19 July 2021
Our Reference: 434-20-DA-WMR-A

Proposed Residential Subdivision

Water Management Report

53A Warriewood Road, Warriewood

Lot 2 DP 1115877

Revision A

For PVD No.21 Pty Ltd

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INDEX

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1 Introduction

Craig & Rhodes has been engaged by PVD No.21 Pty Ltd to prepare the Development Application (DA) documentation for the proposed residential development at 53A Warriewood Road, Warriewood. The proposed civil works include internal site stormwater drainage, stormwater detention and Water Sensitive Urban Design (WSUD) treatment train for the development.

The full set of engineering drawings to accompany the DA is referred to as **Craig & Rhodes Drawings 434-20C-0001 - 0902 Revision A.**

The proposed development is located within the Warriewood Valley Land Release. This site is located within the Northern Beaches Local Government Area.

1.1 Site Description

The development site is located on the southern side of Warriewood Road to the south-east of the intersection with Manooka Place. The site is part of an area defined by Council as Buffer Area 1(b) for planning purposes (refer to Figure 1).

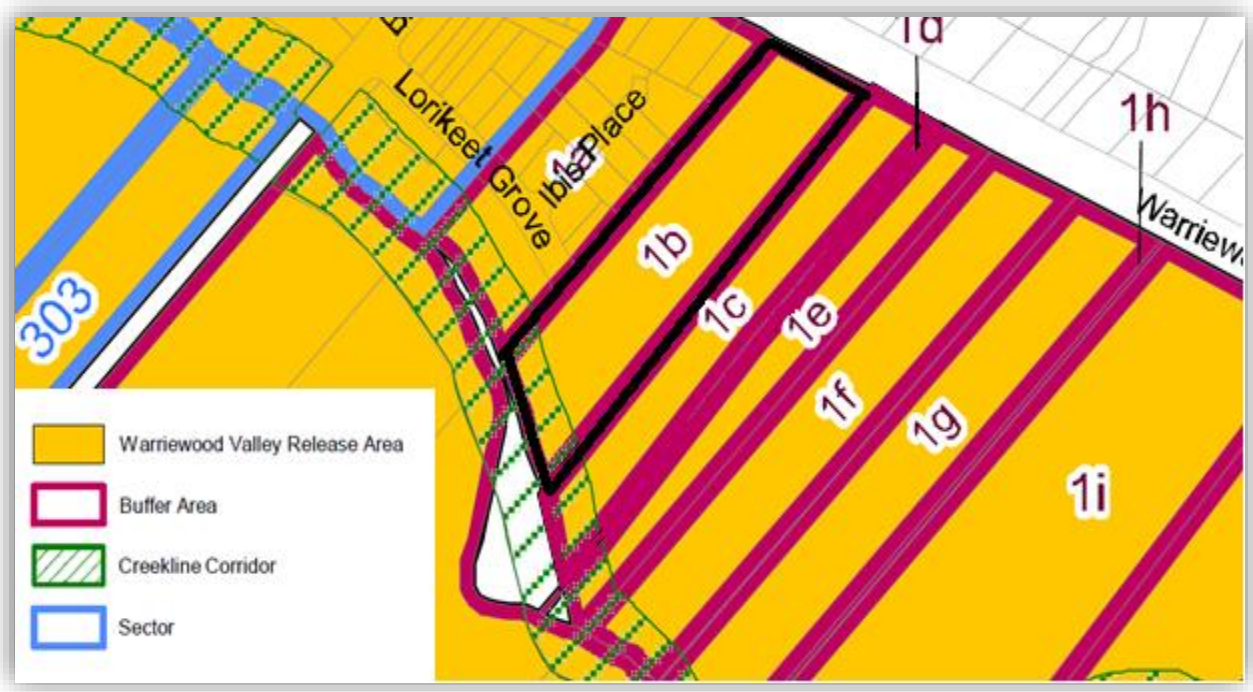

Figure 1 - Northern Beaches Planning Map

The subject site is currently zoned as medium density residential (R3) with a small portion of public recreation (RE1). The site has a total area of approximately 0.925 hectares. This site consists of a residential/farming area (north) and a densely vegetated area (south) (refer to Figure 2 below).

Figure 2 - Site Location Ariel Map (Near Maps 2021)

The existing site has a moderate slope and generally grades in a south-west direction from Warriewood Road towards Narrabeen Creek. The levels of the site range from approximately RL 13.0 AHD down (top north-east corner) to RL 1.0 AHD at the creek. A detailed site survey of the site has been included in Appendix A of this report.

1.2 Proposed Works

The proposed subdivision creates 22 Community lots, together with demolition works, construction of dwelling houses, drainage, earthworks, the extension of existing Lorikeet Grove and Internal Road / Private Accessway within part Community Lot 1.

The development also provides a public reserve adjacent to Narrabeen Creek to be dedicated to Council.

It is proposed to provide stormwater detention and Water Sensitive Urban Design within part Community lot 1 to the south-west of Lorikeet Grove.

1.3 Reference Policies and Guidelines

The following documents have been referenced in developing the stormwater drainage and water sensitive urban design strategy for the proposed development:

1. Pittwater Council, 2015, Pittwater 21 Development Control Plan
2. Pittwater Council, 2001, Warriewood Valley Urban Land Release - Water Management Specification
3. Engineers Australia, Australian Rainfall & Runoff: A Guide to Flood Estimation
4. Commonwealth of Australia, 2016, Australian Rainfall & Runoff: A Guide to Flood Estimation
5. NSW Government, 2010, Draft NSW MUSIC Modelling Guidelines

2 Water Cycle Assessment

The Warriewood Valley Water Management Specification requires a water cycle assessment be carried out for the development. This is to ensure that development does not have detrimental impacts on the Warriewood Valley catchment with regards to peak surface water flow rates, and peak flow volumes of surface runoff.

Craig & Rhodes has carried out an assessment for both peak flow rates and volumes of runoff for the development under three conditions, a low rainfall year, and average rainfall year, and the high rainfall year. The average rainfall for the Warriewood Valley was determined from the Bureau of Meteorology Automatic Weather Station (AWS) at Ingleside (Station 066183). This was considered to provide an appropriate representation of rainfall within the Warriewood Valley.

The average rainfall at Ingleside AWS is 1440 mm per annum. The 10th percentile rainfall is approximately 1071 mm per annum and the 90th percentile is approximately 2094 mm per annum. The rainfall at Ingleside covers a period from 1984 to 2012. During this period rainfall covered annual rainfall from 945 mm to 2161 mm. The rainfall adopted for the Water Cycle Assessment of the proposed development utilised daily rainfall for the following years:

Percentile	Year	Rainfall (mm)
10th	2002	1118
50th	1984	1477
90th	1998	2002

Table 1 - Adopted Rainfall

An additional model was also prepared to look at water balance over a longer period than the individual rainfall years as above. The period covered a 28-year period from 1984 to 2012.

