Williamtown Special Activation Precinct

C3.2E PFAS and non-PFAS Contamination Structure Plan Report

Department of Planning and Environment

Reference: 510674

Revision: 7

2023-01-16

Document control record

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Document control						aurecon
Report title		C3.2E PFAS and non-PFAS Contamination Structure Plan Report				
Document code		C3.2E	**Project number**		510674	
File path		Https://aurecongroup.sharepoint.com/sites/521943/3_Develop/Master Reports/B.3. Contamination/Revised Structure Plan/B3.2E Non-PFAS PFAS Contam Stage 3 Report.docx				
Client		Department of Planning and Environment				
Client contact		Caitlin Elliott	**Client reference**			
Rev	**Date**	**Revision details/status**	**Author**	**Reviewer**	**Verifier** (if required)	**Approver**
1	2021-05-25	Draft for internal review	MM	MT		
2	2021-05-26	Draft for DPE review	MM	MT	DE	
3	2021-07-01	Final Draft	MM	MT	DE	
4	2021-11-26	Final Draft	MT	MT		GL
5	2022-02-11	Final	MT	AL		GL
6	2022-12-05	Revised Structure Plan	MT	AL		GL
7	2023-01-16	Final Draft	MT	AL		GL
Current revision		**7**				

Approval			
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Executive Summary

NSW Department of Planning and Environment (DPE) has engaged Aurecon to prepare a suite of engineering technical studies to support the Williamtown Special Activation Precinct (Williamtown SAP). Aurecon has collected information from a desktop review of the publicly available information related to the presence of PFAS (per- and poly-fluoroalkyl substances) and non-PFAS contaminants throughout the Williamtown SAP. The data collected has been used to establish areas where future development in the Williamtown SAP may be constrained by PFAS and/or non-PFAS contamination.

Multidisciplinary Enquiry by Design (EbD) workshops were held during the constraints analysis. The EbD workshops were part of an iterative process that allowed for the testing of ideas, solutions, and concepts across all technical streams. The workshops discussed and developed numerous constraints and opportunities for various infrastructure relevant to the Williamtown SAP. The contamination (non-PFAS and PFAS) analysis was fed into the EbD workshops to capture the key master planning constraints and opportunities.

Based on the EbDs and opportunities and constraints analysis, the Williamtown SAP Structure Plan refined by Hatch Roberts Day is centred around the existing Williamtown Airport Precinct, which includes Newcastle Airport, Williamtown RAAF base and Astra Aerolab. The Williamtown SAP incorporates a core development area south of the existing airport. The Williamtown SAP development are to incorporate a flexible approach to land uses which prioritise aerospace, freight and logistics, commercial, advanced manufacturing and defence industries.

PFAS Assessment and Constraints

Review of the available background information indicates that extensive PFAS assessment has been conducted at the RAAF Base Williamtown (the Base) and the surrounding areas. The areas of PFAS impacted environmental media are well defined relative to the Williamtown SAP structure plan. Aurecon reviewed environmental media data collected from 2016 to 2021 by AECOM on Base and in the Williamtown SAP area. The previously collected data indicates that soil, sediments, surface water and groundwater within the structure plan boundary are impacted with PFAS. The structure plan boundary is situated directly downgradient of Lake Cochran and other secondary sources on Base. Most of the structure plan area is situated over the groundwater plume that is showing the highest PFAS concentrations. Environmental media analytical data indicates that there are exceedances of the NEMP v2 Tier I screening values. This includes soils and sediment in and around the drainage networks, surface water the emanates from the Base and the groundwater plume as noted above.

Defence is in the final stages of designing a groundwater remediation system in the eastern and southern portions of the future SAP boundary. The proposed remediation includes pumping groundwater from this area, transferring to the Base via an above-ground pipeline and utilising the existing treatment system to remove PFAS from the groundwater. The overall objective of the remedial efforts is to draw back the leading edges of the groundwater plume to limit downgradient migration. Some reduction in dissolved PFAS concentrations/PFAS mass flux may also occur over longer time periods.

During the future construction, the potential risks from the PFAS impacted environmental media will need to be managed. The general measures to mitigate the risk of mobilising PFAS during the future development are summarised below. These mitigation measures should be implemented in conjunction with the flooding, WSUD and geotechnical mitigation strategies.

- Flooding is a major constraint to the developable area within the structure plan boundary. The flooding and WSUD and geotechnical management measures, included under separate cover include a combination of strategies to manage flooding and water quality across the SAP.

- To facilitate development within the floodplain, bulk filling to above the regional 1% Annual Exceedance Probability plus year 2100 climate change flood level (approximately 2-4 m thickness) will be required.
- The filling must strike a balance with not creating flood impacts and not mobilising PFAS. This will require design of floodplain management measures to mitigate and offset flood impacts.
- Bulk filling is also required to facilitate drainage of development lots and roads within the precinct. WSUD measures such as wetlands will also be incorporated to treat stormwater and operate as detention basins during major events. Further details on the WSUD and flooding strategies are included in *B.3.2E: Flooding and Water Cycle Management Report*.

The flooding and stormwater management strategy would possibly include some or all of the following measures:

- Flood detention to mitigate impacts on downstream development.
- Preserving floodways to mitigate impacts on upstream and adjacent development.
- Water quality treatment provided by wetlands within drainage corridors.

The flood mitigation and stormwater management measures must also consider the potential to mobilise PFAS impacted groundwater, sediment, soil and surface water. The measures to mitigate the potential mobilisation of PFAS include:

- Installation of a geosynthetic clay liner (GCL) to segregate the fill material from fluctuating groundwater impacted with PFAS (**Figure 8 Appendix A**).
- Mixing of powdered activated carbon (PAC) into the fill material to prevent dissolved PFAS from adsorbing to fill material.
- Allowing natural conditions to prevail where groundwater is allowed to fluctuate and interact with the fill material.
- Passive stormwater treatment using PAC installed throughout the stormwater conveyance system (i.e, in drains, culverts, etc).
- Integration of mitigation measures into the flood mitigation strategies which includes:
  - Use of a stormwater berm for regional flood management (**Figures 9 and 10 Appendix A**)
  - Water captured off future roofs, hardstands, roads to be routed through constructed wetlands and bioretention systems (**Figure 11 Appendix A**). A total of five systems would be installed for the overall SAP.

An evaluation process of the various mitigation measures was undertaken, using several sources of additional information to recommend the most appropriate strategies. Based on the results of the master planning and concept design, two measures (installation of GCL and requisite drainage layers and mixing of PAC) were identified as being most feasible to mitigate the potential risks of PFAS impacting imported fill material.

Overall, the construction and operation of the Williamtown SAP is not expected to increase the PFAS mass flux moving in groundwater or stormwater nor create a significant secondary source. The initial stages of the development will focus on the NAPL land just south of the airport, some of which is ready for development (**Figure 5-2**) with an overall 40-year masterplan. Defence will continue to undertake on and off-Base remedial efforts during this timeframe. It is expected that reductions in the PFAS mass flux will result from these remedial efforts. The reduced mass flux from Defence's remedial efforts and the staged construction further reduces the future potential for PFAS mobilisation by SAP construction or operation. The staged construction also means excessively large areas will not be disturbed at any one time making it easier to manage risks during construction.

The future land use of the SAP will be light industrial/commercial and be constructed on platforms several metres above the existing grade. Services will be constructed in the elevated platforms and not interact with contaminated soil or groundwater. Water and sewer will be reticulated supply. The elevated platforms also provide a significant separation between workers/visitors and the underlying PFAS groundwater plume.

Any stormwater that is captured from future roofs, hardstands, roads, etc will be captured and routed to constructed wetlands and bioretention system for treatment and discharge. No PFAS is expected in this stormwater but the wetland/bioretention systems can easily facilitate means to remove any incidental PFAS that may occur. No additional volumes of regional stormwater would be produced than currently moves through the system. It will be diverted through a constructed berm/retention system that utilises existing Dawsons and Leary's Drain as is currently occurring.

All these factors indicate that there is a low to negligible risk to human health for future SAP users. Likewise, the platforms would prevent terrestrial fauna from interacting with groundwater plume. The platforms would not significantly alter the groundwater flow regime so the risk to downgradient ecological receptors is not increased by the construction or operation of the SAP.

Based on the information detailed in **Table F-1** in **Appendix F**, the preferred option to mitigate the risks for the fill material is to allow groundwater to fluctuate naturally into the imported fill material.

Like protection of the fill material, it is proposed to allow natural conditions to prevail relating to the regional flood management. That is, utilising the proposed constructed berm to capture the stormwater and be released through Dawsons and Learys Drain as is currently happening. To address any potential incidental PFAS in stormwater produced from the development platforms, the constructed wetlands and bioretention basins should be modified. Plant species that are known to uptake PFAS from the dissolved phase should be integrated into the constructed wetlands. Also, PAC should be introduced into or replace the gravel layer in the bioretention basins.

An additional consideration for the SAP development will be the maintenance of the monitoring well network in the structure plan boundary area. These monitoring wells were installed by Defence and will need to be maintained for long term monitoring of the groundwater plume. Protection of these monitoring wells should be integrated into the bulk filling plan. The location of the network is noted in the AECOM Interim Monitoring Event Report - RAAF Base Williamtown report (2019). Additionally, development control plans or other planning mechanisms will be required for installation of the GCL. The control measures would revolve around foundation design, service installation and plantings with deep root zones to ensure the GCL is not damaged.

Non PFAS Assessment and Constraints

The review of the available background information has identified numerous Areas of Potential Environmental Concern (APECs) throughout the SAP area where non-PFAS Contaminants of Potential Concern (COPCs) may be present at concentrations above the applicable Tier I screening values. There are several APECs within the Williamtown SAP structure plan boundary. However, specific reports related to investigation of these areas have not been reviewed so specific concentrations of COPCs in environmental media are not known at these sites at this time. The constraints rating has been based on the land use at the APEC and Aurecon's experience with previous similar projects. Therefore, the constraints analysis for the non-PFAS APECs is qualitative and can be refined when environmental media samples are analysed to determine if COPCs are present.

Specific mitigation measures cannot be developed without additional information on the APECs and environmental media analytical data. Investigation of soil and / or groundwater should be undertaken as part of, or prior to, concept design to confirm the extent and significance of non-PFAS contamination in the identified APECs. The data collected will inform likelihood of remediation required under the SEPP 55 process, inform potential design constraints, risks to human and ecological receptors as well as establishing a preliminary waste classification of the excavated soils.

1 Introduction

1.1 Background and Context

NSW Department of Planning and Environment (DPE) has engaged Aurecon to prepare a suite of environmental technical studies to support the Williamtown Special Activation Precinct (SAP) Master Plan. The Williamtown SAP Master Plan process follows five key stages as illustrated in **Figure 1-1**.

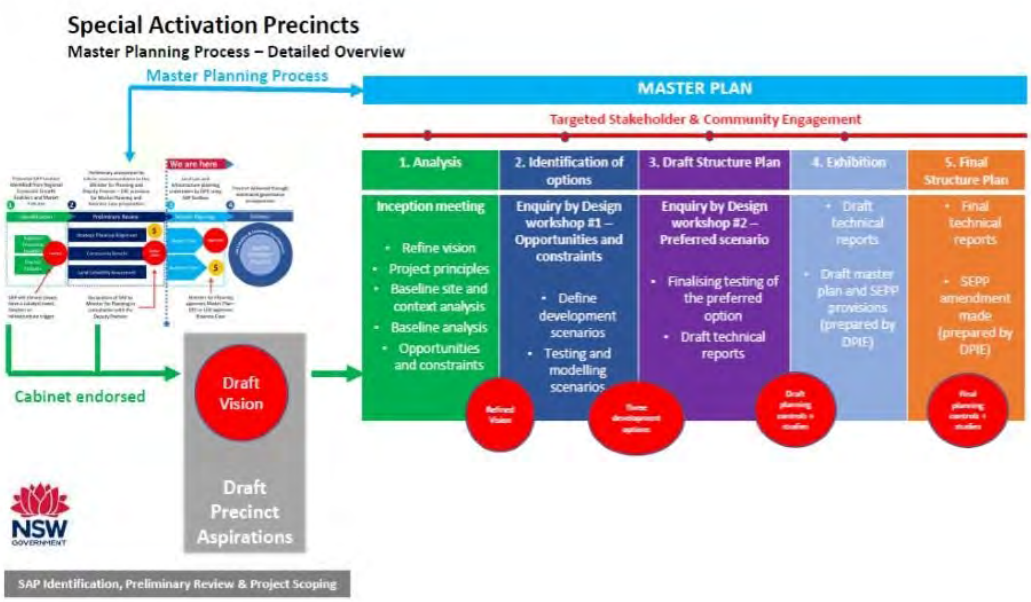

Figure 1-1: Summary of SAP Master Planning Process

Multidisciplinary Enquiry by Design (EbD) workshops were held during the constraints analysis. The EbD workshops were part of an iterative process that allowed for the testing of ideas, solutions, and concepts across all technical streams. The workshops discussed and developed numerous constraints and opportunities for various infrastructure relevant to the Williamtown SAP. The contamination (non-PFAS and PFAS) analysis was fed into the EbD workshops to capture the key master planning constraints and opportunities.

The workshop discussed and developed numerous constraints and opportunities for various infrastructure relevant to the precinct and SAP area. The Structure Plan scenarios were developed to align with the precinct vision. These scenarios are based on spatial outcomes and growth scenarios were further tested throughout the constraints analysis.

Based on the EbDs and opportunities and constraints analysis, the Williamtown SAP Structure Plan refined by Hatch Roberts Day is centred around the existing Williamtown Airport Precinct, which includes Newcastle Airport, Williamtown RAAF base and Astra Aerolab. The Williamtown SAP focuses development area south of the existing airport and is intended to incorporate a flexible approach to landuses which prioritise aerospace, freight and logistics, commercial, advanced manufacturing and defence industries.

To maximise and balance the outcome, the scenarios required assessment by each technical discipline and the overall objectives of the Williamtown SAP. Through the process of a Strength, Weakness, Opportunity and Threat (SWOT) Analysis, the scenarios are tested and evaluated in this report in relation to PFAS and non-PFAS contamination. The following tasks were undertaken during the iterative process to test various constraints and opportunities:

- Updated strategic context and regulatory review based on our developing understanding of the Williamtown SAP development
- Review of the key findings from the Stage 1 baseline analysis, particularly the opportunities and constraints
- Review of the proposed scenarios and updated understanding of the constraints and opportunities from the baseline report and other technical streams
- Establishment of an assessment framework for this technical stream and integrating other technical streams as applicable
- Comparative analysis that assessed and compared opportunities and constraints against established testing criteria
- SWOT analysis to evaluate the strengths, weaknesses, opportunities and threats

In developing the SWOT analysis, collaboration was conducted with the other Williamtown SAP technical packages, particularly geotechnical and flooding. This has helped to integrate our understanding of the constraints and opportunities and align the preliminary mitigation measures required for the proposed scenarios. A broad study area was included which was refined to a final Structure Plan Boundary based on the SWOT analysis.

1.2 Williamtown SAP and Objective

The purpose of this Report is to consolidate and test the opportunities and constraints developed during the constraints analysis phase against the Williamtown SAP's vision. The overall objective is to establish a structure plan that would progress to further stages of design and development.

The vision has been iteratively tested and refined throughout this process, while identifying project ideas and opportunities for the precinct. All consultant teams met for two rounds of EbD workshops to align constraints and opportunities, which were based off their findings from prior assessments and investigations.

1.3 Williamtown SAP Scope

During the Preliminary EbD workshop, the broader consultant team were briefed on opportunities and constraints of all the discipliners, which were further tested, modelled and refined in this Report. The scope of works for this Report includes:

- An assessment of the relevant opportunities and constraints from other disciplines to identify the strengths and weaknesses in terms of potential constraints posed by the presence of PFAS and non-PFAS contamination.
- Areas where further assessment, management or remediation may be required to facilitate development of the Williamtown SAP structure plan boundary.
- Proposed general mitigation measures to manage PFAS and non-PFAS contamination that may be encountered during future SAP development.
- An understanding of the interdependencies between the technical studies, opportunities and constraints.
- A demonstration that future development within the precinct will not result in the further mobilisation of PFAS and / or non-PFAS contamination or generate negative impacts to local stakeholders or the natural or built environment.
- General recommendations on any further assessment required to support each scenario.

1.4 Williamtown SAP Contamination (PFAS and non-PFAS) Strategic Context

1.4.1 Non-PFAS Contamination

Non-PFAS contamination within NSW and the Williamtown SAP is managed and monitored by the NSW Environment Protection Agency (EPA) and planning authorities, including the Department of Planning and Environment and local councils. The EPA regulates the investigation, remediation, and ongoing monitoring of contaminated land to protect human health and the environment.

Contamination may pose a potential risk to human health and / or the environment, limit one or more beneficial land uses and / or increase development costs for the Williamtown SAP. Contaminated land is typically grouped in areas that have been used for heavy development or industry such as Defence bases and operations, airports, industrial facilities or agricultural activities, or individual sites that store chemicals, such as service stations and dry cleaners. Based on the analysis in Section

The management framework for contaminated land in NSW broadly consists of two tiers:

- The EPA, which uses its' authority under the *Contaminated Land Management Act 1997* (CLM Act) to regulate sites with COPC concentrations that are "significant enough to warrant regulation" given the site's current or approved use. There is a wide range of local, state and federal legislation and guidelines that are enforced by the EPA during this process.
- Planning authorities, who regulate potentially contaminated sites under the planning and development process, including State Environmental Planning Policy No. 55 - Remediation of Land and the Managing Land Contamination - Planning Guidelines (SEPP 55). These are sites that may contain measurable COPC concentrations and pose potential risks to human health or the environment but are not deemed to be "significant enough to warrant regulation." The SEPP55 process is managed through the Development Application process. The requirements for assessment and / or remediation are listed as Conditions of Consent with which a developer or responsible party must comply. The SEPP55 process also typically requires the engagement of a NSW EPA Accredited Auditor. An Auditor is a private company or individual that acts on behalf of the EPA to ensure assessment and remediation works are completed in accordance with all relevant local, state and federal legislation guidelines.

The EPA also administers the NSW site auditor scheme, makes or approves guidelines for assessing and remediating contaminated land, and manages the public record of regulated sites under the CLM Act. The EPA may also:

- Review technologies under the *Environmentally Hazardous Chemicals Act 1985* (EHC Act) and assess proposed technologies for treating certain chemical wastes (such as scheduled chemical wastes) to establish their effectiveness.
- Assess licence applications for remediation proposals as part of the integrated development assessment process.
- Issue and enforce licences that regulate waste treatment, storage and/or disposal facilities, under the *Protection of the Environment Operations Act 1997* (POEO Act) or the EHC Act.
- Issue clean-up and prevention notices under the POEO Act.

The National Environmental Protection (Assessment of Site Contamination) Measure 2013 is the primary piece of federal legislation that governs the assessment of site contamination in Australia. It is a statutory instrument that specifies national standards for a variety of environmental issues when investigating contaminated sites. The NEPM is binding on all Governments that are members of the National Environment Protection Council (NEPC), which was established under the *Commonwealth National Environment Protection Council Act 1995*.

1.4.2 PFAS Contamination

PFAS stands for per- and poly-fluoroalkyl substances and are manufactured chemicals used in products that resist heat, oil, stains and water. The chemicals have been used in Australia and around the world in many common household products and specialty applications.

Legacy firefighting foams containing perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) as active ingredients were once used extensively worldwide and within Australia, including at Defence bases, due to their effectiveness in fighting liquid fuel fires. Perfluorohexane sulfonate (PFHxS) is also commonly found in the legacy firefighting foam as an impurity in the manufacturing process.

The Williamtown SAP includes properties impacted by PFAS contamination; landholders may have suffered loss or damage as a result of this contamination. During future stages of the SAP process, it will be critical to engage with the local stakeholders to help develop the mitigation measures that will have the least impact on the local community and the sensitive local environment.

PFAS contamination within the RAAF Base Williamtown is not regulated by NSW state or local government agencies as the Base is Commonwealth property. Aurecon understands that the Department of Defence has engaged an NSW EPA Accredited Auditor who reviews the assessment and remediation works completed and endorses that the works meet the applicable guidelines and legislation. However, the NSW EPA has regulatory jurisdiction for areas outside the RAAF Base Williamtown boundary but within the Williamtown SAP area.

In 2015, NSW EPA promulgated a ‘PFAS Investigation Area’, along with health advisories for businesses, properties and residents within the boundaries. In 2017, the Williamtown PFAS Management Area Map was issued which divided the PFAS impacted region into three ‘Management Zones’ where certain activities were prescribed or not recommended:

- Primary Management Zone – significant PFAS concentrations where strongest health advice applies.
- Secondary Management Zone – areas which have elevated levels of PFAS.
- Broader Management Zone – topography and hydrology of the area indicates PFAS may be detected in the future in this area.

The intent of the management zones was to enable the effective application of health advice regarding use and management of groundwater across the wider Williamtown region, along with health advisories issued by NSW Health regarding contact with impacted water and home grown produce. The PFAS management zones cover the entire Williamtown SAP structure plan area.

Immediately south of the base and extending to Cabbage Tree Road is the Primary Management Zone, this area contains the highest groundwater PFAS concentrations. The groundwater plume extends south from the base covering this area, being driven by hydraulic head from Lake Cochran on the south boundary of the Base. Between Cabbage Tree Road and Fourteen Foot Drain to the south, and from the eastern base boundary extending east along Nelson Bay Road to Tilligerry Creek is the Secondary Management Zone, and the remainder of the areas adjacent are classified as the Broader Management Zone.

1.5 Regulatory Framework – PFAS Contamination

The PFAS National Environmental Management Plan (NEMP) provides nationally agreed guidance on the management of PFAS contamination in the environment, including prevention of the spread of contamination. It supports collaborative action on PFAS by the Commonwealth, state and territory and local governments around Australia. The NEMP is an Appendix to the Intergovernmental Agreement on a National Framework Responding to PFAS Contamination.

The NSW EPA regulates the off-Base areas primarily based on requirements of the following legislation and guidelines:

- National Environmental Protection Measure for the Assessment of Contaminated Sites 1999 (Amendment 2013)
- National Environmental Management Plan on PFAS version 2. 2020, Heads of EPA Australia
- NSW Contaminated Land Act 1997, Protection of the Environment Operations Act 1997 (POEO Act)
- Protection of the Environment Operations (Waste) Regulation 2014 and associated Resource Recovery Orders/Exemptions

These documents contain a range of requirements and responsibilities for responsible parties, regulators, environmental consultants and accredited Auditors. The CLM Act 1997 is underpinned by the party responsible for contaminating the environment is financially accountable to mitigate the identified risks to human health and the environment.

1.6 Regulatory Framework – Non-PFAS Contamination

The following section provides a summary of the legislation and guidelines relating to the assessing, managing and remediating sites where sites have been “traditional” chemicals of potential concern (COPCs).

- National Environmental Protection Measure for the Assessment of Contaminated Sites 1999 (Amendment 2013)
- Contaminated Land Management Act 1997 (CLM Act)
- Protection of the Environment Operations Act 1997 (POEO Act)
- Protection of the Environment Operations (Waste) Regulation 2014
- Protection of the Environment (Operations) Excavated Natural Material Exemption 2014
- Waste Avoidance and Resource Recovery Act 2001
- NSW EPA, Guidelines for Consultants Reporting on Contaminated Sites, 2020
- NSW EPA, Waste Classification Guidelines Parts 1 to 4, 2014
- New South Wales State Environmental Planning Policy Number 55 – Remediation of Land
- NSW Protection of the Environment Operations (Underground Petroleum Storage Systems [UPSS]) Regulation 2014
- Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act)

2 Summary of Baseline Assessment Information

2.1 Non-PFAS Baseline Analysis Summary

Contamination may limit a particular beneficial land use or increase costs for developers. The investigation and remediation of contaminated land is important to protect human health and the local environment. This sub-section presents a preliminary assessment of sites that may be impacted by non-PFAS chemicals of potential concern (COPCs) based on the information collected from desktop assessments and its suitability for land development. The following descriptions are general provisions that apply to any contaminated land project associated with a redevelopment project. The exact planning pathways for the Williamtown SAP may differ slightly than the general provisions below.

2.1.1 Areas of Environmental Concern

Available site historical data and observations review identified the Areas of Environmental Concern (AECs) and COPCs within the Williamtown Study Area in **Table 1**, below and also shown on **Figure 1 Appendix A.** Additional details on the APECs are included in **Appendix B.** If there are significant COPC concentrations these could migrate and lead to subsurface impacts in the SAP. Management or remediation may be required to restore one or more beneficial land uses.

There is also potential to encounter Acid Sulfate Soils and Potential Acid Sulfate Soils in the Williamtown Study Area. The ASS/PASS risk mapping produced from the NSW SEED web portal is included in **Figure 2 Appendix A.**

Table 1 Potentially Contaminated Land in the Williamtown Study Area

Activity	Location
Car and bus washes	Located throughout the Williamtown study area.
Department of Defence – Williamtown RAAF Base and Airport	Centre of the Williamtown SAP with historical legacy and operational issues associated with hydrocarbons spills, metal contamination, sewage treatment, UXO and waste materials.
Energy Australia Sub Station	A small site located south of Tomago Road near the southern boundary adjacent to Nelsons Bay Road
Filing of Land	Medium sized site located near the eastern boundary adjacent to Lemon Tree Passage Road
Landfills	Numerous small and large landfills located throughout the Williamtown Study Area.
Landfill – Effluent Lagoon	Large site located directly south of Williamtown RAAF Base Airport, north of the intersection of Tomago Road and Nelsons Bay Road
Landscape supplies	Two medium sized sites, one located to the immediate north of the Williamtown SAP, adjacent to Richardson Road and another located near the eastern boundary of the SAP, adjacent to Lemon Tree Passage Road
Large area used for truck parking / storage	Located near the eastern boundary adjacent to Lemon Tree Passage Road
Lattice Manufacturing	Medium sized site located to the immediate north of the Williamtown SAP, adjacent to Richardson Road
Plant Driving School – Mechanical Workshop	Small site located near the north western boundary.
Pontoon and Dredging	Large site located near the north-eastern boundary
Retail Plant Nursery	Numerous small and medium sized sites located predominately near the eastern boundary.

Activity	Location
Sand mining and extraction	Numerous small and large sites located throughout the Williamtown Study Area. Large site located adjacent to the south eastern boundary of the Williamtown SAP, immediately south of Nelsons Bay Road.
Small Industrial Sheds	Small site located near the eastern boundary, south of Nelsons Bay Road
Small Light Industrial Workshop	Small site located near the eastern boundary south of Nelsons Bay Road
Timber Yard	Small site located near the south eastern boundary adjacent to Nelsons Bay Road

2.1.2 Preliminary Constraints Analysis Approach

Qualitative hazards assessed for each of these AEC's were completed by estimating the likelihood of each identified potential Source-Pathway-Receptor linkage occurring and the foreseeable consequence of the exposure. The process followed in completing this is detailed in **Table B-1** in **Appendix B**. Hazard ratings generated from this analysis are defined as:

- **Highly constrained**: High likelihood of encountering non-PFAS contamination at concentrations that may require additional assessment, remediation or management.
- **Moderately constrained**: Moderate likelihood of encountering non-PFAS contamination at concentrations in some areas of the Scenario boundary that may require additional assessment, remediation or management.
- **Minimally constrained**: Low likelihood of encountering non-PFAS contamination at concentrations that may require additional assessment, remediation or management or limited / isolated areas where non-PFAS contamination may require assessment, remediation or management.
- **Negligible**: No APECs identified within the Williamtown SAP.

It should be noted that the constraint rankings showed on **Figure 1 Appendix A,** are grouped as Negligible. Minimal, Moderate and High. The hazard ratings indicate the potential to encounter COPCs at concentrations above the applicable Tier I screening values as outlined in the NEPM 2013 and other applicable guidelines. The hazard ratings do not indicate that the AEC is actually contaminated rather the potential to encounter contamination that may be a constraint to consider in future stages of the project.

2.1.3 Constraints Analysis Findings

A qualitative assessment of the exposure potential and a hazard rating of the AECs identified through desktop study are listed in **Table B-1** (**Appendix B**). This includes an assessment of the potential exposure pathways and receptors that may be affected through land development within the Williamtown SAP.

It is likely that chemicals of potential concern (COPCs) are present at concentrations above the applicable Tier 1 screening values at some specific sites within the Williamtown SAP. Overall, the likelihood of contaminants being present at concentrations that pose a risk of harm is considered to be 'Low' and 'High' in some specific areas, near landfills and mining activities.

The spread of hazard ratings for the Williamtown study area was as follows:

- Seven ‘Negligible to Low’ ratings
- Thirteen ‘Low’ ratings
- Three ‘Low to Moderate’ ratings
- Six ‘Moderate’ ratings
- Eleven ‘Moderate to High’ ratings
- Seven ‘High’ ratings

The seven ‘High ratings included the following descriptions / contaminating activities:

- Demolition and liquid waste on land
- Department of Defence RAAF Williamtown RAAF Base & Airport development & land disturbance
- Department of Defence UXO
- Filling of land
- RAAF Drop Zone
- Sand extraction

2.1.4 Constraints Analysis Review Findings

To manage the risks of non-PFAS contamination as part of the land development, remediation and further quantification of the extent of contamination may be required.

Any additional assessment, management or remediation that may be required would be in accordance with the process in the State Environmental Planning Policy No 55 - Remediation of Land (SEPP 55). The SEPP55 provides for a State-wide planning approach to the remediation of contaminated land. In particular, it aims to promote the remediation of contaminated land for the purpose of reducing the risk of harm to human health or any other aspect of the environment:

- By specifying when consent is required, and when it is not required, for a remediation work, and
- By specifying certain considerations that are relevant in rezoning land and in determining development applications in general and development applications for consent to carry out a remediation work in particular, and
- By requiring that a remediation work meet certain standards and notification requirements.

It contains the following provisions:

- A consent authority must not consent to the carrying out of any development on land unless:
  - It has considered whether the land is contaminated, and
  - If the land is contaminated, it is satisfied that the land is suitable in its contaminated state (or will be suitable, after remediation) for the purpose for which the development is proposed to be carried out, and
  - If the land requires remediation to be made suitable for the purpose for which the development is proposed to be carried out, it is satisfied that the land will be remediated before the land is used for that purpose.
  - Before determining an application for consent to carry out development that would involve a change of use on any of the land, the consent authority must consider a report specifying the findings of a preliminary investigation of the land concerned carried out in accordance with the contaminated land planning guidelines.

- The applicant for development consent must carry out the investigation required and must provide a report on it to the consent authority. The consent authority may require the applicant to carry out, and provide a report on, a detailed investigation (as referred to in the contaminated land planning guidelines) if it considers that the findings of the preliminary investigation warrant such an investigation.

- The land concerned is:
  - land that is within an investigation area,
  - land on which development for a purpose referred to in **Table 1** to the contaminated land planning guidelines is being, or is known to have been, carried out,
  - to the extent to which it is proposed to carry out development on it for residential, educational, recreational or childcare purposes, or for the purposes of a hospital-land:
  - in relation to which there is no knowledge (or incomplete knowledge) as to whether development for a purpose referred to in **Table 1** to the contaminated land planning guidelines has been carried out, and
  - on which it would have been lawful to carry out such development during any period in respect of which there is no knowledge (or incomplete knowledge).
- General Procedures Post Rezoning:
  - A Phase 1 investigation will generally be required for each individual land parcel as part of the Development Application requirements, regardless of whether contamination is thought to be present. This is a preliminary site investigation which should identify all past and present potentially contaminating activities and potential contamination types and discuss the site condition and provide a preliminary assessment of the contamination and the need for further investigations.
  - Should further investigation be required, a Phase 2 detailed investigation (intrusive) and a subsequent Remediation Action Plan (RAP) will also be required to be prepared to support the Development Application. Development consent will not be granted for the intended land use unless these requirements are met.

NSW Guidelines for Reporting on Contaminated Sites (EPA, 2020) advises that a Phase 2 investigation should provide comprehensive information on the type, extent and level of contamination and any other issues raised in the preliminary investigation. The Phase 2 should provide to an assessment of:

- Contaminant dispersal in air, surface water, groundwater, soil and dust
- Potential effects on public health, the environment and building structures
- Off-site soil, sediment and biota impacts (if applicable)
- The adequacy and completeness of all information used to make decisions on remediation.

A Phase 2 investigation would likely be required on lots where a land use change is proposed, such as existing commercial or open space areas proposed for residential development. As the remediation requirements are more lenient for commercial and open space areas, this assessment will ensure that the more rigorous requirements for residential developments can be achieved. Following the Phase 2 investigation and should the investigation identify the need to remediate the site, a Remediation Action Plan (RAP) may need to be prepared (by a suitably qualified person) for sites where contamination has been identified. The objective of the RAP is to set remediation goals to ensure the site is suitable for its proposed use and will pose no unacceptable risk to human health or the environment.

The appropriate environmental safeguards will need to be established, and proof of necessary approvals and licences required by regulatory authorities should also be included.

After remediation works are complete, a validation report must be prepared (by a suitably qualified person) to ensure that all objectives in the RAP have been achieved. This report must assess the results of post-remediation testing and provide reasons where targets have not been achieved. The report should also confirm that all licence conditions and approvals have been met, including evidence that any soil disposed of off site is done in accordance with the RAP. Guidance on these requirements can be found in the Contaminated Sites Sampling Design Guidelines (NSW EPA, 1995).

An ongoing site monitoring program may be required where full remediation cannot be achieved, or where on-site containment of contamination is proposed. The program should detail the strategy, parameters, locations and frequency of monitoring, as well as the associated reporting requirements.

2.1.5 Preliminary non-PFAS contaminated land constraints map

Based on the information gathered from the baseline data review (Aurecon 2020) and the risk assessment the potential contaminated land constraints within the Williamtown area presented in **Figure 1 Appendix A**.

Based on the combination of non-PFAS contamination hazards, the following potential risks to the construction and operations activities during future Williamtown SAP are possible:

- Hazards to future site users;
- Hazards to onsite construction workers;
- Hazards to the onsite and adjacent environment from construction activities disturbing or mobilising contaminated materials; and
- Hazards to the onsite and adjacent environment from site operations disturbing or mobilising contaminated materials.

The AECs identified have been categorised into 'highly', 'moderately' and 'minimally' constrained areas for **Figure 1 Appendix A**. These are defined as:

- **Highly constrained**: High likelihood of encountering non-PFAS contamination at concentrations that may require additional assessment, remediation or management
- **Moderately constrained**: Moderate likelihood of encountering non-PFAS contamination at concentrations in some areas of the Scenario boundary that may require additional assessment, remediation or management
- **Minimally constrained**: Low likelihood of encountering non-PFAS contamination at concentrations that may require additional assessment, remediation or management or limited / isolated areas where non-PFAS contamination may require assessment, remediation or management
- **Negligible**: No APECs identified within the Scenario Boundary.

It should be noted that the information included in this report is based on review of publicly available information and information supplied by Port Stephens Council and Hunter Water. Specific reports or information on these AECs were not reviewed as part of this Baseline Analysis. The identification of potentially contaminating activities and related COPCs are based on the nature of the activities at the identified AEC. Aurecon utilised our experience with similar sites and information included in the POEO to summarise the potentially contaminating activities and COPCs. It is important to note that activities at the identified AECs may not have led to subsurface contamination or with all the listed COPCs. As a conservative baseline of information, to inform future stages of the project, all potentially contaminated sites have been identified as an AEC. During future stages of this project, additional detail will be requested and reviewed to further refine the AEC table. This could include the need to undertake intrusive investigations at select AECs to further refine the information included in **Table B-1** in **Appendix B**.

