Appendix K

Groundwater Bore Search
Groundwater Bore Search - Summary Table
<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Depth (m)</th>
<th>Date</th>
<th>Purpose</th>
<th>Property</th>
<th>Lithology Description</th>
<th>Lithology Description</th>
<th>Notes</th>
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<tbody>
<tr>
<td>GW052226</td>
<td>11.9</td>
<td>11/1/1980</td>
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<td>Location referenced in Hydrogeological Model (see Appendix F)</td>
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<td>GW054780</td>
<td>7</td>
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<td>Sand - grey</td>
<td>Sand - grey</td>
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<td>Sand</td>
<td>Sand - grey</td>
<td>Sand - grey</td>
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<td>GW000358</td>
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<td>Drilled Date</td>
<td>Purpose</td>
<td>Property</td>
<td>Latitude</td>
<td>Longitude</td>
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</tr>
</tbody>
</table>

**Notes:**

- SWL: Standing Water Level
- WBZ: Water Bearing Zone
- nHHD: metres Australian Height Datum
- Blank cells indicate information not available from EPA or NSW Office of Water Registered Groundwater Bore Database.

This table is based on available bore data from NSW Office of Water on SWL and lithology, registered bores used in the hydrogeological model that were not sampled during the Stage 2B investigation as well as unregistered private bores sampled by NSW EPA.

Not all available data is presented herein. For privacy reasons, personal details have been removed.
Groundwater Bore Search - Borelogs
GW050968

Licence: 20BL108810
License Status: CONVERTED

Authorised Purpose: FARMING
(s):
Intended Purpose(s): NOT KNOWN

Work Type: Bore
Work Status: Supply Obtained

Construct.Method:
Owner Type: Private

Commenced Date: 
Completion Date: 

Contractor Name: 
Driller: 
Assistant Driller: 

Property: 
GWMA: 025 - TOMAGO TOMAREE STOCKTON
GW Zone: 001 - TOMAGO

Standing Water Level (m):
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:
County Form A: GLOUC Licensed: GLOUCESTER
Parish: GLOUC.040 STOWELL
Cadastre: L22 DP533736 (94) Whole Lot 403/1048673

Region: 20 - Hunter
River Basin: 209 - KARUAH RIVER
Area/District: 

Elevation: 0.00 m (A.H.D.)
Elevation (Unknown)
Source:

GS Map: -
MGA Zone: 0
Coordinate Source:

Construction
Negative depths indicate Above Ground Level: C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Casing</td>
<td>Corrugated Galvanised Iron</td>
<td>0.00</td>
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<td>51</td>
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</table>

Water Bearing Zones

| From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|----------|--------|---------------|----------|------------|------------|-------------|----------------|---------------|-----------------|----------------|

27/04/2016
### Geologists Log
### Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
</table>

**Remarks**

*** End of GW050968 ***

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NSW Office of Water
Work Summary

GW052226

Licence: 20BL115674
Licence Status: CONVERTED

Authorised Purpose: STOCK, DOMESTIC
Intended Purpose(s): GENERAL USE

Work Type: Spear

Construct.Method: Pre-drilled
Owner Type: Private

Commenced Date: 01/01/1981
Completion Date: 01/01/1981

Contractor Name:
Driller:
Assistant Driller:

Property: 18
GWMA: 025 - TOMAGO TOMAREE STOCKTON
GW Zone: 001 - TOMAGO

Standing Water Level (m):
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

County Form A: GLOUC
Licensed: GLOUCESTER
Parish: GLOUC.039
Stockton: Whole Lot
Cadastre: 21/567466
Region: 20 - Hunter
CMA Map: 9232-2N
River Basin: 210 - HUNTER RIVER
Grid Zone: 0
Scale: PR., ACC. MAP

Elevation (m): 0.00 (A.H.D.)
Elevation (Unknown)
Source: -

GS Map: -
MGA Zone: 0
Coordinate Source: PR., ACC. MAP

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Opening</td>
<td>Screen - Gauze/Mesh</td>
<td>9.20</td>
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<td>90</td>
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<td>1</td>
<td>Stainless Steel, A: 0.30mm</td>
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Water Bearing Zones

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<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
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### Geologists Log

#### Drillers Log

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<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
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<tbody>
<tr>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>Sand Grey</td>
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<td>Sand Light Brown</td>
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### Remarks

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*** End of GW052226 ***

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NSW Office of Water
Work Summary

GW054682

Licence: 20BL117304
Licence Status: CONVERTED

Authorised Purpose(s): DOMESTIC
Intended Purpose(s): GENERAL USE

Work Type: Spear

Construct.Method:
Owner Type: Private

Commenced Date: 01/11/1980
Completion Date: 01/11/1980

Contractor Name:
Driller:
Assistant Driller:

Property
GWMA: 025 - TOMAGO TOMAREE STOCKTON
GW Zone: 001 - TOMAGO

Standing Water Level
(m):
Salinity Description: 0-500 ppm

Yield (L/s):

Site Details

Site Chosen By:

County
Form A: GLOUC
Licensed: GLOUCESTER

Parish
GLOUC.040 STOWELL

Cadastre
L25 DP251567 (116)
Whole Lot 25/251567

Region: 20 - Hunter
CMA Map: 9232-2N
River Basin: 209 - KARUAH RIVER
Area/District:

Elevation: 0.00 m (A.H.D.)
Elevation (Unknown)

GS Map: -
MGA Zone: 0
Coordinate GD,ACC.MAP

Construction
Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
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Water Bearing Zones

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<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (mm)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
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27/04/2016
### Geologists Log

### Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
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### Remarks

01/11/1983: TWO SPEARS SEPARATELY PUMPED EACH YIELDING 3.789 L/S

*** End of GW054682 ***

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NSW Office of Water
Work Summary

GW054780

Licence: 20BL117125
Licence Status: CONVERTED

Authorised Purpose (s): STOCK
Intended Purpose(s): GENERAL USE

Work Type: Spear
Construct.Method: Jetted
Owner Type: Private

Commenced Date: 01/01/1973
Completion Date: 01/01/1973

Contractor Name:
Driller:
Assistant Driller:

Property: GW054780
Standing Water Level (m):
GWMA: 025 - TOMAGO TOMAREE STOCKTON
GW Zone: 001 - TOMAGO

Site Details

Site Chosen By:
Region: 20 - Hunter
River Basin: 210 - HUNTER RIVER
Area/District: 

Elevation: 0.00 m (A.H.D.)
Elevation (Unknown)
Source:

GS Map: -
MGA Zone: 0
Coordinate GD.ACC.MAP
Source:

Construction
Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
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<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
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<th>Interval</th>
<th>Details</th>
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Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Geologists Log

Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
</table>

Remarks

*** End of GW054780 ***

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NSW Office of Water
Work Summary

GW058143

Licence: 20BL126181  Licence Status: CONVERTED

Authorised Purpose(s): STOCK, DOMESTIC
Intended Purpose(s): GENERAL USE

Work Type: Spear
Work Status: 
Construct.Method: Auger
Owner Type: Private

Commenced Date: 01/01/1984  Final Depth: 13.00 m
Completion Date: 01/01/1984  Drilled Depth: 13.00 m

Contractor Name: 
Driller: 
Assistant Driller: 

Property: 
GWMA: 025 - TOMAGO TOMAREE STOCKTON
GW Zone: 001 - TOMAGO

Standing Water Level
(m):

Salinity Description:

Yield (L/s):

Site Details

Site Chosen By: 

Region: 20 - Hunter
River Basin: 209 - KARUAH RIVER
Area/District: 

Elevation: 0.00 m (A.H.D.)
Elevation Source: (Unknown)

GS Map: -
MGA Zone: 0
Coordinate Source: GD., ACC, MAP

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Annulus</td>
<td>Waterworn/Rounded</td>
<td>10.00</td>
<td>13.00</td>
<td>175</td>
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<td></td>
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</tr>
<tr>
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<td>P.V.C.</td>
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<td>13.00</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>Opening</td>
<td>Perforations &amp; Gauze</td>
<td>11.80</td>
<td>13.00</td>
<td>65</td>
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<td>1</td>
<td>Stainless Steel, A: 0.30mm</td>
</tr>
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Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
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<tbody>
<tr>
<td>8.60</td>
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<td>5.60</td>
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### Geologists Log

#### Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>2.00</td>
<td>2.00</td>
<td>Sand Grey</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>2.00</td>
<td>9.00</td>
<td>7.00</td>
<td>Sand Indurated Water Supply</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>9.00</td>
<td>13.00</td>
<td>4.00</td>
<td>Sand Yellow Water Supply</td>
<td>Sand</td>
<td></td>
</tr>
</tbody>
</table>

#### Remarks

---

*** End of GW058143 ***

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NSW Office of Water
Work Summary

GW060358

Licence: 20BL132708  Licence Status: CONVERTED
Authorised Purpose: MINING
Intended Purpose(s): MINING

Work Type: Battery Spears

Construct.Method: Auger
Owner Type: Private

Commenced Date: Final Depth: 8.50 m
Completion Date: Drilled Depth: 8.50 m

Contractor Name:
Driller:
Assistant Driller:

Property: GWMA: 025 - TOMAGO TOMAREE STOCKTON
GW Zone: 003 - STOCKTON

Standing Water Level
(m):
Salinity Description: 0-500 ppm
Yield (L/s):

Site Details

Site Chosen By:

GWMA: 025 - TOMAGO TOMAREE STOCKTON
GW Zone: 003 - STOCKTON

Region: 20 - Hunter
CMA Map: 9232-2N
River Basin: 210 - HUNTER RIVER
Grid Zone: Scale:

Elevation: 0.00 m (A.H.D.)
Elevation (Unknown)
Source:

GS Map: -
MGA Zone: 0
Coordinate GD.,ACC.MAP
Source:

Construction
Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Annulus</td>
<td>Waterworn/Rounded</td>
<td>6.00</td>
<td>8.50</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Casing</td>
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<td>0.00</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Opening</td>
<td>Screen - Gauze/Mesh</td>
<td>6.90</td>
<td>8.50</td>
<td>80</td>
<td></td>
<td>1</td>
<td>Stainless Steel, A: 0.30mm</td>
</tr>
</tbody>
</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
</table>

### Geologists Log

#### Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.20</td>
<td>1.20</td>
<td>Sand Aeolian (refer Eolian)</td>
<td>Sand</td>
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</tr>
<tr>
<td>1.20</td>
<td>2.20</td>
<td>1.00</td>
<td>Peat</td>
<td>Peat</td>
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<tr>
<td>2.20</td>
<td>5.00</td>
<td>2.80</td>
<td>Sand Light Brown</td>
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</tr>
<tr>
<td>5.00</td>
<td>8.50</td>
<td>3.50</td>
<td>Sand Light Grey Water Supply</td>
<td>Sand</td>
<td></td>
</tr>
</tbody>
</table>

### Remarks

02/11/1987: BATTERY OF 8 SPEARS EACH 12M APART
**NSW Office of Water**

**Work Summary**

GW060459

 Licence: 20BL134880  Licence Status: LAPSED

 Authorised Purpose(s): MINING

 Intended Purpose(s): MINING

 Work Type: Bore

 Work Status:

 Construct.Method: Rotary Mud

 Owner Type: Private

 Commenced Date: 01/11/1986  Final Depth: 30.00 m

 Completion Date: 01/11/1986  Drilled Depth: 34.00 m

 Contractor Name:  Driller: [Redacted]

 Assistant Driller: [Redacted]

 Property: N/A NSW  Standing Water Level (m):

 GWMA: -  Salinity Description:

 GW Zone: -  Yield (L/s):

 Site Details

 Site Chosen By:

 County Form A: GLOUC Parish GLOUCESTER Cadastre 173

 Licensed: GLOUCESTER Licensed: STOWELL Cadastre Whole Lot //

 Region: 20 - Hunter  CMA Map: 9232-2N

 River Basin: 210 - HUNTER RIVER  Grid Zone: [Redacted]

 Area/District:  Elevation: 0.00 m (A.H.D.)

 Elevation (Unknown)  Source:

 GS Map: -  MGA Zone: 0  Coordinate GD.,ACC.MAP Source:

 Construction

 Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Annulus</td>
<td>(Unknown)</td>
<td>10.00</td>
<td>34.00</td>
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<td>Graded</td>
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<td></td>
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</tr>
<tr>
<td>1</td>
<td>Backfill</td>
<td>Backfill</td>
<td>31.00</td>
<td>34.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>1</td>
<td>Casing</td>
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<td>220</td>
<td>Seated on Bottom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Opening</td>
<td>Screen</td>
<td>20.00</td>
<td>29.00</td>
<td>220</td>
<td>Stainless Steel, A: 0.75mm</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Casing</td>
<td>Welded Steel</td>
<td>29.00</td>
<td>31.00</td>
<td>220</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
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</table>

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>Sand Yellow</td>
<td>Sand</td>
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</tr>
<tr>
<td>1.00</td>
<td>2.00</td>
<td>1.00</td>
<td>Sand White</td>
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</tr>
<tr>
<td>2.00</td>
<td>4.00</td>
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</tr>
<tr>
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<td>Sand Grey Fine</td>
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</tr>
<tr>
<td>6.00</td>
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<td>3.00</td>
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<tr>
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<td>19.00</td>
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<td>4.00</td>
<td>Sand Light Brown Coarse</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>23.00</td>
<td>30.00</td>
<td>7.00</td>
<td>Sand Grey Coarse</td>
<td>Sand</td>
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</tr>
<tr>
<td>30.00</td>
<td>32.00</td>
<td>2.00</td>
<td>Sand Light Yellow Coarse</td>
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</tr>
<tr>
<td>32.00</td>
<td>33.00</td>
<td>1.00</td>
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<tr>
<td>33.00</td>
<td>34.00</td>
<td>1.00</td>
<td>Clay Grey</td>
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</tbody>
</table>

**Remarks**

18/08/1988: BACKFILL IS GRAVEL

*** End of GW060459 ***

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NSW Office of Water
Work Summary

GW060460

License: 20BL134935
Licence Status: LAPSED

Authorised Purpose(s): MINING
Intended Purpose(s): MINING

Work Type: Bore

Construct. Method: Rotary Air
Owner Type: Private

Commenced Date: 01/11/1986
Completion Date: 01/11/1986

Contractor Name: [Redacted]
Driller: [Redacted]
Assistant Driller: [Redacted]

Property: N/A NSW

Standing Water Level (m):
GWMA: -
GW Zone: -

Site Details

Site Chosen By: County Parish Cadastre
Form A: GLOUCESTER Licensed: GLOUCESTER
Parish: STOWELL Cadastre: Whole Lot //
Region: 20 - Hunter CMA Map: 9232-2N
River Basin: 210 - HUNTER RIVER Grid Zone: Scale:
Area/District: Elevation: 0.00 m (A.H.D.)
Elevation (Unknown) Source: GS Map: -
MGA Zone: 0 Coordinate GD.,ACC,MAP
Source: Coordinate GD.,ACC.,MAP

Construction
Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Annulus</td>
<td>Waterworn/Rounded</td>
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</tr>
<tr>
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<td>1</td>
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<td>Welded Steel</td>
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<td>Seated on Bottom</td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Opening</td>
<td>Screen</td>
<td>21.00</td>
<td>30.00</td>
<td>220</td>
<td>Stainless Steel, A: 0.75mm</td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Casing</td>
<td>Welded Steel</td>
<td>30.00</td>
<td>31.00</td>
<td>220</td>
<td>Seated on Bottom</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
</table>

## Geologists Log

### Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>7.00</td>
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<td>Sand Yellow Soft Fine</td>
<td>Sand</td>
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</tr>
<tr>
<td>7.00</td>
<td>14.00</td>
<td>7.00</td>
<td>Sand Some Peat</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>14.00</td>
<td>24.50</td>
<td>10.50</td>
<td>Sand Light Grey Fine-medium Water Supply</td>
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</tr>
<tr>
<td>24.50</td>
<td>26.00</td>
<td>1.50</td>
<td>Sand Hard Shell Water Supply</td>
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</tr>
<tr>
<td>26.00</td>
<td>29.00</td>
<td>3.00</td>
<td>Sand Coarse Some Gravel Water Supply</td>
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</tr>
<tr>
<td>29.00</td>
<td>32.00</td>
<td>3.00</td>
<td>Gravel Dirty Sand Water Supply</td>
<td>Gravel</td>
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</tr>
<tr>
<td>32.00</td>
<td>34.00</td>
<td>2.00</td>
<td>Gravel Large</td>
<td>Gravel</td>
<td></td>
</tr>
</tbody>
</table>

## Remarks

*** End of GW060460 ***

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**NSW Office of Water**

**Work Summary**

GW062439

<table>
<thead>
<tr>
<th>Licence: 20BL136178</th>
<th>Licence Status: CONVERTED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Authorised Purpose</strong></td>
<td>MINING</td>
</tr>
<tr>
<td><strong>Intended Purpose(s):</strong></td>
<td>MINING</td>
</tr>
</tbody>
</table>

**Work Type:** Bore  
**Construct.Method:** Rotary Mud  
**Owner Type:** Private  
**Commenced Date:** 01/04/1989  
**Completion Date:** 01/04/1989  
**Final Depth:** 30.00 m  
**Drilled Depth:** 31.00 m  
**Contractor Name:**  
**Driller:**  
**Assistant Driller:**

**Property:**  
**GWMA:** 025 - TOMAGO TOMAREE STOCKTON  
**GW Zone:** 003 - STOCKTON

**Standing Water Level**

- **Property:**  
- **GWMA:** 025 - TOMAGO TOMAREE STOCKTON  
- **GW Zone:** 003 - STOCKTON

**Site Details**

**Site Chosen By:** County Parish Cadastre  
Form A: GLOUC  
Licensed: GLOUCESTER

**Region:** 20 - Hunter  
**CMA Map:** 9232-2N

**River Basin:** 210 - HUNTER RIVER  
**Grid Zone:**  
**Elevation:** 0.00 m (A.H.D.)  
**Elevation (Unknown)**

**GS Map:** -  
**MGA Zone:** 0  
**Coordinate GD.,ACC.MAP**

**Construction**

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>Annulus (Unknown)</td>
<td>1.00</td>
<td>31.00</td>
<td>400</td>
<td></td>
<td></td>
<td>Graded</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Casing Steel</td>
<td>-1.00</td>
<td>20.00</td>
<td>220</td>
<td></td>
<td></td>
<td>Sealed on Bottom</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Opening Screen</td>
<td>20.00</td>
<td>29.00</td>
<td>220</td>
<td>1 Stainless Steel, A: 0.75mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Casing Steel</td>
<td>29.00</td>
<td>30.00</td>
<td>220</td>
<td></td>
<td></td>
<td>Sealed on Bottom</td>
</tr>
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**Water Bearing Zones**

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
</table>

27/04/2016
### Geologists Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>3.00</td>
<td>3.00</td>
<td>Sand Yellow Water Supply</td>
<td>Sand</td>
<td></td>
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<tr>
<td>3.00</td>
<td>5.00</td>
<td>2.00</td>
<td>Sand Light Brown Water Supply</td>
<td>Sand</td>
<td></td>
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<tr>
<td>5.00</td>
<td>10.00</td>
<td>5.00</td>
<td>Clay Grey Veined Water Supply</td>
<td>Clay</td>
<td></td>
</tr>
<tr>
<td>10.00</td>
<td>12.00</td>
<td>2.00</td>
<td>Sand Grey Silty Water Supply</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>12.00</td>
<td>20.00</td>
<td>8.00</td>
<td>Sand Light Grey Medium Water Supply</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>20.00</td>
<td>27.00</td>
<td>7.00</td>
<td>Sand Light Grey Coarse Water Supply</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>27.00</td>
<td>29.00</td>
<td>2.00</td>
<td>Sand Dark Grey Coarse Water Supply</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>29.00</td>
<td>30.00</td>
<td>1.00</td>
<td>Sand Grey Silty Water Supply</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>30.00</td>
<td>31.00</td>
<td>1.00</td>
<td>Clay Grey</td>
<td>Clay</td>
<td></td>
</tr>
</tbody>
</table>

### Remarks

*** End of GW062439 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW067175

License: 20BL144361

Licence Status: CONVERTED

Authorized Purpose(s): DOMESTIC

Intended Purpose(s): DOMESTIC

Work Type: Bore

Work Status: Supply Obtained

Construct.Method:

Owner Type: Private

Commenced Date: Final Depth: 11.00 m
Completion Date: Drilled Depth: 11.00 m

Contractor Name:

Driller:

Assistant Driller:

Property: GWMA: 025 - TOMAGO TOMAREE STOCKTON
GW Zone: 001 - TOMAGO

Standing Water Level (m): 1.500

Salinity Description:

Yield (L/s): 5.620

Site Details

Site Chosen By:

County: GLOUC Parish: GLOUC.039 Cadastre: UNKNOWN FROM HYDSYS
Licensed: GLOUCESTER Licensed: STOCKTON Whole Lot 133/734906

Region: 20 - Hunter CMA Map:
River Basin: 209 - KARUAH RIVER Grid Zone:
Area/District:

Elevation: 15.00 m (A.H.D.) Scale:
Elevation Est. Contour 8-15M.
Source:

GS Map: MGA Zone: 0 Coordinate GD.ACC.MAP Source:

Construction

Negative depths indicate Above Ground Level: C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Annulus</td>
<td>Waterworn/Rounded</td>
<td>7.00</td>
<td>11.00</td>
<td>200</td>
<td>Graded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Opening</td>
<td>Screen</td>
<td>9.80</td>
<td>11.00</td>
<td>65</td>
<td>1 Stainless Steel</td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
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</thead>
<tbody>
<tr>
<td>4.00</td>
<td>11.00</td>
<td>7.00</td>
<td>Unconsolidated</td>
<td>1.50</td>
<td>5.62</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Geologists Log
### Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
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</table>

#### Remarks

25/11/2009: Updated details as per existing data.

---

*** End of GW067175 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW078012

Licence: 20BL144360  Licence Status: CANCELLED
Authorised Purpose: TEST BORE (s):
Intended Purpose(s): DOMESTIC

Work Type: Bore  Work Status:
Construct.Method: Other  Owner Type:

Commened Date: 24/11/1992  Completion Date: 24/11/1992
Final Depth: 7.00 m  Drilled Depth: 7.00 m

Contractor Name:  Assistant Driller:

Property: N/A NSW  Standing Water Level (m):
GWMA: -  Salinity Description:
GW Zone: -  Yield (L/s):

Site Details

Site Chosen By: County Form A: GLOUC Parish Cadastre
licensed: GLOUCESTER STOCKTON DP734906 / LOT 133

Region: 20 - Hunter  CMA Map:
River Basin: - Unknown  Grid Zone: Scale:
Area/District:

Elevation: 0.00 m (A.H.D.)  Source:
Elevation Unknown  Source:

GS Map: -  MGA Zone: 0  Coordinate Source:

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
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<tbody>
<tr>
<td>1</td>
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<td></td>
<td></td>
<td>Auger</td>
</tr>
<tr>
<td>1</td>
<td>Annulus</td>
<td>Waterworn/Rounded</td>
<td>1.00</td>
<td>7.00</td>
<td></td>
<td></td>
<td></td>
<td>Graded</td>
</tr>
<tr>
<td>1</td>
<td>Casing</td>
<td>PVC Class 6</td>
<td>0.00</td>
<td>7.00</td>
<td>100</td>
<td></td>
<td></td>
<td>Seated on Bottom, Glued</td>
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<tr>
<td>1</td>
<td>Opening</td>
<td>Slots - Horizontal</td>
<td>1.50</td>
<td>7.00</td>
<td>100</td>
<td>1</td>
<td></td>
<td>PVC, SL: 5.5mm</td>
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Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
</table>

27/04/2016
### Geologists Log

### Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.50</td>
<td>0.50</td>
<td>Topsoil</td>
<td>Topsoil</td>
<td></td>
</tr>
<tr>
<td>0.50</td>
<td>1.50</td>
<td>1.00</td>
<td>Sand</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>1.50</td>
<td>7.00</td>
<td>5.50</td>
<td>Unknown</td>
<td>Unknown</td>
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</table>

### Remarks

---

*** End of GW078012 ***

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NSW Office of Water
Work Summary

GW079378

Licence: Licence Status:
Authorised Purpose(s):
Intended Purpose(s):

Work Type: Bore
Work Status:
Construct.Method:
Owner Type:

Commenced Date: Final Depth:
Completion Date: Drilled Depth:

Contractor Name:
Driller:
Assistant Driller:

Property: Standing Water Level
GWMA: Salinity Description:
GW Zone: Yield (L/s):

Site Details

Site Chosen By:

Region: 20 - Hunter
River Basin: - Unknown
Area/District:

Elevation: 0.00 m (A.H.D.)
Elevation Unknown
Source:

GS Map: -
MGA Zone: 0
Coordinate Unknown
Source:

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
</table>

Water Bearing Zones

| From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|----------|--------|---------------|----------|------------|------------|-------------|----------------|---------------|----------------|----------------|

Geologists Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
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</table>
19/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
NORTH STOCKTON
BORE: JCB20

*** End of GW079378 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW079379

Licence: 
Licence Status:

Authorised Purpose(s):
Intended Purpose(s):

Work Type: Bore
Work Status:
Construct.Method:
Owner Type:

Commenced Date: 
Completion Date: 

Final Depth: 
Drilled Depth:

Contractor Name:
Driller:
Assistant Driller:

Property: 
Standing Water Level (m):
GWMA: 
Salinity Description:
GW Zone: 
Yield (L/s):

Site Details

Site Chosen By:

Form A:
County 
Parish 
Cadastre:

Licensed:

Region: 20 - Hunter
River Basin: - Unknown
Area/District:

CMA Map:
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Unknown
Source:

GS Map: -
MGA Zone: 0
Coordinate Unknown Source:

Construction
Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
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</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
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Geologists Log

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<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
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</table>
Remarks

19/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
NORTH STOCKTON
BORE: JCB21

*** End of GW079379 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW079384

Licence: 

Licence Status: 

Authorised Purpose(s): 
Intended Purpose(s): 

Work Type: Bore 

Work Status: 

Construct.Method: 

Owner Type: 

Commenced Date: 
Completion Date: 

Final Depth: 
Drilled Depth: 

Contractor Name: 
Driller: 
Assistant Driller: 

Property: 

Standing Water Level (m): 

GWMA: 

Salinity Description: 

GW Zone: 

Yield (L/s): 

Site Details

Site Chosen By: 

Form A: 
Licensed: 

County 
Parish 
Cadastre 

Region: 20 - Hunter 

CMA Map: 

River Basin: - Unknown 

Grid Zone: 

Area/District: 

Scale: 

Elevation: 0.00 m (A.H.D.) 

Elevation Unknown 

Source: 

GS Map: - 

MGA Zone: 0 

 Coordinate Unknown 

Source: 

Construction
Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
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</thead>
</table>

Geologists Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
</table>
19/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
NORTH STOCKTON
BORE: JCB9

*** End of GW079384 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW079470

Licence: Licence Status:

Authorised Purpose(s):
Intended Purpose(s):

Work Type: Bore
Work Status:
Construct.Method:
Owner Type:

Commenced Date:
Completion Date:

Contractor Name:
Driller:
Assistant Driller:

Owner Type:

Property: Standing Water Level (m):
GWMA: Salinity Description:
GW Zone: Yield (L/s):

Site Details

Site Chosen By:

County Parish Cadastre
Form A: Licensed:

Region: 20 - Hunter
River Basin: - Unknown
Area/District:

Elevation: 0.00 m (A.H.D.)
Elevation: Unknown
Source:

GS Map: -
MGA Zone: 0
Coordinate Source:

Construction
Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

| Hole Pipe Component Type From (m) To (m) Outside Diameter (mm) Inside Diameter (mm) Interval Details |
|---|---|---|---|---|---|

Water Bearing Zones

From (m) To (m) Thickness (m) WBZ Type S.W.L. (m) D.D.L. (m) Yield (L/s) Hole Depth (m) Duration (hr) Salinity (mg/L)

Geologists Log

Drillers Log

From (m) To (m) Thickness (m) Drillers Description Geological Material Comments
Remarks

20/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
TOMAGO
BORE: PS11(1)

*** End of GW079470 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW079472

<table>
<thead>
<tr>
<th>Licence:</th>
<th>Licence Status:</th>
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<tbody>
<tr>
<td></td>
<td>Authorised Purpose(s):</td>
</tr>
<tr>
<td></td>
<td>Intended Purpose(s):</td>
</tr>
</tbody>
</table>

Work Type: Bore

Work Status:

Construct.Method:

Owner Type:

Commenced Date:

Completion Date:

Contractor Name:

Driller:

Assistant Driller:

Property: Standing Water Level (m):

GWMA: Salinity Description:

GW Zone: Yield (L/s):

Site Details

Site Chosen By:

County  Parish  Cadastre

Form A:

Region: 20 - Hunter

CMA Map:

River Basin: - Unknown

Grid Zone:

Area/District:

Scale:

Elevation: 0.00 m (A.H.D.)

Elevation Unknown

Source:

GS Map: -

MGA Zone: 0

Coordinate Source:

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
</table>

Geologists Log

<table>
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<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
</table>

Drillers Log


28/06/2016
Remarks

20/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
TOMAGO
BORE: PS12(1)

*** End of GW079472 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
GW079486

Licence:

Licence Status:

Authorised Purpose(s):

Intended Purpose(s):

Work Type: Bore

Work Status:

Construct.Method:

Owner Type:

Commenced Date:

Completion Date:

Contractor Name:

Driller:

Assistant Driller:

Property: Standing Water Level (m):

GWMA:

GW Zone:

Site Details

Site Chosen By:

County

Parish

Cadastre

Form A:

Licensed:

Region: 20 - Hunter

CMA Map:

River Basin: - Unknown

Grid Zone:

Area/District:

Scale:

Elevation: 0.00 m (A.H.D.)

Elevation Unknown

Source:

GS Map: -

MGA Zone: 0

Coordinate Source: Unknown

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
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</thead>
</table>

Geologists Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
</table>
Remarks

21/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
TOMAGO
BORE: PS3(1)

*** End of GW079486 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW079490

Licence: Licence Status:

Authorised Purpose(s):

Intended Purpose(s):

Work Type: Bore

Work Status:

Construct.Method:

Owner Type:

Commenced Date: Final Depth:

Completion Date: Drilled Depth:

Contractor Name:

Driller:

Assistant Driller:

Property: Standing Water Level

GWMA:

GW Zone:

Salinity Description:

Yield (L/s):

Site Details

Site Chosen By:

County

Parish

Cadastre

Form A: Licensed:

Region: 20 - Hunter

CMA Map:

River Basin: - Unknown

Grid Zone:

Area/District:

Scale:

Elevation: 0.00 m (A.H.D.)

