# NORTHERN TERRITORY OF AUSTRALIA

## PROPOSAL TO AMEND NT PLANNING SCHEME
## PA2025/0376

The Minister for Lands, Planning and Environment has accepted an application to amend the NT Planning Scheme 2020, made by Element Advisory Pty Ltd, for exhibition. The application seeks to:

- rezone Lot 04360 Town of Darwin (12 Dinah Beach Road, Darwin City) from Zone GI (General Industry) to Zone MR (Medium Density Residential) and Zone HR (High Density Residential).

Attached are:

- a locality map and extracts of the Central Darwin Area Plan;
- extracts from the NT Planning Scheme 2020 relating to Zone GI (General Industry);
- extracts from the NT Planning Scheme 2020 relating to Zone MR (Medium Density Residential);
- extracts from the NT Planning Scheme 2020 relating to Zone HR (High Density Residential); and
- a copy of the application.

**Period of Exhibition and Lodging a Submission**

The exhibition period is from **Friday 21 November 2025** to **Friday 19 December 2025**.

Submissions in relation to this application must be in writing and include the name and postal address of the author and may be made publicly available in full.

Written submissions about the proposed planning scheme amendment are to be received by 11.59pm on **Friday 19 December 2025** and addressed to:

Lands Planning
Department of Lands, Planning and Environment
GPO Box 1680
DARWIN NT 0801; or

Email: planning.ntg@nt.gov.au; or

Hand delivered to Level 1 Energy House 18-20 Cavenagh Street, Darwin.

For more information contact Fletcher Willis, on 8924 7341 or fletcher.willis@nt.cov.au

## 4.15 Zone GI – General Industry

Zone Purpose

Provide for industrial developments that require separation from more sensitive uses as the nature of activities may detrimentally impact on the ***amenity*** of the locality, in locations with ***access*** to services and transport networks capable of supporting heavy ***industry***.

Zone Outcomes

1. Predominantly industrial activities that require separation from sensitive uses due to the nature of operations and the scale of activities, including **fuel depot**, **industry-general, industry-light, industry-primary, motor body works, recycling depot**, **transport terminal** and **warehouse**.

2. Non-industrial activities, including **bar-public**, **food premises-cafe/takeaway**, primarily servicing local employees, and **office**, **shop**, and **showroom sales**, may be established where they serve the needs of the industrial uses on the ***site*** and are compatible with the ongoing industrial use of the zone.

3. Other non-industrial activities such as **education establishments,** indoor **leisure and recreation,** and **hotel/motel**, may also be established where they do not jeopardise the ongoing operation and viability of industrial activities.

4. Any other non-industrial activities may only be established where they do not compromise or conflict with the ongoing ***primary use*** of the locality for ***industry*** purposes.

5. Subdivision primarily provides for a range of lot sizes, including an appropriate proportion of larger lots to cater for larger format ***industry*** uses.

6. Industrial activities have ***access*** to the appropriate level of transport infrastructure and do not interfere with the safe and efficient operation of the surrounding road network.

7. Development does not impose unsustainable demands on surface water and groundwater.

8. Appropriate urban services including, roads, reticulated electricity, water, sewerage, stormwater drainage and telecommunication infrastructure are available. If lots are unsewered, provision for the disposal of effluent must be made on-site so that the effluent does not pollute ground or surface waters.

9. Development that is not defined in Schedule 2 (Definitions) may occur only when assessment has determined that the development is appropriate in the zone, having regard to the purpose and outcomes of this zone and such matters as the location, nature, scale and intensity of the development.

**ASSESSMENT TABLE – ZONE GI – GENERAL INDUSTRY**

| Defined Use | Assessment Category | Overlays | General Development Requirements | Location Specific Development Requirements | Specific Development Requirements |
|---|---|---|---|---|---|
| **Agriculture** | **Impact assessable** | 3.4 CR – Coastal Reclamation<br>3.6 LSF – Land Subject to Flooding<br>3.7 LSSS – Land Subject to Storm Surge<br>3.8 LADR – Land Adjacent to a Designated Road<br>3.9 DHD – Dredging in Darwin Harbour<br>3.14 HHLSI – Land in proximity to Helicopter Landing Sites of Strategic Importance | 5.2.1 General Height Control<br>5.2.4 Car Parking<br>5.2.5 Loading Bays<br>5.2.6 Landscaping<br>5.2.7 Setbacks for Development Adjacent to Land in Zones LR, LMR, MR or HR | | 5.7.1 Rural Development (Agriculture, Horticulture and Intensive Animal Husbandry) |
| **Animal Boarding** | **Impact assessable** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI<br>5.7.2 Animal Related Use (Animal Boarding and Stables) |
| **Bar-Public** | **Impact assessable** | | | | 5.5.10 Nightclub Entertainment Venue, Bar-Public and Bar-Small<br>5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Caravan Accommodation** | **Permitted** | | | | 5.4.11 Caravan Accommodation |
| **Car Park** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Car Wash** | **Merit assessable** | | | | 5.5.9 Car Wash<br>5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Demountable Structures** | **Permitted** | | | | 5.8.7 Demountable Structures |
| **Dwelling-Caretakers** | **Permitted** | | | | 5.4.12 Dwelling-Caretakers<br>5.6.1 Setbacks and Building Design in Zones LI, GI and DV |
| **Education Establishment** | **Impact assessable** | | | | 5.6.1 Setbacks and Building Design Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI<br>5.8.2 Education Establishment |

**ASSESSMENT TABLE – ZONE GI – GENERAL INDUSTRY**

| Defined Use | Assessment Category | Overlays | General Development Requirements | Location Specific Development Requirements | Specific Development Requirements |
|---|---|---|---|---|---|
| **Emergency Services Facility** | **Merit assessable** | 3.4 CR – Coastal Reclamation<br><br>3.6 LSF – Land Subject to Flooding<br><br>3.7 LSSS – Land Subject to Storm Surge<br><br>3.8 LADR – Land Adjacent to a Designated Road<br><br>3.9 DHD – Dredging in Darwin Harbour<br><br>3.14 HHLSI – Land in proximity to Helicopter Landing Sites of Strategic Importance | 5.2.1 General Height Control<br><br>5.2.4 Car Parking<br><br>5.2.5 Loading Bays<br><br>5.2.6 Landscaping<br><br>5.2.7 Setbacks for Development Adjacent to Land in Zones LR, LMR, MR or HR | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI<br>5.8.6 Emergency Service Facility |
| **Excavation and Fill** | **Impact assessable** | | | | 5.8.9 Excavation and Fill |
| **Food Premises-Café/Take Away** | **Merit assessable** | | | | 5.5.11 Food Premises<br>5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Food Premises-Restaurant** | **Impact assessable** | | | | 5.5.11 Food Premises<br>5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Fuel Depot** | **Impact assessable** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Hotel/Motel** | **Impact assessable** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Industry-General** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Industry-Light** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Industry-Primary** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |

| ASSESSMENT TABLE – ZONE GI – GENERAL INDUSTRY | | | | | |
|---|---|---|---|---|---|
| **Defined Use** | **Assessment Category** | **Overlays** | **General Development Requirements** | **Location Specific Development Requirements** | **Specific Development Requirements** |
| **Leisure and Recreation** | **Impact assessable** | 3.4 CR – Coastal Reclamation<br>3.6 LSF – Land Subject to Flooding<br>3.7 LSSS – Land Subject to Storm Surge<br>3.8 LADR – Land Adjacent to a Designated Road<br>3.9 DHD – Dredging in Darwin Harbour<br>3.14 HHLSI – Land in proximity to Helicopter Landing Sites of Strategic Importance | 5.2.1 General Height Control<br>5.2.4 Car Parking<br>5.2.5 Loading Bays<br>5.2.6 Landscaping<br>5.2.7 Setbacks for Development Adjacent to Land in Zones LR, LMR, MR or HR | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI<br>5.8.5 Leisure and Recreation |
| **Medical Clinic** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Motor Body Works** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI<br>5.6.3 Motor Body Works and Motor Repair Station |
| **Motor Repair Station** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI<br>5.6.3 Motor Body Works and Motor Repair Station |
| **Office** | **Impact assessable** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Passenger Terminal** | **Impact assessable** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Place of Worship** | **Impact assessable** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI<br>5.8.4 Exhibition Centre, Place of Assembly and Place of Worship |

| ASSESSMENT TABLE – ZONE GI – GENERAL INDUSTRY | | | | | |
|---|---|---|---|---|---|
| **Defined Use** | **Assessment Category** | **Overlays** | **General Development Requirements** | **Location Specific Development Requirements** | **Specific Development Requirements** |
| **Plant Nursery** | **Impact assessable** | 3.4 CR – Coastal Reclamation<br>3.6 LSF – Land Subject to Flooding<br>3.7 LSSS – Land Subject to Storm Surge<br>3.8 LADR – Land Adjacent to a Designated Road<br>3.9 DHD – Dredging in Darwin Harbour<br>3.14 HHLSI – Land in proximity to Helicopter Landing Sites of Strategic Importance | 5.2.1 General Height Control<br>5.2.4 Car Parking<br>5.2.5 Loading Bays<br>5.2.6 Landscaping<br>5.2.7 Setbacks for Development Adjacent to Land in Zones LR, LMR, MR or HR | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Recycling Depot** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Renewable Energy Facility** | **Impact assessable** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI<br>5.8.8 Renewable Energy Facility |
| **Service Station** | **Merit assessable** | | | | 5.5.8 Service Station<br>5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Sex Services-Commercial Premises** | **Permitted** | | | | 5.5.14 Sex Services-Commercial Premises<br>5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Sex Services-Home Based Business** | **Permitted** | | | | 5.4.10 Home Based Businesses |
| **Shop** | **Impact assessable** | | | | 5.5.5 Shops in Zones CV, CL, LI, GI, DV, OR and CN<br>5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Showroom Sales** | **Impact assessable** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |

| ASSESSMENT TABLE – ZONE GI – GENERAL INDUSTRY | | | | | |
|---|---|---|---|---|---|
| **Defined Use** | **Assessment Category** | **Overlays** | **General Development Requirements** | **Location Specific Development Requirements** | **Specific Development Requirements** |
| **Telecommunications Facility** | **Impact assessable** | 3.4 CR – Coastal Reclamation<br><br>3.6 LSF – Land Subject to Flooding<br><br>3.7 LSSS – Land Subject to Storm Surge<br><br>3.8 LADR – Land Adjacent to a Designated Road<br><br>3.9 DHD – Dredging in Darwin Harbour<br><br>3.14 HHLSI – Land in proximity to Helicopter Landing Sites of Strategic Importance | 5.2.1 General Height Control<br><br>5.2.4 Car Parking<br><br>5.2.5 Loading Bays<br><br>5.2.6 Landscaping<br><br>5.2.7 Setbacks for Development Adjacent to Land in Zones LR, LMR, MR or HR | | 5.8.10 Telecommunications Facility |
| **Transport terminal** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Vehicle Sales and Hire** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Veterinary Clinic** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **Warehouse** | **Permitted** | | | | 5.6.1 Setbacks and Building Design in Zones LI, GI and DV<br>5.6.2 Expansion of existing Developments in Zones LI and GI |
| **All other uses defined in Schedule 2 (Definitions)** | **Prohibited** | | | | |
| **Undefined Uses**<br>**Any use not defined in Schedule 2 (Definitions)** | **Impact assessable** | | | | Part 2, Part 3, Part 4, Part 5 of this Planning Scheme |

## 4.4 Zone MR – Medium Density Residential

Zone Purpose

Provide for a range of mid-rise housing options close to community facilities, commercial uses, public transport or open space, where reticulated services can support medium density residential development.

Zone Outcomes

1. Predominantly medium density residential developments generally not exceeding four ***storeys***.

2. **Home based businesses** and **dwellings-community residence** are operated in a manner consistent with residential ***amenity***.

3. **Residential care facilities** are of a scale and operated in a way that is compatible with the character and ***amenity*** associated with medium density residential development.

4. Non-residential activities, such as **child care centre** and **community centre**:
   (a) support the needs of the immediate residential community;
   (b) are of a scale and intensity compatible with the residential character and ***amenity*** of the area;
   (c) wherever possible, are co-located with other non-residential activities in the locality;
   (d) avoid adverse impacts on the surrounding road network; and
   (e) are managed to minimise unreasonable impacts on the ***amenity*** of surrounding residents.

5. Building design, ***site*** layout and landscaping provide a sympathetic interface to the adjoining public spaces and to adjoining lots, and provides privacy and attractive outdoor spaces.

6. An efficient pattern of land use with all lots connected to reticulated services, integrated with existing transport networks and with convenient ***access*** to open space, community and educational facilities.

| ASSESSMENT TABLE – ZONE MR – MEDIUM DENSITY RESIDENTIAL | | | | | |
|---|---|---|---|---|---|
| **Defined Use** | **Assessment Category** | **Overlays** | **General Development Requirements** | **Location Specific Development Requirements** | **Specific Development Requirements** |
| **Caravan Accommodation** | **Permitted** | 3.4 CR – Coastal Reclamation<br>3.6 LSF – Land Subject to Flooding<br>3.7 LSSS – Land Subject to Storm Surge<br>3.8 LADR – Land Adjacent to a Designated Road<br>3.14 HHLSI – Land in proximity to Helicopter Landing Sites of Strategic Importance | 5.2.1 General Height control<br>5.2.4 Car Parking<br>5.2.6 Landscaping<br>5.2.7 Setbacks for Development Adjacent to Land in Zones LR, LMR, MR or HR | | 5.4.11 Caravan Accommodation |
| **Child Care Centre** | **Impact assessable** | | | | 5.5.7 Child Care Centre<br>5.4.18 Fencing |
| **Community Centre** | **Impact assessable** | | | | 5.4.18 Fencing |
| **Demountable Structures** | **Merit assessable** | | | | 5.8.7 Demountable Structures |
| **Dwelling-Community Residence** | **Permitted** | | | | 5.4.14 Dwelling-Community Residence |
| **Dwelling-Group** | **Impact assessable** | | | | 5.4.1 Residential Density<br>5.4.3 Building Setbacks of Residential Buildings and Ancillary Structures<br>5.4.4 Extensions and Structures Ancillary to a Dwelling-group or Dwelling-Multiple Development<br>5.4.6 Private Open Space<br>5.4.8 Residential Building Design<br>5.4.17 Building Articulation<br>5.4.18 Fencing |
| **Dwelling-Independent** | **Permitted** | | | | 5.4.3 Building Setbacks of Residential Buildings and Ancillary Structures<br>5.4.6 Private Open Space<br>5.4.13 Dwelling-Independent |
| **Dwelling-Multiple** | **Merit assessable** | | | | 5.4.3 Building Setbacks of Residential Buildings and Ancillary Structures<br>5.4.4 Extensions and Structures Ancillary to a Dwelling-group or Dwelling-Multiple Development<br>5.4.6 Private Open Space<br>5.4.7 Communal Open Space<br>5.4.8 Residential Building Design<br>5.4.17 Building Articulation<br>5.4.18 Fencing<br>5.4.19 Residential Plot Ratio |

<table>
<tr><th colspan="6">ASSESSMENT TABLE – ZONE MR – MEDIUM DENSITY RESIDENTIAL</th></tr>
<tr><th>Defined Use</th><th>Assessment Category</th><th>Overlays</th><th>General Development Requirements</th><th>Location Specific Development Requirements</th><th>Specific Development Requirements</th></tr>
<tr><td>Dwelling-Single</td><td>Permitted</td><td rowspan="9">3.4 CR – Coastal Reclamation<br><br>3.6 LSF – Land Subject to Flooding<br><br>3.7 LSSS – Land Subject to Storm Surge<br><br>3.8 LADR – Land Adjacent to a Designated Road<br><br>3.14 HHLSI – Land in proximity to Helicopter Landing Sites of Strategic Importance</td><td rowspan="9">5.2.1 General Height control<br><br>5.2.4 Car Parking<br><br>5.2.6 Landscaping<br><br>5.2.7 Setbacks for Development Adjacent to Land in Zones LR, LMR, MR or HR</td><td rowspan="9"></td><td>5.4.1 Residential Density<br>5.4.3 Building Setbacks of Residential Buildings and Ancillary Structures<br>5.4.6 Private Open Space<br>5.4.18 Fencing</td></tr>
<tr><td>Excavation and Fill</td><td>Impact assessable</td><td>5.8.9 Excavation and fill</td></tr>
<tr><td>Home Based Business</td><td>Permitted</td><td>5.4.10 Home Based Businesses</td></tr>
<tr><td>Residential Care Facility</td><td>Impact assessable</td><td>5.4.3 Building Setbacks of Residential Buildings and Ancillary Structures<br>5.4.7 Communal Open Space<br>5.4.8 Residential Building Design<br>5.4.15 Residential Care Facility<br>5.4.17 Building Articulation<br>5.4.18 Fencing</td></tr>
<tr><td>Sex Services-Home Based Business</td><td>Permitted</td><td>5.4.10 Home Based Businesses</td></tr>
<tr><td>Telecommunications Facility</td><td>Impact assessable</td><td>5.8.10 Telecommunications Facility</td></tr>
<tr><td>All other uses defined in Schedule 2 (Definitions)</td><td>Prohibited</td><td></td></tr>
<tr><td>Undefined Uses<br>Any use not defined in Schedule 2 (Definitions)</td><td>Prohibited</td><td></td></tr>
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## 4.5 Zone HR – High Density Residential

Zone Purpose
Provide for a range of high rise housing options close to activity centres, public transport, open space and community facilities, where reticulated services can support high density residential development.

Zone Outcomes

1. High density residential developments generally not exceeding eight ***storeys*** in height that maximise the utilisation of the reticulated services and the development potential of the ***site***.

2. **Home based businesses** and **dwellings-community residence** are conducted in a manner consistent with residential ***amenity***.

3. **Hotel/motels**, **residential care facilities** and **rooming accommodation** are operated in a manner that is compatible with the ***amenity*** associated with high density residential development.

4. Non-residential activities, such as **education establishment**, **leisure and recreation**, **medical clinic, place of worship**, and **restaurant**:
   (a) are integrated with residential uses;
   (b) avoid adverse impacts on the local road networks:
   (c) are managed to minimise unreasonable impacts to the ***amenity*** of surrounding residents; and
   (d) are of a scale, intensity and nature that reflects the predominantly residential character of the zone.

5. Development integrates with walking, cycling and public transport networks to promote accessibility and use.

6. Innovative building design, ***site*** layout and landscaping that:
   (a) responds to microclimates, including breeze flow;
   (b) minimises privacy and overlooking impacts;
   (c) reduces the appearance of building mass relative to its surroundings; and
   (d) creates attractive outdoor spaces and enhances the streetscape.

7. An efficient pattern of land use with all lots connected to reticulated services, integrated with existing transport networks and with convenient ***access*** to open space, community and educational facilities.

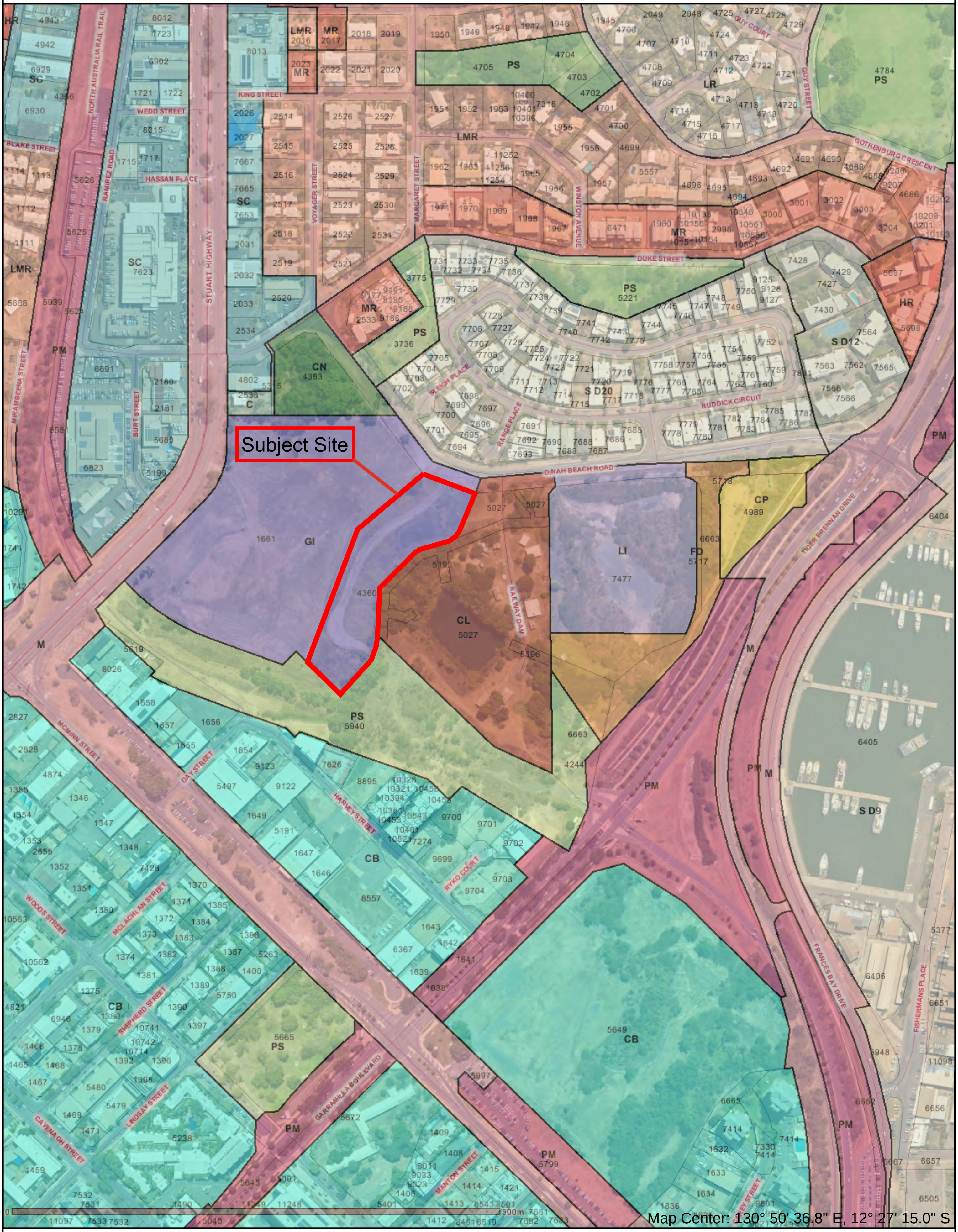
| ASSESSMENT TABLE – ZONE HR – HIGH DENSITY RESIDENTIAL | | | | | |
|---|---|---|---|---|---|
| **Defined Use** | **Assessment Category** | **Overlays** | **General Development Requirements** | **Location Specific Development Requirements** | **Specific Development Requirements** |
| **Caravan Accommodation** | **Permitted** | 3.4 CR – Coastal Reclamation<br>3.6 LSF – Land Subject to Flooding<br>3.7 LSSS – Land Subject to Storm Surge<br>3.8 LADR – Land Adjacent to a Designated Road<br>3.14 HHLSI – Land in proximity to Helicopter Landing Sites of Strategic Importance | 5.2.1 General Height Control<br>5.2.4 Car Parking<br>5.2.5 Loading Bays<br>5.2.6 Landscaping<br>5.2.7 Setbacks for Development Adjacent to Land in Zones LR, LMR, MR or HR<br>5.3.7 End of Trip Facilities in Zones HR, CB, C, SC and TC | | 5.4.11 Caravan Accommodation |
| **Child Care Centre** | **Merit assessable** | | | | 5.4.18 Fencing<br>5.5.3 General Building and Site Design<br>5.5.7 Child Care Centre |
| **Community Centre** | **Merit assessable** | | | | 5.4.18 Fencing<br>5.5.3 General Building and Site Design |
| **Demountable Structures** | **Merit assessable** | | | | 5.8.7 Demountable Structures |
| **Dwelling-Community Residence** | **Permitted** | | | | 5.4.14 Dwelling-Community Residence |
| **Dwelling-Group** | **Impact assessable** | | | | 5.4.1 Residential Density<br>5.4.3 Building Setbacks of Residential Buildings and Ancillary Structures<br>5.4.4 Extensions and Structures Ancillary to a Dwelling-Group or Dwelling-Multiple Development<br>5.4.6 Private Open Space<br>5.4.8 Residential Building Design<br>5.4.17 Building Articulation<br>5.4.18 Fencing |
| **Dwelling-Independent** | **Permitted** | | | | 5.4.3 Building Setbacks of Residential Buildings and Ancillary Structures<br>5.4.6 Private Open Space<br>5.4.13 Dwelling-Independent |
| **Dwelling-Multiple** | **Merit assessable** | | | | 5.4.3 Building Setbacks of Residential Buildings and Ancillary Structures<br>5.4.4 Extensions and Structures Ancillary to a Dwelling-Group or Dwelling-Multiple Development<br>5.4.6 Private Open Space<br>5.4.7 Communal Open Space<br>5.4.8 Residential Building Design<br>5.4.17 Building Articulation<br>5.4.18 Fencing<br>5.4.19 Residential Plot Ratio |

**ASSESSMENT TABLE – ZONE HR – HIGH DENSITY RESIDENTIAL**

| Defined Use | Assessment Category | Overlays | General Development Requirements | Location Specific Development Requirements | Specific Development Requirements |
|---|---|---|---|---|---|
| **Dwelling-Single** | **Permitted** | 3.4 CR – Coastal Reclamation<br>3.6 LSF – Land Subject to Flooding<br>3.7 LSSS – Land Subject to Storm Surge<br>3.8 LADR – Land Adjacent to a Designated Road<br>3.14 HHLSI – Land in proximity to Helicopter Landing Sites of Strategic Importance | 5.2.1 General Height Control<br>5.2.4 Car Parking<br>5.2.5 Loading Bays<br>5.2.6 Landscaping<br>5.2.7 Setbacks for Development Adjacent to Land in Zones LR, LMR, MR or HR<br>5.3.7 End of Trip Facilities in Zones HR, CB, C, SC and TC | | 5.4.1 Residential Density<br>5.4.3 Building Setbacks of Residential Buildings and Ancillary Structures<br>5.4.6 Private Open Space<br>5.4.18 Fencing |
| **Education Establishment** | **Impact assessable** | | | | 5.4.18 Fencing<br>5.8.2 Education Establishment |
| **Excavation and Fill** | **Impact assessable** | | | | 5.8.9 Excavation and Fill |
| **Food Premises-Café/Take Away** | **Merit assessable** | | | | 5.4.18 Fencing<br>5.5.3 General Building and Site Design5.5.3 General Building and Site Design<br>5.5.11 Food Premises |
| **Food Premises-Restaurant** | **Impact assessable** | | | | 5.4.18 Fencing<br>5.5.3 General Building and Site Design5.5.3 General Building and Site Design<br>5.5.11 Food Premises |
| **Home Based Business** | **Permitted** | | | | 5.4.10 Home Based Businesses |
| **Hotel/Motel** | **Impact assessable** | | | | 5.4.3 Building Setbacks of Residential Buildings and Ancillary Structures<br>5.4.18 Fencing<br>5.5.3 General Building and Site Design |
| **Leisure and Recreation** | **Impact assessable** | | | | 5.4.18 Fencing<br>5.5.3 General Building and Site Design<br>5.8.5 Leisure and Recreation |
| **Medical Clinic** | **Impact assessable** | | | | 5.4.18 Fencing<br>5.5.3 General Building and Site Design |
| **Place of Worship** | **Impact assessable** | | | | 5.4.18 Fencing<br>5.5.3 General Building and Site Design<br>5.8.4 Exhibition Centre, Place of Assembly and Place of Worship |

| ASSESSMENT TABLE – ZONE HR – HIGH DENSITY RESIDENTIAL | | | | | |
|---|---|---|---|---|---|
| **Defined Use** | **Assessment Category** | **Overlays** | **General Development Requirements** | **Location Specific Development Requirements** | **Specific Development Requirements** |
| **Residential Care Facility** | **Impact assessable** | 3.4 CR – Coastal Reclamation<br>3.6 LSF – Land Subject to Flooding<br>3.7 LSSS – Land Subject to Storm Surge<br>3.8 LADR – Land Adjacent to a Designated Road<br>3.14 HHLSI – Land in proximity to Helicopter Landing Sites of Strategic Importance | 5.2.1 General Height Control<br>5.2.4 Car Parking<br>5.2.5 Loading Bays<br>5.2.6 Landscaping<br>5.2.7 Setbacks for Development Adjacent to Land in Zones LR, LMR, MR or HR<br>5.3.7 End of Trip Facilities in Zones HR, CB, C, SC and TC | | 5.4.3 Building Setbacks of Residential Buildings and Ancillary Structures<br>5.4.7 Communal Open Space<br>5.4.8 Residential Building Design<br>5.4.15 Residential Care Facility<br>5.4.17 Building Articulation<br>5.4.18 Fencing |
| **Sex Services-Home Based Business** | **Permitted** | | | | 5.4.10 Home Based Businesses |
| **Rooming Accommodation** | **Impact assessable** | | | | 5.4.3 Building setbacks of Residential Buildings and Ancillary Structures<br>5.4.7 Communal Open Space<br>5.4.8 Residential Building Design<br>5.4.17 Building Articulation<br>5.4.19 Residential Plot Ratio |
| **Telecommunications Facility** | **Impact assessable** | | | | 5.8.10 Telecommunications Facility |
| **All other uses defined in Schedule 2 (Definitions)** | **Prohibited** | | | | |
| **Undefined Uses**<br>**Any use not defined in Schedule 2 (Definitions)** | **Prohibited** | | | | |

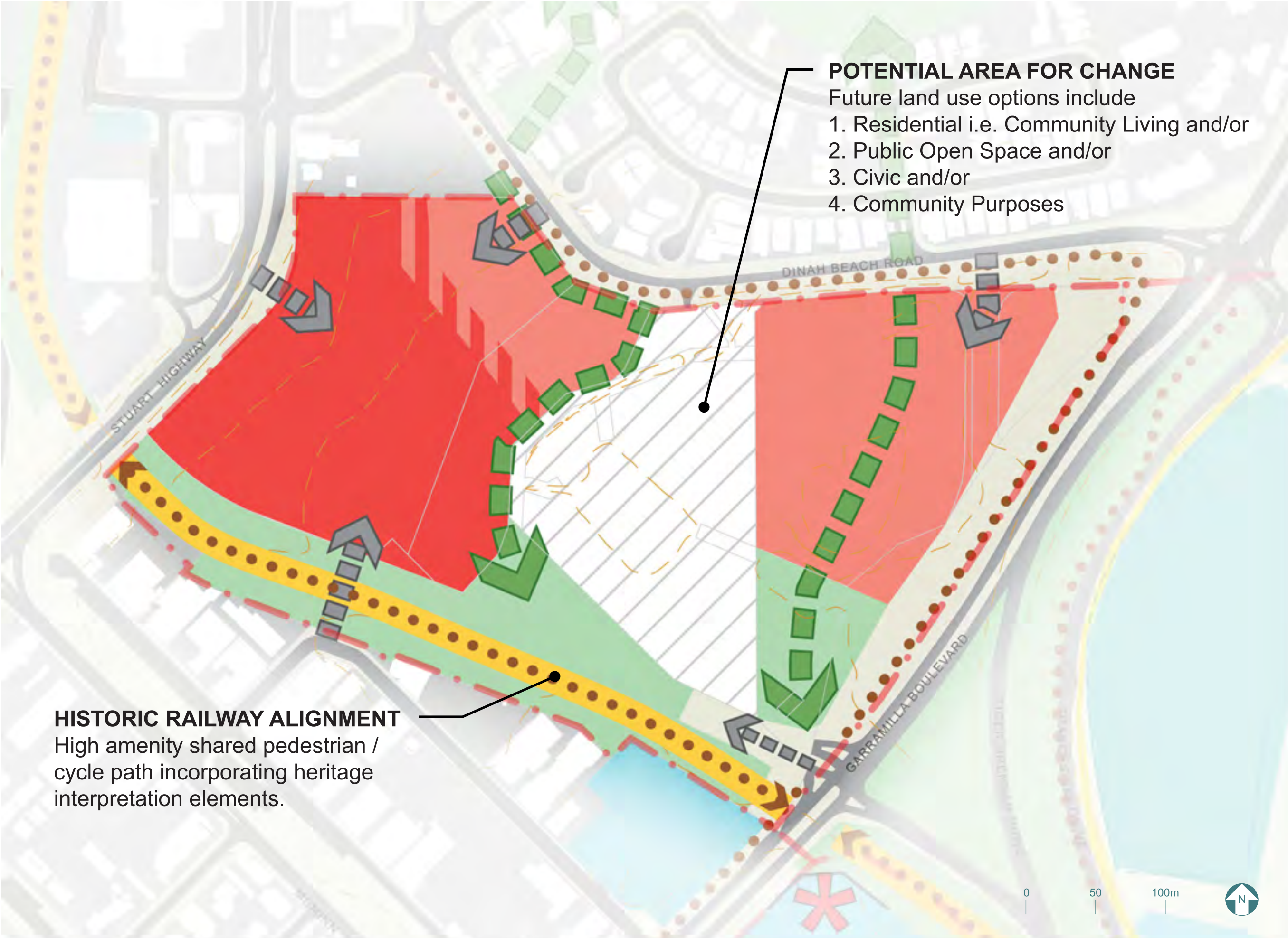
# Locality Map




Created by WFLET

Bottom Left: -12° 27' 23", 130° 50' 20" Top Right: -12° 27' 06", 130° 50' 53" Approximate Scale: 1:4,900 Datum: GDA 1994

Data for information purposes only - accuracy not guaranteed




# E

# Former Tank Farm

**LEGEND**

- Focus Area Boundary
- Public Open Space
- Pedestrian Priority Area (Hardscape Open Space)
- Priority pedestrian / cycleway network
- Medium Density Residential (Transition to 4 storeys approx.)
- High Density Residential (Transition to 8 storeys approx.)
- Potential Area for Change
- Potential New Street Connection
- Key Pedestrian Connection

# E

# Former Tank Farm

The current zoning of Light and General Industry over much of the Former Tank Farm area reflects previous uses for fuel storage. This land has been underdeveloped for some time but close proximity to the city centre, Stuart Park, Botanic Gardens and golf course signifies high development potential. There is now an opportunity to develop this land for residential uses incorporating the cultural and environmental values of the area. The size and location of the former Tank Farm area presents a large-scale opportunity for growth that transitions, and provides connectivity, between the city centre and Stuart Park.

The area is well connected regionally, being framed by two higher order roads and Garramilla Boulevard. However, the locality is currently constrained by limited local access with sites in the area only available from Dinah Beach Road. Equally important for the development of the area will be good internal access including pedestrian and cyclist connections, and open space.

A new public open space area along the former railway corridor will provide a significant connection to the regional open space, pedestrian and cycle networks.

Development in this area will need to respond to site constraints including contamination from former petrol storage uses and mosquito breeding areas.

Landowners are encouraged to collaborate with other landowners within the Former Tank Farm Focus Area, including the NT Government, to co-ordinate development and infrastructure provision prior to the preparation of detailed design. This approach aims to minimise costs and facilitate development consistent with the potential of the area.

| 15. Allow for the redevelopment within the Former Tank Farm Focus Area for residential and open space while recognising the social, cultural, and historical value of parts of the locality | |
|---|---|
| **Objectives** | **Acceptable Responses** |
| 15.1 Encourage redevelopment of land for residential uses. | i. Development and rezoning provides a transition in density from the Focus Area Map to surrounding areas.<br>ii. Development of surrounding sites provides an appropriate interface to the One Mile Dam area to minimise impacts on the amenity of the residents. |
| 15.2 Commercial land uses cater for the daily, lower order needs of the local community. | i. The net floor area of a commercial land use does not exceed 200sqm per development.<br>ii. Leisure and recreation, sports and community facilities (including places of worship, libraries, meeting halls and the like) that demonstrate compatibility with the residential character of the area. |
| 15.3 Facilitate the extension and enhancement of a regionally significant open space network. | i. Provide a shared movement corridor with open space along the former rail corridor to facilitate pedestrian and cycle access between The Gardens, the city centre and Frances Bay.<br>ii. The remnant rainforest is connected with other natural systems through considered provision of open space and pedestrian links.<br>iii. The design of open space corridors acknowledges and interprets the history of the area. This may be achieved through plaques, artwork, landscape architecture or similar. |
| 15.4 Facilitate the provision of an integrated local road network. | i. Development proposals are to address the potential need for the realignment of Stuart Highway to Day Street.<br>ii. Limited road access is provided to Tiger Brennan Drive, Stuart Highway and Dinah Beach Road.<br>iii. A local road is developed along the southern side of this focus area that services all current lots; development on any site ensures access to this road from neighbouring sites. |
| 15.5 Respond appropriately to constraints of the land. | i. Development demonstrates a response to stormwater management and the rehabilitation of areas that allow mosquito breeding to the requirements of the relevant authorities. |

# Lot 4360 (No. 12) Dinah Beach Road, Darwin

## Proposed Planning Scheme Amendment

October 2025 | 25164

| Document ID: 25-164 | | | | | |
|---|---|---|---|---|---|
| Issue | Date | Status | Prepared by | Approved by | |
| | | | Name | Name | Signature |
| D1 | 21.10.25 | Draft | Emily Greenwood | Lewis Shugar | |
| F1 | 23.10.25 | Final | Emily Greenwood | Lewis Shugar | |

element. | PART OF SLR

We acknowledge the Whadjuk people of the Noongar nation as Traditional Owners of the land on which we live and work. We acknowledge and respect their enduring culture, their contribution to the life of this city, and Elders, past and present.

# Contents

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# 1. Introduction

This report has been prepared by Element Advisory (part of SLR) (Element Advisory) on behalf of Richmond + Ross and the landowner, to request a Planning Scheme Amendment (PSA) to the *Northern Territory Planning Scheme 2020* (NTPS 2020).

The proposed PSA seeks to rezone Lot 4360 (No. 12) Dinah Beach Road, Darwin (the subject site) from General Industry (GI) to High Density Residential (HR) and Medium Density Residential (MR). Details of the Certificate of Title for the subject site are provided in Appendix A, confirming the registered proprietorship and cadastral information for the subject site.

*Refer to Appendix A – Title Details*

The proposed PSA will facilitate future development in alignment with the intended land use outcomes identified in the Central Darwin Area Plan (Area Plan).

This request is made pursuant to Section 13(1) of the *Planning Act 1999* (the Act), with an assessment against the relevant provisions of the Act included in this report.

## 1.1 Background

In 2015, a PSA request was lodged with the NT Government that proposed to rezone the subject site from GI to Central Business (CB). At the time, the PSA request was not supported by the Minister as there was no existing strategic planning framework in place to guide future development in this location.

Following this, the Northern Territory Planning Commission (NTPC) commenced the preparation of the Darwin City Centre and Periphery Area Plan between 2016 to 2017. The Area Plan was finalised in 2019 and updated in 2020 to align with the NTPS 2020.

This PSA request has been prepared in accordance with the Area Plan, which provides the strategic planning framework to allow this request to be supported.

In support of this PSA request and to facilitate a more substantial development outcome at the subject site, comprehensive remediation and groundwater validation works have been undertaken at the subject site between 2014 and 2018 under the Northern Territory Environment Protection Authority's (NT EPA) voluntary environmental audit framework. These works have suitably remediated the subject site, making it capable of supporting future development, including residential uses envisaged by the Area Plan.

## 1.2 Approval Required

Approval of this PSA is sought from the Minister for Infrastructure, Planning and Logistics. Landowner consent has been provided by the landowner, authorising Element Advisory to lodge the request on their behalf.

# 2. The Proposal

## 2.1 Proposed Zoning

This PSA proposes to rezone the subject site from its current GI zoning to a residential zoning (MR and HR) that will support appropriately scaled development that aligns with the Area Plan. In this respect, the subject site is proposed to be rezoned as follows:

**Table 1: Current and Proposed Zonings**

| Subject Site Areas | Current Zoning | Proposed Zoning |
|---|---|---|
| Northern portion (6,274m²) | General Industry | Medium Density Residential |
| Southern portion (7,778m²) | General Industry | High Density Residential |

Table 1 is also visually represented in Figures 1 and 2 below.

*Refer to Figure 1 – Current Zoning (General Industry)*

*Refer to Figure 2 – Proposed Zoning (Medium Density Residential and High Density Residential)*


*Figure 1 – Current Zoning (General Industry)*


*Figure 2 - Proposed Zoning (Medium Density Residential and High Density Residential)*

## 2.2 Supporting Development Concept

Development concept plans have been prepared to support the proposed PSA and visually reflect the scale of development that could be achieved by applying the medium density and high density residential zones to the subject site. The concept plans have been prepared to illustrate a possible future mixed-use development that could be achieved at the subject site following the proposed PSA being formalised.

Consistent with the scale of development envisaged by the Area Plan, the supporting development concept indicatively includes the following key components:

- Built form and scale that reflects the proposed zoning as follows:
  - Two residential towers of eight and seven storeys within the HR portion of the subject site.
  - One residential tower of four storeys within the MR portion of the subject site.
  - Approximately 200m$^2$ of commercial floorspace at the ground level of each residential tower (total 600m$^2$).
- Indicative access roads on the western and southern lot boundaries to provide vehicle access to a potential future development; and
- A pedestrian link along the eastern boundary located primarily within the subject site. This link has been indicatively shown to also utilise the existing Crown land (Lot 5193), which is believed to be a drainage reserve, and therefore may provide an opportunity for co-location of its drainage function with a wider strategic need for pedestrian linkages.

The development concept plans can be referred to in Appendix B and extracts provided in figures 3, 4 and 5 below.

*Refer to Figure 3 – Proposed 3D Development Concept*

*Refer to Figure 4 – Proposed Development Concept Site Plan*

*Refer to Figure 5 – Proposed Development Concept Ground Floor Plan*

*Refer to Appendix B – Proposed Development Concept*

It is anticipated that a more detailed design process will occur in the future to fully realise a development opportunity at the subject site.

A detailed analysis of the subject site and an assessment of the proposed PSA is considered in further detail within the following sections of this report.


*Figure 3 - Proposed 3D Development Concept*

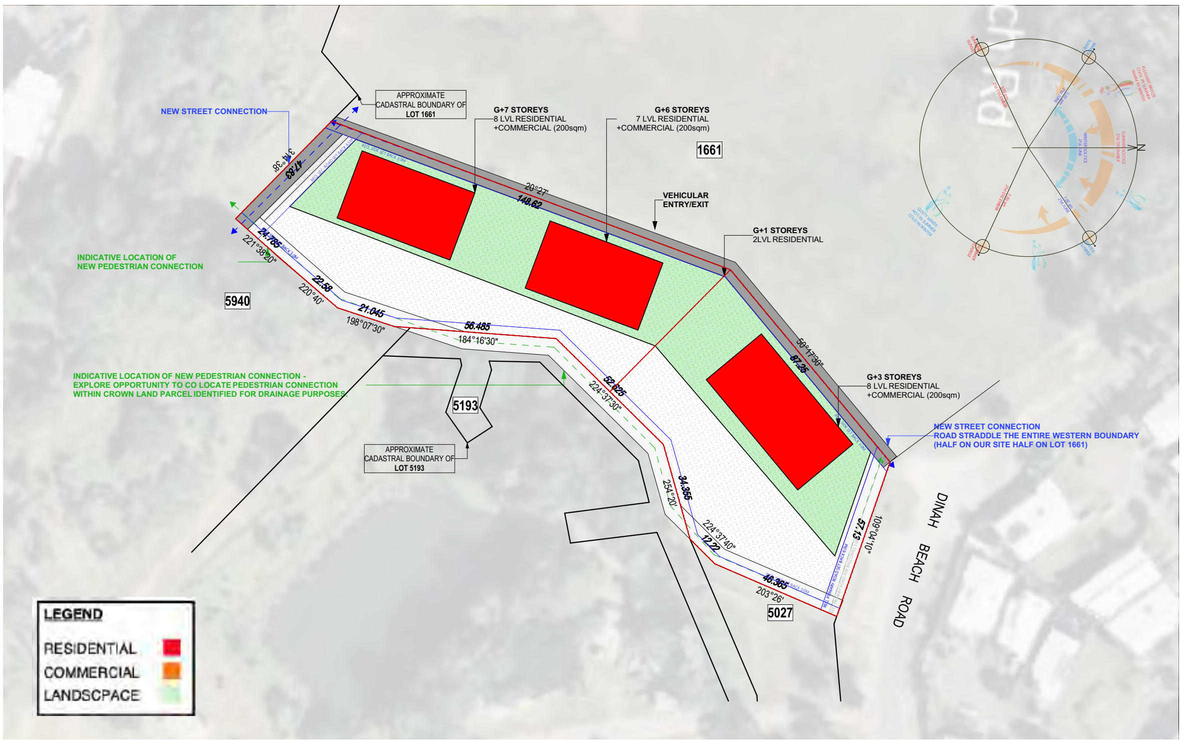



*Figure 4 – Proposed Development Concept Site Plan*


*Figure 5 - Proposed Development Concept Ground Floor*

# 3. Site Details

## 3.1 Site Location and Property Description

The subject site is located at Lot 4360 (No. 12) Dinah Beach Road, Darwin, within the City of Darwin municipality. It is bounded to the east by the One Mile Dam Aboriginal Community, vacant land to the west formerly used as a Mobil depot that has since been remediated and the former railway reservation to the south.

The subject site is accessed from Dinah Beach Road to the north, which connects to Garramilla Boulevard to the east and Daly Street to the west. To the north of the subject site lies the suburb of Stuart Park, an established residential area.

The title details of the subject site are set out in the table below.

**Table 2: Site Particulars**

| Lot | Address | Survey Plan | Volume | Folio | Area |
|---|---|---|---|---|---|
| 4360 | 12 Dinah Road, Darwin | A 000413 | 164 | 25 | 14,052m² |

*Refer to Appendix A – Title Details*

*Refer to Figure 6 – Site Plan*

*Refer to Figure 7 – Current Zoning Map*

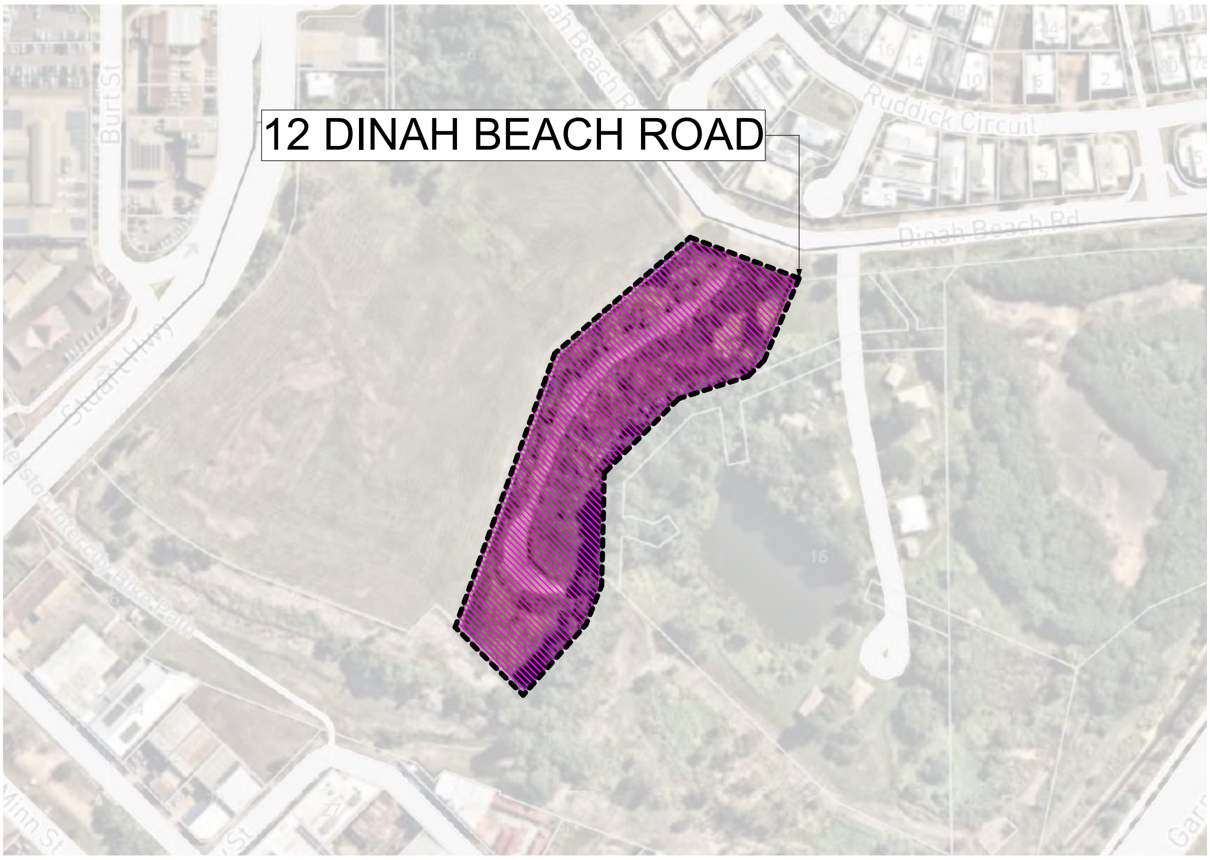



*Figure 6 - Site Plan*

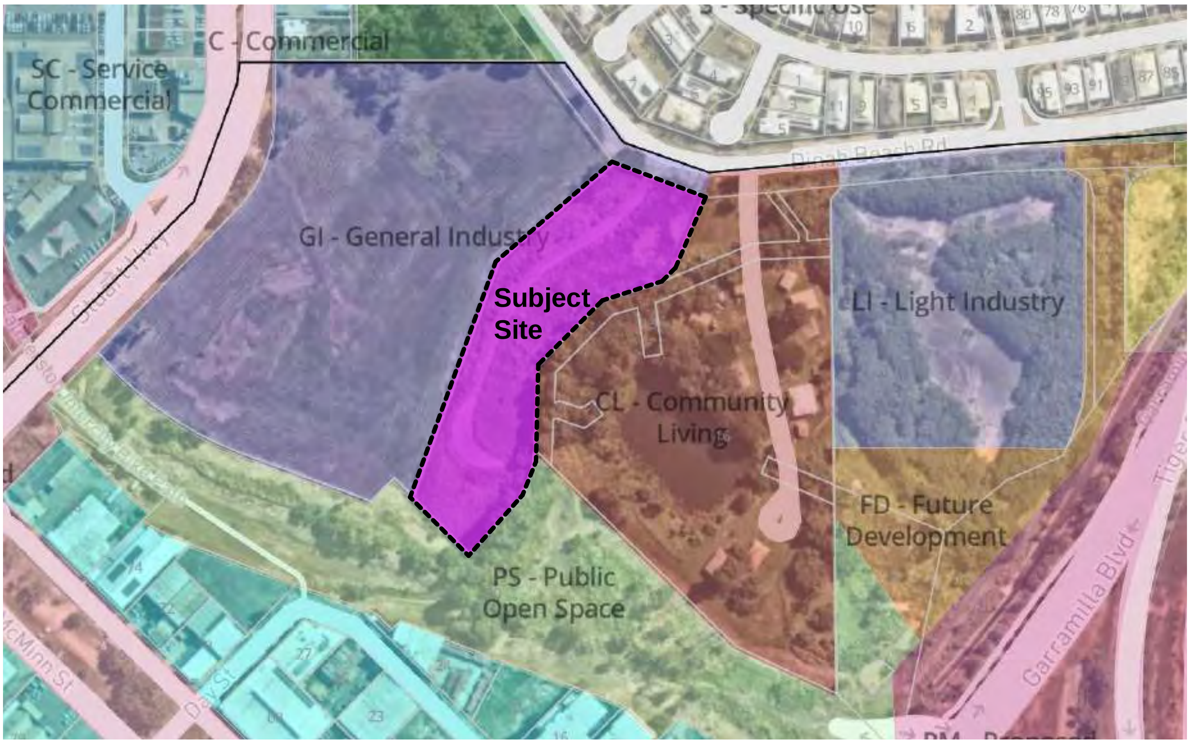



*Figure 7 – Current Zoning Map (highlighting the subject site and adjoining zonings)*

## 3.2 Site Considerations

### 3.2.1 Contamination

The subject site has undergone numerous environmental assessments, and remediation works following its historic use as a fuel depot. Investigations commenced in the late 1990s and confirmed the presence of hydrocarbon-impacted soils and groundwater associated with the long-term storage and handling of petroleum products. To address these impacts, remediation was undertaken in two stages under the NT EPA's voluntary environmental audit framework. The northern portion of the subject site was remediated during the 2014 dry season, with the southern portion completed in 2015. Works involved excavation, removal and treatment of contaminated soils, followed by validation sampling to confirm the effectiveness of remediation.

Following remediation, groundwater was monitored between 2014 and 2018 to confirm that contamination had been reduced to safe levels. In 2018, additional testing was carried out for the presence of per- and poly-fluoroalkyl substances (PFAS) in groundwater and nearby surface waters after concerns were raised by the NT EPA.

While some PFAS were detected, investigations showed they came from off-site sources and were not linked to the Caltex depot. No further work was required, and the independent audit process confirmed the land has been made suitable for future residential and other sensitive uses.

The final Condition Report prepared in 2020 is included at Appendix C for reference.

*Please Refer to Appendix C – Final Condition Report 2020*

### 3.2.2 Stormwater

Stormwater is managed through an open drain along the eastern boundary of the subject site and a network of reinforced concrete pipes connecting to the wider CBD drainage system. Environmental investigations as part of the remedial works have confirmed that downstream surface waters have been assessed, with no further stormwater-related remediation required to support future redevelopment.

### 3.2.3 Storm Surge

A minor section of the subject site's north-east corner is mapped within the Secondary Storm Surge Area (SSSA), representing potential inundation associated with a 1,000 year ARI (average recurrence interval) tropical cyclone storm surge. The pink line shown on mapping identifies the Extreme Storm Surge Extent (ESSE), corresponding to a 10,000 year ARI event.

Whilst the SSSA does impact a portion of the subject site, it is anticipated that a future development proposal will be able to consider this in detail, responding to and mitigating any impacts through a design response.

