LandDynamics AUSTRALIA

Stormwater Quality Report

Issue and revision record

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1. Executive Summary

This Stormwater Quality Report has been prepared by Land Dynamics Pty Ltd as part of the Part 3A 75W modification application for the proposed Coast Residential Subdivision development (formerly referred to as Saltwater) to be constructed on Lot 52 DP 831284 and Lot 84 DP 792945 located off Belle O'Conner Street, South West Rocks NSW. It should be noted that this report is not a primary report for water quality parameters and methodology but rather an addendum to the Part 3A approved report "Amended Water Cycle Management Plan: Proposed Residential Sub-division, South West Rocks, NSW." July 2010 by Martens Consulting Engineers.

This report by Land Dynamics Australia documents the methodology involved in determining the design of the proposed stormwater drainage system mainly pertaining to the stormwater quality management of the site runoff. However in some sections the stormwater water quantity is also being addressed as some adjustments to the flow regimes have been made. The main purpose of this report is to highlight the variations to the approved design and also to introduce additional water quality treatment for the post development stormwater runoff.

Previously the post development stormwater runoff was to be treated within the estate via series of swale drains before being discharged into the conservation zone. Martens Consulting Engineers have modelled the aforementioned treatment train and concluded that this treatment met the criteria for water quality. The main concern with post approval implementation of the Martens Consulting Engineers model is the ability of the swales to provide the necessary treatment given their location within private property and as such this amendment proposes to pipe interallotment drainage. Land Dynamics Australia is of the opinion that there is little ability to police the maintenance of these swales if located in private property. Similarly the effectiveness of these swales is subject to having sufficient grades to allow the runoff to flow. With the minimum effective slope for swales set at 1% this will lead to excessive amounts of fill material needed to achieve the minimum grades.

The methodology adopted by Land Dynamics Australia is to pipe interallotment drainage where possible and to use swales only in road reserves and drainage reserve areas. These swales have been set at minimum grades and therefore have been assumed to have little water quality treatment ability within the MUSIC model. Runoff is then collected in a large bio-retention swale located along the northern boundary of the estate where the proposed treatment is through infiltration and evapotranspiration. Although it is acknowledged that the groundwater is relatively high compared to the natural surface, there remains some depth for infiltration into the sandy substrata or vadose zone. Groundwater monitoring suggests that this vadose zone has substantial hydraulic conductivity both vertically and horizontally to allow for infiltration and groundwater recharge. Therefore significant infiltration and groundwater recharge are capable on the site as a result.

Land Dynamics Australia is of the opinion that the revised stormwater quality methodology will meet the relevant quality targets and also improve the general effectiveness of the site to treat the surface runoff. The effectiveness of the amended layout in meeting ANZECC is therefore not compromised; on the contrary, it is enhanced as all the runoff now reports to bio-retention basins for treatment.

2. Guidelines Standards & Reference Documents

The local government authority is Kempsey Shire Council (KSC) and the design of these works has therefore been undertaken in accordance with the relevant sections of the following Council documents:

- Kempsey Shire Council Development Control Plan DCP36
- Aus-Spec Design Specification D5 – Stormwater Drainage Design – Kempsey Shire Council 2003
- WSUD MUSIC Modelling Guidelines

Based on the above, the proposed drainage system for a residential development is to be designed to convey the 10 year ARI storm event (refer Clause D5.04 of Design Specification D5).

In addition, the site is to accommodate the 1%AEP flood event with finished floor levels to achieve a minimum of 4.1m AHD. The 1% AEP level was set at RL3.7m AHD

This report draws on additional information from a number of specialist consultants reports completed for either Kempsey Shire Council or this project and some have been lodged with the Part 3A application. These reports include:

- Martens Consulting Engineers: Engineering Services and Stormwater Management Report: Proposed Residential Sub-division, South West Rocks, NSW. July 2010
- Douglas Partners (2007) - Hydrogeological and contamination assessment.
- WBM Oceanics Australia Pty Ltd (2005) - flood study.
- WBM (June 2006) Saltwater Creek & Lagoon Estuary Management Study and Plan

3. Introduction

3.1 Objectives of this Report

The objectives of this report are to supplement the work completed by Martens Consulting Engineers in their Engineering Services and Stormwater Management Report: Proposed Residential Sub-division, South West Rocks, NSW. July 2010

Land Dynamics Australia saw an opportunity to provide an amended treatment train that will not only complement the work that Martens have done but to enhance the proposed treatment train capabilities over the whole of the site by capturing all runoff and reporting this to two main bio-retention swales and the bio-retention swale along the northern periphery of the site.

Areas identified for improvement are;

- The interallotment swale system – this is now proposed to be piped and not open swales as previously suggested.
- Treatment to be achieved in designated bio-retention systems dedicated to council rather than relying on maintenance of swales in private property and nature strip areas within the road reserve.
- Removal from the approved plans of the constructed wetlands due to the difficult hydraulic regime required to make these work effectively on very flat terrain.
- Increased surface area for evapotranspiration via the use of broad leave native plants within the bio-retention systems rather than the use of grassed swales.
- Provide more opportunity for infiltration/groundwater recharge
- Reduced maintenance requirements of stormwater quality systems by council.

3.2 The Pre-Development Site Conditions

3.2.1 Site Description

"South West Rocks is a coastal village located on the North Coast of NSW, approximately 35km northwest of Kempsey and in the Kempsey local government area (LGA). The subject site has an overall area of 39.5 ha and comprises the following allotments:

- Lot 52 DP 831284
- Lot 84 DP 792945

The site is bounded by rural residential development to the east, Belle O'Connor Drive to the south, a golf course to the west, and the existing Saltwater creek to the north. This creek flows from the west out of the South West Rock Golf Course (north west of the site) to Saltwater Lagoon (north east of the site). Saltwater Lagoon is connected to the ocean by Saltwater Creek which, together, make up an intermittently closed and open lake or lagoon (ICOLL). The entrance is located at the western end of Trial Bay Beach and is closed 70% of the time (WBM, 2006) by a sand berm. Figure 1 shows the locality of the site in a regional context and indicates these features. The proposed development is part of a larger land release area encompassing land to the north." (source: Martens, March 2009).