Elevation Unknown

Source:

GS Map: -

MGA Zone: 0

Coordinate Source:

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
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<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
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</thead>
</table>

Water Bearing Zones

<table>
<thead>
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<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
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Geologists Log

<table>
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<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
</table>

Drillers Log
Remarks

21/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
TOMAGO
BORE: PSS(1)

*** End of GW079490 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
# NSW Office of Water

## Work Summary

**GW079494**

**Licence:**

**Licence Status:**

**Authorised Purpose(s):**

**Intended Purpose(s):**

**Work Type:** Bore

**Work Status:**

**Construct.Method:**

**Owner Type:**

**Commenced Date:**

**Completion Date:**

**Contractor Name:**

**Driller:**

**Assistant Driller:**

**Property:**

**Standing Water Level (m):**

**GWMA:**

**Salinity Description:**

**GW Zone:**

**Yield (L/s):**

## Site Details

**Site Chosen By:**

**County**

**Parish**

**Cadastre**

**Form A:**

**Licensed:**

**Region:** 20 - Hunter

**River Basin:** - Unknown

**Area/District:**

**Elevation:** 0.00 m (A.H.D.)

**Elevation Source:**

**Grid Zone:**

**Scale:**

**CMA Map:**

**GS Map:** -

**MGA Zone:** 0

**Coordinate Source:** Unknown

## Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
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<th>Hole</th>
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<th>From (m)</th>
<th>To (m)</th>
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</thead>
</table>

## Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
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## Geologists Log

## Drillers Log

<table>
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<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
</table>

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28/06/2016
Remarks

21/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
TOMAGO
BORE: PS7(1)

*** End of GW079494 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW079496

 Licence: 
 Licence Status: 

 Authorised Purpose(s): 
 Intended Purpose(s): 

 Work Type: Bore 
 Work Status: 
 Construct.Method: 
 Owner Type: 

 Commenced Date: 
 Completion Date: 
 Contractor Name: 
 Driller: 
 Assistant Driller: 

 Property: Standing Water Level (m): 
 GWMA: Salinity Description: 
 GW Zone: Yield (L/s): 

 Site Details 

 Site Chosen By: 

 County Parish Cadastre 
 Form A: 
 Licensed: 

 Region: 20 - Hunter 
 River Basin: - Unknown 
 Area/District: 

 CMA Map: 
 Grid Zone: 
 Scale: 

 Elevation: 0.00 m (A.H.D.) 
 Elevation Unknown 
 Source: 

 GS Map: - 
 MGA Zone: 0 
 Coordinate Source: Unknown 

 Construction 
 Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers 

 Water Bearing Zones 

 Hole Pipe Component Type From (m) To (m) Outside Diameter (mm) Inside Diameter (mm) Interval Details 

 Geologists Log 

 Drillers Log 

 From (m) To (m) Thickness (m) Drillers Description Geological Material Comments 

Remarks

21/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
TOMAGO
BORE: PS7A(1)

*** End of GW079496 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW079498

Licence: Licence Status:

Authorised Purpose(s):
Intended Purpose(s):

Work Type: Bore

Work Status:
Construct.Method:
Owner Type:

Commenced Date:
Completion Date:

Contractor Name:
Driller:
Assistant Driller:

Property: Standing Water Level (m):
GWMA:
GW Zone:
Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

County Parish Cadastre
Form A: Licensed:

Region: 20 - Hunter
River Basin: - Unknown
Area/District:

Elevation: 0.00 m (A.H.D.)
Elevation Unknown
Source:

GS Map: -
MGA Zone: 0
Coordinate Source:

Construction
Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

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<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
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</thead>
</table>

Water Bearing Zones

From (m) To (m) Thickness (m) WBZ Type S.W.L. (m) D.D.L. (m) Yield (L/s) Hole Depth (m) Duration (hr) Salinity (mg/L)

Geologists Log

Drillers Log

From (m) To (m) Thickness (m) Drillers Description Geological Material Comments

28/06/2016

Remarks

21/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
TOMAGO
BORE: PS8(1)

*** End of GW079498 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water

Work Summary

GW079500

Licence: 
Licence Status: 

Authorised Purpose(s): 
Intended Purpose(s): 

Work Type: Bore

Work Status: 

Construct. Method: 

Owner Type: 

Commenced Date: 
Completion Date: 

Contractor Name: 
Driller: 
Assistant Driller: 

Property: 
GWMA: 
GW Zone: 

Standing Water Level (m): 
Salinity Description: 
Yield (L/s): 

Site Details

Site Chosen By: 

County 
Parish 
Cadastre 

Form A: 
Licensed: 

Region: 20 - Hunter 
River Basin: - Unknown 
Area/District: 

CMA Map: 
Grid Zone: 
Scale: 

Elevation: 0.00 m (A.H.D.) 
Elevation Unknown 
Source: 

GS Map: - 
MGA Zone: 0 
Coordinate Source: Unknown 

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
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<th>Details</th>
</tr>
</thead>
</table>

Water Bearing Zones

From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|--------|--------|---------------|---------|------------|-----------|-------------|----------------|----------------|-----------------|

Geologists Log

Drillers Log

From (m) | To (m) | Thickness (m) | Drillers Description | Geological Material | Comments |
|--------|--------|---------------|----------------------|---------------------|---------|
Remarks

21/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
TOMAGO
BORE: PS9(1)

*** End of GW079500 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW079679

<table>
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<th>Licence:</th>
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<td>Authorised Purpose(s):</td>
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<tr>
<td></td>
<td>Intended Purpose(s):</td>
</tr>
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</table>

| Work Type: | Bore |
| Work Status: |    |
| Construct.Method: |    |
| Owner Type: |    |

| Commenced Date: | Final Depth: |
| Completion Date: | Drilled Depth: |
| Contractor Name: |    |
| Driller: |    |
| Assistant Driller: |    |

| Property: | Standing Water Level (m): |
| GWMA: | Salinity Description: |
| GW Zone: | Yield (L/s): |

Site Details

Site Chosen By:

<table>
<thead>
<tr>
<th>County</th>
<th>Parish</th>
<th>Cadastre</th>
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<tbody>
<tr>
<td>Form A:</td>
<td>Licensed:</td>
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</table>

| Region: | 20 - Hunter |
| River Basin: | - Unknown |
| Area/District: |    |

| Elevation: | 0.00 m (A.H.D.) |
| Elevation Unknown | Source: |

| GS Map: | - |
| MGA Zone: | 0 |
| Coordinate Source: | Unknown |

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
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<th>Details</th>
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</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
</table>

Geologists Log

<p>| Drillers Log |</p>
<table>
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<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
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28/06/2016
Remarks

28/10/1999: Form A Remarks:
HUNTER WATER CORPORATION
TOMAGO
BORE: SK6348

*** End of GW079679 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
GW080079

 Licence: Licence Status:

 Authorised Purpose (s):

 Intended Purpose(s): MONITORING BORE

 Work Type: Bore
 Work Status: Instrumented, LT300
 Construct. Method: Jetted - Water
 Owner Type: NSW Office of Water

 Commenced Date: 16/07/2002
 Completion Date: 16/07/2002

 Contractor Name

 Assistant Driller:

 Property: Standing Water Level 1.100 (m):

 GWMA: Salinity Description:

 GW Zone: Yield (L/s): 0.160

 Site Details

 Site Chosen By:

 County Form A: Licensed:

 Region: 20 - Hunter
 River Basin: 210 - HUNTER RIVER
 Area/District: 

 Elevation: 2.65 m (A.H.D.)
 Elevation R.L. at W.L.M.Pt.
 Source:

 CMA Map: 9232-2N
 Grid Zone: 
 Scale:

 GS Map: -
 MGA Zone: 56
 Coordinate Source: Unknown

 Construction

 Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
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<tr>
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<th>Pipe</th>
<th>Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
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<tbody>
<tr>
<td>1</td>
<td>Hole</td>
<td>Hole</td>
<td></td>
<td>0.00</td>
<td>8.57</td>
<td>50</td>
<td></td>
<td></td>
<td>Jetted - Air</td>
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<tr>
<td>1 1</td>
<td>Casing</td>
<td>Pvc Class 12</td>
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<td>0.00</td>
<td>7.80</td>
<td>50</td>
<td>40</td>
<td></td>
<td>Other, Glued</td>
</tr>
<tr>
<td>1 1</td>
<td>Opening</td>
<td>Screen - Round Wire</td>
<td></td>
<td>7.80</td>
<td>8.40</td>
<td>1</td>
<td>Stainless Steel, Glued, A: 0.15mm</td>
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<td></td>
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<tr>
<td>1 1</td>
<td>Opening</td>
<td>Slots - Horizontal</td>
<td></td>
<td>7.80</td>
<td>8.40</td>
<td>50</td>
<td>Stainless Steel</td>
<td></td>
<td></td>
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 Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Duration (hr)</th>
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</table>


26/04/2016
### Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
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<tbody>
<tr>
<td>0.00</td>
<td>0.40</td>
<td>0.40</td>
<td>Top soil</td>
<td>Topsoil</td>
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<tr>
<td>0.40</td>
<td>7.00</td>
<td>6.60</td>
<td>Sand - grey</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>7.00</td>
<td>7.50</td>
<td>0.50</td>
<td>Rock - coffee</td>
<td>Rock</td>
<td></td>
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<tr>
<td>7.50</td>
<td>8.40</td>
<td>0.90</td>
<td>Sand</td>
<td>Sand</td>
<td></td>
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<tr>
<td>8.40</td>
<td>8.57</td>
<td>0.17</td>
<td>Rock</td>
<td>Rock</td>
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### Remarks

24/01/2011: AHD established top casing RL 2.646  
23/05/2012: LT300 replaced due to expiration of calibration period. Out: 124625 In: 123941  
26/09/2012: Primary Client changed from GWH to GWA on 26/09/2012.

*** End of GW080079 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
**NSW Office of Water**  
**Work Summary**

**GW080286**

<table>
<thead>
<tr>
<th>Licence:</th>
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<tr>
<td>Licence Status:</td>
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**Authorised Purpose (s): INDUSTRIAL**

**Intended Purpose(s): INDUSTRIAL**

**Work Type:** Spear  
**Construct.Method:**  
**Owner Type:** Private  
**Commenced Date:** 03/09/2002  
**Completion Date:**  
**Contractor Name:**  
**Driller:**  
**Assistant Driller:**

**Property:**  
**GWMA:** 025 - TOMAGO TOMAREE STOCKTON  
**GW Zone:** 001 - TOMAGO  
**Standing Water Level:**  
**Salinity Description:**  
**Yield (L/s):**

### Site Details

**Site Chosen By:** County Parish Cadastre  
**Form A:** GLOUCESTER  
**Licensed:** GLOUC  
**Parish:** 040  
**Cadastre:** LT170 DP753192 Whole Lot  
**Region:** 20 - Hunter  
**River Basin:** 209 - KARUAH RIVER  
**CMA Map:** 9232-2N  
**Grid Zone:**  
**Elevation:** 0.00 m (A.H.D.)  
**Elevation (Unknown) Source:**  
**GS Map:**  
**MGA Zone:** 0  
**Coordinate Source:** Unknown

### Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
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<th>Component</th>
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28/06/2016
**Geologists Log**

**Drillers Log**

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**Remarks**

01/12/2009: Reviewed data - nothing to update.

*** End of GW080286 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW080653

Licence: 20BL169162
Licence Status: ACTIVE

Authorised Purpose: TEST BORE
Intended Purpose(s): EXPERIMENTAL/RESEARCH

Work Type: Bore
Work Status:

Construct.Method:
Owner Type:

Commenced Date: 20/08/2003
Completion Date: 20/08/2003

Final Depth: 3.30 m
Drilled Depth: 3.30 m

Contractor Name: [Redacted]
Driller: [Redacted]
Assistant Driller:

Property: N/A
Standing Water Level (m):
GWMA: -
GW Zone: -

Salinity Description:
Yield (L/s):

Site Details

Site Chosen By:

County Form A: GLOUC
Licensed: GLOUCESTER
Parish: GLOUC.40 STOWELL
Cadastre: LT17 DP567482 Whole Lot 17/567482

Region: 20 - Hunter
CMA Map: 9232-2N
River Basin: 209 - KARUAH RIVER
Grid Zone:
Scale:

Elevation: 0.00 m (A.H.D.)
Elevation (Unknown)
Source:

GS Map: -
MGA Zone: 0
Coordinate Source: Map Interpretation

Construction
Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe</th>
<th>Component Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hole</td>
<td>Hole</td>
<td>0.00</td>
<td>3.30</td>
<td>150</td>
<td></td>
<td></td>
<td>Auger</td>
</tr>
</tbody>
</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
</table>

Geologists Log


27/04/2016
## Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.70</td>
<td>1.70</td>
<td>Fill, silty sand, loose with occasional plastic sheet pieces brown (landfarm backfill)</td>
<td>Fill</td>
<td></td>
</tr>
<tr>
<td>1.70</td>
<td>2.70</td>
<td>1.00</td>
<td>Sand, fine grained, saturated, grey</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>2.70</td>
<td>3.30</td>
<td>0.60</td>
<td>Light grey sand</td>
<td>Sand</td>
<td></td>
</tr>
</tbody>
</table>

## Remarks

20/08/2003: Form A Remarks: Location map received and test bore log
Bore No.: BH1

*** End of GW080653 ***
NSW Office of Water
Work Summary

GW080655

Licence: 20BL169162
Licence Status: ACTIVE

Authorised Purpose: TEST BORE
Intended Purpose(s): EXPERIMENTAL/RESEARCH

Work Type: Bore
Work Status: Construct.Method: Auger
Owner Type:

Commenced Date: 20/08/2003
Completion Date: 20/08/2003

Final Depth: 3.00 m
Drilled Depth: 3.00 m

Contractor Name: [redacted]
Driller: [redacted]
Assistant Driller: [redacted]

Property: N/A
Standing Water Level
GWMA: -
GW Zone: -
Salinity Description: Yield (L/s):

Site Details

Site Chosen By:

County Form A: GLOUC Parish Cadastre
Licensed: GLOUCESTER STOWELL LT17 DP567482
Region: 20 - Hunter Cadastre Region:
CMA Map: 9232-2N River Basin: 209 - KARUAH RIVER Scale:
Area/District:

Elevation: 0.00 m (A.H.D.) Elevation (Unknown)
Source:

GS Map: - MGA Zone: 0 Coordinate Source:

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval (m)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>3.00</td>
<td>150</td>
<td></td>
<td></td>
<td>Auger</td>
</tr>
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</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
</table>

Geologists Log
### Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.90</td>
<td>0.90</td>
<td>Fill sand with pieces of plastic sheet, loose, moist, brown (Landfill backfill)</td>
<td>Fill</td>
<td></td>
</tr>
<tr>
<td>0.90</td>
<td>3.00</td>
<td>2.10</td>
<td>Sand, moist, orange/grey becoming saturated at 1.8 - 1.9</td>
<td>Sand</td>
<td></td>
</tr>
</tbody>
</table>

### Remarks

20/08/2003: Form A Remarks:  
Location map received  
Bore No. BH3

*** End of GW080655 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
### NSW Office of Water

#### Work Summary

**GW080656**

- **Licence:** 208L169162
- **Licence Status:** ACTIVE

#### Authorised Purpose:
- TEST BORE

#### Intended Purpose(s):
- EXPERIMENTAL/RESEARCH

#### Work Type:
- Bore

#### Construct.Method:
- Owner Type:

- **Commenced Date:**
- **Completion Date:** 20/08/2003
- **Final Depth:** 3.10 m
- **Drilled Depth:** 3.10 m

- **Contractor Name:**
- **Driller:**
- **Assistant Driller:**

- **Property:** N/A
- **Standing Water Level:**
  - **GWMA:** -
  - **GW Zone:** -

#### Site Details

- **Site Chosen By:**
- **Form A:** GLOUC GLOUC.40 LT17 DP567482
- **Licensed:** GLOUCESTER STOWELL
- **Cadastre:**
  - **Region:** 20 - Hunter
  - **CMA Map:** 9232-2N
  - **River Basin:** 209 - KARUAH RIVER
  - **Area/District:**
  - **Elevation:** 0.00 m (A.H.D.)
  - **Elevation Source:** (Unknown)
  - **GS Map:** -
  - **MGA Zone:** 0

- **Coordinate Source:** Map Interpretation

#### Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hole</td>
<td>Hole</td>
<td>0.00</td>
<td>3.10</td>
<td>150</td>
<td></td>
<td></td>
<td>Auger</td>
</tr>
</tbody>
</table>

#### Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
</table>

#### Geologists Log
Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.30</td>
<td>0.30</td>
<td>Fill clay/sand mix</td>
<td>Fill</td>
<td></td>
</tr>
<tr>
<td>0.30</td>
<td>0.60</td>
<td>0.30</td>
<td>Topsoil Silty sand, high organic content, moist, dark grey</td>
<td>Topsoil</td>
<td></td>
</tr>
<tr>
<td>0.60</td>
<td>3.10</td>
<td>2.50</td>
<td>Sand, moist, organe/grey becoming saturated at 1.7 m</td>
<td>Sand</td>
<td></td>
</tr>
</tbody>
</table>

Remarks

20/08/2004: Form A Remarks:
Location map provided
Test Bore Log Bore No. BH4

*** End of GW080656 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW080657

Licence: 20BL169162
Licence Status: ACTIVE

Authorised Purpose: TEST BORE
Intended Purpose(s): EXPERIMENTAL/RESEARCH

Work Type: Bore
Work Status:

Construct.Method:
Owner Type:

Commenced Date: 20/08/2003
Completion Date: 20/08/2003

Final Depth: 3.20 m
Drilled Depth: 3.20 m

Contractor Name:
Driller:
Assistant Driller:

Property: N/A
Standing Water Level (m):
GWMA: -
Salinity Description:
GW Zone: -
Yield (L/s):

Site Details

Site Chosen By:

County Form A: GLOUC Parish GLOUC.40 Cadastre LT17 DP567482
Licensed: GLOUCESTER Licensed: STOWELL Whole Lot 17/567482

Region: 20 - Hunter CMA Map: 9232-2N
River Basin: 209 - KARUAH RIVER Grid Zone: Scale:
Area/District: Elevation: 0.00 m (A.H.D.)
Elevation (Unknown) Source:

GS Map: - MGA Zone: 0 Coordinate Source: Map Interpretation

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hole</td>
<td>Hole</td>
<td>0.00</td>
<td>3.20</td>
<td>150</td>
<td></td>
<td></td>
<td>Auger</td>
</tr>
</tbody>
</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
</table>

Geologists Log

### Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.30</td>
<td>0.30</td>
<td>Topsoil, silty sand, high organic content, dark grey</td>
<td>Topsoil</td>
<td></td>
</tr>
<tr>
<td>0.30</td>
<td>3.20</td>
<td>2.90</td>
<td>Sand, fine to medium grained, grey. Light grey at 1.8 m</td>
<td>Sand</td>
<td></td>
</tr>
</tbody>
</table>

### Remarks

20/08/2004: Form A Remarks:
Location map received
Test Bore Log Bore No. BH5

*** End of GW080657 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
NSW Office of Water
Work Summary

GW080658

Licence: 20BL169162
Licence Status: ACTIVE

Authorised Purpose (s):
TEST BORE

Intended Purpose(s): EXPERIMENTAL/RESEARCH

Work Type: Bore
Work Status:

Construct.Method: Auger
Owner Type:

Commenced Date: 20/08/2003
Completion Date: 20/08/2003

Final Depth: 3.20 m
Drilled Depth: 3.20 m

Contractor Name:
Driller:
Assistant Driller:

Property: N/A
Standing Water Level (m):
GWMA: -
Salinity Description:
GW Zone: -
Yield (L/s):

Site Details

Site Chosen By:

County Form A: GLOUC
Parish Licensed: GLOUCESTER
Cadastre Licensed: STOWELL

Region: 20 - Hunter
CMA Map: 9232-2N

River Basin: 209 - KARUAH RIVER
Area/District:

Grid Zone: Scale:

Elevation: 0.00 m (A.H.D.)
Elevation Source:

GS Map: -
MGA Zone: 0
Coordinate Source:

Construction
Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hole</td>
<td>Hole</td>
<td>0.00</td>
<td>3.20</td>
<td>150</td>
<td></td>
<td></td>
<td>Auger</td>
</tr>
</tbody>
</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
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Geologists Log

### Drillers Log

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<th>To (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.30</td>
<td>0.30</td>
<td>Topsoil, silty sand, high organic content, dark grey</td>
<td>Topsoil</td>
<td></td>
</tr>
<tr>
<td>0.30</td>
<td>3.20</td>
<td>2.90</td>
<td>Sand, fine to medium grained, grey. Light grey at 1.8 m</td>
<td>Sand</td>
<td></td>
</tr>
</tbody>
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### Remarks

20/08/2003: Form A Remarks:
- Location map received
- Test Bore Log Bore No. BH6

---

*** End of GW080658 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
Work Summary

License: 20WA211059

Licence Status: CURRENT

Authorised Purpose(s): STOCK, DOMESTIC

Intended Purpose(s): STOCK, DOMESTIC

Work Type: Bore

Work Status: Supply Obtained

Construct.Method: Auger - Hollow Flight

Owner Type: Private

Commenced Date: 04/01/2010

Completion Date: 04/01/2010

Final Depth: 25.00 m

Drilled Depth: 25.00 m

Contractor Name: Driller: P

Property: Standing Water

GWMA: Salinity: 2.300

GW Zone: Yield: 1.000

Site Details

Site Chosen By:

County: GLOUC

Parish: GLOUC.40

Cadastre: 1/1152543

Region: 20 - Hunter

CMA Map: 9232-2N

River Basin: 209 - KARUAH RIVER

Area/District:

Elevation: 0.00 m (A.H.D.)

Source: Unknown

GS Map: -

MGA Zone: 0

Coordinate Source: GIS - Geographic Information System

Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

<table>
<thead>
<tr>
<th>Hole</th>
<th>Pipe Component</th>
<th>Type</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Outside Diameter (mm)</th>
<th>Inside Diameter (mm)</th>
<th>Interval</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hole Hole</td>
<td>0.00</td>
<td>25.00</td>
<td>150</td>
<td>Auger - Hollow Flight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Casing PVC Class 9</td>
<td>0.00</td>
<td>25.00</td>
<td>60</td>
<td>53 Seated on Bottom, Glued</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Opening Screen - Gauze/Mesh</td>
<td>23.50</td>
<td>25.00</td>
<td>60</td>
<td>1 PVC Class 9, Glued</td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

Water Bearing Zones

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To (m)</th>
<th>Thickness (m)</th>
<th>WBZ Type</th>
<th>S.W.L. (m)</th>
<th>D.D.L. (m)</th>
<th>Yield (L/s)</th>
<th>Hole Depth (m)</th>
<th>Duration (hr)</th>
<th>Salinity (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.30</td>
<td>25.00</td>
<td>22.70</td>
<td>Unknown</td>
<td>2.30</td>
<td>1.00</td>
<td>227.00</td>
<td>2.30</td>
<td>2.30</td>
<td>227.00</td>
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</tbody>
</table>

## Geologists Log

### Drillers Log

<table>
<thead>
<tr>
<th>From (m)</th>
<th>To  (m)</th>
<th>Thickness (m)</th>
<th>Drillers Description</th>
<th>Geological Material</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>5.00</td>
<td>5.00</td>
<td>Sand, amber, medium grained</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>5.00</td>
<td>12.00</td>
<td>7.00</td>
<td>Sand, amber, coarse grained</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>12.00</td>
<td>16.00</td>
<td>4.00</td>
<td>Sand, white, fine grained</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>16.00</td>
<td>18.00</td>
<td>2.00</td>
<td>Mud, grey, with shell</td>
<td>Mud</td>
<td></td>
</tr>
<tr>
<td>18.00</td>
<td>25.00</td>
<td>7.00</td>
<td>Sand, white, coarse grained</td>
<td>Sand</td>
<td></td>
</tr>
</tbody>
</table>

### Remarks

04/01/2010: Form A Remarks:
Nat Carling, 20-Apr-2012; Coordinates based on location map provided with the Form-A.

---

*** End of GW201574 ***

Warning To Clients: This raw data has been supplied to the NSW Office of Water by drillers, licensees and other sources. The NOW does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.
Groundwater Bore Search - Figure
Appendix L

Modelling Report
RAAF Williamtown

Groundwater Modelling

FOR
AECOM Services Pty Ltd

BY
Heritage Computing Pty Ltd
trading as
HydroSimulations

Project number: AEC002
Report: HC2016/09d
Date: June 2016
## DOCUMENT REGISTER

<table>
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<th>Revision</th>
<th>Description</th>
<th>Authors</th>
<th>Reviewers</th>
<th>Date</th>
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<td>A</td>
<td>First Draft</td>
<td>C Turvey, W Minchin</td>
<td>Dr N Merrick - HydroSimulations</td>
<td>22 April 2016</td>
<td>Initial draft for review</td>
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<tr>
<td>B</td>
<td>Second Draft</td>
<td>C Turvey, W Minchin</td>
<td>Dr N Merrick</td>
<td>11 May 2016</td>
<td>For inclusion with AECOM draft Stage 2B to Defence</td>
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<tr>
<td>C</td>
<td>Final Draft</td>
<td>C Turvey, W Minchin</td>
<td>Dr N Merrick</td>
<td>06 June 2016</td>
<td>Incorporates comments from Site Auditor</td>
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<tr>
<td>D</td>
<td>Final Report</td>
<td>C Turvey, W Minchin</td>
<td>Dr N Merrick</td>
<td>24 June 2016</td>
<td>Incorporates secondary comments from Site Auditor</td>
</tr>
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</table>

**File:**

X:\HYDROSIM\WILLIAMTOWN\Reports\AEC002\HC2016-09d Williamtown Groundwater Modelling.docx
# TABLE OF CONTENTS

1 Introduction .................................................................................................................. 1
  1.1 Summary of Historical Use of AFFF at Williamtown ................................................. 1
  1.2 Nature of the Contaminant ...................................................................................... 2
  1.3 Scope of Work ......................................................................................................... 3
  1.4 Modelling Objectives ............................................................................................. 3
  1.5 Model Confidence and Complexity .......................................................................... 3

2 Hydrogeological Conceptual Model ............................................................................ 4
  2.1 Geology ................................................................................................................. 4
  2.2 Climate ................................................................................................................... 4
  2.3 Surface Water ........................................................................................................ 5
  2.4 Hydrogeology ........................................................................................................ 6
    2.4.1 Anthropogenic Groundwater Use ...................................................................... 7
    2.4.2 Aquifer Properties ........................................................................................... 7

3 Groundwater Simulation Model .................................................................................. 10
  3.1 Previous Models .................................................................................................... 10
  3.2 Model Software ..................................................................................................... 10
    3.2.1 Software ........................................................................................................... 10
    3.3 Model Mesh .......................................................................................................... 10
    3.4 Model Geometry and Hydrostratigraphy ............................................................... 11
    3.5 Model Temporal Discretisation ............................................................................. 12
    3.6 Boundary Conditions ............................................................................................ 12
      3.6.1 Constant Head Boundaries ............................................................................. 12
      3.6.2 ‘River’ Boundaries ........................................................................................ 12
      3.6.3 Recharge ........................................................................................................... 12
      3.6.4 Evapotranspiration ........................................................................................ 14
      3.6.5 Pumping Wells ............................................................................................... 15
      3.6.6 Contaminant Sources ..................................................................................... 15
  3.7 Flow Model Calibration ........................................................................................ 16
    3.7.1 Approach .......................................................................................................... 16
    3.7.2 Groundwater Levels ........................................................................................ 17
    3.7.3 Calibrated Model Parameters .......................................................................... 18
    3.7.4 Mass Balance ................................................................................................... 18
  3.8 Transport Model Calibration .................................................................................. 19
    3.8.1 Baseline Model Run (WLM029) ...................................................................... 19
    3.8.2 Additional Model Runs .................................................................................... 20
  3.9 Model Performance ................................................................................................. 21

4 Predictive Modelling ................................................................................................. 23
  4.1 Future Contaminant Distributions ........................................................................... 23
  4.2 Site Specific Concentrations .................................................................................. 23
  4.3 Particle Tracking .................................................................................................... 24

5 Limitations and Recommendations ............................................................................ 26

6 Conclusions ................................................................................................................ 28

References ..................................................................................................................... 30

Figures ............................................................................................................................ 33

Appendix A List of Calibration Target Locations ........................................................... 71
Appendix B Calibration Hydrographs ............................................................................ 76
Appendix C Model Classification Tables ....................................................................... 78
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Identified likely AFFF contamination sources at Williamtown</td>
<td>1</td>
</tr>
<tr>
<td>Table 2</td>
<td>Chemical properties of PFOS and PFOA (after USA EPA, 2014)</td>
<td>2</td>
</tr>
<tr>
<td>Table 3</td>
<td>Monthly average rainfall and evaporation at Williamtown</td>
<td>5</td>
</tr>
<tr>
<td>Table 4</td>
<td>Summary of hydraulic properties from literature review</td>
<td>7</td>
</tr>
<tr>
<td>Table 5</td>
<td>Published ranges in specific storage</td>
<td>8</td>
</tr>
<tr>
<td>Table 6</td>
<td>Hydraulic conductivity values obtained through slug testing and PSD analysis</td>
<td>8</td>
</tr>
<tr>
<td>Table 7</td>
<td>Model layer assignment</td>
<td>11</td>
</tr>
<tr>
<td>Table 8</td>
<td>Model simulation timing</td>
<td>12</td>
</tr>
<tr>
<td>Table 9</td>
<td>Model recharge zones</td>
<td>13</td>
</tr>
<tr>
<td>Table 10</td>
<td>Evapotranspiration extinction depth by zone</td>
<td>14</td>
</tr>
<tr>
<td>Table 11</td>
<td>Relative concentrations applied in the groundwater transport model</td>
<td>16</td>
</tr>
<tr>
<td>Table 12</td>
<td>Calibrated model aquifer parameters</td>
<td>18</td>
</tr>
<tr>
<td>Table 13</td>
<td>Calibrated model mass balance (1970-2016)</td>
<td>18</td>
</tr>
<tr>
<td>Table 14</td>
<td>Aquifer properties used for transport modelling</td>
<td>19</td>
</tr>
<tr>
<td>Table 15</td>
<td>Location of wells chosen for concentration profiles</td>
<td>20</td>
</tr>
<tr>
<td>Table 16</td>
<td>Summary of particle tracking by area</td>
<td>24</td>
</tr>
<tr>
<td>FIGURE</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Figure 1</td>
<td>Project Location</td>
<td>34</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Contaminant Source Locations</td>
<td>36</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Outcrop Geology around Williamtown</td>
<td>36</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Schematic Cross-section of Geological Conceptual Model</td>
<td>37</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Particle Size Distribution Analysis</td>
<td>38</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Base of Model Layer 1, Extent of Estuarine Clays</td>
<td>39</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Thickness of Model Layer 4, Coarse Sand and Gravel</td>
<td>40</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Base Model Layer 5, Base of Freshwater Aquifer / Top of Pleistocene</td>
<td>41</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Model Boundary Conditions</td>
<td>42</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Hunter Water Corporation Bore Locations</td>
<td>43</td>
</tr>
<tr>
<td>Figure 11</td>
<td>Recharge Model Calibration</td>
<td>44</td>
</tr>
<tr>
<td>Figure 12</td>
<td>Recharge and Evapotranspiration Zones</td>
<td>45</td>
</tr>
<tr>
<td>Figure 13</td>
<td>Groundwater Level Calibration Scatter Plot</td>
<td>46</td>
</tr>
<tr>
<td>Figure 14</td>
<td>Model Calibration Average Target Residuals</td>
<td>47</td>
</tr>
<tr>
<td>Figure 15</td>
<td>Modelled Groundwater Contours and Gradients (January 2016)</td>
<td>48</td>
</tr>
<tr>
<td>Figure 16</td>
<td>Modelled Relative Contaminant Distribution (1976)</td>
<td>49</td>
</tr>
<tr>
<td>Figure 17</td>
<td>Modelled Relative Contaminant Distribution (1980)</td>
<td>50</td>
</tr>
<tr>
<td>Figure 18</td>
<td>Modelled Relative Contaminant Distribution (1990)</td>
<td>51</td>
</tr>
<tr>
<td>Figure 19</td>
<td>Modelled Relative Contaminant Distribution (2000)</td>
<td>52</td>
</tr>
<tr>
<td>Figure 20</td>
<td>Modelled Relative Contaminant Distribution (2010)</td>
<td>53</td>
</tr>
<tr>
<td>Figure 21</td>
<td>Modelled Relative Contaminant Distribution (2016)</td>
<td>54</td>
</tr>
<tr>
<td>Figure 22</td>
<td>Modelled Relative Contaminant Distribution (2020)</td>
<td>55</td>
</tr>
<tr>
<td>Figure 23</td>
<td>Modelled Relative Contaminant Distribution (2030)</td>
<td>56</td>
</tr>
<tr>
<td>Figure 24</td>
<td>Modelled Relative Contaminant Distribution (2035)</td>
<td>57</td>
</tr>
<tr>
<td>Figure 25</td>
<td>Modelled Relative Contaminant Distribution (Traffic Accident)</td>
<td>58</td>
</tr>
<tr>
<td>Figure 26</td>
<td>Modelled Relative Contaminant Distribution (Hangar 279)</td>
<td>59</td>
</tr>
<tr>
<td>Figure 27</td>
<td>Modelled Relative Contaminant Distribution (Hangar 19)</td>
<td>60</td>
</tr>
<tr>
<td>Figure 28</td>
<td>Modelled Relative Contaminant Distribution (Hangar 11)</td>
<td>61</td>
</tr>
<tr>
<td>Figure 29</td>
<td>Particles Travel Times and Extents</td>
<td>62</td>
</tr>
<tr>
<td>Figure 30</td>
<td>3D Particle Profile – View from West (subsurface)</td>
<td>63</td>
</tr>
<tr>
<td>Figure 31</td>
<td>3D Particle Profile - View from East (above)</td>
<td>64</td>
</tr>
<tr>
<td>Figure 32</td>
<td>Modelled Concentrations at MW157, WLM029 groundwater source only</td>
<td>65</td>
</tr>
<tr>
<td>Figure 33</td>
<td>Modelled Concentrations at MW110, WLM029 groundwater source only</td>
<td>65</td>
</tr>
<tr>
<td>Figure 34</td>
<td>Modelled Concentrations at MW107, WLM029 groundwater source only</td>
<td>66</td>
</tr>
<tr>
<td>Figure 35</td>
<td>Modelled Concentrations at MW175, WLM029 groundwater source only</td>
<td>66</td>
</tr>
<tr>
<td>Figure 36</td>
<td>Modelled Concentrations at MW101, WLM029 groundwater source only</td>
<td>67</td>
</tr>
<tr>
<td>Figure 37</td>
<td>Modelled Concentrations at MW161, WLM029 groundwater source only</td>
<td>67</td>
</tr>
<tr>
<td>Figure 38</td>
<td>Modelled Concentrations at MW161, WLM034 additional channel source</td>
<td>68</td>
</tr>
<tr>
<td>Figure 39</td>
<td>Modelled Concentrations at MW171, WLM029 groundwater source only</td>
<td>68</td>
</tr>
<tr>
<td>Figure 40</td>
<td>Modelled Concentrations at MW147, WLM029 groundwater source only</td>
<td>69</td>
</tr>
<tr>
<td>Figure 41</td>
<td>Modelled Concentrations at MW153, WLM029 groundwater source only</td>
<td>69</td>
</tr>
<tr>
<td>Figure 42</td>
<td>Modelled Concentrations at MW162, WLM029 groundwater source only</td>
<td>70</td>
</tr>
<tr>
<td>Figure 43</td>
<td>Modelled Concentrations at MW162, WLM032 additional channel source</td>
<td>70</td>
</tr>
</tbody>
</table>
1 INTRODUCTION

HydroSimulations\textsuperscript{1} was engaged by AECOM Services Pty Ltd (AECOM) to carry out the groundwater modelling at the RAAF Base Williamtown, herein referred to as the ‘Site’, and its surrounds. The Site is located about 15 kilometres (km) northeast of Newcastle (NSW) and in the local government area of Port Stephens (\textbf{Figure 1}). The Site is adjacent to the civilian airfield facilities of Newcastle Airport. The Site was opened in 1941, and has been active since then.

Firefighting training and operations are a regular and necessary activity. Firefighting foam known as Aqueous Film-Forming Foam (AFFF) has been used at the Site since 1976 or 1977 to extinguish fires, particularly those involving hydrocarbons. The constituents of AFFF, including Perfluorooctane Sulfonate (PFOS), Perfluorooctanoic Acid (PFOA), and fluorotelomer sulfonate compounds (FTS) have been detected in soil, sediment, surface water and groundwater on and near the Site (URS, 2015). Collectively PFOS, PFOA and FTS are referred to as per- and polyfluorinated alkyl substances (PFAS). Beginning in about 2004, there was a changeover between AFFF products ‘Lightwater™’ manufactured by 3M, to ‘Ansulite®’ manufactured by Ansul. At this time, Ansulite® was used for firefighting equipment checking.

Because of the position of the Site over a permeable aquifer, and one used for water supply, as well as being close to fisheries, the spread of the PFAS has become an issue requiring investigation. Part of the investigative studies is to construct and run a groundwater flow model to test and investigate likely pathways from the base.

1.1 SUMMARY OF HISTORICAL USE OF AFFF AT WILLIAMTOWN

AFFF has been used at the Site for:

\begin{itemize}
  \item Emergency response (aircraft incident or spillage of hazardous liquids etc.)
  \item Training of firefighting personnel to ensure readiness and competency for emergency response
  \item Testing of firefighting equipment
  \item Protection of assets (in fixed fire suppression systems).
\end{itemize}

As a result, there are a number of ‘hotspots’ at the Site that have been located via identification of the activities carried out as well as through soil and water quality sampling. These include training areas, and waste or water facilities, as listed in Table 1 and shown on Figure 2. More detailed information on the use of AFFF and source areas of contamination is presented in environmental site investigations (URS, 2015; AECOM, 2016).

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
\textbf{AREA} & \textbf{FACILITY ID} & \textbf{ACTIVITY} & \textbf{APPROXIMATE TIMING OF 3M LIGHTWATER AFFF USE} \\
\hline
1 & Current fire training pad and fire station & Facility 165 & Firefighting training & 1976 - 2005 \\
3 & Waste and UXO landfill (former) & Facility 394 & Potential disposal of material with residual PFAS (unconfirmed) & 1985 - 1994 \\
\hline
\end{tabular}
\caption{Identified likely AFFF contamination sources at Williamtown}
\end{table}

\textsuperscript{1} HydroSimulations is the trading name of ‘Heritage Computing Pty Ltd’.
1.2 NATURE OF THE CONTAMINANT

PFOS and PFOA are considered “emerging contaminants” meaning that there is a perceived potential threat to human or environmental health; however not enough information has yet been collected to form published health standards (US EPA, 2014).

