FINAL REPORT

Currie & Brown (on behalf of Department of Defence)

Bulimba Barracks 167 Apollo Road, Bulimba Queensland, 4171

Stage 2 Detailed Site Investigation

November 2018

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ABBREVIATIONS

ABCs	Ambient Background Soil Concentration
ACM	Asbestos Containing Material
AEC	Areas of Environmental Concern
ALS	Australian Laboratory Services Pty Ltd
ANZECC	Australian and New Zealand Environment Conservation Council
ASC	Assessment of Site Contamination
ASLP	Australian Soil Leaching Procedure
ASRIS	Australian Soil Resource Information System
ASS	Acid Sulfate Soil
AST	Above-ground Storage Tank
BCC	Brisbane City Council
CBD	Central Business District
CLR	Contaminated Land Register
COC	Chain Of Custody
COPC	Contaminants of Potential Concern
CSM	Conceptual Site Model
DEHP	Department of Environment and Heritage Protection
DERM	Department of Environment and Resource Management
DES	Department of Environment and Science
DO	Dissolved Oxygen
DQO	Data Quality Objective
DSI	Detailed Site Investigation
EC	Electrical Conductivity
Eh	Oxidation-Reduction Potential
EIL	Environmental Investigation Level
EMR	Environmental Management Register
ERA	Environmentally Relevant Activity
ERM	Environmental Resources Management Australia Pty Ltd
ESL	Ecological Screening Level
EV	Environmental Value
GIL	Groundwater Investigation Level
GME	Groundwater Monitoring Event
GTLD	Gaseous Tritium Light Devices
HIL	Health Investigation Level
HMTV	Hardness Modified Trigger Values
HSL	Health Screening Level
IP	Interface Probe
JLU	Joint Logistics Unit
km	Kilometre
LDPE	Low Density Polyethylene

LNAPL	Light Non-Aqueous Stage Liquid
LOR	Limit Of Reporting
LRTV	Low Reliability Trigger Value
mAHD	Metres above Australian Height Datum
mbgs	Metres below ground surface
mbTOC	Metres below Top Of Casing
NATA	National Association of Testing Authorities
NDD	Non-Destructive Drilling
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
PAH	Polycyclic Aromatic Hydrocarbon
PARCC	Precision, accuracy, representativeness, comparability and completeness
PASS	Potential Acid Sulfate Soil
PID	Photo-Ionisation Detector
QA	Quality Assurance
QC	Quality Control
RPD	Relative percentage Difference
RTI	Right To Information
SAQP	Sampling and Analysis Quality Plan
SL	Screening Level
SOP	Standard Operating Procedure
SPR	Source-Pathway-Receptor
SQGV	Sediment Quality Guideline Value
SRN	Sample Receipt Notice
SWL	Static Water Level
TCLP	Toxicity Characteristic Leaching Procedure (USA Leaching Procedure)
TDS	Total Dissolved Solids
TKN	Kjeldahl Nitrogen
TRH	Total Recoverable Hydrocarbons
TV	Trigger Value
UPSS	Underground Petroleum Storage System
UST	Underground Storage Tank
VOC	Volatile Organic Compound
WA	Western Australia

DETAILED SITE INVESTIGATION EXECUTIVE SUMMARY

Environmental Resources Management Australia Pty Ltd (ERM) was commissioned by Currie and Brown on behalf of the Department of Defence (Defence) to conduct a Stage 2 Detailed Site Investigation (DSI) to identify the location, nature and extent of any contamination on-site (or extending off-site) at Bulimba Barracks. Defence is divesting the property on the open market and the purpose of this Stage 2 DSI was to characterise the nature and extent of contamination to assist in determining potential future development opportunities of the site with appropriate remediation or management.

Given that the Brisbane City Council (BCC) Bulimba Barracks Draft Masterplan comprises a combination of low- to medium-density residential use, commercial and retail use, and community open spaces, the purchaser would ultimately need to remediate and validate the site to confirm that it is 'suitable for any use.'

A combination of soil bores, test pits, and monitoring wells were advanced in order to obtain representative soil samples. Groundwater samples were obtained from existing and newly installed monitoring wells, and sediment and surface water (stormwater) samples were obtained from accessible open drains.

Overall, the investigations identified that the condition of the site was similar to that of other land parcels where commercial / industrial activities have occurred. Analytical results indicate that there was no immediate risk to workers or visitors to the site, or to neighbouring residential areas. None of the results would preclude the land being redeveloped for future mixed uses (residential / parkland / commercial), with appropriate management and targeted localised remedial actions.

Analytical results identified the following minor source areas of contamination associated with legacy site use:

- Parade Ground (fill material), Armoury, Metal Shop and Rifle Range – arsenic and/or lead concentrations in soil exceeding adopted criteria for residential land use;

- Sediments in open stormwater drains – petroleum hydrocarbons (TRH >C10-C36) and metals (arsenic, cadmium, copper, nickel, lead and zinc) exceeding adopted ecological screening values;

- Soil surrounding washbay interceptors – petroleum hydrocarbons (TRH >C16-C34) exceeding adopted ecological screening levels for residential and open space land uses; and

- Septic tanks – nitrogen compounds (nitrite, nitrate, ammonia and total nitrogen) exceeding aquatic ecosystem screening values (estuarine), and Coliforms exceeding human health screening values for recreational use.

Five of 113 soil samples analysed recorded an exceedance of the adopted ecological screening levels for residential and open space land uses for Total Recoverable Hydrocarbons >C16-C34 (F3) fraction. Four of 152 soil samples analysed recorded an exceedance of the adopted screening levels for residential land use for Lead. One soil sample of 145 analysed recorded an exceedance of the adopted screening levels for residential land use for Arsenic. No asbestos fibres were detected in any of the 63 soil samples analysed.

Four of the 11 groundwater samples analysed for a suite of 13 metals reported one or more dissolved metals concentrations exceeding the adopted aquatic ecological screening levels. The reported metals exceedances do not appear to be attributable to any of the contamination sources identified in the soils or the reported historical site uses. Further, the concentrations identified in upgradient, "background" wells at the site are consistent with the general observations across the site suggesting the groundwater quality at the site is consistent with the local background conditions.

Sediments impacted with hydrocarbons (TRH F3 fraction) were identified at two of the 13 sampled locations; and heavy metals impacted sediments were identified at 12 of the 13 sampled locations.

Following completion of the Stage 2 DSI, ERM conducted a Supplementary DSI to test soil, sediment and groundwater samples for the potential presence of per- and poly-fluoroalkyl substances (PFAS). The detailed findings of this supplementary investigation are presented in a standalone document, annexed to this report. A brief summary of the findings is as follows:

- Historical information indicates that there has been no firefighting training or bulk storage of Aqueous Film-Forming Foam (AFFF) at the site;

- At least one standard commercial foam fire extinguisher was observed at the site during sampling (affixed to an external wall of Building C006 – Electronic workshop and radio repair);

- Historical flooding has previously occurred in the north-eastern portion of the site during the 1974 floods (due to overtopping of the Brisbane River), and in the southern and central portions of the site in 2011 (due to stormwater backing up);

- There are no known uses of AFFF or firefighting training areas nearby, off-site;

- The scope of the supplementary investigation included installation of one additional monitoring well, 13 soil bores, sediment sampling at 10 locations, and sampling of 11 existing wells and the new well;

- PFAS compounds were detected above standard laboratory limits of reporting (LORs) in 5 of the 36 soil samples analysed. Two soil samples had concentrations of PFOS exceeding the human health direct exposure (residential) value, and one of those samples had PFOS concentrations also exceeding the adopted ecological screening value;

- One PFAS compound (PFOS) was detected above the standard laboratory LOR in one of the 10 sediment samples analysed;

- PFAS compounds were detected above standard laboratory LORs in eight of the 12 groundwater samples. PFOS concentrations exceeded the marine 95% species protection value and adopted drinking water screening levels in one sample. A further seven groundwater samples had concentrations of PFOS exceeding marine 99% species protection value, and the adopted drinking water screening level. It should be noted that there is no known current extraction of groundwater for potable use;

- Based on the locations of PFOS detected in groundwater, there appears to be minor localised on-site sources, and low-level impacts potentially associated with periodic flood events from Brisbane River (off-site);

- The minor on-site sources (in the central and south-western portions of the site) may be attributable to testing of foam fire extinguishers (irregular, undocumented, small volume releases over time).

Remediation options associated with targeted source removal of metals, hydrocarbons and nutrients include:

- Excavation of limited volume of shallow soil at Parade Ground associated with lead "hot spot" for off-site disposal;

- Addition of amendment (to fix metals) at Rifle Range stopbutt prior to disposal off-site;

- Removal of sediments from open stormwater drains (for treatment or off-site disposal);

- Removal of two septic tanks, with limited soil removal at least around the northern tank (adjacent Building B013) to reduce the source;

- Removal of interceptors associated with washbays (AEC05 and AEC12) and limited surrounding soil volume to reduce hydrocarbon source; and

- Possible opportunistic removal of portions of fill material, where present, depending on areas of excavation and disturbance during development. Following testing, this material may be suitable for reuse on site to supplement landscaped areas.

The potential for additional areas of impacted materials (of limited extent) cannot be discounted. Further small burial pits may also be encountered. Validation sampling will be required during excavation / construction activities in order to confirm the suitability of site material for low- to medium-density residential use.

Australia's Environmental Health Standing Committee has advised that there is no consistent evidence that exposure to PFAS causes adverse human health effects. Given these chemicals continue to persist in humans and the environment, exposure to them should be minimised as a precaution. To avoid mobilisation, careful management of PFAS-impacted soil and groundwater will be required during construction activities (and appropriate characterisation for waste management purposes), particularly where dewatering is required. Based on the presence of PFOS concentrations in groundwater, it is unlikely to be feasible to remove the site from the QLD Environment Management Register under current guidelines. However, low-level residual risk can be managed under a Site Management Plan (SMP) so that the site is suitable for redevelopment for low- to medium-density residential use.

In addition to the Stage 2 DSI scope, an investigation of Acid Sulfate Soil conditions and Geotechnical conditions was undertaken concurrently at the site. The findings of these investigations are presented as standalone documents annexed to this report.

1 INTRODUCTION

1.1 INTRODUCTION

Environmental Resources Management Australia Pty Ltd (ERM) was commissioned by Currie & Brown on behalf of the Department of Defence (Defence) to undertake a Stage 2 Detailed Site Investigation (DSI), including Geotechnical, Acid Sulfate Soils and Hazardous Materials assessment, at Bulimba Barracks, 167 Apollo Road, Bulimba, Queensland (the site). The site location and the site boundary are presented in *Figure 1, Annex A.*

1.2 BACKGROUND

ERM understands that Defence intends to divest Bulimba Barracks on the open market. Prior to its sale, ERM was commissioned to assess and delineate any contamination that would restrict future sensitive (including low-density residential) land uses. The Stage 2 DSI aimed to identify the location, nature and extent of any contamination that exists on-site, or that is migrating off-site, that would need to be addressed prior to redevelopment for 'unrestricted' (notably, residential) use.

The Stage 2 DSI was conducted to determine potential impacts to soil, sediment, surface water, or groundwater contamination issues exceeding relevant ecological or human health (residential) screening levels, under the *Environmental Protection Act 1994* (EP Act 1994). Sampling and analysis activities were undertaken to meet the rigours of the EHP *Queensland Auditor Handbook for Contaminated Land, Module 5 Contaminated Land Investigation Documents, Auditor Certification and Compliance Assessment* requirements.

1.3 OBJECTIVE

To enable the satisfactory divestment of the site by Defence, ERM understands that the core objective was to characterise the nature and extent of contamination to assist in determining potential future development opportunities of the site with appropriate remediation or management.

1.4 SCOPE OF WORK

The following general scope of work was proposed in order to assess previously identified potential Areas of Environmental Concern (AECs) as well as characterise the conditions across the site as a whole:

- Test pits – 68 pits to 2 metres below ground surface (mbgs), or refusal on bedrock. Scoped to characterise soil conditions across general areas of the site, and specifically to enable identification of any buried waste materials, potentially including asbestos containing materials (ACM); and

- Soil bores – 31 to 3mbgs (plus nine additional monitoring well locations to be advanced to a maximum of 5mbgs), scoped to enable logging soil type and obtaining soil samples for analysis of potential constituents of concern (based on historic activities undertaken in the vicinity of each location);
- Sediment– 28 samples (if sediment is present in stormwater drains at nominated locations) to be obtained to assess the potential presence of constituents of concern in drains, mobilised from surface runoff into drains; and
- Surface water / stormwater – 7 samples (if rainfall events occur that result in generation of runoff) in order to assess potential constituents able to be mobilised.

ERM successfully implemented this scope of work (or modified where required, to meet a similar outcome, as outlined in *Section 4.1*), the findings of which are described in this report.

2 SITE SETTING

2.1 SITE IDENTIFICATION

Bulimba Barracks is a 20.73 ha riverfront property located at 167 Apollo Road in Bulimba, South-East Queensland, approximately 5 kilometres (km) from the Brisbane central business district (CBD). The site is surrounded by residential properties to the west, south, and southeast; with HMAS Moreton and commercial properties to the east. Brisbane River is located along the northern site boundary. Tugulawa Park is located immediately south of the current site entrance.

The site details are listed in *Table 1* below:

Table 1 Site Identification Details

Item	Relevant Details
Address	167 Apollo Road, Bulimba, Queensland
Area	207,300 m2 (20.73ha)
Owner	Department of Defence
Land Titles	Lot 1 SP276395, (formerly a portion of Lot 24 on RP813319, which also comprised the area that HMAS Moreton is located on). Brisbane City Council
County	Stanley
Parish	Bulimba
Zoning	Currently: Emerging Community (BCC, 2016); Formerly: Special Purpose (Defence).

1. Brisbane City Council (2016).
2. GHD (July 2015).

2.2 SITE FEATURES

A security gate marks the site entry on Apollo Road (at the southern site boundary). The western portion of the site (north of the security gate) comprises a number of small and large warehouse and workshop buildings, along with some office and laboratory facilities. The eastern portion of the site comprises a sports' field and accommodation and meeting facilities. Beyond the eastern site boundary is HMAS Moreton, an active naval facility currently accessed only via the Bulimba Barracks security gate.

Former (recent) building uses are described as follows:

- Buildings B1, B2, B3, B4 and B5 – General administration, ablution facilities and headquarters;
- Buildings B7 and B8 – Officers mess and Quarry Club;
- Buildings B13, B14 and B15 – Former conference rooms and small kitchen facilities (currently used by Naval Cadets);

- Building B17 – Conference rooms and kitchen;
- Buildings B20 and B21 – Medical centre and first aid;
- Building B26 – Pump room for water reservoir (including a diesel above-ground storage tank (AST));
- Building C1 – Activities workshop (engine repair) and workshops for carpentry and electrical work;
- Building C2 – Paint and panel shop;
- Building C3 – Vehicle wash point and ramps;
- Building C4 – Hazardous goods store (paint storage);
- Building C5 – Metal shop (welding and metal fabrication);
- Building C6 – Electronic workshop and radio repair (included handling of radioactive substances);
- Building C7 – Armoury and weapons workshop;
- Building C8 – Indoor weapons range;
- Building C9 – Gas bottle store;
- Buildings C14, C19 and C21 – Joint Logistics Unit (JLU) offices;
- Building C15 – Paint shop and spray booth;
- Building C18 – Sandblasting booth and collection vessel;
- Buildings D1, D2, D3, D4 and D5 – contractor vehicle maintenance, warehouse storage and vehicle compounds;
- Building D6 – Front gatehouse and security; and
- Buildings D7 and D10 – Covered oil and lubricant storage associated with washbay.

The ground surface of the site is approximately 50-60% grassed, with the remainder of the site having gravel, bitumen or concrete surfaces. Hardstand surfaces are generally only present in the immediate vicinity of buildings. A combination of shallow open stormwater drains and belowground-piped drains primarily flow from south to north, discharging into Brisbane River. Shallow open drains are commonly covered with timber boards in the western and southern portions of the site.

The site layout and location of buildings is presented on *Figure 2, Annex A*.

2.3 *SURROUNDING LAND USES*

The following table summarises the surrounding land uses proximal to the site.

