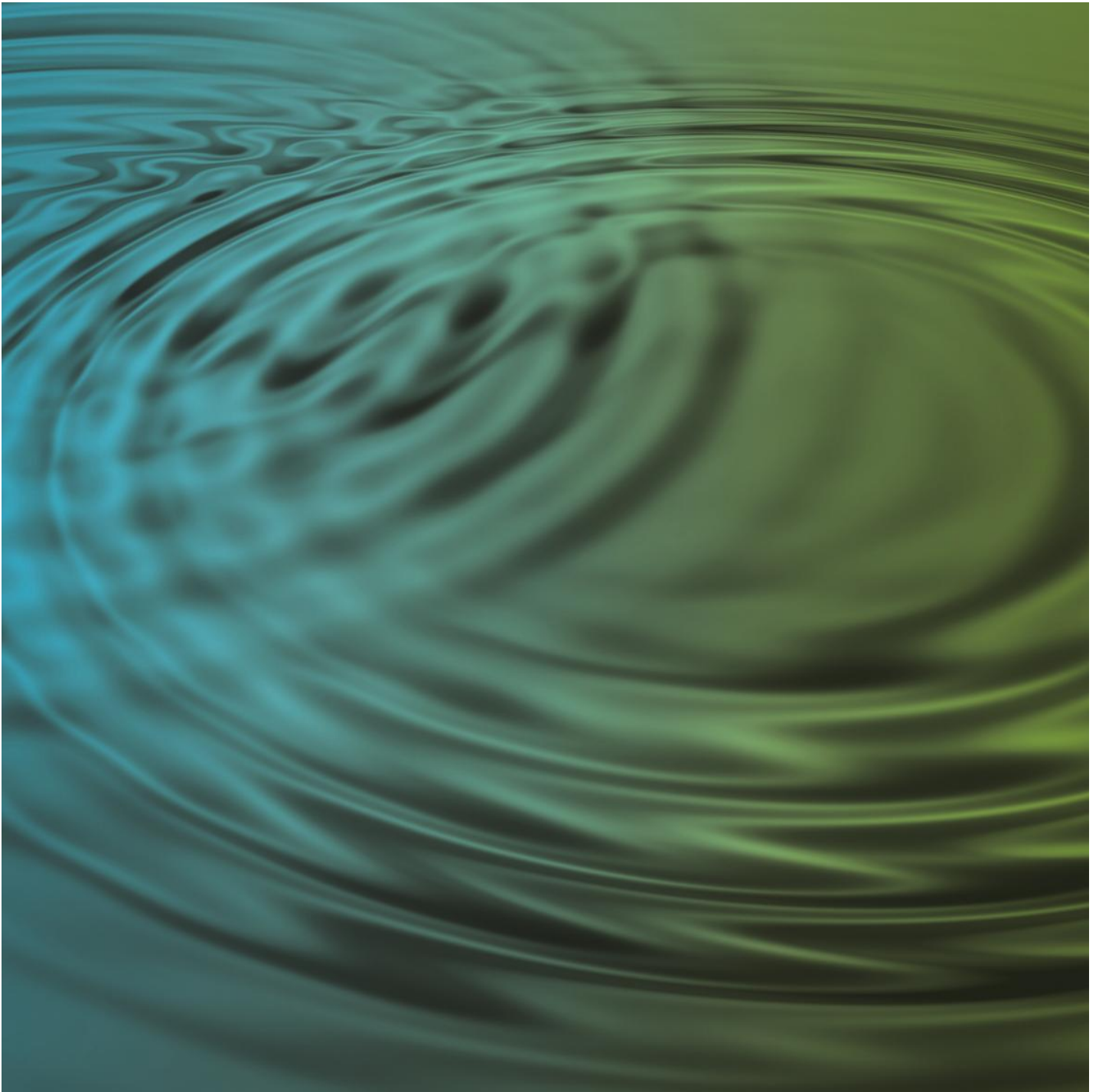


Preliminary Work Plan for In situ Chemical Oxidation

Hickson Road Declaration Area, Barangaroo, NSW



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Hickson Road Declaration Area, Barangaroo, NSW

Client: Lend Lease (Millers Point) Pty Ltd

ABN: 15127727502

Quality Information

Document Preliminary Work Plan for In situ Chemical Oxidation

Ref 60321826

Date 17-Feb-2016

Prepared by Kate McGrath

Reviewed by Michael Jones

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
1	11-Nov-2014	Final	Anthony Davis Principal Scientist	
2	25-Jan-2016	Final	Anthony Davis Principal Scientist	
3	17-Feb-2016	Final	Anthony Davis Principal Scientist	

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Glossary

Term	Description
Block 4 Remediation Area	Portion of the Declaration Area situated within Barangaroo South.
Block 5 Remediation Area	Portion of the Declaration Area located within Barangaroo Central (including remediation of some land adjacent to the Declaration Area on the west)
DECCW	NSW Department of Environment, Climate Change and Water (now Environment Protection Agency)
EPA Declaration Area	Remediation Site Declaration 21122
EPA	New South Wales Environment Protection Authority
Ex-situ Remediation Methodology	Excavation of contamination and off-site disposal (with off-site pre-treatment, where required)
Hickson Road Remediation Area	That part of Hickson Road that requires remediation to facilitate removal of the EPA Remediation Site Declaration 21122.
ISCO	In-situ Chemical Oxidation
In-situ Remediation Methodology	Remediation using in-situ chemical oxidation and/or extraction (product recovery).
ITP	Inspection and Test Plan
LLMP	Lend Lease (Millers Point) Pty Limited
MSDS	Material Safety Data Sheets
MTS	Material Tracking System
PDA	Project Development Agreement
RAP	Remedial Action Plan
RWP	Remediation Works Plan
SEARs	Secretary's Environmental Assessment Requirements
SISCO	Surfactant Enhanced <i>in-situ</i> Chemical Oxidation
Site for the purpose of the Development Application	Area required for the purpose of the Hickson Road Remediation Development Application identified as: - Hickson Road Remediation Area; and - Any other areas of Barangaroo or Hickson Road required for staging and undertaking the in situ remediation.
Site Remediation Area	The Hickson Road Remediation Area
SPGWT	Separate Phase Gasworks Waste and Tar
SROH	significant risk of harm
VMP	Voluntary Management Proposal
WTP	Water Treatment Plant

1.0 Introduction

AECOM Australia Pty Ltd (AECOM) has been engaged by Lend Lease (Millers Point) Pty Ltd (Lend Lease) to prepare a Preliminary Work Plan (here-in referred to as the Work Plan) that outlines the general scope of the proposed Full Scale *in-situ* remediation program to be undertaken in the Site. It is expected that the Work Plan will be provided in support of a Development Application (DA) for Remediation of part of Hickson Road at Millers Point, NSW to be submitted to the Minister for Planning and Environment pursuant to the Part 4 of the *Environmental Planning and Assessment Act, 1979*.

The Work Plan describes the potential ISCO remediation works and the various elements involved but is not intended to be prescriptive or specific. The preferred Remediation Contractor will prepare a detailed remediation Work Plan document, which will be issued to the EPA for review and comment, prior to the commencement of the in situ remediation works.

For the purposes of the Hickson Rd Remediation Development Application, the Site includes the area of Hickson Road to be remediated (Site Remediation Area), plus any adjacent land used for the staging and undertaking of the proposed remediation. The Site Remediation Area comprises that part of Hickson Rd within the Declaration Area that requires remediation.

The location of the Site is shown on **Figure F1** in **Appendix A**.

1.1 Project and Site Background

1.1.1 Hickson Road and adjoining Barangaroo Development

Barangaroo is located on the north western edge of the Sydney Central Business District, bounded by Sydney Harbour to the west and north, the historic precinct of Millers Point (for the northern half), The Rocks and the Sydney Harbour Bridge approach to the east; and bounded to the south by a range of new development dominated by large CBD commercial tenants.

Barangaroo site is roughly rectangular in shape, has an area of approximately 22ha and has frontage to the harbour foreshore of 1.4km. Hickson Road is a public road that is adjacent to the eastern boundary of Barangaroo.

The Barangaroo Delivery Authority (the Authority) is the state government authority that manages and delivers the development of Barangaroo.

1.1.2 EPA Declaration Area (#21122)

In May 2009, the NSW Environment Protection Authority (EPA) determined that a portion of land at Millers Point (part of the Barangaroo and an adjacent portion of Hickson Road), was contaminated in such a way as to present a significant risk of harm (SROH) to human health and the environment. As a consequence the EPA declared the area to be a remediation site (Declaration Number 21122; Area Number 3221) under the Contaminated Land Management Act 1997.

The Remediation Site Declaration 21122 indicates that the area of the declaration ('EPA Declaration Area') coincides with the known footprint of the former Millers Point gasworks facilities. This area is located on part of Barangaroo and part of Hickson Road adjacent to Barangaroo.

In accordance with Declaration Number 21122, the Declaration Area comprises:

- Part Lot 5 and Part Lot 3 DP 876514, Hickson Road, Millers Point, NSW 2000.
- Part of Hickson Road adjacent to:
 - 30-34 Hickson Road (Lot 11, DP1065410)
 - 36 Hickson Road (Lot 5, DP873158)
 - 38 Hickson Road (SP72797) Millers Point

The Authority has entered into a Voluntary Management Proposal (VMP) with the EPA associated with EPA Declaration Area (Approval No. 20101719). Phase 1 of this VMP involves investigative works and undertaking remedial design to determine and obtain agreement on a proposed remediation methodology. Phase 2 of the VMP will involve the implementation of the agreed remediation works.

An independent, EPA-accredited Site Auditor has been appointed to undertake review of proposed remediation works, and prepare statutory audit statements prior to and following completion of remediation.

For the purposes of planning and staging works, the EPA Declaration Area is divided into 3 areas as follows:

- Block 4 Remediation Area - the part of the Declaration Area on Barangaroo South
- Block 5 Remediation Area - the part of the Declaration Area on Barangaroo Central
- Hickson Rd Remediation Area - the part of the Declaration Area located on Hickson Road

This Development Application (DA) is for the Hickson Road Remediation Area only. The indicative Hickson Road staging plans are provided in **Appendix B**. Remediation of the Block 4 and Block 5 Remediation Areas form the subject of separate development applications.

1.1.3 Summary Site History and Key Contaminants

The Millers Point gasworks operated on the Declaration Area between 1840 and 1921. The Site and surrounding area has subsequently been used for various activities, but predominantly a commercial port facility and public road.

When the EPA declared parts of Barangaroo and Hickson Road a "Remediation Site", it described the nature of contamination as gasworks waste, incorporating the following particular substances: polycyclic aromatic hydrocarbons (PAHs); benzene, toluene, ethylbenzene and total xylenes (BTEX); total petroleum hydrocarbons (TPH); ammonia and cyanide.

The Remedial Action Plan (RAP) previously prepared by for the Declaration Area and titled *Remedial Action Plan NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point (AECOM, 2013b)*, (here in referred to as the RAP), provides more specific details regarding the type, magnitude and location of contamination identified in previous site investigations.

1.1.4 Role of Lend Lease

Lend Lease has been appointed by the Authority as the Proponent to undertake the development of Barangaroo South.

Lend Lease has also been contracted by the Authority to undertake remediation of the Declaration Area, which includes the Site Remediation Area.

1.1.5 Remedial Action Plan and Methodology

The remediation proposed in relation to the Declaration Area (including the Site Remediation Area) is detailed in the RAP (AECOM 2013). The RAP includes two potential remediation methodology options, comprising:

- Preferred option - In-situ remediation (chemical oxidation); or
- Alternate option- Ex-situ remediation (excavate, off-site disposal and backfill).

The Development Application for Hickson Rd Remediation seeks approval for undertaking either the preferred or the alternative method above. The final preferred methodology will be selected following discussion and agreement with the NSW Environment Protection Authority (EPA).

1.1.6 Summary of Proposed Works for the Hickson Rd Remediation DA

The following summarises the works proposed as part of the Hickson Rd Remediation Development Application (DA), for both the preferred and alternate methods (with the final method to be selected in consultation with the NSW EPA). For both methods, Hickson Rd will remain open to traffic, with progressive temporary road closures/diversion in place during remediation works.

Preferred Method – In-situ Remediation

The preferred remediation method is remediation of the Site Remediation Area (which includes sections of the footpath) using in-situ chemical oxidation (ISCO) / product extraction.

The overall ISCO remediation approach consists of the following stages:

- Completion of the ISCO and SEPR Pilot Trial Proving Phase (herein referred to as the 'Proving Phase'. Works associated with the Proving Phase were completed in 2013 – refer to Section 4.0)
- Stage 1: Design and planning of the Hickson Road Pilot Trial (subject to separate approval - DA SSD 6617)

- Stage 2: Completion of the Hickson Road Pilot Trial
- Stage 3: Design and planning of full-scale Hickson Road remediation (subject to completion of a successful pilot trial, and agreement with EPA / Site Auditor)
- Stage 4A: Hickson Road remediation – within known structures

The in-situ remediation process will involve the installation of subsurface wells and piping in Site Remediation Area, and establishment of a temporary staging compound in the road reserve, which will facilitate controlled injection of chemical mixtures into the ground, to treat required areas of gasworks contamination in-situ.

The following works are proposed to be undertaken as part of the in situ remediation:

- Localised pruning of street trees where required to facilitate works;
- Temporary lane / traffic diversion as required during works;
- Local service diversion or protection as required;
- Maintain access to the driveways of 30 Hickson Road (The Bond) and 38 Hickson Road;
- Maintain access to Sydney Water Sewer Pump No. 1129 and Barangaroo South Stage 1A/1B/1C development construction access driveways;
- Undertake in-situ remediation in 2 main stages (east and west):
 - Temporary closure of one half of Hickson Road and undertake remediation within it while traffic is diverted to other half
 - Following completion of the first stage, re-instate the remediated area, divert traffic over the remediated area and temporarily close the second half of Hickson Road
- Installation of remediation infrastructure (wells and piping) in Hickson Rd;
- Install temporary remediation compound/staging area in Hickson Rd reserve;
- Install boundary groundwater monitoring wells where required;
- Undertake in-situ chemical oxidation through controlled injection and extraction;
- Management of extracted fluids through either:
 - Limited storage/treatment within the Hickson Rd Site
 - transfer to a temporary water treatment plant on the Barangaroo Site, or
 - transfer to a licensed off-site liquid waste treatment facility
- Undertake detailed environmental monitoring (air, noise, groundwater) for the duration of works;
- Validate completed remediation per the RAP (AECOM, 2013b), including groundwater monitoring where required;
- Decommission (cap and leave in-situ) sub-surface well/piping infrastructure; and
- Temporary restoration of required areas of road/pavement.

If the preferred remediation method is not undertaken, the alternative remediation method will be implemented.

Alternative Method - Ex-situ Remediation

The alternative remediation method is remediation of the Hickson Road Remediation Area through selective excavation of contamination, off-site disposal (and treatment where required) of excavated material at licensed facilities, backfilling of validated excavations and re-instatement of the road/footpath.

1.2 Objectives

1.2.1 Work Plan Objective

The objective of this Work Plan is to provide a document that outlines the general scope and methodology for undertaking the proposed Full Scale ISCO remediation program to be undertaken at the Site and describe the broad work elements involved. The Work Plan is designed to provide sufficient detail to support the Site

Remediation Area Development Application. It is noted that a Pilot Trial is proposed to be undertaken prior to implementation of the Full Scale ISCO remediation.

The Work Plan describes the potential ISCO remediation works and the various elements involved but is not intended to be prescriptive or specific. The preferred Remediation Contractor will prepare a detailed remediation Work Plan document, which will be issued to the EPA for review and comment, prior to the commencement of the in situ remediation works.

1.2.2 Project Remediation Objectives

The remediation objectives for the Site, as defined in the RAP (AECOM, 2013b), are to:

- enable the NSW EPA's declaration of the Declaration Area as a Remediation Site to be revoked (once Block 4 and 5 areas of the Declaration Area have also been remediated);
- ensure that the following NSW EPA policy requirements are met:
 - NSW DEC (2007) *Guidelines for the Assessment and Management of Groundwater Contamination* which incorporate the requirements for removal or treatment of Light or Dense Non-Aqueous Phase Liquids (NAPLs) to the extent practicable and consideration of Clean-up to the extent practicable (CUTEP)
 - the principle of Ecologically Sustainable Development (ESD) as required by **Section 9** of the CLM Act (1997)
 - the *Waste Avoidance and Resource Recovery Act* (2001)
- ensure the remediated Declaration Area is protective human health in the context of its current form and land use;
- ensure that the remediated Site is, *to the extent practicable*, protective of the environment (specifically groundwater within fill material at the down hydraulic gradient Declaration Area (and Site) boundary and ultimately surface water in Darling Harbour) by minimising the risk of ongoing contamination; and
- comply with applicable legislative and policy requirements including the appropriate requirements of the NSW Department of Planning and Environment (DoPE) and NSW Environment Protection Authority (EPA).

2.0 Site Identification and Conditions

2.1 Site Identification

The Site is located within the Hickson Road easement within the NSW EPA Remediation Site Declaration 21122.

Table 1 Site Identification

Item	Description
Land Owner	The Barangaroo Delivery Authority
Address	Hickson Road Barangaroo, NSW 2000
Legal Description	Section of Hickson Road in State Plan 118 and 162
Local Government Authority	City of Sydney
Site Area	5,724 m ²
Current land use	Road, vehicle thoroughfare, vehicle parking, pedestrians use of footpaths on the eastern and western sides of the road
Proposed land use	As above
Location and layout	Figure 1 and 2 in Appendix A

2.2 Topography and drainage

The topography of the Site Remediation Area is relatively flat and is covered in hardstand (concrete and bitumen), with the exception of a number of trees on either side of Hickson Road. Stormwater drains along Hickson Road drain to Sydney Harbour to the west.

2.3 Geology

Information from previous investigations indicates that the former 1880s shoreline ran approximately along the western edge of Hickson Road. The area to the west of Hickson Road is understood to have been progressively reclaimed. Fill materials beneath Hickson Road are underlain by marine clay and sand and then Hawkesbury Sandstone. The sandstone is generally shallower on the eastern side of Hickson Road and in some areas directly underlays fill associated with the road construction.

Fill materials within the Site were generally encountered from depths ranging from 0.4 to 1.5 m and generally consist of sandstone, building rubble, bricks and concrete, silty gravelly sand. Black staining and odours (particularly in proximity to the former gasworks infrastructure) have been observed in the fill.

2.4 Hydrogeology

The *Data Gap Investigation, EPA Declaration Area (Part of Barangaroo Site and Hickson Road, Millers Point, NSW* [herein referred to as the DGI (AECOM, 2010b)] reported groundwater beneath Barangaroo South within fill and underlying natural materials. Groundwater was encountered at depths ranging from 1.38 to 2.92 metres below ground level (m bgs). Water level monitoring within selected wells conducted over a three day period confirmed that groundwater underlying the area was tidally influenced as far-east (inland) as Hickson Road.

The *Groundwater Discharge Study, Stage 1 Barangaroo Development, Hickson Road, Darling Harbour, New South Wales* [here-in referred to as the GDS (AECOM, 2010d)] indicated that due to tidal influences at Barangaroo South there is a discrepancy between the net migration rate and the linear groundwater flow velocity due to the alternation of the hydraulic gradient, which causes water and particles to oscillate rather than move constantly in a single direction.

Recharge to the Site is limited to exposed sandstone and soil areas to the immediate east of the Site at Observatory Hill. Since the Site is currently covered by hardstand areas, the majority of potential recharge flows off Site as stormwater outflow.

2.5 Historic Gasworks Infrastructure

The former Australian Gaslight Company (AGL) (now Jemena) gasworks historically occupied part of Hickson Road. Previous investigations and remediation works (undertaken at The Bond site on Hickson Road) have identified that existing gasworks infrastructure extend across Hickson Road, including part of the annulus of the former main gasholder, a smaller secondary gasholder and a tar tank (Coffey, 2008). The gas works infrastructure identified in Hickson Road are listed in **Table 2** below and shown on **Figure F2** in **Appendix A**.

Table 2 Historic Gas Works Infrastructure Details

Historic gas works infrastructure	Approximate depth of cut into bedrock (m bgs)
Main gas holder annulus (part of)	10
Eastern portion of the 1870 gas holder annulus	9.4
Tar tank	5.5
Small gas holder	approximately 5.5

3.0 Site Contamination and Remediation Extent

3.1 Site Contamination

A summary of soil and groundwater contamination previously identified in proximity to the Site Remediation Area is provided in the following sections. Further detail and analytical results are detailed in the RAP (AECOM, 2013b).

3.1.1 Soil

AECOM (2010b) reported that maximum concentrations of contaminants of potential concern (CoPC) were generally located within and down gradient of the former gasworks infrastructure in Block 4 and Hickson Road. CoPCs including lead, total petroleum hydrocarbons (TPH) (C6-C9 and C10-C36), benzene, toluene, ethylbenzene and xylene (BTEX) compounds, polycyclic aromatic hydrocarbons (PAHs) (including benzo(a)pyrene [B(a)P]) and sulphate variably exceeded the adopted site investigation criteria. The reported results were generally consistent with the findings of previous investigations (i.e. ERM, 2007; ERM, 2008; Coffey, 2008) with respect to the identified CoPC, concentrations and/or impacts concentrated within the former gasworks area.

The definition of separated phase gasworks waste and tar (SPGWT) was originally proposed by AECOM and adopted by Lend Lease/the Authority to define Tar Containing Material (TCM) at Barangaroo South, particularly in the context of material that is unsuitable for beneficial reuse (in conjunction with the site-specific risk based criteria which were derived in the VMP HHERA [AECOM, 2012c]). SPGWT is defined as:

- Tar Containing Materials (TCM), as per the definition described below:
 - Greater than 10% visible coal tar (where coal tar is a phase separated hydrocarbon by-product from coal gasification); and/or
 - Contaminant concentrations exceeding the following limits:
 - Polycyclic Aromatic Hydrocarbons (PAHs) - 2,000 mg/kg; or
 - Benzo(a)Pyrene (B(a)P) - 150 mg/kg.
 - Dense Non Aqueous Phase Liquids (DNAPLs).