2.1 Treatment Measures

The aim of the water cycle assessment is to determine the changes in surface runoff from the development as result of changing the site conditions. An increase in imperviousness of the catchment increases the peak flow rates and volume of runoff from the catchment. The Warriewood Valley Management Specification requires that the volume of runoff maintain existing conditions where possible.

The primary method for maintaining peak volume of runoff is detaining runoff volumes exceeding the existing volumes. This is primarily through the use of rainwater tanks and infiltration to ground water.

2.1.1 Rainwater Tanks

At this stage, as per the preliminary Architectural design prepared by Saturday Studio Pty Ltd, proposed houses are generally three-bedroom dwellings and it is appropriate to adopt values that reflect a three-bedroom dwelling as a minimum.

It is assumed that the proposed dwellings will require rainwater tanks for on-lot reuse of stormwater collected from roofs for both internal and external use as per the requirements of BASIX.

At this stage it is assumed that 3,000L rainwater tanks will be provided for each dwelling.

Rainwater tanks will collect runoff from approximately 50% of the roofs of the proposed dwellings. This water will be used to supply the daily demands for the dwellings, which will include laundry, toilet flushing and watering of landscaping.

There are a number of sources which can be considered when determining water use patterns within residential developments. There are two local government areas within the Sydney Basin that are generally accepted for water reuse values for residential development, these councils are Blacktown City and Ki-ring-gai Council. Alternate policies based on literature is that from the Sydney Catchment Authority (CMA). The CMA adopts the recommendations from Coombes et al (2003). The following table summarised these accepted sources:

Source	Daily Internal Use	Yearly External Use
Blacktown Council Ku-ring-gai Council	0.08kL/day (<320m^2 block) 0.10kL/day (320-520m^2 block)	25kL/yr (<320m^2 block) 50kL/yr (320-520m^2 block)
Coombes et al (2003) (Toilet & Laundry)	0.36kL/day (3 bedroom) 0.47kL/day (4 bedroom)	West Sydney – 55kL/yr Adelaide – 146kL/yr Brisbane – 126kL/yr Melbourne – 81kL/yr (all dwellings)

Table 2 - Rainwater Tank Reuse

As the Warriewood Valley Water Management Specification does not provide reuse values to be assumed for use within the water balance, an assumed value needs to be determined.

As all lots are less than 320m^2 in area, the values adopted by Ku-ring-gai Council appear to be appropriate for the site. However, the values provided by Coombes appears to be more closed based on dwelling occupants than lot area.

For water reuse drawn from the proposed rainwater tanks, a daily use of 0.36kL per dwelling per day and an annual use of 25kL per dwelling per year has been adopted for the water balance and MUSIC modelling.

Based on the above demands, the daily demand for the development of 21 lots is proposed to be 7.56 KL per day, with an annual yearly demand for the development of 525 KL per year.

2.1.2 Ground Infiltration

With dwelling footprints and lot layouts limited due to size, it is proposed to assist with water retention through the use of infiltration of treated stormwater to groundwater and reduce the volume of surface runoff as required by the Warriewood Valley Water Management Specification.

It is proposed to construct the combined WSUD and Detention basin without an impervious liner. Without an impervious liner, the infiltration of treated stormwater, particularly for frequent rainfall events, will ensure that the ground water can be contributed to due to the reduced infiltration within the catchment as a result of increased imperviousness of the development site.

Soils within the Warriewood Valley are generally deep sandy soils that are highly permeable. The bore logs from the geotechnical report for the project indicate that the soils are generally sandy to a depth of 9 metres below the surface.

The Water Balance model assumes that an infiltration rate of 10 mm/hour has been adopted across the area of the bioretention filtration media. This is lower than the generally accepted infiltration range for sandy soils (Max. 180 mm/hour).

2.2 Water Balance Results

Annual flows from the development have been assessed for a dry, average and wet rainfall years utilising daily rainfall data from 2002, 1984 and 1998 respectively.

The results of the water balance have been summarised in the following table:

Percentile	Pre-Development Annual Surface Runoff (ML/year)	Post-Development Annual Surface Runoff (ML/year)	Reduction (%)
10th	3.52	2.21	37.0
50th	5.45	2.47	54.7
90th	12.00	6.75	43.7
Long Term Average			
1984 – 2012	4.73	2.28	51.80

Table 3 - Water Balance Summary

It can be seen that during a dry year, there is a decrease in the volume of runoff from the catchment by up to 37%. The average year indicates that the volume of runoff under post-development conditions is reduced by up to 54.7% compared to pre-development conditions.

Wet years indicate that the volume of runoff under post-development conditions with the introduction of rainwater tanks on each lot and the infiltration of treated stormwater under the bio-retention basin is reduced by up to 43.7%.

Looking at rainfall over a 28-year period, the volume of stormwater runoff from the post-development is reduced by 51.80% from the pre-development scenario. This indicates that the volume of runoff under development conditions is less than existing runoff volumes under pre-development conditions for frequent rainfall events.

Overall, it is expected that there will be a reduction in the volume of runoff in the long-term comparing to which is currently generated by the site, however individual years may vary, and this is to be expected due to seasonal climatic changes.

3 Water Quality Assessment

3.1 Water Quality Monitoring

Water quality monitoring requirements for the project were established in consultation with Council. Discussions with Council indicated that water quality monitoring data for Narrabeen Creek is available from various sources and previous DAs undertaken within the nearby vicinity of the site, particularly by Marine Pollution Research (MPR).

MPR has provided a report to meet the conditions of a Northern Beaches Council Request for water quality monitoring data. As MPR combined project work for this section of the creek ceased in June 2019, it was recommended that MPR undertake a full annual survey to bridge the gap between the last sampling and present (*Ref. Warriewood Valley Land Release Narrabeen Creek Below Brands Lane – Pre-Construction Water Quality Monitoring data for 53A Warriewood Road Report dated June 2021, for the period of November 2017 to June 2019 plus May 2021* – Refer Appendix F). Note all available water quality data at Narrabeen Creek over the above period is presented in Appendix B of the MPR report.

In summary, it can be observed that the nutrient concentrations, for total phosphorus (TP) and total nitrogen (TN), are generally within ANZECC (2000) Guidelines levels for lowland rivers. This is notwithstanding the fact that there have been incidences of elevated levels, particularly for TP, in the samples for the 6 February 2018 and 5 June 2019. Likewise, there have been exceedances for TN, but are not considered to be significant.

Dissolved oxygen levels are generally acceptable upstream of the site, but tend to decrease downstream of the site, at NC4 and NC5. The cause of this is not clear but may be due to decomposing algae in the creek at those locations. Suspended solids are generally low, while conductivity, pH and turbidity levels are also considered to be within an acceptable range.