Table 2 Adjacent Land Uses

Direction	Distance from Site	Land Use Description
North	0m (adjacent site boundary).	Brisbane River
East	0m (adjacent site boundary); and 140m east of site boundary.	HMAS Moreton (operational naval facility). Vacant grassed land (beyond Taylor St) and an open unlined drain lined with mangroves (discharges into Brisbane River).
South	0m (adjacent site boundary); and 20m south.	Low-density residential properties along Carbeen, Bolan, Baldwin, and Hood Streets; and south of Apollo Road. Tugulawa Park (open space / parkland) east of the security gatehouse (southern site entrance).
West	20m (beyond Apollo Road).	Low-density residential properties west of Apollo Road.

1. AECOM (2016).
2. Google Earth (accessed 3 January 2018).

2.4 *ENVIRONMENTAL REGISTER RECORDS*

The site is listed on the QLD Department of Environment and Heritage Protection (EHP) Environmental Management Register (EMR) for the Notifiable Activity – "Gun, Pistol or Rifle Range." The site is not currently listed on the Contaminated Land Register (CLR).

It should be noted that whilst the Lot has been listed on the EMR (a Queensland State register), the land is currently Commonwealth owned and controlled. As such, Queensland State obligations for on-site issues would only be enforceable upon the sale of the property.

Based on a results from a Brisbane City Council Right to Information (RTI) request (GHD, 2014), the site was used for five Environmentally Relevant Activities (ERAs), as of 30 May 2005 (noting that all of these ERAs have since been repealed):

- ERA23 – Abrasive blasting;
- ERA25 – Metal surface coating;
- ERA26 – Fabricating sheet metal;
- ERA28 – Motor vehicle workshop; and
- ERA68 – Wood product manufacture.

2.5 *HISTORICAL SITE ACTIVITIES*

The Apollo Stearine Candle Company (which manufactured candles and laundry soap) was previously located in the north-western portion of the site, operating from the early 1880s (officially opened 2 September 1881). A report in the Brisbane Courier newspaper (3 September 1881) noted that there was a swamp on the land, which was used as a water supply for the candle works. Review of a 1936 aerial photograph indicates that the centre of the swamp area was approximately at the location of Building D010 (oil and lubricant store) within the truck parking area.

During the Second World War, the United States Forces constructed the Apollo Barge Assembly Depot at Bulimba Barracks. The Barge Assembly Depot comprised six large warehouses, now known as C001 (Fabrication Workshop), D001, D002, D003, D004 and D005, as shown on *Figure 2, Annex A*. The three buildings comprising the former candle works facility were taken over by the Australian Army during the Second World War and repurposed as an anti-aircraft battery. Camp A was located at Bulimba Barracks and included the barge assembly works and barracks. The Barge Assembly Depot was formally acquired by the Commonwealth of Australia on 15 March 1945. Most of the workers at the Assembly Depot were Chinese, and approximately 1000 Chinese workers were housed at the Barracks (shown as AEC11 (Chinese Camp) on *Figure 2, Annex A*.

2.6 *GEOLOGY AND SOILS*

Reference to the Moreton Geology 1:500,000 Geological Survey of Queensland Map (1980) indicates that Quaternary sediments (floodplain alluvium and river terraces) underlie the northern portion of the site (closest to Brisbane River). The geology of the southern and south-western portion of the site is Devonian-Carboniferous aged Neranleigh-Fernvale beds (mudstone, shale, greywacke, chert, jasper, conglomerate, basic metavolcanics and pillow lava).

Soils are mapped as Tenosols according to the CSIRO Australian Soil Resource Information System (ASRIS) (GHD, 2014). Tenosols are generally characterised as having low fertility, low water capacity, and are shallow, sandy and stony. The ASRIS Atlas of Australian Acid Sulfate Soils indicates that there is a high probability of occurrence of acid sulfate soils (ASS) extending across the entire site.

2.7 *TOPOGRAPHY AND HYDROLOGY*

The site is generally flat, with a gentle slope from approximately 10 metres above Australian Height Datum (mAHD) in the south to close to 0mAHD at the northern site boundary. The southern portion of the site has been cut into the shallow bedrock. The central western and north-eastern portions of the site were formerly flood prone and swampy and have been filled, using primarily native fill material. The source of the material appears have been from "Bulimba Hill", an area cleared for the construction of Bulimba Camp A which is now the area bounded by Lytton Road to the north, Thorpe Street to the west, Wentworth Parade and McIlwraith Avenue to the south, and Bolan Street to the east (www.bulimbahistory.org/Photos/24/658, accessed 19 January, 2018).

A series of open and grated drains run primarily from south to north across the site discharging into Brisbane River. There are no major surface water bodies on the site. However, as outlined in *Section 2.4*, historically there was a swamp area near the centre of the site (at the current truck parking area). The extent of flooding during the 2011 floods indicates that the former swamp area was inundated, as well as the northern fringes of the site adjacent the Brisbane River.

2.8 HYDROGEOLOGY

There were reportedly ten existing monitoring wells on the site (BMW01, BMW03-BMW09, ETMW01 and ETMW02). However, only eight wells were identified during site work (ETMW01 and ETMW02 were assumed to be destroyed or covered over with bitumen). The existing wells were installed in 2006 to depths ranging from 1.425 metres below top of casing (mbTOC) (BMW03) to 4.830mbTOC (BMW05), noting that these wells were installed with stick-up casing. Depth to groundwater ranged from approximately 1.0-4.0 metres below ground surface (mbgs) (GHD, 2014), likely associated with local tidal influence from Brisbane River, and due to the cut and fill nature of the site. Groundwater is expected to flow north / north-east towards Brisbane River, with the potential for some variation in the northern portion of the site (due to tidal movements).

There are three registered bores (based on a search of the Queensland Bore Register conducted on 4 January 2018) within a 1 kilometre radius of the site (on the southern side of the Brisbane River), as follows:

- **Bore 169908 (installed 30 January 2017)** – total depth 31mbgs, screened across grey schist (Neranleigh-Fernvale Beds) from 25mbgs-31mbgs, with a Static Water Level (SWL) of 18mbgs. Installed at a residential property at 36 Duke Street, Bulimba. Assumed domestic use (irrigation, car washing, etc), but potential potable use; and

- **Bores 169046 and 169045 (installed 18 June 2015)** – each to a total depth of 10mbgs, screened across clay from 4.0mbgs or 6.0mbgs to 10mbgs, no SWL recorded. Installed at the Shell Coles Express Service Station at 209 Oxford Street, Bulimba. Assumed installed as Underground Petroleum Storage System (UPSS) monitoring wells.

Based on the above results, there is potential that groundwater is being extracted for domestic use in the area (garden irrigation, car washing or filling of swimming pools), although there are currently no registered bores in the immediate proximity or downgradient of the site. It is considered unlikely that any groundwater extraction is being conducted for potable use, given the inner city suburb location, with piped water readily available.

2.9 *IDENTIFIED POTENTIAL SENSITIVE RECEPTORS*

A summary of identified potential sensitive receptors is as follows:

- Intrusive maintenance workers (current and future);
- Construction workers associated with development of the site (future);
- Defence (including Naval Cadet) personnel (current);
- Brisbane River estuarine ecosystem (current and future);
- Brisbane River recreational users (current and future);
- Groundwater extraction for domestic use, such as watering gardens, car washing or filling swimming pools (current and future);
- On-site residents (future);
- Off-site residents (current and future);
- On-site commercial workers (future); and
- On- and off-site recreational users of parks and open spaces (current and future).

In addition, with reference to the QLD Department of Environment and Resource Management (DERM) (July 2010) *Environmental Protection (Water) Policy 2009 - Brisbane River Estuary Environmental Values and Water Quality Objectives: Basin No. 143 (part), including all creeks of the Brisbane River estuary, other than Oxley Creek*, the following Environmental Values (EVs) were identified specific to the Brisbane River mid-estuary:

- Aquatic ecosystems;
- Human consumer;
- Primary recreation;
- Secondary recreation;
- Visual recreation;
- Industrial use; and
- Cultural and spiritual values.

It should also be noted that the following EVs have been documented for groundwaters:

- Aquatic ecosystems;
- Irrigation;
- Farm supply / use (noting that there are no farms or agricultural land use in this inner city area);
- Stock water (as above, no agricultural land use in the area); and
- Drinking water (noting that due to the tidal effects from the Brisbane River, salinity is likely to be too high for human consumption in areas proximal to the site).

2.10 *PREVIOUS ENVIRONMENTAL INVESTIGATIONS*

Environmental investigations previously undertaken at the site are summarised in *Table 3*, below, and presented in *Table 1, Annex B*.

Table 3 Previous Environmental Investigations at Bulimba Barracks

Author (Date)	Title	Summary of Scope
QHSS (February 2003)	Radiation Survey & Investigation Report No. 02PQ369	Investigation of potential radiological contaminants inside Building C006 – Electronics Workshop and Radio Repair Facility.
QHSS (May 2003)	Radiation Survey & Investigation Report No. 02PQ588	Further investigation of potential radiological contaminants inside Building C006 – Electronics Workshop and Radio Repair Facility.
QHSS (May 2003)	Stage 2 Radiological Characterisation Report EIR – Building C006	Further investigation of potential radiological contaminants inside Building C006 – Electronics Workshop and Radio Repair Facility, as well as external soil and pore water sampling. Decontamination and refitting of the building was recommended (in line with AS2243.4).
QHSS (June 2003)	Solid Radioactive Waste Disposal Clearance Letter	Documented the decontamination, waste disposal and validation of cleaning works (per recommendations in May 2003 report). Recommendation to refit the room (removal of timber benches, and items where tritium contamination had previously been detected). Refurbishments reportedly completed (confirmed by GHD, 2014) but not documented.

Author (Date)	Title	Summary of Scope
HLA (September 2006)	Contamination Investigation at Defence Integrated Distribution System Sites, Joint Logistics Unit (South Queensland) Bulimba Barracks, Apollo Road, Brisbane, Queensland.	Investigation of contaminating activities relating to site use by Tenix Toll. Three ASTs were identified, and four USTs. Other sources of potential contamination identified included storage and use of fuel and other chemicals, leaks from parked vehicles, use of a wash bay, abrasive blasting activities, and imported fill materials. Eight groundwater monitoring wells were installed. Some metals impacts were identified in shallow soils. Low levels of hydrocarbon impact were detected in shallow soil near the C001 AST, and elevated hydrocarbons were detected near the UST and refuelling point near D008 (later remediated (Lambert & Rehbein, 2012)).
EarthTech, subcontracted by QHSS (August 2007)	Installation of Two Groundwater Monitoring Wells – Bulimba Barracks, Bulimba (Letter Report). Provided as an appendix in the QHSS Environmental Tritium Contamination Report.	Two additional groundwater monitoring wells were installed close to Building C006 in support of the QHSS (2007) further environmental investigations of tritium. Tritium concentrations in groundwater were greater than background, but less than WHO drinking water guidelines.
QHSS (October 2007)	Environmental Tritium Contamination Report	Further investigation of tritium present in previous soil and pore water samples. Included sampling of surrounding surface soils, pore water and groundwater in the vicinity of Building C006. Results indicated tritium in shallow soils (0-100mm) and associated pore water. Concentrations were generally elevated immediately outside of doors, loading bays and access ways.
Lambert & Rehbein (February 2012)	Project SQ3181 Demolition of Above Ground Fuel Point Infrastructure & Removal of Underground Fuel Tanks and Associated Infrastructure at JLU-SQ Bulimba Barracks Facility.	Three USTs were removed (one 27kL diesel, and two 5.1kL ULP USTs) and the tank pits backfilled. Residual contamination was detected in the bowser area and potentially beneath the forecourt pavement.
Lambert & Rehbein (May 2012)	Project SQ2652 – Addendum 1 Report to Project SQ3181 – Additional Soil Sampling, Bulimba Barracks Facility.	Further investigation following the UST removals. Nine test pits were advanced west of the tank pit excavation. Exceedances of hydrocarbon guideline values were detected at 1.4-1.8mbgs at two locations.
Golder Associates (May 2013)	Environmental Investigations of USTs/ASTs across the Defence Estate, Stage 1 Report – Bulimba Barracks ("New" 0126).	Desktop review and site visit only, to identify all ASTs and USTs at the site. 1x300L diesel AST (Building B026), 1x5kL waste oil AST (Building D003), 1x2.5kL waste oil AST (Building C001), and 1x1kL-10kL diesel UST (Building C014) – noting three vent pipes, which may indicate three USTs present.

Author (Date)	Title	Summary of Scope
QHSS (July 2015)	Radiological Site Characterisation: Tritium GHD (Report No. 14PX278).	Reassessment of the radiological status of Building C006, including internal building assessment, soil, pore water and groundwater. Results were generally consistent with the 2007 investigation. Tritium concentrations were elevated in the Wet Prep Room fume cupboard and sink trap. These items were subsequently removed. Radiation signage (internal and external) was removed given QHSS were confident of low potential for radiological impact in and around Building C006. The report was submitted to Defence and ARPANSA to remove the building from the list of Defence radiological assets.
GHD (July 2015)	Department of Defence Bulimba Barracks Stage 1 Environmental Investigation (DEHP-ID-052).	The scope included a desktop review, site visit and personnel interviews in order to understand the potential contamination liability and environmental issues at Bulimba Barracks. No sampling was undertaken.

1. GHD (July 2015).

2.11 *PRELIMINARY CONCEPTUAL SITE MODEL*

The following preliminary Conceptual Site Model (CSM) was developed by GHD (2015), and subsequently revised in ERM's (2017) Sampling and Analysis Quality Plan (SAQP) to support sampling conducted Areas of Concern (AECs) and characterising general areas of the site during this Stage 2 DSI. AECs are shown on *Figure 2, Annex A*.

Table 4 Preliminary CSM

Source	Pathway	Receptor / SPR Linkage
Asbestos fragments in soil (buried building materials). *Throughout site.*	Inhalation of respirable asbestos fibres.	Intrusive maintenance workers, future construction workers. Future residents. **Potentially complete SPR linkage, given ACM present on site and historic activities.**
ASTs, USTs / former USTs, Hazmat Store (D007) and oil store (D010) (hydrocarbons, solvents). *AEC01, AEC02, AEC03, AEC04 & AEC13*	Hydrocarbon loss to soil, vertical migration to groundwater, vapour intrusion into buildings.	Intrusive maintenance workers, future construction workers, Brisbane River, on-site terrestrial ecosystem. Future residents. **Potentially complete SPR linkage, given likely age of remaining USTs and ASTs. Evidence of some hydrocarbon impact to soils surrounding former UST.**

Source	Pathway	Receptor / SPR Linkage
Buried waste (metals, hydrocarbons, solvents, nutrients). Potential areas of uncontrolled fill across the site. Possible buried domestic waste at Chinese Camp. *AEC11 & General Fill Across Site.*	Impact to soil in contact with waste materials. Vertical migration into groundwater. Vapour intrusion into buildings for VOCs.	Intrusive maintenance workers (direct contact) – current or future. Terrestrial ecosystems. Brisbane River. **Potentially complete SPR linkage, given previously detected imported fill (e.g. ash). Buried waste likely to be limited in extent.**
Sandblasting areas (radiation / metals). *AEC09 & AEC10*	Impact to shallow soils. Potential impact to surface water (impacted soil entrained in runoff). Vertical migration into groundwater.	Intrusive maintenance workers (direct contact) – current or future. Future residents. Terrestrial ecosystems. Brisbane River. **Potentially complete SPR linkage, if radiation levels are greater than background.**
Rifle Range (metals). *AEC07*	Shallow soil impact. Potential impact to surface water (impacted soil entrained in runoff). Vertical migration into groundwater.	Future residents. Terrestrial ecosystems. Brisbane River. **Potentially complete SPR linkage, if shallow soils have metals concentrations exceeding EILs / HILs.**
Wash Bay (solvents, hydrocarbons, metals). *AEC05 & AEC12*	Shallow soil impact. Vertical migration into groundwater. Vapour intrusion into buildings (VOCs).	Intrusive maintenance workers (current and future). Construction workers (future). Future residents. Brisbane River. **Potentially complete SPR linkage, but any impact expected to be localised to source.**
Paint shop (solvents, hydrocarbons, metals). *AEC08*	Shallow soil impact. Vertical migration into groundwater. Vapour intrusion into buildings (VOCs).	Intrusive maintenance workers (current and future). Construction workers (future). Future residents. Brisbane River. **Potentially complete SPR linkage, but any impact expected to be localised to source.**
Armoury (solvents, hydrocarbons, metals). *AEC06*	Shallow soil impact. Vertical migration into groundwater (especially near separator). Vapour intrusion into buildings (VOCs).	Intrusive maintenance workers (current and future). Construction workers (future). Future residents. Brisbane River. **Potentially complete SPR linkage,**
Electronics workshop (radiation, metals). *AEC10*	Shallow soil and pore water impact (radiation). Vertical migration into groundwater. Radiation in building materials.	Intrusive maintenance workers (direct contact) – current or future; or future construction workers. Future residents. Brisbane River. **SPR linkage unlikely to be complete based on 2012 data, but potential for**

Source	Pathway	Receptor / SPR Linkage
		minor 'hot spots' that have not been previously detected.
Truck parking area (hydrocarbons). *AEC14*	Shallow soil impact. Migration via surface run-off into open unlined drains. Vertical migration into groundwater.	Intrusive maintenance workers (direct contact) – current or future. Future residents. Terrestrial ecosystems. Brisbane River. **Potentially complete SPR linkage, but any impact expected to be localised to source, and unlikely to pose a vapour risk (residual hydrocarbon impact more likely to be associated with oil from parked trucks).**
Septic tank facilities north-east of C006 and north-west of B013 (nutrients, bacteria). *AEC15*	Shallow soil impact. Vertical migration into groundwater and potential migration and discharge to Brisbane River.	Intrusive maintenance workers (direct contact) – current or future; or future construction workers. Brisbane River. **Potentially complete SPR linkage, but any impact is likely to be localised and would decrease over time. Septic systems are understood to be no longer in use.**

1. GHD (2015).
2. ERM SAQP (2017).

Photographs of the site, including each of the potential AECs are presented in *Annex C*.

