4 CONSTRUCTION STRATEGY

4.1 INTRODUCTION

This chapter of the ES describes the proposed demolition and construction strategy and programme, including all key activities that will be undertaken prior to the occupation of the proposed development, for the purposes of identifying and assessing the potential environmental impacts and likely environmental effects of the proposed development in the technical assessments reported within the three volumes of the ES.

Planning for demolition and construction is necessarily broad at this stage, with a draft Construction Method Statement, being prepared through early contractor involvement, however no contractor has yet been appointed to undertake the proposed works. As such, it may be subject to modification during any future detailed demolition and construction planning. For this reason, the following chapter is based on the construction method statement (provided in Appendix 4.1), which is reliant on reasonable assumptions in the demolition and construction programme.

4.2 SUMMARY OF ANTICIPATED WORKS

The proposed development consists of the construction of the 52,888-seat stadium (with associated facilities and infrastructure) to UEFA (Union of European Football Associations) Category 4 and associated external works at the application site. The main construction activities include:

- Protection of the listed structures and removal of heritage assets for reuse;
- Construction of three new openings into the Grade II listed Regent Road wall (one new opening required at start of construction programme) to facilitate safe access / movement around the site during construction;
- Removal of buildings (except for Grade II listed Hydraulic Engine House/Tower) and in-ground obstructions;
- Dock wall heritage repairs;
- Dock isolation (temporary and permanent);
- Dock filling;
- Service diversions, incoming electrical supply;
- Substructure works, including piling;
- Substructure pile cap foundations and lift pits;
- Underground drainage and other services;
- Precast concrete work to columns, walls, slabs and stairs, as well as lower-tier rakers and terrace units;
- Structural steelwork including upper rakers;
- Precast terracing units, vomitories' and step blocks;
- Steelwork roof trusses and purlins;
- Aluminium standing seam roof coverings and polycarbonate;
- Aluminium mesh cladding to roof barrel;
- Brickwork piers;
- Glazing, mesh and brickwork infills;
- Lifts and escalators;
- Handrails, balustrades and bowl barrier rails;
- Mechanical, electrical and public health installations;
- Fit-out activities, including bowl, concessions and concourses;
- Pitch works;
- Testing and commissioning; and
- External works including western water channel.

4.3 CONSTRUCTION PHASE PROGRAMME

For the purposes of the ES, it has been assumed that the 'opening year' for all development within the site is 2024, with construction anticipated to commence in Q1 2021.

The current expectation is that the demolition, construction and fit-out works would take approximately 37 months to complete. This programme includes all enabling work, required to allow efficient access to the site, and fitting out of the stadium. The programme has been informed by specialist contractor input from Laing O'Rourke and Boskalis. It is considered to be based on reasonable assumptions in terms of the sequencing of works and site logistics and is considered to be achievable.

The works covered within this Construction Strategy chapter are anticipated to be carried out in a single phase.

The application site is a unique environment, which means that a traditional stadium construction focus on the more complex West and East stands is not the most beneficial construction sequence to achieve the optimal outcome.

Therefore, the approach is to initially focus construction activities on the North and South stands, both have extremely restricted working zones, particularly behind them, with Nelson Dock behind the South stand and the United Utilities wastewater treatment works (UUWwTW) behind the North stand.

Construction of the South and North stands will begin in conjunction with filling of the dock to reclaim the land for the West and East stands. By overlapping the programme activities, time will be saved, and significant amounts of congestion will be reduced on the pitch area if all stands are constructed concurrently.

The in-ground obstructions will be identified and resolved early as a result of the adopted construction strategy. It is anticipated that the top 2m of ground of both wharf areas will be removed alongside demolition activities (with appropriate protection to the dock walls). What remains in the ground below the 2m zone will be surveyed and will inform whether there will be removal of obstructions or redesign of piling and foundations.

The construction programme activities can be divided into the following construction stages:

Stage 1 – Site preparation including dock filling

- Site establishment hoardings and welfare;
- Protection of listed structures and repairs to dock walls;
- Creation of new opening in Grade II listed Regent Road wall to facilitate pedestrian access to the site compound (two other openings to be created later in construction programme);
- Remove heritage assets and store for reuse;
- Strip-out and demolition of unlisted structures;
- Grub up redundant foundations and remove in-ground obstructions;
- Dock isolation (temporary and permanent);
- Dock in-filling with marine-won aggregate;
- Piling platform from recycled demolition materials;
- Installation of permanent northern isolation structure.

Stage 2 – Substructure including piling

- Continuous Flight Auger (CFA) bore piles;
- Pile caps, including lift pits;
- Suspended ground floor slab.

Stage 3 – Superstructure concrete works for East and West stands

- Precast columns;
- Precast wall units (twinwall);
- Lattice slabs and in situ concrete, power floated;
- Precast staircases and lift shafts.

Stage 4 – Steelwork and precast terracing

- Steelwork rakers at 9.6m centres;
- Precast concrete terrace units, vomitories and step blocks;
- Steelwork structures – North and South stands;
- Lattice concrete slabs – North and South stands.

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Stage 5 – Roof steelwork

- Assemble steelwork planar trusses to South and North stands;
- Erect trusses onto trestles and complete site welding;
- Cantilever trusses to East and West stands;
- Purlins for roof coverings.

Stage 6 – Roofing including mesh cladding to the barrel

- Aluminium standing seam roofing system;
- Polycarbonate roofing;
- Aluminium mesh to roof barrel;
- Flat roofing to accommodation areas.

Stage 7 – Facade

- Secondary steel;
- Brickwork piers in Flemish bond;
- Glazing, mesh and brick infills between brick piers;
- Doors, gates turnstiles, etc.

Stage 8 – MEP and fit-out

- Mechanical, electrical and plumbing installation;
- Blockwork and other partitions;
- Lift installation;
- Escalator installation;
- Handrails, barrier rails and other protection rails;
- Fit-out accommodation and corporate spaces;
- Fit-out concessions and concourses;
- Fit-out bowl including seating.

Stage 9 – Pitch works

Stage 10 – Western Water Channel

Stage 11 – External works

- Hard landscaping;
- Soft landscaping;

Construction of Regent Road wall openings including lintels and piers.