2.2 Summary of Baseline Information – PFAS

2.2.1 Contamination (PFAS)

The Williamtown SAP area includes properties impacted by PFAS contamination; landholders may have suffered loss or damage as a result of this contamination. During future stages of the SAP process, it will be critical to engage with the local stakeholders to help develop the mitigation measures that will have the least impact on the local community and the sensitive environment.

PFAS contamination associated with the RAAF Base Williamtown is not regulated by NSW state or local government agencies as the Base is Commonwealth property. Aurecon understands that the Department of Defence has engaged a NSW EPA Accredited Auditor which reviews the assessment and remediation works completed and endorses that the works meet the applicable guidelines and legislation. However, the NSW EPA has regulatory jurisdiction for areas within the SAP that are outside of the Base boundaries. The PFAS risk ranking and PFAS Management Areas in the Williamtown Study Area are shown on **Figure 4** and **Figure 5,** respectively **Appendix A**.

In 2015, NSW EPA promulgated a 'PFAS Investigation Area', along with health advisories for businesses, properties and residents within the boundaries. In 2017, the Williamtown PFAS Management Area Map was issued which divided the PFAS impacted region into three 'Management Zones' where certain activities were prescribed or not recommended:

- Primary Management Zone – significant PFAS concentrations where strongest health advice applies
- Secondary Management Zone – areas which have elevated levels of PFAS
- Broader Management Zone – topography and hydrology of the area indicates PFAS may be detected in the future in this area

The intent of the management zones was to enable the effective application of health advice regarding use and management of groundwater across the wider Williamtown region, along with health advisories issued by NSW Health regarding contact with impacted water and home grown produce. The most recent PFAS Management Area Map (December 2017) is presented in **Figure 5 Appendix A**. The PFAS management zones cover the entire area of the Williamtown SAP.

Immediately south of the base and extending to Cabbage Tree Road is the Primary Management Zone, this area contains the highest groundwater PFAS concentrations.

The groundwater plume extends south from the base covering this area, being driven by hydraulic head from Lake Cochran on the south boundary of the Base. Between Cabbage Tree Road and Fourteen Foot Drain to the south, and from the eastern base boundary extending east along Nelson Bay Road to Tilligerry Creek is the Secondary Management Zone, and the remainder of the areas adjacent are classified as the Broader Management Zone.

The institutional controls include the NSW Government precautionary advice to minimise exposure to PFAS originating from the Base. These recommendations were initially made for the 2015 Investigation Area and where updated in 2017 for the NSW EPA Williamtown Management Area. These controls are listed in **Table 2.**

Table 2 Institutional Controls

Item	NSW Government Precautionary Advice
Primary Management Zone	Groundwater, bore water and surface water should NOT be used for any purpose. Additionally, do not utilise groundwater or surface water for any beneficial purpose including, including in creeks and drains that might lead to incidental ingestion (swallowing). Home grown foods produced in this area should NOT be consumed. This includes home-slaughtered meat, poultry, eggs, milk, fruit and vegetables.
Secondary and Broader Management Zones	Do not use groundwater, bore water or surface water for drinking or cooking. Avoid swallowing groundwater or surface water when bathing, showering, swimming and paddling (including in creeks and drains). Groundwater and surface water should NOT be used for swimming or paddling pools Avoid eating home grown food produced in your area – including home-slaughtered meat, eggs, milk, poultry, fruit and vegetables

2.2.2 RAAF Base Williamtown Summary

Aurecon has reviewed several recent and historical reports related to the extensive assessment activities conducted on around the RAAF Base Williamtown (the Base). All of the reports were prepared by AECOM and referenced in the following discussions.

The nature, extent, fate and transport of the contamination within the Management Area based on the ESA (AECOM, 2107a) and PFAS Area Management Plan (PMAP, AECOM 2019b) is generally described by the following:

Extent of groundwater impacts:

- Data collected shows multiple overlapping PFAS plumes exist – generally originating from the on-Base Source Areas described in **Table B-2** in **Appendix B**. The AECOM investigations have identified that concentrations decrease with distance from the Base. Sorption-desorption and the transfer of PFAS through both groundwater and surface water are significant processes.
- The dominant groundwater flow direction is to the south and south-east. The PFAS plumes originating from the primary Source Areas on the Base and are merging and moving southward through the Management Area, with the available PFAS data indicating that the PFAS plume is approximately 5 km long and 5 km wide (across the axis of migration).
- PFAS is also present in groundwater to the east of the Base, including Salt Ash, likely to be related to surface water migrating along the drain network (Moors Drain and associated tributaries) before infiltrating to groundwater.
- Groundwater in the Tomago Sand beds aquifer flows to the south-east from the Base and the deeper flow paths in this system discharge upward into the upper reaches of the Tilligerry Creek drainage system. This provides a pathway for the PFAS plume to move deeper in the aquifer south of the Base then discharge upward into the creek's upper reaches to the south-east.
- The isolated detections of PFAS in areas away from the groundwater plume are likely a result of flooding and overbank flow away from the drainage network, or an unidentified off-Base source.

Extent of **surface water** impacts:

- All major on-Base drains contain PFAS in surface water and sediments.
- Runoff from the south-western boundary of the Base principally discharges through Dawsons Drain. The three principle discharge points on the eastern boundary all discharge to Moors Drain. The flow mechanism in Moors Drain is anticipated to be a result of a gaining-losing stream from the adjacent shallow water table, and the vertical flow component would be minor. Where these drains intersect the groundwater plume, it is inferred that when groundwater levels are elevated, discharge to surface water can occur, causing groundwater to enter open drains.
- When groundwater levels are lower (such as in prolonged dry weather) it is inferred that PFAS impacted water in the drains is leaching into underlying shallow groundwater. It is inferred that the separate plume of groundwater impact observed in the Salt Ash / Tilligerry Creek area (from Moors Drain) and along Cabbage Tree Road (from Dawsons Drain), are likely to be caused by this mechanism (although it is also possible that there is an unidentified PFAS source in these areas).
- It is likely that flooding from the major drains has and will disperse PFAS to surface soils and potentially to shallow groundwater as water levels fall.

Extent of **sediment** impacts:

- Approximately 20 sediment samples were collected from the off-Base drains that lead to Fullerton Cove and other discharge points. Nearly all samples showed measurable PFAS concentrations but at very low concentrations <0.001 mg/kg in most instances. Although the low concentrations, there is still potential for PFAS to leach from the sediment to stormwater.
- Given the age of the PFAS groundwater plume, it is likely in chemical equilibrium. PFAS concentrations over time are expected to reduce as Defence continues to remediate the identified primary and secondary sources on the RAAF Base. PFAS impacted groundwater will likely need to be managed in the areas directly south of the Base and up to Cabbage Tree Road. PFAS impacted sediments in off Base drains would also require management during implementation of the flood management strategy. General mitigation measures are outlined in later sections of the report.

2.2.3 Identified Constraints and Consequences

There are multiple PFAS Source Areas spread over a wide area of the Base. Each Source Area has different potential to contribute to PFAS impacts which are variably migrating off the Base via groundwater migration or in stormwater flow via drains across the eastern and western boundaries. The key PFAS migration pathways include:

- Groundwater migration to the south of the Base; and
- Surface water runoff to the east of the Base to Moors Drain and south of the Base to Dawsons Drain.

The relative contribution of PFAS impacts from each of the PFAS source areas identified by the Environmental Site Assessment (ESA, AECOM, 2017a), and other source types and pathways that are identified to be contributing to off-Base exposure risk. PFAS source areas are described as

a) "Primary Sources" – where AFFF containing PFAS is understood to have been used or disposed of (e.g. a fire training area), or

b) "Secondary Sources" – where PFAS has migrated to a location (typically via effluent or surface water) where it creates a concentration of impact that can then migrate from that location into groundwater or surface water (e.g. Southern Area).

A detailed summary of the Conceptual Site Model (CSM) for each of the identified sources on Base is included in **Table B-2 – Appendix B** of the PFAS Management Area Plan 2019. The primary and secondary

PFAS sources are described in which is based on information included in the AECOM reports. The PFAS constraint rating for the Williamtown Study area is presented in **Figure 4 Appendix A.**

Similar to the non-PFAS contamination, the constraints ratings are defined as:

- **Highly constrained**: High likelihood of encountering PFAS contamination at concentrations that may require additional assessment, remediation or management
- **Moderately constrained**: Moderate likelihood of encountering PFAS contamination at concentrations in some areas of the Scenario boundary that may require additional assessment, remediation or management
- **Minimally constrained**: Low likelihood of encountering PFAS contamination at concentrations that may require additional assessment, remediation or management or limited/isolated areas where non-PFAS contamination may require assessment, remediation or management
- **Negligible**: No PFAS identified within the Scenario Boundary or could migrate to the scenario in any environmental media.

2.2.4 Defence planned remediation

Defence is in the final stages of designing a groundwater remediation system in the eastern and southern portions of the future SAP boundary. The proposed remediation includes pumping groundwater from this area, transferring to the Base via an above-ground pipeline and utilising the existing treatment system to remove PFAS from the groundwater. The overall objective of the remedial efforts is to draw back the leading edges of the groundwater plume to limit downgradient migration. Some reduction in dissolved PFAS concentrations/PFAS mass flux may also occur over longer time periods.

The treated groundwater may be re-injected into the aquifer, similar to what is currently occurring on Base. Provided reports also indicate that treated water may be directed to the local drainage systems. Moors Drain is the preferable location based on additional flood analysis. Dawsons Drain has been discounted as a potential discharge route due to the local flooding issues. Based on the available information, the on-site Base remediation system is effectively removing PFAS to concentrations below the limits of reporting.

Generally, a pump and treat system is designed to lower the water table and create a localised zone of influence with a pumping well network to limit downgradient flow. Based on conversations with Defence, the groundwater remediation system would be constructed and commissioned in the next 12-18 months and is anticipated to operate for at least seven to ten years. The operational timeframe is within the same timeframe as commencement of the SAP development which will need to be considered during future stages of the design.

Recently, Defence released a *Remedial Options Assessment* (ROA) report dated 16 September 2022, which provided additional details on the extent of remediation planned within and near the SAP area. Defence engaged Geosyntec Consultants to complete an independent review of the assessment and interim remedial works conducted to date on and off-Base. The independent review was commissioned to determine the efficacy of the remedial efforts and if additional measures were required to reduce/minimise the PFAS mass flux from the Base in both surface water and stormwater. The primary objective of the ROA *was to identify the most effective and efficient combination of remedial technologies and management actions to achieve the remediation objectives of the Base* (Geosyntec, 2022).

Geosyntec divided the Base, downgradient areas and the groundwater plumes into three zones to evaluate the historical assessment and data and to recommend future remedial strategies. Of primary concern to evaluating PFAS mitigation measures to the SAP is the:

  - “Central Zone” which includes the main portion of the groundwater plume that extends from on-Base sources including Lake Cochran and the Sewage Treatment Plant (STP) and extends through the Newcastle Airport Authority (NAPL) Land, the future environmental conservation area to south of Cabbage Tree Road. The Central Zone includes almost the entirety of the SAP.

The ROA presented a number of scenarios for various areas on and off-Base to continue reducing the PFAS mass flux to off Base areas. Additional details proposed remedial works in the Central Zone is included in **Appendix E**, **Table E-1**. Figures extracted from the ROA showing the boundaries of these zones and proposed remedial works are included in **Appendix E**.

The proposed pump and treat strategy have several implications for the SAP construction and operation and PFAS mitigation measures:

3 Scenario testing

In the Williamtown SAP design development process, all existing constraints and opportunities identified in the baseline assessment summarised above, were holistically evaluated to identify preferred elements which should be included in the Structure Plan (**see section 5)** areas for further investigation and no-go zones. This included the main PFAS and non PFAS limitation constraints identified in **Section 2** and **Section 3**.

These baseline investigations resulted in the development of a range of structure plan scenarios based on holistic themes which aimed to maximise certain regional opportunities. As part of the subsequent scenario testing phase of the Williamtown SAP, comparative assessments were conducted to explore the strengths, weaknesses, risk and opportunities of each development scenario.

The risk assessment was based on specific testing criteria such as current and future land use zonings, likelihood of encountering PFAS and non PFAS contamination and mobilisation, likelihood of remediation being required, and volumes of soil that may be disturbed and potential for re-use or need for off-site disposal. The testing methodology and criteria for PFAS and non-PFAS COPCs was aimed to determine the likelihood and relative significance of potential financial and health liabilities associated with the management of excavated soils and/or need for remediation relative to each scenario. Finally, the scenarios were considered in terms of the Williamtown SAP vision and principles, as shown in **Figure 5-1.**

Following the individual specific technical assessments, several rounds of stakeholder review and multi-disciplinary workshops were conducted to explore all the technical findings, provide a holistically balanced approach to managing constraints and develop the Structure Plan Boundary. This included establishing areas where future development in the SAP may be constrained by PFAS and/or non-PFAS contamination, reviewing environmental media, developing mitigation measures to reduce the risk of mobilising PFAS during the construction, after construction and future development, and suggesting strategy for flood and stormwater management.

4 Testing methodology

4.1 Risk Assessment Overview

The risk of encountering elevated non-PFAS COPC concentrations through the Williamtown SAP area is generally considered to be low to moderate, noting specific APECs as identified in **Figure 4 Appendix A**. It is known that measurable PFAS concentrations are present in various environmental media on and near the Base and in areas downgradient to the south and southeast. The testing methodology for PFAS and non-PFAS COPCs is aimed to determine the likelihood and relative significance of potential financial and health liabilities associated with the management of impacted environmental media and/or need for remediation relative to the master plan boundaries.

To provide qualitative information on the potential risks to human health and the environment, this assessment was based on establishing a broad Conceptual Site Model (CSM) across the Williamtown SAP area and the proposed precincts for all scenarios. Generally, a CSM provides an assessment of the fate and transport of COPCs relative to site specific, subsurface conditions with regard to their potential risk to human health and the environment. It is based on evaluating the linkages between potential sources of contamination – pathways by which contamination moves through the environment and potential human or ecological receptors (SPR linkages). If there are linkages between the sources, pathways, and receptors, then there may be potential risks that require management or remediation. The extent of necessary remediation would be based on investigations in the APECs to establish COPC concentrations (if present). The investigation and remediation of elevated COPC concentrations present a cost consideration into future planning decisions. Future investigations and remediation activities in areas off-Base would be conducted in accordance with the SEPP 55 process and the other applicable legislation and guidelines listed above.

Managing PFAS impacted media in off-Base areas would have to be evaluated based on the master plan boundaries and a determination of liability for the necessary mitigation measures. Management of PFAS contaminated media would be required to facilitate a certain type of development or flood mitigation strategy. This would likely be conducted outside of a consent driven planning framework and function more as a waste management exercise.

The evaluation of risk in the CSM is also based on the sensitivity of land use. For example, a low-density residential land use is more sensitive than an industrial/commercial land use. Under a residential land use, there is more potential of exposure to COPCs (if present) as soil is exposed, gardening, maintenance or recreation may occur, and people generally spend more time at home. This is opposed to an industrial setting which would likely have extensive hard stand, limited occupancy times and other occupational health and safety controls to manage risks to employees.

Each scenario has established Tier I screening values that are established in the *National Environmental Protection Measure 1999*, as amended in 2013 and NEMP v2 2020. The Tier I screening values are lower for sensitive land uses (e.g. residential) which indicate more remediation could be necessary if COPCs are present. The Tier I screening values for less sensitive land uses (e.g. industrial) are higher which indicates less remediation could be required if COPCs are present.

It is also necessary to evaluate if the APECs are near to any sensitive environmental receptors that could be impacted by COPCs (if present). Environmental receptors include a broad range of flora and fauna, surface water bodies and groundwater as noted in previous sections of this report.

During future development, disturbance of soil and sediment will likely be required in some areas. Additionally, sediment from the off-site drains would likely be removed to increase the capacity of these drains as a flood mitigation strategy. Bulk filling in the southern and south eastern portions of the SAP will likely be required for development and flood mitigation strategies. These strategies are further discussed in later sections.

Any soil or sediments removed during construction and/or operation will require management and/or disposal in accordance with the *NSW Waste Management Guidelines 2014 Parts 1-4* and Addendum 1 and any applicable Resource Recovery Orders and Exemptions (RRO/RREs) under the *Protection of Environment Operations (Waste) Act 2014* (POEO Act). Management and/or disposal of soil and sediment will be a cost consideration during future development. It is likely that some of the soil across the SAP investigation area (outside of the identified APECs) will meet the definitions of Excavated Natural Material or Virgin Excavated Natural Material (ENM/VENM) and as such could be beneficially reused for a range of uses.

4.2 Assumptions and limitations

It should be noted that the information included below is based on review of publicly available information and information supplied by Port Stephens Council and Hunter Water. Specific reports or information on the non-PFAS APECs were not reviewed as part of this report. The identification of potentially contaminating activities and related COPCs are based on the nature of the activities at the identified non-PFAS APECs. Aurecon utilised our experience with similar sites and information included in the POEO to summarise the potentially contaminating activities and COPCs at or near the non PFAS APECs. It is important to note that activities at the identified APECs may not have led to subsurface contamination or with all the listed COPCs.

The information on the location of PFAS impacts is based on review of publicly available information and reports. Extensive information is publicly available on the Department of Defence PFAS Management web portal. The information most relevant to the Williamtown SAP is included in **Section 5.3** and **Table 5**, below. No sampling of environmental media has been undertaken by Aurecon. Some of the information contained in the following sections will require further evaluation through collection of environmental media samples during future stages of the Williamtown SAP development.

4.3 Testing Criteria

The following testing criteria has been based on information collected through desktop review and is therefore only qualitative. The proposed location and layout of particular land uses are included in the Williamtown SAP structure plan boundary in **Figure 5-2,** below and summarised in **Table 4**. The land use will be generally light industrial/commercial. However, environmental media samples have not been collected and as such, the evaluation of potential risks can be further quantified if/when sampling is undertaken. Typically, this is completed prior to or during concept design. **Table 3** identifies the testing criteria utilised for the scenarios from a soils and contamination perspective.

Table 3 Summary of testing criteria

Testing Criteria	Details
Current and future land use zonings	Evaluate the changes in land uses to determine if a more sensitive or less sensitive land use than the current land use may be proposed. This is broadly between heavy industrial, light commercial/industrial, residential and conservation. Changing to a more sensitive land use may require more remediation or management if elevated COPC concentrations are present. The current land zonings in the Williamtown Study Area are shown on **Figure 5 Appendix A.** Proposed land use zonings throughout the SAP investigation area are detailed in **Table 4**, below**.**
Likelihood of encountering PFAS contamination and mobilisation	Multiple PFAS sources have been identified near RAAF Base Williamtown in the Baseline Analysis. PFAS impacted groundwater has been migrating offsite towards the areas of the SAP for several decades. Therefore, the PFAS concentrations are expected to improve over time. However, the mechanisms that result in PFAS migration off the RAAF base (i.e. mass flux), are not fully understood, with limited temporal and spatial information across the SAP and predicted PFAS extent in environmental media. Plume movement could potentially change under future environmental conditions. It is possible that some mitigation measures and/or management may be required near boundaries adjacent to the Base and for the sediment in the off-Base drains. The necessity for mitigation measures to prevent migration is based on establishing CSM and the likelihood of SPR linkages. The mitigation measures will be implemented in conjunction with the flood mitigation strategies. Investigations and mitigation measures would represent a cost consideration for future development
Likelihood of remediation being required	Multiple non-PFAS APECs were identified throughout the SAP investigation area in the Baseline Analysis. It is possible that some remediation and/or management may be required in and around the APECs if elevated COPCs are present. The necessity for remediation is based on establishing CSM and the likelihood of SPR linkages. Investigations and remediation would represent a cost consideration for future development.
Volumes of soil that may be disturbed and potential for re-use or need for off-site disposal	The volumes of soil that may be disturbed and require management or disposal will be a cost consideration during future development. If soils meet the definition of ENM/VENM, then they can be re-used for a variety of beneficial uses. If soils contain measurable COPC concentrations, they may require off-site disposal. Given the volume of fill material required, limited volumes of spoil are anticipated to be produced but some ground preparation will be required prior to importation of fill material.

5 Structure Plan

5.1 Methodology and Approach

The Final EbD workshop was held on the 27th to 30th of April 2021 and this workshop involved the further testing of the previously prepared scenarios and development of the Williamtown SAP structure plan. The structure plan considers land use, transport, infrastructure, PFAS, environmental, social, aboriginal heritage and economic matters in conjunction with the SAP vision.

Figure 5-1 provides an outline of the key principles which were incorporated into the masterplan.

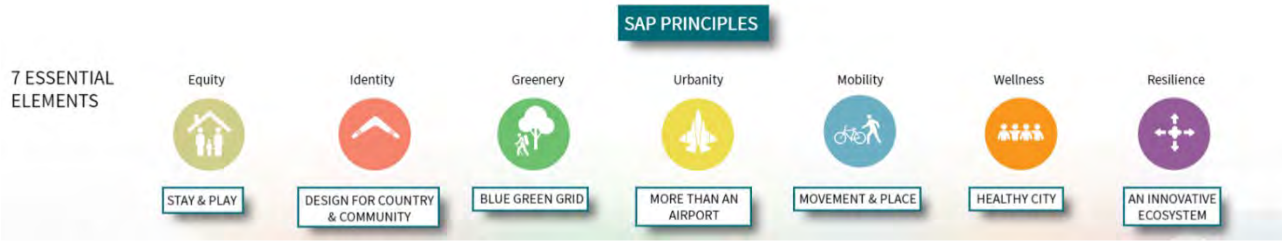

Figure 5-1 The 7 SAP Principles which governed the masterplan

The structure plan leverages the preferred elements of all the scenarios developed, further explores the items under investigation and where possible avoids the identified high constraint zones. The previously identified strengths and opportunities of each scenario were pursed while weaknesses and threats mitigated. This approach was taken to maximise the positive development outcomes rather than considering the previous scenarios as options and adopting one as the structure plan.

5.2 Proposed structure plan

The Structure Plan refined by Hatch Roberts Day is centred around the existing Williamtown Airport Precinct, which includes Newcastle Airport, Williamtown RAAF base and Astra Aerolab. The Williamtown SAP incorporates a core development area south of the existing airport. The Williamtown SAP development are to incorporate a flexible approach to landuses which prioritise aerospace, freight and logistics, commercial, advanced manufacturing and defence industries.

The plan shown in **Figure 5-2** adheres to the existing drainage and flooding characteristics and incorporates the inclusion of the Dawsons Drain and Learys Drain reserve. Additionally, it maintains hydrological regime for the biodiversity corridor, facilitates controlled flooding throughout the SAP precinct and utilises floodplains South of Cabbage Tree Road to offset impacts.

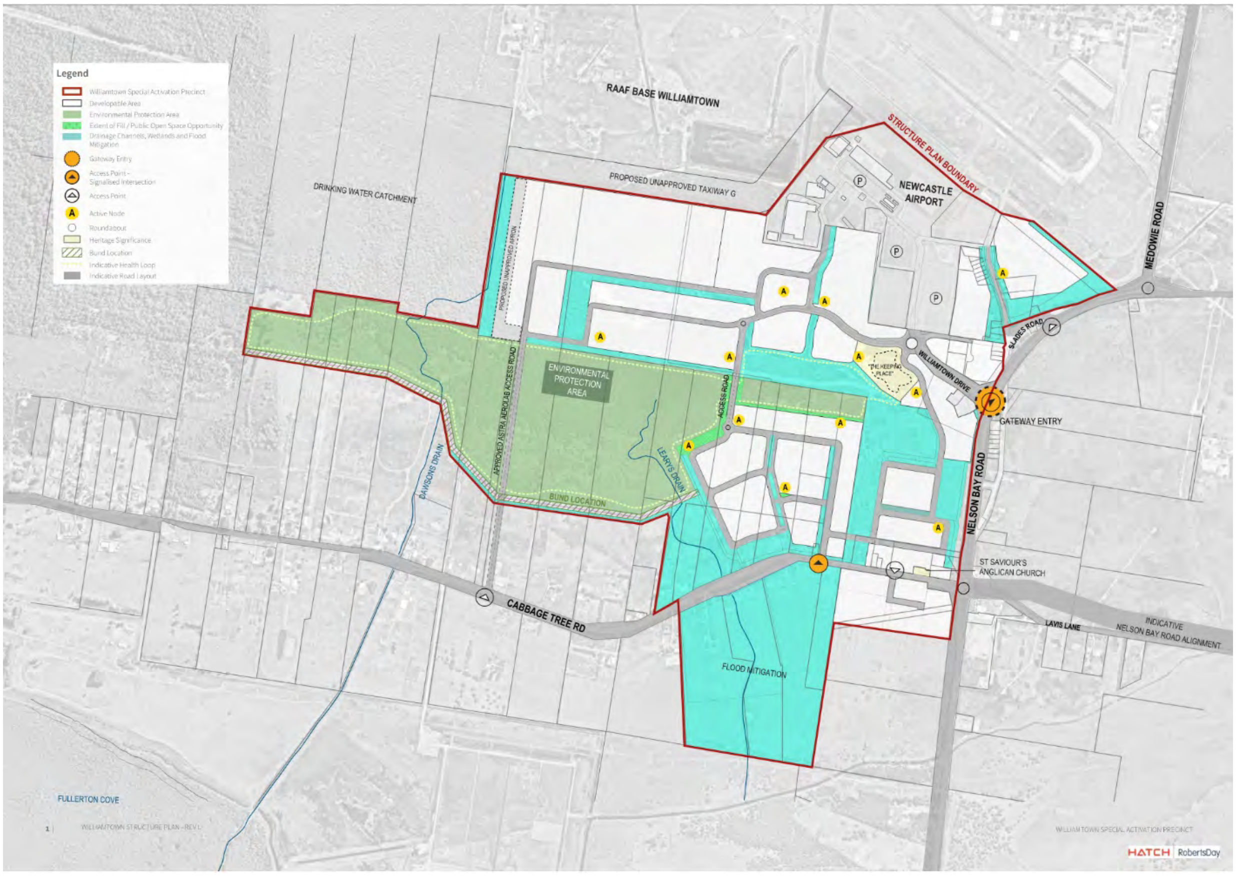

Figure 5-2 Williamtown SAP Structure Plan

During the EBD workshop the area was subdivided into general precincts that have indicative land uses related to each. These are presented in **Table 4** below with our understanding of the probable associated building and infrastructure types for each

.

Table 4 The structural characteristics for each land use in the structure plan

Indicative Land Use	Land Use	Structural characteristics
Freight and Logistics	Refer to Mecone Statutory Report for Permissible Land Uses within each sub-precinct	Shallow foundations in engineered fill typically, with possibly some deeper piles foundations for heavier load areas. Building heights –2 storey buildings expected. Significant live loads e.g. heavy trucks such a loaded B-Double trailers
Defence and Aerospace/ Airside		Buildings might have height limitations. Potentially heavier loads for Airside pavement access.
Commercial Centre		Light industrial developments – warehousing and office space
Light Industrial		Light industrial developments – warehousing and office space Building heights between 1 to 5 storeys for Hi-tech company offices. Retail and entertainment building heights of 1 to 2 storeys maximum.
Advanced Manufacturing		Light industrial developments – warehousing and office space
R&D		Light industrial developments – warehousing and office space Between 1 to 5 storeys for Hi-tech company offices Education or research facility building heights of 1 to 2 storeys maximum.

5.3 PFAS and Non-PFAS assessment of structure plan

5.3.1 PFAS Constraints

The structure plan is situated south and southwest of the airport and directly downgradient from the Lake Cochran and other secondary sources at the Base. The southern approximate half of the structure plan is situated over the groundwater plume showing the highest PFAS concentrations. Extensive sampling of groundwater, surface water, soil and sediment has been undertaken in this area by AECOM. The structure plan overlaid on the PFAs constraints map is shown in **Figure 6 Appendix A.**

The SAP investigation area includes properties impacted by PFAS contamination; landholders may have suffered loss or damage as a result of this contamination. During future stages of the Williamtown SAP process, it will be critical to engage with the local stakeholders to help develop the mitigation measures that will have the least impact on the local community and the surrounding sensitive environment.

Review of the available background information indicates that extensive assessment has been conducted at the Base and the surrounding areas. The areas of PFAS impacted environmental media are well defined relative to the structure plan boundary. The PFAS impacts have migrated from the Base in groundwater to Cabbage Tree Road and to the north-east into Tilligerry Creek. There has been some migration to the east and southeast with ultimate groundwater flow toward Fullerton Cove. Recent groundwater monitoring data indicates that there are limited PFAS concentrations in groundwater to the south of Cabbage Tree Road. It is noted that measurable PFAS concentrations have been detected historically in some monitoring wells to the south of Cabbage Tree Road and in Fullerton Cove but concentrations fluctuate with time.

Upward flow of PFAS impacted groundwater into Fourteen Foot Drain and Tilligerry Creek (and other gaining streams) has been noted in Conceptual Site Models (AECOM, 2017) despite the likely impediment of groundwater-surface water expression by less permeable subsurface estuarine clays in the SAP area. Given the age of the PFAS groundwater plume and the phasing out of PFAS use, PFAS concentrations in groundwater are expected to reduce over time as Defence continues to remediate the identified primary and secondary sources on the Base. There is potential for fluctuations in groundwater, surface water and sediment concentrations and the lateral extents of the groundwater plume due to changing environmental conditions or chemical transformation of PFAS.

Measurable PFAS is still present in stormwater and is a key migration pathway to off Base areas. Stormwater becomes impacted when PFAS leaches from soil or sediment. In some areas, groundwater intersects the drains and daylights which is contributing to PFAS migration and impacting stormwater. The area is prone to flooding, with flood water contributing to PFAS impacts in soil, sediment and surface water and with likely interaction between the shallow groundwater and the drainage network. It is important to note however, that processes at the site are still not fully understood, particularly regarding PFAS migration during heavy rainfall events. Aurecon have reviewed environmental media analytical data collected from the structure plan area from the following reports and sources of information:

- AECOM 2017, *RAAF Base Williamtown Stage 2B Environmental Investigation – Ecological Site Assessment* December 2017
- AECOM 2018, *RAAF Base Williamtown Stage 2B Environmental Investigation – Ecological Risk Assessment* September 2018
- AECOM 2019, *Interim Monitoring Event Report – RAAF Base Williamtown*, December 2018
- AECOM 2019, *Interim Monitoring Event Report – RAAF Base Williamtown*, June 2019
- AECOM 2022a, *Remedial Options Assessment, RAAF Base Williamtown*, September 2022
- AECOM 2022b, *Numerical Groundwater Model Update RAAF Base Williamtown*, September 2022
- AECOM 2022c *Annual Interpretative Report – RAAF Base Williamtown October 2022*

A summary of the analytical data collected from this structure plan area is summarised in **Table 5**, below

Table 5 Summary of analytical data within the structural plan

Environmental Media Investigated	Data Sources	Sampling Locations	Concentration Ranges
Groundwater	AECOM 2017, RAAF Base Williamtown Stage 2B Environmental Investigation – Ecological Site Assessment December 2017	Sampling was completed on a total of 571 new and existing monitoring wells/bores • 132 'deep' wells (total depths ranging between 17.5 – 20 m bgs) • 32 'intermediate' wells (total depths ranging between 10 – 12 m bgs) • 172 'shallow' wells (total depths ranging between 2.8 – 6m m bgs) • 28 HWC bores • 207 residential bores. 56 sample locations within proposed structure plan boundary	**Structure plan area** PFOS = <0.01 – 440 µg/L (MW167) Number of sample locations with concentrations > LOR = 220 PFOA = <0.01 – 10.5 µg/L (MW187S) Number of sample locations with concentrations > LOR = 171 PFOS + PFHxS = <0.02 – 522.5 µg/L (MW167) Number of sample locations with concentrations > LOR = 249 **Groundwater Elevation** December 2016: Number of wells: 70 Min SWL (m btoc) = 0.011 (MW151D) Max SWL (m btoc) = 2.767 (MW132I) March 2017: Number of wells: 145 Min SWL (m btoc) = 0.007 (MW235D) Max SWL (m btoc) = 4.887 (MW177)

	AECOM 2018, RAAF Base Williamtown Stage 2B Environmental Investigation – Ecological Risk Assessment September 2018	PFAS have been reported to be present in groundwater beneath the Site. Groundwater sampled from areas to the south and east of the Site has also been reported to contain detectable concentrations of PFAS. This transport mechanism is of high significance as it has contributed to PFAS transport off-Site. • Groundwater flows comparatively slower than surface water, less than one metre per day. • Groundwater flow is nearly constant over time. Variability occurs within aquifers, but flow is usually slower than in surface water features. • PFAS concentrations in groundwater are comparatively more stable. • Groundwater elevations increase during recharge events but slower (hours to days) than in surface water drains. During dry periods, groundwater elevation decreases slowly. • PFAS is transported slower than the groundwater flow rate because PFAS sorbs to aquifer solids. The rate of retardation varies between individual compounds. The 2016 Stage 2B EI identified that there is a potential for surface water and groundwater interactions as a result of the highly permeable soils and **shallow groundwater table**. The unlined surface drainage lines both on- and off-Site are likely to contribute to aquifer recharge. In addition, it has been reported in the 2016 Stage 2B EI that groundwater infiltration into the unlined drainage network and Lack Cochran is occurring. Groundwater is **typically shallow** (0.5 m bgs) in areas to the south of the Site and near Ten Foot Drain, Fourteen Foot Drain and Tilligerry Creek. It is noted that there are periods of the year where some sections of Dawsons Drain (e.g.DD3) are considered to be losing with surface water migrating to groundwater beneath the drain. The reported concentrations of PFAS in these sections of the drain during gaining conditions indicate that elevated groundwater concentrations are discharging to the surface water and resulting in elevated PFAS concentrations reported at DD3 and in Fourteen Foot Drain. Concentration ranges are narrower in surface water samples from on-Site compared to ranges in the direct receiving environments off-Site (Dawsons Drain and Moors Drain). This indicates that groundwater discharges to these waterways is contributing significantly to temporal variation in surface water concentrations Based on the available information it has therefore been assumed that assessment of exposures to surface water in the drainage channels and estuarine environments and ponded water in terrestrial areas is representative of potential groundwater exposures for ecological receptors in both on- and off-Site environments. There is potential for leaching to groundwater at concentrations which pose a risk to nearby freshwater environments. Risks to aquatic life were further assessed based on reported surface water concentrations.

