



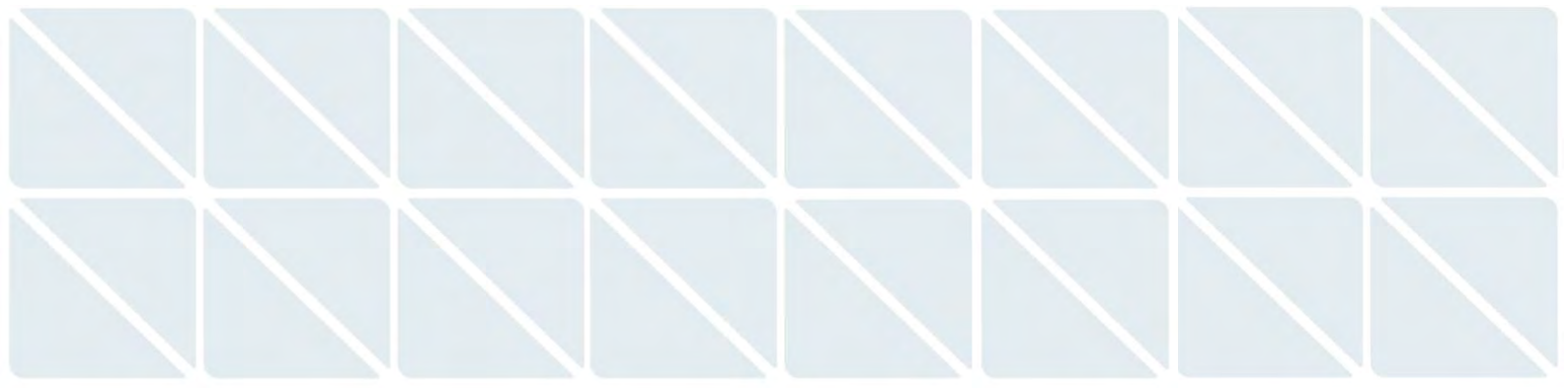
A-squared Studio

Former CSM Site, Holborn

Crossrail Impact Assessment Report – Demolition Only

November 2021

1129-A2S-XX-XX-RP-Y-0006-00





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Document Name	Crossrail Impact Assessment Report – Demolition Only

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1. Introduction

A-squared Studio Engineers Ltd (A-squared) has been appointed by Heyne Tillett Steel Ltd (HTS) to undertake a Ground Movement Assessment (GMA) for the Former Central St Martins (CSM) Site development in Holborn, London.

The A-squared scope comprises an assessment of the potential impact of the proposed demolition works on the existing Crossrail 1 assets located directly south of the site.

1.1. Study Aims & Objectives

A ground movement assessment has been carried out in order to evaluate the impact of the proposed demolition works on the existing Crossrail 1 assets, comprising running tunnels, access adits, and an access shaft, located directly south of the Former CSM site.

The main proposed works comprise the reuse / refurbishment of the existing Lethaby Building, demolition of existing Bridge Link and Innovation Centre and Cochrane Theatre, partial demolition and redevelopment of the existing Red Lion Building, and construction of various mid-rise hotel-led mixed-use buildings. An existing one-level basement underlying the majority of the site will be deepened into a three-level basement, except underneath the Lethaby and Red Lion Buildings wherein the existing one-level basements will be retained.

This report is limited to an assessment of the impact of the proposed demolition works on the Crossrail assets. A full GMA, which will consider the entirety of the proposed works and construction sequencing (i.e. including demolition, phased excavation works, substructure construction, and permanent superstructure loading), will be performed at a later stage of design development as agreed with Crossrail.

The assessment encompasses the Crossrail assets located within the *zone of influence* of the proposed demolition works. The GMA assessment is based on *greenfield* ground movements and results in movement predictions which are unlikely to be exceeded. The adopted assessment methodology provides a robust and conservative assessment, representative of current industry best practice, as detailed in Section 4.

The assessment carried out and described herein aims to:

- Assess the impact on ground movements induced by the proposed demolition works on the adjacent Crossrail 1 running tunnels, access adits, and access shaft.
- Provide performance criteria and inform aspects of substructure construction and design.

This report provides a detailed description of the:

- Site and proposed development.
- Modelling parameters and input.
- Analyses and results.



2. The Site & Development

2.1. Site Location and Proposed Development

The proposed development is located at the former Central St Martins College of Art & Design at Southampton Row, Holborn, London, WC1B 4AF. It is bounded by Theobalds Road, Drake Street, Fisher Street and Southampton Row, as shown in Figure 2.1. The entire site falls within the administrative boundaries of the London Borough of Camden. Holborn and Russel Square Underground Stations are located approximately 150m south and 550m north of the site, respectively.

The site is generally flat, with a ground elevation of approximately +25.0mOD.



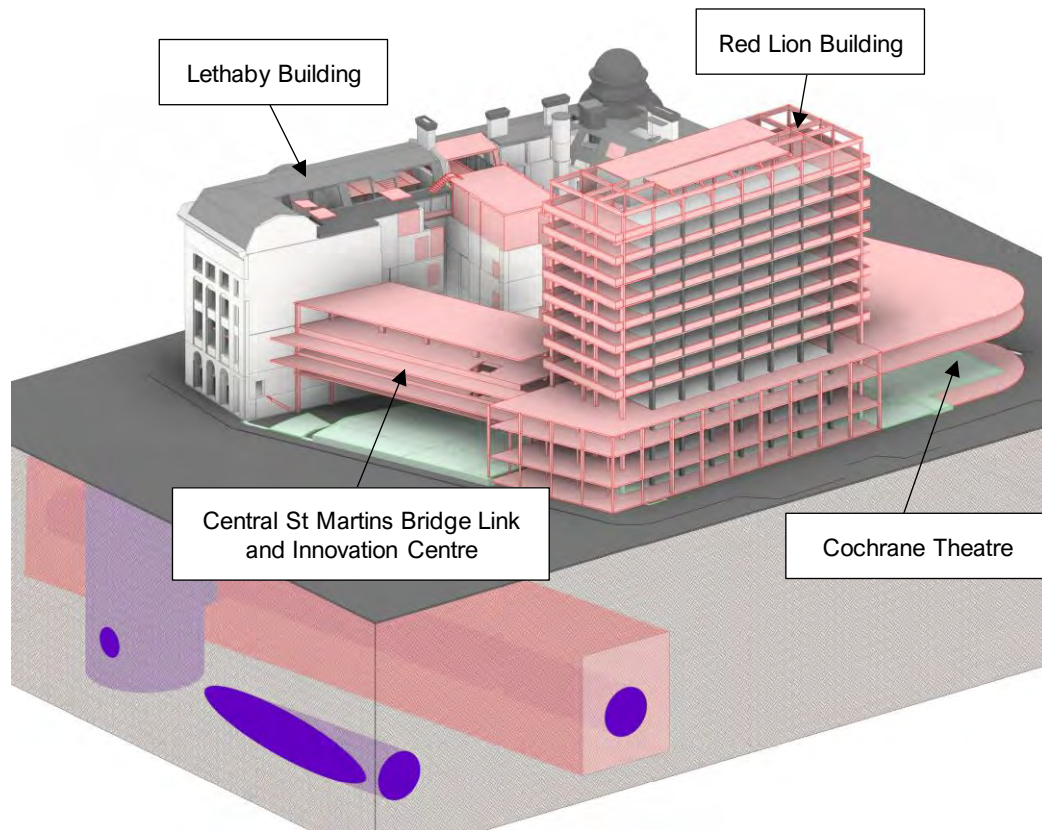
Approximate site boundary marked in red. Image courtesy of Google.

Figure 2.1 Location of the proposed development

The site is currently occupied by four structures: Lethaby Building, CSM Bridge Link and Innovation Centre, Red Lion Building, and Cochrane Theatre. Lethaby Building is a six-storey Grade II* Listed masonry structure occupying the western side of the site, while the CSM Bridge Link and Innovation Centre is a three-storey structure occupying the southern section of the site. Red Lion Building is a thirteen-storey reinforced concrete (RC) frame structure and Cochrane Theatre is a four-storey structure. These two structures occupy the eastern portion of the site and are connected by a three-storey podium. A one-level basement is present underneath all existing structures, occupying majority of the site footprint.

The demolition proposals comprise the complete demolition of Cochrane Theatre and CSM Bridge Link and Innovation Centre, partial demolition of the Red Lion Building, and minor internal alteration of the Lethaby Building, as shown in Figure 2.2 and Figure 2.3.

Later phases of the proposed work comprise the *bottom-up* construction of the proposed three-level basement (including the installation of secant pile walls, underpinning, bulk excavation beneath the existing basement levels to approximately +3.0mOD, installation of bearing piles, and construction of the proposed superstructure). These works phases will be considered in the final GMA.



Note: Areas to be demolished shown in red.

Figure 2.2 Demolition Plan (isometric view)



(a) Basement plan



(b) First floor plan

Note: Areas to be demolished shown in red and green.