3 *DATA QUALITY OBJECTIVES*

Prior to commencement of the intrusive investigation works, Data Quality Objectives (DQOs) were established for the project. These DQOs were developed to define the type and quality of data required from the site assessment program.

The application of the seven-step DQO approach identified in the *National Environment Protection (Assessment of Site Contamination) Measure* (1999, amended 2013), which will be referred to herein as the "ASC NEPM", is presented in full in *Annex D*.

The DQOs were selected with reference to relevant guidelines in AS4482, and the ASC NEPM, which define minimum data requirements and quality control procedures.

4 *FIELDWORK*

4.1 *SCOPE OF WORK COMPLETED*

The proposed scope of work was successfully completed, with the exception of the changes outlined in *Table 5*, below.

In total, the number of sampling locations for various environmental media is as follows:

- 50 test pits – soil sampling (compared with 68 proposed test pits);
- 34 soil bores – soil sampling, with 2 installed as monitoring wells, and 5 combined as ASS sampling locations (compared with 36 proposed soil bores);
- 6 hand auger locations – soil sampling (compared with no proposed hand augers);
- 9 monitoring wells – soil and groundwater sampling, 3 of which were also sampled for ASS testing (compared with 9 proposed new monitoring wells);
- 13 sediment sample locations (compared with 28 proposed sediment sample locations); and
- 2 surface water (stormwater) sample locations (compared with 7 proposed surface water sample locations).

It should be noted that no radiological assessments were included as part of this scope of work, given that previous investigations by QHSS (most recently July 2015) have identified low concentrations of radiological materials. The reports were submitted to ARPANSA and Defence, and the facility is understood to have been removed from Defence's list of radiological assets.

In addition, 29 ASS investigation locations were advanced (including 5 locations combined with soil contamination sampling locations, and 3 locations combined with new monitoring well locations). The results of the ASS investigation have been reported separately, but this report has been included in *Annex E*.

A geotechnical investigation was also undertaken simultaneously in order to assess ground conditions, to support the future redevelopment of the site. Results from this investigation are provided in *Annex F*.

Table 5 Variations to Proposed Scope of Work

Area ID	Description of Use	Soil Sampling Locations	Groundwater Sampling Locations	Changes to Scope
AEC01	Underground storage tanks (USTs)	BMW10, BMW11	BMW10, BMW11	None – proposed scope completed.
AEC02	Former (USTs) - removed but residual impact	BSB01	BMW05, BMW06	None – proposed scope completed.
AEC03	Diesel AST (300L) inside B026 (Fire Booster Pump House)	BSB02, BSB03	-	BSB03 completed but also installed as monitoring well BMW13, as proposed location for BMW13 (closer to AEC07 Rifle Range) was not able to be cleared of underground services.
AEC04	Waste oil AST (5,000L) south of D003	BMW14	BMW14	None – proposed scope completed.
AEC05	Washbay and panel shop. Potential separator overflow	BSB04, BSB05, BSB06, BMW12	BMW12	BMW12 combined with BSB05.
AEC06	Armoury - use of caustic, phenols, degreasers, solvents	BSB07, BSB08, BSB09, BSB11	BMW04, BMW13	BHA01 added near interceptor. BMW13 installed closer to AEC03.
AEC07	Indoor rifle range - disposal and replacement of metals impacted sand (no sealed floor)	BSB12	BMW13	BMW13 installed closer to AEC03
AEC08	Paint shop - use and disposal of paints, thinners, solvents	BSB13	BMW12	BSB06 also located in close proximity (immediately west) of Paint Shop. BMW12 was moved further west to provide coverage for interceptor at Washbay. BMW04 (existing well) may be considered the closest cross/down-gradient well.
AEC09	Sandblasting area (C004) - sandblasting stockpiles (potential metals and radiation)	BSB14, BSB15, BMW12	BMW12	BMW12 combined with BSB005 and moved slightly west. Still providing coverage for AEC09.

Area ID	Description of Use	Soil Sampling Locations	Groundwater Sampling Locations	Changes to Scope
AEC10	Sandblasting & radioactive materials (C006)	BSB10/ASS23, BSB16, BSB17, BSB18, BTP39, BTP05	BMW09, BMW08, ETMW01, ETMW02	BSB16 not drilled, given that field observations determined that the proposed location comprised offices only. BTP39 replaced with a hand auger – BHA03 due to risk of encountering services with backhoe. BTP05 not completed due to presence of services, but BTP35 (proposed general location) moved closer to C006 to provide coverage. Monitoring wells ETMW01 and ETMW02 unable to be located – assume destroyed or covered by bitumen.
AEC11	Chinese Camp - potential buried materials	BTP47-BTP50, BTP56-BTP58	BMW07, BMW09, ETMW01	Clay pipe encountered near surface at BTP48 – location abandoned (no log or sampling). BTP49 not completed – backyard of Defence housing inaccessible by backhoe from Baldwin St. Locations BTP50 and BTP51 mistaken / switched. BTP51 replaces BTP50. BTP56 not completed – located along creek/drain line. Monitoring well ETMW01 unable to be located (assumed destroyed).
AEC12	Washbay (vehicles / boats)	TP44	BMW14	None – proposed scope completed.
AEC13	HazMat Store (D007) and Oil Store (D010)	BSB19, BSB20	BMW06	None – proposed scope completed.
AEC14	Truck Parking Area	BTP40-BTP46, BTP51-BTP55, BTP59-BTP61	BMW05, BMW06	BTP40 not completed due to presence of deep services in area. Locations BTP50 and BTP51 mistaken / switched. BTP50 replaces BTP51. Given buried materials identified at BTP50, additional test pits BTP50A and BTP50B also advanced 5m north and 5m south of the original BTP50. BTP54 not completed.
AEC15	Septic tank facilities	BMW16, BTP14	BMW16	BTP14 not completed due to presence of services. Hand auger BHA06 substituted. BHA05 also advanced (north of B013).

Area ID	Description of Use	Soil Sampling Locations	Groundwater Sampling Locations	Changes to Scope
General	Warehouses / workshops, background conditions & non-specific locations	BSB21-BSB36, BTP01-BTP04, BTP06-BTP38, BTP62-BTP68	BMW03, BMW15, BMW16, BMW17, BMW18	BTP07 not completed due to presence of underground services. BTP08-BTP10 and BTP17-BTP19 not completed due to proximity of comms lines. Replaced to achieve suitable coverage with BTP70-BTP72. BTP20 not completed due to open unlined drain with standing water that did not dry up during fieldwork. BTP23 not completed due to proximity of comms lines. BTP24 not completed due to presence of deep sewer line and other services. BTP27 replaced by BTP73. BTP30-BTP33 not completed due to presence of services, including comms lines. Coverage provided by BHA05, BMW15 and BMW16/ASS25.

In general, locations were moved, not completed or substituted to provide similar coverage due one or more of the following reasons:

- The presence of underground services;
- Inability to accurately locate communication cables due to lack of access to secure (locked) comms pits; and
- Heavy rainfall early in the fieldwork programme, resulting in pooled water in some locations (mainly close to open drains) and boggy conditions, which restricted access to some of the investigation plant.

4.2 SAMPLING METHODOLOGIES

4.2.1 *Soil Sampling*

All works were conducted in accordance with relevant ERM Standard Operating Procedures (SOPs). A summary of the procedures followed is provided below.

Soil samples were obtained from soil bores (advanced using non-destructive drilling (NDD) or hand auger, followed by push tubes, followed by solid flight augers or hollow stem augers, depending on conditions), test pits (advanced using a backhoe), and from hand augers.

Soil observations, including type and presence of staining, odours, buried materials and other relevant information were documented at each sampling locations. Soil samples were obtained for Photo-Ionisation Detector (PID) screening (to assist with selection of samples for laboratory analyses) at regular intervals. PID readings and soil logging data are provided in borehole logs presented in *Annex G*.

All soil samples were placed in ice-filled coolers and collected daily from site under chain of custody (COC) documentation by Eurofins|MGT (a NATA accredited laboratory). Triplicate samples were shipped under COC to ALS Laboratories (also NATA accredited) for analysis. Analytical suites for each sample were selected based on the current and/or historical activities undertaken in that area of the site.

4.2.2 *Groundwater Sampling*

All works were conducted in accordance with relevant ERM Standard Operating Procedures (SOPs). A summary of the procedures followed is provided below.

All existing and new monitoring wells were redeveloped, using disposable plastic bailers, to remove at least three well volumes. Development water was placed in lidded, labelled 20L drums.

A groundwater monitoring event (GME) was conducted on 18-19 December 2017. The GME scope included gauging, purging and sampling all existing and newly installed monitoring wells (BMW01, and BMW02-BMW18). Groundwater monitoring wells were gauged using an interface probe (IP), which was cleaned using a decontamination solution between each well.

Monitoring wells were purged using a peristaltic pump and dedicated low density polyethylene (LDPE) tubing. A water quality meter was used to record groundwater quality parameters during purging for all monitoring wells. Field parameters include temperature, pH, redox (Eh), electrical conductivity (EC), dissolved oxygen (DO) and TDS.

Following field water quality parameter stabilisation, groundwater was sampled. Groundwater samples were collected in laboratory supplied containers appropriate for the intended analyses and stored within coolers containing ice for transport to the laboratory. Samples were submitted to Eurofins|MGT, with the triplicate sample sent to NATA accredited laboratory, ALS Laboratories for analysis under chain of custody documentation.

Field data sheets are included in *Annex H*. Current gauging information is presented in *Table 3, Annex B* and inferred groundwater flow direction based on gauging data is presented on *Figure 5, Annex A*. Current field water quality data is presented in *Table 4, Annex B*.

4.2.3 Sediment Sampling

Sediment samples were obtained from accessible stormwater drains, using a stainless steel trowel (with extension pole, as needed). The trowel was decontaminated between sampling locations using Decon90 and tap water.

All sediment samples were placed in ice-filled coolers and collected daily from site under chain of custody (COC) documentation by Eurofins|MGT (a NATA accredited laboratory). Analytical suites for each sample were selected based on the current and/or historical activities undertaken in that area of the site.

It should be noted that a number of the proposed sediment sampling locations were identified as inaccessible upon further inspection during the site work. In most cases this was due to the proposed sampling locations being marked on a plan using a stormwater drain overlay. Some of the stormwater drains were piped and at depth (>4mbgs) and as such, were not safe to attempt to sample.

4.2.4 Surface Water Sampling

Surface water (stormwater) samples were obtained using a sampling pole or by sampling directly into unpreserved sample bottles (SW01). Field water quality parameters were recorded during sampling. Stormwater was only present during a significant rainfall event which occurred on 3-4 December 2017. Most of the proposed sampling locations were not accessible via a sampling pole. As such, limited samples were obtained (SW01 and SW08 were obtained from "upgradient" locations, and SW04 was obtained from a "downgradient" location).

It should be noted that on high tides, river water enters into the stormwater drains. Tidally influenced water was observed in a sewer pit located to the east of Building C001.

4.3 SOIL OBSERVATIONS

During subsurface activities, various filing materials were encountered across the site including:

- Road base gravels and sands;
- Ash / charcoal matrices (sand / gravel ash, charcoal, with some slag or clinker); and
- Potential cut and filled material (orange and white mottled clays).

Fill materials were generally present up to a maximum of 1.8mbgs.

The depths of fill materials encountered varied across the site and were generally present at more shallow depths at the south western portion of the site (between 0.25mbgs – 0.8mbgs).

A review of historical photos indicated the presence of a former swamp in the central western portion of the site (refer *Photograph 1*, below).

Photograph 1 Brisbane 1936 Aerial Photograph Showing Bulimba Barracks Swamp (Source: QImagery, Queensland Government).

Subsurface conditions encountered in this area were consistent with the historical imagery where high organics and peat materials were observed. Fill materials in this area were present up to a maximum thickness of 1.5mbgs. Refer to *Figures 4a-4b, Annex A*.

The natural soils generally comprised residual clays (orange and white silty and sandy clays) and marine clays (dark brown silty and sandy clays). Bedrock (siltstone or sandstone of the Neranleigh-Fernvale Formation) was encountered generally in the southern portions of the site, and outcropped at surface at some locations.

Ash and charcoal materials (sometimes containing clinker or slag) were encountered across the site at approximately 34 sample locations at thicknesses between 0.01m and 0.75m. The thickest ash layer (0.75m) was present at soil bore location BSB07 (in the centre of the site at AEC06 – Armoury). Refer to *Figure 10, Annex A*, for observed locations and thicknesses of ash.

4.4 SEDIMENT OBSERVATIONS

Various sediment sample materials were encountered across the site including:

- Gravels and sands;
- Organic leaf matter; and
- Silt.

Sediment samples were collected from shallow stormwater pits which were able to be accessed, as well as open, concrete lined drains. Sediment samples SED09, SED10, SED25 and SED26 were collected from stormwater pits, and comprised coarse sands and pebbles. Sediment samples SED06, SED14-SED18, SED20, SED27 and SED28 were collected from concrete lined open drains and comprised gravels, sands and silt.

4.5 SURFACE WATER OBSERVATIONS

Surface water (stormwater) samples were collected from sample locations SW01 and SW08 (upgradient) and SW04 (downgradient). Location SW01 is located at the inlet to a stormwater drain adjacent to the guardhouse near the southern entrance of the site. Location SW08 is located inside the southern boundary of the site (downgradient from SW01), where two stormwater lines merge. Location SW04 was obtained from the outlet of the drain along the northern boundary of the site at the point of discharge to the Brisbane River.

No sheen or odours were observed at any of the locations during sampling. Some foaming was observed at sample location SW04. This may have been due to the volume and rate of flow (as shown in *Photograph 61, Annex C*).

Based on the data collected during this investigation, the following surface water observations have been made:

- Electrical conductivity (EC) indicated fresh water runoff, ranging from 53.9µS/cm (SW01) to 907µS/cm (SW04);
- pH values indicated neutral to alkaline conditions, ranging from 7.17 (SW08) to 9.03 (SW01);
- Redox potential (Eh) indicated oxidizing conditions at SW04 (26.40mV) and SW08 (61.20mV), and reducing conditions at SW01 (-51.10mV);

- Dissolved oxygen (DO) values ranged from 0.22mg/L (SW08) to 6.04mg/L (SW01). The reducing conditions (observed as Redox potential) contrast with the highest DO values at SW01; and

- Total dissolved solids (TDS) values ranged from 36mg/L (SW01) to 579 (SW08).

Observations and field measurements indicate that SW04 may be influenced by tidal inflows from Brisbane River, and that conditions are more stable. In contrast, samples from upgradient locations SW01 and SW08 vary considerably and may represent different off-site conditions and sources (such as road runoff and/or domestic substances).