Stage 12 – Testing, commissioning and move to fully operational

The anticipated construction programme is shown in Table 4.1. Throughout this ES, reference to the 'construction phase' is considered to include the demolition and other enabling works. Further information on the above construction activities is detailed in Appendix 4.1.

Table 4.1

Indicative programme of construction works

PHASE	START DATE	FINISH DATE	DURATION
Enabling Works / Demolition & Dock Infill	28/09/2020	01/06/2021	32 weeks
Construction of North Stand	07/12/2020	08/06/2023	119 weeks
Construction of South Stand	10/12/2020	06/06/2023	123 weeks
Construction of West Stand	29/04/2021	03/08/2023	110 weeks
Construction of East Stand	11/05/2021	27/07/2023	108 weeks
Testing & Commissioning	05/10/2022	24/07/2023	38 weeks
Inspections and Handovers	23/12/2022	08/08/2023	29 weeks
Pitch Works	07/11/2022	23/05/2023	25 weeks
Car Park & Externals	28/09/2020	28/07/2023	148 weeks
Final Stadium Testing	26/07/2023	07/09/2023	6 weeks
Total			**37 months**

A number of the construction phases will be taking place concurrently.

4.4 SITE LOGISTICS

4.4.1 Hours of Operation

All 'noisy activities' such as piling must be carried out within the following 'restricted hours':

- Monday to Friday: 07:00 -19:00
- Saturday: 07:00 -13:00
- Sundays and Bank Holidays: No Working

No work is to be undertaken on Sundays or Public Holidays, unless written consent is obtained from LCC for extreme emergency cases. In this scenario the Contractor would be required to fully justify any proposed deviation from those operating periods, provide written justification to LCC, and notify neighbours in writing, before works outside normal hours commence.

Some elements of the construction process will require alternative working hour arrangements, as a consequence of their technical requirements. During the initial phase of the works, there is a requirement to fill the dock with imported material. This will be managed through a dredging method using sea transportation. This is typically done through 24 hour/7 days-a-week approach. Alternative working hours are also proposed for the dock infill compaction process (07:00-19:00, six days-a-week). These working hours will be used through this phase upon agreement with all parties. As the floor slabs are to be power floated, this will require this (highly localised) activity to continue late into the evenings and sometimes overnight depending on environmental conditions and the concrete setting process.

4.4.2 Transportation of Materials

The number of Heavy Goods Vehicles (HGVs) and Light Goods Vehicles (LGVs) deliveries per day has been forecast for the construction phase. This is presented in Table 4.2.

Table 4.2

Typical average daily delivery plan during construction of the proposed development

	WEEKS	1–25	26–50	51–75	76 – 100	101 – 125	126 – 150
Enabling works	Whole site	25					
Substructure	North	12	12	6			
	South	20	12	6			
	West		10	8			
	East		10	8			
Structure	North		6	4	3		
	South		6	4	3		
	West			5	6	4	
	East			5	6	4	
Envelope	North			5	8		
	South			5	7	5	
	West				6	8	
	East				5	8	
Roof	North				5	2	
	South			2	5		
	West					5	
	East					5	
Fit-out	North				4	6	4
	South				4	6	4
	West				8	10	10
	East				8	10	10
West wind struct			6			8	8
Externals					6	6	6
Pitch						4	4
General		7	7	7	7	7	7
Total		64	69	65	97	98	53

The maximum number of daily 2-way HGV and LGV movements during the construction phase is 98 movements total; of these 2-way movements,

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44 are expected to be made by HGVs. Deliveries will be carefully scheduled to avoid multiple vehicles arriving at the site simultaneously, that would require vehicles having to wait at the site entrance. The application site is accessible directly from the strategic road network. Vehicles can approach from Regents Road. An overview of the haulage roads around site, including proposed access points, is detailed in Figure 4.1.

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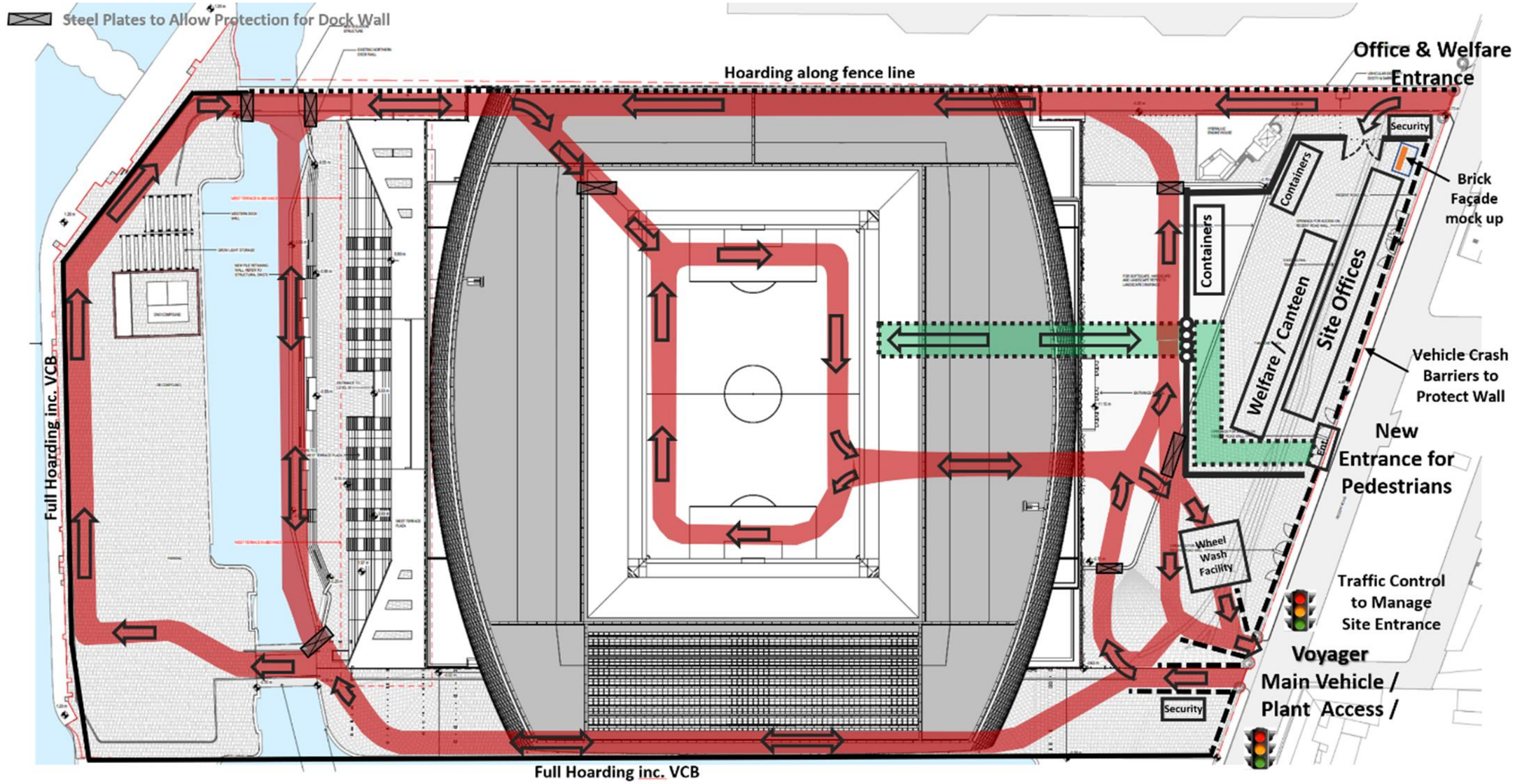
Figure 4.1
Proposed site haulage routes around the site