Figure 2.3 Demolition Plans

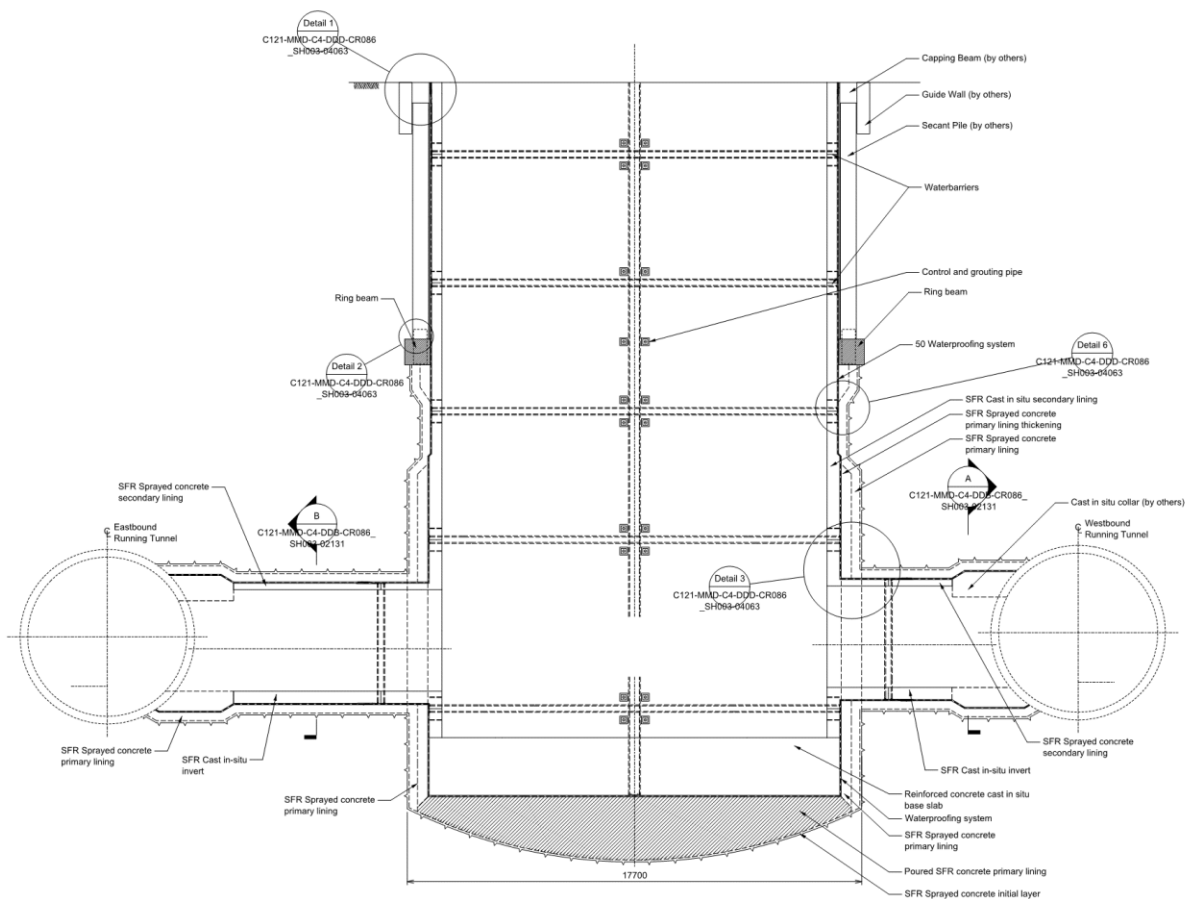


Figure 3.2 Section view of the existing Crossrail assets



Note: Approximate site boundary shown in dashed red outline.

Figure 3.3 Location of Crossrail assets relative to the site



3.2. Adopted Deformation Criteria

For this assessment, which considers the effects of demolition induced unloading across the site only, the following criteria for induced tunnel deformation has been adopted.

These criteria have been adopted based on correspondence with the Crossrail asset protection team and following general guidelines set out in the *Crossrail Information for Developers* (March 2019).

- Minimum radius of curvature of 10km.
- Maximum vertical diametric distortion of +15mm (egging) and -0mm (squatting).
- Maximum horizontal diametric distortion of 15mm.

Currently, no specific deformation criteria have been recommended for the shaft and adits; however, feedback from the tunnel designers will be incorporated in the final GMA. The general predicted movements of these components have been summarised for reference. Further review of the connection / interface between the eastbound running and adit tunnels will also be performed as part of the final GMA assessment.



4. Ground Conditions

Site-specific ground investigation works have been performed by RSK and A2 Site Investigation in May 2020 and September 2021 respectively. The ground conditions at the site were generally found to comprise the following (in order of succession):

- Made Ground – concrete and medium dense clayey sandy gravels with variable anthropogenic deposits.
- Lynch Hill Gravels – dense slightly gravelly sand.
- London Clay – stiff to hard fissured brown silty clay.
- Harwich Formation – very stiff to hard light greyish green silty clay.
- Lambeth Group – very stiff to hard fissured silty clay.
- Thanet Sands – dark greenish grey slightly silty sand
- Chalk – weak, low density white chalk.

The above include the strata of engineering interest and significance, taking cognisance of the scale of the proposed development and zone of influence of the proposed demolition works.

The ground model adopted for this assessment is presented in Table 4.1.

Table 4.1 Ground model and geotechnical parameters adopted for analysis purposes

Stratum	Elevation (mOD)	Thickness (m)	Undrained Young's Modulus, E_u ^[2] (MPa)	Drained Young's Modulus, E' ^[2] (MPa)
Made Ground	+25.0	3.0	-	10.0
Lynch Hill Gravels	+22.0	3.0	-	75.0
London Clay	+18.5	16.5	$40.0 + 7.3z$ ^[5]	$32.0 + 5.9z$ ^[5]
Harwich Formation / Lambeth Group ^[3]	+2.0	17.0	$157.5 + 11.3z$ ^[5]	$126.0 + 9.0z$ ^[5]
Thanet Sands	-15.0	6.7	-	270.0
Chalk	-21.7	Not proven	-	$300.0 + 100.0z$ ^[5]

1. Ground model based on site-specific geotechnical testing. This data has been interpreted specifically for the scope of the GMA presented herein.
2. Stiffness data (E_u and E') has been evaluated empirically from in-situ testing data taking into consideration the nature of the geotechnical/soil-structure interaction mechanisms and level of anticipated strain within the soil mass.
3. Harwich Formation has been shown to be of a similar composition to the Lambeth Group. It has thus been assumed to behave in a similar manner to the Lambeth Group and follow a continuous strength and stiffness profile.
4. The rigid *boundary* was assumed within the Chalk stratum at -50.0mOD / 73.0mbgl for analytical purposes.
5. z refers to the depth in metres below the top of the relevant strata. Lower bound stiffness values have been adopted for GMA purposes only.

The groundwater table has been taken at 1.0m below the basement level.



5. Analysis Methodology

5.1. General Methodology and Model Overview

Unloading mechanisms introduced as part of the proposed demolition works will induce a ground movement field within a *zone of influence* surrounding the existing site footprint. An assessment of the magnitude and extent of the induced ground movements has been carried out using the three-dimensional finite element (FE) analysis software Plaxis 3D. The soil-structure interaction effects captured in the FE analysis provides a more representative understanding of the impact of the demolition works only. In line with criteria set out after liaison with the Crossrail asset protection team, the following deformation mechanisms have been checked:

- Diametric distortion / ovalisation.
- Radius of curvature.
- Absolute movements.

In Plaxis 3D, the soil is modelled as a continuum. All strata have been modelled assuming *linear elastic-perfectly plastic* Mohr-Coulomb constitutive behaviour following the stratigraphy set out in Section 4. The undrained behaviour of the London Clay, Harwich Formation, and Lambeth Group has been ignored in order to present an upper bound prediction of ground movement.

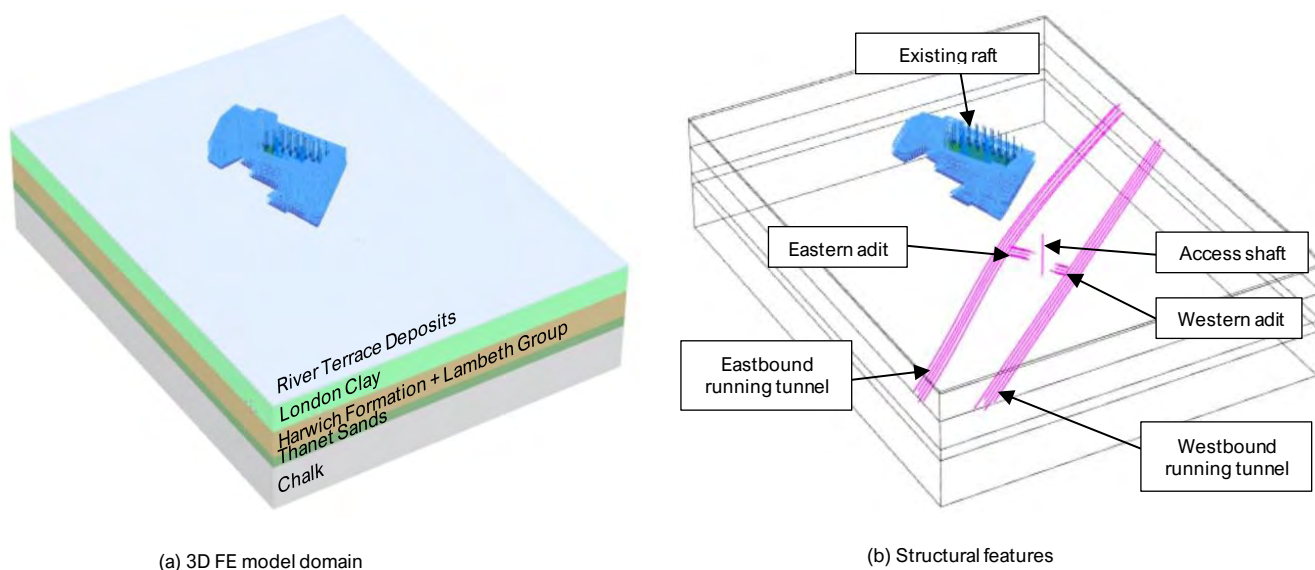


Figure 5.1 Plaxis 3D model geometry

The top of the model has been adopted at +19.9mOD, representing the approximate founding level of the existing basement structures.