Surface water / stormwater sampling locations are shown on *Figure 3c, Annex A*. Field water quality parameters (for surface water and groundwater) are presented in *Table 4, Annex B*.

4.6 GROUNDWATER GAUGING

Groundwater gauging data collected from BMW01 and BMW03-BMW18 during field activities conducted 18-19 December 2017 are presented in *Table 3, Annex B.* During the current investigation, corrected groundwater elevations were encountered at depths ranging from -0.015 metres below Top of Casing (mbTOC) at BMW08 to 1.888 mbTOC at BMW18. Given that the site is immediately adjacent Brisbane River (mid-estuary), it is likely that groundwater is tidally influenced. The thickness of fill materials and presence of bedrock are also expected to exert local influence on groundwater flow direction. Groundwater is estimated to flow towards the north / north-west (refer to *Figure 5, Annex A*).

4.7 GROUNDWATER FIELD PARAMETERS

During gauging and groundwater sampling, the following observations were made:

- EC values ranged from 254.8µS/cm (BMW03) to 35,473µS/cm (BMW15). The highest values were detected at BMW15-BMW17, which are located along the northern site boundary adjacent Brisbane River. However, anomalously elevated values were also recorded at BMW01 (16,212 µS/cm) and BMW09 (11,267 µS/cm);

- Acidic pH values (<6.0) were detected at BMW01, BMW03-BMW07, BWM09 and BWM14, all of which are in the southern half of the site. Neutral pH values (6.0-7.0) were detected at BMW08, BWM10-BMW13, and BWM15-BMW18, which are located in the northern half of the site, closer to Brisbane River;

- Redox values indicated reducing conditions at BMW03, BMW05, BMW08, BMW12 and BWM16, ranging from -17.70mV at BWM03 to -41.60mV at BMW12. Oxidising conditions were recorded at all remaining wells, ranging from 5.30mV (BMW13) to 219.3mV (BMW07);

- DO values ranged from 0.18mg/L (BMW12) and 2.29mg/L (BMW15);

- TDS values ranged from 158mg/L (BMW03) to 23,666mg/L (BMW15);

- No Light Non-Aqueous Stage Liquid (LNAPL) was detected during this investigation; and

- No hydrocarbon odours or sheen were observed during purging and sampling activities.

Locations of monitoring wells are shown on *Figure 5, Annex A*. Field groundwater quality results are presented in *Table 4, Annex B*. Field data sheets are provided in *Annex H.*

4.8 OTHER NOTABLE FIELD OBSERVATIONS

Fill material observed during test pitting and soil boring appeared to be of 'native' origins, from the Bulimba area. Historical information (www.bulimbahistory.org/Photos/24/658, accessed 19 January, 2018) suggests that the material may have been sourced from the World War 2 era Bulimba Camp A location to the south. In addition, a significant volume of ashy / charcoal material (sometimes containing slag or clinker) has been imported, and spread at various thicknesses (ranging from 0.05m at BSB09, BSB26 and BSB28 to 0.67m at BSB21) across the site. In general, a thicker ash layer was observed at locations in the western portion of the site. Additional analyses were requested to assess whether the material may have been sourced from a gasworks or other industrial site. However, results (discussed in *Section 6.1*) do not support this theory. It is possible, instead, that the material came from the Bulimba Power Station, approximately 4 kilometres east of the site. Bulimba A Power Station (located on Gibson Island) commenced operation in 1926. As such, waste (ash) materials generated may have been imported to the Bulimba Barracks site to improve drainage during its development in the 1940s.

Buried materials encountered during the investigation included:

- Disposed rifle butts – possibly formerly used as training props were observed at test pit BTP50. Additional test pits (BTP50 North and BTP50 South) were advanced 5 metres to the north and south, respectively, in order to delineate the extent of the burial pit. No buried rifle butts were observed in the additional pits;

- A hardened resin or paint related substance was recovered from TP47A. This substance appeared to have been buried in a drum (which had subsequently rusted away). The waste material was excavated and placed into a drum and temporarily stored with investigation-derived waste (soil cuttings) drums prior to off-site disposal. A sample of the material was obtained (“WASTE”) for characterisation prior to disposal; and

- General demolition and construction waste, including clay pipes, steel beams and bricks.

No potential asbestos containing materials (ACM), such as fibrous cement sheeting fragments, were observed during test pitting or soil boring. However, small fragments of ACM (in the form of fibrous cement sheeting) were observed on the ground surface close to buildings during the Hazmat survey. These are most likely associated with previous ACM removal activities at the site.

Locations of the abovementioned test pits are shown on *Figure 3a, Annex A*. Refer to *Photographs 49-50* and *Photographs 52-53*, *Annex C*, showing the buried rifle butts and hardened resin material, respectively. Results of the waste characterisation sample (from BTP47A) are presented in *Tables 9a-9c, Annex B*.

5 *APPROACH TO ASSESSING CONTAMINATION IN QUEENSLAND*

The Department of Environment and Science (DES), formerly the Department of Environment and Heritage Protection (EHP) made changes to the way contaminated land is assessed and managed in Queensland from 30 September 2015. Guidance for contaminated land investigations is presented in the *Queensland Auditor Handbook for Contaminated Land – Module 5: Contaminated Land Investigation Documents, Auditor Certification and Compliance Assessment* (Queensland Government, September 2015). This guideline refers to the following relevant documents:

- *Environmental Protection Act 1994 (EP Act)*;
- *Environmental Protection (Water) Policy 2009 (EPP(Water))*;
- *Planning Act 2016*; and
- *National Environment Protection (Assessment of Site Contamination (ASC)) Measure* (NEPM) (1999).

Based on these guidelines, the screening levels (SLs) adopted for use for this investigation are outlined in the following sections.

5.1 *ENVIRONMENTAL VALUES AND WATER QUALITY OBJECTIVES*

Based on a review of the Preliminary CSM for the site (outlined in *Section 2.11*), and a review of the Draft Environmental Values (EVs) for the Brisbane River mid-estuary and proximal groundwater, the following EVs were considered:

- Aquatic ecosystems (Surface water and groundwater);
- Human consumer (Surface water only);
- Primary recreation (Surface water only);
- Secondary recreation (Surface water only);
- Visual recreation (Surface water only);
- Irrigation (Groundwater only);
- Farm supply and use (Groundwater only – noting that there are no farms or agricultural land use in this inner city area);
- Stock water (Groundwater only – as above, no agricultural land use in the area);
- Industrial use (Surface water only);

- Drinking water (Groundwater only – noting that due to the tidal effects from the Brisbane River, salinity is likely to be too high for human consumption in areas proximal to the site); and
- Cultural and spiritual values (Surface water only).

5.2 Soil Assessment Criteria

The assessment criteria adopted for soil considers the sites geology, current "Emerging Community" zoning (which identifies and conserves land suitable for urban development in the future). As such the following guidelines have been nominated for this investigation:

- ASC NEPM (1999) Health Screening Level (HSL)-A&B (Residential);
- ASC NEPM (1999) Health Investigation Level (HIL)-A (Residential with gardens);
- ASC NEPM (1999) Ecological Investigation Levels (EILs) for Urban residential and public open space;
- ASC NEPM (1999) Ecological Screening Levels (ESLs) for Urban residential and public open space (coarse); and
- ASC NEPM (1999) Management Limits for Residential, parkland and public open space (coarse).

Nominated SLs are summarised in *Tables 5a-5h, Annex B.*

5.3 Groundwater Assessment Criteria

The assessment criteria adopted for soil considers the sites geology, current "Emerging Community" zoning (which identifies and conserves land suitable for urban development in the future) and nearby receptors or groundwater users.

5.3.1 Human Health – Vapour Intrusion

ASC NEPM Groundwater Vapour Health Screening Levels (HSLs) have been applied to assess the risk of vapour intrusion to the most sensitive (future) on-site users (HSL-A&B – residential). The selection of groundwater SLs was based on depth to groundwater strike (generally 2-<4mbgs) and predominant soil type (silt) overlying the water-bearing unit.

5.3.2 Ecosystem Protection

The ASC NEPM Groundwater Investigation Levels (GILs) have been applied for the protection of marine ecosystems (given that Brisbane River mid-estuary is subject to tidal exchange). Where there are no specified GILs listed in ASC

NEPM, relevant ANZECC Low Reliability Trigger Values (LRTVs) have been applied.

As outlined in ASC NEPM *Schedule B6 – Guideline on The Framework for Risk-Based Assessment of Groundwater Contamination*, GILs are not intended to be clean-up levels. The decision on whether clean-up is required (and to what extent) should be based on site-specific assessment. Additionally, concentrations marginally exceeding GILs do not imply unacceptability or that a significant risk to human health or ecosystem is present. Groundwater should be assessed on the basis of its EVs and the risk that the current (or realistic future) use may pose to human health and/or the environment. With regard to realistic future uses, consideration should be given to the quality and yield of the aquifer, the likely demand for water resources in the vicinity of the site and technological practicalities.

5.3.3 Irrigation, Farm Use, Stock Watering and Human Consumers

The ANZECC guidelines have amalgamated agriculture, aquaculture and human consumers of aquatic foods into one environmental value called "Primary Industries", which is conservatively based on the drinking water guidelines multiplied by a factor of 10.

Whilst there are three registered bores within 500 metres of the site (all of which are hydrogeologically up-gradient), no clear use for extracted groundwater has been recorded. However, given the location of one of the bores (at a residential property), there is the potential that groundwater is currently being extracted for domestic irrigation.

There does not appear to be any nearby use of extracted groundwater for industrial purposes, given that there are no registered bores at the surrounding commercial / industrial properties.

The relevant trigger values for "Primary Industries" are presented in *Tables 6a-6e, Annex B*.

5.3.4 Recreational Use (Primary, Secondary and Visual)

The Brisbane River (mid-estuary) is commonly used for secondary uses such as boating, sailing, fishing, kayaking, jet-skiing and rowing. Visual recreational uses (viewing the river, or walking or picnicking adjacent the waterway) are also common. However, this reach of the Brisbane River is rarely used for primary recreational activities such as swimming, water-skiing or diving. As a conservative measure, in line with ANZECC guidance, drinking water guidelines multiplied by a factor of 10 have been applied.

5.4 SEDIMENT ASSESSMENT CRITERIA

The Revised Sediment Quality Guideline values (CSIRO, 2013) have been adopted for assessment of sediment quality. Revision of the Sediment Quality

Guideline Values (SQGVs) indicated good correlation between freshwater and marine effects based guidelines, meaning that the SQGVs are applicable to both ecosystem types. The SQG and SQG-High values are presented in *Tables 7a-7c, Annex B*.

5.5 SURFACE WATER ASSESSMENT CRITERIA

Based on the EVs identified for the Brisbane River mid-estuary, outlined in *Section 5.1*, adopted assessment criteria are outlined in the sections below.

5.5.1 *Aquatic Ecosystem Protection*

The ANZECC Marine Ecosystem protection trigger values have been applied given that Brisbane River mid-estuary is subject to tidal exchange. LRTVs have been applied where high reliability values are not available.

5.5.2 *Human Consumers*

The ANZECC guidelines have amalgamated agriculture, aquaculture and human consumers of aquatic foods into one environmental value called "Primary Industries", which is conservatively based on the drinking water guidelines multiplied by a factor of 10.

Recreational fishing from the banks of the Brisbane River, from jetties, or from small boats is a common occurrence along the Bulimba reaches of the Brisbane River.

5.5.3 *Cultural and Spiritual Values*

Cultural and spiritual values of water are described as its aesthetic, historical, scientific, social or other significance, to the present generation or past and future generations. Given the disturbed nature of the river and riverbanks, and lack of known indigenous heritage sites along the northern boundary of the site, the primary cultural and spiritual values of the Brisbane River adjacent the site may be:

- The site's Defence heritage, associated with World War II and US Army presence in Brisbane (extending the Bulimba heritage trail) – such as the heritage boat ramp; and

- Brisbane River as a means of transportation and community hub (walking or meeting along the river bank).

As such, the recreational guidelines (as outlined in *Section 5.3.4*, above), relevant to visual amenity, have been applied.

Nominated SLs are summarised in *Tables 8a-8d, Annex B.*

6 ANALYTICAL RESULTS

6.1 SOIL ANALYTICAL RESULTS

6.1.1 *Hydrocarbon Compounds*

A total of 119 soil samples were selected for analysis of Total Recoverable Hydrocarbons (TRH) and/or Benzene, Toluene, Ethylbenzene, Xylenes and Naphthalene (BTEXN). Exceedances of the ASC NEPM ESL for residential and open space (coarse) value for TRH >C16-C34 (F3 fraction) (300mg/kg) were detected in the following samples:

- BSB25_0.2 (350mg/kg);
- BTP34_0.3 (600mg/kg);
- BSB25_0.5 (420mg/kg);
- BSB05/MW12_1.0 (1,000mg/kg); and
- BTP43_1.0 (390mg/kg).

There were no exceedances of BTEXN compounds in any of the samples analysed.

6.1.2 *Metals*

Of the 152 soil samples analysed, 144 were analysed for the NEPM suite of 13 metals (arsenic, beryllium, boron, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium and zinc). One was mistakenly analysed for a slightly smaller suite (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc). Seven samples were analysed for lead only.

One sample reported arsenic concentrations exceeding the ASC NEPM EIL for residential and open space, and the ASC NEPM HIL for residential use with gardens (BHA02_0.5, with a concentration of 180mg/kg, located adjacent the Metal Shop (C005)). Four soil samples recorded lead concentrations exceeding the ASC NEPM HIL for residential use with gardens, as follows: BHA02_0.2 (400mg/kg, Metal Shop), BSB09_1.65 (370mg/kg, Armoury), BSB12A_0.1 (350mg/kg, Rifle Range), and BTP12_0.5 (790mg/kg, Parade Ground, fill).

The National Environment Protection Council (NEPC) *National Environment Protection (Assessment of Site Contamination) Measure 1999 (ASC NEPM) – Schedule B1 – Guideline on Investigation Levels for Soil and Groundwater* requires, as a minimum, that the maximum concentrations and the 95% Upper Confidence Limit (UCL) of the arithmetic mean contaminant concentration should be compared to the Tier 1 screening criteria.

The concentration of lead in soil reported at BTP12 located at the Parade Ground at a depth of 0.5mbgs exceeded the ASC NEPM HIL-A&B and is considered to be representative of a 'hot spot' as the concentration is greater than 250% of the HIL-A&B. The sample was associated with fill material (clay soils) consistent with other samples collected from the Parade Ground and there was no specific identifiable source of lead.

The concentrations of metals in all other soil samples were below the ASC NEPM (2013) HIL-A&B with the exception of arsenic and lead in the vicinity of the Armoury (Building C007), Rifle Range (Building C008) and Metals Shop (Building C005). Statistical analysis of the data demonstrated that the elevated concentrations of metals were not representative of 'hot spots'. The maximum concentration of lead and arsenic was less than 250% of the HIL-A&B; the arithmetic mean and the 95% Upper Confidence Limit (UCL) were less than the HIL-A&B; and the standard deviation was less than 50% of the HIL-A&B (excluding BTP12_0.5).

Six soil samples representative of the different soil types observed at site were selected for analysis of the NEPM soil classification suite (iron, cation exchange capacity, pH, total organic carbon, % clay and electrical conductivity). These parameters are generally used to derive ambient background soil concentrations (ABCs) so that more relevant / site specific EILs can be developed. However, given the limited number of exceedances of the default EILs, and that the concentrations of arsenic and/or lead in these samples were at least 20% greater than the default EIL, development and application of site specific EILs would not change the outcome of the investigation.

Five samples containing ash or charcoal fill material were selected for further analysis (total cyanide, free cyanide and phenols) to assess whether the fill material was associated with gasworks waste. No cyanide or phenols were detected in any of the samples. As such, it is assessed to be unlikely that the fill material was imported from a gasworks site.

Further analyses were requested for the four samples where exceedances of adopted ILs were detected. The four samples outlined above were submitted to Eurofins|MGT for analysis of Australian Leaching Procedure (ASLP) and USA Leaching Procedure (TCLP) for Lead (all samples), and Arsenic (BHA02_0.2 only). Results were assessed against Queensland lined and unlined landfill disposal acceptance criteria (to assist with development of remedial options). All sample results were below both the lined and unlined criteria, following leaching with slightly acidic (representative of rainwater) leach, and acidic (representative of landfill conditions) leach, with the exception of BSB12A_0.1. The concentration of Lead in the resulting leachate fluid for this sample exceeded both the lined and unlined criteria, meaning that soil would require treatment (application of soil amendment) prior to disposal at a landfill. This sample was obtained from shallow fill material adjacent to the butt stop of the rifle range (AEC07). Metals leachate results are presented in *Table 5i, Annex B*.

