outfall, relative to the riverbed and the river level, is presented in Figure 4-5. The figure also identifies the distance to the relative bridge Arches.
- Figure 4-5 River section showing the new CSO outfall position relative to the riverbed.



4.4 Zone of Clapham and Brixton combined CSO discharge impact

4.4.1 The analysis of the tidal cases undertaken by HR Wallingford identified that during the periods of rising or falling tide there was a lack of lateral flow entering the navigational channel due to the rapid dispersion of momentum of the discharge by the background tidal currents. Figure 4-6 presents an example of this for a mid-flood tide. The resulting impact of the lateral flow on the navigational channel is similar for the mid-ebb tide, shown in Figure 4-7.

Figure 4-6 Depth-averaged currents associated with the peak 1:15-year return period at mid flood tide.



Figure 4-7 Depth-averaged currents associated with the peak 1:15-year return period at mid Ebb Tide



4.4.2 During neap high water slacks for the 15-year return period events the discharge creates a lateral flow of 0.2 to 0.4m/s across arch 4. This is presented in Figure 4-8. Notably any flow from the discharge is approximately within 30m from the discharge and therefore the modelling isn't conclusive for the reasons stated in paragraph 4.3.4.

Figure 4-8 Depth-averaged currents associated with the peak 1:15-year return period discharge at neap high water slack.



4.4.3 The Jacobs CFD for the 1:100-year return period event at high water springs is presented in Figure 4-9. The CFD output presents the discharge entering the water column perpendicular to the main flow, mainly along the riverbed, before its energy is quickly dissipated. The diagram supports the statement made in 4.3.3 that the depth average velocity typically occurring at 60% depth measured down from the surface.

Figure 4-9 Jacobs CFD output for 1:100-year return period event at slack high-water springs.



4.4.4 From analysing the above information, it can be determined, for any discharge event, that from mid flood across high water to mid ebb there is no lateral flow, from the CSO, entering arch 4 at

the surface due to the lateral flow velocity being concentrated at river bed level before being dissipated into the main water column, this can be demonstrated as there are no linking vectors from the river bed to the surface. In addition, the sea state will not be changed from its background state by a CSO discharge during the mid flood to mid ebb period.

- 4.4.5 The HRWallingford report is clear that the greatest impact of a CSO discharge on the main river is at low water neaps as the CSO discharges straight into the water column which allows for the retention of greater momentum of the lateral flow within the water column. At low water neaps this lateral flow continues across Arch 3 in the navigational channel, as presented in Figure 4-10.
- 4.4.6 The flow can be seen to enter Arch 2 but the flow has diminished to within 0.2m/sec outside a reasonable minimum safe vessel clearance zone to the bridge pier. The flow only enters the Arch 2 at slack water. This section of the report will therefore establish the potential tidal windows of impact in Arches 3 and 4 only.

Figure 4-10 Depth-averaged currents associated with the peak 1:15-year return period discharge at Neaps LW slack.



4.4.7 To confirm the duration of the impact, HR Wallingford carried out model runs from 50 minutes before low water to 50 minutes after low water at 10-minute intervals. From this information HR Wallingford tabulated a comparison of the lateral flow relative to Arch 3 for all cases that had been modelled, as presented in Table 4-6 (HRW table 4.2). The table shows the assessment of both spring and neap tides and draws the same conclusion for both tidal states that the impact occurs for the same tidal window from 15 minutes before to 15 minutes after slack for a 1 in 15 year event.

	Spri	ng LW Disc	charge Eve	e Event Spring Continuous Peak Discharge Neap LW Discharge Ev			Spring Continuous Peak Discharge			charge Event	Neap Continuous Peak Discharge			
Minutes to LW	Event Discharge	Reaches Arch 3	Reaches Arch 3	Reaches Arch 3	Peak	Reaches Arch 3 100vr	Reaches Arch 3	Reaches	Event	Reaches Arch 3	Peak	Reaches Arch 3	Reaches Arch 3	Reaches
-50	1.7	looyi	isyi		25.1	liveyi	1591	rueno tyt	1.7	looyi	25.1	looyi	1.5yr	Vacino iyi
-40	6.3				25.1			5	6.3		25.1			
-30	12.6			3	25.1			2	12.6		25.1			
-20	18.8				25.1				18.8		25.1			
-10	23.4	1	1	1	25.1	1	1	1	23.4	1	25.1	1	1	1
0	25.1	1	1	1	25.1	1	1	1	25.1	1	25.1	1	1	
10	23.4	1	1		25.1	1	1	1	23.4	1	25.1	1	1	
20	18.8				25.1				18.8		25.1	1		
30	12.6				25.1	(c)			12.6	5	25.1	-		
40	6.3	6			25.1				6.3	1	25.1			
50	1.7			1	25.1			1	1.7		25.1			

Table 4-6 HR Wallingford assessment of Arch 3 impact

- 4.4.8 This assessment will establish the individual tidal window for Arches 3 and 4 separately.
- 4.4.9 Jacobs have analysed the report by HR Wallingford in this section and have produced
- 4.4.10 Table 4-7 to establish the tidal window for Arch 3.
- 4.4.11 It can be seen from Figure 4-11 that the lateral flow has not been completely dominated by the main river flow within Arch 3.
- 4.4.12 It can be seen from Figure 4-12 that the lateral flow has been completely dominated by the main river flow within Arch 3.
- Figure 4-11 1:15-year return period depth averaged currents at 20 minutes before Neap low water slack



Figure 4-12 1:15-year return period depth averaged currents at 30 minutes before Neap low water slack



4.4.13 It can be seen from Figure 4-13 that the lateral flow is still present in Arch 3, 20 minutes after slack water.



Figure 4-13 1:15-year return period depth averaged currents at 20 minutes after Neap low water slack

4.4.14 It can be seen from Figure 4-14 that the lateral flow has been pushed into Arch 4 by the dominant river tidal flow 30 minutes after slack water.

Figure 4-14 1:15-year return period depth averaged currents at 30 minutes after Neap low water slack



4.4.15

4.4.16 Table 4-7 presents Jacobs review of the tidal windows in comparison to the HR Wallingford analysis. The areas highlighted green are periods when the lateral flow does not enter Arch 3, whereas the areas highlighted in red are periods when the lateral flow does enter Arch 3. The assessment of impact on river users transiting through Arch 3 will only need to consider the red periods highlighted in the table.