The existing structures have been modelled founded on an 800mm to 1050mm thick raft slab with an assumed Young's Modulus of 30GPa. The existing depths and typology of all foundations across the site have not been confirmed at the time of writing, however considering the age and massing of the existing structures, it is likely that a number these will comprise discrete pad footings or strips.

The modelled raft slab can thus be considered to provide a relatively conservative estimate of the *zone of influence* of the demolition unloading (i.e. shallow footings / pads / strips would in reality have negligible influence on the tunnels due to their limited zone / depth of influence, which is a function of their breadth, whereas the depth of influence of that which has been assumed for analytical purposes herein is far greater).

The demolition loads have been based on loading plans provided by HTS (provided in Appendix B) and have been modelled as combination of area, line, and point loads. It should be noted that whilst the current proposals indicate that demolition is to be



conducted in 2no. phases, all demolition unloading has been applied concurrently in order to provide an upper bound of movement for the entire demolition unloading stage. All demolition unloading has been applied at the existing founding depth.

The analysis has been performed assuming *greenfield* conditions, i.e. the stiffening effects from surrounding anthropogenic structures and the tunnel / shaft structural elements themselves have not been considered. The various Crossrail assets have been modelled as a series of flexible beam elements with a negligible stiffness, which do not influence the deformation of the soil mass. The beams have been modelled at key locations along the tunnel geometry (i.e. axis, crown, invert, and sides) in order to determine tunnel ovalisation and longitudinal behaviour during the demolition works.

5.2. Construction Sequence

The idealised demolition sequence modelled in Plaxis 3D is summarised in Table 5.1 below.

Table 5.1 Modelled construction stages

	Model Stage	Action
1	Initial Phase	Initialisation of effective stresses and pore pressures
2	Existing	Activation of existing basement structures and existing building loading
		Deactivation of existing building surface loads
3	Demolition	[Displacements are reset to zero at the beginning of this stage in order to capture the movements induced by the proposed demolition works only]



6. Results

6.1. Impact Assessment Results

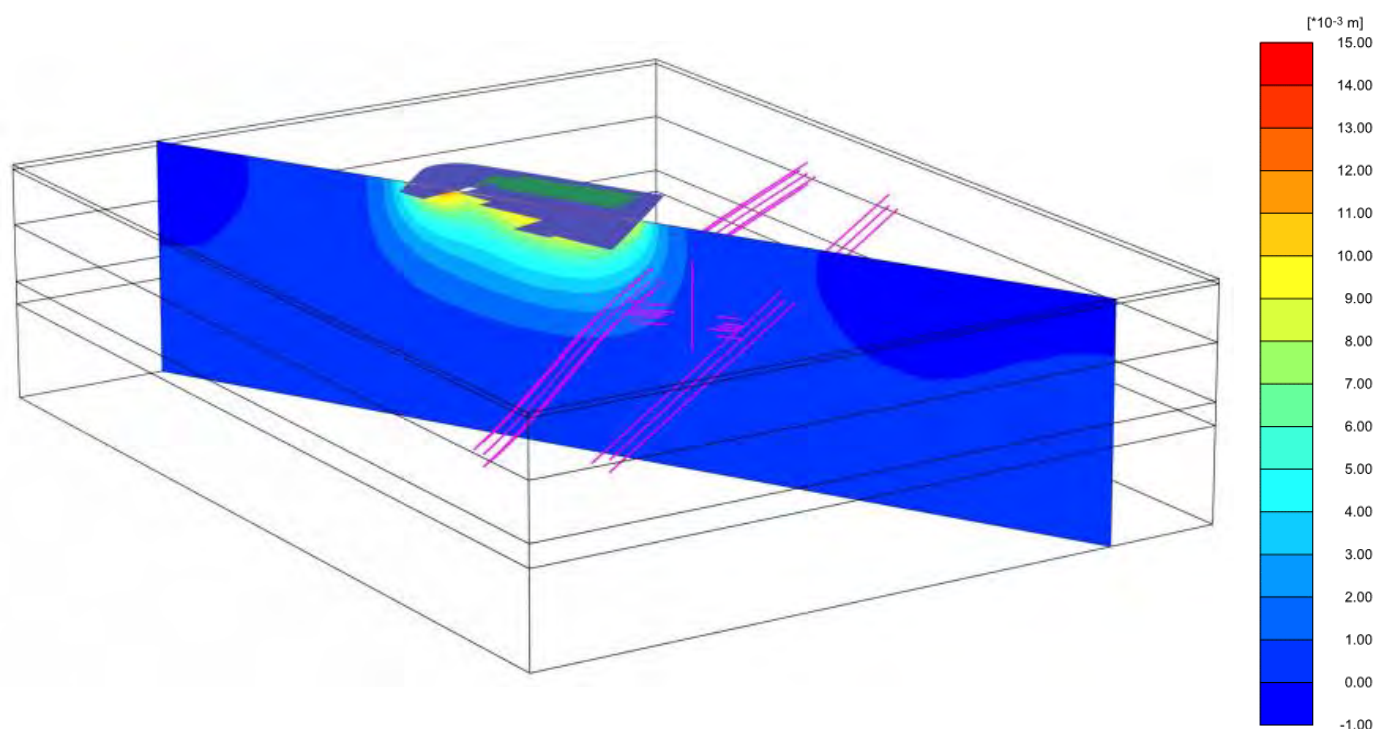
The maximum asset movements associated with the proposed demolition works are summarised in Table 6.1. Considering the relatively conservative assumptions adopted in this analysis, the movements presented below are considered to be a moderately conservative estimate and represent an upper bound range of movements which are unlikely to be exceeded.

The results indicate that the predicted minimum radii of curvature and maximum ovalisation for the running tunnels do not exceed the criteria set out by Crossrail (refer to Section 3.2).

Table 6.1 Summary of Crossrail asset movements

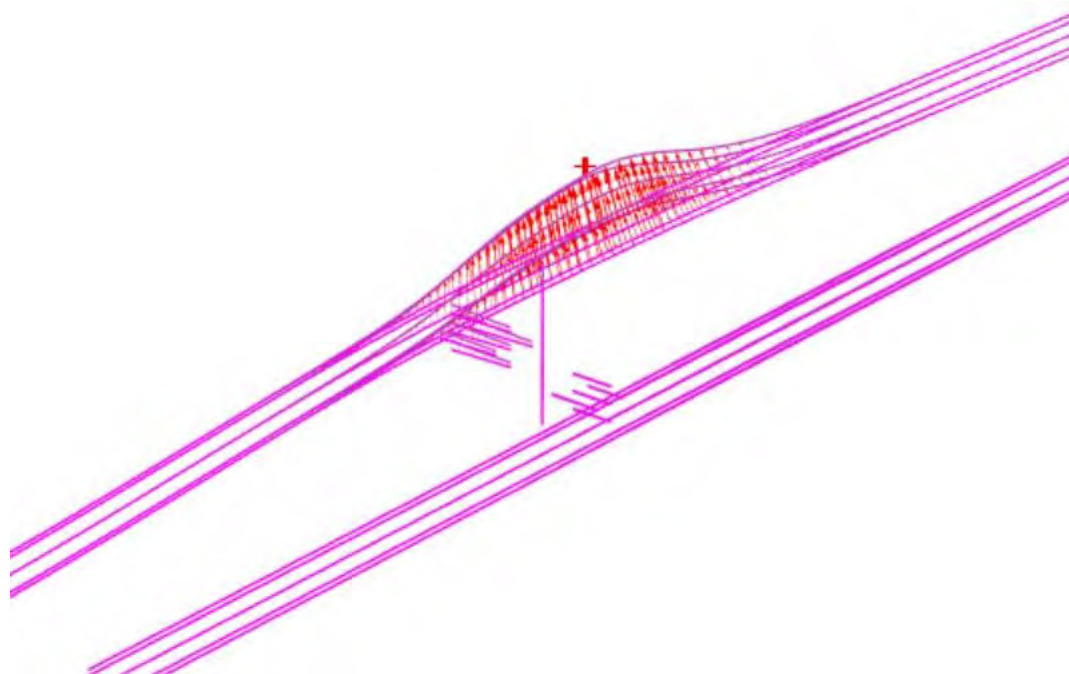
Asset	Maximum Displacement ^[1] (mm)			Maximum Ovalisation ^[1] (mm)		Minimum Radius of Curvature (km)
	Axis	Crown	Invert	Vertical	Horizontal	
Eastbound Running Tunnel	3	3	2	1	0	103
Westbound Running Tunnel	0	0	0	0	0	109
Eastern Adit	1	1	1	0	0	-
Western Adit	0	0	0	0	0	-
Access Shaft	0	0	0	-	-	-

1. Positive displacement values indicate upward movement.
2. Positive ovalisation values indicate tunnel egging. Negative ovalisation values indicate tunnel squatting.



Positive values indicate upward movement. Crossrail tunnel positions shown in pink.

Figure 6.1 Vertical ground movements due to demolition unloading



Note: Tunnel deformations have been scaled up 2500x.