Given that lead concentrations in shallow soil obtained from adjacent the stop butt of the Rifle Range (BSB12A_0.1) were confirmed as being leachable (under acidic and neutral conditions), this potential source of metals should be remediated, removed and residual soils validated.

Exceedances are presented on *Figure 6, Annex A*. Results have been tabulated in *Table 5b, Annex B*. Laboratory analytical certificates are provided in *Annex J*.

6.1.3 Nutrients

Eleven soil samples were selected from AEC11 (Chinese Camp) for analysis of a suite of nutrients (nitrogen and phosphorus compounds), that may be present as a result of buried organic waste. Kjeldahl Nitrogen (TKN) is the sum of total organic nitrogen and total ammonia. Concentrations of TKN ranged from 38mg/kg (BSB32/ASS05_3.0) to 530mg/kg (BTP57_1.0). Given that the TKN concentration was equal to the Total Nitrogen concentration in all but one sample (BHA03_0.5), it appears that there was generally no ammonia present. Nitrate and nitrite concentrations (sum as nitrogen) were all below the laboratory LOR. Phosphorus concentrations ranged from 57mg/kg (BTP58_0.8) to 340mg/kg (BTP58_0.5).

Given the insignificant variations between samples, there were no indications of residual buried organic materials. Evidence of former/historic toilet facilities (clay pipework and foundations indicating very small rooms) were observed in the area between BTP57 and BTP58 at AEC11. Nutrient concentrations do not appear to be significantly higher in this area than other parts of the site.

Results are presented in *Table 5c, Annex B*.

6.1.4 Polycyclic Aromatic Hydrocarbons and Phenols

A total of 94 soil samples were selected from AEC01-AEC06, AEC12-AEC14, general warehouse locations and general site locations for polycyclic aromatic hydrocarbon (PAH) analysis. No PAHs were detected above the laboratory LORs in any of the samples analysed.

A total of 82 soil samples were selected from AEC04-AEC06, AEC13-AEC14 and general warehouse locations for Phenols analysis. No Phenols were detected above the laboratory LORs in any of the samples analysed.

Results are presented in *Table 5d, Annex B*.

6.1.5 Organochlorine Pesticides

A total of 29 soil samples were selected for analysis of Organochlorine Pesticides (OCPs). Results were below the laboratory LORs for all OCP compounds, with the exception of Methoxychlor, which was detected marginally above the LOR (but below the adopted screening criteria) in sample BHA02_0.2, north of the Metal Shop (Building C005).

6.1.6 *Volatile Organic Compounds*

Twelve soil samples were selected from AEC05-AEC06, AEC08 and AEC12 for analysis of volatile organic compounds (VOCs). No VOCs were detected above the laboratory LORs in any of the samples analysed.

Results are presented in *Table 5f, Annex B*.

6.1.7 *Biological*

Four soil samples from adjacent (former) septic tank facilities (AEC15) for analysis of Coliforms and E. Coli (thermotolerant coliforms). No E. Coli was detected above the laboratory LOR. Coliforms (non-thermotolerant) were detected in all samples, with elevated concentrations in samples obtained from 1.0mbgs adjacent both septic systems. The soil samples obtained from 2.0mbgs at each location were two or three orders of magnitude lower. No screening levels were available for assessment.

Results are presented in *Table 5g, Annex B*.

6.1.8 *Asbestos*

A total of 63 soil samples from test pits around the site were submitted for analysis of asbestos in soil (WA and NEPM guidelines). No asbestos was detected at the reporting limit of 0.001%w/w in any of the samples analysed. No respirable fibres were detected in any samples.

Results are presented in *Table 5h, Annex B*.

6.2 *GROUNDWATER ANALYTICAL RESULTS*

There were reportedly 10 existing monitoring wells on site (BMW01, BMW03-BMW09, ETMW01 and ETMW02), but ETMW01 and ETMW02 were unable to be located. ERM installed nine additional wells (BMW10-BMW18). As such a total of 17 monitoring wells were sampled and results are presented below.

6.2.1 *Hydrocarbon Compounds*

Eight of the 17 monitoring wells were selected for analysis of TRH and BTEXN. No TRH or BTEXN compounds were detected above laboratory LOR in any of the samples analysed.

Results are presented in *Table 6a, Annex B*.

6.2.2 *Metals*

A total of 11 of the 17 monitoring wells were analysed for the NEPM suite of 13 metals (total and dissolved) (arsenic, beryllium, boron, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium and zinc). A further five samples were analysed for total and dissolved lead only. All 16 samples analysed for metals were also analysed for Hardness, so that ANZECC Hardness Modified Trigger Values (HMTVs) may be applied, where relevant. HMTVs were calculated for copper, nickel and zinc and these values are presented below the main table in *Table 6b, Annex B*.

Exceedances of the ANZECC marine trigger values (TVs) (or HMTVs, where applicable) were detected as follows:

- BMW03 (upgradient / background well) – dissolved copper (6ug/L) and dissolved selenium (4ug/L);
- BMW07 (upgradient of AEC11 and AEC14) – dissolved nickel (56ug/L) and dissolved zinc (300ug/L);
- BMW08 (downgradient of AEC10) – dissolved arsenic (18ug/L); and
- BMW09 (downgradient of AEC11) – dissolved arsenic (4ug/L).

Given that all the exceedances were less than one order of magnitude greater than the TVs or HMTVs (with the exception of the dissolved zinc exceedance at BMW07), it is considered unlikely that any of the metals concentrations are truly representative of a contamination-related 'hot spot'. Exceedances may relate to the local geology (particularly the clays) present.

There were no exceedances of the "Primary Industries" (or recreational) guideline values.

Results are presented in *Table 6b, Annex B*. Exceedances are represented on *Figure 7, Annex A*.

6.2.3 Nutrients

Three groundwater samples (BMW07, BMW09 and BMW16) were selected for analysis of a nutrient suite (comprising nitrogen and phosphorus compounds). Total nitrogen concentrations exceeded the ANZECC TVs for South-East Australian estuaries in all three samples, ranging from 0.74mg/L (BMW07 – upgradient of AEC11 and AEC14) to 13mg/L (BMW16 – downgradient / adjacent one of the septic tanks of AEC15). Concentrations of Nitrite and Nitrate (as N) exceeded the ANZECC TVs for South-East Australian estuaries in two of the samples, BMW07 (0.24mg/L) and BMW09 (0.21mg/L). Ammonia (as N) exceeded the ANZECC TVs for South-East Australian estuaries in two of the samples, BMW09 (3.2mg/L) and BMW16 (11mg/L). Reactive phosphorus was not detected above the laboratory LOR in any of the samples, but phosphate was detected in BMW09 and BWM16. Overall, nitrogen compound concentrations were an order of magnitude greater in the groundwater sample from BMW16 (adjacent a septic tank).

One groundwater sample (BWM16) was also submitted for analysis of coliforms and E.Coli (thermotolerant bacteria). No E.Coli was detected above the laboratory LOR, but the concentration of coliforms (20,000 organisms per 100mL) exceeded the recreational guideline value for health (which is 1,000 organisms per 100mL). Coupled with the elevated coliform concentrations in soil samples from a depth of 1.0mbgs at proximal location (near the northern septic system), this result may indicate historic or current leakage from the septic tank located adjacent Brisbane River.

Results are presented in *Table 6c, Annex B*. Exceedances are represented on *Figure 7, Annex A*.

6.2.4 Volatile Organic Compounds

Two groundwater samples (BMW04 and BMW12) were selected for analysis of VOCs. No VOCs were detected above the laboratory LORs in either of the samples.

Results are presented in *Table 6e, Annex B*.

6.3 SEDIMENT ANALYTICAL RESULTS

Sediment samples (13 in total) were obtained from accessible locations in open or grated stormwater drains, as shown on *Figure 3c, Annex A*. Analytical results are presented below.

6.3.1 Hydrocarbon Compounds

All 13 sediment samples were analysed for TRH and BTEXN. Concentrations of TRH >C10-C36 (Total TRH) exceeded the ANZECC SQG (Low) of 280mg/kg in sediment samples SED10 (387mg/kg) and SED28 (880mg/kg). Total TRH concentrations at SED28 also exceeded the ANZECC SQG (High) value of 550mg/kg.

No BTEXN compounds were detected above the laboratory LORs in any of the samples analysed.

Results are presented on *Table 7a, Annex B*. TRH exceedances are shown on *Figure 8, Annex A*.

6.3.2 Polycyclic Aromatic Hydrocarbons and Phenols

Eight groundwater samples (from locations proximal to AEC01, AEC02, AEC04, AEC05, AEC06, AEC12 and AEC13) were submitted for analysis of PAHs. Four groundwater samples (from locations proximal to AEC05, AEC06, AEC13 and AEC14) were submitted for analysis of Phenols. No PAHs and no Phenols were detected above the laboratory LORs in any of the samples analysed.

Results are presented in *Table 6d, Annex B*.

6.3.3 *Metals*

All 13 sediment samples were analysed for the NEPM suite of 13 metals (arsenic, beryllium, boron, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium and zinc).

Arsenic concentrations exceeded the ANZECC SQG (Low) value in all but three samples (SED06, SED09 and SED25). Concentrations of samples with exceedances ranged from 10mg/kg (SED28) to 51mg/kg (SED16). There were no exceedances of the ANZECC SQG (High) value for arsenic.

Cadmium concentrations exceeded the ANZECC SQG (Low) value in two samples, SED10 (2mg/kg) and SED28 (6.3mg/kg). There were no exceedances of the ANZECC SQG (High) value.

Copper concentrations exceeded the ANZECC SQG (Low) value in four samples, ranging from 66mg/kg (SED27) to 180mg/kg (SED28). There were no exceedances of the ANZECC SQG (High) value.

Lead concentrations exceeded the ANZECC SQG (Low) value in eight of the 14 sediment samples, ranging from 57mg/kg (SED10) to 240mg/kg (SED28). Concentrations at SED28 also exceeded the ANZECC SQG (High) value.

Nickel concentrations exceeded the ANZECC SQG (Low) value in two samples, SED10 (54mg/kg) and SED26 (24mg/kg). Concentrations at SED10 also exceeded the ANZECC SQG (High) value.

Zinc concentrations exceeded the ANZECC SQG (Low) value in eight of the 14 sediment samples, ranging from 240mg/kg (SED06) to 25,000mg/kg (SED28). Zinc concentrations in five of the samples also exceeded the ANZECC SQG (High) value of 410mg/kg.

In general, the highest concentrations (and greatest number of exceedances) were detected in sample locations along the western site boundary (SED26-SED28) and downgradient of AEC10 (Sandblasting and Radiation Lab).

Exceedances are shown on *Figure 8, Annex A*, and results are presented on *Table 7b, Annex B*.

6.3.4 *Polycyclic Aromatic Hydrocarbons and Phenols*

All 13 sediment samples were analysed for PAHs and Phenols. Concentrations were below the laboratory LORs in all samples.

Results are presented in *Table 7c, Annex B*.

6.4 *SURFACE WATER ANALYTICAL RESULTS*

Three surface water samples were obtained from accessible stormwater drains, when flowing (following rainfall events).

6.4.1 *Hydrocarbon Compounds*

All three surface water samples were analysed for TRH and BTEXN compounds. TRH C6-C10 less BTEX (F1) concentrations were detected above the laboratory LOR in SW01. TRH >C16-C34 (F3) concentrations and TRH >C34-C40 (F4) concentrations were detected in SW08.

No BTEXN compounds were detected in any of the surface water samples.

Results are presented on *Table 8a, Annex B*.

6.4.2 *Metals*

All three surface water samples were analysed for the NEPM suite of 13 metals (total and dissolved), and for hardness, so that HMTVs could be calculated.

Concentrations of dissolved zinc exceeded the ANZECC HMTVs at SW04 and SW08.

Exceedances are presented on *Figure 9, Annex A*. Results are provided in *Table 8b, Annex B*.

6.4.3 *Nutrients*

Two surface water samples (SW01 and SW04) were analysed for nutrients (nitrogen and phosphorus compounds). Total nitrogen concentrations exceeded the ANZECC TVs for South-East Australian Estuaries at SW04 (0.5mg/L). Nitrite and Nitrate (as N) concentrations exceeded the ANZECC TVs for South-East Australian Estuaries in both SW01 (0.1mg/L) and SW04 (0.23mg/L).

Exceedances are presented on *Figure 9, Annex A*. Results are provided in *Table 8c, Annex B*.

6.4.4 *Polycyclic Aromatic Hydrocarbons and Phenols*

All three surface water samples were analysed for PAHs. Samples SW01 and SW04 were also analysed for Phenols. No PAHs or Phenols were detected above the laboratory LORs in any of the samples analysed.

Results are presented on *Table 8d, Annex B*.

6.5 *WASTE CHARACTERISATION*

One sample (WASTE) was obtained from the buried substance (paint or resin type material) encountered in test pit TP48A, which was located in the north-western portion of AEC11 (Chinese Camp). The sample was analysed for BTEX, Metals and VOCs for waste characterisation purposes and assess the potential for associated contamination.

No BTEX compounds were detected above the laboratory LORs. A number of metals were detected at elevated concentrations, notably, arsenic (180mg/kg), cobalt (52mg/kg), copper (470mg/kg), manganese (1,500mg/kg) and nickel (290mg/kg).

No VOCs were detected above the laboratory LORs.

USA Leaching Procedure (TCLP) was requested for metals. Metals concentrations in the leachate did not exceed the Queensland lined or unlined landfill disposal criteria. As such, the waste material is suitable for landfill disposal without treatment.

Results are presented in *Tables 9a-9c, Annex B*.

7 QUALITY ASSURANCE AND QUALITY CONTROL

The quality of analytical data produced for this project has been assessed with reference to the following aspects:

- Sample technique;
- Preservation and storage of samples upon collection and transport to the laboratory;
- Sample holding time;
- Analytical procedure;
- Laboratory LOR;
- Field duplicate agreement;
- Field blanks and trip blanks;
- Laboratory QA procedures; and
- The occurrence of apparently unusual or anomalous results.

A review of QA/QC procedures and controls is presented in *Annex K*.

Although the data indicates some RPDs outside of the acceptable range and anomalous laboratory QA/QC tests, overall the quality assessment completed suggests the dataset is acceptable and may be used to meet the objectives of this assessment.

8 REVISED CONCEPTUAL SITE MODEL

A conceptual site model (CSM) is the qualitative description of plausible mechanisms by which human and/or environmental receptors may be exposed to site impact. For exposure to be considered possible, some mechanism ('pathway') must exist by which impact from a given source can reach a given receptor. This is classed as a source-pathway-receptor (SPR) linkage.

The zones of contamination that have been detected at the source areas across the site are depicted in *Figures 6-10, Annex A,* inclusive.

Based on the findings presented in this report, the following section presents a summary of potential/likely impact sources, exposure pathways and receptors.

8.1 SETTING

The site is owned by the Department of Defence, and has a long history of a combination of commercial / industrial uses (the Apollo Candle Works, 1881-pre-World War 2), residential use (pre- and during World War 2), then commercial/ industrial uses associated with military operations (fabrication, welding, maintenance, fuel storage, etc). More recently, the site was used for five ERAs – Abrasive blasting, Metal surface coating, Fabricating sheet metal, Motor vehicle workshop and Wood product manufacture. However, the site is currently non-operational (other than administrative, storage and training related activities). The site is primarily surrounded (to the west, south and east) by residential properties.

The site surface is generally very flat, and has been cut into bedrock along the southern boundary. The static water level (SWL) was variable across the site, which appears to be influenced by the tidal nature of the Brisbane River estuary (in northern parts of the site), by the presence of bedrock (in southern parts of the site), and by the irregularity of fill material thickness and type throughout the site. However, groundwater flow direction is expected to be generally towards the north. Potential receptors can be summarised as follows:

- Surface water bodies (estuarine ecological environment – Brisbane River);
- Current and future recreational river users (secondary recreation – boating, sailing, fishing, jet-skiing, kayaking);
- Potential (current / future) groundwater users (domestic irrigation or car washing, potable use, swimming pool filling, and commercial / industrial use);
- Current or future intrusive maintenance or construction workers (maintenance workers, pre-divestment; or construction workers);
- Future commercial / retail workers;

- Future low- to medium-density residents;
- Future recreational users (parks and open spaces); and
- Current and future off-site residents.