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4.4.3 Considerate Contractor's Scheme

The site and its constituent construction works will be registered with the UK's "Considerate Contractor's Scheme" by the principle contractor. This scheme ensures that contractors carry out their operations in a safe and considerate manner; with due regard to neighbours, pedestrians and site users.

4.4.4 Site Security & Access

All security operations will be implemented in accordance with the latest British Standards and in full compliance with the Private Security Industry Act 2001 [1].

Security arrangements will ensure unauthorised access is prevented at all times to the work areas. This will include facial recognition access turnstiles provided at the entrance to site. All staff/operatives will undertake a detailed, project-specific induction before being issued with access.

The site will be secured and monitored with two security guards and CCTV outside working hours.

4.4.5 Site Offices & Welfare Accommodation

It will be necessary during the course of the main construction programme, to provide on-site office and site welfare accommodation in accordance with the Construction, Design and Management (CDM) Regulations 2015 [2] Schedule 2.

For the initial activities during the site preparation works, accommodation will be self-contained starter units situated adjacent to the works. These will remain in place until the main accommodation is established.

The site offices and welfare compounds will be positioned as indicated in Figure 4.1. A compound will be constructed from Hardstaff concrete vehicle crash barriers (VCBs) with solid hoarding and gates to ensure any delivery vehicles are totally segregated from pedestrians in the non-PPE (Personal Protective Equipment) site compound. The pedestrian access from the compound to site will be controlled at this location by installing a series of Aurora secure login turnstile booths. Site accommodation will consist of energy-efficient Multiple-stacked units placed with a mobile crane onto temporary concrete strip foundations (formed above the ground not to disturb tram rails, etc).

For the personnel on site, the welfare facilities will be designed for an average of between 800 and 900, with a peak of c.1,300 operatives (including subcontractors) during the internal phase. This will be supported by c.300 staff members that should be more a consistent count through the construction programme. This will be positioned in a separate area away from the main construction works.

4.5 SITE ESTABLISHMENT

One of the first activities will be to establish the area as a construction site. The working areas will be secured, and the general public will be separated from the works, prior to works commencing, with the use of a minimum 2.4m high hardstaff hoarding. Secure access points with wheel cleaning facilities will be established at all site access and egress locations. Pedestrian access points will generally be located close to the main vehicular access gates with separate pedestrian gates and footpaths provided.

Acoustic hoarding will be installed on the western site boundary to mitigate potential noise impacts on wintering birds associated with the surrounding European designated sites as far as practicable.

4.6 PRE-DEMOLITION WORKS

Before any demolition works take place onsite, the following will have been undertaken:

- A full asbestos survey will have been conducted within all structures to be demolished, and any asbestos removed under licence.
- Pre soft strip the necessary restricted access arrangements and fire points with appropriate fire extinguishers and warning signage will be implemented.
- The soft stripping of all non-structural elements, these will then be separated and placed into designated skips for recycling off site. the soft strip will be carried out using hand techniques.

Hardstaff concrete barriers (Vehicle Crash Barriers VCB) with hoardings attached where appropriate will be used to protect all listed structures including the hydraulic tower and any dock walls during demolition and construction activities.

4.7 DEMOLITION WORKS

Ahead of any demolition, any heritage assets designated for reuse will carefully be removed and transported to the west wharf, or a secure offsite storage facility where they will be stored ready to reuse later in the project.

The existing buildings on the south wharf consist of a concrete frame with large doors or bricks infilling. The lightweight steel roof trusses sit on the concrete beam and support the metal roofing sheets. The roof will be removed with a long reach excavator, this will then allow the walls to be dismantled with care to ensure the walls collapse inwards thus avoiding debris in the dock and impact on the dock walls.

All concrete and brickwork from demolition and in ground obstruction removal activities will be crushed on site to produce graded 6F2. The 6F class of aggregates refers to those materials which have been recycled from building, demolition or other construction sites, class 6F2 consists of selected granular material of a coarse grade that will be suitable for the piling platform, with metal and any unsuitable material to be disposed off site.

North and South quay activities will commence concurrently, but the North with less buildings will progress quicker. The ground to a depth of 2m will be excavated and any obstructions to piling removed and crushed to 6F2 for backfilling. Any existing piles not removed will be surveyed to ensure they do not interfere with the new piling layout.

4.8 REGENT ROAD WALL OPENINGS

A total of three new pedestrian openings are proposed to be created within the Grade II listed Regent Road wall to facilitate the approach access / egress during the operation of the stadium.