By comparison, faecal coliforms levels are found to be elevated across the 3 sampling locations, and up to 16,000 CFU/100ml (NC4, 11 May 2018). It is not clear if sewer overflows, or animal waste, is a cause of these high levels of bacteria contamination in the creek. These pollution levels suggest that the creek is not suitable for both primary and secondary recreational purposes.

The available data detailed in Appendix F also includes heavy metals, pesticides, PCBs and PAHs. The data indicates that most of these pollutants are at fairly low levels. However, there have also been instances of exceedances, for pesticides.

For the purposes of this project, we have allowed to undertake water quality monitoring within Narrabeen Creek at the following 3 locations:

- Just upstream of the proposed development site;
- An intermediate location (likely mid-point of the creek alignment through the subject site); and
- Just downstream of the proposed development site.

Monitoring will be undertaken at the following stages of the proposed works:

- Prior to commencement of construction;
- During construction; and
- After construction of the works, up to the occupation certificate.

It is proposed that the frequency of monitoring be as follows:

- At regular three-monthly intervals under dry weather conditions; and
- Supplemented by 3 wet weather events each year, where rainfall is predicted to exceed 20mm over a 24-hour period, if possible.

We propose to sample the following physico-chemical-biological parameters at each of the above locations, as part of the water quality monitoring plan:

- Temperature
- pH
- Electrical conductivity
- DO
- Turbidity
- Nutrients (oxidized nitrogen, ammonia nitrogen, total nitrogen, total phosphorus)
- Total suspended solids, and
- Faecal coliforms

Field observations will be recorded, including weather conditions, air temperature, cloud cover, wind direction, sample depth, sample appearance, water surface conditions, and noting any nuisance organisms.

Laboratory samples will be taken and transported to an analytical laboratory (NATA registered), as per standard sampling procedures.

The results of the sampling will be assessed against baseline water quality data available for the area and ANZECC Guidelines (2000). In the unlikely event that elevated physical, chemical or biological contaminant levels are observed during either the construction or operation phase of the project, mitigation options will be implemented to ensure that any potential adverse impacts on the downstream environment are minimised or rectified.

It is noted that while ANZECC Guidelines (2018) is progressively being updated, it does not currently include any data for this region. In the event that Council may prepare and stipulate specific pollutant levels for the creek at this location at some stage, it may be necessary to review and update assessment of the available data accordingly. Pending any future direction from Council, it is considered ANZECC Guidelines (2000) would still be relevant for the site.

4 Stormwater Quality Management

Stormwater runoff from the development site undergoes two stages, the construction stage and the post-development stages. These two phases are handled with two different methodologies due to the unique loads each of them generates. These will be handled as required to meet a number of guidelines from various sources and requirements.

4.1 Construction Stage

During the bulk earthworks and construction phase of the development, sediment and erosion control facilities will be designed and constructed/installed in accordance with Council's specifications and requirements of the NSW DECC publication titled "Managing Urban Stormwater – Soils & Construction" January 2008.

A detailed sediment and erosion control plan will be prepared prior to construction, outlining the strategies proposed to prevent excessive pollutant loads being exported from the site in runoff during and immediately following construction. Refer **Craig & Rhodes Drawings 434-20C-0901 - 0902 Revision A** for the sediment erosion control plan and details prepared for the project Development Application.

A summary of the principle elements applied to the sediment erosion control plan for the site is summarised below:

- Minimising the extent of disturbed surfaces as any one time through staging of works;
- Stabilising disturbed surfaces immediately following completion of works;
- Diverting clean runoff around disturbed areas via diversion mounds and channels;
- Protecting stockpiles via silt fencing or diversion bunds;
- Sediment control basin;
- Application of silt fencing on the downslopes of disturbed areas;
- Application of silt socks around drainage structures;
- Protection of exposed slopes;
- Restriction of construction vehicles to particular points of entry/exit locations; and
- Application of stabilised site access point sand vehicle wash down bays.

Details for the construction stages of the development have been documented indicatively as part of the DA plans and will be detailed further as part of the Construction Certificate documentation and managed ongoing through the construction process by the selected contractor.

4.2 Post-Development Stage

The proposed water quality treatment for the site consists of the following elements:

- On-lot rainwater tanks (3.0kL per lot) and associated internal & external reuse;
- Underground Gross Pollutant Trap (GPT); and
- Bio-retention Basin (estimated total surface area 380m^2)

An assessment of the post-development stage of proposed development has been carried out using MUSIC and is detailed in the following section of the report.

4.3 MUSIC Modelling (Post-Development)

The software package developed by the CRC for Catchment Hydrology termed “MUSIC” (Model for Urban Stormwater Improvement Conceptualisation) was used to assess the effectiveness of the proposed treatment under the following scenarios:

- Existing pre-development conditions
- Proposed post-development conditions (with treatment measures)

4.3.1 Catchments

For the purposes of water quality assessment, the total catchment of the site is approximately 0.925 hectares for both the existing pre-development and post-development scenarios. Each scenario has been separated into land-use catchments representative of the overall site. The summary of the catchment properties is outlined in the following table.

Catchment	Area (ha)	Impervious Fraction (%)
Pre-Development	0.925	5
Post-Development		
Roofed Catchment	0.232	100
Non-roofed Catchment	0.298	20
Roads	0.234	80
Overall Post-Development	0.764	60

Table 4 - MUSIC Catchment Summary

4.3.2 Rainfall & Evaporation

MUSIC models were prepared using Daily Rainfall data sourced from the Bureau of Meteorology station 066183 (Ingleside). This station has a mean annual rainfall of 1440 mm per year. The rainfall adopted for the models are outlined in Table 1 of this report.

Evaporation data for Sydney was sourced from the Bureau of Meteorology. This was combined with the rainfall data in the MUSIC models.

4.3.3 Soil Properties

The soil properties parameters for the MUSIC Source nodes adopted the default MUSIC/Duncan values.

4.3.4 Pollutant Loads

The Event Mean Concentrations adopted for the total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN) are based on the requirements of Council's WMS (Table 4.1). The EMC values applied to the MUSIC models are provided in the following table.

Land Use	Fraction Impervious	TSS EMC (mg/L)	TP EMC (mg/L)	TN EMC (mg/L)
Existing Site (Rural Residential)	5	35	0.10	1.00
Roof (Urban)	100	100	0.30	1.50
Ground (Urban)	20	100	0.30	1.50
Road (Urban)	80	100	0.30	1.50

Table 5 - Event Mean Concentrations

4.3.5 Treatment Objectives

A common and practical guideline that often applies throughout NSW is setting of the treatment objectives that are achievable using best practice. These best practice treatment objectives are provided in the following table.

Pollutant Elements	Treatment Reduction Targets
Total Suspended Solids (TSS)	80
Total Phosphorus (TP)	65
Total Nitrogen (TN)	45
Gross Pollutants (GP)	90

Table 6 - Best Practice Treatment Targets

However, it should be noted that the Northern Beaches Council (formerly Pittwater Council) Water Management Specification (WMS) clearly sets the requirement that all post-development loads must be equal to or less than the existing site conditions. Therefore, the outcomes of the MUSIC modelling shall comply with these requirements, but also compared against the treatment objectives outlined in Table 7.