The area covered by this report is shown in Figure 1. Note the reference to Lot 84 in figure 1 is incomplete.

Figure 1 – the subject land (source: Maartens, March 2009)

3.2.2 Site Improvements

Lot 52 DP 831284 and Lot 84 DP 792945 are large undeveloped allotments of some 17.6 hectares. The portion earmarked for the proposed Coast residential site is, for the most part, relatively flat, grassed open land with a scattering of large trees on the fringe area. There are a few small trees scattered across the site.

There is a fairly modern dwelling and some outbuildings located on Lot 52. The only other visible improvements are the gravel driveway from Belle O'Conner Street to this dwelling, a gravel track that leads from this dwelling towards the north and a number of low quality tracks towards the east of the property.

A drainage channel dissects Lot 52 running from the southern boundary to the north. This channel provides drainage to the upstream residential development and has an invert of RL3m AHD.

Lot 84 has a dwelling and a single outbuilding on it and access to this lot appears to be via an easement to Arakoon Road.

Fencing of both the aforementioned lots appears to be either non-existing or in various states of disrepair. A section of fence spanning the southern boundary appears to be in reasonable condition.

A number of ground water monitoring bores are located on the property and the location of these are shown in figure 2.

3.2.3 Topography

"The Subject Site is relatively flat with a fall across the Site from south to north/northeast towards the creek. Maximum site elevations are approximately 5.0 – 5.5 metres AhD and minimum site elevations in the vicinity of the creek are 1.0 – 1.5 metres AhD. rising to the east of the Site to a height of 311 metres is the Smoky cape range, then dropping to the sea along the eastern coastline. With a peak at 311 metres on big Smoky, the range falls away to Monument hill which peaks at 70 metres located in the north on the peninsula that is laggers Point. The Site drains to Saltwater creek and Saltwater lagoon to the north and northeast of the Site respectively, which eventually joins the ocean at Monument Point, Front beach." (Aecom, EIS, 2009)

3.2.4 Existing Stormwater Drainage

The only formal stormwater drainage within the proposed Coast site is an earth drain that runs from the south of the property towards the north and discharge into saltwater creek. This drain provides low flow drainage relief for the upstream development Seascape Grove. All other runoff generated by the development is pre development sheet flow which flows overland towards the north and ultimately report to Saltwater Creek.

"The site conveys flow from two discrete catchments to the south which drains through the site and into the creek. The first, flowing into the western portion of the site, is approximately 39.5 ha and largely consists of rural/agricultural properties. The site for a recently approved residential subdivision lies within this catchment with the first stage of this subdivision having already been built. The stormwater modelling assumes this catchment to be in its ultimate developed condition as the worst case scenario. The second catchment, feeding into the eastern portion of the site is approximately 34.7 ha and primarily consists of cleared grazing land." (Martens, March 2009)

The sandy nature of the substrata allows for some infiltration however it is noted that the ground water level is at times near the natural surface and infiltration might be minimal as a result. Nevertheless, despite a very wet first half of 2012 the site still exhibited relatively good infiltration regardless of the water table elevation. Rainfall for the area as is recorded by the Bereau of Meteorology (BOM) at Smokey Cape is listed in table 1 and covers monthly readings for the past 10 years.

Douglas Partners reported groundwater levels in July 2007 following a period of very low rainfall. Only 11mm was recorded in July 2007 compared to 138.6 the month before and then only 36mm for April 2007.

Martens recorded groundwater levels on three occasions in 2010. In February 2010 the rainfall was recorded as 181.4mm, a month later as 166.2mm and then in May as 59mm.

Land Dynamics Australia commenced groundwater level monitoring in July 2012 following some very heavy falls in June of 289.4mm and July of 83.8mm. Thus elevated water levels could be expected and this is reflected in the readings taken immediately following heavy rains in the first half of 2012.

Nevertheless the site appears to drain relatively quickly as in indicated by the groundwater levels especially those recorded by Land Dynamics Australia towards October 2012. This indicates that there is relatively good hydraulic conductivity on the site and especially in the areas where it is proposed to have infiltration occurring. The revised stormwater quality layout intends to use the two main south-north swales as well as bio-retention swales on the northern periphery of the site to achieve infiltration and water quality. Bio-retention systems require a level of infiltration in order to achieve sufficient nitrogen reduction and as such Land Dynamics Australia have set the infiltration rates for these bio-retention swales at a conservative 50mm/hr. Considering the K values as per table 4 hereunder especially for locations 5 and 6, 50mm/hr is considered a reasonable average for the top 300mm given the water table is well below this. It is noted that at location 4 where infiltration from the bio retention system is required the K Value as reported by Martens Consulting Engineers is extremely low. However Martens Consulting Engineers performed hydraulic conductivity testing on the clay/siltstone found at this location. Bore logs by Douglas Partners suggests that there is at least 850mm of silty sand and sand on top of the silty clay and sandstone. Thus it is assumed that a level of infiltration will be achieved.