Figure 6.2 Deformed shape of tunnels



7. Conclusions & Closing Remarks

A-squared Studio Engineers Ltd has been appointed by Heyne Tillett Steel to carry out a Crossrail impact assessment for the demolition works phase of the proposed development at the Former CSM Site in Holborn, London.

The site is currently occupied by four structures: the six-storey Grade II* Listed Lethaby Building, three-storey CSM Bridge Link and Innovation Centre, four-storey Cochrane Theatre, and thirteen-storey Red Lion Building. A single-level basement is present beneath all the existing structures, occupying majority of the site footprint. The proposed demolition works comprise the complete demolition of Cochrane Theatre and CSM Bridge Link and Innovation Centre to exiting basement level, partial demolition of the Red Lion Building to basement level, and minor internal alteration of the Lethaby Building.

The site is generally underlain by Made Ground, River Terrace Deposits, London Clay, Lambeth Group, Thanet Sands, and Chalk.

Four Crossrail assets are present directly south of the site boundary comprising two running tunnels, two connection adits, and an access shaft. An assessment of the asset movements as a result of the proposed demolition works has been undertaken using the commercially available finite element analysis software Plaxis 3D. General asset movement, ovalisation, and radius of curvature have been assessed and compared to deformation criteria set and guidelines set by Crossrail.

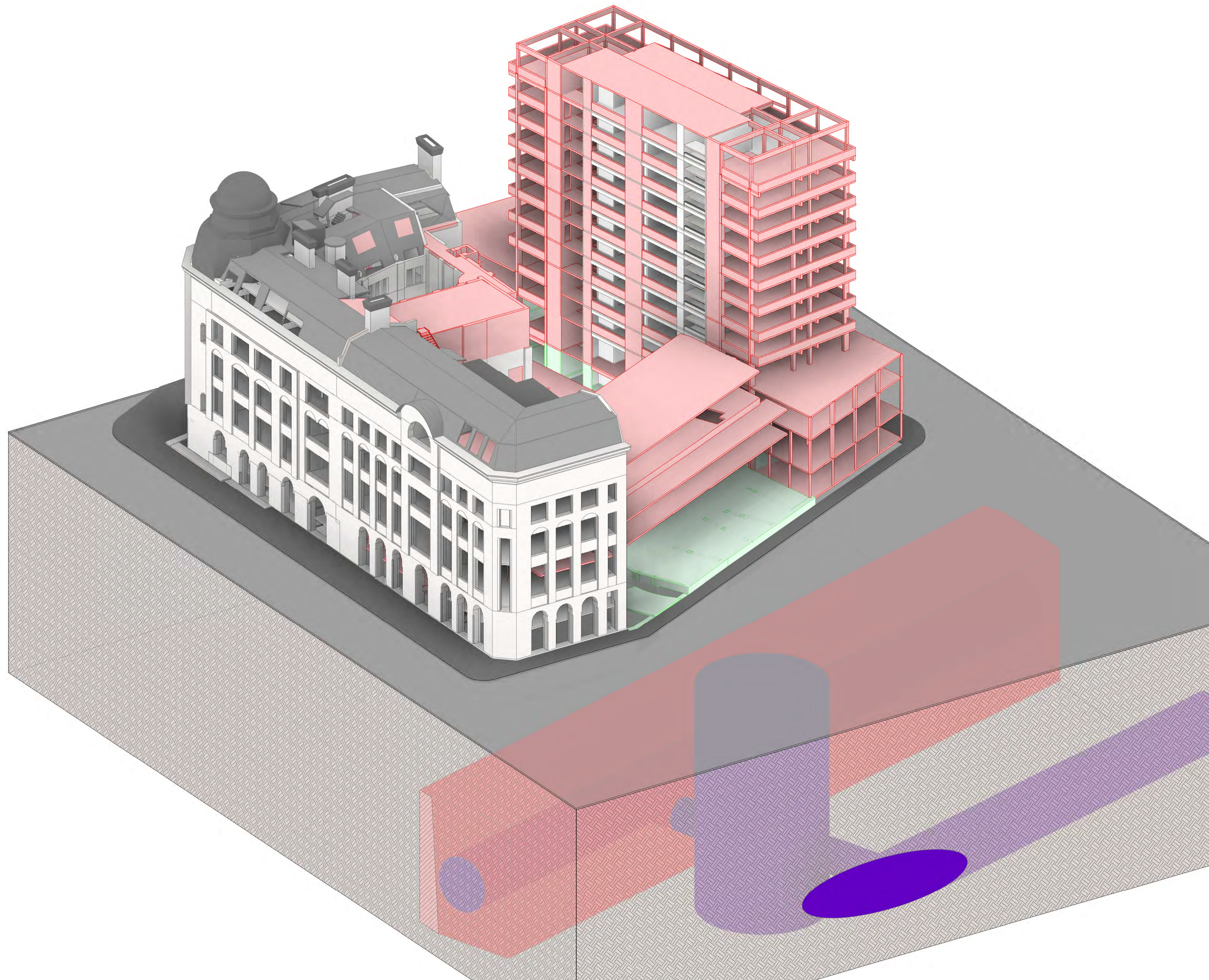
The analysis findings are summarised in Section 6. The worst-case ground movement field impacting the assets in consideration indicate that the nearest asset, the eastbound running tunnel, may experience a maximum ovalisation of 1mm (egging) and a minimum radius of curvature of 103km, which are within the criteria set by Crossrail. The other assets, due to their greater offset from the proposed demolition works, have been demonstrated to experience a lesser degree of movement which are all within the Crossrail criteria.

Due to the relatively conservative assumptions adopted for the analysis, such as the cautious selection of geotechnical parameters, and the *greenfield* ground movement deformation field adopted for impact assessment purposes, there is a significant degree of conservatism in the analysis results. The degree of movement which the Crossrail assets experience during the demolition phase of works is therefore likely to be less than that presented herein (i.e. less than 3mm absolute displacement based on the current results).

It is therefore considered that the demolition phase of works represents a very low risk to the adjacent Crossrail assets. All subsequent phases of the proposed development will be covered in a later impact assessment submission.



Appendix A: Demolition Plans



- 1 This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
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- 5 Care to be taken not to cut / adversely affect existing retained beams / columns while demolition is taking place. Contractor to undertake careful exploratory works and submit appropriate method statement to ensure retained structure is not damaged undertaking areas of demolition
- 6 Treat all cut concrete faces with Ronabond concrete repair system by Ronacrete, or similar concrete repair system
- 7 Temporary bracing required prior to demolition of existing stability cores and until the new stability structure is in place prior to construction of new stability structure. Contractor to submit full temporary works and sequencing proposal to the CA for review prior to commencing work
- 8 The foundations of the existing structure must not be undermined. Upon exposing the retained structures the contractor should identify if any proposed excavation levels are deeper than the existing founding levels and notify the engineer accordingly
- 9 Lintels required for all new wall openings

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Demolition legend

Phasing of demolition to suit Crossrail planning requirements. Phase 1 consists of demolition of the super structure and ground floor/basement areas that will not affect Crossrail assets. A minimum 3-months baseline monitoring of the Crossrail assets is required prior to demolition of these elements U.N.O

Phase 2 consists of demolishing the remaining ground and basement levels as part of the main works. Temporary propping will need to be installed to limit ground movement along these critical elevations. A minimum 3-months baseline monitoring of the the Crossrail assets is required prior to demolition of these elements U.N.O

		Area of floor to be demolished
		Area Low Level slab demolished
		Beam demolished / removed
		Column demolished / removed
		RC / Masonry wall demolished

P3	28.10.21	DG	KK	Crossrail Phase 1 Demo Issue
P2	24.09.21	DG	SL	Revised Tender Issue
P1	17.01.20	JHL	SL	Stage 2 Issue
Rev	Date	By	Eng	Amendment