Environmental Media Investigated	Data Sources	Sampling Locations	Concentration Ranges
		This approach was considered appropriate as the groundwater-surface water interaction study indicates that surface water concentrations are representative of groundwater discharges to aquatic environments surrounding the Site.	
	AECOM 2019, Interim Monitoring Event Report – RAAF Base Williamtown, December 2018	118 locations overall (comprising 113 monitoring wells, 3 pump station bores and 2 HWC monitoring wells) 35 sample locations within proposed structure plan boundary	**Structure Plan** PFOS = <0.01 – 372 ug/L (MW167) Number of sample locations with concentrations > LOR = 67 PFOA = <0.01 – 4.56 ug/L (MW167) Number of sample locations with concentrations > LOR = 84 PFOS + PFHxS = <0.01 – 398 ug/L (MW167) Number of sample locations with concentrations > LOR = 66 **Groundwater Elevation** Groundwater Elevation = 0.18 (MW108S – north) to 2.29 (MW167 – north) m BTOC

Environmental Media Investigated	Data Sources	Sampling Locations	Concentration Ranges
	AECOM 2019, Interim Monitoring Event Report – RAAF Base Williamtown, June 2019	152 locations (comprising 133 monitoring wells, 4 pump station bores, 4 Hunter Water Corporation (HWC) Monitoring Wells and 11 residential boreholes 40 sample locations within proposed structure plan boundary	**Structure Plan** PFOS = <0.01 – 391 ug/L (MW167) Number of sample locations with concentrations > LOR = 69 PFOA = <0.01 – 4.94 ug/L (MW281S) Number of sample locations with concentrations > LOR = 50 PFOS + PFHxS = <0.01 – 402 ug/L (MW167) Number of sample locations with concentrations > LOR = 76 **Groundwater Elevation** Overall: Minimum SWL = 0.007 m btoc (MW235D) Maximum SWL = 3.314 m btoc (MW132D) **Structure Plan:** Groundwater Elevation = 0.15 (MW187S – centre) to 3.11 (MW167 – north) m BTOC

Environmental Media Investigated	Data Sources	Sampling Locations	Concentration Ranges
Surface water	AECOM 2017, RAAF Base Williamtown Stage 2B Environmental Investigation – Ecological Site Assessment December 2017 – Comprehensive	**Overall** Collection of 428 surface water samples (Collection of 21 on-Site and 109 off-Site surface water samples) **Structure Plan** 20 sample locations within proposed structure plan boundary	**Overall/Structure Plan** On-Site: PFOS = <LOR – 14 ug/L (QC502, duplicate of LC_B) Number of sample locations with concentrations > LOR = 20 PFOA = <LOR – 0.13 ug/L (DD1) Number of sample locations with concentrations > LOR = 12 PFOS + PFHxS = 0.02 (OLA2) – 15.2 ug/L (QC502, duplicate of LC_B) Number of sample locations with concentrations > LOR = 21 Off-Site: PFOS = <LOR – 7.82 ug/L (DD3) Number of sample locations with concentrations > LOR = 56 PFOA = <LOR – 0.74 ug/L (DD3) Number of sample locations with concentrations > LOR = 30 PFOS + PFHxS = <LOR – 25.9 ug/L (DD3) Number of sample locations with concentrations > LOR = 56

Environmental Media Investigated	Data Sources	Sampling Locations	Concentration Ranges
	AECOM 2017, RAAF Base Williamtown Stage 2B Environmental Investigation – Ecological Site Assessment December 2017 – Weekly	Collection of 175 samples (39 samples on-Site and 136 samples off-Site) from 20 locations	**On-Site:** PFOS = 0.06 (DD1) – 9.75 ug/L (BD08) Number of sample locations with concentrations > LOR = 39 PFOA = <LOR – 0.19 ug/L (BD08) Number of sample locations with concentrations > LOR = 34 PFOS + PFHxS = 0.12 (DD1) – 12.8 ug/L (BD08) Number of sample locations with concentrations > LOR = 39 **Off-Site:** PFOS = <LOR – 14.2 ug/L (DD3) Number of sample locations with concentrations > LOR = 123 PFOA = <LOR – 0.68 ug/L (DD3) Number of sample locations with concentrations > LOR = 59 PFOS + PFHxS = <LOR – 25.9 ug/L (DD3) Number of sample locations with concentrations > LOR = 124

Environmental Media Investigated	Data Sources	Sampling Locations	Concentration Ranges
	AECOM 2018, RAAF Base Williamtown Stage 2B Environmental Investigation – Ecological Risk Assessment September 2018	**Overall** On-Site: 39 sample locations South and west of the site: 16 sample locations **Structural Plan** On-Site: 3 sample locations (BD03, BD08 and LC) Dawsons Drain: 5 sample locations (DD1, DD2, DD3, DD4 and DD7) Fullerton Cove Ring Drain: 2 sample locations (FCD1 and FCD4) Fourteen Foot Drain: 1 sample location (FFD1)	**Overall:** On-Site: PFOS = 0.02 – 63 ug/L (average = 5.9 ug/L) PFOA = 0.01 – 21 ug/L (average = 0.8 ug/L) South and west of the site: PFOS = 0.02 – 35.3 ug/L (average = 2.0 ug/L) PFOA = 0.01 – 2.3 ug/L (average 0.1 ug/L) **Structural Plan** On-Site: PFOS = 1.7 – 9.8 ug/L PFHxS = 0.09 – 3.1 ug/L PFOA = 0.03 – 0.2 ug/L Dawsons Drain: PFOS = 0.06 – 35.3 ug/L PFHxS = 0.04 – 39.9 ug/L PFOA = 0.01 – 2.3 ug/L Fullerton Cove Ring Drain: PFOS = 0.08 – 1.6 ug/L PFHxS = 0.03 – 2.9 ug/L PFOA = 0.01 – 2.3 ug/L Fourteen Foot Drain: PFOS = 0.1 – 2.1 ug/L PFHxS = 0.05 – 3.5 ug/L PFOA = 0.05 – 0.1 ug/L

	AECOM 2019, Interim Monitoring Event Report – RAAF Base Williamtown, December 2018	**Overall** 24 sample locations (11 sample locations within proposed structure plan boundary) **Structure Plan** On-Site: 4 sample locations (LC_B, LC, MD6 and MD7) Dawsons Drain: 4 sample locations (DD1, DD2, DD3 and DD5) Fourteen Foot Drain: 1 sample location (FFD4) Ten Foot Drain: 2 sample locations (TFD1 and TFD2)	**Overall** PFOS = <0.01 – 30.7 ug/L (DD3) Number of sample locations with concentrations > LOR = 3 PFOA = <0.01 – 1.43 ug/L (DD3) Number of sample locations with concentrations > LOR = 6 PFOS + PFHxS = <0.01 – 53.1 ug/L (DD3) Number of sample locations with concentrations > LOR = 3 **Structure Plan** On-Site: PFOS = 0.83 – 7.43 ug/L PFOS + PFHxS = 1.09 – 8.69 ug/L PFOA = 0.1 – 0.11 ug/L Dawsons Drain: PFOS = 0.83 – 30.7 ug/L PFOS + PFHxS = 1.59 – 53.10 ug/L PFOA = 0.04 – 1.43 ug/L Fourteen Foot Drain: PFOS = 0.96 ug/L PFOS + PFHxS = 1.98 ug/L PFOA = 0.08 ug/L Ten Foot Drain: PFOS = <0.01 – 2.34 ug/L PFOS + PFHxS = <0.01 – 3.26 ug/L PFOA = <0.01 – 0.05 ug/L

Environmental Media Investigated	Data Sources	Sampling Locations	Concentration Ranges
	AECOM 2019, Interim Monitoring Event Report – RAAF Base Williamtown, June 2019	**Overall** 22 sample locations (10 sample locations within proposed structure plan boundary) **Structure Plan** On-Site: 4 sample locations (LC_B, LC, MD6 and MD7) Dawsons Drain: 4 sample locations (DD1, DD2, DD3 and DD5) Ten Foot Drain: 2 sample locations (TFD1 and TFD2)	**Overall** PFOS = <0.01 – 4.78 ug/L (DD3) Number of sample locations with concentrations > LOR = 22 PFOA = <0.01 – 0.4 ug/L (DD3) Number of sample locations with concentrations > LOR = 9 PFOS + PFHxS = <0.01 – 11.9 ug/L (DD3) Number of sample locations with concentrations > LOR = 22 **Structural Plan** On-Site: PFOS = 0.440 – 4.110 ug/L PFOS + PFHxS = 0.570 – 4.910 ug/L PFOA = <0.010 – 0.070 ug/L Dawsons Drain: PFOS = 0.140 – 4.780 ug/L PFOS + PFHxS = 0.530 – 11.900 ug/L PFOA = 0.010 – 0.400 ug/L Ten Foot Drain: PFOS = 0.100 – 0.240 ug/L PFOS + PFHxS = 0.100 – 0.940 ug/L PFOA = <0.010 – <0.050 ug/L

Soil (0.0 – 1.5 mbgs)	AECOM 2017, RAAF Base Williamtown Stage 2B Environmental Investigation – Ecological Site Assessment December 2017	**Overall** Collection of 243 soil samples **Structure Plan** 26 sample locations within proposed structure plan boundary	**Overall:** Shallow unsaturated soil (142): PFOS = <0.0002 – 9.17 mg/kg (F479_BH27_0.5) Number of sample locations with concentrations > LOR = 109 PFOA = <0.0002 – 0.0312 mg/kg (F479_BH32_1.5) Number of sample locations with concentrations > LOR = 51 PFOS + PFHxS = <0.0002 – 9.370 mg/kg (F479_BH27_0.5) Number of sample locations with concentrations > LOR = 109 Saturated soil (47): PFOS = <0.0002 – 0.399 mg/kg (F479_BH47_2.5) Number of sample locations with concentrations > LOR = 31 PFOA = <0.0002 – 0.0012 mg/kg (MW246S_3.0) Number of sample locations with concentrations > LOR = 10 PFOS + PFHxS = <0.0002 – 0.402 mg/kg (F479_BH47_2.5) Number of sample locations with concentrations > LOR = 31 **Structure Plan** PFOS = <0.0002 – 0.3300 mg/kg (MW148D) PFOA = <0.0002 – 0.0122 mg/kg (MW148D)

Environmental Media Investigated	Data Sources	Sampling Locations	Concentration Ranges
			PFOS + PFHxS = <0.0002 – 0.5000 mg/kg (MW148D)
	AECOM 2018, RAAF Base Williamtown Stage 2B Environmental Investigation – Ecological Risk Assessment September 2018	On-Site: 425 sample locations South and west of the site: 31 sample locations	**On-Site:** PFOS = 0.0003 – 9.2 mg/kg (average 0.2 mg/kg) PFOA = 0.002 – 0.06 mg/kg (average 0.004 mg/kg) **South and west of the site:** PFOS = 0.0005 – 0.8 mg/kg (average 0.07 mg/kg) PFOA = 0.0003 – 0.01 mg/kg (average 0.003 mg/kg)

Environmental Media Investigated	Data Sources	Sampling Locations	Concentration Ranges
Sediment	AECOM 2017, RAAF Base Williamtown Stage 2B Environmental Investigation – Ecological Site Assessment December 2017	**Overall** Collection of 181 sediment samples (26 samples on-Site and 155 samples off-Site) **Structure Plan** 22 sample locations within proposed structure plan boundary	**Overall** On-Site (26): PFOS = <LOR – 14.0 mg/kg (BD08) Number of sample locations with concentrations > LOR = 23 PFOA = <LOR – 0.064 mg/kg (BD08) Number of sample locations with concentrations > LOR = 5 PFOS + PFHxS = <LOR – 14.05 mg/kg (BD08) Number of sample locations with concentrations > LOR = 24 Saturated soil (155): PFOS = <LOR – 1.82 mg/kg (RESI018) Number of sample locations with concentrations > LOR = 134 PFOA = <LOR – 0.036 mg/kg (FFD-T6) Number of sample locations with concentrations > LOR = 28 PFOS + PFHxS = <LOR – 1.98 mg/kg (RESI018) Number of sample locations with concentrations > LOR = 134 **Structure Plan** PFOS = <LOR – 1.82 mg/kg (RESI018) PFOA = <LOR – 0.0362 mg/kg (FFD-T6) PFOS + PFHxS = <LOR – 1.98 mg/kg (RESI018 and FFD-T6)

Environmental Media Investigated	Data Sources	Sampling Locations	Concentration Ranges
	AECOM 2018, RAAF Base Williamtown Stage 2B Environmental Investigation – Ecological Risk Assessment September 2018	On-Site: 52 sample locations South and west of the site: 18 sample locations	**On-Site:** PFOS = 0.0002 – 22.4 mg/kg (average 0.6 mg/kg) PFOA = 0.0002 – 0.09 mg/kg (average 0.009 mg/kg) **South and west of the site:** PFOS = 0.001 – 1.8 mg/kg (average 0.009 mg/kg) PFOA = 0.0003 – 0.04 mg/kg (average 0.008 mg/kg)
	AECOM 2019, Interim Monitoring Event Report – RAAF Base Williamtown, December 2018	**Overall** 26 locations (paired with the surface water locations with exception of two sediment samples (FC1A and FC1B) collected in Fullerton Cove) **Structure Plan** 5 sample locations within proposed structure plan boundary	**Overall** PFOS = <0.0002 – 0.146 mg/kg (MD1) Number of sample locations with concentrations > LOR = 2 PFOA = <0.0002 – 0.0036 mg/kg (DD3) Number of sample locations with concentrations > LOR = 19 PFOS + PFHxS = <0.0002 – 0.206 mg/kg (DD3) Number of sample locations with concentrations > LOR = 1 **Structure Plan** PFOS = LOR – 0.05 mg/kg (LC_B) PFOA = <LOR – LOR mg/kg PFOS + PFHxS = 0.0011 – 0.0571 mg/kg (LC_B)

Environmental Media Investigated	Data Sources	Sampling Locations	Concentration Ranges
	AECOM 2019, Interim Monitoring Event Report – RAAF Base Williamtown, June 2019	**Overall** 24 locations (paired with the surface water locations with exception of two sediment samples (FC1A and FC1B) collected in Fullerton Cove) **Structure Plan** 5 sample locations within proposed structure plan boundary	**Overall** PFOS = <0.0002 – 0.13 mg/kg (MD1) Number of sample locations with concentrations > LOR = 22 PFOA = <0.0002 – 0.0014 mg/kg (MD1) Number of sample locations with concentrations > LOR = 5 PFOS + PFHxS = <0.0002 – 0.144 ug/L (MD1) Number of sample locations with concentrations > LOR = 22 **Structure Plan** PFOS = LOR – 0.05 ug/L (LC_B) PFOA = <LOR – LOR ug/L PFOS + PFHxS = 0.0011 – 0.0571 ug/L (LC_B)

5.3.2 Non-PFAS Constraints

The non PFAS APECS located in the structure plan boundary are shown on **Figure 7** in **Appendix A** and summarised in **Table 6**, below. The risk of encountering Acid Sulfate Soils in the structure plan boundary is shown on **Figure 2** in **Appendix A.**

Table 6 Summary of non PFAS APECs in structure plan boundary

APEC	Location
RAAF Base Williamtown and Newcastle Airport (Defence Activities, Ammunitions Production and Testing)	North (adjacent to structure plan)
One Unexploded Ordinance (UXO) Site (north west)	North West (within and adjacent to structure plan)
Seven Landfills	Throughout structure plan (along Cabbage Tree Road)
One Sand Extraction, Landfill – Effluent Lagoon – Heavy metals and PFAS	Within the centre of structure plan (adjacent to Base, Newcastle Airport, Cabbage Tree Road and Nelson Bay Road
Two Car wash bays	North East (adjacent to Newcastle Airport)
Airport – Spray Booth	North East (within Newcastle Airport)
One old service Station	North East (adjacent to the Base)
One notified contaminated land site - Hunter Land Effluent Pond	North (adjacent to the Base)
Two sites where waste has been used filling or land development - Filling of land with demolition waste - Demolition and liquid waste on land (signs of contamination)	Within the centre of the structure plan
No POEO licenses or notices	-
No RFS locations or current Service Stations	-

6 Mitigation Measures

6.1 Mitigation Measures

6.1.1 PFAS Mitigation Measures

During the development of the masterplan and concept design, Aurecon identified several mitigation measures that could be employed to minimise the potential that PFAS are mobilised during construction and operation of the Williamtown SAP. It is well established that the Base and associated infrastructure are sources of PFAS to on and off-Base groundwater, stormwater, surface water and to a lesser extent off-site soil, sediment and vegetation. The generalised location of the PFAS groundwater plume relative to the SAP boundary and the most recent development plan is shown on **Figure 6 Appendix A**.

The mitigation measures have been designed to:

- Minimise the potential that PFAS impacts the fill material that will be imported to construct the Williamtown SAP.
- Address any incidental PFAS that may be present in stormwater flowing across and from the SAP.

Based on these objectives, following are the mitigation measures proposed:

- Installation of a geosynthetic clay liner (GCL) to segregate the fill material from fluctuating groundwater impacted with PFAS (**Figure 8 Appendix A**).
- Mixing of powdered activated carbon (PAC) into the fill material to prevent dissolved PFAS from adsorbing to fill material.
- Allowing natural conditions to prevail where groundwater is allowed to fluctuate and interact with the fill material.
- Passive stormwater treatment using PAC installed throughout the stormwater conveyance system (i.e, in drains, culverts, etc).
- Integration of mitigation measures into the flood mitigation strategies which includes:
  - Use of a stormwater berm for regional flood management (**Figures 9 and10 Appendix A**)
  - Water captured off future roofs, hardstands, roads to be routed through constructed wetlands and bioretention systems (**Figure 11 Appendix A**). A total of eight systems would be installed for the overall SAP with five constructed for Stage 1 and an additional three for Stage 2.

A detailed description of the PFAS mitigation measures, advantages, disadvantages and constructability considerations are summarised in **Table F-1** in **Appendix F**.

An evaluation process of the various mitigation measures was undertaken, using several sources of additional information, described below, to recommend the most appropriate strategies.

Evaluation overview

Based on the results of the master planning and concept design, two measures were identified as being most feasible to mitigate the potential risks of PFAS impacting imported fill material include:

- Installation of a GCL and requisite drainage layers to segregate the existing subsurface/groundwater from imported fill material
- Mixing of PAC into the bottom layers of fill material

It is possible that PFAS concentrations may be contained in stormwater. A potential mitigation measure identified to address this potential risk is to install passive PAC treatment throughout the stormwater conveyance system. Aurecon has further evaluated this option as the stormwater management design has progressed. We have recommended an augmentation stormwater management strategy as a conservative measure.

We have also included additional scenarios based on further evaluation of the SAP's unlikelihood to increase the PFAS mass flux in the area:

- Evaluation of risk to support letting natural conditions prevail during construction and operation of the SAP. Ongoing monitoring of environmental media would be required.
- Augment the recommended mitigation strategies with an adaptive management approach that evaluates environmental conditions at the time of SAP construction and recommends appropriate strategy/ies based on future conditions.

Additional information to evaluate these potential mitigation measures include:

- Discussion with vendors/contractors of GCL and PAC proprietary products.
- Discussions with Department of Defence on assessment and remedial actions at and around the Base.
- Review of additional reports relating to Defence's planned remedial works.
- Discussions with the NSW Government PFAS Technical Advisory Group which includes NSW EPA, NSW Health, NSW Chief Scientist, Department of Primary Industries and the Office of Environment and Heritage representatives.
- Legislative framework review and reiteration.
- Constructability considerations associated with each option.
- Review of similar applications in Australia and globally (literature and case studies).
- Costings for each application provided by the Quantity Surveyor (North Projects).
- Consultation with other related discipline leads within the concept design team, specifically geotechnical, hydrogeology, water cycle management.

6.1.2 Defence planned remediation

Defence is in the final stages of designing a groundwater remediation system in the eastern and southern portions of the future SAP boundary. The proposed remediation includes pumping groundwater from this area, transferring to the Base via an above-ground pipeline and utilising the existing treatment system to remove PFAS from the groundwater. The overall objective of the remedial efforts is to draw back the leading edges of the groundwater plume to limit downgradient migration. Some reduction in dissolved PFAS concentrations/PFAS mass flux may also occur over longer time periods.

The treated groundwater may be re-injected into the aquifer, similar to what is currently occurring on Base. Provided reports also indicate that treated water may be directed to the local drainage systems. Moors Drain is the preferable location based on additional flood analysis. Dawsons Drain has been discounted as a potential discharge route due to the local flooding issues. Based on the available information, the on-site Base remediation system is effectively removing PFAS to concentrations below the limits of reporting.

Generally, a pump and treat system is designed to lower the water table and create a localised zone of influence with a pumping well network to limit downgradient flow. Based on conversations with Defence, the groundwater remediation system would be constructed and commissioned in the next 12-18 months and is anticipated to operate for at least seven to ten years. The operational timeframe is within the same timeframe as commencement of Stage 1 of the SAP development which will need to be considered during future stages of the design.

Recently, Defence released a *Remedial Options Assessment* (ROA) report dated 16 September 2022, which provided additional details on the extent of remediation planned within and near the SAP area. Defence engaged Geosyntec Consultants to complete an independent review of the assessment and interim remedial works conducted to date on and off-Base. The independent review was commissioned to determine the efficacy of the remedial efforts and if additional measures were required to reduce/minimise the PFAS mass flux from the Base in both surface water and stormwater. The primary objective of the ROA *was to identify the most effective and efficient combination of remedial technologies and management actions to achieve the remediation objectives of the Base* (Geosyntec, 2022).

Geosyntec divided the Base, downgradient areas and the groundwater plumes into three zones to evaluate the historical assessment and data and to recommend future remedial strategies. Of primary concern to evaluating PFAS mitigation measures to the SAP is the:

- "Central Zone" which includes the main portion of the groundwater plume that extends from on-Base sources including Lake Cochran and the Sewage Treatment Plant (STP) and extends through the Newcastle Airport Authority (NAPL) Land, the future environmental conservation area to south of Cabbage Tree Road. The Central Zone includes the entirety of the SAP area.

The ROA presented a number of scenarios for various areas on and off-Base to continue reducing the PFAS mass flux to off Base areas. Additional details proposed remedial works in the Central Zone is included in **Appendix E**, **Table E-1**. Figures extracted from the ROA showing the boundaries of these zones and proposed remedial works are included in **Appendix E**.

The proposed pump and treat strategy have several implications for the SAP construction and operation and PFAS mitigation measures:

- The purpose of the pump and treat system is to reduce the PFAS mass flux from Lake Cochran to southern areas of the SAP up to and beyond Cabbage tree Road. This would lead to reduced PFAS mass flux in groundwater below Stage 1 of the SAP that may interact with fill material.
- Pump and treat lowers the water table. Based on presumed remedial timeframes would extend to SAP construction. This would tend limit the groundwater interactions with imported fill material.
- The pump and treat system would produce a significant volume of water that is treated and then discharged into the local drainage system. This could influence the flood mitigation/stormwater management strategies although use of Dawsons Drain has been discounted due to the persistent local flooding issues.

Historical data also indicates that the STP and the effluent are significant contributors to the PFAS mass flux in the area. There are plans to upgrade the STP so the treatment processes can address PFAS from the wastewater and address the water in the existing lagoons.

PFAS remediation nationally and globally

PFAS is ubiquitous in the environment due to its persistence and resistance to biodegradation. Remediation of PFAS in soil, sediment, surface water and stormwater has occurred across Australia and globally, mostly within the past five to seven years. Due to its chemical stability, limited remedial options are available to reduce the risks associated with PFAS.

The predominant strategy being employed to address PFAS in soil/sediment is pathway removal which is eliminating the interaction of impacted soil/sediment with stormwater. Interaction with stormwater has been identified as the primary mechanism of PFAS infiltration into groundwater and transport to surface water bodies (rivers, creeks, streams, oceans). Capping, containing and/or stabilising the soil reduces or eliminates the PFAS mass in soil that can dissolve into stormwater and be transported away. Other less used options to address PFAS impacted soil are thermal treatment, soil washing and excavation and disposal to landfill. Some pilot scale studies show that electrochemical oxidation may physically destroy PFAS. However, the oxidation by-products may be shorter chained PFAS which cannot be detected reliably by current analytical methods.

There are also limited options available to treat PFAS impacted water which mostly rely on removing the PFAS from the dissolved phase by filtration in activated carbon or ion exchange resins. These filtration vessels then need to be treated to regenerate them or disposed in landfill. There are emerging technologies that destroy dissolved phase PFAS but there are limited applications showing effectiveness under a wide range of site conditions. Foam fractionation has been employed at several sites around Australia and globally showing very favourable results. Foam fractionation uses small air bubbles filtered upward through a PFAS impacted water column. The air bubbles remove the dissolved PFAS into a concentrate. The concentrate is then disposed off-site or used for research purposes.

6.1.3 Mitigation measures evaluation

A range of mitigation measures (refer to **Table F-1** in **Appendix F)** have been evaluated since the master planning process and additional scenarios have been included in the concept design phase. The mitigation measures evaluated include:

- Installation of a geosynthetic clay liner to segregate the fill material from fluctuating groundwater impacted with PFAS (Figure 10, Appendix A).
- Mixing of powdered activated carbon (PAC) into the fill material to prevent dissolved PFAS from adsorbing to fill material.
- Allowing natural conditions to prevail where groundwater is allowed to fluctuate and interact with the fill material.
- Passive stormwater treatment using PAC installed throughout the stormwater conveyance system (i.e, in drains, culverts, etc).
- Integration of mitigation measures into the flood mitigation strategies which includes:
  - Use of a stormwater berm for regional flood management (Figures 8, Appendix A)
  - Water captured off future roofs, hardstands, roads to be routed through constructed wetlands and bioretention systems (**Figure 11 Appendix A)**. A total of eight systems would be installed for the overall SAP with five constructed for Stage 1 and an additional three for Stage 2.

6.1.4 Mitigation Measure Analysis

The following sections discuss the most relevant considerations detailed in this report and in **Table F-1** in **Appendix F,** to provide a recommendation on the preferred mitigation measures for both the fill material and stormwater.

Overall, the construction and operation of the Williamtown SAP is not expected to increase the PFAS mass flux moving in groundwater or stormwater nor create a significant secondary source. The initial developments will focus on the NAPL land just south of the airport, some of which is ready for development with platforms constructed. The SAP development **(Figure 5-2**) will commence construction in seven to ten years and be operational in approximately twenty years. Defence will continue to undertake on and off-Base remedial efforts during this timeframe. It is expected that reductions in the PFAS mass flux will result from these remedial efforts. The reduced mass flux from Defence's remedial efforts and the staged construction further reduces the future potential for PFAS mobilisation by SAP construction or operation. The staged construction also means excessively large areas will not be disturbed at any one time making it easier to manage risks during construction.

The future land use of the SAP will be light industrial/commercial and be constructed on platforms several metres above the existing grade. Services will be constructed in the elevated platforms and not interact with contaminated soil or groundwater. Water and sewer will be reticulated supply. The elevated platforms also provide a significant separation between workers/visitors and the underlying PFAS groundwater plume.

Any stormwater that is captured from future roofs, hardstands, roads, etc will be captured and routed to constructed wetlands and bioretention system for treatment and discharge. No PFAS is expected in this stormwater but the wetland/bioretention systems can easily facilitate means to remove any incidental PFAS that may occur. No additional volumes of regional stormwater would be produced than currently moves through the system. It will be diverted through a constructed berm/retention system that utilises existing Dawsons and Leary's Drain as is currently occurring.

All these factors indicate that there is a low to negligible risk to human health for future SAP users. Likewise, the platforms would prevent terrestrial fauna from interacting with groundwater plume. The platforms would not significantly alter the groundwater flow regime so the risk to downgradient ecological receptors is not increased by the construction or operation of the SAP.

Fill Protection Measures

Based on the information detailed in **Table F-1** in **Appendix F**, the preferred option to mitigate the risks for the fill material is to allow groundwater to fluctuate naturally into the imported fill material. The primary reasons to allow natural conditions to prevail are:

- The measured PFAS concentrations in groundwater are derived from on-Base PFAS concentrations and are not the responsibility of DRNSW. The SAP construction or operation will not increase the PFAS mass flux in the area and the SAP construction will facilitate Defence's efforts to the extent practical.
- There are numerous constructability issues with use of a GCL layer and the requisite drainage layers. Differential settlement of the fill material is likely. Differential settlement could lead to localised areas of damage to the GCL, reducing or eliminating its benefits in that area. Deeper foundational piles will be required for the anticipated development due to the poor ground conditions. The GCL cannot accommodate the anticipated diameter of the piles without being damaged. This could lead to multiple, discrete preferential pathways.
- The drainage layers required for the GCL likely would lead to a preferential pathway for any intercepted PFAS impacted groundwater leading to additional volumes of water that require management. This is similar for any stormwater that vertically migrates and would be captured by the upper drainage layer. The volumes of storm/flood water that require management under future scenarios is technically challenging and additional water to manage could make these strategies unfeasible under certain scenarios.
- Addition of PAC into the fill material would tend to preferentially remove PFAS from the groundwater. The PAC would tend to store relatively high concentrations of PFAS which would create a secondary source that could not be accessed. At some point in the future, the PAC will no longer be effective. Once the development platforms are constructed, it will not be possible to replace the PAC.
- To the extent practical, careful selection of fill material and its physical and chemical properties could minimise the potential for PFAS to sorb to soil. Even if measurable concentrations of PFAS sorb to soil, they would not be above the industrial/commercial Tier I screening level concentrations. If PFAS sorbs to soil and does leach downward, the PFAS would leach back to already impacted groundwater which does not increase the PFAS mass flux. Additionally, any PFAS that does sorb to the soil would not be accessible to potential human or ecological receptors. Without a completed pathway, there would not be unacceptable risks to potential receptors.

Stormwater Protection Measures

Similar to protection of the fill material, it is proposed to allow natural conditions to prevail relating to the regional flood management. That is, utilising the proposed constructed berm to capture the stormwater and be released through Dawsons and Learys Drain as is currently happening. To address any potential incidental PFAS in stormwater produced from the development platforms, the constructed wetlands and bioretention basins should be modified. Plant species that are known to uptake PFAS from the dissolved phase should be integrated into the constructed wetlands. Also, PAC should be introduced into or replace the gravel layer in the bioretention basins. Monitoring results over the past several years have shown a reduction in PFAS mass flux in stormwater with some conflicting trends. It is expected a declining mass flux trend would continue as Defence's remedial efforts continue into the future. The primary reasons to adopt these mitigation measures include:

- The measured PFAS concentrations in stormwater are derived from on-Base PFAS concentrations and are not the responsibility of DRNSW.
- PFAS impacted stormwater is currently moving through the system with no treatment. Downstream monitoring results indicate PFAS is below limits of reporting (LOR s). The construction of the stormwater/flood mitigation earthen berm is not anticipated to increase the PFAS mass flux in the system.
- It is highly unlikely that the construction or operation of the SAP would lead to additional PFAS mass flux in stormwater as the SAP will be constructed two to three metres above the current grade. All stormwater captured will be from the elevated construction platforms that would not interact with PFAS impacted environmental media.
- Introduction of passive treatment throughout the stormwater/flood conveyance system would reduce flow velocities leading to significant volumes of water requiring storage for longer periods of time. Under less frequent storm events, this could render the stormwater management strategies unfeasible.
- Modification of the constructed wetlands and bioretention basins would not introduce additional constructability conditions or introduce significant costs.

Maintenance requirements for these strategies include:

- Periodic harvesting of plant foliage and destruction to limit the potential that terrestrial fauna would consume foliage with PFAS. Destruction may include thermal treatment or off-site disposal.
- The PAC in the bioretention basin will need to be periodically replaced. The replacement frequency is difficult to estimate but we have assumed every two years as a conservative measure.
- Under this strategy, the wetlands and bioretention basins would become licenced discharge points under the requirements of an Environmental Protection Licence (EPL). Routine monitoring and reporting will be required in the future to demonstrate compliance with any EPL requirements.

An adaptive management approach is appropriate to augment the preferred fill protection and stormwater mitigation measures. Adaptive management would consider if mitigation measures were required based on the environmental conditions when the SAP construction commences. Construction of the SAP will not commence for several years, and current economic forecasts suggest it will be approximately a decade until the entire SAP development is completed. The ongoing and proposed remedial efforts by Defence would lead to reduced PFAS mass flux in groundwater and surface/stormwater over time. While it is unlikely that mitigation measures would be required, the adaptive management can consider the options discussed in this memorandum and/or new technologies available when SAP construction commences.

6.1.5 Next Steps

These considerations will continue to be integrated into the next stages of design and form a basis of discussions with the NSW EPA and PFAS Technical Advisory Group (TAG) as a primary stakeholder in the decision on a final strategy/ies. Discussions with Defence are ongoing to gain more details on the remediation system design and operation and how this can be facilitated by the SAP construction.

As discussed above, the construction of the earthen bund will require a clay core or similar which will penetrate into the top of the groundwater table. This will have localised effects on groundwater flow and additional consideration/modelling of groundwater intercepted by the earthen bund is required. This includes geotechnical considerations, waste management and if any intercepted water requires capture and treatment. This is a relatively new issue that has arisen as the concept design has progressed with the proposed construction of the earthen bund.

6.1.6 Non PFAS Contamination Mitigation

The review of the available background information has identified numerous Areas of Potential Environmental Concern (APECs) throughout the SAP area where non-PFAS Contaminants of Potential Concern (COPCs) may be present at concentrations above the applicable Tier I screening values. There are several within the structure plan boundary. However, specific reports related to investigation of these areas have not been reviewed so specific concentrations of COPCs in environmental media are not known at these sites is not known at this time. The constraints rating has been based on the land use at the APEC and Aurecon's experience with previous similar projects. Therefore, the constraints analysis for the non-PFAS APECs is qualitative and can be refined when environmental media samples and analysed to determine if COPCs are present most likely during concept or detailed design.

Specific mitigation measures cannot be developed without additional information on the APECs and environmental media analytical data. Investigation of soil and / or groundwater should be undertaken as part of, or prior to, concept design in order to confirm the extent and significance of non-PFAS contamination in the identified APECs. The data collected will inform likelihood of remediation required under the SEPP 55 process, inform potential design constraints, risks to human and ecological receptors as well as establishing a preliminary waste classification of the excavated soils.

7 Conclusions

7.1 PFAS Mitigation

This report has provided a review of the structure plan for the Williamtown SAP. Baseline information pertinent to the SAP was reviewed and refined based on the preliminary scenarios. Several mitigation measures have been proposed that could be employed to minimise the potential that PFAS are mobilised during construction and operation of the Williamtown SAP.

An evaluation process of the various mitigation measures was undertaken, and two measures were identified as being most feasible to mitigate the potential risks of PFAS impacting imported fill material.

Overall, the construction and operation of the Williamtown SAP is not expected to increase the PFAS mass flux moving in groundwater or stormwater nor create a significant secondary source. The initial stages of the development will focus on the NAPL land just south of the airport, some of which is ready for development (**Figure 5-2**) with an overall 40-year masterplan. Defence will continue to undertake on and off-Base remedial efforts during this timeframe. It is expected that reductions in the PFAS mass flux will result from these remedial efforts. The reduced mass flux from Defence's remedial efforts and the staged construction further reduces the future potential for PFAS mobilisation by SAP construction or operation. The staged construction also means excessively large areas will not be disturbed at any one time making it easier to manage risks during construction.

The future land use of the SAP will be light industrial/commercial and be constructed on platforms several metres above the existing grade. Services will be constructed in the elevated platforms and not interact with contaminated soil or groundwater. Water and sewer will be reticulated supply. The elevated platforms also provide a significant separation between workers/visitors and the underlying PFAS groundwater plume.

Any stormwater that is captured from future roofs, hardstands, roads, etc will be captured and routed to constructed wetlands and bioretention system for treatment and discharge. No PFAS is expected in this stormwater but the wetland/bioretention systems can easily facilitate means to remove any incidental PFAS that may occur. No additional volumes of regional stormwater would be produced than currently moves through the system. It will be diverted through a constructed berm/retention system that utilises existing Dawsons and Leary's Drain as is currently occurring.

All these factors indicate that there is a low to negligible risk to human health for future SAP users. Likewise, the platforms would prevent terrestrial fauna from interacting with groundwater plume. The platforms would not significantly alter the groundwater flow regime so the risk to downgradient ecological receptors is not increased by the construction or operation of the SAP.

Based on the information detailed in **Table F-1 Appendix F**, the preferred option to mitigate the risks for the fill material is to allow groundwater to fluctuate naturally into the imported fill material. Like protection of the fill material, it is proposed to allow natural conditions to prevail relating to the regional flood management. That is, utilising the proposed constructed berm to capture the stormwater and be released through Dawsons and Learys Drain as is currently happening. To address any potential incidental PFAS in stormwater produced from the development platforms, the constructed wetlands and bioretention basins should be modified. Plant species that are known to uptake PFAS from the dissolved phase should be integrated into the constructed wetlands. Also, PAC should be introduced into or replace the gravel layer in the bioretention basins. Monitoring results over the past several years have shown a reduction in PFAS mass flux in stormwater with some conflicting trends. It is expected a declining mass flux trend would continue as Defence's remedial efforts continue into the future.