4.3.6 Treatment Controls

<u>On-Lot Based Rainwater Tanks</u>

It is proposed to provide 3.0kL Rainwater Tanks for all future dwelling within the new subdivision. These tanks will reduce runoff volumes, maximise non-potable supply/reuse and reduce peak flows for more frequent storm events by capturing the majority of roof water runoff and re-using within each proposed lot. Roof runoff will be reused for toilet flushing, garden irrigation, car washing and cold water laundry.

Gross Pollutant Trap

The proposed GPT will be used to capture litter and coarse sediment from the majority of the site. This has been modelled in MUYSIC in accordance with capture rates determined in the report, *Removal of Suspended Solids & Associated Pollutants by a GPT* (Cooperative Research Centre for Catchment Hydrology, 1999). These capture rates are:

- Gross Pollutants – 95%
- Total Suspended Solids – 70%
- Total Phosphorus – 30%
- Total Nitrogen – 0%

The proposed GPT will be designed to treat all peak flows up to and include the 1 in 3-month ARI events. Preliminary calculation has shown that a Rocla CDS 1009 or equivalent would be required for the subject site.

Bio-retention Basin

The proposed bio-retention basin will provide a number of functions for the development. These include stormwater quality improvement, ground infiltration, and stormwater detention. The bio-retention basin will consist of an above ground depression containing landscaping of native grasses and shrubs. This is constructed on top of an infiltration area with associated drainage. This infiltration zone typically features topsoil layers, filtration media, transition and gravel layers. Within the drainage gravel layer is subsoil drainage lines to collected filtered water, which cannot enter ground water due to infiltration.

The basin levels have been primarily driven by the existing road levels of the adjoining development. The constraints of the neighbouring site have determined the subject site road levels and subsequent stormwater drainage design within the Lorikeet Grove extension. In compliance with Council's design guidelines for stormwater (i.e. min. 1% grade of pipelines, suitable cover, etc.), the stormwater network design has been continued from the sag in Lorikeet Grove, to the proposed GPT unit and then to the inlet of proposed bio-retention basin.

For this development a basin with an estimated filter media area of 380m^2 will be constructed. The filtration media layer should have the following properties to meet the requirements the water quality management section of the Warriewood Valley Water Management Specification.

Extended Detention Depth (m)	Estimated Basin Surface Area Provided (m^2)	Estimated Filter Media Surface Area Provided (m^2)	Filter Media Layer Depth (m)	Filter Media Infiltration Rate (mm/hr)
0.3	468	380	0.4	125

Table 7 - Bio-retention Media Properties

The invert of the basin filter media and drainage layer (R.L. 2.15m AHD) has been set above the estimated ground water conditions (approx. R.L. 2.0 AHD) as per Council's requirements in Section 4.3.2 of the Warriewood Valley Water Management Specification. This ground water level was obtained from the borehole logs within the geotechnical report undertaken by Construction Sciences Pty Ltd dated 15 June 2021(BH06 – RL.4.70).

4.4 MUSIC Model

The following figure is a screen capture from the MUSIC model showing the model configuration adopted for both the Water Balance and Water Quality modelling.

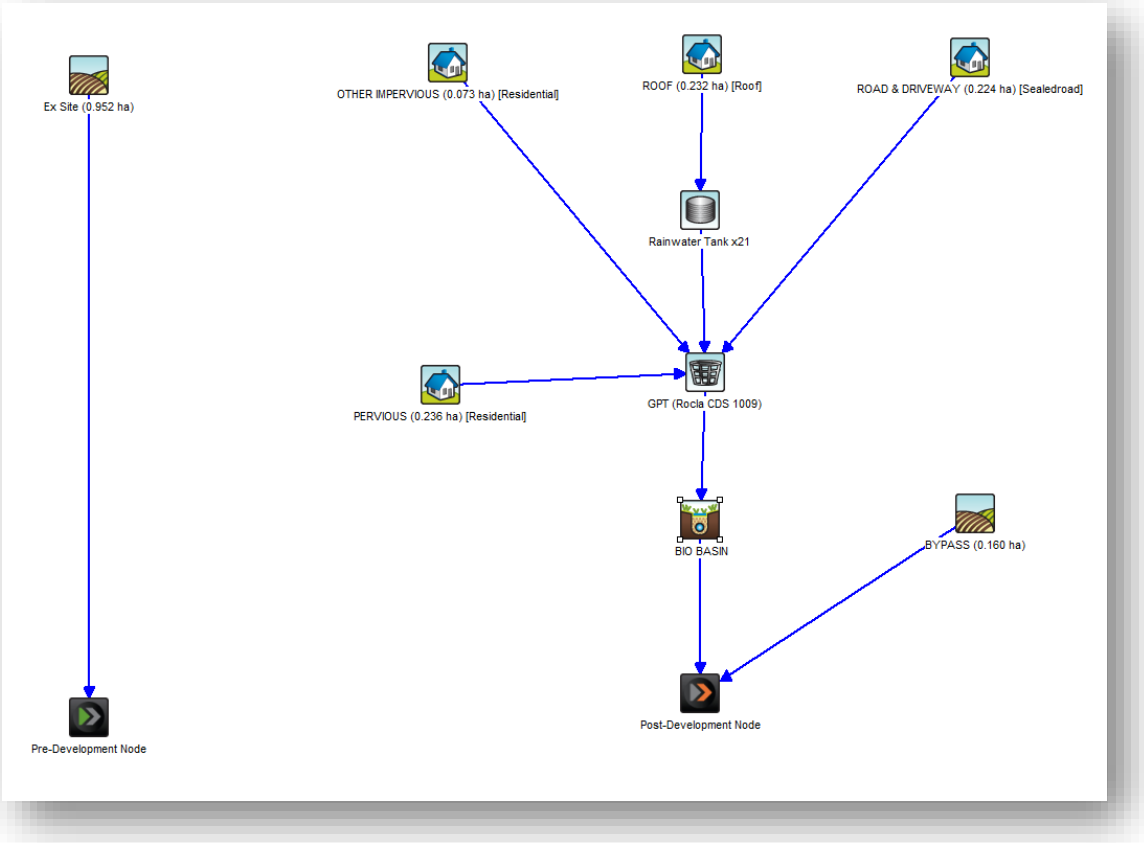

Figure 3 - MUSIC Model Layout

4.5 MUSIC Modelling Results (Post-Development)

The results from the MUSIC model comparing the post-development conditions with the pre-development conditions have been outlined in the following tables. It is evident that the stormwater quality complies with both the best practice treatment performance targets and the requirements outlined in the Warriewood Valley Water Management Specification for the three cases for rainfall, dry, average and wet.