The Stage 1 site preparatory works will require the early creation of one of these new openings in the Grade II listed Regent Road wall to create the necessary pedestrian access into the works compound with the remaining two new access points to be created further into the construction programme. The existing turreted entrances at the north and south of the Regent Road boundary will be used for vehicles, and protected from vehicle damage during the stadium construction

The construction methodology of the new openings involves a phased approach, whereby the new openings will be created at full height during construction to allow for unfettered access for construction vehicles. Once the site reaches a completed condition, the lintel and interim walls will be rebuilt across the top of the openings to return the wall to a near-continuous form.

The physical works to the wall will be subject to the appropriate Listed Building Consent (LBC) submissions.

4.9 DOCK WALL REPAIRS

A comprehensive condition survey of the dock walls will be completed; the extent of repairs and salvage of metalwork will then be agreed with LCC and Historic England prior to the dock filling activities commencing. Installation of displacement and vibration monitoring equipment to the dock walls is proposed. A baseline survey (for the purpose of asset protection) will be undertaken a minimum of two days in advance of the dock infilling works and will continue for a minimum of one week after compaction of the dock infill is completed.

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4.10 DOCK FILLING

4.10.1 First Fish Removal

A first fish rescue and translocation will take place in advance of the raking process. This is required to minimise the potential for fish mortality during the infilling process from reduced dissolved oxygen levels, loss of habitat and exposure. Methods will target all known fish species known to inhabit the dock including pouting, European eel and coal fish. Every effort will be made to remove as many fish as possible, but no guarantee can be given that all fish will be caught and translocated during the rescue due to equipment limitations. Fish will be released back into the wider dock network.

In order to prevent fish from re-colonising Bramley-Moore Dock, a bubble curtain will be installed to deter fish away from the northern water channel adjacent to Sandon Half Tide Dock. Following the raking operation, the bubble curtain will be replaced with a silt screen in order to enable early decommissioning of the bubble screen. The silt screen will prevent fish re-entry but will also act to prevent the migration of any disturbed dock bed deposits during construction of the isolation structure.

Dock Bed Raking and Debris Removal

After the first fish rescue and translocation exercise, the dock bed will be systematically raked by the purpose-built plough vessel, 'Norma', pulling debris to an agreed location where it can be lifted by a mobile crane and taken by road to a licensed disposal area.

Removing debris prior to the reclamation and construction works will reduce the risk of obstructions impacting the piling operations and reduce the potential of differential settlement.

The 'Norma' vessel will operate 12 hours a day, 7 days a week (nominally 0700–1900) and will systematically track across Bramley-Moore Dock.

The size, volume and extent of the debris within Bramley-Moore is currently unclear and as such the duration of the raking programme is unquantifiable. The raking exercise is expected to move through the upper layer of unconsolidated material within the dock bed. This process will cause agitation of the materials within this layer, and it has been assumed there will be a minimum two to three-month period post raking to allow the material to settle, the budget proposal assumes the debris is not contaminated.

4.10.2 Dock Closure

The dock must be fully enclosed prior to commencement of the filling operation. A temporary design solution has been developed, which involves the placement of 6F2 granular material within the northern entrance channel to form a temporary bund/barrier between Bramley Moore Dock and Sandon Half Tide Dock.

The bund will need to be formed so that the edge of the slope is wide enough to enable the piling rig to travel and operate sufficiently to install the permanent twin secant pile isolation structure using the bund as a pilling platform. It is the intention that the bund material encapsulated within the twin secant pile wall structure and the material remaining on the Bramley Moore Dock side of the structure beneath the water channel can be retained as part of the permanent works. Material forming the slope on the north side of the structure and material to the south which will be within the water channel will need to be removed following completion of the permanent works.

Any repairs/modifications to the existing Southern isolation structure to ensure stability throughout construction will be implemented.

During construction, whilst the dock is infilled and the isolation structure in place, it is likely that salinity and dissolved oxygen levels may fluctuate over time to the southern water body (Nelson Dock). Baseline monitoring has established that there is an existing natural variation in salinity and dissolved oxygen levels to this water body, which is impacted to a large degree by activity in the southern dock system. Whilst monitoring will continue through the construction period, any effects on ecology associated with the suspension of the hydrological connection during the construction phase are anticipated to be minimal, given that Nelson Dock receives significant flow input from southern water bodies (including the Leeds/Liverpool Canal), and receives minimal input from BMD. Although there is likely to be a gradual trend toward freshwater conditions within Nelson Dock during construction, the existing species assemblage is likely to comprise a more freshwater dominated community given the current flow conditions and existing isolation structure.

4.10.3 Second Removal of Fish and Transfer Exercise

On completion of the dock closure works, a final fish removal exercise will be undertaken to remove any potential remaining fish from the dock waters. This work will be undertaken by an independent specialist environmental consultant.

4.10.4 Vibration and Displacement Monitoring of the Dock Walls

The dock infilling procedure will confine the dock walls in the permanent structure state and increase the dock's current stability. Although, the infilling procedure may result in movements of the wall. Therefore, displacement and vibration monitoring equipment will be installed to the BMD walls.

Two days before any infilling work, a baseline survey will be carried out and will continue for a minimum of one week after compaction of the dock infill is complete. Once the baseline survey (first two days of monitoring) has been completed, a number of trigger values will be adopted which will be agreed with Historic England for vibration and displacement limits.

4.10.5 Dock Reclamation

Infilling of Bramley-Moore Dock will be undertaken using approximately 480,000m^3 of 'as dredged' sand sourced from BWL Licensed Winning Area 457, hydraulically discharged within the dock footprint. The lower layers will be placed using a floating spreader pontoon, ensuring accurate placement of the material. The upper level will be placed directly using the discharge pipeline network.

4.10.6 Trailing Suction Hopper Dredger

Dredged material will be transported and hydraulically discharged into Bramley-Moore Dock using a 'Freeway' class Trailing Suction Hopper Dredger (TSHD). The TSHD's dredging process consists of a cycle of loading (dredging), transporting (sailing) and discharging.

4.10.7 Discharge Pipeline Installation

Prior to the arrival of the dredger, a discharge pipeline network and spreader pontoon will be mobilised to Bramley-Moore Dock.