Minutes to	Spring Continuou	ıs Peak Discharge
I W Slack	Jacobs Tidal Window	HRW Tidal Window Arch
Lifetaci	Arch 3 15 yr (22m3/s)	3 15yr (22m3/s)
-50		
-40		
-30		
-20		
-10		
0		
10		
20		
30		
40		
50		

Table 4-7 Comparison of lateral flow extent relative to Arch 3.

- 4.4.17 HR Wallingford analyses the scenarios including 5 minutes either side of the time stamp e.g. 10 minutes before low water is defined as the period 15 to 5 minutes before low water. Therefore, the overall tidal window for Arch 3 will be 50 minutes, from 25 minutes before low water slack to 25 minutes after low water and that period should be considered for all low water tidal states.
- 4.4.18 With respect to Arch 4, it can be seen from Figure 4-15 that the lateral flow from the CSO discharge is still present in Arch 4, 50 minutes before low water slack.

Figure 4-15 1:15-year return period depth averaged currents at 50 minutes before Neap low water slack



4.4.19 It can be seen from Figure 4-16 that the lateral flow from the CSO discharge is still present in Arch 4, 50 minutes after low water slack.



Figure 4-16 1:15-year return period depth averaged currents at 50 minutes after Neap low water slack

- 4.4.20 The HR Wallingford report does not model the discharges between mid-ebb to 50 minutes before low water slack and 50 minutes after low water slack to mid-flood. Therefore, the tidal window for Arch 4 can only be determined when there is no lateral flow from the CSO discharge and that period would be from mid-ebb to mid-flood where Figure 4-6 and Figure 4-7 show the river tidal flow to be dominant over the lateral flow.
- 4.4.21 Having determined the zone of impact in the 1 in 15-year probable worst case the zone of impact for a typical year, using the typical year discharge plumes will be assessed.
- 4.4.22 Figure 4-17 shows the CSO discharge from a typical year return period event at neap low water slacks. The lateral flow discharges through the flaps a 4.3m/s before starting to slow down as it impacts on to the scour apron. The flow reduces to approximately 2m/s by the end of the apron and to 1m/s as it reaches the edge of the navigation channel. The lateral flow continues to reduce to 0.6m/s between the channel edge and arch three and averaging 0.4m/s across Arch 3.



Figure 4-17 Typical year return period discharge at neap low water slacks.

4.4.23 Figure 4-18 shows the typical year return period discharge at 20 minutes before neap low water and shows that whilst there is lateral flow of 0.8m/s entering the channel edge, it is only marginally more than the background main river flow.



Figure 4-18 Typical year return period discharge 20 minutes before neap low water slacks.

4.4.24 Figure 4-19 shows the typical year return period discharge at 20 minutes after neap low water and shows that whilst there is lateral flow of 0.6m/s entering the channel edge it is only marginally more than the background main river flow.



Figure 4-19 Typical year return period discharge 20 minutes after neap low water slacks

4.4.25 It has been shown that the CSO discharge from a typical year impacts Arches 3 and 4 albeit to a lesser extent than the worst case of a 1 in 15 year event. It should be noted that during any future discharge it would not be possible to know the extent or magnitude of the discharge. Therefore, conservatively all discharges should be treated as if they were the worst case of a 1 in 15 year event.

5. Assessment of the discharges

5.1 Assessment of discharges

- 5.1.1 The 1:15-year event discharge plumes and sections are taken from document HR Wallingford document 4410-FLOJV-ALBEF-520-VZ-RG-100004_CSO discharge modelling for permanent works Albert Embankment Foreshore_P04.
- 5.1.2 As stated in 4.1.15 the assessment for the impact on vessels on the river will be carried out using a 1:15 return period ALBEF CSO discharge of 22m³/s at low water neaps which is the most likely worst-case scenario and produces the discharge plume that has the biggest projection across the river.
- 5.1.3 The assessment will consider the impact on vessels on the river in relation to the Arches that the vessels need to navigate through.

5.2 Outline which vessels have been assessed for and why.

5.2.1 Table 5-1 presents the vessels, and their characteristics, which have been chosen to represent the different types of vessels on the river that could be affected by a CSO discharge at Albert Embankment Foreshore. These have also been divided into classification groups for the risk assessment.

	Vessel Classification	Vessel Type	Min Speed (knots)(SOG)	Max Speed (knots)(SOG)	Power	Manoeuvrability	VHF
1		Uber Boat	6	25	High	High	Yes
2		RIB/Emergency	3	12 (40+	High	High	Yes
		services		Emergency only)			
3		Sightseeing/Pax	3	12	Medium	Medium	Yes
4	Commercial	Restaurant/Pax	3	10	Medium	Medium	Yes
5	Powered Vessels	Tug vessel engaged in pushing	3	6	High	Low	Yes
6		Tug vessel engaged in towing	3	6	High	Low	Yes
7		Workboats	3	6	Low	Medium	Yes
8	Recreational Powered Vessels	Narrow Boat/cabin cruisers	3	4	Low	Low	No
9	Un-Powered	Dinghy	1	3	V. Low	Low	No
10	Vessels	Kayak/Rowers/SUP	1	2	V. Low	Low	No

Table 5-1 Vessels and their characteristics that could be affected by a ALBEF CSO Discharge

5.3 Impacts of discharge on the different classes of vessel.

5.3.1 This section sets out the vessels that could be impacted by the CSO discharge, where the vessels are in relationship to the discharge and the corresponding drift angle that impact the vessels from the magnitude of the discharge flow.

- 5.3.2 To confirm the impacts of a discharge on vessels Figure 5-1, an extract of chart 317, has been produced to identify the normal course of a vessel undertaking passages upstream through Arches 2 and 3, and downstream through Arches 3 and 4.
- 5.3.3 To confirm the impacts of a discharge on vessels Figure 5-1, an extract of PLA chart 315, has been produced to identify the normal course of a vessel undertaking a passage downstream through arches 3 and 4 as well as upstream through arches 2 and 3.
- 5.3.4 For the purposes of identifying where the impacts of a CSO discharge occur and their magnitude, Figure 5-1 will be used in conjunction with Figure 5-2.



Figure 5-1 Extract of PLA chart 315 showing Arches used by vessels at low water.

- 5.3.5 Figure 5-1 presents the course for the expected safe draft clearance of vessels at periods of low water based on chart datum. It is accepted that there is additional navigable water during low water neaps and springs for a period +/-1hours but it is highly unlikely that this would materially affect the passage planning of an experienced mariner, where they would plan to chart datum
- 5.3.6 From Figure 5-1 it can be determined that all powered vessels with a draft including under keel clearance ≥ 1m would need to use Arch 3 to maintain a safe course upstream or downstream. All other vessels may use either Arch 2 or Arch 4, when transiting upstream or downstream, respectively.