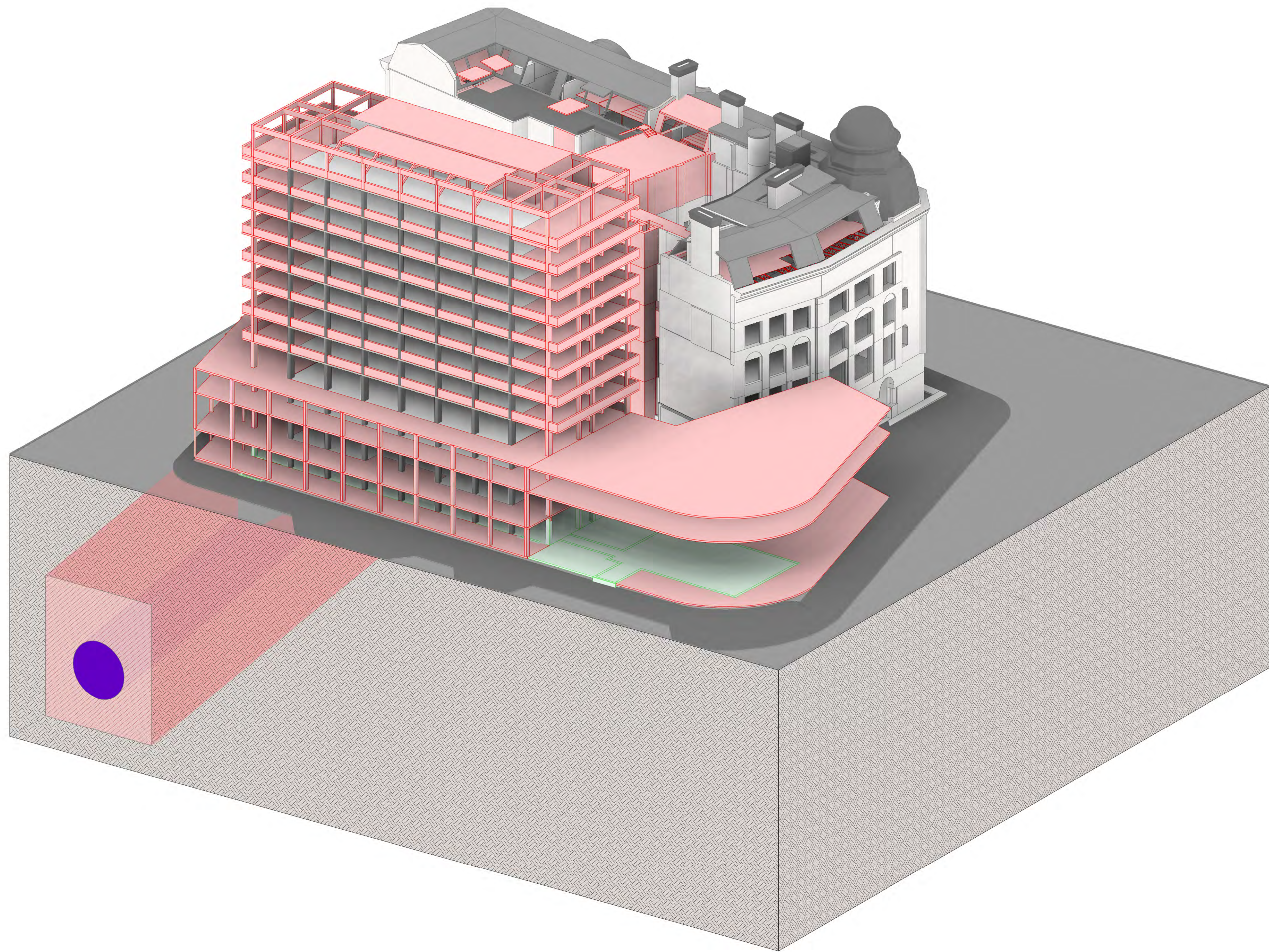
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Job Name
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College of Art & Design
Holborn WC1B 4AF
Drawing Title
Demolition
Overall Site View 1

Purpose of Issue **S0 - Preliminary** Scale at A1 N/A

Drg No **2300-HTS-ZZ-XX-DR-S-3010**

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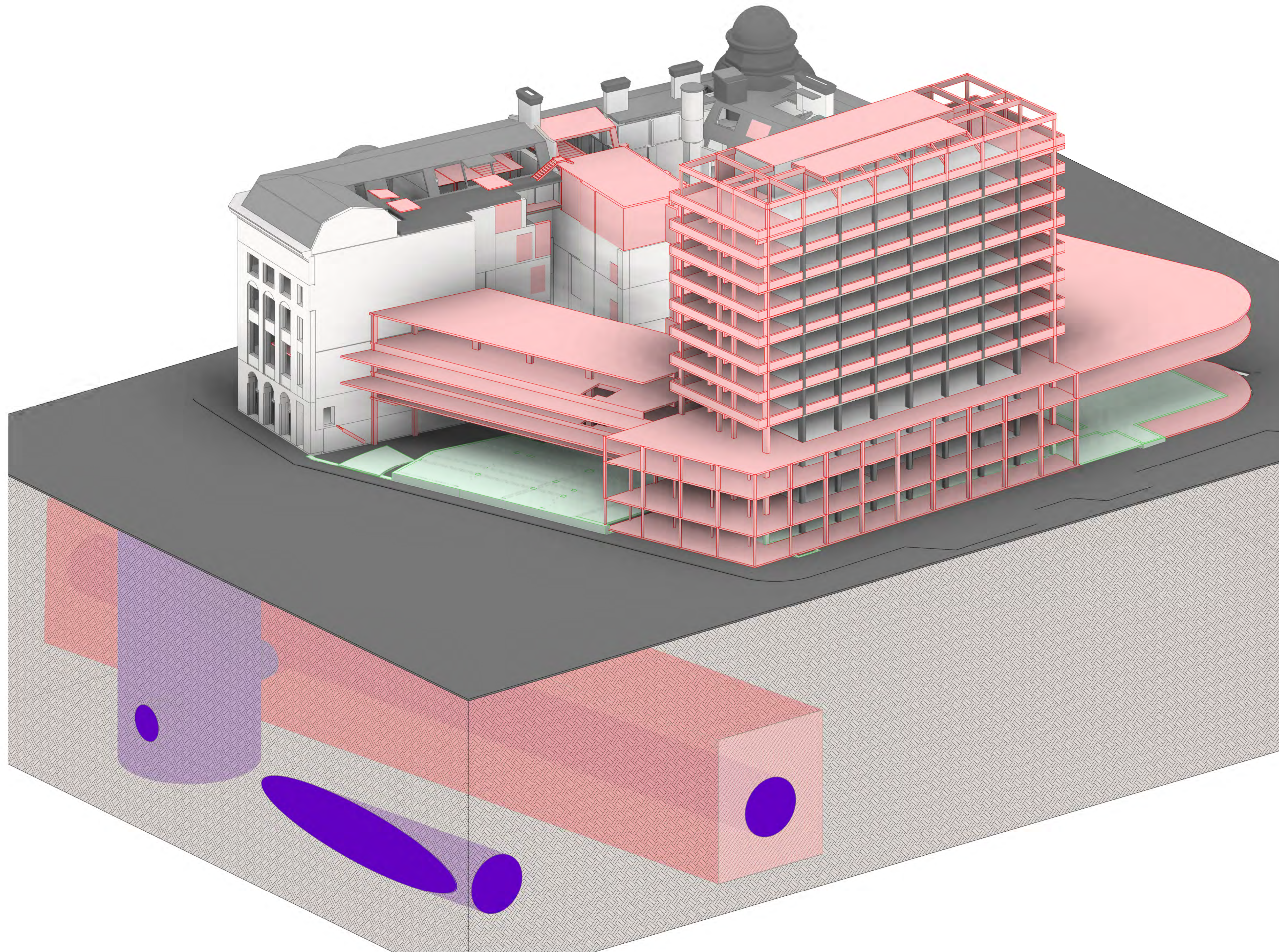
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Demolition
Overall Site View 2

Purpose of Issue **S0 - Preliminary** Scale at A1 N/A

Drg No **2300-HTS-ZZ-XX-DR-S-3011**

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Overall Site View 3

Purpose of Issue **S0 - Preliminary** Scale at A1 N/A

Drg No 2300-HTS-ZZ-XX-DR-S-3012

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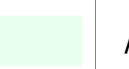



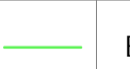

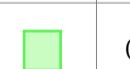
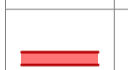
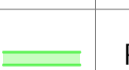
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Demolition legend

Phasing of demolition to suit Crossrail planning requirements. Phase 1 consists of demolition of the super structure and ground floor/basement areas that will not affect Crossrail assets. A minimum 3-months baseline monitoring of the Crossrail assets is required prior to demolition of these elements U.N.O

Phase 2 consists of demolishing the remaining ground and basement levels as part of the main works. Temporary propping will need to be installed to limit ground movement along these critical elevations. A minimum 3-months baseline monitoring of the Crossrail assets is required prior to demolition of these elements U.N.O

		Area of floor to be demolished
		Area Low Level slab demolished
		Beam demolished / removed
		Column demolished / removed
		RC / Masonry wall demolished

P3	28.10.21	DG	KK	Crossrail Phase 1 Demo Issue
P2	24.09.21	DG	SL	Revised Tender Issue
P1	17.01.20	JHL	SL	Stage 2 Issue
Rev	Date	By	Eng	Amendment