A connection point, where the dredger will couple to the floating discharge pipeline, will be agreed with Peel Ports at a suitable location within the River Mersey, close to Bramley-Moore Dock. The pipeline will be anchored and marked, ensuring it is not a hazard to navigation.

The Freeway class vessel's relatively shallow draft allows this point to be located outside the main shipping channel, while allowing a safe mooring over all states of the tide.

The discharge pipeline will follow a mutually agreed route from the dredger's connection point to Bramley-Moore Dock, using a 300m section of floating pipeline to the dock wall. From here it will be linked to steel shoreline, which will continue into the Bramley-Moore site.

The intention is to ship, wherever possible, the floating and shore discharge pipeline, along with the spreader pontoon, to the application site by sea, negating any unnecessary road movements. The steel shore pipeline, which is transported in 12m flanged sections, will be stockpiled in agreed locations during the installation process. This will be placed around the side of the existing dock and we will require a 10m access strip to allow installation and maintenance.

Once ready, the floating pipeline will be towed to a predetermined connection point position and connected to the shoreline. Additional floating pipeline will be used within Bramley-Moore Dock during the initial stages of the reclamation process, linking the spreader pontoon to the pipeline network.

The 'Freeway' class trailer dredger will dredge suitable material sourced from the Crown Estate-licensed Area 457, which is located approximately 23 nautical miles from Bramley-Moore Dock. The material from Area 457 has been used extensively for a variety of projects, including the 2012 Liverpool Wellington Dock infill, and to supply aggregate to the local construction market. Allowing for 24/7 non-tidal working, it is anticipated

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the 'Freeway' will deliver one load every 7 hours from Area 457, in the order of 46,500m^3 per week.

4.10.8 Initial Infilling Using a Spreader Pontoon

'As dredged' sand will be fluidised within the hopper of the dredger and hydraulically pumped through the discharge pipeline network into Bramley-Moore Dock. Water to fluidise the dredged sand will be extracted from the River Mersey. In line with consultation with the Environment Agency, in order to prevent entrainment of elver (juvenile eel), the pipeline will be fitted with a mesh screen of approximately 2mm mesh. The highest abundance of elver will be present in spring/early summer, and therefore abstraction will take place outside of these months.

The initial layers will be accurately placed diligently using a spreader pontoon to ensure the capping of the underlying unconsolidated silts is achieved without causing "mud waves" within the silt/infill interface.

The spreader pontoon will move across the dock using winches and pulling wires.

Water used during the pumping process will be discharged back into the Liverpool Dock (Sandon Half Tide Dock) system by a weir system at the dock closure structure. At present, this approach requires approval from Peel Ports. No allowance has been made for any additional pumping capacity to discharge the water back into the River Mersey or elsewhere within the dock system.

At the displacement location (adjacent to the isolation structure), a stilling pond will be created to slow down the water flow, which will in turn allow any fines to settle out before the water is displaced. This will be created by shaping the infilled sand once it is filled to the existing dock water level.

4.10.9 Reclamation of the Upper layers

Once the reclamation has progressed to a point where there is insufficient water depth for the spreader pontoon to operate further, the remainder of the material will be placed directly using steel shore pipeline, which will be extended as the 'as dredged' sand platform rises above the water level. The final level will be finished to around the required design level of +6.60m AOD using dry plant operating to normal working tolerances to achieve this level.

Overfilling may occur to allow for the later compaction of the material, ensuring the design level is met after the compaction works are achieved. Additional stockpiling of material will also be programmed, allowing suitable material for other elements of the works, where required.

4.10.10 Material Compaction

The 'as dredged' sand will be compacted using proven Cofra CDC (Cofra Dynamic Compaction) and CRC (Cofra Roller Compaction) methods. Production is based on operating a single shift working 12-hour days (0700–1900), six days a week. The works are expected to take approximately six weeks to complete, including for the equipment assembly and testing. Additionally, a five-week lead-in time prior to mobilisation will be required. Post compaction cone penetration tests will then be undertaken to confirm the suitability and performance of the compaction for material placed under the piling platform.

4.10.11 Installation of Permanent Northern Isolation Structure

A bored concrete pile solution is being proposed to permanently isolate Bramley-Moore Dock from the northern waterbodies. Two secant pile walls are proposed which will be formed by constructing a series of reinforced concrete piles that interlock to form a watertight barrier using the temporary bund as a piling platform.

Similar to the existing southern isolation structure, horizontal ties may be required. Pipes will be cast in between the two rows of piles at identical levels to the existing southern isolation structure to enable the exchange of dock water to the north and south.

Further information on the proposed dock infil methodology is provided in Appendix 4.2, ES Volume III.

4.11 PILING AND SUBSTRUCTURE WORKS

4.11.1 Earthworks

In order to deal with the existing ground conditions, a number of solutions will be adopted to transform the ground into a workable condition. The existing wharfs currently contain a number of cobble sets, existing dock infrastructure, mooring points, rail tracks and other dock-related items. These will be removed as part of enabling works to make the ground suitable. These dock materials and artefacts will be retained for future inclusion within the project or public realm works.

Once removed, up to 3.5m of existing ground may need to be excavated, transported to a processing area on site and crushed into a reusable material. The 6F2 type material which has been backfilled will not be of a substantial bearing pressure required to sit piling rigs and other plant, so to achieve this a mix of lime and cement will be combined with the material in order to stabilise the top 600mm of ground and achieve a California Bearing Ratio (CBR) of 10–15%. The formation level for new pile caps will be 5.3m AOD (assuming 100mm blinding). There is a working area of 6,500m^2 within the existing wharf at approximately 6.7m AOD currently. General excavation will be to a level of 5.1m AOD with localised excavations (750m^2) to 4.1m AOD. Backfilled with 300mm stabilised layers of recycled material (6.65m AOD), the working platform will be 6.95m AOD (300mm deep).