Potential off-site sources of contamination associated with selected heavy metals, hydrocarbons, nutrients and pesticides include the general urban / residential surrounds, roads and road runoff.

The geology underlying the site comprised residual clays (orange and white silty and sandy clay) and marine clay. These soils were in turn underlain by sandstone, siltstone or mudstone associated with the Neranleigh-Fernvale Formation.

The natural soils were overlain by varying thicknesses of fill material (up to 1.8m thick), which appears to have been locally sourced (from off-site, but from the Bulimba area) and comprises silty and sandy orange and white mottled clays. Thicker areas of fill were present in the central western portion of the site, which used to be a swamp (pre-World War 2 development). In addition, some areas had (road base) gravel and sand fill material. Ash / charcoal fill (with occasional slag or clinker) was present in a relatively thin but variable layer (0.01-0.75m in thickness) across much of the site and was likely placed to improve drainage conditions. The water-bearing unit was generally encountered at approximately 2.0-3.0mbgs.

8.2 SOURCES

Potential sources of contamination (on-site) relate to the various commercial / industrial activities that have occurred, and also to various imported fill materials previously placed on the site. Potential Areas of Environmental Concern (AECs) that were investigated are outlined in *Table 4* (*Section 2.11*). The following list of AECs has been revised to only include areas / sources where contaminants exceeding adopted screening criteria have been detected.

Table 6 Revised Potential Source Zones (AECs) Based on Results

Area of Environmental Concern	Current / Historical Activities	Detected Contaminants (Exceeding Adopted SLs / ILs)
AEC01 – USTs	One diesel underground storage tank (possibly up to three tanks in total, given three vent pipes, remaining in situ).	Lead, Zinc (sediments).
AEC03 - AST	Above-ground fuel storage and operation of a generator and pump associated with a water tank.	TRH >16-C34 (F3) fraction (soil: 0.3m)
AEC04 – AST	Waste oil AST (5kL).	TRH >C10-C36, Arsenic, Cadmium, Copper, Lead, Zinc (sediments).
AEC05 – Washbay and Panel Shop	Vehicle washbay, with associated interceptor, and panel / repair shop.	TRH >C16-C34 (F3) fraction (soil: 1.0m). Arsenic, Copper, Lead, Nickel, Zinc (sediments).
AEC07 – Rifle Range	Practice firing range (indoor) with stop butt.	Lead (soil: 0.1m). Lead was also leachable in both neutral and acidic conditions.
AEC08 – Armoury	Armoury and weapons workshop.	Lead (soil: 1.85m)* (may be from shallower fill material that was pushed down into the borehole during drilling).
AEC10 – Sandblasting and Radiation	Sandblasting booth, electronics workshop and radio repairs. Maintenance and repair of Gaseous Tritium Light Devices (GTLD).	Dissolved arsenic (groundwater) Arsenic, Cadmium, Copper, Lead, Nickel, Zinc (sediments).
AEC14 – Truck Parking Area	Former truck and heavy vehicle parking area (unsealed/ gravel surface, with open drains topped with wooden grates).	TRH >C16-C34 (F3) fraction (soil: 1.0m). Arsenic, Lead, Zinc (sediments).
AEC15 – Septic Tank General Workshop Areas	Septic tank associated with Building B013. No longer connected but remaining in situ. Vehicle maintenance and repair activities, warehouse storage.	Coliform (groundwater) TRH >C16-C34 (F3) fraction (soil: 0.2m, 0.6m). Dissolved copper (groundwater), Dissolved selenium (groundwater).
General Site – Fill Materials	Ash / charcoal and local (imported) fill material.	Lead (soil: 0.6m)
Building C005 – Metal Shop	Metal items welding and fabrication.	Arsenic (soil: 0.2m), Lead (soil: 0.2m). Arsenic, Zinc (sediments)

In summary, sources of contaminants identified (where exceedances of adopted screening criteria) on site are associated with:

- Oils and lubricants from truck parking and vehicle maintenance (shallow soils <1.0mbgs);

- Lead and Arsenic associated with imported fill material (shallow soil, occasional 'hot spots,' generally <1.0mbgs);
- Lead associated with spent bullets at in and around the Rifle Range (shallow soil <0.5mbgs);
- Dissolved metals (arsenic near the Sandblasting and Radiation Lab; nickel upgradient of the Truck Parking Area and Chinese Camp; Copper and Selenium upgradient of vehicle maintenance workshops) in groundwater, (approximately 2.0mbgs);
- Ammonia and Nitrogen (Nitrite and Nitrate) potentially associated with buried waste in the vicinity of the Chinese Camp (groundwater);
- Coliform, Ammonia and Nitrogen (Nitrite and Nitrate) associated with the septic tank north of Building B013, adjacent Brisbane River (groundwater);
- Total TRH (>C10-C36 fraction), Arsenic, Lead and Zinc in sediments accumulated in stormwater drains around and downgradient of the Truck Parking Area;
- Arsenic, Cadmium, Copper, Lead, Nickel and Zinc in sediments accumulated in stormwater drains proximal to the Washbay and Panel Shop, the Sandblasting and Radiation Lab, and the Armoury;
- Zinc and Nitrogen (Nitrite and Nitrate) in stormwater, both upgradient (entering the site) and at the downgradient point of discharge into Brisbane River, potentially associated with road runoff and general urban environment.

8.3 SOURCE-PATHWAY-RECEPTOR LINKAGES

An SPR linkage is considered complete when a pathway links a source with a receptor. These linkages explain when there may be risks to the receptor, either now or in future. SPR linkages considered potentially complete are detailed in *Table 7*, below. The potential level of risk (high, medium or low) to the identified receptor associated with a complete SPR linkage for future low-to medium-density residential use (without remediation or management) has also been estimated.

Table 7 Considered SPR Linkages and Potential Future Risks

Source	Transport Mechanism / Pathway	Receptor	Potentially Complete?	Future Use Risk Ranking
Hydrocarbon impacted soil (shallow)	Uptake of petroleum hydrocarbons by plants / terrestrial ecosystems	Future on-site terrestrial ecosystems (urban residential & open space)	Not currently, given the site has not yet been developed for residential use. Remediation or management required prior to residential use.	Low. Some level of disturbance, resulting in dilution and potential biodegradation during construction works likely.
Heavy metals impacted soil (shallow), including imported fill materials	Ingestion of soil or ingestion of plants (vegetables, etc) grown on site by human residents.	Future on-site residents.	Not currently, given the site has not yet been developed for residential use. Remediation or management required prior to residential use.	Medium. Associated with Parade Ground hot spot (lead concentrations) and Rifle Range stopbutt soil impact (due to lead leachability) only.
Heavy metals impacted soil (shallow), including imported fill materials	Leaching of lead from soil, into either surface water (shallow soils) and/or groundwater (via vertical migration).	Current and future Brisbane River estuarine organisms	Not currently complete – no exceedances of lead in groundwater detected.	Low. Associated with Parade Ground hot spot (lead concentrations) and Rifle Range stopbutt soil impact (due to lead leachability) only, which are some distance away from Brisbane River.
Total petroleum hydrocarbons and heavy metals in sediments	Uptake by sediment-dwelling organisms or mobilisation via stormwater into Brisbane River	Current and future Brisbane River estuarine organisms (depending on bioavailability)	Yes – potential for impacted sediments to be mobilised and discharged into Brisbane River.	Medium. Current and potential future risk due to potential for mobilisation of sediments in stormwater discharges directly to Brisbane River.
Dissolved metals in groundwater	Migration and discharge of impacted groundwater into Brisbane River, affecting the estuarine ecosystem.	Current and future Brisbane River estuarine organisms	Not currently complete – no exceedances of dissolved metals TVs in monitoring wells closest to Brisbane River.	Low. Minor ecological exceedances (likely reflective of background geology) unlikely to have significant impact via low volume discharge to large tidal water body (Brisbane River).
Nutrients (nitrogen based) in groundwater	Migration and discharge of impacted groundwater into	Current and future Brisbane River estuarine organisms	Not currently complete – no exceedances of nitrogen compound TVs in monitoring wells closest to Brisbane River.	Low.

Source	Transport Mechanism / Pathway	Receptor	Potentially Complete?	Future Use Risk Ranking
	Brisbane River, affecting the estuarine ecosystem.			Small relative volume of nutrients in groundwater gradually discharging into Brisbane River.
Bacteria (coliform) impacted groundwater	Migration and discharge of impacted groundwater into Brisbane River, affecting the estuarine ecosystem.	Recreational users of Brisbane River (human health)	Yes – potentially complete, given coliforms detected in BMW16 adjacent Brisbane River at 20 times above the TV. However, the dilution factor coupled with tidal exchange in Brisbane River will likely mean that the mixing zone where exceedances may be detected would be very small.	Low. Small area of impact, but should be removed at time of infrastructure (septic tank) removal.
Dissolved zinc and Nitrogen compounds in stormwater discharge	Direct discharge of stormwater via drain network into Brisbane River.	Current and future Brisbane River estuarine organisms	Yes – potentially complete given that exceedances were detected at one of the stormwater points of discharge into Brisbane River. However, given that concentrations also exceeded TVs at the upgradient site boundary, the site may not be the only or primary source of these contaminants.	Low. Data does not indicate that the site is contributing a significant proportion of the detected impact (likely due to general urban development).

1. Low (Green), Medium (Yellow) and High (Orange) risk rankings have been applied to each of the potential SPR linkages as a preliminary assessment of the level of risk if the SPR linkage was complete with respect to future (residential) use (if not remediated / managed).

9 *RISK ASSESSMENT*

Based on the results from the Stage 2 DSI, and the revised CSM, an assessment of risks to human and ecological health (based on the future intended low- to medium-density residential use) was conducted.

9.1 *ASSESSMENT OF HEALTH AND ENVIRONMENTAL RISK*

Further detail about the estimated level of risk associated with exceedances detected is outlined in the following sub-sections. For a summary / overview of risk ranking (low, medium or high), refer to *Table 7* in *Section 8.3*.

9.1.1 *Human Health Risk*

Four soil samples (of a total of 152 analysed) exceeded the ASC NEPM HILs (residential) for arsenic and/or lead. Whilst there is potential for the presence of further metals impacted soil beneath inaccessible portions of existing buildings, given the density of sampling conducted, the extent of potentially impacted soil is assessed as being limited. The likelihood of presence of metals impacted soil requiring remediation prior to residential development is greater in the vicinity of AEC07 (Rifle Range), AEC06 (Armoury), AEC10 (Sandblasting and Radiation), and Building C005 (Metal Shop). There is also potential for other limited metals 'hot spots' in the imported fill material.

The (future) risk associated with metals impacted soil relates to ingestion of soil (where soil is accessible in gardens) or consumption of vegetables (from residential gardens). Given that exceedances were detected in shallow fill material, it is likely that the material may be removed or amended (depending on geotechnical properties) prior to being deemed suitable for construction (refer to the Geotechnical Investigation report provided in *Annex F*). Soil validation sampling will be required following demolition of existing buildings and removal (or treatment of) soil 'hot spots'.

Coliforms and nutrients in soil and groundwater adjacent the septic tank near Building B013 may currently pose a risk to recreational users of Brisbane River. Whilst the likelihood of the risk being realised is low, given the rapid and significant rate of dilution upon discharge of groundwater into Brisbane River, the septic tank should be removed.

Fragments of fibrous cement sheeting (potentially containing asbestos) may be present on the ground surface in proximity to existing buildings (potentially as a result of previous asbestos removal works). However, no buried asbestos containing materials were observed (confirmed via laboratory analysis of soil samples, with no asbestos detections).

9.1.2 *Environmental Risk*

Five soil samples (of a total of 113 analysed) reported concentrations of TRH >C16-C34 (F3 fraction) exceeding the ASC NEPM ESL (coarse, residential and open space). In addition, four soil samples (of a total of 152 analysed) had arsenic and/or lead concentrations exceeding the ASC NEPM EILs (residential and open space). The residual hydrocarbons (mid- to long-chain length) are likely associated with the historical activities of vehicle parking and maintenance and the interceptor at the washbay and are unlikely to be mobile. As such, impacts to future trees or plants are likely to be limited to the immediate vicinity of hydrocarbons (if left untreated).

Soil samples with metals exceedances were further analysed to assess whether they were readily leachable, either in the natural environment (ASLP analysis), or in a landfill environment with acidic conditions (TCLP). Results for four of the five soil samples indicated that lead was not leachable (in either conditions) or had very low leachability. Lead in the remaining sample (obtained from adjacent the stop butt at the Rifle Range) was found to be readily leachable in neutral or acidic conditions. As such, there is potential for heavy metals associated with the Rifle Range stopbutt to leach into groundwater and mobilise, ultimately discharging into the Brisbane River estuarine environment. However, it should be noted that there were no lead exceedances in any of the groundwater samples (and most dissolved lead concentrations were below the laboratory LOR). This has the potential to change (with increased metals mobilised) if the known Potential Acid Sulfate Soil (PASS) (refer to the ASS Investigation Report in *Annex E*) is disturbed during construction activities (with inappropriate treatment and management) resulting in release of acid.

Minor exceedances of ANZECC marine TVs (or HMTVs) were detected at four wells for dissolved metals. Given that none of the wells in the northern portion of the site (closest to Brisbane River) had any exceedances of ecological TVs, this potential pathway is not currently complete. As stated above, a decrease in pH (associated with disturbance of PASS) may result in increased dissolved metals concentrations and increased mobility.

Nutrients (nitrogen compounds) were detected at concentrations exceeding the ANZECC TVs for South-East Queensland estuaries in all three of the groundwater samples analysed. There is potential for limited / localised algal growth and/or oxygen depletion where impacted groundwater discharges to Brisbane River. Given the volume of groundwater compared with the volume and the tidal exchange in the river, and the rate of groundwater discharge, the likelihood of significant impact to the aquatic ecosystem is assessed as being low.

Sediments accumulated in stormwater drains at the site contained elevated hydrocarbon (TRH >C10-C36 fraction) concentrations at two locations, both exceeding the ANZECC SQG value. One sample, obtained from a drain adjacent the waste oil AST, recorded concentrations also exceeding the ANZECC SQG-High value. Concentrations of one or more metals exceeded the

ANZECC SQG values in 12 of the 13 samples analysed. Lead concentrations in one sample (SED28), nickel concentrations in one sample (SED10), and zinc concentrations in five samples (SED10, SED15, SED26, SED27 and SED28) also exceeded the ANZECC SQG-High values. Most samples were obtained from the central or southern portions of the site (further away from Brisbane River). However, there is potential for impacted sediments to be mobilised in any one significant rainfall event, resulting in direct discharge to Brisbane River. Exceedances of the SQG values trigger further assessment, but given the impending future development of the site, it is recommended that all sediments are removed from drains during the demolition and removal of infrastructure works.

9.2 PRIORITIES FOR RISK MITIGATION

Based on identified risks to future land users, the priority actions are associated with the following sources:

- Lead 'hot spot' detected in fill material at BTP12_0.5 at the Parade Grounds – potential future risk to residents with access to soil or gardens;
- Lead 'hot spot' detected in shallow soil at BSB12A_0.1 adjacent the stop butt at the Rifle Range – potential future risk to ecological receptors (via both groundwater and/or stormwater) given the leachability of lead;
- Sediments accumulated in drains – impacted sediments may be readily mobilised and discharged directly into Brisbane River during significant rainfall events (current and future risk to the environment); and
- Coliforms and nutrients detected in soil and groundwater adjacent the septic tank near Building B013, on the bank of Brisbane River – potential that pathway is currently complete for Brisbane River environment and recreational users.

Remediation and/or management options to mitigate the above risks are outlined in *Section 9.3* below.

9.3 REMEDIATION AND MANAGEMENT OPTIONS

9.3.1 Soil

Excavation and removal / disposal will be required for a small volume of shallow soil associated with the Parade Ground hot spot (BTP12_0.5), and for the Rifle Range stop butt (BSB12A_0.1). The hot spot at the Rifle Range will also require addition of a soil amendment prior to disposal (due to the leachability of lead). It may also be necessary to remove small volumes of soil in proximity to key source areas (Metal Shop, Armoury, and Sandblasting & Radiation Lab) in the centre of the site as infrastructure is removed and additional soil investigation and validation is completed.