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- 5.3.7 For vessels operating in Arch 4 the CSO discharge impact could be 2m/s when using the normal running position. For vessels operating in Arch 3 in normal running position the CSO discharge impact could be 1m/s depth averaged velocity. For vessels operating in Arch 2 in normal running position the CSO discharge would be negligible at 0.4m/s depth averaged velocity and therefore considered unaffected.
- 5.3.8 Figure 5-2 shows that the velocity of the lateral flow is strong across the face of Arch 4 reducing from 3m/s to 1.6m/s as it passes the pier into Arch 3. The flow then continues to diminish across Arch 3 to 0.6m/s as it approaches the next pier. It can therefore be established that powered vessels navigating through Arch 3 are unlikely to be adversely impacted from the ALBEF CSO discharge flow, whilst there will be no significant effect on all vessels navigating through Arch 2.
- Figure 5-2 1:15 year return period depth average currents at neap low water slacks.

- 5.3.9 The governing parameter is the draft of a vessel which determines the minimum depth of water that the vessel needs to safely operate without grounding. This parameter is therefore listed in Table 5-2.
- 5.3.10 Although it is probable that reporting vessels will operate in Arch 3 there is a possibility that most vessels could transit through or require access to Arch 4. Therefore, all vessel types utilising Arch 4 will be assessed.
- 5.3.11 The drift angle will be determined in relation to the lowest operating speed (Table 5-1) where the lowest speed will incur the highest magnitude impact.
- 5.3.12 The drift angles of the vessels are a function of the vessel speed while impacted by the CSO discharge current speed without any course correction, this will be taken as the worst-case scenario. The results are presented below in Figure 5-3 noting that drift angles are related to the speed of vessel and not category of vessel.

Figure 5-3 Drift angle - Current CSO vs vessel speed¹



- 5.3.13 This approach allows a direct evaluation of the CSO discharge as a potential hazard to the vessels passing the area.
- 5.3.14 Modelled flow velocities from CSO outfall discharge during a 1 in 15-year event with background tidal flows, shown in Figure 5-2.
- 5.3.15 Table 5-2 presents the assessed impact of a 1 in 15-year CSO discharge on the different vessel types, using the drift angle curves when the vessels are operating in the nominated Arches at low water. Where a vessel cannot navigate through the nominated arch within the tidal window where they would be affected by a lateral flow it is deemed not applicable.

Table 5-2 Approximated drift angle in Arch location when passing the CSO, during a 1 in15-year CSO discharge at MLWN.²

Vessel Type	Vessels Speed passing CSO. (Knots SOG)	Minimum Vessels Draft (metres)	Water depth allowing for Under Keel Clearance (Add 0.5m)	Approximation of drift angle (* denotes degrees) when passing the CSO In Arch 2	Approximation of drift angle (* denotes degrees) when passing the CSO In Arch 3	Approximation of drift angle when passing the CSO in Arch 4
Uber Boat (i.e., Hunt Class)	6	1.2	1.7	11º	15°	33°
RIB/Emergency Services	3	0.5	1.0	22°	28°	53°
Sightseeing/Pax	3	1.5	2.0	22º	28º	N/A
Restaurant/Pax (i.e., Symphony)	3	1.8	2.3	22°	28º	N/A
Tug vessel pushing	3	3	3.5	22º	28º	N/A
Tug vessel towing	3	3	3.5	22º	28°	N/A
Workboats	3	0.5	1.0	22º	28°	53°
Narrowboats/Motor cruisers	3	1.0	1.5	22º	28º	53°
Dinghy	1	0.8	1.3	48°	58°	72°
Kayak/Rower/SUP	1	0.2	0.7	48°	58°	72°

5.3.16 Arch 5 has not been assessed for the permanent case as it is assumed that the exclusion zone, put in place for the construction of the works, will be retained.

¹ Drift angle graph extracted from LL1658-R-01 Navigational Risk Assessment Review Port of London Authority"

² Vessel Drift angles assessed from document L1658-R-01 Navigational Risk Assessment Review Port of London Authority,

5.4 Summary of impacted vessels and outcomes.

5.4.1 The summary of the typical year CSO discharge impacts on the different vessel types is presented in Table 5-3 below.

Vessel Type	Transit Arch 3	Impac	t on vessel
	of Arch 4	Normal Running Position	Minimum achievable distance from CSO at MLWN
Uber Boat	Arch 3	Negligible	Minimal impact
	Arch 4	Not Applicable	Minimal impact Course and/or speed adjustment required.
RIB/Emergency services	Arch 3	Minimal impact. Course and/or speed adjustment required	Minimal impact
	Arch 4	Moderate impact. Course and/or speed adjustment required.	Moderate Impact Course and/or speed adjustment required.
Sightseeing/Pax	Arch 3	Minimal impact. Course and/or speed adjustment required	Minimal impact Course and/or speed adjustment required.
	Arch 4	Not Applicable	Not Applicable
Restaurant/Pax	Arch 3	Minimal impact Course and/or speed adjustment required.	Minimal impact Course and/or speed adjustment required.
	Arch 4	Not Applicable	Not Applicable
Tug vessel engaged in pushing/Towing	Arch 3	Minimal impact Course and/or speed adjustment required	Minimal impact Course and/or speed adjustment required
	Arch 4	Not Applicable	Not Applicable
Workboats	Arch 3	Minimal impact Course and/or speed adjustment required	Minimal impact Course and/or speed adjustment required
	Arch 4	Moderate impact Course and/or speed adjustment required.	Moderate Impact Course and/or speed adjustment required.
Narrow boat/Motor cruisers	Arch 3	Minimal impact Course and/or speed adjustment required	Minimal impact Course and/or speed adjustment required.
	Arch 4	Moderate impact Course and/or speed adjustment required.	Moderate impact Course and/or speed adjustment required.
Dinghy/SUP/Kayak/Rower	Arch 3	Not Applicable	Moderate/High impact Potential difficulty to maintain course. Potential risk of collision with other vessels.
	Arch 4	High impact Unable to maintain course and/or speed, Risk of collision with other vessels due to inability to maintain course. Risk of swamping or capsizing if too close.	High impact Unable to maintain course and/or speed, Risk of collision with other vessels due to inability to maintain course. Risk of swamping or capsizing if too close

Table 5-3 Impact of typical year CSO discharge on vessels at Low Water.