Pollutant	Pre-Development (kg / yr)	Post-Development (without treatment) (kg / yr)	Post-Development (with treatment) (kg / yr)	Achieved Reduction (%)	Best Practice Reduction Targets (%)
TSS	121	594	6.41	95	80
TP	0.347	1.8	0.118	66	65
TN	3.5	9.1	1.89	46	45
GP	18.4	130	0	100	90
Compliant with Best Practice Objectives				-	Yes
Compliant with Warriewood WMS Objectives				Yes	-

Table 8 - Low Rainfall Year (2002)

Pollutant	Pre-Development (kg / yr)	Post-Development (without treatment) (kg / yr)	Post-Development (with treatment) (kg / yr)	Achieved Reduction (%)	Best Practice Reduction Targets (%)
TSS	182	783	4.94	97	80
TP	0.522	2.41	0.134	74	65
TN	5.35	12.5	1.48	72	45
GP	29.6	172	0	100	90
Compliant with Best Practice Objectives				-	Yes
Compliant with Warriewood WMS Objectives				Yes	-

Table 9 - Average Rainfall Year (1984)

Pollutant	Pre-Development (kg / yr)	Post-Development (without treatment) (kg / yr)	Post-Development (with treatment) (kg / yr)	Achieved Reduction (%)	Best Practice Reduction Targets (%)
TSS	406	1240	13.3	97	80
TP	1.16	3.83	0.362	69	65
TN	11.8	19.8	4.05	66	45
GP	40.6	184	0	100	90
Compliant with Best Practice Objectives				-	Yes
Compliant with Warriewood WMS Objectives				Yes	-

Table 10 - High Rainfall Year (1998)

4.6 Ongoing Requirements

Upon completion of the proposed development, the WMS requires ongoing monitoring and maintenance for the Stormwater Quality Improvement Devices constructed and installed as part of the subdivision.

Monitoring and maintenance of the stormwater treatment train shall include, but not limited to:

- Measurement of volume/mass of material removed from the GPT and an assessment of relative composition;
- Discrete sampling of stormwater at the inlet & outlet of the proposed bio-retention basin; and
- Qualitative assessment of effectiveness of other proposed water quality control measures.

All reporting shall conform to the requirements outlined in the WMS and forwarded to Council as required.

4.7 Mosquito Risk Assessment

The development does not propose to provide permanent waterbodies. As there are no proposed permanent waterbodies, the risk of mosquito activity is considered to be low.

There are two areas of potential concern in regards to mosquito activity. The stormwater drainage network for the development, and the creek corridor.

The stormwater drainage network consists of a pit and pipe network, with a bio-retention basin and gross pollutant trap. The stormwater network has been designed to drain and not provide areas for stagnant water to collect and allow mosquito and insects to breed. The combined bio-retention and on-site detention basin is not expected to detain stormwater for an extended period of time greater than a few hours. Provided the basin is designed, constructed and maintained in line with the industry best practices, there is minimal risk that the basin will act as a mosquito habitat.

The gross pollutant trap is a wet sump type device. This device will contain a small quantity of standing water, however the volume of the water which is contained underground is relatively small. Additionally, rainfall events will flush out the standing water and minimise the risk that the device will act as a mosquito habitat.

The lot-based rainwater tanks pose a minimal risk for mosquito breeding and habitat. Rainwater tanks must be adequately maintained with an emphasis on screening the inlets to the rainwater tank to prevents insects and pests from entering the tank.

The proposed creek corridor is being re-graded as part of the development. The proposed typical section for the creek corridor is shown on **Craig & Rhodes Drawings 434-20C-1001 - 1901 Revision A** of the Narrabeen Creek Rehabilitation Works set.

The typical section proposed for the development side is to continually fall towards the creek centreline. As the section does not propose permanent pools of water along the creek line, the risk for mosquito forming habitats will be reduced. Natural depressions will form over time which may allow for mosquito habitats to form, however this is not unlike the existing natural site conditions. As a result of the proposed creek rehabilitation works, there will be no increase in mosquito activity from existing site conditions, however as the proposed channel will be formalised, it is expected that mosquito habitats will be reduced.

At this stage it is expected that there is a low risk of forming additional mosquito and insect habitats from what currently exists. It is expected that mosquito habitats will remain static or be reduced due to the proposed works.

A further mosquito risk assessment shall be undertaken as required during the Construction Certificate and Construction stages of the development to ensure that mosquito habitats are not encouraged or formed during the construction process.

5 Watercourse and Creekline Corridor Preservation/Restoration

The subject development has a frontage to Narrabeen Creek to the south-west where it is proposed to dedicate a portion of the site to Council as Public Reserve.

The Warriewood Valley Water Management Specification calls for a creek corridor of up to 100m wide. This is comprised of a 50m publicly owned corridor, with a 25m wide buffer held in private ownership outside of the 50m corridor.

The proposed works within the Narrabeen Creek are generally minimal and limited to reshaping of the creek bank as outlined in Section 4.4.4 of the Warriewood Valley Urban Land Release Water Management Specification (Refer to the Narrabeen Creek Rehabilitation Works drawings prepared by C&R, Ref: **434-20C-1001 - 1901 Revision A).**

6 Flood Impact

Craig & Rhodes has also undertaken a Flood Impact Assessment to accompany the Development Application for the proposed development.

The Flood Impact Assessment includes determination of the peak flood levels and overland flood behaviour for the 50%, 20%, 1%, 1% with climate change and PMF Annual Exceedance Probability (AEP) design events. Flood impacts associated with the proposed subdivision are identified and assessed in accordance with Council's flood policies.

This report titled *Overland Flow Impact Assessment (Craig & Rhodes July 2021)* provides a summary of the analysis and results, which included as part of the DA lodgement package.

7 Flood Protection

The subject site is primarily impacted by floodwater generated by Narrabeen Creek. Storm Consulting has undertaken a flood impact and risk assessment for the proposed development to accompany the DA documentation for the site. This report has been included as part of the DA lodgement package.

TUFLOW modelling has been carried out to assess the impact of the proposed development on flood levels within the catchment.

The following table is a summary of the peak flood levels for the post-development conditions reported along Narrabeen Creek.

Design Event	Peak Water Surface Level (m AHD)
50% AEP	4.12
20% AEP	4.14
5% AEP	4.40
1% AEP + 30% Climate Change	4.52
Probable Maximum Flood	5.67

Table 11 – Proposed Peak Water Surface Levels - Narrabeen Creek

The results of the modelling and assessment have confirmed the following:

- There is minimal off-site flood impacts at the 1% AEP post-development event. This is approximately +0.05m (max.) increase in flood levels within the Narrabeen Creek corridor and along Warriewood Road. Note approximately -0.1m (max.) decrease in flood levels within the adjacent downstream site. There is also negligible impact on surrounding properties for the 1% AEP with Climate Change event;
- No flood prone lots are created within the proposed subdivision; and
- The majority of the development (including all of the allocated lots) are flood free during the PMF event.