Table 1 – BOM rainfall data for station 059030 – Smokey Cape

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2002	47.6	284.0	193.2	190.4	105.6	67.4	0.0	90.2	8.8	76.7	53.2	131.8	1248.9
2003	33.8	217.8	114.4	158.4	351.8	72.0	17.8	10.0	0.4	82.8	99.8	102.2	1261.2
2004	109.4	221.4	154.6	151.8	1.4	17.0	52.8	45.2	49.0	215.2	99.2	62.2	1179.2
2005	454.6	56.0	47.0		121.2	152.4	43.2	5.6	73.4	116.0	136.4	83.6	
2006	107.0	134.8	82.0	7.2	18.4	247.0	177.6	150.0	76.0	42.6	112.8	52.4	1207.8
2007	44.6	161.0	78.4	58.8	36.2	138.6	11.8	169.8	70.6	45.0	193.0	68.4	1076.2
2008	253.9	219.2	65.6	407.4	51.4	66.0	69.2	13.8	122.0	72.0	119.6	58.0	1518.1
2009	32.8	509.2	198.0	342.2	219.8	239.6	64.0	0.6	12.0	146.6	136.6	168.8	2070.2
2010	20.6	181.4	166.2	97.4	59.0	222.8	78.4	27.8	77.8	175.4	145.2	172.8	1424.8
2011	107.0	106.8	177.0	303.0	67.8	573.2	90.0	85.8	65.2	139.0	199.4	77.6	1991.8
2012	*116.0*	*179.4*	*127.2*	*262.0*	*51.6*	*289.4*	*83.8*	*28.9*					

For ease of use the 7 groundwater monitoring bores (GMB's) have been renumbered in table 3 and the historical data associated with water level at these GMB's are summarised in table 2 below. Figure 2 indicates the locations of these bores as numbered in table 3.

Table 2 - GMB water level data (Douglas Partners, Martens and Land Dynamics Australia)

GMB	NSL (m AHD)	Douglas (m AHD)	Martens (m AHD)			Land Dynamics Australia (m AHD)		
		24/7/2007	22/2/2010	26/3/2010	24/05/2010	25/7/2012	14/8/2012	25/10/2012
1	3.85	-	3.23	3.21	3.06	3.40	3.35	2.80
2	3.59	-	3.32	3.17	2.99	3.50	3.26	2.55
3	3.59	0.97	2.94	-	-	3.05	2.92	2.14
4	3.35	-	2.17	2.95	2.61	3.30	3.01	2.41
5	3.45	-	2.75	3.21	2.55	3.25	3.01	2.39
6	3.6	2.17	2.57	2.95	2.61	3.38	3.12	2.31
7	5.4	-	3.45	3.93	3.22	4.49	4.14	3.00

Table 3 – Ground Monitoring Bore Designations

GMB		Bore lip level (m AHD)
New Number	Old designation	
1	209 (25001)	4.426
2	210 (25002)	4.077
3	208 (25003)	4.165
4	3 (25004)	3.852
5	205 (25005)	4.007
6	202 (25006)	4.168
7	201	5.937

(Bore lip levels determined by LDA 2012)

Figure 2 – Borehole locations as numbered in Table 3.

Douglas Partners (2007) reported that the landscape for the area south of Saltwater Creek is typically made up back barrier swamps overlying sands. These sands are reported to be interlaid with some clay layers. In some sections of this area the substrata is reported as weathered rock.

Martens Consulting Engineers (2010) in their Subregional Groundwater Model Report suggest that the sand layer ranges from low to moderate permeability. Table 4 summarises Martens Consulting Engineers' findings for permeability (K Value (mm/hr)). As is evident from this table the highest permeability exists in the east of the development. Borelog information taken on 22 February 2010 for this area also suggests a large depth of sand (>2m) and groundwater 1.5m below the NSL of 3.5m AHD (refer bore log BH202 Appendix E of EA as approved). Similar conditions exist at GMB 5 (BH 205) where the sand is also in excess of 2m in depth. The groundwater was encountered at 1.0m below the surface elevation of 3.5m AHD (refer BH205 of Appendix E of EA as approved).

Immediately north of the development at GMB 3 the soil profile changes to include organic silt on top of a layer of silty clay. This silt and silty clay layer overlays a 1.8m layer of mostly orange sand of medium density. Ground water was encountered at 0.9m below the NSL of 4.0m AHD.

Table x – Martens summary of aquifer K testing results

GMB		Test Medium	K Value (mm/hr)
New Number	Old designation		
1	209 (25001)	Sand	1.7
2	210 (25002)	Sand	16
3	208 (25003)	Sand	49
4	3 (25004)	Clay/Siltstone	0.08
5	205 (25005)	Sand	82
6	202 (25006)	Sand	96
7	201	Clay	2

Since Land Dynamics Australia commenced the water table monitoring the levels have receded on average of 10.7mm/day. It should also be noted that the water levels observed at 25 July 2012 was at the end of an extremely wet period. Note: the rate at which the water table is receding should not be confused with the hydraulic conductivity of the soils.

4. The Development as approved under Part 3A

4.1 Proposed Development

Figure 3 is the Part 3A approved subdivision plan of the proposed development. This layout relies on two central south to north flowing swales to convey the upstream water to the receiving waters of Saltwater Creek. The layout suggests that the low flows from these two swales will report to the two proposed constructed wetlands immediately to the right and at the northern end of these swales. High flows are to bypass these proposed constructed wetlands and report directly to the conservation zone and ultimately the receiving waters via overland flow.

All runoff from the balance of the site is to be collected in a series of grassed swales and these discharges directly into the conservation zone.