3.1.2 Groundwater

Previous reports identified dissolved-phase concentrations of contaminants at the Site Remediation Area were variably above the site investigation criteria e.g. lead, cadmium, chromium (III+VI), cobalt, copper, mercury, nickel, zinc, benzene, naphthalene and phenol (AECOM, 2010b; Coffey, 2008b).

The most significant groundwater contamination was identified in the immediate vicinity of the former gasworks infrastructure and contamination, including BTEX, naphthalene, PAHs, metals and ammonia, was present in both dissolved phase and SPGWT (Coffey, 2008b; ERM, 2008a; AECOM, 2010c). Concentrations of contaminants in excess of the site investigation criteria were also identified in wells down-gradient of the gasworks footprint, indicating the westerly migration of contamination (AECOM, 2010b). The results of the AECOM (2010c) investigation indicated that the variable nature and distribution of fill materials at Barangaroo South caused localised variations in groundwater flow and associated contaminant migration, which is further complicated by tidal influences. The previous investigations indicate that there is contaminated groundwater migrating from the Declaration Area boundary.

3.1.3 Soil vapour

AECOM (2010a and 2010b) soil vapour analysis reported some gasworks-derived impacts which exceeded the adopted ambient air guidelines (adjusted using an attenuation factor of 0.01) for naphthalene (converted ATSDR MRL 2005) at five locations down-gradient of the Site Remediation Area.

3.2 Remediation Extent

The *VMP Remediation Extent* report (AECOM, 2013a) described the remediation goals based on the assessment of risk in the VMP HHERA (AECOM, 2012b) and the extent of remediation required to render the Declaration Area protective of human health and the environment in its current condition.

The indicative lateral extent of remediation required in the saturated zones for the protection of human health and the environment (that is the Site Remediation Area) is shown on **Figure F3** in **Appendix A**.

The vertical extent of remediation has been broadly defined as remediation to the lesser of: (a) the depth to underlying natural bedrock; or (b) a maximum depth of 10 m bgs. The vertical extent of remediation within the Site Remediation Area is based on consideration of the following:

- Locations where SPGWT have been reported.
- Locations where exceedences of the groundwater site specific target criteria (SSTC) and unsaturated soil SSTC have been reported.
- The footprint of historical gasworks structures and infrastructure.
- The depth to bedrock (noting that the depth to bedrock steadily increases to the west beyond the 10 m bgs rock contour).

Remediation of Hickson Road will target CoPC within the defined Site Remediation Area, including both unsaturated and saturated soil (refer to Table 4). According to the RAP (AECOM, 2013b), these areas include areas where SPGWT has been identified, including the:

- BH7/MW7 and BH53 area – the tar tank;
- BH10/MW10 area - eastern portion of the 1870 gas holder;
- eastern portion of the main gas holder annulus;
- small gasholder; BH6, BH15 and BH61 area - located west and down hydraulic gradient of the main gas holder annulus and northern/southern tar tanks.

CoPCs include BTEX, PAHs and petroleum hydrocarbons within the C6 to C36 fractions, which are sorbed onto soils, dissolved in groundwater and present as SPGWT.

Contaminant data has been collected during a number of previous Site investigations including ERM (2007 and 2008), Coffey (2008), J&K (2006), and AECOM (2009, 2010b and 2011).

The highest concentrations of BTEX (5,987 mg/kg), TPH C6-C9 (7,890 mg/kg) and total PAHs (37,081.9 mg/kg) were all reported from MW7 between 5.0 and 5.1 m bgs (within the tar tank). The highest concentration of TPH C10-C36 (13,200 mg/kg) was measured in BH61 between 2.0 and 2.4 m bgs.

Hickson Road is generally characterised by a layer of asphalt pavement overlaying road base fill, from about 0 to 0.5 m bgs. Fill material is then present above shallow sandstone bedrock which is reported to be present at depths ranging from 0.7 m bgs (BH51) to 4.6 m bgs (BH6). The bedrock gets deeper from east to west, toward Darling Harbour.

3.3 Contaminant Mass

The contaminant mass estimates for the Site Remediation Area are summarised below:

3.3.1 Contaminant Mass Estimates

Table 3 below presents the estimated gasworks related contaminant mass calculations for the current conditions across Hickson Road.

Table 3 Site Remediation Area Current Estimated Contaminant Mass Calculations

Zone Area	CoPC	Ave conc (mg/kg)	Estimated volume (m ³)	Estimated Total contaminant mass (kg)
Hickson Road	Naphthalene	1,190	16,000	38,000
	TPH C ₁₀ - C ₁₄	5,956	16,000	190,600

Notes:

- 1) Contaminant mass calculations are based on an assumed soil density of 2,000 kg/m³
- 2) Contaminant mass calculations are based on the average of all contaminant concentrations within Hickson Road (including both concentrations from samples collected from within and outside the historic gasworks structures)
- 3) The estimated volume of soil is based on a total estimated volume of 16,000 m³ including both soil outside the historic gasworks structures and within the historic gasworks structures.
- 4) The estimated volume has been rounded to 16,000m³ to ensure consistency with other specialist reports.

The remediation extent proposed in the Site Remediation Area has been designed to target contamination identified based on available data as well as the footprints of historic structures. **Figure F3** in **Appendix A** depicts the indicative lateral extent of soil requiring treatment and reflects this information. It is noted that the extent of the contaminant mass calculations are estimates only. Final extent and mass calculations may be refined with further data/assessment, subject to agreement with the Site Auditor.

4.0 Preferred Remediation Option

The preferred remediation option for Site Remediation Area identified in the RAP was ISCO and product recovery. The preferred remediation option was selected because, among other reasons, it has the potential to significantly reduce the impact of remediation works on occupants of adjacent buildings and road users.

Specifically the RAP identified S-ISCO[®] and SEPR[™] as the preferred ISCO technology; however similar ISCO and product recovery technologies may also be suitable, such as Surfactant-Enhanced Multiphase Extraction and In situ Chemical Oxidation.

A 'S-ISCO and SEPR Pilot Trial Proving Phase' (here-in referred to as the Proving Phase) was undertaken to assess the effectiveness of the S-ISCO[®] and SEPR[™] technologies to remediate gasworks contamination in heterogeneous fill to concentrations below the adopted Proving Phase success criteria. The Proving Phase was undertaken in a 6 m by 6 m treatment area in Block 4 within the Declaration Area.

In summary, the findings of the Proving Phase were:

- the Success Criteria were only partially achieved;
- the success of the remediation was limited by the contact of the injected chemistry with contamination;
- the effectiveness of the SEPR/S-ISCO remediation could be improved by enhancing the consistency and duration of chemical contact with the targeted contamination;

Based on the findings of the Proving Phase it was recommended that consideration be given to the following regarding the implementation of ISCO at the Site:

- refining the injection, extraction and monitoring well network and design based on:
 - further assessment of underground infrastructure including former gasworks structures and service lines/trenches
 - further investigation of preferential pathways caused by heterogeneous fill conditions
 - careful delineation of underground service pathways which may act as preferential pathways and limit the distribution of injected chemistry
 - use of targeted chemistry injections using temporary injection wells in conjunction with permanent injection well systems designed to target specific lithology at targeted depths
- increasing the duration of injections and post injection monitoring to maximise chemical contact and post-injection chemistry residence time; and
- providing for additional targeted injections to follow initial treatment as a follow up measure to remediated persistent residual contamination hotspots.

The full results and findings of the Proving Phase are detailed in the *S-ISCO and SEPR Pilot Trial Proving Phase Summary Report, EPA Remediation Site 21122* (AECOM 2013).

4.1 ISCO Remediation Overview

The ISCO process involves the chemical injection of oxidants into the subsurface to chemically break down contaminants in soil and groundwater into less harmful chemicals. Oxidants typically used in ISCO are:

- Sodium/potassium permanganate;
- Activated persulfate;
- Hydrogen peroxide (as Fentons reagent); and
- Ozone.

Chemicals are batched and mixed at the required dose and then injected into targeted injection wells over a period of time. Other systems required in the process may be extraction wells and a soil vapour extraction (SVE) system to control build-up and migration of injected chemistry and vapours.

Prior to implementation of ISCO it is desirable to remove product (such as SPGWT) to the extent practicable via physical extraction enhanced by chemical injection and product recovery. Extracted fluids can be disposed off-site to an appropriately licensed waste facility with or without on-site treatment.

Due to the proximity of the Site Remediation Area to underground services, a non-corrosive oxidant such as hydrogen peroxide should be used.

To increase the effectiveness of the oxidant a catalyst such as Fentons reagent may also be required.

An ISCO Pilot Trial is generally undertaken prior to commencement of full scale ISCO. The Pilot Trial is designed to target a portion of the overall Site remediation area and is designed to evaluate the field effectiveness of the chosen ISCO technology and to refine the ISCO processes prior to scaling up to full scale remediation.

5.0 Remedial Design

The following sections describe the indicative design of the proposed *in situ* remediation in Hickson Road. The design of the remediation system will be subject to review and may be updated (if required) following completion of the proposed ISCO Pilot Trials.

5.1 Product Recovery

Data from Site Remediation Area indicates that contamination is concentrated in several areas which generally coincide with the footprint of historic gasworks infrastructure. In consideration of this, product recovery may be implemented in areas in which SPGWT has been observed and/or TPH is present in significant concentrations. Such locations include the areas around:

- The tar tank, eastern portion of the 1870 gas holder and the 1882 gas holder annulus;
- BH61/MW61, in the northwest portion of Hickson Road.

The final determination of whether product recovery will be undertaken will be made during installation of the wells required for ISCO remediation in the vicinity of the areas identified above. If observations indicate significant presence of SPGWT, or soil analytical data indicate significant contamination, product recovery may be conducted.

Based on existing soil data, product recovery is proposed to be implemented at the locations listed in **Table 4**.

Table 4 Hickson Road Enhanced Product Recovery Areas

Boring	Sampled Interval (m bgs)	Average TPH C10-C36 Concentration (mg/kg)	Targeted Interval
BH61/MW61	"Slag" from 2-3 m; tar vein from 3-3.45 m	7,671	2 – 3.5 m bgs
BH53 and BH7 (Tar Tank)	0.5 – 5.4	80,475	0 - 5.4 m bgs
BH10/MW10 (1870 Gasholder)	1.9 to 8.7	121,000	1.5 to 9 m bgs

5.2 Implementation Design

ISCO works in the Site Remediation Area will need to be staged to allow traffic to continue on the roadway throughout the process. The ISCO remediation is anticipated to occur in the following five stages:

- Stage 1; Wells to be installed in the western half of Hickson Road with traffic diverted along eastern half of Hickson Road (NB, subject to the final design, this stage could be deferred to Stage 4);
- Stage 2; Wells to be installed in the eastern half of Hickson Road with traffic diverted along western half of Hickson Road;
- Stage 3; Compound set up and remediation completed in the eastern half of Hickson Road with traffic diverted along western half of Hickson Road;
- Stage 4; Compound set up and remediation completed in the western half of Hickson Road with traffic diverted along eastern half of Hickson Road; and
- Stage 5; Validation monitoring and decommissioning.

It is noted that Traffic diversion works will be undertaken in accordance with an approved Traffic Management plan (TMP) which will allow traffic movement along Hickson Road throughout remediation and monitoring works.

Where wells are installed in public trafficable areas, they will be installed below the ground surface and finished flush with the surface with gatic covers (or equivalent) where required, to allow safe trafficking by pedestrian or vehicular traffic during remediation.

5.2.1 Injection Well Design

A network of injection wells will be installed full-scale ISCO remediation in the Site Remediation Area. The network is estimated to include approximately 40 injection wells located based on available contaminant data and

the assumption that each well can achieve a 5 m radius of influence. Final quantity will be based on contractor design.

Multiple wells potentially with variable screen intervals will be installed based on consideration of the total depth of the soil, the interval(s) in which contamination is identified, and heterogeneities of the subsurface lithology encountered during well installation at each well location.

To target contamination in unsaturated soil, between 0 and 2 m bgs, injection wells will be screened across a 1 to 1.5 m interval, either across the specific interval in which contamination has been identified, or as shallow as practicable.

To target contamination in the saturated soil, deeper wells will be screened across an appropriate interval (e.g. 1 to 1.5m) in which contamination has been identified.

The ISCO chemistry will be injected into the subsurface and migrate through the soil and groundwater. The strategic placement of injection wells and chemical dosing regime will be designed to target contamination present in the heterogeneous soil matrix. In the event that the treatment front moves through preferential pathways, and the influence of the treatment chemistry is not consistent throughout the treatment zone additional injection wells may be installed to increase contact of the injected chemistry with the contamination. This requirement would be determined based on monitoring conducted throughout the remediation process.

5.2.2 Groundwater Monitoring Well Design

The final location and number of injection wells will be determined following the Pilot Trial and detailed contractor design. The final extent of downgradient monitoring will be detailed in the future Groundwater Monitoring Plan (GMP) - which is a requirement of the RAP and the contractor's Detailed ISCO Work Plan - to be prepared prior to commencing works. The GMP and the contractor's Detailed ISCO Work Plan will be reviewed by the Site Auditor, prior to implementation.

A network of groundwater monitoring wells would be installed within, and up, side and down-gradient of the Site Remediation Area to provide information about the movement and performance of the injected chemistry. Existing monitoring wells in suitable locations with the appropriate screened intervals will also be utilised where available. Monitoring wells will be constructed out of materials that are compatible with the chemicals and the potential physical conditions caused by the ISCO process.

Perimeter retention walls are proposed to be installed on the western (down-gradient) boundary as part of the separate Block 4 and Block 5 Remediation (under approved DAs SSD 5897 and SSD 6533). These walls will be considered in assessing appropriate locations and requirements for downgradient monitoring as part of the Hickson Road remediation works.

Monitoring and analysis of groundwater from these wells will indicate the vertical and lateral movement of the chemistry. Refer to Section 10.0 for the details of the indicative groundwater monitoring program.

5.2.3 Injection Parameters

The rates and pressures at which the injections will be informed by the data collected during previous implementations of ISCO, including the Proving Phase and subsequent Pilot Trial.

The analysis of data collected from monitoring the injection and monitoring wells within the Site Remediation Area during treatment will also determine the optimal parameters of the process.

5.2.4 Extraction Wells

As an additional contingency measure, groundwater monitoring wells will have the capacity to function as extraction wells.

Laboratory and field analyses of groundwater from monitoring wells located throughout the injection area will be used to monitor the flow and progression of the injected chemicals and will determine the need and frequency of extraction well operation. Laboratory and field analyses would be used to determine if extraction well operations are needed to intercept the remedial chemistry in groundwater to minimise the potential for impacts to receptors around Hickson Road.

5.2.5 Soil Vapour Extraction Wells

In addition, depending on the oxidant being used (for example, in the case of hydrogen peroxide), a SVE system may be in continuous use to extract and treat vapours generated by the remediation process and to minimise the potential for impacts to receptors around Hickson Road.

5.3 Validation Requirements

The success of the remediation will be validated by soil and groundwater sampling as described in the RAP (AECOM, 2013b).

The timing of validation soil and groundwater sampling will be informed by the results of post-injection performance monitoring. Specifically validation sampling will take place when the post-injection performance monitoring data demonstrates that the remedial chemistry has completed reacting in the subsurface.

The following summarises the Validation process, as described in the RAP (AECOM, 2013b).

5.3.1 Validation Principles

The RAP (AECOM, 2013b) describes the following principles that will be used to validate the success of otherwise of the in-situ remediation.

The validation program will be designed to be generally in accordance with the *National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No.1)*, *National Environment Protection Council 1999* (NEPM, 1999) and will include use of:

- Systematic sampling patterns
- Collection of an appropriate number of samples for estimation of the arithmetic average concentration of contaminant(s) within relevant environmental media and exposure areas
- Estimation of the 95% upper confidence limit (UCL) of the arithmetic average concentration for soils

Where applicable, statistical analysis will be applied to separate areas of the Remediation Site Area, if staged remediation and validation works are to be conducted. It is noted that the use of statistics will not be used in the assessment of groundwater analytical data sets obtained during the validation works. Following remediation, groundwater should meet the groundwater SSTC, and to the extent practicable, approach the Marine Water Quality Criteria (MWQC), at the Declaration Area boundary.

5.3.2 Standard of Remediation to be Achieved

In accordance with the RAP (AECOM, 2013a), the standard of remediation to be achieved is to be equal or higher than the following:

- SPGWT is removed to the extent practicable;
- Concentrations present within unsaturated fill material exceeding the Site Specific Target Criteria for unsaturated soil (SSTC^{VMP}), is to be removed to the extent practicable; and
- The contaminant mass within the Remediation Extent fill material is to be reduced, on average, by 90%, to the extent practicable (calculated based on the estimated mass of naphthalene and TPH C10 - C14).

The extent to which the prescribed standard of remediation can be practicably achieved will be defined by the detailed remediation Work Plan document to be prepared by the preferred Remediation Contractor. It is anticipated that the extent practicable will be expressed in terms of the maximum scope of work that will be conducted in general accordance with the methodology outlined by this Work Plan. In particular, this is likely to include installation of a predetermined and agreed:

- number of injection, extraction and monitoring wells;
- quantity (mass) of chemicals to be injected;
- duration of chemistry injections and extractions; and
- injection methodology.

5.3.3 Soil Validation

According to the RAP, validation of soil will be based on collection and analysis of soil samples before and after completion of the *in situ* remediation works.

Round 1 Soil Validation Sampling

If required, prior to the ISCO injections, additional validation soil samples will be collected across the Site Remediation Area to provide a cumulative data set (comprising of both analysis data from previous investigations and data collected as part of the soil validation program) with a sampling frequency of at least:

- one borehole per 20 m grid interval; and
- for each borehole, soil samples analysed for the CoPCs at appropriate vertical intervals (0.5 m in fill and 1 m in natural) 1m) within the vertical extent of SPGWT and/or CIM requiring remediation as identified by previous investigations.

Soil samples will be collected and analysed as described in **Section 10.7**.

A statistical assessment approach will be adopted for characterising different material types (as required). This approach will be detailed in the Soil Analysis and Quality Plan (SAQP) to be prepared by a suitably qualified environmental consultant. Separate statistical analysis will be conducted for samples collected and analysed from different types of fill materials within Site Remediation Area as required to allow assessment against the relevant SSTCs (i.e. SSTCs for the unsaturated and saturated fill materials/soils).

Round 2 Soil Validation Sampling

At the completion of the remediation works, round 2 soil validation samples will be collected.

Soil sampling will be conducted as described in **Section 10.7**.

Statistical analysis of post-treatment CoPC concentrations within the Site Remediation Area will be undertaken as detailed in the SAQP (to be prepared by a suitably qualified consultant). The objective of the statistical analysis will be to confirm that the *in situ* remediation works have achieved the requirements of the RAP. The statistical data set will mirror the data set generated by the Round 1 Soil Validation Sampling event. That is, Round 2 Soil Validation Samples will be collected the same borehole location and depth as those collected for Round 1.

Sample Collection and Analysis

Soil samples will be collected in accordance with **Section 10.7** and analysed for the relevant soil SSTCs as detailed in the RAP (AECOM, 2013a).

A primary and secondary laboratory will be engaged to analyse original, duplicate and triplicate soil samples using NATA registered methods. Both laboratories must undertake the required analytical testing in accordance with the requirements of the ASC NEPM (1999). Details regarding the analytical methods to be used will be discussed and confirmed with the NSW EPA Accredited Site Auditor prior to commencement of works.

5.3.4 Groundwater Validation

The following groundwater validation works will be undertaken:

- A network of compliance groundwater monitoring wells will be installed at approximately 40 m spacing across the Site Remediation Area;
 - The groundwater monitoring well network may include monitoring wells required for the ISCO treatment and new wells installed to provide the required minimum coverage (as required);
- Groundwater monitoring wells will be installed at 40 m intervals along the down hydraulic gradient Declaration Area boundary in accordance with the RAP (AECOM, 2013a);
- Groundwater samples collected from groundwater monitoring wells:
 - Within the Declaration Area will be analysed for analytes corresponding with the groundwater SSTCs (refer to Appendix A); and
 - At the down gradient Declaration Area boundary will be analysed for analytes corresponding with the MWQCs.

Groundwater samples will be collected using the methodologies detailed in **Section 10.4**.

Groundwater samples will be evaluated as follows:

- groundwater CoPC concentrations within the Site Remediation Area should, on average, not exceed the relevant groundwater SSTCs; and
- groundwater CoPC concentrations at the down hydraulic gradient Declaration Area boundary should approach the MWQC.

6.0 Schedule

It is estimated that the full-scale ISCO remediation of Hickson Road will take approximately 12-15 months, excluding the post remediation monitoring and validation process.

It should be noted that the schedule may be affected by regulatory review time periods, remediation contractor response times, community issues, permit requirements, review and approval timeframes, and other unknown factors.

Table 5 presents the indicative daily schedule for work on the Site. The actual schedule for work will comply with any future planning approval, including observation of relevant holidays and quiet hours.

Table 5 Site Work Schedule

Activity	Extent	Hours/Days of Operation
Drilling/trenching & System Set-up and Post Injection Monitoring	Daily; up to 11 hrs/day	Monday to Friday: 7:00 AM – 6:00 PM Saturday: 7:00 AM – 5:00 PM
Injection & System Operation	Daily; up to 11 hrs/day (note that some system components (e.g. SVE system) may need to operate continuously for 24hrs a day and 7 days per week)	Monday to Saturday 7:00 AM – 5:00 PM (or later)

7.0 Remedial Operations

7.1 Project Overview

The ISCO works in the Site Remediation Area will commence with mobilisation and set up of the remedial equipment and materials in a System Compound. The System Compound will be established in or adjacent to the Site Remediation Area (refer to **Figure F2** in **Appendix A**). The System Compound will contain the injection system, extraction system, soil vapour extraction system, waste storage, the chemicals and site sheds.