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<http://hts.uk.com/>

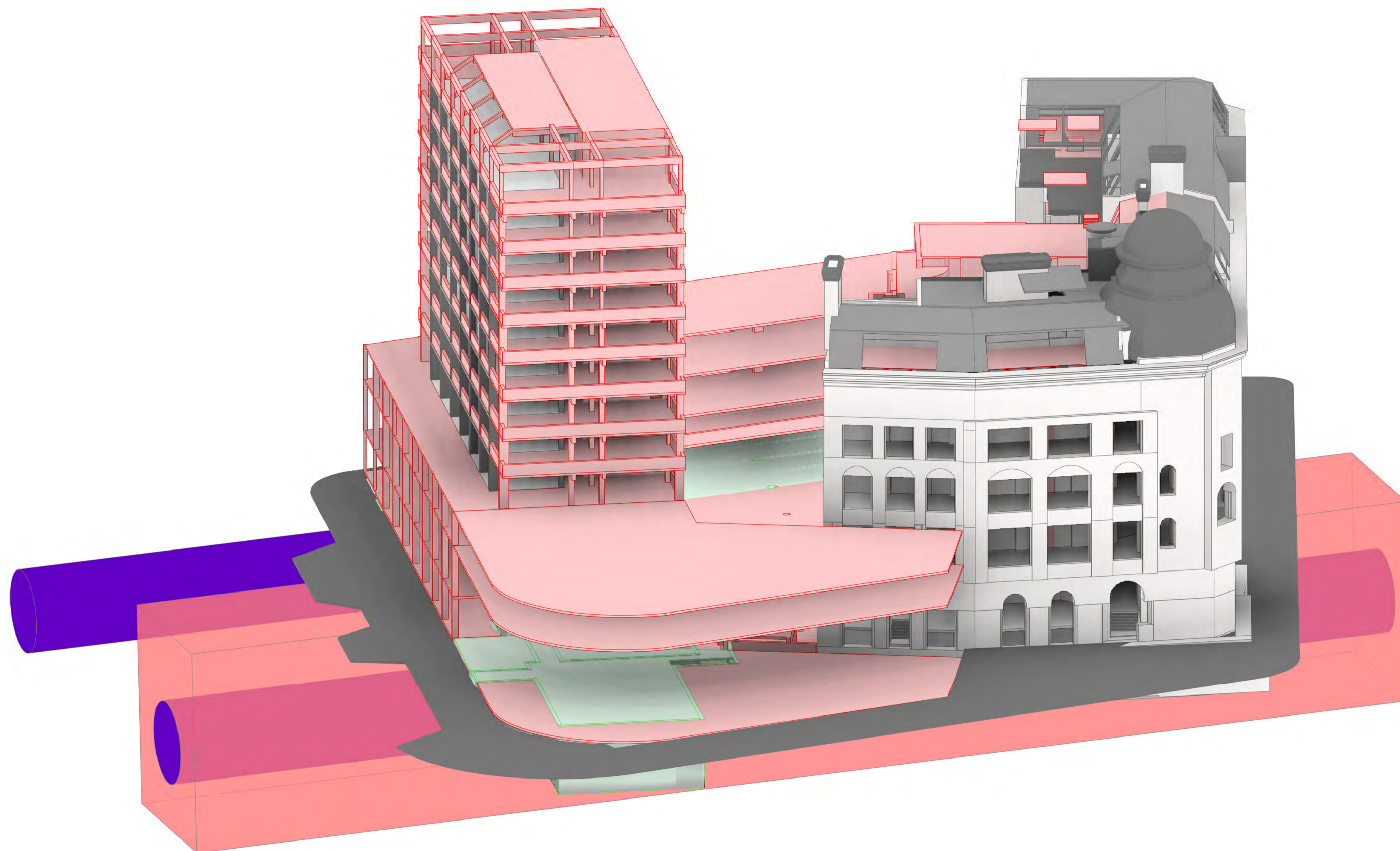
Job Name
Former Central St. Martins
 College of Art & Design
 Holborn WC1B 4AF

Drawing Title
Demolition
Overall Site View 4

Purpose of Issue **S0 - Preliminary** Scale at A1 N/A

Drg No **2300-HTS-ZZ-XX-DR-S-3013**

HTS Job No **2300** Rev **P3**



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		Area of floor to be demolished
		Area Low Level slab demolished
		Beam demolished / removed
		Column demolished / removed
		RC / Masonry wall demolished

P2	28.10.21	DG	KK	Crossrail Phase 1 Demo Issue
P1	24.09.21	DG	SL	Revised Tender Issue
Rev	Date	By	Eng	Amendment

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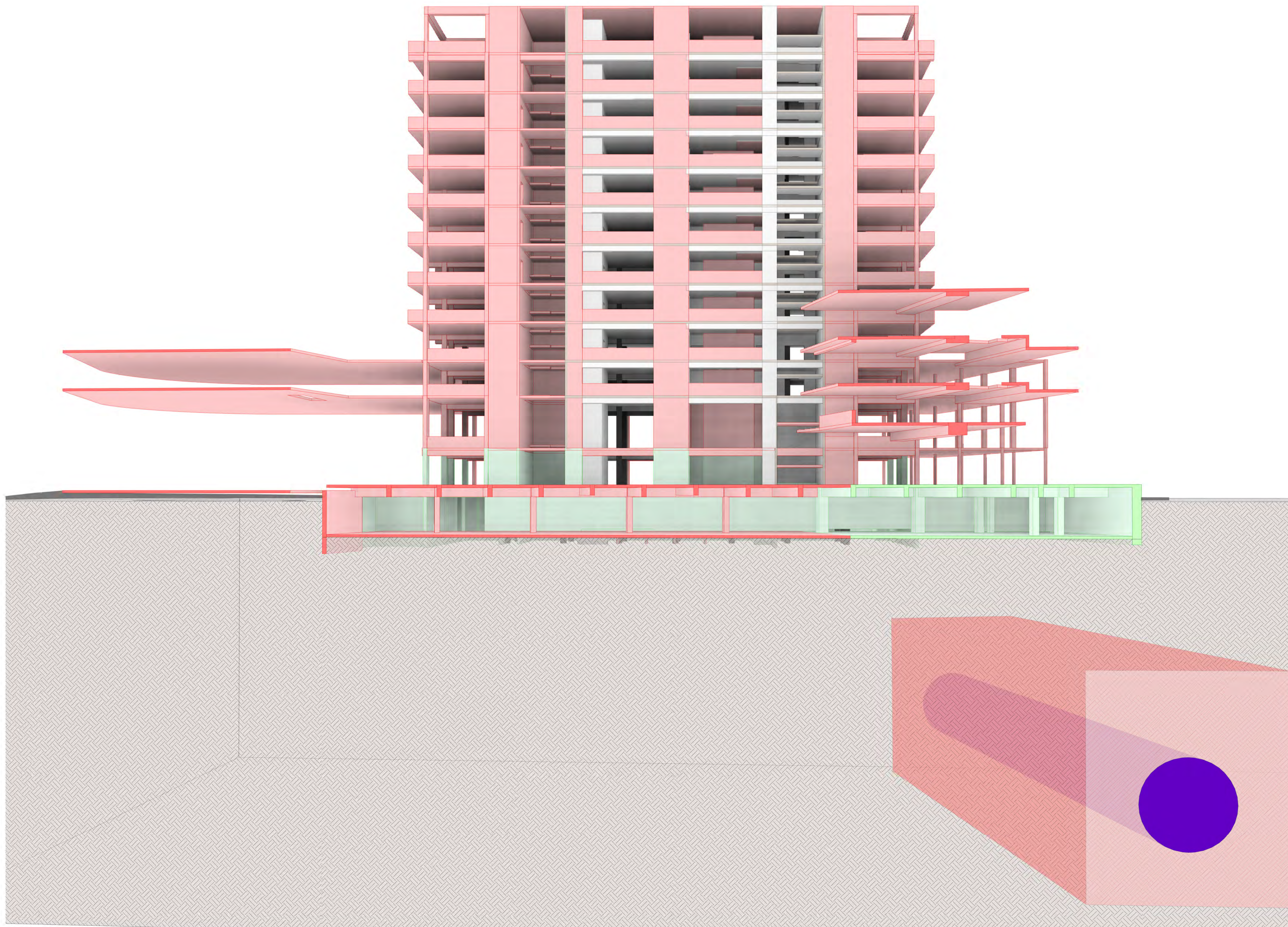
Job Name
Former Central St. Martins
 College of Art & Design
 Holborn WC1B 4AF

Drawing Title
Demolition
Perspective Section 1

Purpose of Issue **S0 - Preliminary** Scale at A1 N/A

Drg No **2300-HTS-ZZ-XX-DR-S-3014**

HTS Job No **2300** Rev **P2**




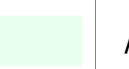



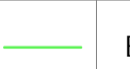

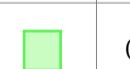
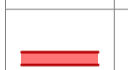
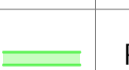
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Demolition legend

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		Area of floor to be demolished
		Area Low Level slab demolished
		Beam demolished / removed
		Column demolished / removed
		RC / Masonry wall demolished

P2	28.10.21	DG	KK	Crossrail Phase 1 Demo Issue
P1	24.09.21	DG	SL	Revised Tender Issue
Rev	Date	By	Eng	Amendment