The proposed subdivision development encroaches on the 1% AEP flood storage area within the site boundaries, however the proposed Narrabeen Creek rehabilitation works provides an amount of offset in volume storage. This results in only minor local increases in the 1% AEP flood levels, which is confined within the creek. Refer to the *Overland Flow Impact Assessment (Craig & Rhodes July 2021)* for further information on this matter.

7.1 NSW Office of Water

A Controlled Activity Approval (CAA) is required from the NSW Office of Water as part of the detailed design phase prior to the issue of the Construction Certificate.

7.2 Flood Planning Levels

The proposed development shall set the habitable floor levels for lots within the development at 500mm (min.) above the 1% AEP + 30% Climate Change creek flood levels (i.e. Flood Planning Level). The minimum proposed finished floor level height is to be set at RL 5.36m AHD, which is over 0.5m above the 1% AEP + CC creek flood level (i.e. RL 4.60 AHD). The current design earthworks levels within the developable lots allow for the finished building floor levels to be set at least 0.5m above the 1% AEP + CC flood level.

Note that no basement entries are proposed.

No interim flood protection measures were determined to be required for the site.

7.3 Flood Emergency Response

No flood warning or response plan will be required for the site given the small size of the upstream catchment. Additionally, all proposed lots in question shall have a ‘shelter in place’ strategy available during the PMF event, in most cases, the second storey level of the building. The period of inundation would be relatively short, being likely less than one hour and assistance for residents would therefore not be required. Note also the PMF Peak Flood hazard of the proposed internal access road is classified as H1 (i.e. relatively benign flow conditions – safe for pedestrians and vehicles). This provides safe access to higher ground if required as well.

A floodway sign shall be installed at regular intervals along the shared pathway which is subject to overtopping during larger flood events.

A handrail will also be installed along the edge of the shared path in accordance with the BCA and Council requirements.

For further details refer to Appendix E for the Flood Assessment Report.

8 Stormwater Quantity Management

The proposed strategy for stormwater quantity management comprises of a series of pits and pipes collecting runoff generated by the development to convey flows to the proposed Water Quality and Detention basin located within the community lot to the south-west of Lorikeet Grove.

8.1 Hydrology

A DRAINS model was prepared to represent both the existing and proposed site conditions as illustrated in the following figure.

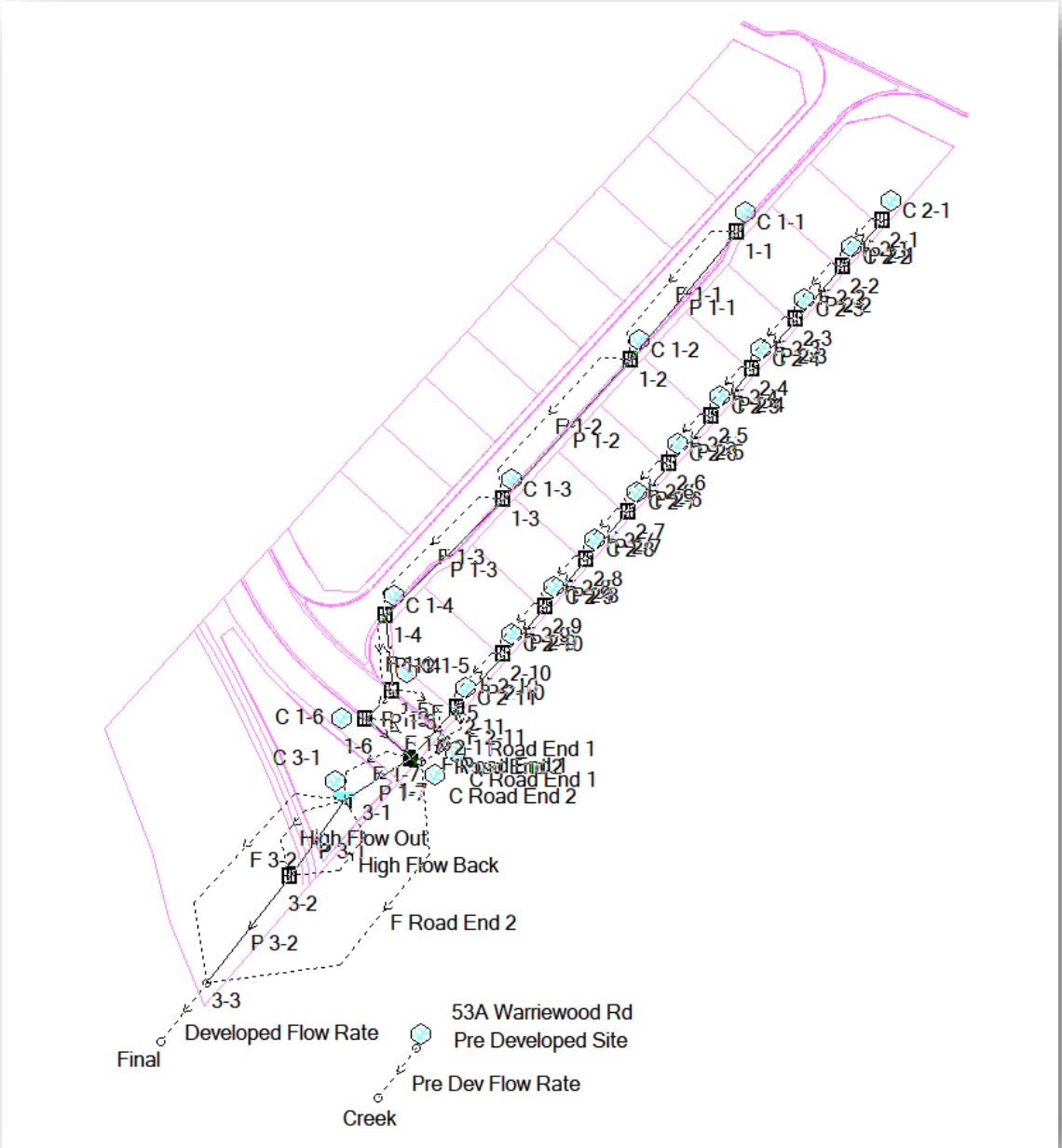

Figure 4 - DRAINS Layout

Event rainfall data was based on Australian Rainfall & Runoff 2019 methodology and Intensity-Frequency-Duration data obtained from the Bureau of Meteorology. This data is summarised in the following table:

Duration	50%	20%	10%	5%	2%	1%
5 min	8.23	10.2	12.6	14.6	16.9	20.1
10 min	13.0	16.2	20.2	23.6	27.4	32.7
1 hour	28.9	35.9	44.1	51.0	58.9	69.9
12 hour	70.8	87.4	108	125	146	175
24 hour	92.7	116	146	172	202	243
48 hour	119	150	193	229	271	326
72 hour	134	170	221	262	310	371
G = 0.0 F_2 = 4.30 F_{50} = 15.88						

Table 12 - Warriewood IFD Data

8.2 External Catchment – Warriewood Road

There is a small external catchment to the north-east of the development site along the Warriewood Road frontage. Since the site is to be raised above existing surface the runoff generated within the road will no longer sheet into the site. It is proposed to provide an interim diversions swale prior to the DA2019-0263 approved road upgrade works along the 53B Warriewood Road. This shall divert any overland flows from the road catchment towards existing drainage infrastructure instead of entering and impacting the 53B Warriewood Road site. For further information refer to the *Overland Flow Impact Assessment (Craig & Rhodes July 2021)*.