During set-up activities, injection wells, groundwater monitoring wells and soil vapour monitoring points will be installed, and trenching activities will be conducted to convey the injection and extraction lines between the System Compound and Site Remediation Area (in accordance with the traffic management plan to minimise impact to the continued use of Hickson Road). Concurrent with well installation, Round 1 soil, groundwater and soil vapour samples will be collected for laboratory analysis. The injection chemistry would be batched to prepare stock solutions for injection and the injection wells will be connected to the injection system.

The full-scale ISCO remediation consists of the following activities:

- Mobilisation and set-up;
- Product recovery;
- ISCO Implementation; and
- Monitoring.

The following sections describe the components of each of these activities.

7.2 Mobilisation and Site Set-Up

During mobilisation and site set-up the equipment and materials required for the remediation will be sourced, and delivered to the Site, and the remedial infrastructure, including wells and systems will be installed. In conjunction with well installation activities, Round 1 groundwater, soil and soil vapour samples will be collected.

Mobilisation and Site Set-Up works will have to be staged to allow for continued pedestrian, vehicular and bicycle use of Hickson Road.

Detailed traffic management plans will be prepared and implemented for each stage off works.

7.2.1 System Compound Set-Up

The System Compound will be within the Site Remediation Area as per the staging described in **Section 5.2**. It will be constructed of Class A Hoarding, and secured and locked fencing.

The Compound will include containment areas to store the chemistry, equipment and wastes, and site sheds. Each containment area, described in the following sections, will be separately fenced to create an exclusion zone. In addition all bulk chemicals will be stored in a secure shipping container which will be locked to prevent theft and vandalism, and all Dangerous Goods will be stored and managed in accordance with occupational health and safety (OHS) regulations. Finally, all equipment used during the remediation will be chemically compatible with the injection chemistry.

Estimated power requirements, operating voltages and running currents associated with each item will be determined by the Remediation Contractor. It is expected that a three-phase power source will be required. It is expected that three-phase power will be supplied by the Remediation Contractor from existing sources or via temporary generators.

A water source will be required to batch and inject the required chemistry. The volume of water required and the rate of its flow parallel the targeted injection volumes and flow rates will be determined by the Remediation Contractor. A standard 275 kPa tap is anticipated to provide adequate water pressure.

The Remediation contractor will provide all temporary services including power and water.

7.2.2 Well Installation

Wells will be designed to target specific strata and will be constructed in accordance with the *Minimum Construction Requirements for Water Bores in Australia (edition 3)* (NUDLC, 2012).

Locations of groundwater monitoring and injection/extraction wells are shown on **Figure F3** in

Appendix A. It is noted that these locations are indicative only, with final locations to be subject to detailed contractor design. Groundwater monitoring wells may include existing monitoring wells where appropriate and accessible.

Injection Wells

Injection wells will be installed in clusters to enable treatment of the entire interval of contamination at each injection location, and also to enable treatment of contamination in varied soil types.

In general, it is expected that each well will consist of a stainless steel or PVC pipe with a Schedule 10 (0.4 mm) slotted screen measuring between 1 and 1.5 m in length. Graded 2-3 mm sand (graded sand) will surround the well screen followed by a layer of bentonite and finally grout beneath concrete at and above ground surface.

Groundwater Monitoring Wells

Groundwater monitoring wells will be installed in and around the Site Remediation Area to enable tracking of the movement and performance of the injected chemistry. These monitoring wells may also function as extraction wells either during product recovery and/or for contingency extractions.

Installation of Injection Wells and Groundwater Monitoring Wells

The injection wells and monitoring wells will be installed using an auger drill rig. Both injection and monitoring wells will likely be constructed from 50-100 mm diameter stainless steel or PVC casings and a 0.5 mm-slot well screen, 3 m in length. Graded sand will fill the annular space around the well to a minimum of 0.3 m above the top of the well screen. A bentonite seal will be placed above the sand pack and wet for 15 minutes before backfilling with manhole covers and lockable well caps. The wells will be installed in clusters of no more than three (3) wells. Each well will be screened variably based on the fill and soils encountered, and the depth at which groundwater and bedrock are encountered during the drilling of the borehole. If the depth to bedrock is greater than approximately 6 meters, intermediate and/or shallow wells may be spread out evenly over the remaining depth.

Newly constructed wells will be developed to remove accumulated sediment and groundwater from the monitoring well and surrounding aquifer. The pumping process is designed to create a surging action that promotes groundwater inflow to the monitoring well.

New wells will be used in conjunction with existing groundwater monitoring wells to carry out the performance monitoring (see **Section 10.3**) and groundwater sampling for contaminant analysis.

7.2.3 Soil Vapour Extraction Points and Monitoring Wells

Where soil vapour extraction is to be implemented, a total of 15 to 20 (indicatively) 50mm diameter soil vapour extraction points and 50mm diameter PVC soil vapour monitoring wells will be installed in and around the Site Remediation Area to enable monitoring and extraction of vapours that may be generated during the treatment.

Soil vapour monitoring wells will be permanently installed by lowering the stainless steel probe and its accompanying Teflon tubing into the borehole to the desired depth. Clean graded sand will be placed around the probe to provide sufficient airflow and a bentonite seal will be inserted so that the soil gas is collected from the specified depth. For monitoring wells with multiple levels, a second probe will be installed above the grout plug, surrounded by a sand filter, and grouted to the surface. The sampling tubes from each of the vapour tips will be labelled and left to protrude from the well. The tubing will be sealed with a vapour cap for at least seven (7) days before sampling to enable the soil gas to reach equilibrium.

The indicative location of the potential soil vapour wells are shown on **Figure F3** in **Appendix A**.

Soil vapour extraction points will be constructed similar to the soil vapour monitoring wells but with PVC slotted screen and casing (instead of Teflon tubing and probe) to allow for sufficient vapour extraction volume.

During site set-up, all soil vapour monitoring points will be connected to the SVE system to enable the SVE system to continuously extract and treat vapours from these locations.

Soil vapour monitoring wells will be located at an appropriate distance away from the soil vapour extraction points to enable representative sample collection and demonstrate the effectiveness of the SVE system.

The depths of the screens in the soil vapour monitoring wells and soil vapour extraction points will be selected to enable monitoring and extraction of the vapour in the shallow fill materials as well as the vapour being generated from the shallow groundwater.

7.2.4 Trenching System

Trenches will be required to accomplish the following:

- Transport the hoses from the injection system, extraction system and SVE system in the System Compound to the Site Remediation Areas; and
- Protect the hoses from traffic and to isolate the hoses from the public.

The location of potential trenches are shown on **Figure F3** in **Appendix A**.

The trenches excavated within Hickson Road will be backfilled as required for reinstatement of the road or footpath.

Erosion control and mitigation measures to be applied during construction of the trench will be described in a CEMP to be prepared by the Remediation Contractor. The preliminary plan for monitoring and managing erosion controls during construction of the trench is in **Section 17.0**.

7.2.5 Injection System Set-Up

The ISCO injection system will be set up within a bunded and fenced-in exclusion area in the System Compound. The actual size of compound will be modified based on Dangerous Goods requirements. The containment area will be lined with 0.5mm high-density polyethylene (HDPE), or equivalent, to provide containment for a volume equal to 110% of the largest chemical volume to be contained in the area.

An indicative layout of the injection system area and compound is shown on **Figure F4** in **Appendix A** and includes the following:

- 1,000 – 10,000 L tanks for dilute chemical (chemical batching);
- 200 L drums of ISCO chemicals;
- Chemical storage containers (IBCs);
- 1,000 – 10,000 L poly-tanks for compatible chemicals and extracted fluids;
- Stormwater and waste water storage;
- Storage container;
- An injection system;
- Multiphase extraction system; and
- SVE system.

All storage vessels, separation distances and overall arrangement of the system compound will be designed to comply with all NSW WorkCover Dangerous Goods requirements.

Process Flow

A Process Flow Diagram (PFD) and description of each element of the injection system will be prepared by the Remediation Contractor to describe the flow of chemistry through the injection system, to the injection wells.

Details for batching the chemicals, to create stock solutions that will be added to the injection stream will also be provided by the Remediation Contractor. It is expected that batching operations will be conducted within a bunded containment area to contain any spills, according to procedures that will be detailed in Safe Work Method Statements (SWMSs) and the project HASP prepared by the Remediation Contractor.

Waste Storage Area

A second bunded containment area will be established for the extraction system, the SVE system and waste storage containers, including the containers for storing and treating (if required) extracted fluid. This containment

area will be lined with a 0.5mm HDPE liner (or equivalent) and will provide containment for a volume equal to 110% of the largest chemical volume to be contained in the area.

SVE System

If required, based on consideration of the proposed injection chemicals, a SVE system will be installed in the waste storage area. The SVE system will consist of pumps that extract, condense and treat vapours that may be displaced by chemical reactions in the subsurface. Hoses will run from the SVE system to the soil vapour monitoring and extraction points installed and proposed to be installed in and around the Site Remediation Area.

The SVE system will be operated continually to extract from soil vapour points during the duration of ISCO injections and extractions. The system will be designed as a contingency measure to minimise the risk that soil vapour that may be generated as a result of the remediation impacts ambient air quality.

Emissions Control System

The SVE system will include an emissions control system. The system will use GAC filters to treat vapours and other gaseous emissions prior their release. The design and level of treatment performed by the emissions control system, including the size and number of GAC filters, and the size of the system itself, will be informed by the results of the Proving Phase and Pilot Trial, during which the system will be closely monitored for effectiveness.

The emissions control system will operate under the requirements of an Environmental Protection Licence (EPL) which will establish emissions limits. Adequate GAC filtration capacity will be designed into the system to ensure compliance with the EPL, while the system will be monitored to confirm compliance.

Liquid Extraction System

A liquid extraction system will be set up within the waste storage area. The system will include extraction pumps and storage tanks.

The extracted fluid will be treated and/or disposed of according to the procedures described in the AECOM Waste Management Plan (WMP, 2016b) (refer to **Table 7**).

7.3 Product Recovery

Extractions to remove gross contamination may be undertaken as a precursor to ISCO. This may consist of injection of a surfactant and/or solvent into the targeted areas using the injection system. The injections would be followed by extraction of the free product and/or emulsified free-product solution using a liquid extraction pump. The extracted fluid would be collected in polyethylene tanks within the waste storage area where the DNAPL and liquid phases would be separated for disposal and treatment, respectively.

Throughout the product recovery process, all groundwater monitoring wells adjacent to the injection locations will be gauged daily for the presence of NAPL. If NAPL is present, the extraction system would be connected to those wells to remove the observed NAPL and/or emulsified fluids.

Throughout the product recovery phase the injection system, groundwater and soil vapour will be monitored according to approved sampling plans.

Injections for product recovery would begin with a start-up phase to assess existing recovery conditions and evaluate the optimal injection conditions in the given area.

Enhanced product recovery start-up injections would then commence. The injections would begin slowly, at rates and concentrations less than targeted for full-scale operation, and gradually rise to full-scale levels. This will enable the remediation contractor to demonstrate the effectiveness of the monitoring program and the safety of the implementation process through close monitoring of the wells in and around the Site Remediation Area.

All liquid collected during the extraction events will be managed in accordance with the Waste Management Plan prepared by the Remediation Contractor.

The extracted fluid would initially be pumped into storage tanks in the waste storage area where gravity would separate the DNAPL and liquid phases. Once settled the DNAPL could be drawn off the bottom of the tanks using the bottom valve (existing in the tank) and stored onsite in sealed drums also within the waste storage containment area prior to disposal. The overlying liquid could then be decanted into larger tanks for treatment or disposal.

7.4 ISCO Injections

ISCO implementation consists of injection of diluted oxidants and activator chemicals into injection wells.

The ISCO process will begin with a start-up phase during which the chemistry is injected at gradually increasing concentrations and gradually increasing rates, until the targeted injection parameters are reached. The process may involve phases of injections of different oxidants and activator combinations.

Concentrations may be modified by the remediation contractor in order to optimise treatment of contamination in the vicinity of individual wells. The results of groundwater monitoring carried out according to approved sampling plans as well as observations in the injection system would inform modifications to the injections. The injections may alternate between different areas of the Site Remediation Area to optimise treatment.

The duration would be dependent on estimate dosages and flow rates required for the calculated mass removal.

7.5 Monitoring

Monitoring will be conducted before, during and after injections in the vicinity of the Site Remediation Area to track the progress and performance of the remedial chemistry, and confirm that the treatment is not negatively impacting sensitive receptors. Monitoring will include soil contaminant concentrations, groundwater contaminant concentrations, the injection parameters and chemistry, extraction parameters and quantities, SVE system parameters, soil vapour and odours.

The monitoring program will inform modifications to the systems and implementation refinements to enhance performance of the remediation and also to mitigate any potential adverse impacts.

An indicative monitoring plan is described in detail in **Section 10.0**.

8.0 Site Management

The following sections describe the general policies and procedures that will be implemented during work at the Site Remediation Area by the Remediation Contractor. Additional information about Site management will be provided in the detailed HASP and work plan prepared by the Remediation Contractor.

8.1 Roles and Responsibilities

Proposed roles and responsibilities for the ISCO remediation of Site Remediation Area are summarised in **Table 6**.

Table 6 Indicative roles and responsibilities

Role	Responsibility
Project Manager (PM)	The PM's responsibilities would include identifying operational goals for the project, including productivity milestones and strategic objectives, and providing the direction to achieve those goals. The PM would coordinate with subcontractors and vendors, and communicate project status and monitoring information to project stakeholders. The PM completes reporting requirements, OHS compliance and oversees plant operation.
Site Manager	Responsibilities would include working with the PM to identify operational goals and implementing strategies to achieve those goals. They would support the PM in interactions with subcontractors and vendors, as well as communicating and reporting to relevant stakeholders. They would also act as the remediation contractors Designated Health and Safety Officer / OHS Site Representative.
Plant Operators	Their responsibilities would include operating the injection system and coordinating with plant support and field personnel to maintain safe and efficient operations. They would have strong knowledge of the system and the requirements for maintaining and repairing the system components. The specific tasks performed would include: collecting and managing system operations data; tracking and communicating chemical consumption and inventory; and coordinating batching of chemicals.
Field Technicians	Responsibilities of field technicians would include collecting and managing groundwater quality, performance monitoring and sampling. Field technicians Specific tasks of field technicians would include: coordinating daily, weekly and strategic sampling events; managing, operating, maintaining and repairing sampling pumps and equipment, as well as well head fixtures and road boxes; documenting and reporting monitoring observations and data.
Laboratory Technician	If proposed by the Remediation Contractor, an on-site laboratory technician may be employed to measure, analyse and report sample data. Specific tasks of the laboratory technician include operating, calibrating, maintaining and repairing all laboratory equipment; preparing, managing and taking inventory of all laboratory reagents; and, communicating all findings of results.

All roles are expected to report to the respective Lend Lease Building construction management team who is proposed to be the party managing the works on behalf of Lend Lease.

8.2 Data Management

The Remediation Contractor would develop a data management system for all data collected during the ISCO remediation and associated monitoring and sampling.

8.3 Communication Plan

A communication plan for the implementation of Site Remediation Works would be developed by the Remediation Contractor and would include protocols for:

- Occupational health and safety briefings
- Emergency and incident reporting
- Communication with relevant stakeholders, including representatives from Lend Lease, and regulatory agencies

The Remediation Contractor's will include a list of key persons and relevant stakeholders affiliated with activities at the Site and their relevant contact information. All contact information will be verified and updated as necessary during the project.

8.4 Waste Management

Wastes that will be generated during the remediation include the following:

- Solids: soil cuttings, pavement scraps and general municipal solid waste related to Site operations
- Liquids: extracted groundwater, accumulated stormwater, extraction fluid and chemistry

Waste management will be based on the AECOM (2016b) WMP for this DA. All waste generated and disposed of, including for export off-site, will be recorded and reported in accordance with the requirements of the WMP and will include:

- Records of the waste quantities, address of the disposal site, the waste's classification, and details about the transporter.
- Minimum requirements for waste management will include: All wastes generated as a result of the remedial works will be properly classified in accordance with EPA's Waste Classification Guidelines (DECCW, 2009) and transported to a facility that can lawfully receive that waste.
- Any trackable wastes will be transported and tracked in accordance with the Protection of the Environment Operations (POEO) Waste Regulation 2005.

Section 13.2 describes the management and treatment of extraction fluid.

8.5 Health and Safety

This section summarises the minimum occupation health and safety (OHS) practices and policies that will be implemented during the remediation, and will be documented in the Remediation Contractor's HASP.

These practices and policies take into account the hazards inherent to the Site and present procedures to be followed to protect against health and/or safety hazards. The HASP will be certified as suitable by a qualified independent occupational hygienist prior to mobilisation.

The HASP will comply with relevant occupational health and safety laws in NSW, including the Work Health and Safety Act 2011, as well as requirements of Lend Lease, the Authority, WorkCover and the NSW EPA.

The guidance for inspecting, maintaining and ensuring the safety and optimal function of all equipment used during Site works will be included the HASP. This guidance will include that all equipment will be certified by its manufacturer for use prior to arrival on Site; and all equipment will be inspected and test according to an Inspection and Test Plan (ITP) to ensure its safe operation.

Sub-contractors to the Remediation Contractor will prepare its own SWMS for its involvement in the work where applicable and to provide required maintenance and inspection records of plant and equipment to be used in accordance with Lend Lease requirements.

8.6 On-Site Chemical Inventory

All Dangerous Goods brought onto the Site will be logged and comply with the Dangerous Goods management plan and requirements.

8.7 Construction Management Planning (CMP) Overview

The following summarises construction management planning for ISCO work in the Site Remediation Area:

- Incident Management: Incident management will be addressed in the Remediation Contractor's HASP.
- Communications, including between Site workers and between Site workers and relevant stakeholders: Communications will be detailed in the HASP.

The Remediation Contractor will be responsible for preparing the project specific management plans specified in **Table 7** prior to the commencement of Site work. The below are to be based on relevant impact assessments or plans prepared as part of the Environmental Impact Statement (EIS) for the Hickson Road Remediation DA.

Table 7 Project specific management plans

Plan	Description
Traffic Management Plan	Traffic planning, as mentioned in Section 5.2 , will address worker safety on Hickson Road during all phases of work (drilling, injections, monitoring and demobilisation), managing the flow of traffic through the roadway during site works, and ensuring the health and safety of civilian users of Hickson Road
Noise and Vibration Management Plan	Noise and vibration planning will address potential impacts to sensitive receptors in the vicinity of the work area due to drilling and equipment operation
Waste Management Plan	The waste management plan as mentioned in Section 5.0 , will address collection, management and disposal of the classes of soil and liquid wastes expected to be generated during and by the works
Water Management Plan	Management of groundwater, stormwater and surface water. The plan will address management of water wastes and will also provide strategies for mitigating and monitoring potential impacts to water resources
Air Quality Management Plan	Air quality and odours management will include plans for the operation and monitoring of the SVE system in order to mitigate potential impacts to sensitive receptors identified in the vicinity of the works

9.0 Potential Risks and Mitigation Measures

9.1 Sensitive Receptors and Potential Risks

Sensitive receptors with the potential to be impacted by ISCO operations have been identified in the vicinity of the Site Remediation Area. These receptors include:

- Impact to an aquatic ecosystem (Darling Harbour);
- Impact to subsurface infrastructure within Hickson Road, including but not limited to those belonging to Telstra, Jemena and Optus;
- Sydney Water Corporation (SWC) resources, including the Sewer Pumping Station number SP1129 (SP1129), and stormwater drains, sewers and water mains in and adjacent to Hickson Road;
- workers who access assets belonging to Ausgrid, Telstra, Jemena and Optus in Hickson Road;
- SWC workers who might access SP1129 as well as workers who access other underground SWC utility assets;
- Impacts to buildings;
- the general public including pedestrian, vehicular and bicycle uses of the Site;
- workers and residents of properties surrounding and adjacent to the Site Remediation Area, the basements at 30 and 38 Hickson Road and construction workers adjacent on the Barangaroo site including Barangaroo South/Central and Headland Park;
- archaeological resources and relics in the subsurface of Barangaroo South;
- basement water treatment system at 38 Hickson Road; and
- trees along Hickson Road.

When considering potential implications to trees on Hickson Road, reference should be made to the AECOM (2012) Tree Root Mass Investigation, Hickson Road, Millers Point, NSW dated 23 November 2012. This document details tree root conditions within the Site Remediation Area.

Mitigation measures to be designed and implemented to address these risks are provided in the following sections.

9.2 Impact to an Aquatic Ecosystem (Darling Harbour)

Darling Harbour is the nearest receptor for groundwater and surface water coming from the Site Remediation Area. The Site Remediation Area is situated in a mixed commercial and residential area and no other environmentally sensitive receptors have been identified. Shallow groundwater passing through Hickson Road and Barangaroo has been historically, and is currently, in contact with the gas works residuals in the subsurface. This shallow groundwater potentially discharges contaminants into Darling Harbour.

During remedial injections, the progression and extent of the injected chemistry will be closely tracked through monitoring of groundwater in wells within the Site Remediation Area as well as wells installed between the Site Remediation Area and the harbor. The monitoring will track the rate of reactions between the injected chemistry and subsurface contaminants to confirm that the injected reagents are being consumed.

Due to the remedial chemistry altering geochemical properties of the groundwater, including pH and interfacial tension, there is a possibility for metals and/or contaminants to become more readily available. To track these potential changes, groundwater samples will be routinely analysed for heavy metals plus PAHs, TPH, cations, bromide and chloride, and total organic carbon (TOC).

In the event that monitoring results indicate that the treatment front is detected in monitoring wells installed down-gradient of the Site Remediation Area, a program of groundwater extraction will be initiated from these wells using the extraction system to minimise the potential for impact to the harbour.