PFOS and PFOA are fluorinated organic compounds that are man-made and do not occur naturally in the environment, however they can also be formed by degradation from related substances or precursor compounds. They have a variety of uses including as surfactants in fire-fighting foams; they are found within many cleaning products and are used as coating agents such as Teflon.

These two compounds do not biodegrade and are persistent within the environment with the potential to bioaccumulate. PFOS is soluble and PFOA is highly soluble making them readily transferable from soil to groundwater where they may be transported over long distances (US EPA, 2014). Table 2 outlines the chemical properties of the PFOS salt and free acid form of PFOA.

<table>
<thead>
<tr>
<th>Property</th>
<th>PFOS (Potassium Salt)</th>
<th>PFOA (Free Acid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Abstracts Service (CAS) Number</td>
<td>2795-39-3</td>
<td>335-67-1</td>
</tr>
<tr>
<td>Physical Description (physical state at room temperature and atmospheric pressure)</td>
<td>White powder</td>
<td>White powder/waxy white solid</td>
</tr>
<tr>
<td>Molecular weight (g/mol)</td>
<td>538</td>
<td>414</td>
</tr>
<tr>
<td>Water solubility at 25°C (mg/L)</td>
<td>550 to 570 (purified), 370 (fresh water), 25 (filtered sea water)</td>
<td>9.5 x 10^4 (purified)</td>
</tr>
<tr>
<td>Melting point (°C)</td>
<td>&gt; 400</td>
<td>45 to 54</td>
</tr>
<tr>
<td>Boiling point (°C)</td>
<td>Not measurable</td>
<td>188 to 192</td>
</tr>
<tr>
<td>Vapor pressure at 20°C (mm Hg)</td>
<td>2.48 x 10^4</td>
<td>0.017</td>
</tr>
<tr>
<td>Octanol-water partition coefficient (log K&lt;sub&gt;ow&lt;/sub&gt;)</td>
<td>Not measurable</td>
<td>Not measurable</td>
</tr>
<tr>
<td>Organic-carbon partition coefficient (log K&lt;sub&gt;oc&lt;/sub&gt;)</td>
<td>2.57 (Value estimated based on anion and not the salt)</td>
<td>2.06</td>
</tr>
<tr>
<td>Henry’s law constant (atm-m&lt;sup&gt;3&lt;/sup&gt;/mol)</td>
<td>3.05 x 10&lt;sup&gt;8&lt;/sup&gt;</td>
<td>Not measurable</td>
</tr>
<tr>
<td>Half-Life</td>
<td>Atmospheric: 114 days Water: &gt; 41 years (at 25°C)</td>
<td>Atmospheric: 90 days Water: &gt; 92 years (at 25°C)</td>
</tr>
</tbody>
</table>

Abbreviations: g/mol – grams per mole; mg/L – milligrams per liter; °C – degree Celsius; mm Hg – millimeters of mercury; atm-m<sup>3</sup>mol – atmosphere-cubic meters per mole.

<sup>1</sup> Extrapolation from measurement.

<sup>2</sup> The atmospheric half-life value identified for PFOA is estimated based on available data determined from short study periods.

Table 2  Chemical properties of PFOS and PFOA (after USA EPA, 2014)
1.3 SCOPE OF WORK

The scope for this assessment is:

1. Review and adaptation of existing groundwater models to build a suitable model platform for contaminant transport.
2. Calibration of model to historical groundwater levels and, as far as practicable, to contaminant concentration.
3. Predictive scenario for a period of 20 years into the future to assess likely transport pathways under the current management regime.
5. Provide recommendations for additional data gathering and treatment focus areas.

1.4 MODELLING OBJECTIVES

The aims and objectives of this groundwater model are to:

- Improve the conceptual understanding of groundwater flow.
- Indicate areas where data is lacking/required to assess risk to receptors and better understand contaminant migration.
- Estimate how far PFOS and related contaminants are likely to move and when/what approximate concentrations of PFOS could reach the receptors.
- Provide input for decision making for management/remediation options.

1.5 MODEL CONFIDENCE AND COMPLEXITY

The groundwater flow model for this study (Section 3) is based on a series of existing calibrated models (Section 3.1) that are currently used for water resource assessment. The model for this study includes improvements to aquifer geometry and has more recent data available as calibration targets. Appendix C provides a summary of the indicators for each confidence level (based on Table 2-1 of Barnett et al., 2012) with an asterisk next to the applicable criteria for both the flow and transport models. The flow model is therefore categorised as “Level 3 Confidence” (or at least a high Level 2) as per the Australian Groundwater Modelling Guidelines (Barnett et al., 2012). The contaminant transport model however is based on limited concentration data with poorly defined source terms, and is therefore expected to be of “Level 1 to 2 Confidence”.

Note that the Confidence Level classification of the 2012 Groundwater Modelling Guidelines is different in approach to the Model Complexity classification of the older Murray-Darling Basin Commission Groundwater Modelling Guidelines (MDBC, 2000). While the model used in this study would satisfy some of the criteria for the Class 3 under that scheme, it would be categorised as Class 2, i.e. an ‘Impact Assessment Model’.
2 HYDROGEOLOGICAL CONCEPTUAL MODEL

2.1 GEOLOGY

A review of the state-wide seamless geology dataset and the Newcastle map-sheet (Rose et al., 1996) indicates that Quaternary deposits are dominant in the Williamtown area. These units have been deposited over Permian rocks that form part of the north-eastern margin of the Sydney Basin (Figure 3).

More detailed geological mapping is available in the Nelson Bay Coastal Quaternary dataset (Hashimoto et al., 2008). This provides more detailed classification and mapping of the various Quaternary deposits. There are many units mapped, including man-made fill and recent fluvial deposits (e.g. along the Hunter River to the west of the base), however the three broad groups described below are of primary importance to this study:

- Holocene estuarine and swamp (paludal) deposits, including the ‘Tilligerry Mud Member’ along Tilligerry Creek.
- Holocene dune and beach deposits of the Stockton Sand Beds. These are the ‘outer barrier’ and the most recent of the two major dune deposits in this area. They include the current Stockton Beach, and both mobile (un-vegetated) and stabilised (vegetated) dunes.
- Holocene dune and beach deposits of the Tomago Sand Beds. These are the ‘inner barrier’, i.e. inland of the Stockton dune system (and inland of the estuarine deposits). These are generally vegetated.

Below these units is a thick sequence of Pleistocene deposits, the uppermost of which is a clay/silt layer known as the Medowie Clay Member. This is considered to be the base of the ‘freshwater aquifer’ system (Merrick, 1980b; SKM, 2005; SKM, 2012; URS, 2015) comprising the Tomago Sand Beds aquifer to the north-northwest of the Tilligerry Creek and the Stockton Sand Beds aquifer to the south-southeast of Tilligerry Creek. Figure 4 presents a schematic cross-section of the key units (after Roy and Boyd, 1996).

In order to understand and map the vertical extent of these units a literature review was conducted alongside analysis of recent and historical bore data. Merrick (1979a and 1979b) carried out geophysical surveys supported by drilling, and presents useful contour maps of the base of the freshwater aquifer. Woolley et al. (1995) present generally similar contouring of this surface based on bore logs and data compiled by Hunter Water Corporation (HWC).

HydroSimulations has carried out stratigraphic interpretation of 197 bores across the area, including both recent bores (URS, 2015; AECOM, 2016) and bores presented in literature (Merrick, 1979b; Wright, 1992). The coverage of bore logs was then significantly increased by the availability of stratigraphic interpretation provided by HWC including data from the Joint Coal Board. The use of the bore logs from the Joint Coal Board was limited to the interpreted base of the freshwater aquifer as more detailed information was not available.

The contouring of the base of the aquifers from literature was then combined and modified taking into consideration more recent bore data.

2.2 CLIMATE

Average annual rainfall at the Williamtown RAAF base (climate station number 061078) is 1130 mm/yr (for data measured from 1942 to 2016) (BoM, 2015a). The months with the highest rainfall occur from January to June, with the lowest rainfall typically occurring in September (Table 3).
Interpolated annual average potential evapotranspiration at Williamtown is 1400 mm/yr using the BoM (2015b) spatially gridded data set, where the definition for Potential ET is “…is the ET that would take place, under the condition of unlimited water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average”. Although average annual evaporation exceeds average rainfall, a rainfall surplus occurs for five months of the year (from April to August inclusive), using the BoM gridded evaporation. This evaporation is greater than average rainfall for the period September to March inclusive, and the average monthly rainfall deficit during this time is up to 100 mm. Interpolated actual evapotranspiration is typically between 45% and 62% of monthly potential evapotranspiration (BoM 2015b), where the definition for actual ET is: “…the ET that actually takes place, under the condition of existing water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average. For example, this represents the ET which would occur over a large area of land under existing (mean) rainfall conditions”.

Table 3  Monthly average rainfall and evaporation at Williamtown

<table>
<thead>
<tr>
<th>MONTH</th>
<th>AVERAGE RAINFALL (mm)</th>
<th>AVERAGE POTENTIAL EVAPORATION (mm)</th>
<th>AVERAGE ACTUAL EVAPORATION (mm)</th>
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<tr>
<td>January</td>
<td>102</td>
<td>185</td>
<td>112</td>
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<tr>
<td>February</td>
<td>120</td>
<td>147</td>
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<td>March</td>
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<td>December</td>
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<tr>
<td>Annual Average</td>
<td>1130</td>
<td>1400</td>
<td>794</td>
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2.3 SURFACE WATER

The Pacific Ocean (Tasman Sea) lies directly to the south of the Stockton dunes. Tidally influenced Fullerton Cove and lower Hunter River are situated to the west of the study area, and Port Stephens and Tilligerry Creek are tidal water bodies at the east.

An extensive network of shallow drainage channels has been constructed in the low lying estuarine sediments to facilitate the removal of shallow water after heavy rainfall events and allow the land to be developed for agriculture, draining towards Tilligerry Creek to the east and Fullerton Cove to the west. Tidal gates have been installed near the town of Salt Ash in Tilligerry Creek and near Fullerton Cove in order to prevent tidal saline water flowing into the drainage system, which has had the effect of progressively freshening the water quality within the shallow estuarine sediments between the tidal gates. The tidal gates release water from the drainage network at low tide if the water level in the drains is higher than in the ocean,
and close when the tide rises again. This has the effect of reducing the groundwater levels on
the upstream side of the tidal to below mean sea level (SKM, 2012).

Within the Site, a large proportion of surface runoff is collected by Lake Cochran, including
runoff from the Fire Training Pad, the Trade Waste Treatment Plant, the runway, and hangars
associated with the civilian airport. The lake is considered to be a significant source of
localised recharge (URS, 2015). Runoff from the former fire training pit and landfill is not
captured by Lake Cochran. Key drainage channels with the potential to transport
contaminated surface water from the Site include Dawsons Drain (which receives effluent
from Lake Cochran); the Fourteen Foot Drain and Ten Foot Drain to the south-west of the
Site which discharge towards Fullerton Cove; and the Moors Drain and Tilligerry Creek to the
east of the base flowing towards Port Stephens.

Grahamstown Dam is a large reservoir situated to the north of the Site that supplies drinking
water to the Hunter Region. The majority of its water is sourced via pumping from the
Williams River and a small catchment area to the north. The Grahamstown Dam is not
considered hydraulically connected in to the surface or groundwater systems to the south due
to the presence of a clay liner and large earth embankment (Hunter Water, 2015).

2.4 HYDROGEOLOGY

Groundwater occurs within all the geological units within the local area to a varying degree;
however, the younger unconsolidated sands of the Newcastle Formation sediments (Tomago
Sand Beds and Stockton Sand Beds) are the most important units for the transmission of
groundwater in the study area. Discontinuous layers of low permeability materials can occur
throughout due to the transgressive and regressive nature of deposition. The low permeability
basal Medowie Clay Member and impermeable bedrock define the base of the aquifer
(Woolley et al., 1995).

Recharge to the aquifer system comes primarily from rainfall infiltration. Various studies
investigating recharge across the Tomago Sand Beds and Stockton Sand Beds aquifers have
been carried out, with an average value of net recharge across the area of roughly 25% of
rainfall being a consistent finding (HWDB, 1957; GHD, 1995; Slatter, 1996; Crosbie, 2003;
SKM, 2012), where net recharge is defined as the recharge due to rainfall minus
evapotranspiration from the saturated zone (water table). Gross recharge (herein referred to a
recharge) represents the water that percolates through the unsaturated zone and is exclusive
of any subsequent evapotranspiration from the water table. Predicted gross recharge ranges
from 5% of rainfall on the inter-barrier depression (SKM, 2005) to up to 60% within the
Tomago Sand Beds, with an annual average of 42% (Crosbie, 2003).

Discharge from the groundwater system occurs naturally at the surface to creeks and
drainage channels and surrounding area, as well as to the ocean. The main groundwater flow
directions within the Tomago Sand Beds aquifer are towards Fullerton Cove and Tilligerry
Creek. Tilligerry Creek forms a locally controlling groundwater discharge location separating
the Tomago Sand Beds and Stockton Sand Beds aquifers, with water from both the north-
west and south-east flowing locally upwards towards the drain with some areas of sub-
artesian pressures due to the confining Tilligerry Mud Member. Within the Stockton Sand
Beds aquifer there is a topographical groundwater divide formed by the Stockton dunes,
resulting in the north-west portion of the aquifer flowing toward Tilligerry Creek, and south-
east to the Pacific Ocean.

Evapotranspiration is also a major component of groundwater discharge, with approximately
50% of gross recharge is lost via evapotranspiration from the saturated zone (Crosbie, 2003).
2.4.1 ANTHROPOGENIC GROUNDWATER USE

Groundwater extraction by private users occurs frequently across the Tomago Sand Beds aquifer and Stockton Sand Beds aquifer via both licensed and unlicensed bores.

Groundwater abstraction from the Tomago Sands Beds aquifer contributes to approximately 25% of Newcastle’s potable water supply, as well as providing an important reserve for drought supply (Crosbie, 2003). Pumping from the Tomago Sand Beds aquifer commenced in 1939, and is undertaken by several spear-point wells connected to 27 pump stations, which pump water to the water treatment plant. Available HWC extraction records provide “best-estimates” of monthly volumes pumped through the individual pump stations since 1999, but do not provide details of volumes per bore. It is common that bores along a pump station line-feed operate intermittently, and several bores are non-operational, however details of these bores were unable to be provided for this study. Two of these pump stations are located in the vicinity of the Site; Pump Station 7 is located at the north of the Site and Pump Station 9 is 250 m east of the site. Neither of these pump stations is currently operational.

A series of unlined lagoons located at the HWC water treatment plant provide approximately 2.6 ML/d of localised recycled recharge. These recharge rates were obtained from input models for a previous groundwater model (SKM, 2012).

2.4.2 AQUIFER PROPERTIES

A summary of aquifer parameters has been obtained discussed in the following sections.

Literature Review

A review of previous investigations carried out within the Tomago Sand Beds and Stockton Sand Beds aquifers was undertaken to determine a range of parameter values for groundwater modelling. Reported values for aquifer properties are fairly consistent between sources. Table 4 provides a summary of reported values for hydraulic conductivity (K), specific yield (Sy) and porosity (n).

<table>
<thead>
<tr>
<th>UNIT</th>
<th>K (m/day)</th>
<th>Sy</th>
<th>n</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TILLIGERRY MUD MEMBER</td>
<td>0.1</td>
<td></td>
<td></td>
<td>SKM, 2005</td>
</tr>
<tr>
<td></td>
<td>0.0001 to 0.001</td>
<td></td>
<td></td>
<td>SKM, 2012</td>
</tr>
<tr>
<td></td>
<td>0.001</td>
<td></td>
<td></td>
<td>URS, 2015</td>
</tr>
<tr>
<td>STOCKTON SAND BEDS</td>
<td>20</td>
<td>0.3</td>
<td></td>
<td>URS, 2015</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.33</td>
<td></td>
<td>Wright, 1992</td>
</tr>
<tr>
<td></td>
<td>10 to 20</td>
<td>0.15</td>
<td>0.3</td>
<td>SKM, 2005</td>
</tr>
<tr>
<td></td>
<td>12 to 20</td>
<td></td>
<td></td>
<td>Woolley et al., 1995</td>
</tr>
<tr>
<td>TOMAGO SAND BEDS</td>
<td>20</td>
<td>0.3</td>
<td></td>
<td>URS, 2015</td>
</tr>
<tr>
<td></td>
<td>10 to 20</td>
<td></td>
<td></td>
<td>Woolley et al., 1995</td>
</tr>
<tr>
<td>ROCK</td>
<td>0.0001 to 0.001</td>
<td></td>
<td></td>
<td>SKM, 2012</td>
</tr>
</tbody>
</table>

Limited information regarding the aquifers’ specific storage is available, which is likely to reflect the relative unimportance of this property in this predominantly unconfined system. Typical ranges of specific storage as published by Batu (1998) are presented in Table 5.
Table 5  Published ranges in specific storage

<table>
<thead>
<tr>
<th>SEDIMENT TYPE</th>
<th>RANGE IN SPECIFIC STORAGE (m(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic clay</td>
<td>2.0E-3 to 2.6E-3</td>
</tr>
<tr>
<td>Stiff clay</td>
<td>2.6E-3 to 1.3E-3</td>
</tr>
<tr>
<td>Medium hard clay</td>
<td>1.3E-3 to 9.2E-4</td>
</tr>
<tr>
<td>Loose sand</td>
<td>1.0E-3 to 5.0E-4</td>
</tr>
<tr>
<td>Dense sand</td>
<td>2.0E-4 to 1.3E-4</td>
</tr>
<tr>
<td>Dense sandy gravel</td>
<td>1.0E-4 to 5.0E-5</td>
</tr>
<tr>
<td>Rock, fissured, jointed</td>
<td>7.0E-5 to 3.3E-6</td>
</tr>
<tr>
<td>Rock, sound/fresh</td>
<td>&lt; 3.3E-6</td>
</tr>
</tbody>
</table>

Recent Field and Laboratory Testing

Slug testing was carried out by AECOM staff in March 2016. This was done to estimate hydraulic conductivities across the range of sediment types that occur in the Williamtown area. It is acknowledged that slug testing, due to the short duration of testing and potentially large interferences from well skin effects, provides order of magnitude estimates only. Pumping tests were considered but not carried out because they would then require the disposal of potentially contaminated water, while slug testing avoids this problem. Both rising and falling head tests were carried out, and the analysed using the Hvorslev (1951) and Bouwer and Rice (1976) methods, with results being fairly consistent between methods.

Laboratory testing of sediment samples provided information on the particle size distribution (PSD) (Figure 5). The PSD information has been used to estimate hydraulic conductivity using the Hazen (1911) method for the Tomago Sand Beds. There are no PSD data available for Stockton Sand Beds, and the Hazen method is not applicable to fine grained sediments such as the Tilligerry Mud Member.

A summary of this testing is shown in Table 6 (see AECOM, 2016 for details).

Table 6  Hydraulic conductivity values obtained through slug testing and PSD analysis
<table>
<thead>
<tr>
<th>LITHOSTRATIGRAPHIC UNIT</th>
<th>NUMBER OF TESTS</th>
<th>TYPE</th>
<th>HYDRAULIC CONDUCTIVITY [m/d]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MIN</td>
<td>MEAN</td>
</tr>
<tr>
<td>Tilligerry Mud Member</td>
<td>4</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Stockton Sand Beds</td>
<td>2</td>
<td>16.0</td>
<td>18.5</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Tomago Sand Beds</td>
<td>24</td>
<td>1.1</td>
<td>21.3</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>1.6</td>
<td>23.4</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>3.4</td>
<td>17.9</td>
</tr>
<tr>
<td>Tomago Sand Beds</td>
<td>14</td>
<td>1.7</td>
<td>24.5</td>
</tr>
<tr>
<td>(coarse facies)</td>
<td>14</td>
<td>1.6</td>
<td>24.3</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>20.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>

NB Slug testing results that were considered to be unreliable by AECOM have been excluded from analysis.

Results of this analysis are also within a similar range to those obtained via slug testing. All results are within expected hydraulic conductivity ranges reported by previous investigations.
3 GROUNDWATER SIMULATION MODEL

3.1 PREVIOUS MODELS

Transient groundwater flow modelling has previously been undertaken in the area surrounding the Site primarily for the assessment of aquifer storage for water supply within the Tomago Sand Beds and Stockton Sand Beds aquifers (SKM, 2012 and SKM, 2005). These models used a coarse grid and few layers (2 and 3 respectively), and both models focused solely on the aquifer of interest, the Tomago Sand Beds model (SKM, 2012) only covering the area north of Tilligerry Creek, and the Stockton Sand Beds model (SKM, 2005) only the area to the south. URS (2015) compiled a more refined four layer groundwater flow model, including both the Tomago Sand Beds and Stockton Sand Beds aquifers as well as the intervening Tilligerry Mud Member, however this model was only run in steady-state with the objective of carrying out a basic assessment of contaminant flow directions using particle tracking methods.

Consideration was given to using the URS model as a template for the current model, however due to its small cell size and large extent (with a total cell count of 3.8 million cells), it was considered that resulting run times for a transient model of this size would be unviable in the given timeframe for project completion. Additionally, the SKM models had a higher degree of calibration to hydraulic conductivity and recharge distributions. Ultimately a selection of features from each of the three previous models has been used as a starting point for this model, however significant re-working has been necessary as discussed in the following sections.

3.2 MODEL SOFTWARE

3.2.1 SOFTWARE

Three dimensional numerical modelling was undertaken using MODFLOW-SURFACT v4 (HydroGeoLogic Inc, 1996). MODFLOW-SURFACT is a finite-difference MODFLOW code that is capable of simulating unsaturated zone flow. Additionally, MODFLOW-SURFACT allows a more robust solution of contaminant transport as the groundwater flow data is passed at a time-step level, whilst when using other versions of MODFLOW it is only updated at a stress period level. Each stress period is divided into several time steps.

The Groundwater Vistas (ESI, 2011) graphical user interface was used for most pre- and post-processing of model files.

3.3 MODEL MESH

The MODFLOW-SURFACT model grid has square cells of 25 m by 25 m dimension across the most part of the model. This cell size was chosen in order to provide a small enough resolution to perform the contaminant transport simulation without inducing inaccuracy caused by instability and numerical dispersion. This is determined by ensuring a Peclet number of <2 is obtained, although Peclet numbers up to 10 still generally yield acceptable results (Anderson and Woessner, 1992). For transport dominated by advective processes (as is expected at this site due to the dominance of medium to coarse grained sandy material), the Peclet number, Pe, is determined by

\[ Pe = \Delta l / \alpha \]

Where \( \Delta l \) is the grid cell dimension in the critical location, and \( \alpha \) is the longitudinal dispersivity.
Gelhar *et al.*, (1992) found a scale-dependant relationship between longitudinal dispersivity and the distance between the source and the receptor, with dispersivity typically in the order of 10% of the total distance. This relationship is a widely accepted “rule of thumb” for estimating dispersivity. For this project Lake Cochran, the former fire training pit and fire training pad were considered primary sources to groundwater and Tilligerry Creek a key receptor, with an approximate distance of 2 km between the sources and receptors, thus a preliminary estimate of dispersivity of 200 m was used. A cell size of 25 m and dispersivity of 200 m, results in a Peclet number of 0.125 (significantly less than 2), allowing for a wide range in dispersivity values to be applied to the transport model during calibration while minimising numerical error.

Areas to the north and west of the model (away from potential source and receptors for contamination) are coarsened to 50 m spacing to minimise the cell count where possible. There are 455 rows and 770 columns in the mesh, with 5 model layers. There is a total of 1,751,750 cells, of which 1,387,870 are active. The remaining cells were treated as inactive as they are located outside of the model domain.

### 3.4 MODEL GEOMETRY AND HYDROSTRATIGRAPHY

Table 7 presents the model layering and stratigraphy adopted in this project. The geological layering within the model is based on the conceptual model postulated by Roy and Boyd (1996) (*Figure 4*). The lateral layer boundaries where determined using the Nelson Bay Coast Quaternary Geology 1:100,000 Geological Map, and the State-wide 1:250,000 Geological Map. Vertical boundaries where interpolated using historical bore log data from HWC and the Joint Coal Board, and a series of newly drilled boreholes specific for the project drilled by URS/AECOM between 2014 and 2016. The topography of the updated model relies on LiDAR data provided by AECOM. The average LiDAR elevation in any model cell has been used to specify the elevation of the uppermost active model layer. Model layer 1 is active only in the areas where the Tilligerry Mud Member is present in order to minimise the cell count (*Figure 6*). All other layers are fully extensive, however where the layer is not present a layer thickness of 0.5 m is assigned and the layer is given the same hydraulic properties as the layer below.

The model extends through the Stockton Sand Beds and Tomago Sand Beds, with a coarse gravelly sand layer at the base of the Tomago Sand Beds (*Figure 7*). Below this is the basal Medowie Clay Member, which is assumed to be a confining layer and is represented as the base of the model. The depth to the clay was determined using the aforementioned bore data where the clay layer was intercepted, as well as the geophysical interpretation carried out by Merrick (1979 and 1980) (*Figure 8*). A palaeochannel has been identified in previous work extending from the coast to Fullerton Cove, and this has been included in the model with its depth and location again interpolated from available borehole data and geophysics. This is hypothesised to be an earlier channel of the Hunter River.

<table>
<thead>
<tr>
<th>LAYER</th>
<th>STRATIGRAPHY</th>
<th>AVERAGE THICKNESS (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tilligerry Mud Member</td>
<td>5.2</td>
</tr>
<tr>
<td>2</td>
<td>Stockton Sand Beds</td>
<td>8.3</td>
</tr>
<tr>
<td>3</td>
<td>Upper Tomago Sand Beds (Fine – Medium Grained)</td>
<td>3.1</td>
</tr>
<tr>
<td>4</td>
<td>Lower Tomago Sand Beds (Fine – Medium Grained)</td>
<td>13.3</td>
</tr>
<tr>
<td>5</td>
<td>Basal Coarse Sands/Gravels</td>
<td>3.7</td>
</tr>
</tbody>
</table>
3.5 MODEL TEMPORAL DISCRETISATION

The model has 793 stress periods to represent monthly time-slices between 1970 and 2036 (to allow prediction of future contaminant transport). Table 8 summarises the model timing. The first stress period is steady state to initialise the heads leading into the transient run.

<table>
<thead>
<tr>
<th>STRESS PERIOD</th>
<th>DATE FROM</th>
<th>DATE TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Conditions</td>
<td>1 Pre 1970</td>
<td>Steady-state</td>
</tr>
<tr>
<td>Calibration</td>
<td>2 - 556</td>
<td>1/01/1970</td>
</tr>
<tr>
<td>Prediction</td>
<td>557 - 793</td>
<td>1/4/2016</td>
</tr>
</tbody>
</table>

3.6 BOUNDARY CONDITIONS

3.6.1 CONSTANT HEAD BOUNDARIES

Constant head (CHD) boundary conditions with a specified head of 0 m AHD were used to represent locations where the water level remains approximately at sea level throughout the duration of the simulation, specifically the coastline and Fullerton Cove and the tidal portion of Tilligerry Creek (Figure 9). The 0 m AHD elevation was adopted based on the accepted SKM Stockton Sandbeds model (SKM, 2005) and was also adopted in the URS (2015) model, however Timms and Anderson (2009) suggests in fact the elevation of the water table at the coastline is likely to be closer to the mean high tide level due to the effects of waves causing mounding of fresh groundwater above saline ocean water. Based on that and available data, the shoreline head could possibly be revised in future to approximately 0.3-0.6 m AHD.

3.6.2 ‘RIVER’ BOUNDARIES

The watercourses in this area, including the extensive drainage network installed across the low permeability units, has been represented in the model using the MODFLOW River (RIV) package. Rivers were set with stage equal to base elevation, effectively prohibiting the flow of water out of the cell such that it acts in the same way as the MODFLOW Drain (DRN) package. The RIV package was chosen in preference to the DRN package as it allows a source concentration term to be applied (requiring a small head of water to be applied to allow leakage), allowing a simplified representation of potential contaminant transport within and from the drainage network. The RIV package does not however simulate the down-stream transfer of contaminant within the drain network, so can only be used to represent a static source of contaminants inferred from local observations of PFAS concentrations.

River boundaries with variable stage heights have also been used to simulate periodic flooding around Moffats Swamp and Campvale Drain to the north of the site.

3.6.3 RECHARGE

The MODFLOW Recharge (RCH) package is used to simulate net diffuse rainfall recharge. Temporal variation in rainfall recharge has been estimated by HydroSimulations from a water balance calculated on a daily time step and accounting for runoff, soil moisture deficit and recharge based on inputs of rainfall and potential evaporation. This is based on the Penman-Grindley method of soil moisture accounting (Finch, 1994). In the absence of any available gauged stream flow data, recharge was calibrated against the long record of measured water levels at monitoring piezometers IP109 and SK4934, assuming a specific yield of 0.3. The groundwater hydrographs at these locations show a strong correlation to the rainfall residual mass, which is a measurement of the cumulative deviation in rainfall from the long term average. An upwards trend in the residual mass curve indicates a period of higher than
average rainfall, while downwards suggests lower than average. It can be seen that as rainfall increases above the long term average the groundwater level rises, and vice versa, suggesting rainfall recharge is strongly controlled by rainfall recharge. The comparison of modelled and observed hydrographs is shown in Figure 11. The outputs of the daily recharge model are then aggregated to give the monthly recharge per stress period for input to the groundwater model.

SKM (2012) previously undertook extensive recharge modelling for the Tomago Sand Beds Aquifer Model, which is currently used by HWC for water resource assessment and has been used as the basis for calculating recharge in this model. They identified and calibrated several highly variable recharge zones based on soil type and vegetation, rainfall distribution and depth to water table. Due to the limited time frame for modelling work, HydroSimulations has not recalibrated average recharge for each zone, but has instead used the relative ratios of average recharge within the SKM (2012) recharge zones to determine a multiplication factor with which to scale the calculated recharge at the aforementioned piezometers (corresponding to SKM Recharge Zone 8) in order to determine an updated transient sequence to apply to the other recharge zones (Table 9 and Figure 12).

### Table 9  Model recharge zones

<table>
<thead>
<tr>
<th>ZONE</th>
<th>SOIL</th>
<th>VEGETATION</th>
<th>ANNUAL AVERAGE GROSS RECHARGE (m/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Estuarine Mud</td>
<td>Grassland</td>
<td>1.28E-05</td>
</tr>
<tr>
<td>3</td>
<td>Sand</td>
<td>Grassland</td>
<td>6.83E-04</td>
</tr>
<tr>
<td>4</td>
<td>Sand</td>
<td>Forest</td>
<td>4.86E-04</td>
</tr>
<tr>
<td>5</td>
<td>Residual Soil</td>
<td>Forest</td>
<td>4.06E-05</td>
</tr>
<tr>
<td>6</td>
<td>Sand</td>
<td>Heath</td>
<td>6.66E-04</td>
</tr>
<tr>
<td>7</td>
<td>Swamp</td>
<td>Forest</td>
<td>6.56E-04</td>
</tr>
<tr>
<td>8</td>
<td>Sand</td>
<td>Forest</td>
<td>9.10E-04</td>
</tr>
<tr>
<td>9</td>
<td>Swamp</td>
<td>Forest</td>
<td>7.60E-04</td>
</tr>
<tr>
<td>10</td>
<td>Sand</td>
<td>Grassland</td>
<td>7.33E-04</td>
</tr>
<tr>
<td>11</td>
<td>Sand</td>
<td>Forest</td>
<td>6.39E-04</td>
</tr>
<tr>
<td>12</td>
<td>Sand</td>
<td>Grassland</td>
<td>6.12E-04</td>
</tr>
<tr>
<td>13</td>
<td>Sand</td>
<td>Forest</td>
<td>6.56E-04</td>
</tr>
<tr>
<td>177</td>
<td>Sand</td>
<td>Heath</td>
<td>6.87E-04</td>
</tr>
<tr>
<td>15</td>
<td>Sand</td>
<td>Grassland</td>
<td>1.37E-03</td>
</tr>
<tr>
<td>16</td>
<td>Sand</td>
<td>Forest</td>
<td>1.26E-03</td>
</tr>
<tr>
<td>17</td>
<td>Sand</td>
<td>Heath</td>
<td>1.25E-03</td>
</tr>
<tr>
<td>14</td>
<td>Rock</td>
<td>Forest</td>
<td>2.59E-05</td>
</tr>
<tr>
<td>18</td>
<td>Sand</td>
<td>Grassland</td>
<td>1.07E-03</td>
</tr>
<tr>
<td>19</td>
<td>Sand</td>
<td>Forest</td>
<td>1.17E-03</td>
</tr>
<tr>
<td>20</td>
<td>Sand</td>
<td>Heath</td>
<td>1.16E-03</td>
</tr>
<tr>
<td>21</td>
<td>Sand</td>
<td>Forest</td>
<td>7.58E-04</td>
</tr>
<tr>
<td>30</td>
<td>Dunes</td>
<td>Non-veg</td>
<td>1.37E-03</td>
</tr>
<tr>
<td>31</td>
<td>Dunes</td>
<td>Veg</td>
<td>1.26E-03</td>
</tr>
</tbody>
</table>

Note – Zone Numbering is consistent with SKM 2012, with the exception of zones 30 and 31 representing the Stockton Sand Beds.
The overall average gross recharge applied in the model corresponds to 28% of annual rainfall, with a range across the model between 1% (on the Tilligerry Mud Member and rock outcrops) to 49% on non-vegetated dunes.

The advantage of this water balance method over methods employing a constant recharge as a percentage of rainfall is that the variation in hydraulic head and groundwater flow between wet and dry periods is better represented, due to the simulation of a soil moisture deficit.

### 3.6.4 EVAPOTRANSPIRATION

Evapotranspiration from the unsaturated zone (i.e. soil water) is calculated in the recharge water balance and is therefore already incorporated into the model by the application of gross recharge. However, when the water table is shallow, further evapotranspiration may occur from the saturated zone (i.e. shallow groundwater). Excess potential evapotranspiration (i.e. total potential evapotranspiration minus soil evapotranspiration, as calculated by HydroSimulations’ water balance model – Section 3.6.3) is applied as the maximum evapotranspiration rate in the model using MODFLOW’s EVT package, which calculates a linear decline in rate to zero corresponding with an extinction depth equivalent to the rooting depth of the major vegetation type in each zone (Table 10 and Figure 12).