5.4.2 The assessment of typical year return period event indicates: -

- There is no impact for all vessels using Arch 2.
- There is minimal impact for most vessels using Arch 3 with the exception of kayaks/SUP/Dinghy/Rowers for which there can still be moderate/high impact due to their low speed over the ground.
- There is moderate impact for vessels that are capable of transiting through Arch 4 at low water with an increased impact on kayaks/SUP/Dinghy/rowers which could prevent them from maintaining course.
- Potential for collision with bridge pier for vessels transiting through Arch 4 where there is an adjustment of course/speed required.

6. Ship simulation comparison

- 6.1.1 As part of the works to identify the impact of a CSO discharge on the safe navigation of vessels passing the area Tideway engaged HR Wallingford to undertake a real time navigation simulation to assist in the assessment of this impacts.
- 6.1.2 The outputs of the simulations would be used to corroborate the desktop analysis undertaken in sections 4.3 and 4.4 of the interim DRA which identified the periods and zones of impact, and section 5 which used predicted drift angles as a function of the lateral flow velocities and the vessel velocities to determine the level of impact on passing vessels or indicate if additional considerations needed to be made.
- 6.1.3 The HR Wallingford ship simulation centre did not have a suitable model that would represent Class V vessels. It was proposed, and agreed by the mariners at both simulation sessions, that the impact of the CSO and the response of Narrowboats, Tug Pushing and clippers would be representative of the response of a range of Class V vessels.
- 6.1.4 The simulations for Albert Embankment Foreshore were undertaken at the HR Wallingford Ship Simulation Centre during the 8th, 9th and 10th of November 2023 with representatives from HR Wallingford, Tideway, Waves, the Port of London Authority and several river operators and the 5th March 2024 with Tideway, Waves and the Port of London Authority.
- 6.1.5 The full table of simulations undertaken for ALBEF on the 8th, 9th and 10th of November 2023 are presented Figure 6-1 in which include the comments on the run, which were agreed by the attendees following each simulation.

Run ID	CSO	Ship	Manceuvre	Bridge arch	Tidal condition	Commenta
41	ALBEF	28m tug pulling unladen 50m barge	Inbound at 3 knots	No. 3	Low water slack	No significant effect from the flow was noticed by the master and no significant correction needed to maintain desired track.
42	ALBEF	Clipper	Outbound at 6 knots	No. 2	Low water slack	Moderate response of vessel to flow that was manageable and the desired track was regained.
43	ALBEF	21m Narrowboat	Outbound at 3 knots	No. 4	Low water slack	Significant response of the vessel to the flow. The desired track was recovered.
44	ALBEF	21m Narrowboat	Outbound at 3 knots	No. 4	50 minutes after low water slack	Significant response of the vessel to the flow. Collision with the bridge pier, noting that vessel entered the bridge close to the abutment.
45	ALBEF	21m Narrowboat	Outbound at 4 knots	No. 4	50 minutes after low water slack	Objective was to maintain the centre of no.4 arch. Significant response of the vessel to the flow. Desired track was recovered.
46	ALBEF	21m Narrowboat and Clipper	21m Narrowboat outbound at 4 knots Clipper outbound at 10 knots	Narrowboat No. 4 Clipper No. 3	70 minutes after low water slack	Significant response of the 2 im Narrowboat to the flow. Desired track was recovered. No notoeable effect from the clipper. The tracks of the two vessels did not cross. The closest point of approach was 20m.
47	ALBEF	21m Narrowboat	Outbound at 4 knots.	No. 4	100 minutes after low water slack	Moderate response of the 21m Narrowboat to the flow. Desired track was recovered.
48	ALBEF	21m Narrowboat	Outbound at 4 knots	No. 4	20 minutes before low water slack	Significant response of the 21m Narrowboat to the flow. Desired track was recovered. The effect occurs further downstream than on the flood tide.
49	ALBEF	21m Narrowboat	Outbound at 4 knots	No. 4	50 minutes before low water slack	Significant response of the 21m Narrowboat to the flow. Desired track was recovered.
50	ALBEF	21m Narrowboat	Inbound at 4 knots	No. 3	Low water slack	Minimal impact with no deviation from desired track.
51	ALBEF	Clipper and kayak	Clipper outbound at 6 knots and Kayak outbound	No. 3	Low water slack	The flow had no notifiable impact on Clipper. Significant impact on kayak which drifted across the downriver side of no.3 arches. The clipper was able to stop and maintain position on its desired track upon sighting the kayak. The clipper was then able to continue on its track with minimal impact.
52	ALBEF	kavak	Kavak Inbound 3 knots	No. 3	Low water slack	Minimal Impact on kavak.
68	ALBEF	Clipper	Outbound at 10 knots	No. 3	Low water slack	No significant effect from the outflow.

- 6.1.6 The full table of simulations undertaken on the 5th of March 2024, presented in Figure 6-2. focused on the transit of kayaks past the CSO outfall at low water slacks.
- 6.1.7 The record and comments on the runs, which were agreed by the attendees following the simulation, are provided in Figure 6-2.

Figure 6-2 Extract of simulated cases for ALBEF from the 5th March 2024

Run ID	CSO	Ship	Manoeuvre	Bridge arch	Tidal condition	Comments
12	ALBEF	Kayak	Outbound 3 knots	Arch 3	Low water slack	Vessel unaffected by the discharge
13	ALBEF	Kayak (Transiting closer to the arch)	Outbound 3 knots	Arch 3	Low water slack	The vessel experienced a marginal deviation (3-4 m) but was able to safely recover
14	ALBEF	Kayak	Outbound 3 knots	Arch 4	Low water slack	Vessel deflected rapidly 40m towards the centre of the river, narrowly missing the arch

- 6.1.8 During the simulations the vessels were operated by a master who established the course and speed of the vessel to align with the case. Once the simulation started the master made the necessary corrections to allow the vessel to maintain course and then feedback to the group.
- 6.1.9 The track of each simulated run was recorded so that it could be reviewed. Figure 6-3 shows track 41 is of a tug towing a barge inbound at 3 knots at low water slacks. There was no significant effect of the CSO discharge on the vessel with no significant effect on the tugs course and minimal correction required by the master.

Figure 6-3 Record of run 41



6.1.10 Figure 6-4 shows track 42 is of a clipper transiting outbound at 6 knots through Arch 4 at low water slack. During the transit there was a moderate impact on the vessel and the course was easily restored.

Figure 6-4 Record of run 42



6.1.11 Figure 6-5 shows track 43 is of a narrowboat transiting the site outbound at 3 knots through Arch 4 at low water slack. There was a significant effect of the CSO discharge on the vessel but the original course was regained.