9.3 Impact to Subsurface Infrastructure

Infrastructure is present in the subsurface of the proposed ISCO treatment areas. These assets may be subject to physical impacts (for example from monitoring well installation, soil sampling and trenching) and/or chemical impacts from the injected chemistry.

Subsurface assets in the vicinity of the Site Remediation Area are listed in **Table 8** along with the entity to which they belong, the potential impacts from ISCO, and mitigation measures that will be taken to protect them.

Table 8 Subsurface Assets within the Site Remediation Area and in the vicinity of the Site Remediation Areas

Entity	Location	Asset	Material	Depth	Potential Conflicts	Mitigation Measures
the Authority	Block 5 (downgradient of Hickson Road)	1.) BDA DN150 mm Sewer Rising Main (SRM) (C.N.119297WW)	Polyethylene (PE) (PE100 class PN20)	Above ground (INV RL 2.62)	Well construction activities; Above-ground lines	Asset is located outside the Site Remediation Area Design operations to avoid SRM; Prevent contact of lines with SRM.
the Authority	Block 5 (downgradient of Hickson Road)	2.) Ramp providing vehicular access over the SRM	Concrete	INV RL to 2.99	Well installation; Above-ground lines	Asset is located outside the Site Remediation Area Design operations to avoid SRM; Prevent contact of lines with SRM.
Maritime Services Board (MSB)	Block 5 (downgradient of Hickson Road)	3.) Maritime Services Board (MSB) Stormwater Pipes	Reinforced Concrete Pipes (RCP)	To be Confirmed; Assumed to between 0.5 to 1.5 mbgl	Well installation; Contact with injected chemistry & treatment front	Asset is located outside the Site Remediation Area Design operations to avoid stormwater pipes; No compatibility issues with oxidants & concrete
Sydney Water	Block 5: SP1129 (downgradient of Hickson Road)	4.) Electrical and telecommunication services	Variable, including polyvinyl chloride (PVC) conduit	To be Confirmed; Assumed to be 0.5 - 1.5 mbgl	Well installations; Contact with injected chemistry & treatment front; Soil vapour*	Asset is located outside the Site Remediation Area Locate services prior to drilling & locate wells to avoid them; Predicted GW level rise not expected to contact assets; Groundwater monitoring to track chemistry; Ability to extract to control treatment; Soil vapour extraction & monitoring.
		5.) Building with easement for sewage pumping station	Concrete with 0.3 mm PVC waterproof membrane ***	Minimum: INV RL -7.5	Contact with treatment front; Soil vapour*	Asset is located outside the Site Remediation Area No material incompatibility with concrete or PVC & peroxide or persulfate; GW monitoring & ability to extract for treatment control; SV monitoring & extraction.
		6.) DN600 mm Stormwater Pipe & Overflow Storage Area	RCP	To be Confirmed; Assumed to 0.5 - 1.5 mbgl	Contact with treatment front; Soil vapour*	Asset is located outside the Site Remediation Area No material incompatibility with concrete & persulfate; GW monitoring & ability to extract at for treatment control; GW level not expected to rise to level of pipe;
	Hickson Road: Western Footpath	7.) DN300 mm Water Main (W.O. 60327) and associated water fittings	Cast Iron Cement Lined (CICL)	~0.5 m bgs**	Contact with treatment front	Main is above expected level of GW rise (and oxidant presence); No material incompatibility between cast iron & peroxide or alkaline-activated persulfate GW monitoring & ability to extract at for process control.
	Hickson Road: Arising from SP1129, to the north	8.) Proposed DN450 mm Sewer (SWC Plan 119297WW)	PE100 (in microtunnel)	INV RL -5.15 (at SP1129)	Contact with treatment front	No material incompatibility between PE and peroxide or alkaline-activated persulfate; GW monitoring & ability to extract at for process control.
	Hickson Road: Center	9.) DN225 mm Sewer (C.N. 14807WW)	Cast Iron (CI)	INV RL -3.11	Trenching	Sewer will be located prior to drilling; Hand auguring or air-knifing will be used in vicinity of asset; Depth of trench (~200 mm) < depth of sewer.
	Hickson Road: Center	10.) 450 mm Sewer (PRO 10008586)	PE	INV RL -5.2 at SP1129; INV RL -4.56 near tar tank	Contact with chemistry; Trenching	No material incompatibility with PE & peroxide; Short-lived oxidant; Extraction & GW monitoring for hydraulic control; Sewer will be located prior to drilling; Hand auguring or air-knifing will be used in vicinity of sewer; Depth of trench (~200 mm) < depth of sewer.
	Hickson Road: Across road, arising from SP1129	11.) DN375 mm Sewer Rising Main (PRO 10008586)	PVC	INV RL -1.95 at SP1129; INV RL -1.37 (near eastern footpath)	Well installations; Trenching	Sewer will be located prior to drilling; Hand auguring or air-knifing will be used in vicinity of sewer; Wells will be relocated to avoid; Depth of trench (~200 mm) < depth of sewer.
	Hickson Road: Eastern footpath	12.) DN300 mm Water Main (W.O.60327) and associated water fittings	CICL	To be Confirmed; Assumed to be ~0.5 to 1.5 mbgl	Well installations; Trenching	Water main will be located prior to drilling & wells will be relocated; Hand auguring or air-knifing will be used in vicinity of main; Depth of trench (~200 mm) < depth of main.

Entity	Location	Asset	Material	Depth	Potential Conflicts	Mitigation Measures
Telstra Cable	Block 5 (downgradient of Hickson Road)	13.) North/south Cable	Asbestos cement conduit; PVC-encased cables; Joints housed in PVC/PE	< 450 mm deep; 1-2 m deep at SP1129	Well installations; Below site set-up area; Contact with treatment front	Cables will be located prior to drilling & wells will avoid them; Hand auguring or air-knifing will be used in vicinity of assets; Spill control plan & containment berms will prevent chemical contact; No compatibility issues identified between peroxide and alkaline-activated persulfate and cables.
	Hickson Road: Western Footpath	14.) Optus Cable	PVC encased cable. To be Confirmed prior to works	To be Confirmed; Assumed to be ~0.5 to 1.5 mbgl	Contact with treatment front	GW monitoring with ability to extract at to control treatment front ; No compatibility issues identified between oxidants and telecoms.
	Hickson Road: Eastern footpath	15.) Telstra Main Cable	Asbestos cement conduit; PVC-encased cables; Joints housed in PVC/PE	~0.6 m bgs** (Junction port depths range from 600 mm to 800 m)	Trenching; Contact with Hickson Road chemistry	Telecoms will be identified prior to drilling & avoided; Hand auguring or air-knifing will be used in vicinity of asset; Depth of trench (~200 mm) < depth of telecoms; No compatibility issues identified between peroxide & cables; Short-lived oxidant; Oxidant will be present below level of telecoms; GW monitoring & extraction to maintain hydraulic control of treatment.
Jemena (Gas)	Hickson Road: Eastern footpath	16.) "9 NB 110MM NY"	110 mm nylon inserted into 9 inch cast iron main	~1 m bgs **	Contact with Hickson Road chemistry	No compatibility issues between peroxide & cast iron main; Short-lived oxidant; Oxidant will be present below level of main; GW monitoring & extraction to maintain hydraulic control of treatment.
State Rail	Hickson Road: Eastern footpath	17.) Electric Cables (June 2004)	Assumed PVC encased cable. To be confirmed prior to works	~1.3 m bgs**	Trenching; Well installations; Contact with Hickson Road chemistry	Cables will be identified prior to drilling; Well location will avoid cables; Hand auguring or air-knifing will be used in vicinity of asset; Depth of trench (~200 mm) < depth of asset; No compatibility issues identified between peroxide and cables; Short-lived oxidant; GW monitoring & extraction to maintain hydraulic control of treatment.
Ausgrid	Hickson Road: Center of Road	18.) Access Pit 50267			None*	GW monitoring & extraction to maintain hydraulic control of treatment; SV monitoring & extraction.
	Hickson Road: Center of Road	19.) Electricity Lines	Concrete-encased PVC (FZ1, GB1, GD1, GE1 Configurations)	~0.5 m bgs**	Contact with Hickson Road chemistry; Trenching	No compatibility issues identified between peroxide & concrete or PVC; Short-lived oxidant; Oxidant will be present below level of the lines; GW monitoring & extraction to maintain hydraulic control of treatment; Lines will be identified prior to drilling; Hand auguring or air-knifing will be used in vicinity of asset; Depth of trench (~200 mm) < depth of asset.
38 The Bond Residential building	38 Hickson Road	20.) Water Treatment Plant			None*	Asset is located outside the Site Remediation Area GW monitoring & extraction to maintain hydraulic control of treatment
30 The Bond Commercial building	30 Hickson Road	21.) Bond Building			None*	Asset is located outside the Site Remediation Area GW monitoring & extraction to maintain hydraulic control of treatment

No infrastructure impacts are projected. Soil vapour impacts are possible and addressed in **Section 9.5**.

** Estimated elevation based on: Sydney Water. "SewerFix Pumping Stations Program: Southern Suburbs Sewerage System SP1129- Hickson Road, Sydney Longitudinal Section." Drawing SP1129 RM2.

*** On all external faces from the surface to bedrock.

**** A potential new subsurface stormwater asset may be installed within the Site. Exact construction details are currently unknown however based on the assessment of existing stormwater infrastructure undertaken in **Table 8**, no compatibility issues are anticipated.

Chemical impacts

The information in **Table 8**, indicates that subsurface assets in the vicinity of the treatment areas are composed of polyethylene (PE), polyvinyl chloride (PVC), concrete, asbestos, reinforced concrete pipe (RCP), cast iron (CI), and CI concrete-lined (CICL). Technical guidelines for trenched pipelines indicate that the following materials can also be used in the construction of trenched pipelines, and may be present in the subsurface: ductile-iron cement lined (DICL); steel concrete-lined (SCL); PVC-lined concrete; vitrified clay (VC); glass-reinforced plastic (GRP); polypropylene (PP); fibre-reinforced concrete (FRC); or high-density PE (HDPE).

Design measures that could be implemented to restrict the contact of the injected oxidants with subsurface assets include:

- Use of a short-lived oxidant (for example hydrogen peroxide). The use of a short-lived oxidant will mitigate the risk of it contacting subsurface assets for a sustained period of time which could present an adverse impact; and
- Use of an oxidant (for example hydrogen peroxide) which is compatible (at the proposed injection concentrations) with the plastic (PVC and PE), concrete and cast iron materials in Hickson Road.

Physical Impacts

With respect to physical impacts to assets as a result of drilling, boring and trenching, the following measures to mitigate any potential impacts will be need to be taken into consideration:

- All assets, including those belonging to SWC, Ausgrid, Telstra, Jemena and Optus, will be identified prior to intrusive work;
- Well drilling and placement will be modified as needed to avoid drilling near identified assets, including SWC, Ausgrid, Telstra, Optus and Jemena assets identified in **Table 8**; and
- After drilling the surface concrete and pavement, hand-augering and/or air-knifing will be used in the vicinity of shallow services to a depth of 1.2 m bgs (or to the depth of hand auger/air knife refusal).

Finally, with respect to trenching, the trench will be shallow, approximately 200 mm deep, and therefore above the depth of known assets. Nevertheless, before any trenching begins, all assets in the vicinity of intrusive activities will be identified.

Other chemicals

Chemicals previously assessed with respect to potential impact to below ground assets are hydrogen peroxide, VeruSOL, VerEX, water, sodium hydroxide and GnA. None of these chemicals were determined to have corrosive impacts at the proposed injection concentrations. If additional chemicals not previously assessed are proposed to be used, then an additional assessment will need to be made regarding compatibility prior to approval for use in injections.

9.4 Impacts to Buildings

There is a potential risk of adverse impacts to the buildings on the eastern side of Hickson Road, including 30 and 38 Hickson Road, including the basement groundwater treatment system at 38 Hickson Road.

Groundwater monitoring will identify if the injected chemistry is moving toward the basement, and whether it will need to be extracted. In the unlikely event that the injected chemistry reaches the basement, the chemistry will not impact but rather will likely improve the water treatment process.

During injections, groundwater levels will be closely monitored to ensure hydraulic control of the process. All wells will be able to connect to the extraction system if needed.

9.5 Impact of Soil Vapours on Humans

There is the risk of impacts from soil vapours to the following:

- users and inhabitants of buildings on the eastern side of Hickson Road, including the Bond Building (30 Hickson Road) and the basement water treatment system (38 Hickson Road);
- workers conducting construction, road or other sub-surface works in the vicinity of the Site, particularly at SWC assets, EA assets, cable pits, utility pits, service access points and monitoring well heads;

- workers at SWC's sewage pumping station (SP1129); and
- pedestrian, bicycle and vehicular users of Hickson Road and its footpaths.

Users of Hickson Road Buildings

To prevent the possibility that vapours generated by the injections enter the buildings or the sub-surface parking garage at 38 Hickson Road, depending on the oxidant selected, soil vapour monitoring and extraction points will be installed in the adjacent footpath. The extraction points will be connected to the SVE system that will be operated throughout the duration of peroxide-base injections to capture and treat gases displaced by peroxide decomposition. They will also be monitored to ensure the success of the extraction process.

Construction and Maintenance Workers

There is the potential for workers conducting subsurface intrusive work in the vicinity of the Site Remediation Area, including utility workers who must access below ground assets, to be exposed to soil vapours generated by the remedial injections. In addition, there is the potential for users of Hickson Road in the vicinity of the Site Remediation Area to be exposed to vapours generated by the injections. To mitigate this risk soil vapour monitoring and extraction points will be installed in publically accessible areas in the vicinity of the Site. The vapour extraction points will be connected to the SVE system to intercept vapours and will be monitored regularly.

In addition, vapours will be monitored with a Photoionization Detector (PID) and gas meter for lower explosive limit (LEL) in utility pits, service access points and monitoring well heads, that is, areas with the potential for preferential migration of vapours.

In the event that unsafe vapours are detected, additional soil vapour extraction may be implemented.

Finally, all workers entering the site will be inducted into the Health and Safety plans regulating work on the Site, and will be made aware of both the risks and mitigation measures in place to protect them.

Pedestrian, Bicycle and Vehicular Users of Hickson Road and its Footpaths

To prevent the possibility that vapours generated by the injections impact users of the footpath in Hickson Road, soil vapour monitoring and extraction points will be installed and the extraction points connected to the SVE system which will extract continuously to mitigate any potential soil vapour exposure. In addition the soil vapour monitoring wells will be monitored with a PID for VOCs, a gas meter for LEL and samples submitted to a NATA-certified laboratory to confirm that the SVE system is adequately extracting vapours.

To prevent obstructions to pedestrians, bicyclists and vehicle users, all hoses and tubes running across the Site Remediation Area, will be contained within trenching and re-finished with the same bitumen/pavement conditions of the surrounding footpath. All monitoring wells will be installed with flush-mount roadboxes to prevent tripping hazards.

Finally, to conceal site operations from the view of pedestrians, bicyclists and vehicular users of Hickson Road, hoardings will be installed around the System Compound.

9.6 Impact due to Day-lighting

Over the course of injections there is a possibility that the injected chemicals may leak upwards, on the outside of a well's casing or appear at the ground surface, an occurrence referred to as "day-lighting". Day-lighting has the potential to pose a hazard to the environment, and to the health and safety of site workers and other persons in the vicinity of the Site Remediation Area. Day-lighting events will be treated as a spill and managed according to the Spill Prevention and Control Plan contained in the CEMP to be prepared by the Remediation Contractor.

As a preventative measure, all injection wells will be inspected continuously for evidence of day-lighting so that this occurrence can be dealt with immediately to prevent risks to human health or the environment. Evidence of day-lighting includes liquid emerging from the ground in the vicinity of an injection well. The liquid may bubble, if hydrogen peroxide is being used, and an odour may be noticeable.

If day-lighting or mounding is observed, injections into the adjacent injection locations will cease until the cause of day-lighting or mounding is confirmed. Use of the MPE system to relieve subsurface pressure will be implemented where necessary to mitigate observed day-lighting and/or mounding effects.

9.7 Impact to Trees

The following is proposed relative to protection of trees:

- An appropriately trained arborist will identify any required tree protection measures required for the remedial works and will monitor the site establishment works.
- Measures to protect the street tree canopy will include:
 - construction vehicles maintaining an adequate clearance of 500 mm from all street tree canopies located along the construction access route, at all times;
 - street trees not to be pruned without the necessary approval obtained;
 - no stockpiling, storage or mixing of materials, or other works associated with the works within 5 m of the trunk of any tree to be retained;
 - no excavation to occur within 5 m of the trunks of street trees located on Hickson Road, unless the arborist has identified and implemented specific tree protection measures and construction methodologies; and
 - protection measures will remain in place for the duration of the works, and shall be removed at the completion of works.

10.0 Monitoring Plan

Media including: soil, groundwater, the remedial chemistry, soil vapour, and odours, as well as the injection, extraction and SVE systems, will be monitored before, during and after the injections. Monitoring will be carried out to track the progress and performance of the remedial chemistry, optimise the parameters of the implementation, ensure that the works do not negatively impact sensitive receptors, and evaluate the success of the project.

Monitoring will be conducted during four phases:

- pre-injection monitoring;
- concurrent-injection monitoring;
- post-injection monitoring; and
- final sampling.

The following activities will comprise but not limited to these phases:

- injection system process monitoring;
- extraction system process monitoring;
- performance monitoring of the injected chemistry in groundwater;
- groundwater sampling for mitigation and contingency;
- soil vapour monitoring;
- soil vapour extraction system monitoring;
- odours monitoring; and
- soil sampling.

The following sections detail these monitoring activities.

10.1 Injection System Process Monitoring

Injection system process monitoring consists of recording flow rates and pressures from the injection feed streams, and analysing samples from these feed streams in the on-site laboratory for chemical concentration.

The frequency of this monitoring will be a function of the injection phase progress. It is anticipated that this monitoring will be more rigorous (hourly) during start-up and immediately after any major process changes and less frequent (daily) during day-to-day operation at steady-state injection conditions.

The results would inform optimisation of the system.

10.2 Extraction System Process Monitoring

Extraction system process monitoring consists of recording extraction rate, pressure, and vacuum from the system, and measuring the volumes of fluid recovered, including DNAPL and liquid. This monitoring may also include collection and on-site analysis of the recovered fluid to determine treatment and/or disposal requirements.

It is anticipated that this monitoring will be more rigorous (hourly) during start-up and immediately after any major process changes and less frequent (daily) during day-to-day operation at steady-state injection conditions.

10.3 Performance Monitoring of the Injected Chemistry in Groundwater

Monitoring of the injected chemistry in groundwater monitoring wells indicates where the injected chemicals are traveling and the nature of their reactions with contaminants in the subsurface. Performance monitoring is also central to mitigating risks to sensitive receptors.

This monitoring will track the reaction, oxidant and interfacial tension (IFT) fronts using a combination of field and laboratory analyses including:

- continuous in situ monitoring;
- *ex situ* monitoring; and
- on-site laboratory analysis.

10.3.1 Field Monitoring

Both continuous in situ monitoring and *ex situ* monitoring will use multiple-parameter groundwater monitoring devices (data-loggers) to measure temperature, pH, turbidity, ORP, dissolved oxygen (DO), and specific conductance. During in situ monitoring the devices will be placed within monitoring wells; during *ex situ* monitoring, the devices will be connected to external flow-through cells from which parameters will be recorded when steady-state conditions are reached. This monitoring will also use a water-interface probe to measure water level.

Table 9 describes the relevance of each of these parameters to understanding the treatment process.

Table 9 Relevance of Data-Logger Performance Monitoring Parameters

Parameter	Relevance	Expected Change
pH	- Depends on oxidant system	- Peroxide: Short-term decrease in immediate vicinity of injections from protons generated - Persulfate: Increase/alkaline conditions indicate adequate hydroxide dosing and transport
ORP	- Indicates capacity of an environment to undergo redox reactions - Strongest in peroxide system	- Increase in presence of oxidation reactions, especially with peroxide - Increase precedes arrival of the peroxide front at a given location, providing earlier indication of the treatment front
DO	- Indicates presence of dissolved oxygen; Strongest in peroxide system	- Increase in response to peroxide decomposition - Increase precedes the peroxide front, providing earlier indication of the treatment front
Turbidity	- Indicates presence of dissolved materials	- Increase in response to desorption of contaminants
Specific Conductance	- Conservative tracer directly related to dissolved solids in solution - Strongest in persulfate system	- Increase in direct response to sulphates generated from the reaction of sodium persulfate - Increase precedes arrival of persulfate front
Temperature	- Indicates presence of oxidation reactions	- Expected to increase in response to exothermic peroxide reactions with contaminants - Affected also by temperature of injected fluid, and heat capacity of the subsurface

In general, the initial selection of the wells that will be monitored using either in situ and/or *ex situ* data loggers will be based on their location relative to the active injection areas. Whether a well is monitored with an in situ or *ex situ* data logger may change based on the results of monitoring data collected.

In Situ Monitoring of Groundwater

Continuous in situ monitoring will begin in wells immediately down-gradient of the immediate injection area to track the arrival of the treatment fronts. The in situ data loggers will be moved once it can be demonstrated that the injection reactions have reached the given wells. The new wells selected for continuous in situ monitoring would be located immediately down-gradient of the wells in which the injection reactions have been most recently detected.

Ex Situ Monitoring of Groundwater

Wells to be monitored using ex situ data loggers include those wells in which the injected chemistry has already been detected, that is, wells within the treatment front, and those wells at which the chemistry has not been detected and which are down-gradient of the wells in which continuous in situ monitoring devices are located. Wells within the treatment front will be monitored up to daily and wells outside of the treatment front will be monitored weekly at a minimum.