#### Table 10  Evapotranspiration extinction depth by zone

<table>
<thead>
<tr>
<th>ZONE</th>
<th>SOIL</th>
<th>VEGETATION</th>
<th>EVAPOTRANSPIRATION EXTINCTION DEPTH (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Estuarine Mud</td>
<td>Grassland</td>
<td>0.8</td>
</tr>
<tr>
<td>3</td>
<td>Sand</td>
<td>Grassland</td>
<td>0.5</td>
</tr>
<tr>
<td>4</td>
<td>Sand</td>
<td>Forest</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Residual Soil</td>
<td>Forest</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Sand</td>
<td>Heath</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Swamp</td>
<td>Forest</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Sand</td>
<td>Forest</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>Swamp</td>
<td>Forest</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Sand</td>
<td>Grassland</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Sand</td>
<td>Forest</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>Sand</td>
<td>Grassland</td>
<td>0.5</td>
</tr>
<tr>
<td>13</td>
<td>Sand</td>
<td>Forest</td>
<td>3</td>
</tr>
<tr>
<td>177</td>
<td>Sand</td>
<td>Heath</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>Sand</td>
<td>Grassland</td>
<td>0.5</td>
</tr>
<tr>
<td>16</td>
<td>Sand</td>
<td>Forest</td>
<td>5</td>
</tr>
<tr>
<td>17</td>
<td>Sand</td>
<td>Heath</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>Rock</td>
<td>Forest</td>
<td>3</td>
</tr>
<tr>
<td>18</td>
<td>Sand</td>
<td>Grassland</td>
<td>0.5</td>
</tr>
<tr>
<td>19</td>
<td>Sand</td>
<td>Forest</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>Sand</td>
<td>Heath</td>
<td>3</td>
</tr>
<tr>
<td>21</td>
<td>Sand</td>
<td>Forest</td>
<td>5</td>
</tr>
<tr>
<td>30</td>
<td>Dunes</td>
<td>Non-veg</td>
<td>0.5</td>
</tr>
<tr>
<td>31</td>
<td>Dunes</td>
<td>Veg</td>
<td>10</td>
</tr>
</tbody>
</table>
Maximum rooting depths are based initially on SKM (2012), but then modified in line with values reported in Canadell et al. (1996) and guided by model calibration and consideration of the mapping of swamp (water logged) areas. Note that rooting (or extinction) depth has been generally been reduced from the values applied in the SKM (2012) model, which used values that were typically 5-20 m (i.e. 2-3 times more than the currently used values reported in Table 10).

The linear function in the MODFLOW-EVT package is used to approximate the true exponential decline in evapotranspiration with depth. Assuming a perfect knowledge of rooting (extinction) depths, this may result in an over estimation of actual evapotranspiration. Scaling factors are sometimes used to counter this possible over-estimation, however HydroSimulations have taken chosen not to do so in this case. Groundwater levels are considered more sensitive to the uncertainty in the actual rooting depth parameter chosen.

3.6.5 PUMPING WELLS

Hunter Water Corporation provided the location details of 71 bores assigned to the 22 active pump stations extracting from the Tomago Sand Beds aquifer that fall within the boundary of the groundwater model (Figure 9). These bores have been assigned pumping rates proportional to the overall volume pumped from the respective pump station, i.e. individual bore pumping rate = pump station monthly volume / number of bores. Due to the available data only covering the period of 1999 to 2015, monthly averaged data has been applied across the remaining model stress periods. Absence of well construction information has made the use of the Fracture Well (FWL) package preferable to the standard WEL package in order simulate the well screen across both model layer 4 and model layer 5 (the primary layers representing the Tomago Sand Beds aquifer).

The WEL package has been used to simulate infiltration (recharge) from the ponds at the HWC treatment plant located approximately 6 km west of the base. Rates ranging between 240 m$^3$/day to 490 m$^3$/day recharge have been applied over the full model duration for seven infiltration ponds.

3.6.6 CONTAMINANT SOURCES

Detailed information regarding the source concentrations, volumes and timings is unavailable. Few records have been kept regarding the use of AFFF products at the Site or elsewhere, as during the period of use there was no knowledge of the fire-fighting chemicals having any potentially harmful side-effects. Thus, information regarding the source zones for contamination is largely anecdotal. Data collected by URS and AECOM between 2014 and 2016 has been used to interpret/confirm the potential source zones. In the groundwater model, relative concentrations have been applied at the source zones based upon the highest current concentrations in nearby groundwater. In the absence of historical information, it is assumed that the contaminant concentrations recently recorded at or near the source locations are representative of the long-term relative inputs from each source (although in reality this is unlikely to be correct). Therefore, all zones have been scaled relative to the former fire training pad, which has the highest concentration of PFOS in groundwater (170 µg/L in a sample collected at W53 in November 2014) and is therefore considered to have been the most significant historical source of AFFF entering groundwater at the Base, with a source “concentration” of 100%. Source terms have been simulated to remain constant over time, however this is an over simplification applied based on limited data and constricted timeframes for model development. Future work should consider detailed analysis the data that is available in order to determine a suitable variable rate for contaminant input.

Sources of contamination and their relative contributions are shown in Table 11 (for locations refer to Figure 2).
Table 11  Relative concentrations applied in the groundwater transport model

<table>
<thead>
<tr>
<th>AREA</th>
<th>PFOS CONCENTRATION³ (µG/L)</th>
<th>NEARBY GROUNDWATER BORE</th>
<th>RELATIVE % OF MAXIMUM CONCENTRATION</th>
<th>APPROXIMATE TIMING OF CONTAMINANT SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire training pad and fire station</td>
<td>35.6</td>
<td>MW196</td>
<td>21</td>
<td>1976 - 2004</td>
</tr>
<tr>
<td>Former fire training pit</td>
<td>170</td>
<td>W53</td>
<td>100</td>
<td>1976 - 2004</td>
</tr>
<tr>
<td>Former DEMS landfill</td>
<td>72</td>
<td>W40</td>
<td>42</td>
<td>1985 - 1994</td>
</tr>
<tr>
<td>Trade waste treatment plant</td>
<td>13.2</td>
<td>MW208</td>
<td>8</td>
<td>1976 - 2016</td>
</tr>
<tr>
<td>Lake Cochran</td>
<td>70</td>
<td>MW104D</td>
<td>41</td>
<td>1976 - 2016</td>
</tr>
<tr>
<td>Sewage treatment plant</td>
<td>13</td>
<td>MW208</td>
<td>8</td>
<td>1976 - 2016</td>
</tr>
<tr>
<td>Corner of Medowie Rd and Richardson Ave</td>
<td>0.03</td>
<td>MW159</td>
<td>1</td>
<td>Jan 1994</td>
</tr>
<tr>
<td>Hangar 279</td>
<td>-</td>
<td>-</td>
<td>60</td>
<td>Jan 2000</td>
</tr>
<tr>
<td>Hangar 19¹</td>
<td>-</td>
<td>-</td>
<td>60</td>
<td>Jan 2005</td>
</tr>
<tr>
<td>Hangar 11²</td>
<td>-</td>
<td>-</td>
<td>60</td>
<td>Jan 2013</td>
</tr>
</tbody>
</table>

³ Relative concentrations are based on groundwater monitoring during the Stage 2A and Stage 2B investigations
1. There is significant uncertainty regarding Hangar 19 as a potential source of AFFF.
2. The timing of the spill at Hangar 11 has been revised to 2005, however remains simulated at 2013 in the groundwater model.

The duration of the source input into the model is increased from the operational activity listed in Table 1 to include a continuing source to the present day, as is consistent with testing undertaken by AECOM indicating the presence of residual PFOS in soils near the source locations. It is expected that this PFOS will have continued to leach to groundwater over time when the soil profile is wetted due to rainfall.

Source zones have been been simulated using the RIV package in the highest active layer (Layer 2) to enable head-dependant fluxes of contaminant to enter the model, replicating in part the expected increase in infiltration of contaminant held within the soil zone during high rainfall events (simulated in the model by increased recharge and raised water table elevations). The model assumes a constant source concentration over time; no attempt has been made to simulate a variable or declining source due to lack of data regarding periods of high and low input of PFAS to groundwater.

3.7 FLOW MODEL CALIBRATION

3.7.1 APPROACH

Calibration has focussed on replicating observed groundwater levels between the period of 1976 to 2016. Averaged pumping conditions simulated in the model prior to 1999 have meant it is not possible to match short term variations in water levels caused by pumping activity, however generally the observed water levels appear to be controlled primarily by recharge and evapotranspiration.

For contaminant transport, due to the lack of known source concentrations, timings and volumes, a generalised match to relative concentrations of recently observed levels of PFOS in both monitoring wells and private bores has been attempted.
Manual calibration methods were used to alter the hydraulic conductivity (horizontal and vertical), specific storage and specific yield of modelled layers or zones. Effective porosity and dispersivity were modified to achieve the expected concentration distribution, as well as the addition of minor source zones along the drainage network where it is interpreted that PFOS has been mobilised by surface water transport.

### 3.7.2 GROUNDWATER LEVELS

Water level records from HWC with approximately monthly readings taken between 1976 and 2015 at wells installed in the Tomago Sand Beds aquifer, and between 1979 and 2014 for the Stockton Sand Beds aquifer, were used to calibrate the model to long term water level trends. A monitoring bore operated by DPI Water that is located near the old Williamtown Primary School (GW080079) has also been included. Several recent bores have been drilled as part of the AFFF contamination assessment since 2014, with each bore having one or two water levels recordings that were used to confirm the most recent water levels as well as assess vertical head gradients. A complete list of the monitoring wells used as calibration targets is included in Appendix A.

Figure 13 presents the groundwater level calibration statistics for the 348 piezometers used in the calibration (219 were used in earlier rounds of modelling). The scaled-root-mean-square error (SRMS) of 6.7% is within the often used criterion of 10% (MDBC, 2001; Barnett et al., 2012). A mean residual (difference between observed and modelled elevations) of 0.37 m indicates a slight tendency of the model to under-predict heads (i.e. modelled water levels are lower than observed on average). It should be noted that there are likely some dubious target points included in the calibration target data set that could have been filtered out (time permitting) which would have increased the apparent calibration accuracy.

Figure 13 shows that the simulated hydraulic gradients across the model extent are well matched to the observed gradients.

Figure 14 shows the distribution of residuals at each location averaged over the duration of the model run. The dominance of ‘green’ -1 to 1 m residuals around the base indicates that water levels are well represented in and around the Base. The bores with greater residuals are typically located near the northern boundary of the model, where less effort has been made to accurately represent surface water elevations and also the known flooding behaviour in these areas (in Moffats Swamp and Campvale Drain) in this round of the modelling.

Model hydrographs showing the observed and modelled heads are presented in Appendix B.

Simulated groundwater contours indicate groundwater flows locally to the major discharge locations including the coast to the south, Fullerton Cove and the Hunter River to the west, and Port Stevens and Tilligerry Creek to the east. Discharge to the drainage channels occurs in the vicinity of the Tilligerry Mud Member. Figure 15 shows the simulated groundwater heads and vertical flow directions at January 2016. Vertical flow is generally downwards within the Tomago Sand Beds and Stockton Sand Beds aquifers, with the exception of in the vicinity of and within the Tilligerry Mud Member, where water from the deeper sand aquifers emerges at the surface and discharges to the main drainage network. Other small areas of locally upwards flow exist where swamp conditions are present. It does not appear that groundwater from the Tomago Sand Beds aquifer north of the Tilligerry Creek flows under the creek to enter the Stockton Sand Beds aquifer. Water within the Stockton Sand Beds aquifer is from rainfall recharge only.
3.7.3 CALIBRATED MODEL PARAMETERS

Table 12 presents the calibrated model aquifer parameters. Calibrated model parameters are all within expected ranges and do not represent a marked departure from previous studies. The Tilligerry Mud Member has a slightly higher hydraulic conductivity than previously calibrated, however is consistent with the average values obtained during recent slug testing (Table 6). Bands of bivalve shells are often intercepted in the Tilligerry Mud Member boreholes (refer to AECOM 2016) which are likely to result in localised areas of increased hydraulic conductivity forming preferential flow pathways. Therefore, the calibrated value of 0.5 m/day for this unit is likely to be representative of the bulk hydraulic conductivity.

Table 12 Calibrated model aquifer parameters

<table>
<thead>
<tr>
<th>Layer</th>
<th>Hydrostratigraphic Unit</th>
<th>Kh (m/d)</th>
<th>Kv (m/d)</th>
<th>Kv/Kh</th>
<th>Ss (m⁻¹)</th>
<th>Sy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tilligerry Mud Member</td>
<td>0.5</td>
<td>0.03</td>
<td>0.06</td>
<td>1.00E-04</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>Stockton Sand Beds</td>
<td>20</td>
<td>0.2</td>
<td>0.01</td>
<td>1.00E-05</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>Upper Tomago Sand Beds</td>
<td>5</td>
<td>0.1</td>
<td>0.02</td>
<td>1.00E-05</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>Lower Tomago Sand Beds</td>
<td>20</td>
<td>0.2</td>
<td>0.05</td>
<td>1.00E-05</td>
<td>0.25</td>
</tr>
<tr>
<td>4</td>
<td>Coarse Sand/Gravel</td>
<td>40</td>
<td>0.5</td>
<td>0.0125</td>
<td>1.00E-05</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Kh – Hydraulic conductivity (horizontal); Kv – Hydraulic conductivity (vertical); Kv/Kh – Ratio of vertical to horizontal hydraulic conductivity; Ss – Specific storage; Sy – Specific yield

3.7.4 MASS BALANCE

The water balance for the transient flow model is presented in Table 13. It can be observed that the majority of recharge to the groundwater system comes from river leakage (including flood recharge around Campvale and Moffats Swamp, leakage from the drainage channels and Tilligerry Creek and inflow from Tilligerry inlet) and from direct rainfall recharge. Most of the discharge occurs via river baseflow (with the overall system being a net gaining system) and via evapotranspiration.

Table 13 Calibrated model mass balance (1970-2016)

<table>
<thead>
<tr>
<th>Layer</th>
<th>Inflow (ML/d)</th>
<th>Outflow (ML/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recharge</td>
<td>134.9</td>
<td>-</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>-</td>
<td>48.9</td>
</tr>
<tr>
<td>Wells</td>
<td>2.6</td>
<td>16.3</td>
</tr>
<tr>
<td>Rivers</td>
<td>220.4</td>
<td>277.9</td>
</tr>
<tr>
<td>Constant Head Boundaries</td>
<td>8.0</td>
<td>25.8</td>
</tr>
<tr>
<td>Groundwater storage</td>
<td>64.5</td>
<td>61.8</td>
</tr>
<tr>
<td>Total</td>
<td>430.5</td>
<td>430.6</td>
</tr>
<tr>
<td>% Error</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Note that the outflow to the River boundaries also includes ‘rejected recharge’, which occurs during intense rainfall events. In these instances, recharge may bring groundwater levels to the ground surface, in which case it is ‘rejected’ by the MODFLOW-SURFACT model. In reality, this would become runoff.
3.8 TRANSPORT MODEL CALIBRATION

Due to the lack of information regarding the contaminant source terms to be used in the model the transport model was not calibrated to PFAS concentrations in individual wells, but instead effort focused on replicating the relative concentrations of PFOS identified in monitoring bores and private user bores. AECOM (2016) details the distribution of boreholes that have been sampled and maximum reported concentrations of PFOS at each location as at February 2016, including PFOS concentrations reported during Stage 2A investigations (URS, 2015), private bore sampling program and groundwater monitoring during the Stage 2B investigation (AECOM, 2016).

The highest reported concentrations of PFOS occur within the RAAF Base boundary and immediately downgradient (south). However, isolated incidences of lower concentrations of PFOS have also been reported in the vicinity of the Salt Ash township, as well as to the west of the Base north of Fullerton Cove. AECOM (2016) discusses in more detail some of the uncertainty and possible processes associated with these isolated cases.

3.8.1 BASELINE MODEL RUN (WLM029)

The baseline model attempts to simulate the observed distribution or extent of PFOS contamination using transport via groundwater flow only. However, advective groundwater transport alone can only replicate the approximate distribution of concentrations within, and immediately downgradient of, the Base (see Figure 16 to Figure 21\(^2\)). The additional parameters used in the model are outlined in Table 14. URS (2015) modelled an effective porosity of 0.3 and a dispersivity of 10 m, therefore it was attempted to keep values within a similar range. Dispersivity parameters are consistent across the full model extent and for all units.

Table 14 Aquifer properties used for transport modelling

<table>
<thead>
<tr>
<th>Layer</th>
<th>Hydrostratigraphic Unit</th>
<th>( n_e )</th>
<th>( \alpha_L )</th>
<th>( \alpha_T )</th>
<th>( \alpha_V )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tilligerry Mud Member</td>
<td>0.35</td>
<td>10</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>Stockton Sand Beds</td>
<td>0.2</td>
<td>10</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>Upper Tomago Sand Beds</td>
<td>0.3</td>
<td>10</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>Lower Tomago Sand Beds</td>
<td>0.3</td>
<td>10</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>4</td>
<td>Coarse Sand/Gravel</td>
<td>0.3</td>
<td>10</td>
<td>5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

\( n_e \) – effective porosity; \( \alpha_L \) – Longitudinal dispersivity (m); \( \alpha_T \) – Transverse dispersivity (m); \( \alpha_V \) – Vertical dispersivity (m).

The model aims to simulate PFOS concentrations because this compound was reported in more samples than any other PFAS and typically at higher concentrations. The model is fully conservative, meaning it does not simulate any loss of mass due to degradation as it is an assumption of the model that PFOS is stable in groundwater. It has also been assumed in this simulation that PFOS does not sorb to sediment due to the sandy nature of the aquifer and limited organic matter, therefore a retardation factor of 1 was applied in the model. Laboratory results were made available very late in this modelling phase of work, and these suggested there is likely to be some retardation. However due to time constraints this information was not able to be included in the modelling. Hence, the rate of species migration through the subsurface is likely to be slower in reality than has been simulated.

\(^2\) Figure 16 to Figure 28 show modelled concentrations in Layer 4 (middle of Tomago Aquifer). Concentration sources are applied to Layer 2 (the uppermost active layer). There is a slight delay in the downwards migration of contaminant resulting in the display of apparently lower concentrations at early times.
Graphs showing model results of how the vertical relative PFOS concentration is predicted to change over time have been prepared at ten locations coinciding with select MW series monitoring wells, as listed in Table 15 and shown in Figure 32 to Figure 43.

Table 15  Location of wells chosen for concentration profiles

<table>
<thead>
<tr>
<th>WELL NAME</th>
<th>EASTING</th>
<th>NORTHING</th>
<th>LOCATION DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW147</td>
<td>39004</td>
<td>6367893</td>
<td>Near Fullerton Cove</td>
</tr>
<tr>
<td>MW153</td>
<td>394498</td>
<td>6369568</td>
<td>South of Tilligerry Creek</td>
</tr>
<tr>
<td>MW162</td>
<td>394444</td>
<td>6370282</td>
<td>SE of Site between Moors Drain and Tilligerry Creek</td>
</tr>
<tr>
<td>MW161</td>
<td>391059</td>
<td>6371267</td>
<td>North of Fire Training Pad</td>
</tr>
<tr>
<td>MW171</td>
<td>390238</td>
<td>6370369</td>
<td>South of Former Fire Training Pit</td>
</tr>
<tr>
<td>MW175</td>
<td>390748</td>
<td>6369706</td>
<td>South of Lake Cochran</td>
</tr>
<tr>
<td>MW110</td>
<td>391444</td>
<td>6369396</td>
<td>South of STP</td>
</tr>
<tr>
<td>MW107</td>
<td>389492</td>
<td>6369999</td>
<td>West of the Site</td>
</tr>
<tr>
<td>MW157</td>
<td>392772</td>
<td>6372120</td>
<td>North east of the Site</td>
</tr>
</tbody>
</table>

Generally, the concentrations are very similar vertically, with a tendency to increasing concentrations with depth over time suggesting that PFOS spreads vertically in the aquifer.

Four sites are modelled to not be currently affected by the migration of contaminant, these being MW147, MW162, MW153 and MW157. MW153 is to the south of Tilligerry Creek, and the lack of contaminant mass at this location further supports the conceptualisation of a lack of mixing of water between the Tomago Sand Beds and Stockton Sand Beds aquifers. MW157 is north-east of the Site and is up-gradient of the modelled contamination sources. The model predicts that PFOS will not reach this monitoring well. The model predicts that PFOS will break through at low concentrations at monitoring wells MW147 and MW162 in the future. These model results will be further discussed in the predictive modelling section (Section 3.1).

3.8.2 ADDITIONAL MODEL RUNS

Three additional model runs were carried out to investigate the potential effects of surface water, aquifer dispersivity, and isolated incidences of short duration PFOS application on the distribution of contaminants. The relative concentrations applied are estimates only, and the total volume of contaminant simulated from these sources is likely to be inaccurate.

Additional Surface Water Sources (WLM032)

The position of some bores in which PFOS has been detected (refer to AECOM, 2016) appears to coincide with the drainage channels in the Tilligerry Mud Member. It is likely that this is due to the transfer of contaminant in surface runoff during high rainfall events. It is conceptualised that this contaminated runoff then re-enters the groundwater through the drainage system. The current groundwater model is not set up to route either water or contaminant mass through the surface drainage system, however the surface water contribution to contamination of groundwater was included by adding a relative source concentration of 5% to the key drainage systems leading off site, namely Dawsons Drain, Moors Drain and the Fourteen Foot Drain. In order to allow leakage from the drains a constant stage of 10 cm was applied to the MODFLOW RIV package in these locations (where previously the stage was equal to the base of the drain permitting water to enter the drain only), however the flux of contaminant from the drainage channel into the groundwater
only occurs when the surrounding groundwater elevation is lower than that of the drain (i.e. when the drains are losing systems). The model results suggest that Dawsons Drain and Fourteen Foot drain are gaining systems for the majority of the time (i.e. groundwater only flows in to the channel) therefore only isolated locations of contamination flux out of Dawsons Drain and Fourteen Foot Drain have been simulated. It is important to note that this model represents a very simplified surface water component and there is significant uncertainty in the model regarding losing/gaining conditions.

The addition of this channel source term results in a continuous low concentration source along and to the south of Moors Drain (Figure 16 to Figure 24), which incorporates the locations of monitoring wells with reported PFOS hits, as opposed to the base model run which does not simulate any concentration along the drainage network. This model is likely to overestimate the area impacted by contamination distribution as several bores which had PFOS levels lower than the laboratory reporting limit also exist within the simulated low concentration plume along Moors Drain; however, this scenario is considered to give the most similar concentrations to the observed distribution and thus it became the base for further sensitivity runs.

**Increased Dispersivity (WLM033)**

Longitudinal dispersivity was set at 10 m in the baseline simulation and additional channel source model runs (Table 14), based on Gelhar et.al. (1992). To assess the effect of increasing dispersivity a model run was carried out using a dispersivity value of 25 m which while higher than before, also fits the findings presented in Gelhar et.al. (1992). Results between the two model runs are very similar, with only a slight widening of the simulated plume extent and slightly faster rate of concentration reduction over time at a given location with the increased dispersivity (Figure 16 to Figure 21).

**Short Term Sources (WLM034)**

A fourth simulation was run which included four additional short term contaminant source events to assess whether these accidental spills may affect the relative distribution of contaminant concentrations. These additional events are listed in Table 11 along with the assigned relative concentrations. Figure 25 to Figure 28 show the short term effects of these additional concentrations, however the overall distribution of contaminants is not noticeably affected by these short term events, with only a very minor change to the distribution of contaminants on Site local to the affected Hangars and no variation in the off-site distribution.

There are several other potential sources for contamination that have not been incorporated into the groundwater model as they are poorly understood, including:

- Leaking pipelines transferring waste water across the Site.
- Irrigation on Site using water pumped from groundwater which may be contaminated.
- Additional drainage channels that may also provide surface water transport pathways, e.g. the Ten Foot Drain.
- Short term incidences of PFOS use e.g. spot fire extinguishing events on the runway.

**3.9 MODEL PERFORMANCE**

The model run times varied from 30 hours (flow only) to 50 hours (including transport), with total run times varying slightly depending on the parameterisation and number of source zones included.
The calibrated flow model is consistent with a Level 3 model as per Barnett et al. (2012) (Appendix C) with the following key indicators:

- Calibration statistics are acceptable and meet agreed targets (RMS of 6.7%).
- Predictive time frame is less than 3 times that of transient calibration (calibration period of 45 years, predictive period of 20 years).
- Stresses are not more than two time greater than those used in calibration (stresses for predictive model are average of those applied for calibration).
- Temporal discretisation is the same for calibration and prediction (monthly stress periods).
- Mass balance closure is less than 0.5% (overall error is 0.02%).
- Model parameters are consistent with conceptualisation (based on previous work and recent hydraulic testing).
- Appropriate computational methods and spatial discretisation have been used.
- The model has been reviewed and deemed fit for purpose by external auditor with modelling experience.

The transport model also meets many of the above criteria, however due to the lack of information regarding historical contaminant sources and concentrations the model was unable to be calibrated. Additionally, the parametrization of many aquifer properties that govern the rate of transport are uncertain. Therefore, the transport model can only provide a Level 1 to 2 confidence rating (Appendix C).
4 PREDICTIVE MODELLING

The predictive model runs for a period of 20 years into the future (until December 2035) in order to predict the spread and dilution of the contaminant plume after all sources of PFOS are stopped. Assumptions used within the predictive model scenario are:

1. Activities using PFAS ceased in about 2004-05 (Table 1), however residual PFAS in soils are simulated to continue leaching until present day (2016) whence it is assumed remediation measures will remove any continuing source. The adopted timing for modelling these contaminant sources is therefore that shown in Table 11. From this point no further PFAS is simulating as leaching and only PFAS present in groundwater continue to migrate within the system.

2. Pumping by HWC continues at the average monthly abstraction rate, including from PS7 and PS9 which are currently not operating. No scenarios of modified abstraction regimes have been carried out so it is not possible to comment on the effect of HWC pumping.

3. Climatic conditions remain consistent with long-term trends.

4.1 FUTURE CONTAMINANT DISTRIBUTIONS

Due to the assumption that the contaminant sources have ceased, the model predicts that the concentration of contaminants in the groundwater would decrease and that impacted groundwater would move downgradient of the source area with time. This means that PFAS concentrations on or near the Site would decrease in concentration over time, while at locations further down-gradient the concentration may strengthen for a time before declining.

The model predicts that by 2035 the maximum relative concentration in groundwater would be only about 50% of the original source, with the highest concentrations centred around Dawsons Drain and directly south of the Site towards the Fourteen Foot Drain. The distributions of highest residual relative concentrations are similar for both the ‘groundwater only’ baseline run (WLM029) and the scenarios which include infiltration of PFAS impacted water via the surface drains, short term release of PFAS due to firefighting associated with a traffic accident, and the accidental activation of the fire suppression system at the three hangars. This suggests that groundwater is the key long-term driver of the majority of contaminant mass transfer.

4.2 SITE SPECIFIC CONCENTRATIONS

Figure 32 to Figure 43 show the concentrations simulated at the representative locations (see Table 15). In the baseline model run (WLM029) that only includes movement of contaminant in groundwater, locations MW162 (between Moors Drain and Tilligerry Creek) (Figure 42), and MW147 (near Fullerton Cove) (Figure 40) show a concentration breakthrough in the late 2020s with increasing concentrations until the end of the model run due to the continuing migration of PFOS in the direction of groundwater flow. When a channel source is included in the model runs the concentration breakthrough at MW162 is earlier, occurring at around 2000 (Figure 43), but remains the same at MW147, likely due to the lack of contaminant source being released from Dawsons Drain presumably due to groundwater being continually higher than the simulated drain stage.

All other locations show declining concentrations by the end of the 20 year predictive period with MW107 (west of base), MW101 (north of fire pad) and MW171 (south of landfill) simulating a return to almost ambient conditions by 2036.
4.3 PARTICLE TRACKING

MODPATH (Pollock, 1994) was used to simulate particle tracking to outline the likely groundwater flow pathways of contaminants originating at the six major source zones. This was undertaken using a steady state model as the majority of individual particles did not reach their ultimate receptor within the time duration of the transient model run (60 years). Steady state stresses are applied using estimated average annual recharge, evapotranspiration and groundwater pumping (by HWC).

Ten particles were simulated for each contaminant location. The longest travel time simulated by the particle tracking is 74,845 days (205 years). The nature of MODPATH and the boundary packages used in the model meant that particles “terminated” upon entering a model cell with a “sink” boundary condition, which in all cases for this simulation was a MODFLOW River cell representing the drainage network. Particle transport down-stream along the drainage network is not simulated. Table 16 summarises the particle tracking results from each source location. Figure 29 shows the lateral extents and travel times for each particle. Figure 30 and Figure 31 show the particle migration in three-dimensions, showing that particles typically migrate gradually laterally downward before travelling vertically upward either within the Tilligerry Mud Member or at its boundary with the Tomago Sand Beds aquifer.

Table 16 Summary of particle tracking by area

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<tr>
<th>SOURCE AREA</th>
<th>MAXIMUM TRAVEL DISTANCE</th>
<th>MAXIMUM TRAVEL TIME</th>
<th>END LOCATION</th>
<th>MINIMUM TRAVEL DISTANCE</th>
<th>MINIMUM TRAVEL TIME</th>
<th>END LOCATION</th>
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Distances in metres [m]; Travel times in years [yr].

Particles from the Former Fire Pit and the Landfill are simulated to discharge to Dawsons Drain with travel times between 29 and 55 years from source to discharge. It is likely that particles continue to travel in surface water to Fullerton Cove, however this is not simulated in the groundwater model.

Particles from Lake Cochran have travel times ranging between 17 and 84 years, mostly discharging to the un-named drainage network to the south of the Site and north of Cabbage Tree Road within 30 years. However, some particles are simulated to flow beneath these drains and re-emerge at the Fourteen Foot Drain with the upflowing hydraulic gradient induced by the Tilligerry Mud Member.

The travel pathways from the Sewerage Treatment Plant are similar to those from Lake Cochran, having variable travel times from less than one year up to 119 years.
Particles from the current Fire Training Pad are simulated to flow around Lake Cochran and the Sewerage Treatment plant due to the slight mounding of groundwater in these locations. Particles are again discharges to shallow un-named drains, with a focus area for discharge being to the south of Moors Drain into an unnamed drain located along the boundary of the Tilligerry Mud Member.

Particles from the Trade Waste Treatment Plant are simulated to flow beneath Moors Drain to emerge at the surface in the drainage network within the estuarine Tilligerry Mud Member.
5 LIMITATIONS AND RECOMMENDATIONS

This model represents a “first pass” at simulating the distribution of contaminants related to the use of AFFF fire-fighting foams at the Site. Due to the very short time frame allowed for this project, modelling has essentially occurred in parallel with data acquisition and analysis, and therefore not all findings from data analysis have been able to be incorporated within this phase of modelling.

There are several uncertainties and limitations associated with the contaminant transport model. These include:

- Lack of understanding of the contaminant source terms. The timing, concentrations and volumes of AFFF used on Site or potentially elsewhere in the area are not certain and are unlikely to ever be determined precisely; therefore, the contamination applied in the model is largely estimated based on few factual details. As a result, the modelled contamination distribution is not calibrated and is able to provide only an estimate of the likely spread of contamination with groundwater flow directions, and is useful as a guide towards potential contamination distributions at best. An improvement to the current model could be made by applying a variable source rate (where any information is available to constrain this). Analysis of residual soil concentrations could be undertaken to determine an appropriate rate of decline to the source term concentration over time from last AFFF use. Time constraints did not permit this to be considered in detail during the current work.

- Some potential sources for contamination have not been incorporated into the groundwater model due to a lack of information that would enable spatial and temporal attribution as a contaminant source in the model. These include leaking pipes (other than those at the Trade Waste Facility) transferring waste water across the Site, irrigation on site (using locally sourced groundwater), additional drainage channels other than those named in Section 3.8.2 (e.g. Ten Foot Drain), and short term incidences of PFOS use e.g. spot fire extinguishing events on the runway.

- Lack of understanding of the nature of the chemical and environmental properties of the contaminant source. PFOS and PFOA are stable compounds that are persistent in the environment and for the purpose of this model have been assumed to be non-reactive from source to receptor, however it is unknown whether compounds in the groundwater may react to form PFOS or PFOA, i.e. so called pre-cursor compounds, or whether PFOS and PFOA may degrade.

- Effective porosity values of all geological units are based only on a literature review and published ranges and are considered somewhat uncertain. However, the effective porosity governs the average linear groundwater velocity and thus the rate of contaminant transport. Macro-pores within the Tilligerry Mud Member are likely to provide localised transport pathways which would result in faster migration of PFAS in groundwater. Additional laboratory testing using undisturbed core samples and/or field scale tracer testing would be required to better constrain the estimated effective porosity of the sediments.

- In the simulation of this model, PFOS is assumed to be a mobile compound that does not sorb to materials within the aquifer sediments. Dissolution of PFOS is assumed not to affect the density of groundwater (i.e. no density driven flow). Retardation due to sorption was not included due to timing constraints and lack of site specific information, however recent information obtained from laboratory sorption testing suggests a retardation factor of approximately 6.4 to be appropriate. This would have the effect of slowing the transfer of contaminant. No sensitivity analyses on the effects of including sorption was undertaken in this assessment but should be considered in any further work.
Surface water flow is likely to be a key mechanism for contaminant transport, and is not able to be simulated with the required detail in the current groundwater model. An assumption of a constant source concentration along the key drainage channels (Moors Drain, Dawsons Drain and Fourteen Foot Drain) is unlikely to represent reality and is likely to over-estimate contamination in some areas while underestimating it in others. It is more probable that surface water runoff causes short-duration spikes in contamination after high rainfall events at specific catchment locations. Thus:

- Further understanding of surface runoff, specifically transient channel stage levels and flow volumes following rainfall events, is required before this can be confidently integrated into the groundwater model.
- It is highly recommended a surface water study is completed, the results if which could feed into an upgraded groundwater model for better representation of the contaminant transfer between surface water and groundwater. An example method is that this could be done via the RIV or Stream-Flow Routing (SFR) packages using detailed stage data (see previous point) or by the more advanced Channel Flow (CHF) package of MODHMS (an even more advanced version of the MODFLOW-SURFACT software that has been employed here). This last option has the advantage of allowing explicit simulation of the in-channel migration of the solute, including interaction with groundwater.

Predictive modelling does not extend for a long enough period of time to predict the complete dispersal of contamination. Notably, contaminant concentrations are simulated to increase in the vicinity of Fullerton Cove at the end of the predictive run. Due to the significance of this potential receptor, it is suggested that a much longer predictive model is run to assess the potential impacts at Fullerton Cove.
6 CONCLUSIONS

A transient groundwater flow and contaminant transport model has been developed to investigate the likely transport pathways and distribution of groundwater contamination caused by the use of firefighting foams at the RAAF Williamtown Site. MODFLOW-SURFACT software was used for both groundwater flow and contaminant fate and transport modelling.