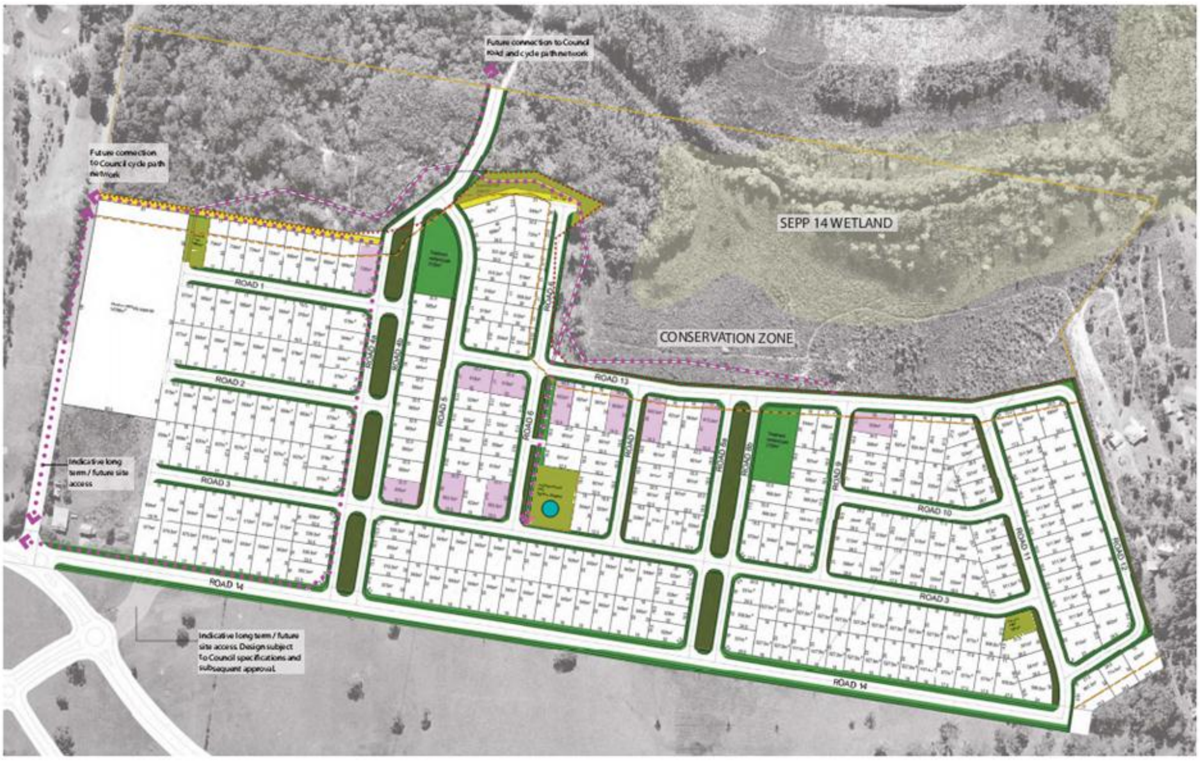


Figure 3 – The Part 3A approved subdivision.

4.2 The approved Stormwater Drainage Methodology

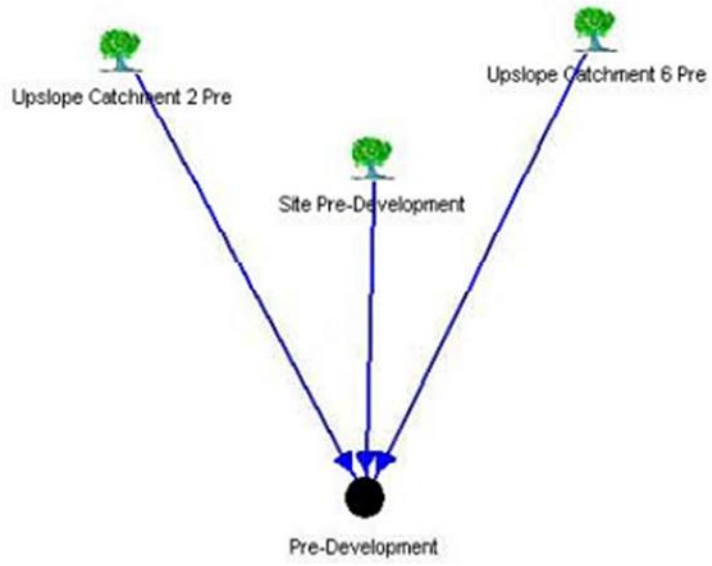
The approved stormwater drainage methodology for the post development scenario as described in the EIS as part of the part 3A application by Aecom states;

"As outlined in detail in chapter 5.2 of this report, an Integrated Water Cycle Management (IWCM) Plan has been developed for the Site, in order to manage a number of hydrological, flooding and stormwater impacts associated with the Proposal. The IWCM Plan proposes a combination of engineering solutions for the treatment of stormwater, conveyance of flows, groundwater replenishment, protection of built infrastructure and protection of surrounding wetland ecosystems. The fundamental engineering elements of the proposed IWCM Plan include the incorporation of roadside and central drainage swales, creation of an artificial wetland and construction of sub-soil drains."

"The IWCM Plan identified two primary options for management of stormwater quantity and quality being provision of roadside and open space drainage swales or provision of a traditional piped drainage network. The topography of the Site is relatively flat and as a result has heavily influenced the stormwater management process selected for the Site. The need to balance the infiltration of stormwater into the groundwater system to maintain the hydrological regime to sensitive downstream habitats is also a driving factor."

"The flat nature of the site limits the effectiveness and practicality of a piped drainage system, which would require significant quantities of fill to be imported to the Site. Major filling of the Site would alter the natural overland flows of the Subject Site which was considered an undesirable outcome and would have undesirable environmental impacts."

"Provision of a water Sensitive urban Design (WSUD) approach incorporating road-side drainage swales along a number of north-south roadways was considered an optimum solution for the Site as their provision minimises the need for importation of fill and maintains the natural topography between adjoining residential lands to the south through the Subject Site to the conservation areas to the north that flow to the SEPP 14 wetlands within and to the northeast of the Subject Site, whilst providing water to landscaped and vegetated areas."