Based on the current Draft Masterplan for Bulimba Barracks, it is expected that much of this material may be removed as part of the construction works (if basement car parking is included in the medium-density residential building design).

Similarly, minor 'hot spots' of metals impact in fill material between the investigation locations may be encountered across the site. Whilst a number of samples of the ash fill layer were analysed, no exceedances were recorded (refer to *Figure 10, Annex A*, for the locations that ash was observed). Reference should also be made to the Geotechnical Investigation report (*Annex F*), as the properties of the fill material (including ash) are variable, which means that compaction and settling rates will vary across the site. As such, removal (or as a minimum, amendment) of fill material may be required. Additionally, excavation may be required as part of the construction process (due to the design of foundations or basement carparks), which will result in incidental removal of this material.

Validation sampling should be conducted across the final surface prior to construction to confirm the site's suitability for future residential land use.

Small volumes of soil removal / treatment may also be required in association with petroleum hydrocarbons exceeding ESLs, in the south-western portion of the site (relating to mechanical workshop facilities, truck parking, and the wash bay interceptor).

Decommissioning and removal of both septic tanks is expected to be conducted as part of the redevelopment and removal of disused infrastructure and services. Limited source removal (soil treatment or removal) in close proximity to the northern septic tank may be required to mitigate the risk of ecological or human health impacts associated with nutrients, and bacteria, respectively.

9.3.2 *Groundwater*

Minor metals exceedances (of ecological TVs) were detected in groundwater. However, these did not appear to correlate with metals exceedances (source areas) in soil. As such, it is possible that metals concentrations relate to the local geology (particularly the clay).

Given that the tidal influence and hardness of groundwater in the northern portion of the site appears to mitigate the risk of metals impact to Brisbane River, no additional remedial actions are recommended (other than removal of metals 'hot spots' in soil). The main constituents of concern in groundwater are nutrients and coliform bacteria, which appear to be primarily associated with the septic tank. Decommissioning and removal of the tank(s) as part of the demolition works (with minor source removal, as outlined above) will mitigate ongoing groundwater impact and migration.

9.3.3 *Sediments and Surface Water / Stormwater*

Metals and hydrocarbon impacted sediments have the greatest risk of potential immediate risk to the environment, given that they may be mobilised and discharged directly into Brisbane River during significant rainfall events. Whilst the surrounding urban environment and roads are likely to be contributing to the general source, there appears to be a correlation between the truck parking area and impacted sediments.

Removal of the sediments should be conducted carefully so that sediments can be captured and treated (fixed) or disposed off-site and not flushed through drains towards the Brisbane River. It is expected that the future development will involve removal of the existing timber grated drains. Remediation and demolition could be conducted concurrently.

10 CONCLUSIONS

ERM conducted a Stage 2 DSI at Bulimba Barracks on behalf of Defence, in order to identify the location, nature and extent of any contamination that exists on site. The assessment was conducted with respect to the future intended land use which is likely to include low-density residential, with the intention of providing sufficient data to support future scoping of any required remedial and validation works by the future purchaser (which would require review by a Queensland Auditor, to be engaged by the future purchaser).

In order to assess Acid Sulfate Soil and Geotechnical conditions at the site, additional scope was undertaken concurrent to the Stage 2 DSI to enable these aspects to be considered for the future intended land use. The findings of these investigations are presented in separate documents annexed to this report.

Soil, sediment, groundwater and surface water (stormwater) sampling was conducted during November and December 2017. Samples were analysed for targeted suites, based on the GHD (2015) Stage 1 EI and information about previous site activities.

Fill material was encountered to a maximum depth of approximately 1.8mbgs, and comprised primarily of orange and white mottled clay (thought to be sourced locally from the suburb of Bulimba). Some areas also contained road base angular gravel and sand, and a thin layer of ash / charcoal fill material (sometimes containing slag or clinker) was detected at thicknesses of between 0.01m and 0.75m at 34 investigation locations across the site. Bedrock (generally comprising sandstone, siltstone or mudstone) was encountered near surface or outcropping in the southern portions of the site. However, in the north-eastern portion of the site, depth to bedrock was encountered at depths of up to approximately 20mbgs (based on geotechnical testing, refer to *Annex F*).

Groundwater was generally encountered at depths between 2.0-3.0mbgs, varying based on the presence of fill, distance from Brisbane River, and the depth / presence of bedrock. Groundwater flow direction was generally to the north (towards Brisbane River).

10.1 FINDINGS OF THE STAGE 2 DSI

Analytical results indicated limited soil impact (4 samples out of a total of 152 analysed) with lead and/or arsenic concentrations exceeding ASC NEPM HIL-A&B (residential). These samples were all obtained from within fill material, generally from shallow depths (<1.0mbgs). Three of the four exceedances were associated with the Armoury, Rifle Range and the Metal Shop. Based on a statistical assessment of the data set (for metals in soil), the elevated concentrations of lead and arsenic were not representative of "hot spots", with the exception of BTP12_0.5 (from the Parade Ground). However, the elevated lead concentrations at the Rifle Range (BSB12A-0.1) were found to be readily leachable (in both neutral and acidic conditions). As such, this shallow soil requires amendment and removal from site.

Five soil samples (out of a total of 113 analysed) exceeded the ASC NEPM ESL (coarse, open space and residential) for TRH >C16-C34 (F3 fraction). Three of the exceedances were detected at depths ≤0.5mbgs, and were close to the former truck parking area. Two of the exceedances were at approximately 1.0mbgs and are likely associated with interceptors at the washbays (AEC05 and AEC12).

Analytical results for the ash / charcoal fill material confirm that this material is not associated with gasworks waste (given that no cyanide, PAHs or Phenols were present). This material may have originated from the former Bulimba Power Station.

Sediments impacted with hydrocarbons (two locations) and heavy metals (12 of the 13 locations) were identified in the western portion of the site. If mobilised during a significant rainfall event, the sediments may pose a risk to the Brisbane River estuarine environment.

Only minor groundwater impact was detected, with minor dissolved metals exceedances of ecological TVs, and elevated coliform bacterial count and nutrients concentrations at locations close to a septic tank.

Targeted source removal should sufficiently mitigate identified risks. In general, the source removal activities can best be carried out during demolition, excavation and construction activities. The potential for encountering additional areas of impacted soil during these activities cannot be discounted, but the minimal number of exceedances of screening levels recorded for the density of sampling completed during this Stage 2 DSI suggests that any additional areas of impact will be limited in extent. Additional small pockets of buried materials may also be encountered. With the exception of one drum of hardened resin or paint-type material, and a small burial pit of rifle butts (both of which would be suitable for lined or unlined landfill), only localised areas of inert demolition and construction waste were encountered.

10.2 FINDINGS OF THE ASS INVESTIGATION

Details of the ASS investigation are included in *Annex E*. The ASS investigation identified that a comprehensive ASS Management Plan (ASSMP) is required, given the likely volume of disturbance and the high treatment rates.

10.3 FINDINGS OF THE GEOTECHNICAL INVESTIGATION

Details of the Geotechnical investigation are included in *Annex F* The findings of the Geotechnical works include the need for further assessment and potential removal or treatment of fill materials, which may not meet requirements for compaction prior to construction in their current state. It is also likely that bored pier foundations will be required for all future buildings.

10.4 SUMMARY

In summary, the objective to characterise potential contamination at Bulimba Barracks has been achieved. The information provided within this Stage 2 DSI report provides preliminary information to assist with assessment of the site for potential future redevelopment. Based on the Stage 2 DSI results, it is considered that with limited remedial works and implementation of management protocols, the site can be made suitable for future residential land use. Any future works will need to be reviewed and approved by a Queensland Auditor, to be engaged by the future purchaser.

The findings of the Stage 2 DSI should be considered in conjunction with the attached ASS Investigation and Geotechnical reports as well as the separate Hazmat report to ensure a holistic perspective on future development requirements.

Further detailed geotechnical investigation and assessment of ASS design consideration will be required for detailed design.

The suggested minor remedial (source removal) and validation activities may be completed either in advance of development or at the time as site development enablement works.

11 *LIMITATIONS*

The findings of this report are based on the Scope of Work in *Section 1.4*. ERM performed the services in a manner consistent with the normal level of care and expertise exercised by members of the environmental assessment profession. No warranties, express or implied, are made.

Although normal standards of professional practice have been applied, the absence of any identified hazardous or toxic materials on the site should not be interpreted as a guarantee that such materials do not exist at the site.

This assessment is based on data and information provided to ERM by the Department of Defence ("client"), via Currie & Brown, including the Stage 1 investigation conducted by GHD (2015). Assessment criteria selections made in the report are the professional opinions of the ERM personnel involved with the project and, while normal checking of the accuracy of the data has been conducted, ERM assumes no responsibility or liability for errors in data obtained from regulatory agencies or any other external sources, nor from occurrences outside the scope of this project.

Use of the sites for any purpose may require planning and other approvals and, in some cases, DES and accredited site auditor approvals. ERM offers no opinion as to the likelihood of obtaining any such approvals, or the conditions and obligations which such approvals may impose, which may include the requirement for additional environment works. ERM makes no warranty or representation about the suitability of the land for any purpose or the permissibility of any use.

ERM is not engaged in environmental assessment and reporting for the purpose of advertising sales promoting, or endorsement of any client interests, including raising investment capital, recommending investment decisions, or other publicity purpose. The client acknowledges that:

(a) this report is for the exclusive use of the client, its representatives and advisors;

(b) this report may be disclosed to prospective purchasers of the relevant land, lenders, underwriters and financiers on a non–reliance basis via controlled access to a data room made available by the client for the purpose of potential transactions involving the land; and

(c) no party other than the client may rely on this report unless such reliance is governed by an agreement between ERM and that party in the form of ERM's standard third party reliance agreement.

The client agrees that ERM's report or correspondences will not be, except as set forth herein, used or reproduced in full or in parts for such promotional purposes, and may not be used to relied upon in any prospectus or offering circular nor for the purpose of advertising, sales, promoting or endorsing any client interests including raising investment capital, recommending investment decisions, or other publicity purposes.

This report should be read in full and no excerpts are to be taken as representative of the whole report. To ensure its contextual integrity, the report is not to be copied, distributed or referred to in part only. No responsibility or liability is accepted by ERM for use of any part of this report in any other context.

This report does not purport to provide or be a recommendation to make or not make any purchase, disposal, investment, divestment, financial commitment or otherwise in or in relation to the site.

This report does not:

(a) does not purport to recommend or induce a decision to make (or not make) any purchase, disposal, investment, divestment, financial commitment or otherwise in or in relation to the land; or

(b) purport to provide, nor should be construed as, legal advice.

12 REFERENCES

AECOM (14 October 2016). *Bulimba Barracks Redevelopment: HMAS Moreton Contaminated Land Investigation – HMAS Moreton, 100 Taylor Street, Bulimba, QLD (DRAFT)*

Australian and New Zealand Environment Conservation Council (ANZECC) (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Trigger Values for Marine Water (95% protection of species).*

EarthTech, subcontracted by QHSS (August 2007). *Installation of Two Groundwater Monitoring Wells – Bulimba Barracks, Bulimba (Letter Report).*

Geological Survey of Queensland (1980). *Moreton Geology 1:150,000 Map.*

GHD (July 2015). *Bulimba Barracks Stage 1 Environmental Investigation (DEHP-ID-052).*

Golder Associates (May 2013). *Environmental Investigations of USTs / ASTs Across the Defence Estate, Stage 1 Report – Bulimba Barracks ("New" 0126).*

Google Earth (accessed 3 January 2018). *Google Earth Imagery, with Queensland Globe Overlay.*

HLA (September 2006). *Contamination Investigation at Defence Integrated Distribution System Sites, Joint Logistics Unit (South Queensland) Bulimba Barracks, Apollo Road, Brisbane, Queensland.*

Lambert & Rehbein (May 2012). *Project SQ2652 – Addendum 1 Report to Project SQ3181 – Additional Soil Sampling, Bulimba Barracks Facility.*

QHSS (February 2003). *Radiation Survey & Investigation Report No. 02PQ369.*

QHSS (May 2003). *Radiation Survey & Investigation Report No. 02PQ588.*

QHSS (May 2003). *Stage 2 Radiological Characterisation Report EIR – Building C006.*

QHSS (June 2003). *Solid Radioactive Waste Disposal Clearance Letter.*

QHSS (October 2007). *Environmental Tritium Contamination Report.*

QHSS (July 2015). *Radiological Site Characterisation: Tritium GHD (Report No. 14PX278).*

Annex A

Figures

Annex B

Tables

Annex C

Photographic Log

Annex D

Data Quality Objectives

D.1 STEP 1: STATE THE PROBLEM

D.1.1 *Objectives*

The objectives of the Stage 2 DSI are presented in *Section 1.3*.

As noted, the Stage 2 DSI data provides a pre-divestment condition assessment relating to potential contaminants of concern in environmental media. The intention of the investigation was to characterise the nature and extent of contamination that may preclude the site from being developed for future residential land use (without remedial actions and/or management protocols).

ERM designed the investigation in line with the Queensland Department of Environment and Heritage Protection (EHP) *Queensland Auditor Handbook for Contaminated Land – Module 5: Contaminated Land Investigation Documents, Auditor Certification and Compliance Assessment* (September 2015) (Module 5). Module 5 requires a risk based assessment, aligning with Schedule A of the National Environment Protection Council (NEPC) *National Environment Protection (Assessment of Site Contamination) Measure* (1999) (ASC NEPM), relevant provisions of the *Environmental Protection Act (EP Act) 1994*, and the *Environmental Protection (Water) Policy 2009*.

D.1.2 *Conceptual Site Model*

The conceptual site model for Bulimba Barracks, based on the information reviewed to date and the results of the Stage 2 DSI, is summarised in *Section 8* of the main report.

D.2 STEP 2: IDENTIFY THE DECISIONS

D.2.1 *Decision Statements*

The decisions to be made during the Stage 2 DSI works include:

- Do environmental media (soil, sediment, surface water and groundwater), meet the adopted criteria suitable for unrestricted (low density residential) land use, and the protection of human health and ecological receptors?
- Is the data collected during this investigation sufficient to provide an assessment of the environmental condition and extent of any existing contamination to environmental media to support risk decision making?
- Do residual impacts (if any) represent a potential risk to identified human health (low density residential) and ecological receptors?

D.3 *STEP 3: IDENTIFY INPUTS TO THE DECISIONS*

The inputs required to make the above decisions are as follows:

- Existing environmental data obtained during previous investigations, taking into consideration the number of investigations/sampling rounds (data set), and the quality and location of sampling locations;
- Identification of representative sampling locations;
- Identification of contaminants of potential concern (COPCs);
- Soil and sediment field screening data (using a Photo-Ionisation Detector (PID));
- Surface water and groundwater field screening data (pH, dissolved oxygen, redox potential, conductivity and turbidity);
- Direct observation of environmental variables including visual disturbance, odours and groundwater elevation;
- Laboratory analytical results for the COPCs;
- Field and laboratory quality assurance/quality control data; and
- Adopted screening levels.

Whilst Potential Acid Sulfate Soils (PASS) is expected to be present at the site (given its location and elevation), Acid Sulfate Soil (ASS) assessment did not form part of the Stage 2 DSI scope, but was investigated separately. Results of the investigation are presented in *Annex E*.

D.4 *STEP 4: DEFINE THE STUDY BOUNDARIES*

The spatial extent of the Stage 2 DSI comprises the area (20.73 hectares) within the site (fenced) and cadastral boundary of Lot 1 on SP276395, as shown on *Figure 1, Annex A*.

Physical constraints that have resulted in changes to the proposed scope included refusal on bedrock before reaching scoped depths using the equipment proposed (a backhoe for test pitting, and a Geoprobe drill rig for soil bores and monitoring wells). In addition, there were some access limitations associated with some parts of the buildings (with a drill rig), and the presence of underground services also resulted in a number of investigation locations being moved (and in some cases eliminated). Of particular note were the secure (locked) access pits associated with communications lines on site. Access to these pits was not granted (requiring a specific security cleared escort) within the time constraints of the fieldwork schedule, and as such, the location of some of the lines was unable to be confirmed by ERM's subcontracted cable locator.