*Refer to Figure 8 - Storm Surge Risk (Source: NT Gov 2020)*

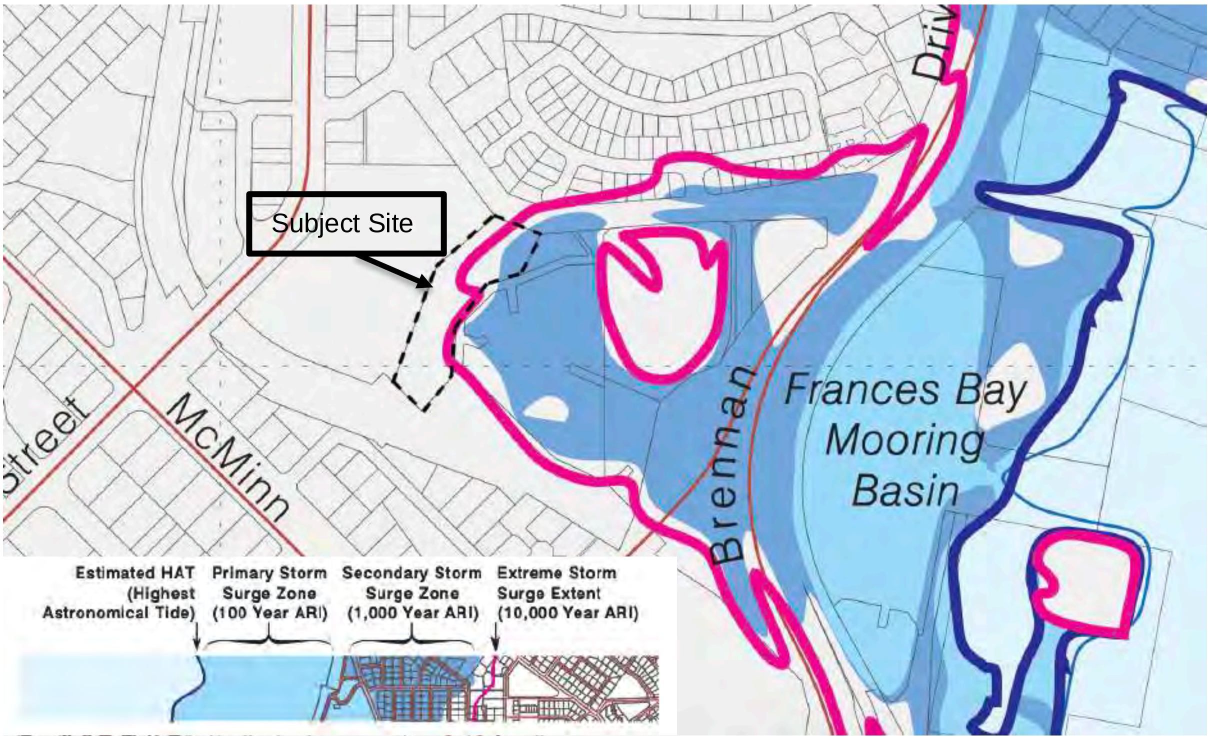



*Figure 8 - Storm Surge Risk (Source: NT Gov 2020)*

### 3.2.4 Topography and Vegetation

Although past industrial use and subsequent remediation works have altered some ground levels, the subject site generally presents as a flat landform with no significant variations in elevation. A slight rise is evident in the south-east corner and along the eastern boundary.

The subject site contains some scattered vegetation along sections of the cadastral boundaries.

*Refer to Figure 9 – Topography*

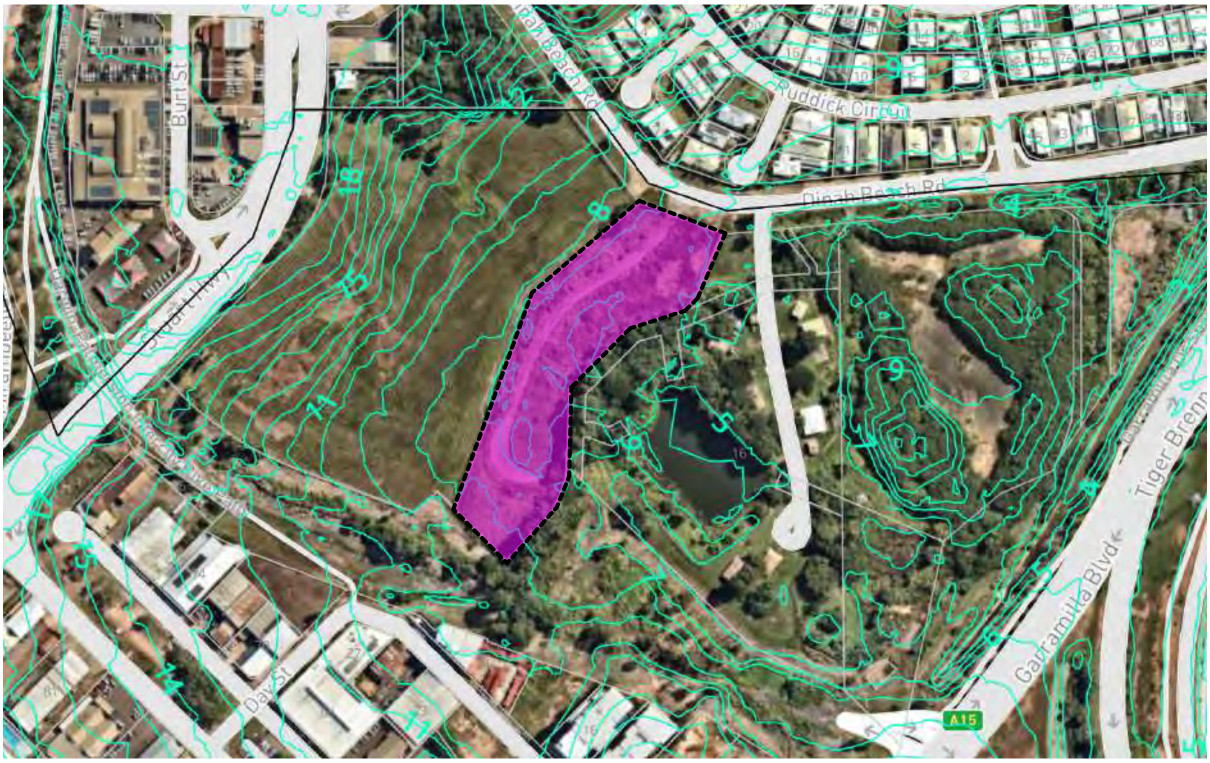


*Figure 9 - Topography*

# 4. Planning Framework and Assessment

## 4.1 Central Darwin Area Plan

The NTPS has prepared this Area Plan to provide a framework to inform consideration of any future proposals to rezone land or alter land use across Darwin from Cullen Bay to Darwin Waterfront, the Former Tank Farm and Stuart Park.

*Refer to Figure 10 – Central Darwin Area Plan – Study Area*

The Area Plan establishes the vision, objectives and land use directions to accommodate population growth, enhance housing choice, and support the delivery of infrastructure, services and employment opportunities.

The subject site is identified within the Area Plan as part of a key transition area for future medium and higher density residential development, reflecting its proximity to the CBD, access to transport, and its relationship with surrounding residential and community uses.

### 4.1.1 Focus Area E – Former Tank Farm

The subject site is located centrally within Focus Area E – Former Tank Farm (Former Tank Farm), as shown in Figure 11.

*Refer to Figure 11 - Central Darwin Area Plan - E Former Tank Farm*


*Figure 10 – Central Darwin Area Plan – Study Area*

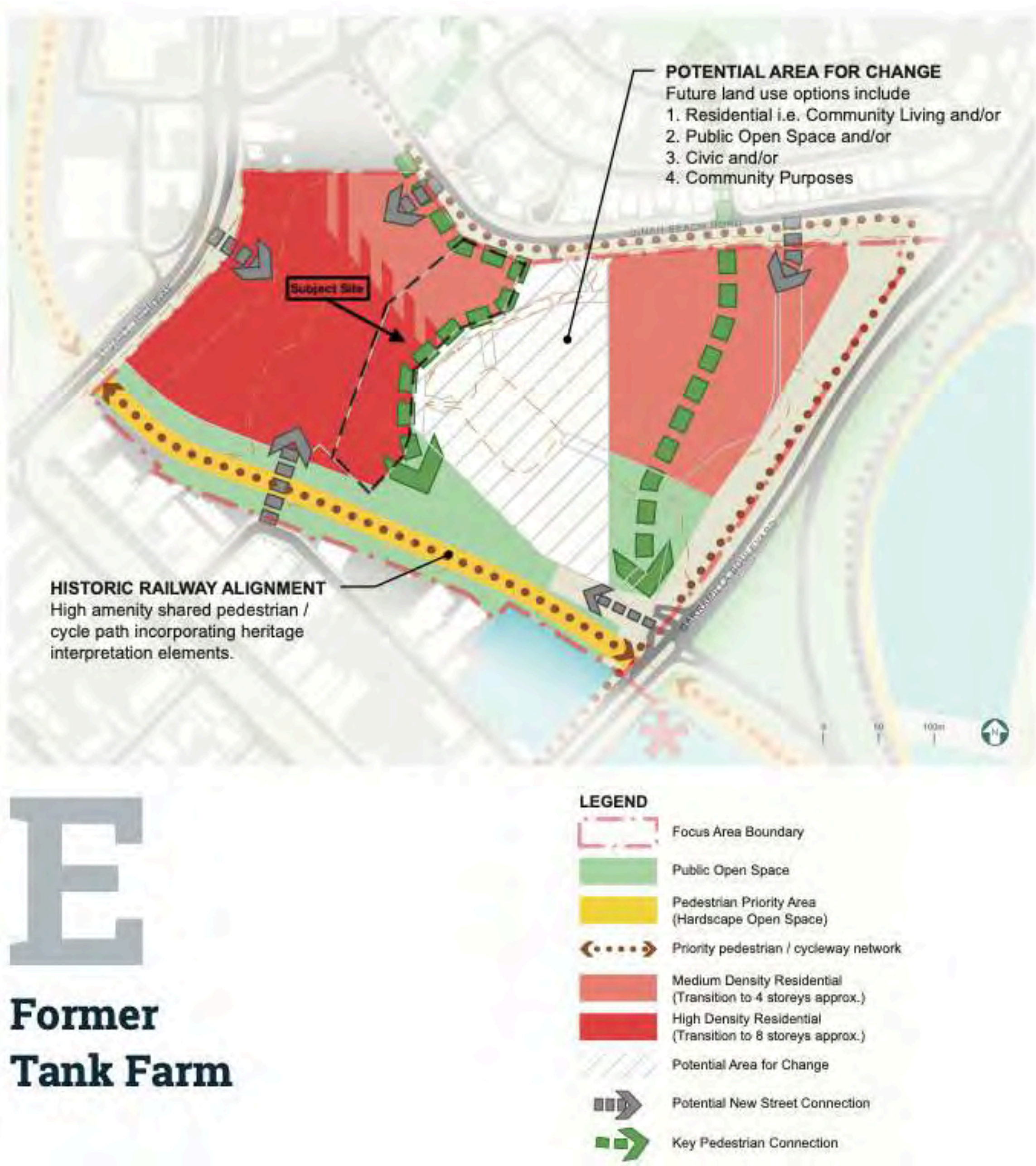



*Figure 11 - Central Darwin Area Plan - E Former Tank Farm*

The Former Tank Farm is identified as a major redevelopment precinct transitioning from its historic industrial use to a medium density residential neighbourhood. The Area Plan envisages a range of residential development opportunities, generally up to four storeys, with higher densities closer to Dinah Beach Road. Redevelopment is intended to integrate with surrounding open space, provide improved pedestrian and cycle connections, and support a mix of housing that meets future demand close to the city centre.

The proposed PSA has been prepared in accordance with the land use zonings established in the Area Plan as seen in Figure 11, which includes the split zoning of MR and HR to accommodate an appropriate development transition.

The objectives of the Area Plan that are relevant to consider as part of this PSA request are as follows:

> *Objective 15.1 Encourage redevelopment of land for residential uses.*

*Objective 15.2 Commercial land uses cater for the daily, lower order needs of the local community.*

*Objective 15.3 Facilitate the extension and enhancement of a regionally significant open space network.*

*Objective 15.4 Facilitate the provision of an integrated local road network.*

*Objective 15.5 Respond appropriately to constraints of the land.*

The proposed PSA supports the objectives of the Area Plan by enabling the transition of the subject site from its former industrial use to residential development. The MR and HR zones proposed through this PSA request will allow for a mix of housing types, supported by small-scale commercial and community uses. It promotes integration with future open space and movement networks, supports the ongoing development of local road systems, and responds appropriately to site constraints through prior remediation.

Future development proposals at the subject site will need to consider the acceptable responses established in the Area Plan and manage potential amenity impacts between residential and industrial activities in the instance where the adjoining land remains GI for an unknown period of time.

## 4.2 Northern Territory Planning Scheme 2020

The purpose of the land use zones proposed to apply to the subject site through this PSA are defined by the NTPS 2020 as follows:

High Density Residential - *Provide for a range of high rise housing options close to activity centres, public transport, open space and community facilities, where reticulated services can support high density residential development.*

Medium Density Residential - *Provide for a range of mid-rise housing options close to community facilities, commercial uses, public transport or open space, where reticulated services can support medium density residential development.*

The proposed PSA meets the purpose of the MR and HR zones by enabling the redevelopment of a vacant site that is well-located and fully serviced, to deliver a mix of mid-rise and high-rise development scale that will deliver residential and commercial opportunities in close proximity to the CBD, public transport, open space and community facilities.

The land use zones proposed through this PSA are consistent with the Area Plan and the zones envisaged within the Former Tank Farm area as shown in Figure 11 above. The HR and MR zones proposed by this PSA are discussed below.

### 4.2.1 High Density Residential Zone Outcomes

Clause 4.5 of the NTPS 2020 outlines the Zone Outcomes for the HR zone as follows:

1. *High density residential developments generally not exceeding eight storeys in height that maximise the utilisation of the reticulated services and the development potential of the site.*
2. *Home based businesses and dwellings-community residence are conducted in a manner consistent with residential amenity.*
3. *Hotel/motels, residential care facilities and rooming accommodation are operated in a manner that is compatible with the amenity associated with high density residential development.*
4. *Non-residential activities, such as education establishment, leisure and recreation, medical clinic, place of worship, and restaurant:*
    a. *are integrated with residential uses;*
    b. *avoid adverse impacts on the local road networks:*

   c. *are managed to minimise unreasonable impacts to the amenity of surrounding residents; and*
   d. *are of a scale, intensity and nature that reflects the predominantly residential character of the zone.*
5. *Development integrates with walking, cycling and public transport networks to promote accessibility and use.*
6. *Innovative building design, site layout and landscaping that:*
   a. *responds to microclimates, including breeze flow;*
   b. *minimises privacy and overlooking impacts;*
   c. *reduces the appearance of building mass relative to its surroundings; and*
   d. *creates attractive outdoor spaces and enhances the streetscape.*
7. *An efficient pattern of land use with all lots connected to reticulated services, integrated with existing transport networks and with convenient access to open space, community and educational facilities.*

The proposed PSA supports the outcomes of the proposed HR zone by enabling development in accordance with the Area Plan that maximises the subject site's potential within the identified eight storey height limit and fully utilises existing reticulated services.

All uses capable of approval under the HR zone are considered to be appropriate at the subject site, providing flexibility for a range of residential and compatible local uses to be developed and thereby maximising the subject site's development potential.

### 4.2.2 Medium Density Residential Zone Outcomes

Clause 4.4 of the NTPS 2020 outlines the Zone Outcomes for the MR zone as follows:

1. *Predominantly medium density residential developments generally not exceeding four storeys.*
2. *Home based businesses and dwellings-community residence are operated in a manner consistent with residential amenity.*
3. *Residential care facilities are of a scale and operated in a way that is compatible with the character and amenity associated with medium density residential development.*
4. *Non-residential activities, such as child care centre and community centre:*
   a. *support the needs of the immediate residential community;*
   b. *are of a scale and intensity compatible with the residential character and amenity of the area;*
   c. *wherever possible, are co-located with other non-residential activities in the locality;*
   d. *avoid adverse impacts on the surrounding road network; and*
   e. *are managed to minimise unreasonable impacts on the amenity of surrounding residents.*
5. *Building design, site layout and landscaping provide a sympathetic interface to the adjoining public spaces and to adjoining lots, and provides privacy and attractive outdoor spaces.*
6. *An efficient pattern of land use with all lots connected to reticulated services, integrated with existing transport networks and with convenient access to open space, community and educational facilities.*

The proposed PSA supports the outcomes of the proposed MR zone by facilitating residential development up to four storeys in height that complements the surrounding urban form and residential character. The zoning allows for compatible non-residential uses, such as child cares and community centres, that support the needs of local residents without adversely impacting amenity or the road network.

All uses capable of approval within the MR zone are considered to be appropriate at the subject site, providing flexibility for a mix of residential and supporting community uses.

## 4.3 Planning Act 1999

The proposed PSA relates to the rezoning of the subject site from GI to MR and HR pursuant to Section 13(1) of the Act to facilitate future development of the subject site in accordance with the Area Plan.

In support of the proposed amendment, the following section provides an assessment of the proposed PSA against the purpose and objectives of the Act, demonstrating how the proposal aligns with the Act's intent to achieve sustainable, orderly and appropriate development outcomes.

### 4.3.1 Purpose and Objectives

*(a) to ensure that strategic planning is applied to planning schemes and implemented in individual planning decisions;*

*(b) to ensure that strategic planning reflects the wishes and needs of the community;*

*(c) to ensure that appropriate public consultation and input are included in the formulation of planning schemes and the making of decisions under planning schemes;*

*(d) to ensure that the planning system is clear, comprehensive, effective, efficient and accessible to the community;*

*(e) to promote the sustainable development of land;*

*(f) to promote the responsible use of land and water resources to limit the adverse effects of development on ecological processes;*

*(g) to maintain the health of the natural environment and ecological processes*

*(h) to protect the quality of life of future generations;*

*(i) to assist the provision of public utilities, infrastructure and facilities for the benefit of the community;*

*(j) to promote the good design of buildings and other works that respects the amenity of the locality;*

The proposed PSA is considered to be consistent with the purpose and objectives as the proposed zoning reflects a strategic and sustainable approach to redevelopment of the subject site in accordance with the Area Plan. It facilitates the transition of remediated industrial land to residential uses that reflect the communities needs, supports the efficient use of land and infrastructure, protects environmental values, and promotes well-designed development that enhances local amenity and quality of life.

### 4.3.2 Section 13 Assessment

The proposal has been assessed against the relevant requirements of Section 13 of the Act in the table below:

**Table 3: Assessment against Section 13 of the Act**

| Purpose | Response |
|---|---|
| *Section 13(1)*<br>*When considering a request to amend a planning scheme, the Minister must also consider the following:* | |
| *(a) whether the proposed amendment promotes the purpose and objectives of this Act;* | The following objectives of the Act are considered to be relevant to the proposed PSA: |

| | |
|---|---|
| | *(e) to promote the sustainable development of land;*<br>*(f) to promote the responsible use of land and water resources to limit the adverse effects of development on ecological processes;*<br>*(h) to protect the quality of life of future generations;*<br>The proposed PSA promotes the abovementioned objectives by implementing endorsed strategic planning, enabling the redevelopment of a remediated site, and supporting orderly and proper planning outcomes. |
| *(b) whether the proposed amendment, other than a proposed amendment to a strategic framework, is contrary to any strategic framework in the planning scheme;* | The proposed PSA directly implements the intent of the Area Plan which identifies the subject site for medium and high density residential development. |
| *(c) whether the proposed amendment is within a declared class of amendments that do not require exhibition;* | The proposed PSA is not within a declared class and is submitted as a stand-alone amendment. |
| *(d) whether the proposed amendment is not significant enough to require exhibition;* | The proposed PSA is not considered significant enough to require exhibition as it gives effect to the Area Plan. |
| *(e) the merits of the proposed amendment and whether the amendment is in the public interest;* | The proposed PSA is considered to be a benefit to the public as it will enable redevelopment of a remediated site for much-needed housing in line with endorsed strategic planning. |
| *(f) any report from the Planning Commission under section 12B(3);* | N/A |
| *(g) any other matters the Minister considers appropriate.* | There are not anticipated to be any additional matters that may be raised that would prevent the proposed PSA from being supported. |
| Section 13(2)<br>*Despite Divisions 3 and 4, the Minister need not take any action under those Divisions in respect of a proposed amendment if satisfied that:* | |
| *(a) the proposed amendment is within a declared class of amendments; or*<br>*(b) the proposed amendment is not significant enough to require exhibition.* | The proposed PSA is not considered significant enough to require exhibition as it gives effect to the Area Plan and does not introduce any new or unexpected land use outcomes. |

# 5. Conclusion

This report has been prepared by Element Advisory on behalf of Richmond + Ross and the landowner to request an amendment to the NTPS 2020 to rezone Lot 4360 (No. 12) Dinah Beach Road, Darwin from GI to HR and MR.

This report sets out the proposed request in detail including the background to this proposal and provides a detailed planning assessment against the applicable planning framework.

Based on the planning assessment set out in Section 4 of this report, it is considered that the proposed PSA will support the strategic development intent for this area of Darwin and is consistent with development standards and requirements of the NTPS 2020 and the Area Plan.

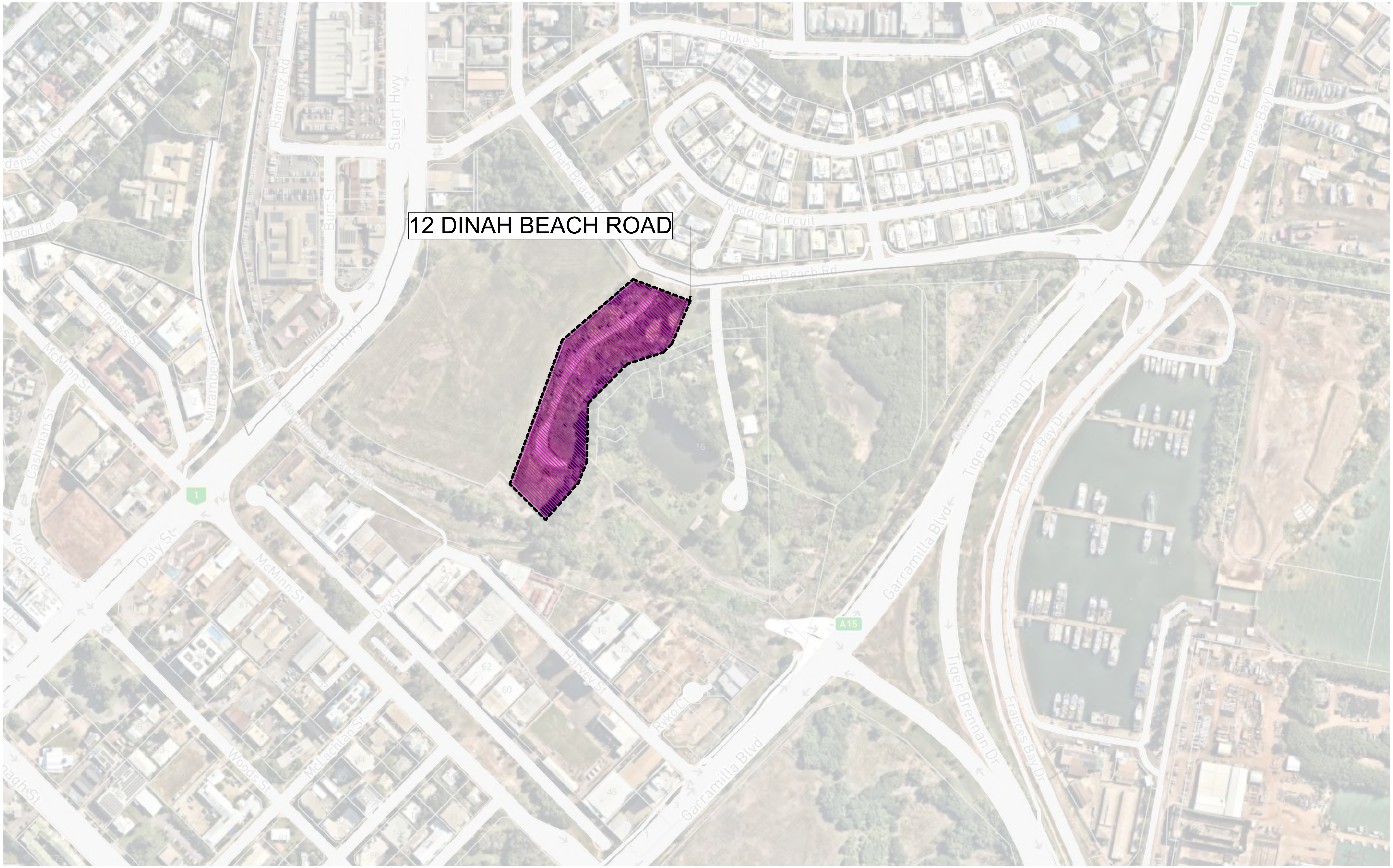
In conclusion, the proposed PSA implements endorsed strategic planning outcomes and will facilitate the redevelopment of a remediated site for residential purposes.

Accordingly, it is respectfully requested that the Minister for Infrastructure, Planning and Logistics supports the proposed PSA.

# Appendix A – Title Details

# Appendix B – Proposed Development Concept

# Appendix C – Final Condition Report 2020




| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

**General Notes**

Do not scale this drawing. The drawing shows design intent only. All dimensions to be checked on site prior to construction or production. Construction details to be confirmed by contractor/manufacturer. This is a computer generated drawing. Do not amend by hand. Figure dimensions are to be used. Contact architect for clarification if dimensions are not clear. All dimensions are in millimeters. All discrepancies and omissions on site must be reported to the architect for their comments or approval prior to commencing work.

**Drawing Notes**

**FOR TENDER**
**NOT TO BE USED DURING CONSTRUCTION**

Architect

ABN 34 001 485 436

**Richmond+Ross**
CONSULTING ENGINEERS AND PROJECT LEADERS

Suite 2.02, 1 Chandos Street St Leonards NSW 2065
TEL: (02) 9490 9600 FAX: (02) 94381224

Client

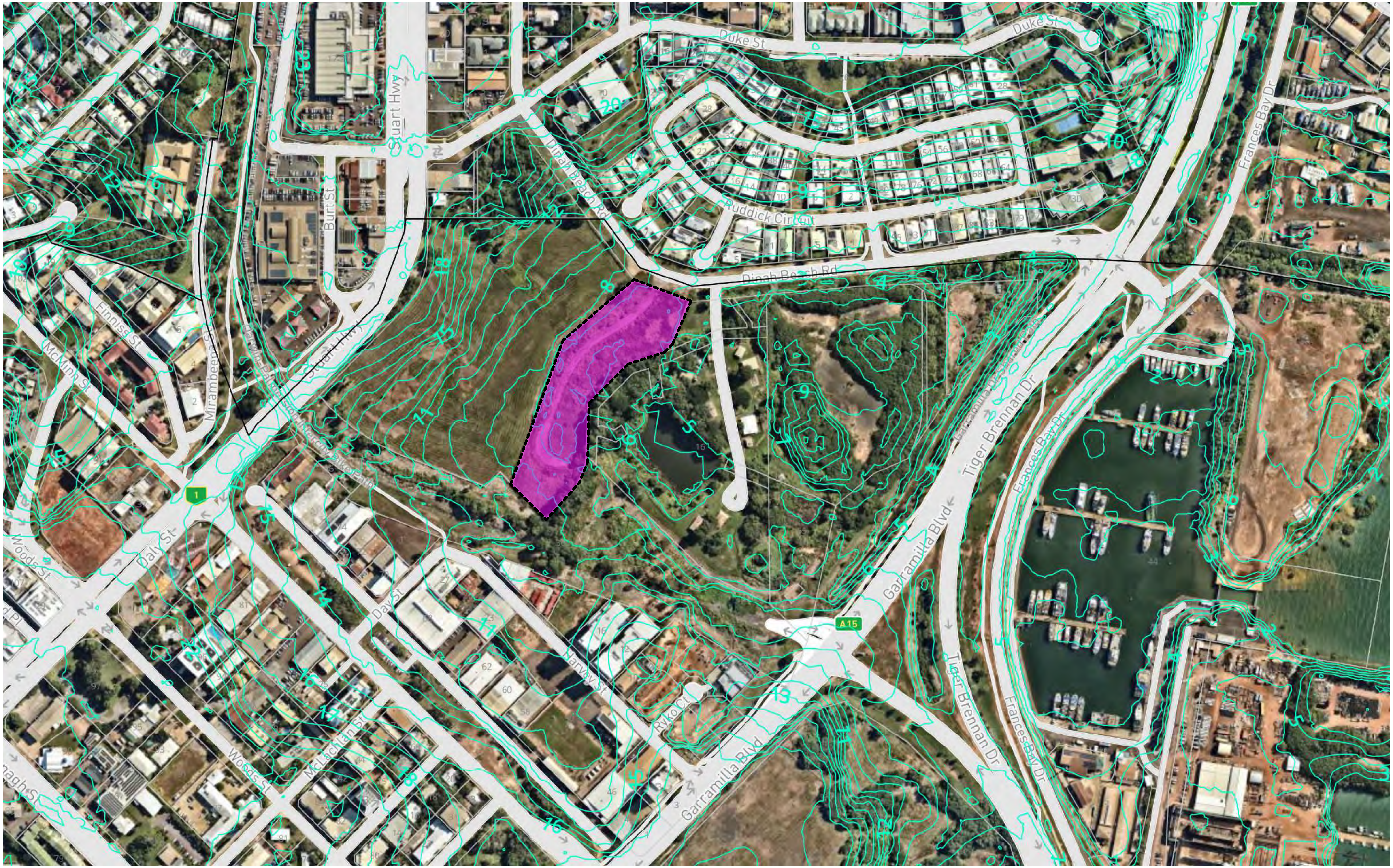
Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
1:2000 @ A3

Drawing
GENERAL MAP

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.1 | P1 |




| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

**General Notes**

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**Drawing Notes**

**FOR TENDER**
**NOT TO BE USED DURING CONSTRUCTION**


Architect ABN 34 001 485 436

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Client

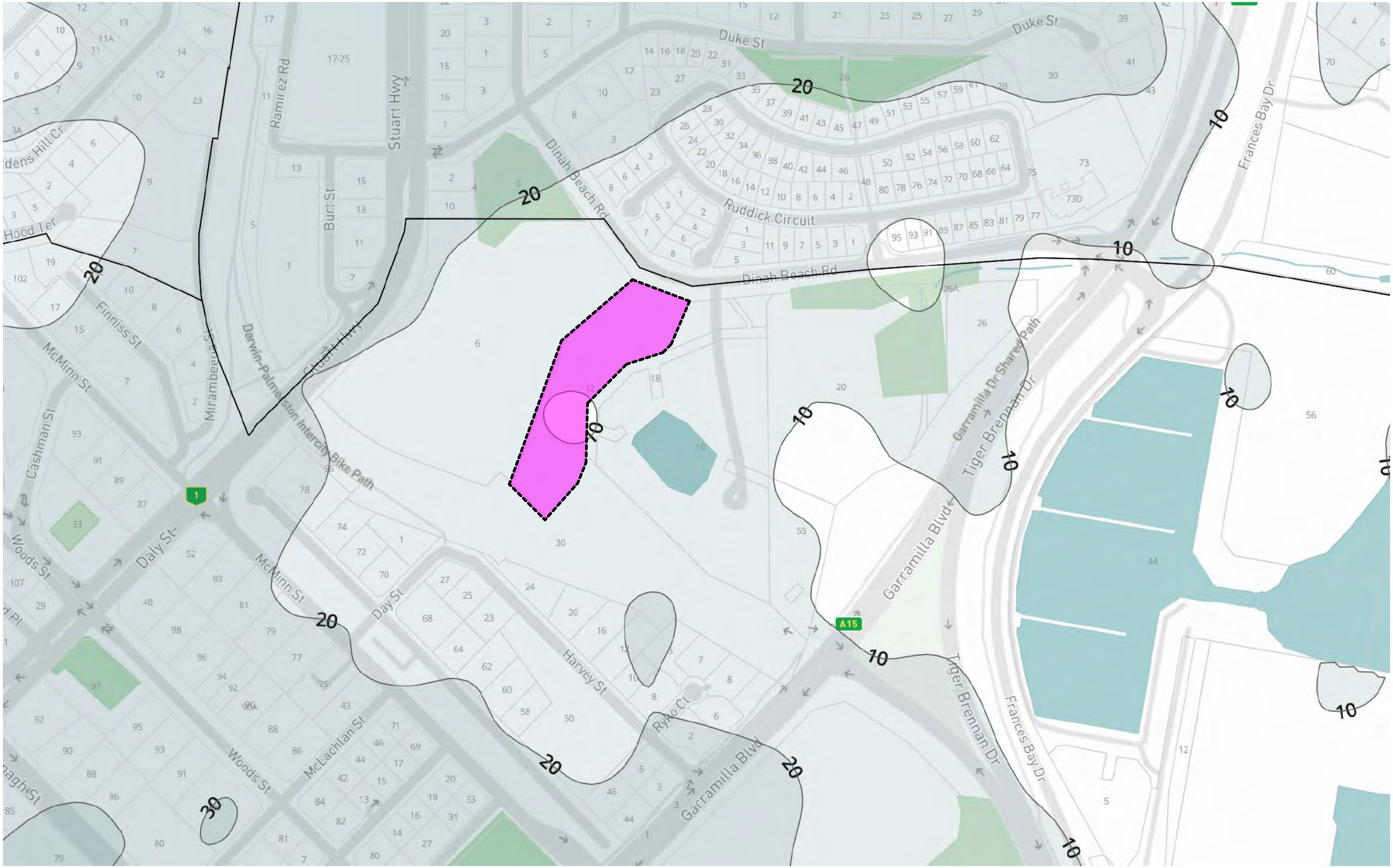
Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
1:2000 @ A3

Drawing
TOPOGRAPHY

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.2 | P1 |




| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | TZ | |
| Issue | Description | Date | Chk | Int |

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Client

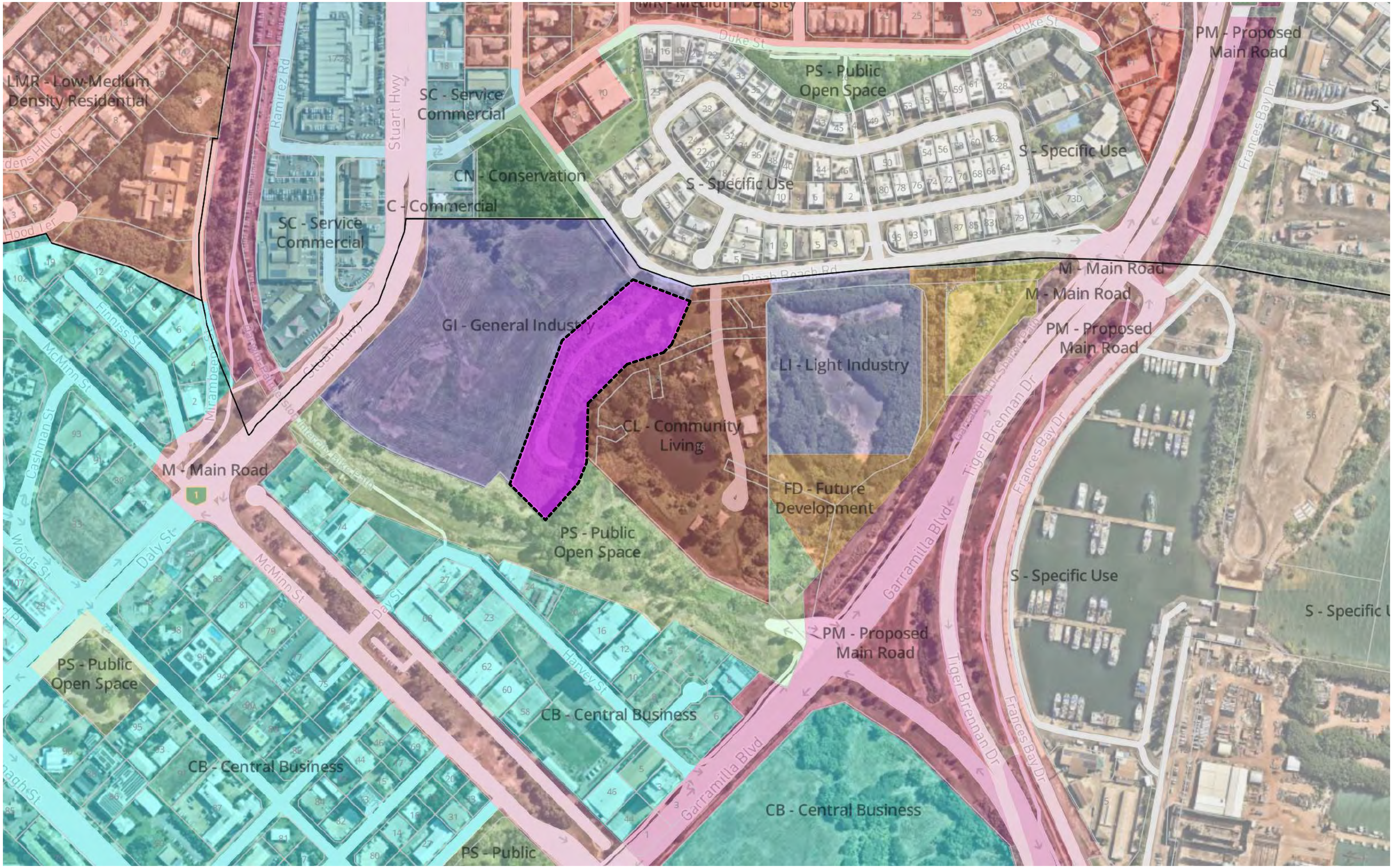
Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
1:2000 @ A3

Drawing
FLOOD SURGE MAPPING

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.3 | P1 |




Revisions

| | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | TZ | |
| Issue | Description | Date | Chk | Int |

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Client

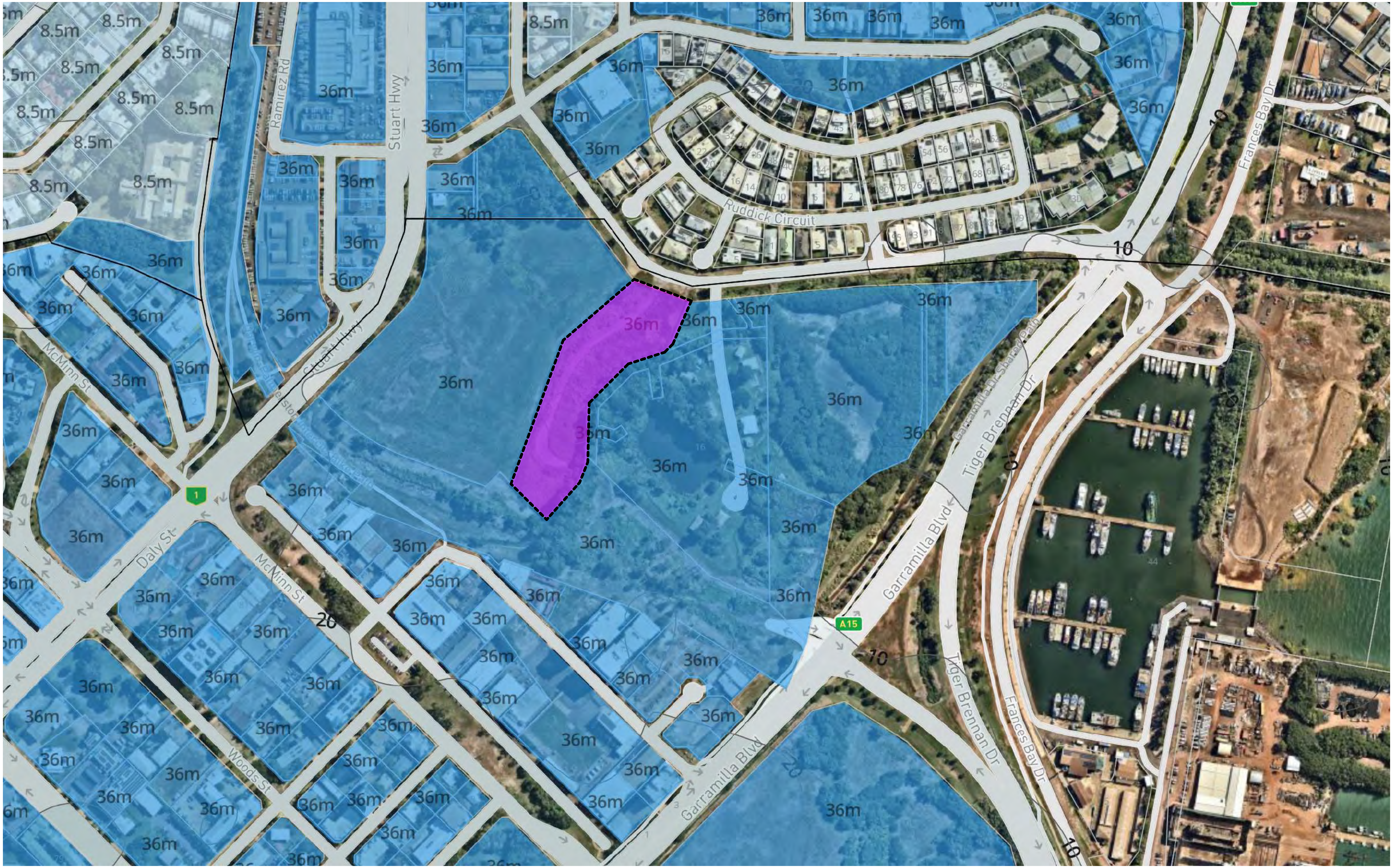
Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
1:2000 @ A3

Drawing
ZONNING

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.4 | P1 |




| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

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TEL: (02) 9490 9600 FAX: (02) 94381224

Client

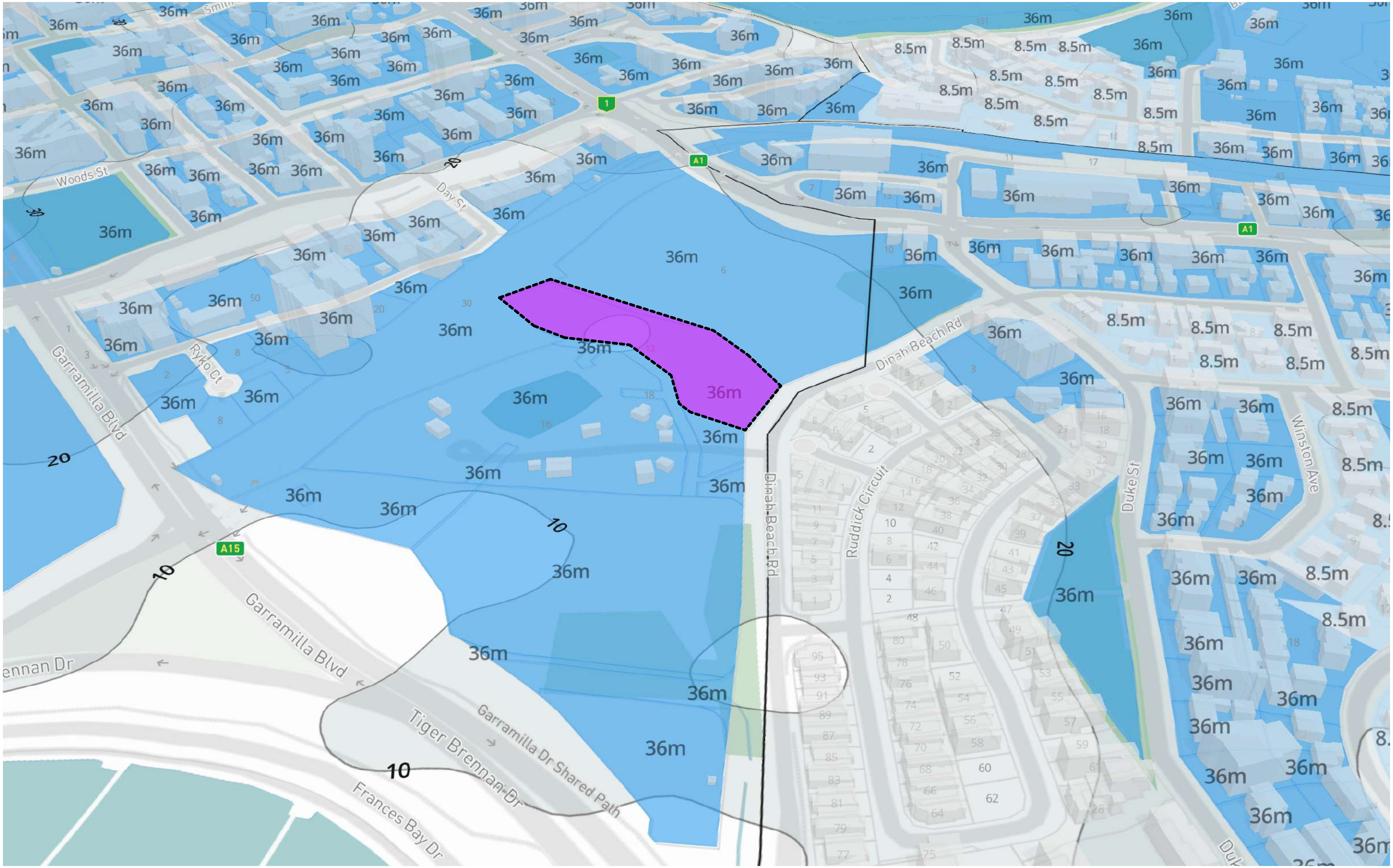
Project: 12 DINAH BEACH ROAD, DARWIN

Location: 12 DINAH BEACH ROAD, DAWRIN, NT 0800

Scale: 1:2000 @ A3

Drawing: MAX HEIGHT

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.5 | P1 |




| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

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Client

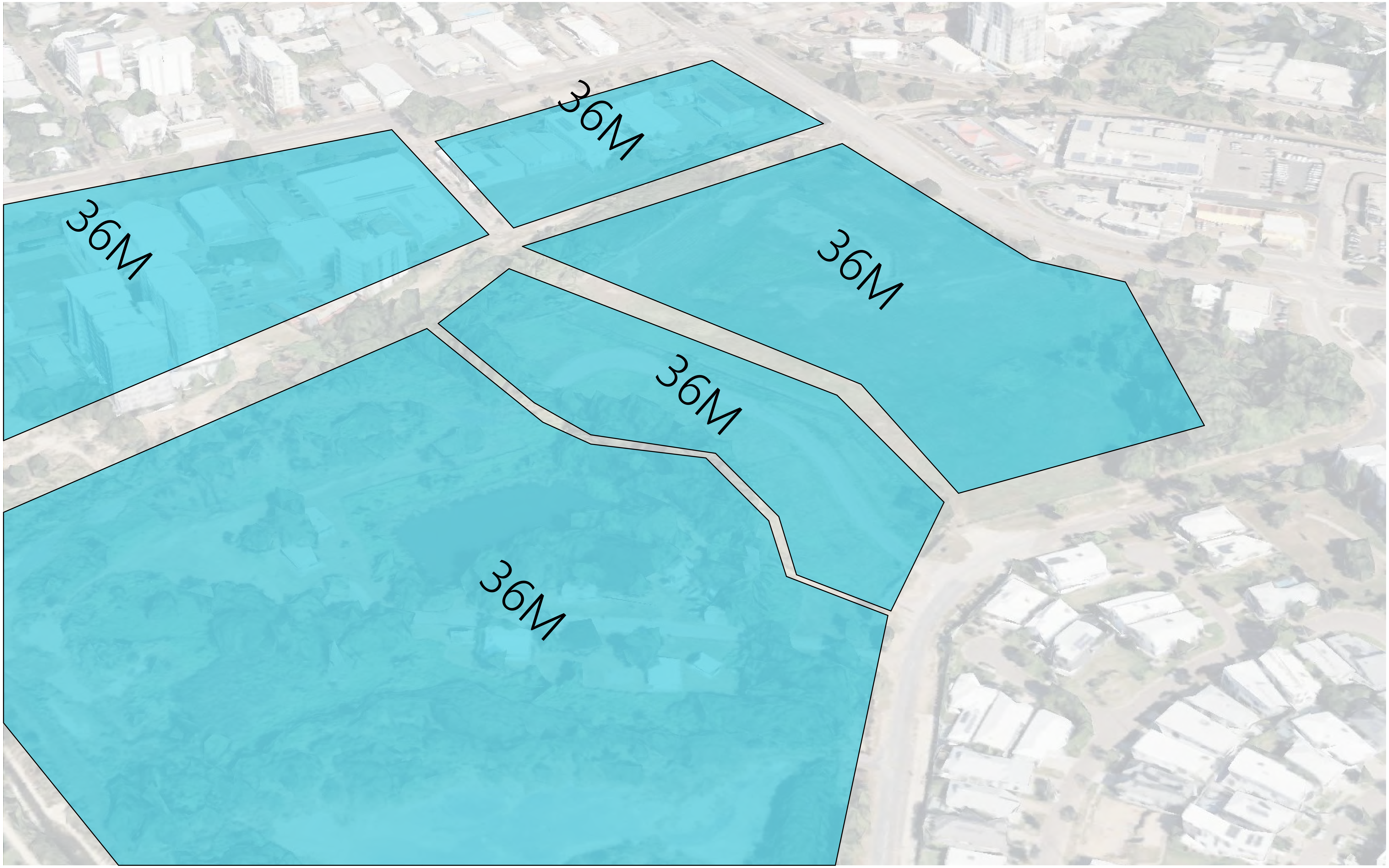
Project: 12 DINAH BEACH ROAD, DARWIN

Location: 12 DINAH BEACH ROAD DAWRIN NT 0800

Scale: 1:2000 @ A3

Drawing: MAX HEIGHT 3D

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.6 | P1 |




| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

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Client

Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
@ A3

Drawing
AERIAL PLAN - MAX HEIGHT

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.7 | P1 |

| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | TZ | |
| Issue | Description | Date | Chk | Int |

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Client

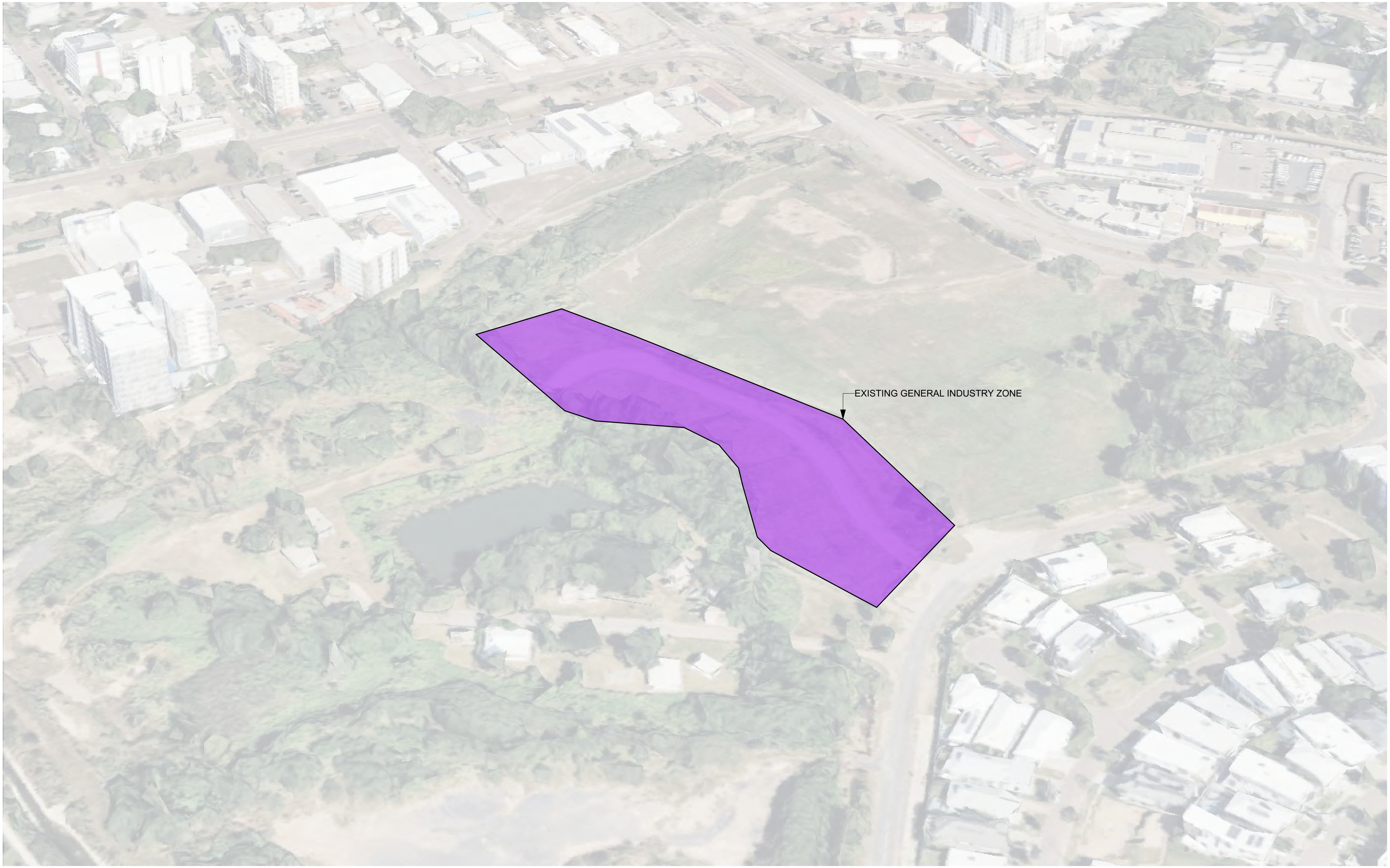
Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
@ A3

Drawing
AERIAL PLAN - EXISTING

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.8 | P1 |




Revisions

| Issue | Description | Date | Chk | Int |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |

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Client

Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
@ A3

Drawing
AERIAL PLAN - INDUSTRIAL

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.9 | P1 |


| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

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Client

Project: 12 DINAH BEACH ROAD, DARWIN

Location: 12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale: @ A3

Drawing: AERIAL PLAN - PROPOSED ZONES

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.10 | P1 |


| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

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Client

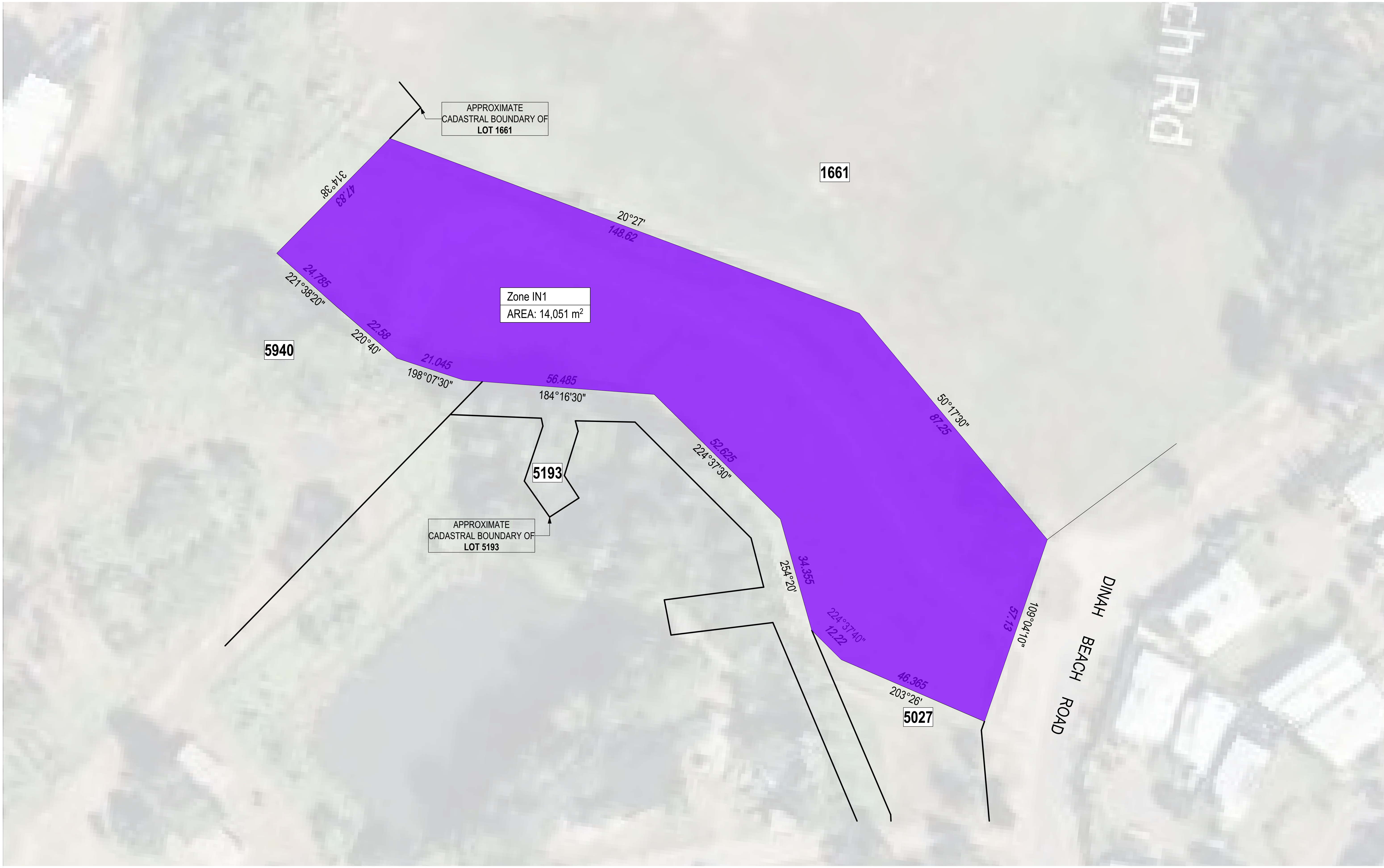
Project: 12 DINAH BEACH ROAD, DARWIN

Location: 12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale: @ A3

Drawing: AERIAL PLAN

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.11 | P1 |




| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | TZ | |
| Issue | Description | Date | Chk | Int |

