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FINAL REPORT

Frenchs Forest Planning Precinct WSUD strategy

December 2019

Document history

Revision:

Revision no.	03
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Approved	

Distribution:

Revision no.	03
Issue date	04/12/19
Issued to	Northern Beaches Council
Description:	This report outlines a WSUD strategy for the Frenchs Forest Planning Precinct.

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Ref:
U:\Work\2019\003_Frenchs_Forest_Precinct_WSUD_Strategy\10_Project\1_Deliverables\P619003.01 Frenchs Forest WSUD strategy 191204.docx

Contents

Figures

Tables

1 Introduction

The NSW government has identified Frenchs Forest as a Planned Precinct within the North District Plan. The Frenchs Forest Planning Precinct (FFPP) includes the Northern Beaches Hospital property, the proposed Frenchs Forest Town Centre (FFTC) and surrounding future medium density residential / mixed use development. FFPP is to be developed over the next 20 years in three phases and will ultimately provide over 4,360 new dwellings and support 3,093 jobs. The extents of each development phase within the FFPP is shown in Figure 1-1.

Figure 1-1 *Frenchs Forest Planning Precinct Phasing Strategy (NBC, 2017 – Structure Plan)*

The Phase 1 precinct including the FFTC is the primary focus of this WSUD strategy. The Draft Frenchs Forest Town Centre Urban Design Report and Public Domain Strategy (CHROFI, 2018) outlines the 'masterplan' for development in the FFTC and includes the design vision and principles that inform the urban design. The FFTC is being planned to include a range of dwelling types, cafes, restaurants, retail shops, public buildings, commercial and health based uses and a large open space area referred to as the village green.

Land within the FFPP is highly valued for a range of future urban land uses. Council is seeking to minimise the land required to be dedicated exclusively to stormwater management, whilst ensuring that stormwater runoff quality and quantity can be managed to protect sensitive receiving environments. The FFTC masterplan does not include dedicated land parcels for managing stormwater quality and other areas in the FFPP have limited potential for centralised stormwater quality management measures.

The FFTC masterplan includes some discussion on future stormwater quality management controls, but to date no specific WSUD strategy has been prepared for the FFPP. Council is seeking a WSUD strategy that focuses on distributed source-based measures that can be strategically positioned within private development lots, private road reserves, public road reserves and public footways. Council intends that road reserves within the FFTC are retained in private ownership. The FFPP also includes three public reserves that are to be improved for the community's use and these upgrades are expected to provide an opportunity to incorporate WSUD measures at a larger sub-catchment scale.

The recommended WSUD strategy is outlined in the following sections of this report:

- Section 2 outlines the existing and planned future development characteristics in the FFPP.
- Section 3 summarises some of the key site characteristics that influence selection of the types and locations of WSUD measures.

- Section 4 summarises key state and local government planning legislation, policies, strategies and guidelines that include objectives that would be supported through the implementation of WSUD.
- Section 5 summarises Council's current stormwater quality management objectives and targets that would apply to development in the FFPP. Recommendations are provided in this section on opportunities to update these objectives and targets.
- Section 6 outlines WSUD measures considered for the FFPP and their suitability based on the objectives, targets, development characteristics and site constraints.
- Section 7 outlines the recommended base WSUD strategy for the FFPP. The base WSUD strategy represent the fundamental components that would be required to achieve the targets.
- Section 8 provides conceptual sketches of base WSUD strategy measures.
- Section 9 outlines the MUSIC modelling completed to evaluate the conceptual configuration and extents of WSUD measures within the base WSUD strategy.
- Section 11 outlines preliminary cost estimates for the measures.

2 Development planning

2.1 Existing development

The Northern Beaches Hospital that was recently constructed adjacent to the existing Forest High School is a major development in the area. Major roads including Warringah Road, Wakehurst Parkway, Forest Way and Frenchs Forest Road traverse the FFPP. Historically, the Forest High School site was a large orchard where loquats, persimmons, lemons and other fruit were grown. Remnants of this orchard exist adjacent to the Forest High School grounds. Other existing major developments in the FFPP include the Forestway Shopping Centre, Frenchs Forest Public School and Frenchs Forest Police Station. A number of other businesses front Forest Way. The remaining land is primarily low density residential comprising individual detached dwellings.

2.2 Future development

The Northern Beaches Hospital was constructed over the 2015 to 2018 period. During construction of the Northern Beaches Hospital, the NSW government announced that Frenchs Forest would be included as a Planned Precinct in the North District Plan. The Frenchs Forest Planning Precinct (FFPP) was delineated to incorporate the Northern Beaches Hospital site, the adjacent Frenchs Forest Town Centre (FFTC) and surrounding increased density residential and mixed use development. The proposed LEP land zoning incorporated into the FFPP structure plan is shown in Figure 2-1.

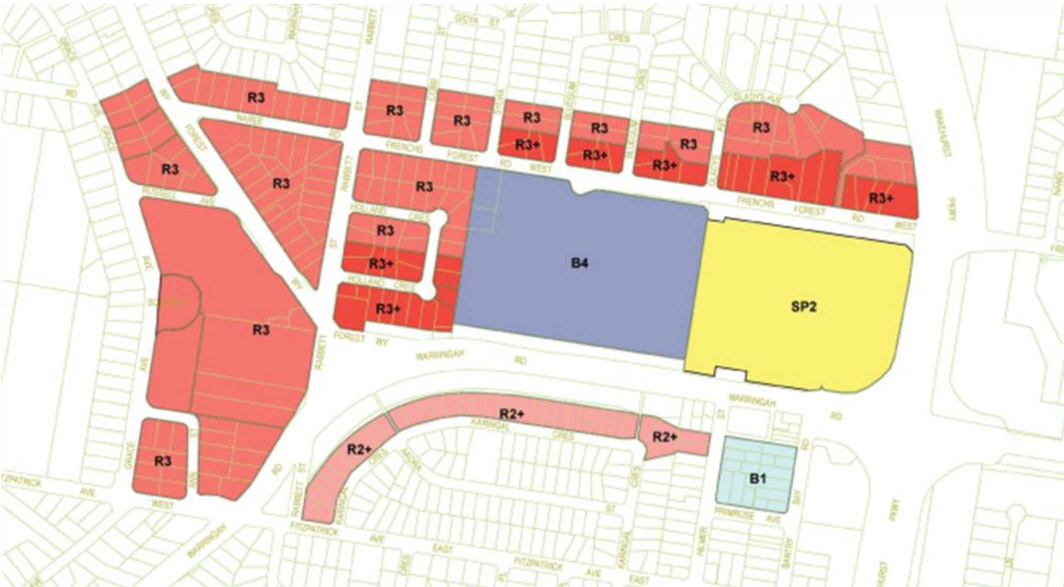


Figure 2-1 *Frenchs Forest Planning Precinct – Proposed land uses (NBC, 2017 – Structure Plan)*

The FFPP is to be developed over the next 20 years in 3 phases including Phase 1 (immediate), Phase 2 (< 10 years) and Phase 3 (> 10 years). The extents for each development phase are shown in Figure 1-1 and discussed further below.

2.3 Phase 1 precinct

Phase 1 of the FFPP includes the Northern Beaches Hospital, the proposed Frenchs Forest Town Centre (FFTC) (the current Forest High School site), a neighbourhood centre and a proportion of the low and medium density residential development. The Phase 1 precinct is the primary focus of this WSUD strategy.

Phase 1 will provide over 1,930 of the planned 4,360 new dwellings, and 2,981 of the planned 3,093 new jobs. The FFTC is being planned to include a range of housing types, cafes, restaurants, retail shops, public buildings, commercial and health based uses, and a large central open space area.

Figure 2-2 *Frenchs Forest Planning Precinct – Phase 1 extents (source: NSW Department of Planning and Environment)*

The Frenchs Forest Town Centre Urban Design Report and Public Domain Strategy (CHROFI, 2018) outlines the 'masterplan' for development in the FFTC and includes the design vision and principles that inform the urban design.

The masterplan promotes the inclusion of a large central park or village green (area exceeding 6,000 m^2) in the FFTC development to provide a significant space that supports a diverse range of passive and active recreational uses for the community. It is envisaged that the village green would be utilised by office and retail workers, university students and residents. Initial concepts indicate this area would include a high proportion of level grassed open space. We understand that the design intent for this area is to keep the village green open and relatively free of obstructions that may impede views across the space.

The masterplan includes provision for retention of remnant mature urban forest for utilisation as an informal exercise and play area that enhances community well-being and social interactions. This space would be adjacent to the village green area.

The FFTC includes a number of key public domain areas that are intended to have different functions and landscaping objectives. The key public domain areas are described below and shown in Figure 2-3.

1. Piazza – Hard paved landscaped area central to the town centre.
2. Village green – Large open lawn park for exercise and potentially events including outdoor cinema and weekend markets.
3. Remnant forest and orchard – Remnant urban forest and orchard providing space for community gardens, exercise and picnics.
4. Fresh food court – Forecourt near access to retail areas including water features and lush planting.
5. Hospital connector – Linear pedestrian connection from the piazza to the hospital.
6. High street – Frenchs Forest Road footway.
7. Southern gateway – Existing pedestrian link and bridge over Warringah Road.
8. Future overpass - New pedestrian bridge over Warringah Road.
9. Neighbourhood centre – Retail centre separated from the main FFTC site by Warringah Road.

Figure 2-3 *Public domain and landscaping spaces (CHROFI, 2018)*

Major roads surrounding the hospital are currently being upgraded to support the hospital and urban renewal in Frenchs Forest.

Residential units are planned for multi-storey buildings ranging in height from 2 storeys up to 12 storeys throughout the FFPP.

2.4 Phase 2 precinct

The Phase 2 precinct includes land between the FFTC and Forest Way. The existing land is primarily low density detached residential dwellings with the exception of the Frenchs Forest Police Station and some small businesses with frontages to Forest Way. All existing low density residential development in this precinct is planned to be converted to medium and high density housing.

Multi-storey high density residential apartment buildings are planned in the elevated parts of this precinct adjacent to the Forest Way / Warringah Road intersection. Residential units will be included in multi-storey buildings ranging in height from 2 storeys up to 12 storeys.

Opportunities for centralised management of stormwater runoff within this precinct are limited by steep terrain and with the exception of Rabbett Reserve, limited availability of appropriately zoned land. It is likely that distributed source based treatment of stormwater will necessarily be a key focus for the area.

2.5 Phase 3 precinct

The Phase 3 development precinct includes land between Forest Way, Warringah Road and the riparian areas in the upper reaches of Carroll Creek. A large proportion of the Phase 3 precinct is currently occupied by the Forestway Shopping Centre, Frenchs Forest Public School and surrounding mixed business and low density residential uses. All land in this precinct is planned to be converted to medium density housing. Residential units will be included in multi-storey buildings ranging in height from 2 storeys up to 12 storeys.

2.6 Preliminary stormwater management strategy

The masterplan outlines a preliminary stormwater management strategy for the FFTC. Preliminary ideas for management of stormwater quality within FFTC were suggested for that site. Key themes include providing permeable paving in the piazza, bioretention tree bays along streets, stormwater gardens/bioretention basins in the village green, green roofs, linear ponds, rainwater tanks, gross pollutant traps and OSD/drainage infrastructure. Many of the ideas included in this preliminary strategy are considered applicable to FFTC.

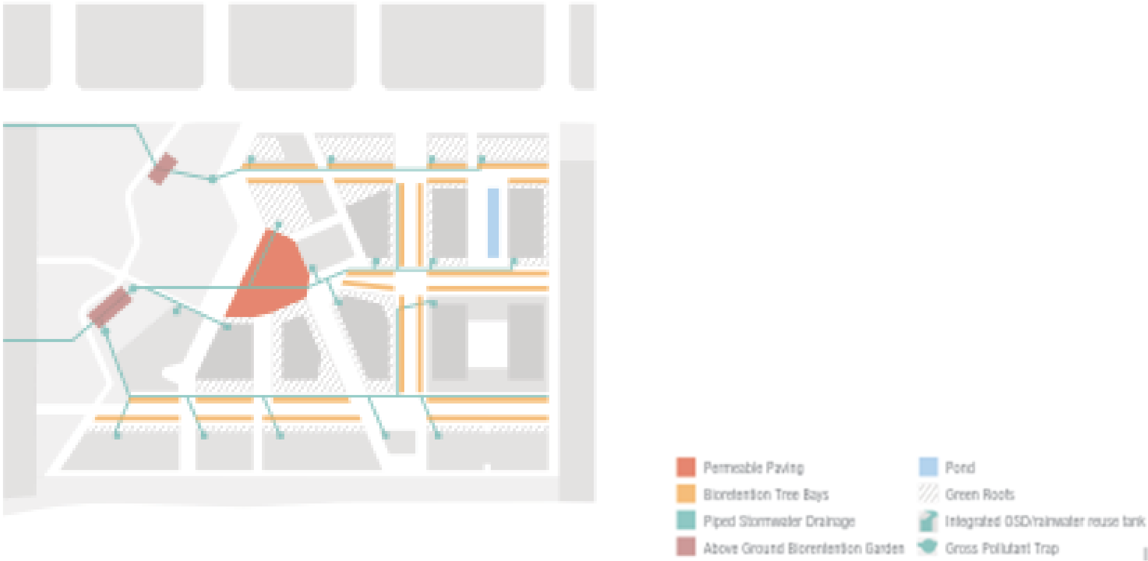


Figure 2-4 *Preliminary WSUD strategy (CHROFI, 2018)*

3 Site analysis

3.1 Drainage and overland flooding

The FFPP follows a ridgeline that separates the precinct into upper catchment areas for multiple receiving environments including Narrabeen Lagoon, Manly Dam, Bantry Bay and Middle Harbour. The majority of planned re-development areas within the FFPP will drain in a northerly directly to Narrabeen Lagoon. The sub-catchment extents for particular receiving waterways are shown on Figure 3-1.

The existing stormwater drainage system in the FFPP is generally aligned with public roads. The main exception is an existing piped drainage system through private residential land between the FFTC site and Rabbett Reserve. This drainage system follows what previously would have been a natural creek. It is apparent that this creek has been infilled and residential development constructed over. Review of contours and available flood mapping (Mott McDonald, 2018) indicate that extensive overland flow would occur through these properties during large flooding events and periods where the existing drainage system is blocked, or the flow capacity of the drainage system exceeded. Ideally, re-development of land in this existing residential area located within the Phase 2 Precinct would include redefining an overland flow path through public land. WSUD measures in this precinct should be provided outside overland flow paths to avoid impacts on flooding behaviour or redistribution of flows.

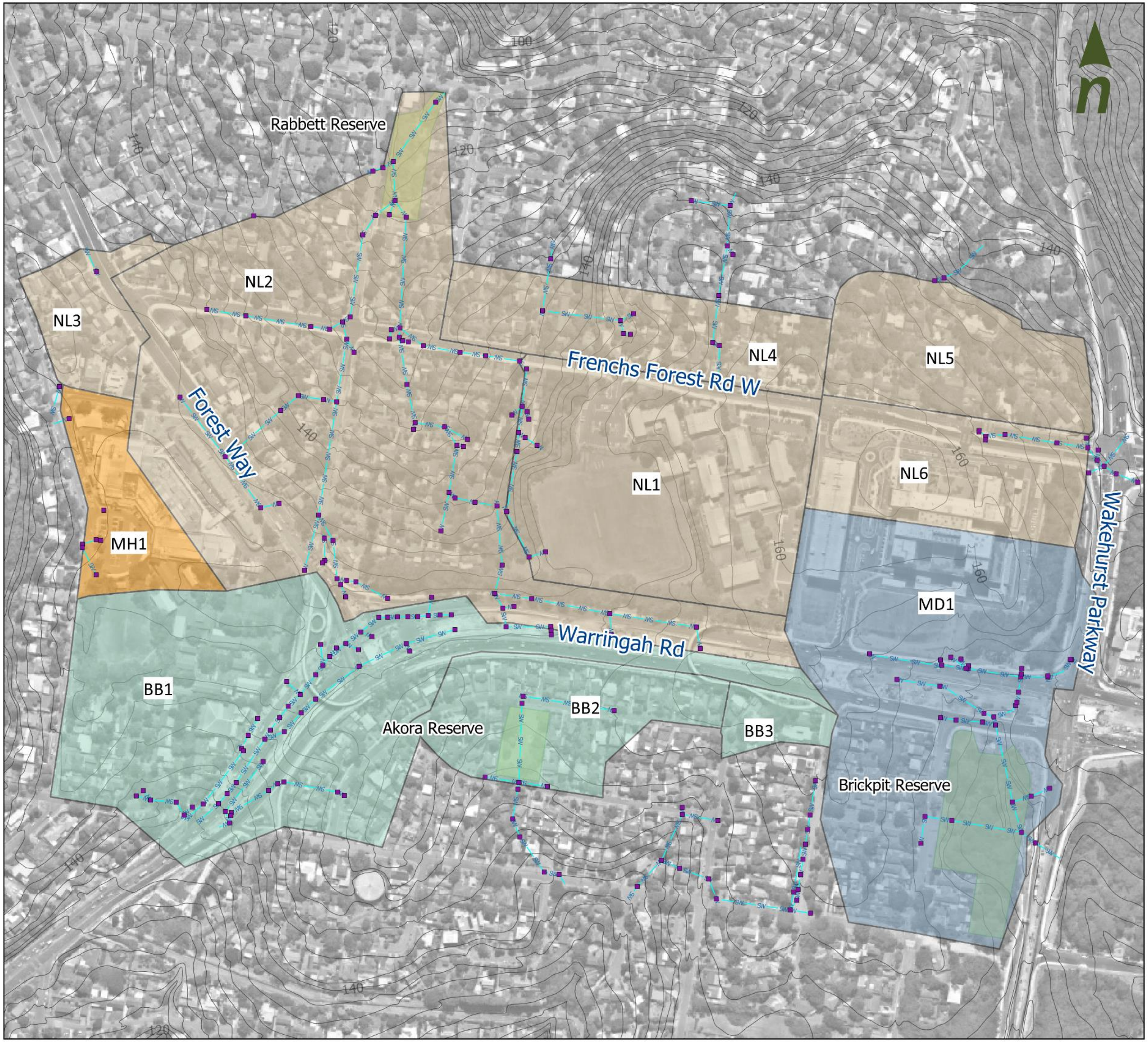
3.2 Terrain

The existing terrain is typically a key challenge to WSUD in any development area. Typical gradients across the FFPP are show in Figure 3-2. Within the FFPP there are distinctive differences in gradient across the future development areas.