Figure 6-5 Record of run 43



6.1.12 Figure 6-6 shows tracks 44 and 45 which are of a narrowboat transiting the site outbound through Arch 4 at 50 minutes after low water slack at different speeds. In run 44 the narrowboat was transiting at 3 knots and was near to the bridge abutment, this led to a contact with the bridge pier before being force across the main fairway. In run 45 the narrowboat was transiting at 4 knots and was closer the CSO outfall. Whilst there was a significant response the track of the vessel was recovered.

Figure 6-6 Record of runs 44 and 45



6.1.13 Figure 6-7 shows the track of run 46 is of a narrowboat transiting outbound through Arch 4 at 70 minutes after low water slacks at the same time whilst a Clipper transits outbound through Arch 3. Whilst there was a significant impact on the narrowboat the desired track was recovered. There was no noticeable effect from the clipper and the tracks didn't cross. The closest point between the two tracks was 20m.

Figure 6-7 Record of run 46



- 6.1.14 Figure 6-8 shows the track from run 50 and is of a narrowboat transiting the site inbound at 4 knots through Arch 3 at low water slack. There was a minimal impact from the CSO discharge on the vessel.
- Figure 6-8 Record of run 50



6.1.15 Figure 6-9 shows tracks 12, 13 and 14 are all a kayak transiting past the CSO outbound at 3 knots at low water slacks. Track 12 is a kayak transiting through the centre of Arch 3 and its course was unaffected by the discharge. Track 13 is a kayak transiting through Arch 3, near to the Arch 4 bridge pier and whilst there was a small course deviation, approximately 3-4m, but was able to recover the course. Track 14 is a kayak transiting through Arch 4. When the Kayak reached the CSO discharge it's course was deviated by approximately 40m into the main channel before being able to slowly regain its course.

Figure 6-9 Record of Runs 12, 13 and 14.



6.1.16 Following the completion of the ship simulations past the ALBEF CSO outfall the impacts on the vessels were considered against the desk top assessment presented in Table 5-3. The summary of these changes are presented in Table 6-1.

Vessel Type	Transit Arch 3	Impact on vessel						
	of Arch 4	Normal Running Position	Minimum achievable distance from CSO at MLWN					
Uber Boat	Arch 3	No Change	No Change					
	Arch 4	Not Applicable	No change					
RIB/Emergency services	Arch 3	No Change	No change					
	Arch 4	No change.	No change					
Sightseeing/Pax	Arch 3	No change	No change.					
	Arch 4	Not Applicable	Not Applicable					
Restaurant/Pax	Arch 3	No change	No change.					
	Arch 4	Not Applicable	Not Applicable					
Tug vessel engaged in pushing/Towing	Arch 3	No change	No change					
	Arch 4	Not Applicable	Not Applicable					
Workboats	Arch 3	No change	No change					
	Arch 4	No change	No change.					
Narrow boat/Motor cruisers	Arch 3	No change	No change					
	Arch 4	Moderate/high impact Course and/or speed adjustment required.	High impact Potential difficulty to maintain course. Potential risk of collision with other vessels.					
Dinghy/SUP/Kayak/Rower	Arch 3	Not Applicable	Moderate impact Course and/or speed adjustment required					
	Arch 4	No change	No change					

Table 6-1 Record of changes of impact on vessels.

7. Risk Assessment

7.1 Risk Assessment

- 7.1.1 The Risk Assessment is undertaken using the Jacobs design hazard elimination and risk reduction register and can be found in Appendix A.
- 7.1.2 The following sections of this document present the risk associated with the hazard linked to a ALBEF CSO discharge impacting on vessels operating on the Thames.
- 7.1.3 The risk assessment has been undertaken to eliminate or reduce risk to vessels on the Thames and provide mitigations for the risk so far as reasonably practicable by assessing the design and operation risks for the permanent state of the ALBEF CSO outfall.
- 7.1.4 The residual design / operational risks identified in this will be used to inform an NRA. The NRA will be produced by navigational experts for consideration by the PLA and any further mitigations established if required.
- 7.1.5 The Risk Assessment considers Low tide as the tidal window identified within section 4.4.7 from 25 minutes before Low water to 25 minutes after low water.
- 7.1.6 The Risk Assessment considers all other states of tide as the period from 25 minutes after low water to 25 minutes before low water.

7.2 Hazards

- 7.2.1 The Risk Assessment considers the impact of the flows from the ALBEF CSO discharge to Vessels on the river with consideration to the change in drift angle incurred by contact with the flow. The hazards associated with the impact are:
 - i) Swamping
 - ii) Capsizing
 - iii) Grounding
 - iv) Collision between two vessels
 - v) Contact between a vessel and a bridge pier

7.3 Receptors

- 7.3.1 CCTV Surveys of the river were undertaken at ALBEF from the 22nd September 2023 to the 31st December 2023, but data has been processed from the period 22nd September 2023 to the 10th of November 2023 giving a 7 week data set and the analysis of the data is presented in document "Tideway Central ALBEF Traffic Survey Report 15I02".
- 7.3.2 The analysis was carried out to determine the class of vessel and which area of the river the vessel was operating from nearshore, authorised channel and farshore, as indicated in Figure 7-1.





7.3.3 Table 7-1 presents the data received from the CCTV surveys, which were also correlated with the AIS information.

Table 7 1 Number of record	ممانية محمد المعمد بالمما	s na such sus thus us	ممطعب مطعما	channel and farchers
Table 7-1 Number of record	leu vessels transiting	j nearsnore, unoug	jii ule autionseu	channel and faishore

PLA Vessel Class	Nearshore	Authorised Channel	Farshore	Total
Uber Boat	15	3,581	0	3596
RIB/Emergency Services	10	387	15	412
Class 5 Passenger	2	742	3	747
Tug	32	278	86	396
Tug (Pushing)	9	71	0	80
Tug (Towing)	1	225	1	227
Workboat	97	670	13	780
Recreational Cruiser	0	170	1	171
Narrowboat	0	32	0	32
Kayak	4	5	23	32
Rowing Boat	0	18	5	23
Coach / Safety Boat	0	15	1	16
Total	170	6194	148	6,512

7.3.4 For the impacts of a discharge from the ALBEF CSO outfall and the area that needs to be considered are vessels transiting in the nearshore and authorised channel past the outfall. Over the analysed period there were 6,364 vessel transits past the outfall within nearshore and authorised channel.