8.3 Internal Catchments

The following table summarises the general parameters adopted for each of the catchments within the DRAINS model for both pre- and post-development conditions.

Parameter	Pre-Development Catchments	Post-Development Catchments
Total Catchment Area (ha)	0.925	0.764 (excludes creek)
Fraction Impervious (%)	5	Varies (75 – 95)* Average: 85 - Refer DRAINS Model
Time of Concentration (min)	Impervious: 6 min Pervious: 10 min	Impervious: 5 min Pervious: 10 min

Table 13 - DRAINS Catchment Conditions

8.4 Post-Development (On-Site Detention)

To accommodate the change in imperviousness of the catchment as a result of the proposed development, it is proposed to provide a detention basin to assist with reducing peak flow rates to pre-development peak flow rates. The on-site detention basin has been combined with the proposed bio-retention basin to provide both a detention and temporary retention of stormwater runoff from the development.

In DRAINS, this has been modelled by introducing a basin node with outlet control. This configuration was determined through several iterations to optimise the design and ensure compliance with Council's stormwater management objective outlined in the Warriewood Valley Water Management Specification.

The following table provides a summary for the drainage modelling results for both the pre- and post-development scenarios of the development.

Design Storm Event	Pre-Development Flow – PSD (m^3/s)	Post-Development Basin Outflow (m^3/s)	Top Water Level (m)
1% AEP + 30% Climate Change	0.577	0.537	4.72
5% AEP	0.269	0.250	4.62
10% AEP	0.212	0.104	4.43
20% AEP	0.150	0.091	4.37
50% AEP	0.073	0.072	4.28

Table 14 - Site Discharge Summary

It can be seen that with the increase in imperviousness of the catchment, there is a significant increase in the post-development flow rates towards the detention basin. However, with the inclusion of the combined detention and water quality basin, the peak flow rates discharging from the site into Narrabeen Creek are equal to or lower than the pre-development flow rates.

9 Stormwater Drainage Concept Plan

The elements of the proposed stormwater drainage concept plan for the subject site are illustrated by the **Craig & Rhodes Drawings 434-20C-0001 - 0902 Revision A** and are summarised as follows:

- All roof water is firstly captured by rainwater tanks on each lot and then reused for toilet flushing, garden irrigation, car washing and laundry cold water;
- Impervious surface is restricted to maximize infiltration (limited to 60% impervious for the site area);
- Runoff leaving the lots along the north-west side boundary drain to the community road via a kerb outlets and collected via road stormwater pits.
- Runoff leaving the lots along the south east side boundary connects directly to individual lot stormwater pits;
- A 20% AEP + 30% Climate Change (minor) capacity drainage system will convey all local site flows to the bio–retention/detention basin. Flows in excess of the 20% AEP + 30% Climate Change and up to the 1% AEP + 30% Climate Change (major) shall be conveyed by the road carriageway into the basin. All flows will then discharge to Narrabeen Creek;
- Local runoff will be treated in a single GPT near the basin outlet into the basin. The GPT will be located adjacent to the road reserve and have clear access for maintenance; and
- Outflows form the GPT will receive tertiary treatment in the bio-retention basin.

Stormwater detention measures are proposed, primarily in the form of free storage. These measures ensure flows generated by the site do not exceed those under existing conditions.

Runoff water quality is proposed to be managed through a combination of treatment measures. These measures ensure post development stormwater loads generated by the site do not exceed those under existing conditions.

No development structures are proposed within the site that do not comply with Council flood planning levels.

The proposed development generally complies with Council guidelines and achieves best practice standards in sustainability and stormwater management.

10 Maintenance Operations and Checklist

10.1 Maintenance Objectives

The stormwater quality devices constructed and occurring naturally within an urban environment suffer from a number of constraints placed upon them by disturbance within the upstream contributing catchment. Consequently, these structures will not be able to perform efficiently and continuously without regular maintenance.

Maintenance is required to increase the functionality of each design element and increases the aesthetic amenity and reduces public health and safety risks.

The purpose for this maintenance manual is as follows:

- To set out the procedures of maintenance operations and checklists whereby it can be maintained to a standard that ensure it remains operation in accordance with its original design objectives and intent;
- To provide a systematic monitoring and review procedures for the water quality devices, so that they will remain functionally effective as its original design throughout the design life of the structure.

An overall summary of the maintenance operations related to the stormwater quality improvement devices associated with the development are summarised in the following sections.

10.2 Signage

Signage outlining the nature of hazards and descriptions for the stormwater detention and water quality devices shall be inspected twice yearly for vandalism. Signs should be repaired or replaced as required.

10.3 On-Site Detention Basin

The On-Site Stormwater Detention (OSD) system is designed to temporarily store water during significant rainfall events so that stormwater runoff from the development does not have an impact on flooding downstream of the development. The ponding of water will occur but should not last for more than a few hours in most storms. If ponding persists, it is likely that maintenance is required.

The following schedule (Table 15) provides a guide to the timing of typical maintenance actions for an On-Site Stormwater Detention (OSD) System as well as defining the person responsible and describing the actions required.

Most components of the system should be checked for blockages after each significant storm to ensure that they continue to function effectively. The build-up of sludge and debris depends on the individual site and more frequent maintenance may be required where there are many trees, especially after windy conditions.

Access to the basin will be provided off Lorikeet Grove, with a gate and step irons provided to gain access to the basin. Maintenance for the basin shall be undertaken by a Maintenance Contractor. For major cleans, a small bobcat shall be floated into the basin to move/remove material. Excess material (i.e. large debris) that cannot be manually moved by hand shall be removed by lifting out of the basin via mechanical means.

Item	Period	Responsibility	Maintenance Procedure
Inspection – Minor Maintenance	3 months and after major storms	Council / Maintenance Contractor	• Inspect pit and grate conditions
Inspection – Minor Maintenance	3 months and after major storms	Council / Maintenance Contractor	• Remove debris & accumulated sediment for disposal
Inspection – Minor Maintenance	3 months and after major storms	Council / Maintenance Contractor	• Inspect berm for erosion
Inspection – Minor Maintenance	3 months and after major storms	Council / Maintenance Contractor	• Check signage for vandalism and repair as required
Inspection – Major Maintenance	3 months and after major storms	Council / Maintenance Contractor	• Inspect pit and grate conditions. Evidence of cracking or spalling of concrete structures.
Inspection – Major Maintenance	3 months and after major storms	Council / Maintenance Contractor	• Repair erosion downstream of basin outlet

Table 15 - On-Site Detention Basin Maintenance

Refer to Appendix B for a draft Maintenance Schedule.