The Phase 1 precinct aligns with a ridge that separates the Narrabeen Lagoon and Middle Harbour catchments. The Phase 1 precinct will primarily be gently grading except in the proposed residential areas on the northern side of Frenchs Forest Road and within a remnant urban forest area adjacent to the future FFTC. The existing terrain in this precinct is likely to be amenable to a range of source, street and precinct scale WSUD measures.

The Phase 2 precinct includes relatively steep land with gradients exceeding 10% over a high proportion of the precinct. The steep gradients in this precinct form a major constraint to a range of WSUD measures. There is potential that stormwater treatment of minor flows could be incorporated into the downstream Rabbett Reserve, although the size of the upstream catchment is likely to result in minor treatment outcomes. The steep gradients are likely to restrict WSUD measures to lot scale source based controls in planned residential development lots and localised street scale measures in locations where road gradients are amenable.

The Phase 3 precinct straddles a ridge separating the Narrabeen Lagoon and Carroll Creek catchments. Similarly, to the Phase 1 precinct, the land is primarily gently grading and would be appropriate for a range of source, street and precinct scale WSUD measures.



French's Forest Precinct

Figure 3-1 - Subcatchments and drainage

Legend

Stormwater assets

- Pits
- Drainage pipes

Cadastral

- Reserves
- Contours (2m)

Receiving waters

- Carroll Creek to Middle Harbour
- Manly Creek to Manly Dam
- Unnamed Creek to Bantry Bay
- Middle Creek to Narrabeen Lagoon

0 100 200 m

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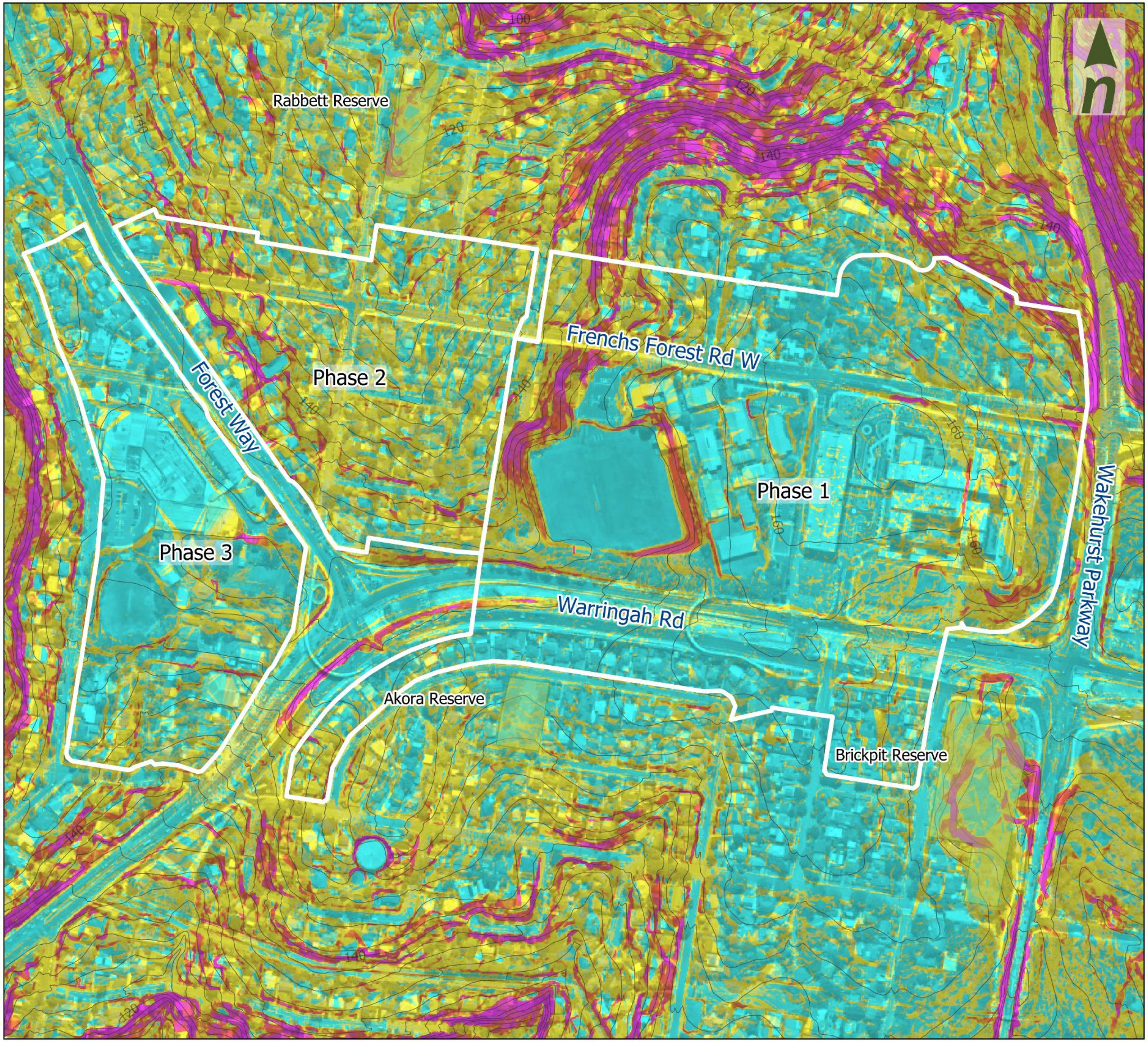

French's Forest Precinct

Figure 3-2 - Terrain

Legend

2m Contours

Slope gradient (%)

- 0-5%
- 5-10%
- 10-25%
- 25-50%
- > 50%

0 100 200 m

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3.3 Soils and groundwater

The soil landscapes found across the FFPP are shown on Figure 3-4 . As can be observed, most of the FFPP aligns with the Lucas Heights (lh) soil landscape formed along an undulating plateau where gradients less than 10% are typical. Lucas Heights soils typically comprise a loose fine grained sandy loam (lh1) layer up to 0.3m overlying a 0.1 to 0.3m layer of stony hard setting fine grained sandy clay loam (lh2). The sandy clay loam layer is typically underlain by a sandy to heavy clay layer (lh4) with a depth up to 1m. The depth to shale bedrock is typically less than 1m. On the edges of the plateau, soils may lie directly on Hawkesbury sandstone bedrock. The typical soil profile is show in Figure 3-3.

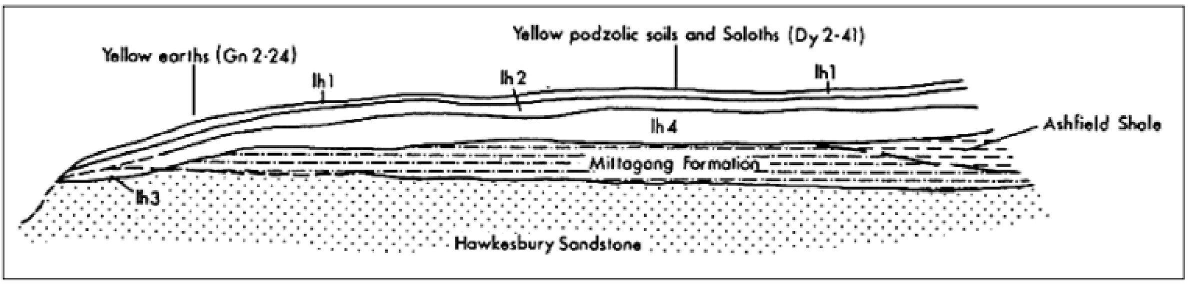

Figure 3-3 *Typical Lucas Heights soil landscape cross section (Chapman and Murphy, 1989)*

Along the western and northern fringes of the FFPP the land transitions to steeper gullies and the soils change to typical Hawkesbury soils. These soils are typically discontinuous in the areas with sandstone outcrops and boulders covering over 50% of the surface. On rock benches, shallow sandy soil layers have formed with the total soil depth typically less than 0.7m.

The upper Lucas Heights soil layers typically have high permeability and would be suitable for shallow infiltration of stormwater. Sandy loam soils are ideal for a range of biofiltration measures including tree pit filters, stormwater gardens, biofiltration swales and basins. The total soil depth of around 1m is relatively shallow and requires consideration when designing treatment measures. As gradients increase above 5% there would be increased risk of erosion where stormwater is concentrated across these soils.

Hawkesbury soils will typically be unsuitable for many WSUD measures due to the widespread presence of sandstone outcrops and boulders. The shallow depth to bedrock would be a key constraint in these areas.

It is expected that shallow groundwater would be recharged by local rainfall and move along the interface between the sandy and clay soils layers during large recharge events. It is envisaged that groundwater would emerge as baseflow at the interface between the bedrock and soils in gullies and creeks that drain the area, and potentially through springs along the hillslopes. Ensuring that concentrated infiltration of stormwater at particular locations in the development area does not increase seepage into existing downslope properties is an important consideration for the WSUD strategy.

3.4 Existing services and infrastructure

Existing services and infrastructure have been identified through a dial-before-you-dig enquiry focusing on the public reserves where consideration is being given to constructing centralised stormwater treatment measures. Indicative locations of services are shown on concept figures for the reserves.

French's Forest Precinct

Figure 3-4 - Soil landscapes

Legend

Soil Landscapes

- DISTURBED TERRAIN
- GYMEA
- HAWKESBURY
- LAMBERT
- LUCAS HEIGHTS
- OXFORD FALLS

Phases

- Phase 1
- Phase 2
- Phase 3

0 100 200 m

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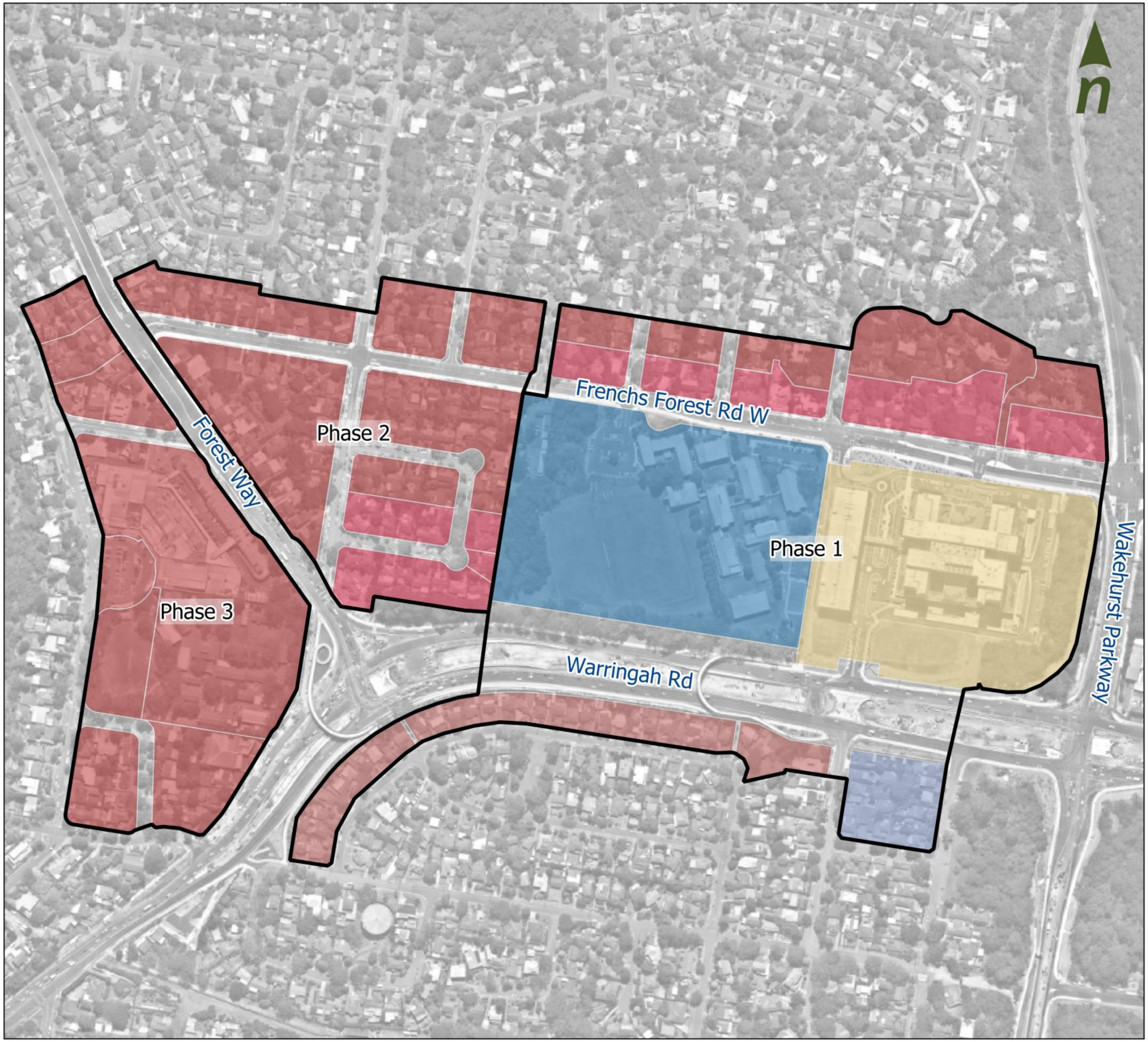

French's Forest Precinct

Figure 3-5 - Anticipated land zoning

Legend

LEP land zoning

- B1
- B4
- R2+
- R3
- R3+
- SP2
- Phases

0 100 200 m

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3.5 Receiving environments

The receiving environments that accept stormwater runoff from the FFPP are shown in Figure 3-6 and briefly discussed below.

The FFPP straddles a ridge aligned with Warringah Road and Forest Way that traverses the precinct. The Phase 1 precinct includes the FFTC and future residential development initially draining north to Middle Creek prior to flowing into Narrabeen Lagoon. The Phase 1 precinct also includes future residential development south of Warringah Road that drains south to an unnamed creek and then into Bantry Bay. The existing Northern Beaches Hospital within the Phase 1 precinct and a small area of future business and residential development south of Warringah Road drains through Brickpit Reserve to Curl Curl Creek and then into Manly Dam.

The initial receiving environments for stormwater runoff from FFPP are all ephemeral creeks that are typically steep due to their location in the upper reaches of each catchment. Management of both runoff quality and quantity from the development areas will be important to mitigate potential impacts on these creeks. Protection of these creeks will assist to protect water quality in downstream receiving environments including Narrabeen Lagoon, Middle Harbour and Manly Dam that are highly valued by the community.

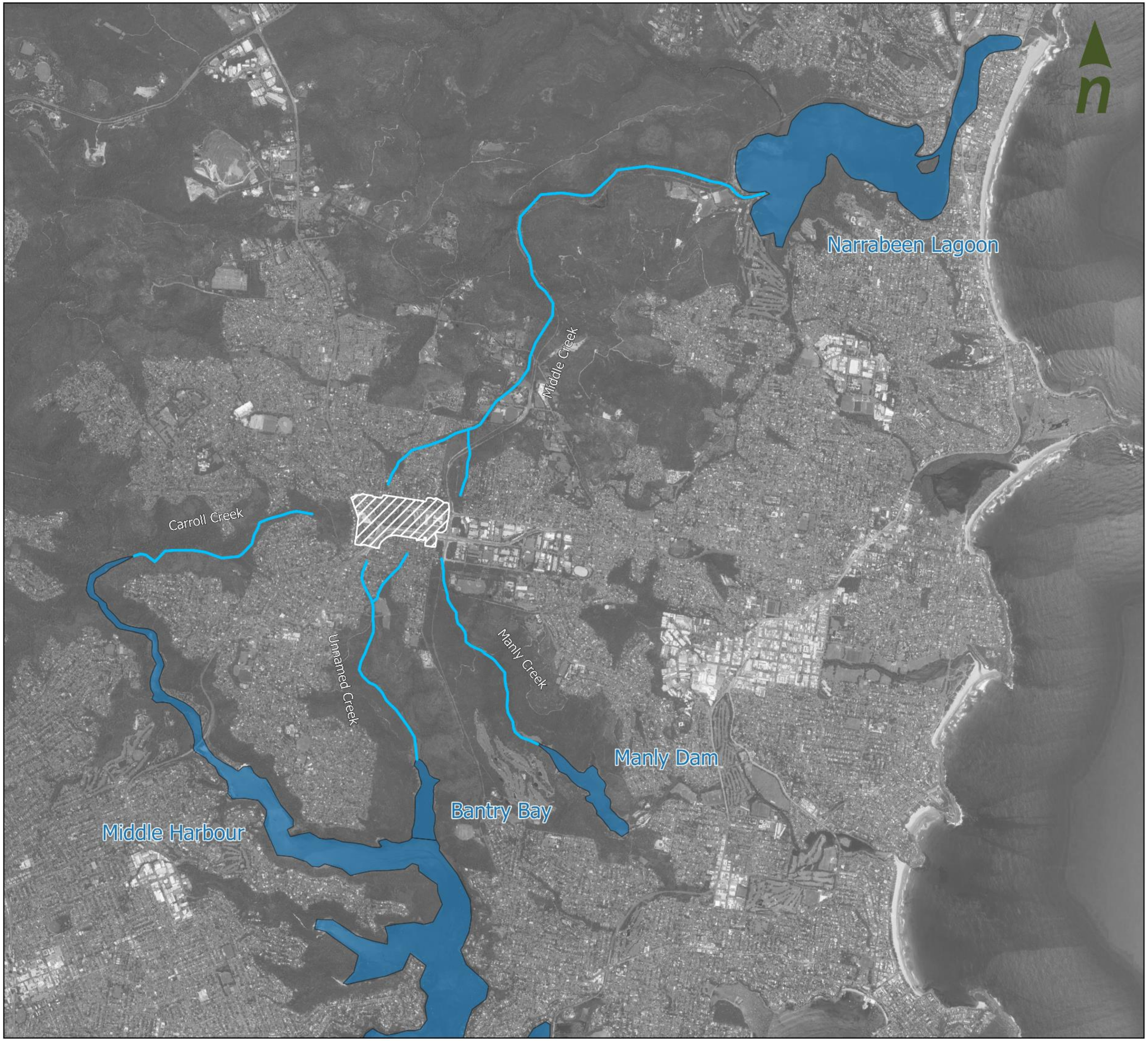
The Warringah Creeks Study (Warringah Council, 2004) identified a number of key threats to the creeks that receive runoff from the FFPP. A large portion of the FFPP drains to Middle Creek, and the upper reaches of Middle Creek downstream of the FFPP were observed to have bank erosion issues due to altered flow conditions associated with urban development. It was recommended that bank stabilisation in the steeper upper reaches be planned to reduce weed transfer and sediment supply to lower reaches of the creek and Narrabeen Lagoon.