- 7.3.5 From the analysis of the impacts of the discharges on vessels and the ship simulation tracks the summary tables indicate that the vessels which are most impacted are narrowboats and kayaks transiting outbound through Arch 4 at low water slacks. There were 17 narrow boats that transited the site downstream during the survey period along with 9 kayaks. From the 17 narrowboats there were 6 that transited the site between an hour before low water and an hour after low water. From the 9 kayaks that transited the site, none transited during the impacting period, in fact all of the kayaks transited the site over the high water period with just 4 of them being in the nearshore zone but these were in the authorised channels.
- 7.3.6 Of the 185 recorded passages of tugs transiting downstream past the site whilst towing, within the key period of concern, 15 minutes before low water to 45 minutes after low water, there were just 5 passages identified as taking place between 1 and 2 hours after low water, but none within the impact window. In addition, there are 28 transits by tugs towing at around high water (± 15 minutes) could receive the minor impact as presented in 6.1.10.
- 7.3.7 Table 5-3 serves to list the vessels that are subject to the impact of the ALBEF CSO discharge flow. Table 6-1 presents the update of impacts on vessels following the work undertaken using the ship simulations.
- 7.3.8 Figure 5-1 provides the normal operating passage through the Vauxhall bridge whilst considering the vessels draft.
- 7.3.9 It has been determined that only vessels undertaking a passage through Arch 4 during a 1:15 year return period discharge in the low water tidal windows will be impacted by the ALBEF CSO with Narrowboats and non-powered vessels being the most affected.

7.4 Severity of Harm

- 7.4.1 Jacobs rate the hazard on worst potential severity:
 - i) 1: Nil or slight injury / illness, property damage or environmental issue.
 - ii) 2: Minor injury / illness, property damage or environmental issue.
 - iii) 3: Moderate injury or illness, property damage or environmental issue.
 - iv) 4: Major injury or illness, property damage or environmental issue.
 - v) 5: Fatal or long-term disabling injury or illness. Significant property damage or environmental issue.
 - vi) 10. Multiple fatalities and catastrophic event
- 7.4.2 The hazard identified above has potential to cause harm to the vessel users:
 - i) Swamping leading to a major injury or drowning.
 - ii) Capsizing leading to a major injury or drowning.
 - iii) Grounding leading to major Injury or illness due to exposure to sewage.
 - iv) Collision with another vessel due to a CSO discharge event forcing non-powered vessel to drift from previous course leading to major injury or drowning.

- v) Collision between third party vessels caused by one of the vessels changing course to avoid collision with a non-powered vessel leading to major injury or drowning.
- vi) Contact with a bridge pier caused by a CSO discharge which could cause a moderate injury.

7.5 Likelihood of Harm

7.5.1 Jacobs risk assessment rates the likelihood of harm with the following probabilities:

1: Highly Unlikely 2: Unlikely 3: Possible 4: Likely 5: Highly Likely

- 7.5.2 The assessment has been undertaken by analysing the 1:15 year return period data presented in the document 4410-FLOJV-ALBEF-520-VZ-RG-100004_CSO discharge modelling for permanent works Albert Embankment Foreshore_P04 as this is the most realistically probable event, to present the discharge characteristics.
- 7.5.3 From the analysis of the HR Wallingford plumes in Section 4.3
- 7.5.4 Table 4-7 it has been determined that the Peak CSO discharge from ALBEF will impact upon the main channel in Arch 4 for a period of 80 minutes, from 25 minutes before low water to 55 minutes after low water.
- 7.5.5 The tidal window identified in 6.5.4 is considered conservative because of the very brief period of approximately 20 minutes of instantaneous peak flow that is shown in the hydrograph for a 1 in 15-year event in Figure 4-1. And the reduction in impact evidenced in the ship simulation work as presented in Table 6-1.
- 7.5.6 The coincidence of the instantaneous peak flow and the minimal 10-minute period of still water, or indeed a period of dominant flow from the ALBEF CSO discharge are extremely low for the worst-case scenario.
- 7.5.7 The current annual frequency of discharge has been established as an average of 114.25 with a maximum record of 152 discharges which could impact river users. This is forecast to be reduced to 1 to 3 discharges in a typical year once the tunnel is operational.
- 7.5.8 The data from the CCTV river surveys indicate there are minimal numbers of vessels that would be impacted by a discharge that transit the site in a part of the river that would expose them to a discharge.

8. Mitigation

8.1 ERIC

- 8.1.1 The ERIC, the hierarchy of risk management, approach will be adopted to review mitigation for this DRA.
 - ERIC stands for Eliminate, Reduce, Inform and Control.
 - This is a four-level hierarchy that outlines the steps it should take to mitigate risk.

8.2 Eliminate

8.2.1 The ALBEF CSO outfall is needed to allow sewers to discharge when they reach capacity and prevent the risk of flooding upstream in the catchment area. To eliminate the flows entirely would require the closing of the CSO outfall and would flood the upstream catchment area during storm events and is therefore not feasible.

8.3 Reduce

- 8.3.1 The number of discharges will be reduced by bringing the tideway tunnel into operation. This will be reduced the number of discharges from the average of 114.25 discharges per typical year down to 1 to 3 discharges in a typical year.
- 8.3.2 To reduce the risk of impact to vessels transiting the site a warning system could be adopted for the permanent works in line with the proof of concept which is being developed in consultation with the PLA and main works contractors.
- 8.3.3 Retention of Arch 5 closure to reduce the risk of a small non-powered craft passing between the new foreshore structure and the bridge pier to a pass in close proximity to the ALBEF CSO outfall.

8.4 Inform

- 8.4.1 During the development in the interim phase warning lights and signs have been developed and designed by the MWC and offered for to the PLA for acceptance. Any warning lights installed as part of the agreed interim arrangements to be adopted for the permanent case once their efficiency has been assessed.
- 8.4.2 Promulgation of the operational plan to river users.
- 8.4.3 It is likely that the PLA will need to provide a new notice to mariners identifying new CSO operation and mitigations.
- 8.4.4 It is likely that the PLA will need to issue a notice to mariners during periods of LTT maintenance to identify that there could be an increase in the frequency and severity of a CSO discharge, given a suitable notice period from Tideway or TWUL of the maintenance.

8.5 Control

8.5.1 All agreed CSO signage and warning lights to be installed and adopted.

8.5.2 Operation plan for the warning system to include warning trigger points, which will need to be considered and agreed with the PLA.