Maintenance requirements for these strategies include:

- Periodic harvesting of plant foliage and destruction to limit the potential that terrestrial fauna would consume foliage with PFAS. Destruction may include thermal treatment or off-site disposal.

- The PAC in the bioretention basin will need to be periodically replaced. The replacement frequency is difficult to estimate but we have assumed every two years as a conservative measure.
- Under this strategy, the wetlands and bioretention basins would become licenced discharge points under the requirements of an Environmental Protection Licence (EPL). Routine monitoring and reporting will be required in the future to demonstrate compliance with any EPL requirements.

An adaptive management approach is appropriate to augment the preferred fill protection and stormwater mitigation measures. Adaptive management would consider if mitigation measures were required based on the environmental conditions when SAP construction commences. The master planning timeframe is 40 years. The ongoing and proposed remedial efforts by Defence would lead to reduced PFAS mass flux in groundwater and surface/stormwater over time. While it is unlikely that mitigation measures would be required, the adaptive management can consider the options discussed in this memorandum and/or new technologies available when SAP construction commences.

7.2 Non-PFAS mitigation

The review of the available background information has identified numerous Areas of Potential Environmental Concern (APECs) throughout the SAP area where non-PFAS Contaminants of Potential Concern (COPCs) may be present at concentrations above the applicable Tier I screening values. There are several within the structure plan boundary. However, specific reports related to investigation of these areas have not been reviewed so specific concentrations of COPCs in environmental media are not known at these sites is not known at this time. The constraints rating has been based on the land use at the APEC and Aurecon's experience with previous similar projects. Therefore, the constraints analysis for the non-PFAS APECs is qualitative and can be refined when environmental media samples and analysed to determine if COPCs are present.

Specific mitigation measures cannot be developed without additional information on the APECs and environmental media analytical data. Investigation of soil and / or groundwater should be undertaken as part of, or prior to, concept design in order to confirm the extent and significance of non-PFAS contamination in the identified APECs. The data collected will inform likelihood of remediation required under the SEPP 55 process, inform potential design constraints, risks to human and ecological receptors as well as establishing a preliminary waste classification of the excavated soils.

8 References

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Appendix A
Figures

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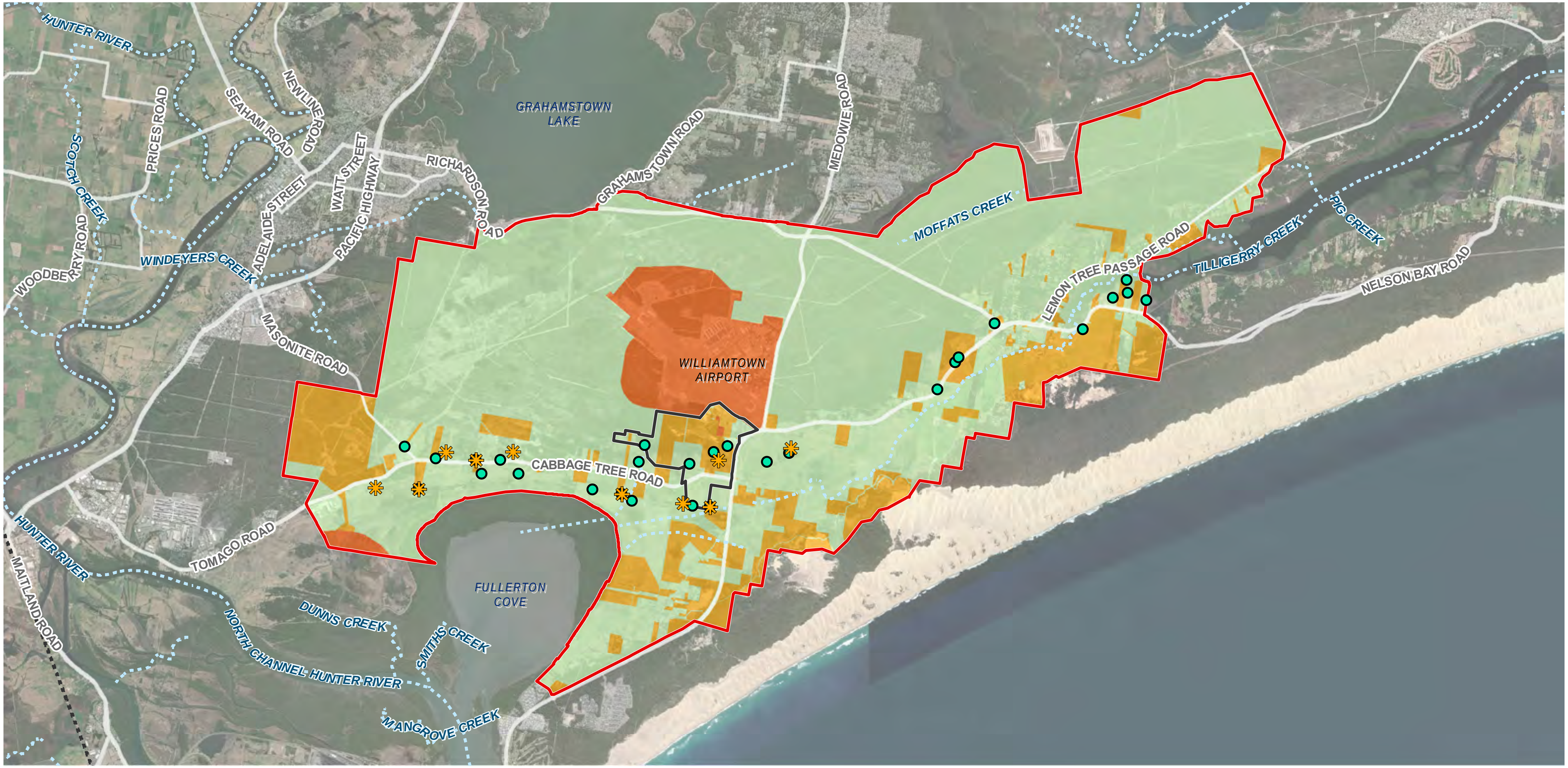
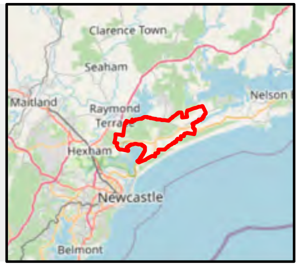


Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Waterway
Railway
Wetland locations
Flooding retention basins

Non-PFAS Contamination Constraints

	Highly constrained	*High likelihood of encountering non-PFAS contamination at concentrations that may require additional assessment, remediation or management*
	Moderately constrained	*Moderate likelihood of encountering non-PFAS contamination at concentrations in some areas of the Scenario boundary that may require additional assessment, remediation or management*
	Minimally constrained	*Low likelihood of encountering non-PFAS contamination at concentrations that may require additional assessment, remediation or management or limited/isolated areas where non-PFAS contamination may require assessment, remediation or management*



Source: Aurecon, TfNSW, NSW Spatial Services, DPE, EPA, Port Stephens Council, Esri

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Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Groundwater**

FIGURE 1: Non-PFAS Contamination Constraints Map

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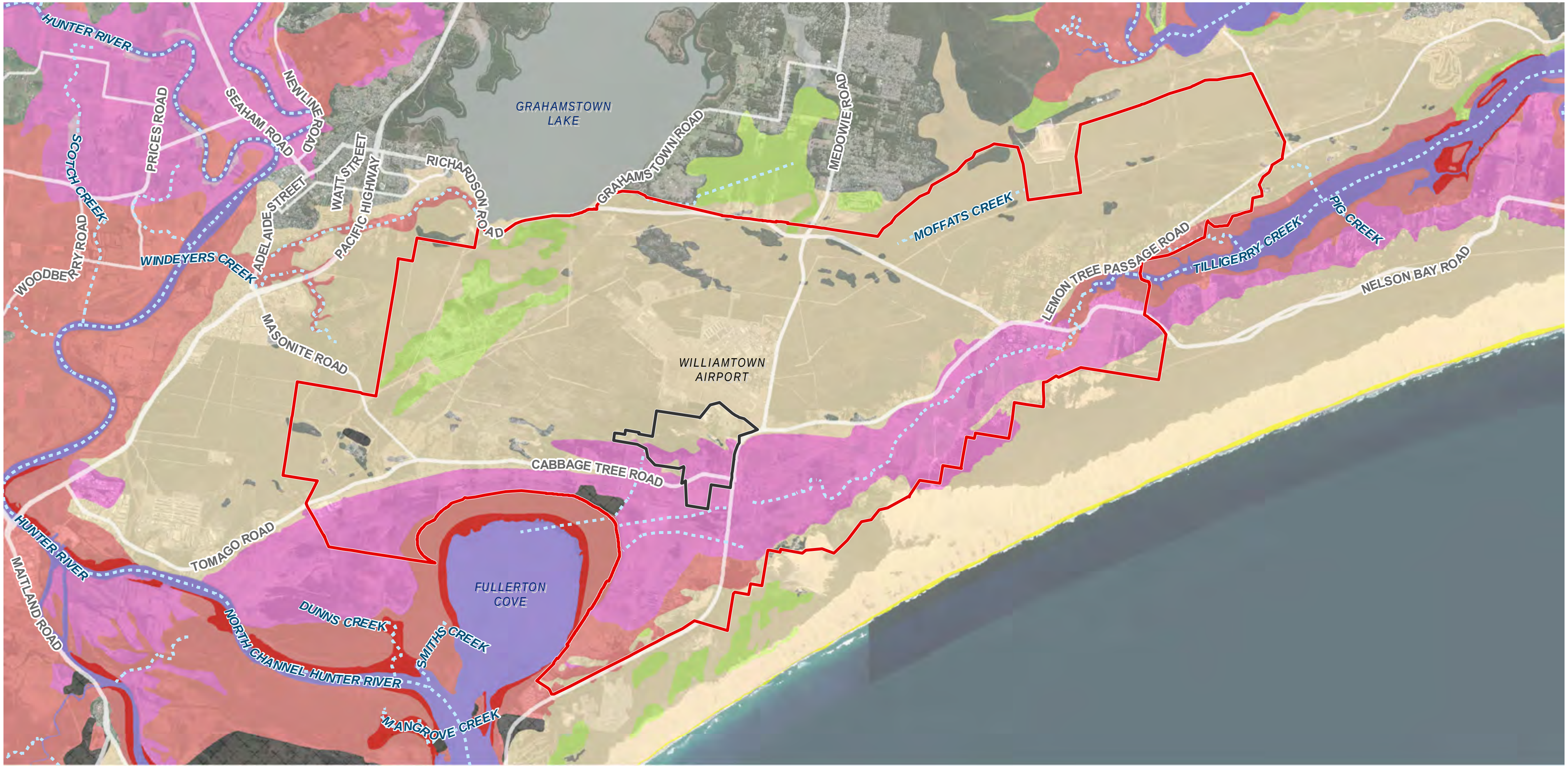

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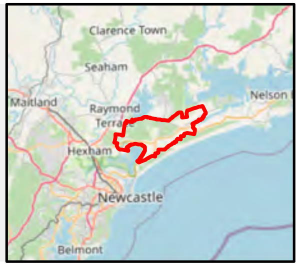
Williamtown Study Area
Williamtown SAP Structure Plan Boundary
Waterway
Railway

Acid Sulfate Soil Risk

High Risk 0-1m
High Risk 1-2m
High Risk 2-4m
High Risk above 4m
High Risk Sediments
Low Risk 2-4m
Low Risk above 4m
No Risk
Disturbed Terrain
Beach



Source: Aurecon, TfNSW, NSW Spatial Services, DPE, Esri

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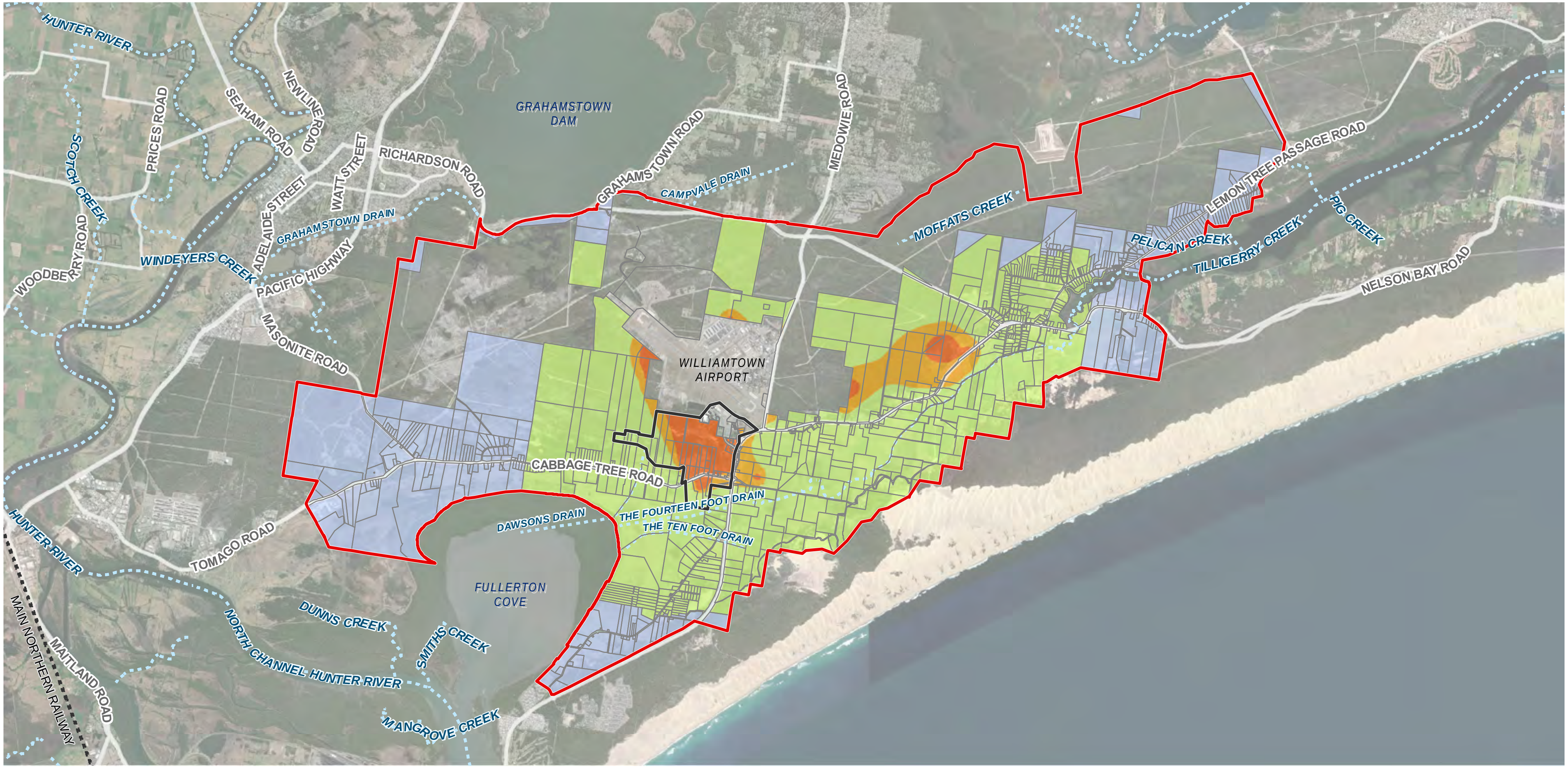
Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Groundwater**

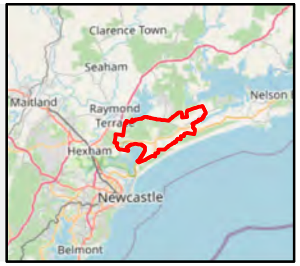
FIGURE 2: Acid Sulfate Soils



- Williamtown Study Area
- Williamtown SAP Structure Plan Boundary
- Waterway
- Railway

PFAS Constraints

Highly constrained	*High likelihood of encountering PFAS contamination at concentrations that may require additional assessment, remediation or management*
Moderately constrained	*Moderate likelihood of encountering PFAS contamination at concentrations in some areas of the Scenario boundary that may require additional assessment, remediation or management*
Minimally constrained	*Low likelihood of encountering PFAS contamination at concentrations that may require additional assessment, remediation or management or limited/isolated areas where non-PFAS contamination may require assessment, remediation or management*
Negligible	*No PFAS identified within the Scenario Boundary or could migrate to the scenario in any environmental media*



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Source: Aurecon, TfNSW, EPA, NSW Spatial Services, Esri

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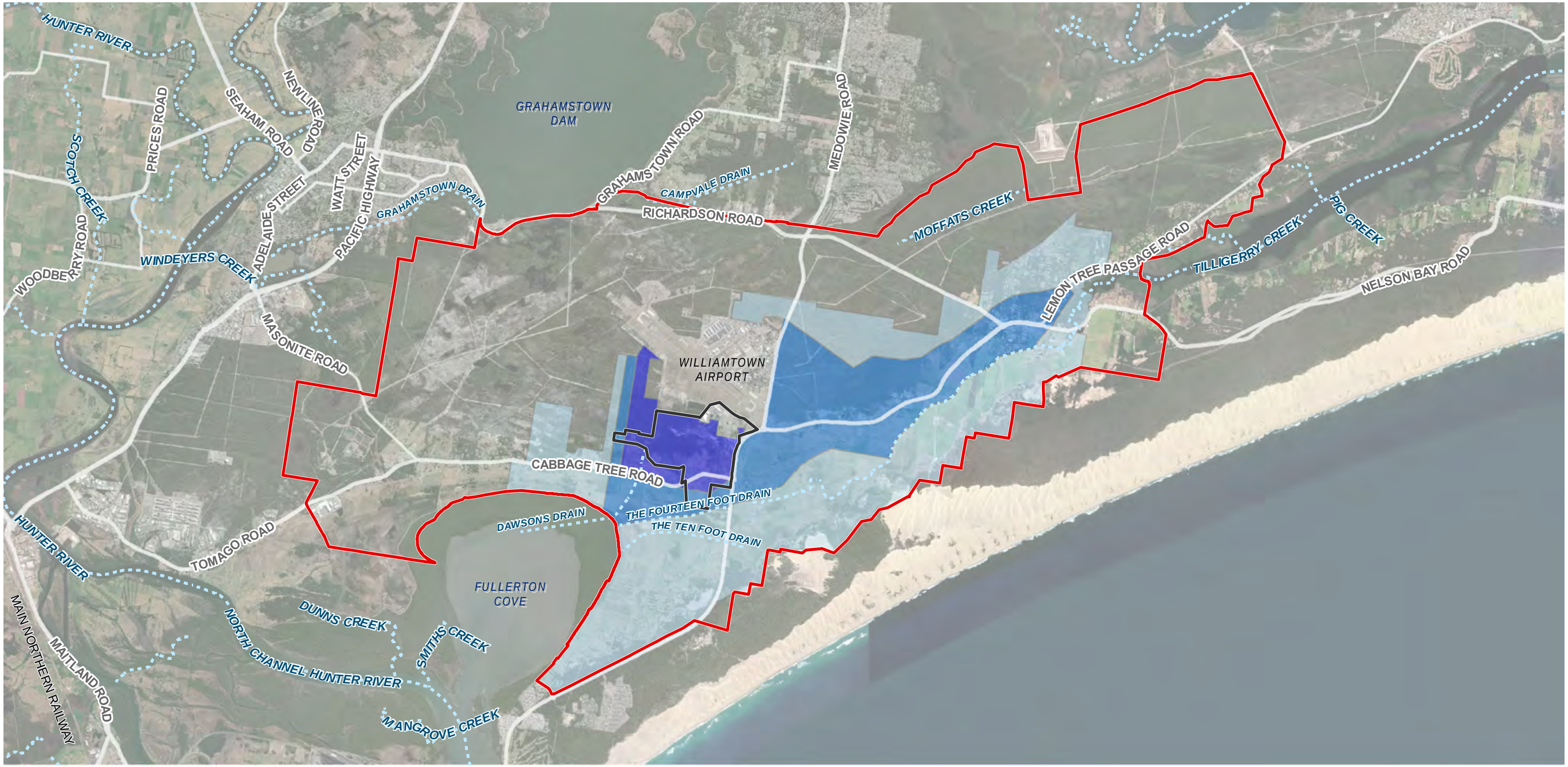
Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Groundwater**

FIGURE 3: PFAS Groundwater Constraints



Williamtown Study Area

Williamtown SAP Structure Plan Boundary

Waterway

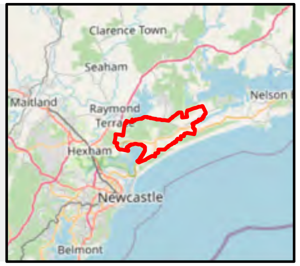
Railway

NSW EPA PFAS Management Area

Primary Management Zone

Secondary Management Zone

Broader Management Zone



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Source: Aurecon, TfNSW, EPA, NSW Spatial Services, Esri

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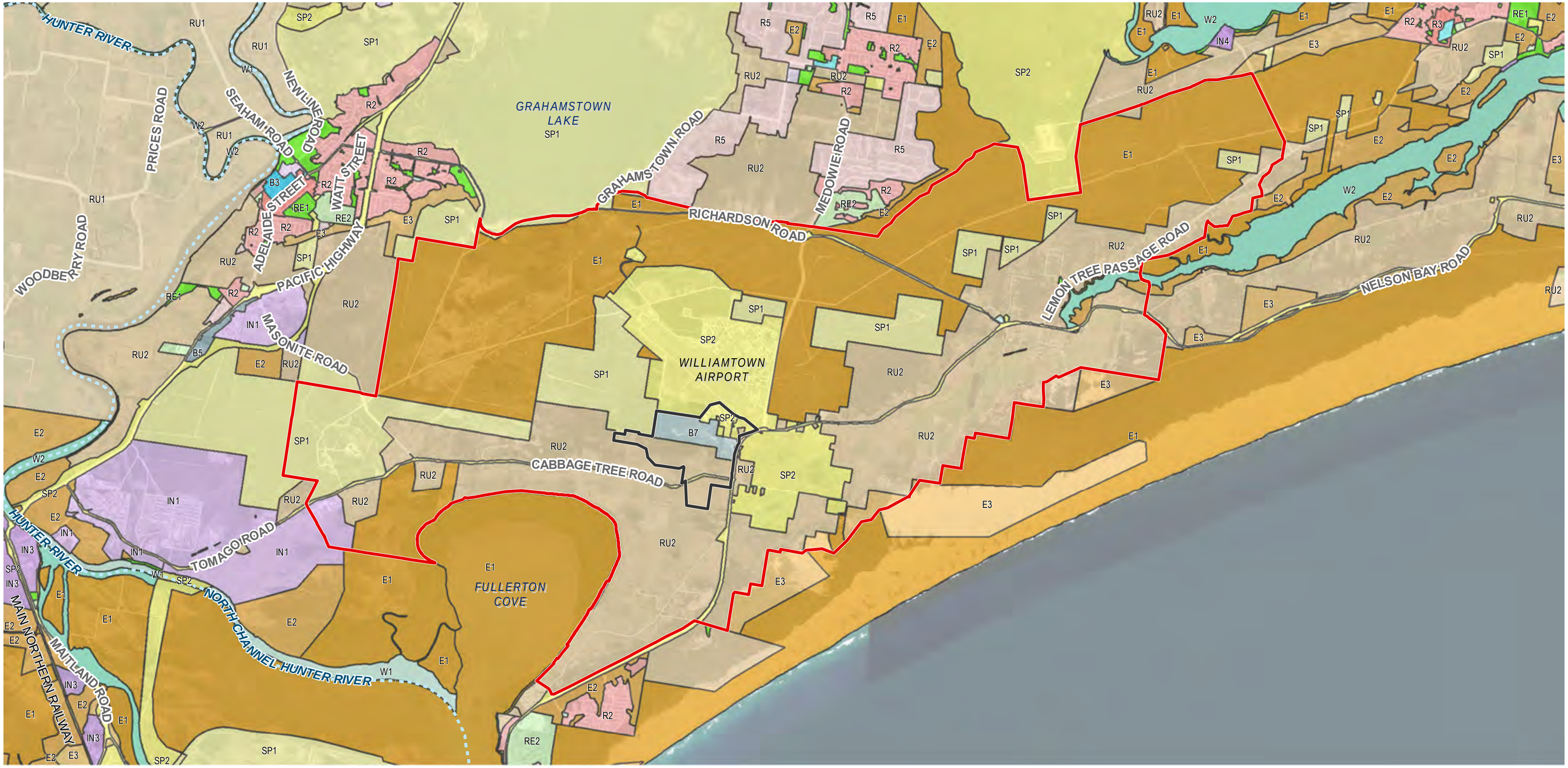
0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Groundwater**

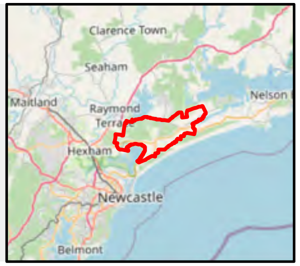
FIGURE 4: PFAS Management Area



- Williamtown Study Area
- Williamtown SAP Structure Plan Boundary
- River

Land Zoning

- B1 Neighbourhood Centre
- B2 Local Centre
- B3 Commercial Core
- B5 Business Development
- B7 Business Park
- E1 National Parks and Nature Reserves
- E2 Environmental Conservation
- E3 Environmental Management
- IN1 General Industrial
- IN2 Light Industrial
- IN3 Heavy Industrial
- IN4 Working Waterfront
- R1 General Residential
- R2 Low Density Residential
- R3 Medium Density Residential
- R5 Large Lot Residential
- RE1 Public Recreation
- RE2 Private Recreation
- RU1 Primary Production
- RU2 Rural Landscape
- SP1 Special Activities
- SP2 Infrastructure
- W1 Natural Waterways
- W2 Recreational Waterways



Source: Aurecon, TfNSW, NSW Spatial Services, Esri

1:120,000 @ A4

0 2 4km

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Groundwater**

FIGURE 5: Land zoning

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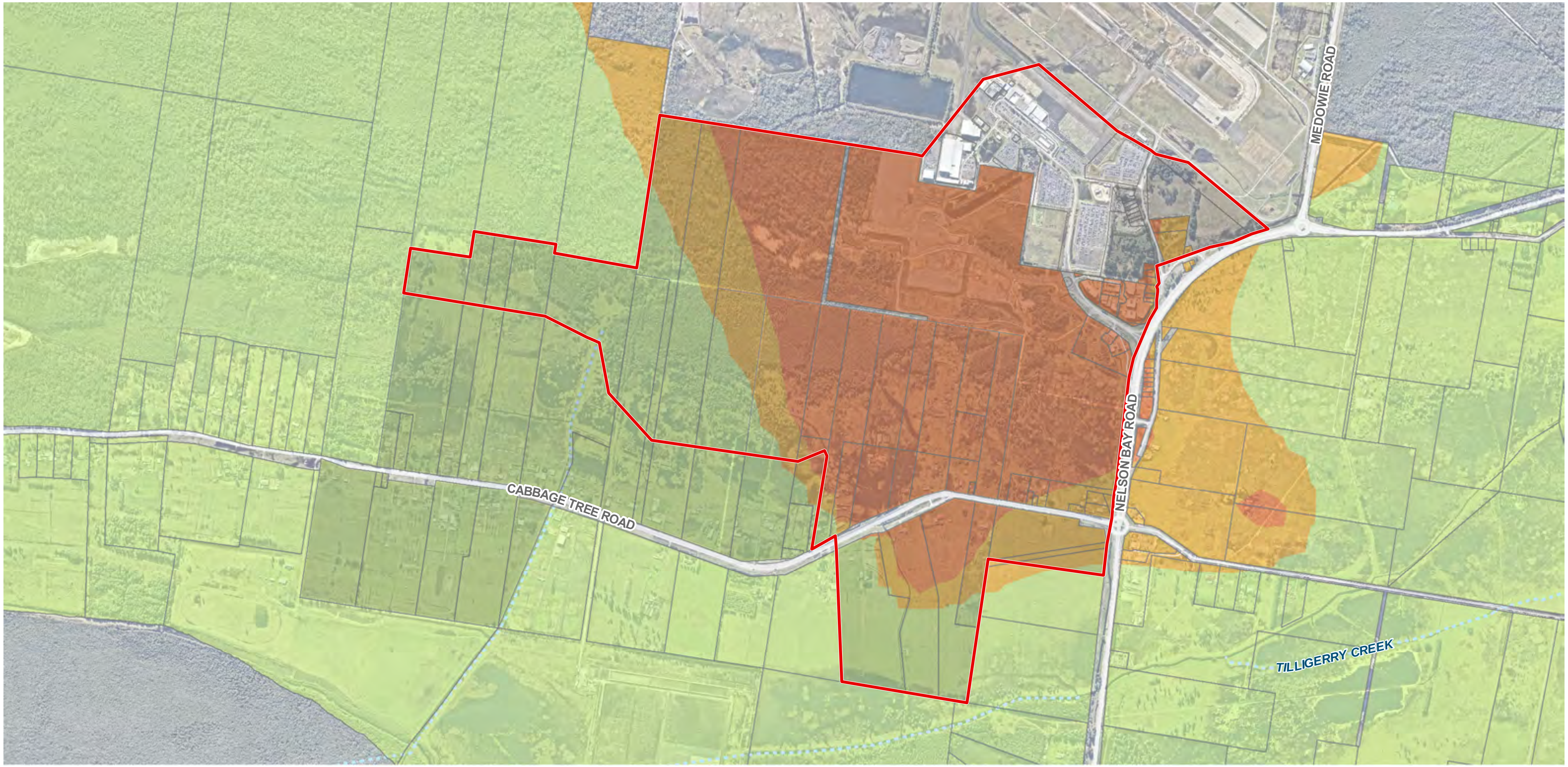

Williamtown SAP Structure Plan Boundary

Waterway

PFAS Constraints

	Highly constrained	*High likelihood of encountering PFAS contamination at concentrations that may require additional assessment, remediation or management*
	Moderately constrained	*Moderate likelihood of encountering PFAS contamination at concentrations in some areas of the Scenario boundary that may require additional assessment, remediation or management*
	Minimally constrained	*Low likelihood of encountering PFAS contamination at concentrations that may require additional assessment, remediation or management or limited/isolated areas where non-PFAS contamination may require assessment, remediation or management*
	Negligible	*No PFAS identified within the Scenario Boundary or could migrate to the scenario in any environmental media*

Source: Aurecon, TfNSW, EPA, NSW Spatial Services, Aerometrex, Esri

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0 200 400 m

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Groundwater**

FIGURE 6: PFAS Groudwater Constraints | Structure Plan

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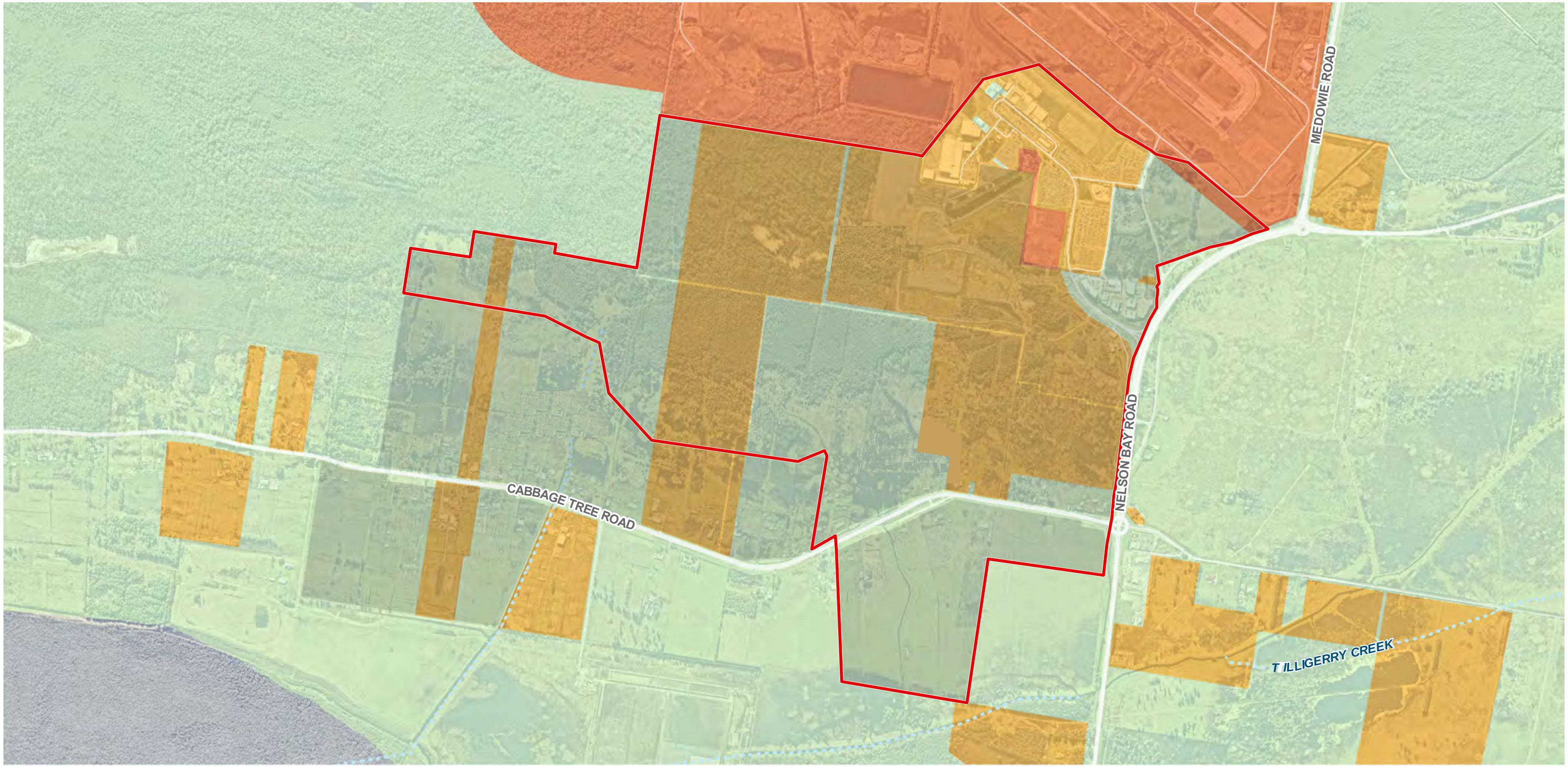

Williamtown SAP Structure Plan Boundary
Waterway

Non-PFAS Contamination Constraints

Highly constrained	*High likelihood of encountering non-PFAS contamination at concentrations that may require additional assessment, remediation or management*	
Moderately constrained	*Moderate likelihood of encountering non-PFAS contamination at concentrations in some areas of the Scenario boundary that may require additional assessment, remediation or management*	
Minimally constrained	*Low likelihood of encountering non-PFAS contamination at concentrations that may require additional assessment, remediation or management or limited/isolated areas where non-PFAS contamination may require assessment, remediation or management*	

Source: Aurecon, TfNSW, NSW Spatial Services, DPE, EPA, Port Stephens Council, Aerometrex, Esri