Pre-Development Results

Parameter	Annual Load
Flow (ML/yr)	508
Total Suspended Solids (kg/yr)	33300
Total Phosphorus (kg/yr)	126
Total Nitrogen (kg/yr)	538

Figure 4 – The Martens Consulting Engineers' pre-development flow model and pollutants loads.

4.3 The approved Water Quality Treatment Train

The approved treatment train comprises 10 urban nodes or catchments, 9 road catchments and two upper reach catchments. The latter is upslope catchment 2 which encompasses the Seascape Grove Development to the south of the subject development. Upslope catchment 6 is currently undeveloped and consists mainly of open grass land and a scattering of trees.

As is evident from the treatment train in figure 5, the proposed wetland 2 only treats the subject site runoff from urban node 2 and road node 2. The same applies for wetland 6 which only proposes to treat the subject site runoff from urban node 6 and road node 6. However both these wetlands also appear to be treating upstream runoff from upslope catchment 2 and 6. This methodology appears to favour upstream runoff treatment instead of providing treatment for the whole of the subject development. All the remaining urban and road nodes are treated via swales before being discharged into the immediate north of the subject subdivision.

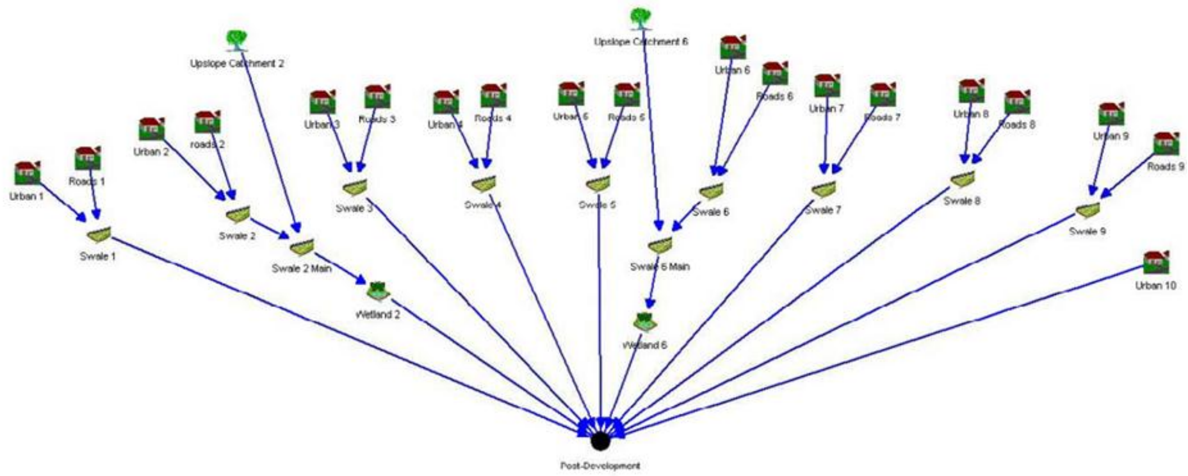


Figure 5 – Martens Consulting Engineers' treatment train as approved. Note: only nodes numbered 2 and 6 are routed via the wetlands.

From figure 5 it is evident that all nodes numbered 1, 3, 4, 5, 6, 7, 8 and 9 rely solely on swales for treatment. Node 10 discharges directly into the receiving waters. The MUSIC model setting in figure 5 for infiltration was set a 0mm/hr assuming a totally saturated condition or heavy clay.

From figure 5, the main swales, 2 & 6, have the following settings;

	Main Swale 2	Main Swale 6
Upstream catchment area (Ha)	39.52	36.29
% Pervious (%)	80	96
Swale Length (m)	168	107.6
Swale slope (%)	0.4	0.4
Bed width (m)	6.3	8.3
Top Width (m)	15	15
Swale depth (m)	0.87	0.67
Vegetation height (m)	0.2	0.2

Although this model produced satisfactory results the practicalities with the hydraulics of getting water into and out of the wetlands remained questionable given the upstream discharge for swale 2 is RL3.65 as per the approved plans for Seascape Grove (Figure 6) and the receiving elevation at the northern boundary is RL3.2m AHD. This results in a 0.26% grade without routing the swale via a wetland. The receiving elevation is fixed due to the conservation status of this zone as per the Kempsey Shire Council LEP.

Furthermore, the upstream development is now proposing to detain its runoff and according to the engineering plans (refer major project register; Seascape Grove Stage 1C, Application number 07_0129) is also providing a level of water quality treatment. Thus given that the two constructed wetlands on the subject site were to mainly treat upstream runoff and that the upstream development is now proposing to treat its own runoff, it could be argued that the two proposed wetlands are no longer needed.