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Client

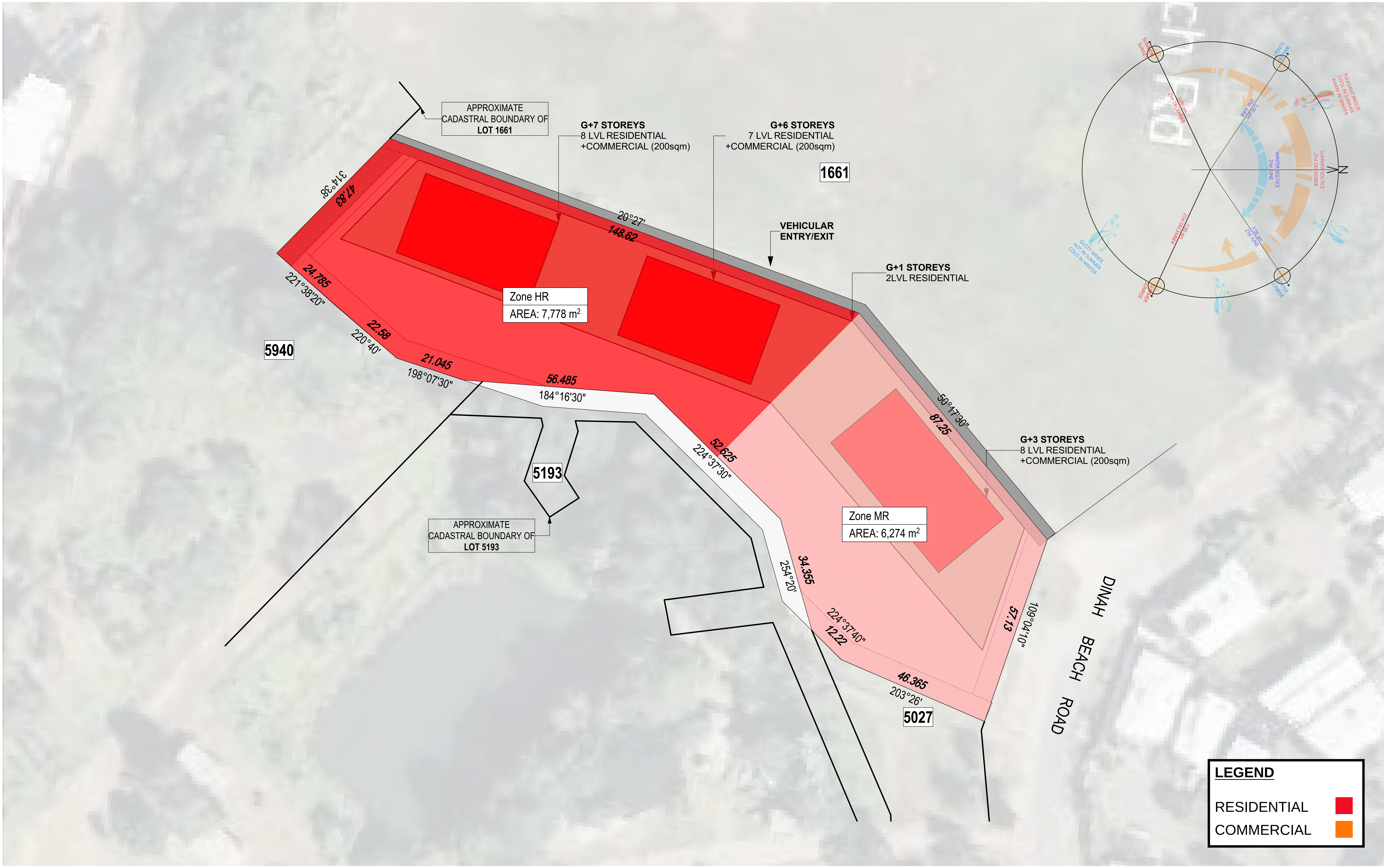
Project: 12 DINAH BEACH ROAD, DARWIN

Location: 12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale: 1:1000 @ A3

Drawing: ZONING MAPS

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.12 | P1 |




Revisions

| Issue | Description | Date | Chk | Int |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | TZ | |

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Drawing Notes

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Client

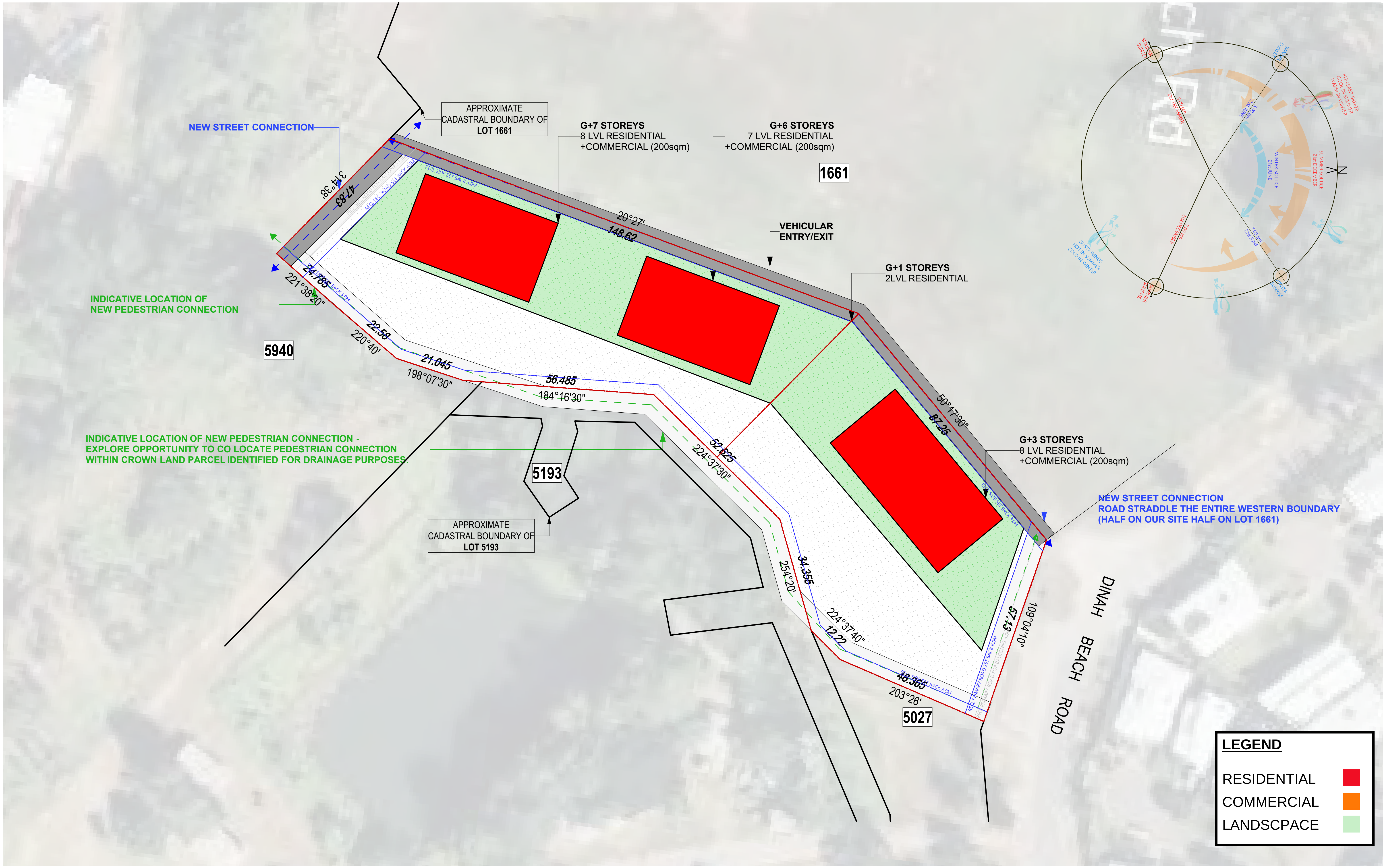
Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
1:1000, 1:200 @ A3

Drawing
ZONING MAPS

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.C.13 | P1 |




Revisions

| Issue | Description | Date | Chk | Int |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | TZ | |

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Client

Project: 12 DINAH BEACH ROAD, DARWIN

Location: 12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale: 1:1000 @ A3

Drawing: SITE PLAN

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.1.1 | P1 |


| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

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Client

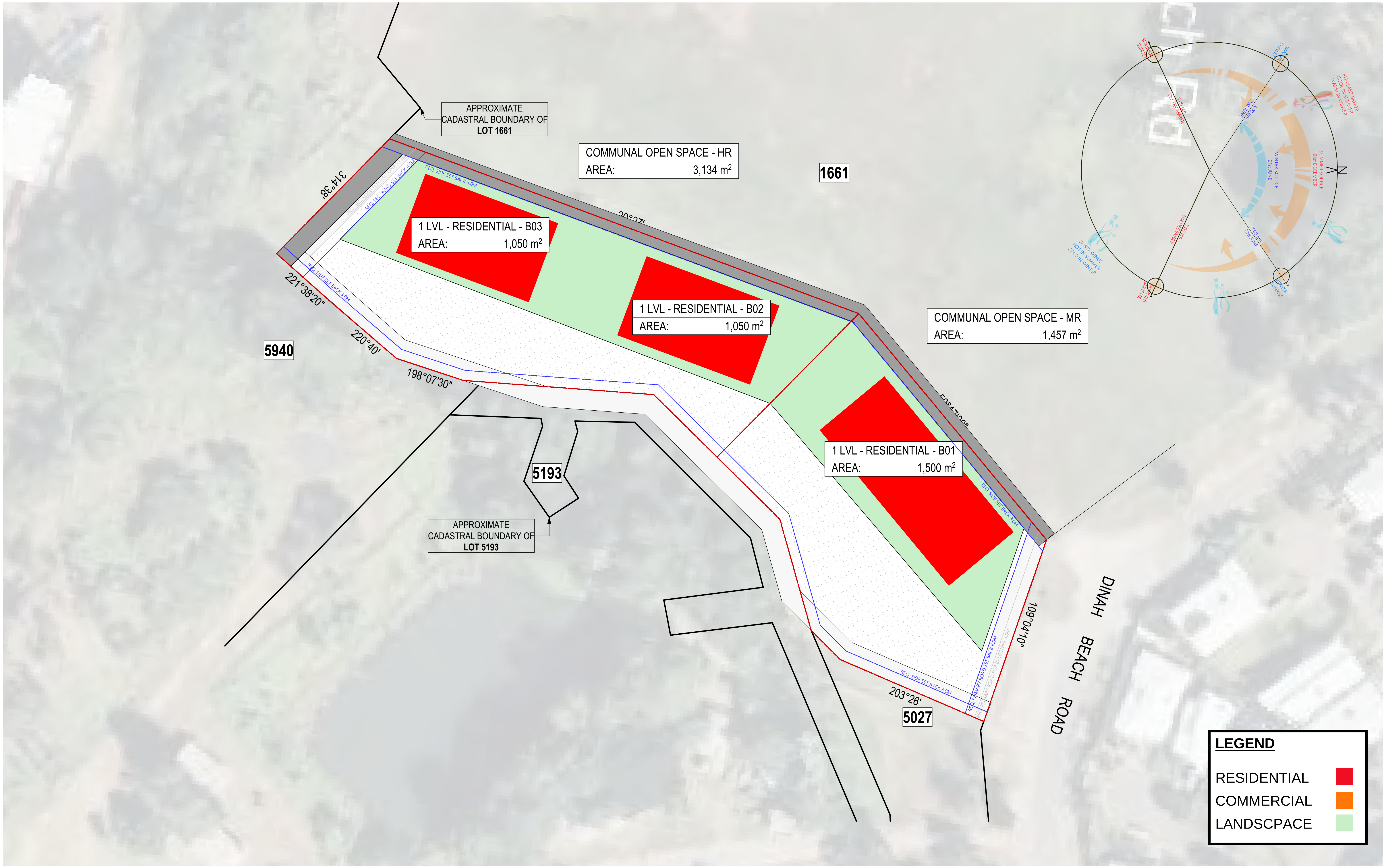
Project: 12 DINAH BEACH ROAD, DARWIN

Location: 12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale: 1:1000 @ A3

Drawing: GROUND FLOOR

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.1.2 | P1 |




| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

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Client

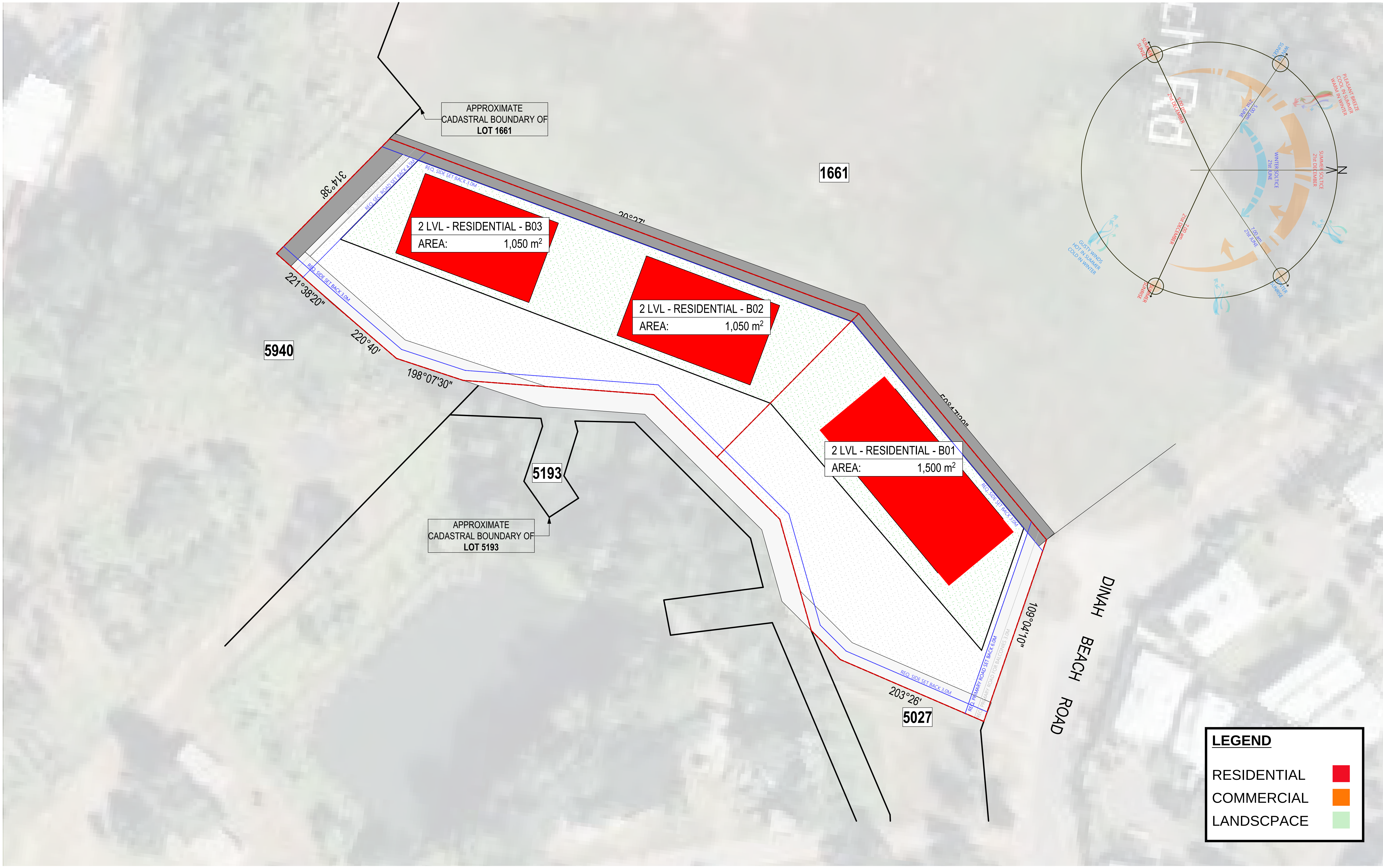
Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
1:1000 @ A3

Drawing
1 LVL

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.1.3 | P1 |




| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

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Client

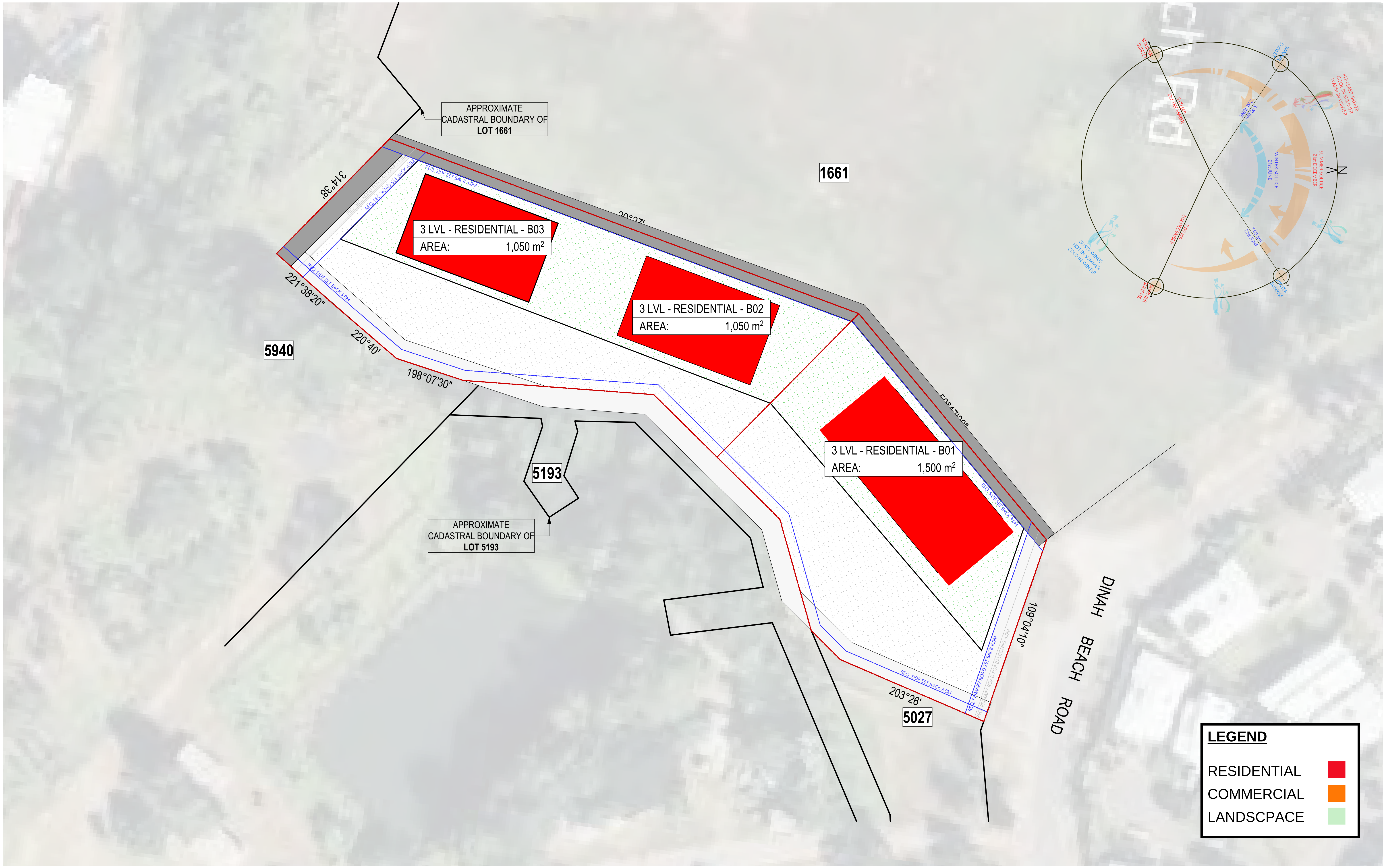
Project: 12 DINAH BEACH ROAD, DARWIN

Location: 12 DINAH BEACH ROAD, DAWRIN, NT 0800

Scale: 1:1000 @ A3

Drawing: 2 LVL

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.1.4 | P1 |




| Revisions | | | | |
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Client

Project: 12 DINAH BEACH ROAD, DARWIN

Location: 12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale: 1:1000 @ A3

Drawing: 3 LVL

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.1.5 | P1 |


| Revisions | | | | |
|---|---|---|---|---|
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Client

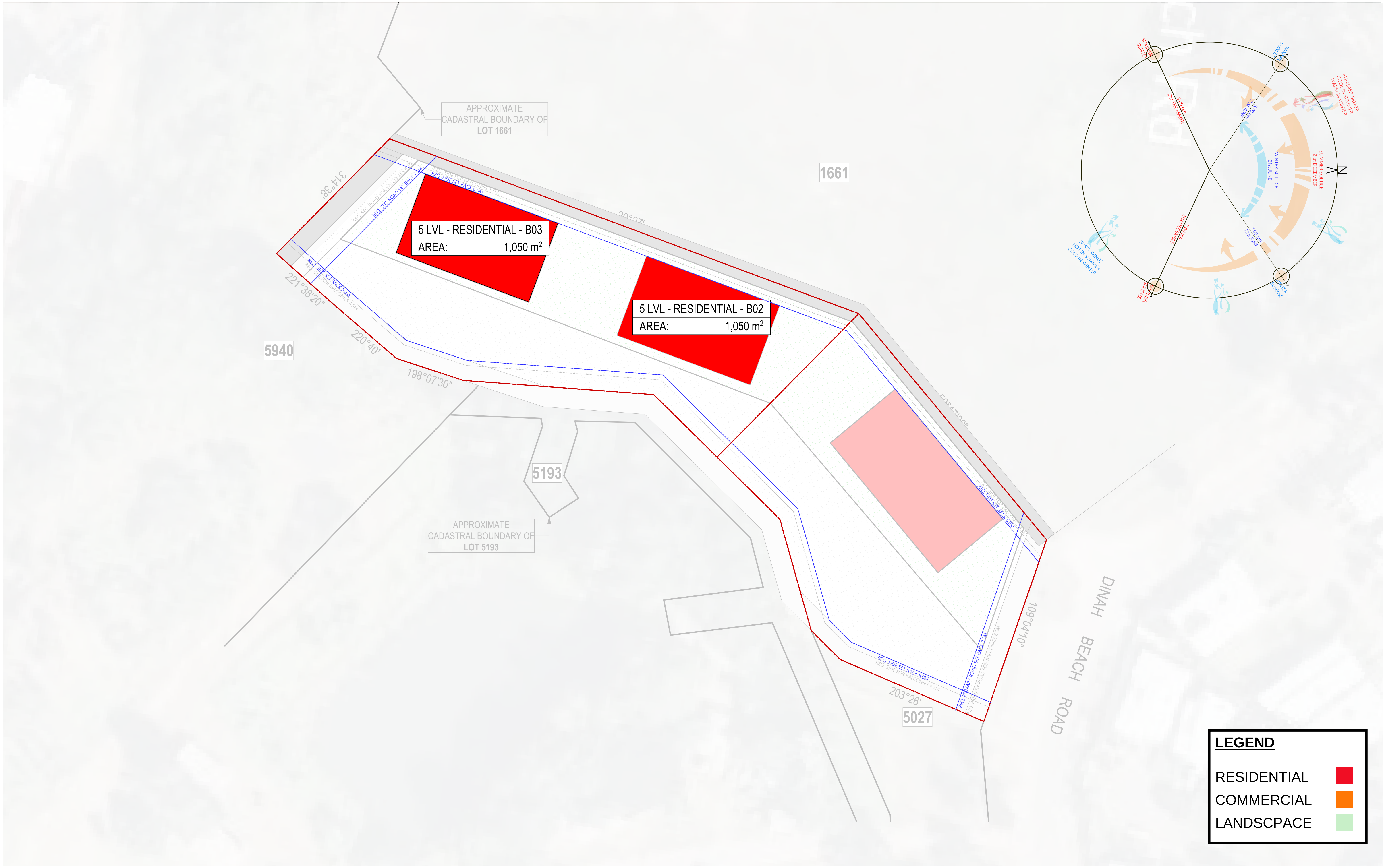
Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
1:1000 @ A3

Drawing
4 LVL

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.1.6 | P1 |




| Revisions | | | | |
|---|---|---|---|---|
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TEL: (02) 9490 9600 FAX: (02) 94381224

Client

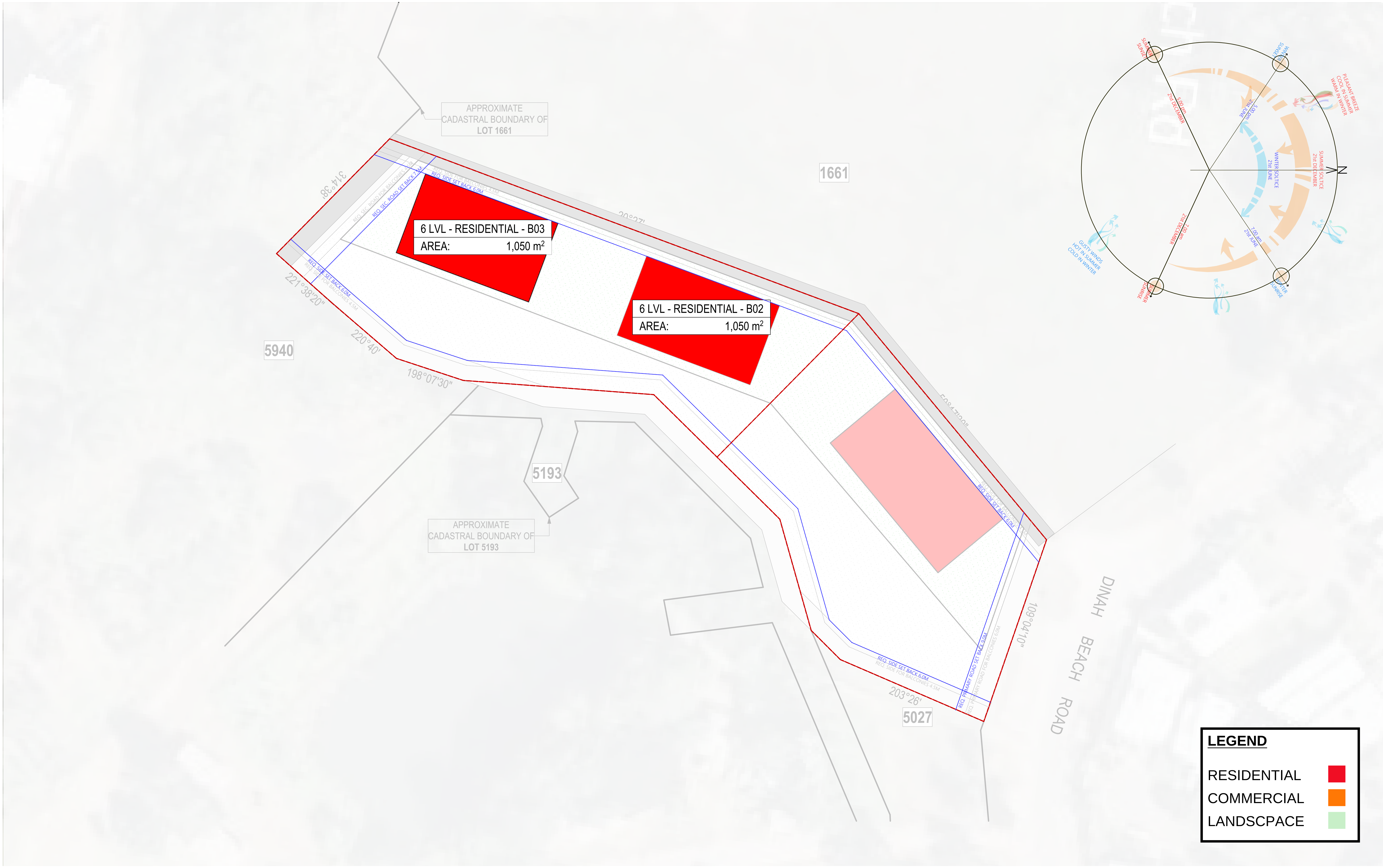
Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
1:1000 @ A3

Drawing
5 LVL

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.1.7 | P1 |




Revisions

| | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | TZ | |
| | Issue Description | Date | Chk | Int |

General Notes

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Drawing Notes

**FOR TENDER**
NOT TO BE USED DURING CONSTRUCTION

Architect ABN 34 001 485 436

**Richmond+Ross**
CONSULTING ENGINEERS AND PROJECT LEADERS

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TEL: (02) 9490 9600 FAX: (02) 94381224

Client

Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
1:1000 @ A3

Drawing
6 LVL

| Project Number | Drawing Number | Issue |
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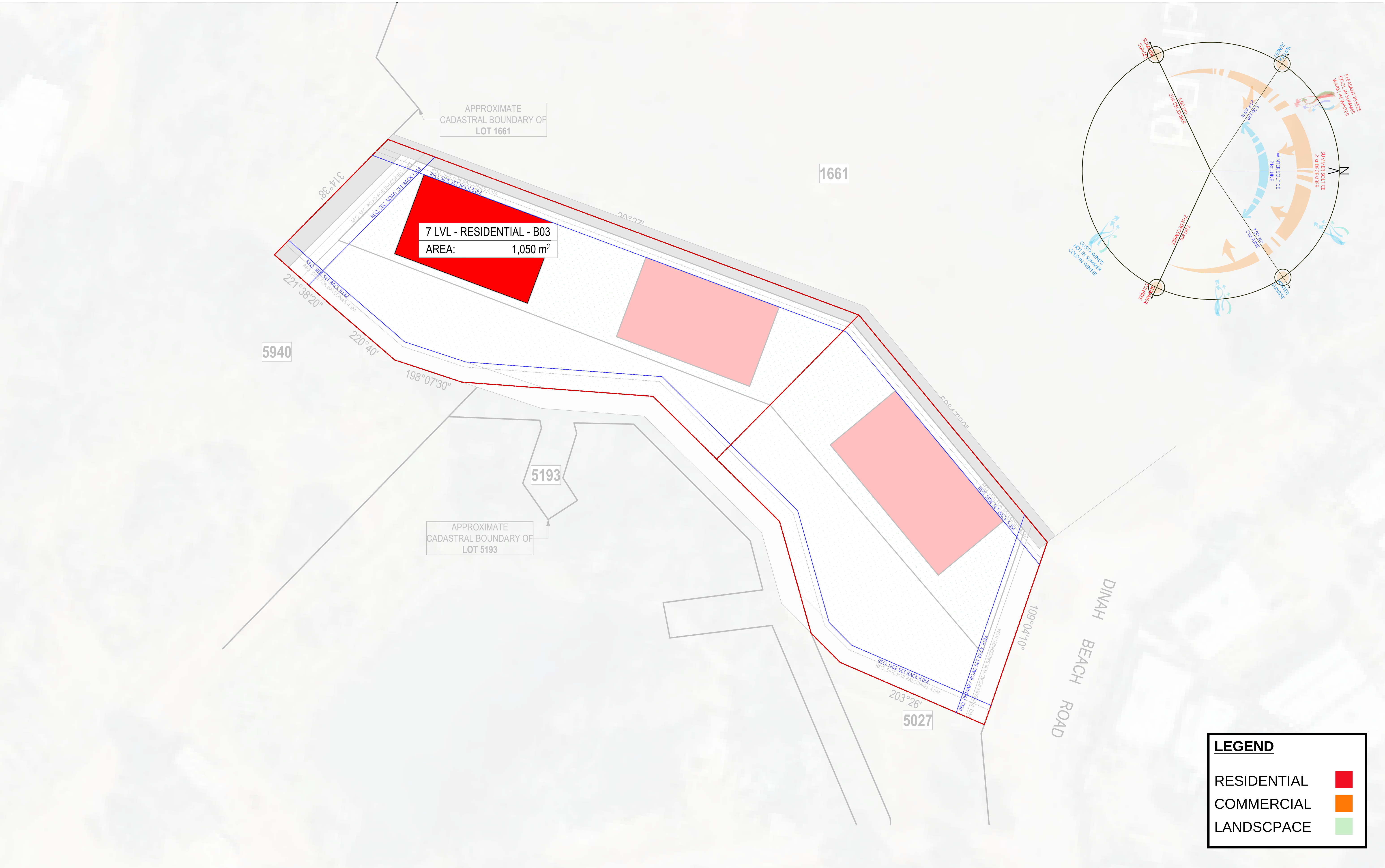


| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

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Client

Project: 12 DINAH BEACH ROAD, DARWIN

Location: 12 DINAH BEACH ROAD, DAWRIN, NT 0800

Scale: 1:1000 @ A3

Drawing: 7 LVL

| Project Number | Drawing Number | Issue |
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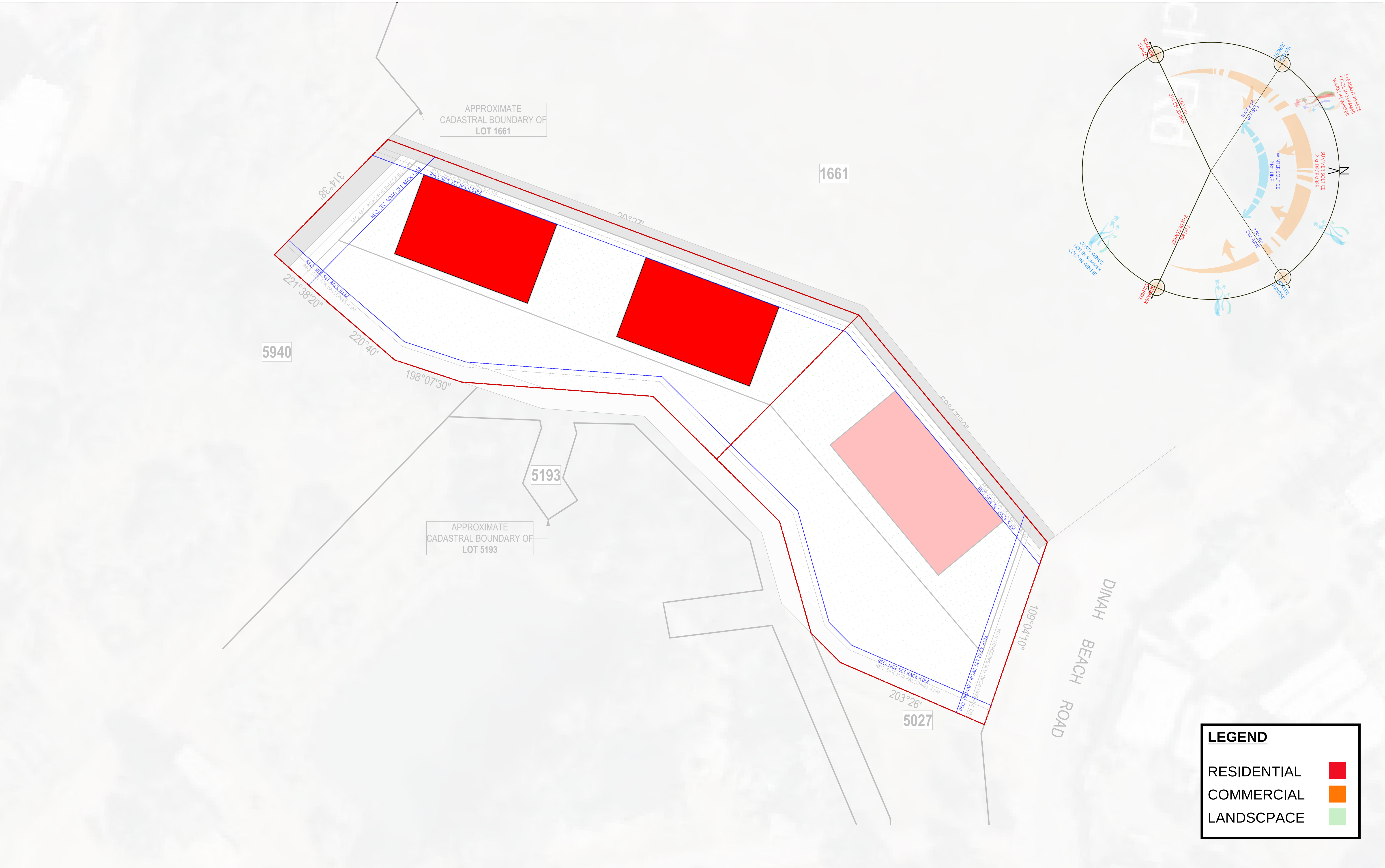


| Revisions | | | | |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |
| Issue | Description | Date | Chk | Int |

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Suite 2.02, 1 Chandos Street St Leonards NSW 2065
TEL: (02) 9490 9600 FAX: (02) 94381224

Client

Project: 12 DINAH BEACH ROAD, DARWIN

Location: 12 DINAH BEACH ROAD, DAWRIN, NT 0800

Scale: 1:1000 @ A3

Drawing: 8 LVL

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | A.1.10 | P1 |

| | |
|---|---|
| TOTAL SITE AREA | APPROX. 14,052 $m^2$ |
| MR ZONE AREA | APPROX. 6,274 $m^2$ |
| HR ZONE AREA | APPROX. 7,778 $m^2$ |
| ALLOWED MAX GFA | |
| MR ZONE AREA (1:3:1) | MAX GFA APPROX. 8,156 $m^2$ |
| HR ZONE AREA (2:3:1) | MAX GFA APPROX. 17,889 $m^2$ |
| REQUIRED OPEN COMUNAL SPACE | |
| MR ZONE AREA (15%) | MIN. 941 $m^2$ |
| HR ZONE AREA (15%) | MIN. 1,166 $m^2$ |

| PROPOSED GFA - MR | |
|---|---|
| 1 LVL - RESIDENTIAL - B01 | 1,500 |
| 2 LVL - RESIDENTIAL - B01 | 1,500 |
| 3 LVL - RESIDENTIAL - B01 | 1,500 |
| GF - RESIDENTIAL - B01 | 2,754 |
| GF COMMERCIAL | 200 |
| | 7,454 $m^2$ |

| PROPOSED GFA - HR | |
|---|---|
| 1 LVL - RESIDENTIAL - B02 | 1,050 |
| 1 LVL - RESIDENTIAL - B03 | 1,050 |
| 2 LVL - RESIDENTIAL - B02 | 1,050 |
| 2 LVL - RESIDENTIAL - B03 | 1,050 |
| 3 LVL - RESIDENTIAL - B02 | 1,050 |
| 3 LVL - RESIDENTIAL - B03 | 1,050 |
| 4 LVL - RESIDENTIAL - B02 | 1,050 |
| 4 LVL - RESIDENTIAL - B03 | 1,050 |
| 5 LVL - RESIDENTIAL - B02 | 1,050 |
| 5 LVL - RESIDENTIAL - B03 | 1,050 |
| 6 LVL - RESIDENTIAL - B02 | 1,050 |
| 6 LVL - RESIDENTIAL - B03 | 1,050 |
| 7 LVL - RESIDENTIAL - B03 | 1,050 |
| GF - RESIDENTIAL - B02/B03 | 3,783 |
| GF COMMERCIAL | 200 |
| GF COMMERCIAL | 200 |
| | 17,833 $m^2$ |

| A-04 PROPOSED LANDSCAPE | |
|---|---|
| COMMUNAL OPEN SPACE - HR | 3,134 |
| COMMUNAL OPEN SPACE - MR | 1,457 |
| GF - COMMUNAL OPEN SPACE - MR | 2,759 |
| | 7,350 $m^2$ |

Revisions

| Issue | Description | Date | Chk | Int |
|---|---|---|---|---|
| P1 | CONCEPT ISSUE | 2/09/2025 | | TZ |

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Client

Project
12 DINAH BEACH ROAD, DARWIN

Location
12 DINAH BEACH ROAD
DAWRIN
NT 0800

Scale
1:1 @ A3

Drawing
GFA CALCULATION

| Project Number | Drawing Number | Issue |
|---|---|---|
| 250091 | AD.10 | P1 |

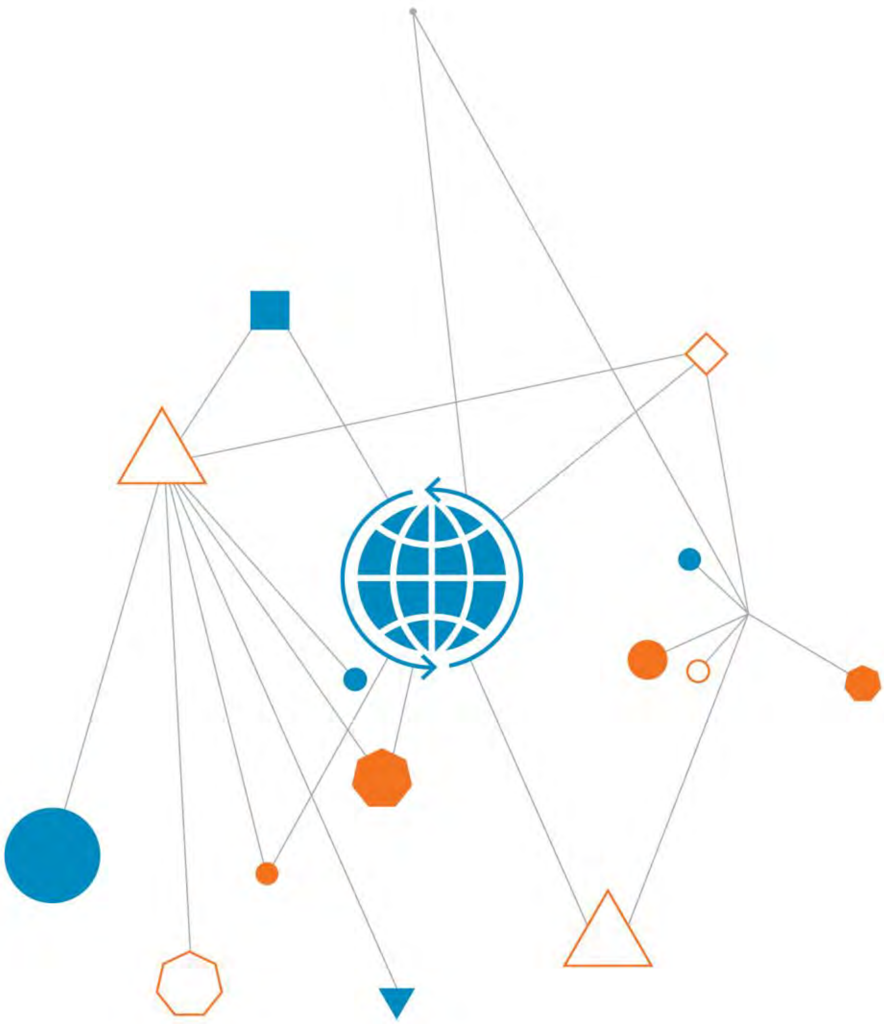
coffey
A TETRA TECH COMPANY

# Caltex Australia Petroleum Pty Ltd

## Final Condition Report

Former Caltex Darwin Depot
12 Dinah Beach Road
Darwin, NT

14 January 2020



When you
think with a
global mind
problems
get smaller

# Final Condition Report

Prepared for
Caltex Australia Petroleum Pty Ltd

Prepared by
Coffey Environments Australia Pty Ltd
Level 1, 436 Johnston Street
Abbotsford VIC 3067 Australia
t: +61 3 9290 7000 f: +61 3 9290 7499
ABN: 65 140 765 902

14 January 2020

ENAUABTF08105AI

| | |
|---|---|
| **Project Director** | David Lam<br>Senior Principal |
| **Project Manager** | Liz Geer<br>Environmental Scientist |



# Quality information

## Revision history

| Revision | Description | Date | Author | Reviewer | Approver |
|---|---|---|---|---|---|
| R02a | Preliminary Draft | 26/06/2016 | Dale McKenzie<br>Nick Woodford<br>Casey O'Farrell | Clinton Smiljanic<br>Sarah Richards<br>Karen Teague<br>David Lam | David Lam |
| R02b | Draft | 22/07/2016 | Dale McKenzie<br>Nick Woodford<br>Casey O'Farrell | Clinton Smiljanic<br>Sarah Richards<br>Karen Teague<br>David Lam | David Lam |
| R02c | Draft | 14/01/2020 | Liz Geer<br>Ian Newby<br>Casey O'Farrell<br>Sarah Richards | David Lam | Sarah Richards |

## Distribution

| Report Status | No. of copies | Format | Distributed to | Date |
|---|---|---|---|---|
| R02a, preliminary draft | 1 | PDF | Mr Todd Mitchell, Auditor, AECOM Australia Pty Ltd. | 24/06/2016 |
| R02b, draft | 1 | PDF | Mr Todd Mitchell, Auditor, AECOM Australia Pty Ltd | 22/07/2016 |
| R02c, draft | 1 | PDF | Mr Todd Mitchell, Auditor, AECOM Australia Pty Ltd | 14/01/2020 |

# Executive summary

Caltex Australia Petroleum Pty Ltd (Caltex) contracted Coffey Environments Australia Pty Ltd (Coffey) to complete soil remedial and validation works at the former Caltex Darwin Depot, located at 12 Dinah Beach Road, Darwin (‘the site’).

The site was utilised as a petroleum storage depot from circa 1971 until demolition of site infrastructure in 2006. Potentially contaminating activities associated with the day to day operation of a petroleum depot occurred during the period of operation. Previous environmental works identified residual soil and groundwater petroleum hydrocarbon impacts at the site.

The site is the subject of a voluntary Environmental Audit, in accordance with Northern Territory Environmental Protection Authority (EPA) requirements, to aid divestment of the site for a sensitive land use (residential). Consistent with current Northern Territory EPA advice, the Victorian EPA Environmental Audit (S53X) system has been adopted, and Mr Todd Mitchell of AECOM Pty Ltd has been engaged as the Auditor for this site.

To make the site suitable for future residential use, soil remediation and validation works were undertaken. Remediation works were divided into two separate phases. The first phase of works, focusing on the northern half of the site, was completed during the dry season of 2014 (May – September 2014). The second phase of works, focusing on the southern half of the site, was undertaken during the 2015 dry season (early May – September 2015). Active remediation was followed by four groundwater monitoring events and associated aquifer testing to support the development of a hydrogeological conceptual model, including the characterisation of post-remediation groundwater conditions in the context of future site use and preclusion of protected beneficial uses.

Based on the contamination characteristics and levels measured, the clean-up measures already implemented, a review of the options for further clean-up of soil and groundwater, consideration of the risks to existing or likely beneficial uses associated with the site (including the manageability of the residual risks), it is concluded that soil and groundwater clean-up to the extent practicable has been achieved, and that the site can be used for the proposed residential use. Therefore, it is considered that further active remediation at the site is not warranted.

The following summarises residual contamination, remediation works conducted, residual risks, and appropriate options for management of the residual risks..

**Residual Contamination**

- Residual hydrocarbon concentrations above the laboratory LOR are present in soil across the site. These concentrations are generally consistent with criteria adopted for sensitive site use. The exception to this is along the western title boundary where residual soil impacts exceeding the vapour intrusion HSL criteria were identified (inferred to be associated with the upgradient former Mobil site).
- LNAPL has not been observed at the site since circa 1999.
- Site-sourced dissolved hydrocarbon impact has been delineated in all directions. However, an ongoing source of groundwater contamination exists upgradient of the site (former Mobil site).
- Site sourced ammonia is present at the eastern boundary of the site at concentrations that exceed adopted Maintenance of Ecosystems and Aesthetics guidance values.

**Remediation**

- Contaminated soil was excavated from above and below the water table.
- Contaminated soil was stockpiled and underwent an enhanced bioremediation process to degrade residual hydrocarbon contamination to levels that were appropriate for reinstatement and would support future sensitive use of the site. This approach targeted soil and groundwater impacts.
- Remediation activities were undertaken in the dry seasons of 2014 and 2015, with subsequent groundwater motoring extending throughout 2016 and completed in November 2018.
- An estimated 20 tonnes of hydrocarbons were removed from the site via biodegradation. It is estimated that approximately 13 tonnes of residual hydrocarbons remained at the site at the completion of soil excavation works, further biodegradation that is expected to be ongoing since then.

**Residual Risk**

- Residual ammonia, petroleum hydrocarbons and metals preclude groundwater from being used for any protected extractive beneficial use.
- The health risk assessment identified a potential vapour inhalation risk (for an inhabited below grade room with in 3 m of the western boundary), associated with elevated hydrocarbons in soil migrating across the western boundary. Other scenarios, including slab-on-grade at the western boundary or an uninhabited basement were indicated to be acceptable.
- Residual dissolved phase hydrocarbon impact is present in the groundwater along the western boundary of the site, which is attributed to transient mobilisation of contamination from the former Mobil depot beyond this boundary. The residual concentrations are not considered to pose an unacceptable direct contact or vapour intrusion risk.
- The data provide strong primary line evidence (supported by statistical analysis) that natural attenuation is occurring, and is sufficient to prevent future (petroleum hydrocarbon and ammonia) plume migration.
- Dissolved arsenic, iron and manganese in groundwater are by-products of the natural attenuation of hydrocarbon contaminants and will precipitate under aerobic conditions at the leading edge of the plume.
- It is considered unlikely that the residual groundwater contamination at the site poses a risk to the beneficial uses of groundwater off-site.

**Consideration of CUTEP**

- A review of potential remediation technologies did not identify any remediation technology that would significantly change the risk profile of the site based on further active clean-up of site–sourced contaminants. It is acknowledged that some off-site sourced hydrocarbon contamination exists and is migrating across parts of the Caltex site. However, without accessing the Mobil site to remove or otherwise remediate residual contamination, it is not possible to reduce contamination to any further significant extent through active remediation.
- Based on post-remediation soil and groundwater conditions, and the absence of potential risk associated with on-site sources, the remedial works undertaken at the site are considered to have been effective and have met the remediation targets.
- Based on the above, it is considered that CUTEP has been achieved for the site, subject to the agreement of the Auditor and EPA.

**Management of Residual Risk**

Residual soil and groundwater pollution remain at the site. As such an Environmental Management Plan (EMP) will be produced and appended to the Audit to detail clearly the management measures required. The EMP would be available for the Auditor to append to the Statement of Environmental Audit.

A summary of proposed management measures is provided below.

- Residual groundwater contamination precludes extraction of groundwater for any beneficial use unless specific testing confirms that the water is suitable for that use. Management of the extractive use risks would be by warning site occupiers of the unsuitability for use of groundwater, in the EMP.
- Aesthetic issues may be present in deeper soils at the site and at the western boundary. In addition to awareness of aesthetic issues, management of subsurface works that may occur in these areas is required to manage odours and appropriate movement of impacted soils being brought to the surface. The EMP should include requirements for intrusive works which would manage potential aesthetic risks (possible hydrocarbon odour/staining) in the event of excavations, such as:
  - Minimising excavation extents.
  - Reinstating or disposing soils according to NTEPA requirements, ensuring no odorous/stained soil remains at the surface.
- Based on the current understanding of the nature and extent of petroleum hydrocarbon pollution at the site, the following mitigation measures/options will be included in the EMP.
  - If residential buildings are to be constructed up to the western boundary of the site, residential spaces should be at or above the current ground level, or if below grade, then set back from the site boundary by at least 3 m.
  - Basement structures would be expected to be below the groundwater level at some times of the year and may receive seepage of odorous water. Engineering controls such as tanking or increased drainage and ventilation may be appropriate to manage this aesthetic impact.

It is acknowledged that the Statement of Environmental Audit will be the mechanism to define the required management controls, and that the conditions incorporated into the Statement of Environmental Audit will need to be crafted by the auditor. The management measures proposed represent Coffey's suggested approach to managing the residual risks but will be subject to the considerations of the auditor.

Given the requirement for controls to manage residual risk at the site, it is likely that the most sensitive allowable use for the site will be medium to high density residential, with an owner's corporation. This is due to Northern Territory EPA likely preference for management conditions to be enacted by an owner's corporation (or similar body).

This executive summary should be read in conjunction with the report proper and in the context of the limitations described in the attached "Important Information about your Coffey Environmental Report".

# Table of contents

## In-Text Tables

## In-Text Figures



## Appendices

# 1. Introduction

## 1.1. Background

Caltex Australia Petroleum Pty Ltd (Caltex) contracted Coffey Environments Australia Pty Ltd (Coffey) to complete soil remedial and validation works at the former Caltex Darwin Depot, located at 12 Dinah Beach Road, Darwin ('the site').

The site was used as a petroleum storage depot from circa 1971 until demolition of site infrastructure in 2006. Potentially contaminating activities associated with the petroleum depot occurred during the period of operation. Previous environmental works identified residual soil and groundwater petroleum hydrocarbon impacts at the site. A summary of previous environmental investigations is provided in Section 2.6.

The site is the subject of a voluntary Environmental Audit, in accordance with Northern Territory Environmental Protection Authority (EPA) requirements, to aid in the proposed divestment of the site for future sensitive land uses (i.e. residential development)). Consistent with the Northern Territory *Waste Management and Pollution Control Act 1998* and the EPA fact sheet *Register of Qualified Persons* Mr Todd Mitchell of AECOM Pty Ltd has been engaged as the Auditor for this site, and the Victorian EPA Environmental Audit (S53X) system has been adopted.

## 1.2. Objectives

The overarching objective of the site clean-up was to render the site suitable, from a contamination perspective, for sensitive land use (residential use).

In proposing remediation objectives, is it acknowledged that development restrictions (associated with contamination) may result after site clean-up.

It is understood that planning requirements (such as rezoning or development in an area with shallow groundwater/adjacent to a waterway) are additional to the clean-up of the site and will be managed by Caltex.

## 1.3. Summary of Clean-up Approach

To make the site suitable for future residential use, soil remediation and validation works were undertaken. Remediation works were divided into two separate phases. The first phase of works, focusing on the northern half of the site, was completed during the dry season of 2014 (May – September 2014). The second phase of works, focusing on the southern half of the site, was undertaken during the 2015 dry season (early May – September 2015).