10.3.2 Laboratory Analysis

In conjunction with collecting *in situ* and *ex situ* field measurements as described above, low-flow groundwater samples will be collected from these wells when parameters have stabilised. These samples may be analysed in the on-site laboratory for some parameters such as oxidant concentration, activator concentration, IFT, pH, specific conductance, ORP, temperature, turbidity and TPH (using on-site analyser).

Both *in situ* and *ex situ* logger data will be analysed to determine the approximate location of the conductivity front on a daily basis. The results of the data analysis will be acted upon immediately, through modifications to injection parameters (concentrations, pressures, flow rate and locations), for example.

After the injection phase, performance monitoring of wells will be reduced to a weekly basis.

The frequency of monitoring the monitoring wells for these parameters will be dependent on data analysed from the previous day's activities. The frequency will decrease as the front passes the monitoring location. Generally the sampling frequency would be:

- a monitoring well known to be immediately down-gradient of the injection front will be monitored daily, at a minimum;
- monitoring wells within the injection front will also be monitored a minimum of once daily; and
- all other monitoring wells will be monitored weekly, at a minimum.

10.3.3 Additional Product Recovery Performance Monitoring

During product recovery injections groundwater monitoring wells nearest to the injection and extraction locations will be gauged daily with a NAPL probe to assess the presence of NAPL. If NAPL is present, extraction pumps connected to the given well will be activated to remove any NAPL and/or emulsified fluids.

10.4 Indicative Groundwater Sampling for Off-Site Laboratory Analysis

Groundwater will be sampled before, during and after the remediation to evaluate contaminant conditions, confirm that the treatment is not negatively impacting sensitive receptors, determine whether mitigation or contingency measures are required, and evaluate the success of the project in attaining the remedial objectives. Groundwater sampling will be conducted at the following time frames:

- Round 1: (Baseline) Prior to injections;
- Round 2: During injections, and during the post-injection monitoring period;
- Round 3: (Interim) Approximately one month after the completion of injections in a given area; and
- Round 4: (Final) After completion of the remediation works to the extent practical.

These samples will be analysed at an off-laboratory for the parameters described in the following sections.

10.4.1 Rounds 1, 3 and 4: All COCs

Groundwater samples will be collected from the selected monitoring wells. These wells will be purged and then sampled using the low flow sampling procedure. Samples will be analysed by an external NATA accredited laboratory as detailed in **Table 10**.

Table 10 Rounds 1, 3 and 4 Off-Site Analyses

Analytes	Method
SVOCs (112 analytes)	USEPA 3510/8270 GC/MS
VOCs (68 analytes)	USEPA 5030/8260 P&T- GC/MS
TPH C ₁₀ -C ₃₆	USEPA 3510/8015
TPH C ₆ -C ₉	USEPA 5030/8260
Metals (As, Ba, Be, Co, Fe, Mn, V, Cu, Cd, Cr, Pb, Ni, Zn)	ICP/MS
Hg	CV/FIMS

Appropriate QA/QC samples will be collected including: intra-laboratory duplicates (5% of total groundwater samples collected); inter-laboratory triplicates (5%); trip blanks; rinsate blanks (one per day of sampling); and laboratory-prepared trip spikes.

- Groundwater samples collected prior to the injection phase (Round 1) will supplement the current groundwater monitoring data to provide a complete set of groundwater analytical results for the site;
- Interim samples (Round 3) will be collected to provide a third data point for use in determining asymptotic decreases; and
- Post injection (Round 4) samples will be collected after analysis of data trends in a given well indicate that the remedial chemistry is no longer occurring at that location. Post-injection samples will be collected by an independent consultant to evaluate whether the Remediation Contractor has achieved the project goals.

10.4.2 Round 2: Metals, TPH and PAHs

During Round 2, which includes the period after the completion of the injections, duplicates from approximately 10% of the performance monitoring samples analysed in the on-site laboratory during a defined period will be sent to a NATA-certified laboratory for analyses listed in **Table 11**.

Table 11 Weekly Off-Site Groundwater Analyses

Parameter	Analytes	Technique/Reference Method
Chloride	Cl ⁻	APHA 4500-Cl ⁻ -B
Bromide	Br	APHA 4500-Br
Sulphate	SO ₄	APHA 4500-SO ₄
Total Organic Carbon	TOC	APHA 5310 B
Cations	Ca, Mg, K	3120 Ca-B, Mg-B, 3120 Na-B, K-B
Metals	As, Ba, Be, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, V & Zn	ICP/MS
Hg	Hg	CV/FIMS
TPH	(C ₆ -C ₉)	USEPA 5030/8260 P&T/GC/MS
	(C ₁₀ -C ₃₆)	USEPA 3510/8015 GC/FID
PAHs	16 analytes*	USEPA 3510/8270

Metals

Duplicates from approximately 10% of the performance monitoring samples analysed in the on-site laboratory which have the lowest pH (measured in the on-site lab) will be sent to a NATA-certified laboratory for metals analysis. Samples with the lowest pH will be submitted for metals analysis because they suggest the greatest potential that metals may be present.

TPH and PAHs

Duplicates from approximately 10% of the performance monitoring samples analysed in the on-site laboratory that have the highest TPH concentration (measured in the on-site lab) will also be submitted to a NATA accredited external laboratory for PAH and TPH analysis.

Consideration will need to be given the impact of oxidants and other chemicals present in the sample that may impact the results.

10.5 Soil Vapour Monitoring

Soil vapour will be monitored to check that any potentially hazardous soil vapours generated as a result of the injection reactions are effectively removed by the SVE system, and do not pose a threat to sensitive receptors. Soil vapour will be monitored in the following locations:

- soil vapour monitoring wells;
- SVE system outlets;
- service access points and utility pits;
- occupied areas adjacent to the treatment areas; and
- within trenches.

Soil vapour monitoring includes:

- collection of soil vapour samples for off-site laboratory analysis; and
- field monitoring of soil vapour.

10.5.1 Soil Vapour Sampling for Laboratory Analysis

Before (to establish baseline conditions), during and after injections, soil vapour samples will be collected from selected locations, including the soil vapour monitoring wells and the SVE system. Samples will be collected by appropriately qualified and trained personnel using stainless steel, Summa canisters equipped with stainless steel flow controller attachments provided and calibrated by the contract laboratory. The Summa canisters will be fitted with an 8-hour regulator that enables collection of a soil vapour sample at a constant rate over the 8-hour sampling period. A time-weighted average air concentration will be obtained. Soil vapour samples will be submitted to an external NATA accredited laboratory, for the analyses listed in **Table 12**. The frequency of this sampling will be based on the results of soil vapour monitoring conducted during the Proving Phase.

Table 12 Soil Vapour Laboratory Analyses

Analytes	Method	QAQC
TO-17 VOC analytes and naphthalene	USEPA Method TO-15	Field duplicates, 1 per 10 samples, collected at the same time as a primary sample

With respect to the SVE system in particular, samples will be collected from the system exhaust and between filters. This data will inform the injection process and operation of the SVE system. **Section 12** describes the criteria that will be used to determine optimal SVE system function, as well as the contingency measures that will be implemented in response to adverse results.

10.5.2 Field Soil Vapour Monitoring

Soil vapour will be monitored from the soil vapour monitoring wells as well as the sensitive receptors identified, using the following equipment:

- PID (with a 10.6 eV lamp); and
- Multi-Gas Meter with a Combustible Gas Indicator (CGI), LEL, Oxygen (O₂), Hydrogen Sulfide (H₂S), Carbon Monoxide (CO) sensor.

All air monitoring equipment will be calibrated and maintained in accordance with the manufacturer's requirements.

PID and/or Multi-Gas Meter measurements will be taken during all drilling activities, and at identified receptors. In consideration of the potential for preferential migration of vapours through service pits and monitoring well heads, ambient PID monitoring will be undertaken within the breathing zone immediately adjacent to utility pits, service access points, and monitoring well heads, as well as within utility pits to detect accumulated gases.

Based on the results of this monitoring and the progress of the treatment, the frequency of monitoring the soil vapour monitoring locations may be reduced.

To the extent practical, ambient air quality monitoring will be undertaken in parallel with monitoring of soil vapour in soil vapour monitoring wells to enable the ambient air quality results to be related to soil vapour monitoring results, if applicable, or provide an indication of whether ambient air quality is being impacted by a source other than the remediation.

In the event that elevated levels are detected above the nominated criteria the PM and relevant Site stakeholders will be notified and injections may be suspended or modified and the SVE system operation amended to prevent recurrence.

All monitoring activities will be recorded and will be compiled into a monitoring report on a monthly basis.

10.6 Odour Monitoring

Odour monitoring will be undertaken in parallel with ambient soil vapour monitoring. Odour monitoring consists of:

- quantitative monitoring using a nasal ranger odour monitoring device
- qualitative monitoring using workers trained to recognise strong or offensive odours.

10.6.1 Quantitative Odour Monitoring

The Nasal Ranger will be used at no less than ten locations spaced evenly among the locations at which field soil vapour monitoring will be conducted. This monitoring will be undertaken at approximately the same time during each day of work at the site. Specifically, this monitoring will take place during the early morning, between 7:00 and 9:00 AM, when dispersion conditions are expected to be at their worst.

The Nasal Ranger will be used to record the following:

- odour dilution concentrations at the defined monitoring locations surrounding the monitoring locations;
- odour character; and
- prevailing weather conditions.

Odour measurements during the injection process will be compared with baseline monitoring data.

In the event that odour levels are detected above the nominated criteria the PM and relevant Site stakeholders will be notified and injections may be suspended or modified and the SVE system operation amended to prevent recurrence.

All monitoring activities will be recorded on field sheets that will be compiled into a monitoring report on a monthly basis.

10.6.2 Qualitative Odour Monitoring

All Site workers engaged in the remediation will be trained to identify any strong or offensive odours. These workers will report these odours to the project manager along with the following information:

- a description of the odour character;
- the prevailing weather conditions;
- current remediation activities at the time of the detection; and
- any other activities occurring in the vicinity of the treatment areas at the time of the detection.

In the event that offensive odours are detected, the PM and relevant Site stakeholders will be notified and injections may be suspended or modified and the SVE system operation amended to prevent recurrence.

10.7 Soil Sampling

Soil will be analysed before, during and after the completion of injections. Soil analysis includes constructing boring logs and photo-documenting soil cores, and collecting soil samples for on and off-site laboratory analysis.

- Boring logs and photographs will be used to identify the areas of contamination at which to target treatment as well as the various soil strata into which the chemistry will be injected. This data will be collected during installation of injection, extraction and groundwater monitoring wells, as well as during the drilling of borings for the collection of soil samples; and
- Analysis of soil samples will provide objective information about the areas in which to target treatment and also about the success of the treatment. Samples will be collected from representative boring locations space evenly across the treatment areas. The borehole selection process is described below.

10.7.1 Sampling Procedure

Before intrusive work begins, all borehole locations will be cleared for subsurface utilities.

Statistically representative soil samples will be collected on a 20 m grid. Soil samples collected within the unsaturated zone will be sampled at depths of 0.5 and 1.5 m bgs. Soil samples will be collected from within the saturated zone at depths of 1.0 m. If required, a final 'base sample' will also be collected within the top 0.5 m of natural residual material (unless sandstone bedrock is encountered).

Soil samples will be collected and analysed from zones of highest impacts based on field observations (including visual/olfactory observations and PID readings). In all cases the depth interval selected for sampling will not exceed 1.0 m. Each soil boring will be completed to the top of bedrock or refusal (whichever comes first).

Depending on the encountered lithology, drilling techniques will consist of a combination of solid and hollow flight augers and/or push tube sampling methods. Soil from boreholes drilled with augers will be collected using a split tube sampler. The push-tube samplers will be hammered into undisturbed soil in one continuous uniform motion without rotating. Samples will be collected by hand (using new disposable nitrile gloves, changed between sample locations) directly from the SPT or push tube. Where the presence of subsurface obstructions prevents the advancement of boreholes, other drilling techniques may be used. The adopted methodology will depend on the depth and nature of the encountered material. Samples will not be homogenised to minimise the potential for loss of volatiles. The soil samples will be placed into laboratory supplied containers. Samples for VOC analysis will be collected first; samples for SVOC and TPH analysis will be collected next.

Borehole locations will be reinstated with grout, and the boreholes will be reinstated to the original surface levels and conditions. Soil cuttings generated from drilling will be collected in drums and stored on-site for future disposal.

Samples will be analysed as described in **Table 13**. Refer to the RAP for the detailed description of soil sampling methodology.

Table 13 Soil Sample Analyses

Analytes	Method	QA/QC
VOCs (68), including TICs	USEPA 5030/8260 P&T- GC/MS	Field duplicates (10% of number collected); triplicates (5%); rinsate blanks (one per day of sampling); laboratory-prepared trip spikes; and trip blanks (one per sample batch). Field duplicates will be prepared in the field by splitting soil samples.
SVOCs (112), including TICs	USEPA 3510/8270 GC/MS	
TPH C ₆ -C ₉	USEPA 5030/8260 P&T/GC/MS	
TPH C ₁₀ -C ₃₆	USEPA 3510/8015 GC/FID	

10.7.2 Borehole Selection for Sampling

Table 14 Borehole selection for soil sampling

Round	Rationale
Round 1 Soil Sampling	If required, prior to the injections, additional validation soil samples will be collected across each of the proposed remediation areas to ensure a sampling frequency of at least one borehole per 20 m grid interval and that soil samples have been analysed for the CoPCs at appropriate vertical intervals based on the identified vertical extent of SPGWT or CIM.
Interim Sampling	The Remediation Contractor may conduct additional interim round(s) of soil sampling during remediation operations to understand the success of the treatment and identify additional areas which may require treatment.
Final, Round 2 Soil Sampling	At the completion of the injections the Round 2 soil validation samples will be collected. Soil sampling will be conducted at similar locations and in accordance with the same requirements as the Round 1 soil sampling event. However, to increase the likelihood that the validation sampling is representative of CoPC concentrations within the treated Remediation Area, the positioning of the Round 2 soil validation boreholes will be as follows: - Each borehole will be located approximately 500 mm from any original site investigation borehole and Round 1 soil validation boreholes to avoid sampling disturbances from re-instated boreholes; and - Each borehole will be located at least 5 m away from any ISCO and/or product recovery injection locations.

11.0 Groundwater Contingency Plans

The following section provides details about how the results of groundwater monitoring data will be interpreted and acted upon through modifications to the implementation process, in order to optimise the performance of the remediation and also protect sensitive receptors.

11.1 Indicative *in Situ* Continuous Performance Monitoring

In situ continuous performance will take place at wells down-gradient of the injection areas. Relocation of data-loggers will ultimately be based on data collected in the field.

Table 15 and **Table 16** provide indicative criteria that may be used to determine when the reaction and oxidant fronts have arrived at *in situ* monitoring locations.

Table 15 Criteria for Identifying Arrival of the Peroxide Front

ISCO/product recovery with Peroxide		
Parameter	Criteria	Action
ORP	Increase > 450 mV	Double frequency of peroxide measurement.
DO	>10%	
Peroxide Concentration	> 0.5%	Move <i>in situ</i> data logger. Begin daily <i>ex situ</i> data logger monitoring & sampling for on-site lab analysis.

Table 16 Criteria for Identifying Arrival of the Persulfate Front

ISCO with Persulfate		
Parameter	Criteria	Action
Conductivity	Increase >500 $\mu\text{S}/\text{cm}$	Double frequency of persulfate measurement.
	Increase >1000 $\mu\text{S}/\text{cm}$	Move <i>in situ</i> data logger. Begin daily <i>ex situ</i> data logger monitoring and sampling for on-site lab analysis.
Persulfate Concentration	> 0.1 g/L	Move <i>in situ</i> data logger. Begin daily <i>ex situ</i> data logger monitoring and sampling for on-site lab analysis.

Additional parameters, including pH and temperature will also provide information about the location and progress of the treatment front. These parameters will be taken into account during decisions to move the *in situ* data loggers and assess the treatment. Since these are weaker indicators, they provide more general information.

11.2 Indicative *Ex Situ* Parameter Monitoring

Wells to be monitored using *ex situ* data loggers include those wells in which the injected chemistry has already been detected, and those wells at which the chemistry has not been detected and which are down-gradient of the *in situ* monitoring locations.

When the injected chemistry is detected a given location, more frequent (up to daily) monitoring will begin.

Additional parameters, including pH and temperature will also provide information about the location and progress of the treatment front, and will be taken into account during decisions to move the *in situ* data loggers and assess the treatment.

11.3 Tracking the Treatment Fronts

The monitoring plan will be designed to enable the treatment front (i.e. the extent of injected chemicals present in the groundwater) to be followed easily throughout the treatment. In particular, the treatment fronts will be tracked at all times using a combination of:

- continuous in situ data logger performance monitoring;
- daily and weekly ex situ data logger performance monitoring; and
- daily and weekly analysis of groundwater samples in the on-site laboratory, as well as at an off-site NATA-accredited laboratory.

The monitoring plan is dynamically structured and will be modified in response to data collected. This will enable the monitoring protocol to address the specific conditions seen in the field and the specific movement and behaviour of the treatment front. For example, the frequency of on-site and off-site laboratory analysis will be increased (up to daily) as the injection front moves toward the groundwater monitoring wells immediately down-gradient of the reaction front (as evidenced by the continuous measurements made by the in situ data loggers and analysis of samples collected from these locations). Once the reaction front has reached subject wells, the continuous monitoring program will be moved to the next set of groundwater monitoring wells down-gradient from the newly detected reaction front.

11.4 Contingency Plans

The results of the groundwater monitoring program will be used to confirm both the progress and also the safety of the injections. **Table 17** describes the indicative criteria that will be used to evaluate the results of this monitoring as well as indicative contingency measures that will be implemented if the listed criteria are exceeded. The contingency plan will be refined by the Remediation Contractor once the ISCO chemicals have been selected. Implementation of the contingency plan will ensure that the treatment is controlled at all times.

Table 17 Indicative Groundwater Contingency Plans, Data Loggers and On-Site Lab Measurements

Parameter	Location	Criteria	Contingency Measures
Interfacial Tension (IFT), measured in on-site lab	Outside active injection area	>5% decrease from baseline measurements	First, reduce surfactant injection rate and continue monitoring plan. If reduced surfactant injections are not effective, then use the extraction system to extract from locations with exceedances.
Hydrogen peroxide, measured in on-site lab	Any well outside active injection area	Above detection limit (0.01%)	Use extraction system to extract from locations with exceedances. Continue monitoring program to confirm effectiveness of extractions.
Water level	Hickson Road: Any well	> 0.15 m increase over maximum baseline	Extract from wells with exceedances to regain hydraulic control of injection/extraction process. Continue water level monitoring to confirm effectiveness of extractions.
Temperature	Hickson Road: Any well near receptors	Increase >10°C.	Double the frequency of temperature monitoring at locations with exceedances.
	Hickson Road: Any well near receptors	Increase >20°C	Modify injections-- inject cold water into the area with the exceedance. Monitor to gauge effectiveness of the contingency and when the regular injection program can resume.
	Hickson Road: Any well near receptors	Increase >10°C.	Install temperature probe between injection area and sewer main running through the eastern edge of the tank.

12.0 Post-injection Monitoring Plan

Post-injection monitoring in treatment areas will be conducted daily for the first week after the end of injections, and then weekly until the data indicates that the injected chemistry is no longer reacting in the subsurface. This monitoring may include in situ, ex situ data loggers, analysis at the on-site laboratory, and analysis at a NATA-accredited laboratory.

12.1 Treatment completion

The completion of injections with peroxide will be characterised by changes in water quality parameters and concentrations of injected chemistry.

12.2 Post-injection contingency plans

The contingency plans for the injection phase will also be applied during the post injection monitoring. The only exception will be that the contingency measure of stopping injections will not be applicable. Increasing the frequency of monitoring; groundwater extraction; and increased operation of the SVE system will therefore be the primary contingencies available for implementation if the results of post injection monitoring indicate that the nominated criteria have been exceeded.

13.0 Waste Treatments

13.1 Contaminated water

Wastewater generated during the Site works will consist of the following:

- groundwater extracted during groundwater monitoring and/or as part of contingency mitigation measures
- stormwater collected within the system compound containment berms
- fluid extracted during product recovery
- excess chemicals

The CMP will detail management, treatment, monitoring and disposal of these waste streams.

The following sections detail the management, treatment and disposal of indicative fluids extracted during treatment. Extracted fluid would be mixture of groundwater, emulsified contamination, the remains of the injected chemistry.

13.2 Extracted fluid

All extracted fluid collected will be transferred through a dedicated pipe network to 1000 - 10000 L polyethylene tanks in the waste storage area in the system compound.

Extracted fluid will be treated on-site, to the extent possible, and disposed in accordance with the requirements outlined in the WMP. It is noted that the WMP may make allowance for:

- Re-use as part of the remedial works provided that the treated water quality meets the ANZECC (2000) 95% level of protection marine water quality criteria multiplied by a factor of 5; and
- Offsite disposal at an appropriately licensed facility (after removal by tanker).

13.3 On-site treatment

The following process controls will be employed:

- Pressure: The tanks will be vented to prevent pressure build-up. In addition a gauge will be used to measure increases.
- Temperature: The tanks will be equipped with thermometers to monitor temperature changes. On-site treatment of wastewater will be implemented in a controlled, gradual manner in order to closely monitor and manage the process. Chemicals would be added gradually, accompanied by close monitoring and observation of the treatment and subsequent reactions. This careful, cautious approach will enable control of the process at all times and prevent the parameters of the fluid and/or process from fluctuating into unsafe or undesirable ranges.
- Vapours: Vapour generation will be monitored using a PID, LEL and the SVE system will be used to collect and treat any gases generated. Gases generated will not be vented directly to the environment.
- Odours: Odours will be managed through the use of coverings, the SVE system and adequate ventilation.
- Spills: The volume of the tank and speed of the pump will be moderated to prevent spills. Any spilled material will be contained within the bunded area and will be cleaned up immediately, according to the Spill Management Plan in the CMP.