The flow model was calibrated to historical and current water level records. Long term regional water level records were obtained from the Hunter Water Corporation and Department of Primary Industries (DPI) Water, and short term or single point measurements of water elevation in the vicinity of the Site were used from boreholes installed during the current and previous stages of the environmental assessments. The resulting calibrated groundwater flow model has a scaled RMS error of 6.9% which is within the recommended 10% suggested in modelling guidelines (Barnett et al., 2012).

Simulated groundwater flow paths show regional groundwater flow to the south-east, with localised discharge to Fullerton Cove, Tilligerry Creek and other shallow drainage networks established in the Tilligerry Mud Member. The groundwater flow gradient is horizontal or downwards within both the Tomago Sand Beds aquifer and Stockton Sand Beds aquifer, with a net upward gradient at the Tilligerry Mud Member along Tilligerry Creek and Fullerton Cove. The upwards flow at the Tilligerry Mud Member forms a flow barrier between the Tomago Sand Beds and Stockton Sand Beds aquifers.

Contaminant transport was simulated using relative concentrations due to the lack of information regarding source volumes, timings and concentrations. Ten contaminant source zones were modelled and scaled relative to the maximum reported PFOS concentration of 170 µg/L in a sample collected from monitoring well W53 during the Stage 2A investigation (URS, 2015). This monitoring well is located down hydraulic gradient of the former fire training pit. Additional sources were included in a separate model scenario to assess the likelihood of contaminant transfer in surface water to Moors Drain, Dawsons Drain and the Fourteen Foot Drain and infiltration to groundwater. These are the three major drains discharging surface water away from the Base.

Results indicate contaminant transport from the former fire training pit results in groundwater with the highest concentrations. Groundwater impacts originating from this source area merge with groundwater impacts potentially resulting from waste disposal within the former DEMS landfill. Groundwater migrates in a south-south-westerly direction before travelling in the direction of Dawsons Drain. The groundwater model does not indicate any impacted groundwater directly discharging to Fullerton Cove; however, this may occur at a date beyond the end of the model simulation (December 2035) as nearby monitoring borehole MW147 is predicted to be reached by the leading edge of the contaminant plume at around 2025. It is also probable that groundwater daylighting in the drainage network is likely to discharge as surface water to Fullerton Cove.

Areas of lower PFOS concentration include the fire training pad, the Trade Waste Treatment Plant, the Sewage Treatment Plant and Lake Cochran. The contaminant from these sources migrates predominantly south to south-easterly terminating at the Fourteen Foot Drain and Tilligerry Creek. No contaminated groundwater is predicted by the model to the south of Tilligerry Creek, reinforcing the conceptualisation of no mixing between the Tomago Sand Beds and Stockton Sand Beds aquifers.

PFAS impacted surface water within Moors Drain was simulated in the model and was predicted to infiltrate to the groundwater and migrate southwards towards Tilligerry Creek and the associated drainage network. Short term sources of known PFOS application were simulated in the model for one monthly stress period but did not have a noticeable impact on the distribution of contaminants.
Due to the significant uncertainties associated with the contaminant source, aquifer properties which govern the rate and spread of contaminant transport, and the chemical behavior of the contaminant, this model should only be used as a guide for potential contaminant distribution in groundwater. It should not be used to quantitatively assess the contaminant concentrations at a given time and location.
REFERENCES


Hunter District Water Board, 1957. Water supplies from underground sources. Conference of Professional Officers Representing the Authorities Controlling Water Supply and Sewerage Undertakings Serving the Cities and Towns on Australia


HydroGeoLogic Inc., 1996. *MODFLOW SURFACE Software (Version 4.0)*, Herndon, VA, USA.


FIGURES
FIGURE 1

Project Location
Contaminant Source Locations  Figure 2
Figure 3 Outcrop Geology around Williamtown

Model extent
RAAF Base Williamtown
Rivers and Drainage
Geology (simplified)
- Estuarine Clay (Holocene)
- Stockton Sands (Holocene)
- Tomago Sands (Pleistocene)
- Bedrock

Scale: 110,000 at A4
GDA 1994 MGA Zone 56

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Outcrop Geology around Williamtown
Figure 4  Schematic Cross-section of Geological Conceptual Model
Figure 5   Particle Size Distribution Analysis
Figure 6 Base of Estuarine Muds (Model Layer 1)
Figure 7

Thickness of Model Layer 4
Coarse Sand and Gravel

Borehole Data
Stratigraphic Interpretation
- Estuarine/Paludal Deposits
- Stockton Sand
- Inter Barrier Sand
- Tomago
- Tomago-Coarse
- Medowie Clay
- Bedrock

Model boundary
Rivers and Drainage
RAAF Base Williamtown

Thickness of layer (m)
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14

Scale: 1:10,000 at A4
GDA 1994 MGA Zone 56

Williamtown Groundwater Modelling
Figure 8 Base of Freshwater Aquifer / Top of Pleistocene (Base of model)

Borehole Data
Stratigraphic Interpretation
- Estuarine/Paludal Deposits
- Stockton Sand
- Inter Barrier Sand
- Tomago
- Tomago-Coarse
- Medowie Clay
- Bedrock

HWC bore
- intersects Medowie Clay
- no Medowie Clay interp.

Coastline
Rivers and Drainage
RAAF Base Williamtown

Base of Model Layer 5
Base of Freshwater Aquifer / Top of Pleistocene

Figure 8

Williamtown Groundwater Modelling
Figure 9 Model Boundary Conditions
Figure 11  Recharge Model Calibration
Figure 12: Model Recharge and Evapotranspiration Zones

Recharge and Evapotranspiration Zones

Williamstown Groundwater Modelling
Figure 13  Groundwater Level Calibration Scatter Plot
Figure 14 Model Calibration Average Target Residuals

Average Residual (m) [modelled - observed groundwater level]

-5 - 2.5
-2.5 - -1
-1 - 1
1 - 2.5
2.5 - 5

Model boundary
RAAF Base Williamtown
Rivers and Drainage

Scale: 110,000 at A4
GDA 1994 MGA Zone 56

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Model Calibration Average Target Residuals   Figure 14
Figure 15  Modelled Groundwater Contours and Gradients (January 2016)
Note: The model results are illustrative and have high enough confidence to support the conceptual model but should not be used to infer actual groundwater concentrations. Refer to main report for a discussion about uncertainties.
Note: The model results are illustrative and have high enough confidence to support the conceptual model but should not be used to infer actual groundwater concentrations. Refer to main report for a discussion about uncertainties.
Figure 18 Modelled Relative Contaminant Distribution

Year: 1990

Note: The model results are illustrative and have high enough confidence to support the conceptual model but should not be used to infer actual groundwater concentrations. Refer to main report for a discussion about uncertainties.
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Figure 23 Modelled Relative Contaminant Distribution

Year: 2030

- Modelled drains and rivers
- Williamstown RAAF Boundary
- EPA investigation area
- Hunter Water bore

Relative Concentration (%)

Note: The model results are illustrative and have high enough confidence to support the conceptual model but should not be used to infer actual groundwater concentrations. Refer to main report for a discussion about uncertainties.
Figure 24 Modelled Relative Contaminant Distribution

Year: 2035

Note: The model results are illustrative and have high enough confidence to support the conceptual model but should not be used to infer actual groundwater concentrations. Refer to main report for a discussion about uncertainties.
Note: The model results are illustrative and have high enough confidence to support the conceptual model but should not be used to infer actual groundwater concentrations. Refer to main report for a discussion about uncertainties.
Figure 26: Modelled Relative Contaminant Distribution (Hangar 279)

Note: The model results are illustrative and have high enough confidence to support the conceptual model but should not be used to infer actual groundwater concentrations. Refer to main report for a discussion about uncertainties.
Note: The model results are illustrative and have high enough confidence to support the conceptual model but should not be used to infer actual groundwater concentrations. Refer to main report for a discussion about uncertainties.
Note: The model results are illustrative and have high enough confidence to support the conceptual model but should not be used to infer actual groundwater concentrations. Refer to main report for a discussion about uncertainties.
Figure 29 Particles Travel Times and Extents
Figure 30  3D Particle Profile – View from West (subsurface)

A fraction of particles (e.g. this one from the Fire Training Pad) move rapidly into the deep coarse facies of the Tomago Sand Bed aquifer. This particle travels the furthest (up through the clay/mud to Fourteen Foot Draze).
Figure 31  3D Particle Profile - View from East (above)
Figure 32  Modelled Concentrations at MW157, WLM029 groundwater source only

Figure 33  Modelled Concentrations at MW110, WLM029 groundwater source only
Figure 34  Modelled Concentrations at MW107, WLM029 groundwater source only

Figure 35  Modelled Concentrations at MW175, WLM029 groundwater source only
Figure 36  Modelled Concentrations at MW101, WLM029 groundwater source only

Figure 37  Modelled Concentrations at MW161, WLM029 groundwater source only
Figure 38  Modelled Concentrations at MW161, WLM034 additional channel source

Figure 39  Modelled Concentrations at MW171, WLM029 groundwater source only
Figure 40  Modelled Concentrations at MW147, WLM029 groundwater source only

Figure 41  Modelled Concentrations at MW153, WLM029 groundwater source only
Figure 42  Modelled Concentrations at MW162, WLM029 groundwater source only

Figure 43  Modelled Concentrations at MW162, WLM032 additional channel source
APPENDIX A  LIST OF CALIBRATION TARGET LOCATIONS
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APPENDIX C  MODEL CLASSIFICATION TABLES
Appendix M

AFFF History Review
AFFF History Review

RAAF Base Williamtown, NSW
AFFF History Review
RAAF Base Williamtown, NSW

Client: Department of Defence
ABN: N/A

Prepared by
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30-Jun-2016

Job No.: 60479059

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This report has been prepared by AECOM, an independent consultant engaged by Defence, based on information and sources described in the report. The findings and interpretations set out in the report are based on data gathered by AECOM within the time available, including publically available information, data reports prepared for the Site, inspection of on-Site and off-Site areas and interviews of current and former Site personnel (where available).
Quality Information

Document: AFFF History Review
Ref: 60479059
Date: 30-Jun-2016
Prepared by: Rachael Casson
Reviewed by: Paul McCabe

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Table of Contents

1.0 Introduction 1
  1.1 Requirement for this Report 1
  1.2 Previous PFAS source reviews 1
  1.3 Objective 2
  1.4 Scope of Review and Report Structure 2

2.0 Previous AFFF/PFAS Related Reports Review 3

3.0 Site Inspection and Interviews 20
  3.1 Site Inspection 20
  3.2 Interviews 20
    3.2.1 On-Site Interviews 20
    3.2.2 Off-Site (Face to Face and Telephone) Interviews 20

4.0 Potential Off-Site PFAS Sources 21

5.0 Site Fire Fighting Training, Responses and Operations (AFFF Use) 22
  5.1 Derivation of Information for Interpretation 22
  5.2 Former Fire Fighting Training, Responses and Operations 22
    5.2.1 3M Lightwater™ Period - 1976 to 2004 22
    5.2.2 3% Ansulite® AFFF Period - 2004 to Current 30
  5.3 Infrastructure PFAS Sources 38
    5.3.1 Hangars – Fixed Deluge Systems (cannon and floor pop-up units) 38
    5.3.2 Bulk Fuel Storage and Flammable Liquid Areas 43
    5.3.3 Lake Cochran 43
    5.3.4 On-Site Landfills (North East, Western and South Western) 45
    5.3.5 NACC Development 45
  5.4 Chronology of AFFF Use at the Site 46
  5.5 Estimated Volumes of AFFF Discharges 46
    5.5.1 AFFF Generation 1 – 3M Lightwater™ Dominated Period (1976-2004) 46
    5.5.2 AFFF Generation 2 – Ansulite® Dominated Period (2004-2015) 47
  5.6 Summary of Identified On-Site PFAS Sources 47

6.0 References 49

Appendix A
  Figures A

Appendix B
  Chronology of Defence AFFF Use B

Appendix C
  Site Inspection Records and Interviews C

Appendix D
  Potential Off-Site Sources D

List of Tables

Table 1 Summary of Previous PFAS Report Findings 4
Table 2 Summary of PFAS Results - Disused Former Fire Training Pit (Facility 479) (Sampled 2/12/15 and 9/3/16) 29
Table 3 Summary of PFAS Results - AFFF Concentrate and Concrete Pavement at the Fire Station (Facility 165) (sampled 12 January 2016, 9 February 2016, 9 March 2016) 33
Table 4 Hangar Static / Fixed Fire Suppression Systems 40
Table 5 Chemical Characterisation of AFFF Concentrate stored at Hangars 11 and 279 (sampled 3 May 2016) 42
Table 6 PFAS source summary table 48
1.0 Introduction

1.1 Requirement for this Report

As part of the RAAF Base Williamtown (the ‘Site’), Stage 2B Environmental Investigation (Stage 2B EI), AECOM Services Pty Ltd (AECOM) was engaged by the Department of Defence (Defence) to review the historical use of Aqueous Film Forming Foam (AFFF) at the Site and surrounding areas (Figure F1 and Figure F2 in Appendix A). This Review was conducted to better understand the activities completed at the Site that involved the use of AFFF containing per- and poly-fluorinated alkyl substances (PFAS) to identify locations where the environment may be impacted.

The Review included the Site and NSW EPA Investigation Area, hereafter referred to as the Stage 2B Investigation Area. The Review area is shown on Figure F1 in Appendix A.

The Site has been an active airbase since 1941 and has functioned primarily as an operational aircraft training and maintenance facility. As a consequence, a range of chemical products have been stored and utilised which have variably impacted soil, groundwater, surface water and sediment.

AFFF formulations containing PFAS such perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) as the active ingredients, have historically been discharged at a number of areas across the Site creating a number of source areas. Environmental investigations have identified a diffuse PFOS and PFOA groundwater contamination plume extending off-Site and measuring in the order of five to seven kilometres wide. This plume has not considered other PFAS which have been predicted to migrate further in the environment, from their source. PFAS impact has also been detected on and off-Site in surface water bodies, sediment and biota (URS, 2015).

Investigations to date have not established the magnitude of historical AFFF discharge across the Site, the nature of the sources and the mechanisms for migration (e.g. leaching capacity).

The focus of this report has been to identify locations at the Site and operations where AFFF firefighting retardants/suppression foams, containing PFAS, have been discharged or spilt. This research includes an estimation of the frequency and magnitude of AFFF concentrate releases to the environment over the period of use. The Review does not focus on other retardants / suppression foams potentially used at the Site, nor compounds in addition to PFAS in the AFFF fire retardant used at the Site.

The information in this report will be used to further refine the Conceptual Site Model (CSM) of contamination and provide key input data to the modelling of PFAS fate and transport.

1.2 Previous PFAS source reviews

This Review has considered and built upon information provided in previous environmental reports prepared for the Site since 1993. Three previous reports in particular have focussed on PFAS issues at the Site including:

- Aurecon Australia (Aurecon) - Environmental Review of Fire Fighting Training Facilities report (Aurecon, 2009).
- GHD Stage 1 - Conceptual Site Model for AFFF Contamination (GHD, 2013).
- URS Australia Corporation (URS) - Stage 2 Environmental Investigation AFFF, PFAS RAAF Base Williamtown NSW (URS, 2015).

A more comprehensive summary of previous investigations complete at the Site is provided in Table 4. These reports describe with varying levels of detail, the history of AFFF use and discharges, geological and hydrogeological conditions, and the nature of the PFAS contamination identified at the Site. This Review consolidates and expands upon PFAS related issues and presents and incorporates new information, particularly relating to:

- Off-site sources (e.g., fire stations, fire training grounds, and fire emergency response sites) which potentially contribute to the PFAS load to the main surface water bodies within the NSW EPA Investigation Area and beyond to include the associated Fishery Closure Areas identified by the NSW EPA (including the Hunter River, Fullerton Cove and Tilligerry Creek – refer to Figure F1 and F3 in Appendix A).
- The history of the PFAS source areas on-Site.
- Characterisation of PFAS sources (e.g. PFAS characterisation of AFFF concentrate stores and PFAS impacted concrete slabs).
- Estimates of the potential volumes of the different types of AFFF concentrates discharged at selected source areas (e.g. former and current fire training areas or during hangar testing).
- The presence / absence of mitigation measures implemented by the Defence firefighting section and environmental officers over the last 15 years (e.g. zero use of AFFF in training) and the potential historical contamination of soil, sediment, groundwater and surface waters that may have occurred through:
  - Overspray of AFFF onto the pervious ground beyond the past and current training facilities where it may infiltrate through soils and leach to the aquifer and/or drainage system.
  - Leakage of spent AFFF solution and residues through the concrete / brick bases of the facilities and permeation to the subsurface below or leaching into runoff water that it comes into contact with this infrastructure.
  - Emergency response and the related discharge of AFFF to quell a fire or prevent a fuel spill from igniting.
  - Spillage of AFFF concentrate during transport, handling, storage or decanting.

1.3 Objective
The primary objective was to compile, review and interpret desktop related information identifying current and historical sources of PFAS, originating from AFFF fire retardants, and to present this information in a consolidated form that can be used to direct future investigations and management decisions regarding PFAS contamination sourced from the Site. The desktop based research has been supplemented by the chemical characterisation of stocks of AFFF concentrate and associated infrastructure for the presence of PFAS.

1.4 Scope of Review and Report Structure
In order to meet the project objective, the following scope of work was undertaken:
- Review of environmental reports relating to AFFF operations and usage on the Site (Section 2.0).
- Site inspection of the former and current fire training grounds and fire station and interviews with current and past Site personnel (Section 3.0).
- Identification of potential off-Site or non-Defence AFFF usage to determine the potential for additional off-Site PFAS sources (Section 4.0).
- Review of publically available and / or unclassified Defence information relating to historical and current AFFF usage / discharge. This included reviewing of:
  - Site firefighting training activities
  - Results of sampling and laboratory analysis of current stocks of AFFF concentrate and infrastructure at selected locations for PFAS (Section 5.2).
- Inspection and review of infrastructure at PFAS source areas (Section 5.3).
- Development of a chronology of AFFF use on-Site and off-Site (Section 5.4).
- Estimation of volumes of AFFF discharges and evaluation of effectiveness of PFAS control measures for on-Site (Section 5.5).
- Preparation of a summary of PFAS source areas, for on-Site and off-Site (Section 5.6).
2.0 Previous AFFF/PFAS Related Reports Review

A series of environmental reports have been prepared for the Site since the early 1990s (circa 1993). Reports pertaining specifically to AFFF use and potential sources have been prepared over the last 10 to 13 years as Defence recognised the potential environmental issues associated with the use of AFFF containing PFAS.

Specific PFAS investigations commenced after commercial PFAS laboratory analysis became routinely available. The first investigations assessing the potential presence of PFAS was conducted in 2003 by GHD. These investigations utilised the Methyl Blue Activated Substance (MBAS)\(^1\) analysis on groundwater and surface water samples as a surrogate indicator of the presence of surfactant chemicals arising from AFFF discharges. MBAS results cannot be used to establish the magnitude of PFAS concentrations.

The first PFAS laboratory analytical testing was conducted as part of the GHD investigation in December 2011 (GHD, 2012b). Testing was conducted on groundwater samples collected from the Site and reported in March 2012 (refer to Appendix B).

Table 1 below summarises the findings of selected previous investigations to build on the understanding of historical AFFF use, storage and handling to refine the CSM, including migration mechanisms and areas of potential impact.

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\(^1\) MBAS is a colorimetric screening assay for anionic surfactants (it is non-specific to PFAS) and may detect the presence of hydrocarbon surfactants and detergents.
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| Parsons Brinckerhoff Australia Pty Limited (PB, 2006). Stormwater Monitoring Program RAAF Base Williamtown. May 2006. | Parsons Brinckerhoff was engaged to undertake monthly surface water quality and flow gauging at the Site for a period of four years commencing in May 2003. The data from the monitoring program was to be used in determining the impact of site operations on the surrounding environment and to collect baseline data to assess impact of proposed redevelopment works on the Site. This report included the results for samples collected on 7 June 2006. | - MBAS was reported in surface water samples above the assessment criteria both at the discharge point in Dawsons Drain (DD1) and Moors Drain (MD1)  
- PB (2006) concluded that Site redevelopment works, involving construction of stormwater management controls to treat runoff from hardstand areas, did not appear to adversely impact surface water quality. | - MBAS is a low sensitivity screening colorimetric assay used to detect the presence of anionic surfactants. The test cannot distinguish between the types of surfactants (including fluorinated surfactants containing PFOS and PFOA). Therefore its application can be considered as limited.  
- The above limitation notwithstanding, it is possible that the elevated MBAS results were associated with the presence of AFFF compounds and it can be inferred that PFAS were potentially present in the water discharging into Dawsons Drain and Moors Drain in 2006. |
| HLA Envirosiences Pty Ltd (HLA ENSR now AECOM [2007]) Stage 2 Environmental Investigations. RAAF Base Williamtown, Williamtown, NSW. 24 September 2007. | HLA was engaged to identify and evaluate the risks to Defence associated with site contamination and to detail practical risk-based management strategies for each of the 13 areas of environmental concern identified on Site in the SMEC Stage 1 Report (SMEC, 2006). Contaminant compounds investigated included petroleum hydrocarbons, chlorinated hydrocarbons, heavy metals and nutrients. | - Petroleum hydrocarbons and nutrients were detected that was indicative of infrastructure failure or overflow discharge sourced from the Trade Waste Treatment Plant (Facility 480). This implies some spent AFFF solution directed to the Trade Waste Treatment Plant following maintenance testing of the Hangars may have leaked into the subsurface.  
- Discharge from the Trade Waste Treatment Plant (Facility 480) was directed to the Sewage Treatment Plant (Facility 410). The effluent lagoons at the Sewage Treatment Plant are unlined, therefore AFFF impacted wastewaters received may have migrated to the environment (groundwater). | - Hangar maintenance is a source of AFFF to the Trade Waste Treatment Plant (Facility 480).  
- The Sewage Treatment Plant (Facility 410) may have received AFFF impacted influent. |
<table>
<thead>
<tr>
<th>Report</th>
<th>Investigation Objectives</th>
<th>Findings Relating to PFAS</th>
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</tr>
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<tr>
<td>ENSR AECOM Australia Pty Ltd (ENSR AECOM, 2008). Designer for Stage 3 Environmental Remediation and Validation - Supplementary Investigation Report, RAAF Williamtown, NSW. March 2008.</td>
<td>ENSR AECOM undertook a Supplementary Investigation (SI) of soil and groundwater at five locations across the Site including: - CNN0045 - North Eastern Landfill - CNN0139 - Salt Ash Air Weapons Range (SAWR) - CNN0064 - Engine Maintenance Section (EMS) - CNN0176 and CNN0002 Sewage Treatment Works and Effluent Lagoons - CNN0057 - Fuel Farm 3 (FF3). The assessment did not assess PFAS impact.</td>
<td>- Nil</td>
<td>- There is a potential that AFFF related or impacted soil or waste materials may have been disposed of at both the North Eastern Landfill and the Former DEMS Landfill (Facility 394). - The magnetometer survey identified anomalies in the vicinity of the ‘U’ shaped section of the Effluent Lagoons. This suggested that the south western waste burial site may extend from Lake Cochran to the Sewage Treatment Plant (Facility 410). This shows the potential extent of the former burial site, and hence potential additional sources of PFAS contaminated waste.</td>
</tr>
</tbody>
</table>

Maunsell AECOM prepared an Operations and Maintenance Manual for the Sewage Treatment Plant (Facility 410).

- Effluent from the Sewage Treatment Plant (Facility 410) is discharged to the primary effluent lagoons, overflows are directed to the secondary effluent lagoons.
- Thickened sludge from the secondary digesters is pumped to sludge disposal channels where it is removed by Veolia Environmental Services (Veolia) trucks equipped with pumping facilities. Veolia transports the sludge to Transpacific Waste Services located in Homebush, Sydney, where it is processed and disposed to landfill.
- Grit which has settled in the hopper below the main chamber of the grit trap is pumped to the grit classifier, where it dried before the collected grit it is disposed offsite.
- The Sewage Treatment Plant (Facility 410) contains three primary sedimentation tanks (PST No1 to PST No 3). Sludge (comprising mostly organic matter) is sent to the anaerobic digesters.
- Bore water is stored in a tank at the plant and is designed to provide a continuous high pressure supply for distribution to several points on the treatment works. The bore water is used in the chlorination system, for general purpose hosing down and washing, lawn watering and sewage pumpsets and services.
- The secondary effluent lagoons may have been filled sometime between 2012 and 2014/15.
- It is unclear where the collected grit is disposed of.
- The fines are also separated from the water, and disposed of in “wheelie” bins, it is unclear where this material is disposed of.
- Water required for washing, flushing and cleaning purposes during the Sewage Treatment Plant (Facility 410) operation was supplied from non-potable water sources (although it is not clear if this includes bore water). Groundwater beneath the site is affected with PFAS and hence any groundwater use could involve PFAS impacted groundwater.
- It is unclear where the floating scum from the sedimentation tanks is directed to/dispersed of.
- The Sewage Treatment Plant (Facility 410) process is unlikely to treat or remove PFAS. Elevated PFAS are likely to accumulate in the grit trap, the sludge, the anaerobic digesters. PFAS concentrations are likely to be present in the effluent which when discharged to the ponds, are inferred to migrate to groundwater.
<table>
<thead>
<tr>
<th>Report</th>
<th>Investigation Objectives</th>
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</tr>
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<tr>
<td>Aurecon Australia (Aurecon, 2009). Environmental Review of Fire Fighting Training Facilities, Department of Defence, RAAF Base Williamtown – Site Report. October 2009</td>
<td>Aurecon undertook an environmental review of pollution control associated with fire training and testing at the Site. The investigation aimed to: - assess the nature and extent of AFFF and hydrocarbon use during fire training - assess the adequacy of pollution control structures associated with fire training activities - assess options to address any identified deficiencies.</td>
<td>- 6% Ansulite® AFFF was the primary fire retardant used on Site at that time.  - Seven firefighting vehicles were housed at the Fire Station (Facility 165). The vehicles are understood to be were tested monthly for foam production.  - A 5000 L AFFF Aboveground Storage Tank (AST) was located within a concrete bund which is plumbed to two spent AFFF wastewater underground storage tanks (USTs) (20 kL and 35 kL).  - The two spent AFFF waste water USTs were pumped out by a contractor.  - 9 x 200L AFFF concentrate drums were stored beneath the AST within the uncovered bund.  - Vehicle foam induction testing was conducted monthly at the wash bay (concrete paved with three bunded walls). The wash bay was plumbed to the two spent AFFF wastewater USTs.  - The wash bay was designed to capture spent AFFF wastewater from the Trident fire vehicles which were smaller than the current Panther fire vehicles.  - Vehicle testing generated 80 kL – 90 kL of spent AFFF solution / wastewater monthly.  - The Disused Fire Training Pit (Facility 479) was no longer in use.  - Hangars 8, 11, 19, 141, 279 and 339 had static / fixed fire suppression systems that contained 3M Lightwater™.  - Stocks of AFFF concentrate were stored in the bund of the AFFF AST.  - No active fire training was being conducted at this time.</td>
<td>This report provided a good summary of the firefighting operations undertaken at the Site in 2009. Aurecon’s findings were generally consistent with AECOM’s findings from other sources in this Review.</td>
</tr>
</tbody>
</table>
## Investigation Objectives

- There was no on-site wastewater treatment systems designed to treat AFFF/PFAS impacted waste water.
- The report prioritised the associated environmental risks, made recommendations and provided cost estimates for those recommendations.

## Findings Relating to PFAS

- As noted above, MBAS is a low sensitivity screening colorimetric assay that does not measure PFAS concentrations. However, it is possible that the elevated MBAS results were associated with the presence of AFFF compounds and it can be inferred that PFAS were potentially present in the water discharging the Site via the drainage lines in 2011.

## Comparison to AECOM findings or Comment

### GHD Pty Ltd (GHD, 2011a).

- GHD was commissioned to undertake quarterly surface water quality monitoring at the Site between April 2010 and December 2010, to satisfy Condition of Consent No. 18 of the EIS for the introduction into the service of the Hawk Lead-In Fighter.
  - The analytical suite conducted did not include PFAS, however, MBAS was tested for in surface water samples.
  - Water quality monitoring commenced at the discharge points in Moors and Dawsons Drains in 2003 (by others) at two locations (MD1 and DD1).
  - MBAS concentrations were reported between 300 µg/L (June 2010) and 900 µg/L (April 2010) for Moors Drain (MD1), and between 100 µg/L (April and June 2010) and 200 µg/L (December 2010) in Dawsons Drain (DD1).

  Assessment criteria for MBAS was not stated or referenced in this document.
<table>
<thead>
<tr>
<th>Report</th>
<th>Investigation Objectives</th>
<th>Findings Relating to PFAS</th>
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</tr>
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<tr>
<td>GHD (2011b). RAAF Base Williamtown and Salt Ash Air Weapons Range (SAWR) Groundwater Monitoring Program - 2010 Annual Report. March 2011.</td>
<td>GHD was commissioned to undertake quarterly groundwater monitoring at the Site and SAWR (outside the investigation area) for four monitoring rounds (April 2010, June 2010, September 2010 and December 2010). The number of groundwater samples collected for each quarterly sampling event varied between 56 and 77 monitoring wells (of which 14 are located on the SAWR). The analytical suite conducted did not include PFAS, however, MBAS was tested for in groundwater samples.</td>
<td>- 1998 fuel spill occurred near the Former Fuel Farm 2 (E03) (on-Site). - Elevated MBAS concentrations were detected down-gradient of the Fire Training Pad (Facility 165), the Disused Fire Training Pit (Facility 479) and the South Western Landfill (CN0053) (all located on-Site).</td>
<td>- See comments above, regarding the limitations and inferences of utilising MBAS results. MBAS was not analysed for at the SAWR.</td>
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| GHD (2011c). Groundwater Monitoring Program, RAAF Base Williamtown and SAWR - Assessment of Risk to Hunter Water Pump Station 5. April 2011. | GHD evaluated the risk that groundwater contamination originating from the Site (in particular from the Former Fire Training Pit [Facility 479] and the former Demolitions Landfill [Facility 394]) represent to the drinking quality of groundwater extracted by the Hunter Water Corporation (HWC) at Pump Station 5 (PS5). | GHD reported that:  
  - MBAS groundwater results at the Disused Fire Training Pit (Facility 479) and at the Former Demolitions Landfill (Facility 394) ranged between <0.1 µg/L and 9.4 µg/L.  
  - “The currently available data suggests that AFFF contaminated groundwater at Facility 479 is unlikely to pose a significant risk to HWC groundwater resources in the vicinity of PS5, primarily given the relatively limited extent of contamination and the unlikely future release of AFFF into the environment. However, further derivation of appropriate health based criteria for PFOS and PFOA, and more specific testing for AFFF in groundwater at Facility 479 are required to provide a more definitive assessment of risk posed by this contamination to HWC resources.”  
  - GHD concluded that given the limited extent of AFFF contamination it is unlikely to pose a significant risk. | GHD conclusions and data set have been superseded by the collection and analysis of information regarding PFAS impacts during subsequent investigations. |
### Investigation Objectives

The investigation objective was to classify soil excavated from an area where approximately 1000 L of Ansulite® AFFF concentrate was spilt.

### Findings Relating to PFAS

- Approximately 1,000 L of 3% AFFF concentrate was spilt on 15 December 2011. The sampling was conducted on 27 January 2012.
- The spill was located adjacent to a drain along the northern boundary of the Site.
- The impacted soil (approximately 25 m$^3$) was excavated and placed into 12 skip bins (2 x 10 m$^3$ bins and 10 x 3 m$^3$ bins). It is unclear when the impacted soil was excavated and placed into the skip bins.
- Seven composited samples were submitted for PFOS, PFOA and 6:2 FtS analysis.
- PFOS concentrations ranged from 0.0101 mg/kg to 0.0742 mg/kg.
- PFOA concentrations ranged between below the laboratory LOR and 0.0011 mg/kg.
- 6:2 FtS was not detected above the laboratory LOR.
- GHD (2012) classified the materials as general solid waste.

### Comparison to AECOM findings or Comment

- GHD utilised the Minnesota Pollution Controls Agency 2005 soil reference values for residential and industrial land uses. It is noted that these criteria were updated in 2008 and that the criteria were not appropriately amended to accommodate for the composite sampling undertaken.
- The waste classification does not appear to conform with NSW EPA waste disposal requirements for emerging contaminants of concern where waste classification criteria is absent.
- AECOM was unable to determine if, at the time of the spill, Ansulite® was transported laterally into the drain, dissolved in water, or soaked into the ground, due to the absence of a figure showing the location of the spill. Hence, an understanding of the migration pathway of concentrate to the environment could not be made.
### Report


**Investigation Objectives**

GHD undertook the December 2011 quarterly groundwater monitoring program at 69 locations variably across the Site (61 locations) and the SAWR (eight locations). MBAS, PFOS and PFOA were tested at select on-Site locations, including the current fire training area (Facility 165) and the former fire training pit (Facility 479). MBAS was only tested for samples collected from the STP (Facility 410) and legacy site E03 (former fuel farm).

**Findings Relating to PFAS**

- MBAS was detected at 0.1 mg/L in both wells at E03
- PFOS and PFOA concentrations were reported above the assessment criteria in groundwater at the current Fire Training Pad (Facility 165) and the Disused Fire Training Pit (Facility 479).
- PFOS concentrations ranged from 14.2 µg/L and 300 µg/L at the current Fire Training Pad (Facility 165) and 45.8 µg/L and 314 µg/L at the Disused Fire Training Pit (Facility 479).
- PFOA concentrations ranged from 0.94 µg/L and 3.09 µg/L at the current Fire Training Pad (Facility 165) and 0.35 µg/L and 1.43 µg/L at the Disused Fire Training Pit (Facility 479).
- GHD reported that statistical trend analysis of MBAS concentrations reported since 2006 indicated that MBAS has been decreasing. GHD extrapolated that the decrease in MBAS suggested that PFOS and PFOA concentrations in groundwater may also have reduced over this time, even in the absence of PFOS and PFOA results.

**Comparison to AECOM findings or Comment**

- As discussed above, the limitations of using MBAS as an indicator for PFOS and PFOA mean that it may be unreliable to conclude that the dissolved PFOS and PFOA concentrations are decreasing.
- PFOS and PFOA groundwater results were consistent with URS (2015) findings.
- MBAS, PFOS and PFOA were not analysed for samples collected at the SAWR.
### Investigation Objectives

AECOM was engaged by John Holland Group (JHG) to undertake a baseline contamination assessment on land proposed for the 4 Squadron development. This included testing of groundwater for PFOS, PFOA and 6:2 FtS at four locations.

- **PFOS** was reported at concentrations greater than the Site-specific assessment criterion (Minnesota Department of Health [MDH]) at monitoring well W17 with a concentration of 4.6 μg/L. The remaining monitoring wells reported PFOS concentrations above the laboratory LOR, but below Site assessment criteria adopted for this investigation.
- Three wells (W17, W116 and W117) reported concentrations greater than the laboratory LOR for PFOA but less than the assessment criterion adopted for this investigation.
- All monitoring wells sampled on the Site reported concentrations of 6:2 FtS less than the laboratory LOR.