1:20,000 @ A4

0 200 400 m

Projection: GDA 1994 MGA Zone 56

Williamtown SAP **Groundwater**

FIGURE 7: PFAS Groundwater Constraints

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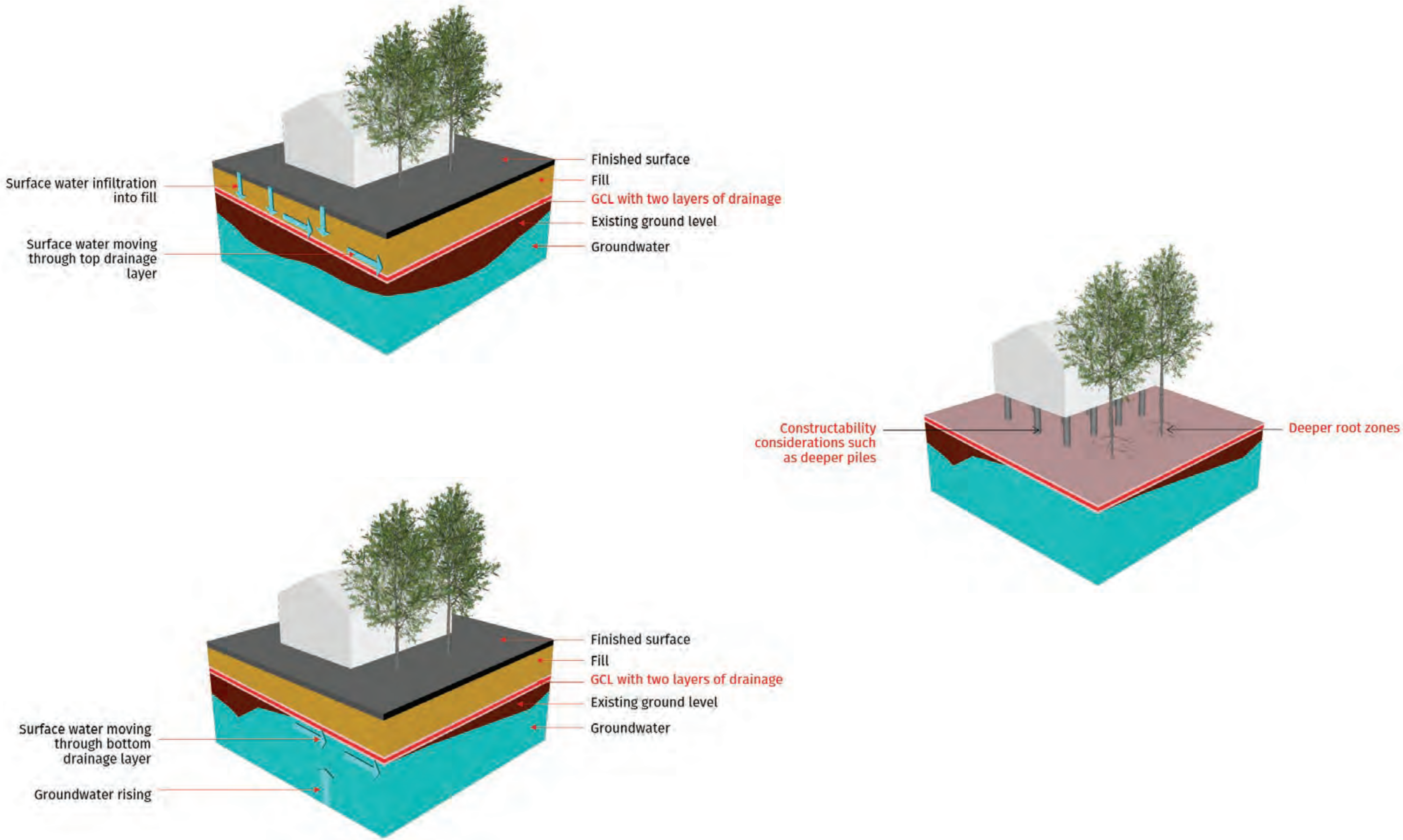

Figure 8: SAP development platform with GCL

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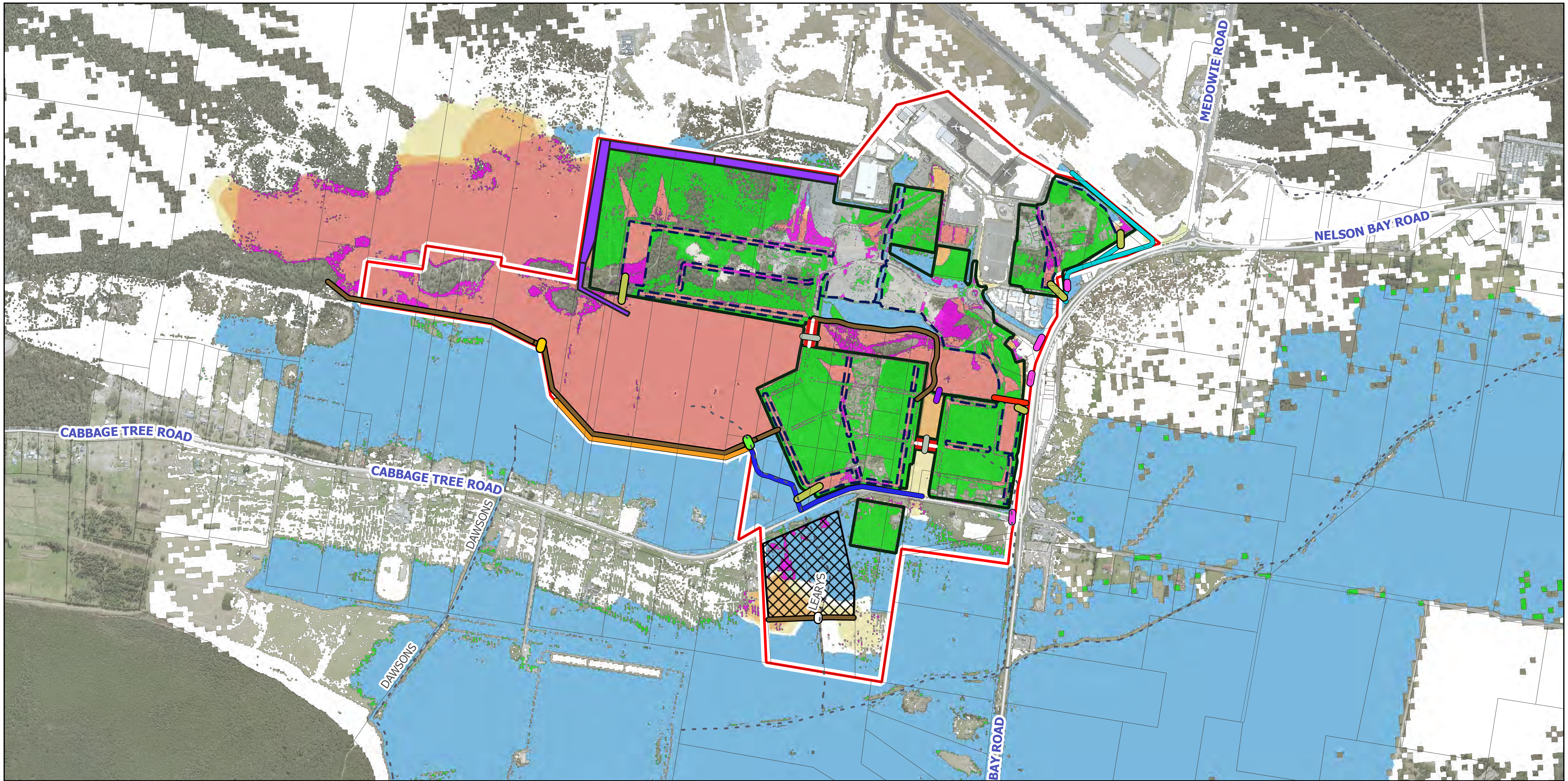

- Williamtown SAP Structure Plan Boundary
- Bulk filled extent
- Major waterway
- Lot
- Astra basin major outlet
- Astra basin minr outlet
- Secondary road culverts
- Table drain additional culverts
- Dawsons drain psuedo detention basin outlet
- Learys drain psuedo detention basin outlet
- Wetland outlet
- Offset flood storage outlet
- North-west cut-off drain
- Access road
- Earth bund
- North-east cut-off drain
- Minor drainage works
- Regrading The Existing Drain
- Channels
- Offset flood storage area

Flood Impact (m)

- <= -0.01
- -0.01 - 0.01
- 0.01 - 0.04
- 0.04 - 0.1
- > 0.1
- Was Wet Now Dry
- Was Dry Now Wet

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0 600 1200 m

A3 Scale: 1:15000

Projecion: GDA 1994 MGA Zone 56

Williamtown SAP

Figure 9: Proposed flood management measures

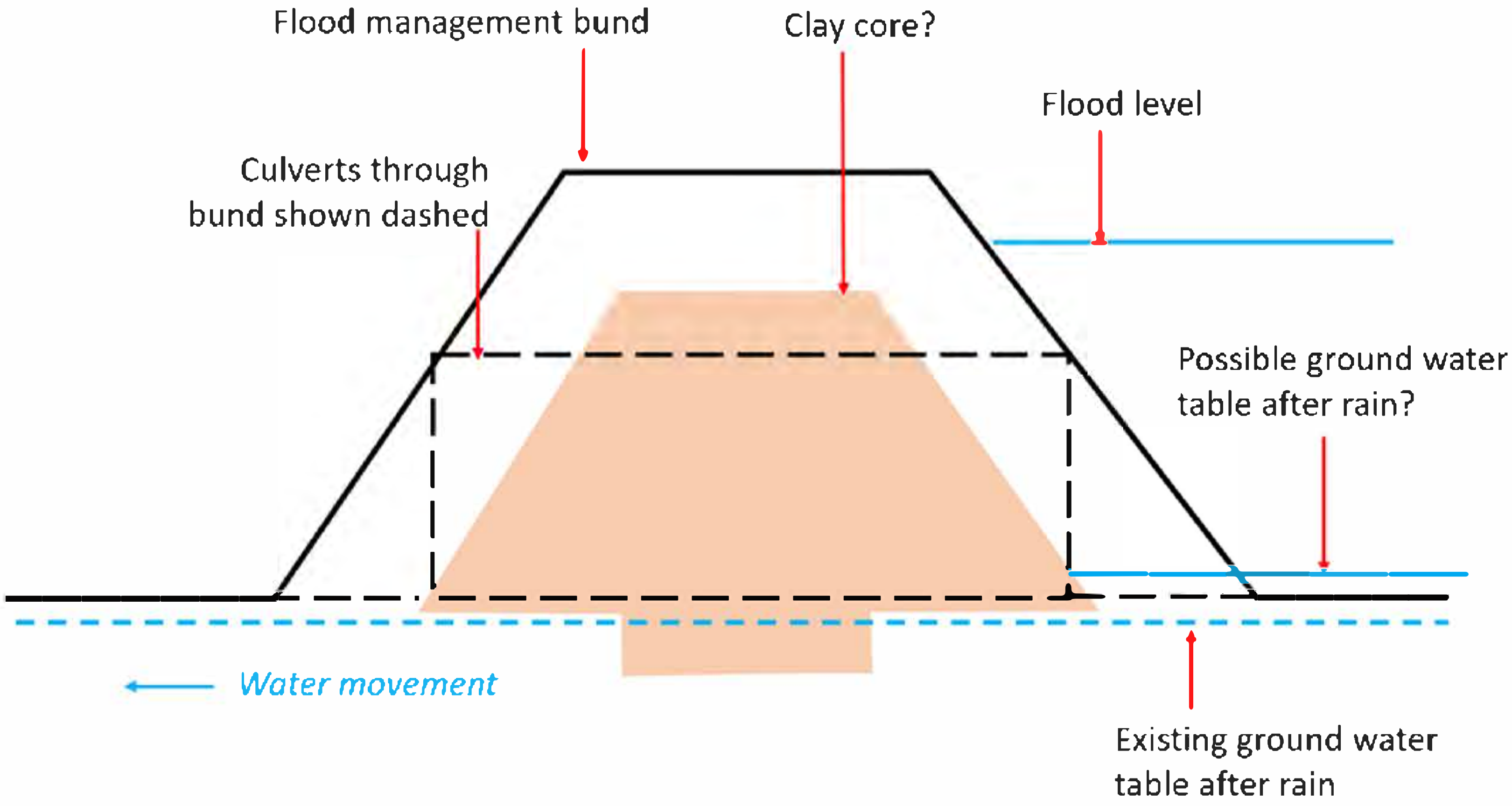

Figure 10: Cross sectional conceptual design of flood retention berm

INTENAL WETLAND AND BIOFILTRATION

NTS

CATCHMENT	W4	W5	W6	W7	W8
CATCHMENT (Ha)	24.14	12.83	38.81	4.05	6.55
IMPERVIOUS FRACTION (%) EXCLUDING PUBLIC OPEN SPACE AND TRUNK DRAINAGE	86%	86%	86%	86%	86%
VEGETATED WETLAND	**W4**	**W5**	**W6**	**W7**	**W8**
INLET ZONE (sq.m)	105	150	470	70	114
MARSH ZONE (sq.m)	1050	1750	4233	688	1768
PERIMETER EDGE (ln.m)	439	554	836	304	432
WETLAND PITS (units)	3	3	5	1	1
BIORETENTION	**W4**	**W5**	**W6**	**W7**	**W8**
NUMBER OF SEPARATE CELLS < 1000 sq.m	3	2	5	1	1
PLANTED FILTER SURFACE AREA (sq.m)	3000	1750	4830	957	710
SLOTTED PIPE NETWORK AT 2m CENTRES (ln.m)	1022	1049	1932	245	283
RISERS WITH FLUSH POINTS (number)	85	87	161	20	24
MAINTENANCE ACCESS TRACKS (ln.m)	841	804	1275	448	539
BIOFILTRATION PITS	3	2	5	1	1

KEY

- 4 EY FLOW VIA RISER
- < 1 EY FLOW VIA PIT (1 IN 1 YEAR)
- > 1 EY UP TO 1% VIA FLODD DETENTION OUTLET

NOTES

1. 0.0mRL=MIN1.6m AHD
2. EDD = EXTEND DETENTION DEPTH
3. NWL = NORMAL WATER LEVEL
4. MAX DEPTH BELOW NWL=600mm
5. AVERAGE DEPTH BELOW NWL=300mm
6. ALL 1:6 BATTERS TO BE TURF
7. CURRENT CERST=MIN 2.2mRL.
8. BIORETENTION CELLS NO GREATER THAN 1000m2
9. SLOTTED PIPES TO BE LAID FLAT AT 2m CENTRES
10. ALL SLOTTED PIPES TO BE FITTED WITH RISERS AND FLUSH POINTS

Plot Date: 2022-12-09 12:01 PM Filename: 521943-WTSAP-DRG-CV-1170.DWG

REFERENCE DRAWINGS

REFERENCE MODELS

REV	DATE	REVISION DETAILS	REV	DRAWN	DESIGNED	VERIFIED	APPROVED
A	2022-12-09	ISSUED FOR 90% CONCEPT DESIGN	A	D. NGUYEN	B. LOLLBACK	A. NADAYAVE	A. LU

All written dimensions take precedence over scaled dimensions.

PREPARED BY: aurecon www.aurecongroup.com

CLIENT: NSW GOVERNMENT Regional NSW

CERTIFICATION | No. | CERTIFIER | DATE

CLIENT DOCUMENT NUMBER | REV

Coordinate system MGA
Height datum AHD

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CONSTRUCTION STATUS: NOT FOR CONSTRUCTION
DRAWN BY: D. NGUYEN
DESIGNED BY: B. LOLLBACK
STATUS: REVISED | CODE: W2
DOCUMENT STATE: WORK IN PROGRESS

PROJECT: WILLIAMTOWN SAP CD AND CE
TITLE: WILLIAMTOWN SAP CONCEPT DESIGN TYPICAL BASIN PLAN & SECTIONS
DOCUMENT CODE: 521943-WTSAP-DRG-CV-1170
SCALE: AS SHOWN | SIZE: A1 | REFERENCE No.: DRG-CV-1170 | REV: A

Appendix B

APECs, PFAS CSAM and Groundwater Elevations

Table B-1 Interim Monitoring Event Report – RAAF Base Williamtown, December 2018

Well ID	Sample ID	Date	Depth to Water (mBTOC)
			mBTOC
MW130D	MW130D_GW_27042018	27/4/2018	1.351
MW260D	0908_MW260D_19112018	19/11/2018	1.730
MW260S	0908_MW260S_19112019	19/11/2018	1.380
MW263D	0908_MW263D_19112020	19/11/2018	0.655
MW263S	0908_MW263S_19112021	19/11/2018	0.650
MW258S	0908_MW258S_19112022	19/11/2018	0.950
MW258D	0908_MW258D_19112023	19/11/2018	0.960
MS257D	0908_MW257D_19112024	19/11/2018	1.210
MW257S	0908_MW257S_19112025	19/11/2018	1.110
MW256D	0908_MW256D_19112026	19/11/2018	0.943
MW118	0908_MW118_19112027	19/11/2018	0.550
MW188S	0908_MW188S_20112018	19/11/2018	0.660
MW188D	0908_MW188D_20112018	20/11/2018	0.574
MW125D	0908_MW125D_20112018	20/11/2018	1.478
MW125S	0908_MW125S_20112018	20/11/2018	1.514
MW146D_A	0908_MW146D_A_20112018	20/11/2018	1.015
MW146S	0908_MW146S_20112018	20/11/2018	1.165
MW126D	0908_MW126D_20112018	20/11/2018	1.160
MW256S	0908_MW256S_20112018	20/11/2018	0.958
MW162D	0908_MW162D_20112018	20/11/2018	2.080
MW121	0908_MW121_20112018	20/11/2018	0.569
MW123	0908_MW123_20112018	20/11/2018	1.120
MW255D	0908_MW255D_20112018	20/11/2018	1.325
MW255S	0908_MW255S_20112018	20/11/2018	1.300
MW130S	0908_MW130S_21112018	21/11/2018	0.843
MW106S	0908_MW1606S_21112018	21/11/2018	1.506
MW106D	0908_MW106D_21112018	21/11/2018	1.503
MW209S	0908_MW209S_21112018	21/11/2018	1.088
MW209D	0908_MW209D_21112018	21/11/2018	1.157
W6	0908_W6_21112018	21/11/2018	1.955
W33	0908_W33_21112018	21/11/2018	1.379

MW156D	0908_MW156D_21112018	21/11/2018	1.772
MW124	0908_MW124_21112018	21/11/2018	1.224
MW159D	0908_MW159D_21112018	21/11/2018	2.070
MW159S	0908_MW159S_21112018	21/11/2018	1.800
MW160	0908_MW160_21112018	21/11/2018	1.515
MW155	0908_MW155_21112018	21/11/2018	1.155
MW165	0908_MW165_21112018	21/11/2018	1.141
MW122	0908_MW122_21112018	21/11/2018	1.340
MW162S	0908_MW162S_21112018	21/11/2018	1.940
MW179D	0908_MW179D_22112018	22/11/2018	1.093
MW171S	0908_MW171S_22112018	22/11/2018	0.549
MW281S	0908_MW281S_22112018	22/11/2018	0.989
MW240D	0908_MW240D_22112018	22/11/2018	1.326
MW179S	0908_MW179S_22112018	22/11/2018	1.063
MW202S	0908_MW202S_22112018	22/11/2018	1.150
MW202D	0908_MW202D_22112018	22/11/2018	1.120
MW171D	0908_MW171D_22112018	22/11/2018	0.505
MW240S	0908_MW240S_22112018	22/11/2018	1.233
MW279S	0908_MW279S_26112018	26/112018	1.460
MW128	0908_MW128_26112018	26/11/2018	1.290
MW126S	0908_MW126S_26112018	26/11/2018	1.282
MW178	0908_MW178_26112018	26/11/2018	1.122
MW212	0908_MW212_26112018	26/11/2018	1.702
MW163	0908_MW163_26112018	26/11/2018	1.450
MW128D	0908_MW128D_26112018	26/11/2018	0.670
MW103D	0908_MW103D_27112018	27/11/2018	0.905
MW103S	0908_MW103S_27112018	27/11/2018	1.055
MW107S	0908_MW107S_27112018	27/11/2018	0.490
MW107D	0908_MW107D_27112018	27/11/2018	0.535
MW241S	0908_MW241S_27112018	27/11/2018	1.515
MW241D	0908_MW241D_27112018	27/11/2018	1.461
MW195	0908_MW195_27112018	27/11/2018	0.502
MW132D	0908_MW132D_27112018	27/11/2018	2.805
MW132S	0908_MW132S_27112018	27/11/2018	2.820
MW130D	0908_MW130D_27112018	27/11/2018	0.962

Well ID	Sample ID	Date	Depth to Water (mBTOC) mBTOC
MW266S	M0908_MW266S_28112018	28/11/2018	0.470
MW139	0908_MW139_28112018	28/11/2018	0.622
MW271S	0908_MW271S_28112018	28/11/2018	0.615
MW187S	0908_MW187S_28112018	28/11/2018	0.272
MW266D	0908_MW266D_28112018	28/11/2018	0.340
MW271D	0908_MW271D_28112018	28/11/2018	0.645
MW274D	0908_MW274D_28112018	28/11/2018	0.499
MW219S	0908_MW219S_28112018	28/11/2018	0.729
MW223S	0908_MW233S_28112018	28/11/2018	0.878
MW238D	0908_MW238D_28112018	28/11/2018	0.984

MW274S	0908_MW274S_28112018	28/11/2018	0.620
MW225D	0908_MW225D_28112018	28/11/2018	0.360
MW238S	0908_MW238S_28112018	28/11/2018	1.075
MW219D	0908_MW219D_28112018	28/11/2018	0.810
MW187D	0908_MW187D_28112018	28/11/2018	0.285
MW172	0908_MW172_29112018	29/11/2018	0.000
W68	0908_W68_29112018	29/11/2018	0.832
N66	0908_N66_29112018	29/11/2018	1.285
MW175D	0908_MW175D_29112018	29/11/2019	0.960
MW108S	0908_MW108S_29112018	29/11/2019	0.180
MW108D	0908_MW108D_29112018	29/11/2018	0.239
MW168	0908_MW168_29112018	29/11/2018	1.365
MW166	0908_MW166_29112018	29/11/2018	1.350
MW167	0908_MW167_29112018	29/11/2018	2.290
MW236D	0908_MW236D_30112018	30/11/2018	1.080
MW198	0908_MW198_30112018	30/11/2018	1.080
MW196	0908_MW196_30112018	30/11/2018	0.860
MW134I	0908_MW134I_30112018	30/11/2018	2.110
MW134D	0908_MW134D_30112018	30/11/2018	2.170
MW137	0908_MW137_0412018	4/12/2018	1.030
MW140	0908_MW140_04122018	4/12/2018	0.910
MW265D	0908_MW256D_04122018	4/12/2018	0.895
MW229S	0908_MW229S_06122018	6/12/2018	1.095
MW229D	0908_MW229D_06122018	6/12/2018	1.270
MW257D	0908_MW257D_06122018	6/12/2018	1.160
PS9 - Bore 30	0908_PS9(30)_181206	5/12/2018	2.115
PS9(i)	0908_PS9(i)_181206	6/12/2018	1.550
PS59	0908_PS59_181207	6/12/2018	0.100
MW276D	0908_MW276D_06122018	6/12/2018	0.440
MW232D	0908_MW232D_06122018	6/12/2018	1.080
MW232S	0908_MW232S_06122018	6/12/2018	1.130
MW267D	0908_MW267D_07122018	7/12/2018	1.150
MW267S	0908_MW267S_07122018	7/12/2018	1.160
MW235D	0908_MW235D_07122018	7/12/2018	0.260
MW265S	0908_MW235S_07122018	7/12/2018	0.390

Table B-2 Monitoring Wells within the Structure Plan study area (south and south east of RAAF BASE Williamtown)

Monitoring Well ID (PFOS ug/L)	Location	Date Sampled	Groundwater Level (mBTOC)
MW167 (372)	North	29/11/2018	2.290
MW103D (0.03)	North	27/11/2018	0.905
MW103S (<0.01)	North	27/11/2018	1.055
MW240D (<0.01)	North	22/11/2018	1.326
MW240S (0.02)	North	22/11/2018	1.233
MW107D (<0.01)	Centre (North)	27/11/2018	0.535
MW107S (<0.01)	Centre (North)	27/11/2018	0.490
MW108D (<0.01)	Centre (North)	29/11/2018	0.239
MW108S (0.07)	Centre (North)	29/11/2019	0.180
MW175D (4.43)	Centre (North)	29/11/2019	0.960
W66 (14.8)	Centre (North)	-	-
W68 (15.7)	Centre (North to North East)	29/11/2018	0.832
MW238D (<0.01)	Centre (West)	28/11/2018	0.984
MW238S (<0.01)	Centre (West)	28/11/2018	1.075
MW187D (19.4)	Centre (East)	28/11/2018	0.285
MW187S (148)	Centre (East)	28/11/2018	0.272
MW139 (<0.01)	West (near boundary)	28/11/2018	0.622
MW178 (<0.01)	Centre (South)	26/11/2018	1.122
MW271S (<0.01)	Centre (South)	28/11/2018	0.615
MW271D (<0.01)	Centre (South)	28/11/2018	0.645
MW274D (0.02)	Centre (South East)	28/11/2018	0.499
MW274S (67.6)	Centre (South East)	28/11/2018	0.620
MW140 (<0.01)	South West (Cabbage Tree Road)	4/12/2018	0.910
MW124 (<0.01)	South West (Cabbage Tree Road)	21/11/2018	1.224
MW125D (<0.01)	South (Cabbage Tree Road)	20/11/2018	1.478
MW125S (<0.01)	South (Cabbage Tree Road)	20/11/2018	1.514
MW229D (<0.01)	South (Cabbage Tree Road)	6/12/2018	1.270
MW229S (<0.01)	South (Cabbage Tree Road)	6/12/2018	1.095
MW146S (<0.01)	South (Cabbage Tree Road)	20/11/2018	1.165
MW146D_A (<0.01)	South (Cabbage Tree Road)	20/11/2018	1.015
MW126D (<0.01)	South East (Cabbage Tree Road)	20/11/2018	1.160

Monitoring Well ID (PFOS ug/L)	Location	Date Sampled	Groundwater Level (mBTOC)
MW126S (1.63)	South East (Cabbage Tree Road)	26/11/2018	1.282
MW188D (0.38)	South East (Cabbage Tree Road)	20/11/2018	0.574
MW188S (0.68)	South East (Cabbage Tree Road)	19/11/2018	0.660
MW195 (0.06)	South East (Cabbage Tree Road)	27/11/2018	0.502

Table B-3 Surface and sediment locations within the structure plan

Surface and sediment sample locations	Location
DD1 (SW 0.83, SD 0.00)	North (adjacent to Base)
DD2 (SW 0.91, SD 0.00)	South (along Cabbage Tree Road)
DD3 (SW 30.7, SD 0.14)	South East (along Cabbage Tree Road)
LC_B (SW 5.41, SD 0.03)	North (within Base)
LC (SW 4.85, SD 0.03)	North (within Base)
MD6 (SW 0.83, SD 0.02)	North East (adjacent to Base)
MD7 (SW 7.34, SD 0.02)	North East (adjacent to Base)
DD5 (SW 2.64, SD 0.01)	South (South of Cabbage Tree Road)
FFD4 (SW 0.96, SD 0.01)	South (South of Cabbage Tree Road)
TFD1 (SW <<0.01, SD 0.02)	South (South of Cabbage Tree Road)
TFD2 (SW 2.34, SD 0.01)	South (South of Cabbage Tree Road)

AECOM 2019, Interim Monitoring Event Report – RAAF Base Williamtown, June 2019

Table B-4 Monitoring Wells within the Structure Plan study area (south and south east of RAAF BASE Williamtown)

Monitoring Well ID	Location	Date Sampled	Groundwater Level (mBTOC)
MW167	North	30/05/2019	3.11
MW103D	North	31/05/2019	1.71
MW103S	North	31/05/2019	1.99
MW240D	North	31/05/2019	2.118
MW240S	North	31/05/2019	-
MW107D	Centre (North)	31/05/2019	1.00
MW107S	Centre (North)	31/05/2019	0.95
MW108D	Centre (North)	31/05/2019	0.74
MW108S	Centre (North)	31/05/2019	0.63
MW175D	Centre (North)	31/05/2019	1.991
W66	Centre (North)	31/05/2019	2.475
W68	Centre (North to North East)	31/05/2019	2.102
MW238D	Centre (West)	6/06/2019	0.89
MW238S	Centre (West)	6/06/2019	0.98
MW187D	Centre (East)	5/06/2019	~0.200
MW187S	Centre (East)	5/06/2019	~0.150
MW139	West (near boundary)	4/06/2019	0.83
MW178	Centre (South)	21/05/2019	1.23
MW271S	Centre (South)	13/06/2019	0.57
MW271D	Centre (South)	13/06/2019	0.55
MW274D	Centre (South East)	5/06/2019	0.30
MW274S	Centre (South East)	5/06/2019	0.36
MW140	South West (Cabbage Tree Road)	-	-
MW124	South West (Cabbage Tree Road)	22/05/2019	1.82
MW125D	South (Cabbage Tree Road)	22/05/2019	1.66
MW125S	South (Cabbage Tree Road)	22/05/2019	1.70
MW229D	South (Cabbage Tree Road)	24/05/2019	1.47
MW229S	South (Cabbage Tree Road)	24/05/2019	1.26
MW146S	South (Cabbage Tree Road)	21/05/2019	1.40
MW146D_A	South (Cabbage Tree Road)	21/05/2019	1.24

Monitoring Well ID	Location	Date Sampled	Groundwater Level (mBTOC)
MW126D	South East (Cabbage Tree Road)	21/05/2019	1.40
MW126S	South East (Cabbage Tree Road)	21/05/2019	1.38
MW188D	South East (Cabbage Tree Road)	22/05/2019	0.94
MW188S	South East (Cabbage Tree Road)	21/05/2019	0.98
MW195	South East (Cabbage Tree Road)	27/05/2019	0.69
Additional monitoring wells sampled during June 2019 monitoring event			
MW109D	Centre (East)	31/05/2019	0.868
MW282S	North (adjacent to base)	20/06/2019	1.561
BWS107	South West	4/06/2019	-
MW278S	South (Cabbage Tree Road)	23/05/2019	0.89
MW278D	South (Cabbage Tree Road)	23/05/2019	0.90

Table B-5 Surface and sediment locations within the structure plan

Surface and sediment sample locations within structure plan	Location
DD1	North (adjacent to Base)
DD2	South (along Cabbage Tree Road)
DD3	South East (along Cabbage Tree Road)
LC_B	North (within Base)
LC	North (within Base)
MD6	North East (adjacent to Base)
MD7	North East (adjacent to Base)
DD5	South (South of Cabbage Tree Road)
FFD4	South (South of Cabbage Tree Road)
TFD1	South (South of Cabbage Tree Road)
TFD2	South (South of Cabbage Tree Road)

Appendix C
Additional Information – GCL Layer

GEOFABRICS®
Smarter Infrastructure

ELCOSEAL®

Geosynthetic Clay Liner Installation Guide

ABOUT ELCOSEAL

ELCOSEAL is a needle-punched Geosynthetic Clay Liner (or GCL) produced in Australia in accordance with the ISO 9001:2015 Quality Management System.

ELCOSEAL consists of premium grade sodium bentonite powder, which acts as the swelling and sealing component, embedded and sandwiched between two or more geotextiles. The composite is then needle-punched through all layers and thermally-locked developing high connection strength. Thus, ELCOSEAL is a shear strength transmitting GCL.

ELCOSEAL is generally fast and easy to install, however the performance of the GCL is dependent on the quality of its installation. It is the installer's responsibility to follow these guidelines and the project specifications and drawings whenever possible. It is the engineer's and owner's responsibility to provide construction quality assurance (CQA) for the installation to ensure that the installation has been executed properly. Variance from this guideline is at the engineer's discretion.

Recommended further reading:

- ASTM D 5888 - *Standard Guide for Storage and Handling of GCLs*
- ASTM D 6102 - *Standard Guide for Installation of GCLs*
- ASTM D 5889 - *Standard Practice for Quality Control of GCLs*
- ASTM D 6072 - *Standard Guide for Obtaining Samples of GCLs*

BEFORE YOU BEGIN

Prior to delivery of ElcoSeal on-site ensure the project team has:

- Read these guidelines;
- Raise any questions not answered by these guidelines with Geofabrics;
- Read the ElcoSeal Safety Data Sheet and Bentonite Material Safety Datasheet (available on the Geofabrics website);
- All the required equipment to unload, store and install ElcoSeal on site;
- All the required PPE for safe handling and installation of ElcoSeal.

Personal Protective Equipment

The use of respiratory, eye, hand and body protection is recommended when handling ElcoSeal Geosynthetic Clay Liners. Please refer to the ElcoSeal Safety Data Sheet for more information prior to any commencement of work. ElcoSeal contains powdered sodium bentonite which contains quartz/cristobalite which is classified as hazardous according to the Globally Harmonised System of Classification and Labelling of Chemicals (GHS).

A respirator with a removable dust mask should be used

Safety glasses with side shields should be worn

Wear gloves of impervious material

Wear suitable protective workwear. Overalls are recommended.

GHS Classified as hazardous

PACKAGING, TRANSPORTATION, UNLOADING & STORAGE

Packaging

ELCOSEAL rolls are packed in moisture tight plastic wrapping. The standard roll dimensions and weights are listed in Table 1 below.

Every ELCOSEAL roll has a unique roll number on the wrapping label and on the panel itself. This information allows for matching of manufacturing quality assurance (MQA) records.

! *After transportation and unloading the plastic wrapping should be checked. Minor damage should be repaired with weather-resistant adhesive tape. Wrapping should only be removed immediately before use.*

Table 1: ELCOSEAL Roll Dimensions & Freight Capacities

Grade	Width (m)	Length (m)	Diameter (m)	Roll Mass (kg)	Rolls per B Double	Rolls per 20ft Container	Rolls per 40ft Container
X800	4.7	45	~0.56	~1,035	20	15	22
X1000	4.7	35	~0.52	~915	23	15	24
X2000	4.7	30	~0.56	~890	23	15	25
X3000	4.7	30	~0.57	~940	23	16	23

Transportation

ELCOSEAL rolls are usually delivered to site in closed containers or covered trailers on flatbed trucks. At the point of unloading, the rolls need to be accessible either from the top of the trailer or the container opening. Please see the table above for average freight capacities for B Double and 20ft and 40ft containers.

Should any damage to rolls occur in transit it must be immediately brought to the attention of Geofabrics, who will advise on the required course of action.

Unloading

A flat, hard, dry and free draining surface must be provided for unloading and storage. Offloading on site will require heavy equipment: an excavator (tracked or wheeled); front-end loader; or a forklift. Heavy equipment must be correctly rated for the expected load (see Table 1 on the previous page). Rolls may be offloaded using:

A A Spreader Bar with steel tube insert through the core of the rolls. Refer to the *ELCOSEAL Spreader Bar Safe Usage Guideline* from the Geofabrics website for detailed information; **OR**

B A 'carpet prong', rated to 1,200 kg and matched to the forklift, protruding from the front end of the forklift (>4.5 tonne) or other equipment. The prong should be at least ¾ the length of the ELCOSEAL core and also must be capable of supporting the full weight of ELCOSEAL without significant bending; **OR**

C The two slings provided by the Geofabrics (upon request) wrapped around the ELCOSEAL roll at third (⅓) points along the roll, fixed to an excavator bucket or a front-end loader. Slings should not be used for general lifting and transportation around the site. If excessive deformation or bending of the roll occurs the integrity of the geocomposite may be affected. A steel tube or similar reinforcement can be inserted into the core of the roll to prevent excessive deformation across the roll during off-

Storage

ELCOSEAL rolls should be stored in their original, unopened packaging in a location away from construction traffic but sufficiently close to the active work area to minimise handling.