Each of these parameters (pressure, temperature, vapours, odours and spills) will be monitored hourly until they have stabilised and daily after that. **Table 18** describes the indicative criteria that will be used to evaluate the results of this monitoring program as well as contingency measures that will be implemented if the listed criteria are exceeded.

Table 18 On-site Wastewater Treatment Monitoring Plan

Parameter	Location	Criteria	Contingency Measures
Temperature	Within tank	Increase > 20°C	- Suspend treatment process, which may include suspending further addition of chemistry and/or deactivating the circulation pump. - Increase ventilation, which may include increased use of the SVE system. - Continue monitoring temperature until it decreases by at least 10°C.
Pressure	Gauge on tank	Any increase above baseline	- Increase ventilation and vapour extraction. - If pressure does not decrease, suspend treatment process until it does.
Vapours (VOCs measured by a PID)	In the airspace above the tank opening; downwind of the treatment tank, outside of the containment berm	PID > 5.0 ppm over the background in the breathing zone for > 5 minutes	- Increase ventilation and vapour extraction. Monitor effectiveness. - Suspend treatment process until monitoring indicates safe levels.
Odours	In the vicinity of the treatment tank; downwind of the treatment tank, outside of the containment berm	Workers identify a strong or offensive odour associated with tanks, that is, a naphthalene-like odour	- Increase ventilation and vapour extraction. Monitor effectiveness. - Suspend treatment process until odour is eliminated.
Spills	Outside of the tank, in the containment berm	- Liquid is observed spilling over the top of the container; - Liquid is observed in the berm, around the container; - Splashes are seen emerging from the container.	- Return liquid to its storage container by pumping with a submersible pump. - Place absorbent materials such as sand, sawdust or commercial sorbents directly on the substance to contain the spill and aid recovery. - Dispose of materials according to Waste Management Plan. Use bunds of earthen or sorbent materials to contain the leading edge of the spill, if needed. - Clean up residual material.

13.4 Treated water quality

The contents of each treated batch / tank of liquid will be tested and characterised. Analysis will be completed in accordance with NSW DECC 2008 and ANZECC 2000 guidelines.

The suite of chemicals analysed to demonstrate the treated water quality has met the requisite standards will be:

- 1) For treated liquid to be disposed of to the the harbour, the suite of chemicals listed in the discharge criteria specified in the EPL for the Barangaroo Site (if available).
- 2) For treated liquid to be disposed of to an appropriately licensed offsite disposal facility, the suite of chemicals prescribed by the receiving waste water treatment facility.

14.0 SVE system operation maintenance and monitoring

14.1 SVE system details

Where soil vapour extraction is to be implemented, details of the SVE system design will be included in the Remediation Contractors detailed work plan.

14.2 SVE system inspection and test plan

The SVE system will be inspected and maintained according to the manufacturer's specifications. A maintenance program will be adopted and implemented.

The maintenance program will include at a minimum inspection of the system before its use by a qualified person; daily by a competent person; and monthly by a competent person. An indicative inspection plan is provided in **Table 19** below.

Table 19 Indicative SVE system inspection and test plan

Item	Criteria	Inspection Frequency	Action	Recording Location
Air Intake filter (T1)	Indications of clogging by the vacuum gauge readings	Before use; Daily (when personnel on site)	Clean filter according to manufacturer's specifications.	Checklist
Vacuum pressure gauge (P1)	Max. vacuum pressure is not exceeded.		Adjust vacuum pressure, which may include opening the vacuum relief valve.	
Temperature (T1)	Temp. is within range specified by system rating.		Adjust parameters of cooling system.	
Filter chamber	Water or debris accumulation		Remove accumulation and dispose of properly, according to Waste Management Plan.	
Amp draw at switch box	Moisture accumulation.		Remove moisture.	
Moisture separator	Fluid level		Remove fluid to waste storage/treatment containers.	
Hoses	Connections at hose junctions, SV points, and SVE pump		Secure connections.	
	Damage to hoses		Repair damages or replace hosing segments.	
Carbon Filters	PID reading: >5.0 ppm over background for >5 min; or	Daily (when personnel on site)	Replace filters;* Monitor with a PID to confirm effectiveness of new filter.	Checklist; monitoring report
	Laboratory analysis: 10 mg/m ³ total VOCs (5.0 ppm n-propane).	Weekly		

14.3 SVE system contingency plans

An air dispersion model will be run to calculate the maximum stack emission concentration that would be permissible in order to meet the DECCW Approved Methods ground level concentration (GLC) criteria for each pollutant specified. Models run with this proposed stack licence limit for the stack returned allowable emissions concentrations that well exceeded the POEO Clean Air Regulation Group 6 standard for vapour recovery units.

Table 20 describes provides indicative criteria that would be used to evaluate the results of the SVE monitoring program as well as contingency measures that will be implemented if the listed criteria are exceeded.

Table 20 SVE System contingency plan

Parameter	Location	Criteria	Contingency Measures
TO-14A VOC analytes and naphthalene (Stack Testing Method TM-34)	SVE System Stack Emissions	Trigger level: 10 mg/m ³ total VOCs (5.1 ppm n-propane)	Change carbon filter in SVE system. Modify SVE system operational parameters, which may include the blower/vacuum rates and operational power.
		Maximum limit of POEO Licence: 20mg/m ³ total VOCs (as n-propane)	Suspend injections. Notify required regulators. Modify SVE system, including operational parameters of existing equipment, and continue monitoring the system's performance. If needed, replace system or add additional SVE units.

15.0 Soil Vapour Contingency Plans

15.1 Field Soil Vapour Monitoring

The results of field soil vapour monitoring conducted using a PID and other field air monitoring devices, will be evaluated against the criteria to determine whether the contingency measures listed will be required to protect sensitive receptors in the treatment area. **Table 21** provides an indicative monitoring contingency plan.

Table 21 Field Vapour Monitoring Contingency Plan

Parameter	Location	Criteria	Contingency Measures
PID readings	Ambient monitoring; SV monitoring points; SVE system effluent; utility pits ² ; Service access points; Monitoring well heads ³	PID > 5.0 ppm over the background nominated VOC species ¹ in the breathing zone for >5 minutes	- Modify the SVE system, including: extract from additional areas in the vicinity of the exceedance or increase the extraction from areas at which extraction is already taking place. Monitor effectiveness of modifications. - If SVE modifications do not address the problem, collect Draeger Tube samples to confirm that PID reading is representative of one or a collection of the nominated individual VOC species. - If Draeger confirms the presence of one or a collection of the nominated individual VOC species, then work will be suspended until appropriate PPE/management protocols can be implemented, as detailed in site safety plans; and the PM and stakeholders will be notified. - Implement additional measures to prevent recurrence, including: modification of injections; doubled frequency of monitoring; and modification to the SVE system.
LEL, O ₂ , CO, H ₂ S		>20% change from baseline conditions	Initiate soil vapour extraction at these locations. Continue monitoring to confirm success of measures.

Notes:

1. The individual VOC species nominated for the initial monitoring are Benzene, Ethylbenzene, Toluene, Xylene and Naphthalene. This is based on the currently assessed pollutants expected to be present in the gas stream. Once the project sampling has commenced it is expected that additional compounds may be added (or removed) from this screening list. (Notes continued)
2. The breathing zone within a utility pit will be taken as approximately 0.5 m below the top of the pit.
3. The breathing zone associated with a well head will be taken as approximately 1.5m above the ground surface.

15.2 Soil Vapour Sampling

Table 22 presents the criteria that would be used to evaluate the results of soil vapour analysis conducted at a NATA-certified laboratory, as well as the contingency measures that will be implemented in response to exceedances or continued non-detections.

Table 22 Soil Vapour Monitoring Point Contingency Plan

Parameter	Location	Criteria	Contingency Measures
	Hickson Road	Non-detect for two consecutive rounds	- Reduce (by half) the frequency of monitoring at these locations. - Reduce SVE system operation to workday hours (7AM-7PM).
		Above background	- Mobilise additional SVE system capacity to extract from locations of exceedances. - Continue monitoring at all soil vapour points to confirm success of contingency.
	Hickson Road: [near sensitive receptors]	Above background	- Suspend or modify injections. - Install additional soil vapour extraction points.

15.3 Post-Injection SVE System Operation Plan

This section describes the plan for operation of the SVE system during post-injection performance monitoring. **Table 23** lists the criteria that will be used to determine whether conditions warrant decreased operation of the SVE system.

Table 23 Post-Injection SVE System Operation

Post-Injection Time Period	SVE System Operation Frequency	Monitoring	Criteria	Contingency Measure
Week 1	Continuous	Daily PID Monitoring of SV wells in Hickson Road,	No detections with PID at any soil vapour monitoring well for 4 consecutive days.	Reduce SVE system operation to daily work hours (7AM-7PM).
Weeks 2 – 6	Daily (< 12 hrs/day)	PID Monitoring of SV wells in Hickson Road	No detections with PID at any soil vapour monitoring point for 4 consecutive days.	Stop SVE operation in Hickson Road. Continue weekly monitoring.

16.0 Odour Contingency Plans

The results of the quantitative and qualitative odour monitoring will be evaluated against the criteria presented in this section to determine whether contingency measures will be required to protect sensitive receptors in the treatment area.

16.1 Quantitative Odour Monitoring

If an elevated dilution-to-threshold (D/T) response is registered during daily odour analysis using the Nasal Ranger field olfactometer and the meteorological conditions show the location of the response to be downwind of the injection areas and the nature of the odour can be linked to treatment activities (i.e. chemical smell) the following will be undertaken:

- Two additional monitoring events, each separated by two (2) hour intervals, will be undertaken that day.
- If the subsequent events also exceed the criteria stated above (elevated D/T, downwind location, and injection-related odour), then the contingency measures listed in **Table 24** will be implemented.

Table 24 Quantitative Odour Monitoring Contingency Plan

Parameter	Location	Criteria	Contingency Measures
Quantitative Odour Measured Using Nasal Ranger	System Compound area and Hickson Road injection areas; monitoring well heads; utility pits; service access points	Elevated D/T response is registered; Elevated location is down-wind of the injection area; and The nature of the odour is linked to the remedial works (i.e. chemical odour)	Criteria exceeded during 1 st daily monitoring event: Conduct 2 additional rounds of Nasal Ranger monitoring, separated by 2-hour intervals.
			Criteria exceeded during 2 subsequent monitoring events: - Corrective actions will be taken that include: - suspension and/or modification of injections; - use of odour-suppression sprays such as BioSolve; - modification of the SVE system operation, including increased extraction if the elevated area is already covered by the SVE system or extraction from additional areas; and - consideration of the collection of ambient VOC samples from the elevated location to determine whether the well emissions have increased (relative to background VOC concentrations)

16.2 Qualitative Odour Monitoring

The results of qualitative odour monitoring conducted will be evaluated against the criteria in **Table 25** to determine whether the contingency measures listed will be required.

Table 25 Qualitative Odour Monitoring Contingency Plan

Parameter	Location	Criteria	Contingency Measures
Qualitative Odour	System Compound area and Hickson Road treatment areas; monitoring well heads; utility pits; service access points	Workers identify a strong or offensive odour associated with the treatment, that is, a naphthalene-like odour*	- Suspend or modify injections - Use odour-suppression sprays such as BioSolve - Modify SVE system operation (including increase extraction if the area is already covered by the SVE system or extract from additional areas). - If the odour persists, consider* collection of ambient VOC samples from the location in question to determine whether the well emissions have increased (relative to background VOC concentrations). *

17.0 Erosion & Sedimentation Control Monitoring & Contingency Plans

Erosion and sedimentation control strategies will be implemented as part of the CMP. These strategies include:

- stormwater control devices;
- water diversions to minimise water infiltrating into trenches;
- impermeable berms and coverings, and diversion drains;
- sediment control devices in gutters and before stormwater pits;
- sloping the trenches in Hickson Road toward the sump in Hickson Road;
- enclosing the injection lines within the trenches in PVC piping;
- backfilling the trenches and re-finishing disturbed pavement; and
- establishing containment berms for the injection system, chemical tanks, spoils and waste containers in the System Compound area.

Throughout both drilling operations as well as injections, a qualified environmental scientist will oversee, inspect and document the implementation of erosion/sedimentation control measures. **Table 26** details the inspection plans for Erosion/Sedimentation control measures.

In addition vehicles will be inspected for dust, mud and sediments before leaving the Site. Since the Site is predominantly characterised by hardstands / sealed areas and with no planned earthworks resulting in unsealed areas being tracked by vehicles, vehicle cleansing is not seen as a requirement.

Table 26 Erosion & Sedimentation Controls Inspection & Test Plan

Item	Criteria	Inspection Frequency	Action	Recording Location
Stormwater and sediment control devices in gutters and before stormwater pits	Device effectively controls stormwater and sediment flows. Device is enduring and is not damaged.	Daily; More often during rain/storm events (<i>frequency determined by magnitude of the event</i>); After rain events.	Correct installation to enhance effectiveness. Clean/replace devices that a qualified person deems are compromised.	Checklist
Road surface diversion parallel to the trenches in Hickson Road				
Steel plates	Stability of plates over trench. Effectiveness of coverage over trench.		Re-position plates over trench. Replace damaged plates.	
Sumps at end of trenches	Accumulation of liquid.		Pump out liquid. Containerise in waste storage area, test and characterise for disposal according to Waste Management Plan. Identify source of liquid and eliminate.	
Junction boxes				
Waste Storage Area and Containers	Integrity of the impermeable lining; The effectiveness of the berm at containing water; Integrity of the storage containers.		Repair compromises to lining. Repair areas where liquid can escape or run off. Repair/replace damaged containers. Remove accumulated stormwater according to Stormwater Management Plan.	

18.0 Spill Monitoring & Contingency Plan

Table 27 describes the process for identifying spills and/or spilled material, and the measures that will be taken in response to spills. The Spill Management Plan is part of the CMP.

In general, for spills in the secondary containment bund, the identity of the spill can be determined by the spill's location, that is, by identifying which chemical tank or injection stream hose the spill is beneath, beside or emerging from.

Table 27 Spill Monitoring and Contingency Plan

Parameter	Criteria	Contingency Measures
Spill in the System Compound area containment berm	Incidental release of hazardous liquid: fluid beneath, next to or emerging from a tank, hose, pipe or pump	- Dilution of concentrated reagents in a spill emergency with water mains. As a precautionary measure, the entire pilot trial enclosure will be bunded to contain any spilled liquids that may occur during field implementation. This will prevent any chemicals from accidentally leaving the site. Liquids to be captured in sumps and transferred to the wastewater storage tank. - Place absorbent materials such as sand, sawdust or commercial sorbents directly on the substance to contain the spill and aid recovery. At least three boxes of absorbent pads will be maintained on site. Dispose of materials according to Waste Management Plan. - Use berms of earthen or sorbent materials to contain the leading edge of the spill, if needed. - Block surface water drains or drainage areas using sand bags placed around the drain or an inflatable bladder placed inside the drain.
	Incidental Solid Spill—powdery material in the chemical storage area or the chemical batching area	- Use tarpaulins or black plastic to cover/protect spill from environmental elements such as wind and/or rain. - Pick up materials using plastic shovels and scoops, maintained on site, immediately after the spill. - Collect released materials and contaminated media in drums to be characterised and either disposed of or introduced into the injection process stream.
Spill in the injection line or well head	Fluid accumulation beneath injection line or at well head	- Suspend injection process and isolate product lines. - If necessary, use berms of earthen or sorbent materials to contain the leading edge of the spill and block surface water drains or drainage areas with sand bags or an inflatable bladder. - Depending on volume of fluid, either use a submersible pump to remove fluid to waste storage container (in containment berm) or place absorbent materials such as sand, sawdust or commercial sorbents directly on the spill to contain the spill and aid recovery. - Test impacted media for process chemicals that would require collection and management. - Repair and/or replace the cause of the release prior to restarting injections.

Parameter	Criteria	Contingency Measures
Spill in the Containment berm, injection line, or well head	Sodium persulfate release: fluid from storage tank or powder from storage container or batching	- Neutralise aqueous material with bicarbonate powder by broadcasting on top of chemical spill until it is absorbed. After absorption shovel powder into drums to be characterised and disposed of properly. - Sweep up spilled persulfate powder and return to the chemical storage area.
	Peroxide spill- fluid beneath or emerging from the peroxide IBCs or injection lines	- Dilute material with copious amounts of water within the secondary containment unit and return to peroxide storage container by pumping with a submersible pump. - Use sorbent material to remove residual material; dispose of according to Waste Management Plan.
Day-lighting in the Injection well heads	Visual detection of injected fluid on the ground surface near an injection well	- Treat emergence as a spill. - Temporarily suspend injection to area of occurrence. - Assess causes and alter operational parameters of system (rate, concentration, pressure), and correct/modify system and injection parameters. - Resume injections gradually and ramp up to desired levels with a doubled frequency of monitoring the injection well.

19.0 Reporting and Documentation

19.1 OHS Reporting

The Remediation Contractors HASP will describe OHS reporting and documentation that will be carried out during Site works, and contains the forms for this reporting and documentation. This reporting and documentation includes:

- plant certifications, to be provided to lend lease prior to arrival on-site and after any modifications are made;
- records of plant maintenance (according to manufacturer's specifications and the ITP);
- copies of design certificates;
- daily log books; and
- work statistics addressing safety, labour, inspection and waste.

19.2 Regulatory Authority Reporting

Following completion of the remediation activities the Remediation Contractor will prepare a Remedial Summary Report which describes the remediation activities; documents any changes to the Work Plan; documents the final disposal of wastes; evaluates the success of the remediation in achieving its goals and objectives.

Specific components of the Remedial Summary Report include:

- chemical injection totals;
- system operational data and analysis;
- process and performance monitoring data and analysis, including: analysis of the subsurface distribution of injected chemistry; and volatile emissions;
- pre- and post-injection soil sampling data and analysis, including an evaluation of remedial effectiveness;
- pre- and post-injection groundwater contaminant data, including an evaluation of remedial effectiveness; and
- soil vapour monitoring data and analysis.

20.0 References

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- NSW Department of Environment and Climate Change and Water (DECCW), 2007. Storing and Handling Liquids: A guide to managing environmental risks associated with the storage and handling of liquid substances. Environmental Protection.
- NSW Department of Environment and Climate Change (DECC), 2009. Waste Classification Guidelines, Part 1: Classifying Waste.
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Appendix A

Figures

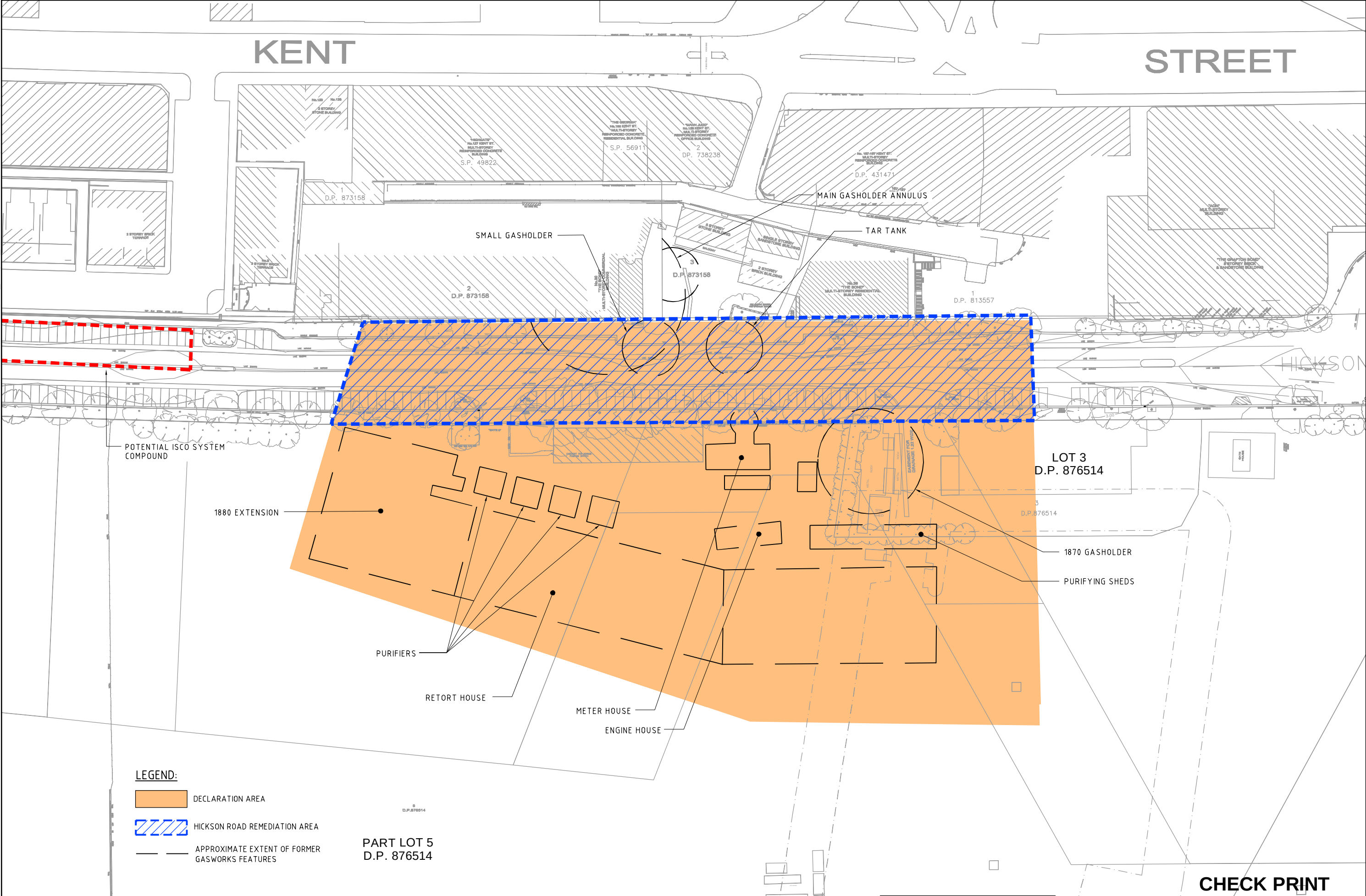
Appendix A Figures

- Figure F1 Barangaroo Site Location**
- Figure F2 Outline of Gaswork Remnants and Structures**
- Figure F3 Indicative Full Scale Well, Trench and System Compound Location Plan**
- Figure F4 Indicative Full Scale Injection System Compound Layout**