The following activities were completed as part of remediation and post remediation monitoring works undertaken at the site between 2014 and 2016:

- Excavation of approximately 17,000 loose cubic metres (LCM) of petroleum hydrocarbon impacted soil for remediation.
- Excavation and off-site disposal of approximately 250 LCM of soil containing general waste (glass bottles, bricks and wire) from the north eastern portion of the site (buried waste area).
- Excavation and off-site disposal of 10 LCM of fill material containing bonded asbestos cement sheeting from the north eastern portion of the site (portion of the buried waste).
- Remediation of approximately 17,000 LCM of soil for re-use on site.
- Soil sampling and testing to validate all excavations.
- Testing and classification of remediated stockpiled soil prior to backfilling.
- Backfilling and compaction of excavations with remediated soils (nominally compacted by track rolling or vibrating roller).

- Test pitting in the south site to assist with characterisation of unexcavated areas (20 locations), and along the western boundary to assess the potential for ongoing migration of petroleum hydrocarbons from the former Mobil Depot (up-gradient of the site).
- Installation of 21 new groundwater monitoring wells on-site (MW31 to MW49, MW38D and MW41D), in addition to the (ten) pre-existing groundwater monitoring well network (MW1, MW2, MW5, MW9, MW18, MW23 and MW24 installed in 2007 and MW29, MW31 and MW32 installed in 2010), a total of 31 wells (note, two MW31 and MW32 were created and where relevant are distinguished by the installation year).
- Six ‘post remediation’ groundwater monitoring events to characterise and assess post remediation groundwater conditions at the site (between October 2015 to October 2018).

# 2. Site Information

## 2.1. Site Identification

General site information is summarised in Table 2-1 below.

The location of the site is shown on Figure 1 (Appendix A). Figures showing the former site layout pre and post-demolition are provided in Figures 2 and 3 respectively (Appendix A).

**Table 2-1 - Site Identification details**

| Item | Detail |
|---|---|
| Site Name | Former Caltex Darwin Depot |
| Site Owner | Ampol Petroleum Pty Limited |
| Caltex Site Number | 11591d |
| Site Address | 12 Dinah Beach Road, Darwin, Northern Territory |
| Total Site Area | 14,000 square metres ($m^2$) (i.e. 1.4 hectares (Ha)) |
| Title Identification Details | Title Reference: CUFT 164 25<br><br>Parcel Reference: Lot 04360 town of Darwin from plan(s) A 000413 |
| Local Government Area | Darwin Municipality |
| Current Zoning | General Industry (GI) |
| Current Site Use | Vacant Industrial Land. Formerly Caltex Darwin Depot. |
| Proposed Site Use | Coffey understands that the site is ultimately to be divested for residential development. |
| Adjoining Site Uses | North: Dinah Beach Road with residential properties beyond.<br><br>East: One Mile Dam Indigenous Community<br><br>South: Mixed residential (medium – high density) and commercial properties.<br><br>West: Former Mobil Depot, currently vacant. |
| Topography | The site is relatively flat with a slight slope down toward the east. (Approximately 1.0 m fall from west to east). |
| Surface Water Bodies | The closest downgradient surface water body to the site (based on the inferred groundwater flow direction) is the creek/drainage line which runs along the eastern boundary of the site. Midway along the eastern boundary of the site, a channel links the creek to One Mile Dam, which is located within the One Mile Dam Aboriginal Community. The Dam also includes an outflow point along its western bank. Beyond the dam the next down gradient surface water body is Frances Bay, approximately 650m to the east. |

## 2.2. On-site Chemical Storage and Infrastructure Summary

Prior to Coffey's engagement to undertake the site clean-up, all infrastructure had been decommissioned and removed from the site. Figures 2 (Appendix A) shows the location of the former depot infrastructure prior to final demolition in 2006. Table 2-2 provides details of the former petroleum storage tanks and infrastructure on the site. Caltex property summary information prepared in 2005 indicated that the loading rack and small pencil tank storage was decommissioned in 1999. In 2005, the Caltex reseller was operating a truck refuelling facility at the location.

**Table 2-2 - Former Infrastructure Details**

| Tank Type | Product | Capacity (L) | Date Tank Installed | Construction Material | Status |
|---|---|---|---|---|---|
| AST | ULP | 55,000 | NK | Steel | Removed in 2005 |
| AST | PULP | 55,000 | NK | Steel | Removed in 2005 |
| AST | PULP | 55,000 | NK | Steel | Removed in 2005 |
| AST | Gas Oil | 85,000 | NK | Steel | Removed in 2005 |
| AST | Diesel | 55,000 | 1999 | Steel | Removed in 2006 |
| AST | Diesel | 55,000 | ~2006 | Steel. Internally bunded | Removed in 2006 |
| UST | ULP (formerly diesel) | 9,400 | NK | Steel | Removed in 2006 |
| UST | NK | 5,000 | NK | Steel | Removed in 2006 |
| UST | NK | 5,000 | NK | Steel | Removed in 2006 |
| Product Lines | NK | - | - | - | Removed in 2006 |
| Fuel Manifolds | NK | - | - | - | Removed |
| Drum Storage Shed | 205L drums of mostly Lube Oil and other small drums of products for distribution (Fluor Daniel GTI 1997). | | - | Timber raised store, with concrete underfloor. | Removed in 2006 |
| Fuel Gantry | NK | - | - | - | Removed |
| Triple Interceptor traps | - | - | - | - | Removed in 2006 |
| Site Buildings | - | - | - | - | Removed in 2006 |

*NK – Not Known*
*ULP – Unleaded Petrol*
*PULP – Premium Unleaded Petrol*

## 2.3. Land Titles

Land titles and boundary re-establishment survey data associated with the site are provided in Appendix D.

The fence along the western boundary was not on the actual property title boundary (see Figures 2 and 3 Appendix A) at the commencement of soil remediation works in 2014. The fence was located several metres inside the former Mobil Coastal Bulk Plant (Mobil) site boundary but was repositioned onto the correct title boundary in August 2015.

## 2.4. Surrounding Environment

The site is situated approximately 750 m north of Darwin's central business district (CBD), in a mixed residential and commercial area. The ratio of commercial to residential properties increases towards the CBD (to the south). West beyond the CBD is Port Darwin, while to the east lies Frances Bay, part of the East Arm of Port Darwin.

The historical use of surrounding properties and the present zoning according to Northern Territory Planning Scheme is outlined in Table 2-3 with further details on the condition of the former surrounding fuel sites described below.

**Table 2-3 - Surrounding Land Use Details**

| Surrounding Property Aspect | Surrounding Land Use Details |
|---|---|
| North | Former BP Darwin Terminal, the area was re-developed into residential subdivisions north of Dinah Beach Road, currently zoned as Specific Use - Residential. |
| South | Bushland and an unnamed creek are located directly south of the site and is zoned as Public Open Space. Located further southeast of Harvey Street was the former Shell Bulk Fuel Storage Depot, which was developed into a multi-level residential apartment building |
| East | An unnamed creek is located directly adjacent to the site. Further east of the creek is an area designated as Community Living, which is the One Mile Dam Indigenous Community. |
| West | Former Mobil Coastal Bulk Plant, the area is currently vacant and zoned for General Industry. |

The northern boundary of the Caltex site abuts Dinah Beach Road. North and beyond the road, was the former BP Darwin Terminal. An Environmental Audit was completed for that site by Mr Adrian Hall, in June 2007. The audit concluded that the site was deemed suitable for beneficial uses associated with single dwelling residential living and Specific Uses permitted under SD20 classification zone. The audit report also included the condition that there should be no use of groundwater from the site other than for environmental monitoring, as the groundwater contained elevated levels of heavy metals (arsenic, chromium, cobalt and copper, lead, manganese, mercury, nickel, and zinc).

Elevated concentrations of arsenic which were also detected in the soil were indicated to either be naturally occurring at the site or related to past herbicide use.

The southern boundary of the Caltex site is adjacent to an unnamed creek (which continues along the eastern boundary of the site) and a small area of bushland, which is currently zoned as Public Space. The bushland area extends to Harvey Street, beyond which was the former Shell Bulk Fuel Storage Terminal. An Environmental Audit was completed for that site by Mr Steven Kirsanovs in July 2015. The site was considered suitable for multi-level residential apartment buildings with the condition that groundwater must not be extracted except for environmental monitoring or remediation purposes, as the groundwater was identified to be naturally acidic and contained elevated levels of metals including arsenic, nickel and zinc. Based on fate and transport modelling, it was suggested that the impacts in groundwater had reached their maximum extent and were in steady state conditions, and therefore were unlikely to migrate further than 40m from the original source zone. Therefore, risks to Frances Bay marine ecosystem were considered negligible.

The western boundary of the Caltex site is shared with the former Mobil Coastal Bulk Plant (Mobil) site. Remediation was undertaken at this site between (circa) 2002 and 2013. An Environmental Audit was completed by Mr Charlie Barber in October 2013 (NT EPA reference number: EN2010/0198-02~0071). The site is currently vacant and was designated as General Industry. The condition of the site was determined to be suitable for high-density sensitive use and commercial/industrial use, and groundwater was identified as not suitable for potable use. A Certificate of Audit was not issued on the basis that residual hydrocarbons existed in the soil and groundwater along the eastern boundary, which would require remediation to restore all beneficial uses. The final condition of the former Mobil site and data from the Environmental Audit, in relation to the final conditions at the Caltex site, is discussed in Section 12.

## 2.5. Recent Site Use

A temporary access road was constructed through the middle of the Caltex site in June 2018, to support road extension works into the Darwin CBD. A temporary Licence for Access agreement was signed between the Northern Territory Government Department of Infrastructure Planning and Logistics (DIPL) and Caltex from 1 March 2018 to 28 February 2019. On 20 March 2018, the “Terminating Date” in the agreement was extended to 31 May 2020.

Before construction of the temporary access road, monitoring wells were fenced and communicated to construction personnel prior to the commencement of ground disturbance activities. Later, a broader site boundary was defined along the access road with “no go areas” for the Caltex site identified. Construction of the temporary access road commenced June 2018 and was used by various construction contractors to transport equipment and materials.

As of 1 November 2019, DIPL has completed their works and use of the temporary access road was terminated by signing a termination agreement on xx November 2019.

## 2.6. Site History

A summary of the site’s historical use is provided below. The summary is based on information obtained from previous investigation reports, and anecdotal information previously supplied by members of the Northern Territory Government and local subcontractors (with prior experience on the Caltex site)

- The site was acquired by Ampol Petroleum Limited in 1971 for the purpose of operating a petroleum storage depot, prior to this, the site was classified ‘vacant’ crown land.
- As a petroleum storage depot, the site historically stored a variety of petroleum products, including (but not limited to), diesel, leaded petroleum, unleaded petroleum, premium unleaded petroleum, gas oil and motor oil.

- Potential sources of petroleum hydrocarbon contamination at the site included:
  - USTs and ASTs and associated pipe work.
  - Fuel gantry (two diesel bowsers).
  - Fuel manifold.
  - Drum storage shed with drum washing area and drum filling point.
  - An oil triple interceptor and interception traps.

The southern portion of the Caltex site was not actively used in the Caltex Depot operations (refer to Figure 2, Appendix A). The southern part of the site was divided by two above-ground product lines which are understood to have transferred a variety of petroleum hydrocarbon products from the wharf at Stokes Hill across the Caltex site to the Mobil site, from where other transfer lines ran to the BP site to the north.

It is also understood that petroleum hydrocarbon product was transferred from large ASTs on the Mobil Depot to the four ASTs in the centre of the Caltex site. The product was transferred to the Mobil Depot via underground product lines and a fuel manifold located on the western boundary of the Caltex site (refer to Figure 2, Appendix A).

Based on the Fluor Daniel GTI October 1997 Environmental Site Assessment report, it is understood that a significant fuel spill occurred in 1996, up-gradient at the Mobil site .The report indicates that there was a fuel leak in a subsurface pressurized fuel line connected to the filling gantry and likely to have impacted the former Ampol property (Caltex site).likely causing free-phase hydrocarbons to float on top of the local groundwater and migrate from the Mobil site down-gradient to the southwestern corner of the Caltex site.

In May 1997, product was observed in groundwater seepage at the centre of the Caltex site and was considered to be a second petroleum spill originating at the Mobile site. During the May 1997 ESA, LNAPL was also recorded in two monitoring wells installed by Mobil in the central portion of the western boundary of the Caltex site (refer to Fluor Daniel GTI Report, October 1997 report). Sheen in trenches and seeps was also observed in 2007 during demolition and early investigation works (Coffey 2010).

### 2.6.1. Historical Environmental Site Investigations and Reports

Table 2-4 lists the various investigations and reports completed for the site and provides a summary of works undertaken prior to remediation, based on the information available.

**Table 2-4 - Summary of Historic Environmental Reports**

| Consultant | Date | Summary of Activities |
|---|---|---|
| **PPK (on behalf of Mobil Oil Australia Pty Ltd)** | Full report not available<br><br>A summary of findings provided in Fluor Daniel GTI (2 October 1997) ESA Report | • Initial assessment undertaken at Caltex Depot (formerly Ampol) by Mobil Oil Australia Pty Ltd in response to a spill that occurred in late 1996 at the south of the Mobil Depot (adjacent site). Evidence of a spill was first noted at the Caltex site when product was observed in drain/creek located south of the site.<br>• Mobil immediately began fuel recovery works.<br>• Surface staining appeared on the former Caltex Depot site in early 1997, which was considered to be a result of a second petroleum spill. A leak was identified in a subsurface fuel line, which originated from the adjacent Mobil Depot, and terminated at the fuel manifold on the Caltex site.<br>• Mobil fuel recovery works were conducted, including works on the Caltex Site. |

| Consultant | Date | Summary of Activities |
|---|---|---|
| | | • Works on the Caltex site included installation of seven groundwater monitoring wells (PPK1-PPK7), and two interception traps located on the southwestern corner of the site (refer to Figure 2 in the Fluor Daniel GTI October 1997 report)<br>• Groundwater monitoring wells and interception trenches were pumped periodically by Mobil contractors. |
| Fluor Daniel GTI | 2 October 1997 | **Environmental Site Assessment (ESA) Report**<br>• Seven monitoring wells (MW1-MW7) installed by Flour Daniel GTI in May 2017<br>• Three off-site monitoring wells (MW9-MW11) installed by Flour Daniel GTI in December 1997<br>• The ESA scope of work included sampling of seven monitoring wells (MW1-MW7), three off-site monitoring wells (MW9-MW11) and soil sampling at five hand auger locations (SB1-SB5) (refer to Figure 2, Fluor Daniel GTI October 1997 report). MW8 already existed at the site and was not installed by Fluor Daniel GTI.<br>• Selected soil samples were analysed for TPH, BTEX and metals.<br>• Groundwater samples were collected from ten groundwater monitoring wells and were analysed for TPH, BTEX and lead.<br>• Elevated concentrations of TPH in soil were reported to the southwest of the above-ground fuel storage tanks, within the product seepage area in the centre of the depot area, in the south west corner of the depot area, and within the bunded above-ground fuel storage tank area.<br>• Elevated concentrations of BTEX were reported in a number of soil samples collected across the site.<br>• LNAPL was detected in two monitoring wells MW6 (in vicinity of product seepage) and Mobil well PPK6, located in the southwest portion of the site (in the vicinity of the Mobil fuel spill).<br>• Elevated and/or detectable concentrations of TPH in groundwater were reported in most groundwater monitoring wells.<br>• Concentrations of lead, below the adopted investigation criteria, were detected in all groundwater samples. Due to the relatively consistent concentrations observed, these concentrations were attributed to background levels rather than contamination at the site. |
| Fluor Daniel GTI | 6 February 1998 | **Limited On-Site and Off-Site Investigation Report**<br>• Workers from Darwin City Council observed what appeared to be motor spirit seeping into the unnamed creek (located east of the site) during October 1997, triggering a Limited On-Site and Off-Site Investigation by Fluor Daniel GTI<br>• Initial responses included damming the creek and removing water and motor spirit from the creek, followed by the installation of five interception traps on the Caltex site surrounding the above ground storage tanks.<br>• Investigations centred on the above-ground fuel storage tanks, however, analysis showed that soil within the bunded tank farm was not greatly impacted, and there were no breaches in the bund itself.<br>• The subsurface leaded fuel line which supplied the Caltex site from the adjacent Mobil site failed an integrity test.<br>• Upon excavation, a leak in the leaded fuel line was observed.<br>• A total volume of 16,610 litres of motor spirit was recovered from the initial pumping of the interception traps and in the groundwater monitoring well MW2.<br>• The scope of work included a soil gas survey, groundwater monitoring of 10 wells (except MW2), collection of four creek surface water |

| Consultant | Date | Summary of Activities |
|---|---|---|
| | | samples (east of site) and collection of eight soil samples from the creek bank.<br>• Elevated concentrations of TPH and BTEX were identified in soil samples collected from two of the three off-site soil bores. Both were later converted to groundwater monitoring wells (MW9 and MW10).<br>• Elevated concentrations of BTEX was reported in one creek bank sample.<br>• Elevated concentrations of TPH and/or BTEX in groundwater were reported in all on-site and off-site groundwater monitoring wells.<br>• Elevated concentrations of TPH, BTEX and lead were reported in all surface water samples collected from the creek.<br>• Soil gas concentrations were above 2500 $ppm_v$ in the vicinity of the above-ground fuel storage tanks (analysed using a PID). |
| Fluor Daniel GTI | 4 March 1998 | **Site Monitoring Report February 1998**<br><br>• Site works included collection of five surface water samples, three sediment samples, a groundwater monitoring event of on-site and off-site groundwater monitoring wells, the collection of shallow soil samples (in areas of surface seepage) and a surface water sample from the creek/drain to the south of the site.<br>• Detectable concentrations of TPH and BTEX were reported in shallow soil samples collected from areas where surface seepage had been observed.<br>• Detectable concentrations of TPH and/or BTEX were reported in creek sediment samples.<br>• Seven of the twelve groundwater monitoring wells sampled reported elevated concentrations of TPH and/or BTEX in groundwater. These included four on-site groundwater monitoring wells in the central portion of the depot and all off-site groundwater monitoring wells to the east of the site.<br>• Elevated concentrations of TPH and BTEX were reported in the five surface water samples collected from the creek immediately east of the site.<br>• Elevated concentrations of TPH were reported in the surface water sample collected from the drainage line located to the south of the site. |
| Fluor Daniel GTI | 17 July 1998 | **Groundwater and Creek Monitoring for June 1998**<br><br>• Site works included groundwater gauging and collection of six surface water samples.<br>• No LNAPL was detected in on-site or off-site groundwater monitoring wells during gauging (using an interface probe) however hydrocarbon odour was detected in some monitoring wells<br>• Laboratory analysis of groundwater was not undertaken during this phase of work.<br>• Elevated concentrations of TPH and/or BTEX were reported in four surface water samples collected from the creek/drainage line immediately east of the site, but not in the surface water sample from the creek/drainage line south of the site. |
| Fluor Daniel GTI | 18 December 1998 | **Continuous Monitoring Program and Creek Sampling October 1998**<br><br>• Site works included monitoring of groundwater monitoring wells MW1, MW2-MW11,4 PPK monitoring wells, and collection of five creek/drainage line surface water samples. |

| Consultant | Date | Summary of Activities |
|---|---|---|
| | | • LNAPL was detected in six groundwater monitoring wells (MW2, MW9, MW10, PPK1, PPK4 and PPK7). Laboratory analysis was not undertaken on groundwater from these wells.<br>• Elevated concentrations of TPH and/or BTEX were reported in all groundwater monitoring wells.<br>• Elevated concentrations of TPH and/or BTEX were reported in four surface water samples collected from the creek immediately east of the site and in the surface water sample collected from the drainage line located to the south of the site. |
| IT Environmental | 28 June 1999 | **Monitoring Program May 1999**<br>• Site works included sampling of seventeen groundwater monitoring wells (MW1-MW11 and PPK1-PPK8), and collection of five creek / drainage-line surface water samples.<br>• LNAPL was not detected in any of the groundwater monitoring wells sampled.<br>• Elevated concentrations of TPH and/or BTEX were reported in all but two of the groundwater monitoring wells sampled.<br>• Elevated concentrations of TPH were reported in the four surface water samples collected from the creek immediately east of the site and the surface water sample collected from the drainage line located to the south of the site.<br>• Elevated concentrations of BTEX were reported in the surface water sample collected from the creek immediately east of the site. |
| URS | 31 January 2006 | **Phase 1 and 2 Environmental Site Assessment**<br>• A Phase 1 ESA found the site had operated as a coastal bulk plant since 1971, prior to which it was vacant crown land. Properties to the north of the site were predominantly residential prior to the 1960s.<br>• The Phase 2 ESA included drilling eight soil bores, six of which were converted into new groundwater monitoring wells (MW12-MW17), (refer to Figure 4, URS January 2006 report).<br>• Soil samples were collected and analysed for TPH, BTEX and lead. Selected samples were also analysed for metals, PAHs and phenolic compounds.<br>• Twelve monitoring wells were gauged.<br>• Eleven monitoring wells (MW7 was dry) were purged, sampled and analysed for TPH, BTEX and lead with selected samples analysed for metals, PAHs and phenolic compounds.<br>• Elevated concentrations of TPH or BTEX were reported in soil samples from seven of eight soil bores, including the western-most driveway, east of triple interceptor trap, east of fuel gantry, north of fuel manifold / pump slab, east of AST farm (pencil tanks) and north and east of interception trap (near the spoon drain).<br>• No LNAPL was detected in any of the on-site or off-site groundwater monitoring wells.<br>• Groundwater from the eleven monitoring wells sampled, with the exception of MW14, detected concentrations of TPH and/or BTEX compounds above laboratory LOR.<br>• All phenol compounds and PAHs were below LOR in groundwater, except for naphthalene in MW15, which exceeded adopted guidelines.<br>• Lead in groundwater exceeded adopted guidelines at MW2.<br>• Arsenic (MW14), copper (MW12 and MW15) and zinc (MW14, MW15 and MW17) exceeded adopted guidelines. |

| Consultant | Date | Summary of Activities |
|---|---|---|
| **Other Works**<br><br>**Mark Cundall Earthmoving** | May 2006 | Prior to Coffey undertaking investigative works, all petroleum-related infrastructure was removed from the site. The demolition and removal works were undertaken during May 2006 by Mark Cundall Earthmoving, under the supervision of JFTA Pty Ltd, and involved the removal of the on-site infrastructure including buildings, footings and foundations, above-ground and underground fuel storage tanks and product lines, interceptor traps and the reinstatement of excavations.<br><br>Coffey considers all residual infrastructure – with the exception of some minor concrete slabs and footings - was removed as part of these pre-remediation works. The remediation works undertaken in 2014-2016 have removed any residual infrastructure (e.g. concrete footings) or buried waste. |
| **Coffey** | 18 June 2010 | **Environmental Site Assessment, Former Caltex Darwin Depot, 12 Dinah Beach Road, Darwin, Northern Territory**<br><br>• The ESA was undertaken as part of a due diligence process prior to site divestment for residential purposes, and to provide Caltex with an understanding of current contamination status to inform a remediation strategy for the site (if required).<br>• The Phase 1 component identified that the Caltex site and the up-gradient Mobil Depot site had both experienced hydrocarbon leakages / spills documented to have occurred historically in 1997 and was concluded to have contributed to the contamination of soil and groundwater at the site.<br>• Sixteen (16) new groundwater monitoring wells were installed in January 2007 (MW1-MW10, MW14, MW15, where MW4A, MW5A and MW15A were installed to assess the potential for a separate, deeper aquifer). In July 2007, an additional eleven (11) monitoring wells were installed (MW11-MW13, MW16-MW23).<br>• Three groundwater monitoring events took place at six-month intervals (July 2007, January 2008 and July 2008) to allow for a comparison between seasons.<br>• Surface water samples were collected from ten (10) sample locations within the creek, which ran along the southern and eastern site boundaries. One sample was also taken within One Mile Dam.<br>• Concentrations of petroleum hydrocarbon related contaminants at concentrations above the adopted guidelines were identified for both soil and groundwater.<br>• Soil contamination in the northern portion of the site was identified between 0.5 m and 1.5 m depth and was likely to coincide with groundwater fluctuations between the wet and dry seasons in existing source areas.<br>• It was considered likely that soil and potentially groundwater contamination extended off-site to the east (groundwater plume had not been delineated to the east of site).<br>• No petroleum hydrocarbon contamination was detected from water samples taken from One Mile Dam (hydraulically down-gradient of site).<br>• Remediation of soil and groundwater was recommended to reduce the risk to potential receptors; in line with the proposed re-zoning to residential. A remediation action plan was also recommended to be developed to assess available options for site remediation methods and techniques. Consideration of recontamination potential from off-site sources, and the prevention of this was highlighted. |
| **Coffey** | 8 September 2010 | **Off-Site Health Risk Assessment, Former Caltex Darwin Depot, 12 Dinah Beach Road, Darwin, Northern Territory** |

| Consultant | Date | Summary of Activities |
|---|---|---|
| | | • This report addressed the potential health risks to off-site human populations associated with petroleum hydrocarbon impact to soil and groundwater, notably the current land use by the One Mile Dam Indigenous Community and potential future residential land use on the property located hydraulically down-gradient of the site.<br>• Five (5) new off-site monitoring wells were installed in July 2010 (MW28 - MW32) to assess the groundwater down-gradient of the site. All five groundwater monitoring wells were within the One Mile Dam Community property.<br>• It was considered that soil and groundwater impacts at the time were *unlikely* to pose and unacceptable health risk to:<br>o One Mile Dam Indigenous Community members<br>o Off-site residential occupants within a slab-on-ground dwelling<br>o Off-site maintenance workers within a 1 m deep trench<br>• Groundwater was considered *unsuitable* for extractive uses based on the reported petroleum hydrocarbon concentrations in groundwater. At the time of this report, the site was not under any regulatory notice, and no off-site health risks were identified, therefore, the recommendation to restrict groundwater extraction was not communicated beyond the site owner (Caltex).<br>• The exposure pathway for groundwater was considered incomplete as no groundwater extraction bores were present. Groundwater extraction was recommended to be restricted until off-site contaminant concentrations reach an acceptable level. |
| Coffey | 8 March 2013 | **Factual Groundwater Monitoring Report, Former Caltex Darwin Depot (11591D), 12 Dinah Beach Road, Darwin, Northern Territory (issued as a draft)**<br><br>• The ESA was undertaken to provide Caltex with an updated understanding of the contamination status of the site with a view to potential divestment of the site for residential use.<br>• Groundwater sampling was conducted in November 2012 on twenty (20) monitoring wells (MW1-MW3, MW5A-MW14, MW15A, MW23 and MW24).<br>• Concentrations of TPH contaminants were found above the adopted guidelines in ten monitoring wells and one well reported elevated concentrations of BTEX. |
| Coffey | 3 July 2014 | **Remediation Action Plan, Former Caltex Darwin Depot, 12 Dinah Beach Road, Darwin, Northern Territory**<br><br>A Remediation Action Plan (RAP) was developed for the site to provide a remediation strategy and validation plan to supporting the Environmental Audit being undertaken, and the ultimate proposed divestment of the site for future sensitive land uses (such as residential development). |
| Other Works<br><br>Coffey | 22 October 2013 | **Caltex Darwin Terminal: Buried Waste and Off-site Pipeline Due Diligence Assessment**<br><br>• A due diligence assessment was conducted to assess contamination of an off-site pipeline located southeast, which was presumed to be shared between the Mobil Depot and BP Terminal and to delineate the former on-site landfilling area (Figure 2).<br>• Soil samples were analysed for petroleum hydrocarbons.<br>• Buried waste comprised mostly of broken and intact glass bottles, which was likely originated pre-Caltex site occupation. Other items encountered in fill material included concrete fragments and buried concrete structures. |

# 2.7. Contaminants of Potential Concern

## 2.7.1. On-site Contaminant Sources

Table 2-5 below summarises the contaminants of potential concern (COPC) that were found on the site prior to remediation based on the potential sources identified in historical assessment reports (Table 2-4), historical site uses, and sampling undertaken at the site post-remediation.

**Table 2-5 - Contaminants of Potential Concern**

| Source (On-Site) | Location | Potential Contaminants based on site use | Contaminants identified in site assessments |
|---|---|---|---|
| **On-Site Above-Ground and Below-Ground Fuel Storage Tanks and Associated Infrastructure (product lines, bowsers, etc.), Triple interceptor trap (Removed in 2006)** | Predominantly in the northern (depot) portion of the site. Product lines were also located in southern portion of the site. | TPHs<br>BTEX<br>PAHs<br>Phenols<br>Chlorinated Hydrocarbons<br>Metals | TPH<br>BTEX |
| **Product/Waste Oil Drums (Removed in 2006)** | Former drum storage shed located in the north west portion of site | TPHs<br>BTEX<br>PAHs<br>Phenols<br>Chlorinated Hydrocarbons<br>Metals | TPH<br>BTEX |
| **Fill Material** | Across the general site surface | Metals<br>PAHs<br>Asbestos | Metals |
| **Interceptor Traps (Removed in 2006)** | Central portion of the site down to approximately 2.0 m bgs. | TPHs<br>BTEX<br>PAHs<br>Phenols<br>Chlorinated Hydrocarbons<br>Metals | TPHs |
| **Buried Waste** | North eastern boundary of site. | As above, plus potential asbestos containing materials (ACM), as well as inert waste (e.g. concrete and glass). | ACM<br>Metals |

The available site layout plans and anecdotal information did not describe fire suppression equipment such as foam deluge systems or AFFF storage facilities on the Ampol/Caltex site. Testing of groundwater conducted in 2018 identified per- and poly-fluorinated alkyl substances, but did not indicate primary sources on site.

### 2.7.2. Off-site Contaminant Sources

Based on historical environmental site investigations and reports, two significant spills were recorded on and at the up-gradient Mobil site. The first spill event is believed to have occurred in late 1996 due to a fuel release from a transfer line connected to the filling gantry area. Approximately 27,000 L of diesel was recovered.

Another fuel spill event occurred in 1997 due to a major underground fuel line failure that was providing leaded product between the Mobil and Caltex terminals. The exact volume of product lost was not known or recorded. Approximately 16,610 L of fuel product was recovered. It is likely that petroleum hydrocarbons from the two fuel leaks at the Mobil site, migrated down-gradient onto the Caltex site, introducing contaminants (such as TPH, BTEX and some PAHs) to surface soils and into the shallow groundwater to parts of the Caltex site.

Investigations in 2018 identified PFAS (perfluoro-alkyl substances) in surface water and groundwater around the site. The distribution of concentrations and compounds suggested a large proportion was coming from up-gradient sources:= from the former Mobil site, which potentially included fire protection services, and broader urban run-off.

# 3. Site Geology

## 3.1. Regional Geology

According to the 1:100,000 'Darwin' (1983) Geological Survey of Northern Territory Map, Sheet Number 5073 (Pietsch, B.A, 1983), the site is underlain by the following geological units:

**Bathurst Island Formation** - Darwin Member: Lower Cretaceous sediments, comprising radiolarian claystone; sandy claystone; clayey sandstone; quartz sandstone; ferruginous sandstone; glauconitic sandstone, commonly with basal conglomerate. The depth of this formation is expected to be 0 – 12 mbgs (metres below ground surface).

**Burrell Creek Formation** – Finniss River group, comprising siltstone; shale; sandstone; (quartz arenite, sublitharenite); quartz pebbles conglomerate; metamorphosed to lower greenschist facies (phyllite). The depth of this formation is expected to be within a range 12 - 30 mbgs.

Quaternary marine alluvial sediments (mud, silt and clay) can also be expected to occur along the coastal margins of this region.

## 3.2. Site Specific Geology

Information relating to the sub-surface lithology at the site from historical investigations and recent soil remedial works is summarised in Table 3-1 below.

All available current and historical borelogs and test pit logs are provided in Appendix C.

**Table 3-1 - Generalised Site Lithology**

| Depth Interval (mBGS) | Lithology Description |
|---|---|
| **Northern Portion of Site** | |
| **0 – 0.8** | (FILL) Sandy / Gravelly CLAY: low plasticity, light brown, sub-rounded fine grained sands. |
| **0.8 to 2.0** | Silty CLAY, low plasticity, pale grey. |
| **2.0 – 7 (limit of investigation)** | Weathered SILTSTONE: weathered, grey with some red / brown mottling, fine grained. |
| **Southern Portion of Site** | |
| **0 – 0.3** | Gravelly SAND, fine grained, brown, fine gravels, some organic matter (roots). |
| **0.3 – 0.9** | Silty SAND / Sandy SILT: fine grained, well graded, grey – black. Some organic matter. |
| **0.9 – 2.0** | Silty CLAY: fine grained, low – medium plasticity, grey with red mottling, fine – medium gravels. |
| **2.0 – 7.0 (limit of investigation)** | Weathered SILTSTONE: weathered, grey with some red / brown mottling, fine grained. |

**Northern part of the Site**

The northern part of the site generally comprised a layer of fill material (sandy gravelly clays) overlying the natural material. Natural materials were generally more uniform, and were composed of sandy clays associated with weathering of the underlying siltstone.

**Central West part of the Site**

Similar to the northern part of the site, the lithology in the central west of the site was also weathered siltstone. The siltstone was generally shallower in the centre of the site along the western boundary compared to across the rest of the site.

**Central East part of the Site**

The lithology in the centre of the site along the eastern boundary was in-situ weathered material, partially overlain by alluvial silty clays and clayey sands deposited along the creek. Sandy lenses were more prevalent in the upper 1 to 1.5 m of the unit.

Concrete and waste (including plastic metal, glass and plant waste) was also found buried along the central eastern boundary.

**Southern part of the Site**

Weathered material in the southern part of the site was also partially overlain by alluvial silty clays and clayey sands associated with the creek, resulting in the increased occurrence of preferential pathways (i.e. sandy lenses) in the upper 1 to 1.5 m of the unit.

Visual inspection of excavation walls during remedial activities suggest the Creek path (or a now buried tributary) may have once cut along the south and or south east corner of the site.

## 3.3. Regional Topography

The topography of the region is undulating, generally sloping to the east toward Frances Bay. The gradient is greater to the west of the site, sloping steeply across the former Mobil Depot site (an approximate 9 m vertical fall, at a gradient of approximately 1:20). The gradient across the Caltex site, and east towards Frances Bay, is comparatively flat (approximately 3 m vertical fall, at a gradient of approximately 1:160).

Regionally, surface water runoff east of the Stuart highway flows east into the creek which flows eventually into Frances Bay.

## 3.4. On-site Topography

The site is generally flat, with an elevation of approximately 7 mAHD (Australian Height Datum). A break of slope (drop of ~1 m) exists just west of the western boundary where the new site fence was re-established after remediation works in 2015.

# 4. Hydrogeology

Groundwater is a major pathway for migration of contamination associated with petroleum hydrocarbon impact. A solid understanding of the hydrogeological setting on and off-site, and the connection between identified contamination and off-site receptors, is critical to the assessment of potential risk to off-site ecosystems and human health.

The following sections present the regional and local hydrogeological settings of the site, and a conceptual model for groundwater at the site, including discussion of:

- General groundwater quality;
- Depth to groundwater (including seasonal fluctuations);
- Groundwater flow direction;
- Groundwater gradients;
- Aquifer hydraulic conductivity and flow velocity; and
- Completeness of connection with potential groundwater receptors.

## 4.1. Regional Hydrogeology

Groundwater beneath the Darwin area is expected to occur within the shallow Bathurst Island Formation sediments or the deeper Burrell Creek Formation aquifer. The aquifers are likely recharged via direct infiltration from the surface during the wet season. Recharge occurs during prolonged rain events and via seepage along creeks, river channels and any other minor depressions in the area of the site that may accumulate surface water for prolonged periods.

Information provided on the Northern Territory Department of Land Resource Management (DLRM) water data portal website indicated that groundwater within the Bathurst Island Formation is likely to occur at depths less than 5 mBGS and exhibit variable TDS concentrations. The deeper Burrell Creek Formation aquifer is expected to yield between <0.5 and 5.0 L/second, with concentrations of total dissolved solids (TDS) above 3,000 mg/L. Due to the high rainfall during the wet season, local shallow groundwater may generally be less saline than that reported in the DLRM website. Depths to groundwater can vary significantly between the wet and dry seasons, due to the significant rainfall observed in the Darwin area.

## 4.2. Groundwater Database Search

A search of the NT Government Department of Land Resource Management (DLRM) Water Data Portal (undertaken in June 2016), indicated that no registered bores existed within a 2 km radius of the site.

Verbal communications with DLRM in June 2016 has indicated the following in relation to registration and licencing of bores and groundwater extraction in the NT.

- In the Northern Territory, the NT DLRM, manages licencing of bores and extraction of groundwater. As part of the existing system the department defines two 'districts' associated with licencing of bores. Areas of the NT can fall within or outside of a Water control District (WCD).
- Where a site falls within a WCD, a permit is required to install a bore and a licence may be required to extract groundwater. Outside of a WCD the permitting system does not apply, however, drillers are expected to register bore details with DLRM.

- Historically is was understood that registration of bore details outside of a WCD was not reliably undertaken. This indicates that the presence or absence of bores outside of a WCD, based on information from the Water Data Portal, is not necessarily reliable.

The site, and the area down gradient of the site (extending to the harbour) is not within a WCD. This indicates that water bore data obtained through the Water Data Portal may not be reliable.

## 4.3. Site Hydrogeology

The current understanding of the hydrogeological setting at the site is based on a combination of both pre and post remediation work undertaken between 2014 and 2018. The current and historical monitoring well network is summarised in Table 4-1, with additional detail provided in Table 7, Appendix B.

Historical and current groundwater monitoring well locations are provided in Figures 4 and 5, respectively (Appendix A).

**Table 4-1 - Groundwater Monitoring Well Network**

| Well ID | Screened Lithology | Screen Interval mBTOC | Existing / Destroyed | On-site or Off-site | Times sampled since 2015 |
|---|---|---|---|---|---|
| MW01 | Clayey SAND/Silty CLAY | 1.6 – 4.9 | Existing | On-site | 6 |
| MW02 | Silty CLAY | not known (depth 4.8m) | Existing | On-site | 7 |
| MW03 | Silty CLAY/ SILTSTONE | 3.5 – 5.5 | Destroyed | On-site | - |
| MW04 | Silty CLAY/ SILTSTONE | 3.6 – 5.6 | Destroyed | On-site | - |
| MW04A | Silty CLAY/ SILTSTONE | 6.7- 10.7 | Destroyed | On-site | - |
| MW05 | Silty CLAY/ SILTSTONE | 2.0 – 4.3 | Existing | On-site | 6 |
| MW05A | Silty CLAY/ SILTSTONE | 2.1 – 13.4 | Destroyed | On-site | - |
| MW06 | Gravelly SILT/ Silty CLAY | 1.1 – 4.6 | Destroyed | On-site | - |
| MW07 | Gravelly SILT/ Silty CLAY | 1.0 – 4.5 | Destroyed | On-site | - |
| MW08 | Gravelly SILT/ Silty CLAY | 1.0 - 4.5 | Destroyed | On-site | - |
| MW09 | Gravelly SILT/ Silty CLAY | not known (depth 3.8m) | Existing | On-site | 6 |
| MW10 | GRAVEL/ Clayey GRAVEL | 1.1 – 3.6 | Destroyed | On-site | - |
| MW11 | CLAY/ SILTSTONE | 1.3 – 4.8 | Destroyed | On-site | - |

| Well ID | Screened Lithology | Screen Interval mBTOC | Existing / Destroyed | On-site or Off-site | Times sampled since 2015 |
|---|---|---|---|---|---|
| MW12 | CLAY/ Silty CLAY | 1.3 – 5.8 | Destroyed | On-site | - |
| MW13 | Gravelly CLAY/ Silty CLAY | 1.3 – 4.8 | Destroyed (replaced by MW36) | On-site | - |
| MW14 | Sandy GRAVEL/ SILTSTONE | 1.2 – 3.2 | Destroyed (replaced by MW41S, MW41D) | On-site | - |
| MW15 | Silty GRAVEL/ SILTSTONE | 1.1 – 2.9 | | On-site | - |
| MW15A | Clayey GRAVEL/ SILTSTONE | 4.4 – 12.4 | | On-site | - |
| MW16 | Clayey GRAVEL/ Silty CLAY | 1.3 – 4.8 | Destroyed (replaced by MW47) | On-site | - |
| MW17 | Clayey GRAVEL/ Silty CLAY | 1.3 – 4.8 | Destroyed (replaced by MW48) | On-site | - |
| MW18 | Sandy GRAVEL/ Clayey SAND | not known (depth 2.8m) | Existing | On-site | 7 |
| MW19 | Silty CLAY | 0 – 3.0 | Destroyed (replaced by MW46) | Offsite | - |
| MW20 | Clayey GRAVEL/ Silty CLAY | 1.3 – 4.8 | Destroyed | Offsite | - |
| MW21 | Silty CLAY/ SILTSTONE | 1.3 – 4.8 | Destroyed (replaced by MW34) | On-site | - |
| MW22 | Silty CLAY/ SILTSTONE | 1.3 – 4.8 | | On-site | - |
| MW23 | not known | not known (depth 2.8m) | Existing | On-site | 6 |
| MW24 | not known | 1.9 – 4.6 | Existing | On-site | 4 |
| MW25 | not known | not known | Destroyed (replaced by MW34) | On-site | - |
| MW26 | not known | not known | Destroyed (replaced by MW38S and MW38D) | On-site | - |
| MW27 | not known | not known | | On-site | - |
| MW28 | Gravelly CLAY/ CLAY | 1.2 – 4.7 | Destroyed | Offsite | - |
| MW29 | Gravelly SILT/ CLAY | 1.2 – 4.7 | Existing | Offsite | 4 |

| Well ID | Screened Lithology | Screen Interval mBTOC | Existing / Destroyed | On-site or Off-site | Times sampled since 2015 |
|---|---|---|---|---|---|
| MW30 | Clayey GRAVEL/ Silty CLAY | 1.2 - 3.7 | Destroyed | Offsite | - |
| MW31 | Silty, gravelly CLAY/ SILTSTONE | 1.7 – 4.7 | Existing | On-site | 8* |
| MW32 | Silty, gravelly CLAY/ SILTSTONE | 1.7 – 4.7 | Existing | On-site | 7 |
| MW31 (2010) | Sandy silt/ CLAY | 1.2 – 3.7 | Existing | Offsite | 2 |
| MW32 (2010) | SILT/ CLAY | 1.2 – 3.7 | Existing | Offsite | 2 |
| MW33 | Silty, gravelly CLAY/ SILTSTONE | 1.7 – 3.5 | Existing | On-site | 9* |
| MW34 | Silty, gravelly CLAY/ Silty CLAY | 1.7 – 4.7 | Existing | On-site | 7 |
| MW35 | Silty, gravelly CLAY/ Silty CLAY | 1.7 – 4.8 | Existing | On-site | 9* |
| MW36 | Silty, gravelly CLAY/ Sandy CLAY | 1.7 – 3.5 | Existing | On-site | 7 |
| MW37 | Gravelly, silty CLAY/ Silty CLAY | 1.7 – 4.8 | Existing | On-site | 6 |
| MW38S | Silty, gravelly CLAY/ Silty CLAY | 1.7 – 4.8 | Existing | On-site | 6 |
| MW38D | Silty, gravelly CLAY/ Silty CLAY | 5.7 – 7.7 | Existing | On-site | 6 |
| MW39 | Silty, sandy CLAY/ Silty CLAY | 1.7 – 4.7 | Existing | On-site | 6 |
| MW40 | Silty, sandy CLAY/ Silty CLAY | 1.7 – 4.8 | Existing | On-site | 6 |
| MW41S | Silty, gravelly CLAY/ Silty CLAY | 1.7 – 4.7 | Existing | On-site | 6 |
| MW41D | Silty, gravelly CLAY/ Silty CLAY | 5.7 – 7.8 | Existing | On-site | 6 |
| MW42 | Silty, sandy CLAY/ Silty CLAY | 1.7 – 4.7 | Existing | On-site | 6 |
| MW43 | Silty, gravelly CLAY/ Silty CLAY | 1.7 – 4.8 | Existing | On-site | 6 |
| MW44 | Sandy, gravelly CLAY/ Silty CLAY | 1.7 – 4.7 | Existing | On-site | 6 |

| Well ID | Screened Lithology | Screen Interval mBTOC | Existing / Destroyed | On-site or Off-site | Times sampled since 2015 |
|---|---|---|---|---|---|
| MW45 | Silty, gravelly CLAY/ Silty CLAY | 1.7 – 4.7 | Existing | On-site | 7 |
| MW46 | Silty, gravelly CLAY/ Silty CLAY | 1.7 – 4.9 | Existing | On-site | 7 |
| MW47 | Silty CLAY/ Sandy CLAY | 1.7 – 4.7 | Existing | On-site | 6 |
| MW48 | Silty CLAY/ Silty, sandy CLAY | 1.7 – 4.8 | Existing | On-site | 7 |
| MW49 | Silty, sandy CLAY | 1.7 – 4.7 | Existing | On-site | 6 |

* includes multiple samples collected during vertical profiling.



### 4.3.1. Aquifer Description

Groundwater at the site exists within an unconfined aquifer (Bathurst Island Formation) at depths ranging from surface level to less than 2.5 mBGS all year round. The variation in groundwater levels across the site and seasons is discussed in detail in Section 4.3.3.

The undisturbed aquifer comprises predominantly of silty clay overlying siltstone in the north and centre of the site; and sandy clay (containing alluvial material associated with the creek) overlying siltstone in the south of the site. During the remediation works between 2014 and 2015, the top 1.5 m - 2.5 m of soil across much of the site was re-worked mechanically as part of the remediation process. The reworking has resulted in removal of the layers within in the aquifer, and the soils becoming a relatively homogenised mix of silty, sandy, gravelly, clay, which is likely to have affected flow within the upper part of the aquifer across the remediation area.

### 4.3.2. Groundwater Quality

Field groundwater quality data is provided in Table 8 (Appendix B). Laboratory analytical data from pre and post-remediation groundwater sampling rounds is provided in Tables 10 and 11 (Appendix B).

**Salinity**

Groundwater salinity (as laboratory total dissolved solids (TDS) at the site ranged from 31 mg/L (MW44 in April 2016) at the end of the Wet, to 1,900 mg/L (MW41D in November 2015), with a median value of 250 mg/L. This range of TDSs is attributed to several factors, including preferential surface water infiltration up gradient of the site and increased evaporation (and concentration of dissolved solids) of pooled water in the centre and north of the site.

Groundwater is generally less saline in the south and east of the site, with higher TDS concentrations in the northern and central areas of the site. Groundwater downgradient to the east, between the site and One Mile Dam is more saline than on-site, with TDS reported between 2,100 mg/L (MW32 (2010) in May 2016) and 5,700mg/L (MW31 (2010) in July 2016).

Nested groundwater monitoring wells (MW38S-MW38D and MW41S-MW41D) were installed at two locations to assess the variation of groundwater conditions within and below the zone disturbed by remediation works (see Section 8.1). Comparison of TDS concentrations at nested locations indicated no significant difference in salinity with depth or aquifer material, indicating that shallow groundwater (within the soil profile) and groundwater below the remediated zone (within the siltstone) receive recharge from a similar source, and are part of the same aquifer.

The distribution of TDS concentrations across the site is shown in Figure 7 (Appendix A).

**pH**

The pH of groundwater measured at the site ranged from acidic (3.92 in MW17 in November 2012) to slightly alkaline (7.53 in MW5 in April 2016), with a slightly acidic median value of 5.91.

**Dissolved Oxygen**

Dissolved Oxygen (DO) measured at the site ranged from 0.0 mg/L (MW23, MW31, MW33, MW37 and MW45 in February 2018) to 4.89 mg/L (MW36 in November 2018), with a median value of 0.65 mg/L. The low concentrations seen at the site may be due to a combination of factors including:

- Reduced solubility of dissolved oxygen at warmer temperatures, as groundwater at the site is typically >25ºC (see section on groundwater temperature below); and
- Biological consumption of dissolved oxygen in the presence of soil organic matter and/or petroleum hydrocarbons in the soil (discussed in detail in Appendix P).

Although dissolved oxygen concentrations at the site fluctuate slightly between monitoring events there has been no significant change in site values since monitoring began.

**Temperature**

Due to shallow groundwater levels and the high ambient temperature observed in Darwin year-round, groundwater temperatures are relativity warm, ranging from 24.97˚C (MW21 in July 2008) to 38.8 ˚C (MW41D in July 2016 and October 2018).

**Redox Potential**

The observed redox potential values at the site ranged from - 43 mV (MW15 in July 2007) to 500 mV (MW33 in November 2018), with a median value of 233 mV.

*Note: Redox potentials discussed in this report have been converted from the field ORP values to Eh (standard hydrogen electrode) values based on temperature, and conversion tables provided by the manufacturer of the water quality meter used for monitoring groundwater field parameters.*

## 4.3.3. Groundwater Levels

Groundwater levels observed at the site have ranged from 4.078 mAHD (MW24 in July 2017) to 8.304 mAHD (MW36 in January 2018), with the potentiometric surface above ground level observed in MW14, MW22, MW31, MW35, MW36, MW37, MW38S, MW40, MW41S, MW41D, MW42, MW43 and MW44.

Groundwater levels were manually gauged in all groundwater monitoring wells during each of the six post remediation GMEs.

Solinst© level loggers were installed in nine selected monitoring wells across the site in 2014 to 2016 to assess the changes in groundwater level and gradients due to remediation, and to assess the influence of rainfall and seasonal effects.

Each logger was programmed to continuously record groundwater level and temperature at 15 minute intervals, to allow for (relatively) continuous monitoring across the entire nine-month groundwater investigation period. A Solinst© "barometric logger" was also installed at a secure (open air) location, located on-site to record barometric pressure and temperature (over the same time interval as the level loggers). The data collected by the barometric logger is used during data processing to compensate groundwater levels for fluctuations in barometric pressure.

Five loggers were again deployed in early 2018 to characterise groundwater levels post remediation.

Barometric data was not available from February 2018 to September 2018 due to the loss of the baralogger in a tropical storm. Pressure data from Darwin Airport (www.bom.gov.au) was used across this period to compensate the logger data for barometric effects. Graphical outputs of all levels and barometric data over time are provided in Appendix E. barometric pressure over the monitoring periods showed a diurnal pattern as expected, and seasonal variation resulted in a maximum of 0.1m equivalence. Note that as the aquifer is shallow and unconfined, barometric efficiency will be high and does not need to be taken into consideration.

Levels fluctuate seasonally in response with the monsoonal rainfall patterns observed in Darwin and the NT, with lower groundwater levels reported in the dry season (refer to **Figure 4-1**).

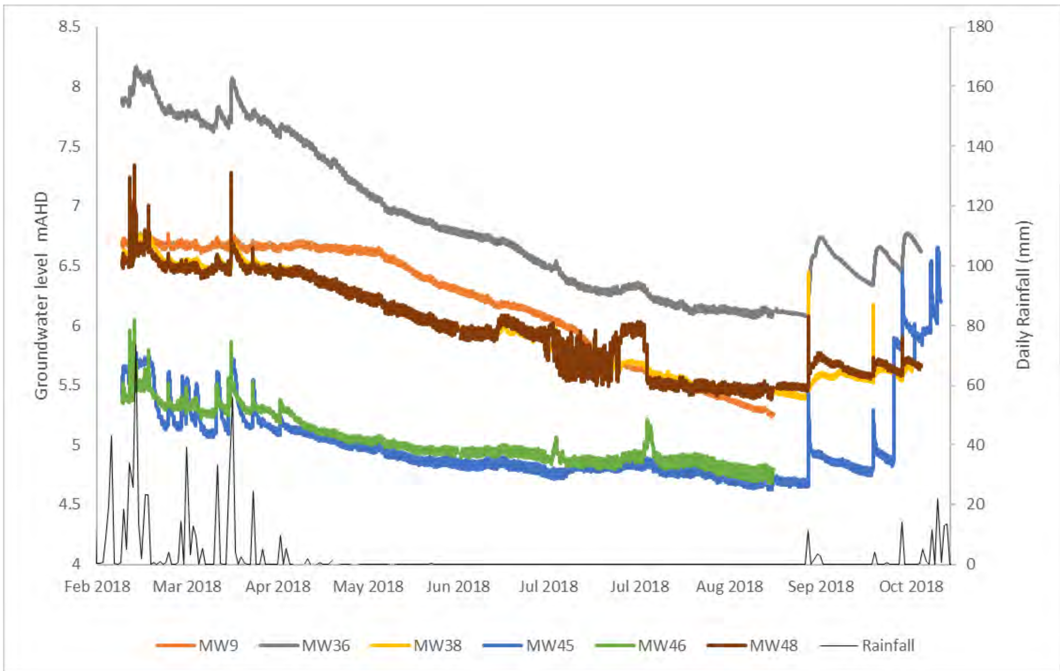



**Figure 4-1: Groundwater levels and rainfall across the site in 2018.**

Figure 4.2 and Figure 4.3 present the relative difference in groundwater levels from west (MW9) to east (MW45) across the site in 2015 when soil remediation works were undertaken, and in 2018 representing current groundwater levels. Groundwater level hydrographs showing levels in selected monitored wells are provided in Appendix E, the survey data for monitoring wells is presented in Appendix F and historical gauging data for the site is provided in Table 8 (Appendix B).

The groundwater levels during and post remediation indicate a strong, and rapid response to rainfall events, particularly on the eastern boundary in MW45 adjacent to the creek where the lithology is typically sandier, and permeability is higher in the wet season (discussed further in Section 4.3.6).