### Findings Relating to PFAS

PFOS and PFOA groundwater results are consistent with URS (2015).

### Comparison to AECOM findings or Comment

Findings are consistent with previous and subsequent investigations.

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<tr>
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<th>Investigation Objectives</th>
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</table>
| AECOM (2012b) Sewage Treatment Plant Effluent Lagoon Investigation Report. AEC-ES01-RP-EM-0004-B-STP. 7 September 2012. | AECOM undertook a contamination investigation surrounding the existing effluent lagoon servicing the RAAF Williamtown Sewage Treatment Plant (STP) (Facility 410). The investigation was completed as part of the RAAF Base Williamtown Stage 2 Redevelopment Contract. | - The effluent lagoons were unlined.  
- It was reported that land to the west of the existing effluent lagoon was investigated via a geophysical magnetometer survey (circa 2007) and a number of anomalies / burials indicative of waste were identified to the west of the effluent lagoons. A magnetometer survey investigation was also conducted and anomalies were identified in three separate areas along the northern bank of the effluent ponds and near the ‘U’ shaped section. This shows the potential extent of the former burial site, and hence potential additional sources of PFAS contaminated waste, in the form of disposal of AFFF concentrate drums, for example.  
- Elevated concentrations of PFOS and PFOA in groundwater were reported (maximum PFOS concentration of 17.3 μg/L and a | Findings are consistent with previous and subsequent investigations. |
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<tr>
<th>Investigation Objectives</th>
<th>Findings Relating to PFAS</th>
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<td>maximum PFOA concentration of 0.36 µg/L. The risk was evaluated using the Defence Contamination Risk Assessment Tool (CRAT) at medium to high with possible severe consequences. Severe consequences include irreversible damage to human health, substantial pollution of a sensitive water resource, significant change to the number or one or more species or ecosystems and irreparable damage to crops, buildings, structures or the environment.</td>
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<td>- The surface water and sediment within the effluent lagoons was not tested for PFOS or PFOA.</td>
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<td>- As per previous note of burial areas on site being potential sources of PFAS, shallow buried items were identified and included car parts, building rubble, communication debris, sections of water pipes, empty acetylene bottles and clay lining of the effluent lagoon.</td>
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<td>Report</td>
<td>Investigation Objectives</td>
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| AECOM (AECOM, 2012c). Sewage Treatment Plant Overflow Area Investigation Report. AEC-ES01-RP-EN-0002-B-STP. September 2012. | AECOM undertook an investigation of the contamination status of the STP Overflow Area (secondary effluent lagoons), as part of the Site Stage 2 Redevelopment Contract | - Concentrations of PFOS and PFOA were reported above the assessment criteria in both groundwater monitoring wells sampled.  
- Additionally, MBAS and 6.2 FtS were reported in both groundwater monitoring wells sampled near the overflow lagoons.  
- The Defence CRAT assessed the site as having a Moderate to High Risk.  
- The identified PFAS impact was attributed to trade waste influent.  
- AECOM concluded that contamination was potentially migrating towards the boundary of the Site and toward off-Site areas. The potential for chemical degradation of these products in groundwater was considered to be low and therefore compounds were considered to persist in the groundwater. | Findings are consistent with previous and subsequent investigations. |
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</table>
| GHD (2013). RAAF Williamtown, Stage 1 – Conceptual Site Model for AFFF Contamination. GHD, February 2013. | GHD’s objectives were to:  
- Establish the extent of the AFFF contamination.  
- Identify risks associated with associated with AFFF contamination.  
- Identify data gaps.  
- Provide recommendations for future sampling programs. | - 6% 3M Lightwater™ AFFF was used for a period of 40 to 50 years at the Site since the early 1970s until Defence transitioned to Ansulite® in 2010.  
- It is understood that the fixed fire suppression systems in the Hangars (H19, H11, H8, H279 and H141) were charged with 3M Lightwater™ until circa 2010. The use commenced around the 1980s.  
- A fire suppression system was installed in Hangar 339 in 1999  
- Until 2009, fire training activities were conducted in the Disused Fire Training Pit (Facility 479). AVTUR (Aviation Turbine Fuel), similar to kerosene, was added to water within the Disused Fire Training Pit (Facility 479) and then lit, the fire was extinguished using AFFF.  
- Spent AFFF generated during Hangar testing was discharged directly to the trade waste system until circa 2006. Post 2006 spent AFFF is captured for off-site disposal.  
- Monthly training was conducted at the training pad near the fire station (Facility 165).  
- Three different specific incidents were reported where AFFF was released: 1988 crash of a Winjeel aircraft; incorrect initiation of Hangar test (undated); and in 2009 AFFF used on runway to suppress fire.  
- The Sewage Treatment Plant (STP) (Facility 410) and the Northern and Western landfills were also identified as possible PFAS sources.  
- PFAS was detected on and off-Site variably in soil, sediment, groundwater and surface water. | - The dates of the different types of AFFF concentrate used do not match those of Aurecon (2009) and this Review.  
- The remainder of the findings were consistent. |
### Investigation Objectives

  - GHD undertook a groundwater monitoring program (GMP) across the Site (78 monitoring wells) and the SAWR (14 monitoring wells) between 2 and 17 June 2014. Specifically, the GMP was designed to meet the following objectives:
    - "Verify that the impact of contaminated areas on sensitive receptors remains low by monitoring groundwater quality entering and leaving these areas and identifying long term trends and early detection of losses from potential source areas of contamination at current facilities".
    - "Inform stakeholders of these trends."
  - Detected on-Site PFOS concentrations remained similar to the March 2013 results collected at the Fire Training Pad (Facility 165) and the Disused Fire Training Pit (Facility 479).
  - Detected PFOA concentrations increased from the March 2013 results collected at the Fire Training Pad (Facility 165) and the Disused Fire Training Pit (Facility 479).
  - Reported PFOS and PFOA concentrations at the Former DEMS Landfill (Facility 394) were consistent with previous monitoring events.
  - Reported PFOS and PFOA concentrations at the South West Burial Site (CN0053) were either greater or consistent with previous monitoring events.

- **URS, 2015. Stage 2 Environmental Investigation, AFFF PFAS, RAAF Base Williamtown, Williamtown, NSW. 43218467/01/04. 14 September 2015.**
  - URS undertook an environmental investigation (soil, groundwater, surface water and biota) to advise Defence on the:
    - Nature and extent of AFFF related impact.
    - Risks posed by the identified impact.
    - Potential management and/or remediation options.
  - The following PFAS source areas were identified:
    - Fire Training Pit (Facility 165)
    - Disused Fire Training Pit (Facility 479)
    - Trade Waste Treatment Plant (TWTP – Facility 410)
    - Sewage Treatment Plant (STP – Facility 410)
    - Former Demolitions Western Landfill (Facility 394)
    - Lake Cochran
  - PFAS was detected on and off-Site variably in soil, sediment, groundwater, surface water, biota (aquatic and terrestrial flora and aquatic fauna).

### Findings Relating to PFAS

  - Detected on-Site PFOS concentrations remained similar to the March 2013 results collected at the Fire Training Pad (Facility 165) and the Disused Fire Training Pit (Facility 479).
  - Detected PFOA concentrations increased from the March 2013 results collected at the Fire Training Pad (Facility 165) and the Disused Fire Training Pit (Facility 479).
  - Reported PFOS and PFOA concentrations at the Former DEMS Landfill (Facility 394) were consistent with previous monitoring events.
  - Reported PFOS and PFOA concentrations at the South West Burial Site (CN0053) were either greater or consistent with previous monitoring events.

- **URS, 2015. Stage 2 Environmental Investigation, AFFF PFAS, RAAF Base Williamtown, Williamtown, NSW. 43218467/01/04. 14 September 2015.**
  - PFAS was detected on and off-Site variably in soil, sediment, groundwater, surface water, biota (aquatic and terrestrial flora and aquatic fauna).

### Comparison to AECOM findings or Comment

- Findings are consistent with previous and subsequent investigations. PFOS and PFOA were not analysed for samples collected at the SAWR.
<table>
<thead>
<tr>
<th>Report</th>
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<td>EHS Support 2015. Assessment of Building 165, Fire Training Pad Wastewater Treatment RAAF Base Williamtown, NSW Australia.</td>
<td>As part of the Stage 2A EI works, EHS Support was engaged to characterise the wastewater collected at the Fire Training Pad (Facility 165) wastewater storage tank; describe the wastewater process; assess the effectiveness of PFAS removal.</td>
<td>The three stage “AdTech System” comprised a two-stage adsorption system (sugar cane bagasse ash and modified clay) which became operational in 2011. It was found to be effective at removing many of the PFAS compounds found in historical formulations of 3M Lightwater™ and current formulations of Ansulite®. The removal efficiency of PFAS was generally to a level greater than 80% and up to 98%.</td>
<td>The “AdTech System”, whilst operating, appeared to be an effective treatment option for removal of PFAS found in wastewater generated at the Fire Training Pad (Facility 165). However, the system is longer operational.</td>
</tr>
<tr>
<td>GHD (2015). RAAF Williamtown Inflow / Infiltration Study, Phase 1 Flow Gauge Report. September 2015.</td>
<td>The objectives of this work were to:  - Investigate and determine the key contributors to inflow and infiltration (I/I) to the sewerage system.  - Identify actions that will yield the greatest benefit in reducing the I/I for the least cost. As part of the assessment, GHD evaluated the inflows for PFOS and PFOA and 6:2 F1S.</td>
<td>GHD reported that:  - “The sampling results indicated that there are high levels of PFOS in the trade waste system”.  - “These levels are generally higher than the historical levels found in the groundwater on the site in previous groundwater monitoring undertaken by GHD”.  - “The PFOS levels found in the sewerage system at Sewage Pump Station (SPS) 189 and then at the STP indicate that the PFOS levels in the trade waste system are diluted significantly by the flows in the sewerage system.”  - PFOS concentrations at the three sampled locations (TWTP, SPS189 and STP) ranged between 1.5 µg/L and 3,960 µg/L.  - PFOA concentrations ranged between 0.1 µg/L and 53.2 µg/L. GHD concluded that there is significant infiltration of groundwater in to the sewerage network.</td>
<td>GHD findings support the finding of this Report.</td>
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| GHD (2016). RAAF Williamtown Inflow / Infiltration Study, Phase 2 Study. March 2016. | GHD’s key objectives for this work were:  
- “Investigation of the impact of stormwater flows and I/I in the trade waste network” (system).  
- “Identification of actions which will yield the greatest benefit in reducing I/I in the trade waste network (system) for the least cost”.  
- “Isolation of specific sources of PFOS contamination in the trade waste and sewer systems.” | GHD (2016) reported the following for the sampled locations (TWPS 1, 4, 6 and 8, TWTP Inlet and SPS189):  
- PFOS concentrations ranged between 0.3 µg/L and 233 µg/L.  
- PFOA concentrations ranged between > LOR and 5.0 µg/L.  
Furthermore:  
- An average weekly mass of PFOS discharged from sewer/ trade waste system = 24.089 kg/week  
- An average weekly mass of PFOS discharged from sewer/ trade waste system = 15.984 kg/week  
The levels of PFOS contaminants in the trade waste system are two orders of magnitude higher than the sewerage network. | GHD findings support the finding of this Review. |
3.0 Site Inspection and Interviews

3.1 Site Inspection

On 15 and 16 December 2015, AECOM undertook an inspection of selected areas of the Site, the external perimeter of the on-Site British Aerospace Engineering (BAE) facility and the Jetstar Hangar located at the Newcastle Airport.

Areas of the Site inspected included the:

- Fire Station and Training Pad (Facility 165 / CNN0177)
- Former Fire Training Pit (Facility 479 / CNN0051)
- Lake Cochran and surrounds
- Fuel Farms 3a and 3 (Facilities 384 and 508 / CNN0057)
- Perimeter of the Sewage Treatment Plant (STP [Facility 410 / CNN0176]) and evapotranspiration ponds (CN0002).

AECOM also observed two temporary wastewater treatment plants on the Site in the vicinity of the New Air Combat Capability (NACC) works being conducted in the northern part of the Site.

The Hangars serviced by static / fixed fire suppression systems could not be inspected at that time because of security sensitivities and operations restricting access.

Areas that were inspected off-Site included the:

- Jetstar Maintenance Hangar at Newcastle Airport
- Perimeter of the BAE facility, which was constructed in 1997.

The relevant Site observations made during the inspection are detailed in Appendix C.

3.2 Interviews

3.2.1 On-Site Interviews

During the December 2015 site inspection, AECOM interviewed the following Site personnel:

- Flight Sergeant
- Defence Assistant Director of Environment & Sustainability Estate Services Division (Northern NSW Region)
- Project Manager Contract Administrator (PMCA) for the New Air Combat Capability (NACC) development.

The anecdotal data obtained from the discussions are included in Appendix C.


3.2.2 Off-Site (Face to Face and Telephone) Interviews

During the December 2015 off-Site inspection and also during subsequent telephone discussions, AECOM interviewed the following:

- the Jetstart Maintenance Manager
- an ex-Fitter and current site contractor (40 year involvement with the Site)
- a former firefighter who worked at the Site in the 1990s
- a former serviceman who worked at the Site between 1992 to 1996 and 2006 to 2009
- the NACC PMCA (in March 2016).

The findings of the interviews are presented in Appendix C.

4.0 Potential Off-Site PFAS Sources

A number of operations, incident responses and facilities located off-Site have been identified as possible contributors of PFAS concentrations to the environment in the Hunter and Port Stephen regions, including the Hunter River, Fullerton Cove and Tilligerry Lake.

In addition to local metal plating facilities, local water treatment and waste water facilities and landfills, the following off-Site PFAS sources were identified:

- 10 fire stations: potential AFFF storage and use / discharge, although likely in small volumes.
- Four bulk fuel farms / depots / terminals: likely to have static / fixed AFFF fire suppression systems to protect assets from potential fire and / or explosion.
- Approximately 65 road vehicle crash incidents in the region over the last five years: where possible emergency responses included potential one-off discharges of AFFF to control fuel spills and / or fires. It is noted that AFFF would not have been used at every single incident. The emergency response entity has noted that they discontinued use of AFFF containing PFAS circa 2007.
- Approximately five aircraft crash incidents where AFFF was potentially discharged.
- Local airfield and related operations, including the BAE facility.

A detailed list of each potential off-Site source is listed in Appendix D.
5.0 Site Fire Fighting Training, Responses and Operations (AFFF Use)

5.1 Derivation of Information for Interpretation

The information provided in the following sections has been based on the consideration of all of the materials and data findings provided in the previous PFAS related reports, the interviews conducted, the review of unclassified Defence documents, including various emails and reports, and correspondence and internet research.

5.2 Former Fire Fighting Training, Responses and Operations

5.2.1 3M Lightwater™ Period - 1976 to 2004

Historical and Operational Observations

The Site’s firefighting section has provided aviation rescue and firefighting support to the RAAF operations and ancillary facilities, as well as providing response for civilian aviation incidents associated with Newcastle Airport. In addition, it is understood that the firefighters have also been infrequently called to respond to off-Site incidents.

A firefighting presence has likely been on the Site since at least the late 1950s to early 1960s, however, AFFF was not likely used at the Site until after 1976 with the introduction of the Oshkosh P4 fire tender (fire truck) in 1976/1977. The Oshkosh can pump approximately 3,800 L per minute and has a 5,700 L water tank and a 650 L AFFF concentrate tank.

Plate 1 RAAF Williamtown Firefighting Crew (1964/65)

The firefighting section (Plate 1) was originally housed in a shed located at the rear of the motor transport and alongside the tanker pool (not shown in Plate 1). The vehicle parking was located adjacent to the shed in area that was previously used as a firing range stop butt. The fire station, including garage, was relocated to the current location circa 1974. The historical photograph below shows the station and the four bay garage next to the air traffic control tower.
Plate 2 Photograph looking towards the current fire station and air traffic control tower and former fuel farm (1974)  

Drainage channels are evident in the above the photograph (Plate 2) to the front (south towards the taxiway) of the Station / Tower and to the left of the photograph. It is understood that the former fire station was demolished and rebuilt in the same location in 1990, and that during the construction the firefighting personnel were temporarily based near the Ordnance Loading Area (OLA). It is inferred that routine fire station related activities were conducted in this area (tender cleaning, monitor and foam induction testing, hose drying and AFFF concentrate storage and handling) during this short period.

AFFF Usage and Incidents  

Based on the review finding, it is estimated that 3M Lightwater™ AFFF concentrate was stored and discharged at the Site for approximately 28 years (from circa 1976/77 to approximately 2004), when procurement of the product was discontinued by Defence, (Refer Appendix B for chronology of Defence AFFF usage). It is understood that initially 6% AFFF concentrate was procured and used and then switched to 3% AFFF concentrate, but the date of the switch is unknown.

Anecdotal information suggested that 3M Lightwater™ 3% AFFF concentrate was in use at the Site until late 2004. Therefore it is inferred that between 1976 and 2004, spent AFFF solution was likely to have been discharged at the fire station during:

- daily or at the least weekly, routine monitor testing for each tender
- weekly testing of foam induction, expansion ratios and water draining time.

As there was no purpose-built training infrastructure and / or wastewater capture system, the release or discharge of AFFF solution would be expected to infiltrate into the sandy ground and / or flowed towards the nearby drainage channels. Foaming on water surface within in the drainage lines has been previously observed at the Site (refer to Plate 3 below).
It is possible that AFFF solution was also released to the environment near the Fire Station during the removal / cleaning of residual foam that had accumulated on the tenders or within hoses during training and maintenance exercises. It is noted that the bunded wash bay / Fire Training Pad (Facility 165) and associated wastewater infrastructure that is present today at the Fire Station (Facility 165) was not constructed until sometime between 2001 and 2004.

It was also reported that between the period of 1994 to 1998, and maybe even longer, that fire training exercises and foam testing were undertaken in the area to the front of the Fire Station (Facility 165) (i.e. south / southwest towards the runway).

The release of AFFF concentrate during decanting operations in windy conditions was reportedly not uncommon, the concentrate would spill on the firemen and their uniforms or on the tender or to ground.

Firefighting Equipment
During this 40 year period (between the 1970s and 2000s), it was anecdotally reported that the fire station generally housed 4 to 6 fire tenders, including the following:

- **1970s: Oshkosh P4.** These tenders reportedly carried and discharged 3M Lightwater™ AFFF concentrate. These tenders carried approximately 250 L – 300 L of concentrate. The front of the tenders had double monitors, the water tank in the middle and the AFFF concentrate tank at the rear, a pre-mixer valve was utilised to control the water and concentrate mixture. It is understood that the Oshkosh could be depleted of AFFF concentrate in 2 minutes.

- **1990s and early 2000s: Austral Trident Mark 6 and rescue tenders.** These tenders reportedly carried and discharged 3M Lightwater™ concentrate. The Tridents had a front and roof monitor able to discharge AFFF solution in a stationary position or moving.
- **1990s and early 2000s: Titan Truck Fire General Purpose (TFGP).** These tenders held approximately 2,800 L of water and approximately 400 L of AFFF concentrate. The TFGP was fitted with a roof monitor and hose turret and under tender nozzles. It is understood that this tender could spray stationary and whilst rolling, and only carried 3M Lightwater™ AFFF concentrate.

- **1990s: Hino Rural Fire Tanker (4 x 4).** These tenders could hold approximately 3,500 L of water and approximately 200 L of AFFF concentrate. It is understood that these tenders only carried and discharged 3M Lightwater™ concentrate.

- **2000s Trident Mk 6 and rescue tenders.** These tenders can hold approximately 5,600 L of water and approximately 900 L of AFFF concentrate. The Trident has a front monitor. It is understood that these tenders possibly held and discharged both 3M Lightwater™ AFFF concentrate and Ansulite® AFFF concentrate.

Based on anecdotal information, it is understood that from at least the 1990s, Airforce / Site non-firefighting personnel were expected to undertake annual firefighting training at the fire station, this occurred twice a week, although only 1 to 2 people were permitted to extinguish a fire lit in a metal tray with a hand held extinguisher. It has been inferred by AECOM that the fires were likely extinguished using a dry chemical powder cylinder and not AFFF during these exercises.

There were no reported recollections by the personnel interviewed of the spent AFFF concentrate being used for non-fire related purposes, such as:

- cleaning agent for vehicles and / or building floors and / or crockery etc.

- celebratory occasions. It is noted that discharge of AFFF solution has occurred at other Defence and Non-Defence facilities nationally where there has been a fire fighting presence to celebrate milestones such as:
  - marking the introduction of a new aircraft to service.
  - dousing of personnel who were promoted or achieved a significant milestone such as 500 hours of flight training.
  - celebrating birthdays etc.
Former Disused Fire Training Pit (Facility 479) – 1970s – 2003/04

Based on the review and anecdotal information, it is understood that to maintain firefighting competency and fire response readiness, it was essential that “hot” fire training exercises were undertaken. During these exercises firefighting foams were utilised to extinguish fires that had been ignited to simulate conditions that may be experienced during potential aircraft accidents / incidents.

The Disused Fire Training Pit (Facility 479) is located in the south-western part of the airfield and was the primary location for the hot fire training sometime between 1979 and 2003. The training area may have started as a depression in the ground which underwent an up-grade to become a four walled rectangular pit constructed using bricks. It is understood that originally, the base of the brick walled pit base was unlined and any fuel or foam residues would have soaked into the ground.

Currently, the pit has four bricked / masonry walls, and a concrete base that has a small drain in the south western end. The drain discharges into a 4 inch PVC pipe which extended approximately 26 m away from the pit and terminated in ballast.

Based on the review findings, training operations comprised ignition of petroleum hydrocarbon fuels (mostly AVTUR), however, it is likely that other combustible liquids were burnt as well. The fires were extinguished by discharging AFFF solution directly onto the fire (refer to Plate 5, below). The volumes of combustible liquids burnt in the exercises varied significantly and depended upon the duration of each training event however, it is understood that a typical fire training event would use more than 1,000 L of fuel.

Plate 5  Fire Training Activities at the Disused Fire Training Pit (2002)

AECOM understands that training was generally conducted weekly by each crew and at least four crews were stationed at the Site (therefore four training exercises per week), this was undertaken to conform to Defence and Civil Aviation Safety Authority (CASA) requirements (90 day competency re-certification).

During training, single (but on occasion, multiple) fire tenders could be deployed to respond to a mock-up fire. The tenders would typically approach the fire from the north of the pit and commence discharging / laying foam solution on ground in the order of a 2 m radius from the pit and then into the pit (refer to Plate 6). Hand held hoses were then employed to fight the fire once the tender was in position (refer to Plate 7). Based on anecdotal information, Site inspection and photographs provided below, there was no collection system for the spent AFFF solution or wastewater generated during and after hot fire training exercises, the AFFF solution in the pit was discharged via a PVC pipe draining directly to the ground.
Plate 6  Overspray at Disused Fire Training Pit (Facility 479) (2002)

Plate 7  Use of hoses at Disused Fire Training Pit (Facility 479) (2002)
AECOM understands that hot fire training at the Disused Fire Training Pit (Facility 479) ceased in 2003. A letter dated 15 September 2004 from the then Senior Environmental Advisor of Corporate Services and Infrastructure Central and Northern NSW (CSI CNNSW) also indicated that on:

- 3 June 1998 the fire section temporarily suspended fire training exercises at the pit.
- June 1998, Defence considered upgrading the pit.
- 7 June 2000 an Environmental Clearance Certificate (ECC) issued with restrictions for training. There was a non-compliance of the ECC reported in 2001.
- 16 August 2002 another ECC was issued with further restrictions.
- National Industrial Chemicals Notification and Assessment Scheme (NICNAS) and Corporate Services and Infrastructure Group (CSIG) released alerts regarding environmental issues related with AFFF in April and May 2003 respectively.
- Between November 2001 and June 2003 an ‘Options Report’ for the upgrade of the fire training pit was undertaken.
- A new ECC was issued but a request was made by the senior fire fighter to increase the volume of fuel permitted to be burnt to between 400 L and 1,000 L.
- April 2004, CSIG completed up-grades to the fire training pit (it is inferred that this included placement of a concrete base within the pit).

Laboratory testing of the brick walls, the concrete base and sludge that had collected on the base of the pit by AECOM (in early 2016) indicated that the pit’s construction material and accumulated sludge was impacted with PFAS, that leach under neutral conditions (refer to Tables T22B in Appendix B of the Stage 2B EI). Testing indicated that:

- Eleven different PFAS compounds were detected, comprising both carboxylates and sulfonates, as summarised in Table 2 below.
- PFOS concentrations were an order of magnitude greater that the other compounds detected.
- Minor concentrations of 8:2 Fluorotelomer Sulfonate (8:2 FtS) were detected. This indicates that impact had occurred even after only a few training events where Ansulite® AFFF solution or Ansulite® impacted water (potentially from residual contamination from within the tenders) was possibly discharged in 2006, when approximately 1-2 training events may have been undertaken at the Disused Fire Training Pit (Facility 479), after it was abandoned in 2004.
- The sulfonates, primarily PFOS and PFHxS, leached at greater concentrations, almost an order of magnitude greater than the carboxylates detected.
- 3M Lightwater™ AFFF was the primary suppressant utilised at the Disused Fire Training Pit (Facility 479) and that the infrastructure is an on-going source of PFAS.
Table 2       Summary of PFAS Results - Disused Former Fire Training Pit (Facility 479) (Sampled 2/12/15 and 9/3/16)

<table>
<thead>
<tr>
<th>Sample Name</th>
<th>DFTP Base mg/kg</th>
<th>DFTP Brickwall mg/kg</th>
<th>DFTP Sludge mg/kg</th>
<th>DFTP Wall mg/kg</th>
<th>DFTP Wall – Leachate µg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFOS</td>
<td>1.26</td>
<td>0.157</td>
<td>1.35</td>
<td>1.98</td>
<td>95.6</td>
</tr>
<tr>
<td>PFOA</td>
<td>0.0602</td>
<td>0.0042</td>
<td>0.067</td>
<td>0.0146</td>
<td>9.56</td>
</tr>
<tr>
<td>6:2 Fluorotelomer sulfonate (6:2 FtS)</td>
<td>&lt; 0.005</td>
<td>&lt; 0.005</td>
<td>&lt; 0.005</td>
<td>&lt; 0.005</td>
<td>0.1</td>
</tr>
<tr>
<td>Perfluoroundecanoic Acid (PFUnA)</td>
<td>0.0014</td>
<td>&lt;0.0002</td>
<td>0.0061</td>
<td>0.0004</td>
<td>0.06</td>
</tr>
<tr>
<td>Perfluorohexanoic Acid (PFhxA)</td>
<td>0.185</td>
<td>0.019</td>
<td>0.442</td>
<td>0.0195</td>
<td>17.0</td>
</tr>
<tr>
<td>Perfluorododecanoic Acid (PFDoA)</td>
<td>0.0005</td>
<td>&lt;0.0002</td>
<td>0.0048</td>
<td>0.0005</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Perfluorodecanoic Acid (PFDA)</td>
<td>0.0011</td>
<td>0.0003</td>
<td>0.0049</td>
<td>0.0004</td>
<td>0.17</td>
</tr>
<tr>
<td>perfluorohexane sulfonic acid (PFHxS)</td>
<td>0.268</td>
<td>0.0404</td>
<td>0.322</td>
<td>0.113</td>
<td>87.0</td>
</tr>
<tr>
<td>Perfluorobutane Sulfonic Acid (PFBS)</td>
<td>0.0317</td>
<td>0.0052</td>
<td>0.118</td>
<td>0.0048</td>
<td>8.02</td>
</tr>
<tr>
<td>Perfluorooctanoic Acid (PFhPA)</td>
<td>0.0292</td>
<td>0.0032</td>
<td>0.0472</td>
<td>0.0036</td>
<td>3.20</td>
</tr>
<tr>
<td>Perfluorononanoic Acid (PFNA)</td>
<td>0.0002</td>
<td>0.0003</td>
<td>0.0022</td>
<td>&lt;0.0002</td>
<td>0.20</td>
</tr>
<tr>
<td>Perfluorotetradecanoic Acid (PFTeDA)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Perfluorotridecanoic Acid (PFTrDA)</td>
<td>&lt;0.0002</td>
<td>&lt;0.0002</td>
<td>0.0019</td>
<td>0.0002</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Perfluorooctane sulfonamide (PFOSA)</td>
<td>0.0062</td>
<td>0.0022</td>
<td>0.0365</td>
<td>0.0333</td>
<td>1.81</td>
</tr>
<tr>
<td>8:2 FtS</td>
<td>0.001</td>
<td>&lt;0.001</td>
<td>0.003</td>
<td>&lt;0.001</td>
<td>0.6</td>
</tr>
<tr>
<td>PFDeS</td>
<td>0.0063</td>
<td>0.0009</td>
<td>0.0313</td>
<td>0.0127</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Notes: DFTP = Disused Fire Training Pit (Facility 479)

Reported AFFF Spills and Incident Response 1976 - 2004

The following aircraft incidents, where AFFF solution was potentially discharged and / or spills of AFFF concentrate were obtained from past and current Site personnel and / or found by internet history search:

- 16 March 1976 - RAAF Mirage crash. The aircraft crashed near Site due to a stalled compressor during a low level four-ship formation practice for an air display.
- 10 August 1976 - RAAF Mirage crash. The aircraft crashed 1 nautical mile (approx. 1.8 km) north of Site. The undercarriage malfunctioned; and the port undercarriage collapsed on touchdown.
- 7 August 1979 - RAAF Mirage crash. The undercarriage malfunctioned 8 nautical miles (nm) north northeast of the Site.
- 3 May 1980 - RAAF Mirage crash. The aircraft crashed near Tanilba Bay Beach, Port Stephens, approximately 9 km northeast of the Site. The undercarriage malfunctioned and the aircraft crashed on the shore line near houses.
- 19 August 1985 - Macchi MB326 trainer engine fire during strafing run. Crashed at SAWR, Williamtown NSW.

- It was recalled that in the 1980’s (unconfirmed date) approximately 1,000 L of AFFF concentrate may have been lost near the K Group. The location of the K Group was not provided to AECOM.

- 1996 – American FA-18 Hornet had undercarriage problems, once the emergency landing was completed, the aircraft and the runway were doused in AFFF solution.

- March 1998 - Winjeel aircraft crashed on the western end of the airfield between the runway and the gateway near Taxi Alpha. Two tenders responded and discharged full loads of AFFF concentrate and water.

- 1996 and 1998 - In response to the 1996 and 1998 incidents, it is estimated that approximately 1,600 L of 3M Lightwater™ AFFF concentrate was discharged on or near the runway and approximately 1,000 L of Ansulite® AFFF concentrate was lost near the engine run-up area.

- In the 1990s, anecdotal information suggested that while responding to a fuel spill, a TFGP accidentally lost a tank full of AFFF concentrate (approximately 400 L) on the southern side of air management Hangar.

- 31 December 1999 – Approximately 80,000 L of a fuel water mix was identified in the drainage system by a neighbour. The fuel (test result indicated fresh AVTUR) was traced back to the Trade Waste Treatment Plant (Facility 480) and flight line, however, there was no loss from the bulk fuel tanks or RAAF aircraft. It was suspected that the spill was related to a visiting aircraft. It was not known if AFFF was blanketed across the spill.

- Circa 2013 approximately 1,000 L of 3% Ansulite® AFFF concentrate was lost from a fire tender when a switch was inadvertently activated whilst the tender was at the engine run up area. It is understood that the spill discharged into the nearby drain.

5.2.2 3% Ansulite® AFFF Period - 2004 to Current

Historical and Operational Observations

The Fire Station (Facility 165) comprises tender bays, located immediately adjacent the air traffic control tower, an administration space, quarters and training area (refer to Plate 8 below). Discussions with current firefighting personnel and review of historical documents have indicated that for the last 15 years strict controls have been implemented to limit the discharge of AFFF concentrate and spent AFFF solution at the Site including:

- Training using water only (zero training with AFFF)
- Training is conducted within metal trays contained within the wash bay / Fire Training Pad (Facility 165), with the liquid waste being drained to the wastewater capture system
- Reducing the frequency of monitor testing from weekly to monthly and only conducted testing at the wash bay / Fire Training Pad (Facility 165), so that the spent AFFF solution was captured by the wastewater system
- Activation of the manual control valve to divert captured spent AFFF solution to capture tanks for off-site disposal
- Flushing and scrubbing of rubber lined hoses to remove residual contents to the northeast of the Fire Training Pad (Facility 165)
- Water utilised for firefighting purposes is obtained from the reticulated system.
AFFF Concentrate Storage

The Fire Station (Facility 165) currently holds approximately 200% of operational requirements of 3% Ansulite® AFFF concentrate in reserve. The concentrate is transported to Site in 200 L drums and stored securely in the stores shed located to the south / southeast of the Fire Station (Facility 165) (refer to Plate 9, below).

The batches observed during the site inspection were dated between 19 March 2008 and 31 August 2015 (noting that some of the drums were empty at the time of the inspection).
It is understood that the concentrate is transferred from the drums to a 5,300 L bunded AST using a pump (refer to Plate 10, below). Any spills from the storage area are captured and diverted to the wastewater system.

Plate 10  AFFF AST located at the Fire Station (December 2015)

It is noted that the reserve AFFF concentrate drums were stored beneath the AST within the concrete bund until after 2009 (Aurecon, 2009).

Analytical Testing Results

Chemical characterisation testing of the stores of AFFF concentrate and associated infrastructure was undertaken by AECOM and is reported in Table 22A in Appendix B of the Stage 2B EI report. Key findings included:

- The stored AFFF concentrate stocks (Ansulite®) contain detectable concentrations of PFOS, PFOA and a number of other PFAS (refer to Table 3 below).
- The composition of the AFFF concentrate tested is dominated by the fluorotelomers and other medium to long chained carboxylates.
- Testing of the concrete pavement that forms the base of the wash bay / Fire Training Pad (Facility 165), the AST bund and at the entrance of the tender bays indicated that the concrete had been impacted with PFAS that leach under neutral conditions.
- The results of the concrete testing indicated that PFOS was the highest reported PFAS followed by 8:2 FIS. Other long chained carboxylates were the next highest reported concentrations.
- The PFAS that leached from concrete samples at the highest concentrations, were the sulfonates PFOS and PFHxS.