The designated storage area should be level, dry, well-drained, stable, and should protect the product from:

- Precipitation;
- Chemicals;
- Standing water;
- Excessive heat;
- Ultraviolet radiation;
- Vandalism and animals.

ELCOSEAL rolls should always be stored lying flat, continuously supported, and should never be stored standing on one end. Enclosed indoor storage such as shipping containers or a warehouse environment is preferred if ELCOSEAL® is to be stored for long periods.

The maximum storage height is four rolls.

! *ELCOSEAL rolls should not exposed to moisture prior to installation. Damaged wrappers should immediately be repaired with weather resistant tape. Wrapping should only be removed from ELCOSEAL rolls immediately prior to installation.*

INSTALLATION

What You'll Need On Site

Prior to commencement of installation the following equipment will be required:

- Excavator (tracked or wheeled) or a front-end loader. Equipment should be rated for the expected load. Please see Table 1 on page 2 of this document for roll masses;
- Spreader bar/loading frame;
- HP Paste;
- Trowel;
- Carpet knife or safety knife;
- Felt pens or chalk;
- Measuring tape;
- Broom;
- PPE including dust mask, goggles, gloves and protective workwear.

Weather Conditions for Installation

Light rainfall (defined as <5mm/hour intensity) should not affect the installation of ELCOSEAL provided deployed panels are covered and confined by 300 mm of cover soil (or equivalent) within 2 hours of first exposure to the light rain. Heavy direct raindrop impact should be avoided. The ELCOSEAL panels can be covered during heavy rainfall events with a tarpaulin or plastic sheet if there is not enough time to complete soil cover placement.

Avoid placing ELCOSEAL in areas where water is ponding unless panels can be confined immediately (with 300 mm cover soil or equivalent).

! *ELCOSEAL rolls should not be exposed to moisture prior to installation. During installation ELCOSEAL panels should be covered with a tarpaulin or plastic sheet during heavy rain events.*

Subgrade Preparation

The preparation of the subgrade before placement of any lining material is critical to the system's performance. The surface(s) upon which ELCOSEAL is to be laid should be suitable for the intended application and function.

ELCOSEAL will generally be placed on either an earthen e.g. compacted clay, or geosynthetic e.g. geotextile or geocomposite) subgrade.

Earthen Subgrades

The surface upon which ELCOSEAL® will be deployed should conform to the following:

- The subgrade should be firm and unyielding (typically compacted to >90% density), without abrupt elevation changes, and be proof rolled with a smooth drum roller immediately prior to deployment of the ELCOSEAL panels. The subgrade should not be disturbed or rutted by the equipment deploying the rolls or other traffic. No foreign matter or stones loose on the surface or penetrating out of the subgrade >10 mm should be allowed. The engineer's approval of the subgrade needs to be obtained immediately prior to roll deployment;
- In applications where ELCOSEAL is the sole or primary barrier, and will be subjected to constant or long-term hydraulic heads exceeding 300 mm (1 ft), subgrade surfaces consisting of gravel or granular soils may not be appropriate due to their large void contents and puncture potential. In these applications, the top 150 mm of the subgrade should possess a particle size distribution where at least 80% of the soil is finer than 0.25 mm (or #60 sieve) - unless the ELCOSEAL grades X2000 or X3000 are being used (see below);
- For X2000 and X3000 grades (with a composite woven/nonwoven carrier geotextile) in high hydraulic head applications:

  Subgrade materials recommended without further investigation are:

  » Clays or clay-based mixes;

  » Sandy clays (with > 20% fines);

  » Silty or loamy clays (with > 20% fines)
  [fine grained soils should be placed at suitable moisture contents for construction operations and roll deployment - that provide adequate bearing capacity to deploy the rolls without disturbance of the subgrade - i.e no rutting or large deflections];

  » Well graded sands and gravels (max < 32 mm, d60 < 5 mm, d20 < 0.15 mm).
  [these materials should bind and have good bearing capacity when compacted/rolled].

  Subgrade materials not recommended without further investigation:

  » Single-sized and gap-graded sands and gravels of any size or description;

  » Sands or soils that have low bearing capacity at the moisture contents during the construction/deployment operations i.e. materials that do not bind when rolled; will heave/shove under equipment or foot traffic during or after deployment);

  » Subgrades that have a bony or porous appearance after compaction and rolling.

Geosynthetic Subgrades

When deploying ELCOSEAL over a geosynthetic material such as a geomembrane or geotextile, the surface should be firm and unyielding as per the requirements for earthen subgrades. The equipment used to deploy ELCOSEAL should be approved for use by the Design Engineer and/or the Supplier of the underlying geosynthetic material. Generally, the underlying geosynthetic and ELCOSEAL® rolls will be deployed consecutively such that each layer is side-cast from equipment tracking over the earthen subgrade - unless specialised light rubber tyred dispensers are available and approved by the Design Engineer that allow direct trafficking over the geosynthetics.

GCL Placement

The ELCOSEAL roll wrapping should only be removed immediately prior to installation. On site, ELCOSEAL is unrolled along the prepared subgrade using the Spreader Bar assembly as shown in Figures 1 and 2 (overleaf).

! *ELCOSEAL should only be trafficked by light, low tyre pressure vehicles (no tracked vehicles).*

Rolls must be laid without folds on the subgrade with a standard overlap of 300 mm in both the longitudinal and transverse direction as detailed in Figures 3, 4 and 5. For longitudinal or edge overlaps, the blue coloured line on the underside of the panels can be used to ensure the correct overlap width. The edge of deployed or previously placed panels needs to coincide or match with the visible blue line on the roll being deployed.

The transverse or end overlaps need to be sealed using bentonite paste. The treatment of end (transverse) overlaps is detailed in Figures 6 and 7.

Rolls can be cut to length with a carpet/Stanley knife. When overlapping cut panels, bentonite paste will need to be applied as per the requirements for end (transverse) overlaps on the following page under *ELCOSEAL Panel Overlaps*.

No trafficking or walking should occur over the overlap region during installation. The overlap must also be free from folds and foreign matter e.g. soil. Any soil particles on the laps must be swept away carefully.

Overlaps should occur in the direction of ground slope in a similar manner to roof tiles.

Damage to ELCOSEAL During Installation

Where ELCOSEAL has been damaged during installation, covering with an overlapping piece of ELCOSEAL can repair such areas. The overlap should be at least 500 mm and should be completed in accordance with the ELOSEAL Panel Overlaps section.

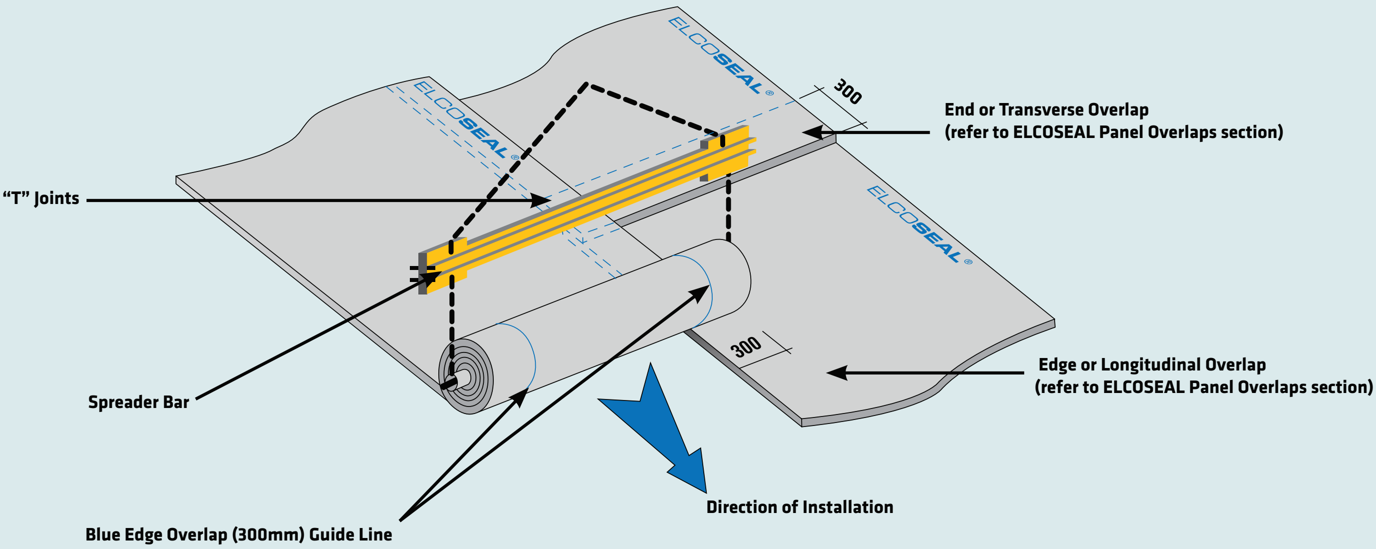


Figure 1 ELCOSEAL deployment using the standard ELCOSEAL Spreader Bar

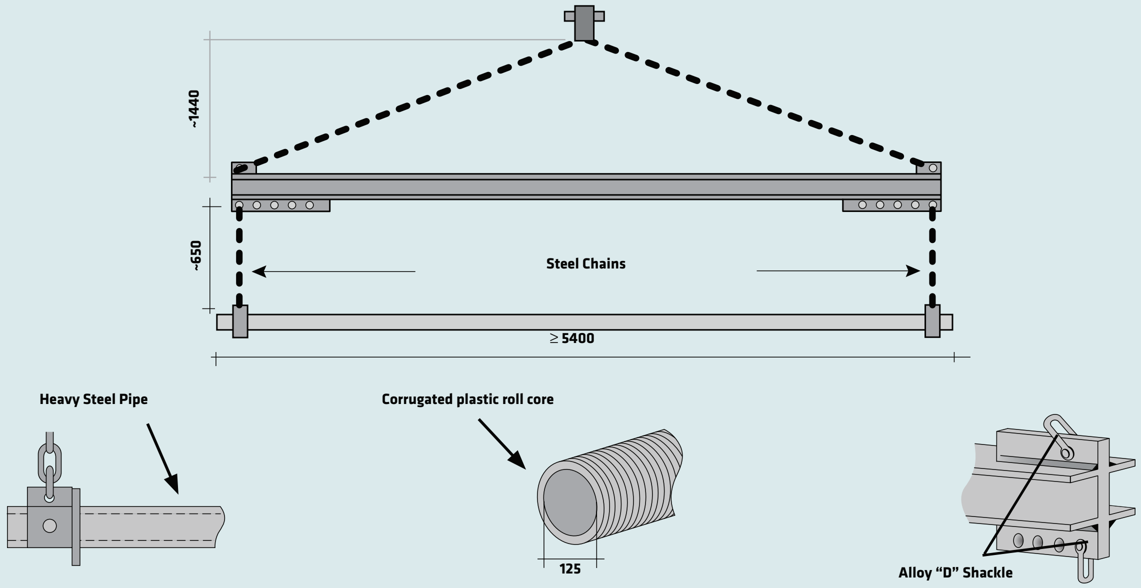


Figure 2 ELCOSEAL typical Spreader Bar assembly

! *Refer to the ELCOSEAL Spreader Bar Safe Use Guide prior to using the lifting equipment and ensure that occupational health and safety requirements have been met and potential hazards eliminated.*

ELCOSEAL Panel Overlaps

Logitudinal Overlaps

The longitudinal overlap is where GCL rolls overlap along their length. The installation of a longitudinal overlap can be seen in Figure 1. The width of this overlap shall be a minimum of 300 mm which is indicated by a blue marker line printed on the bottom of the roll. The overlapping area has bentonite powder impregnated into the top nonwoven fibres of the GCL as seen in Figure 3 for grades X800 and X1000 and in Figure 4 for grades X2000 and X3000. When hydrated, the impregnated bentonite will swell into the fibre porespace to provide a sealed hydraulic barrier. An installed cross section can be seen in Figure 5.

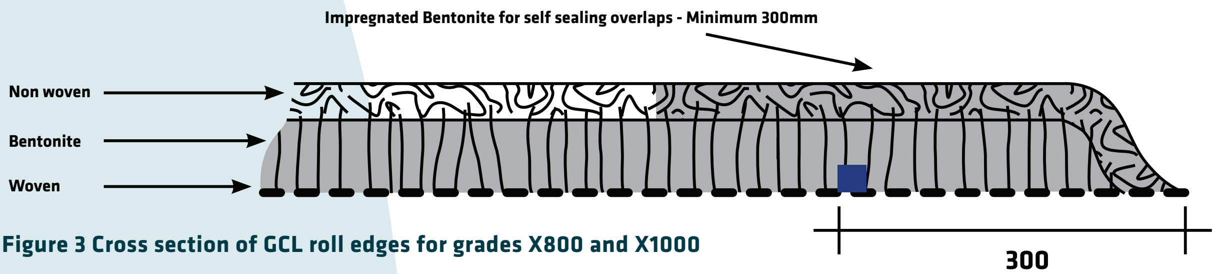


Figure 3 Cross section of GCL roll edges for grades X800 and X1000

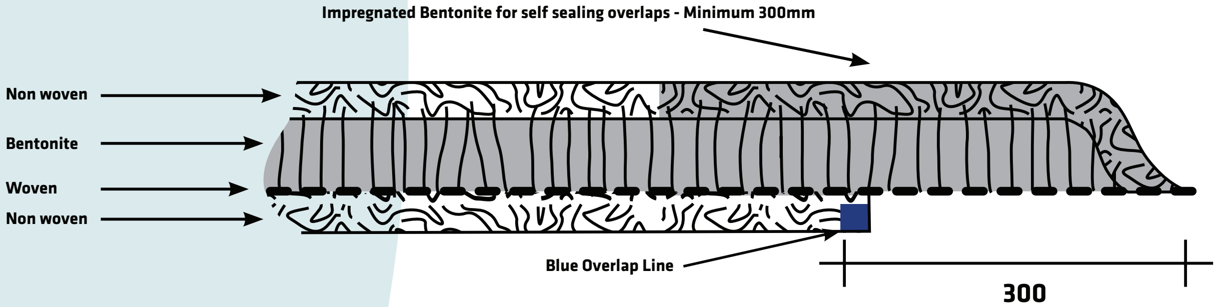


Figure 4 Cross section of GCL roll edges for grades X2000 and X3000

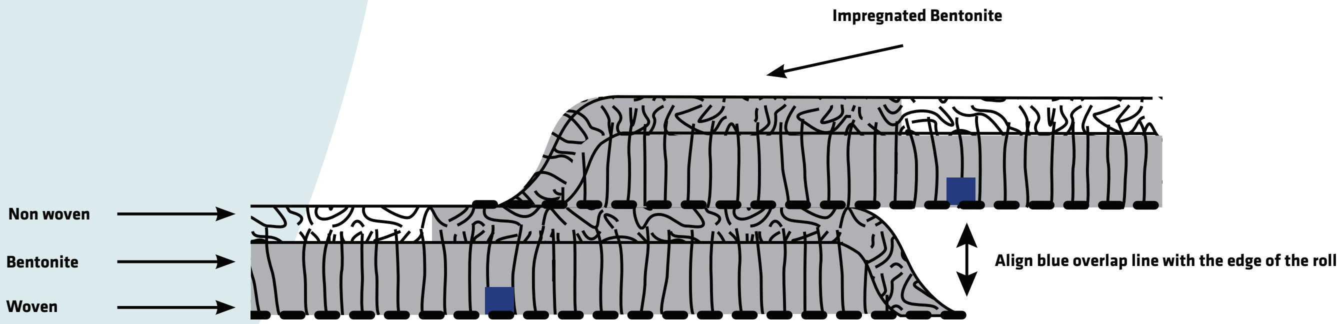


Figure 5 Longitudinal (or edge) overlap with self-sealing impregnated bentonite (X1000 shown)

Transverse Overlaps

Transverse overlaps occur at the end of rolls. The width of the GCL transverse overlap shall be a minimum of 300 mm. It is recommended that the topside of the underlying ELCOSEAL panel be marked as per Figure 6, as a reference point for paste placement. The top ELCOSEAL panel is then pulled back after marking.

All transverse/roll end overlaps should be sealed with bentonite paste. Geofabrics supplies HP paste which is an extensively tested sealing solution available in 20 L containers. As indicated in Figure 6, HP paste should be placed within the 300 mm overlap with a minimum width of 200 mm and a nominal thickness of 10 mm. The paste can be easily poured from the 20 L container and spread into place using a trowel or broom. Approximately 10L or ½ of a container is used for each roll width at the transverse overlap. Once the paste is applied, the top panel is then rolled back into place and pressed down (Figure 6). Care should be taken to prevent folds or creases. The end overlap cross section for X1000 is shown in Figure 7. If an alternative method of end of roll overlap sealing is required, please consult your local Geofabrics office.

To ensure the integrity of the ELCOSEAL® lining system it is essential that the treatment of end overlaps be carefully supervised. End overlaps in sumps or inverts are to be avoided.

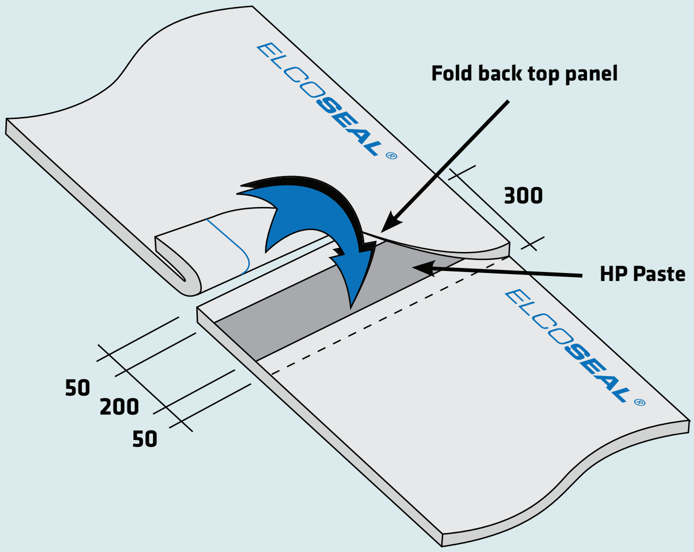


Figure 6 Transverse (end) overlap installation with applied HP Paste of minimum 200 mm width

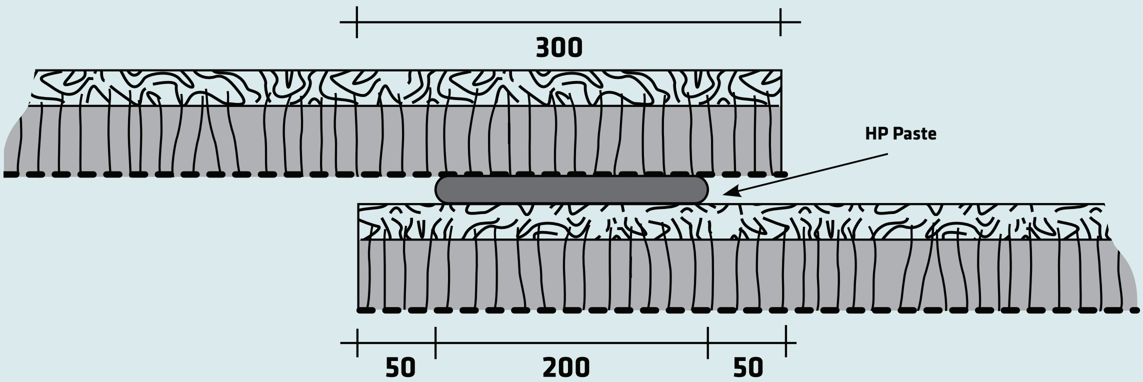


Figure 7 Transverse (end) overlap cross section (X1000 shown)

Installation on Slopes

The stability of lining system components on slopes should be assessed on a case-by-case basis. Geofabrics can assist in this respect upon request.

ELCOSEAL panels should be deployed in the direction of the slope as per Figure 8 and anchored at the crest of the slope (Figure 9). End (or transverse) overlaps on steep slopes should be avoided. If overlaps on slopes are unavoidable, please consult your local Geofabrics branch for information on custom extra-long GCL rolls.

Cover soil should be placed up the slope (starting at the toe). It must not be installed down the slope unless stability for this approach has been carefully investigated.

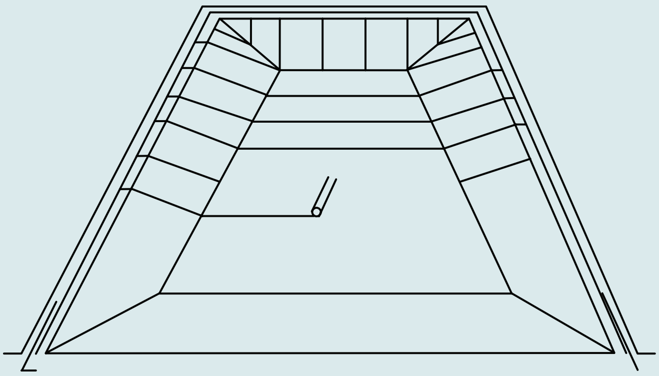


Figure 8 Recommended panel layout for sloping sites

Anchor Trenches

Anchor trench and slope stability considerations should be assessed by the Design Engineer.

As a general guide:

- An anchor trench should be used at the top of slopes steeper than 7H: 1V. (see Figure 9 for a typical anchor trench detail);
- The anchor trench should be constructed free of sharp edges or corners and maintained in a dry condition. The ELCOSEAL panels should be placed down the front face and along the base of the anchor trench. The base of the anchor trench should not contain large gravel or loose material and the trench backfill material should be compacted.

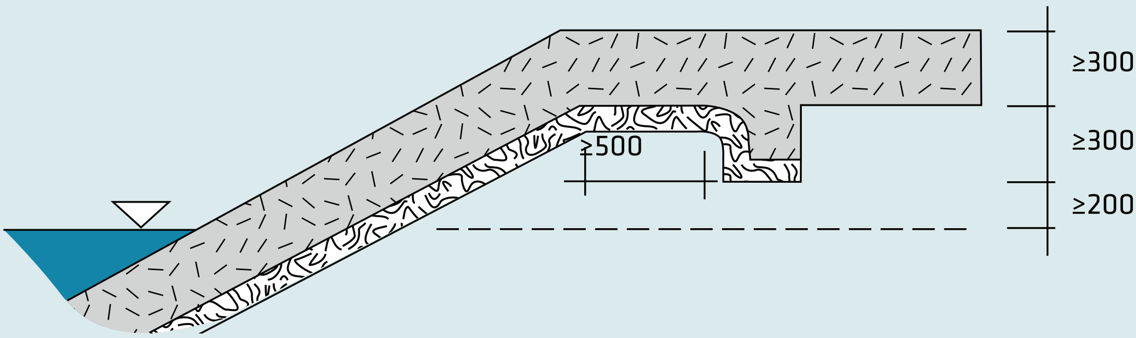


Figure 9 Typical anchor trench (all dimensions shown are typical values only)

Connections & Penetrations

Overlaps around connections, penetrations, and where panels have been cut should be carried out according to the principles outlined in Figures 5, 6 and 7. Most situations require site specific design input, however some commonly used details are shown below:

- Integration with thick compacted clay liners is shown in Figure 10;
- Cut-off trenches using ELCOSEAL GCL in cohesive soil are typically constructed as shown in Figure 11;
- Attachment and sealing against concrete structures, can be achieved according to Figures 12a and 12b. These typical connections are appropriate where the structure needs to be waterproofed to a height above and below the maximum containment level. Temporary fixing of the vertical ELCOSEAL panel to the structure (as shown) is required to allow the backfill placement;
- Penetrations such as pipe ducts are typically carried out according to Figure 13;
- Further connection methods and penetrations details can be discussed with Geofabrics.

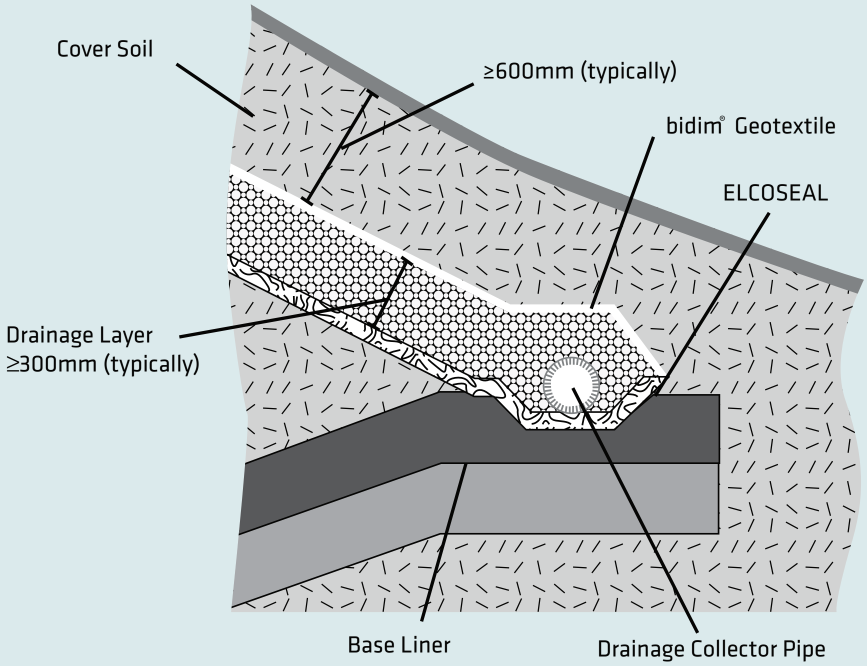


Figure 10 ELCOSEAL cap connection with base liner

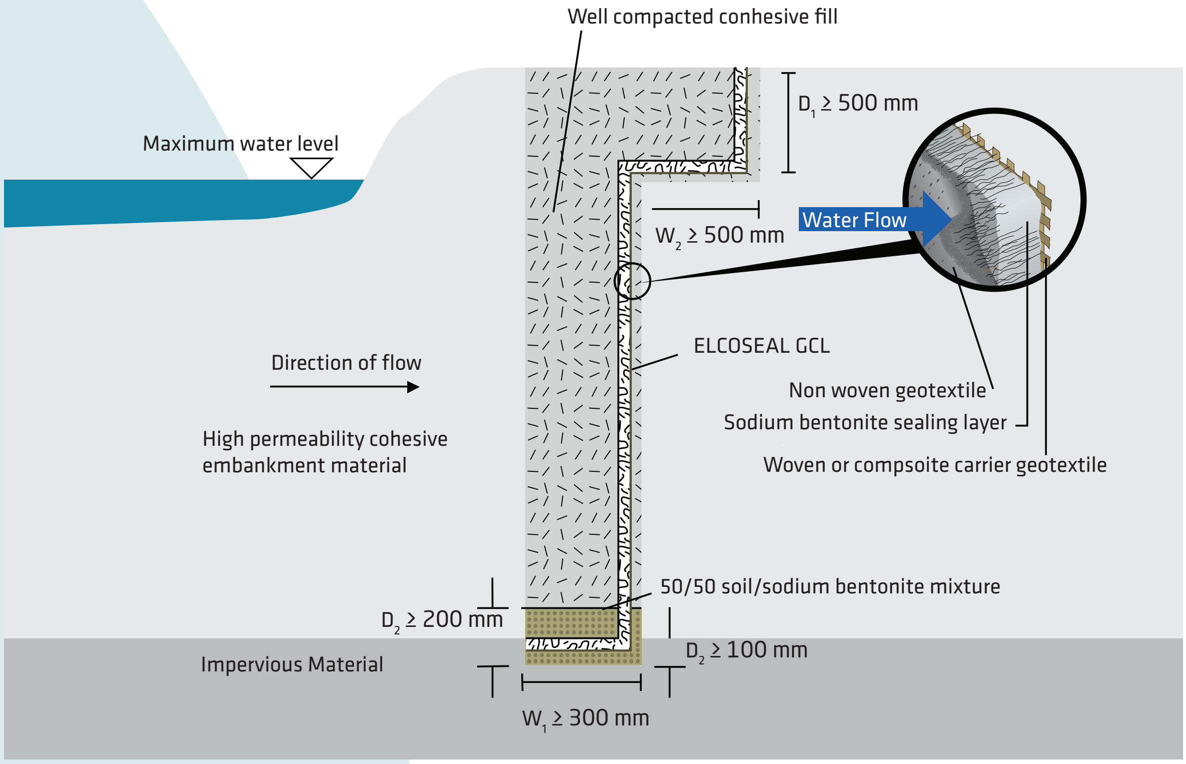


Figure 11 ELCOSEAL cut off trench detail for cohesive soils

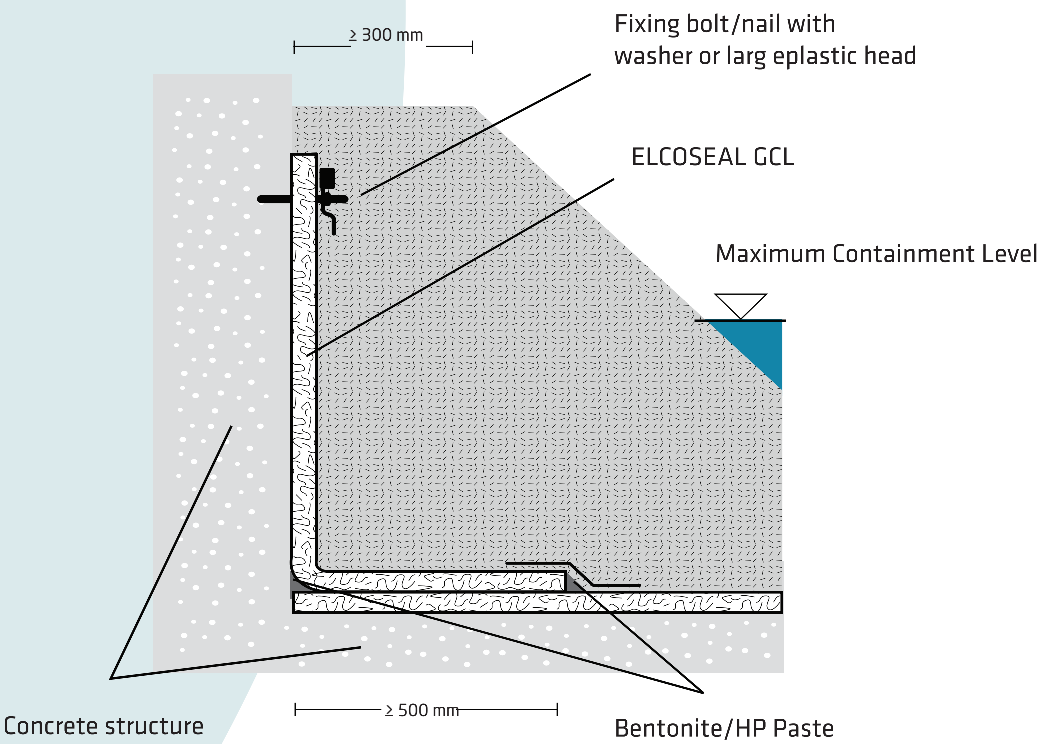


Figure 12a Typical connection to a concrete structure where the ELCOSEAL panel if required to extend above the maximum containment level

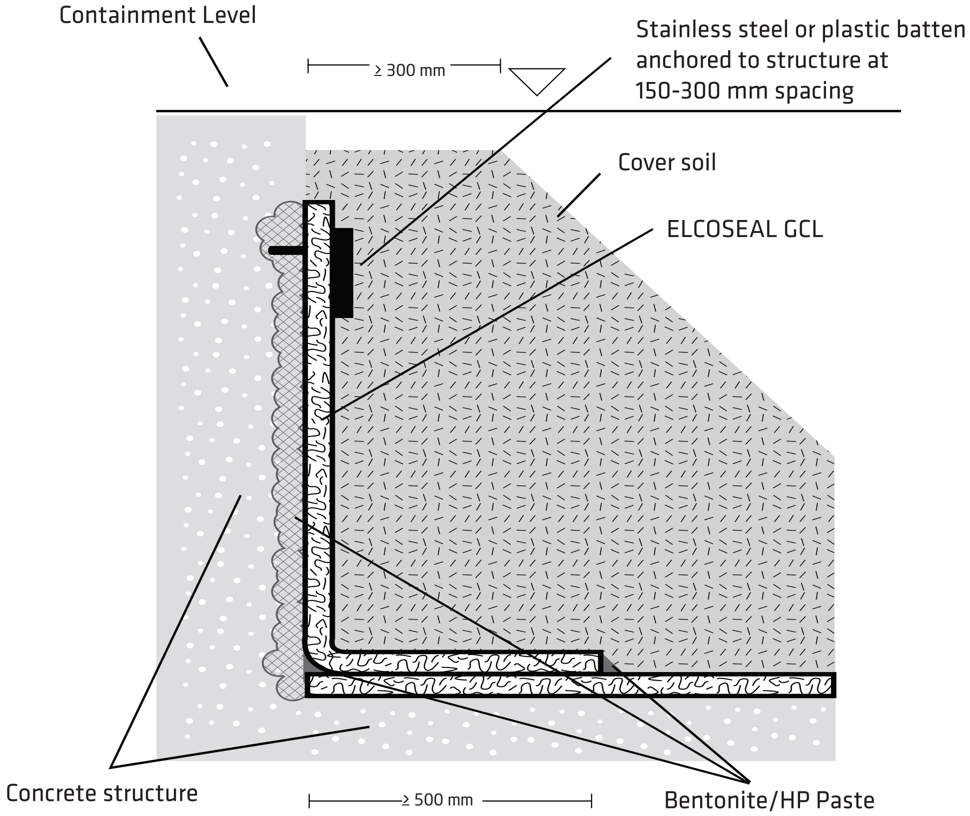


Figure 12b Typical connection to a concrete structure where the ELCOSEAL panel if required to extend below the maximum containment level

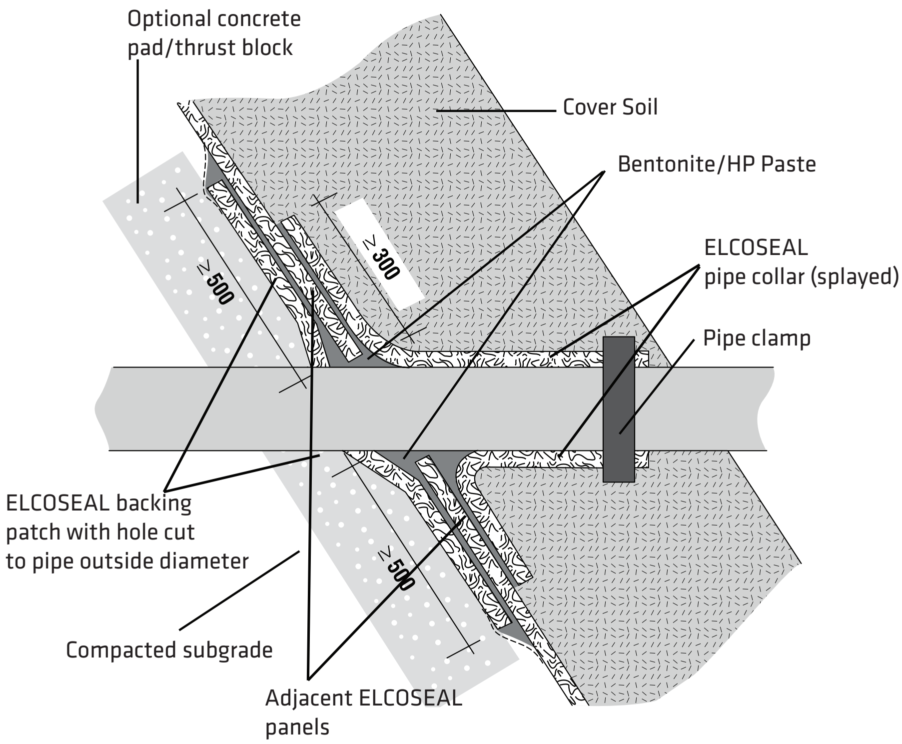


Figure 13 Typical pipe penetration detail

Preparation for Placing Soil Cover

Where the ELCOSEAL is not confined by the cover soil the same working day as deployment, a temporary layer of plastic should be laid to protect ELCOSEAL from prematurely hydrating (Figure 14).