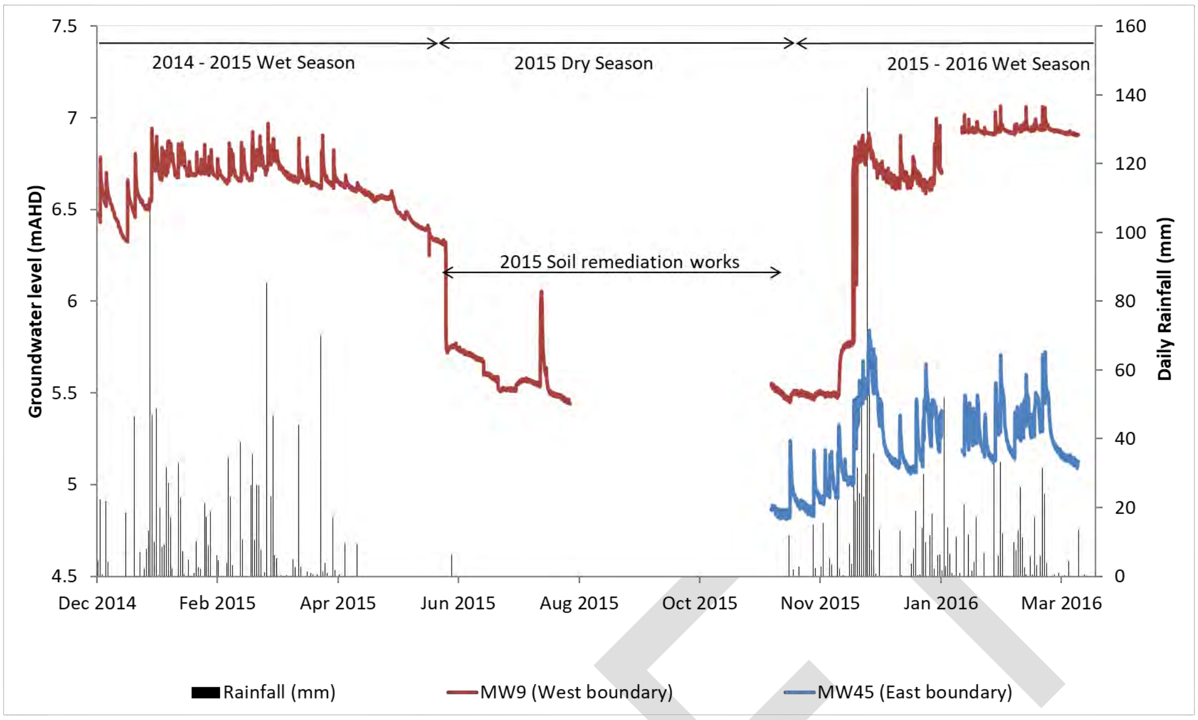



**Figure 4-2: Rainfall and groundwater levels from 2015 to 2016 on the western and eastern boundaries.**

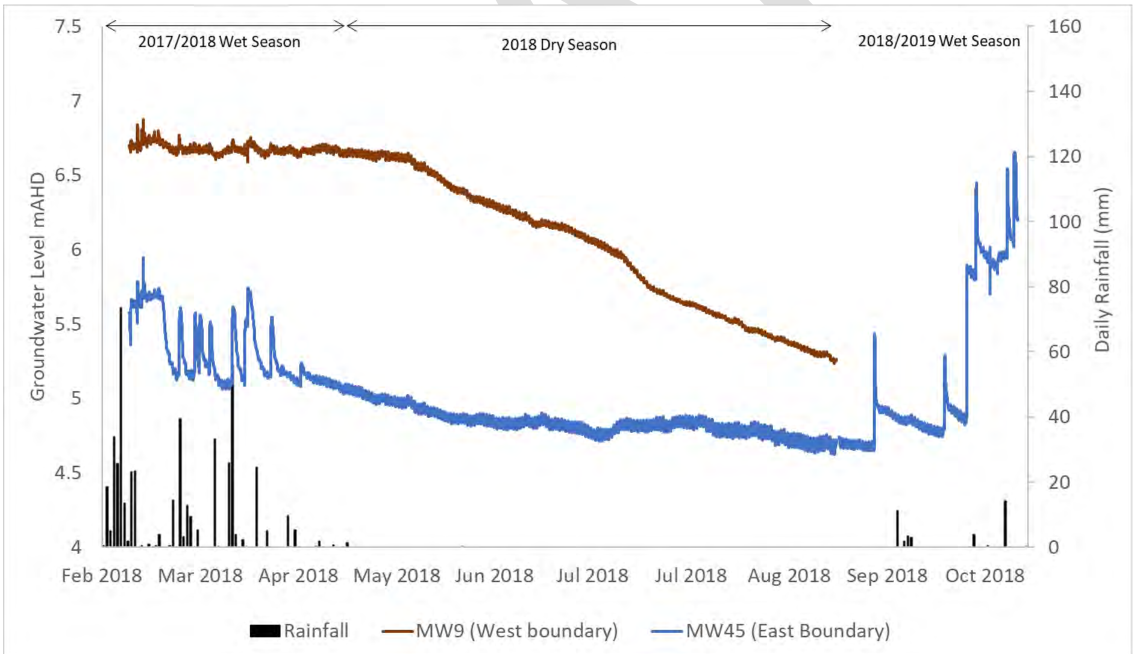



**Figure 4-3: Rainfall and post remediation groundwater levels in 2018 on the western and eastern boundaries.**

The sharp drop in level seen in MW9 at the onset of the 2015 dry season is attributed to excavation and dewatering of the site associated with soil remediation works between the start of June and end of October.

Surface water runoff from the Mobil site (relatively steep gradient across that site) may also affect groundwater levels on the Caltex site.

Long term logging data also revealed smaller scale (<0.1 m), highly regular, groundwater level fluctuations across the site. These fluctuations have been interpreted as tidal driven pressure fluctuations, based on the site's proximity to the coast, and the frequency of fluctuations compared to Darwin tidal data (www.bom.gov.au), Figure 4-4, albeit with a lag of ~2hrs. Tidal fluctuations are induced across the site as a whole, and therefore do not affect the overall groundwater flow direction or gradients at the site.

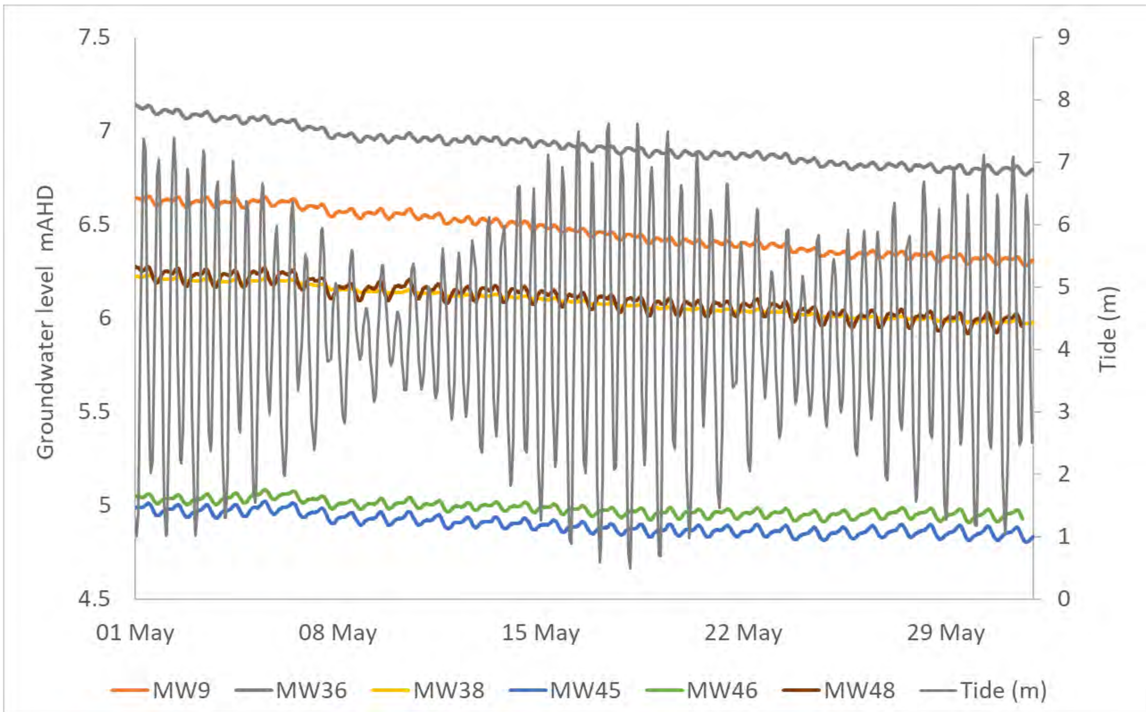



**Figure 4-4: Groundwater levels in May 2018 and Darwin tide levels (www.bom.gov.au).**

### 4.3.4. Groundwater Flow Direction

Groundwater level contours (pre- and post- remediation) show the inferred groundwater flow direction is to the northeast in the south of the site, and to the southeast in the north of the site, with a consistent low point on the central eastern boundary. The groundwater flow direction indicates that the Former Mobil Depot, is upgradient of the site along the entire western boundary. Flow direction appears to be generally toward the creek located to the east of the site (Figure 8a to 8g, Appendix A).

There is some groundwater mounding in the south-western part of the site (around MW36, MW37 and MW49), and a minor trough in the central east of the site (MW23, MW45, and MW46). The increased gradient in the south west of the site is attributed to recharge from higher creek levels at the south of the site during the wet season.

Remediation at the site does not appear to have significantly altered groundwater flow direction.

**Vertical Flow**

Comparisons of groundwater levels at the two nested well locations indicate groundwater levels are comparable in the deeper and shallower monitoring wells, indicating that there is no significant vertical flow occurring at the site, and groundwater within the remediated soil is in hydraulic connection with the underlying siltstone. This means there is no inferred hydraulic driver for the vertical migration of contamination at the site.

### 4.3.5. Groundwater Gradient

The groundwater gradient at the site ranges over an order of magnitude from 0.003 to 0.028, with the highest gradient occurring between the mounding in the south west of the site (MW36) and the central east of the site (MW46) in the wet season. Gradients below 0.01 were only observed for short periods, therefore the typical gradient range is considered to be from 0.01 to 0.028.

The gradient over time from the western boundary (MW9) to the eastern boundary (MW45) across the site appears to double in the wet season (Figure 4-5 below). Gradient trends for two additional transects across the site; MW2 to MW45 (centre to north) and MW36 to MW46 (south to centre of the site) show a similar increase in gradient during the wet season (refer to hydrographs provided in Appendix E).

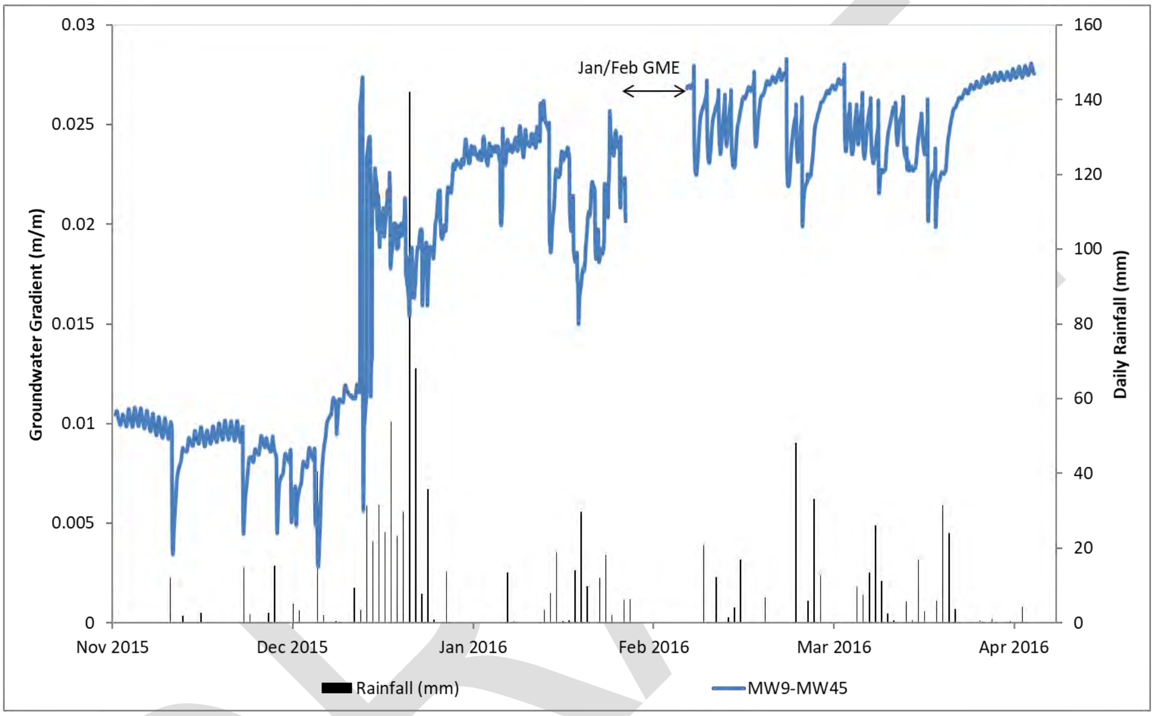



**Figure 4-5: Groundwater gradient, Wet season 2015/2016 (MW9 to MW45)**

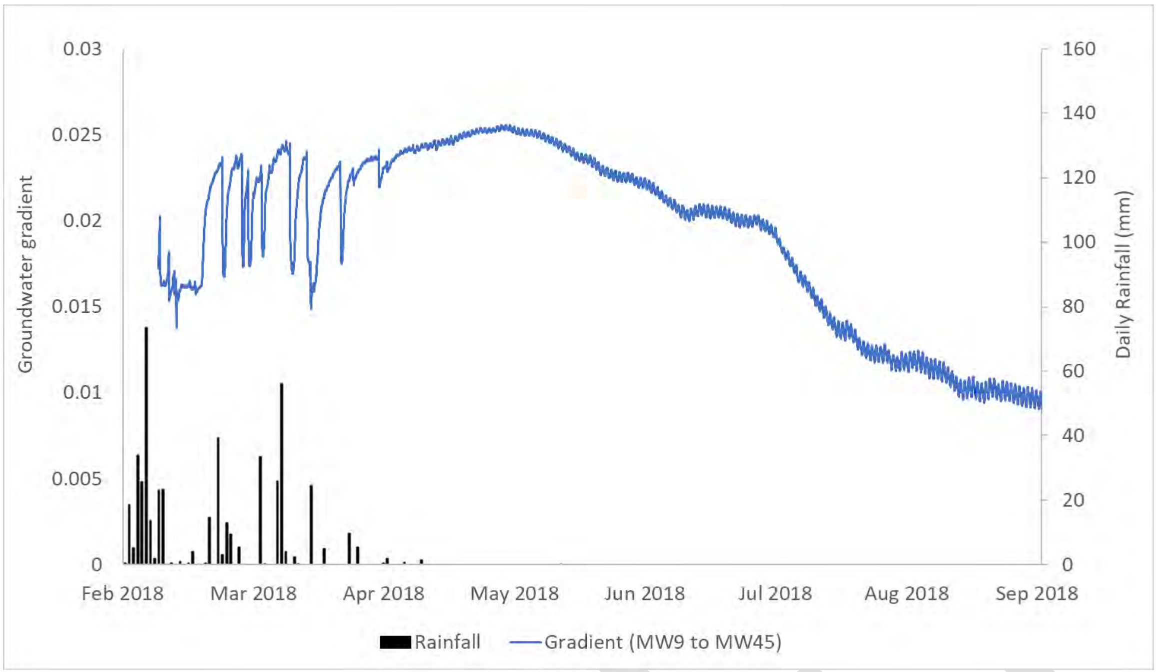



**Figure 4-6: Groundwater gradient, Wet and Dry seasons 2018 (MW9 to MW45).**

Gradients calculated using logger data from 2015 and 2018 indicates that during wet season gradients are more variable and typically twice the gradient at the end of the Dry season (Figures 4-5 and 4-6).

The gradients estimated based on logger data agree well with those calculated based on gauging data. In January 2018, the gradient between MW9 and MW45 was 0.017, approximately double the gradient of 0.009 reported in October 2018 at the end of the Dry.

The increase in gradient in the Wet is attributed to several factors; recharge upgradient, and the lower hydraulic conductivity values observed along the western boundary compared to along the eastern boundary closer to the creek (refer Section 4.3.6). The lower hydraulic conductivities observed in the west of the site appear to sustain steeper groundwater gradients for the first few months of the Dry. As groundwater levels rise, groundwater in the east of the site drains to the creek faster than it is recharged in the west, resulting in an increased gradient from west to east across the site.

However, during rain events groundwater gradients drop sharply (when compared to the seasonal variation). This effect is be attributed to higher infiltration in the east, where permeability is higher than in the west, resulting in rapid increases in groundwater levels (Figure 4-3), and a short-term reduction in groundwater gradient (period of several days).

The gradient data suggests that that during rainfall events (when elevated groundwater levels would otherwise suggest increased base flow to the Creek) groundwater discharge to the Creek may be minimal.

The small, highly regular fluctuations seen in groundwater levels are also reflected in the observed gradients and are attributed to the relationship between lag time of tidal influences and distance of monitoring well from the coast. The fluctuations are minor in comparison to the effects of rainfall, or seasonal effects, are not considered to affect contaminant migration or discharge volumes at the site.

### 4.3.6. Hydraulic Conductivity

To assess the hydraulic conductivity within the aquifer at the site, rising head tests were undertaken on nine monitoring wells as part of validation works in December 2014 and October 2015.

To supplement test data including the characterisation of post-remediation groundwater flow conditions, rising head tests were repeated on six monitoring wells as part of the January – February 2018 GME. Four additional monitoring wells (MW5, MW42, MW45 and MW49) were also tested.

Test data was analysed via a solution appropriate for unconfined aquifers; Bouwer and Rice (1976) using the software package AQTESOLV Pro ©. Analysis outputs are provided in Appendix E. Calculated hydraulic conductivities are summarised in Table 4-2 below.

**Table 4-2 – Summary of calculated hydraulic conductivities**

| Well ID | Screened Lithology | Screen Interval mBGS | Test Date | Hydraulic Conductivity (K) (m/day) |
|---|---|---|---|---|
| **Monitoring wells installed in undisturbed soils** | | | | |
| MW1 | Clayey SAND/Silty CLAY | 0.3 – 4.3 | 3 December 2014 | 0.44 |
| | | | 31 January 2018 | 2.5 |
| MW2 | Silty CLAY | 0.1* – 4.1 | 3 December 2014 | 0.18 |
| | | | 31 January 2018 | 4.0 |
| MW5 | Silty CLAY/SILTSTONE/SAND | 1.5 – 3.8 | 31 January 2018 | 0.17 |
| MW9 | FILL/Silty CLAY | 0.1* - 4.1 | 3 December 2014 | 1.8 |
| MW12 | CLAY/Silty CLAY/SILTSTONE | 0.5 – 5.0 | 3 December 2014 | 3.2 |
| **Monitoring wells installed in disturbed soils** | | | | |
| MW31 | disturbed soils/Silty CLAY/SILTSTONE | 1.0 – 4.0 | 26 October 2015 | 0.13 |
| | | | 2 February 2018 | 0.23 |
| MW32 | disturbed soils/ Silty CLAY/SILTSTONE | 1.0 – 4.0 | 26 October 2015 | 0.22 |
| MW35 | disturbed soils / Silty Sandy CLAY/ Silty CLAY | 1.0 – 4.0 | 27 October 2015 | 0.15 |
| | | | 31 January 2018 | 0.71 |
| MW38S | disturbed soils/ Silty CLAY | 1.0 - 4.0 | 27 October 2015 | 0.12 |
| | | | 31 January 2018 | 0.09 |
| MW42 | disturbed soils/ Silty CLAY | 1.0 – 4.0 | 2 February 2018 | 0.42 |
| MW45 | disturbed soils/ Silty CLAY | 1.0 – 4.0 | 2 February 2018 | 0.91 |
| MW46 | disturbed soils /Silty CLAY | 1.0 – 4.0 | 27 October 2015 | 1.3 |
| | | | 31 January 2018 | 2.2 |
| MW49 | disturbed soils /Gravelly Silty CLAY/Silty Sandy CLAY | 1.0 – 4.0 | 2 February 2018 | 3.5 |

**Screen interval unknown. Active screen length assumed to extend from gauged SWL to base of the* monitoring well *i.e. non-submerged screen.*
*"disturbed soils" refers to silty, sandy, gravelly CLAY soils remediated and backfilled/compacted across the site.*

Calculated hydraulic conductivity values ranged from 0.09 m/day (MW38S) to 4.0 m/day (MW2), with the average conductivity for disturbed soils (0.83 m/day) less than half the average K calculated in undisturbed soil (1.8). The average hydraulic conductivity in the two broad soil types considered is in the same order of magnitude, and so the differences are marginal. The slightly lower hydraulic conductivity in the reworked soils may be due to the following.

- The homogenisation of soils during the remediation process eliminating preferential flow pathways, such as lenses of higher K materials (sands).
- Reduced K due to compaction of disturbed soils as part of the backfilling operations (further discussed in Section 7.3).

The variation in hydraulic conductivity suggests that groundwater flow within remediated soils may be slightly reduced compared to in undisturbed areas.

Where the hydraulic conductivity was tested in undisturbed soils in both 2014/2015 and 2018, a much higher value was reported in 2018. A review of groundwater levels, and the lithology in the screened area tested, identified that when the testing was undertaken in 2018 groundwater levels were 0.8 m higher than in 2014, and the upper lithology now included in the test was sandier with some gravels/cobbles present (refer borelogs for MW1 and MW2). The testing indicates that prior to remediation the seepage velocity of groundwater during the wet season was potentially an order of magnitude higher than in the dry season due to flow through more permeable shallow layers of soil.

In disturbed soils, the differences in calculated hydraulic conductivities between tests undertaken in 2014/15 and 2018 were less marked, which is attributed to the homogenisation and compaction of soil layers through the backfilling processes.

The estimated hydraulic conductivities fall within the published range of values for sandy clay and clayey sand (Freeze & Cherry, 1979). The range in hydraulic conductivities was considered reasonable based on lithology, and the variation in values is consistent with the variable amounts of sand and clay noted in the borelogs.

### 4.3.7. Groundwater Velocity

Flow velocities have been estimated based on calculated gradients, the average hydraulic conductivity for disturbed and non-disturbed soil (depending on the transect of interest), and effective porosity values estimated based on literature values. While a total porosity of 0.3 to 0.6 (30% to 60%) is listed by Domenico and Schwartz (1997) for clay, the effective porosityis typically much lowerin poorly sorted materials, as is found on-site where the aquifer is a mixture of grain sizes (such as clay with sand and silt). Based on conditions observed at the site a realistic range of effective porosity is considered to be 0.1 (10%) to 0.15 (15%).

Estimated groundwater velocities for the site would reasonably be expected to vary by up to an order of magnitude, depending on location, and time of year (associated with fluctuating groundwater levels and gradients).

Based on a hydraulic conductivity range of 0.09 m/day to 4 m/day, gradients from 0.01 to 0.028, and an effective porosity of 10% to 15%, seepage velocities are estimated to range from low to high values as follows.

- Low range seepage velocity: 0.009 m/day (3.3 m/year) between MW9 to MW45 (in the centre of the site) during the dry season, when gradients typically around 0.01.
- High range seepage velocity: 0.75 m/day (272 m/year) between MW36 to MW46 (in the south of the site) during the wet season, when gradients are highest, and flow is within the sandier (with some gravels) upper layer.

The estimates suggest that groundwater velocity, and therefore the potential for contaminant migration, is much higher when potential groundwater receptors (Creek and dam) are also subject to significant surface water runoff collected from the surrounding area, which will dilute any impact contributed by groundwater. The discharge of groundwater to the surface water bodies is however complex, as levels in the creek and dam are also higher in the wet, which may transiently reduce the discharge rate of groundwater. Groundwater and surface water interaction are discussed in detail below in Section 4.4.

## 4.4. Groundwater-Surface Water Interaction

Conceptual hydrogeological cross sections of the site have been developed based on all available information, to visualise the interaction between groundwater and surface water (Figure 6a and 6b, Appendix A)

The interaction between groundwater and surface water at the site, and how it changes over time, can affect the risk to potential receptors.

The groundwater level data provided in Section 4.3.3, combined with surveyed levels of the Creek bed and bank, and the bank of One Mile Dam (see Figure 4-7), indicate the following.

- Creek is a 'losing stream' during the dry season.
- The relative groundwater levels along the eastern boundary of the site during the wet season, and the Creek bed east of the site, suggest that the Creek could theoretically receive base flow from groundwater during the wet season.
- Groundwater levels indicate that One Mile Dam may receive a contribution from groundwater year round. However, Dam invert or water surface level survey data was not able to be obtained as the Dam was inaccessible by Surveyors. Anecdotal information received from residents of the (One Mile Dam) property indicated that the Dam had 'silted up' over time, and was approximately only 0.5 m deep, and therefore unlikely to receive groundwater. Given the uncertainty surrounding the depth of the dam, for the purpose of this assessment it has conservatively been assumed that the dam may receive some groundwater.

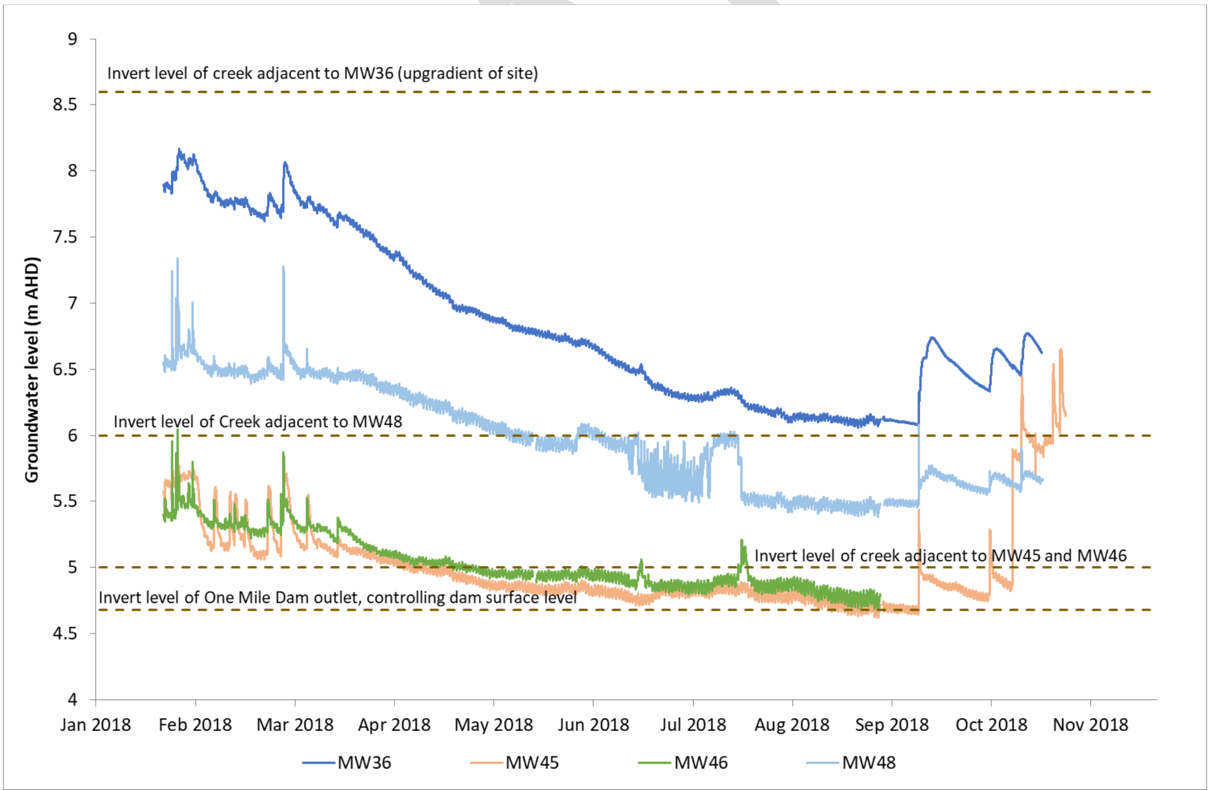



**Figure 4-7: Groundwater levels on the site boundary, and relative to creek and One Mile Dam invert levels in 2018.**
**Note - Dam invert level conservatively estimated based on bank level and verbal approximate depth information.**

In the dry season, water is often still seen in the creek, which appears contrary to groundwater and creek invert level data indicating that the creek was not in connection with groundwater at this time. An inspection was undertaken of the extent of the creek along the site boundary to identify other possible water input sources. Water was found to be flowing into the creek from a drain beneath a concrete car park to the south of the site (near MW49), Figure 4-8.

**Figure 4-8: Discharge from stormwater pipe to creek from car park to south of site.**

## 4.5. Conceptual Hydrogeological Model

Based on the available data the principal features of the hydrogeological conceptual model are:

- Groundwater levels are generally shallow (<2.5 mBGS), with the potentiometric surface equal to and higher than the ground surface in many locations across the site during the wet season (resulting in groundwater seeps in some locations on-site).
- Groundwater quality is fresh, with a general increase in TDS from west to east, and fresh water around the groundwater high at the southern end of the site. Groundwater downgradient between the site and One Mile Dam is significantly more saline.
- Groundwater level fluctuations are dominated by seasonal rainfall in the long term, and individual rainfall events in the short term. Small tidal influences are also evident in the absence of rainfall events, although they do not have a significant effect on the interpretation of groundwater movement and interaction at the site.
- The groundwater flow direction at the site is predominantly to the east, and appears to be controlled by surface topography, geology, and preferential recharge and discharge zones.
- Groundwater hydraulic gradients are variable throughout the year. They increase during the wet season as groundwater levels rise and decrease during the dry season as the lack of rainfall leads to relatively flat groundwater levels across the site.
- Flow velocities fluctuate both temporally, controlled by relative changes in groundwater levels across the site during the year, as well as spatially (dependent on hydraulic conductivity).

Calculated groundwater velocities at the site range from 3.3 m/year during dry season, to 272 m/year during wet season.

- The Creek, east of the site, is a ‘losing’ stream during the dry season, with flow being due to off-site surface water inputs. And, although there is potential for the creek to receive limited base flow during the wet season, it is unlikely that groundwater forms a significant contribution to the overall flow within the Creek.
- It is unclear whether or not groundwater contributes to some base flow within One Mile Dam throughout the year, as the invert level of the dam is unknown. For the purpose of this assessment it has been conservatively assumed that the dam is the closest downgradient surface water receptor to the site.

# 5. Regulatory Framework

The NT EPA requires contaminated sites that pose or threaten to pose serious or material environmental harm as defined in the Waste *Management and Pollution Control Act 1998* to be assessed in accordance with the requirements for environmental audits in the Act (Part 6 s47).

Site contamination assessment is to be conducted in accordance with the *National Environment Protection (Assessment of Site Contamination) Measure 1999* ("the NEPM"), and in the current absence of Environmental Protection Objectives (under development) in the NT, that Auditors refer to the relevant environmental protection policy in their State of accreditation. In this case, the Victoria Land and Groundwater State Environment Protection Policies (SEPP).

## 5.1. Soil

The Victorian Land SEPP (Prevention and Management of Contamination of Land) establishes general uses of land in Victoria and provides a mechanism for determining whether these uses are being protected, such as indicators and objectives of use in assessing impacts.

Based on the Land SEPP, the beneficial uses of land requiring protection for the proposed residential land use are displayed in Table 5-1.

**Table 5-1 - Protected Beneficial Uses of Land**

| Beneficial Uses | Land Use | | | | | | |
|---|---|---|---|---|---|---|---|
| | Parks & Reserves | Agricultural | Sensitive Use | | Recreational/ Open Space | Commercial | Industrial |
| | | | High Density | Other | | | |
| Maintenance of Ecosystems | | | | | | | |
| Natural Ecosystems | ✓ | | | | | | |
| Modified Ecosystems | ✓ | ✓ | | ✓ | ✓ | | |
| Highly Modified Ecosystems | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Human | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Buildings & Structures | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Aesthetics | ✓ | | ✓ | ✓ | ✓ | ✓ | |
| Production of Food, Flora & | ✓ | ✓ | | ✓ | | | |

Note: The above table is a reproduction of Table 1 from the State Environment Protection Policy Prevention and Management of Contamination of Land (June 2002).

### 5.1.1. Human Health Criteria

As part of remediation works undertaken to render the site suitable for future residential use, screening and investigation levels from the NEPM (NEPC 2013) have been considered in this investigation and include:

a) Health Investigation Level (HIL) A/B – Low - high density residential. HIL A has been included to assess the most sensitive plausible use of low density residential use and support assessment of all beneficial uses by the Environmental Site Auditor. HIL B has also been adopted as a screening tool to support the likely potential development for medium/high density residential use.
b) Health Screen Level (HSL) 'A/B' – Low - high density residential land use criteria protective of vapour intrusion with silt profile. Consistent with reuse guidance developed, the sub setting for Silt was adopted as a conservative (i.e. more conservative than Clay) approach to screening, whilst still remaining consistent with the observed soil profile at the site.
c) CRC CARE 2011 HSL for Vapour Intrusion, intrusive maintenance workers, Silt
d) CRC CARE 2011 HSL for Maintenance Workers - Direct Contact with Soil
e) CRC CARE 2011 HSL-A Residential (Low Density) Direct Contact
f) CRC CARE 2011 HSL-D Commercial / Industrial Direct Contact

In the absence of any Australian screening values for analytes exceeding detection limits, Regional Screening Levels (RSLs) derived by the US EPA for residential use have been adopted. The NEPM Screening levels have been derived to incorporate a range of petroleum hydrocarbon compounds including MAHs, and as such this takes precedence over international sourced triggers.

In earlier investigations, (pre-NEPC 2013) where HILs had not been defined in the NEPM (1999) for organics such as TPH and BTEX, the NSW EPA (1994) Guidelines for Assessing Service Stations Sites criteria were adopted. Previously applied screening criteria have not been documented in this report, apart from the summary of previous investigation findings in Section 2.6.1.

For analytes without published criteria, the laboratory limit of reporting (LOR) was used as a screening value.

### 5.1.2. Ecological Screening Criteria

The NEPM 2013 outlines screening and investigation levels for ecological receptors. The screening criteria adopted for this investigation include:

a) Ecological Investigation Levels (EILs), Urban residential and public open space,
b) Ecological Screening Levels (ESLs), Urban residential and public open space, Fine Soil

Urban residential and public open space has been adopted as the most sensitive scenario for ecological exposure relevant to this site, which is surrounded by sites in urban use.

Tier 1 screening for ecological risks has been conducted in accordance with NEPM 2013. The ESLs/EILs have only been applied to the top 2 m of soil as this is the portion of the soil profile that relates to the root zone of plants and habitation zone from most soil organisms. Soil below 2 m at the site is saturated by groundwater throughout the year. The ESLs/EILs have been used to assess the beneficial use of 'Maintenance of Ecosystems' and 'Production of Food, Flora, and Fibre'.

As with the selected soil HSLs, ESLs have been assessed consistent with site soil conditions, when selecting the soil type (fine). Conservative estimates of EILs have been adopted by assuming an Ambient Background Concentration (ABC) of zero, and the lowest Added Contaminant Level (ACL), which is based on a soil pH of 4.5 (or 5) and cation exchange capacity (CEC) of 5 cmol/kg.

Based on limited soil pH testing, which indicated typical pH of 5.5 – 7.5, and the observed presence of some clay in soils, the estimate of EIL is conservative.

### 5.1.3. Buildings and Structures

The Victorian Land SEPP states that "contamination must not cause the land to be corrosive to or adversely affect the integrity of structures or building materials".

Soil and groundwater laboratory data for sulfate, pH and chloride will be compared to exposure classifications for concrete pile in soil set out in AS2159-2009 *Australian Standard, Piling – Design and Installation*.

Concentrations of petroleum hydrocarbons will be compared to the Management Limits for Petroleum Hydrocarbons provided in the NEPM, specifically where they relate to effects on buried infrastructure.

### 5.1.4. Aesthetics

The Victorian Land SEPP states that "contamination must not cause the land to be offensive to the senses of human beings". Currently, there are no concentration-based aesthetic criteria for soil. While aesthetic observations are subjective, it is considered that if there is discolouration, noticeable odour from the soil on the site or if there are obvious components of waste, such as rubble, slag, bagged waste or similar, then there is a potential aesthetic concern. Aesthetic observations made in the field are detailed on the bore logs and are considered in our discussion.

### 5.1.5. Soil Classification for Reuse and/or Disposal

The classification of stockpiled soils both for reuse on-site and off-site disposal was undertaken as per Vic EPA industrial waste resource guidelines outlined in EPA documents IWRG621, IWRG701, and IWRG702. These documents outline the methodology for sample collection, handling, analysis (including the need for leachate analysis), frequency (per volume of soil), and application of statistical approaches for assessment (specifically the application of 95% UCLs).

Stockpiles were classified as per the above guidelines, and screened against the site-specific reuse criteria developed for the site (Appendix I).

Stockpiled soil unable to be reused on-site were classified as per IWRG621. This was as agreed with City of Darwin's Team Leader Waste and Recycling, with consideration given as to how the Victorian Guidance related to NSW DECC guidance for waste classification. Soils taken off site were disposed of to an appropriate landfill.

## 5.2. Groundwater

In Victorian legislation, the quality of groundwater is protected under the State Environment Protection Policy (Waters), (October 2018) issued under the *Environment Protection Act 1970*. The stated goal of this policy is to "maintain and where necessary improve groundwater quality sufficient to protect existing and potential beneficial uses of groundwater throughout Victoria".

The significance of contaminant impact upon groundwater is assessed in conjunction with the applicable beneficial use. EPA Victoria provides guidance for the assessment and management of impacted groundwater under *clause 54, SEPP (Waters)*,and EPA Victoria Publication 840.2 – *The Clean-up and Management of Polluted Groundwater (April 2016)*.

The SEPP (Waters) defines a range of protected beneficial uses for specific segments of the groundwater environment, which are based on groundwater salinity.

EPA Victoria considers that groundwater is polluted where current and/or future protected beneficial uses for the relevant segment are precluded.

Beneficial uses of groundwater are considered to be precluded when relevant groundwater quality objectives for those beneficial uses have been exceeded, or where non-aqueous phase liquid is present on or within the groundwater aquifer.

Where groundwater has been polluted, groundwater must be cleaned up so that the protection of any beneficial use is restored or restored to the extent practicable. Note that in Victoria, only the EPA can determine whether or not clean-up to the extent practicable (CUTEP) has been achieved where site-sourced pollution has been reported to extend beyond the site boundary, or for instance where LNAPL is present. Where site-sourced pollution is confined to the site, CUTEP can be determined by the Auditor in particular circumstances (refer to EPA Publication 840.2). However, in the NT, it is likely that the EPA will be more reliant on recommendations provided by the Auditor.

## 5.2.1. Relevant Segment and Potential Beneficial Uses

The SEPP (Waters) defines a range of beneficial uses on the basis of groundwater salinity (i.e. the lower the salinity, the greater the range of potential beneficial uses).

During pre-remediation groundwater sampling events undertaken at the site, laboratory dissolved solids (TDS) in groundwater beneath the site ranged from 60 mg/L to 1,200 mg/L, with an average value of 384 mg/L. TDS values were compared to the SEPP (Waters) segments, which indicated groundwater beneath the site falls into Segment A1 to B. Segment A1 was adopted for assessment based on the TDS measured in most locations, and the average TDS.

Table 5-2 reproduces the relevant beneficial uses table from the SEPP (Waters) and highlights the uses that must be protected for Segment A1 classified groundwater.

**Table 5-2 - Aquifer Classification Based on Site TDS Concentrations**

| Beneficial Use | Segment (TDS mg/L) | | | | | | |
|---|---|---|---|---|---|---|---|
| | A1 (0-600) (0-600) | A2 (601-1,200) (601-1,200) | B (1,201-3,100) (1,201-3,100) | C ((3,101-5,400) (3,101-5,400) | D (5,401-7,100) (5,401-7,100) | E (7,101-10,000) (7,101-10,000) | F (>10,000) (>10,001) |
| Water dependant ecosystems and species | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Potable water supply (desirable) | ✓ | | | | | | |
| Potable water supply (acceptable) | | ✓ | | | | | |
| Potable mineral water supply | ✓ | ✓ | ✓ | ✓ | | | |
| Agriculture and irrigation (irrigation) | ✓ | ✓ | ✓ | | | | |
| Agriculture and | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |

| Beneficial Use | Segment (TDS mg/L) | | | | | | |
|---|---|---|---|---|---|---|---|
| | A1 (0-600) (0-600) | A2 (601-1,200) (601-1,200) | B (1,201-3,100) (1,201-3,100) | C ((3,101-5,400) (3,101-5,400) | D (5,401-7,100) (5,401-7,100) | E (7,101-10,000) (7,101-10,000) | F (>10,000) (>10,001) |
| irrigation (stock watering) | | | | | | | |
| Industrial and commercial | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| Water-based recreation (primary contact recreation) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Tradition Owner cultural values | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Cultural and spiritual values | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Buildings and structures | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Geothermal properties | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

*Note: Shading denotes beneficial uses to be protected for the site.*
*^ The above table is a reproduction of Table 2 - Beneficial Uses for Groundwater from SEPP (Waters), October 2018.*



### 5.2.2. Groundwater Quality Objectives

In accordance with the SEPP (Waters), groundwater quality objectives for the protected beneficial uses considered as part of this investigation were primarily sourced from *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ, 2000).

Groundwater criteria was adopted from the guidelines, listed below (a to g), to assess if the site sourced contamination precludes protected beneficial uses.

A summary table containing analytical results compared to the adopted criteria values has been provided in Table 10 and Table 11, Appendix B.

**a) Water Dependant Ecosystems and Species**

ANZECC/ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* for Fresh Aquatic Ecosystems for 95% protection have been adopted. In the absence of screening levels for certain organic compounds in Table 3.4.1 of ANZECC 2000, the 'low reliability' trigger levels specified in Volume 2 (Section 8.3) of ANZECC/ARMCANZ 2000 have been used subject to applicability considerations.

Australian & New Zealand Guidelines for Fresh & Marine Water Quality (ANZG) guidelines have been referred to as part of this assessment and were found to be consistent with ANZECC 2000 for all toxicants assessed.

Where applicable ANZECC/ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* for Fresh Aquatic Ecosystems for 95% protection values have been adjusted for total hardness, the value for ammonia adjusted for pH, and the value for nitrate updated in line with Hickey (2013).

Dutch 2009 Intervention Values have been adopted where Australian guidelines do not exist.

PFAS National Environmental Management Plan (NEMP) 99% species protection values for freshwater ecosystems have been used for the screening of PFAS chemicals.

**b) Potable Water Supply (desirable)**

NHMRC (2011, version 3.5 August 2018) *Australian Drinking Water Guidelines (ADWG) 6, Physical and Chemical Characteristics,* has been adopted.

In the absence of guideline values for certain compounds in ADWG 2011, values specified in WHO (2017) *Guidelines for Drinking Water Quality*: *fourth edition* incorporating *the first addendum* have been used, while *US EPA Regional Screening Level – Tap water (USEPA RSL)* values have also been adopted for some metals and PAHs. When USEPA RSLs have been used and the value was derived based on carcinogenic endpoints, the criteria have been modified to adjust the target risk from $10^{-6}$ used in the RSL derivation to $10^{-5}$ consistent with Australian guidance.

- To assess groundwater conditions in the context of protecting the beneficial use of Potable Water Supply with respect to petroleum products, guidance values presented in WHO, *Petroleum Products in Drinking-Water* (2008) have been considered. Application of WHO (2008) values has been based on conservative comparison against relevant carbon length fractions, or results of analysis of samples for TPHCWG fractions (including aromatic/aliphatic fractions). Guideline values for aromatic TPH fraction C5-C6Arom and C6-C8Arom have not be assessed as guidelines already exist for benzene and toluene, the main constituents of this fraction.
- In the absence of a recommended guideline value for aliphatic TPH fractions C16-C21Aliph and C21-C36Aliph a conservative value of 0.3 mg/l (based on the aliphatic fraction for C12-C16Aliph) has been adopted for both.
- It is noted that the limit of reporting (LOR) for aromatic TPH fractions C12-C16Arom, C16-C21Arom and C21-C36Arom (0.1 mg/L) is marginally above the WHO Petroleum Products in Drinking-Water guideline value of 0.09 mg/L. In light of the limited residual hydrocarbon impacts on site and to aid in application of historical data from the site, the assessment criteria has been to raised to 0.1 mg/L. This increase is considered acceptable based on WHO, Petroleum Products in Drinking-Water (2008) stating that a greater allocation of the daily RfD (conservatively set at 10%) could be applied to drinking water if required. Raising the assessment criterion from 0.09 mg/L to 0.1 mg/L equates to raising the percentage application of the RfD from drinking water from 10% to 11%. Given the site is located within the Darwin city area (which has reticulated potable water) and acknowledging the limited extractive capacity of the surface aquifer at the site (sandy clay), it is considered highly unlikely that groundwater at the site would ever be realised as the as a person's sole drinking water source. Therefore raising the percentage allocation of the RfD from drinking water 10 to 11% (i.e. assuming that groundwater at the site would not constitute >90% of a person's daily drinking water intake) to accommodate the LOR is considered acceptably conservative for the purpose of the site assessment.

Department of Health (DoH) *Final health based guidance values (drinking water) for PFAS site investigations in Australia* (April 2017) values have been used for the screening of PFAS chemicals.

#### c) Potable mineral water supply

At the time of assessment, EPA Victoria advice was that potable mineral water supply can be discounted away from mineral spring districts. Consequently, the use of groundwater for potable mineral water supply was not considered relevant given that the site was not located in a mineral spring district.

The same would apply for the beneficial use of geothermal properties in that the site was not located within an area of known potential for geothermal energy resources.

#### d) Agricultural and Irrigation (Irrigation)

ANZECC/ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* Water Quality Guidelines for Agricultural Water Use (short-term Irrigation). Short term values are considered appropriate as the area is urban and is not compatible with long-term agriculture.

Where specific irrigation values did not exist, screening values to reflect protection of human health during contact with water in irrigation have been applied as described for “Water Based Recreation” below.

#### e) Agricultural and Irrigation (Stock Watering)

ANZECC/ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* Water Quality Guidelines for Agricultural Water Use (Livestock) have been adopted.

Where specific stock watering values did not exist, conservative screening values have been adopted based on “Potable Water Supply” values above, to protect health of stock.

#### f) Industrial and Commercial

As the applicable criteria for *Industrial Water Use* are highly specific to the type of process, criteria for industrial water use have not been included in this assessment.

#### g) Water Based Recreation (Primary Contact Recreation)

The principle described in NHMRC (2008) Guidelines *for Managing Risks in Recreational Water* (GMRRW) for screening of non-volatile toxicants has been adopted for primary contact and recreation.

- *NHMRC ADWG 2011 Health* values have been conservatively adjusted for non-volatiles by a factor of ten (*average consumption during primary contact and recreation estimated at 200ml, instead of the 2 litres assumed for potable water*).
- Un-adjusted *NHMRC ADWG 2011 Health* values have been adopted for assessment of volatile chemicals as ingestion may not be the dominant exposure pathway
- Department of Health (DoH) *Final health based guidance values (recreation) for PFAS site investigations in Australia* (April 2017) values have been adopted for the screening of PFAS chemicals.
- Where Australian guidance for drinking water values was not available, WHO (2017 and 2008) and USEPA RSLs for tap water have been adopted and modified as above.

#### h) Traditional Owner cultural values

No specific environmental quality indicators or objectives are provided in the SEPP Waters for the two beneficial uses of Traditional Owner cultural values; and Cultural and spiritual values. It is recognised that the environmental quality objectives for other beneficial uses such as recreation, water dependent ecosystems and their species go some way to protecting the cultural and spiritual values, including spiritual relationships, sacred sites and customary use.

#### i) Cultural and spiritual values

No specific environmental quality indicators or objectives are provided in the SEPP Waters for the two beneficial uses of Traditional Owner cultural values; and Cultural and spiritual values. It is recognised that the environmental quality objectives for other beneficial uses such as recreational use, water dependent ecosystems and their species go some way to protecting the cultural and spiritual values, including spiritual relationships, sacred sites and customary use.

#### j) Buildings and Structures

The SEPP (Waters) states that "*introduced contaminants shall not cause groundwater to become corrosive to structures or building materials*". Consideration will be given to analytical results( i.e. pH, chloride and sulfate) as well as redox water quality readings.

NHMRC (2008) states that ammonia concentrations above 0.5 mg/L may attack copper fittings or result in nuisance growth of microorganisms. Nuisance growth of microorganisms and the potential attack of copper fittings were also considered when assessing potential impact to Buildings and Structures and aesthetic concerns.

#### k) Geothermal properties

See c) above.

#### l) Vapour Intrusion

CRC Care (2011) *CRC for Contamination Assessment and Remediation of the Environment. Health Screening Levels for Petroleum hydrocarbons in soil and groundwater* notes that the HSLs for groundwater vapour intrusion are only relevant where the shallowest depth to groundwater is 2 m. As groundwater is seasonally shallower than 2 m at the site, HSLs are not considered to be directly relevant. Therefore, the potential risk from residual concentrations of petroleum hydrocarbons, including BTEX, has been addressed in the HRA (Appendix R).

## 5.3. Surface water

In accordance with the SEPP (Waters), groundwater quality objectives for the protected beneficial uses considered as part of this investigation will be primarily sourced from Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ, 2000).

The surface water discharge point for groundwater leaving the site is the adjacent creek along the eastern boundary of the site. This is classified as being in the *Urban* segment. Based on this classification, the protected beneficial uses as set out in *SEPP (Waters)* (GoV, 2018) are summarised in **Table 5-3**.

**Table 5-3 - Beneficial uses for surface waters**

| Beneficial uses | Water | Aquatic Reserves | Rivers and Streams | | | | | | Wetlands |
|---|---|---|---|---|---|---|---|---|---|
| | Segment | Aquatic Reserves | Highlands | Uplands A | Uplands B | Central Foothills and Coastal Plains | Urban | Murray and Western Plains | Lakes and Swamps |
| Water dependent ecosystems and species that are: | Largely unmodified | ✓ | ✓ | ✓ | ✓ | | | | |
| | Slightly or moderately modified | | | | | ✓ | | ✓ | ✓ |
| | Highly modified | | | | | | ✓ | | |
| Human consumption after appropriate treatment | | ✓° where water is sourced for supply in accordance with the special water supply catchments area set out in Schedule 5 of the **Catchment and Land Protection Act 1994** or the **Safe Drinking Water Act 2003**. | | | | | | | |
| Agriculture and Irrigation | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Human consumption of aquatic foods | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Aquaculture | | ✓°where the environmental quality is suitable and an aquaculture licence has been approved in accordance with the **Fisheries Act 1995** | | | | | | | |
| Industrial and commercial | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Water-based recreation (primary contact) | | ✓* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Water-based recreation (secondary contact) | | ✓* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Water-based recreation (aesthetic enjoyment) | | ✓* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Tradition Owner cultural values | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Cultural and spiritual values | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Navigation and Shipping | | | | | | | | | |

***Note**: If a segment is marked with a tick that is asterisked there is an exclusion identified in Table 5 (see clause 1(4) of Schedule 2 of SEPP Waters).*

The adopted assessment criteria for groundwater in Section 5.2.2 are considered appropriate to also protect many of the beneficial uses of surface water. Surface water criteria will be adopted from the guidelines, listed in Section 5.2.2 and below to assess if the site sourced contamination precludes any of the protected beneficial uses.

**a) Human consumption of aquatic food**

ANZECC/ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* Water Quality Guidelines for chemical compounds in water found to cause tainting of fish flesh and other aquatic organisms.

Where ANZECC 2000 tainting guidelines do not exist for a compound, the criterion for water dependent ecosystems has been adopted.

The surface water in the adjacent creek drains downgradient in north east towards Frances Bay and Darwin Harbour, therefore surface water quality objectives for protected beneficial use (i.e. aquatic ecosystem protection) have also been sourced from the Water Quality Objectives for the Darwin Harbour Region (WQODHR). The WQODHR have been declared under the Northern Territory Water Act for the Darwin Harbour Region (including the site) and act as benchmarks to help guide water quality planning and management.

The beneficial uses listed in the WQODHR are:

- Agriculture
- Aquaculture
- Public water supply
- Environment
- Cultural and recreation
- Industry
- Rural stock and domestic

In addition to the criteria adopted in Section 5.2.2 and above, Water Quality Objectives for physico-chemical indicators for ecosystem protection have been adopted from the WQODHR, where applicable.

# 6. Site Conditions Prior to Remediation Works

Numerous phases of assessment were completed to characterise the contamination status of the site, prior to remedial works commencing in 2014 (as detailed in Section 2.6.1). This section summarises the data from these investigations and provides an overview of the contamination status of the site prior to remediation works started in 2014.

## 6.1. Soil

Historical soil investigation results are provided in Table 1a to Table 1e (Appendix B), with historic soil sampling locations shown on Figure 9 (Appendix A).

Characterisation of site soil conditions prior to remediation was used to understand the type, concentration and distribution of soil contamination at the site; as well as the mechanisms responsible for the release and distribution of those contaminants. This information was then used to develop a site remediation action plan (RAP) and to guide remediation works.

Characterisation of soil impacts at the site and the development of a soil RAP followed the guidance of AS 4482.1 and Coffey experience, and relied on:

- Historical reports and soil investigations
- Identification of COPCs
- Detailed delineation of COPCs, and
- Identification of the mechanisms likely responsible for COPCs' release and distribution.

### 6.1.1. Historical Soil Investigations

Several phases of soil assessment work were carried out by Coffey at the site between 2007 and 2013, these assessments are summarized in **Table 6-1Error! Reference source not found.** below and shown on Figure 9a (Appendix A). These assessments represent the pre-remediation site condition. Subsequent soil investigations and validation works conducted in 2014 and 2015 have been presented in Section 7.

**Table 6-1 - Summary of Historical Coffey Soil Assessments**

| Timeline | Site Works | Assessment Purpose |
|---|---|---|
| 17 – 26 January 2007 | Drilling and soil sampling of bore holes associated with installing the groundwater monitoring network. | Soil sampling and screening for COPC |
| 29 June – 24 July 2007 | Drilling and sampling of grid based and targeted soil bores. And further soil sampling of bore holes associated with installing the groundwater monitoring network. | Site soil assessment; identification (characterisation and delineation) of on-site soil contamination based on targeted and grid based sampling, as per *AS 4482.1* |
| | Excavation of four test-pits to visually assess the smear zone caused by seasonal groundwater level fluctuations.<br>Excavation and test pits to investigate the presence of former USTs in the tank pit in the north western corner of the site. | Additional assessment (characterisation and delineation) of identified on-site soil contamination. |
| | Exploratory excavation works to identify former interception traps. | Additional assessment (characterisation and delineation) of identified on-site soil contamination. |
| 2008 | Excavation and sampling of former UST pit in north-western corner of site.<br>Excavation works to assess the vertical and lateral extent of the former localised dumping area.<br>Off-site test pitting | Additional assessment (characterisation and delineation) of identified on-site soil contamination.<br>Limited off-site soil investigations to characterise potential impacts and risk. |
| 2010 | Drilling and soil sampling of bore holes associated with installing the groundwater monitoring network. | Soil sampling as part of the 2010 off-site risk assessment. |
| 2013-2014 | Tests pitting around the identified buried waste in the central east of the site | Additional assessment (characterisation and delineation) of identified on-site soil contamination. |

### 6.1.2. Soil COPCs

Contaminants of potential concern at the site where identified based on historical site use, and intrusive soil assessments undertaken at the site. Historical assessments included analysis of a broad range of contaminants potentially associated with historical site use, which included;

- Polycyclic aromatic hydrocarbons (PAHs)
- Phenols
- Metals
- Total petroleum hydrocarbons (TPH)
- Polychlorinated biphenyls (PCBs)
- Organochlorine pesticides (OCPs)
- Organophosphate pesticides (OPPs)
- Volatile halogenated compounds (VHCs)

- Monocyclic aromatic hydrocarbons (MAHs)
- Asbestos

Whilst a broad range of potential contaminants were historically assessed for, historical assessments demonstrated that the contaminants occurring on-site were limited. Refer to Section 2.6.1 which provides a summary of contaminants that were found to occur on the site, based on historical assessments. Whereas Section 6.1.3 summarises the distribution of contaminants reported.

### 6.1.3. Distribution of Soil Contaminants

Based on the historical assessments, petroleum hydrocarbons and metals were identified as key COPCs at the site pre-remediation. Observed exceedances of current criteria are summarised in Table 6-2.