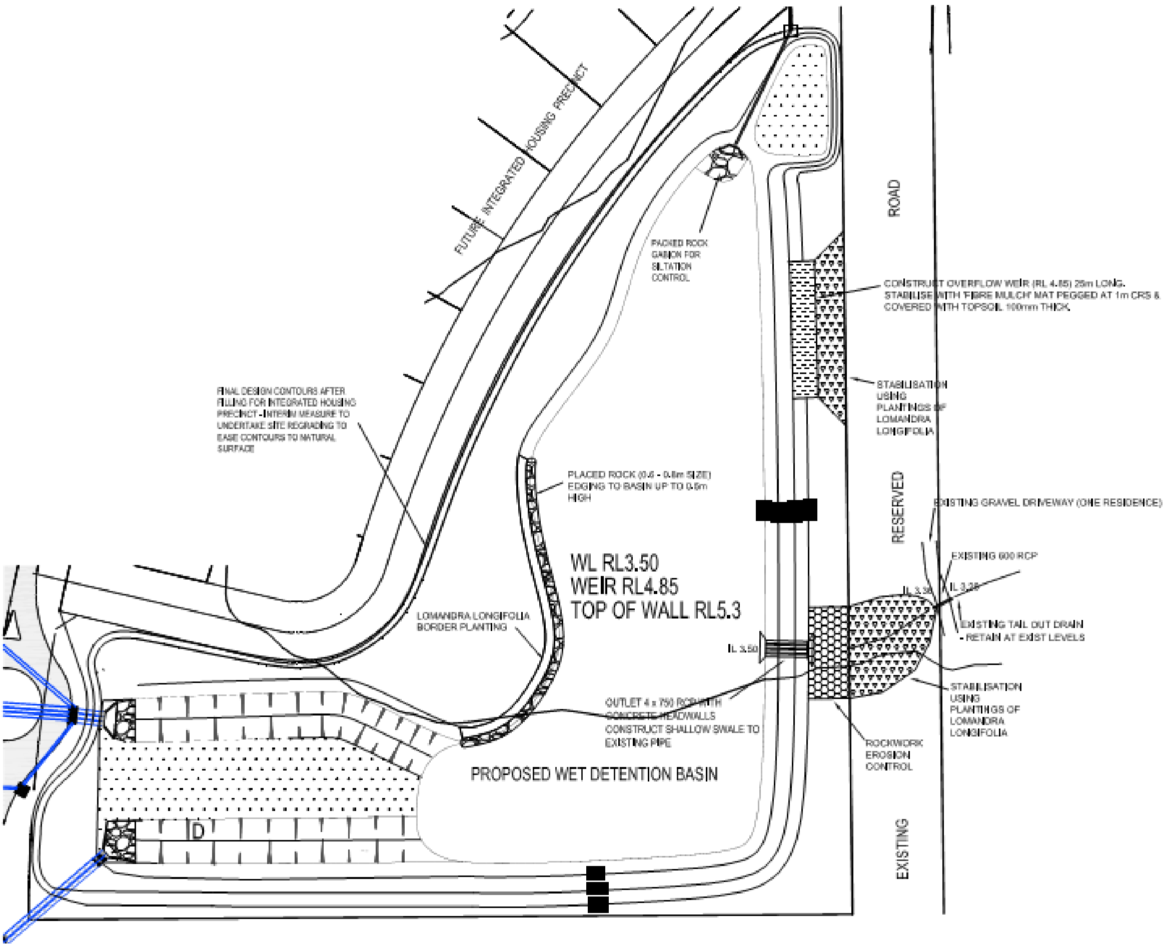


Figure 6 – Seascape Grove approved plan (source: planning NSW major project register)

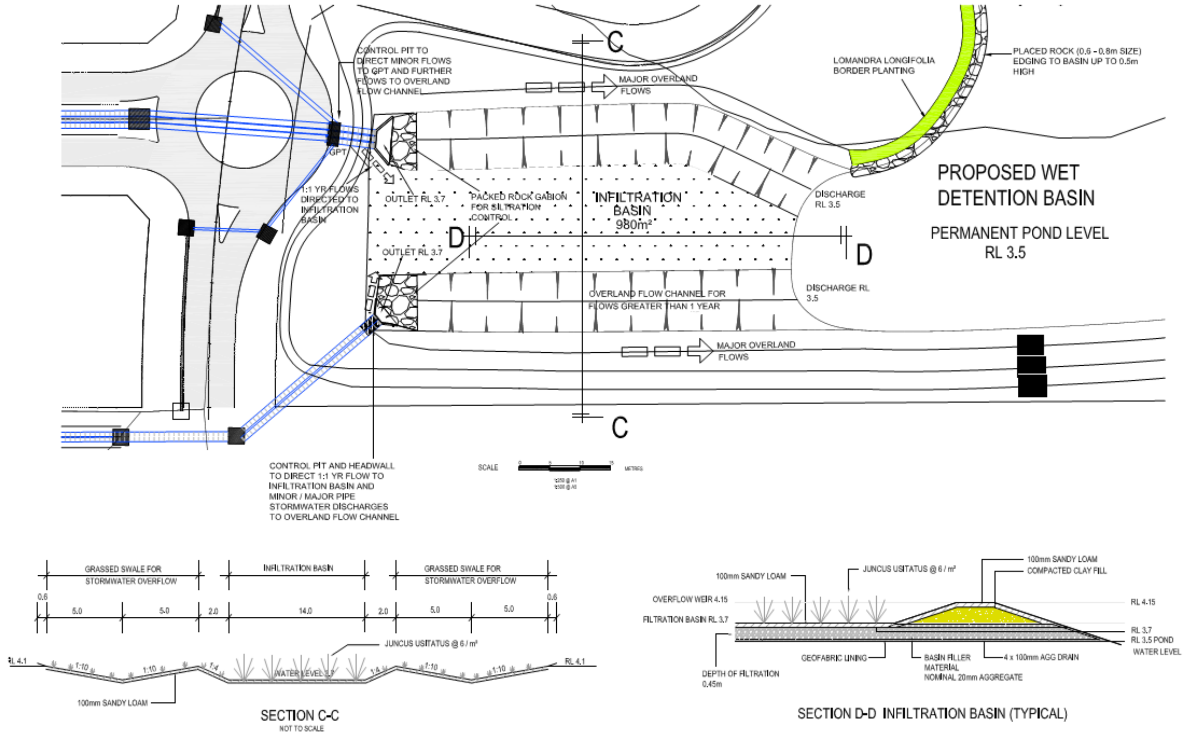


Figure 7 – proposed upstream development's water quality treatment facility (source: planning NSW major project register)

Apart from nodes numbered 2 & 6 all other nodes in the approved model rely on vegetated swales for treatment. This treatment was modelled by Martens Consulting Engineers (July 2010) and they report that the swales provide sufficient results in meeting the ANZECC targets. Nevertheless, it was considered that given the flat terrain that swales will most likely not provide sufficient flows in unmanaged areas such as private property.