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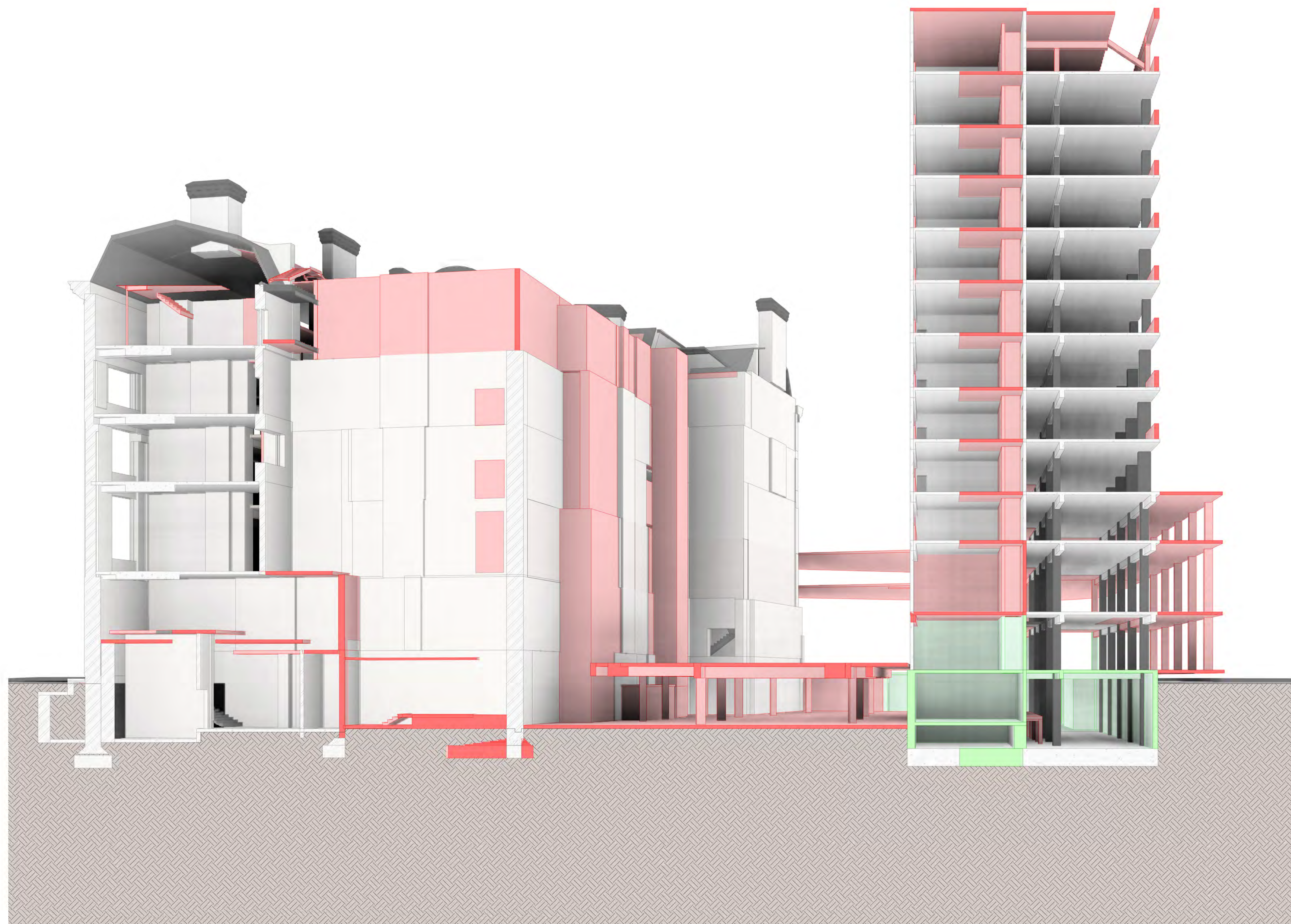
Job Name
**Former Central St. Martins
College of Art & Design
Holborn WC1B 4AF**

Drawing Title
**Demolition
Perspective Section 2**

Purpose of Issue **S0 - Preliminary** Scale at A1 N/A

Drg No **2300-HTS-ZZ-XX-DR-S-3015**

HTS Job No **2300** Rev **P2**



- 1 This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
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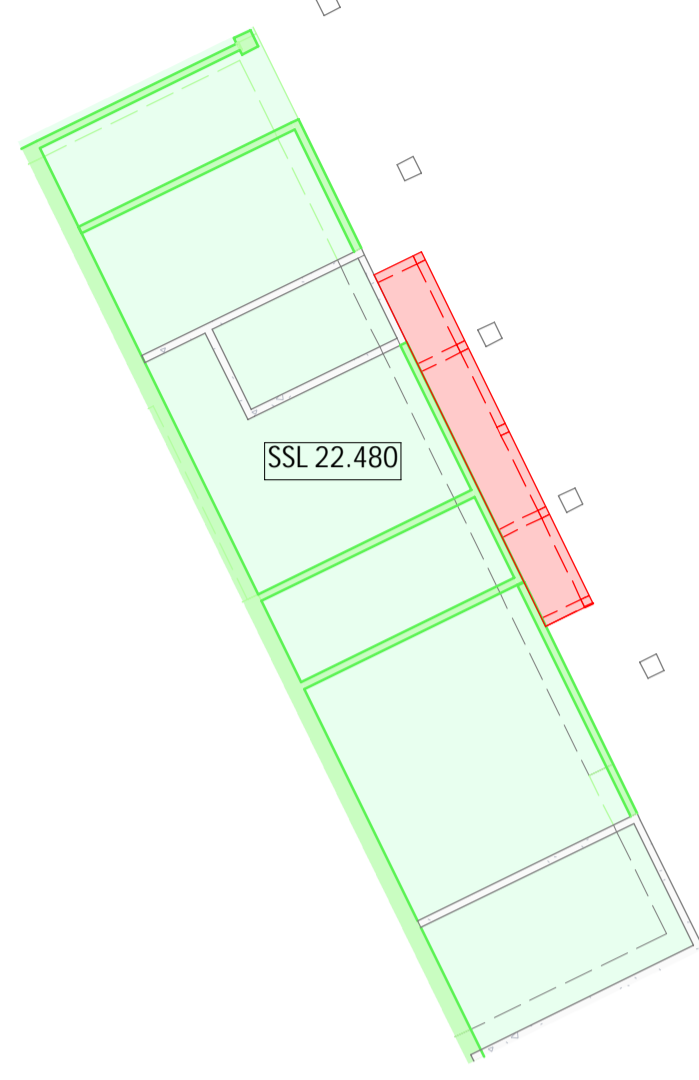
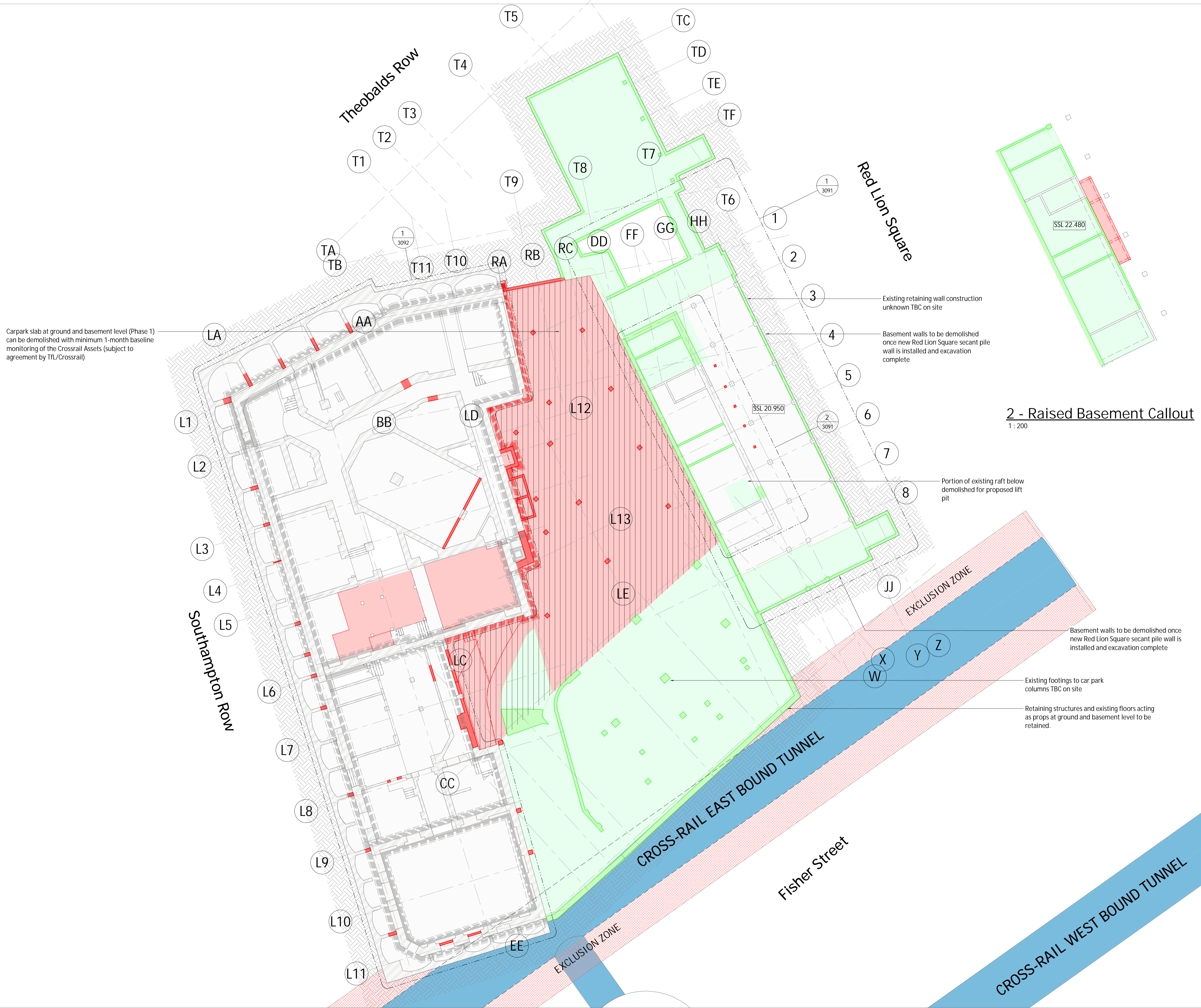
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		Area of floor to be demolished
		Area Low Level slab demolished
		Beam demolished / removed
		Column demolished / removed
		RC / Masonry wall demolished

P4	28.10.21	DG	KK	Crossrail Phase 1 Demo Issue
P3	24.09.21	DG	SL	Revised Tender Issue
P2	20.08.21	DG	SL	Initial Tender Issue
P1	17.01.20	JHL	SL	Stage 2 Issue
Rev	Date	By	Eng	Amendment

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<http://hts.uk.com/>

Job Name
 Former Central St. Martins
 College of Art & Design
 Holborn WC1B 4AF
 Drawing Title
Demolition
Overall Basement Plan



Carpark slab at ground and basement level (Phase 1) can be demolished with minimum 1-month baseline monitoring of the Crossrail Assets (subject to agreement by TfL/Crossrail)