**Table 6-2 - Pre-Remediation Soil COPC Summary**

| Beneficial Use | Guideline Exceeded (criteria value) | Level of Protection Exceeded | General Location | Number of Samples Exceeding Guideline Value | Depth (mBGS) | Concentration Range |
|---|---|---|---|---|---|---|
| Maintenance of Ecosystems | Zinc (180 mg/kg) | ACL - Urban residential and public open space (pH 4, CEC 5) | Grid and targeted soil locations across the site | 2 | 0.2 - 1 m | <5 – 460 mg/kg |
| | TPH $C_6$-$C_{10}$ (less BTEX) (180 mg/kg) (also includes TPH $C_6$-$C_9$ data) | ESL - Urban Residential and public open space (fine soil) | Grid and targeted soil locations across the site | 12 | 0.5 – 2 m | <20 – 900 mg/kg |
| | TPH $C_{10}$-$C_{16}$ (120 mg/kg) (also includes TPH $C_{10}$-$C_{14}$ data) | ESL - Urban Residential and public open space (fine/course soil) | Grid and targeted soil locations across the site | 43 | 0.5 – 2 m | <50 – 2200 mg/kg |
| | TPH $C_{16}$-$C_{34}$ (1300 mg/kg) (also includes TPH $C_{15}$-$C_{28}$ data) | ESL - Urban Residential and public open space (fine soil) | Grid and targeted soil locations across the site | 18 | 0.2 – 1.5 m | <50 – 5000 mg/kg |
| | Toluene (105 mg/kg) | ESL - Urban Residential and public open space (fine soil) | Fuel Gantry Area | 1 | 1 m | <0.05 to 110 mg/kg |
| | Xylene (45 mg/kg) | ESL - Urban Residential and public open space (fine soil) | Fuel Gantry Area | 2 | 1 - 2 m | <0.05 - 400 mg/kg |
| | TPH $C_6$-$C_{10}$ less BTEX (40 mg/kg) (also includes TPH $C_6$-$C_9$ data) | HSL A/B - Low - high density residential (F1) 0 to <1m, Silt | Grid and targeted soil locations across the site | 27 | 1 – 2 m | <20 – 1500 mg/kg |
| | TPH $C_{10}$-$C_{16}$ less Naphthalene | HSL A/B - Low - high density | Grid and targeted soil locations | 36 | 1 – 2 m | <50 – 2200 mg/kg |

| Beneficial Use | Guideline Exceeded (criteria value) | Level of Protection Exceeded | General Location | Number of Samples Exceeding Guideline Value | Depth (mBGS) | Concentration Range |
|---|---|---|---|---|---|---|
| | (230 mg/kg)[v] (also includes TPH $C_{10}$-$C_{14}$ data) | residential (F2) 0 to <1m, Silt | across the site | | | |
| | Benzene (0.6 mg/kg) | HSL-B 0 to <1m, Silt | UST, AST & Fuel Gantry Areas | 4 | 1 – 2 m | <0.05 – 28 mg/kg |
| | Xylene (95 mg/kg) | HSL-B 0 to <1m, Silt | Fuel Gantry Area | 2 | 1 – 2 m | <0.05 – 400 mg/kg |
| Human Health | Naphthalene (4 mg/kg) | HSL-B, 0 to <1m, Silt | UST Area and centre of site (down-gradient of former Mobil spill) | 3 | 1.9 – 2 m | <0.1 – 11 mg/kg |
| | Soil pH (>5.5) | | Buried Waste Area | 1 | 3 m | 5.3 – 7.5 |
| | TPH $C_6$-$C_{10}$ (800 mg/kg) (also includes TPH $C_6$-$C_9$ data) | NEPM Management Limits – Residential, parkland and open space (fine soil) | Fuel Gantry Areas and Centre of site | 3 | 1 – 2 m | <20 – 1700 mg/kg |
| | TPH $C_{10}$-$C_{16}$ (1000 mg/kg) (also includes TPH $C_{10}$-$C_{14}$ data) | | AST, UST and centre of site | 10 | 1 – 2 m | <50 – 2200 mg/kg |
| | TPH $C_{16}$-$C_{34}$ (3500 mg/kg) (also includes TPH $C_{15}$-$C_{28}$ data) | | Drum store and UST areas | 5 | 0.2 – 0.5 mg/kg | <100 – 5000 mg/kg |
| | Inert Waste | | Buried Waste Area | NA | 1 - 2.7 m | Glass, Plastic, debris, & Odour. |
| | Odour | | UST, AST, Fuel Gantry Areas and Centre of site (down-gradient of former Mobil spill) | NA | 0.5 – 2 m | Petroleum hydrocarbon odour. |



### 6.1.4. Discussion of Pre-remediation of Soil Impacts

Assessment works were conducted between 2007 and 2014 and reported the following.

- Petroleum hydrocarbon impacts in fill and natural soils in the north of the site (in the vicinity of the fuel gantry, fuel manifold, ASTs, USTs, triple interceptor, and buried waste area) and in the south of the site (in the vicinity of the above ground product line and down-gradient of the former spill from the Mobil site). These impacts were likely the result of localised spills of petroleum products at the site during operation of the Caltex and Mobil fuel depots.

- Petroleum hydrocarbon impacts in fill and natural soils between 1 and 2 mBGS across the north, central and southwest of the site. These impacts were interpreted as being likely associated with petroleum hydrocarbon impact that had migrated with groundwater (see Section 6.2).
- Buried waste in an area approximately half way along the eastern boundary.
- Detectable concentrations of metals were identified in fill and natural soils and were broadly distributed across the site. Metals concentrations reported on-site were considered naturally occurring.

The concentrations and distribution of these impacts were used to develop a remediation action plan for the site and to help direct a focus for the initial soil excavation and remediation efforts on-site.

### 6.1.5. Precluded Beneficial Uses of Land

Based on the identified impacts discussed in Section 6.1.4 several of the protected beneficial uses of land (see Section 5.1) at the site were potentially precluded.

**Maintenance of Ecosystems**

Maintenance of ecosystems was precluded by petroleum hydrocarbon contamination in areas of former petroleum storage and distribution infrastructure.

**Human Health**

Human health was precluded for some land-use scenarios on the basis of reported petroleum hydrocarbon contamination across most of the northern portion of the site.

**Building and Structures**

Buildings and structures was potentially precluded in an isolated area on the basis of low soil pH (<5.5) within the buried waste material identified in the east of the site. Petroleum hydrocarbons above management limits also potentially precluded beneficial use of the site based on potential impact to structures and maintenance works.

**Aesthetics**

Aesthetics was precluded on the basis of petroleum hydrocarbon odour in shallow soils (<1 m) across the site, and by the presence of inert waste including glass, plastic, wood, concrete, metal and various debris within the buried waste material identified in the east of the site.

## 6.2. Groundwater

Historical groundwater monitoring well locations and corresponding analytical results are provided in Figure 4 (Appendix A), and Table 10 (Appendix B) respectively. Groundwater exceedances for TPH, Benzene and Ethylbenzene, and ammonia are shown in Figures 13a to c, Figures 14a and b and Figure 15, respectively.

### 6.2.1. Historical Groundwater Investigations

Several phases of groundwater assessment work were carried out by Coffey at the site between 2007 and 2012, as well as limited investigations conducted at the end of 2014. A summary of these investigations is provided in Table 6-3 below. These investigations represent pre-remediation conditions. The investigation conducted in 2014 was during soil remediation works, and represents an interim condition.

**Table 6-3 - Summary of Coffey Groundwater Assessment Works**

| Timeline | Site Works | Assessment Purpose |
|---|---|---|
| **July 2007** | Installation and sampling of groundwater wells MW1 – MW27. | Determine hydrogeological setting and contamination status of groundwater at the site. |
| **January 2008** | Groundwater Sample Event | Expand the understanding of the hydrogeological setting and contamination status of groundwater at the site. |
| **July 2008** | Groundwater Sample Event | Expand the understanding of the hydrogeological setting and contamination status of groundwater at the site. |
| **August 2010** | Installation and sampling of groundwater wells MW28 – MW32*. | Assess potential off-site (down gradient) impacts of site sources contaminated groundwater. Conducted as part of off-site risk assessment works |
| **November 2012** | Groundwater Sample Event | Expand the understanding of the hydrogeological setting and contamination status of groundwater at the site. |
| **December 2014** | Intra Soil Remediation and Groundwater Sample Event | Assess impact of soil remediation works on site hydrogeological settings and groundwater contamination status during soil works. |

* MW31 and MW32 were installed off site in 2010. On-site monitoring wells MW31 and MW32 were subsequently installed in 2015 an inadvertently given the same ID. Off-site wells have been identified as MW31(2010) and MW32(2010) to reduce confusion.

### 6.2.2. Groundwater COPC

Contaminants of potential concern at the site were identified based on historical site uses and investigations at the site and included broad screen chemical analysis of groundwater across the site.

Pre-remediation assessment included analysis for:

- PAHs
- Phenols
- Metals
- TPH
- MAHs
- PCBs
- OCPs
- OPPs
- VHCs
- And various other solvents, organic and inorganic chemicals

### 6.2.3. Distribution of Groundwater Contamination

Table 6-4 below summarises the pre-remediation (July 2007 to November 2012) groundwater contamination status at the site based on current nominated protected beneficial uses. Results from

December 2014 have not been included as the event was conducted during remediation works and does not represent either pre-remediation nor post-remediation conditions.

**Table 6-4 - Summary of Groundwater Guideline Exceedances – Pre-remediation**

| Beneficial Use | Guideline Exceeded (criteria value) | Location | Concentration Range |
|---|---|---|---|
| Water dependent ecosystems and species | Cyanide (0.007 mg/L) | MW9 | <0.005 – 0.008 mg/L |
| | Arsenic (0.013 mg/L) | MW3, MW4, MW5, MW5A, MW9, MW15A, MW23, MW24 | <0.005 - 0.089 mg/L |
| | Barium (0.625 mg/L) | MW5A | <0.02 - 0.67 mg/L |
| | Boron (0.37 mg/L) | MW18 | <0.05 - 0.59 mg/L |
| | Chromium (0.0025 mg/L) | MW3, MW5, MW5A, MW15A | <0.001 – 0.026 [1] mg/L |
| | Cobalt (0.0014 mg/L) | MW2, MW5, MW15A, MW18 | <0.001 – 0.006 mg/L |
| | Copper (0.0035 mg/L) | MW3, MW8, MW9, MW10, MW12, MW13, MW28, MW30 | <0.001 - 0.047 [2] mg/L |
| | Nickel (0.0275 mg/L) | MW2, MW3, MW4, MW5A, MW9, MW15A, MW18, MW24, MW30 | <0.001 - 0.15 mg/L |
| | Selenium (0.005 mg/L) | MW2, MW3, MW4, MW5A, MW9, MW15A, MW18, MW24MW5 | <0.001 - 0.008 mg/L |
| | Zinc (0.02 mg/L) | MW1, MW2, MW3, MW4, MW8, MW9, MW10, MW11, MW12, MW13, MW16, MW18, MW23, MW27, MW28, MW29, MW30, MW31(2010), MW32(2010) | <0.001 - 0.65 mg/L |
| | pH (lab) (6.5 - 8.0) | MW1, MW2, MW3, MW4, MW5, MW5A, MW6, MW8, MW9, MW11, MW12, MW13, MW15, MW15A, MW16, MW17, MW18, MW19, MW20, MW21, MW22, MW23, MW26, MW27 | 4.1 - 7.08 |
| | Iron (0.03 mg/L) | MW3, MW6, MW8, MW9, MW10, MW12, MW13, MW14, MW17, MW18, MW21, MW243 | 0.095 – 56 mg/L [3] |
| | TPHP $C_{10}$-$C_{36}$ (Sum of total) (600 µg/L) | MW4A, MW5, MW5A, MW8, MW10, MW12, MW13, MW14, MW15, MW15A, MW21, MW26, MW27, MW29 | <250 - 10,6500 µg/L |
| | Ethylybenzene (180 µg/L) | MW5, MW10, MW14, MW15 | <1 – 390 µg/L |
| | Toluene (1180 µg/L) | MW5 | <1 – 910 µg/L |
| | Xylene (total) (75350 µg/L) | MW5, MW12 | <1 –- 1400 µg/L |
| | Naphthalene (16 µg/L) | MW5, MW12, MW14 | <1 –- 110 µg/L |

| Beneficial Use | Guideline Exceeded (criteria value) | Location | Concentration Range |
|---|---|---|---|
| | Phenanthrene (2 µg/L) | MW14 | <1 –– 5 µg/L |
| | 2, 4 dimethylphenol (2 µg/L) | MW5 | <1 – 16 µg/L |
| Potable water supply | Ammonia as N (410 µg/L) | MW12, MW18, MW29 | <10 - 2900 µg/L |
| | Fluoride (1.5 mg/L) | MW5, MW9, MW10 | <0.5 – 2.7 mg/L |
| | pH (lab) (6.5 - 8.5) | MW1, MW2, MW3, MW4, MW5, MW5A, MW6, MW8, MW9, MW11, MW12, MW13, MW15, MW15A, MW16, MW17, MW18, MW19, MW20, MW21, MW22, MW23, MW26, MW27 | 4.1 - 7.08 |
| | TDS (600[a] mg/L) | MW3, MW4, MW5, MW5A, MW10, MW11, MW14, MW15, MW15A, MW18, MW24 | 60 - 1200 mg/L |
| | Arsenic (0.01 mg/L) | MW2, MW3, MW4, MW5, MW5A, MW7, MW9, MW14, MW15A, MW23, MW24MW3, | <0.001 - 0.089 mg/L |
| | Cobalt (0.006 mg/L) | MW2 | <0.001 - 0.006 mg/L |
| | Iron (0.3[a] mg/L) | MW3, MW6, MW8, MW9, MW10, MW12, MW13, MW14, MW17, MW18, MW21, MW243 | 0.095 – 56 mg/L [3] |
| | Manganese (0.1[a] mg/L) | MW2, MW5, MW4, MW5A, MW12, MW15A, MW18, MW20, MW23, MW29 | <0.005 – 0.27 mg/L |
| | Nickel (0.02 mg/L) | MW3, MW15A, MW18, MW20, MW24, MW26, MW29, MW2, MW3, MW4, MW5, MW5A, MW6, MW8, MW9, MW11, MW15A, MW20, MW23, MW24, MW26, MW28 | <0.001 – 0.07315 mg/L |
| | Zinc (0.06 mg/L) | MW3 | <0.001 - 0.65 |
| | Benzene (1 µg/L) | MW5, MW8, MW10, MW12, MW14, MW15, MW23 | <1 – 310 µg/L |
| | Ethylbenzene (253[a] µg/L) | MW5, (MW6)?, (MW8)?, MW10, MW12, MW14, MW15 | <1 – 390 µg/L |
| | Toluene (325[a] µg/L) | MW5, MW10, MW12 | <1 – 910 µg/L |
| | Xylene (total) (20[a] µg/L) | MW5, MW8, MW12 | <1 – 1400 µg/L |
| | Naphthalene (6.1 µg/L) | MW5, MW12, MW14 | <1 – 110 µg/L |
| | TPH $C_{10}$-$C_{16}$ (0.1 mg/L) | MW1, MW4A, MW7, MW8, MW10, MW11, MW12, MW14, MW21, MW23, MW24, MW29 [4] | <0.1 – 1.14 |

| Beneficial Use | Guideline Exceeded (criteria value) | Location | Concentration Range |
|---|---|---|---|
| | TPH $C_{16}$-$C_{34}$ (0.09 mg/L) | MW10, MW12, MW14, MW21, MW29 | <0.05 – 1.41 |
| **Agriculture and irrigation (irrigation)**<br><br>**In addition to water-based recreation exceedances** | Fluoride (21 mg/L) | MW4, MW5, MW9, MW10, MW11, MW15, MW21 | <0.2 - 2.7 mg/L |
| | Boron (0.5 mg/L) | MW18 | <0.05 – 0.59 mg/L |
| | Iron (0.2 mg/L) | MW3, MW6, MW9, MW10, MW12, MW13, MW14, MW17, MW18, MW21, MW24 | 0.5 – 56 mg/L |
| | Manganese (0.02 mg/L) | MW2, MW4, MW5A, MW15A, MW18, | <0.005 – 0.27 mg/L |
| | Fluoride (21 mg/L) | MW4, MW5, MW9, MW10, MW11, MW15, MW21 | <0.2 - 2.7 mg/L |
| | Benzene (1 µg/L) | MW5, MW8, MW10, MW12, MW14, MW15, MW23 | <1 – 310 µg/L |
| | Ethylbenzene (800 µg/L) | MW5, MW6, MW8, MW10, MW12, MW14, MW15 | <1 – 390 µg/L |
| | Toluene (300 µg/L) | MW5 | <1 – 910 µg/L |
| | Xylene (total) (600 µg/L) | MW5, MW8, MW12 | <1 – 1400 µg/L |
| | Naphthalene (6.1 µg/L) | MW5, MW12, MW14 | <1 – 110 µg/L |
| | TPH $C_{10}$-$C_{16}$ (0.1 mg/L) | MW1, MW4A, MW7, MW8, MW10, MW11, MW12, MW14, MW21, MW23, MW24, MW29 [4] | <0.1 – 1.4 |
| | TPH $C_{16}$-$C_{34}$ (0.09 mg/L) | MW10, MW12, MW14, MW21, MW29 | <0.05 – 1.1 |
| **Agricultural and irrigation (stock watering)** | Fluoride (21 mg/L) | MW4, MW5, MW9, MW10, MW11, MW15, MW21 | <0.2 - 2.7 mg/L |
| | Benzene (1 µg/L) | MW5, MW8, MW10, MW12, MW14, MW15, MW23 | <1 – 310 µg/L |
| | Ethylbenzene (800 µg/L) | MW5, MW6, MW8, MW10, MW12, MW14, MW15 | <1 – 390 µg/L |
| | Toluene (300 µg/L) | MW5 | <1 – 910 µg/L |
| | Xylene (total) (600 µg/L) | MW5, MW8, MW12 | <1 – 1400 µg/L |
| | Naphthalene (6.1 µg/L) | MW5, MW12, MW14 | <1 – 110 µg/L |
| | TPH $C_{10}$-$C_{16}$ (0.1 mg/L) | MW1, MW4A, MW7, MW8, MW10, MW11, MW12, MW14, MW21, MW23, MW24, MW29 [4] | <0.1 – 1.4 |
| | TPH $C_{16}$-$C_{34}$ (0.09 mg/L) | MW10, MW12, MW14, MW21, MW29 | <0.05 – 1.1 |
| | pH (6.5 – 8.5) | MW1, MW2, MW3, MW4, MW5, MW5A, MW6, MW8, MW9, MW11, MW12, MW13, | 4.1 - 7.0 |

| Beneficial Use | Guideline Exceeded (criteria value) | Location | Concentration Range |
|---|---|---|---|
| Water-based recreation (primary contact recreation) | | MW15, MW15A, MW16, MW17, MW18, MW19, MW20, MW21, MW22, MW23, MW26, MW27 | |
| | TDS (600[a] mg/L) | MW3, MW4, MW5, MW5A, MW10, MW11, MW14, MW15, MW15A, MW18, MW24 | 60 - 1200 mg/L |
| | Iron (0.03[a] mg/L) | MW3, MW6, MW8, MW9, MW10, MW12, MW13, MW14, MW17, MW18, MW21, MW234 | 0.095 – 56 mg/L |
| | Manganese (0.1[a] mg/L) | MW2, MW4, MW5A, MW12, MW15A, MW18, MW20, MW23, MW29 | <0.005 – 0.27 mg/L |
| | Benzene (1 µg/L) | MW5, MW8, MW10, MW12, MW14, MW15, MW23 | <1 – 310 µg/L |
| | Toluene (3[a] µg/L) | MW5, MW10, MW12 | <1 – 910 µg/L |
| | Xylene (total) (20[a] µg/L) | MW5, MW8, MW12 | <1 – 1400 µg/L |
| | Naphthalene (6.1 µg/L) | MW5, MW12, MW14 | <1 – 110 µg/L |
| Buildings and Structures | pH (< 5.5) | MW2, MW8, MW16, MW17, MW22 | 4.1 - 6.8 |
| Aesthetics | Hydrocarbon sheen | MW14, MW21, MW11 [5] | |

a - Denotes aesthetic criteria
1 – Hexavalent chromium criteria applied to Cr(III) results in the absence of speciated analysis pre-remediation
2 – Most elevated copper results were recorded during the November 2012 event.
3 – Only a limited number of wells were analysed for iron, pre-remediation. All well assessed (other than MW11) exceeded the aesthetic criteria.
4 – Exceedance of potable water criteria in MW29 based on sum of relevant speciated TPH fractions.
5 – Occurrence of sheen only noted from November 2012 event due to significant time to previous 2008 event.

### 6.2.4. Discussion of Pre-remediation Groundwater Impacts

Investigation of the distribution of groundwater impacts at the site was investigated between 2007 and 2012 found the following.

- Petroleum hydrocarbon impacts along the western boundary of the site were considered to be associated with petroleum product spills at the Mobil site during historical fuel depot operations located on and up-gradient of the Caltex site (in particular the fuel manifold, and above ground product line).
- Petroleum hydrocarbon impacts around and down gradient of the ASTs and triple interceptor traps. These may be associated with localised on-site spills of petroleum products during historical fuel depot operations, and/or migration of impacts from off-site sources beyond the western boundary.
- Petroleum hydrocarbon impacts around the fuel gantry. These were most likely associated with localised on-site spills of petroleum products during historical fuel depot operations.
- Petroleum hydrocarbon impacts around the above ground product lines in the south of the site. These are most likely associated with localised on-site spills of petroleum products during historical fuel depot operations.

- Observations of hydrocarbon sheen in three groundwater wells sampled in 2012.
- Fluoride was identified in three groundwater wells above stockwatering, irrigation and drinking water criteria.
- Several metals including arsenic, barium, boron, copper, iron, manganese, nickel and zinc have been detected above the nominated criteria in several monitoring wells across the site. Based on the distribution and relatively consistent concentrations across the site, these metals are interpreted as being naturally occurring and not the result of contamination at the site. Although considered naturally occurring, metals were still assessed at the site to confirm that they were not increased or converted to more mobile forms as a result of remediation activities altering the geochemistry of groundwater at the site (changes to oxidation reduction potential and/or pH).

### 6.2.5. Precluded Beneficial Uses of Groundwater

Based on the identified impacts reported prior to remediation, several of the protected beneficial uses of groundwater (see Section 5.2) at the site were precluded by on-site groundwater contamination.

| Protected beneficial use | Precluded (Y/N) | Description |
|---|---|---|
| **Water dependent ecosystems and species** | Y | Water dependent ecosystems and species was precluded on the basis of petroleum hydrocarbon contamination at the site, and potentially precluded due to elevated ammonia as a result of localised waste and some metals mobilised by reducing conditions. |
| **Potable water supply** | Y | Potable water supply was precluded on the basis of petroleum hydrocarbon contamination at the site, and potentially precluded due to elevated ammonia as a result of localised waste and some metals mobilised by reducing conditions. |
| **Agriculture and irrigation (irrigation)** | Y | Agriculture and irrigation (irrigation) was precluded on the basis of petroleum hydrocarbon contamination at the site and some metals potentially mobilised by reducing conditions. |
| **Agriculture and irrigation (livestock)** | Y | Agriculture and irrigation (livestock) was precluded on the basis of petroleum hydrocarbon contamination at the site and some metals potentially mobilised by reducing conditions. |
| **Water-based recreation (primary contact recreation)** | Y | Primary contact and recreation (PCR) was precluded based on petroleum hydrocarbon contamination at the site. |
| **Building and structures** | N | Buildings and structures was not precluded by contamination identified in groundwater at the site, based on the criteria available. Separate phase petroleum hydrocarbons potentially impact buildings and structures through staining, inhibiting curing of concrete or permeating PE and PVC pipework. Although historically identified, separate phase hydrocarbons were not reported in recent years prior to remediation. |

| Protected beneficial use | Precluded (Y/N) | Description |
|---|---|---|
| | | Site pH was outside the Building and Structures screening criteria but was considered to be naturally occurring, and only below a pH of 5.5 pH units in isolated instances. |

# 7. Remedial Works

After developing an understanding of soil and groundwater conditions on site (outlined in Section 6) a site remediation action plan (RAP, Coffey 2014) was developed, to establish remediation objectives for the site, consistent with the Victorian EPA Environmental Audit (S53X) System.

The goals of the RAP were to develop a methodology for remediation of soil and groundwater contamination (on site) to facilitate future residential land-use. The intent was that the remediation methodology be consistent with Audit requirements, and to mitigate potential risk to human health and the environment (on and off-site) as a result of contamination originating from the site.

The RAP concluded that the optimum remediation strategy was to excavate, remediate and reuse petroleum hydrocarbon impacted soils on-site. Buried waste material, and any soil too contaminated to remediate in the allotted timeframe, was to be disposed of offsite. Excavations were to target areas of known contamination, and progressively ‘chase out’ the remaining contamination, based on field observations and validation sample results. Any unexcavated areas would be considered using historical samples results, and additional sampling where deemed necessary, to characterise the areas and either show they were not impacted or should be included in remediation activities.

Under the RAP, groundwater was to be monitored post-remediation, to observe groundwater impacts once the on-site sources of contamination were removed. The RAP considered that once the on-site sources of contamination were removed, groundwater contamination should stabilise and/or decrease. Further, the methods used for remediation of the soil (which included addition of di-ammonium phosphate (DAP), oxygenation, to promote biological activity), were considered likely to enhance natural attenuation in the period following active soil remediation works.

The location and extent of excavations, and validation sample locations, are shown on Figure 10 and Figure 11a to e (Appendix A). All post-remediation soil validation results (including removed and in-situ soil results) are provided in Tables 2a to 2e (Appendix B). Soil classification results and calculations (including 95% UCLs, stockpile groupings, and re-use summaries) are provided in Appendix G and Appendix H.

## 7.1. Excavation and Validation

Soil remediation and validation works were conducted in two stages.

- Stage 1 was completed during the 2014 dry season and focussed on the northern part of the site.
- Stage 2 was completed the 2015 dry season and focused on the southern part of the site.

In broad terms, the soil remediation and validation methodology were as follows.

- Excavation of non-impacted overburden soil.
- Excavation of petroleum hydrocarbon impacted soil.
- Stockpiling of excavated soil.
- Validation of excavations.
- Characterisation of contaminated stockpiles to support soil remediation.
- Characterisation of non-impacted stockpiles for re-use.
- Disposal of material considered unsuitable for remediation or reuse.
- Remediation of impacted stockpiles.

- Characterise remediated stockpiles to confirm appropriateness for re-use.
- Backfilling of excavations.
- Validation of areas used for stockpiling.

### 7.1.1. Excavation

- This section summarises the excavation methodology undertaken. Excavation was completed using 30 and 37 tonne excavators. Tip trucks were used to help segregate soil of different types grades of contamination into separate stockpiles (see Section 7.2).
- The lateral extent of excavation was initially guided by the contaminant distribution determined during pre-remediation assessment. However, it was understood that actual subsurface conditions were likely to vary from those interpreted from historical data. Therefore, on-site excavation extent was guided by field observations, field screening measurements, and progressive soil analytical results.
- The vertical extent of excavation was generally intended to be sufficient to remove contamination within the vadose zone, the groundwater smear zone and potentially the upper portion of the shallow aquifer. The vertical extent of excavation was guided by field observations, field screening and progressive soil analytical results.
- In some areas, the presence of rock limited the extent to which excavation could progress. Areas of concern were systematically excavated, with the top approximately 0.5 - 1 m of soil (generally less impacted) stripped and stockpiled. Impacted soil (generally below 0.5 m), was then excavated to the limit of excavation.
- For the purpose of this discussion, “limit of excavation” refers to the excavation of impacted soil to a depth which was like to be free of contamination based on field observations. In some instances, the presence of competent rock dictated the limit of excavation. In all cases, soil analytical results were obtained to confirm the contamination status of the soil remaining in place after all excavation.
- After excavating each initial (previously identified) area of concern, excavations were progressively expanded laterally, based on field screening/observations. Once all observable impacts had been removed, the excavation floor and walls were validated (see Section 7.1.2). In cases where validation samples indicated concentrations of COPC exceeding adopted criteria, excavations were extended further, and re-validated. This process was continued until a ‘clean’ excavation extent was achieved, or the excavation reached the property boundary of the site. In some instances, the vertical extent of excavation was limited by the presence of rock, in which case validation samples were collected within small clay seams observed to be present within the rock structure.

Notes:

- Excavations were not extended beyond the title boundary of the site, except along parts of the western boundary where some sections of the fence were initially west of the actual title boundary (by up to approximately 1 m).
- As a part of safe work practice, all excavation walls greater than 1.5 m height were benched to prevent collapse. As a result, (limited) non-impacted material was removed in some areas.
- Limited excavation/landscaping at the base of some excavations (EX2, EX5 and EX6) was undertaken to form channels and sumps to drain and collect groundwater seepage from the base of the excavation. Non-impacted soil from these limited works was added to stockpiles of similar contamination status.

### 7.1.2. Validation

The following summarises the adopted excavation validation approach.

- Soil samples were collected for laboratory testing once field observations indicated that contaminated soil had been excavated.
- Soil samples were collected from the walls and floor of each excavation to validate the removal of hydrocarbon impacted soil and confirm the resulting contamination status of residual soil.
- Soil validation samples were collected at a (minimum) rate of:
  - One sample per 25 $m^2$ on the base of each excavation (minimum three per excavation base).
  - One sample per 5 linear metres of each excavation wall (minimum one per wall). Additional wall samples were collected where more than one distinct soil stratum existed.
  - Additional samples were collected where preferential migration pathways on the walls or base of the excavation were indicated, or there was likely to be residual contamination at the excavation limit (e.g. at the title boundary, or where refusal on rock was encountered and small clay seams, possibly containing residual contamination, were evident).

Based on the validation sampling results, one of the following actions was undertaken:

- If validation samples exceeded adopted criteria, further excavation, and validation sampling, was undertaken.
- Where validation samples failed, and further excavation was not practicable, residual contamination was considered further though site specific risk assessment.
- Where validation samples met the validation criteria, no further excavation was considered required.

Due to the shallow depth to groundwater at the site, groundwater ingress into some excavations was observed. In order to allow the excavations to be validated correctly, groundwater was managed by one of the following methods.

- Where infiltration rates were low, soil samples were collected prior to significant groundwater ingress occurring.
- Channels and sumps were installed to control groundwater ingress and allow proper validation of newly excavated areas.
- Groundwater was pumped from the excavations into holding tanks on-site where was allowed to settle, to reduce the concentration of suspended solids. Extracted water was then disposed of via the sewer under a trade waste agreement (Appendix J).

**Soil Validation Criteria**

Excavation validation samples were submitted for laboratory analysis and results were compared to the relevant human health and ecological screening criteria.

Validation (screening) assessment criteria for key COPC are detailed in Table 7-1 Further discussion regarding soil conditions, specifically where an exceedance of screening criteria was observed, is provided within the risk assessment section (Section 12).

**Table 7-1 - Validation Assessment Criteria for key COPCs (mg/kg)**

| Key COPC | Ecosystem Protection (ESL)[1] | Residential Land Use (HSL A/B, silt) | | | Maintenance Worker[5] |
|---|---|---|---|---|---|
| | | 0 - <1m[2] | 1m - <2m[3] | 2m - <4m[4] | |
| Benzene | 65 | 0.6 | 0.7 | 1 | 1,100 |
| Toluene | 105 | 390 | NL | NL | 120,000 |
| Ethylbenzene | 125 | NL | NL | NL | 85,000 |
| Xylenes (total) | 45 | 95 | 210 | NL | 130,000 |
| Naphthalene | - | 4 | NL | NL | 29,000 |
| F1* | - | 40 | 65 | 100 | - |
| F2^ | - | 230 | NL | NL | - |
| TRH $C_6$-$C_{10}$ | 180 | - | - | - | 82,000 |
| TRH >$C_{10}$-$C_{16}$ | 120 | - | - | - | 62,000 |
| TRH >$C_{16}$-$C_{34}$ | 1300 | - | - | - | 85,000 |
| TRH >$C_{34}$-$C_{40}$ | 5600 | - | - | - | 120,000 |

[1] *NEPM (2013) Environmental Screening Level (ESL), Urban residential and public open space, fine soil.*
[2] *NEPM (2013) Health Screening Level (HSL), Setting A and B (low to high density residential), silt, 0 - <1m depth.*
[3] *NEPM (2013) HSL, Setting A and B (low to high density residential), silt, 1 - <2m depth*
[4] NEPM (2013) *HSL, Setting A and B (low to high density residential), silt, 2 - <4m depth*
[5] Friebel and Nadebaum (2011) *HSL (soil) for direct contact, intrusive maintenance worker*
*F1 = TRH $C_6$-$C_{10}$ less BTEX
^ F2 = TRH >$C_{10}$-$C_{16}$ less Naphthalene
NL = Non limiting

### 7.1.3. Validation Analysis

The analytical suite applied to excavation validation samples was refined based on evidence of COPCs obtained from historical assessment at the site. Soil samples were submitted to the laboratory for analysis as follows:

- Fill Material: TPH, BTEX, PAH, phenol and lead.
- Natural Soil: TPH, BTEX, PAH (plus a broad analytical suite (refer to tables, Appendix B) in a number of selected samples, to screen for potential contaminants outside the suite of identified COPC).

Soil stockpiles were analysed for a broad suite of analytes as part of soil classification, which also screened for COPCs that may not have been identified during the pre-remediation characterisation of the site.

## 7.2. Stockpiling Methodology

Excavated soil was stockpiled for characterisation, treatment (remediation), and storage prior to reinstatement or disposal.

- During excavation, soil was transported via tip truck to designated stockpiles for subsequent classification and treatment.
- Stockpiles were constructed so that each was of similar material type, similar level of impact, and common source area. This approach supported the segregation of clean material from impacted soil. Stockpiles were numbered systematically in order of creation as follows.
  - USP (untreated stockpile) prefix as used to describe pre-treated stockpiles (e.g. 'USP-01').
  - Once stockpiles were treated, each was re-designated as a TSP (treated stockpile), keeping the same identification number (e.g. the stockpile numbered 'USP-01' prior to treatment became 'TSP-01' after treatment).
  - In the case where a stockpile was assessed to be inappropriate for remediation and reuse on-site, either due to gross contamination or the presence of ACM, it was re-designated as an OSP (off-site stockpile) e.g. 'OSP-022'. OSPs were sampled and classified for off-site disposal, and disposed off-site at an appropriately licenced facility.

Each USP was sampled to assess its level of impact. This information was used to design a customised remediation approach for each stockpile (e.g. mass of nutrients needed, moisture content required). Following treatment, each TSP was re-sampled to classify it for reuse against the adopted soil re-use assessment criteria (see Section 7.1.2). In cases where the post-remediation sample results indicated a stockpile was not yet remediated to a condition appropriate for re-use on-site, or where it was considered stockpile could be remediated to a more desirable level, the treatment process was continued. This process was repeated until the desired remediation endpoint was achieved.

### 7.2.1. Stockpile Remediation

Stockpiles were remediated for petroleum hydrocarbons through a process of assisted bioremediation.

Soil was broken up via the use of an 'allu' bucket and excavator to increase surface area and oxygen availability, while soil nutrients, temperature, and moisture levels were monitored and optimised (via addition of di-ammonium phosphate (DAP) and water) to maximise biological activity.

DAP application rates for each stockpile were calculated using stoichiometric estimations of the required mass of nutrient needed, taking into account:

- Concentration of TPH impacts in the soil
- Proportional mass of individual TPH fractions in the soil
- The mass, form and bio-availability of pre-existing nutrients within the soil
- Potential toxicity (natural and anthropologic) within the soil.

The even application of DAP and water was controlled via manual addition, during mixing of the soil using the 'allu' bucket and excavator.

### 7.2.2. Stockpile Classification (for re-use).

Stockpile soil samples were collected and analysed at a rate of one sample per 25 $m^3$ (with a minimum of three samples) in stockpiles up to 200 $m^3$. Stockpiles greater than 200 $m^3$ required a minimum of 10 samples to be analysed to apply a statistical method for classification, specifically the 95% UCL of the mean concentration.

- Stockpile classification using less than 10 soil samples (for some stockpiles less than 200 m3), was based on the maximum analytical result for each COPC.
- Where maximum concentration values exceeded the soil re-use criteria, but the use of statistical methods was appropriate (consistent with IWRG702), 95% UCL values were calculated for each COPC and used to develop the appropriate classification.
- In some cases where smaller stockpiles (less than 200 $m^3$), were 'grouped' to allow the use of statistical methods (95%UCL) for classification and future handling of the group as a whole (e.g. 'Group 1' consisted of TSP-01, TSP-18, TSP-19, TSP-20, TSP-24, and TSP-29).

The reported soil analytical results for each stockpile were compared against the adopted soil re-use acceptance criteria, to determine reuse potential.

**Soil Re-use Criteria**

The acceptance criteria for on-site re-use of treated soils were developed by Coffey using a risk-based approach, and were reviewed by the Environmental Auditor. The criteria are summarised in Table 7-2. The detailed derivation of the re-use acceptance criteria is provided in Appendix I.

**Table 7-2 - Soil Re-use Acceptance Criteria**

| Acceptance for Re-use On-site | Max. Concentration | 95% UCL Concentration | Hydrocarbon Odour | ASLP Concentration |
|---|---|---|---|---|
| **Unrestricted** | <2.5x ESL<br><2.5x HSL | <ESL<br><HSL | No hydrocarbon odour | < GIL<br>(or not tested as all results <500 mg/kg TRH) |
| **Use anywhere below 1m (depth from surface)** | >2.5x ESL<br><2.5x HSL | <1.5x ESL<br><HSL | No hydrocarbon odour | < GIL<br>(or not tested as all results <500 mg/kg TRH) |
| **Use below 2m (depth from surface)** | >2.5x ESL<br>>2.5x HSL | >ESL<br>>HSL | Hydrocarbon odour | < GIL |
| **Treat or dispose off-site** | >2.5x ESL<br>>2.5x HSL | >ESL<br>>570 mg/kg F2 | - | >GIL |

Notes:

- HSL – NEPM (2013) Health Screening Level (HSL), Setting A and B (low to high density residential), silt, 0 - <1 m depth
- ESL - NEPM (2013) Environmental Screening Level (ESL), Urban residential and public open space, fine soil
- GIL –Groundwater Investigation Level for protected beneficial uses (Section 5.2).

## 7.3. Backfilling Methodology

The backfill methodology is summarised below.

- Once excavation validation sample results were reviewed, and the resulting contamination status of soils was considered appropriate, excavations were backfilled using remediated soils.

- The depth of reinstatement was based on each stockpile's classifications for re-use (refer Table 7 above).

- Where material was classified for re-use below a certain depth (e.g. >2.0 m), a surveyor was engaged to measure the depth of backfilled material relative to the final ground surface. This approach ensured the appropriate placement of soil under the specific reuse restrictions.

## 7.4. Waste Disposal

The need to dispose of soil from the site at an off-site facility was triggered twice during the investigation.

- The disposal of buried waste materials and surrounding soils identified during pre-remediation characterisation of the site. Approximately 250 $m^3$ of waste material and impacted soil was stockpiled as OSP-022 for off-site disposal.

- The disposal of soil impacted by ACM associated with a small volume of waste and building debris within fill material discovered when excavating soils in the east end of EX6. Approximately 10 $m^3$ of soil (14.09 tonne) was stockpiled separately as USP-57B for off-site disposal.

Soils were classified for off-site disposal as per IWRG621 and IWRG702 and as arranged with the receiving facility.

Soils disposed off-site were sent to the Shoal Bay Waste Management Facility, a licenced landfill facility operated by the City of Darwin. Soil classification letters and waste disposal certificates are provided in Appendix H.

Following disposal of soil containing ACM, the remainder of USP-57 and the surrounding area was cleared by Global Environmental Solutions, a licenced asbestos removalist contractor. The corresponding asbestos clearance certificate is provided in Appendix H.

## 7.5. Soil Sampling Methodology

The soil sampling was undertaken in accordance with the principles provided in:

- the Australian Standard AS4482.1-2005 'Guide to the Investigation and sampling of sites with potentially contaminated soil – Part 1: Non-volatile and semi-volatile compounds',
- the Australian Standard AS4482.2-1999 'Guide to the sampling and investigation of potentially contaminated soil – Part 2: Volatile substances' and
- the National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended 2013 (NEPM, 2013).

Consideration was also given to the guidance provided in EPA Publication IWRG621 (Industrial Waste Resource Guidelines – Soil Hazard Characterisation and Management) when collecting samples from stockpiles for off-site disposal.

# 8. Post Remediation Groundwater Assessment

Following completion of the soil remediation works in 2015, a groundwater sampling and analysis quality plan (SAQP) (Coffey November 2015) was developed in consultation with the Auditor, to capture the requirements of post soil remediation groundwater monitoring. The full Groundwater SAQP is provided in Appendix K, and included the following.

- The objectives of post soil remediation groundwater monitoring:
  - Characterise (post-remediation) groundwater contamination at the site.
  - Characterise groundwater contamination associated with potential up gradient contaminant sources.
  - Characterise groundwater contamination in the context of potential risk to off-site receptors, originating from site-sourced contamination.
- The location, installation methodology, and design of new groundwater monitoring wells (including surveying requirements).
- Groundwater Monitoring Event (GME) frequency and scheduling.
- Requirements for gauging groundwater levels, and use of long-term loggers.
- Aquifer testing (rising head tests).
- Groundwater sampling methodology.
- Applicable regulatory framework and screenings criteria (as presented in Section 5.2).
- Proposed NATA accredited laboratory analytical suite for samples.

The groundwater monitoring locations are shown on Figure 5 (Appendix A). Gauging data, field water quality data, and laboratory results are in Tables 8, 9 and 11 (Appendix B).

Groundwater sampling was conducted in December 2014, during soil remediation works, to assess the impact that soil movement may have been having on groundwater quality. That event is not considered to represent post-remediation water quality and not been considered in more detail in this section. The data is included in Table 10, with pre-remediation groundwater assessments, but is also not considered to represent pre-remediation water quality and has not been considered in detail in Section 6.2.

## 8.1. Groundwater Monitoring Well Network Installation

Groundwater monitoring well bore construction logs are provided in Appendix C and construction is summarised in Table 7, Appendix B.

Twenty-one (21) new groundwater monitoring wells were installed at the site post-remediation to assess the condition of groundwater beneath the site post remediation. The groundwater well network was considered appropriate to assess the groundwater flow patterns present at the site, the condition of groundwater entering the site, the condition of groundwater on-site, and the condition of groundwater leaving the site.

Due to an oversight in the naming of monitoring wells, there are two sets of wells named MW31 and MW32. Off-site wells MW31 and MW32 were installed in 2010, but were (temporarily) lost, and presumed removed or destroyed. When new wells were installed in 2015, the well IDs MW31 and MW32 were mistakenly re-used. For clarity the ‘old’ off-site MW31 and MW32 have therefore been referred to as ‘MW31 (2010)’ and ‘MW32 (2010)’, and are labelled accordingly in the figures.

A rationale for well installation is presented in Table 8-1 below.

**Table 8-1 - Groundwater Well Installation Rationale**

| Area | Well Location | Direction from Contaminating Activity Areas and Rationale for Location |
|---|---|---|
| Western (up gradient) boundary | 6 x monitoring wells along western boundary in of the site. | To assess the condition of groundwater entering the site. |
| Northern Boundary | 1 x monitoring well on the Northern boundary. | To target groundwater conditions in the vicinity of a historical UST, as well as assess hydrogeological conditions in an area undisturbed by recent soil remediation activities. |
| Site Central Line (north-south) | 9 x monitoring wells along the north-south central line of the site including:<br>○ *2 x deeper wells at 'nested' locations, and;*<br>○ *1 x monitoring well in the south of the site.* | Central line to assess groundwater condition across the site.<br>Nested sites to assess groundwater conditions below the area recently disturbed by soil remediation activities. Wells have been intentionally installed with a submerged screen. Therefore, data acquired from these locations must be assessed appropriately (e.g. not as an indication of LNAPL presence).<br>Southern monitoring well targeting the area 'undisturbed' by recent soil remediation activities. |
| Eastern (down gradient) boundary | 5 x monitoring well along the eastern boundary of the site. | To assess the condition of groundwater leaving the site. |
| TOTAL | 21 new monitoring wells | |

The methodology for the drilling and installation program was as follows:

- Solid stem augers were used to drill each bore to the proposed depth (3 mBGS to 4 mBGS).
- Groundwater monitoring wells were constructed using 50 mm, Class 18 uPVC threaded screen and casing.
- Each monitoring well was installed with a monument cover above surrounding surface level to prevent surface water ingress. The monument cover on existing well MW24 was also repaired.
- All monitoring wells were developed by agitating the standing water column and removing water using a bailer or equivalent. Typically, three well volumes were removed with the aim to also stabilise water quality parameters prior to cessation of bailing.
- Groundwater monitoring wells were installed as per the *Minimum Construction Requirements for Water Bores in Australia (3rd Edition)*, and standard industry practices, by a suitably licenced Drilling Contractor.

- Monitoring wells were surveyed by a licensed surveyor to assess reduced groundwater levels.

Several of the wells along the western boundary were installed up to 5 metres inside the site boundary, to avoid installation in the erosion sediment control drain.

## 8.2. Post Remediation GMEs

The SAQP, dated November 2015, outlined four post remediation GMEs to be undertaken over nine months (October/November 2015, January 2016, April 2016 and July 2016). Each GME was intended to establish groundwater conditions at the site during different stages of the wet and dry seasons (early and late seasonal changes).

Additional groundwater investigations were conducted, including a limited groundwater sampling event in August 2017, to assess concentrations of petroleum hydrocarbons along the Mobil-Caltex boundary. Queries were raised to the Auditor from the Northern Territory Environmental Protection Authority (NTEPA) about the potential for per- and poly fluorinated alkyl substances (PFAS) contamination at the site and the Auditor requested Coffey provide an opinion. Two additional GMEs (one early wet season GME in January-February 2018 and one late dry season GME in October-November 2018) and a supplementary investigation (June 2018) were also conducted to assess the potential for PFAS to be a COPC related to the site.

In response to the NTEPA concerns, an updated SAQP was created, dated June 2018, in correspondence with the auditor to provide additional data related to groundwater conditions, contamination extent, and natural attenuation (NA) capacity, to provide an indication of possible seasonal variations (in water level) observed in the Northern Territory. Surface water samples were also collected at four locations along the alignment of the creek to the south and east of the site, during each of the 2018 GMEs.

**Table 8-2 - Summary of Post-remediation Groundwater Monitoring Events**

| Date | Wells | Analytes |
|---|---|---|
| October/ November 2015 | MW1, MW2, MW5, MW9, MW18, MW23, MW24, MW31, MW32, MW33, MW34, MW35, MW36, MW37, MW38S, MW38D, MW39, MW40, MW41S, MW41D, MW42, MW43, MW44, MW45, MW46, MW47, MW48, MW49 | Metals, anions and cations, nitrogen forms, pH, TDS, TPH, BTEX, PAHs |
| January/ February 2016 | MW1, MW2, MW5, MW9, MW18, MW23, MW24, MW29, MW31, MW32, MW33, MW34, MW35, MW36, MW37, MW38S, MW38D, MW39, MW40, MW41S, MW41D, MW42, MW43, MW44, MW45, MW46, MW47, MW48, MW49 | Metals, anions and cations, nitrogen forms, phosphate, TOC, pH, TDS, TPH, BTEX, PAHs |
| April 2016 | MW1, MW2, MW5, MW9, MW18, MW23, MW24, MW29[1], MW31, MW31(2010), MW32, MW32(2010), MW33, MW34, MW35, MW36, MW37, MW38S, MW38D, MW39, MW40[2], MW41S, MW41D, MW42, MW43, MW44, MW45, MW46, MW47, MW48, MW49 | Metals, anions and cations, nitrogen forms, phosphate, TOC, pH, TDS, TPH, BTEX, PAHs [3]<br><br>Speciated TPH [4] |
| July 2016 | MW1, MW2, MW5, MW9, MW18, MW23, MW24, MW29, MW31[5], MW31(2010), MW32, MW32(2010), MW33[5], MW34, MW35[5], MW36, MW37, MW38S, MW38D, MW39, MW40, MW41S, | Metals, anions and cations, nitrogen forms, phosphate, TOC, pH, TDS, TPH, BTEX, PAHs [6] |

| Date | Wells | Analytes |
|---|---|---|
| | MW41D, MW42, MW43, MW44, MW45, MW46, MW47, MW48, MW49 | |
| **August 2017** | MW21, MW32, MW33, MW34, MW35, MW5, MW9 | Total alkalinity, nitrate, sulfate, iron, manganese, TPH, BTEX |
| **February 2018** | MW1, MW2, MW18, MW32, MW33, MW34, MW35, MW36, MW45, MW46, MW48 | PFAS |
| | MW1, MW2, MW5, MW9, MW18, MW23, MW31, MW32, MW33, MW34, MW35, MW36, MW37, MW38S, MW38D, MW39, MW40, MW41S, MW41D, MW42, MW43, MW44, MW45, MW46, MW47, MW48, MW49 | Metals, fluoride, anions and cations, nitrogen forms, phosphate, TOC, pH, TDS, TPH, BTEX, PAHs, Speciated TPH [7] |
| **November 2018** | MW1, MW2, MW18, MW32, MW33, MW34, MW35, MW36, MW46, MW48 | PFAS |
| | MW1, MW2, MW5, MW9, MW18, MW23, MW31, MW32, MW33, MW34, MW35, MW36, MW37, MW38S, MW38D, MW39, MW41S, MW41D, MW42, MW43, MW44, MW45, MW46, MW47, MW48, MW49 | Metals[8], fluoride, anions and cations, nitrogen forms, phosphate, TOC, TDS, TPH, BTEX, PAHs |

[1] MW29 Resampled in May 2016

[2] MW40 sampled twice in April 2016

[3] Suite for MW31(2010), MW32(2010) and resample of MW29 limited to anions and cations, nitrogen forms, TOC, TDS, arsenic, boron, manganese, iron, zinc

[4] Speciated TPH conducted for wells MW1, MW2, MW5, MW9, MW23, MW291, MW31, MW32, MW33, MW34, MW35, MW36, MW37, MW39, MW402, MW41D, MW46, MW47

[5] MW31, MW33, MW35 were sampled at three depths through the wetted screened section

[6] MW31(2010) and MW32(2010) did not include TPH, BTEX and PAH analysis. MW33_3.9 included speciated TPH.

[7] Speciated TPH not conducted for MW2, MW9, MW18, MW32, MW42, MW44.

[8] Metals limited to arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc.



### 8.2.1. Aquifer Testing (Rising-Head Tests)

Rising-head (slug) tests were performed on five monitoring wells within the remediated material to supplement test data collected on the existing monitoring wells during the intra remediation GME conducted in December 2014 and October 2015. Additional post-remediation testing was performed on 10 monitoring wells as part of the January – February 2018 GME. This data is included in the hydrogeology section of this report (Section 4.3.6), and the outputs attached in Appendix E.

The test involved use of electronic level logger that was programmed to continuously record groundwater drawdown and recovery in the bore at 1 second intervals.

Initial, mid-test and final groundwater levels were measured manually using an electronic water level meter to establish initial conditions within the well, and to validate the recorded logger data. New disposable bailers and cord were used to remove the slug of water for each test, to prevent cross contamination between wells. Non-disposable loggers and electronic water level meter were decontaminated between wells.

### 8.2.2. Groundwater Sampling Methodology

The groundwater sampling undertaken was in accordance with the principles provided in the Victorian EPA publication 669 – *Groundwater Sampling Guidelines (2000).*

Samples were collected in laboratory provided sample containers (including preservatives as required) via "low flow' sampling techniques. Specifically, a QED© micro purge pump was used with disposable bladders and tubing.

During sampling:

- Groundwater samples were collected from the midpoint of the wetted groundwater monitoring well screens via low-flow sampling techniques after groundwater quality parameters stabilised and to ensure that the sample collected was representative of groundwater within the target aquifer zone
- In July 2016, stratified sampling was also conducted with the samples collected from the top middle and base of the screened intervals, in monitoring wells MW31, MW33 and MW35 to investigate the vertical dispersion of petroleum hydrocarbons.
- The groundwater monitoring wells were gauged for depth to LNAPL (where present), standing water level and total well depth. Gauging data was acquired using an oil/water interface probe and visual confirmation and observations of LNAPL were made using a bailer.
- Physico-chemical water quality parameters (electrical conductivity, pH, redox potential, dissolved oxygen, and temperature) were monitored via a calibrated field water quality meter and flow through cell during purging. These have been recorded in Table 9, Appendix B.
- Sampling flow rates were monitored during sampling, such that drawdown during purging was limited to less than 10cm.
- All groundwater samples were collected in laboratory supplied, preserved and unpreserved sample bottles. Samples were chilled immediately, before being transported under chain of custody (COC) to Eurofins or ALS, NATA accredited laboratories for analysis

### 8.2.3. Surface Water Sampling

Surface water was sampled post remediation in January, June and October 2018.

**Table 8-3 - Summary of Post-remediation Surface Water Monitoring Events**

| Date | Locations | Analytes |
|---|---|---|
| **January/ February 2018** | SW01, SW02, SW03, SW04 (in creek along the southern and eastern site boundaries) | Metals, anions and cations, nitrogen forms, fluoride, TDS, TPH, BTEX, PAHs, PFAS |
| **June 2018** | SW05, SW06, SW07 (in creek south-east offsite) | anions and cations, nitrogen forms, TDS, PFAS |
| **October 2018** | SW01, SW02, SW03, SW04 (in creek along the southern and eastern site boundaries) | Metals, anions and cations, nitrogen forms, phosphate, fluoride, TDS, TPH, BTEX, PAHs, PFAS |

The surface water sampling undertaken was in accordance with the principles provided in the Victorian EPA publication 701 – *Sampling and Analysis of Waters, Wastewaters, Soils and Wastes* (2009) and Coffey Standard Operating Procedures (SOPs).

Surface water samples were collected from 100 mm below the surface, away from the bank, and away the bottom of creek to avoid disturbing sediment, using a telescopic sampling pole.

### 8.2.4. Additional Investigations

Following the identification of the potential for ammonia migration down gradient of the site post remediation, groundwater sampling in addition to that proposed in the SAQP was undertaken in May 2016. The sampling was focused on the western boundary and off-site between the Creek and One Mile Dam.

The sampling included: the following.

- Additional gauging and sampling of offsite monitoring well MW29, where highest ammonia concentrations were identified.
- Gauging and sampling of off-site monitoring wells MW31(2010) and MW32(2010).
- Analysis of groundwater samples for ammonia, nitrate, nitrite, total nitrogen, TKN, selected metals, major ions and natural attenuation parameters.

A limited groundwater sampling round was completed in August 2017, which focused on the following.

- Gauging of all on-site groundwater monitoring wells.
- Development and sampling of 7 groundwater monitoring wells (MW21, MW32, MW33, MW34, MW35, MW5 and MW9) along the western (up gradient) boundary, to assess concentrations of petroleum hydrocarbons along the Mobil-Caltex boundary.

Two additional GMEs were also completed in 2018, one early wet season GME (January-February) and one late dry season GME (October-November).

The GMEs were conducted consistent with the methodology outlined in Section 8.2.2, with the addition that at the start of the 2018 wet season GME, all wells were re-developed by removing a minimum of three well volumes, and/or bailed dry, using a disposable bailer, and allowed to recover and stabilise before sampling was undertaken.