G:\Projects\603 Projects\60323955 Barangaroo\FIGURES\Contam\60323955 F1 Barangaroo Site Location 01 09 2014 TO

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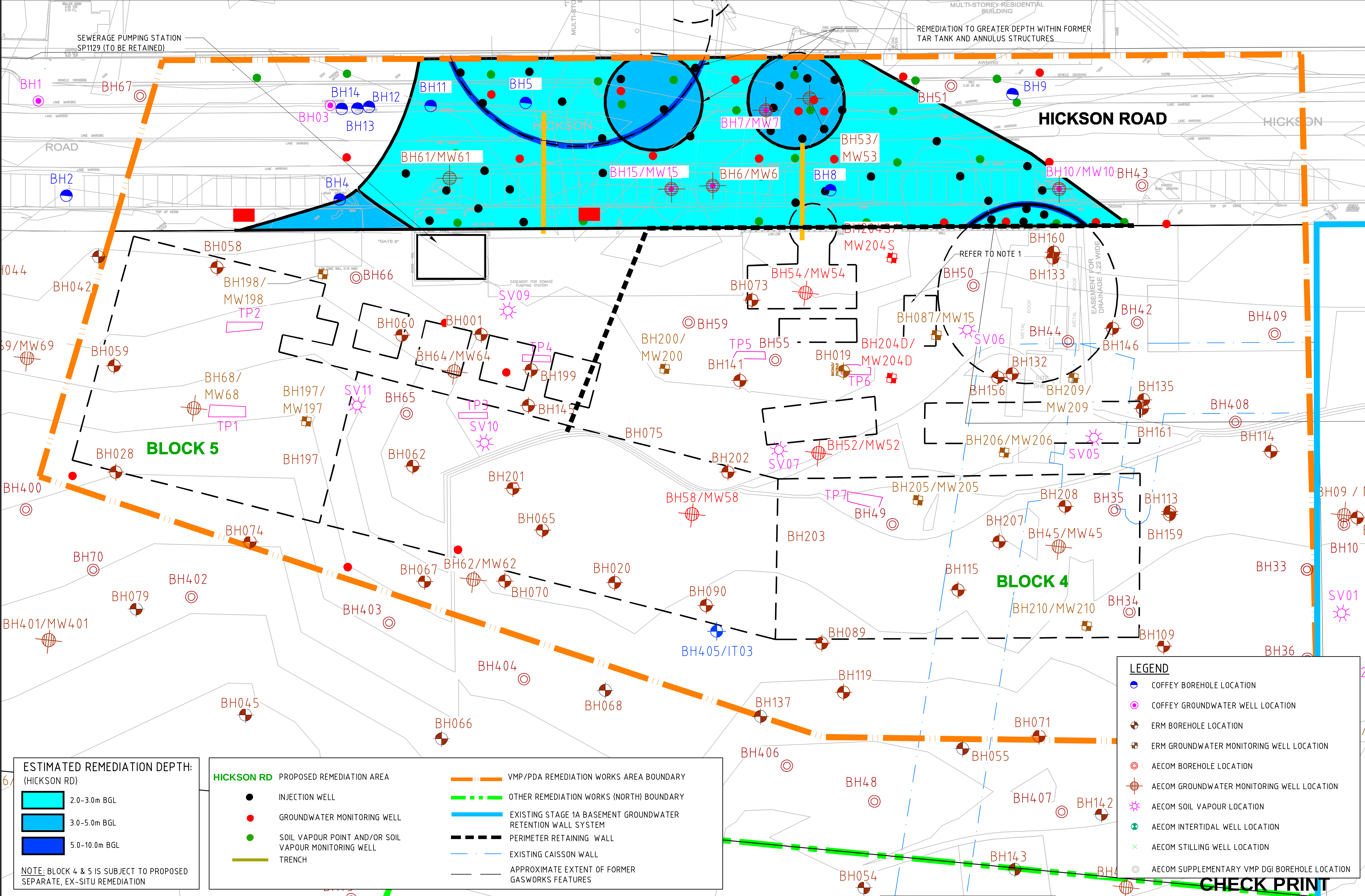
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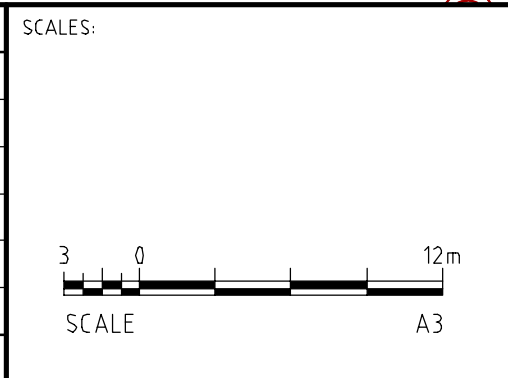
INSITU CHEMICAL OXIDATION FULL SCALE WORK PLAN, BARANGAROO			
FIGURE F2: OUTLINE OF GASWORK REMNANTS AND STRUCTURES			
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INSITU CHEMICAL OXIDATION FULL SCALE WORK PLAN, BARANGAROO

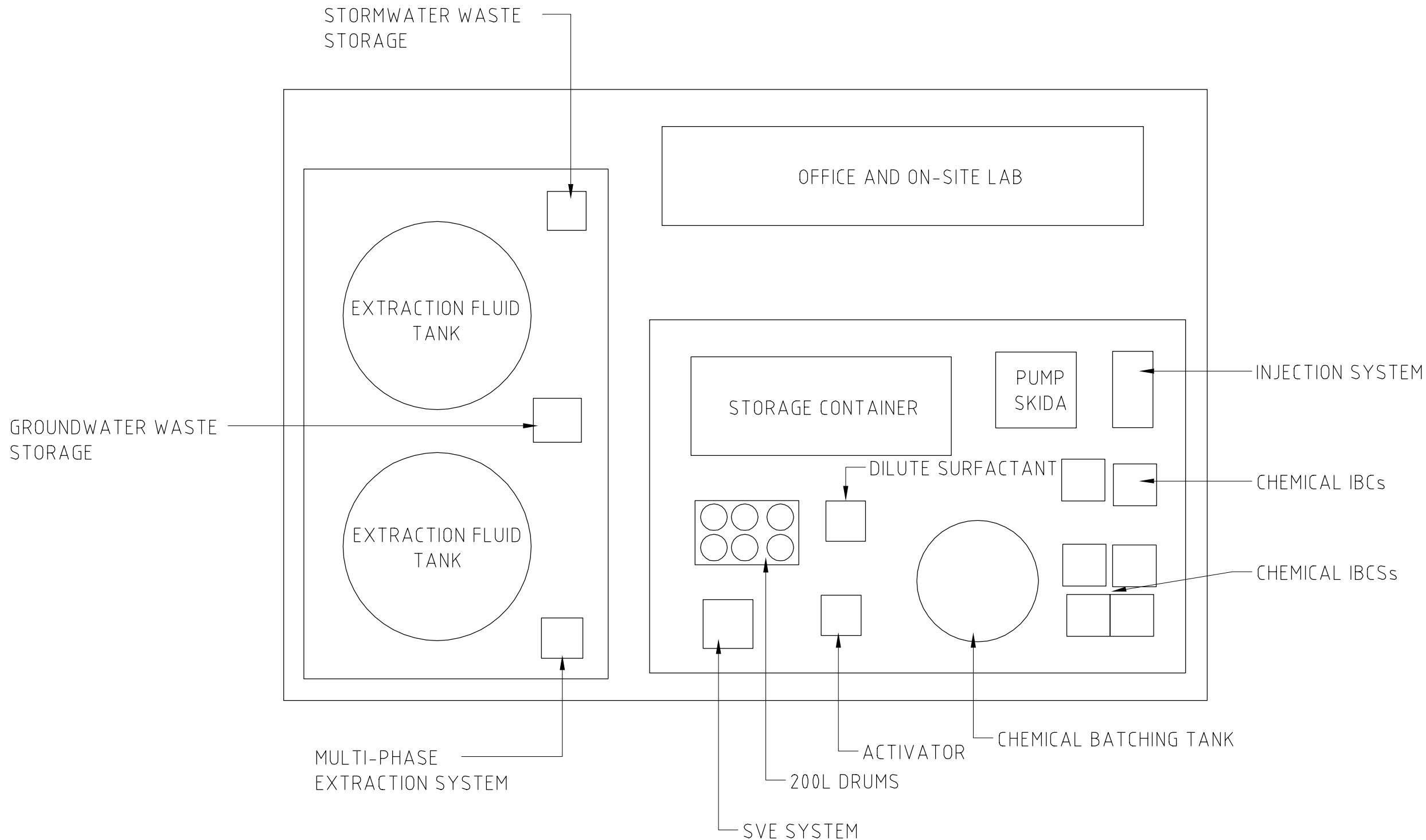
FIGURE F3: INDICATIVE FULL SCALE WELL, TRENCH AND SYSTEM COMPOUND LOCATION PLAN

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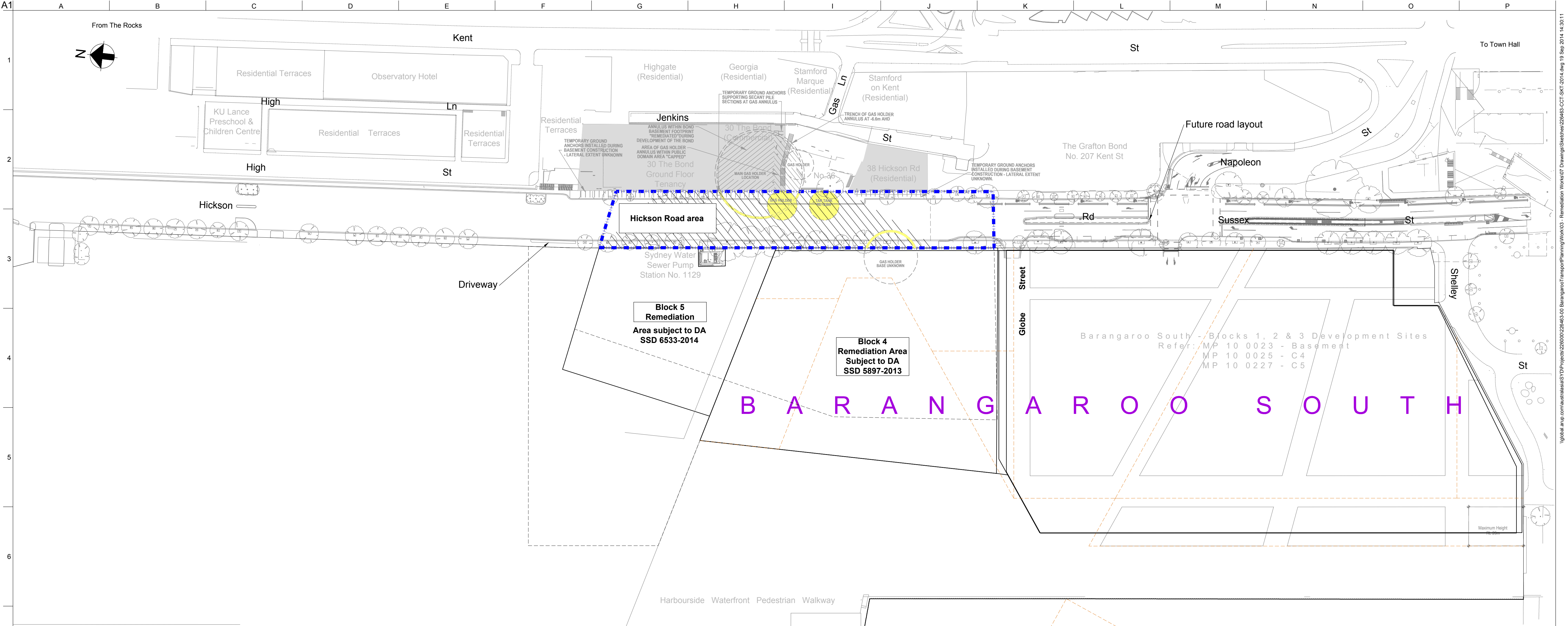
INSITU CHEMICAL OXIDATION FULL SCALE WORK PLAN, BARANGAROO

FIGURE F4:
 INDICATIVE FULL SCALE
 INJECTION SYSTEM COMPOUND LAYOUT

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Appendix B

Staging Plans



Definition of Site:

For the purposes of the Development Application, the **Site** includes the area of land to be remediated (**Site Remediation Area**), plus any adjacent land used for the staging and undertaking of the proposed remediation work.

The **Site Remediation Area** includes the Hickson Road part of the Declaration Area.

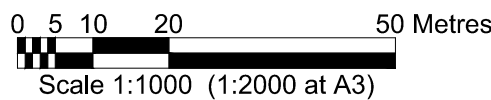
Staging Plans:

These Staging Plans are indicative of the works proposed for Hickson Road remediation. All the layouts and staging arrangements depicted on the Staging Plans are indicative only and subject to further detailed design and approvals. The various specialist reports that accompany the Development Application setout in more detail the specific requirements of the works.

Staging for Preferred (in-situ) Method:

Legend:

- 1 Barangaroo Planning Blocks (SEPP)
- EPA Declaration Area No. 21122
- Indicative extent of Hickson Road Remediation
- Hickson Road Remediation Area
- Indicative gasworks structures



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Issue	Date	By	Chkd	Appd

C	18/09/14	OW	JM	JM
For Information				
B	21/08/14	OW	JM	JM
For Information				
A	06/08/14	OW	JM	JM
For Information				
Issue	Date	By	Chkd	Appd

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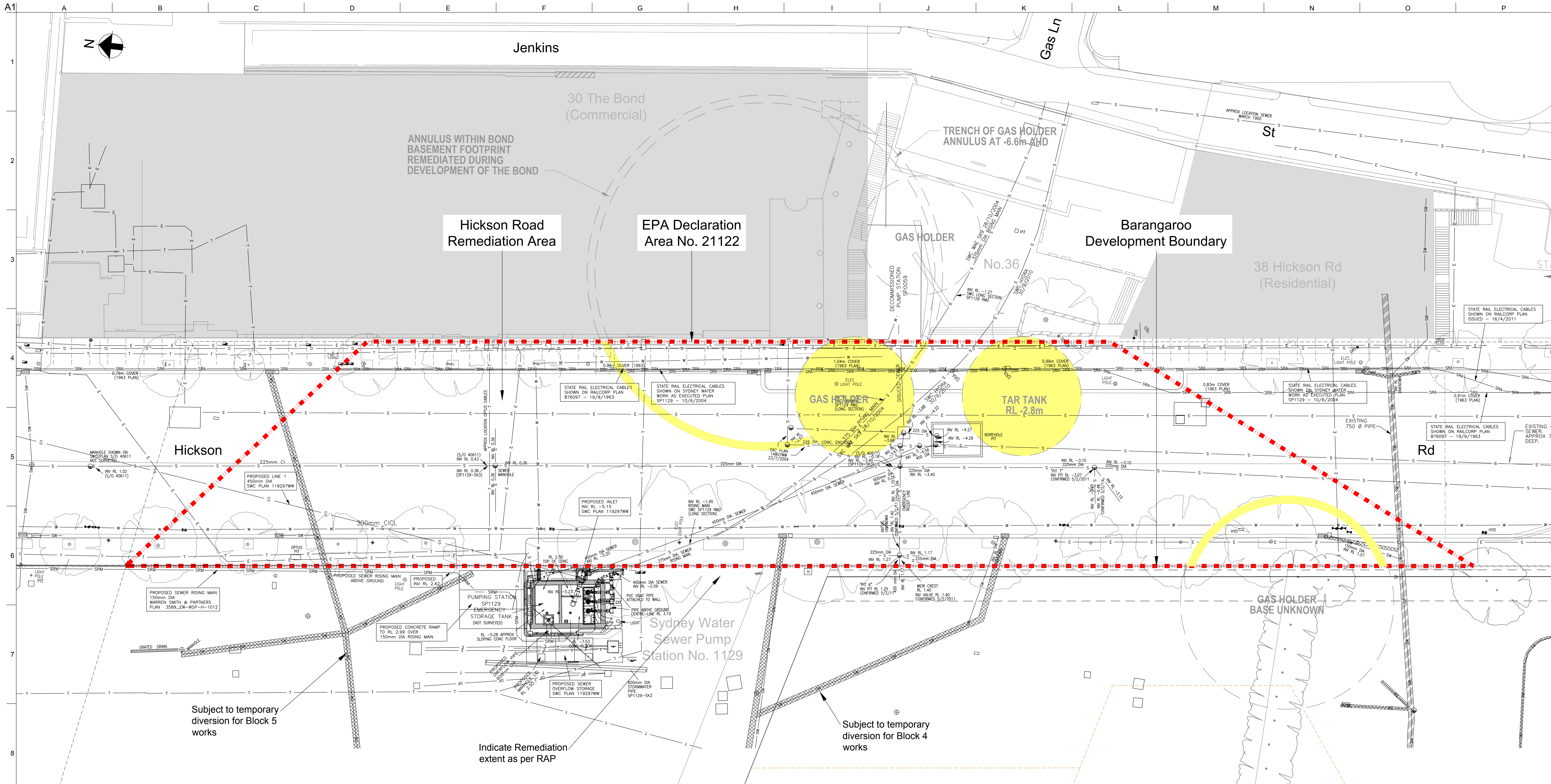


Client
Lend Lease
Level 4 The Bond, 30 Hickson Road
Millers Point
New South Wales, 2000

Job Title
BARANGAROO
REMEDICATION
DEVELOPMENT APPLICATION
HICKSON ROAD

Hickson Road Remediation
Overview Drawing
In-situ Remediation Method
Works Staging

Scale at A1 1:1000 (1:2000 at A3)	
Discipline	CIVIL
Job No	Drawing Status
226463	Preliminary
Drawing No	Issue
226463-CCT-SKT-2014	C



Legend for Services:

Telecom DBYD	T	Telecom
Water DBYD	W	Unknown Services
Stormwater DBYD	SW	
Gas DBYD	G	
Electric DBYD	E	
Sewer Proposed RM	SRM	
Sewer Design	S	
SP1129 SRA Electrical	SRA	
SP1129 Pipelines	OF	

Legend for Development Application

	Barangaroo Planning Blocks (SEPP)
	EPA Declaration Area No. 21122
	Former gasworks structure (indicative)
	Indicative maximum remediation extent per RAP
	Extent of Hickson Rd Remediation Area

Notes:

1. All existing and proposed services shown on this plan are indicative only.
All service locations to be checked prior to commencing works.

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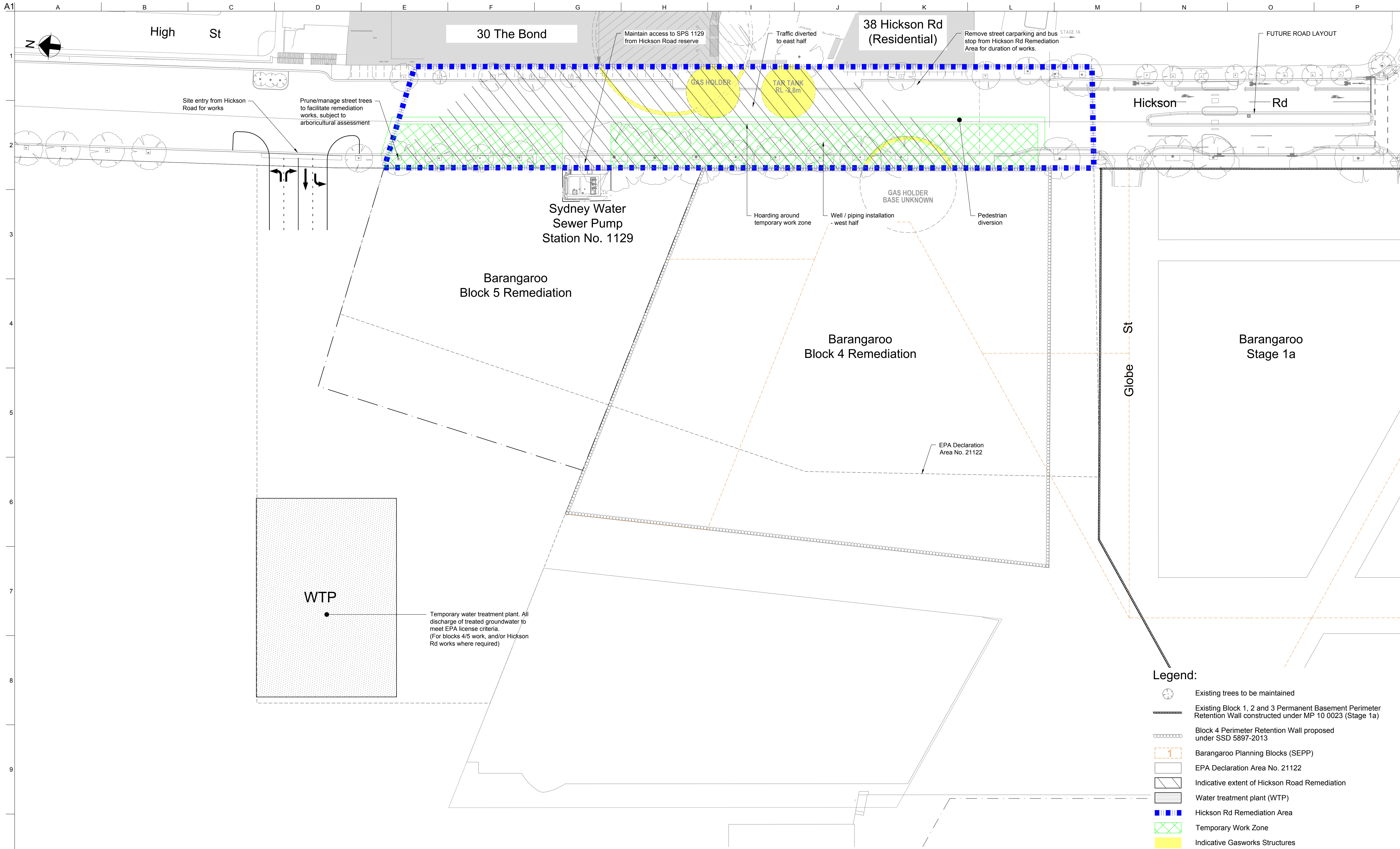


Client
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Job Title
BARANGAROO
REMEDATION
DEVELOPMENT APPLICATION
HICKSON ROAD

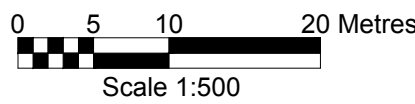
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Hickson Road Remediation
Detailed Overview

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Discipline CIVIL	
Job No 226463	Drawing Status Preliminary
Drawing No 226463-CCT-SKT-2015	Issue C



Notes:
1. All layouts and staging arrangements are indicative and subject to detailed design.