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P4	28.10.21	DG	KK	Crossrail Phase 1 Demo Issue
P3	24.09.21	DG	SL	Revised Tender Issue
P2	20.08.21	DG	SL	Initial Tender Issue
P1	17.01.20	JHL	SL	Stage 2 Issue
Rev	Date	By	Eng	Amendment

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<http://hts.uk.com/>

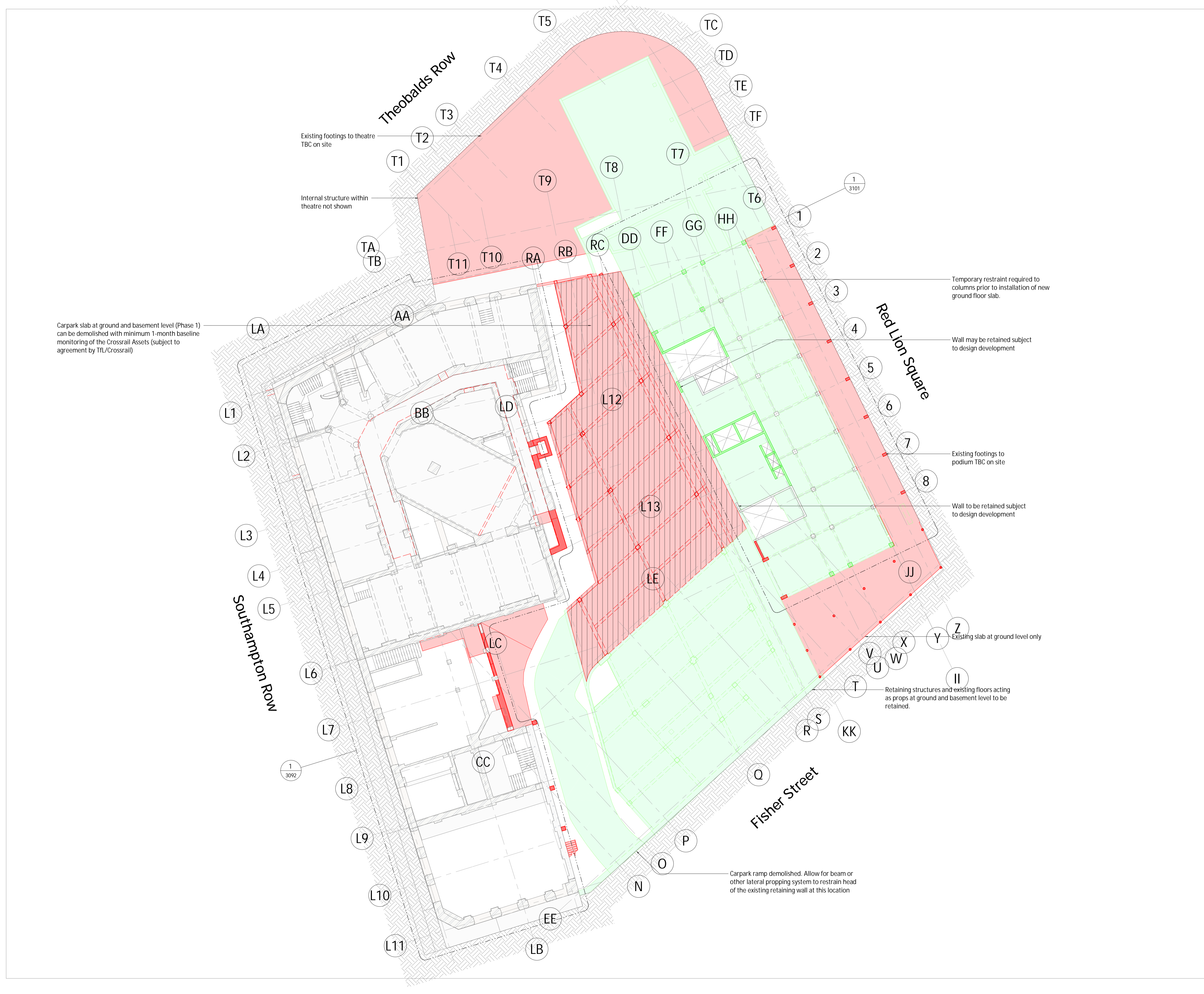
Job Name
 Former Central St. Martins
 College of Art & Design
 Holborn WC1B 4AF

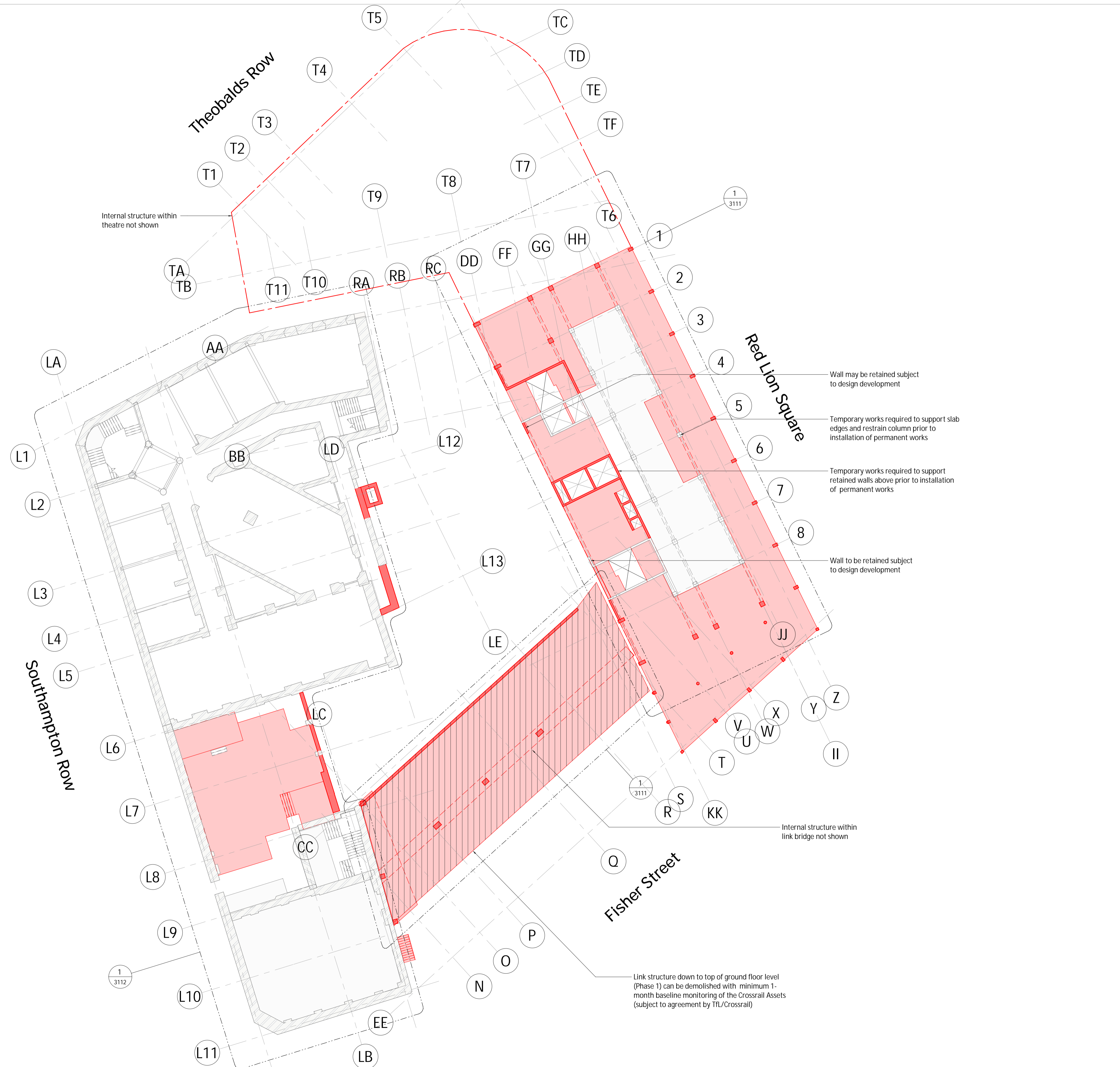
Drawing Title
Demolition
Overall Ground Floor Plan

Purpose of Issue **S0 - Preliminary** Scale at A1 1 : 200

Drg No **2300-HTS-ZZ-00-DR-S-3100**

HTS Job No **2300** Rev **P4**





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P4	28.10.21	DG	KK	Crossrail Phase 1 Demo Issue
P3	24.09.21	DG	SL	Revised Tender Issue
P2	20.08.21	DG	SL	Initial Tender Issue
P1	17.01.20	JHL	SL	Stage 2 Issue
Rev	Date	By	Eng	Amendment

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<http://hts.uk.com/>

Job Name
Former Central St. Martins
 College of Art & Design
 Holborn WC1B 4AF

Drawing Title
Demolition
Overall First Floor Plan



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		Area Low Level slab demolished
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P4	28.10.21	DG	KK	Crossrail Phase 1 Demo Issue
P3	24.09.21	DG	SL	Revised Tender Issue
P2	20.08.21	DG	SL	Initial Tender Issue
P1	17.01.20	JHL	SL	Stage 2 Issue
Rev	Date	By	Eng	Amendment

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Job Name
Former Central St. Martins
 College of Art & Design
 Holborn WC1B 4AF

Drawing Title
Demolition
Overall Third Floor Plan

Purpose of Issue **S0 - Preliminary** Scale at A1 **1 : 200**

Drg No **2300-HTS-ZZ-03-DR-S-3130**

HTS Job No **2300** Rev **P4**