It is inferred that the presence of PFOS and PFHxS in the AFFF concentrate is likely related to trace cross contamination occurring during the handling storage of the product before the product is used.
Table 3 Summary of PFAS Results - AFFF Concentrate and Concrete Pavement at the Fire Station (Facility 165) (sampled 12 January 2016, 9 February 2016, 9 March 2016)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Concrete Samples</th>
<th>FTA_1 (soil beneath the former LMU &amp; old fire training area)</th>
<th>AnsuLite® Concentrate Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max</td>
<td>Min</td>
<td>µg/L</td>
</tr>
<tr>
<td>PFOS</td>
<td>4.92000</td>
<td>0.00070</td>
<td>47.0</td>
</tr>
<tr>
<td>PFOA</td>
<td>0.24200</td>
<td>&lt;0.0005</td>
<td>9.29</td>
</tr>
<tr>
<td>PFDCS</td>
<td>0.16300</td>
<td>&lt;0.0002</td>
<td>0.09</td>
</tr>
<tr>
<td>Perfluoroundecanoic Acid (PFUnA)</td>
<td>1.27000</td>
<td>0.00030</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Perfluorotridecanoic Acid (PFTrDA)</td>
<td>0.05710</td>
<td>0.00010</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Perfluorotetradecanoic Acid (PFTeDA)</td>
<td>0.01300</td>
<td>&lt;0.0002</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Perfluoroctanoic Acid (PFOSA)</td>
<td>0.25000</td>
<td>&lt;0.0002</td>
<td>1.04</td>
</tr>
<tr>
<td>Perfluoromononanoic Acid (PFNA)</td>
<td>0.88300</td>
<td>0.00020</td>
<td>0.69</td>
</tr>
<tr>
<td>Perfluorohexanoic Acid (PFHxA)</td>
<td>0.44200</td>
<td>0.00033</td>
<td>27.8</td>
</tr>
<tr>
<td>Perfluorohexane sulfonic Acid (PFHxS)</td>
<td>0.33000</td>
<td>0.00080</td>
<td>32.8</td>
</tr>
<tr>
<td>Perfluoroheptanoic Acid (PFHpA)</td>
<td>0.19100</td>
<td>0.00140</td>
<td>5.54</td>
</tr>
<tr>
<td>Perfluorododecanoic Acid (PFDoA)</td>
<td>0.17600</td>
<td>0.00050</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Perfluorodecanoic Acid (PFDA)</td>
<td>1.98000</td>
<td>&lt;0.0002</td>
<td>0.54</td>
</tr>
<tr>
<td>Perfluorobutane Sulfinic Acid (PFBS)</td>
<td>0.06850</td>
<td>0.00040</td>
<td>9.63</td>
</tr>
<tr>
<td>8:2 Fluorotelomer Sulfonic Acid</td>
<td>2.97000</td>
<td>0.00400</td>
<td>0.8</td>
</tr>
<tr>
<td>6:2 Fluorotelomer sulfonate (6:2 FtS)</td>
<td>0.23200</td>
<td>&lt;0.025</td>
<td>1.8</td>
</tr>
</tbody>
</table>
**Fire Tenders**

In 2004, the Fire Station (Facility 165) housed a fleet of four Titan tenders (including 2 x DS Titans), two Trident tenders and a water tanker. By 2009, the Station housed a fleet of four Panthers, two Titans and one bush tanker. The tenders were tested monthly in 2009.

In 2015, the Site was serviced by Rosenbauer Panther tenders. These tenders have proportioning valves designed for 3% AFFF, therefore it is inferred that these tenders have only ever held 3% Ansulite® AFFF concentrate.

Four new Panther models commenced service on the Site in 2008, these newer models weighed approximately 36 tonnes, can carry about 8,500 litres of water, about 1,300 litres of fire-retardant foam concentrate and can produce approximately 7,000 litres a minute from the roof and bumper-mounted water monitors (refer to Plate 11, below). These tenders have a roof monitor that can project up to 90 m, a bumper monitor that can project up to 46 m and under tender nozzles. These tenders can spray in a stationary position or whilst moving. It is understood that the older and newer Panther models have only carried and discharged 3% Ansulite® concentrate.

Vehicle maintenance is undertaken on Site at the vehicle maintenance workshop, it is likely that only minor quantities of AFFF concentrate may have been discharged as part of the servicing operations.


**Fire Training Areas and AFFF Usage Estimates**

Based on the review findings, it is understood that hot fire training occurred in the following two areas at the Fire Station (Facility 165) since circa 2004:

- in metal trays within the wash bay / Fire Training Pad (Facility 165)
- at the former Macchi fuselage Large Mock-Up (LMU) area.

AFFF has reportedly not been employed during hot fire training operations since 2004, it is understood that only water and operational training foam, containing non-fluorinated surfactants, have been used.

The Macchi LMU was previously located to the southwest of the station garage and was planned to be used to simulate aircraft crashes, engine, wheel and brake fires. It was formerly located on a gravel area until it was removed in 2015. AFFF solution was reportedly never discharged in this area because of strict conditions outlined in the ECC. It is noted that the Macchi LMU was located in the vicinity of the former fire station fire training area.
Presently (in 2016), the wash bay / Fire Training Pad (Facility 165), which has three bunded walls and forms a multipurpose function (refer to Plate 12, below), including:
- vehicle wash bay.
- fire training area (for firefighting and non-firefighting personnel).
- monitor induction and foam refraction testing area.
- misting sprays are used to control the aerial emissions of foam.

In January 2016, AECOM noted that parts of the concrete base within the wash bay / Fire Training Pad (Facility 165) were corroded, pitted and stained. This was also reported by Aurecon in 2009. It was estimated that the height of the vertical bund is insufficient to capture AFFF solution released by the roof monitor of the larger Panther. It is understood that for the last four to five years, foam testing occurred once every month (the previous routine was once a week).

Plate 12 Wash Bay / Fire Training Pad (Facility 165) (January 2016)

AECOM understands that recently, care has been taken to produce only small volumes of foam during the testing. However, Aurecon (2009) reported that approximately 80,000 L to 90,000 L of spent AFFF solution / wastewater was generated monthly during foam testing. That rate of generation would equate to nine to ten full water tank loads a month from the Panther tender or eight to nine full tank loads of water and AFFF concentrate over the month. This is inferred to be equivalent to training twice weekly.

Since 2010, four to six tenders required weekly then monthly testing of monitor performance, which typically would comprise about a 10 to 20 second release of AFFF. Therefore, it is inferred that approximately 1,200 L to 1,920 L of AFFF concentrate was discharged weekly. More recently those volumes were discharged monthly at the wash bay compound. This would equate to a calculated volume of approximately 99,840 L of AFFF concentrate annually during the weekly testing regime, and approximately 23,040 L of AFFF concentrate annually when the firefighting section started a monthly testing regime. It is likely that all of the discharged AFFF would have been captured by the wastewater system and eventually disposed of off-site.

In summary, it is calculated that, between approximately 253,440 L and 1,098,240 L of AFFF concentrate could have been discharged and captured at the wash bay / Fire Training Pad (Facility 165) since 2004.

Wastewater System

The wastewater system was installed in about 2004 to capture spent AFFF solution and wastewater generated at the wash bay / Fire Training Pad (Facility 165). It is likely that water that comes into contact with the wash bay / Fire Training Pad (Facility 165) may become impacted by PFAS, which is then diverted to wastewater collection system.
The waste liquids are diverted to a drain in the corner of the pad / compound which, depending on the position of the diversion valve, is diverted either to stormwater or if suspected or known to contain residual hydrocarbon / spent AFFF solution, is diverted to the collection tanks that have a combined capacity of 55,000 L (20,000 L and 35,000 L capacity in each tank).

The diversion valve can be manually manipulated. When the liquid waste capacity of the collection tanks reaches 40,000 L, a contractor pumps out the liquid and disposes off-site. (Refer to Plate 13, Plate 14 and Plate 15, below).

As part of an initiative to reduce the volume of wastewater being disposed off-site, AdTech Environmental Pty Limited (Adtech) was engaged in 2011 for a period of approximately three to four years to treat the generated wastewater. A summary is provided below:

- Wastewater was treated monthly utilising a small dual stage carbon bed (in metal trays) system with a gravel filter.
- Treated water was discharged to the on-Site trade waste system.
- The system remains on-Site but is now unused.

No information has been obtained on where the spent filtration medium was disposed of and no proof of performance data was available for the system. The operational capacity of the system has not been provided to AECOM, and it is possible that the system effluent which was directed to the trade waste may still have contained residual PFAS.
Plate 14  Wastewater storage tank (15 December 2015)

Plate 15  Wastewater storage tank - showing flood related damage. Note the tank has floated above ground surface, compared to Plate 14 (16 January 2016)
Disused Former Fire Training Pit (Facility 479) – 2003 to current (2016)

As noted above, the hot fire training exercises at the Disused Fire Training Pit (Facility 479) ceased in 2003. However, in 2006 an initiative was made to recommence firefighting activities under the conditions of an ECC (dated 17 July 2006), issued by the Environmental Officer. It is understood that training activities were discontinued after two or three events because of concerns that fuel was potentially being lost from the system.

It was noted that the ECC prohibited the use of AFFF and also limited the amount of fuel to a maximum of 600 L for each monthly fire training exercise. Firefighting personnel estimated that at least 800 L to 1000 L of fuel per activity would provide a more realistic simulation of emergency situations. Hot fire training ceased at this location and facility is now dormant.

The loss of fuel suggests that the integrity of the pit may have been compromised.

Incident Responses 2004 – March 2016

The following was obtained from anecdotal information and confirmed by the review of internet website [http://theaussiedigger.com/TheAussieDiggerForum/index.php?topic=358.45;wap2]:

- 26 September 2008: F/A-18 Hornet emergency landing at the Site. On 26 September 2008, at approximately 12.15 pm, an F/A-18 Hornet declared a Mayday and immediately returned to the Site. The standard emergency approach was followed, including use of the aircraft arrestor cable. Fire tenders used foam to reduce the risk of fire from a fuel leak. Site Airfield emergency response procedures were followed with Fire and Rescue crews on standby to meet the aircraft on landing. The runway was closed to other military and civilian aircraft for about 30 minutes.

- It is calculated that approximately 1,800 L of 3% Ansulite® AFFF concentrate was discharged in response to this incident.

During the Site interviews it was reported that there have been no fuel spill responses in the last three years (between 2013 and 2016) and therefore no requirement for the application of AFFF.

5.3 Infrastructure PFAS Sources

5.3.1 Hangars – Fixed Deluge Systems (cannon and floor pop-up units)

Six Hangars on Site have static / fixed fire suppression systems that require four to five yearly partial activation to confirm that the systems are functioning (refer to Table 4 below). A summary is provided below:

- Anecdotal information indicated that it was difficult to gain access to the Hangars, therefore testing was more likely undertaken every four years to ensure compliance with the required frequency of testing (which was every five years).

- The testing was managed by contractors (understood to be either Chubb or Wormald). This involved the placement of buckets across the Hangar to collect the foam so that the foam production ratio can be assessed. Whilst testing is only performed for approximately two minutes, approximately 25,000 L of AFFF solution is produced during the testing for each Hangar.

- The AFFF / water pumping systems were electrically operated with a diesel back-up generator.

- Prior to 2005, the spent AFFF solution was directed to trade waste drains, holding tanks at the Trade Waste Treatment Plant (Facility 480) permitted the foam to settle, the liquids were then redirected to the Sewage Treatment Plant (Facility 410). Annual testing of the systems is also conducted but using water only, the wastewater is directed to trade waste system.

- Post 2005, spent AFFF solution was captured into pits / sumps which have been isolated / disconnected from the trade waste system and the liquid waste was collected by a contractor for off-site disposal. Plastic lining was placed around the internal perimeter of the Hangar to prevent loss (refer to Plate 16, below).
There have been two main accidental activations reported within the Hangars:
- early 2000s in Hangar 279, which was deactivated relatively quickly.
- 2013 in Hangar 11.

There may have been other minor activations, which have not been reported.

It is noted that each Hangar has closed-circuit TV (CCTV) vision fed directly to either the fire station or tower and therefore activation can be detected early. The systems can be manually overridden by the firefighters and deactivated remotely, therefore limiting the volumes lost.

It is also noted that some spent AFFF solution can be lost during the testing, which occurred in 2005 at Hangar 19, refer to Plate 17 below.
### Table 4  Hangar Static / Fixed Fire Suppression Systems

<table>
<thead>
<tr>
<th>Hangar # and Use</th>
<th>Type</th>
<th>3m Lightwater™ AFF 6% (Estimated Period)</th>
<th>Ansulite® AFF 6% (Estimated Period)</th>
<th>Approximate Tank (AFFF) Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Corrosion Control</td>
<td>Infrared / heat detecting wall mounted cannons. Spent AFFF drains to a sump which is directed to a steel AST. Spent AFFF wastewater is not directed to the trade waste system, but to a nearby disconnected sump and collected for off-Site disposal.</td>
<td>1983 - 2010</td>
<td>2010 – current</td>
<td>2 x 900 L = 1,800 L</td>
</tr>
<tr>
<td>11 (Boeing) 481 Squadron</td>
<td>Two isolated AFFF units which need to be tested separately.</td>
<td>1983 – 2010</td>
<td>2010 – current</td>
<td>6 x 1325 L = 7,950 L</td>
</tr>
<tr>
<td>141 - 3 Squadron</td>
<td>30 – 40 floor deluge pop-up systems</td>
<td>1983 – 2010</td>
<td>2010 – current</td>
<td>3 x 1850 L = 5,500</td>
</tr>
<tr>
<td>339 (Old Bellman Hangar) - 76 Squadron</td>
<td>30 – 40 floor deluge pop-up systems</td>
<td>The suppression system was installed in 1999/2000 during the refurbishment of the Hangar.</td>
<td>2010 – current</td>
<td>1 x 2500 L = 2,500 L</td>
</tr>
<tr>
<td>Approximate spent AFFF Tank Capacity</td>
<td></td>
<td></td>
<td></td>
<td>27,350 L</td>
</tr>
</tbody>
</table>
In 2010, it is understood that the 3M Lightwater™ 6% AFFF concentrate was removed from the systems and they were flushed with water and reactivated with Ansulite® 6% AFFF. Based on a review of Defence communications 3M Lightwater™ AFFF concentrate was decanted into 113 x 200 L² drums and temporarily stored at the hazardous materials store until transfer to the Defence National Stores and Distribution Centre (DNSDC) at Moorebank in 24 April 2014 (refer to Plate 18 below).

Plate 18 On-Site Temporary Storage of 3M Lightwater™ AFFF Concentrate at the hazardous materials store (April 2014)

- Approximately 25,000 L of spent AFFF solution is generated during each testing event for each Hangar (a full activation generates approximately 50,000 L).
- Between about 1983 and 2010, it is estimated that there were six activations for 5 Hangars (excluding the Bellman Hangar) prior to 2005 (when Defence began capturing the spent AFFF solution for off-site disposal), and one activation after 2005 which utilised 3M Lightwater™ 6% AFFF concentrate. This equates to approximately 45,000 L³ of 3M Lightwater™ 6% AFFF concentrate may have been discharged to the Sewage Treatment Plant (Facility 410) via the trade waste system between about 1983 and 2005 and approximately 7,500 L of 3M Lightwater™ 6% AFFF concentrate may have been discharged between about 2005 and 2010 and captured for off-site disposal.
- Between about 1999/2000 and 2005, it is estimated that the Bellman Hangar had two test activations. Therefore, it is estimated that approximately 9,000 L⁴ of 3M Lightwater™ 6% AFFF concentrate may have been discharged to the trade waste system and then the Sewage Treatment Plant (Facility 410) between about 1999/2000 and 2005. It is noted that previous environmental investigations have indicated that sections of the trade waste reticulation system have leaked to the subsurface.
- Since 2010 it is estimated that approximately 18,000 L of Ansulite® 6% AFFF concentration may have been discharged during Hangar testing, however, this liquid waste was captured and disposed off-Site.

Chemical testing of the Ansulite® AFFF concentrate held in Hangar 11 and Hangar 279 collected by AECOM (in May 2016) indicated that the concentrate contains PFOS and PFOA (refer to Table 22C in Appendix B in the Stage 2B EI Report and Table 5 below).

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² It’s not clear in the communications if some of the drums contained 3M Lightwater™ AFFF concentrate from other parts of the Site.
³ 6% of 750,000 L = 45,000 L
⁴ 6% of 150,000 L = 9,000 L
### Table 5  Chemical Characterisation of AFFF Concentrate stored at Hangars 11 and 279 (sampled 3 May 2016)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Hangar (Tank) 11 - Ansulite® Concentrate Sample Results</th>
<th>Hangar 279 - Top of Tank 76 Ansulite® Concentrate Sample Results</th>
<th>Hangar 279 - Bottom of Tank 76 Ansulite® Concentrate Sample Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFOS</td>
<td>11,700</td>
<td>229</td>
<td>228</td>
</tr>
<tr>
<td>PFOA</td>
<td>461</td>
<td>162</td>
<td>196</td>
</tr>
<tr>
<td>PFDeS</td>
<td>79.0</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
</tr>
<tr>
<td>PFUnDA</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
</tr>
<tr>
<td>PFTrDA</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
</tr>
<tr>
<td>PFTeDA</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>FOSA</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
</tr>
<tr>
<td>PFPeA</td>
<td>202</td>
<td>59.0</td>
<td>80.0</td>
</tr>
<tr>
<td>PFNA</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
</tr>
<tr>
<td>PFBA</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
</tr>
<tr>
<td>PFHxA</td>
<td>1710</td>
<td>761</td>
<td>901</td>
</tr>
<tr>
<td>PFHxS</td>
<td>2,820</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td>PFHxA</td>
<td>140</td>
<td>21.0</td>
<td>31.0</td>
</tr>
<tr>
<td>PFDoA</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
</tr>
<tr>
<td>PFDA</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
</tr>
<tr>
<td>PFBS</td>
<td>572</td>
<td>&lt; 20.0</td>
<td>&lt; 20.0</td>
</tr>
<tr>
<td>N-Methyl-Perfluorooctanesulfonamidoacetic Acid (NMEFOSAA)</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>N-Methyl-heptadecafluorooctane sulfonamidoethanol (N-Me-FOSE)</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>N-Methyl-heptadecafluorooctane sulfonamide (N-Me-FOSA)</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>N-Ethyl-Perfluorooctanesulfonamidoacetic Acid (NEtFOSAA)</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>N-Ethyl-heptadecafluorooctane sulfonamidoethanol (N-Et-FOSE)</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
</tr>
</tbody>
</table>
5.3.2 Bulk Fuel Storage and Flammable Liquid Areas

A summary of the storage and discharge of AFFF at the bulk fuel storage and flammable liquid areas is provided below:

- Static / fixed fire suppression systems were installed in about 2006 at the two bulk fuel farms (Facilities 384 and 509 – CNN0057), each area contains vertical storage tanks (VST), which store petroleum hydrocarbons. These areas also have a separate AFFF concentrate storage tank. The systems utilise Ansulite® 3% AFFF concentrate which is stored at pumping stations connected by a series of pipes leading to the VST. It is understood that the performance of the systems are required to be tested every three years. During this testing the valves are isolated and section of the piping is removed so that the spent AFFF solution can be directly pumped into a tanker which disposes of the liquid waste off-site. There have been no reported accidental activations of the systems since installation.

- It is unlikely that the former fuel stores (E03 [former fuel store to the north of the fire station] and E01 [former fuel store to the south east of the workshops]) were protected by static / fixed fire suppression systems. However, AFFF solution may have been discharged at these locations in response to fuel spills.

- At the points where flammable liquids are handled or stored, 50 L pressured cylinders containing Ansulite® 3% AFFF are mounted on carts / trolleys. It is understood that the maintenance of the cylinders is managed by a contractor and it is likely that the cylinders are refilled off-site.

5.3.3 Lake Cochran

Lake Cochran was constructed sometime before mid-1954 as was the Catchment C (refer to Stage 2B EI report for further details) drainage line which is a primary influent source, refer to Plate 19, below showing Lake Cochran.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Hangar (Tank) 11 - Ansulite® Concentrate Sample Results</th>
<th>Hangar 279 - Top of Tank 76 Ansulite® Concentrate Sample Results</th>
<th>Hangar 279 - Bottom of Tank 76 Ansulite® Concentrate Sample Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-Ethylheptadecafluoroctane sulfonamide (N-Et-FOSA)</td>
<td>&lt;100</td>
<td>&lt;100</td>
<td>&lt;100</td>
</tr>
<tr>
<td>8:2 FtS</td>
<td>144</td>
<td>&lt;100</td>
<td>132</td>
</tr>
<tr>
<td>6:2 FtS</td>
<td>16,400</td>
<td>26,000</td>
<td>30,300</td>
</tr>
<tr>
<td>4:2 FtS</td>
<td>&lt;20</td>
<td>&lt;20.0</td>
<td>&lt;20.0</td>
</tr>
</tbody>
</table>
The URS (2015) Stage 2A report stated that there was anecdotal evidence that fire training had occurred in the vicinity of Lake Cochran. However, this Review could not identify any supporting confirmation, as detailed below:

- Interview of current and former firefighters, environmental officers and other long serving Site personnel who were posted at the Site indicated that it was unlikely that the area immediately surrounding Lake Cochran was used as a fire training ground or large quantities of AFFF solution may have been discharged in this area.

- It was considered unlikely that the tenders were regularly driven in this area given the absence of hardstand, the weight of the tenders and the sandy uneven surface surrounding Lake Cochran. However, during the Site inspection, AECOM were informed that the fire tenders had on one occasion parked nearby to Lake Cochran to test / practice the tender’s capacity to extract saline / fresh waters. It is understood that this was completed as it simulates opportunistic acquisition of water in locations where a fire hydrants may not be available.

- Lake Cochran receives significant annual volumes (estimated to be around 400,000 m$^3$) of run-off from Catchment C, including the Fire Station (Facility 165), where the infrastructure has been impacted with residual PFAS that has the potential to leach when in contact with water. Based on the data obtained, it has been calculated that Lake Cochran has potentially received about 16,800,000 L of PFAS impacted water over the past 42 years (since the approximate date the fire stations have operated at the Site). It is therefore inferred that the elevated PFAS concentrations historically identified in groundwater, surface water and sediment at Lake Cochran is potentially related to Lake Cochran behaving as a retention dam for impacted surface water runoff, which is interconnected with the underlying aquifer.

- It is understood that in circa October / November 2015, water was pumped out of Lake Cochran and discharged to the ground surface immediately north of Lake Cochran for a short period of time. This was apparently undertaken to lower the level of Lake Cochran to temporarily increase its holding capacity. AECOM considers that the NACC related drainage works may significantly change the surface water drainage inputs to Lake Cochran.
5.3.4 On-Site Landfills (North East, Western and South Western)

There are three known primary waste burial / landfill sites on-Site. However, it is unclear if PFAS impacted waste and debris were disposed to any of the three. It is noted that dissolved phase PFAS have been detected in groundwater at or in the vicinity of all three sites.

The former burial area (CNN0053) located to the south and west of Lake Cochran and previously extending to beneath the BAE facility (debris was removed during the construction of this facility) reportedly contains building debris, vehicles, aircraft parts etc. These waste materials were placed in this area in about 1954 (SKM, 2006). The presence and extent of the debris has been assessed by geophysical surveys that identified anomalies and by AECOM’s Site inspection where waste materials were observed at the surface. Given that the age of the burial site predates the introduction of AFFF to the Site, it is unlikely that PFAS related material may have been disposed of in this area.

It is understood that waste disposal operations commenced at the Former DEMS Landfill (Facility 394) after the closure of the North Eastern Landfill (CNN0045). It is possible that AFFF impacted waste was disposed at both of these locations, but has not been confirmed. It has not been confirmed where the biosolids and dried sludge sourced from the Sewage Treatment Plant (Facility 410) were disposed of.

PFAS impacted waste and articles that could have been unintentionally disposed of at the two landfills include PFAS impacted soil, redundant drums or firefighting equipment or clothing etc.

5.3.5 NACC Development

The NACC development is currently in progress (in early 2016), and it is understood that the works involve the assessment and management PFAS impacted soil or groundwater. A summary is provided below:

- PFAS impacted soil was being stockpiled in the NACC Precinct in the north eastern part of Site for future management. The soil has been covered to prevent mobility either by wind dispersal or water (refer to Plate 20 below). The NACC project has undertaken a number of studies to characterise the materials prior to disturbance.

Plate 20 NACC PFAS Impacted Spoil Stockpile (December 2015)

- Construction dewatering activities were also being managed, via volume minimisation where possible and by treatment of extracted water. It is understood that the treatment system is a multi-staged activated carbon filtration plant. The design specifications of the system have not been reviewed.
5.4 Chronology of AFFF Use at the Site

In summary, based on the Review findings, AECOM understands that:

- 3M Lightwater™ AFFF concentrate (6% and then 3%) was introduced to the Site circa 1976/1977 and was used until about late 2004 by the firefighting squadron. During this period, it is understood that environmental and pollution prevention controls were not as comprehensive as current standards and it is inferred that, particularly in the 1970s and 1980s, AFFF application and use was reasonably liberal. It is noted that 3M Lightwater™ was continued to be used in the hangar static fire suppression systems until circa 2010.

- 3M Lighwater™ AFFF concentrate was discharged frequently in three areas: the Disused Fire Training Pit (Facility 479); the Fire Training Pad (Facility 165); and in the vicinity of the Hangars with fire suppression systems. The migration of PFAS impact via surface water, wastewater and groundwater from these three areas has potentially impacted the following with 3M Lightwater™ (PFAS) residues:
  - Lake Cochran.
  - Trade Waste Treatment Plant (Facility 480) and Sewage Treatment Plant (Facility 410).
  - Site drains.

- discharge of AFFF across the remainder of the Site was less frequent.

- Ansulite® 3% AFFF concentrate has been discharged at the Site since about late 2004, although the use and discharge was significantly more controlled than previous years. The Ansulite® 3% AFFF concentrate was primarily used at the Fire Station (Facility 165) and hangars and possibly only two to three times at the Disused Fire Training Pit (Facility 479). At each location, AFFF solution was predominantly captured and disposed off-Site. Therefore, it is inferred that there has been a significant reduction in the volumes of Ansulite® 3% AFFF concentrate that has been discharged to the environment. However, Ansulite® 3% AFFF concentrate (PFAS) residues are inferred to have impacted the Fire Station (Facility 165) infrastructure (wash bay / Fire Training Pad (Facility 165), tender bays, beneath the AST and possibly the wastewater infrastructure).

5.5 Estimated Volumes of AFFF Discharges

Manifests and / or AFFF procurement records could not be obtained during this Review, therefore past practices and vehicle specifications as reported by former and current personnel were used to estimate the volumes of AFFF concentrate discharged at the Site.

The following estimates of ‘AFFF discharge to environment’ do not incorporate the spent AFFF solution volumes or the volume of PFAS impacted waters resulting from water contact with residual PFAS impacted soil, sediment and infrastructure.

5.5.1 AFFF Generation 1 – 3M Lightwater™ Dominated Period (1976- 2004)

Between about 1976 and 2004, it is estimated that approximately:

- 1,747,200 L of AFFF concentrate was calculated to have been discharged at the Disused Fire Training Pit (Facility 479). This is based on assumptions that about three to four crew training events occurred weekly in which a single tender was deployed and that about 50 - 60% of the fire tender’s AFFF storage capacity was discharged (50% average capacity of all the different tenders equals about 300 L of concentrate per tender training drill event).

- 280,000 L of AFFF concentrate was calculated to have been discharged between the Fire Station (Facility 165) and the runway. On average four tenders required weekly testing of monitor performance, which typically comprised about a 20 – 30 second release of AFFF solution, therefore it is estimated that approximately 200 L (about 50 L per tender) of AFFF was discharged weekly.

- 1,400 L of 3M Lightwater™ AFFF concentrate was calculated to have been lost during two accidental activations (near air management hangar and K Group).

- 1,600 L of 3M Lightwater™ AFFF concentrate was calculated to have been discharged on or near the runway in response to the 1996 and 1998 aircraft incidents.
- 45,000 L of 3M Lightwater™ AFFF concentrate was calculated to have been discharged to the trade waste system which drained to the Sewage Treatment Plant (Facility 410).

In summary, it has been estimated that a cumulative volume of approximately 2,075,200 L of 3M Lightwater™ AFFF concentrate was discharged at the Site.

Additionally, from at least the 1990s, Airforce / Site personnel were expected to undertake annual firefighting training at the fire station, this occurred twice a week, although only one to two people were permitted to extinguish a fire lit in a metal tray with a hand held extinguisher.

5.5.2 AFFF Generation 2 – Ansulite® Dominated Period (2004-2015)

Between about 2004 and 2015, it estimated that approximately:

- 250,000 L to 1,100,000 L of AFFF concentrate was calculated to have been discharged but captured and disposed off-Site.
- 1,800 L of 3% Ansulite® AFFF concentrate was calculated to have been discharged on/near the runway in response to the 2008 F18 Hornet incident.
- 7,500 L of 3M Lightwater™ 6% AFFF concentrate was calculated to have been discharged during Hangar testing between 2005 and 2010 but was captured for off-Site disposal.
- 18,000 L of Ansulite® 6% AFFF concentration was calculated to have been discharged since 2010, during Hangar testing but was captured and disposed off-Site.

Although, it has been estimated that between 280,740 and 1,125,540 L of AFFF concentrate, predominantly Ansulite® AFFF concentrate, was discharged at the Site, it is understood that majority of this volume was captured for off-site disposal. Therefore, it is estimated that approximately 1,800 L of Ansulite® AFFF concentrate may have been discharged to the environment during ‘Generation 2’. This much reduced volume from the previous 3M Lightwater™ dominated period is reflective of the stricter controls implemented at the Site to limit the discharge of AFFF concentrate to the environment between approximately 1976 and 2004.

5.6 Summary of Identified On-Site PFAS Sources

Based on the historical and current practices associated with AFFF use and discharge, the sources of PFAS contamination identified within this Review are listed below and shown on Figure F2 (in Appendix A):

2. Source 2 – Former and current Fire Station (Facility 165) and associated former informal fire training and monitor testing areas.
3. Source 3 - Hangar infrastructure (Hangars 8, 11, 19, 141, 279 and 339).
4. Source 4 - Lake Cochran.(recharge zone)
5. Source 5 – Trade Waste Treatment Plant (Facility 480, CNN0127) and infrastructure, including underground infrastructure (concrete holding tanks).
6. Source 6 - Sewage Treatment Plant and effluent ponds (Facility 410, CNN0176 and CNN0002).
7. Source 7 - Current Fire Training Pad / Wash Bay (Facility 165 [FTA], CNN0177).
8. Source 8 – Former DEMS Landfill (Facility 394).