The sampling included:

- Gauging of all on-site monitoring wells.
- Sampling all on-site monitoring wells during each GME.
- Sampling of four surface water samples (SW01, SW02, SW03 and SW04) along the alignment of the creek to the south and east of the site, during each GME (refer Figure 3, Appendix A).

Further, a supplementary investigation was conducted in May/June 2018 to identify the potential sources of PFAS contamination observed in groundwater at the site and in the downgradient creek during a GME conducted in the January/February 2018 (early wet season GME). The investigation included the following.

- Gauging of selected four wells, located on the south-eastern boundary (MW46, MW47, MW48 and MW49).
- Sampling of selected four wells using disposable bailers.
- Collection of four surface water samples, one at the surface water drain outlet (up gradient) and three along the alignment of creek to the south and east of the site (SW05, SW06 and SW07).

### 8.2.5. Sample Analysis

**Groundwater**

Groundwater samples were analysed for known COPC (as outlined in Section 6.2.2), standard geochemical parameters, and natural attenuation indicators, as summarised in **Table 8-2** and listed below.

- Benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN).
- Total recoverable hydrocarbons (TRH).
- Polycyclic aromatic hydrocarbons (PAH).
- Metals suite (antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, tin, vanadium and zinc).
- Total dissolved solids (TDS).
- Major cations and anions (sodium, potassium, calcium, magnesium, chloride, sulfate, carbonate, and bicarbonate).
- pH.
- Total organic carbon (TOC).
- Total phosphate.
- Fluoride.
- Nitrate and Nitrite as N and ammonia as N.

Selected wells in the most contaminated areas along up/down gradient boundaries and within the central part of the site were analysed for TPHCWG aromatic/aliphatic fractions to support health risk assessment.

**Surface water**

Surface water samples were analysed for the following COPC:

- BTEXN.
- TRH.
- PAH.
- Total metals suite (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc).
- TDS.
- Major cations and anions (sodium, potassium, calcium, magnesium, chloride, sulfate, carbonate, and bicarbonate),
- Nitrate, nitrite and ammonia as N.

**PFAS**

As part of the January-February 2018 and October-November 2018 GMEs, groundwater and surface water samples were analysed for PFAS on 11 selected monitoring wells (MW1, MW2, MW18, MW32, MW33, MW34, MW35, MW36, MW45, MW46, and MW48) and at four selected surface water locations (SW01, SW02, SW03 and SW04). During a supplementary investigation undertaken in June 2018, targeted samples collected from four monitoring wells ((MW46, MW47, MW48 and MW49) and at four surface water locations (SD01 (drain pit), SW05, SW06 and SW07) were analysed for PFAS.

# 9. Site Condition after Clean Up

The following section summarises the contamination status of soil and groundwater at the site post-clean-up.

The following key items are presented in this section, with additional detailed provided in the referenced appendices.

- Excavation validation results provided in Table 2 (Appendix B)
- Excavation validation location are presented in Figure 10 and 11a to e (Appendix A)
- Stockpile sampling, classification for re-use and or off-site disposal data is provided in Table 4, Appendix G and Appendix H respectively.
- Stockpile tracking as presented in Table 5, Appendix B and stockpile disposal as discussed in Section 7.4.
- Post remediation groundwater monitoring results are provided in Tables 8, 9 and 11 (Appendix B). A summary of pre-remediation groundwater data is provided in Table 10, Appendix B.
- Laboratory reports and COCs are provided in Appendix L (soil) and M (waters).

## 9.1. Post-Remediation Soil Conditions

Assessment of post remediation soil conditions at the site has been undertaken based on:

- Excavation validation results;
- Stockpile classification for re-use; and
- Additional test pitting in undisturbed portions of the site.

### 9.1.1. Excavation Validation Results

The excavations undertaken as part of the 2014 and 2015 soil remediation works, as well as the targeted impacts and any residual impacts remaining are summarised below in Table 9-1.

**Table 9-1 - Excavations Summary**

| Excavation ID | Site Area | Stage | Targeted Impacts | Residual Impacts |
|---|---|---|---|---|
| EX1 | North | Stage 1 | Former petroleum infrastructure | EX1_N2_1.1 Situated on the eastern site boundary (i.e. off-site) |
| EX2 | North | Stage 1 | Former petroleum infrastructure | EX2-NW5-0.5 and EX2-NW6-1.0. Situated on the western site boundary (i.e. off-site). See western boundary discussion below. |
| EX3 | North | Stage 1 | Stormwater pipe infrastructure, and validation failures and under stockpile validation areas | No |
| EX4 | North | Stage 2 | Material reburied in 2014 | No. |
| EX5 | South | Stage 2 | Former petroleum infrastructure | Multiple locations along the western boundary. See 'western boundary' discussion below. |
| EX6 | North | Stage 2 | Stormwater pipe infrastructure. | No |

| Excavation ID | Site Area | Stage | Targeted Impacts | Residual Impacts |
|---|---|---|---|---|
| EX7 | North | Stage 2 | Groundwater seepage impacts along western Boundary | See 'western boundary' discussion below. |
| EX8 | South | Stage 2 | Material reburied in 2014 | No |
| EX9 | North | Stage 2 | Material reburied in 2014 | No |
| EX10 | North | Stage 2 | Stormwater pipe infrastructure – extension of EX6 | No |
| EX11 | South | Stage 2 | Validation failures and under stockpile validation areas | No |

Based on the results of the soil validation assessment, all known soil impacted above the site-specific criteria on-site was excavated from the site, with the following exceptions.

- TPH impact at location EX1_N2_1.1, on the eastern boundary of the site. This exceedance was not removed as this location exists at the property title boundary (remediation / excavation works have not extended beyond the property boundary in this area).
- TPH impacts at location EX2-NW5-0.5 and EX2-NW6-1.0, on the western boundary of the site. These exceedances were not removed as this location exists at the property boundary (remediation / excavation works have not extended beyond the property boundary in this area).
- TPH impacts at location EX2-NW29-1.2, near the western boundary of the site. This validation sample was located in soil located just above rock. Additional excavation works were conducted to remove all impacted material in this area. Consequently, no residual soil was available for confirmatory sampling (i.e. only rock remained at the excavation surface).

The potential implications of residual impacts noted above are addressed in the health risk assessment (Appendix R).

### 9.1.2. Western Boundary Impacts

During excavation and validation works undertaken in 2015, petroleum hydrocarbon impacts were identified at multiple locations along the site's western boundary (shared with the former Mobil Depot site). This section summarises conditions observed along the western boundary (i.e. off-site) which are considered to be the result of an up gradient contaminant source located at the Mobil site. Some excavation extents extended marginally into the adjacent property, as the fenceline was constructed within the former Mobil Depot site.

A summary of petroleum hydrocarbon impacted soil samples collected from along the western boundary is provided in Table 9-2. Figures 12a and 12b (Appendix A) show the location of TPH and Benzene exceedances along the western boundary of the site.

- Significant soil impacts along the western boundary were initially detected when hydrocarbon odours were observed in groundwater seeping from the western boundary in the vicinity of the historical fuel manifold (see Figure 2, Appendix A). This observation was made after validation works were conducted in the south west corner of EX2 during the 2014 remediation works. Observed contamination was considered to be potential re-contamination of the Caltex site originating from an upgradient source.
- Observed re-contaminated soils were excavated for remediation (EX7). Sampling and field observations (staining and odour) in EX7 confirmed the presence of petroleum impacted soil at the Mobil/Caltex site boundary.

- In response to the observations made in EX7, eleven test pits (called western test pits, WTP) were excavated along the western boundary to delineate the extent of impacted soils, and investigate the potential for the migration of petroleum hydrocarbons onto the Caltex site.

The contamination reported in the western test pits were confirmed by field observations, and analytical results along the western wall of EX5.The potential implications of the residual impacts are addressed in more detail in the Fate and Transport of Contaminants assessment and the HRA (Appendix P and R respectively)

**Table 9-2 - Western Boundary - Petroleum Hydrocarbon Impacted Soils Summary**

| Sample ID | TPH $C_{10}$-$C_{16}$ (minus Naphthalene) | TPH $C_{10}$-$C_{16}$ | Benzene | TPH $C_6$-$C_{10}$ (minus BTEX) |
|---|---|---|---|---|
| | (mg/kg) | (mg/kg) | (mg/kg) | (mg/kg) |
| EX2-NW5-0.5 | 1500[1] | 1500[2] | <0.1 | <20 |
| EX2-NW6-1.0 | 3600[1] | 3600[3] | <0.1 | <20 |
| EX5_W07_2.0 | 210[2] | 210[2] | <0.1 | 380[1] |
| EX5_W22_1.5 | 190[2] | 190[2] | <0.1 | <20 |
| EX5_W31_2.0 | 1000[2] | 1000[2] | <0.1 | *27* |
| EX5_W34_1.5 | 790[2] | 790[2] | <0.1 | 67[1] |
| EX5_W38_1.5 | 980[2] | 980[2] | <0.1 | <20 |
| EX5_W43_1.5 | 600[2] | 600[2] | <0.1 | <20 |
| EX5_W48_1.5 | 930[2] | 930[2] | <0.1 | <20 |
| EX5_W61_1.5 | 390[2] | 390[2] | <0.1 | <20 |
| EX5_W65_1.5 | 1600[2] | 1600[2] | <0.1 | <20 |
| EX5_W69_1.5 | 1100[2] | 1100[2] | <0.1 | <20 |
| EX5_W73_1.5 | 220[2] | 220[2] | <0.1 | <20 |
| EX5_W74_2.0 | 4200[2] | 4200[3] | <0.1 | *52* |
| EX5_W77_1.5 | 5600[2] | 5600[3] | <0.1 | *49* |
| EX5_W78_2.0 | 2000[2] | 2000[2] | <0.1 | *55* |
| EX5_W81_1.5 | 560[2] | 560[2] | <0.1 | <20 |
| EX5_W82_2.0 | 1900[2] | 1900[2] | <0.1 | <20 |
| EX5_W85_1.5 | 160[2] | 160[2] | <0.1 | <20 |
| EX5_W86_2.0 | 560[2] | 560[2] | <0.1 | <20 |
| EX5_W89_1.5 | 5100[2] | 5100[3] | <0.1 | *55* |
| EX5_W92_1.0 | 380[2] | 380[2] | <0.1 | <20 |
| EX5_W93_1.5 | 770[2] | 770[2] | <0.1 | *53* |

| Sample ID | TPH $C_{10}$-$C_{16}$ (minus Naphthalene) | TPH $C_{10}$-$C_{16}$ | Benzene | TPH $C_{6}$-$C_{10}$ (minus BTEX) |
|---|---|---|---|---|
| | (mg/kg) | (mg/kg) | (mg/kg) | (mg/kg) |
| EX5_W94_2.0 | 1800[2] | 1800[2] | <0.1 | *58* |
| EX7_B01_2.0 | 670[2] | 670[2] | <0.1 | 220[1] |
| EX7_S02_1.8 | 120[2] | 120[2] | <0.1 | *48* |
| EX7_W02_2.0 | 890[2] | 890[2] | <0.1 | *78* |
| WTP02_B01_2.0 | 400[2] | 400[2] | <0.1 | <20 |
| WTP02_W03_1.5 | 720[2] | 720[2] | <0.1 | <20 |
| WTP02_W04_2.0 | 3300[2] | 3300[2] | <0.1 | 68 |
| WTP03_B01_2.0 | 2400[2] | 2400[2] | 7.1[1] | 850[1] |
| WTP03_W03_1.5 | 980[2] | 980[2] | *0.6* | 130[1] |
| WTP03_W04_2.0 | 5800[2] | 5800[2] | 29[1] | 1500[1] |
| WTP-06_2.0 | 140[2] | 140[2] | <0.1 | *71* |
| WTP-07_2.0 | 440[2] | 440[2] | <0.1 | 120[1] |
| WTP-08_2.0 | 640[2] | 640[2] | <0.1 | *38* |
| WTP-08_2.4 | *1000* | *1000* | <0.1 | *160[1]* |
| WTP-09_2.0 | 240[2] | 240[2] | <0.1 | *25* |
| WTP-11_2.0 | 390[2] | 390[2] | <0.1 | <20 |

1 – Exceed NEPM 2013 Residential Soil HSL A/B for Vapour Intrusion

2 – Exceed NEPM ESL Urban residential and public open space, fine soil

3 – Exceed NEPM 2013 Residential Soil HSL-A Residential (Low Density) Direct Contact

Shaded cells – Non exceedance based on depth of sample

### 9.1.3. Stockpile Classification

Following validation, all excavations were backfilled with stockpiled remediated soil, consistent with the methodology outlined in Section 7.3.

The source, re-use classification and final destination of each stockpile generated at the site is summarised in Table 9-3. Additional detail (including stockpile volumes) is presented in Tables 4 and 5, Appendix B, which present the basis of classification and the material movement tracking. Individual stockpile classification sample results, and, where applicable, ProUCL 95% UCL calculations/outputs are provided in Appendix G.

**Table 9-3 - Stockpile Reuse Classification Summary**

| Stockpile ID | Source | Stockpile Grouping | Classification | Classification Methodology | Fate of Soil |
|---|---|---|---|---|---|
| **Stockpiles Grouped for Classification** | | | | | |
| TSP-01 | EX1 & USP-23 | Group 1 | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | EX2 |
| TSP-18 | EX2 | | | | |
| TSP-19 | EX2 | | | | |
| TSP-20 | EX2 | | | | |
| TSP-24 | EX2 | | | | |
| TSP-29 | EX2 | | | | |
| TSP-05 | EX2 | Group 2 | Below 1 m | TPH concentrations < HSL<br>TPH 95% UCL < 1.5 x ESL | EX2 (Below 2 m) |
| TSP-08 | EX2 & USP-07 | | | | |
| TSP-09 | EX2 | | | | |
| TSP-12 | EX2 | | | | |
| TSP-13 | EX2 | | | | |
| TSP-15 | EX2 | Group 3 | Below 1 m | TPH 95% UCL < HSL<br>TPH 95% UCL < 1.5 x ESL | EX2 (Below 1 m) |
| TSP-16 | EX2 | | | | |
| TSP-17 | EX2 | | | | |
| TSP-25 | EX2 | | | | |
| TSP-30 | EX2 | | | | |
| TSP-03 | EX2 | Group 4 | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations< ESL | EX2 |
| TSP-04 | EX2 | | | | |
| TSP-06 | EX2 & USP-07 | | | | |
| TSP-14 | EX2 | | | | |
| TSP-27 | EX2 | Group 5 | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | EX2 |
| TSP-28 | XE2 | | | | |

| Stockpile ID | Source | Stockpile Grouping | Classification | Classification Methodology | Fate of Soil |
|---|---|---|---|---|---|
| TSP-10 | EX2 | Group 6 | Below 2 m | TPH 95% UCL > HSL<br>TPH 95% UCL > ESL<br>TPH ASLP > GIL1 | EX2 (Below 2 m) |
| TSP-21 | EX1 | | | | |
| TSP-41 | EX6 | Group 7 | Below 1 m | TPH concentrations < HSL<br>TPH concentrations < ESL | EX6 (Below 1 m) |
| TSP-49 | EX6 | | | | |
| TSP-50 | EX7 | Group 8 | Unrestricted use | TPH concentrations < HSL<br>TPH 95% UCL< ESL' | EX7 |
| TSP-56 | EX5 | | | | EX5 |
| TSP-42 | EX5 & USP-44 | Group 9 | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | EX5 |
| TSP-45 | EX5 | | | | |
| TSP-52 | EX5 | | | | |
| **Individually Classified Stockpiles** | | | | | |
| TSP-34 | EX8<br>(Material from 2014) | Treated soil retained in-situ for ongoing treatment over the 2014-2015 wet seasons in EX8. | Unrestricted use | TPH concentrations < HSL<br>TPH 95% UCL< ESL | EX8 |
| TSP-37 | EX4<br>(Material from 2014) | Treated soil retained in-situ for ongoing treatment over the 2014-2015 wet seasons in EX4 | Unrestricted use | TPH concentrations < HSL<br>TPH 95% UCL< ESL | EX4, EX9 and haul roads |
| USP-38 | EX5 | - | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | EX5 |
| TSP-39 | EX5 | - | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | EX5 |

| Stockpile ID | Source | Stockpile Grouping | Classification | Classification Methodology | Fate of Soil |
|---|---|---|---|---|---|
| **TSP-40** | EX6 | - | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | EX5 |
| **TSP-43** | EX5 | - | Unrestricted use | TPH concentrations < HSL<br>TPH 95% UCL< ESL | EX5 |
| **TSP-46** | EX5 & USP-47 | - | Unrestricted use | TPH concentrations < HSL<br>TPH 95% UCL< ESL\ | EX5 |
| **TSP-48** | EX4 & EX5 | - | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | Site contouring (surface) |
| **TSP-51** | EX6 | - | Unrestricted use | TPH concentrations < HSL<br>TPH 95% UCL< ESL | EX6 |
| **TSP-53** | EX5 | - | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | EX5 |
| **TSP-54** | EX5 | - | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | EX5 |
| **TSP-57** | EX6 | - | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | EX6 |
| **TSP-58** | USP-55 | - | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | EX5 |
| **TSP-59** | USP-55 | - | Unrestricted use | TPH concentrations < HSL<br>TPH 95% UCL< ESL | EX5 |
| **TSP-60** | USP-55 & EX5 | - | Reuse below 2 m | TPH 95% UCL > HSL<br>TPH 95% UCL > ESL<br>TPH ASLP > GIL | EX5 (below 2m) |
| **TSP-61** | USP-60 | - | Reuse below 1 m | TPH 95% UCL < HSL<br>TPH 95% UCL < 1.5 x ESL | EX5 (below 1m) |

| Stockpile ID | Source | Stockpile Grouping | Classification | Classification Methodology | Fate of Soil |
|---|---|---|---|---|---|
| **TSP-62** | EX10 | - | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | EX10 and site contouring (surface) |
| **Stockpiles amalgamated with; or split into; smaller stockpiles prior to treatment and classification** | | | | | |
| **USP-02** | EX1 & EX2 | - | Unrestricted use | TPH concentrations < HSL<br>TPH concentrations < ESL | Used to cap material re-buried over the 2014 wet season. |
| **USP-07** | EX2 | - | - | - | USP-06 & USP-08 |
| **USP-11** | EX2 | - | - | - | USP-31 |
| **USP-23** | EX2 | - | - | - | USP-01 |
| **TSP-31** | EX2 & USP-11 | - | - | - | Treated soil retained in-situ for ongoing treatment over the 2014-2015 wet seasons in EX8. |
| **TSP-32** | EX3, TSP-11 & TSP-31 | | | | |
| **TSP-33** | EX3 | | | | |
| **TSP-26** | Under south haul road | | | | |
| **USP-35** | EX2 | | | | USP-02 |
| **USP-44** | EX5 | - | - | - | USP-42 |
| **USP-47** | EX5 | - | - | - | USP-46 |
| **USP-55** | EX5 | - | - | - | USP-58, USP-59, USP-60 |
| **Stockpiles Disposed of Off-site** | | | | | |
| **OSP-22** | EX2 (buried waste material) | | IWRG621 - Fill | Contaminant concentrations > IWRG621 Fill criteria<br>Copper 95% UCL > IWRG621 Fill criteria | Off-site disposal as Fill |
| **SP-36** | Sub set of OSP-22 | | IWRG621 - Fill | Contaminant concentrations > IWRG621 Fill criteria<br>Copper 95% UCL > IWRG621 Fill criteria | OSP-22 |

| Stockpile ID | Source | Stockpile Grouping | Classification | Classification Methodology | Fate of Soil |
|---|---|---|---|---|---|
| **TSP-57B** | EX6 (fill / overburden containing building debris | | Contained ACM | Laboratory analysis positive for ACM | Off-site disposal as ACM |

1 – ASLP analyses were <LOR for all analytes (see Table 3, Appendix B)

## 9.2. Post-Remediation Groundwater Conditions

### 9.2.1. Post-remediation Groundwater Investigations

This section describes the observations and results of the post-remediation groundwater assessments.

**Table 9-4 - Summary of Post-remediation Groundwater Assessment Rationale**

| Date | Rationale |
|---|---|
| **2015 dry season (November 2015)** | Assessment of post-remediation groundwater conditions. |
| **2015-2016 wet season (January 2016)** | Assessment of post-remediation groundwater conditions. |
| **2015-2016 wet season (April 2016);** | Assessment of post-remediation groundwater conditions. (including TPH CWG analysis of groundwater from select wells. |
| **May 2016** | Additional gauging and sampling to support assessment of the potential for off-site migration of ammonia. |
| **June 2016** | Assessment of post-remediation groundwater conditions. |
| **July 2017** | Assessment of groundwater conditions along the western site boundary. |
| **January 2018** | Assessment of post-remediation groundwater conditions, including the assessment of PFAS impact. |
| **October 2018** | Assessment of post-remediation groundwater conditions, including the assessment of PFAS impact. |

### 9.2.2. Field Observations

A summary of depth to water, apparent flow direction, pH and temperature from the post-remediation monitoring events is provided in Table 9-5 below. Other field parameters varied significantly across the site and are not well described by a site range. The location specific data is presented in Table 8 and 9, Appendix B.

The maximum and minimum salinity (TDS) is presented in Figure 7, Appendix A and shows that most of the site represented low salinity groundwater. A region of higher salinity was present off-site to the east of the centre of the site.

Inferred groundwater surface contours are presented in Figures 8a to 8g.

**Table 9-5 - Groundwater Field Observations**

| Item | Monitoring Event | | | | | | |
|---|---|---|---|---|---|---|---|
| | Nov-15 | Jan-16 | Apr-16 | Jul-16 | Aug -17 | Jan-18 | Oct-18 |
| **Water level (mBGS)** | 0.24 - 2.31 (1.37) | -0.40 – 1.13 (0.31) | -0.25 – 1.25 (0.51) | 0.10 – 1.562 (1.03) | 0.28 – 1.803 (1.271) | -0.69 – 0.90 (0.04) | 0.254 – 2.063 (1.243) |
| **Water level (mAHD)** | 4.56 – 6.26 (5.24) | 5.18 – 7.87 (6.47) | 4.88 – 7.52 (6.35) | 4.62 – 6.56 (5.73) | 4.08 – 6.38 (5.63) | 5.41 – 8.30 (6.65) | 4.851 – 6.523 (5.429) |
| **Flow direction** | Generally to the east. Flow in the south is to north east, Flow in the north is south east. | Generally to the east. Flow in the south is to the north east. | Generally to the east. Flow in the south is to north east. | | | Generally to the east. Flow in the south is to north east. | Generally to the east. Flow in the south is to north east. |
| **pH** | 4.85 – 6.8 (5.80) | 4.58 – 7.26 (5.76) | 4.61 – 7.53 (6.22) | 4.68 – 6.87 (6.03) | 5.11 – 6.47 (5.93) | 4.58 – 6.37 (5.70) | 4.0 – 6.6 (5.7) |
| **Temperature (˚C)** | 29.9 – 37.9 (32.1) | 28.6 – 35.8 (31.5) | 30.5 – 38.1 (34.6) | 25.9 – 38.8 (31.9) | 29.90 – 32.10 (31.20) | 27.80 – 33.60 (30.60) | 29.1 – 38.8 (31.8) |

Note: minimum – maximum and (median) values provided

# 9.2.3. Summary of Post Remediation Groundwater Results

Post-remediation groundwater analytical results are presented in Table 11 (Appendix B).

Figures 13b, 13c, 14b and 15 (Appendix A) also summarise concentrations of $TPHC_{10}$-$C_{36}$; TPH $C_{10}$-$C_{16}$ and $C_{16}$-$C_{34}$; benzene and ethylbenzene; and ammonia respectively, at the site post-remediation. Pre-remediation concentrations of $TPHC_{10}$-$C_{36}$; and benzene and ethylbenzene are presented on Figure 13a and 14a respectively. No pre-remediation ammonia data existed for the site, therefore Figure 15 only presents maximum and minimum post-remediation values for ammonia.

**Table 9-6** below summarises exceedances of the adopted groundwater criteria at the site since 2017. Results of monitoring events in 2015 and 2016 post-remediation are included in Table 11, Appendix B, but have not been included in the range of results below, due to the availability of several rounds of more recent results.

**Table 9-6 - Summary of Criteria Exceedances - Post-remediation**

| Beneficial Use | Compound (criteria value) | Locations exceeding adopted criteria | Concentration Range |
|---|---|---|---|
| Maintenance of Ecosystems | Ammonia as N (2,490 µg/L) | **MW23**, MW24, MW29, | <10 – 6,000 µg/L |
| | Arsenic (Filtered) (0.001mg/L) | MW2, MW5, **MW23**, MW29, **MW31**, MW9, MW34, MW24, **MW42**, MW45, | <0.001 – 0.42 mg/L |
| | Boron (0.37 mg/L) | MW24, **MW18**, MW41D | <0.05 – 0.46 mg/L |
| | Cadmium (0.00054 mg/L) | MW46 | <0.0002 – 0.0007 mg/L |
| | Chromium (Filtered) (0.001 mg/L) | MW45 | <0.001 – 0.017 mg/L |
| | Cobalt (Filtered) (0.0014mg/L) | MW32, MW42, MW43, MW44, MW33, MW41S, MW41D, MW34, **MW40**, MW35, MW38S, MW38D, MW36, MW24, MW2, | <0.001 – 0.009 mg/L |
| | Copper (0.0035 mg/L) | MW42, MW44, MW40, MW41S, MW49, MW43, MW33, MW2, MW34, | <0.001 – 0.013 mg/L |
| | Iron (Filtered) (0.03 mg/L) | MW9, MW24, **MW1**, **MW2**, **MW31**, **MW32**, **MW42**, **MW43**, **MW44**, MW45, **MW5**, **MW18**, **MW33**, **MW41S**, **MW23**, MW29, **MW34**, MW40, **MW35**, MW38S, **MW46**, **MW47**, MW49 | <0.005 – 42 mg/L |
| | Nickel (0.0275 mg/L) | MW31, MW32, MW42, MW44, **MW41S**, MW35, **MW38D**, MW40, MW31, MW33, MW35, MW34, MW36, MW39, MW2, **MW43**, MW45, MW18, MW38S | <0.001 – 0.095 mg/L |
| | Zinc (0.02 mg/L) | MW1, **MW2**, **MW5**, **MW18**, **MW23**, MW29, **MW31**, **MW32**, **MW33**, **MW34**, **MW35**, **MW36**, **MW37**, **MW38D**, **MW38S**, MW39, **MW40**, **MW41D**, **MW41S**, MW42, **MW43**, **MW44**, MW45, MW46, MW47, **MW48**, **MW49** | 0.005 – 0.26 mg/L |

| Beneficial Use | Compound (criteria value) | Locations exceeding adopted criteria | Concentration Range |
|---|---|---|---|
| | TPH $C_{10}$-$C_{36}$ (Sum of total) (600 µg/L) | MW31 | <100 – 2,000 µg/L |
| | Perfluoro-n-octane sulfonic acid (PFOS) (0.00023 µg/L) | MW1, MW2, MW18, MW32, MW33, MW34, MW35, MW36, MW45, MW46, MW48, | 0.007 – 0.61 µg/L |
| Potable Water Supply | Ammonia as N (412[a] µg/L) | MW9, **MW18**, **MW23**, MW24, MW29, MW31 (2010), MW32 (2010), MW35, MW43, **MW45**, MW46 | <10 – 6,000 µg/L |
| | Chloride (250[a] mg/L) | MW24, MW29 MW31, MW31 (2010), MW32, MW32 (2010), **MW41D**, **MW41S**, MW45, | 10 – 3,100 mg/L |
| | pH (6.5 – 8.5[a]) | MW42, MW44, MW30, MW36, MW49, MW2, MW33, MW34, MW1, MW37, MW41S, MW41D, MW48, MW46, | 5.1 – 8.4 |
| | Sodium (180[a] mg/L) | MW24, MW29, MW31, MW31 (2010), MW32, MW32 (2010) **MW41D**, **MW41S**, **MW45** | 5.9 – 430 mg/L |
| | Sulfate as S (83.5[a] mg/L) | MW31 (2010) | <5 – 150 mg/L |
| | TDS (600[a] mg/L) | MW5, MW9, MW24, MW29, MW31, MW31 (2010), MW32, MW32 (2010), **MW41D**, **MW41S**, MW42, MW45, MW46 | 31 – 5,700 mg/L |
| | Arsenic (0.01 mg/L) | MW2, MW5, **MW23**, MW29, **MW31**, MW9, MW34, MW24, **MW42**, MW45, MW32 | <0.001 – 0.42 mg/L |
| | Cobalt (0.006 mg/L) | MW32, MW 42, MW44, Mw33, MW41S, | <0.001 – 0.063 mg/L |
| | Iron (0.3[a] mg/L) | MW9, MW24, **MW1**, **MW2**, **MW31**, **MW32**, **MW42**, **MW43**, **MW44**, MW45, **MW5**, **MW18**, **MW33**, **MW41S**, **MW23**, MW29, **MW34**, MW40, **MW35**, MW38S, **MW46**, **MW47**, MW49 | <0.05 – 46 mg/L |
| | Manganese (0.01[a] mg/L) | MW5, MW18, **MW23**, MW31, MW32, MW33, MW35, MW38D, MW38S, MW40, **MW41D**, MW41S, **MW42**, MW43, MW44 | 0.01 – 0.45 mg /L |
| | Nickel (0.02 mg/L) | **MW1**, MW2, MW5, MW18, MW23, MW31, MW32, MW33, **MW34**, **MW35**, MW36, **MW38D**, **MW38S**, MW39, MW40, **MW41D**, **MW41S**, **MW42**, **MW43**, MW44, MW48 | <0.001 – 0.52 mg/L |
| | Aromatic >C10-C12 (0.1 mg/L) | MW35 | <0.05 – 0.16 mg/L |
| | TRH >C12-C16 Aromatic (0.1 mg/L) | MW35 | <0.05 – 0.2 mg/L |
| | TRH >C12-C16 Aliphatic (0.3 mg/L) | MW31 | <0.1 – 0.2 mg/L |
| | TRH >C16-C21 Aromatic (0.09mg/L) | MW31 | <0.1 – 0.3 mg/L |
| | Benzene (1 µg/L) | MW5, MW33 | <1 – 56 µg/L |

| Beneficial Use | Compound (criteria value) | Locations exceeding adopted criteria | Concentration Range |
|---|---|---|---|
| | Ethylbenzene (3[a] µg/L) | MW33 | <1 – 10 µg/L |
| | C10-C16 (100 µg/L) | MW31, **MW35**, | <50 – 1000 µg/L |
| | C16-C34 (90 µg/L) | MW9, MW31, MW29, **MW35**, | <100 – 1100 µg/L |
| | PFH$_x$S + PFOS (0.07 µg/L) | MW1, MW32, MW33 MW34, MW35, MW46, MW45, | <0.01 – 0.93 µg/L |
| Agriculture and Irrigation (irrigation) | Chloride (175 mg/L) | MW24, MW23, MW32, MW32, MW42, **MW18**, MW5, **MW41S**, **MW41D**, MW29, MW45, **MW31**, MW31 (2010), MW32 (2010), MW46 | 10 – 3100 mg/L |
| | Alkalinity (total) as CaCO3 (60 mg/L) | MW1, MW38D, MW38S, MW41S, MW41D, MW35, MW39, MW5, MW23, MW45, MW46, MW2, MW9, MW31, MW32, MW18, MW42, MW46, MW34, | <20 – 220 mg/L |
| | Sodium (115 mg/L) | MW5, MW18, MW24, MW29, MW31**,** MW31 (2010)**,** MW32, MW32 (2010) **MW41D**, **MW41S**, **MW45,** MW46, | 5.9 – 430 mg/L |
| | Boron (0.5 mg/L) | **MW18, MW31 (2010)** | <0.05 – 0.75 mg/L |
| | Iron (10 mg/L) | **MW1**, MW2, MW5, MW9, **MW23**, MW24, MW29, MW30, MW31 (2010) **MW31**, MW32, MW32 (2010), MW33, MW35, **MW46**, **MW47** | <0.05 – 46 mg/L |
| | C10-C16 (100 µg/L) | MW31, **MW35**, | <50 – 1000 µg/L |
| | C16-C34 (900 µg/L) | MW31 | <100 – 1100 µg/L |
| | Benzene (1 µg/L) | MW5, **MW33** | <1 – 52 µg/L |
| | PFH$_x$S + PFOS (0.7 µg/L) | MW33 MW34, MW46, | <0.01 – 0.93 µg/L |
| Agriculture and Irrigation (Stock Watering) | Ammonia as N (1500 mg/L) | MW9, **MW23**, MW24, MW29, | <10 – 6,000 µg/L |
| | Chloride (175 mg/L) | MW24, MW23, MW32, MW32, MW42, **MW18**, MW5, **MW41S**, **MW41D**, MW29, MW45, **MW31**, MW31 (2010), MW32 (2010), MW46 | 10 – 3100 mg/L |
| | Sodium (115 mg/L) | MW5, MW18, MW24, MW29, MW31**,** MW31 (2010)**,** MW32, MW32 (2010) **MW41D**, **MW41S**, **MW45,** MW46, | 5.9 – 430 mg/L |
| | Iron (14 mg/L) | **MW1**, MW2, MW9, **MW23**, MW24, MW29, MW30, MW31 (2010) **MW31**, MW32, MW32 (2010), MW35, **MW46**, **MW47** | <0.05 – 46 mg/L |
| | C10-C16 (100 µg/L) | MW31, **MW35**, | <50 – 1000 µg/L |
| | C16-C34 (90 µg/L) | MW9, MW31, MW29, **MW35**, | C16-C34 (90 µg/L) |

| Beneficial Use | Compound (criteria value) | Locations exceeding adopted criteria | Concentration Range |
|---|---|---|---|
| | Benzene (1 µg/L) | MW5, **MW33** | <1 – 52 µg/L |
| | PFHxS + PFOS (0.07 µg/L) | MW1, MW32, MW33 MW34, MW35, MW46, MW45, | <0.01 – 0.93 µg/L |
| Primary Contact and Recreation | Ammonia as N (412[a] µg/L) | MW9, **MW18**, **MW23**, MW24, MW29, MW31 (2010), MW32 (2010), MW35, MW43, **MW45**, MW46 | <10 – 6,000 µg/L |
| | Chloride (250[a] mg/L) | MW24, MW29 MW31, MW31 (2010), MW32, MW32 (2010), **MW41D**, **MW41S**, MW45, | 10 – 3,100 mg/L |
| | pH (6.5 – 8.5[a]) | MW42, MW44, MW30, MW36, MW49, MW2, MW33, MW34, MW1, MW37, MW41S, MW41D, MW48, MW46, | 5.1 – 8.4 |
| | TDS (600[a] mg/L) | MW5, MW9, MW24, MW29, MW31, MW31 (2010), MW32, MW32 (2010), **MW41D**, **MW41S**, MW42, MW45, MW46 | 31 – 5,700 mg/L |
| | Sodium (180[a] mg/L) | MW24, MW29, MW31, MW31 (2010), MW32, MW32 (2010) **MW41D**, **MW41S**, **MW45** | 5.9 – 430 mg/L |
| | Sulfate as S (83.5[a] mg/L) | MW31 (2010) | <5 – 150 mg/L |
| | Arsenic (0.1 mg/L) | MW29 | <0.001 – 0.42 mg/L |
| | Iron (0.3[a] mg/L) | MW9, MW24, **MW1**, **MW2**, **MW31**, **MW32**, **MW42**, **MW43**, **MW44**, MW45, **MW5**, **MW18**, **MW33**, **MW41S**, **MW23**, MW29, **MW34**, MW40, **MW35**, MW38S, **MW46**, **MW47**, MW49 | <0.05 – 46 mg/L |
| | Manganese (0.01[a] mg/L) | MW5, MW18, **MW23**, MW31, MW32, MW33, MW35, MW38D, MW38S, MW40, **MW41D**, MW41S, **MW42**, MW43, MW44 | 0.01 – 0.45 mg /L |
| | Nickel (Filtered) (0.2 mg/L) | MW41D | <0.001 – 0.52 mg/L |
| | Benzene (1 µg/L) | MW5, **MW33** | <1 – 52 µg/L |
| | PFHxS + PFOS (0.07 µg/L) | MW1, MW32, MW33 MW34, MW35, MW46, MW45, | <0.01 – 0.93 µg/L |
| Buildings and Structures | pH (<5.5.) | MW40 | 5.1 – 8.4 |

a - aesthetic criteria
**Bold** - indicates that an exceedance of the relevant screening value has been recorded post-remediation (i.e. 2015), in monitoring rounds for all years.

The potentially precluded beneficial uses of groundwater due to site-sourced pollution are discussed in detail in Section 12.

Concentrations of most metals, sodium, chloride, TDS, and pH reported above nominated groundwater assessment criteria at the site are considered to be naturally occurring background water quality, and not the result of anthropogenic pollution of groundwater at the site.

Concentrations of COPCs exceeding adopted criteria in groundwater post remediation, that are attributable to anthropogenic activity, include:

- Petroleum hydrocarbons; TPH (various fractions), benzene and ethylbenzene;
- Metals – Arsenic, Boron, Iron, Manganese; and
- Ammonia.

## 9.2.4. Impact to Beneficial Use of Groundwater

The beneficial uses of groundwater to be protected based on the Victorian groundwater classifications are summarised in Section 5.2. Exceedances of relevant criteria for each beneficial use are summarised in Table 9.5. A discussion of the impact to beneficial uses is presented below. This includes an assessment of the beneficial uses being realised at and near the site, within the extent of the dissolved phase plume. Additional discussion on the existing and likely future risk to receptors is provided in Section 12.

### Water Dependant Ecosystems and Species

Although some of the contaminant concentrations in groundwater summarised above exceed the adopted criteria for Maintenance of Ecosystems, impact to this beneficial use is determined at the point of discharge. The nearest surface water discharge point is the unnamed Creek along the eastern boundary in the wet season, and potentially the One Mile Dam. Based on the hydrogeological assessment. Discharge of groundwater to the Creek is considered unlikely as the groundwater levels are likely to be below the invert level of the creek during the dry season. Shallow water observed in the creek in the Dry Season (as discussed in Section 4.4) may be due to flows emerging from higher ground, upstream of the site. The Creek is unlikely to receive a significant contribution from groundwater during the wet season owing to extremely high dilution in wet season surface water flows (refer discussion in Section 4.3). This limits the potential for impacted groundwater to discharge into the creek. Both the TPH and ammonia plume are considered to be delineated to the east of the site by MW31(2010) and MW32(2010), therefore it is considered unlikely that this beneficial use would be precluded if groundwater was to discharge to One Mile Dam.

### Potable Water Supply

Concentrations of petroleum hydrocarbons and ammonia (aesthetics) exceed the criteria for potable water supply. However, this beneficial use is also precluded by the presence of naturally occurring background metals concentrations, and the variable TDS (and associated sodium and chloride concentrations) found in groundwater at the site.

Given the presence of reticulated water in the area and the likely low yield from the mostly clayey soils, it is considered unlikely that the beneficial use of groundwater for drinking water would be realised on or off-site.

### Agricultural and Irrigation and (Stock Watering) and Water Based Recreation (Primary Contact Recreation)

Concentrations of metals and ammonia (aesthetic only) exceed the applicable beneficial uses. As naturally-occurring metals at their respective background concentrations also preclude these beneficial uses, groundwater at the site is considered to be generally unsuitable for these uses, irrespective on any anthropogenic contamination. The availability of a reticulated water supply in the area indicate these beneficial uses are unlikely to ever be realised.

## Industrial and Commercial

As groundwater guidelines for industrial water use are highly specific to the type of process, guideline values for industrial water use have not been included in this assessment. As the beneficial use 'Primary Contact Recreation' may be precluded, it is considered that 'Industrial Water Use' may also be precluded. However, it is considered that extractive industrial water use is unlikely to be realised that the site given the light commercial and residential setting in the surrounding areas.

## Buildings and Structures

In accordance with Table 6.4.2(C) in AS2159-2009 (Piling Design and Installation) the groundwater at the site is considered to be "non-aggressive", and thus it is considered that structures/buildings are unlikely to be adversely affected by the quality of groundwater at the site. This is based on the sulfate concentrations (as $SO_4^{2-}$) in groundwater all being below 1,000 mg/L, the groundwater pH being above 5.0 pH units and the fact that site has moderate permeability soils (based on site specific soil property testing), which reduces the corrosion potential compared to high permeability setiings.

## Human Health

The presence of volatile hydrocarbons above the adopted health screening levels for vapour intrusion, means there is potential for the health of humans within buildings to be impacted by contaminated groundwater beneath the site without management measures, which is further discussed in Section 12.3.

**Table 9-7 - Likelihood of Beneficial Uses Being Realised**

| Beneficial Uses | Likelihood of Groundwater Use | |
|---|---|---|
| | On-Site | Off-Site |
| Maintenance of Ecosystems | **Unlikely –** Given the current and proposed Land Use and absence of on-site surface water body | **Potential** – the adjacent creek may receive some groundwater during the wet season, and groundwater may discharge to One Mile Dam. |
| Agriculture, Parks and Gardens | **Unlikely –** Given the current and proposed land use. | **Unlikely** – Given the ready availability of a higher quality, lower cost reticulated town water supply. |
| Stock Watering | **Unlikely** – Given the location of the site within a residential, commercial, industrial area. | **Unlikely –** Given the increasingly residential/urban land use of the surrounding area. |
| Industrial Water Use | **Unlikely** – Given the ready availability of a higher quality, lower cost reticulated town water supply. | **Unlikely** – Given the ready availability of a higher quality, lower cost reticulated town water supply. |
| Primary Contact Recreation | **Unlikely** – Given the current and proposed land Use | **Potential** – One Mile Dam is reportedly used for recreational purposes, however based on the current extent of impact, the dam is expected to be unaffected. |
| Buildings & Structures | **Unlikely** – Groundwater at the site indicates pH conditions >5, and low sulfate concentrations. | **Unlikely** – Groundwater at the site indicates pH conditions >5, and low sulfate concentrations. |

# 9.3. Post-Remediation Surface Water Conditions

## 9.3.1. Post-remediation Surface Water Investigations

The surface water monitoring was included as part of the 2018 GMEs (January/February 2018 and October/November 2018) in response to the queries raised from the Northern Territory Environmental Protection Authority (NTEPA) related to potential for PFAS as a COPC at the site. The monitoring was conducted over eleven months in three rounds, including one supplementary investigation (June 2018), to investigate associated impacts in adjacent surface water. The following sections discuss the results of monitoring undertaken along the alignment of the creek to the south and east of the site, during each of the 2018 monitoring events.

## 9.3.2. Field Observations

A summary of field observations from the monitoring events is provided in **Table 9-8** below.

**Table 9-8 – Surface Water Field Observations**

| Items | Monitoring events | | |
|---|---|---|---|
| | Jan-18 | June-18 | Oct-18 |
| **EC (µS/cm)** | 104.0 – 298.0 (207.0) | 360.9 – 557.8 (467.65) | 339.6 – 1031 (385.3) |
| **pH** | 5.77 – 6.95 (6.87) | 6.7 – 7.15 (6.99) | 6.15 – 8.51 (6.92) |
| **Temperature (˚C)** | 28.8 – 30.1 (30.0) | 26.09 – 32.0 (29.02) | 30.7 – 34.4 (33.2) |

Note: minimum – maximum and (median) values provided

## 9.3.3. Summary of Post-remediation Surface Water Results

Post-remediation surface water analytical results are presented in Table 13 (Appendix B). **Table 9-9** below summarises exceedances of the adopted surface water criteria along the alignment of creek.

**Table 9-9 - Summary of Criteria Exceedances – Post-remediation**

| Beneficial Use | Compound (criteria value) | Locations exceeding adopted criteria | Concentration Range |
|---|---|---|---|
| Maintenance of Ecosystems | Chromium (0.001 mg/L) | SW04 | <0.001 – 0.001 mg/L |
| | Copper (0.0039 mg/L) | SW01 | <0.001 – 0.005 mg/L |
| | Zinc (0.02 mg/L) | SW01, SW02, SW03 and SW04 | <0.005 – 0.089 mg/L |
| | PFOS (0.00023 ug/L) | SW01, SW02, SW03 and SW04 | 0.027 – 0.5 mg/L |
| Potable Water Supply | Ammonia as N* (412 ug/L) | SW03 | <10 – 490 mg/L |
| | Sulfate (83.5 mg/L) | SW01 | 6.6 – 85 mg/L |
| | Iron* (0.3 mg/L) | SW02, SW03 and SW04 | <0.05 – 7.6 mg/L |
| | PFHxS + PFOS (0.07 ug/L) | SD01, SW02, SW03, SW04, SW06 and SW07 | 0.035 – 0.64 ug/L |
| Agriculture and Irrigation | Alkalinity as CaCO3 (60 mg/L) | SW03, SW04 | 49 – 120 mg/L |
| | Manganese (0.2 mg/L) | SW02, SW03 | <0.005 – 0.30 mg/L |
| Human Consumption of Aquatic Food | Chromium (0.001 mg/L) | SW04 | <0.001 – 0.001 mg/L |
| | PFOS (0.00023 ug/L) | SW01, SW02, SW03 and SW04 | 0.027 – 0.5 mg/L |
| | Ammonia as N (412 mg/L) | SW03 | <10 – 490 mg/L |
| | Sulfate* (83.5 mg/L) | SW01 | 6.6 – 85 mg/L |

| Beneficial Use | Compound (criteria value) | Locations exceeding adopted criteria | Concentration Range |
|---|---|---|---|
| Primary Contact and Recreation | Iron* (0.3 mg/L) | SW02, SW03, SW04 | <0.05 – 7.6 mg/L |
| Buildings and Structures | None | - | - |
| Aquatic Ecosystem Protection of the Darwin Harbour Region | Total Nitrogen (0.23 mg/L) | SW01, SW02, SW03, SW04 | 0.3 – 0.9 mg/L |
| | Nitrogen oxides (0.008 mg/L) | SW01, SW02 | <0.05 – 0.76 mg/L |
| | Total Phosphorus (0.01 mg/L) | SW01, SW02, SW03, SW04 | 0.11 – 0.34 mg/L |
| | Reactive phosphate (0.005 mg/L) | SW03 | <0.05 – 0.08 mg/L |
| | Chromium (0.001 mg/L) | SW04 | <0.001 – 0.001 mg/L |
| | Copper (0.0039 mg/L) | SW01 | <0.001 – 0.005 mg/L |
| | Zinc (0.02 mg/L) | SW01, SW02, SW03 and SW04 | <0.005 – 0.089 mg/L |

*aesthetic criteria

Concentrations of most analytes (metals, nitrogen and phosphorus compounds) reported above nominated surface water assessment criteria are considered to be naturally occurring based on underlying geology and late dry conditions (i.e. lack of stream flows), with the exception of zinc and ammonia. PFAS compounds are also not naturally occurring.

Concentrations of zinc and PFAS compounds recorded along the alignment of the creek are attributable to two or more off-site run-off sources, and not the result of anthropogenic activities undertaken at the site. Only the ammonia concentration recorded above nominated criteria at SW03 is attributable to site source anthropogenic activities: the bioremediation process undertaken at the site to remove the primary contaminants of concern.

### 9.3.4. Impact to Beneficial Uses of Surface water

The beneficial uses of surface water to be protected based on the Victorian groundwater classifications are summarised in Section 5.3. Exceedances of relevant criteria for each beneficial use are summarised in Table 9-9. A discussion of the impact to beneficial uses is presented below. Additional discussion on the existing and likely future risk to receptors is provided in Section 12.

**Maintenance of Ecosystems**

Maintenance of Ecosystems is precluded on the basis of PFOS contamination in the surface water.

**Potable Water Supply**

Potable mineral water supply is precluded on the basis of ammonia, PFHxS and PFOS contamination in the surface water.

Given the presence of reticulated water in the area, it is considered unlikely that the beneficial use of surface water for drinking water would be realised on or off-site.

**Agriculture and Irrigation**

Agriculture and Irrigation is not precluded by manganese contamination in the surface water, due to its inferred natural occurrence from the underlying geology.

**Human Consumption of Aquatic Food**

Human Consumption of Aquatic Food is precluded by chromium contamination in the surface water. The source of this contamination is considered to be natural from the local geology.

**Primary Contact and Recreation**

Primary contact and recreation (PCR) is precluded on the basis of ammonia contamination in the surface water.

**Buildings and Structures**

Buildings and structures are not considered to be compromised by contamination identified in the surface water.

# 10. Data Validation

Coffey has completed a review of the QA steps and QC results for the current phase of works, according to the following documents.

- NEPC, National Environment Protection (Assessment of Site Contamination) Measure, National Environment Protection Council (2013).
- Standards Australia "AS4482.1: Guide to the Investigation and Sampling of Sites with Potentially Contaminated Soil; Part 1: Non-Volatile and Semi-Volatile Compounds" (2005).
- US EPA Guidance on Environmental Data Verification and Data Validation (2004); and
- US EPA Contract Laboratory Program for Organic (1994) Data Review;

This included examining sample representativeness, collection methods, holding times, laboratory accreditation, sample preservation methods, a review of field quality control sample results and a review of laboratory quality control sample results.

A more detailed analysis and discussion of the data quality is provided in Appendix N for soil assessment and Appendix O for groundwater and surface water assessment.

Coffey considers that the quality assurance procedures were appropriate and quality control results indicate acceptable data quality for the purposes of this assessment. That is, the data used can be considered representative of site conditions, at the points sampled.

# 11. Conceptual Site Model

A conceptual site model (CSM) has been developed using available information to determine plausible exposure pathways posing a risk to susceptible receptors/beneficial uses such as humans, ecosystems or the built environment. For a risk to exist, an exposure pathway must be present, which requires:

- The presence of substances that may cause harm (SOURCE);
- The presence of a receptor which may be harmed at an exposure point (RECEPTOR); and
- The existence of means of exposing a receptor to the source (EXPOSURE ROUTE).

In the absence of a plausible exposure pathway, there is no risk. Therefore, the presence of measurable concentrations of contaminants does not automatically imply that the site conditions will cause harm. The nature and importance of both receptors and exposure routes will vary according to a site's specific characteristics, intended end-use and environmental setting.

A diagrammatic representation of the hydrogeological CSM has been provided as Figure 6 (Appendix A) and a description and visual presentation of potentially complete pathways for human receptors are presented in the health risk assessment (Appendix R).

## 11.1. Contaminant Sources

All primary sources of contamination have been removed from the site.

Following completion of soil remediation works in 2015, some secondary sources of contamination from historical operations at and up gradient of the site remain in the form of residual petroleum hydrocarbon soil impacts. The most significant secondary source is petroleum hydrocarbon impacted soil that is present at and outside of the western boundary. The residual impact is predominantly present on the adjacent site (from historic activities undertaken on that site), and has some potential to contaminate groundwater as it moves towards the boundary of the subject site from the west. Post-remediation groundwater conditions in 2016 indicated some mobilisation of the residual impact, and low levels of dissolved phase petroleum impact appeared to have potentially migrated onto the subject site during the wet season whilst groundwater elevation was high. During groundwater monitoring events in 2017 and 2018, only trace levels of hydrocarbon contamination were reported intermittently at isolated wells.

A number of non-petroleum analytes have also been detected in groundwater and are considered to be COPCs that are associated with remedial activities undertaken at the subject site, or off-site sources. These include:

- **Ammonia:** Groundwater sampling conducted 'post remediation' identified concentrations of ammonia in groundwater along the eastern boundary (MW18, MW23, MW29, and MW45) and at MW35. In the case of the eastern boundary, the source of this ammonia may be a result of excess DAP within remediated soil, or may potentially be associated with the sewer along the eastern boundary. Ammonia at MW35 could also be a result of excess DAP within remediated soils, and or remediation works conducted at the Mobil site (upgradient), or as yet unidentified sources up gradient of the site.
- **Metals**: The mobilisation of naturally occurring metals including arsenic, iron and manganese. Although not a considered a COPC pre-remediation (elevated metals in groundwater at the site are considered naturally occurring, and therefore are not considered to constitute pollution at the site). Concerns that remediation works may have altered the geochemistry of groundwater at the site, allowing increased mobilisation of some metals, have also been investigated (refer Appendix P and Section 9.2).

- **PFAS**: In November 2017, additional concerns were raised by NT EPA relating to the potential for per- and poly-fluoroalkyl substances (PFAS) possibly sourced from the former Caltex Depot. Additional investigations were included in the program to determine the presence or absence of PFAS, the relative concentrations and compositions and likely source . Additional analysis was included during both the January-February 2018 and October-November 2018 GMEs, and a supplementary investigation undertaken in June 2018 to investigate the potential sources of PFAS. The available results indicated the presence of PFAS, and relative concentrations indicated up-gradient sources to groundwater and surface water. There was no indication of site-derived PFAS impact, or risk to beneficial use of the site (beyond extraction of groundwater for sensitive use).

### 11.1.1. Chemicals of Potential Concern (COPCs)

Contaminants of potential concern are selected on the basis of their presence in petroleum products, human toxicity, volatility, mobility and persistence. On this basis, BTEX compounds and naphthalene are considered to be the risk drivers at this site as they exhibit a relatively high potential for exposure of receptors and a relatively high toxicity. Consistent with the use of an indicator chemical approach to risk assessment, TPH fractions were also considered due to their prevalence at the site, exceedance of criteria and potential to cause adverse health impacts. TPH fractions with carbon chain-length above C16 exhibit limited volatilisation potential and therefore will only be considered as COPCs where direct contact with the contaminated media occurs.

Relevant COPCs are considered to be:

- Petroleum hydrocarbon:
  - BTEXN (benzene, toluene, ethylbenzene, xylenes, naphthalene);
  - TPH fraction C6-C10 less BTEX (F1)
  - TPH fraction >C10-C16 (F2);
  - TPH fraction >C16-C34 (F3), and
  - TPH fraction >C34-C40 (F4).
- Ammonia; and
- Metals (arsenic, cobalt, iron, manganese and nickel).

## 11.2. Receptors of Concern

Based on the proposed future site use and the existing surrounding land uses, receptors of concern located on-site and down-gradient from the site are considered to be:

- Future on-site residential occupants;
- Current off-site residential occupants at the One Mile Dam Community;
- On-site and off-site maintenance workers accessing or constructing sub-surface excavations, manholes and utilities;
- Users of extracted groundwater; and
- Recreational users and ecological receptors of the Creek and One Mile Dam.

## 11.3. Potential Transport Mechanisms and Exposure Routes

The primary transport mechanisms applicable to the migration of impact identified at site include:

- Leaching of soil impact into groundwater;
- Vapour migration from soil and/or groundwater for volatile contamination;
- Groundwater transport of dissolved phase contaminants; and
- Discharge of groundwater to down-gradient surface water receptors potentially including One Mile Dam and the adjacent creek. Based on the hydrogeological assessment, impacted groundwater discharging to the Creek is considered unlikely to have a significant influence on water quality because:
  - The Creek is unlikely to be receiving groundwater input during the dry season; and
  - Surface water flows in the wet season, combined with lower concentrations in groundwater from higher infiltration rates, will result in high dilution of any contaminants that do discharge to the creek.

The main exposure routes of concern include:

- Inhalation of volatile contaminants emitted into indoor air, outdoor air and enclosed spaces (such as future buildings at the site, residential properties in close proximity to the site, excavations or service trench);
- Dermal contact with, or accidental ingestion of soil, and inhalation dust derived from soil;
- Dermal contact with impacted groundwater in-situ;
- Dermal contact or ingestion of extracted groundwater; and
- Dermal contact or ingestion of surface water.