The western portion of the FFPP drains to Carroll Creek comprising steep headwater reaches draining to narrow gorge upstream of Middle Harbour. Management of runoff quality from urban development was identified as particularly critical for this creek. The southern parts of the FFPP drain to an unnamed creek that drains into Bantry Bay. Bank stabilisation and weed removal were identified as priorities for this creek. A minor proportion of the FFPP including part of the new Northern Beaches Hospital and land south of Warringah Road drains to the uppermost reach of Curl Curl Creek flowing to Manly Dam. Curl Curl Creek was identified as being highly impacted by weeds and high concentrations of water pollutants were detected.

3.6 Improved liveability

In addition to managing stormwater quality and quantity, sensitive integration of the stormwater quality management elements into the urban landscape can support a range of physical health, mental health and social co-benefits. Some key benefits that can be supported by WSUD include:

- Urban cooling benefits through the provision of increased vegetation canopy and reduced impervious surfaces.
- Improved amenity through the integration of stormwater management facilities with landscaping treatments.
- Increased opportunities for social interactions through the creation of attractive landscaped public open spaces that merge stormwater quality management with passive recreation.
- Integration of physical exercise equipment into enhanced urban forest areas.



French's Forest Precinct

Figure 3-6 - Frenchs Forest receiving environments

Legend

- Watercourses
- Receiving environment
- Frenchs Forest precinct

0 1 2 km

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4 Planning policies and guidelines

4.1 NSW environmental planning hierarchy

The current NSW environmental planning hierarchy is shown in Figure 4-1. The relevance of the various planning instruments to the management of stormwater from new development in the FFPP is discussed below.

Figure 4-1 *NSW environmental planning hierarchy*

4.2 State Environmental Planning Policies

SEPP (Coastal Management) 2018

This SEPP combines three repealed SEPPs (coastal wetlands, littoral rainforests and coastal protection)

The FFPP lies outside (but is close to) the mapped Coastal Environment Area in SEPP (Coastal Management) 2018 and other mapped coastal wetland and littoral rainforest areas. At this stage, no mapping is available for coastal vulnerability areas. The SEPP requires that development consent for development located with the mapped Coastal Environment Area shall not be granted unless the consent authority has considered whether the development is likely to cause an adverse impact on a range of issues, include a number that are relevant to urban stormwater management including:

- *the integrity and resilience of the biophysical, hydrological (surface and groundwater) and ecological environment,*
- *coastal environmental values and natural coastal processes,*
- *the water quality of the marine estate (within the meaning of the Marine Estate Management Act 2014), in particular, the cumulative impacts of the proposed development on any of the sensitive coastal lakes identified in Schedule 1,*
- *marine vegetation, native vegetation and fauna and their habitats, undeveloped headlands and rock platforms,*
- *Aboriginal cultural heritage, practices and places,*

Although the FFPP lies just beyond the mapped Coastal Environment Area extents, the principles outlined in the SEPP are also relevant to future development in this area as stormwater from the FFPP also drains to these protected areas.

4.3 Regional Plan - The Greater Sydney Region Plan – A Metropolis of Three Cities

This document outlines the Greater Sydney regional plan for the next 40 years. The regional plan provides a vision for the city that includes directions for future infrastructure, liveability, employment and sustainability.

The plan includes 40 objectives. *Objective 25 - The coast and waterways are protected and healthier* is the main objective that would be addressed through management of urban stormwater runoff in the FFPP. Other objectives relevant to stormwater management include:

- *Objective 27 – Biodiversity is protected, urban bushland and remnant vegetation is enhanced.*
- *Objective 30 – Urban tree canopy cover is increased.*
- *Objective 31 – Public open space is accessible, protected and enhanced.*
- *Objective 32 – The green links parks, open spaces, bushland and walking and cycling paths.*

Key strategies linked to Objective 25 include protecting environmentally sensitive waterways and coastal environments, enhancing liveability and improving the health of catchments and waterways. Strategy 25.3 has a specific target to improve the health of catchments and waterways through a risk-based approach to managing the cumulative impacts of development. DPIE promotes the use of a risk-based framework across catchments to help improve the health of catchments and waterways through a structured approach that:

- Considers the effects of land use change, development and the management of public land on waterways;
- Shows how better management of development can help meet environmental targets for waterways; and
- Provides options for appropriate management responses across entire catchments.

Whilst the risk-based approach promoted by DPIE has not specifically been progressed for the catchments impacted by future development in the FFPP, consideration of the potential impacts on the creeks, lagoons and estuaries receiving stormwater runoff from the FFPP has been included in preparation of this WSUD strategy.

4.4 District Plan - North District Plan

The North District Plan (NDP) sets out planning priorities and actions for improving the quality of life for residents as urban areas change and development progresses in the district. The NDP includes Frenchs Forest as key strategic centre and planned precinct. Frenchs Forest is an emerging strategic centre supporting employment growth associated with the recently constructed Northern Beaches Hospital.

The NDP outlines infrastructure, liveability, productivity and sustainability planning priorities for areas within the Sydney Metropolitan Area north of the Parramatta River, east of Castle Hill and south of the Hawkesbury River. Key planning priorities that are relevant considerations for WSUD in the FFPP include:

N6 – Creating and renewing great places and local centres and respecting the District's heritage.

This involves improving community access to open spaces. From a stormwater management perspective, it could involve creating shared spaces that function for community recreation during dry weather that can also function to support stormwater runoff management during wet weather.

N15 – Protecting and improving the health and enjoyment of Sydney Harbour and the District's waterways.

Waterways are identified as a key contributor to green infrastructure for cooling urban areas, providing a recreational destination and supporting a range of ecological communities reliant on water. The waterways also form a key component of the stormwater drainage system for urban catchments including French Forest.

The NDP identifies that urban development in Frenchs Forest will significantly increase impervious area and this has the potential to significantly increase stormwater runoff, leading to reduced water quality, discharge of contaminants into the waterways and loss of habitat. The WSUD strategy for the FFPP should assist to prevent impacts in existing waterways and enhance their values wherever possible.

The NDP aims to integrate the waterway objectives set out in legislation, policies and plans by prioritising the management of waterways and green infrastructure by:

- Reconceptualising waterways as an infrastructure asset;
- Integrating protection of waterways with other urban infrastructure; and
- Addressing the cumulative impacts of development and land use management across the catchments on the waterways

N16 – Protecting and enhancing bushland and biodiversity.

Many urban bushland areas are susceptible to edge effects from stormwater pollution.

N19 – Increasing urban tree cover and delivering Green Grid connections.

A key objective is to increase urban tree canopy. Tree lined streets have a significant impact on mitigating the urban heat island effect. It is recognised that urban renewal and transformation projects such as the FFPP have a critical role to play in increasing urban tree cover. Whilst opportunities for planting large trees may be limited in highly built up areas such as FFPP, provision of smaller trees, ground covers and native grasses can play a significant role through incorporation into stormwater gardens, green roofs and green walls. This planting can also perform a dual role of treating stormwater quality by filtering out pollutants.

N20 – Delivering high quality open space.

Urban renewal in areas such as FFPP creates opportunities to increase and improve the quality of open space areas. For the FFPP, local open space areas will be highly valuable spaces for workers to relax and for residents to meet and socialise. Ensuring that a large proportion of these areas is not exclusively dedicated to stormwater treatment and can serve multiple uses will be important.

N21 – Reducing carbon emissions and managing energy, water and waste efficiently.

Stormwater harvesting from roofs and potentially ground level paved areas can support many of the water efficiency approaches to be incorporated into sustainable building design.

N22 – Adapting to the impacts of urban and natural hazards and climate change.

Local overland flooding in FFPP will need to be managed to avoid exposing the community to high hazard flooding or increased flooding impacts. Development in FFPP should aim to cool the landscape by retaining water and increasing urban tree canopy.

4.5 Northern Beaches Council

Shape 2028 (Northern Beaches Community Strategic Plan 2018 – 2028)
Shape 2028 outlines the Northern Beaches Communities 10-year plan that identifies the main priorities and aspirations of the community for their local government area. Shape 2028 represents the highest level of strategic planning undertaken by Council. Whilst Council has the responsibility to prepare and maintain the community strategic plan, responsibility for implementing the plan is shared by state agencies, community groups and individuals within the community.

Shape 2028 clearly outlines the communities desire to see protection of the natural environment from the risks and impacts of local pressures. Key goals include that bushland, coast and waterways are protected to ensure safe and sustainable use for present and future generations; and that the built environment is developed in line with best practice sustainability principles. Strategies proposed to achieve this include:

- Protect and restore local biodiversity and bushland.
- Protect and improve ecological conditions in catchments, creeks and lagoons.
- Protect sustainable access to the natural environment, whilst recognising and protecting its cultural and heritage value.
- Ensure integrated land use planning balances the environmental, social and economic needs of present and future generations.
- Create green and resilient urban environments by improving tree cover, native vegetation, landscaping and water management systems.
- Promote the savings and benefits of ecologically sustainable development.
- Continually improve environmental standards and compliance in new and existing developments.

Local Strategic Planning Statement
The Environmental Planning and Assessment Act 1979 (EP&A Act) was amended in 2018 to introduce new requirements for councils to prepare and make local strategic planning statements (LSPS). An LSPS outlines a 20-year vision for land use in the local area including:

- the special characteristics which contribute to local identity;
- shared community values to be maintained and enhanced; and
- how growth and change will be managed into the future.

Councils will need to illustrate how their vision gives effect to the regional and district plans, based on local characteristics and opportunities, and the council's own priorities in the community strategic plan prepared under the Local Government Act 1993. The local area may be an entire local government area or could be based on separate wards in each LGA. They differ to community strategic plans which have a broader focus on social, environmental and economic aspirations of the community.

Once implemented, the LSPS will be the key resource to understand how strategic and statutory plans will be implemented at the local level. It will be important that the LSPS includes statements supporting the implementation of a WSUD strategy in the FFPP.

Warringah Local Environment Plan 2011
Northern Beaches Council is progressing the consolidation of the Warringah LEP, Pittwater LEP and Manly LEP into a new Northern Beaches LEP. The Warringah LEP 2011 currently applies to development in the FFPP.

The Warringah LEP 2011 does not include any specific miscellaneous or local provisions directly addressing the protection and management of water quality. We understand that specific clauses relevant to water quality are being considered for incorporation into the new Northern Beaches LEP.

Warringah Development Control Plan 2011
Similarly to the LEP, Northern Beaches Council is currently progressing with consolidating existing DCPs for the merged Councils into one Northern Beaches DCP.

The Warringah DCP 2011 currently applies to development in the FFPP. Section C4 Stormwater within the Warringah DCP 2011 outlines objectives and requirements applicable to the management of stormwater within the FFPP. The objectives of Section C4 of the DCP include:

- To protect and improve the ecological condition of Warringah's beaches, lagoons, waterways, wetlands and surrounding bushland.
- To minimise the risk to public health and safety.
- To reduce the risk to life and property from flooding.
- Integrate Water Sensitive Urban Design measures into the landscape and built form to maximise amenity.
- To manage and minimise stormwater overland flow, nuisance flooding and groundwater related damage to properties.
- To protect Council's stormwater drainage assets during development works and to ensure Council's drainage rights are not compromised.
- To minimise the quantity of stormwater runoff from new development discharged to Council's drainage system.

The requirements for new developments include:

- Stormwater runoff must not cause downstream flooding and must have minimal environmental impact on any receiving stormwater infrastructure, watercourse, stream, lagoon, lake and waterway or the like.
- The stormwater drainage systems for all developments are to be designed, installed and maintained in accordance with Council's Water Management Policy.

Warringah Council PL 850 Water Management Policy (Version 3) 2017
This policy outlines specific objectives and targets for new development in the former Warringah Council LGA. These objectives and targets remain relevant to development in Frenchs Forest. The objectives and targets relevant to stormwater quality management are discussed further in Section 5.

4.6 Other NSW government policies and plans

Marine Estate Management Act 2014, Draft Marine Estate Management Strategy 2018-28 (Marine Estate Management Authority, 2018)
The Marine Estate includes the coastal waters, estuaries, lakes, lagoons and coastal wetlands of NSW. This Strategy was developed by the NSW Government to coordinate marine estate management in accordance with the objectives of the Marine Estate Management Act 2014 and the NSW Government's vision for the marine estate.

The strategy identified water pollution as the highest threat to the environmental, social, cultural and economic benefits of the marine estate. Litter, oil spills and catchment runoff contributing to water pollution were identified as the greatest environmental threat to the marine environment.

Greener Places Draft Policy (NSW Government Architect, 2017)
The policy objectives include providing liveable and resilient places for the NSW community by promoting healthy living, encouraging exercise, social activities and enhancing wellbeing. These liveable places would comprise a network of well-designed green spaces through urban communities that address environmental challenges that occur as urban communities grow.

Greater Sydney Local Strategic Plan 2016-2021 (Greater Sydney Local Land Services, 2016)
Local Land Services (LLS) has a primary function to deliver local land services that are necessary to support productive agriculture and other land managers to achieve benefits for their economies, environments and communities. In the Greater Sydney area, Greater Sydney Local Land Services (GSLLS) has prepared the Greater Sydney Local Strategic Plan 2016-2021 (GSLSP) to address local land management.

The GSLSP was developed following extensive community consultation. A key objective of the GSLSP is to achieve healthy harbours, rivers and waterways. Strategies identified in the GSLSP to achieve this include improving the condition of urban waterways to enhance amenity value, ecosystem health and the quality of receiving waters to support recreational, commercial and environmental values.

Flood Prone Land Policy (NSW Government, 2005)
The primary objective of this policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property. Minimising private and public losses from floods is a key focus, and the policy emphasises that ecologically positive flood mitigation measures should be adopted wherever possible.

Flood prone lands are categorised into floodway, flood storage and flood fringe areas. The appropriate category is confirmed through floodplain risk management and associated flood studies. A key principle of the policy is that flood prone land is managed in a manner that is consistent with the flood risk and does not cause undue future distress or unduly increase potential flood liability for individuals or the community.

Existing overland flow paths and waterways typically form a key element of the flood management system in urban catchments. We understand that flooding behaviour in the FFPP is being investigated separately by others. It is envisaged that a key area for consideration will be the existing overland flow paths through residential development upstream of Rabbett Reserve.

NSW Water Quality and River Flow Objectives (NSW government, 1999)
The NSW Government established the NSW Water Quality and River Flow Objectives in 1999 for most NSW catchments (the Hawkesbury-Nepean catchment was one exception).

These include high level water quality and river flow objectives for each catchment to address issues that were identified by the community. These objectives are intended to be considered by local councils, catchment management organisations and state agencies when completing strategic, catchment and land use planning activities. Water quality objectives are provided for aquatic ecosystems, visual amenity, secondary recreation, primary recreation, aquatic foods.

River flow objectives are provided for the protection of pools, low flows, high flows (i.e. water rises), wetland and floodplain inundation, drying in temporary waterways, natural flow variability, groundwater, effects of weirs and other structures, and effects of dams.

Water Management Act 2000 (WMA) & 'Controlled activities on waterfront land - Guidelines for riparian corridors on waterfront land' (Natural Resources Access Regulator (NRAR), 2018)
These guidelines recommend appropriate minimum riparian corridor widths for protection of waterways. The riparian corridor includes the channel and banks of a watercourse, and land immediately adjacent to the banks on either side of the watercourse. Riparian corridors provide a range of functions including bed and bank stability, water quality protection, aquatic and terrestrial habitat, flood conveyance, buffering to development and passive recreation.