9. Summary

9.1 Summary

- 9.1.1 Jacobs as Designer for the reference design have a duty to eliminate and reduce risks so far as reasonably practicable (SFARP) and to identify residual risks. Jacobs have undertaken this risk assessment to assess the magnitude of this risk for each vessel type and to consider whether mitigation measures can be adopted that can reduce the risks to an acceptable low level.
- 9.1.2 Overall, the residual risk has been determined as low due to: -
 - (a) limited impact of CSO discharges on powered vessels.
 - (b) Limited number of transits past the CSO by vessels that could be impacted by a CSO discharge.
 - (c) The introduction of a warning light and sign to advise powered vessels that the CSO is discharging and to proceed with caution.
 - (d) The introduction of a warning light and sign to advise non-powered vessels that the CSO is discharging and to proceed with caution or follow any additional advice generated by the NRA.

Powered Vessels

- 9.1.3 In the case of powered vessels during low water periods, for vessels transiting through Arch 3, the risk is considered minimal as all powered vessels can transit a CSO outfall discharge without their course being affected.
- 9.1.4 In the case of powered vessels during low water periods, for vessels capable of transiting through Arch 4, the risk is considered low as it is unlikely that powered vessels that can transit through Arch 4 over the low water period will do so.

Unpowered Vessels

- 9.1.5 In the case of manually operated or unpowered vessels transiting through Arch 3 over the low water period the risk is considered low. Where the simulations evidenced that the vessels could recover from the impact created by the CSO outfall discharge.
- 9.1.6 In the case of manually operated or unpowered vessels transiting through Arch 4 the risk is considered moderate. The risk would be reduced to low assuming the use of an effective warning system and the operator is following any advice from the NRA and promulgated by the PLA.

Navigational Risk Assessment

- 9.1.7 A Navigational Risk Assessment (NRA) is to be undertaken by navigational specialists with expert knowledge of waterway traffic and the conditions in the area of the ALBEF CSO outfall.
- 9.1.8 This designers risk assessment will be considered by the MWC in addition to the navigation risk assessment as part of the iterative process to develop the detailed design and Operational Plan. The navigational risk specialists will need to consider both the DRA and the Operational Plan to produce the Navigational Risk Assessment

- 9.1.9 The MWC should consider the following in the development of the detailed design and the operational plan,
 - The recommendations of the NRA,
 - the optimal "on" time for the live warning signal(s), taking account of the discharge hydrograph and the actions to be taken by powered vessels and unpowered vessels or a member of the public on the foreshore nearby,
 - the locations, lux, visibility, and particulars of the warning signs,
 - the optimal "off" time for the warning signal,
 - the manner of promulgation of information and communication with the river community, including what is required of Tideway, the PLA and the river users.
- 9.1.10 The NRA will assess this Designers Risk Assessment to consider the residual risks and determine the most appropriate mitigations in consultation with the PLA and other river users. In particular, the NRA should consider: -
 - The MWC's operational plan to assess whether there is any change to the hazards and risk levels through the introduction of the mitigations,
 - the necessary responses of powered vessels to a discharge (e.g., adjust course as require, proceed with caution and look out for unpowered vessels affected by a discharge) and the time needed to action the responses,
 - the necessary responses of unpowered vessels to a discharge (e.g. pull up on the foreshore, cross the river and return upstream, adhere to the main fairway, etc.) and the time needed to action the responses,
 - The assessment of any increased risk to normal river operations arising from the implementation of mitigations.
- 9.1.11 In the development of the NRA the timings of the mitigation implementation should also be considered and detailed for agreement with the PLA.
- 9.1.12 The updated NRA with its proposed mitigations will be reviewed to confirm that the design risks have been mitigated insofar as is reasonably practicable for the permanent phase.

9.2 Key information

- 9.2.1 The most credible worst case CSO discharge is for a 1:15 year return period storm without the tunnel in operation with a discharge of 22m³/s. The frequency of discharges once the tunnel in operation is expected to be between 2 and 6 per year when the tunnel is in operation. When the tunnel is to be taken out of operation additional information will need to be made available to stakeholders outlining the potential for increased frequency of discharges.
- 9.2.2 The assessment considers the river in three zones as defined in Figure 7-1 and the critical discharge occurring at low-water neaps. The discharges are considered to impact within the following tidal windows, shown in Table 9-1.

Arc	:h 4	Arch 3				
Start	End	Start	End			
Mid-Ebb	Mid-flood	LW -25 minutes	LW +25 minutes			

Table 9-1 Tidal windows of potential impact

- 9.2.3 It should be noted it is not possible to predict the discharges within 30m of the CSO outfall at any state of the tide and in this instance that zone is in the fairway.
- 9.2.4 For any periods of slack water, such as a Thames Barrier closure, the same considerations should be given to low or high slack water period.
- 9.2.5 This document provides information on the timing and intensity of the discharges and the hydrographs are presented in Figures 4.1 and 4.2. The proof of concept document (LONDON TIDEWAY TUNNELS PROOF OF CONCEPT CSO DISCHARGE WARNING DRAFT 27/02/24) provides further detailed discharge hydrographs that should be utilised in the development of suitable warning times in the development of the detailed design undertaken by the MWC.
- 9.2.6 Any unmitigated risks arising from the detail design development, such as insufficient warning time, should be identified in the MWCs design documentation and potential mitigation measures identified for consideration by the PLA.
- 9.2.7 A warning a system, such as lights and signs, has been established as a mitigation measure suitable to reduce the risk to vessels. During the development of the NRA and the operational plan the MWC should assess the suitability of the mitigation measures and substantiate their proposals within the detailed design documentation.