A significant rainfall event in the first week of fieldwork also resulted in some delays (where cable locating equipment was unable to be used in heavy rain, the potential for lightning restricted the use of drill rigs, and the trafficability of unsealed areas of the site restricted the location of works).

Temporal constraints included the requirement to submit a final Stage 2 DSI report by 31 January 2018. In order to meet this objective, all fieldwork needed to be completed and all samples submitted to the analytical laboratories prior to Christmas. Some delays with laboratory results reporting and the need for supplementary analyses (including further analysis of ash fill material to assess its source, and further analysis of samples with concentrations (particularly metals) exceeding adopted screening criteria for leachability) have resulted in an extended reporting period.

D.5 STEP 5: DEVELOP A DECISION RULE

The investigation was designed to facilitate the collection of adequate soil, sediment, groundwater and surface water (stormwater) data to address the decisions in Step 2 of the DQO process. Adequate data to address the objective is considered to have been gathered. Assessment of the data, and the nature, extent and risks posed by any site contamination encountered will be conducted with reference to Schedules B1, B4, B5a and B5c of the ASC NEPM, in order to formulate appropriate responses to the matters described in Step 2.

It is acknowledged that some project constraints have impacted on the implementation of Stage 2 DSI program as described in the preceding section. Deviations from the SAQP were clearly stated in this report (*Table 5, Section 4.1*). Such constraints are judged not to materially constrain the decisions to be made as set out in Step 2.

D.5.1 Field and Laboratory QA/QC

The suitability of soil and groundwater data was assessed based on the acceptable limits for field and laboratory QA/QC samples outlined in *Annex J* and *Annex K*. In the event that acceptable limits were not met by laboratory analyses, the field observations relating to the nature of the samples was reviewed and if no obvious source for the non-conformance was identified, such as an error in sampling, preservation of sample(s) or heterogeneity of sample(s), liaison with the laboratories was be undertaken in an effort to identify the issue that has given rise to the non-conformance. If no explanation for the non-conformance was identified, the concentrations for the affected samples were considered as estimates.

D.5.2 Assessment Criteria

The adopted soil and groundwater assessment criteria are outlined in *Section 5* within the main body of this report.

D.6 STEP 6: SPECIFY THE PERFORMANCE OR ACCEPTANCE CRITERIA

The acceptable limits on decision errors applied during the review of the results will be based on the Data Quality Indicators (DQIs) of precision, accuracy, representativeness, comparability and completeness (PARCC) in accordance with the requirements of the ASC NEPM.

The potential for significant decision errors were minimised by:

- Completing a robust QA/QC assessment of the validation data and application of the probability that 95% of data will satisfy the DQIs, therefore a limit on the decision error would be 5% that a conclusive statement may be incorrect;
- Assessing whether appropriate sampling and analytical density has been achieved for the purposes of providing a baseline of soil, sediment and groundwater conditions at the point of transaction; and
- Ensuring that the criteria set was appropriate for the proposed future use of the site, including low- to medium-density residential; as such there was an objective to have the site assessed for suitability for unrestricted use and removal of the site from the EMR.

D.7 STEP 7: OPTIMISE THE DESIGN FOR OBTAINING DATA

The Stage 2 DSI scope and program was developed based on a review of existing data and discussions with the Currie and Brown, and the Department of Defence.

Historical reports were supplied to ERM during the project and where these warranted adjustment of the sampling design (sampling locations and analytes), the assessment was adjusted accordingly. During fieldwork, where observations identified unexpected materials (such as the ash fill material and the buried resin / paint material), the analytical suite was amended to include additional relevant analytes in order to adequately characterise materials and provide sufficient information to support future remedial measures (including off-site disposal).

Annex E

ASS Investigation Report

Annex F

Geotechnical Investigation Report

Annex G

Borehole Logs

Annex H

Field Data Sheets

Annex I

Equipment Calibration Certificates

Annex J

Laboratory Certificates

Annex K

Quality Assurance and Quality Control Documentation

K.1 *FIELD QUALITY CONTROL AND ASSURANCE*

Equipment decontamination, sample collection, handling and transportation were conducted in accordance with ERM's standard operating procedures (SOP's). The samples were reportedly received in good condition.

K.1.1 *Field QA/QC Assessment*

Soil, groundwater and surface water samples collected as part of this field program were completed by suitably qualified environmental consultants from targeted locations. Field QA/QC results are discussed in the following section.

K.1.2 *Field QA/QC Program*

An allowance has been made for the collection of 1 duplicate and 1 inter laboratory triplicate per 20 samples collected. Rinsates were collected at a rate of one per day. Field Quality Control (QC) summary results are presented in *Tables 10a-10d, Annex B.* Laboratory certificates are included in *Annex J.*

K.1.3 *Sampling Technique, Handling and Transportation Procedures*

Soil and sediment samples were collected directly into laboratory supplied containers using nitrile gloves to prevent contamination. Ground water samples were collected using a peristaltic pump with new LDPE tubing used at each well. Surface water samples were collected either by hand or using a sample pole at certain locations, which was suitably decontaminated at each location.

Field instruments used as part of the investigation were appropriately calibrated and used according to the manufacturer's instructions. Calibration certificates for water quality meters used and PID gas detectors are presented in *Annex I.*

Samples were placed in laboratory-supplied sample jars suitable for each analytical suite analysed, stored in a chilled cooler on ice, and forwarded to the NATA-accredited laboratories under Chain of Custody (COC) documentation. Laboratory certificates and COCs are included in *Annex J.*

K.1.4 *Decontamination Procedures*

Decontamination procedures were implemented during the investigation. Sampling equipment was triple rinsed, and no detergent was used. Rinsate water provided by the laboratory, tap water used to wash equipment, and reagent samples were submitted to assess potential sources of contamination during the sampling process. Please refer to the ERM decontamination SOPs for more information.

Nine rinsate samples were submitted for analysis throughout the duration of fieldwork (QC01-QC08 and R01). Seven of the rinsate samples were analysed for the NEPM suite of 13 metals, one rinsate was analysed for TRH, and one rinsate sample was analysed for TRH C6-C10 fraction. No analytes were detected above the laboratory limits of reporting in any of the rinsate samples. Results are tabulated in *Tables 11a-11b, Annex B*.

K.2 LABORATORY QUALITY CONTROL AND ASSURANCE RESULTS

K.2.1 Laboratory QA/QC Assessment

Primary laboratory analysis of soil, sediment, groundwater and surface water was conducted by Eurofins|MGT Pty Ltd, and secondary analysis was by Australian Laboratory Services (ALS). Both laboratories are accredited by the National Association of Testing Authorities (NATA). Analytical methods completed by each laboratory were NATA approved as documented on the laboratory reports.

Upon receipt of samples, copies of signed chain of custody forms and sample receipt notices (SRNs) were returned by the laboratory.

K.2.2 Laboratory QA/QC Plan

The accuracy and precision of laboratory quality control (QC) results are measured by percentage recovery and relative percentage differences (RPD), respectively. These checks are made to assess data in terms of completeness, representativeness, comparability, accuracy and precision in order to meet the data quality objectives.

All RPDs generated were within the acceptable range, according to AS4482.1-2005, or were not able to be calculated due to the results being below the detection limits, with the exception of the sample pairs summarised in *Table 8*, below.

Table 8 Summary of Duplicate Pair Samples with RPDs outside Acceptable Range

Lab Report	Primary Sample ID	Sample ID	Sample Type	Analyte	RPD (%)
575400	BSB29_0.5	QA09	Duplicate	Manganese	63
EB1725519	BSB29_0.5	QA10	Triplicate	Manganese	67
EB1725519	BSB29_0.5	QA10	Triplicate	Cobalt	55
575842	BSB35_0.5	QA11	Duplicate	Lead	82
576274	BTP43_0.5	DUP 2	Duplicate	Moisture Content (dried @ 103°C)	43
EB1726443	BTP43_0.5	Trip 2	Triplicate	Manganese	121
575065	SB27_1.0	QA05	Duplicate	Manganese	36
EB1725519	SB27_1.0	QA06	Triplicate	Nickel	62
EB1725519	SB27_1.0	QA06	Triplicate	Lead	57
EB1725519	SB27_1.0	QA06	Triplicate	Cobalt	70

Lab Report	Primary Sample ID	Sample ID	Sample Type	Analyte	RPD (%)
575319	BSB32/ASS05_3.0	QA07	Duplicate	Kjeldahl Nitrogen Total	67
576864	BTP01_1.0	DUP05	Duplicate	Manganese	51
576864	BTP34_1.0	DUP06	Duplicate	Arsenic	77
575842	BSB12_0.5	QA13	Duplicate	Copper	143
575842	BSB12_0.5	QA13	Duplicate	Lead	175
575842	BSB12_0.5	QA13	Duplicate	Mercury	67
575842	BSB12_0.5	QA13	Duplicate	Nickel	89
575842	BSB12_0.5	QA13	Duplicate	Zinc	125
576864	BSB14_0.5	QA17	Duplicate	Copper	109
576864	BSB14_0.5	QA17	Duplicate	Lead	161
576864	BSB14_0.5	QA17	Duplicate	Manganese	101
576864	BSB14_0.5	QA17	Duplicate	Zinc	124
576864	BTP57_1.0	DUP07	Duplicate	Kjeldahl Nitrogen Total	47
EB1727195	BSB14_0.5	QA18	Triplicate	Copper	151
EB1727195	BSB14_0.5	QA18	Triplicate	Lead	153
EB1727195	BSB14_0.5	QA18	Triplicate	Zinc	111
577087	BTP03_0.5	DUP03	Duplicate	Manganese	39
577087	BTP21_0.5	DUP04	Duplicate	Manganese	56
578316	MW13	D01	Duplicate	Chromium	67
EB1727119	MW13	TO1	Triplicate	Copper (Filtered)	67
EB1727119	MW13	TO1	Triplicate	Copper	67

1. Refer to *Annex J* for full laboratory analytical reports.

The statistical data presented in the laboratory QA/QC reports were typically considered adequate in demonstrating the precision and accuracy of the methods used to analyse field samples. Laboratory quality control samples included matrix spikes, laboratory control samples, internal laboratory duplicates, and method blanks. The quality control sample frequencies were acceptable for all sample batches with the exception of those outlined in *Table 9*, below.

Table 9 Laboratory Quality Control Sample Result Outliers

Lab Report	Method Blank	LCS - % Recovery	Spike - % Recovery	Duplicate	Comment
574795	Pass	Pass	Pass except 1×Managanese, 1×Zinc	Pass except 1×Cadmium	The matrix spike recovery is outside of the recommended acceptance criteria. An acceptable recovery was obtained for the laboratory control sample indicating sample matrix interference. The RPD reported passes Eurofins Acceptance Criteria as defined in the Internal Quality Control Review and Glossary Page of the Laboratory Report.
574810	Pass	Pass	Pass	Pass	
575065	Pass	Pass	Pass except 1×Lead	Pass except 1×Chromium	The matrix spike recovery is outside of the recommended acceptance criteria. An acceptable recovery was obtained for the laboratory control sample indicating sample matrix interference. The RPD reported passes Eurofins Acceptance Criteria as defined in the Internal Quality Control Review and Glossary Page of the Laboratory Report
575319	Pass	Pass	Pass	Pass	
575400	Pass	Pass	Pass	Pass	
575842	Pass	Pass	Pass	Pass except 1×TRH C6-C9, 1×TRH C6-C10	The RPD reported passes Eurofins Acceptance Criteria as defined in the Internal Quality Control Review and Glossary Page of the Laboratory Report
575895	Pass	Pass	Pass	Pass	

Lab Report	Method Blank	LCS - % Recovery	Spike - % Recovery	Duplicate	Comment
576274	Pass	Pass	Pass except 1×Boron, 1×Beryllium, 1×Manganese	Pass except 1×Phospohorous	The matrix spike recovery is outside of the recommended acceptance criteria. An acceptable recovery was obtained for the laboratory control sample indicating sample matrix interference. The RPD reported passes Eurofins Acceptance Criteria as defined in the Internal Quality Control Review and Glossary Page of the Laboratory Report.
576864	Pass	Pass	Pass except 1×Lead	Pass except 1×Acenaphthene, 1×Acenaphthylene, 1×Anthracene, 1×Fluorene, 2 × Arsenic	The matrix spike recovery is outside of the recommended acceptance criteria. An acceptable recovery was obtained for the laboratory control sample indicating sample matrix interference. The RPD reported passes Eurofins Acceptance Criteria as defined in the Internal Quality Control Review and Glossary Page of the Laboratory Report.
577018	Pass	Pass	Pass	Pass	
577087	Pass	Pass	Pass except 1× 3&4-Methylphenol (m&p-Cresol)	Pass	The matrix spike recovery is outside of the recommended acceptance criteria.
577213	Pass	Pass	Pass except 1×Copper	Pass	The matrix spike recovery is outside of the recommended acceptance criteria.
577215	Pass	Pass	Pass	Pass	
577225	Pass	Pass	Pass	Pass	
577520	Pass	Pass	Pass	Pass	
577592	Pass	Pass	Pass	Pass	

Lab Report	Method Blank	LCS - % Recovery	Spike - % Recovery	Duplicate	Comment
578007	Pass	Pass	Pass except 1×Arsenic, 1×Beryllium, 1×Copper, 1×Lead, 1×Manganese, 1×Zinc	Pass	The matrix spike recovery is outside of the recommended acceptance criteria.
578144	Pass	Pass	Pass except 1×Boron (filtered), 1×Manganese (filtered)	Pass except 1×Mercury, 1×Selenium, 1×Selenium (filtered)	The matrix spike recovery is outside of the recommended acceptance criteria. An acceptable recovery was obtained for the laboratory control sample indicating sample matrix interference. The RPD reported passes Eurofins Acceptance Criteria as defined in the Internal Quality Control Review and Glossary Page of the Laboratory Report
578316	Pass	Pass	Pass	Pass except 1×Arsenic, 1×Chromium	The RPD reported passes Eurofins Acceptance Criteria as defined in the Internal Quality Control Review and Glossary Page of the Laboratory Report
578550	Pass	Pass	Pass	Pass	
577018	Pass	Pass	Pass	Pass	
578865	Pass	Pass	Pass	Pass	
579026	Pass	Pass	Pass	Pass	
579083	Pass	Pass	Pass	Pass	
579221	Pass	Pass	Pass	Pass	
EB1725384	Pass	Pass	Pass	Pass	
EB1725519	Pass	Pass except 1×Acenaphthylene and 1×Fluorene	Pass	Pass	Recovery less than lower control limit
EB1726443	Pass	Pass except Phenol, 2-Chlorophenol, Naphthalene	Pass except 1×Lead, 1×Manganese, 1×Zinc	Pass	Recovery less than lower control limit, recovery less than lower data quality objective

Lab Report	Method Blank	LCS - % Recovery	Spike - % Recovery	Duplicate	Comment
EB1727119	Pass	Pass	Pass	Pass	
EB1727195	Pass	Pass except 1×Fluorene	Pass except 1×Manganese, 1×C10-C14 Fraction, 1×>C10-C16 Fraction, 1×>C16-C34 Fraction	Pass except 1×Manganese	Recovery less than lower control limit, Recovery less than lower control limit, MS recovery not determined-background level greater than or equal to 4 times spike level, RPD exceeds LOR based limits.

1. Refer to *Annex J* for full laboratory analytical reports.

K.2.3 Laboratory Limits of Reporting

The laboratory Limits of Reporting (LORs) applied for the analytical suites requested are depicted in *Tables 5a-5h*, *Tables 6a-6e*, *Tables 7a-7c, Tables 8a-8d* and *Tables 9a-9c, Annex B*.

K.2.4 Review of Anomalous Results

No significant anomalies (between duplicate pairs or between primary or secondary laboratory analyses) were observed.

K.2.5 Summary

Although the data indicates some RPDs outside of the acceptable range and anomalous laboratory QA/QC tests, overall the quality assessment completed suggests the dataset is acceptable and may be used to meet the objectives of this assessment.

Field Quality Control (QC) summary results are presented in *Tables 10a-10d,* and *Tables 11a-11b, Annex B.* Laboratory certificates are included in *Annex J.*

Annex L

Supplementary Stage 2 DSI: Per- And Poly-Fluoroalkyl Substances Assessment