These guidelines list activities that are allowable within the riparian corridor with a controlled activity approval. Guidance is provided on appropriate locations for cycleways, paths, dry detention basins, stormwater outlets, realignment, bridges and culverts. Construction of stormwater quality treatment measures in riparian corridors is not allowed under these guidelines.

The guidance relates specifically to functions of watercourses covered by the WMA. Whilst public authorities do not require approval for planning interventions within riparian corridors, principles outlined in guidance provided by NRAR remain relevant.

This legislation and policy are most applicable within the FFPP to the provision of stormwater management measures within existing public reserves that include potential riparian corridors (i.e. Rabbett and Brickpit Reserves).

5 Water management objectives and targets

5.1 Water Management Policy objectives

The Warringah Council PL 850 Water Management Policy (Version 3) 2017 (the "Water Management Policy") outlines specific objectives and targets for new development in the former Warringah Council LGA. These objectives and targets remain relevant to development in Frenchs Forest. The Water Management Policy aims to protect and improve the health of Council's waterways through the appropriate planning, design and operation of stormwater treatments measures for urban development. The outcomes Council seeks include:

- The integration of water sensitive urban design measures in new developments to address stormwater and floodplain management issues.
- Improve the quality of stormwater from urban development.
- Mimic natural stormwater flows by minimising impervious areas, reusing rainwater and stormwater and providing treatment measures that replicate the natural water cycle.
- Preserve, restore and enhance riparian corridors as natural systems.

Key elements of the current Water Management Policy that are particularly relevant to stormwater quality management in the FFPP are summarised below.

5.2 Stormwater runoff quality

The location of a proposed development in the former Warringah Council LGA determines if Council's stormwater quality objectives or general stormwater quality requirements apply to the development site.

Middle Creek, Carroll Creek, Curl Curl Creek and Bantry Creek are categorised as Group C creeks in the Warringah Creeks Study (2004). Section 8.1 of the Water Management Policy indicates that stormwater quality management requirements for catchments draining to Group C creeks are Council's "General Stormwater Requirements". The general stormwater quality requirements that are relevant to development in the FFPP are summarised in Table 5-1.

Table 5-1 *Northern Beaches Council general stormwater runoff quality targets*

Pollutant	Target
Total Suspended Solids	85% reduction in the mean annual post development (untreated) load
Total Nitrogen	45% reduction in the mean annual post development (untreated) load
Total Phosphorous	65% reduction in the mean annual post development (untreated) load
Gross Pollutants	90% reduction in the mean annual post development (untreated) load (for pollutants greater than 5mm in diameter)
pH	6.5 - 8.5

The Water Management Policy also outlines a range of criteria relevant to stormwater quality management including:

- All stormwater treatment measures must be designed in accordance with the requirements of this Policy and the Water by Design Technical Guidelines and modified for local conditions as appropriate.
- Stormwater treatment measures must be sited on private land. Council will not accept the ownership or maintenance responsibilities of any stormwater treatment devices.
- For alterations and additions and the like, the stormwater quality targets only apply to the new works.

- Stormwater treatment measures must not be sited within riparian zones or within remnant vegetation.
- All stormwater treatment measures must be sited in an area which is easily and safely accessible (e.g. roadside) and have wet weather access.

To demonstrate compliance with the stormwater performance targets, Council prefers that a MUSIC model (or equivalent widely accepted model) be prepared and provided. The policy requires MUSIC modelling to be undertaken in accordance with the Northern Beaches WSUD Technical Guide unless alternative modelling parameters are justified on the basis of local studies.

5.3 Stormwater runoff quantity

Stormwater runoff quantity management for new development is required to achieve the target outlined in Table 5-2.

Table 5-2 *Northern Beaches Council stormwater runoff quantity target*

Pollutant	Target
Hydrology	The post-development peak discharge must not exceed the pre-development peak discharge for flows up to the 2 year ARI

5.4 Other

Whilst the focus of this WSUD strategy is on the management of stormwater quality and quantity during frequent storm events, there are a range of other water management elements that required consideration under Council's Water Management Policy. These elements will typically need to be integrated with the WSUD measures and can be complimentary. Some key considerations are outlined below:

- Stormwater drainage – WSUD measures installed in the streetscape can assist with reducing the number of drainage inlet pits required and can assist to pre-treat stormwater to minimise the potential for the drainage system inlets to become blocked by litter, organic debris and sediment.
- On-site detention (OSD) – WSUD measures provided to harvest stormwater and manage frequent flows, can be integrated with OSD systems to reduce costs and land requirements for separate systems. Many individual commercial and residential developments in FFPP will require OSD and identifying an appropriate standard arrangement for these systems would be important.
- Potable water conservation – WSUD can provide stormwater as an alternative water source for many non-potable uses including toilet flushing and irrigation. By harvesting stormwater, impacts on natural waterways can be reduced.
- Flooding and overland flow – WSUD measures encourage the management of stormwater close to the source including retention and infiltration opportunities. This can help to reduce the frequency of overland flow events (particularly for more frequent design storms) and function as distributed passive detention systems.
- Groundwater management – WSUD measures can assist to increase groundwater recharge in urban areas through distributed infiltration to assist with restoring hydrology closer to natural conditions.
- Erosion and sediment controls – WSUD measures can perform a temporary erosion and sediment control function during construction phase. WSUD measures can be staged to ensure that construction activities do not damage the required final post building condition of the measure.

6 WSUD measure selection

6.1 Targeted stormwater pollutants

A primary consideration in the selection of appropriate WSUD measures for any development is that the measures selected are capable of capturing the targeted stormwater pollutants.

Between the initial source of the stormwater within the FFPP and the creeks receiving the runoff, a series of WSUD measures should be provided to manage runoff quality and quantity to achieve Council's objectives. The upstream and typically source control WSUD measures should aim to intercept larger pollutants (e.g. litter, organic debris and coarse sediment) with WSUD measures capable of removing finer and dissolved pollutants introduced after the larger pollutants have initially been removed. In some catchments, separate WSUD measures in series may be achievable, whilst in more constrained areas all WSUD measures may be required in close proximity or as one integrated treatment measure with multiple functions.

In some circumstances, compromises may be required in the treatment series due to site constraints and availability of land. This may result in some measures requiring increased maintenance to ensure that the WSUD measures continue to function as designed. An example of this would be a stormwater garden installed within a public street. It would be expected that these measures would capture litter for either stormwater flows, wind-blown or from littering by the community. Frequent manual maintenance would be expected for these measures to remove this litter.

6.2 Urban design integration

There are a number of urban design factors that require consideration when selecting appropriate locations for WSUD measures within a development. Some of the key considerations when confirming appropriate locations include:

- The characteristics of the development surfaces to be treated by the WSUD measure.
- Compatibility of the scale of the WSUD measure with the catchment being treated.
- The availability of sufficient land to position the WSUD measure.
- Compatibility with other private and community uses of the space.
- Compatibility with visual, acoustics and heritage considerations.
- Compatibility with pedestrian and vehicular traffic at the location.
- Opportunity to integrate the WSUD measure into landscaping.
- Opportunity to support and improve liveability conditions for the community.
- Financial sustainability of long term maintenance requirements of the WSUD at the location.

6.3 Physical site characteristics

The physical characteristics of the development site will have a large influence on the types of WSUD measures that are suitable. A range of environmental considerations that potentially form constraints to WSUD within the site including:

- Flooding.
- Terrain and drainage.
- Soils and groundwater.
- Tides.

- Existing land uses and potential contamination.
- Adjacent land uses.
- Watercourses and riparian corridors.
- Vegetation and protected habitats.
- Existing services and infrastructure.

An appreciation of the downstream receiving environments (e.g. creek, wetland, lagoon, river, estuary, beach) will assist with focusing on key water management objectives.

Table 6-1 *Potential locations of WSUD measures in the Frenchs Forest Planning Precinct*

WSUD Measure	Residential building/dwelling lot	Multi-residential common property	Commercial building lot	Commercial forecourt	Paved pedestrian areas	Open carpark	Commercial roads and parking bays	Residential roads and parking bays	Road reserve footway	Riparian corridor	Parklands and public reserves
Rainwater tank	High ✓	Moderate	High ✓	Low	Low	Low	Low	Low	Low	Low	Moderate
Pit insert	Low	Low	Low	Low	Moderate	High	High ✓	Moderate	Low	Low	Low
Gross pollutant trap	Low	Low	Low	Low	Low	Low	High ✓	Moderate	Low	Low	High ✓
Sediment forebay	Low	Low	Low	Low	Low	Moderate	Low	Low	Low	Low	High
Vegetated filter strip	Low	High	Low	Low	High ✓	High	High	High	High ✓	Low	High
Vegetated swale	Low	High	Low	Low	High	High	High	High	High	Low	High ✓
Permeable paving	High ✓	High ✓	Low	High	High ✓	Moderate	Moderate	Moderate	Low	Low	Low
Sand filter	Low	High	Moderate	Low	High	High	High	High	High	Low	High
Tree pit filter	Low	High	Moderate	Moderate	High ✓	High	High ✓	High	High	Low	High
Stormwater garden	Moderate	High ✓	Moderate	Moderate	High ✓	High	High ✓	High ✓	High	Low	High
Biofiltration swale	Low	High ✓	Moderate	Low	High ✓	High	High ✓	High ✓	High	Low	High
Infiltration measure	High ✓	High ✓	Moderate	Low	High ✓	High	Moderate	Moderate	Moderate	Low	High
Retention basin	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	High
Constructed wetland	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	High
Biofiltration basin	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	High ✓
Green roof	Moderate ✓	Low	Moderate ✓	Low	Low	Low	Low	Low	Low	Low	Low
Urban forest	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	High ✓
Stormwater harvesting basin	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	High
Stormwater harvesting tank	Low	Moderate	High	Low	Moderate	Moderate	Moderate	Moderate	High	Low	High ✓
Proprietary devices	Low	Low	Low	Low	Moderate	High	High	Low	Low	Low	High ✓

(bright green)	High potential
(pale green)	Moderate potential
(dark green)	Low potential
✓	Appropriate for FFPP

Table 6-2 *Stormwater pollutants targeted by WSUD measures*

WSUD Measure	Targeted stormwater pollutants							
	Litter and organic debris	Coarse sediment	Total suspended solids	Heavy metals	Total phosphorus	Total nitrogen	Runoff volumes	Runoff flow rates
Rainwater tank	P	T	T	T	M	M	T	M
Pit insert	T	T	M	M	M			
Gross pollutant trap	T	T	M	M	M			
Sediment forebay	T	T	M	M	M			
Vegetated filter strip	T	T	M	M	M			
Vegetated swale	M	T	T	T	M	M		
Permeable paving	P	P	T	T	M		T	
Sand filter	P	P	T	T	M			
Tree pit filter	P	P	T	T	T	T	T	
Stormwater garden	P	P	T	T	T	T	T	
Biofiltration swale	P	P	T	T	T	T	T	
Infiltration measure	P	P	T	T	M	M	T	T
Retention basin	T	T	M	M	M		T	T
Constructed wetland	P	P	T	T	T	T	T	T
Biofiltration basin	P	P	T	T	T	T	T	T
Green roof			M	M	M	T	T	M
Urban forest							T	
Stormwater harvesting basin	P	P	M	M	M	M	T	T
Stormwater harvesting tank	P	P	M	M	M	M	T	T
Proprietary devices	T	T	T	T	M	M		
P (dark green)	Pre-treatment to remove pollutant preferred to optimise maintenance							
T (bright green)	Targeted stormwater pollutants							
M (pale green)	Potential to manage a minor proportion of the stormwater pollutant							

Table 6-3 *Site constraints for WSUD measures*

WSUD Measure	Steep terrain (>5%)	Flat terrain (<1%)	Shallow bedrock	Clay soils	Sandy soils	High groundwater	High sediment load	Highly dispersive or erodible soils	Saline or sodic soils	Riparian land	Services or infrastructure
Rainwater tank	✓ Low	Low	✓ Low	Low	✓ Low	Low	Low	Low	Low	High	✓ Low
Pit insert	✓ Low	Low	✓ Low	Low	✓ Low	Low	Low	Low	Low	High	✓ Low
Gross pollutant trap	✓ Moderate	Moderate	✓ Moderate	Low	✓ Low	High	Moderate	Low	Low	High	✓ Moderate
Sediment forebay	✓ High	Low	✓ High	Low	✓ Low	High	Low	Moderate	Low	High	✓ Moderate
Vegetated filter strip	✓ High	Moderate	✓ Moderate	Low	✓ Low	Low	Low	Low	Moderate	High	✓ Low
Vegetated swale	✓ High	Moderate	✓ High	Low	✓ Low	Moderate	Low	Low	Moderate	High	✓ Low
Permeable paving	✓ High	Low	✓ High	Moderate	✓ Low	High	High	Low	Low	High	✓ Low
Sand filter	✓ High	Low	✓ High	Low	✓ Low	High	Moderate	Low	Moderate	High	✓ Moderate
Tree pit filter	✓ Moderate	Low	✓ High	Low	✓ Moderate	High	Moderate	Low	Moderate	High	✓ Moderate
Stormwater garden	✓ High	Low	✓ High	Low	✓ Moderate	High	Moderate	Low	Moderate	High	✓ Moderate
Biofiltration swale	✓ High	Low	✓ High	Low	✓ Moderate	High	Moderate	Low	Moderate	High	✓ Moderate
Infiltration measure	✓ High	Low	✓ High	High	✓ Low	High	Moderate	High	High	High	✓ Moderate
Retention basin	✓ High	Low	✓ High	Low	✓ Low	High	Low	Moderate	Low	High	✓ Moderate
Constructed wetland	✓ High	Low	✓ High	Low	✓ Moderate	Moderate	Moderate	Moderate	Moderate	High	✓ Moderate
Biofiltration basin	✓ High	Low	✓ High	Low	✓ Moderate	High	Moderate	Low	Moderate	High	✓ Moderate
Green roof	✓ Low	Low	✓ Low	Low	✓ Low	Low	Low	Low	Low	High	✓ Low
Urban forest	✓ Low	Low	✓ Low	Low	✓ Low	Low	Low	Low	Low	Low	✓ Low
Stormwater harvesting basin	✓ High	Low	✓ High	Low	✓ Moderate	High	Moderate	High	High	High	✓ Moderate
Stormwater harvesting tank	✓ Moderate	Low	✓ High	Low	✓ Low	Moderate	Moderate	High	High	High	Moderate
Proprietary devices	✓ Moderate	Moderate	✓ High	Low	✓ Low	Moderate	Moderate	Low	Low	High	Moderate

(light green)	Low constraint
(pale green)	Moderate constraint
(dark green)	High constraint

7 WSUD options

7.1 Mechanical sweeping

Mechanical sweeping involves vehicles with sweeping and suction capabilities removing litter, organic debris and sediment from paved surfaces. Typically, larger vehicles would be utilised in trafficable areas and smaller, lighter and more manoeuvrable vehicles in pedestrian areas. Sweeping would typically target larger solid pollutants.

Regular mechanical sweeping of road pavement and pedestrian areas would be an important control for minimising the potential for blockage of permeable pavements and filter media in other measures distributed throughout the development areas.

Figure 7-1 *Mechanical street sweeper (LHS) and footpath sweeper (RHS)*

Suitable applications for FFPP include:

- All public streets and paved pedestrian areas in the FFTC.
- All public streets in other areas of the FFPP.

7.2 Community education

On-going education of the community focused around the FFTC can be an effective source control to assist with reducing the volume of litter generated in highly pedestrianised areas. Ideally the education activities would focus on reducing the volume of materials such as cigarettes, glass, cans, sediment, paper, cardboard and plastics that could be conveyed into the conventional drainage system.

Incorporation of recycling facilities within the development and utilising recycled materials as mulch (e.g. crushed glass) within treatment measures are options that could be considered. The provision of explanatory signage adjacent to selected stormwater measures in highly used public spaces can also be an effective education tool for the community.

Figure 7-2 *Container recycling facility (LHS) and recycled glass biofilter mulch (RHS)*

Suitable applications for FFPP include:

- Areas with the FFTC that will be a focus for community uses.

7.3 Reduce directly connected impervious areas

The efficient drainage of urban areas is typically undertaken to minimise nuisance flooding for the community and minimise the potential for overland flooding damage. Whilst this approach is effective for these objectives, it is now recognised that efficient drainage of urban areas results in significant impacts on the ecology and physical condition of natural waterways that receive runoff from these areas.

Increasingly WSUD approaches are being applied across urban areas to reduce the drainage efficiency during frequent smaller rainfall events that cumulatively generate a high proportion (often over 90%) of stormwater runoff volume discharged from urban areas to waterways. The function of conventional minor drainage systems (i.e. pits and pipes) is retained for infrequent larger storm events, with modern stormwater management systems designed to retain, filter, infiltrate and divert runoff during the many smaller storm events.

Suitable applications for FFPP include:

- Green roof feasibility to be considered for multi-storey buildings.
- All impervious roof areas to be connected to rainwater tanks or drain to a centralised stormwater harvesting tank.
- Road carriageways to be the minimum width required to achieve the traffic planning requirements.
- Permeable paving to be encouraged in parking bays and other low traffic load areas.
- Paved pedestrian areas to be constructed from permeable concrete/asphalt/pavers where feasible.
- Surface runoff and infiltrated runoff from paved pedestrian areas to be directed to perimeter swales, stormwater gardens and distributed tree pit filters where feasible.
- Road pavement runoff to be initially drained to a stormwater garden or biofiltration swale prior to overflow to a conventional stormwater drainage system.
- Vegetated filter strips to be provided adjacent to footpath areas to encourage filtration and infiltration.