Appendix A. Designers Risk Assessment

Jaco	bs						DESIG	N HAZ	ARD ELIMINATION AN	D RISK REDUCTION	REGISTER					
Latest Mee	ting Date			Probability			Wor	st Potentia	al Severity (WPS) of Impact				Risk F	tating		
Pha C M U D Project Name: Project Number: Client:	Construction Maintain/Clean Use as a Workplace Demolish Tidaway 065397CH Bazalgette Tunnel Limited	Upda Risk 3	te Critical Summary Tab	1: Highly Unlikely 2: Unlikelv 3: Possible 4: Likely 5: Highly Likely			1: N d 2: Mino 3: N d 4: Major 5: Fa illne: 10. Mul	ii or sligh amage or or injury / envir loderate i amage or r injury or envir tal or lon ss. Signifi envir tiple fatal	ht injury / illness, property r environmental issue. illness, property damage or ronmental issue. injury or illness, property r environmental issue. r illness, property damage or ronmental issue. Ing term disabling injury or licant property damage or ronmental issue. Itites and catastrophic event	NOTE: The purpose of determine which risks an subjective assessment an precise determ	Risk Rating is to significant. It is a d not an absolute or hination	High Medium Low	HSEID risi design is i Revise de HSEID risi design is i approprisi and mana HSEID risi design is i	k resulting from unscceptably high, sign to reduce k resulting from permitted with te design controls gement oversight in k resulting from permitted.	L 6 8 S 8 4 4 3 3 2 2 2 1 5 1 5 1 5 3 5 5 5 5 5 5 5 5 5 5 5 5 5	NISK 10 15 20 35 6 12 40 30 4 6 80 10 2 3 4 5 2 3 4 5
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1 Risk ID.	2 Formal Review Description	3 Phase	4 Activity	5 Potential Hazard	6 Person(s) Most at Risk	7 Prob	8 WPS	9 Initial Risk Rating	10 Discipline	11 Design Measures to Eliminate Hazards	12 Design Measures to Reduce Risk	13 Residual Prob	14 Residua WPS	15 Residual Risk Rating	16 Residual Risk Description	17 Included on Drawing No(s) or other doc. (give ref.)
CDM-ALBEF-024-A	Non-powered craft underway - Low tide	Permanent	Kayak/Rower/Dinghy/SUP navigating in Arch 4 in the vicinity of a CSO discharge	Swamping due to CSO discharge event	Public: Major injury and/or drowning	2	5	10	Civi / Strudursl	Unable to eliminate Hazaro - The foreshore site is fixed	1. CSO Signage 2. CSO Warning light 3. Reduction in number of discharges by intercepting flows.	1	5	5	Public: Major injury and/or drowning	Notice to Mariners, Por Information Guide, Tideway Code and any other pertinent documents
CDM-ALBEF-024-B	Non-powered craft underway - Low tide	Permanent	Kayak/Rower/Dinghy/SUP navigating in Arch 4 in the vicinity of a CSO discharge	Capsizing due to a CSO discharge event	Public: Major injury and/or drowning	2	5	10	Civil / Structural	Unable to eliminate Hazard - The foreshore site is fixed	 CSO Signage CSO Warning light 3. Reduction in number of discharges by intercepting flows. 	1	5	5	Public: Major injury and/or drowning	Notice to Maniners, Port Information Guide, Tideway Code and any other pertinent documents
CDM-ALBEF-024-C	Non-powered craft underway - Low tide	Permanent	Kayak/Rower/Dinghy/SUP navigating in Arch 4 in the vicinity of a CSO discharge	Grounding due to a CSO discharge event	Public:Major Injury or illness due to exposure to sewage	2	4	8	Civil / Structural	Unable to eliminate Hazaro - The foreshore site is fixed	 1. CSO Signage 2. CSO Warning light 3. Reduction in number of discharges by intercepting flows. 	1	4	4	Public:Major Injury or illness due to exposure to sewage	Notice to Mariners, Por Information Guide, Tideway Code and any other pertinent documents
CDM-ALBEF-024-D	Non-powered craft underway - Low tide	Permanent	Kayak/Rower/Dinghy/SUP navigating in Arch 4 in the vicinity of a CSO discharge	Contact with bridge pier leading to capsize and entrapment	Public: Major injury and/or drowning	2	5	10	Civil / Structural	Unable to eliminate Hazard - The foreshore site is fixed	 CSO Signage CSO Warning light 3. Reduction in number of discharges by intercepting flows. 	1	5	5	Public: Major injury and/or drowning	Notice to Mariners, Por Information Guide, Tideway Code and any other pertinent documents
CDM-ALBEF-024-E	Non-powered and Rec. powered vessel underway - Low Tide	Permanent	Kayak/Rower/Dinghy/SUP and recreational powered vessel navigating in Arch 4 in the vidnity of a CSO discharge	Collision due to a CSO discharge event forcing non-powered craft to drift from a previous course	Public: Major injury and or drowning	2	5	10	Civil / Structural	Unable to eliminate Hazard - The foreshore site is fixed	 CSO Signage CSO Warning light 3. Reduction in number of discharges by intercepting flows. 	1	5	5	Public: Major injury and or drowning	Notice to Mariners, Por Information Guide, Tideway Code and any other pertinent documents
CDM-ALBEF-024-F	Non-powered and Rec. powered vessel underway - Low Tide	Permanent	Kayak/Rower/Dinghy/SUP navigating in Arch 4 and recreational powered vessel navigating in Arch 3 in the vicinity of a CSO discharge	Collision due to a CSO discharge event forcing non-powered craft to drift from previous course	Public: Major injury and or drowning	2	5	10	Civil / Structural	Unable to eliminate Hazard - The foreshore site is fixed	 CSO Signage CSO Warning light 3. Reduction in number of discharges by intercepting flows. 	1	5	5	Public: Major injury and or drowning	Notice to Mariners, Por Information Guide, Tideway Code and any other perlinent documents
CDM-ALBEF-024-G	Non-powered and Commercial powered vessel underway - Low tide	Permanent	Kayak/Rower/Dinghy/SUP navigating in Arch 4 and a commercial powered vessel navigating in Arch 3 in the vicinity of a CSO discharge	Collision due to a CSO discharge event forcing non-powered craft to drift from previous course	Public: Major injury and or drowning	2	5	10	Civil / Structural	Unable to eliminate Hazard - The foreshore site is fixed	 CSO Signage CSO Warning light 3. Reduction in number of discharges by intercepting flows. 	1	5	5	Public: Major injury and or drowning	Notice to Mariners, Por Information Guide, Tideway Code and any other pertinent documents



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Residual Risk Description	Included on Drawing No(s) or other doc. (give ref.)
Public: Injury Property damage (bridge pier), Disruption	Notice to Mariners, Port Information Guide, Tideway Code and any other pertinent documents
Public: Illness due to exposure to sewage or Drowning	Notice to Mariners, Port Information Guide, Tideway Code and any other pertinent documents
Public: Illness due to exposure to sewage or Drowning	Notice to Mariners, Port Information Guide, Tideway Code and any other pertinent documents
Public: Major injury and or drowning	Notice to Mariners, Port Information Guide, Tideway Code and any other pertinent documents
Public: Major injury and or drowning	Notice to Mariners, Port Information Guide, Tideway Code and any other pertinent documents
Public: Major injury and or drowning	Notice to Mariners, Port Information Guide, Tideway Code and any other pertinent documents
Public: Injury or Illness due to exposure to sewage	Notice to Mariners, Port Information Guide, Tideway Code and any other partinent documents

discharges by intercepting flows



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