- Legend:**
- Existing trees to be maintained
 - Existing Block 1, 2 and 3 Permanent Basement Perimeter Retention Wall constructed under MP 10 0023 (Stage 1a)
 - Block 4 Perimeter Retention Wall proposed under SSD 5897-2013
 - Barangaroo Planning Blocks (SEPP)
 - EPA Declaration Area No. 21122
 - Indicative extent of Hickson Road Remediation
 - Water treatment plant (WTP)
 - Hickson Rd Remediation Area
 - Temporary Work Zone
 - Indicative Gasworks Structures



Issue	Date	By	Chkd	Appd

Issue	Date	By	Chkd	Appd

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For Information				
B	21/08/14	OW	JM	JM
For Information				
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For Information				
Issue	Date	By	Chkd	Appd

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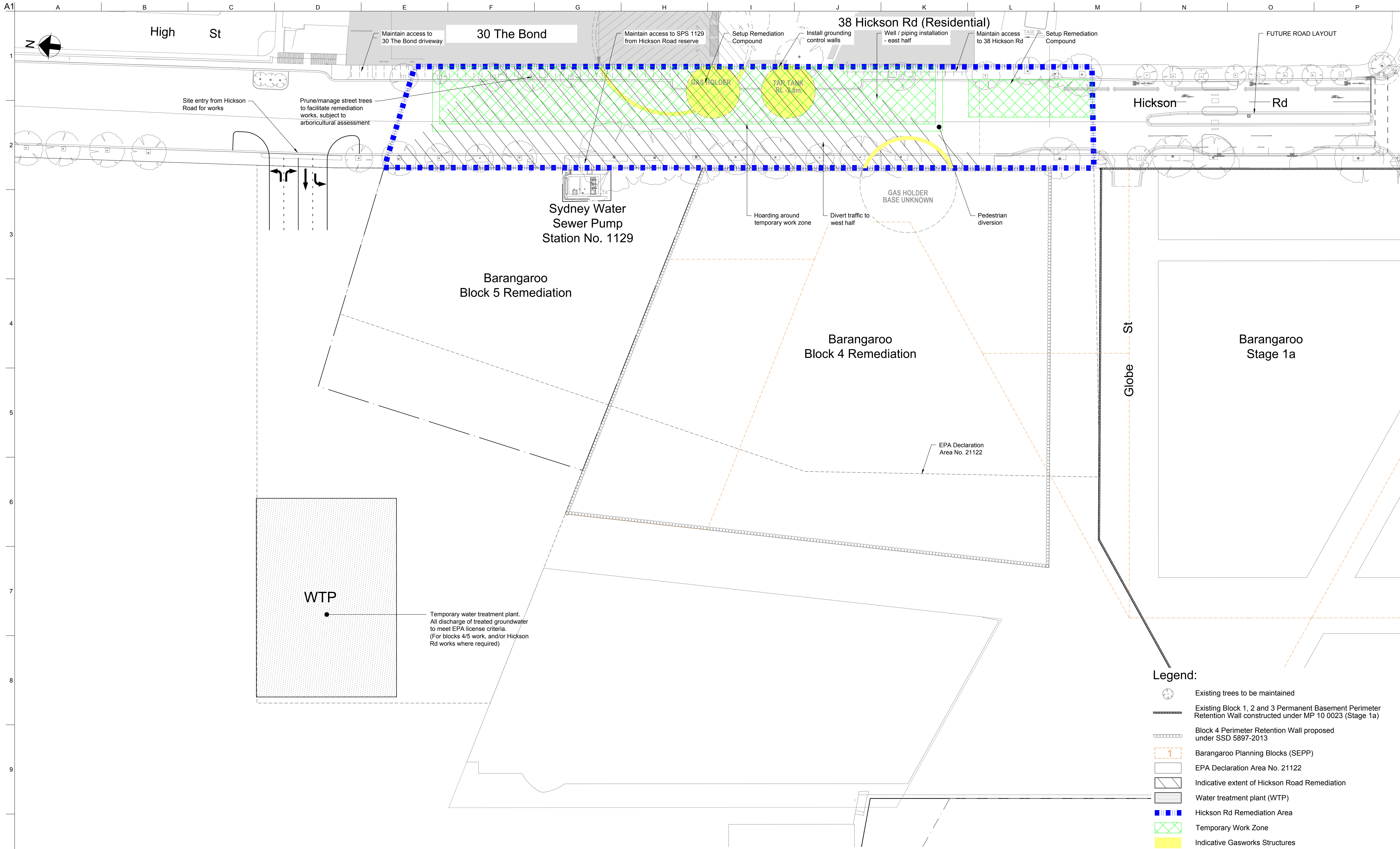
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Millers Point
New South Wales, 2000

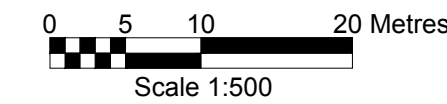
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REMEDICATION
DEVELOPMENT APPLICATION
HICKSON ROAD**

**Hickson Road Remediation
In-situ Method
Staging Plans
Stage 1**

Scale at A1 1:500 (1:1000 at A3)	
Discipline CIVIL	
Job No 226463	Drawing Status Preliminary
Drawing No 226463-CCT-SKT-2018	Issue C



Notes:
1. All layouts and staging arrangements are indicative and subject to detailed design.



Issue	Date	By	Chkd	Appd

Issue	Date	By	Chkd	Appd

C	18/09/14	OW	JM	JM
For Information				
B	21/08/14	OW	JM	JM
For Information				
A	06/08/14	CM	JM	JM
For Information				
Issue	Date	By	Chkd	Appd

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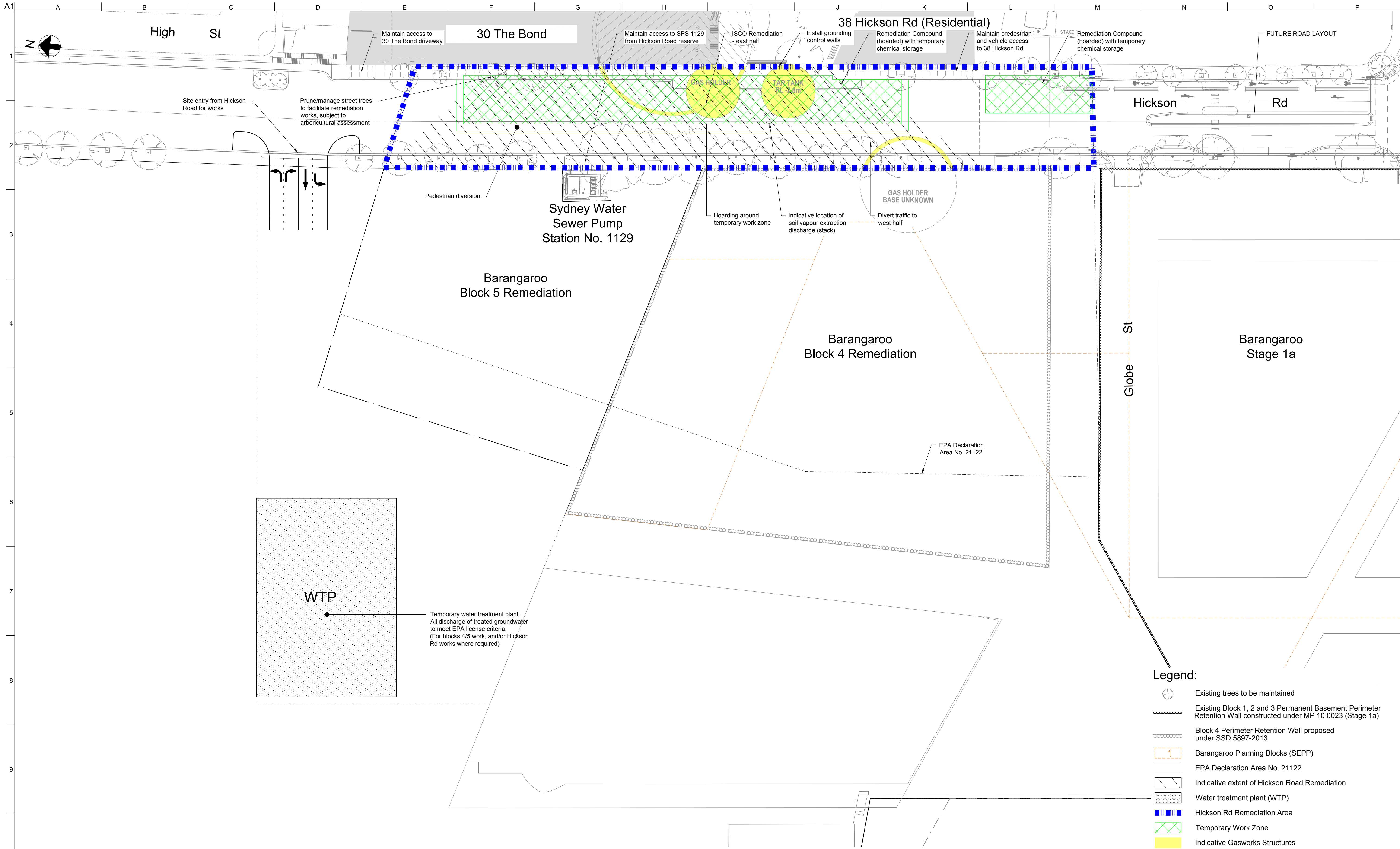
Arup Pty Ltd
ABN 18 000 968 165

Client
Lend Lease
Level 4 The Bond, 30 Hickson Road
Millers Point
New South Wales, 2000

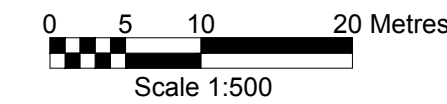
Job Title
BARANGAROO
REMEDICATION
DEVELOPMENT APPLICATION
HICKSON ROAD

Hickson Road Remediation
In-situ Method
Staging Plans
Stage 2

Scale at A1 1:500 (1:1000 at A3)	
Discipline CIVIL	Drawing Status
Job No 226463	Preliminary
Drawing No 226463-CCT-SKT-2019	Issue C



Notes:
1. All layouts and staging arrangements are indicative and subject to detailed design.



Issue	Date	By	Chkd	Appd

Issue	Date	By	Chkd	Appd

C	18/09/14	OW	JM	JM
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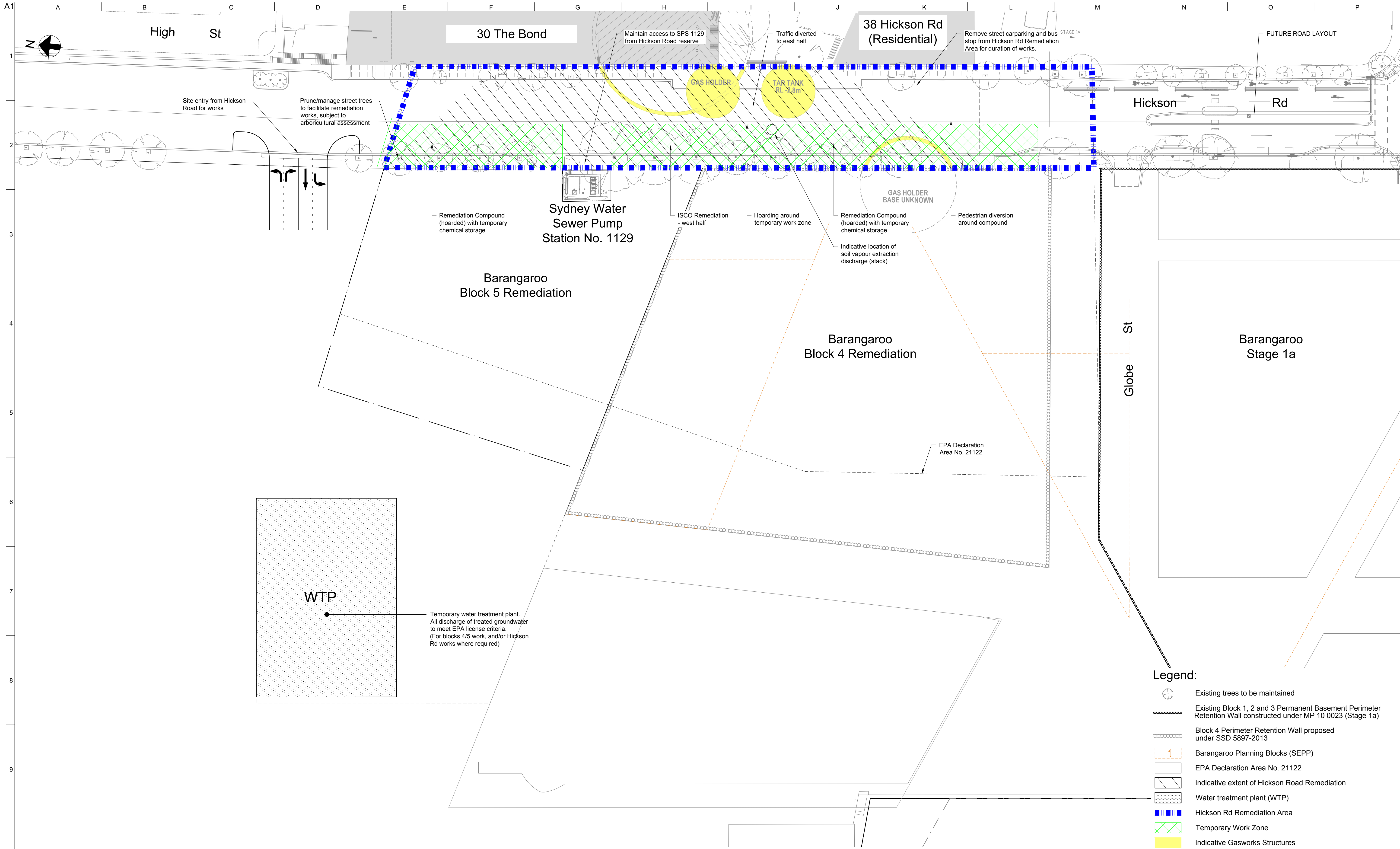
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Lend Lease
Level 4 The Bond, 30 Hickson Road
Millers Point
New South Wales, 2000

Job Title
BARANGAROO
REMEDICATION
DEVELOPMENT APPLICATION
HICKSON ROAD

Hickson Road Remediation
In-situ Method
Staging Plans
Stage 3

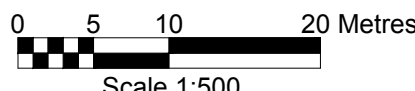
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Discipline CIVIL	
Job No 226463	Drawing Status Preliminary
Drawing No 226463-CCT-SKT-2020	Issue C

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Notes:
1. All layouts and staging arrangements are indicative and subject to detailed design.

- Legend:**
- Existing trees to be maintained
 - Existing Block 1, 2 and 3 Permanent Basement Perimeter Retention Wall constructed under MP 10 0023 (Stage 1a)
 - Block 4 Perimeter Retention Wall proposed under SSD 5897-2013
 - Barangaroo Planning Blocks (SEPP)
 - EPA Declaration Area No. 21122
 - Indicative extent of Hickson Road Remediation
 - Water treatment plant (WTP)
 - Hickson Rd Remediation Area
 - Temporary Work Zone
 - Indicative Gasworks Structures



Issue	Date	By	Chkd	Appd

Issue	Date	By	Chkd	Appd

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For Information				
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A	06/08/14	CM	JM	JM
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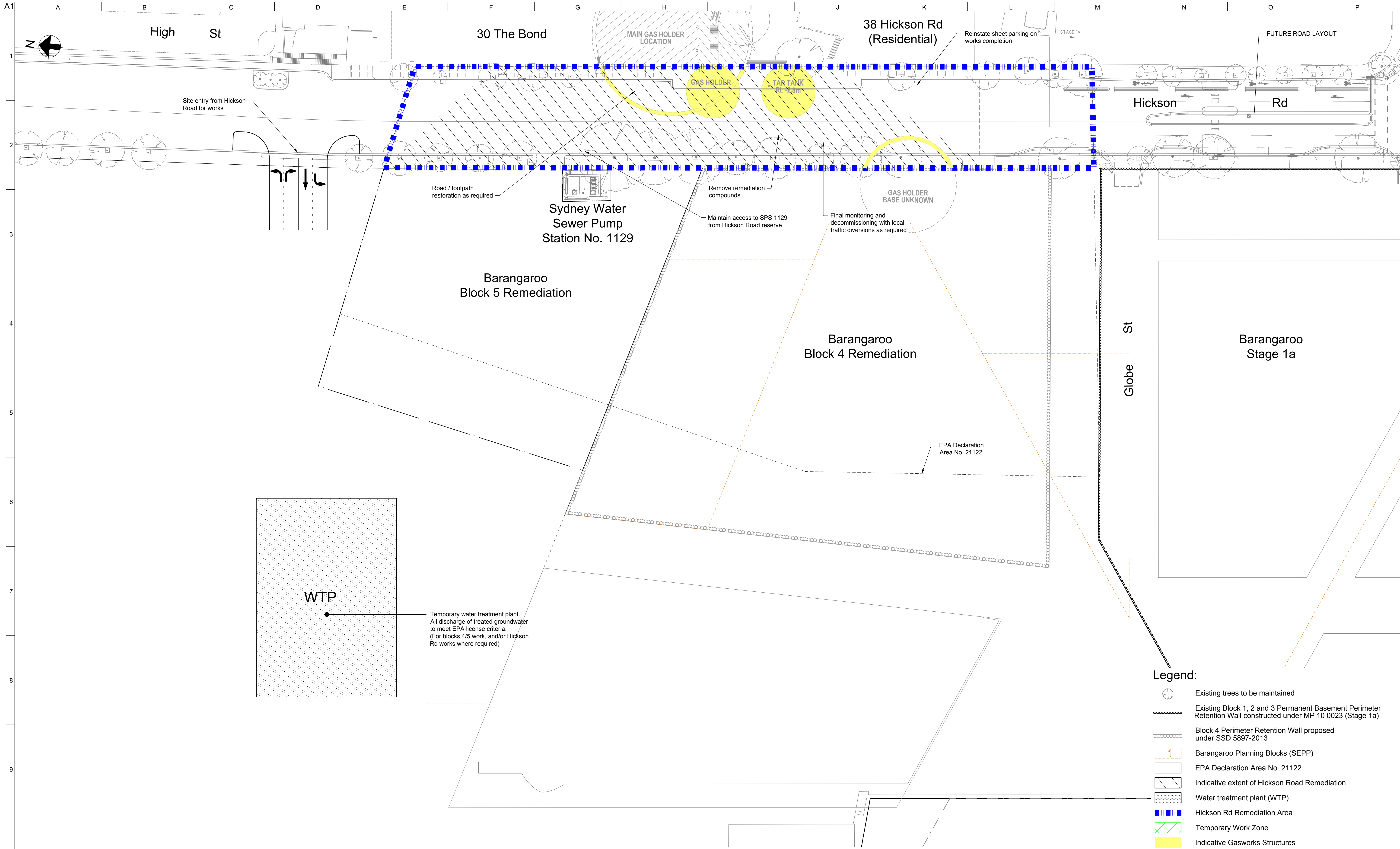
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Client
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Millers Point
New South Wales, 2000

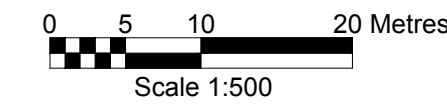
Job Title
**BARANGAROO
REMEDICATION
DEVELOPMENT APPLICATION
HICKSON ROAD**

**Hickson Road Remediation
In-situ Method
Staging Plans
Stage 4**

Scale at A1 1:500 (1:1000 at A3)	
Discipline CIVIL	
Job No 226463	Drawing Status Preliminary
Drawing No 226463-CCT-SKT-2021	Issue C



Notes:
1. All layouts and staging arrangements are indicative and subject to detailed design.



Issue	Date	By	Chkd	Appd

Issue	Date	By	Chkd	Appd

C	18/09/14	OW	JM	JM
For Information				
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A	06/08/14	CM	JM	JM
For Information				
Issue	Date	By	Chkd	Appd

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New South Wales, 2000

Job Title
BARANGAROO
REMEDICATION
DEVELOPMENT APPLICATION
HICKSON ROAD

Hickson Road Remediation
In-situ Method
Staging Plans
Stage 5

Scale at A1 1:500 (1:1000 at A3)	
Discipline CIVIL	
Job No 226463	Drawing Status Preliminary
Drawing No 226463-CCT-SKT-2022	Issue C

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