7.4 Green roofs

Green roofs should be encouraged within the FFPP where these are financially sustainable to construct and maintain. Within the FFPP, the total roof area is likely to represent approximately 50% of the potential directly connected impervious area and therefore management of rainfall on roofs will be important. In many areas within the FFPP, steep terrain will form a key constraint to the provision of appropriate WSUD infrastructure at ground level. Green roofs provide the opportunity to manage roof runoff close to the source and provide additional private open space area for use by residents and building occupants.

Figure 7-3 *Green roofs*

Suitable applications for FFPP include:

- Multi-storey commercial and residential buildings.

7.5 Rainwater tanks

Rainwater tanks are typically installed within private lots in urban areas to capture roof runoff (rainwater) for internal and external uses. Benefits of harvesting rainwater include potable water conservation, stormwater detention and water quality improvement. Retaining and using rainwater reduces reliance on potable water supply systems in urban areas and as such can assist with deferring upgrades of potable water systems. Distributed rainwater harvesting across urban areas also assists with maintaining dam storages at higher levels than otherwise would occur without tanks. This provides additional drought resilience in the water supply system and can delay the introduction of drought management measures.

The retention of roof runoff can also contribute to reducing the duration of elevated stream flows from urban catchments. Rainwater tanks will typically have limited influence on water quality concentrations, although retention and diversion of stormwater to the sewer and garden areas reduces the volume of stormwater pollutants discharging to watercourses in the catchment of the development.

Rainwater tanks are more efficient when the retained water is used to supply multiple water demands within a development. Within urban residential areas, rainwater can typically supplement/replace potable water demands including toilet flushing, garden watering, laundry, hot water and pool filling. Typically, a potable water service connection is still required for situations where the rainwater tank is empty, and water is unable to be accessed from another source. Rainwater tanks are typically required for many residential developments to achieve BASIX criteria. In these circumstances, rainwater tanks will also form a part of the treatment series.

Whilst rainwater tanks are often considered in isolation, they actually form one element in a rainwater supply system comprising:

- A rainwater catchment and drainage system (i.e. roof, roof gutters, downpipes, rainheads and drainage lines).
- A rainwater treatment system (i.e. screens, first flush device, filters, disinfection).
- A rainwater tank (i.e. storage, inlets, outlets).
- A rainwater distribution system (i.e. pumps, pressure tanks, mains supply control switches and valves, trickle top-up, backflow prevention).

- Rainwater supplied fixtures (i.e. toilets, outdoor taps, washing machines, hot water systems).

Suitable applications for FFPP include:

- All future residential developments required to achieve BASIX targets.
- Future commercial buildings where sufficient non-potable demands are available for rainwater use considering other water sources available to achieve an integrated water cycle management solution for each building (e.g. grey water and black water sources).
- Increasing the required minimum BASIX rainwater tank size by 50% is recommended to assist with managing stormwater discharges to the existing creeks. Due to the steep terrain in many areas, increasing the minimum size of rainwater tanks (either permanent storage or temporary detention storage) to manage hydrology would be a cost effective option.

7.6 Permeable paving

Permeable paving comprises a semi-permeable surface layer overlaying a depth of granular material. The surface layer is typically formed from modular concrete pavers, concrete/plastic grids or porous asphalt. More recently concrete paving products are being designed with increased porosity that enable stormwater to infiltrate directly through the surface layer. The surface layer incorporates voids that enable water to infiltrate into the lower granular layer. The lower granular layer functions to filter, detain and retain stormwater, and also provide structural support to transfer surface loads to the underlying soils.

Permeable paving filters stormwater during frequent runoff events to remove fine sediment and associated particulates. Detention and retention of stormwater is achieved by storage on the surface and within the granular base. During infrequent high runoff events the infiltration capacity of the voids is exceeded, and the excess rainfall is converted to runoff. During these events runoff is directed to an appropriate minor or major drainage system and conveyed to the receiving environment.

Permeable paving is typically positioned close to the source of pollutant generation. Permeable paving provides an option in urban areas for disconnecting impervious surfaces from receiving environments. Typically. permeable paving is provided in pedestrian areas, plazas, residential driveways, shared accesses and car parking spaces where traffic loadings are relatively low. Permeable paving can be relatively simple and efficient to maintain provided appropriate pre-treatment of surface runoff is undertaken.

Stormwater that is retained in the permeable pavement base/drainage layer can either infiltrate to underlying soils where conditions are appropriate or be collected by sub-surface drainage and directed to a biofiltration measure, stormwater harvesting facility for use or a conventional drainage system. The drainage layer will hold a proportion of infiltrated water within the voids between adjacent gravel stones and this water would be available for evaporation through the permeable concrete. Even without stormwater harvesting or extensive infiltration, significant stormwater volume reductions can be achieved by evaporation from the base layer. A major benefit of permeable paving is that the retention provided can assist with reducing large flow pulses of stormwater discharged to a waterway to assist with reducing erosion potential.

Figure 7-4 *Pervious concrete (LHS) and permeable pavers (RHS)*

Suitable applications for FFPP include:

- Driveways, shared accesses and paths within residential development.
- Footpaths, plazas and other pedestrian areas.
- Car parking bays and other low traffic areas.
- Areas where infiltrated stormwater can be managed to prevent impacts on infrastructure including underground carparks and building basement areas.

7.7 Vegetated filter strips

Vegetated filter strips typically comprise a grassed or otherwise vegetated strip of land directly adjacent to a paved area. Vegetated filter strips can be effective as a pre-treatment measure for intercepting litter, organic debris, coarse to medium sized sediment particles and attached pollutants. Filter strips can also assist with shallow infiltration of stormwater runoff.

Filter strips are typically provided directly adjacent to road pavements or other paved areas for filtering of sheet flow runoff from these impervious surfaces. Runoff from paved areas is typically able to flow as unconcentrated sheet flow onto the filter strip. The sheet flow is distributed across the filter strip and treatment occurs through friction with the grasses which slows the flow and enables sedimentation to occur.

The vegetation is typically maintained at around 150mm to provide effective filtration. This height may be varied as a catchment becomes more stabilised and coarse sediment loads reduce. Low growing tufted native grasses could also be planted to achieve a similar function.

Typically, a vertical step is provided between the paving edge and filter strip to reduce edge trimming requirements and minimise sediment accumulation on the paved area.

Figure 7-5 *Grassed roadside filter strips*

Suitable applications for FFPP include:

- Adjacent to paved areas in FFTC that drain runoff as sheet flow into a biofiltration measure. Typically provide around the perimeter of large paved areas.
- Short sections at inlets to biofiltration measures.

7.8 Pit inserts

Pit inserts are a form of source control gross pollutant trap installed within individual drainage pits. These devices are primarily designed to intercept litter, organic debris and coarse sediment. Well planned, designed, constructed and maintained pit inserts can be very effective at capturing these pollutants.

Conventional proprietary stormwater treatment devices can efficiently capture these larger pollutants where space is highly constrained and the potential for litter loads is elevated (i.e. commercial or industrial developments) above other land uses that typically generate lower volumes of litter (e.g. residential development).

Pit inserts should only be used to target hot spot locations in highly impervious commercial and carparking areas where litter generation potential is high. The devices are generally not appropriate in residential streets where the maintenance costs can exceed the benefits able to be achieved. In commercial areas pit inserts can generally be maintained using a mechanical footpath sweeper.

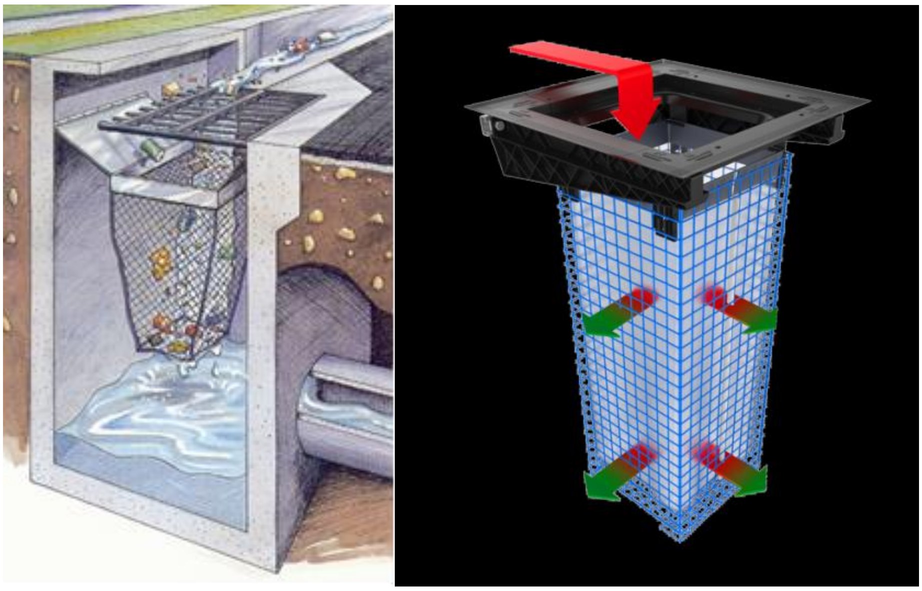


Figure 7-6 *Pit inserts*

Suitable applications for FFPP include:

- Localised areas in the FFTC with high pedestrian and traffic volumes.

7.9 Biofiltration measures

Biofiltration measures are ephemeral treatment measures that assist with achieving stormwater quality and stormwater retention objectives. All biofiltration measures comprise an extended detention storage and below ground filter media. The extended detention storage enables settling of sediment and other particles which is a function of the hydraulic residence time. The below ground filter intercepts finer particles including heavy metals. Nutrients are removed through interception and uptake by appropriate vegetation planted within the measure. Biofiltration measures assist with disconnecting impervious areas from urban streams by retaining stormwater for an extended period. Biofiltration measures are generally suitable in areas where gradients are typically less than 2%.

Biofiltration measures include tree pit filters, stormwater gardens, biofiltration swales and biofiltration basins. These measures all perform a similar function, although at different scales including:

- **Tree pit filters** – Close to source biofiltration measure typically accepting runoff from road pavement through a kerb inlet directing runoff to an individual tree incorporated into a footway area.

- **Stormwater gardens** – Close to source biofiltration measure comprising a shallow (typically 150 mm) above ground extended detention. Usually formed in a pod or cell arrangement directly adjacent to an impervious surface.

- **Biofiltration swales** – Typically a trapezoidal shaped biofiltration measure with a large length to width ratio. May accepts runoff from multiple stormwater drainage outlets in a gently grading area.

- **Biofiltration basin** – Typically a larger end-of-line biofiltration measure with a larger catchment area. Measure may have a deeper extended detention and incorporate flood detention. Important to include a dedicated pre-treatment measure for larger catchments.

Some examples of these measures are shown in Figure 7-7.

Figure 7-7 *Biofiltration measures (top left clockwise) - Tree pit filter, stormwater garden, biofiltration basin, biofiltration swale*

Suitable applications for FFPP include:

- Tree pit filters could be distributed throughout large paved footpaths or plazas in the FFTC. Individual tree pit filters will only treat a minor volume of stormwater sufficient to sustain tree growth. Tree pit filters can assist with providing increased shade for the community in otherwise continuous hard and hot paved areas.

- Stormwater gardens are often provided close to a runoff source and are typically small retention cells/basins within the streetscape. Suitable locations would be within the FFTC precinct behind kerb returns at road intersections co-ordinated with the stormwater inlet pits.

- Biofiltration swales could be provided as linear biofiltration measures between road pavement areas and footways to function as a combined flow and water quality management measure. Biofiltration swales can assist to control road crossing locations for pedestrians by forming a barrier and also to separate footway dining areas from roads. Biofiltration swales can also be used to prevent unauthorised vehicle access to high use pedestrian areas. Suitable locations for biofiltration swales would include adjacent to road pavement in FFTC and around the perimeter of the piazza area.

- Biofiltration basins are typically provided as large end-of-line measures that may be combined with other community functions (e.g. detention basins, sporting fields, parks). Smaller biofiltration basins may also be distributed throughout a development precinct. It is envisaged that biofiltration basins could be incorporated into re-development of existing parks and reserves that receive stormwater runoff from the FFPP.

7.10 Gross pollutant traps

Conventional proprietary gross pollutant traps (GPTs) include a range of pit inserts, in-line gross pollutant traps and end-of-line gross pollutant traps. These devices are primarily designed to intercept litter, organic debris, and sediment. Well planned, designed, constructed and maintained proprietary GPTs can be effective at capturing these pollutants.

Conventional proprietary GPTs can efficiently capture larger stormwater pollutants where space is highly constrained and the potential for litter loads is elevated (i.e. commercial or industrial developments) above other land uses that typically generate lower volumes of litter (e.g. residential development).

GPTs that store captured sediment, organic debris and litter in a dry state are preferable. GPTs that store and decompose organic debris in a wet sump between runoff events characteristically have low dissolved oxygen conditions that contribute to the release of nutrients into the water column within the device. Capturing increased loads of dissolved nutrients (nitrogen and phosphorus species) conveyed by stormwater is a key focus for coastal waterways and minimising the potential for GPTs to create conditions conducive to the release of nutrient rich waters should be avoided.

GPTs should be easily accessible for maintenance using machinery that Council has access to and have acceptable ongoing maintenance costs.

Any proposed proprietary devices should be comprised of materials that have sufficient strength and are resistance to fatigue failure. Screens, filtration mechanisms and other key elements required to sustain forces from stormwater flows and the weight of debris shall not be constructed from plastics. GPTs should also not have small inlets that are prone to regular blockage from organic debris and litter.

Suitable applications for FFPP include:

- Pre-treatment of stormwater runoff draining to centralised biofiltration systems positioned in Council parks or reserves.
- Pre-treatment of stormwater runoff draining to stormwater harvesting tanks.

7.11 Stormwater harvesting system

Stormwater harvesting provides an alternative water source to potable water for irrigation of public recreational land. A stormwater harvesting system typically comprises a number of elements including diversion structures, pipes, pre-treatment devices, pumps, storage tanks/ponds, biological treatment, filtration, disinfection and a distribution system.

Maintaining public recreation areas in a good condition is a high priority for many urban communities. This maintenance requires the availability of appropriate water sources for irrigation. Many Council recreational areas have conventionally been irrigated using potable water. As water restrictions have come into play during periods of drought and falling water storages, increased awareness of the need for improved water efficiency and potable water conservation has occurred. This has resulted in changes to policies on potable water use. These changes and increased water charges have driven a response to find alternative water sources to potable water for irrigation of recreational areas.

Suitable applications for FFPP include:

- A centralised stormwater harvesting system within the Village Green area of the FFTC to reduce potable water use and reduce stormwater runoff volumes from the FFPP. Treated stormwater could be utilised for irrigation of the Village Green and potentially interpretation area of the historical orchard in the adjacent urban forest area. A stormwater harvesting system would require closer consideration of other water sources within the FFPP including rainwater harvesting, grey water and blackwater treatment and re-use to confirm the optimum integrated water cycle management solution for the area.

7.12 Integrated water cycle management

The optimum solution for stormwater management within the FFTC precinct is influenced by interactions with the drinking water supply and wastewater management systems. Runoff from building roofs can readily be captured in rainwater tanks, treated and utilised as a water source for non-potable uses within the buildings. Internal building uses for non-potable water can also be supplied by recycled wastewater treated to an appropriate standard.

The stormwater management strategy for FFTC assumes that non-potable uses within the buildings will be managed by a combination of drinking water, recycled wastewater and water conservation measures. It is assumed that the provision of green walls on the buildings would be irrigated using recycled wastewater.

For this strategy, it is assumed that any roof runoff will be drained through the buildings drainage system and connected to a public piped drainage system that directs stormwater to a centralised stormwater tank for harvesting and re-use.

7.13 Green Star Communities (Credit 24A IWCM)

The Green Star rating system comprises four rating tools available for certification; Communities, Design and as built, Interiors and Performance. Each tool assesses a set of credits containing specific criteria to determine the overall Green Star score.

The Communities rating tool is applicable to precinct-wide developments and is the assessment tool applicable to the FFPP. Credit 24A (Integrated Water Cycle Management) is listed under the Environment category, and the elements to be considered under this category focus on stormwater drainage, stormwater quality, potable water conservation, flow regimes and climate change mitigation (water related elements of).

A successful claim of points for each credit is determined by the evidence and justifications outlined in a credit submission. The Green Star website provides a submission template for 24A outlining the requirements to be met. These requirements range from explicit targets and objectives to descriptions of the overall behaviour and management of the water cycle.

The submission template states that in order to be eligible for points for this pathway, the project must meet the following minimum stormwater requirements:

1. 75% of the total annual stormwater runoff is evaporated or retained within the project site, via both harvesting and infiltration;
2. The post-development peak 1-year Average Recurrence Interval (ARI) event discharge from the project site does not exceed the pre-development peak 1-year ARI event discharge; and
3. The quantity of key pollutants discharged in site stormwater is limited, based on the percentage reduction of sediment, phosphorus, nitrogen, and litter in project runoff when compared to untreated runoff.

The first requirement will be challenging to achieve across the FFPP and particularly for runoff from footways and roads. MUSIC modelling of the base WSUD strategy indicates that a reduction of 20% in stormwater runoff volume could be achieved through stormwater harvesting and evapotranspiration. The feasibility of large scale infiltration would be constrained in some part of the FFPP by the steep terrain.