In the existing dock area, the dock will be filled to 5.8m AOD with marine-won sand. It is proposed to use the sand combined with ground stabilisation methodologies by backfilling 300mm stabilised layers to 7.0m AOD. This sand will be combined with cement. The working platform over the top will be installed to 7.3m AOD and a stone piling platform installed on top. Using this stabilisation methodology will help to achieve the bearing pressures required for working plant, as well as achieving better excavation batters after piling completion. This optimises the volume of material being brought on and off site.

4.11.2 Groundwater

Levels vary across the site, with the shallowest point at c.1.8m. More typically, groundwater is found at 2–3m below ground level across the site.

There are issues with localised groundwater contamination, but this again is considered likely to be confined to the North Wharf area and is likely to be related to contamination in the made ground. Visual evidence of contaminated water is observed within TSS1.2 and P101. Further chemical testing confirmed contamination within OH102 at 3m, relating to hydrocarbon content. It is likely that groundwater treatment may be required in these areas before discharge, unless an agreement can be reached with UU WwTW. Further details regarding contamination and water may be found in Chapters 10 and 11, respectively.

4.11.3 Piling Methodology

It is proposed to construct the piles at Bramley-Moore using the continuous flight auger piling technique. This technique involves screwing hollow-stem augers into the ground until the target design depth is reached. The soil-laden augers remain in the ground on reaching the required depth. Concrete is pumped under pressure through the hollow stem as the augers are withdrawn at a controlled rate, ensuring that a positive concreting pressure is maintained to immediately fill the space in the ground left by the retreating auger. Concrete is placed to piling platform level. Pile reinforcement is inserted into the fluid concrete following removal of the augers from the pile position.

The project team are aware of, and have direct experience of, the issues experienced by the piling contractor who constructed the piles at the neighbouring site, Wellington Dock, using the contiguous flight auger technique. As such, the team have subsequently included an allowance for similar contingency measures that were proven to be successful on the Wellington Dock site.

4.11.4 Drainage

A drainage run will be installed during North Wharf enabling works while ground level is at 5.1m. For the run contaminated materials will be

removed, as will any obstructions/voids, install pipework and associated manholes, process materials and backfill; the excavation level will be to 4.6m AOD.

For surface water drainage a solution has been adopted which minimises the volume of drainage within the existing dock area, reducing the impact from ground settlement and minimising the works required to ensure the drainage does not move. Under-slab drainage will be suspended from the reinforced concrete slab using steel ties, while drainage external to the stadium but within the existing dock area will be installed on top of reinforced concrete piles. This will eliminate the risk to drainage from settlement of silts below the sand infill.

Foul water drainage will be installed with a similar strategy, but as a result of the layout of the drainage there will be no requirement to install in the existing dock area outside the footprint of the ground floor slab. This means piling techniques will not be required on the foul drainage in order to eliminate the risk of settlement.

4.11.5 Pile Cap and Ground Floor Slab Methodology

Approximately, 1,100no. CFA piles will be installed on the North and South wharfs and 1,200no. CFA piles installed in the existing dock area. Once complete, the stabilised ground will enable the construction of the pile caps with almost shear batters to excavations. This creates a great advantage in being able to wrap the pile caps in pre-formed Pecafil® which acts as the formwork shutter for the concrete. This methodology will greatly reduce the amount of excavation and formwork required for the pile caps.

For the ground floor slab, a gas proof membrane and vapour barrier are required. This is specified as SikaProof® A-08, providing water ingress protection, damp protection, preventing ground gasses and protecting the structure. It is estimated that the gas characteristic situation under BS 8485:2015, would be Characteristic Situation 2 (CS2) Low Risk, which would mean that a combination of Passive Gas Protection and the 400mm concrete slab and membrane would be sufficient.

4.12 SUPERSTRUCTURE

The superstructure concrete works include:

- Vertical elements (precast columns and twinwall);
- Horizontal elements (lattice slabs);
- Stairs landings and lift shafts; and
- Lower Tier East and West.

4.12.1 Vertical Elements

4.12.1.1 Precast columns and twinwall sections

Precast columns and twinwall are proposed for the main vertical load-carrying members. The precast columns will be made up of grey concrete and would be rectangular or square in shape. The columns can be produced either as multi-storey corbelled columns or single floor to floor elements. They can be connected either using bolted column shoe or a grouted dowel connection.

The twinwall sections are made up of two thin reinforced concrete panels joined by open web lattices. Due to the unique manufacturing process, the walls panels will be of a high quality smooth finish on both sides. The twinwalls will be used to construct the core walls (stairs and lifts) and the shear walls up to 400cm thick. Where appropriate the precast columns and twinwalls will be used to support the slab system.

Twinwall cores in all four corners will be installed in advance of the connecting steel frame. Due to the sequence of construction, the twinwall panels must be 'jumped'. Landings at each floor are to be installed simultaneously for the panels to be propped against and for the overall stability of the core throughout the construction phase. Cast-in plates will be required at interfaces with structural steel so that connections can be made.

Core construction including panel installation and concreting will be facilitated by a 100t crawler crane, and all four cores will be constructed concurrently. The concrete infill will be poured using a $2m^3$ skip. The specified rate of rise must be adhered to, as overfilling can cause structural failure to the twinwall panels. Self-compacting concrete will be used for the infill, as it is not feasible to pass a poker through the panel void.

All units will be offloaded from the transport in a designated area and positioned ready for installation. Columns will be pitched vertically using the tower crane, lifting points will be designed and integral to the units, RE lifting eyes will be used.

Double-height columns will be waisted so that the slab can be tied in at each level. This means that additional reinforcement will be required for pitching so that they do not bend during the lifting operation. Single-height columns can be installed prior to casting the structural slab.

4.12.2 Horizontal Elements

4.12.2.1 Lattice slabs

Lattice plank floor units are used as permanent structural precast concrete framework to in situ concrete slabs. This type of composite floor is suited for use in almost every building type. The floor slabs are made up of a standard 75mm thick precast concrete soffit slab, containing individually designed main and transverse reinforcement cast on steel moulds.

This is a hybrid system that uses thin preassembled concrete plates containing inserted reinforcement in orthogonal directions. These will be embedded with steel lattice girders to provide extra rigidity in the temporary condition and additional shear capacity. These plate elements will take the form of the principal plates and secondary plates.