If the deployed ELCOSEAL panels have hydrated (for example during a rainfall event) without confinement, special operating conditions may need to be imposed during cover soil placement. For example:

- If ELCOSEAL m.c.[1] <50% — No special considerations;
- If ELCOSEAL 50% <m.c. <100% — Avoid direct traffic (including foot traffic) on panels;
- If ELCOSEAL m.c. >100% — Contact Geofabrics for advice.

1. m.c. = moisture content of the bentonite, % by weight

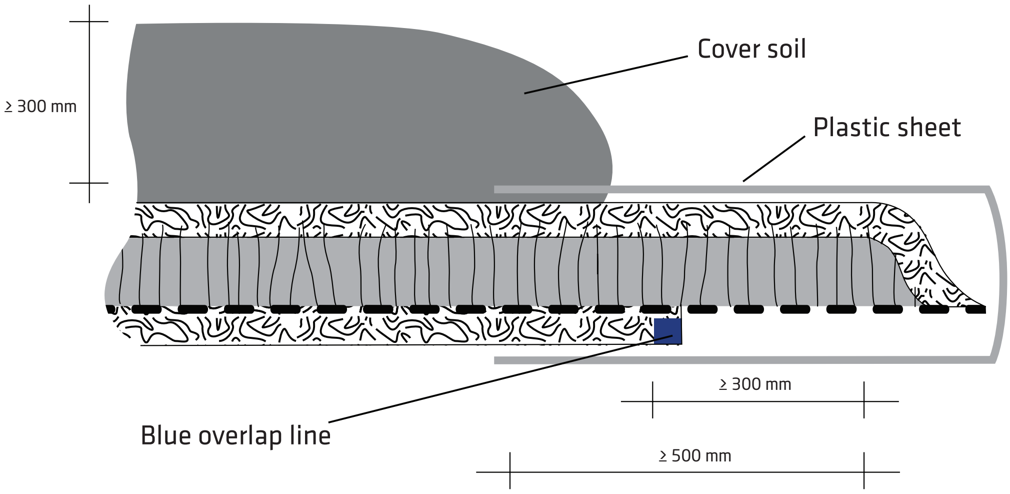


Figure 14 Covering ELCOSEAL with plastic sheet overnight or during wet weather

Soil Cover Placement

A cover soil layer of at least 300 mm thick (approx. 6 kN/m² confining stress) should be placed and compacted over ELCOSEAL each working day immediately after the deployed panels have been inspected. In general, fine-grained cohesive material is recommended, although stones up to 32 mm are acceptable if the material is well graded (Cμ >5) or stones up to 16 mm if single sized. Silty soils or organic material are not recommended without further stability analysis. Calcareous or limestone based cover soils should be evaluated prior to use.

Disturbance of the overlap area during placement (by means of vehicles spreading cover soil) must be avoided. It may be necessary to place the cover soil in this area manually or carefully using vertical placement by an excavator. The cover should not be pushed or graded in a direction that may cause the overlap to move (Figure 15).

ELCOSEAL may not be trafficked directly. The cover material should be pushed in front of the construction equipment thus creating a safe working platform. Overlaps should not be moved or squeezed during this process. In the case of an expected repeated dynamic load on ELCOSEAL, a sand layer of at least 300 mm should be laid first on the ELCOSEAL.

Generally, temporary access roads should not go over deployed panels. These areas should be sealed last to minimise traffic volume over deployed material. Where site traffic cannot be avoided e.g. the delivery of cover material by lorries) additional protection measures will be required. For temporary roads, a minimum roadbase thickness over ELCOSEAL of 600 mm is acceptable without any further analysis. Shallower coverage or alternative cover materials may be allowed after further analysis or field trials to assess the damage potential.

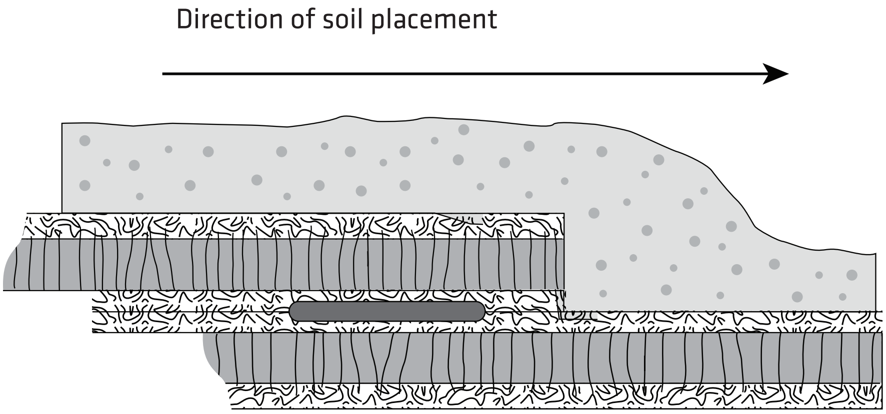


Figure 15 Cover soil placement

TECHNICAL DATA SHEET:

ELCOSEAL

Geosynthetic Clay Liners

ELCOSEAL Geosynthetic Clay Liners (GCLs) are used as a lining system in landfills and waste containment structures, and for liquid containment in effluent ponds, wetlands and canals.

Australian made ELCOSEAL GCLs consist of a layer of bentonite bonded between two layers of woven and nonwoven geotextiles. The needle-punching process reinforces the bentonite layer with thousands of fibres, maximising the product's internal resistance. An additional heat treating process called "thermal locking" secures the needle-punched fibres, further improving strength and performance.

ELCOSEAL GCLs have been used in environmental, civil and landfill liner applications since 1996. They have an unmatched sealing capability and are cheaper to install than natural clay layers. When hydrated, the sodium bentonite layer forms a barrier that prevents contamination of surrounding groundwater.

ELCOSEAL GCLs can replace thick, compacted clay layers in composite landfill liners and caps, thanks to the fast swelling sodium bentonite clay liner. This creates a highly effective containment barrier for landfill final cover systems and base landfill liner systems. ELCOSEAL GCLs can self-heal around holes or punctures so there is less chance of leaks due to installation damage.

SUGGESTED SECTOR APPLICATIONS

Roads | Rail | Coastal | **Waste** | **Mining** | Civic & Landscaping | Ports & Aviation | **Water** | Primary Industries | Sports & Recreation | Slopes & Walls | Building

GEOFABRICS®
Smarter Infrastructure

ELCOSEAL GEOSYNTHETIC CLAY LINERS

The values published in this leaflet are to the best of our knowledge true and correct. The product specification may change at any time without prior notice. No warranty is expressed or implied. Manufactured by Geofabrics Australasia Pty Ltd to the ISO 9001:2015 Quality Management System Standard.

PROPERTY		TEST METHOD	MQC[1] REQUENCY	UNITS	ELCOSEAL® GRADE X800	X1000	X2000	X3000
GCL Hydraulic Properties								
Hydraulic Conductivity, k	MaxArv[2]	ASTM D5887	40,000 m²	m/s	3.5×10^{-11}	2.8×10^{-11}	3×10^{-11}	2.4×10^{-11}
	Typical[3]				2.5×10^{-11}	1.9×10^{-11}	2.4×10^{-11}	1.7×10^{-11}
Bentonite Characteristics								
Swell Index	Typical	ASTM D5890	40,000 m²	mL/2g	≥ 24	≥ 24	≥ 24	≥ 24
Fluid Loss	Typical	ASTM D5891	40,000 m²	mL	≤ 15	≤ 15	≤ 15	≤ 15
GCL Components - Mass								
Cover Nonwoven Geotextile Mass per Unit Area	MARV[4]	AS 3706.1	10,000 m²	g/m²	220	220	220	260
	Typical				250	250	250	300
Bentonite Mass per Unit Area @ 0% Moisture Content	MARV	ASTM D5993	2,500 m²	g/m²	3,700	4,000	3,700	4,250
	Typical				4,100	4,500	4,250	4,700
Carrier / Composite Geotextile Mass per Unit Area	MARV	AS 3706.1	70,000 m²	g/m²	110	110	320	350
	Typical				110	110	360	380
Geotextile Configuration (Carrier / Cover)					W / NW[5]	W / NW	W+NW / NW	W+NW / NW
GCL - Mass								
GCL Total Mass per Unit Area @ 0% Moisture Content	MARV	ASTM D5993	2,500 m²	g/m²	4,030	4,330	4,240	4,860
	Typical				4,460	4,860	4,860	5,380
GCL - Strength Properties								
Strip Tensile Strength (MD)[6]	MARV	ASTM D6768	10,000 m²	kN/m	7	8	12	12
	Typical				10	11	15	16
CBR Strength	MARV	AS 3706.4	25,000 m²	N	1,400	1,600	3,500	4,100
	Typical				2,000	2,100	4,100	5,300
CBR Elongation	MARV	AS 3706.4	25,000 m²	%	10	15	30	30
	Typical				30	40	80	80
GCL - Shear Strength Properties								
Hydrated Peak Internal Shear Strength @ 10kPa Normal Stress	Typical[7]	ASTM D6243	Periodic	kPa	30	30	35	40
Hydrated Peak Internal Shear Strength @ 30kPa Normal Stress	Typical	ASTM D6243	Periodic	kPa	50	50	60	70
GCL Longitudinal Edge Treatment								
Bentonite Impregnation - Width ≥ 300 mm - Typical				-	√	√	√	√
Edge Sealing Performance	Typical[7]	ASTM STP 1308 (Mod.)10,11	Periodic	m/s	2.5×10^{-11}	1.9×10^{-11}	2.4×10^{-11}	1.7×10^{-11}
GCL Roll Dimensions								
Standard Roll Dimensions (Width x Length)				m	4.7 x 45	4.7 x 35	4.7 x 30	4.7 x 30
Typical Roll Mass (standard roll length). Note: Longer custom roll lengths are available to suit project requirements.			(Weighed every roll)	kg	1,395	1,050	960	950
GCL Spreader Bar Requirement				-	Heavy-Duty[8]	Heavy-Duty[8]	Standard[9]	Standard[9]

1. **MQC** = Manufacturing Quality Control – an ongoing system that monitors and tests materials during manufacture to ensure compliance with certification documents and contract specifications.
2. **MaxARV** = Maximum Average Roll Value – a MaxARV is defined as the Mean or Typical values plus 2 standard deviations. Mathematically, it is implied that 97.5% of the results of the tested specimens will be less than the MaxARV. A MaxARV provides a confidence level of 97.5%. **NOTE** – in reference to GCL Permeability, **LOWER IS BETTER**.
3. **Typical** = A typical value is the arithmetic mean of a set of results. This implies that 50% of the tested specimens will typically exceed this value and 50% will typically not meet this value.
4. **MARV** = Minimum Average Roll Value – a MARV is defined as the Mean or Typical values less 2 standard deviations. Mathematically, it is implied that 97.5% of the results of the tested specimens will exceed the MARV. A MARV provides a confidence level of 97.5%.
5. **W**= Woven, **NW**= Nonwoven.
6. **MD** = Roll Machine Direction.
7. **Peak Value** reported at 10kPa or 30kPa normal stress. [The reported values are not intended to replace site specific internal shear or interface friction testing required for design].
8. **Heavy-Duty WLL** (Working Load Limit) = 1,400kg.
9. **Standard WLL** (Working Load Limit) = 1,000kg.
10. **Reference** - Daniel, D.E. Trautwein, S.J. and Goswami, P.K. 1997. Measurement of Hydraulic Properties of Geosynthetic Clay Liners Using a Flow Box, Testing and Acceptance Criteria for Geosynthetic Clay Liners, ASTM STP 1308, p. 196-207.
11. **Modification Reference** - Kendall, P.M., Austin, R. A. 2014. Investigation of GCL Overlap Techniques Using a Large Scale Flow Box, 7th International Congress on Environmental Geotechnics, 3B-3, p. 746-753.

TECHNICAL DATA SHEET

MEGAFLO® GREEN

PANEL DRAIN & SUBSOIL DRAINAGE SYSTEM

The Megaflo® Green panel drain provides the dimensional stability and field-proven structural strength for quick, effective subsurface drainage. Megaflo® Green consists of a perforated HDPE core wrapped with bidim® Green nonwoven geotextile to prevent soil ingress into the drainage system.

Performance is the distinguishing feature of the panel drain due to its ability to rapidly collect and remove water. Compared to slotted round pipe, **Megaflo® Green** has twice the inflow capacity for an equivalent length and will collect and drain 60% more water in a similar time frame. Its slim 40mm wide profile permits faster and more cost effective installation in a narrower trench.

ADVANTAGES:

VERTICAL CRUSH STRENGTH	The high vertical crush strength means **Megaflo® Green** can be installed closer to the surface reducing the cost of excavation.
ENHANCED PERFORMANCE	The increased height and rapid response times associated with **Megaflo® Green** ensures the system outperforms traditional drainage options. The flat pipe construction prevents intrusion of the cover geotextile allowing flow rates to be maintained despite soil confinement pressure.
COST EFFECTIVE	The narrow trench width requirement combines rapid installation of the geotextile encapsulated **Megaflo® Green** to provide significant cost savings when compared to traditional French drain systems.
ENVIRONMENTALLY FRIENDLY	**Megaflo® Green** is manufactured from recycled HDPE, minimising the carbon footprint of the project.

GEOFABRICS®
Smarter Infrastructure

Megaflo® Green - Technical Data Sheet

Megaflo® Green panel drain is made in Australia, manufactured in a facility certified to ISO9001, Certificate No. FS673633.

MEGAFLO PANEL PROPERTIES		TEST METHOD	UNITS	MEG170G	MEG300G	MEG450G	MEG170G ULTRA	MEG300G ULTRA	MEG450G ULTRA
Panel Width		ASTM D2122	mm	170	315	460	170	315	460
Slot Size		ASTM D2122	mm	> 40			> 40		
Wide Strip Tensile[1]		ASTM D2122	mm	2.8 x 30			2.8 x 30		
Compressive Strength[1,2]	Horizontal	ASTM D2412 (mod)	kPa	> 200			> 200		
	Vertical			> 300			> 300		
Planar Flow @ 0.01 Gradient & 200kPa Confining Pressure (***Megaflo® Green*** *installed horizontally)*	Rigid Plate Interface	ASTM D4716	litres/min	25	47	68	25	47	68
	Coarse Sand Interface			25	47	68	25	47	68
Planar Flow @ 0.1 Gradient & 200kPa Confining Pressure (***Megaflo® Green*** *installed horizontally)*	Rigid Plate Interface	ASTM D4716	litres/min	66	122	178	66	122	178
	Coarse Sand Interface			66	122	178	66	122	178
Change in Core Cross-sectional Area under confining pressure of 156.5 kPa		ASTM D6244	%	< 5%			< 5%		

1. The compressive strength of **Megaflo® Green** should be considered in conjunction with the granular drainage medium. Geofabrics engaged an external consultant to perform a Finite Element Analysis which established that under extreme loads, the effective stress imposed on a **Megaflo® Green** panel due to it's stiffness and profile is significantly reduced through soil arching of the granular cover.
2. Geofabrics has also conducted compressive testing in a purpose made crush test rig to show **Megaflo® Green** can withstand extreme loads of up to 1580kPa due to the soil arching effect of the granular fill.

While **Megaflo® Green** comes standard with **bidim® Green** A14G, Australian manufacturing allows flexibility of geotextile choice to suit site conditions. Performance testing is available at the Geosynthetic Centre of Excellence to determine filter suitability in critical applications. The data and specifications contained in this table are obtained from the manufacturer's laboratory testing. To ensure this information is current, please contact your local branch of Geofabrics Australasia. The product values listed on this sheet are Typical Values.

GEOTEXTILE PROPERTIES	WIDE STRIP TENSILE STRENGTH	TRAPEZOIDAL TEAR STRENGTH	PORE SIZE	FLOW RATE @100mm HEAD
Test	AS 3706.2	AS 3706.3	AS 3706.7	AS 3706.9
bidim® A14G	11 kN/m	300 N	110 µm	320 l/m2/sec

bidim® Green nonwoven geotextile complies with the following road authority specifications: TfNSW R63, Queensland MRTS 27, MRTS 03, MRTS 38, NZ Transit TNZ F/7.

M160G-08/20

Megaflo® Green panel drains are manufactured in a facility certified to ISO9001, Certificate No. FS673633.

Proud member of the Infrastructure Sustainability Council of Australia (ISCA). Our products directly contribute to IS credits in infrastructure and civil engineering projects.

MEGAFLO® GREEN

PANEL DRAIN & SUBSOIL DRAINAGE SYSTEM

GEOFABRICS®
Smarter Infrastructure

GEOFABRICS
A Green Drainage Panel Solution

Geofabrics has been providing geosynthetic solutions to the civil engineering market for over 40 years in Australia, New Zealand, Papua New Guinea and across the South Pacific.

On every project we undertake, we have a singular focus: to provide smarter solutions for our clients. For us, smarter infrastructure is about using smart products, smart solutions, and smart people to help our clients develop value engineering opportunities for their projects. We believe this delivers greater opportunities to lower risk, cost and construction time frames whilst increasing maintenance cycles and the whole of life opportunities.

SUSTAINABILITY

Geofabrics is committed to building a strong, sustainable future for Australia. We are making a positive environmental impact by manufacturing and supplying products that reduce our customer's carbon footprint.

Traditional drainage products are made from unsustainable virgin materials. **Megaflo® Green** is the only Australian made recycled alternative made from 100% recycled HDPE – with no compromise on product quality or performance. **Megaflo® Green** is more environmentally sound than any other drainage product in Australia, has a lower carbon footprint and helps reduce greenhouse gas emissions and reliance on fossil fuels.

INNOVATION & DEVELOPMENT

Geofabrics' Centre for Geosynthetic Research, Innovation & Development (GRID) is a specialist R&D laboratory that works with clients to develop the right geosynthetic solution for their complex problems.

Please speak to your local representative to understand how Geofabrics can assist you with your specific or bespoke drainage needs.

AUSTRALIAN MADE

Megaflo® Green is 100% Australian made with locally sourced recycled polymer. Many of the products we supply are manufactured in our two manufacturing plants in Albury (New South Wales) and Ormeau (Queensland).

We employ more than 100 manufacturing staff, and we support over 1,000 Australian suppliers, many located in regional Australia.

By choosing Geofabrics, you are not only supporting the local economy and reducing your product delivery lead time; you can rest assured that the product you receive meets project specifications - ensuring that performance and life-cycle costs are optimised.

ISCA

Geofabrics is a proud member of the Infrastructure Sustainability Council of Australia (ISCA).

Megaflo® Green is now available on the ISupply directory. Find out how using **Megaflo® Green** on your next project can assist you in achieving IS credits.

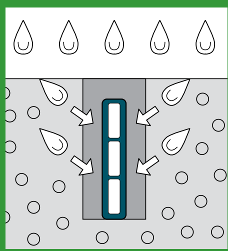
SUPERIOR DRAINAGE

Megaflo® Green panel drain provides the dimensional stability and field-proven structural strength for quick, effective subsurface drainage. **Megaflo® Green** consists of a perforated HDPE core wrapped with **bidim® Green** nonwoven geotextile to prevent soil ingress into the drainage system.

Performance is the distinguishing feature of the panel drain due to its ability to collect and remove water rapidly. Compared to 100mm diameter round pipe, **Megaflo® Green** has **twice the inflow capacity** for an equivalent length and will drain water in less than **60% of the response time**. Its slim 40mm wide profile permits faster and more cost-effective installation in a narrower trench. The design of the **Megaflo® Green** panel drain permits significantly higher flow velocity at the lower head.

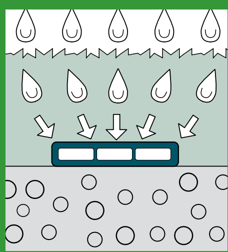
Megaflo® Green Ultra is a heavier grade offering greater crush resistance for extreme high fill, high load applications without compromising any of its proven flow.

PERFORMANCE



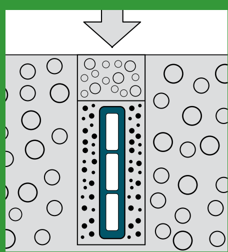
DRAINAGE

Removal of excess water from a structure whether it be a road, retaining wall or rail is key to long term performance of the structure. **Megaflo® Green** is a unique composite drainage system with an unsurpassed infiltration rate and rigid flow path which ensures effective drainage under the most challenging conditions.



RAPID RESPONSE TIME

A rapid removal of excess water is a key consideration in roads where excess water can result in significant damage to the pavement surface. The long flat shape of **Megaflo® Green** incorporates a high open area for the inflow of water - allowing rapid response time well over conventional drainage systems.



STRENGTH

Vertical installation of the **Megaflo® Green** panel utilises a ribbed structure to provide higher strength under traffic loads.

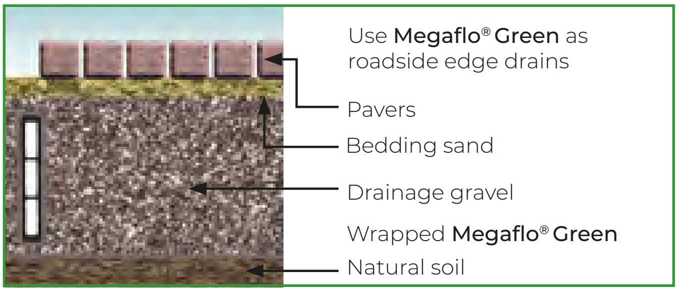
The properties of high compressive modulus, longitudinal stiffness and structural rigidity aids the mechanical performance of **Megaflo® Green**, ensuring the long term hydraulic flow capacity of the drain. High structural strength allows for a minimum cover depth of 100mm recommended in most applications.

Megaflo® Green typically requires less backfill in comparison to a traditional trench which results in cost savings and faster installation.

APPLICATIONS

ROADSIDE EDGE DRAINS

Megaflo® Green provides a faster and higher inflow capacity due to its high trench installation profile and earlier interception of pavement infiltration. **Megaflo® Green** has a high compressive modulus and structural rigidity (preventing deflection under normal service loads), due to its elongated ribbed profile incorporating internal support.



RAIL

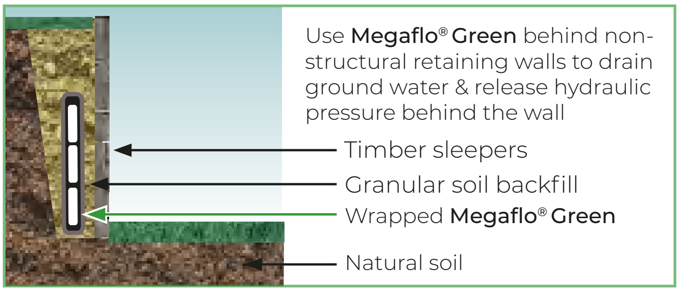
Megaflo® Green is manufactured as a corrugated panel supported by internal pillars along the length of the drain. This shape gives a high rush resistance whether the drainage system is used vertically or horizontally.

Bearing capacity of foundation material below ballast is affected by excess moisture unless adequate subsurface drainage is in place. **Megaflo® Green** has a profile that offers higher resistance to deformation and loss in discharge capacity required for use under rail track.

RETAINING WALLS

Megaflo® Green provides reliable drainage in specialist construction applications such as retaining walls, shotcrete walls and tunnels.

Megaflo® Green drainage system can be utilised vertically or horizontally to remove excess water, preventing the build up of water pressures induced on the structure.



MINING

Megaflo® Green is ideally suited for use as collector drains in mining applications. Its high compressive modulus and structural rigidity prevent deflection and the loss of flow capacity under high load or localised settlement.

LANDFILL

The high compressive strength of **Megaflo® Green** under normal and inclined loads makes it the ideal product for a range of landfill drainage applications.

ADVANTAGES

COST EFFECTIVE

The narrow trench width requirement, coupled with easy and rapid installation of **Megaflo® Green** drastically reduces costs on your project, compared to traditional draining systems.

Furthermore, with a high vertical crush strength, **Megaflo® Green** can be installed closer to the surface, reducing excavation costs.

ENHANCED PERFORMANCE

The increased height and rapid response times associated with **Megaflo® Green** ensures the system outperforms traditional drainage options. The flat pipe construction prevents intrusion of the cover geotextile allowing flow rates to be maintained despite soil confinement pressure.

ENVIRONMENTALLY SUSTAINABLE

Megaflo® Green is manufactured from recycled HDPE, minimising the carbon footprint of the project.

MEGAFLO® GREEN DIMENSIONS

PRODUCT DESCRIPTION	HEIGHT	ROLL LENGTH
Megaflo® Green **170**	170mm	50m or 100m
Megaflo® Green **300**	315mm	50m or 100m
Megaflo® Green **450**	450mm	50m or 100m
Megaflo® Green **900**	900mm	50m

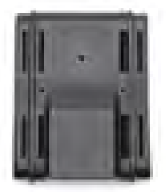
FITTINGS

A full range of fittings are available to compliment **Megaflo® Green**. The fitting will assist you in:

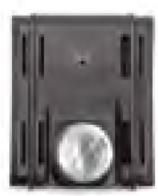
- Connecting **Megaflo® Green** to round pipe in roads, basement walls, shotcrete and retaining wall applications.
- Finish lengths of **Megaflo® Green** with end caps.
- Pin the **Megaflo® Green** to the surface, for stability in windy conditions.

Please use the QR code to view the full range of standard and non-standard **Megaflo® Green** fittings.

OUTLET FITTINGS

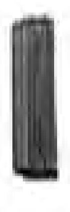


JOINER COUPLING (CO)

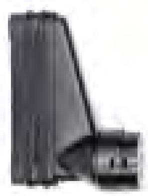


SIDE OUTLET (SO)

RIGHT OUTLET (RO)



END CAP (EC)



END OUTLET (EO)

4mm THICK

150mm U-PINS

Contact your nearest sales branch for our nonstandard **Megaflo® Green** fittings.

GEOFABRICS®

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1300 60 60 20

AUSTRALIA

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HOBART (03) 6273 0511 Fax: (03) 6273 0686	**BRISBANE** (07) 3279 1588 Fax: (07) 3279 1589	**TOWNSVILLE** (07) 4774 8222 Fax: (07) 4774 8655
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NEW ZEALAND

AUCKLAND	CHRISTCHURCH
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bsi. ISO 9001 Quality Management

Megaflo® Green panel drains are manufactured in a facility certified to ISO9001, Certificate No. FS673633.

ISCA

Proud member of the Infrastructure Sustainability Council of Australia (ISCA). Our products directly contribute to IS credits in infrastructure and civil engineering projects.

Appendix D
Additional Information – Aqua Gate

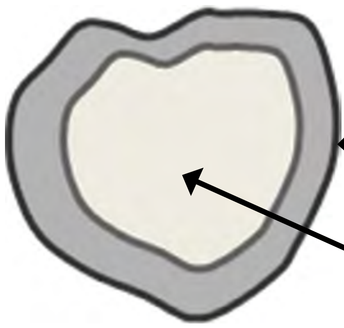
PFAS Surface and Groundwater Remediation

AquaGate⁺RemBind is a composite particle consisting of an aggregate core coated with the reactive commercial adsorbent RemBind.

This unique product facilitates the uniform delivery of powdered RemBind, for the *in-situ* passive removal of Per- and Polyfluoroalkyl Substances (PFAS) in groundwater or surface drainage systems.

The AquaGate⁺RemBind product design combines two proven world-class technologies:

- RemBind is a powdered adsorbent that permanently binds up long- and short-chain PFASs in soil and water. It has been independently validated by government and industry and used commercially worldwide over the past decade.
- AquaBlok (USA) has spent the last decade demonstrating the effectiveness of using powder coated aggregates to treat organic contaminants using permeable reactive barriers (PRBs).



Benefits

- Cost effective - passive process
- Uniform placement of reactive powders
- Easy to apply with conventional equipment
- Can be manufactured at site
- Combines proven technologies

Leachate control from stockpiles

AquaGATE+RemBind®

RemBind®

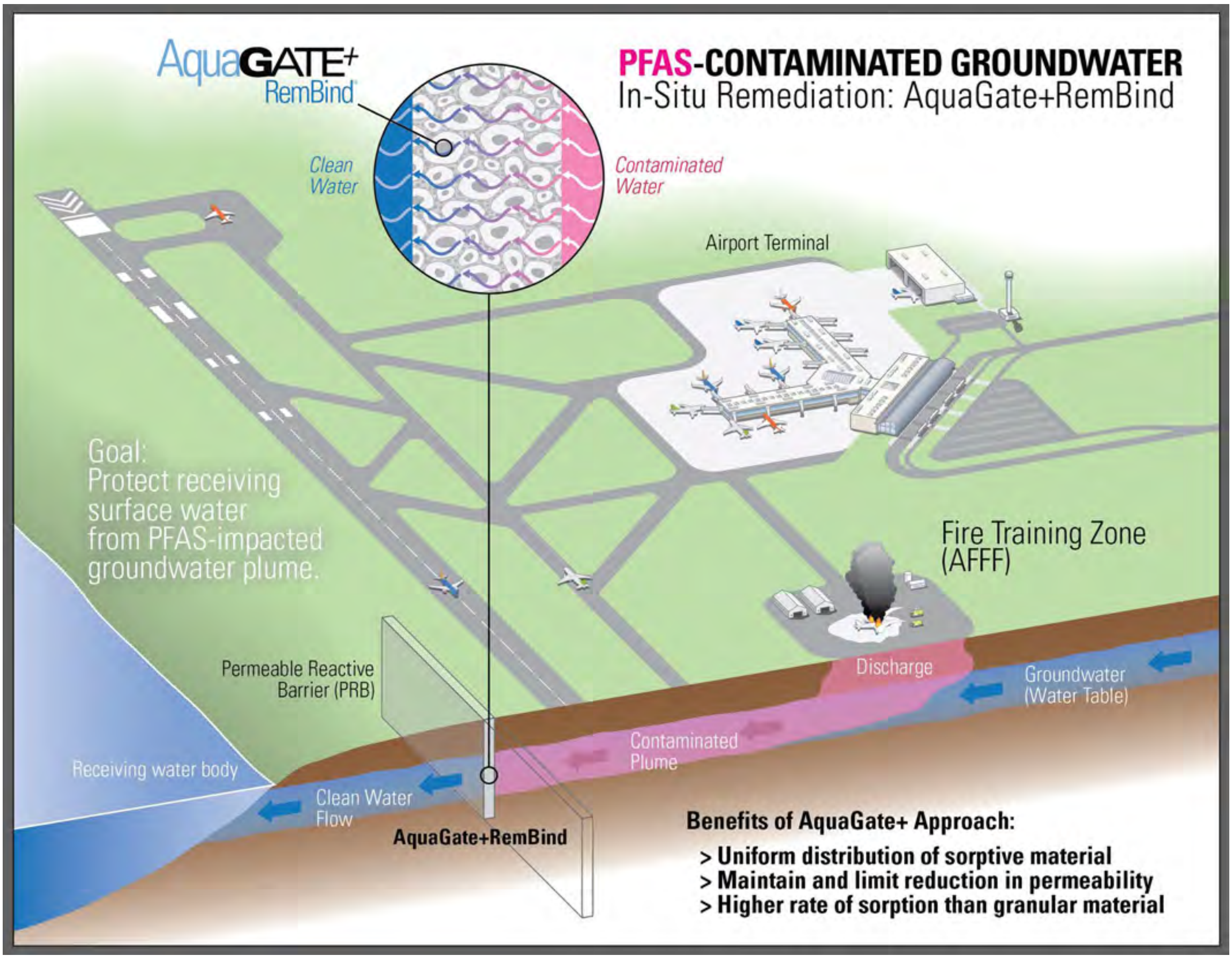
PFAS Surface and Groundwater Remediation

Field Applications

Groundwater Remediation (Permeable Reactive Barriers)

PFAS compounds are highly soluble in water and are transported rapidly through surface run-off, infiltrating groundwater and impacting surface water and sediments (i.e. in a basin, detention pond, lake or river).

Currently groundwater contaminated with PFAS, the most common approach is to remove the water via a pump-and-treat system and discharge the clean water to a nearby sewer or surface water body. Although it's generally agreed that this approach is expensive and an unsustainable solution, few *in-situ* approaches have been developed or proven. However, AquaBlok's AquaGate approach now offers the ability to utilize RemBind adsorptive materials in a Permeable Reactive Barrier (PRB) configuration to prevent migration of a PFAS groundwater plume.



PFAS compounds are highly soluble in water and are transported rapidly through surface run-off, infiltrating groundwater and impacting surface water.

AquaGATE+RemBind

RemBind®

PFAS Surface and Groundwater Remediation

Field Applications

Sediment Remediation

At present, the focus on PFAS remediation is on groundwater and drinking water. However, as contaminated groundwater migrates to surface water bodies, such as rivers and lakes, aquatic biota and fish are impacted, as well. There is increasing evidence that these sensitive ecological receptors are impacting the food chain.

To address PFAS accumulations in sediments, AquaGate+RemBind can be applied to limit the impact of PFAS on sensitive biological receptors. In the past the same approach using AquaGate+PAC (powdered activated carbon) and AquaGate+Organoclay have been successful in addressing contamination in sediments.

Sediment Remediation

Surface Water Remediation

At most airports and Defence sites, surface water is managed using an above-ground drain system. To minimize the amount of PFAS contamination leaving site in these drains, above ground PRBs containing AquaGate+RemBind can be installed. Testing and design work for this type of system commenced in Australia in 2018.

Soil Stockpile Leachate Management

Stockpiles of PFAS contaminated soil often require a liner to be installed to manage leachate runoff. For temporary stockpiles, a layer of AquaGate+RemBind can be used as a liner as a practical, simple method for leachate containment. When the stockpile is moved, the product can be sacrificed with the soil.