8 Base WSUD strategy

8.1 Overview

The WSUD strategy for the Frenchs Forest Planning Precinct is summarised in Table 8-1. The WSUD options and potential locations outlined in Section 7 were reviewed to identify a base WSUD strategy for the FFPP that would address Council's targets and appropriately responds to the constraints and opportunities identified from the site analysis. The base WSUD strategy elements are highlighted in Table 8-1. The other non-highlighted WSUD elements are considered relevant for consideration as planning progresses and these potentially could be included as components of a WSUD+ strategy that facilitates the optimisation of base WSUD strategy measures. The WSUD+ strategy elements are discussed further in Section 9.

The base WSUD strategy was modelled in MUSIC to confirm appropriate scales and sizes of WSUD measures (refer Section 10). Preliminary cost estimates were also completed to provide an indication of the costs associated with constructing and maintaining the base WSUD strategy measures (refer Section 11).

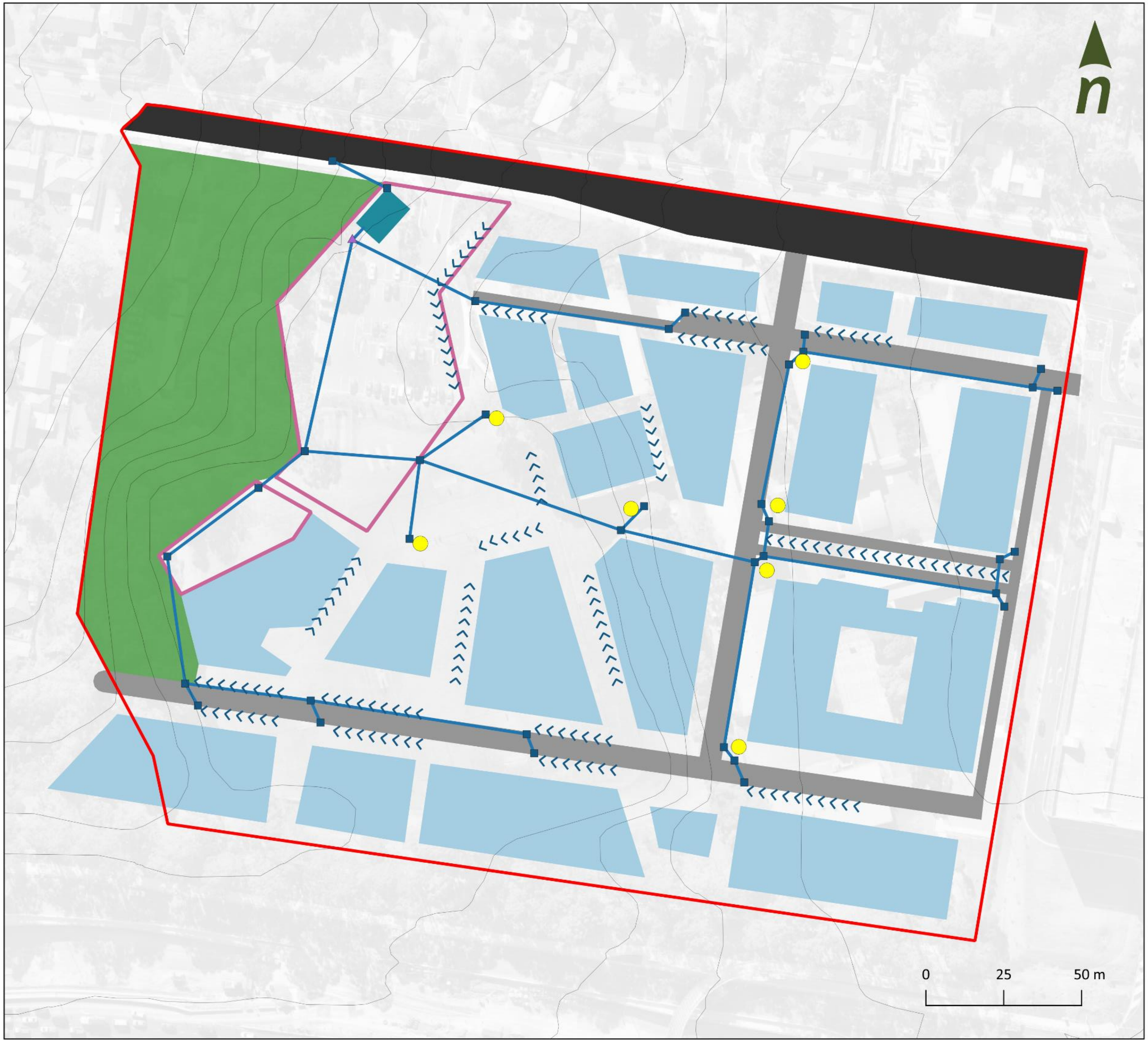
Conceptual figures outlining the base WSUD strategy configuration for FFTC, Brickpit Reserve and Akora Reserve are shown on Figure 8-1, Figure 8-2 and Figure 8-3 respectively.

It is considered that the base WSUD strategy would represent the likely maximum footprint within the development layout to assist with further development planning.

Table 8-1 *Summary of WSUD strategy for the Frenchs Forest Planning Precinct*

Scale	WSD measure	Conceptual treatment measure options/arrangement
FFTC precinct	Education	On-going education of the community focused around the FFTC.
Street	Mechanical street sweeper	Regular street sweeping as a source control to reduce volumes of litter, organic debris and coarse sediment exposed to stormwater. Would be important in areas where other options for trapping gross pollutants would not be cost effective.
Footways	Mechanical footpath sweeper	Regular footpath sweeping of pedestrian areas would be an important control for minimising the potential for blockage of permeable pavements and filter media in other measures distributed throughout the development areas.
Residential roofs	Rainwater tank	Base WSUD strategy measure to be provided in multi-dwelling residential lots to address BASIX targets and reduce potable water consumption. Base WSUD strategy includes capturing roof runoff from multi-dwelling residential developments for irrigation use. WSUD+ strategy could include supplying internal non-potable uses and consideration of increasing BASIX tanks size by 50% to manage hydrology in steep land.
Multi-storey commercial and residential buildings	Green roofs	Green roof feasibility to be considered as a component of a WSUD+ strategy for individual multi-storey commercial and residential buildings in the FFPP. Steep terrain in many of the future residential lots will challenge the provision of vegetated treatment systems in some sites.
Commercial building lot	Rainwater tank	Rainwater tanks to be considered as a component of a WSUD+ strategy for all future commercial buildings to confirm an optimal integrated water cycle management solution considering all available sources of non-potable water to reduce potable water consumption.
Residential lot	Permeable paving	The feasibility of permeable paving to be considered as a component of the WSUD+ strategy for driveways, shared accessways and parking spaces in low traffic areas and within private multi-dwelling residential lots.
Footways	Pervious concrete	The feasibility of pervious concrete to be considered for all public footway, plaza and other pedestrian areas as a component of a WSUD+ strategy. It is likely to be feasible to connect sub-surface drainage collecting the infiltrated stormwater to Base WSUD strategy measures including tree pit filters, stormwater gardens and biofiltration swales.

Scale	WSD measure	Conceptual treatment measure options/arrangement
Multi-storey residential building lots	Terraced stormwater gardens	Base WSUD strategy measure to be provide in multi-residential developments to treat runoff prior to site discharge. Terraced measures utilising retaining walls likely to be necessary to respond to the steep terrain.
Footways	Vegetated filter strips	Base WSUD strategy measure for pre-treatment of sheet flow from paved footways that drain to biofiltration swales or stormwater gardens.
Street	Vegetated filter strips	Vegetated filter strips to be considered adjacent to road pavements in gently grading residential streets to pre-filter runoff and intercept coarse sediment prior to the runoff draining to a biofiltration swale or stormwater garden.
Street	Pit insert	Pit inserts to be considered for installation at localised areas within the FFTC where planning indicates pedestrian and traffic volumes will be high and litter would not initially be intercepted by a filter strip or biofiltration measure.
Footways	Tree pit filters	Base WSUD strategy measure to be distributed throughout large pedestrian and plaza areas in the FFTC to treat runoff from footway areas.
Street	Stormwater gardens	Base WSUD strategy measure to be provided adjacent to stormwater pits in gently grading streets at locations where biofiltration swales would be impractical or where the measures could be utilised to form a feature in the urban landscape.
Street	Biofiltration swales	Base WSUD strategy measure to be provided in gently grading streets at locations where these linear measures can be co-ordinated with pedestrians and traffic. Biofiltration swales can assist to control pedestrian road crossing locations, separate dining areas from roads and prevent unauthorised vehicle access to footways.
Piazza	Biofiltration swales	Base WSUD strategy measure to be provided around the perimeter of plaza areas.
Precinct/sub-catchment	Gross pollutant traps	Base WSUD strategy measure to pre-treat runoff draining to biofiltration basins or stormwater harvesting tanks.
Precinct/sub-catchment	Biofiltration basin	Base WSUD strategy measure to be incorporated into the re-development of Brickpit Reserve to treat stormwater runoff draining to Curl Curl Creek from the new Northern Beaches Hospital, future business development, major roads and existing residential development.
Precinct	Stormwater harvesting tank	Base WSUD strategy measure to be located underground within the Village Green area. Treated stormwater from the FFTC precinct to be harvested for irrigation use and to reduce stormwater runoff volumes draining to Middle Creek and Narrabeen Lagoon.



Frenchs Forest Precinct

Figure 8-1 - Frenchs Forest Town Centre - Base WSUD strategy

Legend

- 2m contour
- Sub-catchment NL1
- Existing sealed road
- Future sealed road
- Buildings
- Urban forest
- Village green
- Stormwater garden
- Biofiltration swale
- Stormwater inlet pit
- Gross pollutant trap
- Stormwater drainage pipe
- Stormwater harvesting tank

NOTE: LOCATIONS OF EXISTING SERVICES NOT SHOWN. LOCATIONS TO BE CONFIRMED PRIOR TO FINALISING WSUD MEASURE LOCATIONS.

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Frenchs Forest Precinct

Figure 8-2 - Brickpit Reserve WSUD concept

Legend

- Existing stormwater pipe
- Existing stormwater pit
- New stormwater pit
- New headwall
- New stormwater pipe
- Spillway
- Low flow swale
- Brickpit Reserve extents
- New zoning (B1)
- Telecommunication
- Gas main
- Sewer PVC
- Water CICL
- Biofilter

NOTE: EXISTING SERVICE LOCATIONS ARE INDICATIVE ONLY AND MAY BE INCOMPLETE. LOCATIONS SHOULD BE CONFIRMED BEFORE FINALISING TREATMENT

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Frenchs Forest Precinct

Figure 8-3 - Akora Reserve WSUD concept

Legend

- SW — Existing stormwater pipe
- Existing stormwater pit
- New stormwater pit
- New headwall
- New stormwater pipe
- Spillway
- Flow bypass
- Akora Reserve extents
- New zoning (R2+)
- Biofilter
- Stormwater garden
- T — Telecommunication
- G — Gas main
- S — Sewer PVC
- W — Water CICL

NOTE: EXISTING SERVICE LOCATIONS ARE INDICATIVE ONLY AND MAY BE INCOMPLETE. LOCATIONS SHOULD BE CONFIRMED BEFORE FINALISING TREATMENT

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8.2 WSUD elements

Rainwater tanks

The base WSUD strategy assumes that rainwater tanks would be provided in multi-residential lots to capture stormwater from roofs for irrigation use only. For the base WSUD strategy, it was assumed that BASIX water conservation targets would be achieved for multi-residential developments by including other options that reduce potable water consumption (i.e. low demand showerheads, taps and appliance, native landscaping etc). A typical arrangement of a rainwater tank is shown in Figure 8-4.

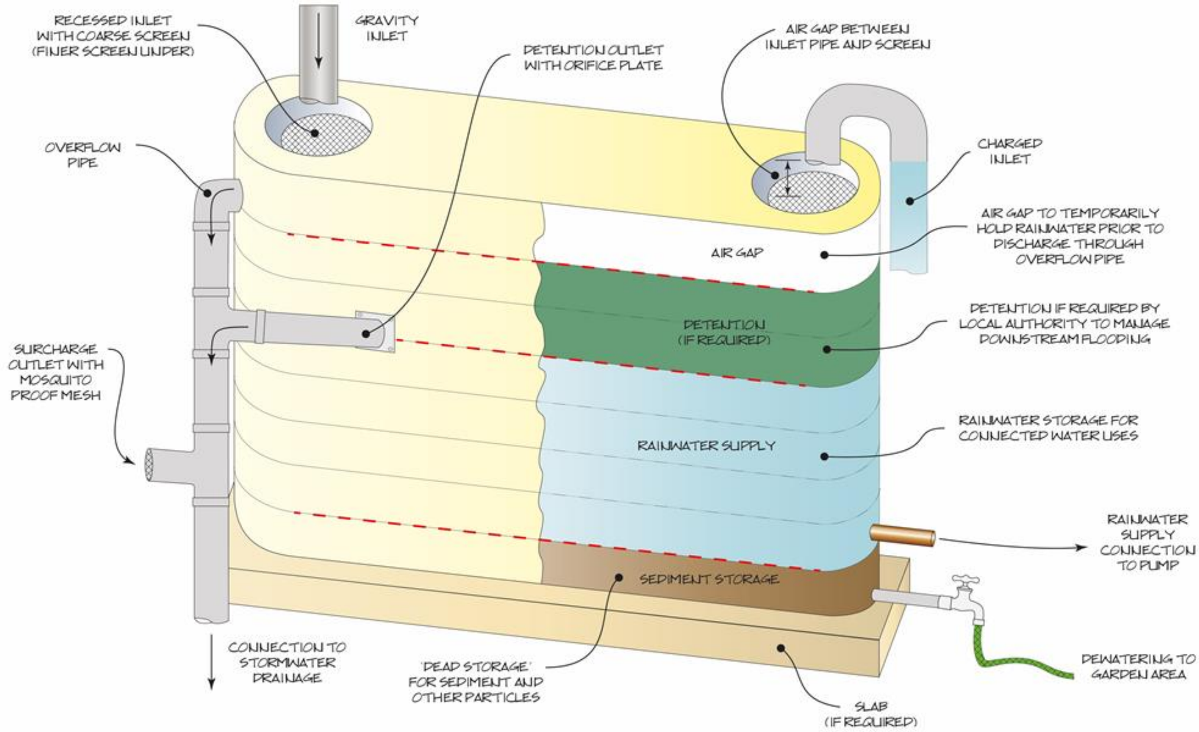

Figure 8-4 *Example rainwater tank configuration*

Tree pit filters

The base WSUD strategy includes tree pit filters distributed throughout large paved pedestrian areas in the FFTC. Conceptual sketches of the typical configuration of tree pit filters are shown in Figure 8-5 and Figure 8-6.

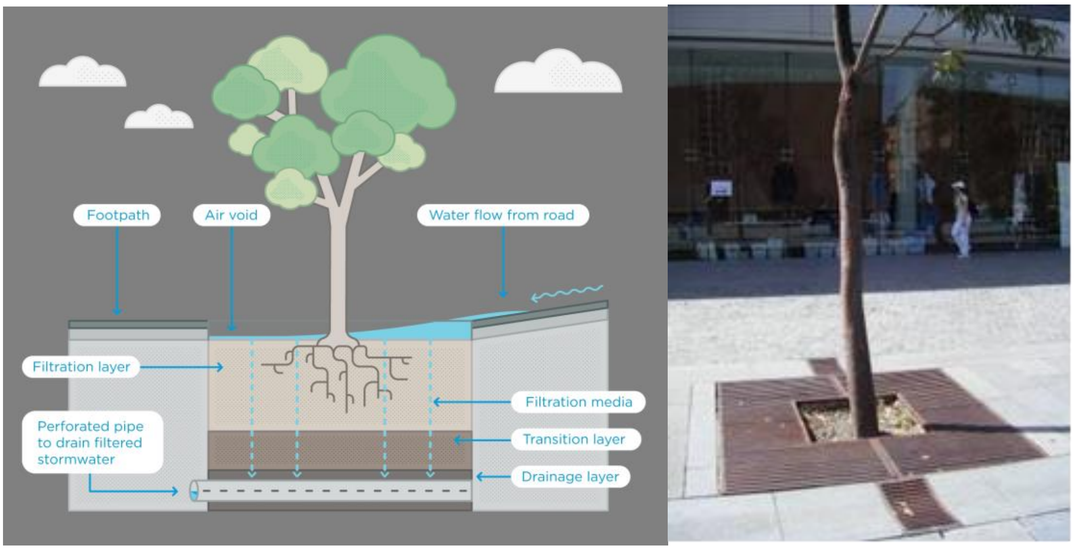

Figure 8-5 *Example tree pit filter configuration (LHS image source: http://urbanwater.melbourne.vic.gov.au)*

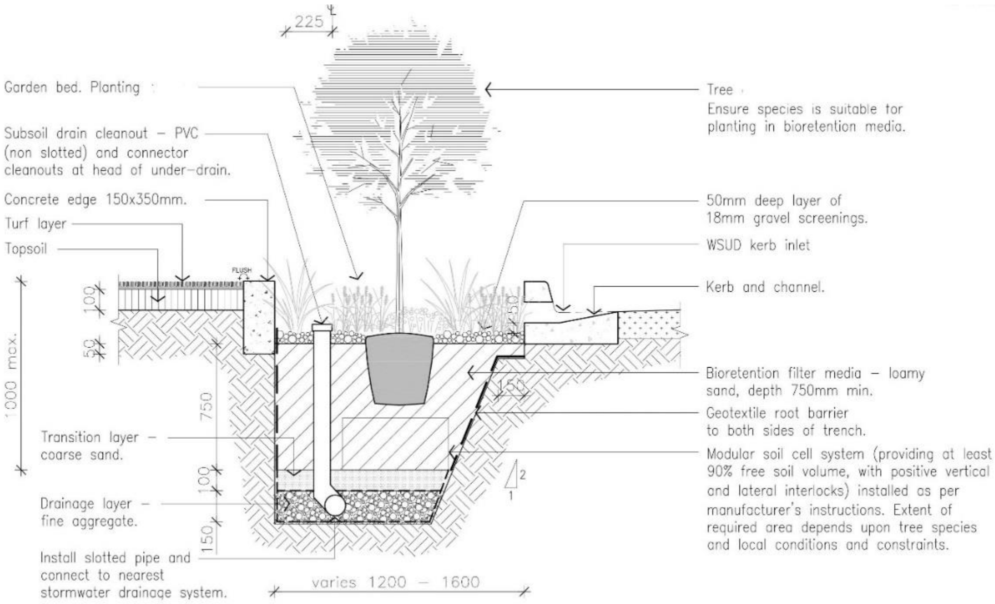

Figure 8-6 *Typical tree pit filter detail (adapted from Brisbane City Council, 2010)*

Tree pit filters typically have vertical sides with open grates covering the extended detention storage. The extended detention temporarily stores runoff prior to filtration through the media filter. During events that exceed the available volume in the extended detention storage, excess runoff typically overflows into a minor drainage system through structures positioned within the measure.