E03 – Legacy site – former fuel storage – formerly located to the north west of the Fire Station (near the OLA).
E01 – Former Fuel Store 1 – formerly located to the south east of workshops.
### Table 6 PFAS source summary table

<table>
<thead>
<tr>
<th>Source Area</th>
<th>Approximate Date of PFAS Use</th>
<th>PFAS Activity</th>
<th>PFAS Type</th>
<th>Preliminary Estimate of PFAS Related Discharge to the Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>isused Fire Training Pit (Facility 479)</td>
<td>1976 - 2003</td>
<td>Firefighting training</td>
<td>3M Lightwater™ (1976 - 2003)</td>
<td>Approximately 1,747,200 L 3M Lightwater™ concentrate (3% - 6%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ansulite® was not used</td>
<td>Ansulite® was not discharged</td>
</tr>
<tr>
<td>Fire Station and Fire Training Pad (Facility 165)</td>
<td>1976 – 2004</td>
<td>Firefighting training, equipment checking.</td>
<td>3M Lightwater™</td>
<td>Approximately 280,000 L of 3M Lightwater™ concentrate (3% - 6%)</td>
</tr>
<tr>
<td>Fire Station and Fire Training Pad (Facility 165).</td>
<td>2004 – present</td>
<td>Firefighting equipment checking</td>
<td>Ansulite®</td>
<td>Minimal volumes of Ansulite® likely to have been discharged</td>
</tr>
<tr>
<td>Lake Cochran</td>
<td>1976 - present</td>
<td>Received runoff from Site</td>
<td>PFAS dissolved in water</td>
<td>Approximately 16,800,000 L of PFAS impacted water with unknown concentrations of PFAS</td>
</tr>
<tr>
<td>Trade Waste Treatment Plant (Facility 480)</td>
<td>1976-2004</td>
<td>Received AFFF concentrate and runoff</td>
<td>3M Lightwater™</td>
<td>Approximately 45,000 L of 3M Lightwater™ concentrate discharged to the Trade Waste Treatment Plant (Facility 480) and then drained to the Sewage Treatment Plant (Facility 410)</td>
</tr>
<tr>
<td>Sewage Treatment Plant (Facility 410)</td>
<td>1976 - present</td>
<td>Wastewater generated on the Site treated at the Sewage Treatment Plant</td>
<td>Dissolved PFAS</td>
<td>3M Lightwater™ concentrate from Trade Waste Treatment Plant (Facility 480) ultimately discharged to Sewage Treatment Plant (Facility 410), where it may have infiltrated</td>
</tr>
<tr>
<td>Former DEMS Landfill (Facility 394)</td>
<td>After closure of North Eastern Landfill</td>
<td>Potential disposal of material with residual PFAS (unconfirmed)</td>
<td>Unknown</td>
<td>Unknown mass</td>
</tr>
<tr>
<td>North Eastern Landfill</td>
<td>Prior to operation of Former DEMS Landfill (Facility 394)</td>
<td>Potential disposal of material with residual PFAS (unconfirmed)</td>
<td>Unknown</td>
<td>Unknown mass</td>
</tr>
<tr>
<td>Air Management Hangar and K Group</td>
<td>1980s (unconfirmed date)</td>
<td>Two accidental activations of fire suppression system</td>
<td>3M Lightwater™</td>
<td>Approximately between 1,000 - 1,400 L 3M Lightwater™ concentrate (3% - 6%)</td>
</tr>
<tr>
<td>Runway</td>
<td>1996 and 1998</td>
<td>AFFF use associated with aircraft accidents</td>
<td>AFFF concentrate</td>
<td>Approximately 1,000 L AFFF concentrate</td>
</tr>
<tr>
<td>Medowie Road between Richardson Ave and Nelson Bay Road, Williamtown (off-Site)</td>
<td>1994</td>
<td>Accident involving a hazardous oil tanker, Firefighting by local authority</td>
<td>Dissolved PFAS</td>
<td>A 'significant amount', approximately 1,000 L AFFF</td>
</tr>
</tbody>
</table>
6.0 References


Appendix A

Figures
Appendix B

Chronology of Defence AFFF Use
<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 2008</td>
<td>Defence Minute Replacement of 3M AFFF held within facility fire suppression systems</td>
<td>Requires 3M lightwater to be replaced across facilities with fire suppression systems. DGLMS/OUT/2008/576 to Director General Regions and Bases advises method of replacement and what is to be done with the 3M lightwater.</td>
</tr>
<tr>
<td>2009</td>
<td>DEF(AUST) 5706 Foam Liquid fire extinguishing 3% and 6% concentrate specification</td>
<td>Revised specification covers the supply and testing of foam concentrates for controlling and extinguishing fires in hydrocarbons. In 2009 the publication is revised to take into account Defence AFFF policy as well as specifically excluding foam concentrate containing PFOS.</td>
</tr>
<tr>
<td>2009</td>
<td>PFOS added to Stockholm Convention Annex</td>
<td>The Stockholm Convention characterises PFOS as: PFOS is extremely persistent and has substantial bioaccumulating and biomagnifying properties, although it does not follow the classic pattern of other POPs [persistent organic pollutants] by partitioning into fatty tissues but instead binds to proteins in the blood and the liver. It has a capacity to undergo long-range transport and also fulfils the toxicity criteria of the Stockholm Convention. The Stockholm Convention specifically provides that the production of PFOS for use in fire-fighting foam is an ‘acceptable purpose’. To date (Dec 15), Australia has not ratified this amendment to the Stockholm Convention.</td>
</tr>
<tr>
<td>2009</td>
<td>Environmental Review of Fire Fighting Training and Facilities</td>
<td>This report is focussed on current use of Ansultie AFFF and recommends improvements to infrastructure to allow for improved on-site treatment and management, including improved bunding, installation of water treatment facilities and construction of a dedicated training pad for ARFF vehicles.</td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>PFOS and PFOA had been difficult to measure as ‘most data was not based on validated methods’. Comparisons between different data sets difficult. Techniques for the measurement of PFOS and PFOA in environmental samples improve significantly.</td>
</tr>
<tr>
<td>December 2011</td>
<td>Routine monitoring</td>
<td>Routine monitoring includes testing for PFOS and PFOA. Monitoring finds two elevated detections on base. Prior to this, the levels of PFOS/PFOA were not known (due to inability to measure).</td>
</tr>
<tr>
<td>March 2012</td>
<td>GHD report of surface water results first quarter 2012</td>
<td>Results from routine monitoring finds elevated levels at 8 out of 12 locations on base and elevated levels in storm water exiting the base. Surface Water Samples collected in March identify elevated levels of PFOS in water leaving the base.</td>
</tr>
<tr>
<td>10 May 2012</td>
<td>Defence advised NSW EPA</td>
<td>Defence sends NSW EPA email on 02 May 12 advising of surface water detections off site. On 10 May 12 NSW EPA is verbally advised of PFOS/PFA elevated detections in surface water and that a detailed Stage 1 contamination investigation is to be undertaken.</td>
</tr>
<tr>
<td>20 January 2013</td>
<td>Defence letter to NSW EPA</td>
<td>Defence letter to NSW EPA notifying of contamination at effluent lagoons. Reports are</td>
</tr>
<tr>
<td>Date</td>
<td>Activity</td>
<td>Comment</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>28 March 2013</td>
<td>NSW EPA letter to Defence</td>
<td>NSW EPA requests advice on Defence’s management strategy for the contamination.</td>
</tr>
<tr>
<td>17 May 2013</td>
<td>Defence provides copy of Stage 1 report to NSW EPA</td>
<td>Stage 1 report is completed in March 2013. A copy is sent to NSW EPA on 17 May 2013. Stage 1 identifies potential contamination risks on the base such as the locations of former fire training facilities. Report provided recommendations for further sampling and analysis and was used to inform the scope of the Stage 2 investigation.</td>
</tr>
<tr>
<td>2013</td>
<td>Initial contractor engaged</td>
<td>Contractor goes into business liquidation.</td>
</tr>
<tr>
<td>April 2014</td>
<td>New contractor engaged</td>
<td>Stage 2 Environmental Investigation Commissioned.</td>
</tr>
<tr>
<td>May 2014</td>
<td>On site investigations</td>
<td>Sampling on site commences.</td>
</tr>
<tr>
<td>September 2014</td>
<td>Letter to NSW EPA and stakeholders</td>
<td>NSW EPA advised of commencement of Stage 2. Regional Manager – Graham Clarke. Stakeholders: Hunter Water Corporation; NSW EPA; Port Stephens Council; Department of Primary Industries (Office of Water); NSW Health (Hunter New England District); Newcastle Airport Limited; NSW Office of Environment and Heritage.</td>
</tr>
<tr>
<td>October 2014</td>
<td>Publicly available Website established.</td>
<td>Site included: Flyer of drilling activities, FAQs, overview of project. NSW EPA - Adam Gilligan - Newcastle office advised of commencement of drilling and sampling program. Location map of proposed wells and FAQ provided as attachments. Stakeholders: Hunter Water Corporation; NSW EPA; Port Stephens Council; Department of Primary Industries (Office of Water); NSW Health (Hunter New England District); Newcastle Airport Limited; NSW Office of Environment and Heritage.</td>
</tr>
<tr>
<td>November 2014</td>
<td>Sampling and Drilling commenced off site</td>
<td>Total sampling on and off site: 185 groundwater samples 20 surface water samples 230 soil samples 35 sediment samples 30 vegetation samples 18 biota samples.</td>
</tr>
<tr>
<td>14 May 2015</td>
<td>Stage 2 Project Technical Workshop</td>
<td>URS provides a verbal overview to Defence of preliminary data, indicating contamination on and off site. This data had not been quality checked or technically verified by the Technical Advisor at this time.</td>
</tr>
<tr>
<td>9 June 2015</td>
<td>Preliminary Stage 2 data received</td>
<td>This data had not been quality checked or technically verified by the Technical Advisor.</td>
</tr>
<tr>
<td>23 June 2015</td>
<td>Preliminary Stage 2 Environmental Investigation Report received</td>
<td>Preliminary reports are reports that have not been quality checked or technically verified by the Technical Advisor. Typically these reports are not relied upon for community advice or formal decision making due to potential for significant errors being detected during quality assurance/technical verification stages.</td>
</tr>
<tr>
<td>23 June 2015</td>
<td>Preliminary Stage 2 Environmental Investigation Report sent to Technical Advisor</td>
<td>Report is technically complex and involves 40 maps and 51 pages of laboratory analysis.</td>
</tr>
<tr>
<td>Date</td>
<td>Event Description</td>
<td>Details</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>3 August 2015</td>
<td>Draft Stage 2 Environmental Investigation report received in Defence</td>
<td>Draft report is one that has been quality checked and technically verified by the Technical Advisor ready for client and stakeholder comment. Results confirm elevated levels of PFOS/PFOA being detected on and off site.</td>
</tr>
<tr>
<td>4 August 2015</td>
<td>Draft Stage 2 Environmental Investigation report sent to stakeholders.</td>
<td>Hunter Water Corporation; NSW EPA; Port Stephens Council; Department of Primary Industries (Office of Water); NSW Health (Hunter New England District); Newcastle Airport Limited invited to a meeting on 12 August to discuss attached report and next steps. Provided proposed Power Point presentation to be provided to community on 2 September. Requested comments by 21 August.</td>
</tr>
<tr>
<td>12 August 2015</td>
<td>Defence holds stakeholder meeting to go through draft report.</td>
<td>Attendees, as above (except for NSW Health). Sought comments by 4 September 2015.</td>
</tr>
<tr>
<td>3 September 2015</td>
<td>NSW EPA advises Defence of precautionary measures</td>
<td>NSW EPA advises Defence that it is about to impose precautionary bans on fishing and oyster harvesting.</td>
</tr>
<tr>
<td>16 September 2015</td>
<td>Advice to industry reps and local reps</td>
<td>Defence met with industry leaders and local representatives ahead of the community forum.</td>
</tr>
<tr>
<td>16 September 2015</td>
<td>Community meeting</td>
<td>Defence held a community forum along with NSW agencies (including health, primary industries, NSW EPA) and Hunter Water Corp.</td>
</tr>
<tr>
<td>Sept - Nov 2015</td>
<td>Weekly telecons</td>
<td>Defence and NSW agencies hold weekly (then fortnightly) telephone conferences.</td>
</tr>
<tr>
<td>1 October 2015</td>
<td>Community Reference Group</td>
<td>Defence has attended all weekly formal meetings of the community reference group as well as community information sessions organised by the group.</td>
</tr>
<tr>
<td>8 October 2015</td>
<td>Elected Reps Reference Group</td>
<td>Defence has attended all formal fortnightly meetings of the Williamstown Elected Representatives Reference Group.</td>
</tr>
<tr>
<td>8 October 2015</td>
<td>NSW Government Williamstown Expert Panel Meeting</td>
<td>The NSW Government Williamstown Expert Panel extended the NSW EPA’s investigation area. A revised map of the investigation area was issued by NSW EPA on 9 October 2015.</td>
</tr>
<tr>
<td>26 October 2015</td>
<td>Stage 2B Environmental Investigation Commenced</td>
<td>Defence commenced Stage 2B investigation.</td>
</tr>
<tr>
<td>27 October 2015</td>
<td>Fishing Ban Extended</td>
<td>Fishing ban extended by NSW EPA to June 2016.</td>
</tr>
<tr>
<td>4 November 2015</td>
<td>Financial Assistance Package Announced</td>
<td>Assistant Minister for Defence announced a financial assistance package for fishers affected by the NSW Government precautionary fishing closures in Fullerton Cove and Tilligerry Creek.</td>
</tr>
<tr>
<td>11 November 2015</td>
<td>Updated NSW EPA Advice</td>
<td>The NSW EPA updated its advice that, as a precaution, residents and young children should not swim in pools filled from private bores, or in local creeks, dams, drains and ponds in the Williamstown investigation area.</td>
</tr>
</tbody>
</table>
Appendix C

Site Inspection Records and Interviews
Appendix C  Site Inspection Records and Interviews

Site Inspection and Interviews

C.1  Site Inspection

On 15 and 16 December 2015, AECOM undertook an inspection of selected areas of the Site, along with selected off-Site facilities including the British Aerospace Engineering (BAE) facility and the Jetstar Hangar located at the Newcastle Airport.

Areas of the Site inspected included the:

- Fire Station and Training Pad (Facility 165 / CNN0177)
- Disused Fire Training Pit (Facility 479 / CNN0051)
- Lake Cochran and surrounds
- Fuel Farms 3a and 3 (Facilities 384 and 508 / CNN0057)
- Perimeter of the Sewage Treatment Plant (STP [Facility 410 / CNN0176]) and evaporation ponds (CN0002).
- Two temporary wastewater treatment plants (WWTPs) on the Site in the vicinity of the New Air Combat Capability (NACC) works being conducted in the northern part of the Site.

The Hangars serviced by static / fixed fire suppression systems could not be inspected at that time because of security sensitivities and operations restricting access.

Areas that were inspected off-Site included the:

- Jetstar Maintenance Hangar at Newcastle Airport
- Perimeter of the BAE facility, which was constructed in about 1997.

C.1.1  On-Site Interviews

During the December 2015 site inspection AECOM interviewed a Flight Sergeant, the Defence Assistant Director of Environment & Sustainability Estate Services Division (Northern NSW Region), and the Project Manager Contract Administrator (PMCA) for the New Air Combat Capability (NACC) development. The anecdotal data obtained from the discussions are included in the figures within Appendix A and are summarised below. AECOM notes that the accuracy and reliability of some of the information cannot be confirmed because it's anecdotal origin:

Historical and Operational Observations

- Currently, the Fire Station (Facility 165) has six vehicle (fire tender) bays however, at the time of inspection; there were only three vehicles online. In the late 2000s, the Rosenbauer Panther Tenders were bought online, these tenders have a capacity to hold about 8,500 L of water and about 1,300 L 3% AFFF concentrate. The Panther roof monitors can spray AFFF foam up to approximately 70 m+.
- Fire Station (Facility 165) operations ceased using 3M Lightwater™ AFFF around 2004 and commenced using Ansulite®.
- Since around 1999 the Titan Truck Fire General Purposes (TFGP) has been online, it has capacity to hold 400 L of AFFF concentrate.
- Trident tenders were in use prior to the Panthers.
- In the last 4 to 5 years, live foam testing of the tenders has been conducted monthly; prior to this it was weekly. Testing is presently conducted in the bunded wash bay / Fire Training Pad (Facility 165).
- Historically a Macchi Large Mock-Up (LMU) was located on the road base area to the south west of the tender bays. This LMU was installed sometime after ceasing use of the 3M Lightwater™ and AFFF was not sprayed onto the LMU. It was only used as a reference to simulate wheel, brake and engine fires, for water training. The Macchi has been recently relocated to the western area of the Site.
Operational AFFF has not been used in fire training for the last 15 years. Training presently only employs a specialised training foam and/or water.

The Fire Station (Facility 165), in its current configuration, is approximately 20 years old or greater.

There are strict procedures in place to control use and manage discharge of AFFF, such as the use of the bunded Fire Training Pad (Facility 165).

Hot refuelling was generally not conducted at the Site, except infrequently at the ordinance readiness platform (ORP), no associated firefighting responses are known in this area.

The southwestern landfill (CN0053) was created during the construction of Lake Cochran circa the 1960s.

The Disused Fire Training Pit (Facility 479 / CNN0051) was discontinued circa 2003. In about 2006, training recommenced at the pit, however, after two to three training events it was decided to abandon the pit again because it was noted that aviation turbine fuel (AVTUR) was being lost. It was understood that the base of the pit was not always concrete lined.

The Fire Station (Facility 165 / CNN0177) presently uses reticulated water.

Approximately 200% of the on-line vehicle’s AFFF concentrate tank capacity is held in reserve at the Fire Station (Facility 165) in the AST and drums.

Between about 1976 and 2003, hot fire training involved practising extinguishing the fire using water walls, hoses and tenders.

**AFFF Release Incidents**

- The fire tenders were noted on one occasion to have parked nearby to Lake Cochran to test / practice the tender’s capacity to extract saline/fresh waters. This simulates opportunistic acquisition of water in locations where a fire hydrant may not be available.

- Unknown date - US Marines or Navy aircraft – emergency landing, Ansulite® AFFF concentrate was used.

- In 1999, approximately 80,000 L of a fuel and water mix was lost off-Site via a drain running along the eastern boundary. It was unknown if AFFF was blanketed across the spill as precautionary measure.

- In 2008, AFFF was sprayed around an aircraft on the runway.

- During the AFFF change over in the hangar static / fixed systems approximately 60 to 80 drums of 3M Lightwater™ concentrate and about 32 x 200L drums (empty Ansulite® AFFF concentrate drums) were in storage on-Site at the hazardous materials store sometime between 2011 and 2013 until being transported to Moorebank Defence National Storage and Distribution (DNSDC).

- Foaming was previously observed in the drainage channels near the Fire Station (Facility 165 / CNN0177).

- Approximately 1,000 L of AFFF was lost to ground near the K Group after an accidental activation. No other information could be provided by the interviewee.

- Circa April 2015, there was an accidental release of foam from the JetStar static / fixed fire suppression system and the discharged foam solution was hosed out by the local NSW Fire Brigade. Subsequent discussions with Jetstar personnel, are outlined below, and certificates of analysis sighted by AECOM confirmed that the AFFF concentrate used in the Hangar did not contain detections of PFOS and PFOA, and the extended suite of other 19 PFAS compounds tested for.

- There have been no reported fuel spills or related responses on-Site in the last three years.

**Environmental Management**

- Controls were implemented in about 2005/6 to capture 100% of the spent AFFF solution generated during Hangar testing.

- Fuel farms (Facilities 384 and 509 / CNN0057) were upgraded to include static / fixed fire suppression systems approximately seven years ago (circa 2008).

- Waste debris has historically been buried around the south western banks of Lake Cochran.

- The NACC development temporarily installed two pumping stations in Lake Cochran to lower the water level, removed in about December 2015.
C.1.2 Off-Site (Face to Face and Telephone) Interviews

AECOM undertook off-Site interviews and recorded the following summarised anecdotal information. AECOM notes that the accuracy and reliability of some of the information cannot be confirmed because it’s anecdotal origin:

1. **Jetstar Maintenance Manager (16 December 2015)**
   - The Hangar has a roof mounted deluge fire suppression system which was built approximately 5 to 7 years ago when the Hangar construction works were undertaken.
   - The static / fixed suppression system was designed by, and is maintained / managed by Total Fire Solutions.
   - Jet 2X High Expansion foam concentrate (Jet 2X) is used. The analytical testing undertaken as part of this Review did not detect any of the extended suite of PFAS above laboratory LOR in the concentrate sample tested. It is noted that Jet 2X is an Ansul product distributed by Tyco and is a hydrocarbon based surfactant foam, it also contains solvents and a wetting agent.

2. **Ex-Fitter and Current Site Contractor - commenced apprenticeship approximately 40 years ago on the Site (18 February 2016)**

   **Historical and Operational Observations**
   - 3M Lightwater™ AFFF concentrate was used in the Hangar static / fixed fire suppression systems until circa 2010 when the systems were recommissioned/reactivated using Ansulite® AFFF concentrate.
   - The systems were flushed during the change-over, the residual 3M Lightwater™ AFFF concentrate was collected in 200 L drums then temporarily stored at the hazardous materials store before being transported to a Defence facility at Moorebank.
   - In 2005, Defence’s policy was to capture and recover all spent AFFF solution produced during routine Hangar testing for off-Site disposal. Plastic lining was placed around the perimeter and opening of the Hangar to prevent external release of the spent AFFF. The off-Site destination of the spent AFFF solution was not known.
   - Prior to the implementation of the 2005 capture and recovery policy, spent AFFF solution generated during testing was diverted to the Trade Waste Treatment Plant (Facility 480). Foaming at the Trade Waste Treatment Plant (Facility 480 / CNN0127) was frequently observed. Foam was settled out at the Trade Waste Treatment Plant (Facility 480) and then re-diverted to the Sewage Treatment Plant (Facility 410 / CNN0176). It was recalled that approximately 20 years ago the sediment in the base of the effluent ponds at the Sewage Treatment Plant (Facility 410 / CNN0176) was excavated and removed to an unknown destination.
   - The fire suppression system in Hangar 8 (corrosion control hangar) is an automatic infrared thermal detection system with cannon release. The other Hangars are floor pop-up foam deluge units.
   - The routine testing of the Hangar suppression systems is controlled by a contractor and usually only run for about one to two minutes.
   - During the 1999/2000 refurbishment of Hangar 339 (Old Bellman Hangar), a floor pop-up fire suppression system was installed. The Bellman Hangar was constructed in the 1940s/50s and the remaining Hangars were constructed in about 1983 to accommodate the introduction of the FA-18 Hornet aircraft to service.
- It is understood that AFFF was released during the Hangar foam testing of the static / fixed fire suppression systems, which was carried out approximately every 4 to 5 years, whilst annual testing was conducted using water only. The wastewater generated during annual testing is discharged directly to the trade waste system (i.e. no capture). It was estimated that approximately 25,000 L of spent AFFF solution was discharged during each Hangar testing event (excluding the corrosion control hangar). It was estimated that about 20 to 30 foam test activation events have occurred over the last 23 years.

- The static / fixed fire suppression systems at Fuel Farms 3 and 3a were installed in 2006 and contain 3% Ansulite® AFFF. It is understood that foam tests are conducted every three years. The testing involves isolation of the valves, temporary removal of a section of piping and direct injection of the spent AFFF solution into a waste tender and is then disposed of off-Site. There have been no recorded accidental activations of these systems.

- The individual AFFF cylinders (on trolleys) contain 3% AFFF concentrate and are the responsibility of the various individual units. It is understood that the testing of these cylinders occurs approximately every two years and is undertaken by a contractor.

**AFFF Release Incidents**

- The following two accidental Hangar releases of AFFF solution were reported anecdotally:
  - In the early 2000s in Hangar 279 the system was activated but was deactivated quickly.
  - Approximately 3 years ago in the Boeing Hangar.

- Large uncontrolled accidental releases are unlikely due to the use of closed-circuit television (CCTV), which is transmitted to the control tower. The system can be deactivated remotely.

- No recollection of AFFF releases at or immediately near Lake Cochran, although it was noted that on numerous occasions foaming would be observed in the channels leading to the Lake.


**Historical and Operational Observations**

- Weekly foam testing of tenders was conducted either immediately out the front of the Fire Station (Facility 165) or in the wash bay (and current training pad) although it was noted that the wall bunding was absent. It was possible that there would be infrequent ‘adhoc’ AFFF release from tenders during Site drive arounds.

- Oshkosh P4 fire tenders were used between the 1970s and 1980s. In 1993 to 2003 Trident Angus tenders were used (contained 6% 3M Lightwater™) and since 2003 the Panthers (containing 3% Ansulite®) have been used.

- Foam production testing was conducted every Monday morning.

- Every crew (3 to 4 members) conducted fire training activities at least once a week at the Disused Fire Training Pit (Facility 479). The tenders would commence response mostly from the north and lay approximately a 2 m radius of foam around the pit.

- Fire tenders were serviced on-Site at the mechanical workshop.

- The NSW Rural Fire Service local brigade have stocked, used and trained with AFFF.

**AFFF Release Incidents**

- The following incidents were recalled:
  - In the 1980s, AFFF foam was reported as a hazardous spillage in front of the K Group liquid storage area
  - Sometime between January and July 1994 at the intersection of Medowie Road and Richardson Road, external fire services responded to an overturned tanker. A significant amount of AFFF was discharged in response.
  - Circa 1996 American F18 had an undercarriage problem so couldn’t land on its aircraft carrier, so was diverted to the Site and was immersed in foam on the airstrip.

- No recollection of AFFF being discharged or released at or near Lake Cochran.

Historical and Operational Observations
- Between 1984 and 1988 3M Lightwater™ AFFF concentrate was used.
- The fire tenders historically used at the Site included an Oshkosh, International, rescue tender and hopper (pre-mixed AFFF), Tridents and Panthers.
- The fire station was demolished in 1990 and replaced with the current fire station. The fire fighters were temporarily located near the ordnance loading area prior to and during the construction works.
- Weekly (mostly on Mondays) foam induction and monitor testing were conducted on the grassed area to the south-west and south of the fire station or at the Disused Fire Training Pit (Facility 479).
- Fire training was conducted at the Disused Fire Training Pit (Facility 479) at least once a week for each crew (approximately four crews). Between 4 to 15 x 200L drums of Avgas could be used to fuel the fires during exercises. The fire tender monitors were initially used to douse/push the fire to one end of the pit and then crews would utilise hose lines to extinguish the fire. The tenders usually attacked the fire from the northern and southern ends of the pit (i.e. the narrowest sections).

AFFF Release Incidents
- In the mid-1980s, it is understood that there were no controls or restrictions on foam testing and for a number of years the current wash bay was not paved. Foam was discharged during testing for approximately 20 to 30 seconds or until the crew were satisfied with the foam production or based on foam refractrometry testing.
- Residual foam was washed from the tenders, hoses and firemen at the fire station.
- Unknown date – 60,000 L of AVTUR was spilt at Fuel Farm 1 (E01) and an AFFF blanket (from several tender loads) was placed across the spill. The bund walls were in poor condition and cracked and a lot of the discharge entered the nearby northeast-southwest drain (flowed towards the western end of the runway).
- Empty AFFF concentrate drums were either taken home by Site personnel for use or were sent to the K Group for disposal.
- In 1988, two tenders discharged full tanks of AFFF during response to the Winjeel Aircraft crash at the western end of the airfield / runway and gateway (taxiway Alpha and runway).
- AFFF concentrate (not foam) from one of the international tenders was accidentally discharged during the response to fuel spillage that occurred when one of the lines on a refuelling truck split (near the southern side of the air movement Hanger). Reportedly the foam wasn’t being proportioned appropriately, and a full truck load was lost to ground and the nearby drain.
- Relatively small volumes AFFF concentrate / foam was intermittently discharged during maintenance by mechanics.

- Uniformed servicemen were required to undertake annual firefighting training. Training comprised utilising AFFF cylinders to extinguish ignited fuel in metal trays. It was believed that this training occurred approximately twice a week (usually only a couple of people discharged the AFFF).
- Aircraft engines contained small one-shot internal fire suppression systems which contained approximately 2 L to 3 L of AFFF concentrate. Accidental releases intermittently occurred because of dust or corrosion build up.
- Wheel and brake fires occurred regularly, although it was unclear if AFFF was discharged to control these fires.
- At sometime between 1992 and 1996, a US Marine Corp Hornet undertook an emergency landing at the Site (it was not clear not sure when and can’t confirm if AFFF was discharged).
- Additionally, it is likely that fires may have occurred at the engine run-up, however these may not always have been reported. Therefore, likewise the possible use of AFFF to extinguish such fires may not have been reported / recorded.

- **6. NACC PMCA (March 2016)**
  - In 2016, PFOS concentrations reported in water in excavations near the Fire Station (Facility 165) and air traffic control have increased from 2015 results (from approximately 500 µg/L to 3,000 µg/L). Reasons for the fluctuation are unclear but may be related to an increase in the groundwater table related to rainfall and / or dewatering / groundwater extraction activities in the area.
  - Foam has been noted on the recreational fields at different unspecified times.
  - Foam has been observed on groundwater in open excavations near the Fire Station (Facility 165) and air traffic control tower.

**C.1.3 Media Reports**

A retired RAAF firefighter for 16 years (including time at Williamtown) “remembers spraying ‘copious amounts’ of fire-fighting foam around Williamtown RAAF Base to control the dust 30 years ago. Several times every day fire trucks would roar out across the tarmac and discharge their toxic cargo as far as they could.” It was reported that AFFF solution was sprayed daily before and after jet and helicopter flights as a dust suppressant ([http://www.theherald.com.au/story/3460039/toxic-truth-raaf-firefighters-cancer-battle/](http://www.theherald.com.au/story/3460039/toxic-truth-raaf-firefighters-cancer-battle/))

AECOM understands that the retired RAAF firefighter was posted at Williamtown for a relatively short period (few months) and that similar recollections have not been reported by other serving personnel interviewed for this project.
Appendix D

Potential Off-Site Sources
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A number of operations, incident responses and facilities located off-Site have been identified as possible contributors of per- and poly-fluorinated alkyl substances (PFAS) concentrations to the environment in the Hunter and Port Stephen regions, including the Hunter River, Fullerton Cove and Tilligerry Lake. These include:

**Fire stations and/or Fire Training Grounds (potential AFFF storage and use is likely although it is understood that relatively small use / discharge volumes would have been involved)**
- Raymond Terrace Fire Station.
- Stockton Fire Station.
- Carrington Fire Station.
- NSW Rural Fire Service Medowie.
- NSW Rural Fire Service Salt Ash.
- NSW Rural Fire Service Soldiers Point.
- NSW Rural Fire Service Tilligerry.
- Williamtown / Salt Ash Rural Fire Brigade.
- Salamander Bay Fire Station.
- Medowie Fire Station.

**Bulk Fuel farms/depots/terminals (AFFF fire suppression systems for asset protection)**
- ExxonMobil Tighes Hill.
- BP Carrington Oil Terminal.
- Shell / Mobil Hamilton.
- Caltex Wickham.

**Crash sites and possible emergency responses over the last five years (potential one-off discharges of AFFF to control fuel spill and/or fire)**
- 10 December 2009 - Nelson Bay Road at Marsh Road, Salt Ash (two cars).
- 9 January 2010 – Nelson Bay Road at Lavis Lane, Williamtown (car).
- 10 January 2010 – Lemon Tree Passage at Brownes Road, Salt Ash (car).
- 25 January 2010 – Nelson Bay Road near Trotter Road, Salt Ash (car).
- 3 February 2010 – Nelson Bay Road at Seaside Boulevard, Fullerton Cove (car accident).
- 9 February 2010 - Nelson Bay Road at Richardson Road, Salt Ash (car).
- 19 February 2010 – Medowie Road near Nelson Bay Road, Williamtown (car).
- 16 April 2010 – Cabbage Tree Road at Nelson Bay Road, Williamtown (car).
- 23 August 2010 – Hazardous oil spill at Nelson Bay Road near Medowie Road, Williamtown.
- 30 October 2010 – Nelson Bay Road, Fullerton Cove (car accident).
- 25 November 2010 – Nelson Bay Road just past Fullerton Cove Road, Williamtown (multiple vehicle).
- 14 January 2011 - Nelson Bay Road at Richardson Road, Salt Ash (car).
- 16 January 2011 – Nelson Bay Road at Richardson Road, Salt Ash (car).
- 9 May 2011 – Medowie Road at Nelson Bay Road, Williamtown (car).

- 22 July 2011 – Cabbage Tree Road at Nelson Bay Road, Williamtown (car / truck).
- 26 August 2011 – Nelson Bay Road just past Fullerton Cove Road, Fullerton Cove (car accident).
- 15 November 2011 – Nelson Bay Road near Salt Ash Road, Williamtown (motorcycle).
- 21 November 2011 – Medowie Road between Nelson Bay Road and Richardson Road, Williamtown (car and truck).
- 1 December 2011 – Richardson Road between Salt Ash Roundabout and Medowie Road Roundabout (car).
- 14 February 2012 – Nelson Bay Road at Lemon Tree Passage, Salt Ash (two cars).
- 18 March 2012 – Richardson Road between Nelson Bay Road and Medowie Road, Williamtown (car).
- 5 April 2012 – Nelson Bay Road near the airport, Williamtown (three vehicles).
- 6 July 2012 – Cabbage Tree Road near Masonite Road, Williamtown (vehicle on fire).
- 13 November 2012 – Nelson Bay Road near Richardson Road, Salt Ash (two cars).
- 17 November 2012 – Nelson Bay Road at Lemon Tree Passage, Salt Ash (two cars).
- 19 November 2012 – Cabbage Tree Road near Nelson Bay Road, Williamtown (truck).
- 24 November 2012 – Nelson Bay Road near Richardson Road, Salt Ash (car).
- 19 December 2012 – Nelson Bay Road near Oakville Drive, Salt Ash (two cars).
- 27 January 2013 – Nelson Bay Road at Medowie Road, Williamtown (car accident).
- 16 February 2013 – Nelson Bay Road at Richardson Road, Salt Ash (multiple vehicle – 5).
- 14 March 2013 – Nelson Bay Road approaching Cabbage Tree Road, Williamtown (car accident / vehicle recovery).
- 20 June 2013 – Nelson Bay Road approaching Medowie Road, Williamtown (car).
- 26 June 2013 – Nelson Bay Road and Medowie Road, Williamtown (car).
- 26 September 2013 – Richardson Road near Nelson Bay Road (multiple vehicle).
- 6 November 2013 – Nelson Bay Road at Marsh Road, Salt Ash (car). No comment on fire present or foam used.
- 30 November 2013 – Cabbage Tree Road and Nelson Bay Road, Williamtown (two cars)
- 10 March 2014 – Nelson Bay Road at Richardson Road (car and truck), Salt Ash. No comment on fire present or foam used.
- 4 April 2014 – Nelson Bay Road at Richardson Road (truck), Salt Ash. No comment on fire present or foam used.
- 4 April 2014 – Lemon Tree Passage at Brownes Road (accident, traffic diverted), Salt Ash. No comment on fire present or foam used.
- 21 June 2014 – Nelson Bay Road at Richardson Road (two car accident), Salt Ash. No comment on fire present or foam used.
- 24 June 2014 – Nelson Bay Road between Cox Road and Fullerton Cove Road North, Fullerton Cove (truck).
- 6 July 2014 – Nelson Bay Road at Medowie Road, Williamtown (two cars).
- 17 July 2014 – Nelson Bay Road at Lemon Tree Passage (accident), Salt Ash. No comment on fire present or foam used.
- 18 July 2014 – Nelson Bay Drive at Williamtown Drive, Williamtown (truck).
- 30 August 2014 – Nelson Bay Road at Richardson Road (accident), Salt Ash. No comment on fire present or foam used.
21 January 2015 – Nelson Bay Road at Sansom Road, Williamtown (over turned truck).
- 17 March 2015 – Nelson Bay Road near Medowie Road, Williamtown (accident).
- 8 May 2015 - Richardson Road near Medowie Road (accident), Salt Ash. No comment on fire present or foam used.
- 10 May 2015 – Nelson Bay Road near Medowie Road, Williamtown (car accident).
- 25 June 2015 – Nelson Bay Road near Janet Parade (accident), Salt Ash. No comment on fire present or foam used.
- 17 July 2015 – Nelson Bay Road near Williamtown Drive, Williamtown (two cars).
- 19 July 2015 – Cabbage Tree Road 2 km west of Nelson Bay Road, Williamtown (accident).
- 16 September 2015 - Nelson Bay Road near Janet Parade (car / truck), Salt Ash. No comment on fire present or foam used.
- 23 September 2015 – Nelson Bay Road at Medowie Road, Williamtown (4 vehicle accident).
- 4 October 2015 – Nelson Bay Road near Medowie Road, Williamtown (accident).
- 5 October 2015 – Nelson Bay Road near Marsh Road (car / motorcycle), Salt Ash. No comment on fire present or foam used.
- 18 December 2015 – Nelson Bay Road at Steel Road, Williamtown (car).
- 20 December 2015 – Nelson Bay Road near Sansom Road, Williamtown (fuel reported on the road)
- 20 December 2015 – Nelson Bay Road and Medowie Road and Richardson Road, Williamtown (emergency response to fight fires).
- 4 January 2016 – Nelson Bay Road, Salt Ash (car / bus). No comment on fire present or foam used.
- 15 January 2016 – Nelson Bay Road – west bound lane closed. No comment on fire present or foam used.

Airfields and Related Operations
- Newcastle Airport – Operations commenced in 1948/49 although the airfield was not sold to Newcastle and Port Stephens Shire Councils until 1993.
- British Aerospace Engineering (BAE) – Built in 1997 for the purpose of assembling aircraft.

Metal plating facilities (PFAS can be used in control of fumes)
- Hunter Chrome – Newcastle West.
- Gonian Platers Pty Ltd – Georgetown.

Local Water Treatment and Wastewater Facilities
- Raymond Waste Water Treatment Plant - Biosolids produced at the plant are beneficially used for mine site rehabilitation and pasture improvement projects. It is not uncommon for biosolids to contain elevated PFAS concentrations if the influent also contains PFAS. Recycled water from the plant is used for grit and screen washing, general washdown around the plant and for grounds irrigation and the remainder of the treated effluent is discharged to Windseysers Creek via Grahamstown Drain. The plant was upgraded in 2000 and 2009. Anecdotal evidence suggests that the Raymond Terrace WWTP may have received PFAS impacted liquid waste originating from the Site.
- In 1936 Hunter Water Corporation (Hunter Water) commenced extracting water from the Tomago Sand Beds and in 1942 Hunter Water started providing water to the Site.
- Australian Waste Oil Refineries at Rutherford - 62 Kyle St, Rutherford: website -
  PFAS has been reportedly detected at this location and it is understood that the facility operations were suspended.

**Landfills**

- The nearest landfill facility is located at 330 Newline Road, Raymond Terrace NSW, whilst it is not located up gradient of the Site, it is located in the vicinity of Williams River which is a tributary of the Hunter River. It is not uncommon for landfills to have historically received house-hold articles and debris containing PFAS.