## 11.4. Plausible Exposure Pathways

The potential for exposure pathways to be complete has been assessed based on the physico-chemical characteristics and extent of the of secondary sources of contamination, the potential transport mechanisms and exposure routes, the location and behaviour of the identified receptors and the screening assessment of the final site condition.

The plausible exposure pathways present in relation to soil and groundwater impact, based on the potential future land use on-site and existing land use off-site, are presented in Table 11.1 and Table 11-2 and discussed below.

**Table 11-1 - Exposure Pathway Evaluation - Soil**

| Source | Transport | Exposure Point | Exposure Route | Potential Receptors | Potential Complete Pathway | | |
|---|---|---|---|---|---|---|---|
| | | | | | On-Site (West Boundary) | On-Site (Rest of Site) | Off-Site (down gradient) |
| Soil | Volatilisation | Indoor Air | Inhalation | Residential | ✓ | × | ×× |
| | | Outdoor Air(2) | | Residential | × | × | ×× |
| | | | | Subsurface Worker | × | × | ×× |
| | | Subsurface Works | | Sub-Surface Worker | ✓ | × | ×× |
| | Direct Contact | Surficial Soils | Incidental Ingestion | Residential | × | × | ×× |
| | | | | Subsurface Worker | × | × | ×× |
| | | | Particulate inhalation | Residential | × | × | ×× |
| | | | | Subsurface Worker | × | × | ×× |
| | | | Dermal contact | Residential | × | × | ×× |
| | | | | Subsurface Worker | × | × | ×× |
| | | Sub-surface works | Incidental Ingestion | Subsurface Worker | ✓ | × | ×× |
| | | | Particulate inhalation | Subsurface Worker | ✓ | × | ×× |
| | | | Dermal contact | Subsurface Worker | ✓ | × | ×× |

*✓ Pathway potentially complete; × Pathway insignificant (based on screening); ×× Pathway incomplete; NA Pathway not applicable*

**Table 11-2 - Exposure Pathway Evaluation - Groundwater**

| Source | Transport | Exposure Point | Exposure Route | Potential Receptors | Potential Complete Pathway | |
|---|---|---|---|---|---|---|
| | | | | | On-Site | Off-Site (down gradient) |
| Groundwater | Volatilisation | Indoor Air | Inhalation | Residential | ✓ | ×× |
| | | Outdoor Air | | Residential | × | ×× |
| | | | | Subsurface Worker | × | × |
| | | Subsurface Works | | Subsurface Worker | ✓ | × |
| | Subsurface Works | | Direct Contact | Subsurface Worker | ✓ | × |
| | Groundwater Extraction | Domestic Purposes | Accidental Ingestion / Aerosol / Inhalation / Dermal Contact | Residential | ✓ | ✓ |
| | | Irrigation | Aerosol / Inhalation / Dermal Contact | Residential | ✓ | ✓ |
| | Surface Water Receptors | Domestic Purposes | Accidental Ingestion / Aerosol / Inhalation / Dermal Contact | Residential | NA | ✓ |
| | | Irrigation | Aerosol / Inhalation / Dermal Contact | Residential | NA | ✓ |
| | | Primary Contact | Accidental Ingestion / Aerosol / Inhalation / Dermal Contact | Residential | NA | ✓ |
| | | Ecological Impacts | | | NA | ✓ |

*✓ Pathway potentially complete; × Pathway insignificant (based on screening); ×× Pathway incomplete; NA Pathway not applicable*

### 11.4.1. Soil Exposures

Petroleum hydrocarbons are present above the laboratory LOR in soils across the site including in reinstated material. The screening risk assessment identified that the residual hydrocarbons are present at levels below the adopted vapour intrusion and direct contact HSL criteria and therefore exposures through these pathways areconsidered to be insignificant.

The exception to this is along the western boundary where residual soil impacts exceeding the vapour intrusion HSL criteria were identified. In this case, volatilisation followed by vapour intrusion and subsequent inhalation in a future below-grade building or trench is considered to be a potentially complete exposure pathway. These exposure pathways have been addressed in the health risk assessment (refer Section 12.3 and Appendix R).

Several soil samples present at depths of >1.0 mbgs at or beyond the site boundary exceeded the HSL-A criteria for direct contact, however exposure to these soils is considered incomplete for residential users, given that residential receptors would not be expected to dig below 1 mbgs along or beyond a site boundary during normal site use. All soil results were below the intrusive maintenance worker direct contact HSLs.

Off-site (down-gradient) exposure pathways are considered to be incomplete based on the extent of impact having been delineated on-site. It is noted that up-gradient exposures have not been assessed as part of this investigation as these impacts are considered to be associated with the Mobil property and are not associated with historical activities from the former Caltex site.

### 11.4.2. Groundwater Exposures: vapour inhalation

Petroleum hydrocarbons have been reported above the laboratory LOR in several wells across the site. The HSL criteria are only relevant for groundwater located at a depth of 2 mbgs or greater and therefore, based on the shallow nature of groundwater at the site a screening assessment is not considered to be protective of future site use.

The potentially complete exposure pathways associated with both volatilisation followed by vapour intrusion and subsequent inhalation in a future building or trench as well as direct contact with groundwater have been addressed in the health risk assessment (refer Section 12.3 and Appendix R).

### 11.4.3. Groundwater Exposures: protected beneficial uses

A detailed comparison of the post-remediation groundwater analytical results against the adopted beneficial use criteria is presented Section 9.2.3. The COPC concentrations preclude groundwater from being used for any extractive beneficial use. It is recommended that shallow groundwater at the site is not extracted for any beneficial use based on current groundwater concentrations. Groundwater extracted from deeper aquifers may be suitable, but would require specific assessment.

Information gathered from discussion with surrounding residents at the One Mile Dam Community indicates that the dam water is not currently used for domestic or irrigation purposes; however, the dam is used for recreational use. Although discharge of groundwater to the down-gradient surface water receptor (One Mile Dam) is plausible, based on groundwater COPC concentrations in wells between the site and One Mile Dam, groundwater impact does not currently extend to the dam, and is not expected to in the future (refer Section 12.2).

# 12. Existing and Likely Future Risk

## 12.1. Existing Conditions

### 12.1.1. Petroleum Hydrocarbons

Concentrations of TPH measured following soil remediation exceeded the nominated groundwater criteria during the November 2015 and January 2016 GMEs:

- along the western boundary, in monitoring wells MW31, MW32, MW33, and MW35;
- in the central part of the site, at monitoring wells MW38D, and MW41S; and
- Down gradient (east) of the site at MW29.

Concentrations were notably lower in April and July 2016 and then detectable concentrations were only inconsistently reported in isolated wells in the 2017 and 2018 events.

The hydrocarbon impacts along the western boundary in 2016 were attributed to the migration of impacted groundwater from up gradient of the site.

COPC trend analysis and discussion of the potential for natural attenuation of petroleum hydrocarbons is provided in Appendix P and summarised in Section 12.2 below.

Concentrations of TPH fractions, benzene and ethylbenzene which may pose a vapour risk to health, are discussed in the health risk assessment provided in Appendix R, and summarised in Section 12.3.

### 12.1.2. Nitrogen Based Compounds

Concentrations of ammonia exceeding nominated groundwater criteria were reported during the November 2015 and January 2016 GMEs in a number of locations:

- along the western boundary, in monitoring wells MW9 and MW35;
- in the central part of the site, at monitoring well MW43;
- along the eastern boundary at monitoring wells MW18, MW23, MW24,and MW45; and
- in off-site well MW29.

By 2018, the ammonia (as N) concentration had generally reduced across the site, with concentrations above criteria only reported in three wells (MW23, MW45 and MW46). Concentrations recorded in MW23 exceeded the assessment criterion for maintenance of ecosystems (2,460 µg/L at pH <6.5) and the odour threshold assessment criterion for stock watering (1,500 µg/L). The ammonia (as N) concentration recorded in all three wells exceeded the assessment criterion for primary contact recreation (412 µg/L). No observations of ammonia (or any other chemical) odour were noted while sampling MW23. Nitrate (as N) concentrations in all groundwater samples were below all protected beneficial use assessment criteria, except for the assessment criterion for maintenance of ecosystems (2.4 mg/L) in MW33 (4.4 mg/L) and MW5 (3.7 mg/L).

The maximum and minimum concentration range of ammonia reported in each well is shown in Figure 15.

The occurrence, trend and potential attenuation of ammonia in groundwater at the site is discussed in detail in Appendix P, and summarised in Section 12.2 below.

### 12.1.3. Metals

Groundwater concentrations of arsenic, boron, cadmium, cobalt, copper, iron, manganese, nickel, and zinc, above nominated criteria have been reported in one or more wells at the site, at least once post remediation.

Concentrations of arsenic, cobalt, iron and manganese are associated with a combination of background conditions and degradation processes associated with petroleum hydrocarbon impact. Concentrations of these metals have decreased as the available hydrocarbons have depleted and geochemistry has become less reducing, and by 2018 the number of locations where concentrations of arsenic, cobalt and manganese were above extractive use criteria were limited to three wells for arsenic, none for cobalt and five for the aesthetic criteria for manganese.

Copper, nickel and zinc concentrations are attributed to background conditions as similar concentrations were observed in upgradient wells (MW2, MW44, MW36).

## 12.2. Ecosystem Risk Assessment

The potential risk from groundwater contamination to ecological receptors is considered to be limited to the ecosystem of One Mile Dam, which is approximately 50 metres beyond the eastern site boundary and the creek immediately east of the site boundary. The potential for interaction between groundwater from the site and the Dam has been investigated, is discussed in Section 4.4, and shown on Figure 6B. The relative contribution of site groundwater discharge to the creek in the wet season is likely be small compared to surface run-off contribution.

The conceptual hydrogeological model indicates that groundwater that has migrated beneath the site and is not diverted by the creek, may potentially discharge to the dam during both the dry and wet season, which is consistent with the presence of water in this dam all year round.

To evaluate the potential risk to the dam ecosystem and its users, an assessment of ammonia and petroleum hydrocarbon fate and transport, both of which are controlled by natural attenuation processes, has been conducted. The assessment includes analysis to identify if, and by what processes, natural attenuation has occurred, how this has changed with remediation, and also the future potential for degradation. The full assessment is provided in Appendix P, and is summarised below.

### 12.2.1. Petroleum Hydrocarbons

The primary line of evidence for natural attenuation is provided by reduction in concentrations of identified impact in the groundwater. Secondary lines of evidence are provided by geochemical indicators of degradation processes.

Statistical analysis of TPH trends post remediation indicates that concentrations are <LOR, stable or show no trend (Appendix P and Q). The data provide strong primary line evidence that natural attenuation is occurring and is sufficient to prevent future plume migration.

Historical TPH concentration trends in wells on-site and upgradient at the Former Mobil Depot also indicate that attenuation of hydrocarbon impact has occurred (see Figure 13a to c and 14a and b, Appendix A). Historical trends also indicate that concentrations were typically higher in the dry season, presumably due to dilution via recharge in the wet season.

Groundwater geochemistry indicates that both aerobic and anaerobic degradation of petroleum hydrocarbons is occurring in the groundwater beneath the site where electron acceptors are available.

The assimilative capacity of the groundwater between the site and One Mile Dam is significantly higher than on-site, as up to an order of magnitude higher concentrations of sulfate are available for use as electron acceptors.

The theoretical assimilative capacity in this area is sufficient to degrade between 8mg/L and 30mg/L of TPH, which is several orders of magnitude higher than the maximum historical TPH concentration reported on the eastern boundary.

Based on the primary and secondary lines of evidence of natural attenuation, the high assimilative capacity within groundwater between the site and One Mile Dam, and the low concentrations of TPH reported on the eastern boundary, the risk to the ecosystem and users of One Mile Dam is considered to be negligible.

Petroleum hydrocarbons were not reported in creek surface water samples at concentrations likely to present a risk to aquatic ecosystems.

### 12.2.2. Nitrogen Based Compounds

*In situ* natural attenuation processes for nitrogen based compounds include biodegradation, dispersion, dilution, sorption, volatilisation, and chemical or biological stabilisation or destruction of contaminants (Wiedemeier et al., 1999). The attenuation mechanisms for different forms of nitrogen vary greatly, with much of biologically mediated conversion and removal dependant on the geochemistry of the groundwater.

Sorption is the most important attenuation physical attenuation process for ammonia, but not for nitrate. Ammonia adsorbs to soil via cation exchange, which is influenced by both the clay content and percentage organic carbon. Given the high amount of clay present, and TOC concentrations in groundwater, there is expected to be significant attenuation capacity for ammonia within the aquifer material.

Where oxygen is present in the groundwater, biologically mediated nitrification rapidly occurs, and ammonia is converted to nitrate. Under oxygenated conditions nitrate then acts as an un-retarded, conservative compound and migrates at the same velocity as groundwater. The biodegradation and removal of nitrate from groundwater is dependent on a carbon donor being present in the groundwater so that nitrate is used as an electron acceptor and denitrified to nitrogen gas ($N_2$).

Statistical analysis of ammonia in groundwater post-remediation indicates that concentrations are predominantly stable or potentially decreasing (Appendix P and Q), consistent with the assumption that the elevated concentrations are transient, and will therefore decrease over time.

Ammonia concentrations in groundwater decrease with distance from the site (Figure 12-1), indicating that attenuation is occurring. The groundwater geochemistry in MW31(2010) and MW32(2010) is similar to on-site, albeit with a higher TDS, and appears to be reducing, indicating that the amount of nitrification occurring is likely to be limited to where oxygenated water mixes with ammonia impacted groundwater. The reducing conditions are also consistent with the low concentrations of nitrate reported in these wells, as TOC concentrations are relatively high (9 mg/L to 15 mg/L), and so where nitrate is produced it will rapidly be denitrified to nitrogen gas.

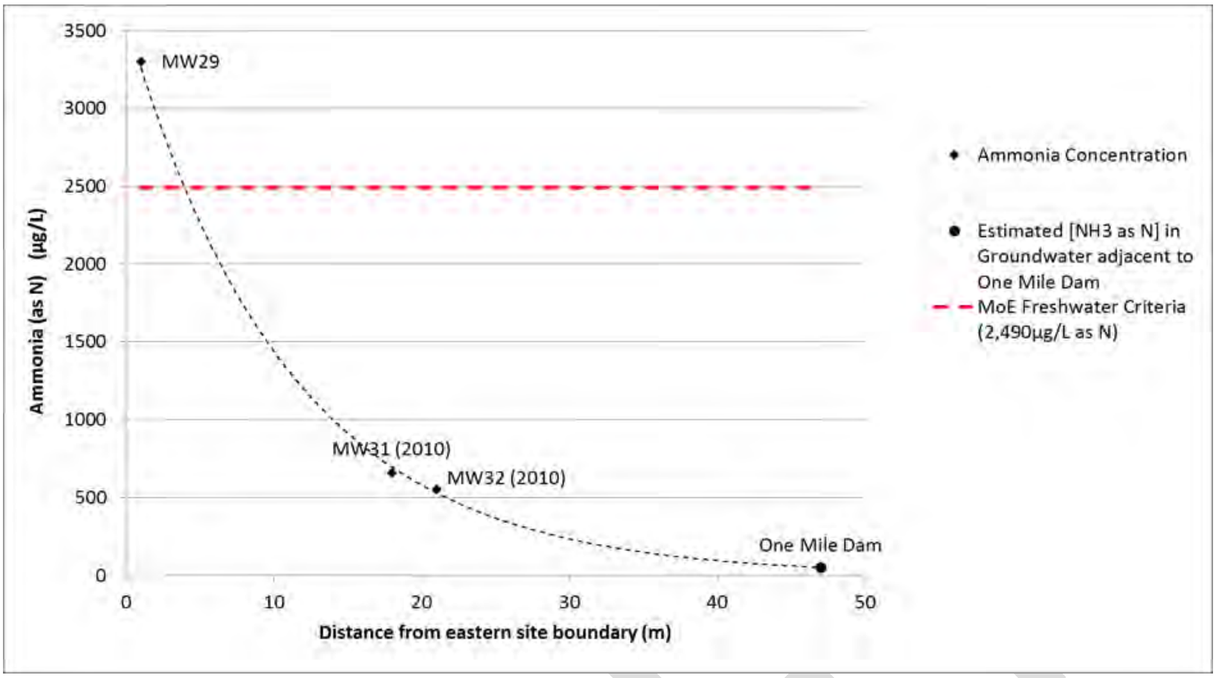



**Figure 12-1: Ammonia concentrations with distance from the eastern site boundary, and predicted concentration at One Mile Dam.**

In addition to attenuation via physical and biological processes, as the groundwater is relatively shallow, and the area is heavily vegetated, any available nitrogen compounds in the shallow groundwater is also likely to be taken up by the vegetation.

Based on the clayey nature of the aquifer, reducing conditions within the groundwater, shallowness of groundwater and heavy vegetation present downgradient of the site, any ammonia in the groundwater migrating off-site is expected to be attenuated over a relatively short distance from the site boundary. These lines of evidence are supported by the attenuation of ammonia over distance, and confirm that this impact is not considered to pose a risk to the ecosystem or users of One Mile Dam.

Ammonia (as N), nitrate (as N) and nitrite (as N) concentrations in creek surface water samples were all below the ecosystem protection criteria.

## 12.2.3. Metals

Elevated concentrations of arsenic, iron and manganese are associated with the biodegradation of petroleum hydrocarbon impact in the groundwater. The occurrence of these elevated concentrations is expected to be limited, and transient, as all three metals will either precipitate or sorb to the aquifer matrix once they enter an area of un-impacted and oxygenated groundwater. Arsenic concentrations in both MW31 (2010) and MW32 (2010) were below the adopted criteria, confirming that attenuation of this metal is occurring, likely due to the availability of iron hydroxides where iron precipitates. Iron concentrations remain elevated in these wells (based on 2016 groundwater data), indicating that GW ORP continues to reflect reducing conditions (consistent with oxygen depletion). The concentrations of iron are similar to those upgradient on the northern boundary in MW1 and MW2, and so not necessarily due to on-site sources/processes. Regardless of whether concentrations are due to degradation of an on or off-site source, once the groundwater mixes with the oxygenated water of a surface water receptor, the iron is expected to rapidly precipitate and drop out of solution.

Elevated concentrations of boron appear to be limited to wells on the northern section of the eastern boundary; MW18, MW24 and MW31 (2010).

The source of the boron is not known, however the plume is relatively localised and concentrations appear to be very stable, as similar concentrations were reported in MW18 and MW24 in 2008. The boron concentrations are expected to attenuate over the distance to a surface water receptor (potentially One Mile Dam), and are considered unlikely to discharge at concentrations exceeding the freshwater ecosystems criteria of 0.37 mg/L. The primary contact recreation criterion for boron was not exceeded in any groundwater well, therefore this compound does not pose a risk to the recreational users of the dam.

In summary, no metal concentrations identified in groundwater is considered to impact the receptors a surface water receptor (potentially One Mile Dam).

Concentrations of COPCs reported in the surface water of the creek to the east did not indicate contamination above ecosystem protection values, with the exception of zinc which was likely from off-site run-off sources. Concentrations were typically consistent across different events, with the exception of increases in manganese and iron in dry season compared to the wet season. Iron and manganese are significant elements in the natural geology and increases in the concentration in surface water are likely to reflect the increased contribution to flow of groundwater seepage in the dry season compared to rainfall run-off.

## 12.3. Health Risk Assessment

A health risk assessment (HRA) has been conducted by Coffey to evaluate the potential impacts to human health posed by petroleum hydrocarbon impacted soil and groundwater at the site.

Residual petroleum hydrocarbon soil impacts were identified around the western boundary of the site, predominantly associated with hydrocarbon impact known to remain at the adjacent Mobil property. Dissolved phase hydrocarbons have been identified in several groundwater wells, with the most significant impacts at the western boundary, directly down-gradient of the residual soil impacts at the adjacent property. Between 2015 and 2018 post-remediation, the concentrations have reduced and in 2018 detectable concentrations were isolated.

Future site use is likely to be redevelopment for residential purposes, with potential human receptors being future on-site residential receptors, on-site and off-site maintenance workers, and users of extracted groundwater. The site development layout will influence the potential exposure pathways. The future use and development layout is not known, and therefore a series of assumptions were made about potential scenarios to evaluate risk. Residential development was assumed to be the likely and most sensitive use, with the layout potentially involving:

- slab on grade residential rooms;
- development cut into the site slope, with
  - residential rooms against the western boundary;
  - basement storerooms against the western boundary, with residential rooms above;
  - car park against the western boundary, with residential rooms above;
- Opportunities for access to surface soils and shallow groundwater.

COPC concentrations (occasional petroleum hydrocarbons, various metals and ammonia) preclude groundwater from being used for sensitive extractive beneficial uses. It is recommended that groundwater at the site is not extracted.

Quantitative modelling was undertaken to assess impacts to human health from identified impacted media from potential exposure via the vapour intrusion (soil and groundwater) and direct contact pathways (groundwater only). The quantitative HRA is presented in Appendix R, and a summary of the outcomes is provided below.

Based on available data, exposure assumptions and constraints of the exposure assessment model, the potential health risks associated with the residual hydrocarbon COPC concentrations identified in soil and groundwater, as presented in this report, are as follows.

- Petroleum hydrocarbon impacts identified in soil are considered unlikely to pose an unacceptable vapour intrusion / inhalation health risk to residential receptors in a slab-on-ground building at the current site surface level.
- Petroleum hydrocarbon impacts detected in groundwater are considered unlikely to pose an unacceptable vapour intrusion / inhalation health risk to residential receptors in a slab-on-ground building.
- Petroleum hydrocarbon impacts detected in groundwater are considered unlikely to pose an unacceptable vapour intrusion / inhalation health risk to residential receptors in a building with a basement carpark or basement storerooms.
- Petroleum hydrocarbon impact detected in soil along the western boundary, indicates a potential unacceptable inhalation health risk may be present for residential receptors in residential space cut into the site slope, which results in contaminated soil adjacent to the building wall (within 3 m).
- Petroleum hydrocarbon impact detected in groundwater, across the remainder of the site is considered unlikely to pose an unacceptable direct contact health risk to residential receptors;
- Petroleum hydrocarbon impact detected in groundwater is considered unlikely to pose an unacceptable vapour intrusion / inhalation or direct contact health risk to excavation workers conducting sub-surface works in excavations that intercept groundwater.
- Petroleum hydrocarbon impact detected in soil on the western boundary is considered unlikely to pose an unacceptable vapour intrusion / inhalation or direct contact health risk to maintenance workers conducting sub-surface works.

Hydrocarbon concentrations were reported to decrease across the post-remediation monitoring events. Whilst there is concern that the Mobil site may act as a source of contamination in the short term, it is considered unlikely to result in increases in concentrations on-site. In the long term it would be expected that the limited residual mass of hydrocarbons would bio attenuate to the point that the identified health risks from soil on the boundary would be lowered to acceptable or negligible levels.

It is noted aesthetic issues may be present in deeper soils at the site and at the boundary adjacent to the Mobil site. Management of subsurface works that may occur in these areas is required to manage odours and appropriate movement of impacted soils being brought to the surface.

# 13. Demonstration of Clean Up to Extent Practicable

## 13.1. Background

EPA Victoria has established a process for determining the practicable limit of groundwater remediation, under its Publication 840.2 “The Clean Up and Management of Polluted Groundwater” (20 April 2016). This process recognises the impracticability in some cases of full remediation, to the point where groundwater contamination no longer compromises any potential beneficial uses. In Victoria, the option is available for remediation to be carried out (to the extent practicable), and for this to be demonstrated to EPA Victoria in a formal submission.

This Northern Territory site is being assessed and audited by applying the Victorian approach, as the auditor is an EPA Victoria appointed auditor who is approved to undertake audits in NT in accordance with Part 6 of the NT’s Waste Management and Pollution Control Act. However, as there is no mechanism in NT for EPA to approve a “clean-up to the extent practical (CUTEP)” approach, the endorsement of sufficient clean-up will need to be made by the auditor, based on information provided in this section.

The precluded beneficial uses of groundwater on and off-site based on current groundwater conditions is summarised in Table 13-1.

**Table 13-1 - Precluded Beneficial Use Summary [1]**

| Precluded Beneficial Use | Contaminants | |
|---|---|---|
| | **On-site** | **Off-site** |
| Maintenance of Ecosystems | NA (no surface water on-site) | Zinc (n), boron (b) |
| Potable Water | Ammonia (AV), chloride (n), pH (n), TDS (n), sodium (n), arsenic, cobalt (n), iron, manganese, nickel (n), benzene, ethylbenzene | Ammonia (AV), manganese (AV), iron (AV), sodium (n), TDS (n), sulfate (n), chloride (n) |
| Agriculture, Parks and Gardens | Arsenic, boron (b), cobalt (n), iron, manganese, | Boron (b) |
| Stock Watering | Chloride (n), pH (n), TDS (n). | NE |
| Primary Contact Recreation | Ammonia (AV), chloride (n), pH (n), TDS (n), sodium (n), arsenic, iron, manganese, benzene, ethylbenzene | Manganese (AV), iron (AV), sodium (n), TDS (n), sulfate (n), chloride (n) |
| Industrial Water Use | NA | NA |
| Buildings and Structures | pH (n) | NE |

Notes:
[1] As per Attachment B, EPA Victoria Publication 840.2 (April 2016)
(n) – naturally occurring
(b) – background/regional pollution
NA – Not applicable
NE – No exceedance
AV – Aesthetic value only

COPC concentrations on-site preclude groundwater from being used for any extractive beneficial use (Table 13.1). Restrictions on the use of groundwater may be specified in the Auditors Statement of Environmental Audit. EPA NT will include these conditions on a Pollution Abatement Notice (PAN), which may also be included as a Caution Note placed on the site’s Certificate of Title.

All exceedances off-site are from naturally occurring or background conditions, or only exceed aesthetic (not health) based drinking water values. The TDS of groundwater off-site (1,700 mg/L to

4,700 mg/L) was higher than on-site (mostly <1,000mg/L). The use of groundwater off-site for drinking water is therefore not considered to be a realistic use.

One Mile Dam is reportedly used for recreational purposes (although we note that signs have been erected to warn against swimming), and potentially receives groundwater from the site, therefore the concentration of manganese and iron in groundwater theoretically affects the potential use for primary contact recreation. Although the aesthetics criteria apply for primary contact recreation, both the iron and manganese are expected to rapidly precipitate once exposed to oxygen. In a swimming pool the visible precipitate could affect aesthetics, however in a dam the precipitation is not expected to result in any loss of amenity.

To date, remediation of the sources of the groundwater impact at the site has involved an extremely extensive program including the physical removal of petroleum hydrocarbon infrastructure (the primary sources), excavation and remediation of petroleum hydrocarbon impacted soil (the secondary source), validation of the on-site soil (in accordance with Australian Standards and/or other relevant guidelines), and monitoring of groundwater conditions at the site.

Residual hydrocarbon impact remains along the western site boundary due to off-site contamination associated with the former Mobil depot. Soil was excavated to the title boundary where contamination was identified as remaining. EPA was also approached during 2015 civil works regarding the potential for recontamination of material from the adjacent site, and informed Coffey that an audit had been completed, and EPA was not in a position to assist with the mitigation of risk associated with off-site impact.

Demonstration that CUTEP has been achieved at the site is presented in the sub-sections below and is based on the following reasoning:

a) The residual concentrations in groundwater are not presenting an unacceptable risk to actual or likely uses of groundwater (above and in Section 12);
b) Groundwater contamination from on-site sources has been delineated and is not expanding (Section 9.2 and Section 12.2.1);
c) The mass of hydrocarbon contaminants has decreased significantly as a result of remediation activities at the site (Section 9.1 and below in Section 13.2),
d) Remediation has reached a point of diminishing returns at the site (Sections 13.3), and;
e) A review of alternative remediation technologies has not identified any cost effective means of reducing the level of impact and/or risk associated with the residual impact (Section 13.4).

## 13.2. Hydrocarbon Mass

The mass of petroleum hydrocarbons removed via the remediation process has been estimated based on the difference in TPH concentrations in stockpiles pre and post treatment. The average TPH $C_6$-$C_9$ and TPH $C_{10}$ – $C_{36}$ concentration was calculated for each stockpile and then multiplied by the stockpile mass. The TPH concentration and volume data used for the estimate is provided in Table 6, Appendix B, and summarised in Table 13.2 below. Note that where TPH $C_6$-$C_9$ concentrations were below the LOR (20 mg/kg), half LOR was adopted for the estimates (10 mg/kg).

**Table 13-2 - Hydrocarbon mass pre and post treatment.**

| | Pre-treatment (kg) | Post Treatment (kg) | % change |
|---|---|---|---|
| $C_6$-$C_9$ | 870 | <180kg (All <20mg/kg) | >80% |
| TPH $C_{10}$ – $C_{36}$ | 32,000 | 12,800 | 60% |
| Total TPH | 33,000 | 13,000 | 60% |

Of the estimated 33 tonnes of hydrocarbon present at site in the soil prior to remediation, approximately 20 tonnes (equivalent to 60%) was removed by remedial works. Importantly, the concentration of the TPH $C_6$-$C_9$ fraction, which represents the most mobile and volatile hydrocarbons, were all below the level of detection post treatment, indicating that the risk to groundwater and via vapour intrusion has been significantly reduced.

Given the site was fully excavated to the title boundary where impact was detected, the approach adopted is considered a reasonable representation of the mass of hydrocarbon removed via remediation.

The mass of hydrocarbon in groundwater was not estimated as it is typically negligible compared to the sorbed mass and is expected to be in the order of 1 to 10kg at most.

## 13.3. Soil Remediation Met Remediation Targets

The site has been fully excavated to the title boundary where hydrocarbon impact was detected. All soils excavated have been sampled and analysed consistent with NEPM (amended 2013). Where soils exceeded the site specific soil re-use criteria (Table 7.2 and Appendix G), which also considered the potential for leaching to groundwater, they have been treated until TPH concentrations were acceptable, prior to reinstatement on-site.

Post treatment soil analysis confirms that significant source mass removal has occurred (Section 13.2), particularly of the more mobile and volatile hydrocarbon fraction (TPH $C_6$-$C_9$), which typically results in potential risk to health and the environment.

The four rounds of post remediation groundwater monitoring have confirmed that any residual hydrocarbon adsorbed to soil poses a negligible risk to groundwater receptors as concentrations on-site are all below detect, with the exception of where impact is migrating from an off-site source (Former Mobil depot).

Based on post remediation soil and groundwater conditions, and the absence of potential risk associated with on-site sources (as summarised in Section 13.1), the remedial works undertaken at the site are considered to have been effective, and have met the remediation targets.

## 13.4. Review of Alternative Remediation Technologies

### 13.4.1. Summary of Remediation Options

A number of potential remediation technologies for dissolved petroleum hydrocarbon contamination were assessed. The techniques reviewed address all petroleum hydrocarbon pollutants at the site.

Residual dissolved phase hydrocarbon impact in the groundwater is attributed to the migration of impact from upgradient, beyond the site boundary, and therefore the source of this impact is not the focus of this remediation technology review.

The following technologies were considered plausible for the remediation of the residual hydrocarbon contamination in groundwater:

- Option 1a – Groundwater Interception, treatment and reinjection
- Option 1b – Groundwater Interception, and disposal
- Option 2 – Multi Phase Vacuum Extraction
- Option 3 –Impermeable Barrier
- Option 4 – Permeable Reactive Barrier
- Option 5 – Enhanced Monitored Natural Attenuation
- Option 6 – Amendment Injection

The key objective in selecting a remediation approach at this site was to provide suitable removal and/or hydraulic containment of the impacted groundwater on-site, and to prevent further movement of contaminants on site from up gradient.

The assessment of the suitability of the available technologies for the remediation of hydrocarbon impacted groundwater is presented in Table 13-3 below. In accordance with EPA Victoria Publication 840.2, a number of factors were considered in assessing the suitability of the above remediation technologies for the residual impact at the site, including; technical feasibility, logistical feasibility, costs, time.

Table 13-3 - **Assessment of Suitability of Technologies for the Remediation of Hydrocarbons**

| | 1. Groundwater Interception (a and b) | 2. Multi-Phase Vacuum Extraction | 3. Impermeable Barrier | 4. Permeable Reactive Barrier | 5. Enhanced Monitored Natural Attenuation | 6. ISCO Injection |
|---|---|---|---|---|---|---|
| **Description** | Interception and removal of groundwater and dissolved phase hydrocarbons via extraction bores and or groundwater interception trenches. Contaminated groundwater is treated on site and reinjected, or disposed of off site. | Vacuum extraction of contaminated groundwater removing dissolved phase hydrocarbons and vapour. Contaminated groundwater is disposed of off site, vapours are treated prior to release to atmosphere. | Interruption of groundwater movement via installation of impermeable barriers (trenches) to contain impacted groundwater on-site, and prevent future migration of impacted groundwater on site from up gradient. | In situ treatment of groundwater via installation of reactive materials and/or amendments (within trenches) perpendicular to groundwater flow, to either directly oxidise hydrocarbons and/or supplement the natural attenuation capacity of groundwater passing through the barrier. | Groundwater is supplemented with amendments to boost the natural attenuation capacity of the aquifer. | Injection of oxidants to directly oxidise dissolved and adsorbed hydrocarbons in situ. |

| | 1. Groundwater Interception (a and b) | 2. Multi-Phase Vacuum Extraction | 3. Impermeable Barrier | 4. Permeable Reactive Barrier | 5. Enhanced Monitored Natural Attenuation | 6. ISCO Injection |
|---|---|---|---|---|---|---|
| **Technical Considerations** | Removal of large volumes of groundwater may decrease local groundwater levels and impact on base flow within the Creek and One Mile Dam.<br><br>The amount of mass recovery will be dependent on the mass flux, hence is likely to be much slower than a source mass removal exercise. | MPVE would operate with negligible returns with respect to dissolved phase impacts.<br><br>Potentially no long term added benefit compared to the current site condition. | Impermeable barriers form a physical barrier affecting the flow of groundwater and migration of contaminants.<br><br>Do not actively treat impacted groundwater. | The amount of mass recovery will be dependent on the mass flux, hence is likely to be much slower than a source mass removal exercise. | The amendments used for boosting the natural attenuation potential of the aquifer are soluble nutrients (i.e. phosphorus, nitrogen) and electron acceptors (e.g. iron, sulfate).<br><br>Amendments can be delivered by passive injection into the aquifer, which does not require as many resources or as extensive a well network as required for ISCO. | Oxidant addition relies on contact between the amendment and the hydrocarbon. The distribution of chemicals is critical for injection to be effective. Potential for no long term added benefit if no contact between oxidants and contaminants.<br><br>ISCO can mobilise other non-leachable elements (e.g. naturally occurring metals), that would otherwise be innocuous in the formation. |

| | 1. Groundwater Interception (a and b) | 2. Multi-Phase Vacuum Extraction | 3. Impermeable Barrier | 4. Permeable Reactive Barrier | 5. Enhanced Monitored Natural Attenuation | 6. ISCO Injection |
|---|---|---|---|---|---|---|
| **Financial Considerations** | Installation of the system will add to additional costs to the site development in the order of several $100 k. Ongoing maintenance of a recovery system will be borne by an owners corporation or the previous landowners for several years. | Operational Costs (incl. water disposal) $120 k for 3-4 events per annum. MPVE events would potentially be required for several years to create any significant reduction below current levels. | Installation of the system will add to additional costs to the site development in the order of several $100 k. This would include the need to provide other drainage/ treatment alternatives for banked up groundwater. | Installation of the system will add to additional costs to the site development in the order of several $100 k.<br><br>This would include the need to provide contingent drainage/ treatment alternatives for banked up groundwater, if the barrier was to become blocked or fouled. | Installation of the injection wells will add to additional costs to the site development in the order of several $10k.<br><br>Ongoing operational and maintenance costs, including groundwater monitoring and periodic injection events of $20 kto $50 k per year. | Cost is expected for the installation of injection wells.<br><br>Ongoing operational and maintenance costs, including groundwater monitoring and periodic injection events between $150 k and $300 k per year. |
| **Logistical considerations** | Installation of extraction trenches and or groundwater extraction bores.<br>Viable disposal options for extracted groundwater may be limited during the wet season.<br>Access to the western side of the site will be required for several years following development. This could impact on the general amenity of the site. | Access to the western side of the site will be required for several years following development. This could impact on the general amenity of the site. | Would limit the ability to conduct other development-based civil works in this area of the site. | Access to the western side of the site will be required for several years following development to allow for periodic inspection and maintenance. This could impact on the general amenity of the site.<br>Would limit the ability to conduct other development-based civil works in this area of the site. | The continued presence of a network of wells at the site and of the requirement for operation and maintenance could limit the long term development of the site.<br>EPA notification required for injection events. | A number of injection wells are required to achieve a uniform distribution of the ISCO chemicals and contact with the contaminant.<br>Long term development of the site can be affected by continued presence of a network of wells at the site required for operation and maintenance<br>EPA notification may be required for injection events. |

| | 1. Groundwater Interception (a and b) | 2. Multi-Phase Vacuum Extraction | 3. Impermeable Barrier | 4. Permeable Reactive Barrier | 5. Enhanced Monitored Natural Attenuation | 6. ISCO Injection |
|---|---|---|---|---|---|---|
| On-going management | Periodic operations and maintenance visits (assume quarterly).<br><br>Access pit and well maintenance. | Periodic groundwater monitoring of areas of dissolved hydrocarbon impact. | Ongoing maintenance of civil works exclusion zone. | Ongoing maintenance of civil works exclusion zone.<br>Periodic groundwater monitoring of areas of dissolved hydrocarbon impact. | Periodic groundwater monitoring and operation and maintenance of amendment injection equipment. | Injection equipment and injection wells would require ongoing monitoring and maintenance. |
| Environmental Considerations | Vehicle use - 100 to 200 km driving per year.<br>Production of materials (pipe, hosing, fittings, etc.)<br>Waste generation (repairs/ contaminated water)<br><br>Moderate Environmental impact. | Vehicle use 750 – 1500 km driving/year.<br>Pumps / Vac truck noise (40 hrs/event).<br>Material production (pipe, hosing, fittings, etc.)<br>Waste generation (contaminated water).<br><br>Moderate Environmental impact. | Potential to divert impacted groundwater to site surface or into surface drainage during periods of high rainfall, which could have immediate/ acute environmental effects. | Addition of treatment media/ admixtures can have other environmental effects, due to the residues that can be produced.<br>Vehicle use - 100 to 200 km driving/year.<br>Waste generation (construction and maintenance).<br><br>Moderate Environmental impact. | Vehicle use 100 - 200 km driving required per annum.<br>Production of materials (amendment, hosing, fittings, etc.)<br>Water usage (1000s L)<br><br>Low Environmental impact. | Vehicle use 2000 km driving per year.<br>Injection equipment use (40 hrs/event).<br>Production of materials (Oxidants, hosing, etc.)<br>Water usage (1000s L)<br>Potential to mobilise other contaminants.<br><br>Moderate Environmental impact. |
| Timeline | Several years to decades to achieve restoration of beneficial uses of groundwater | Several years to decades to achieve restoration of beneficial uses of groundwater | Decades to achieve restoration of beneficial uses of groundwater. | | Several years to decades to achieve restoration of beneficial uses of groundwater. | Several years to decades to achieve restoration of beneficial uses of groundwater |

## 13.5. Consideration of CUTEP

To assist the auditor in determining whether CUTEP has effectively been reached for the site, the CUTEP checklist provided in EPA Publication 840.2 is provided below in Table 13-4, with reference to where relevant details have been provided in the current document.

**Table 13-4 - CUTEP Checklist [1]**

| Information | | Section | Included |
|---|---|---|---|
| Title Details | | Table 2.1 | ✓ |
| Land Area | | Table 2.1 | ✓ |
| Past Use | | Sections 1.1 2.1 and 2.5 | ✓ |
| Surrounding land use | | Table 2.1 and Section 2.4 | ✓ |
| Proposed future use | | Table 2.1 | ✓ |
| Geology | | Section 3 | ✓ |
| Groundwater depth (m) | | Section 4.2.3 | ✓ |
| Groundwater flow direction | | Section 4.2.4 | ✓ |
| Nearest surface water receptor (distance and direction) | | Section 4.3 | ✓ |
| Bore search (2km radius) | | Discussed in Section 4.2 | NA |
| Groundwater segment (based on SEPP GoV) | | Section 5.2.1 | ✓ |
| Beneficial use of groundwater identified | | Section 5.2.1 | ✓ |
| Summary table of precluded beneficial uses, with associated contaminants | | Table 13.1 | ✓ |
| Remediation Options Table | Discussion of specific options | Section 13.2 | ✓ |
| | Cost | Table 13.2 | ✓ |
| | Technical feasibility | Table 13.2 | ✓ |
| | Logistical feasibility | Table 13.2 | ✓ |
| Vapour risk considered | | Section 12.3, Appendix R | ✓ |
| GQMP | Responsible party identified | NR | ✓ |
| | Cost – establishment and annual | NR | ✓ |
| | Duration | NR | ✓ |
| Water quality summary table showing results from all rounds | | Tables 10 & 11, Appendix B | ✓ |

| Information | Section | Included |
|---|---|---|
| Table showing latest water quality results above guidelines | Table 11, Appendix B | ✓ |
| An opinion on the source of all contaminants over criteria in groundwater | Section 13, Table 13.1 | ✓ |
| Groundwater and soil contamination maps | Appendix A | ✓ |
| Hydrogeological cross-sections | Figure 6A and 6B, Appendix A | ✓ |
| Discussion of proposed Groundwater Quality Restricted Use Zone | NA | NA |
| Details and records of communication with off-site property owners associated with GQRUZ | NA | NA |
| Any other issues of significance | Impact from upgradient | ✓ |
| A clear and concise executive summary of above information | Exec Summary | ✓ |

[1] Based on EPA Victoria Publication 840.2 April 2016.
NR Not required
NA Not applicable

In considering the practicability of further remedial action, the following points are considered important:

- Extensive remediation works have already proceeded and been conducted to a practicable extent.
    - The on-site source of impact was removed from the site during the remediation of petroleum impacted soil in 2014 and 2015, following prior removal of the on-site primary sources of contamination (infrastructure).
    - The total mass of hydrocarbons bioremediated from soil in 2014/2015 was estimated to be ~20,000 kg (>60% of the total estimated mass present).
    - Since January 2014, in excess of $2,500,000 has been spent on remediation activities, including six post remediation groundwater events
- The primary source of the intermittent impacted groundwater on-site is the migration of dissolved phase hydrocarbons from sources up gradient of the site.
- The presence of dissolved arsenic, iron and manganese in groundwater is a by-product of the natural attenuation of hydrocarbon contaminants, and will precipitate under aerobic conditions at the leading edge of the plume, with monitoring indicating that this is occurring effectively.
- It is considered unlikely that the residual groundwater contamination at the site poses a risk to the beneficial uses of groundwater off-site (those likely to be realised).
- A HRA conducted using conservative assumptions identified that.
    - Petroleum hydrocarbon impacts identified in soil are considered unlikely to pose an unacceptable vapour intrusion / inhalation health risk to residential receptors in a slab-on-ground building at the current site surface level, and so will require management through environmental audit conditions.

- Petroleum hydrocarbon impacts detected in groundwater are considered unlikely to pose an unacceptable vapour intrusion / inhalation health risk to residential receptors in a slab-on-ground building.
- Petroleum hydrocarbon impacts detected in groundwater are considered unlikely to pose an unacceptable vapour intrusion / inhalation health risk to residential receptors in a building with a basement carpark or basement storerooms.
- Petroleum hydrocarbon impact detected in soil along the western boundary, indicates a potential unacceptable inhalation health risk may be present for residential receptors in residential space cut into the site slope, which results in contaminated soil adjacent to the building wall (within 3 m);.
- Petroleum hydrocarbon impact detected in groundwater, across the remainder of the site is considered unlikely to pose an unacceptable direct contact health risk to residential receptors.
- Petroleum hydrocarbon impact detected in groundwater is considered unlikely to pose an unacceptable vapour intrusion / inhalation or direct contact health risk to excavation workers conducting sub-surface works in excavations that intercept groundwater.
- Petroleum hydrocarbon impact detected in soil on the western boundary is considered unlikely to pose an unacceptable vapour intrusion / inhalation or direct contact health risk to maintenance workers conducting sub-surface works.

- The potential risk to users of extracted groundwater on-site can be managed via specified conditions in the Auditor's Statement of Environmental Audit, and as a Caution Note placed on the site's Certificate of Title by EPA NT.
- In the absence of off-site source removal, the potential benefits of further on-site remediation are unlikely to outweigh the negatives of energy consumption / carbon footprint, waste generation, significant timeframes, and the financial costs they would incur.

Further active remediation of groundwater impact identified at the site and its surroundings is considered technically and financially impracticable, particularly given the primary remaining source of the impact is off-site.

Based on the absence of applicable remedial options that would be effective in terms of cost, timeframe and logistical factors, and an appraisal of likely risks to the protected beneficial uses of land and groundwater, further remediation will not have a significant net benefit to the site or its surroundings. It is therefore considered appropriate to allow natural attenuation processes to continue the remediation of groundwater at the site.

Based on the information presented above, it is considered that the groundwater at the site has been cleaned-up to the extent practicable.

# 14. Site Management

Clean up at the site has reduced concentrations of all site-sourced contaminants to a level that does not pose an unacceptable risk to future residential site users, where extraction of groundwater is restricted or demonstrated to be suitable for the specific purpose. It is proposed that no further groundwater monitoring is undertaken. It is considered that there is sufficient data available to confidently demonstrate low risk now and in the future, based on stable or decreasing trends in groundwater contamination associated with the site.

An Environmental Management Plan (EMP) is proposed, which will consist of management measures to restrict extraction of groundwater from the site, and health risk mitigation measures should the site be developed for residential use.

An outline of the EMP is given in Section 14.3. The full EMP will be drafted once the identified health and aesthetic risks and appropriate controls are agreed with the auditor and Caltex. Any advice or requests provided as part of the Auditor’s decision or EPA NT’s feedback will also be incorporated into the EMP.

Remediated soil was re-instated on the site based on depth-specific criteria, in order to prevent human health, ecological and groundwater impacts. In some locations, soils were re-instated at depth to minimise exposures to terrestrial ecology. In these areas, soil excavation controls are required to ensure future excavation of soil does not result in environmental impact. These areas are described in Section 9.1, and the controls will be defined in the EMP.

## 14.1. Restrictions on Groundwater Extraction

Because groundwater beneath the site is impacted by in some areas by occasional petroleum hydrocarbons, ammonia and metals, which preclude beneficial uses of groundwater, it is recommended that extraction of groundwater from the site be restricted unless groundwater is demonstrated to be suitable for the specific proposed use.

As there is not a formal mechanism for nominating groundwater restrictions in the Northern Territory outside of a Water Protection Area, if extractive use of groundwater is required to be formally managed, then the requirement could be described via Audit statement conditions restricting the use of groundwater, on site. These restrictions could then be detailed in a Pollution Abatement Notice issued by EPA on completion of the Audit, and appended to the relevant land title documentation.

Several beneficial uses of groundwater are precluded on-site, but not downgradient of the site, and therefore the proposed area where groundwater extraction should be restricted is the same as the current title boundary.

## 14.2. Health Based Mitigation Measures

The health risk assessment (Section 12.3) identified a potential vapour intrusion risk to users of a below grade residential space. These risks are associated with hydrocarbons migrating from soil along the western site boundary and into a below grade room that is within 3 m of the contaminated soil. Risks were acceptable for carpark or store room basements, or residential spaces at the current surface level.

Based on the current understanding of the nature and extent of petroleum hydrocarbons pollution in groundwater at the site, the following mitigation measures/options are proposed to be included in the EMP.

*Vapour Risk Mitigation*

- If residential buildings are to be constructed up to the western boundary of the site, residential spaces should be at or above the current ground level, or if below grade, then set back from the site boundary by at least 3 m.

- Basement structures would be expected to be below the groundwater level during some periods of the year, and may be subject to seepage of odorous water. Engineering controls such as tanking or increased drainage and ventilation may be appropriate to manage this aesthetic impact, which is not considered to pose a health risk for a non-occupied basement.

*Environmental Management Plan*

- It is recommended the requirements for the management of identified exposures and aesthetic impacts be detailed in the Environmental Management Plan for the site.

It is acknowledged that the statement of Environmental Audit will be the mechanism to define the required management controls.

# 14.3. Environmental Management Plan

The requirement and content for an EMP will be refined following Auditor comment on the final site conditions as outlined in this report.

The objectives of the EMP are expected to be to:

- Inform site managers of the residual soil and groundwater contamination and associated risks;

- Define soil management measures, where relevant.

The EMP will document management controls to be implemented to provide a framework under which excavation works can be conducted safely, and to manage environmental impacts associated with the movement of residual soil impact on-site, or the disposal of soil off-site. The EMP should also document the procedures required to address potential odour issues should they be encountered during excavation works at depth.

# 15. Conclusions and Recommendations

Based on the contamination characteristics and levels measured, the clean-up measures already implemented, a review of the options for further clean-up of soil and groundwater, and consideration of the manageable risks of exposure to existing or likely beneficial uses associated with the site, it is concluded that soil and groundwater clean-up to the extent practicable has been achieved. Therefore, it is considered that further active remediation at the site is not warranted.

The following summarises the conditions at the site:

**Residual Contamination**

- Residual hydrocarbon concentrations above the laboratory LOR are present in soil across the site. These concentrations are generally considered to be consistent with criteria adopted for sensitive site use. The exception to this is along the western title boundary where residual soil impacts exceeding the vapour intrusion HSL criteria were identified (likely associated with the upgradient former Mobil site).
- Aesthetic issues (hydrocarbon odours) may be present in soils deeper than 2 m below current surface at the site and at any depth along the western boundary.
- LNAPL has not been observed at the site since circa 1999.
- Site-sourced dissolved hydrocarbon impact has been delineated in all directions. However, an ongoing source of groundwater contamination exists upgradient of the site (former Mobil site).
- Site sourced ammonia is present at the eastern boundary of the site at concentrations that exceed adopted Maintenance of Ecosystems and Aesthetics guidance values.

**Remediation**

- Remediation of soil impact was conducted using excavation equipment to excavate contaminated soil above and below the water table.
- Contaminated soil was stockpiled and underwent an enhanced bioremediation process to degrade residual hydrocarbon contamination to levels that were appropriate for reinstatement and would support future sensitive use of the site. This approach effectively targeted soil and groundwater impacts.
- Remediation activities were undertaken in the dry seasons of 2014 and 2015 with subsequent groundwater motoring extending until July 2016.
- An estimated 20 tonnes of hydrocarbons were removed from the site via biodegradation. It is estimated that approximately 13 tonnes of residual hydrocarbons are remaining at the site, however, it should be noted that this estimate does not account for the amount of contamination biodegradation that could have occurred since the completion of soil excavation works.

**Residual Risk**

- Residual ammonia, petroleum hydrocarbons and metals potentially preclude groundwater from being used for any protected beneficial use.
- The health risk assessment identified a potential vapour inhalation risk (for an inhabited below grade room with in 3 m of the western boundary), associated with elevated hydrocarbons in soil migrating across the western boundary. Other scenarios, including slab-on-grade at the western boundary or an uninhabited basement were indicated to be acceptable.

- Residual dissolved phase hydrocarbon impact is present in the groundwater along the western boundary of the site, which is attributed to transient mobilisation of contamination from the former Mobil depot beyond this boundary. The residual concentrations are not considered to pose an unacceptable direct contact or vapour intrusion risk.
- The data provide strong primary line evidence (supported by statistical analysis) that natural attenuation is occurring and is sufficient to prevent future (petroleum hydrocarbon and ammonia) plume migration.
- The presence of dissolved arsenic, iron and manganese in groundwater is a by-product of the natural attenuation of hydrocarbon contaminants, and will precipitate under aerobic conditions at the leading edge of the plume.
- It is considered unlikely that the residual groundwater contamination at the site poses a risk to the beneficial uses of groundwater off-site.

**Consideration of CUTEP**

- A review of potential remediation technologies did not identify any remediation technology that would significantly change the risk profile of the site based on further active clean-up of site – sourced contaminants. It is acknowledged that some off-site hydrocarbon contamination exists and is migrating across parts of the Caltex site. However, without accessing the Mobil site to remove or otherwise remediate residual contamination, it is not possible to further attenuate contamination to any further significant extent through active remediation.
- Based on post remediation soil and groundwater conditions, and the absence of potential risk associated with on-site sources, the remedial works undertaken at the site are considered to have been effective, and have met the remediation targets.
- Based on the above, it is considered that CUTEP has been achieved for the site, subject to the agreement of the Auditor and EPA.

**Management of Residual Risk**

Residual soil and groundwater pollution exists at the site. As such an Environmental Management Plan will be produced and appended to the Auditor's Statement of Environmental Audit to clearly detail management measures required.

A summary of proposed management measures is provided below.

- Residual groundwater contamination precludes extraction of groundwater for any beneficial use unless specific testing confirms that the water is suitable for that use.
- Aesthetic issues may be present in deeper soils at the site and at the western boundary. In addition to awareness of aesthetic issues, management of subsurface works that may occur in these areas is required to manage odours and appropriate movement of impacted soils being brought to the surface.
- Based on the current understanding of the nature and extent of petroleum hydrocarbon pollution at the site, the following mitigation measures/options will be included in the EMP.
  - If residential buildings are to be constructed up to the western boundary of the site, residential spaces should be at or above the current ground level, or if below grade, then set back from the site boundary by at least 3 m.
  - Basement structures would be expected to be below the groundwater level at some times of the year and may receive seepage of odorous water. Engineering controls such as tanking or increased drainage and ventilation may be appropriate to manage this aesthetic impact.

- It is recommended the requirements for the management of identified exposures and aesthetic impacts are detailed in the Environmental Management Plan for the site.

It is acknowledged that the Statement of Environmental Audit will be the mechanism to define the required management controls, and that the conditions incorporated into the Statement of Environmental Audit will need to be crafted by the auditor. The management measures proposed represent Coffey's suggested approach to managing the residual risks, but will be subject to the considerations of the auditor.

Given the requirement for controls to manage residual risk at the site, it is likely that the most sensitive allowable use for the site will be medium to high density residential, with an owner's corporation. This is due to EPA NT's likely preference for management conditions to be enacted by an owner's corporation (or similar body).

This report should be considered with the attached Important Information about your Coffey Environmental Report.

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# Appendix A – Figures

# Appendix B - Tables

# Appendix C - Borelogs

# Appendix D - Titles and Survey Data

# Appendix E - Hydrographs and AQTESOLV Outputs

# Appendix F - Survey Data

# Appendix G - Stockpile Classification Information

# Appendix H - Stockpile Disposal Information

# Appendix I - Soil Re-use Acceptance Criteria

# Appendix J - Waste Trade Agreement

# Appendix K - 2015 SAP

# Appendix L - Laboratory Reports (soil)

# Appendix M - Laboratory Reports (water)

# Appendix N - Data Validation (soil)

# Appendix O - Data Validation (water)

# Appendix P - Fate and Transport of Contaminants

# Appendix Q - Statistical Analysis

# Appendix R - Health Risk Assessment

# Appendix S - Groundwater Sampling Forms and Calibration Certificate

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