Once the reinforcement and any other cast-in items for connections or services are installed, a final sign off as part of the progressive pre-pour inspection can be issued, after which the concrete can be poured.

Screed levels will be used as well as a rotating laser. This will ensure that the concrete is installed within level and flatness tolerance. All slabs will receive a power float finish, which will require 24/7 working however noise from these operations will be minimal and specific task lighting will be used.

4.12.3 Precast Concrete Stairs and Landings

To offer a more robust solution than steel, precast concrete staircases will be used, this will be able to withstand the marine environment and is vital for fire protection. Precast concrete landings will be installed well in advance of the stairs. Not only are the landings required to support the stairs, they are also required to tie the core together throughout the build process and provide a structural slab for the core twinwall panels to be propped back to.

4.12.4 Lift Shafts

Lift shafts will be constructed from twinwall, or, precast lift sections will be used if not required for the structural stability of the frame.

4.13 STEELWORK AND PRECAST TERRACING

Single precast terracing units (9.6m for this project) are the optimum solution. These can include a cast-in flexible seat-fixing system to avoid the requirement to drill and fix expansion bolts into the precast units for individual seats. The step blocks will also be manufactured as precast units.

An integral part of the terracing system is the vomitories, these will be formed from precast solid walls and installed by the steelwork contractor alongside the steelwork rakers and secondary beams and terracing units. To allow for the fitting out of the lounges and concourses, the precast terrace units, all mastic painting and temporary waterproof measures over the vomitories must be completed. This usually takes place before the completion of the roof, therefore, early completion and quick installation of these parts of the stadium's structure is vital.

4.14 ROOF STEELWORK

4.14.1 North and South Stands

The current design includes two plane primary trusses to the North and three to the South. The original construction methodology looked to fabricate these on the ground in a large section as possible, but this is not ideal given the current project design.

It is envisaged that at least two temporary support towers will be deployed (one at the mid-span of each truss half) to allow these 85m-long preassembled truss segments to be lifted from the ground. This may need

three towers and four sections per truss depending on the final weight and lifting characteristics of the trusses.

An intermediate horizontal resistant to the truss top boom will be required at the mid-span of each half truss before any load is released, providing support for any wind loads. These restraints will take the form of a system of three large diameter raking props from the stand structure below, equipped with a vertical sliding connection to the truss top chord to prevent transmission of vertical loads.

Both of the temporary towers need either to be braced together or to cantilever from the foundation and therefore, both will interfere with the stand structure, particularly if placed on the stand piled plinths to counteract the need for extra foundations. Consequently, the terraced and steel stand structure around the towers will need to be appropriately designed to make sure they can be provisionally left out and installed after the towers are removed.

4.14.2 Cantilever Truss to East and West Roofs

Similar to the North and South stands, the roof panels will be made of two cantilever trusses and all the infill steel at ground level (ideally with roof coverings, or at least safety nets). These will be lifted into position with crawler cranes from the pitch and the infill between the roof panels will again be built by mobile cranes.

4.14.3 Outer Roof and Central Roof Surfaces

The outer and central surfaces of the upper roof are aluminium standing seam. The current solution requires this to be built up in situ as a liner tray, with standing seam top hat brackets fixed individually, insulation added and then the coils of aluminium machined on the roof to form trays.

The inner surface of the roof on a football stand is usually transparent. This is currently of polycarbonate construction and will be non-walkable. During installation, great care will need to be given to the safety of the roofing operatives, including the provision of nets and edge protection, until all permanent measures such as walkways are completed. Polycarbonate element to front section of the stand will require mobile crane to position any secondary steelwork and preload sheets in the correct zone.

4.15 FACADE

The majority of the lower facade works to the West, East, South and North stands will consist of:

- Brickwork piers in three different widths, bricks laid in a Flemish bond, connected to steelwork columns;
- Spaces between piers will be infilled with glazing, mesh or brickwork depending on the specific location.

Following consultation with the Brickwork supply chain, it has been established that the quantity, detail, and quality requirements, as well as the exposed locations and heights of these brick facades, will result in the near impossibility of constructing these using traditional hand-laid methods.

All four of the supply chain engaged with have confirmed it would be extremely challenging to get suitably skilled bricklaying operatives to work off traditional tube and fitting scaffolding – with associated loading towers for the bricks and premixed mortar, all serviced by forklifts, feeding into fully sheeted enclosures around each brick pier – in these conditions and in this location.

The brickwork will therefore be prefabricated off site as preformed concrete units, with bricks positioned in the forms ahead of casting in factory conditions. By adopting this process for the brick piers it will allow all of the limited available brickwork labour force to concentrate on the infill brickwork panels and the blockwork to the concourses. Off site manufactured brick façade samples have been developed in consultation with HE & LCC and a large sample is currently being manufactured for review in the summer of 2020.

Bespoke locations, e.g. behind the North and South upper tiers, will be glazed, requiring installation with mobile cranes and a Bronto boom winch attachment. This will need to be carried out before the roof can be completed.

4.16 MECHANICAL, ELECTRICAL & PUBLIC HEALTH ENGINEERING (MEP) AND FIT-OUT

The MEP and fit out internally will start with offsite manufacture distribution modules to both vertical and horizontal systems. These will consist of pipework ductwork, electrical trays and trucking. Each service will have the appropriate fire rated components on the line of the fire compartments.

MEP offsite-manufactured packaged systems will be delivered to site fully assembled and ready for immediate installation. Each system is designed to meet the individual needs of a building and its specific requirements, to maximise performance and efficiency.

4.16.1 Risers and plantrooms

Multi-service riser modules are designed to pass through up to four levels and can be fitted either internally in a riser shaft or externally to the side of the building.

When fitted internally the riser frames will be supported on a single floor, with the other floors using guide brackets. Is means that work can commence to connect the services on the lower floors while the building structure progresses, reducing the installation time of the service programme. The modules can also include a firewall divide between services if necessary.

Modules/plant items can be assembled on site into embedded/rooftop plantrooms. These fall into two sets, either the plant items procured from the MEP supply chain e.g. Air Handling Units (AHUs), chillers and generators or the modules manufactured off site that are traditionally assembled on site using traditional methods e.g. pump assemblies and value assemblies. The modular construction approach allows larger systems to be supplied in sections, for reconnection on site.