4.4 The Approved Modelled Water Quality Results

Table 5 – Results from the MUSIC model as depicted in Figure 5

Post-Development Results

Parameter	Annual Load
Flow (ML/yr)	618
Total Suspended Solids (kg/yr)	9490
Total Phosphorus (kg/yr)	59.3
Total Nitrogen (kg/yr)	537

Table 6 – ANZECC target results as per the MUSIC model depicted in Figure 5

Parameter	Pre-Development (kg/yr)	No Treatment (kg/yr)	With Treatment (kg/yr)	Load Reduction (pre vs with treatment)	Criteria Met (Y/N)
Suspended Solids	33 300	75 300	9490	72%	Y
Phosphorus	126	190	59	53%	Y
Nitrogen	538	1 070	537	0%	Y
Flow	508 ML/y	618 ML/y	618 ML/y	-22%	Y

Table 7 – Results from Martens Consulting Engineers' final model as received by LDA.

	Sources	Residential Load	% Reduction
Flow (ML/yr)	623	618	0.9
Peak Flow (m3/s)	0.919	2.33	-153.5
Total Suspended Solids (kg/yr)	93.2E3	9.74E3	89.6
Total Phosphorus (kg/yr)	206	60.1	70.8
Total Nitrogen (kg/yr)	1.13E3	539	52.3
Gross Pollutants (kg/yr)	10.9E3	0.00	100.0

5. The Amendment

5.1 The Amendment to the Approved Layout

During preparation of the construction certificate by Land Dynamics Australia it became evident that the hydraulics required to effectively convey surface flows from the top of the catchment into a constructed wetland and then into the receiving waters was going to be very difficult. The flat terrain did not have enough vertical change in elevation to provide for sophisticated conveyance via the system as approved. Having said this, the approved system could be implemented and work well if large quantities of fill material are imported to provide sufficient elevation and grades. This fill will allow the modification of the site to occur so that conveyance of runoff can effectively make its way through the system as approved. However it became evident that filling of the site purely for this purpose would be very costly and therefore not be economically feasible. Furthermore, the upstream catchments have been designed to suit current downstream levels and any filling of the subject land would have impeded flows from upstream or required more piping as open swale batter grades becomes steeper and occupy more land as a result.

Figure 8 - the proposed/amended layout

5.2 Alternative Drainage Methodology

The proposed alternative drainage system essentially conveys the upstream runoff via two large swales running from the south to the north. During low flow conditions (≤ 3 months) these swales will act as bio-retention systems which will slow the runoff and allow for some infiltration to occur and in doing so provide for groundwater recharge. It is proposed to plant the swale with broad leave native plants that will remove the nutrients from the low flow and also provide evapotranspiration opportunities. The latter is designed to ensure the swale will dry relatively quickly.

High flows (≥ 3 month) from a water quality perspective do not need to be treated for quality and as such will be conveyed through these two swales and discharge into the conservation zone. The western most major drainage swale will require a shallow tail-out drain along the western side of the road leading north as the upstream levels dictates levels downstream. It is proposed that this tail-out drain be planted with broad leave native plants to further enhance any runoff that is to be conveyed this way (Note: this tail-out drain has not been included in the water quality calculations and provides bonus treatment). This tail-out drain also acts as a level spreader for higher flows forcing the runoff to evenly spread across the conservation zone.

The major swale to the east is also to provide the same water quality treatment as is proposed for the major swale to the west. This swale discharges its major flows into the conservation zone as well and it is proposed to provide an energy dissipater/level spreader to change the flow from concentrated to sheet flow.

All the remaining swales and pipes discharge into the perimeter bio-retention swale. Thus all runoff from the proposal is at some stage reporting to the perimeter swale or the two major bio-retention swales which dissects the site.

5.3 The Proposed Alternative Treatment Train

Following careful consideration of the proposed treatment train the model was amended to provide a larger bio-retention area and also amended to remove the constructed wetlands. Figure 9 hereunder depicts the amended model and the contributing catchments. This model also includes the predevelopment scenario.