10.4 Stormwater Pits & Pipes

Stormwater pits and pipes are designed to convey stormwater runoff during significant rainfall events so that surface flows are reduced to reduce inconvenience to users. Pits and pipes should minimise ponding of surface water but if ponding persists after rainfall events, it is likely that maintenance is required.

Pits and pipes should be checked for blockages after each storm event to ensure they continue to function effectively. The build-up of sludge and sediment depends on the upstream catchment and stormwater flows. More frequent maintenance may be required in areas where there is significant bare earth or heavy leaf litter material is conveyed in surface runoff.

In general, land managers could maintain pit and pipe systems where the depth is less than 1.2 metres. For pits deeper than 1.2m, experienced personnel with appropriate experience and qualifications (i.e. confined space training) should maintain the system.

Refer to Appendix B for a draft Maintenance Schedule.

10.5 Water Sensitive Urban Design

There is a number of WSUD devices proposed for this development that operate in a treatment train approach. The development runoff passes through a gross pollutant trap prior to discharging through a bio-retention basin planted with grasses and native plants. The recommended maintenance procedures by the manufacturers of these products are

summarised in this section. The detailed maintenance procedure is included in the appendices.

10.5.1 Rocla CDS Gross Pollutant Trap (GPT)

Rocla CDS units have been proposed on low-flow pipe inlets to the bio-retention basin cells as per the C&R Engineering Drawings. These are offline to reduce the resuspension of pollutants that have been removed in previous storm events.

These units are to be cleaned and maintained on a quarterly basis and when it reaves 100% of its holding capacity (level reaches the top of the sump). Additionally, Rocla recommends that non-scheduled inspection shall be carried out after heavy weather and prolonged periods of rainfall within the catchment.

As per the Rocla Operational Manual provided in Appendix C, it is to be mechanically cleaned using a vacuum truck. During the inspection, any damage identified to the device shall need to be rectified to ensure that system maintains treatment performance as per the design intent.

Item	Period	Responsibility	Maintenance Procedure
Inspection – Minor Maintenance	Monthly and after major storms	Council / Maintenance Contractor	Follow recommended procedure set out in the Manufacturer "Operation and Maintenance Guidelines"
Inspection – Major Maintenance	2-3 years (except in case of oil spill)	Council / Maintenance Contractor	Follow recommended procedure set out in the Manufacturer "Operation and Maintenance Guidelines"

Table 16 - Gross Pollutant Trap Maintenance

10.5.2 Bio-retention Basin

Following its construction, the bio-retention pond should be inspected every 1 to 3 months (and after each major rainfall event) during the initial vegetation establishment period to determine whether or not the bio-retention zone requires maintenance, or the media requires replacement. The following critical items should be monitored:

- Ponding, clogging and blockage of the filter media;
- Establishment of desired vegetation/plants and density; and
- Blockage of the outlet from the bio-retention system.

After the initial establishment period (typically 1 to 2 years), inspections may be extended to the frequencies shown in the maintenance frequency table below.

If the bio-retention system is not maintained frequently, the entire filter media may need to be replaced due to clogging of the media material with fine particles. This can result in frequent maintenance being more cost effective in the long-term.

Access to the basin will as per the methods previously mentioned in Section 10.3, via a 5.5m concrete access handle provided off Lorikeet Grove, with a gate and step irons provided to gain access to the basin. Maintenance for the bioretention component shall again undertaken by a Maintenance Contractor. For major cleans and filter media replacement, a small bobcat shall be floated into the basin to move/remove material. Excess material (i.e. large debris) that

cannot be manually moved by hand shall be removed by lifting out of the basin via mechanical means.

The following maintenance activities will be required with inspection frequencies shown below.

- Maintenance of flow to and through the system;
- Maintaining the surface vegetation;
- Preventing undesired overgrowth vegetation/weeds from taking over the area;
- Removal of accumulated sediments; and
- Debris removal

The recommended maintenance frequency for the bio-retention pond is provided below.

Item	Period	Responsibility	Maintenance Procedure
Inspection – Minor Maintenance	3 months and after major storms	Council / Maintenance Contractor	• Check for sediment deposition, oily or clayey sediment on filtration media • Remove depositions or sediment
Inspection – Minor Maintenance	3 months and after major storms	Council / Maintenance Contractor	• Check for erosion and scour of filtration media • Infill holes and repair erosion and scour
Inspection – Minor Maintenance	3 months and after major storms	Council / Maintenance Contractor	• Check for litter • Remove both organic and anthropogenic litter
Inspection – Minor Maintenance	3 months	Council / Maintenance Contractor	• Assess plants for disease and pest infestation • Check plants for signs of stunted growth or die off • Check original plant densities are maintained • Treat and replace plans as necessary
Inspection – Minor Maintenance	3 months	Council / Maintenance Contractor	• Check for presence of weeds • Manually remove weeds where possible or use spot treatment with herbicide appropriate for use near waterways
Inspection – Minor Maintenance	Annually and after major storms	Council / Maintenance Contractor	• Check underdrains are not blocked with sediment or roots • Clear underdrains as required
Inspection – Minor Maintenance	3 months and after major storms	Council / Maintenance Contractor	• Pit and grate conditions. Evidence of cracking or spalling of concrete structures.
Major Maintenance	2 years	Council / Maintenance Contractor	• In situ hydraulic conductivity testing • Replace transition layer and filtration media when hydraulic conductivity falls below Council acceptable limits

Table 17 - Bio-retention Basin Maintenance

10.6 Annual Review

An annual review of all stormwater drainage and water quality infrastructure should be carried out to record changes for the infrastructure over time. This should be in the form of photographs and documentation

10.6.1 Photographs

Monitoring should incorporate photography of the infrastructure to record changes. Annual photos should generally be taken at the same time of year from the same location.

10.6.2 Procedures

The monitoring and maintenance program should be reviewed each year to determine if the maintenance objectives are being fulfilled and to ensure that maintenance staff are finding that the maintenance program is adequate for performing maintenance tasks.

The yearly review should include and assessment of the maintenance database to determine the effectiveness of inspections, reporting mechanisms and scheduled maintenance tasks that are effective.

Information in the database should be assessed to determine whether any noticeable changes are evident in vegetation, bird usage of the basin, and operational efficiency of any structure. This will further provide indications as to whether sufficient information is being recorded for management purposes.

Appendix A – Lot Layout & Detailed Site Survey

Appendix B – Draft Maintenance Schedule

Appendix C – Rocla Operational Manual

Appendix D – MUSIC Results

Appendix E – Water Quality Data - Marine Pollution Research (2021)