4.17 SITE WASTE MANAGEMENT

4.17.1 Construction Waste Management Strategy

In accordance with the principles of the UK Government's 'Waste Strategy 2010', a principal aim during demolition and construction will be to reduce the amount of waste generated and exported from the site.

The proposed approach will comply with the waste hierarchy whereby the intention is first to minimise, then to treat at source or compact and, finally, to dispose of off-site as necessary. The waste hierarchy is shown in Figure 4.3.

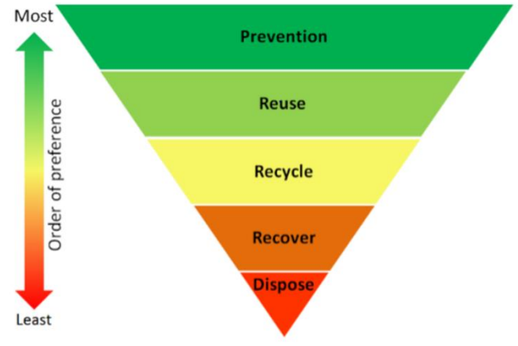

Figure 4.3
The Waste Hierarchy

The Contractors will carry out the works in such a way that, as far as is reasonably practicable, the amount of spoil and waste to be disposed of is minimised.

Any waste arising from the site will be properly categorised and dealt with in accordance with appropriate legislation. Opportunities for minimising and reducing waste generation will be explored and implemented wherever possible. Measures that will be investigated will include:

CONSTRUCTION STRATEGY

- Agreements with material suppliers to reduce the amount of packaging or to participate in a packaging take-back scheme;
- Implementation of a 'just-in-time' material delivery system to avoid materials being stockpiled, which increases the risk of their damage and disposal as waste;
- Attention to material quantity requirements to avoid over-ordering and generation of waste materials;
- Re-use of materials wherever feasible (e.g. re-use of crushed concrete from demolition for the piling platform or hardstanding's off site; re-use of excavated sub-soil for fill or landscaping);
- The Government has set broad targets for the use of reclaimed aggregate, and in keeping with best practice, contractors will be required to maximise the proportion of materials recycled;
- Segregation of waste at source;
- Re-use and recycling of materials off-site where re-use on-site is not practical (e.g. through use of an off-site waste segregation facility and re-sale for direct re-use or re-processing);
- Identification and use of online reuse platforms that support reuse of materials in their highest value; and
- Identification of overall recycling rates, reuse targets and overall landfill diversion rates.

The disposal of all waste or other materials removed from the site will be in accordance with the requirements of the Environment Agency, Control of Pollution Act (COPA) 1974 [3], Environment Act 1995 [4], Special Waste Regulations 1996 [5], Duty of Care Regulations 1991 [6] and the Waste Management Regulations 2011 [7].

The Construction Waste Management Strategy is provided in Appendix 4.3. A Site Waste Management Plan (SWMP) will be provided within the final CEMP in due course.

4.17.2 Construction Waste Generation

During demolition and construction phase, requirements for waste management will be communicated to all sub-contractors to ensure that waste is manged in accordance with the waste hierarchy and relevant statutory controls. These will be controlled through the Environmental Management Plan (EMP) and Resource Management Plan (RMP) in consultation with the relevant authorities.

The RMP details waste generation and landfill diversion targets once agreed. At this stage it is envisaged the projects aims to be:

- Landfill diversion rate (non-hazardous construction waste)- 95%;
- Waste generation (non-hazardous construction waste)- 6.5T/100m^2 Gross Internal Floor Area (GIFA); and
- Use of closed loop recycling schemes such as community wood recycling.

4.18 MACHINERY AND PLANT REQUIREMENTS

Consideration has been given to the type of plant that is likely to be used during the demolition and construction works. The plant and equipment associated with the enabling works, demolition and construction process is set out in 4.3.

Table 4.3
Typical Construction Plant Requirements

PLANT	SITE ESTABLISHMENT	DEMOLITION	SUBSTRUCTURE	SUPER STRUCTURE	ENVELOPE	FIT-OUT
Wheeled and Tracked Excavators (30t, 12t and 5t)	✓	✓	✓			
Mechanical Breakers	✓	✓	✓			
Bored piling rig	✓	✓	✓			
Crawler Cranes (tracked)			✓	✓	✓	
Mobile Cranes	✓	✓	✓			
Mobile concrete pump			✓	✓		
Power floats			✓	✓		
Cutters, drills and small tools	✓	✓	✓	✓	✓	✓
Floodlights	✓	✓	✓	✓	✓	
Road roller		✓	✓	✓		
Dozer 28t		✓	✓			
Dumpers (9t, 6t and 3t)		✓	✓	✓	✓	
CDC compactor 9t hammer			✓	✓		
HGVs/lorries/vans	✓	✓	✓	✓	✓	✓

4.19 CONSTRUCTION ENVIRONMENTAL MANAGEMENT PLAN (CEMP)

All works on site will be undertaken in accordance with Best Practice and will be governed by a CEMP. This document will provide the management framework required for the planning and implementation of construction activities in accordance with the environmental commitments identified within this ES. It will also address the requirements of any subsequent planning conditions imposed by LCC. Its purpose is to avoid or minimise the risks of adverse impacts on environmental resources and local residents and businesses.

The Construction Management Plan provided in Appendix 4.1, ES Volume III provides initial detail of the environmental considerations associated with construction of the proposed development. It is anticipated that the final CEMP will be secured by planning condition on any future consent.

4.20 WORKS CITED

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[3] D. f. E. F. a. R. Affairs, "Control of Pollution Act (COPA)," 1974.

[4] S. o. State, "Environment Act," 1995.

[5] S. o. S. f. t. Environment, "The Special Waste Regulations," 1996.

[6] S. o. S. f. t. Environment, "The Environmental Protection (Duty of Care) Regulations," 1991.

[7] S. o. State, "The Waste (England and Wales) Regulations," 2011.

[8] C. o. Westminster, "Code of Construction Practice," July 2016.