Groundwater Remediation
(Permeable Reactive Barrier)

Emergency Spill Response

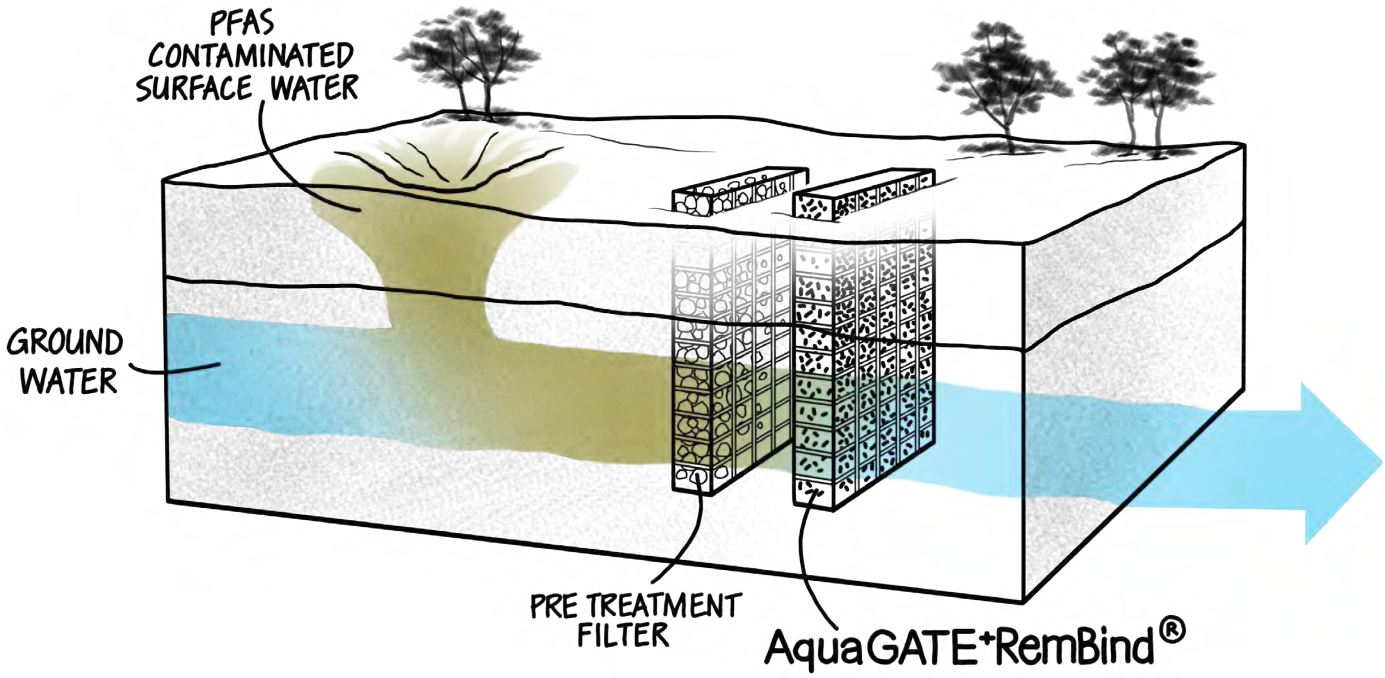
AquaGate+RemBind can be used to mitigate runoff during emergency flood or spill response involving PFAS contaminated water or liquids.

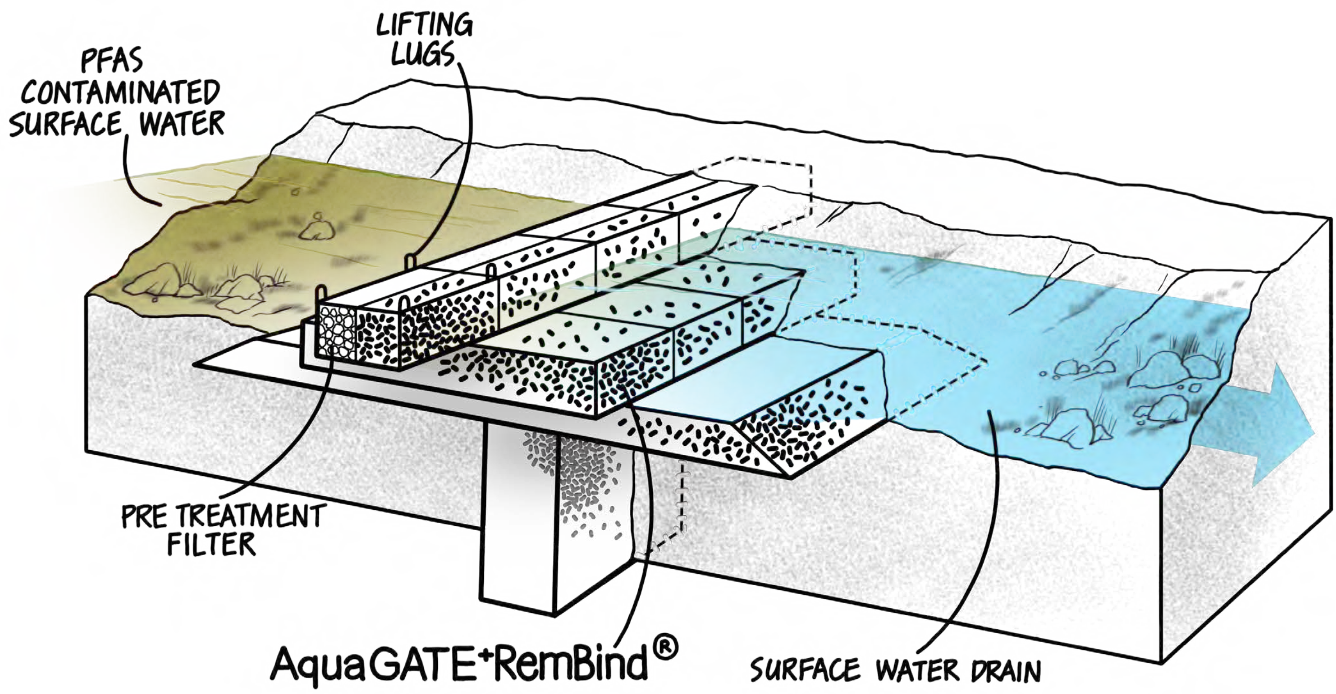
AquaGATE+RemBind®

RemBind®

PFAS Surface and Groundwater Remediation

Site Conceptual Designs



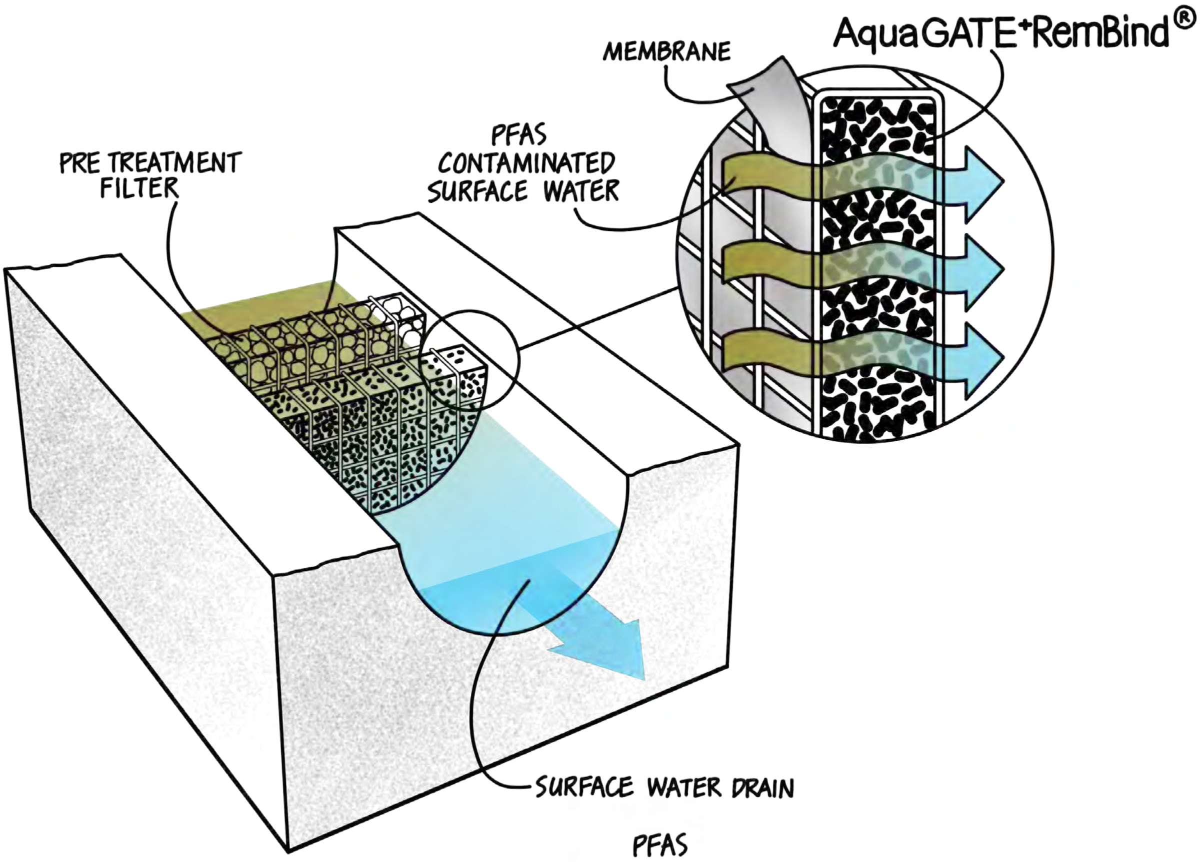


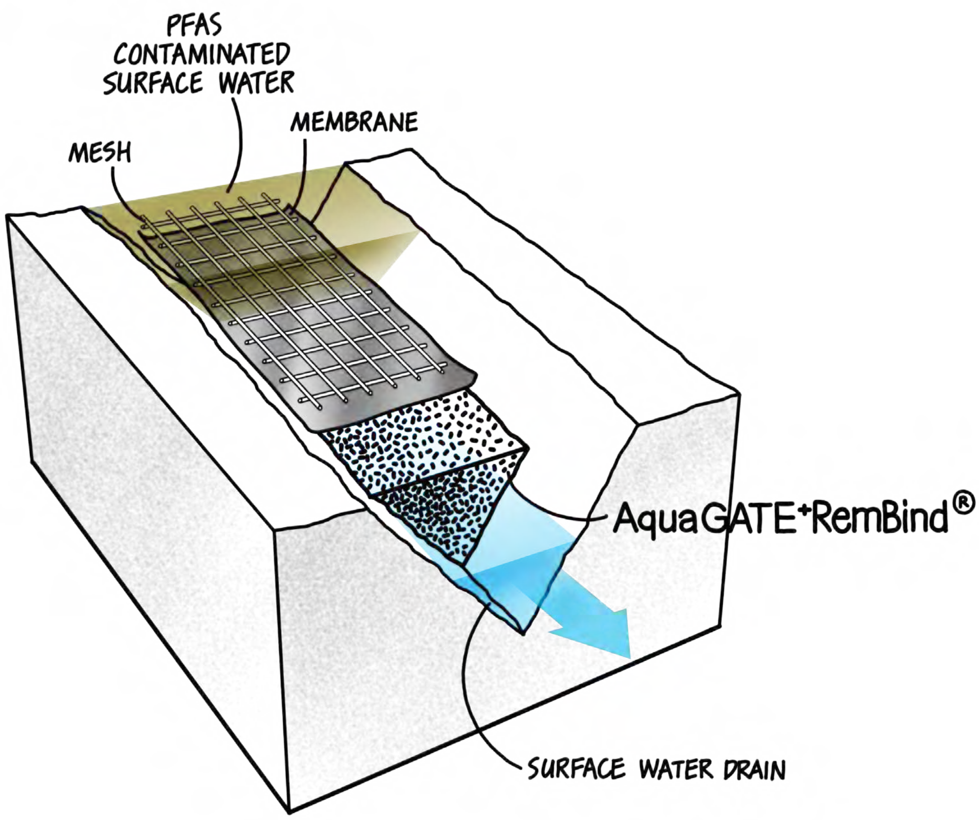
AquaGATE+RemBind®

RemBind®

PFAS Surface and Groundwater Remediation

Site Conceptual Designs





Ref: 2019 217674 AquaGate+RemBind Ziltek PL AS1289.6.7.1 CHPerm

Report Template Rev 0 Jan 09 Authorised by A. Mendoza

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Materials Technical Services

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www.boral.com.au

TEST REPORT

CLIENT:	ZILTEK PTY LTD	FILE No:	890/19
ADDRESS :	2 ANN NELSON DRIVE, THEBARTON, SA 5031	REQUEST No:	83185
PROJECT:	Testing of AquaGate+RemBind for Permeability	DATE RECEIVED:	11.3.19
MATERIAL:	AquaGate+RemBind	DATE TESTED:	14.3.19 to 18.3.19

Test Method AS1289.6.7.1	Results		
Determination of the permeability of a soil - Constant head method for a remoulded specimen.	**Field/Client Sample No.** 1 **Laboratory Sample No.** 217674		
Compaction method	Sample compacted into permeability mould in 3 equal layers by tapping the side of the mould for each layer		
Permeability mould diameter (mm)	151		
Permeability mould cross sectional area (mm^2)	17979		
Average height of compacted specimen (mm)	96		
	Before test		After test
Wet density (t/m^3)	1.446		1.653
Dry density (t/m^3)	1.297		1.297
Moisture content as per AS1289.2.1.1 (%)	11.5		27.5
Dry density ratio (%)	-		-
Moisture content ratio (%)	-		-
Surcharge used in test (KPa)		3.0	
Percentage of material retained on 19.0mm sieve		-	
Degree of saturation (%)	-		-
Hydraulic gradient		1.2	
Average Coefficient of permeability (m/sec)		**3.8×10^{-04}**	

Note : Sample provided by client.

SONYA CARR, FILE.

Approved Signatory **Artemio Mendoza**

Date 18.3.19 Serial No. 178291

Appendix E
Defence Remedial Details

Table E-1: Details of Defence Remedial Options Assessment

Source	Description	Proposed remedial works	Implications for SAP development/construction
Facility 165	This is an on Base soil secondary source area resulting from use of firefighting foams historically.	Two stages of soil excavation have been completed by Defence; one in 2019 to facilitate redevelopment and one in July 2020 to address additional soils. Soils were excavated and removed from this area. However, PFAS impacted soil remains in the area which will lead to continued off Base PFAS concentrations in groundwater and surface water	The details of the on-Base soil remediation do not directly relate to the SAP construction or operation. The remediation of the on-Base soils is expected to lead to a reduction in continued PFAS mass flux to on and off-site groundwater and surface water.
Lake Cochran	This is a constructed stormwater capture and control device located just north of the SAP. Lake Cochran receives stormwater runoff from the Base historically and currently and is known to interact with groundwater. The Lake is a known to interact with groundwater and is a source of PFAS to the "southern area" groundwater plume	A passive activated carbon-based surface water remediation system has been installed on both the inlet and outlet of the Lake in August 2020. Due to high water levels, the efficacy of this system has not been able to be evaluated. The ROA discussed a number of strategies and scenarios to address the groundwater plume in this area. The preferred option included installation of up to 24 groundwater pumping wells installed to depts of 27m. A modelled total pumping rate of 914 m^3/day was used for cost estimation purposes. Another scenario includes injection of colloidal activated carbon (CAC) through 10 temporary injection points. The CAC extracts PFAS from the groundwater/soil minimising its mobility in the subsurface.	Pump and treat systems are designed to create a zone of groundwater capture by lowering the water table. The intention is to extract the PFAS impacted groundwater, pump it to the on Base treatment system and discharge to local drain system or re-injection into the aquifer. This strategy has several implications for the SAP construction and operation: 1. The purpose of the pump and treat system is to reduce the PFAS mass flux from Lake Cochran to southern areas of the SAP up to and beyond Cabbage tree Road. This would lead to reduced concentrations in groundwater below Stage 1 of the SAP that may interact with fill material. 2. Pump and treat lowers the water table and based on presumed remedial timeframes would extend to SAP construction. This would tend limit the groundwater interactions with imported fill material. 3. The pump and treat system would produce a significant volume of water that is treated and then discharged into the local drainage system. This could have an affect on the flood mitigation/stormwater management strategies
Sewage Treatment Plant	The STP (Facility 410) is acting as a source of PFAS through infiltration and run-off of PFAS-impacted effluent water from the plant, which is disposed to the lagoon and ponds, as well as potentially through leaching from soils surrounding the lagoon and ponds. The STP is the largest PFAS mass contributor to the "southern area plume."	The ROA discussed a number of strategies and scenarios to address the impacted soil, sediment and surface water in the STP lagoon and the groundwater plume emanating from this area. It is understood that the STP may be upgraded in the near future so that it is capable of removing PFAS from wastewater. During these upgrades, it is assumed the water in the lagoons would be addressed and some of the soil and sediment. The ROA concluded that remediation of the soil/sediment in the STP lagoon would not lead to a significant reduction in PFAS mass flux. The ROA preferred option to address impacted groundwater emanating from the STP is the pump and treat system described above.	Refurbishment of the STP is forming a portion of the SAP concept design. The process and details of this refurbishment are outside of the scope of this technical memorandum. However, upgrades to the STP would reduce an ongoing source of PFAS to the local environment. Efforts to remove the water/soils/sediments in the STP lagoon would likely occur during STP upgrades. The implications of a pump and treat system for the SAP construction and operation are summarised above.

Appendix F
Evaluation of PFAS Mitigation

Table F-1: PFAS Mitigation Measure Details and Constructability Considerations

Potential mitigation measure	Conceptual application description	Advantages	Disadvantages	Constructability Considerations
Installation of a GCL	Installation of a GCL in areas of bulk filling to separate imported material from potentially PFAS impacted groundwater/soil. A GCL is an extremely low permeable liner that provides the equivalent permeability of one metre of compacted clay. New fabrication techniques of the GCLs are incorporating activated carbon with the bentonite to specifically limit PFAS migration through the GCL. The conceptual application includes preparation of the current ground surface and removal of existing vegetation. GCLs are manufactured off-site by specialised companies and delivered in rolls that are approximately 4.7 metres wide and 30 to 45 metres long. Specialised equipment and personnel are required to ensure a GCL is installed in accordance with the manufacturer's specifications and that it will perform as designed. The panels are laid out with a recommended 500 millimetres overlap to ensure there are no gaps in coverage A drainage layer would be required above and below the GCL. The drainage layer below the GCL is required to relieve any pressure produced from increasing groundwater levels. The drainage layer above the GCL would be required to manage stormwater that infiltrates vertically down through the fill material and would tend to accumulate on the GCL.	Advantages of this mitigation measure are: ▪ The effectiveness of using GCLs to provide containment of wastes and liquids is well established with numerous applications across Australia and globally. ▪ A GCL will provide long-term protection between the impacted groundwater and clean fill material if installed correctly. A GCL is more durable in the long term versus other types of liners such as HDPE liners. ▪ While some specialised equipment and personnel are required, the installation process is relatively straightforward. ▪ The addition of activated carbon to new designs of GCLs increases the protection from PFAS migration.	Disadvantages of this mitigation measure are: ▪ Installation of a GCL may present a constraint to foundation design for future buildings. If deeper piles are required, their design will need to consider penetrations through a GCL to ensure a preferential pathway is not created. ▪ Landscaping vegetation, installed for amenity, with deeper root systems could penetrate the GCL which could create a preferential pathway. ▪ The drainage layer required below the GCL would be designed to relieve the pressure from rising groundwater levels. Intercepting rising groundwater may create a preferential pathway for groundwater movement and consequently affect PFAS fate and transport. ▪ A drainage layer will be required above the GCL to capture and manage stormwater that vertically infiltrates down through the fill layer. The collected stormwater would have to be captured and managed in the same manner as described above.	Constructability considerations related to fill importation and pre-loading include: ▪ Expectation is 300-500mm of settlement over one year. ▪ This could lead to differential settlement including of the GCL. Larger pockets of differential settlement are easier to manage. Differential settlement could be more problematic in overlap regions. GCL has a 10 kilonewtons/metre tensile strength. ▪ Sufficient ground preparation is important which is specific for boggy grounds. This includes applications such as geogrids. Constructability considerations related to penetration of GCL by piles / root zones: ▪ Significant pressure is required to keep GCL in place during pile driving. ▪ GCL is self-healing up to 10-millimetre diameter hole. The space between the pile and GCL is the critical design element. ▪ Long term compatibility of GCL with water chemistry would need to be established. Unit Cost: Approximately $400K per hectare Estimated Cost for 34 hectares: $13.6 M

Table F-1: PFAS Mitigation Measure Details and Constructability Considerations

Potential mitigation measure	Conceptual application description	Advantages	Disadvantages	Constructability Considerations
Mixing of PAC in bulk fill	As an alternative or complimentary measure to a GCL, PAC could be mixed with the bulk fill material. Theoretically, the PAC would preclude dissolved phase PFAS adsorbing to the clean fill. If PFAS did transfer from the groundwater to the particulate phase adsorbing onto the clean fill material, it would be preferentially adsorbed by the PAC. Once adsorbed to the PAC, the PFAS would be less likely to leach and act as a secondary source. Given the historical groundwater fluctuations, groundwater would be expected to only interact with the bottom 0.5-0.75 m of the fill material. As such, the PAC would only need to be mixed with the bottom fill layers. This would require further analysis to confirm the potential interactions between fluctuating groundwater and the fill material.	Advantages of this mitigation measure are: ▪ Relatively simple method to prevent PFAS from adsorbing to clean fill and act as a future secondary source. ▪ Relatively easy to implement by mixing 2% weight PAC / weight fill material as it is being placed. ▪ PAC has shown to be an effective for a range of contaminants including PFAS. ▪ The PAC can be mixed uniformly into the fill material. ▪ Use of PAC could increase the geotechnical stability of the fill material. ▪ Based on the measured PFAS concentrations in groundwater, use of PAC could preclude the need for a GCL in some areas across the structure plan boundary that present a lower risk of impacting the fill.	Disadvantages of this mitigation measure are: ▪ During the operational phase of the SAP (i.e. after construction), the PAC will have a finite timeframe for being effective. It is difficult to predict the lifespan of the PAC. ▪ It is not possible to replace the PAC once mixed in bottom layers of fill material. ▪ Could potentially create a long-term secondary source as the PAC will preferentially sorb the PFAS from the groundwater to soil. At some point in the future, the PAC would be unable to sorb any more PFAS and could eventually begin leaching PFAS. ▪ If clay is used as the fill material, it would make the uniform mixing of PAC more challenging. ▪ Limited supplies of PAC are currently available in Australia due to it being used extensively in environmental remediation applications. Depending on the timing of the bulk filling, the procurement of PAC could present a long lead time.	Constructability considerations related to mixing PAC with fill material include: ▪ Homogenous mixing into the fill material would be required. This could lead to additional material handling and/or plant being required. ▪ Depending on the composition of the fill, homogenous mixing may be difficult to achieve. ▪ At this phase of the concept design, it is assumed that PAC may be required in up to the bottom 0.75 metres. However, this needs to be verified by additional modelling to understand how the weight of the fill would affect the groundwater table. ▪ Bench-scale or treatability studies should be conducted to determine optimal dosing ratios and confirm the effectiveness of this application. ▪ The physical and chemical properties of the fill material can impact the effectiveness of PAC. High organic content in soil can reduce its effectiveness (NGWA 2017). Low pH, the presence of polyvalent cations in the soil, or treatment amendment also increases sorption, retardation, and metals precipitation. Unit Cost: $3,050 per tonne Estimated: 16,381 tonnes required Estimated Cost: Approximately $50M

Table F-1: PFAS Mitigation Measure Details and Constructability Considerations

Potential mitigation measure	Conceptual application description	Advantages	Disadvantages	Constructability Considerations
Natural conditions prevail	Due to the constructability and long-term maintenance issues with the above measures, it is appropriate to consider letting natural conditions prevail during and after the construction of the SAP. This entails allowing the groundwater table to naturally fluctuate and interact with the bottom layers of the fill material. PFOS concentrations in groundwater (AECOM 2021) in the SAP area have ranged from below laboratory detection limits to 9.1 µg/L. Groundwater in areas of the SAP ranges from 2.09 metres below current ground level in the northern portion to 0.44 metres below current ground level in the southern portion. Based on historical gauging results from AECOM (2021), groundwater fluctuates by approximately two to three metres and sometimes daylights following high rainfall conditions, under certain conditions. When PFAS impacted groundwater fluctuates and interacts with unsaturated soil, PFAS will partition to various phases as follows 1) remain in dissolved phase or 2) sorb to unsaturated soil and/or 3) accumulate at air water interfaces. The partitioning of PFAS to solid-phase minerals is thought to occur through two primary processes: 1) adsorption to organic carbon via hydrophobic interactions, and 2) electrostatic interactions (Guelfo and Higgins, 2013 and Higgins and Luthy 2006, Oliver et al., 2019). The relative contribution of each process can vary depending on the PFAS isomer/s present, surface chemistry and other geochemical factors. In general, PFAS sorption is lower to soils with lower carbon content. Additionally, for anionic PFAS such as PFOS, PFOA and PFHxS, an overall negative charge on the soil would tend to limit sorption of PFAS onto unsaturated soils. If PFAS did sorb to unsaturated soils, its mobility in the sub-surface would be influenced by future interactions with groundwater where it could re-dissolve or through stormwater infiltrating downward through the soil, dissolving the PFAS and then transporting it from there.	The advantages of this approach are: ▪ Ease in constructability as there are no special considerations ▪ Significantly reduced costs over mitigation measures discussed above. ▪ Use of PAC would lead to increased sorption of PFAS and thus a long-term secondary source. ▪ The fill material that may interact with fluctuating groundwater will not be accessible to potential human or ecological receptors. Even if PFAS sorbs to fill, there is not a completed pathway for direct exposure to potential human or ecological receptors. ▪ Sorption to imported fill material is expected to be much less than to PAC and below the Tier I screening levels for the intended land use. Under an industrial/commercial land use, the HIL D is 20-50 mg/kg. Given the low groundwater concentrations, it is highly unlikely that PFAS would sorb and create exceedances of the HIL D. ▪ The ecological screening values range from 1-10 mg/kg for direct exposure which is highly unlikely. For indirect exposure, the ecological screening value is 0.01 mg/kg for indirect exposure but 0.14 mg/kg for highly developed site with no secondary consumers (Table 3, NEMPv2.0) ▪ Eliminates need for drainage layers under a GCL installation application. Management of expected volumes of stormwater during some storm events is technically feasible but challenging. Introducing additional water that requires management would make the stormwater management strategy even more problematic or not feasible. ▪ The thickness and permeability of the fill material and increased hard stand area would tend to reduce downward infiltration of stormwater.	The disadvantages of this approach are: ▪ Perceived risk of not employing a mitigation measure to minimise interaction between groundwater and soil ▪ Sorption of PFAS to soil is non-linear meaning some PFASs would sorb more strongly at lower concentrations. However, under this scenario desorption of a portion of PFAS mass will occur very slowly (Xiao et al 2019). ▪ Further analysis / modelling is required to determine the impact the weight of the fill material will have on groundwater fluctuation and interaction with fill material. ▪ Some PFAS tends to sorb more strongly to acidic soils and there are known ASS in the SAP area. However, it is unlikely these will be disturbed or interact with PFAS. The existing water table is within high-risk area of Acid Sulfate Soils. The locations of ASS/PASS will be investigated as part of future site works. ▪ Ongoing monitoring would be required to demonstrate that PFAS is not being mobilised into areas where it is not currently detected.	The potential for PFAS to sorb to unsaturated soil can be limited by sourcing fill material with the following properties: ▪ Low organic carbon content ▪ Overall negative charge ▪ pH of 6-8 Given the large volumes of fill required, it may not be possible for all the material to have these properties consistently. In this case, fill in the bottom layers that are expected to interact with the groundwater should have these properties. Modelling to be conducted in future stages of design will inform the thickness of fill expected to interact with the groundwater. Additional details and analysis on the chemical and physical properties of the fill material should be undertaken. Ideally, this would be completed during identification of potential fill material sources. Additional evaluation/modelling to estimate PFAS concentrations that may be expected to sorb to soil and the long-term leachability of any sorbed PFAS. This could be used to inform a quantitative Human Health and Environmental Risk Assessment (HHERA), if necessary.

Table F-1: PFAS Mitigation Measure Details and Constructability Considerations

<table>
<tr><th>Potential mitigation measure</th><th>Conceptual application description</th><th>Advantages</th><th>Disadvantages</th><th>Constructability Considerations</th></tr>
<tr>
<td>Passive stormwater treatment</td>
<td>The SAP area will be built up several metres. The water cycle management strategy includes the collection of stormwater from these elevated platforms, buildings and impermeable surfaces. The stormwater would be collected through a pit and pipe network installed in each sub-precinct. The stormwater would then flow to constructed wetlands and a bioretention systems. The wetlands and bioretention basin are proposed south of the SAP area. There are five proposed for the SAP. The concept design for the stormwater management and wetland / bioretention system are shown on Figure 4.

It is anticipated that the vast majority of stormwater captured by this system would be PFAS free as it would not interact with PFAS impacted environmental media.

PFAS has been measured in stormwater/surface water in downstream areas of the Base resulting from the secondary sources remaining at the Base. These continue to be Defence's responsibility to address. Reported PFAS mass flux in surface water has reduced over time but there are some conflicting trends (AECOM 2017, 2019 and 2021). This indicates that the on-Base remedial efforts are leading to some reduced PFAS concentrations in stormwater and this would be expected to continue. Reducing concentrations are also attributed to cessation of use of PFAS/AFFF thus not introducing additional mass to the system. Additionally, the stormwater/surface water is currently not being treated directly and PFAS samples downstream of the future SAP area are below laboratory limits of reporting (LORs). The declining concentration trend is expected to continue given the ongoing remedial efforts by Defence. Given the water cycle management strategy only captures stormwater from the elevated platforms, it is not anticipated that this would lead to an increase in PFAS load in the stormwater/surface water systems.

As a conservative measure, installation of a passive treatment incorporating PAC could be installed in the bioretention basins. Emerging research has shown that some plant species can preferentially remove PFAS from the dissolved phase (Awad et al 2022, Wang et al, 2020). Inclusion of plants capable of PFAS phytoremediation could be considered for installation in the constructed wetland.</td>
<td>If a passive stormwater treatment is necessary, advantages of this mitigation measure are:
▪ This application would remove soluble PFAS in the stormwater in downstream areas
▪ Relatively low-cost strategy that can be implemented with a commercially available off-the-shelf solution and potentially integrated into the constructed wetlands/bioretention basins.
▪ A similar system has been recently installed at Lake Cochran on the Base and is understood to show early favourable results.
▪ Ability to demonstrate an innovative solution. Although the technology is relatively simple there are limited examples nationally and globally of passive treatment of PFAS impacted stormwater.</td>
<td>Disadvantages of this mitigation measure are:
▪ The measured PFAS concentrations in stormwater are derived from on-Base PFAS sources and are not the responsibility of DRNSW.
▪ Time-trend PFAS concentrations indicate that concentrations in stormwater have been reducing and this trend is expected to continue into the future.
▪ It is highly unlikely that the construction or operation of the SAP would lead to additional PFAS concentrations in stormwater as the new strategy will be constructed 2-3 metres above the current grade. All stormwater captured will be from the elevated construction platforms which would not interact with PFAS impacted environmental media
▪ The reported hydraulic conductivity of this system is approximately 3.8 x 10^{-4} m/sec. A passive filtration system installed within the conveyance system would tend to reduce water discharge velocities and thus increase required storage volumes. In certain areas and under certain storm events, additional retention times/volumes would make the stormwater management strategy unfeasible.
▪ Introduction of a passive treatment strategy within the stormwater conveyance system is not recommended.</td>
<td>If natural conditions prevail, there are no constructability considerations other than those for the stormwater collection and treatment system to function.

If some treatment is necessary, the following options could be considered in future stages of the design:
▪ Use of activated carbon impregnated gravel in the bioretention basin in lieu of just gravel. This is specified as a 300-millimetre-thick layer
▪ Employ phytoremediation techniques through choice of plants in the constructed wetland. Plants that are currently specified target nutrient removal but also could uptake PFAS.

If either of these options are required, they would not introduce significant additional constructability considerations. The stormwater treatment system already includes these components so minor modification would be required to make them PFAS specific.

<u>Cost Estimate</u>

Bioretention basin footprint ~6,700 square metres

Gravel layer thickness = 300 millimetres

PAC required (if used) = 2,010 cubic metres

Mass PAC required (if used) = 70 tonnes

Cost = $213,500 per application

The PAC would need to be periodically replaced which is dependent on PFAS concentrations and other competing adsorbents. As a conservative estimate, the PAC would need to be replaced every two years

Lifecycle costs (40 years) ~ $4.3M</td>
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Table F-1: PFAS Mitigation Measure Details and Constructability Considerations

Potential mitigation measure	Conceptual application description	Advantages	Disadvantages	Constructability Considerations
Flood Mitigation Strategy	The broader flood mitigation strategy current design includes construction of an earthen bund (top width approximately 2 metres with 1:4 batters, 3 metres tall, approximately 1,575 metres long) just south of the environmental protection area (**Figure 5**). The bund is proposed to be constructed to mitigate flood impacts during construction of the overall SAP. The berm will be constructed with the foundations below existing ground level and a highly compacted clay core (**Figure 6**). The berm is designed to capture stormwater flowing from the north and would route it to either Dawsons or Learys Drain under frequent events. Under large storm events, the captured water would infiltrate into the ground and provide flows for the environmental conservation area. A detention basin will be constructed in Learys Drain, above current grade to minimise the potential for groundwater infiltration. Once discharged to Dawsons or Learys Drain, the water would flow along existing, natural flow channels. Given the stormwater would flow across/from the Base, it is possible it will have measurable concentrations of PFAS. The stormwater re-routed by the bund would drain through a system that already records measurable PFAS concentrations which have declined over time (AECOM 2017, 2019, 2021). It is unlikely that PFAS in the captured water would significantly increase the PFAS mass flux in the drains. This is due to the stormwater that would be re-routed across the SAP boundary 1) flowing overland along the existing flow channels 2) infiltrating into ground and/or 3) pooling and eventually evaporating. Therefore, the proposed flood mitigation strategy would not produce additional volumes of stormwater, rather just re-route what is already produced to create flood immune development platforms. If the flood water requires treatment, this could be integrated with the stormwater management strategy above. The water could be lifted and pumped to the constructed wetland/bioretention basin. The potential modifications described above would treat any water that is pumped to the wetland/bioretention basin assuming the volume of water does not affect the function of the treatment system. The construction of the berm would also intercept groundwater along its length. This is due to the foundations being below current grade and the compacted clay core. Further analysis is required to determine the impact on the water table along the length of the berm including geotechnical considerations. Groundwater may need to be captured and routed along the berm.	The advantages of letting natural conditions prevail include: ▪ Minimises costs and constructability issues ▪ Allows re-routed flood waters to flow naturally and not introduce restrictions to the flow paths. This would cause significant volumes of water to be retained under large storm events. ▪ PFAS impacted stormwater and surface water is already moving through the SAP area untreated. Downstream monitoring results show PFAS concentrations not above the LOR. The proposed flood mitigation strategy will not add to the PFAS mass flux. If a mitigation measure is necessary, advantages of this mitigation measure are: ▪ Integration into the stormwater management strategy with modifications to the constructed wetland/bioretention basin ▪ Lifting and pumping water from Dawsons and Learys Drain to the stormwater treatment system would be more effective than installation of passive filtration throughout the stormwater conveyance system. ▪ Modifications to the stormwater treatment system will be more cost effective than passive treatment throughout the stormwater conveyance system. ▪ Replacement of PAC/phytoremediation species can be achieved more easily than passive treatment throughout the conveyance system.	The disadvantages of letting natural conditions prevail include: ▪ Perceived risk of not employing a mitigation measure to minimise PFAS in stormwater ▪ Without intervention groundwater flow conditions will be affected by the earthen berm. Further consideration of this is required ▪ The clay core or similar will extend below current grade. Soil waste will be produced that requires management. Dewatering may also be required and if the groundwater is impacted, may require treatment. A suitable discharge location would be required for any removed/treated groundwater. If a mitigation measure is required, the disadvantages include: ▪ Excessive volumes of water being pumped to the stormwater treatment ▪ The measured PFAS concentrations in stormwater are derived from on-Base PFAS concentrations and are not the responsibility of RDNSW. ▪ Careful selection of plant species would be required to ensure the constructed wetland functioned as designed to primarily remove nutrients.	If natural conditions prevail, there are no constructability considerations other than those for the construction of the earthen bund. If some treatment is necessary, the following options could be considered in future stages of the design: ▪ Use of activated carbon impregnated gravel in the bioretention basin in lieu of just gravel. This is specified as a 300-millimetre-thick layer ▪ Employ phytoremediation techniques through choice of plants in the constructed wetland. Plants that are currently specified target nutrient removal but also could update PFAS. Recent research shows there are some species that preferentially uptake PFAS from the dissolved phase. If either of these options are required, they would not introduce significant additional constructability considerations. The stormwater treatment system already includes these components so minor modification would be required to make them PFAS specific.

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