The media filter typically consists of a biofilter layer and drainage layer. The biofilter layer is the upper layer and incorporates soil that has a reasonable water holding capacity that is capable of sustaining vegetation growth. The biofilter layer must also have a reasonable saturated hydraulic conductivity to enable steady percolation of runoff when the water holding capacity is exceeded. The lower layer comprises fine gravel that typically surrounds slotted agricultural drainage pipe and captures the filtered stormwater before directing it to a constructed drainage system.

Biofiltration swales
The base WSUD strategy includes recommendations to provide linear biofiltration swales between road pavement areas and footways across the FFTC precinct. Biofiltration swales would function as a source control treating runoff from road surfaces and footways. A goal would be to ensure that all surface runoff from roads and footways within the FFTC initially passes through a biofiltration system prior to discharge into a conventional stormwater pit or infiltration to the natural soils where appropriate.

In addition to providing stormwater quality and quantity management, biofiltration swales would assist with managing road crossing locations for pedestrians by forming a barrier and also to separate footway dining areas from roads. The biofiltration swales can also be utilised to prevent unauthorised vehicle access to high use pedestrian areas.

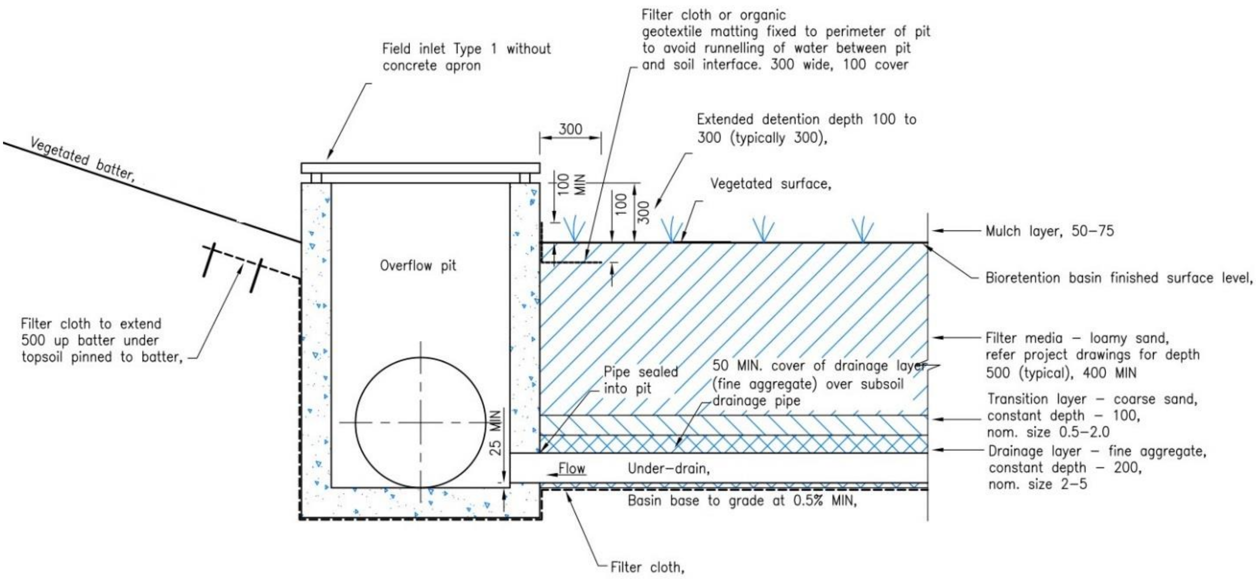

Figure 8-7 *Example biofiltration swale configuration (source: adapted from Water by Design, 2010)*

Stormwater gardens
The base WSUD strategy includes stormwater gardens positioned within the FFTC. Stormwater gardens are recommended to be located behind kerb returns at road intersections with locations co-ordinated with the stormwater inlet pits. An example concept sketch for a typical stormwater garden and installed example is shown in Figure 8-8.

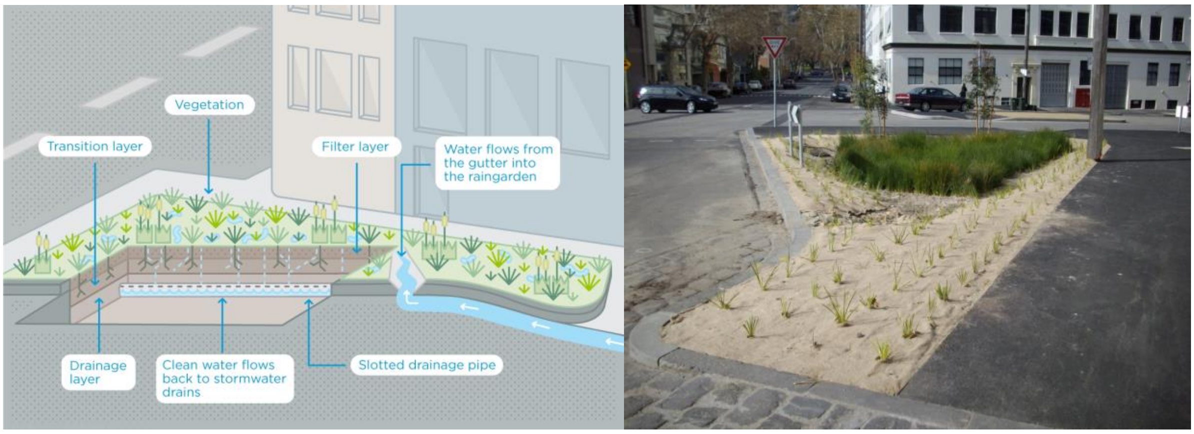

Figure 8-8 *Example stormwater garden configuration (source: http://urbanwater.melbourne.vic.gov.au)*

Pit inserts and gross pollutant traps
Pit inserts are not included in the base WSUD strategy and it is recommended these only be considered in localised areas where pedestrian or vehicular traffic is high. It is envisaged that most footway areas in FFTC would be drained to flush grates that would be effective at excluding most gross pollutants. Typically pit inserts would be most effective in kerb inlet pits installed in road reserves. The base WSUD strategy assumes that most road pavement areas would initially be drained to a biofiltration swale or raingarden, and therefore litter would be intercepted by these measures before entering a piped drainage system. Pit inserts would therefore only be applicable to a small proportion of the FFTC, and where provided, these would be maintained by private owners of the road reserve in FFTC (rather than Council).

Provision of a biofiltration basin in Brickpit Reserve downstream of the hospital and major roads in a larger urban catchment warrants consideration of a central pre-treatment GPT to intercept litter prior to it mixing with vegetation in the biofiltration basin. This will typically be more important in circumstances where a high proportion of litter is not able to be effectively intercepted in FFTC close to the source (e.g. pit inserts, flush grates or similar exclusion measures). Selection of an appropriate GPT for Brickpit Reserve would need to be undertaken in close consultation with Council. Key considerations would include:

- ensuring an appropriate all-weather access is feasible to the GPT for cleaning; and
- that sufficient independent monitoring data is available supporting the long-term effectiveness of the GPT.

Biofiltration basins
The base WSUD strategy includes recommendations to provide biofiltration basins within Akora and Brickpit Reserves as a component of future redevelopment of these community assets. An example of a biofiltration basin integrated with a public park is shown in Figure 8-9. In this example, the park functions to manage stormwater flows during low flows (biofiltration basin activates) and higher overland flooding flows (detention basin activates). The configuration of the biofilter is similar to that shown in Figure 8-7.

Figure 8-9 *Example biofiltration basin integrated within community park (source: Lake Macquarie City Council, 2013)*

Vegetated filter strips
The base WSUD strategy incorporates vegetated filter strips adjacent to road pavements, carparking and footways areas for filtering of sheet flow runoff from these impervious surfaces. Vegetated filter strips typically perform a primary treatment function and also assist with shallow infiltration of stormwater runoff.

Filter strips provide pre-treatment by removing a high proportion of coarse matter to reduce the potential for blockage of following measures designed to manage finer and dissolved pollutants. Filter strips would be provided adjacent to stormwater gardens or biofiltration swales in appropriate locations to provide pre-treatment of flows draining to these WSUD measures.

Vegetation in the filter strips is typically maintained at around 150mm or higher to provide effective filtration. This height may be varied as a catchment becomes more stabilised and coarse sediment loads reduce. Low growing tufted native grasses could also be planted to achieve a similar function.

Stormwater harvesting system
The base WSUD strategy includes a recommendation to incorporate a stormwater harvesting system into the Village Green area. Stormwater initially treated within biofiltration systems would be directed through a piped stormwater drainage system to a below ground stormwater tank positioned adjacent to the Village Green. Pre-treatment of runoff draining to the tank would be achieved through the provision of a below ground GPT.

The base WSUD strategy includes allowance for the stormwater to be filtered and treated prior to application as irrigation water within the Village Green area. The focus of the stormwater harvesting system would be to conserve potable water. Overflow from the stormwater harvesting tank would be connected into the existing stormwater drainage system in Frenchs Forest Road for discharge to Middle Creek.

Private residential lots
Residential development in the FFPP outside of the FFTC is proposed in areas where centralised management of stormwater quality is unlikely to be feasible considering natural drainage paths, existing steep terrain and limited availability of land in appropriate locations. It is likely that distributed treatment measures within private land will be required as a component of individual developments to address Council's water quality objectives to overcome this lack of available centralised land.

The base WSUD strategy assumes that lot scale WSUD treatment systems comprising rainwater tanks, permeable paving, stormwater gardens and vegetated filter strips would be required within private residential lots to address Council's targets. It is envisaged that these measures would be incorporated into the landscape design with common areas of multi-dwelling residential developments.

It is likely that many of the multi-dwelling residential lots will be highly constrained by steep terrain and this may require terraced and retained stormwater gardens to be constructed to fit in with the landscape (refer example for an individual dwelling shown in Figure 8-10).

Figure 8-10 *Example of a terraced biofiltration system for an individual residential lot (source: MidCoast Council)*

It is also likely to be impractical to drain 100% of the lot area to a stormwater garden, leading to a portion of the site draining across the boundary untreated (e.g. part of driveways). This has been allowed for in evaluating typical WSUD provisions for future residential development.

In some circumstances, stormwater treatment of future residential development and business developments can be achieved through the provision of stormwater treatment in public land (e.g. FFTC, Akora Reserve and Brickpit Reserve). In these circumstances, Council could progress the implementation of a mechanism for future developers to contribute to the cost of constructing these facilities. The base WSUD strategy measures within Akora Reserve and Brickpit Reserve have been sized to achieve Council's targets including consideration of future development in the catchment draining to each reserve.

9 WSUD+ strategy

The base WSUD strategy includes WSUD measures that provide some flexibility for integration within the future development as planning of the final development layout and staging progresses. A number of additional WSUD measures summarised in Table 8-1 warrant further consideration as development planning progresses and further details of the development configuration are resolved. Where feasible, incorporation of these other elements into the WSUD strategy could assist to reduce the footprint and cost of the base WSUD strategy measures.

WSUD measures including commercial building rainwater harvesting, green roofs, permeable paving and pervious concrete have the potential to significantly reduce runoff volumes. A WSUD strategy incorporating these additional measures (referred to here as the WSUD+ strategy) would reduce runoff volumes and along with other source control activities including street sweeping would assist to reduce the size of base WSUD measures. For example, permeable paving or porous concrete can provide significant detention and retention capability of stormwater by storage on the surface and within the granular base.

Permeable paving typically comprises a semi-permeable surface layer overlaying a depth of granular material. The surface layer is typically formed from modular concrete pavers, concrete/plastic grids, porous asphalt and porous concrete. The surface layer incorporates voids that enable water to infiltrate into the lower granular layer. The lower granular layer functions to filter, detain and retain stormwater and can also provide structural support to transfer vehicular loads (light vehicles only) to the underlying soils.

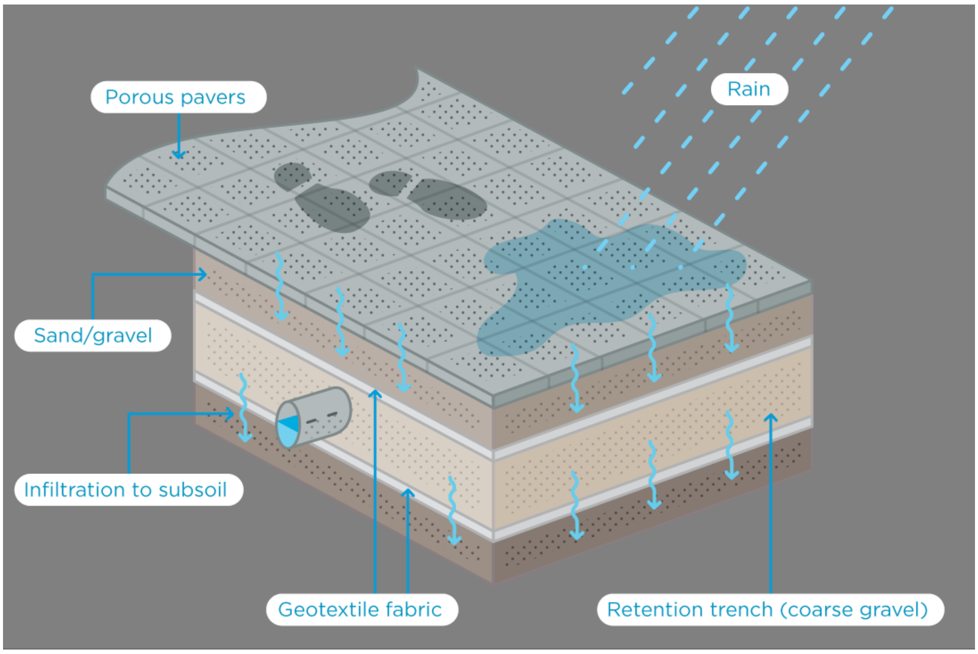

Figure 9-1 *Example permeable/porous paving configuration (source: http://urbanwater.melbourne.vic.gov.au)*

Permeable paving is not included in the base WSUD strategy and is not recommended in areas that will be owned/maintained by Council. Permeable paving is included for consideration as a source control option in private multi-dwelling residential lot scale developments where traffic loads would be low (e.g. shared driveways, visitor parking bays).

Pervious concrete is suggested for consideration in non-trafficable footway areas to assist with disconnecting large areas of paving from the drainage system. This material differs from typical permeable paving as it has a surface appearance similar to standard concrete paving. Pervious concrete is designed to enable rain to permeate the surface into an underlying gravel media. This material has the advantage that infiltrated stormwater could be harvested close to the source and used for landscape irrigation and other uses to assist with conserving potable water.

10 MUSIC modelling

10.1 Modelling Approach

Stormwater quantity and quality modelling was undertaken using the Model for Urban Stormwater Improvement and Conceptualisation (MUSIC) to estimate runoff volumes and loads of common stormwater pollutants including Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN).

MUSIC includes algorithms to evaluate the hydrology and concentrations / loads of common stormwater pollutants (i.e. TSS, TP and TN) from urban catchments and estimate the performance of WSUD measures at capturing these pollutants.

MUSIC was designed to continuously simulate urban stormwater systems over a range of temporal and spatial scales utilising historically representative rainfall data. MUSIC is considered within the industry to be an appropriate conceptual design tool for the assessment and sizing of stormwater treatment measures.

The hydrologic algorithm in MUSIC is based on the model developed by Chiew & McMahon (1997). The model simplifies the rainfall-runoff processes and requires input of the following variables to perform the hydrological assessment:

- Rainfall data (time steps varying from 6 minutes to 1 days);
- Potential evapotranspiration rates;
- Catchment parameters (area, % impervious and pervious areas);
- Impervious and pervious area parameters (rainfall threshold, soil and groundwater parameters) and
- Storm event and base flow stormwater pollutant concentrations.

MUSIC can be utilised for comparison of alternative scenarios that adopt the same base inputs. Although the magnitude of the estimates may not be equivalent to actual site conditions (due to limitations in available data for a particular site), the relative differences between scenarios is expected to be appropriate for supporting decision making. MUSIC can also be applied to evaluate the performance of stormwater treatment measures against load-based objectives. The MUSIC modelling approach applied to derive estimates catchment loads for the FFPP is described in the following sections.

10.2 Meteorological Input Data

The meteorological template includes the rainfall and areal potential evapotranspiration data. It forms the basis for the hydrologic calculations within MUSIC.

Rainfall data were sourced from Bureau of Meteorology (BoM) Station 66062 Sydney (Observatory Hill). Data were available for the 1914 to 2015 period. Interpolated data were also sourced from the SILO database for comparison with Stn. 66062.

Review of the rainfall data indicated that a 20 year period between 1966 to 1985 was relatively free of data gaps. The mean annual rainfall for this period is 1220mm which is similar to the long term mean of 1216mm for this station. The long term average calculated from the SILO data is similar. Council's MUSIC guidelines recommend utilising rainfall for a 5 year period between 1981 and 1985 for stormwater quality modelling. This period provides a mean annual rainfall of 1240mm which is also close to the long term average. The 1981 to 1985 period was adopted for modelling stormwater quality.

Monthly average potential evapotranspiration (PET) rates are often input to MUSIC utilising average values for the 1961 to 1990 period sourced from the Bureau of Meteorology's Climatic Atlas of Australia (BoM, 2001). For the MUSIC modelling, daily estimates of areal potential evapotranspiration rates were sourced from the SILO database for the same period as the rainfall data (i.e. 1981 to 1985). Morton wet environment daily areal potential evapotranspiration rates were adopted as being appropriate for the modelling.

The adopted average monthly PET values (based on the daily values) for Frenchs Forest are presented in Table 10-1 along with BoM averages for the 1961 to 1990 period. The areal PET values for the 1981 to 1985 period indicate that potential evapotranspiration during this period was higher than long term averages.

Table 10-1 *Monthly Average PET Rates for Frenchs Forest*

	Areal PET (mm/month)	
Scale	**1961 - 1990 averages (BoM, 2001)**	**1981 – 1985 averages (based on daily SILO estimates)**
January	176	170
February	132	135
March	121	125
April	80	84
May	52	56
June	39	41
July	41	46
August	57	73
September	80	99
October	126	128
November	150	152
December	158	170
Annual total	1212	1278

A 6-minute model time step was adopted for the MUSIC modelling.

10.3 Catchment Parameters

Sub-catchments were estimated considering the existing terrain and constructed drainage system. The sub-catchments are shown on Figure 3-1. Sub-catchment areas are summarised in Table 10-2.

Phase 1 Precinct - Frenchs Forest Town Centre (Sub-catchment NL1)
There is currently no detailed road and super lot layout available for the future development in FFTC. The MUSIC models were prepared based on digitising of the masterplan layout (CHROFI, 2018). The future configuration of development surfaces in Sub-catchment NL1 (the sub-catchment including the future FFTC, refer Figure 3-1) was estimated based on the masterplan layout and these are summarised in Table 10-2.

Table 10-2 *Modelled surfaces for FFTC (Sub-catchment NL1)*

Surface type	Area ha	% effective imperviousness
Village green	0.567	0%
Building roofs	2.244	100%
Existing sealed road	0.382	100%
New sealed road	0.529	100%
Public footways including piazza	2.354	75%
Urban forest	0.840	0%
Total	6.916	

Phase 1 Precinct – Brickpit Reserve (Sub-catchment MD1)
The sub-catchment draining to Brickpit Reserve was modelled considering the existing catchment characteristics allowing for increased imperviousness associated with the planned commercial area in rezoned residential land on the southern side of Warringah Road. The modelled configurations of surfaces within this sub-catchment is summarised in Table 10-3.

Table 10-3 *Modelled surfaces for Brickpit Reserve sub-catchment (Sub-catchment MD1)*

Surface type	Area ha (% of total)	% effective imperviousness
Hospital roof	0.800	100%
Hospital remnant urban forest	0.630	0%
Hospital landscaping	1.640	5%
Existing sealed road and carparking	3.080	100%
New business area	0.880	80%
Existing low density residential	1.850	65%
Brickpit Reserve	1.320	0%
Total	10.200	

Phase 1 Precinct – Akora Reserve (Sub-catchment BB2)
The sub-catchment draining to Akora was modelled considering the existing catchment characteristics and allowing for increased imperviousness associated with the planned higher density residential land along Karingal Crescent to the north of the reserve. The modelled configurations of surfaces within this sub-catchment is summarised in Table 10-4.

Table 10-4 *Modelled surfaces for Akora Reserve sub-catchment (Sub-catchment BB2)*

Surface type	Area ha (% of total)	% effective imperviousness
Future R2+ land on Karingal Cr	1.170	70%
Existing low density residential	1.300	65%
Existing sealed roads	0.280	100%
Akora Reserve	0.310	100%
Total	3.06	

Phase 1 Precinct – Rabbett Reserve (Sub-catchments NL1, NL2 and NL3)
Rabbett Reserve in located in the northern portion of the FFPP and includes a steep upper reach of Middle Creek that drains to Narrabeen Lagoon. Compared to the other public reserves in the FFPP, the upstream sub-catchment area draining to Rabbett Reserve is relatively large with related runoff volumes being significantly higher. The typical terrain in this reserve has gradients exceeding 10%. The reserve is effectively bisected by the existing creek and constrained by road embankments and residential lot on either side of the riparian zone.

The potential for incorporating WSUD measures to manage stormwater quality in this reserve is considered low due to the site constraints. There would be some potential to divert very small flows into stormwater gardens or similar measures on the eastern side of the reserve for treatment, although it is considered that any benefits are likely to be far exceeded by the costs.

It is recommended in this strategy that the focus should be on positioning closer to source WSUD measures within the upslope catchment areas either within public land or private lots.

Phases 1, 2 and 3 Precincts - R3 and R3+ Residential
A large proportion of planned residential development corresponds with terrain exceeding 10% in gradient with no feasible locations available for positioning centralised WSUD measures to treat runoff from multiple development lots. Therefore, the residential building lots in Phases 1, 2 and 3 are likely to each require the provision of a lot scale treatment system to manage stormwater runoff quality and quantity. It is assumed that any on-site detention requirements would be integrated with the stormwater quality treatment measures.

To evaluate future WSUD treatment measures for residential development in locations where lot scale treatment is likely to be the only feasible option, example lot configurations have been modelled in MUSIC considering the masterplan and associated proposed development controls. Within the future residential precincts there will be a range of different residential buildings varying in height and number of units.

For the WSUD strategy, treatment requirements have been estimated and modelled based on example residential development scenarios derived from the masterplan including consideration of floor space ratios, proposed building heights and number of dwellings for the following scenarios:

- Three storey residential building including 12 units.
- Five storey residential building including 40 units.
- Six storey residential building including 72 units.

MUSIC modelling of each of the residential scenarios adopted the following assumptions:

- Residential units would have an average floor area of 80 m^2 with a roof area equivalent to 100 m^2 for each unit on the upper level.
- The roof area would cover up to 40% of the lot considering the proposed floor space ratios and building heights. The remaining lot area would comprise driveways, carparking, paths, lawns, patios, pools, vegetated landscaping and other common residential surfaces. It was assumed that the non-roof area within the lot would be up to 50% impervious.
- All roof areas would be directed to a shared rainwater tank for each building. Non-potable water demands from the tanks would be for outdoor irrigation of common property.
- Overflow from the rainwater tank and surface runoff from 80% of paved and landscaping areas within the lot would be directed to a biofiltration system. The biofilters would have a minimum biofilter area equivalent to 3% of the total lot area.
- It may be impractical to drain up to 20% of the paved and landscaping areas within each lot to the biofiltration system due to terrain constraints. 80% of this bypassing area would be treated through landscaped buffers adjacent to the bypassing paved areas (nominally a 0.5m wide indigenous grass buffer strip).

10.4 Rainfall-runoff parameters

Modelling of the rainfall-runoff process in MUSIC requires the definition of two impervious surface parameters and eight pervious surface parameters. These parameters can be determined through a calibration and validation exercise where concurrent stream flow, rainfall and evapotranspiration data are available for the catchment being considered.

Rainfall-runoff parameters for the FFPP were adopted from the 2015 NSW MUSIC Modelling Guidelines based on a characteristic sandy clay loam soil across the precinct indicated from a review of available soil landscape mapping data (refer Section 3.3). The adopted rainfall runoff parameters are summarised in Table 10-5. These parameters were adopted for developing the MUSIC models.

Table 10-5 ***Adopted MUSIC rainfall-runoff parameters***

Parameter	Adopted value
Impervious Area Parameters	
Rainfall Threshold (roofs, mm)	0.5
Rainfall Threshold (road pavement, mm)	1.5
Rainfall Threshold (mixed urban surfaces, mm)	1.5
Pervious Area Parameters	
Soil Storage Capacity (mm)	108
Initial Storage (% of capacity)	25
Field Capacity (mm)	73
Infiltration Capacity Coefficient – a	250
Infiltration Capacity Exponent - b	1.3
Groundwater Properties	
Initial Depth (mm)	10
Daily Recharge Rate (%)	60
Daily Baseflow Rate (%)	45
Daily Deep Seepage Rate (%)	0

10.5 Runoff quality parameters

The MUSIC input stormwater constituent concentrations were based on those recommended in the 2015 NSW MUSIC Modelling Guidelines. The adopted $\log_{10}$ values are summarised in Table 10-6 and

Table 10-7.

Table 10-6 *Storm flow concentrations for MUSIC modelling in NSW (mg/L - $\log_{10}$)*

	TSS		TP		TN	
	mean	std. dev	mean	std. dev	mean	std. dev
Residential landscaping	2.15	0.32	-0.60	0.25	0.30	0.19
Public open space	2.15	0.32	-0.60	0.25	0.30	0.19
Paved footways	2.15	0.32	-0.60	0.25	0.30	0.19
Hard roof	1.30	0.32	-0.89	0.25	0.30	0.19
Road pavement	2.43	0.32	-0.30	0.25	0.34	0.19

Table 10-7 *Base flow concentrations for MUSIC modelling in NSW (mg/L - $\log_{10}$)*

	TSS		TP		TN	
	mean	std. dev	mean	std. dev	mean	std. dev
Residential landscaping	1.20	0.17	-0.85	0.19	0.11	0.12
Public open space	1.20	0.17	-0.85	0.19	0.11	0.12
Paved footways	1.20	0.17	-0.85	0.19	0.11	0.12
Hard roof	n/a	n/a	n/a	n/a	n/a	n/a
Road pavement	1.20	0.17	-0.85	0.19	0.11	0.12

10.6 Modelled treatment measures

The configuration of the modelled treatment measures is summarised in Table 10-8.

Table 10-8 *Modelled treatment measures*

Treatment measure	Locations	Modelled configuration
Rainwater tanks	Multi-dwelling lots	Volume = 5 to 15 kL Water demands = irrigation only
Tree pit filters	Public footways in FFTC	Surface area = 30 x 2m^2 (total across FFTC) Biofilter area =30 x 2m^2 (total across FFTC) Extended detention = 0.15m Biofilter depth = 0.45m
Stormwater gardens	Intersections in FFTC	Surface area = 290m^2 (total across FFTC) Biofilter area =290m^2 (total across FFTC Extended detention = 0.15m Biofilter depth = 0.45m
Biofiltration swales	Public streets in FFTC	Surface area = 690m^2 (total across FFTC) Biofilter area =690m^2 (total across FFTC Extended detention = 0.15m Biofilter depth = 0.45m
GPT	Village Green	Not modelled
Stormwater harvesting tank	Village Green	Storage volume = 150 kL Water demand = 2150 kL/year
GPT	Brickpit Reserve	Not modelled
Biofiltration basin	Brickpit Reserve	Surface area = 850m^2 Biofilter area =700m^2 (total across FFTC Extended detention = 0.45m Biofilter depth = 0.45m
Vegetated swale	Brickpit Reserve	Length = 100m, Slope = 3% Top width = 4m Base width = 1m Depth = 0.3m
Biofiltration basin	Akora Reserve	Surface area = 390m^2 Biofilter area =350m^2 (total across FFTC Extended detention = 0.30m Biofilter depth = 0.45m
Stormwater gardens	Akora Reserve, Akora St	Surface area = 2 x 15m^2 Biofilter area =2 x 15m^2 (total across FFTC Extended detention = 0.15m Biofilter depth = 0.45m

10.7 MUSIC modelling results

The MUSIC modelling results for the FFTC, Brickpit Reserve and Akora Reserve are summarised in Table 10-9, Table 10-10 and Table 10-11 respectively. The modelling results indicate that the base WSUD strategy for each location would achieve Council's targets.

Table 10-9 *Phase 1 Precinct Frenchs Forest Town Centre*

Stormwater quality parameter	Source load	Treated load	% reduction
Flow (ML/yr)	63.6	59.2	7.1%
Total Suspended Solids (kg/yr)	9590	1350	85.9%
Total Phosphorus (kg/yr)	18.2	6.29	65.4%
Total Nitrogen (kg/yr)	136	63.4	53.3%
Gross Pollutants (kg/yr)	1490	0.00	100.0%

Table 10-10 *Brickpit Reserve sub-catchment*

Stormwater quality parameter	Source load	Treated load	% reduction
Flow (ML/yr)	86.1	84.5	1.8%
Total Suspended Solids (kg/yr)	17500	2480	86.1%
Total Phosphorus (kg/yr)	31.6	8.69	71.8%
Total Nitrogen (kg/yr)	177	86.2	51.7%
Gross Pollutants (kg/yr)	1790	0.00	100%

Table 10-11 *Akora Reserve sub-catchment*

Stormwater quality parameter	Source load	Treated load	% reduction
Flow (ML/yr)	26.7	25.9	3.1
Total Suspended Solids (kg/yr)	4860	706	85.5
Total Phosphorus (kg/yr)	8.30	2.66	68.0
Total Nitrogen (kg/yr)	56.1	26.6	52.6
Gross Pollutants (kg/yr)	667	0.00	100.0

11 Preliminary cost estimates

Preliminary cost estimates have been prepared for base WSUD strategy measures within pedestrian areas, road reserves and public open space within the FFTC, Brickpit Reserve and Akora Reserve. These estimates are summarised in Table 11-1, Table 11-2 and Table 11-3. We understand that Council's preference will be for all road reserves within the FFTC (including WSUD measures) to be privately owned and maintained.

The preliminary cost estimates were derived from detailed cost estimates prepared by Alluvium for the ACT government in 2015 for over 25 WSUD and stormwater harvesting projects. The ACT rates were adjusted for inflation and NSW conditions for this project. Costs were also compared with $/ha estimates derived for similar development categories that are outlined in the publication "A Business Case for Best Practice Urban Stormwater Management" (waterbydesign, 2010).

The preliminary cost estimates are based on (but not limited to) the following key assumptions:

- Adjustments to existing services would not be required.
- Site establishment and clearance costs required for all works would be costed separately by others (including items such as tree removal, demolition of concrete, removal of debris/waste, fencing, erosion and sediment control etc).
- Only minimal excavation in rock would be required.
- Conventional pit and pipe stormwater drainage system elements required to achieve Council's design standards for drainage would be available to connect new WSUD infrastructure to.
- We have assumed that the capital, operation and maintenance costs of new stormwater drainage infrastructure associated with the WSUD infrastructure will be evaluated separately by others.
- Excavated soil within the site would be uncontaminated and excavated soil would be utilised as fill with the site.
- Additional landscaping outside the extents of the WSUD measures to integrate the measures into the urban landscape would be costed separately by others.

Table 11-1 *Preliminary cost estimate for FFTC WSUD measures*

Treatment measure	Unit	Quantity	Rate	Capital	Annual O&M
Biofiltration swales	m2 of biofilter	690	$515	$355,350	$8,900
Stormwater gardens	m2 of biofilter	290	$515	$149,350	$3,800
Tree pit filters	each	30	$4,000	$120,000	$6,000
Below ground GPT	item	1	$110,000	$110,000	$5,500
Stormwater harvesting system	item	1	$550,000	$550,000	$27,500
			Contingency (30%)	$385,400	$15,500
			Total	**$1,670,100**	**$67,200**

Table 11-2 *Preliminary cost estimate for Akora Reserve WSUD measures*

Treatment measure	Unit	Quantity	Rate	Capital	Annual O&M
Diversion pit on existing drainage line	item	1	$10,000	$10,000	
Drainage diversion pipe	m	15	$550	$8,250	
Biofilter inlet headwall	item	1	$1,100	$1,100	
Local regrading and landscaping of overland flowpath	m2	150	$50	$7,500	

Biofiltration basin	m2 of biofilter	350	$515	$180,250	$4,500
Street stormwater gardens	m2 of biofilter	30	$750	$22,500	$1,150
Outlet pit on existing drainage line	item	1	$5,000	$5,000	
			30% contingency	$70,380	$1,700
			Total	**$304,980**	**$7,350**

Table 11-3 *Preliminary cost estimate for Brickpit Reserve WSUD measures*

Treatment measure	**Unit**	**Quantity**	**Rate**	**Capital**	**Annual O&M**
Diversion pit on existing drainage line	item	1	$7,500	$7,500	
Modify existing drainage pit to incorporate diversion weir	item	1	$5,000	$5,000	
Drainage diversion pipe	m	60	$550	$33,000	
Biofilter inlet headwall	item	1	$1,100	$1,100	
GPT	item	1	$30,000	$30,000	$1,500
Low flow landscaped swale	m2	300	$50	$15,000	$1,500
Biofiltration basin	m2 of biofilter	700	$515	$360,500	$9,000
Biofiltration spillway	item	1	$10,000	$10,000	$300
Drainage outlet line	m	25	$550	$13,750	
Headwall outlet	m	1	$1,100	$1,100	
			30% contingency	$143,085	$3,700
			Total	**$620,035**	**$16,000**