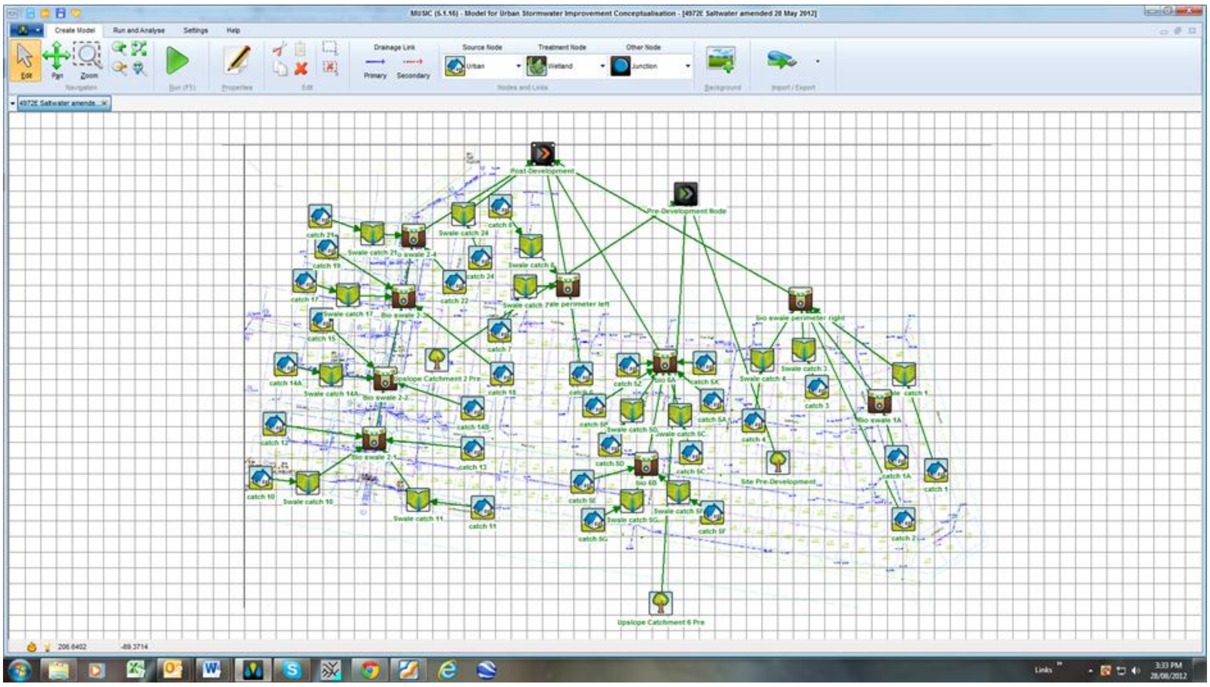


Figure 9 – the amended layout in MUSIC version 5.1.6

5.4 MUSIC Model

The treatment train as depicted in figure x was compiled as follows;

All urban nodes include the roads within the catchment these nodes have had its pervious versus impervious ratio adjusted individually to accurately reflect the real world post development conditions. Where possible, road side swales have been included as part of the pre-treatment methodology and is shown as receiving nodes for the urban runoff. Where road side swales do not perform a water quality function, it was excluded from the treatment train. This methodology is on the more conservative end of the continuum however it was also considered to be prudent to not include some swales due to their negligible impact. Most nodes then discharge into the two major south-north bio-retention swales which have been designed to allow a level of infiltration into the sandy substrata. Nodes that are not capable of discharging into these swales then report to the northern perimeter swale.

The bio-retention swales infiltration settings have been set at a 50mm/hr. This setting is believed to be realistic given the hydraulic conductivity of the immediate substrata at borehole locations 3, 5 & 6.

It is acknowledged that the relatively high water table will reduce the infiltration opportunities however recent groundwater monitoring suggests that there is still sufficient 'free board' to the groundwater table. This vadose zone (free board) appears to increase in depth at a rate of about 10.7mm/d during drier periods.

Table 8 - The proposed model Mean Annual Loads – Pre and Post Development

Parameter	Pre-development	Post-development
Flow (ML/yr)	205	31.7
Total Suspended Solids (TSS) (kg/yr)	12,200	1,410
Total Phosphorous (TP) (kg/yr)	59.8	5.79
Total Nitrogen (TN) (kg/yr)	224	74.3
Gross Pollutants (kg/yr)	2,860	0

Table 9 – The proposed model treatment Train Effectiveness

Parameter	Sources		Residual Loads		% Reduction	
	Pre	Post	Pre	Post	Pre	Post
Flow (ML/yr)	205	185	205	31.7	0	82.9
Total Suspended Solids (kg/yr)	12,200	36,300	12,200	1,410	0	96.1
Total Phosphorus (kg/yr)	59.8	74.9	59.8	5.79	0	92.3
Total Nitrogen (kg/yr)	224	526	224	74.3	0	85.9
Gross Pollutants (kg/yr)	2,860	5,330	2,860	0	0	100

5.5 Treatment Device Detail

A number of Stormwater Quality Improvement Devices (SQID's) have been used in the treatment train in order to achieve the desired reduction in pollution loads. The main device for the subject site water quality treatment is the bio-retention swale which can be divided into two distinct systems for this particular site.

The first is the south-north swales that dissect the residential areas and the second is the bio-retention swale that is located on the northern periphery of the site. These bio-retention systems have been designed to not only provide water quality for runoff but also to convey the 1% AEP event.

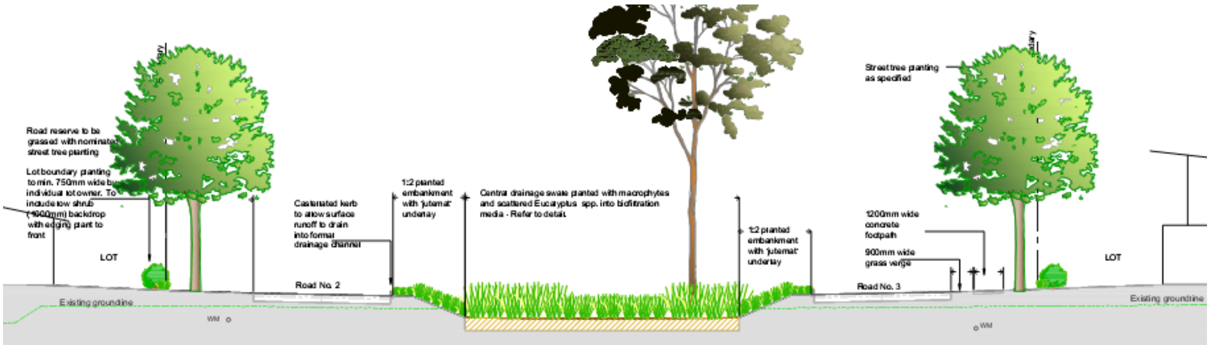


Figure 10 - Typical south to north swale cross section

The main treatment devices are complemented by a series of vegetated (grass) swales which are all upstream of the bio-retention systems and therefore provide a level of pre-treatment before discharging into the bio-retention swales.

5.5.1 Swales

Vegetated swales are used to convey stormwater in lieu of pipes and to provide for removal of coarse and medium sediment. Vegetated swales are commonly combined with buffer strips.

5.5.2 Bio-Retention Swales

Bio-retention systems provide both stormwater quality and conveyance functions. The conveyance function is generally confined to smaller flood flows however in some instances if designed appropriately these systems could also convey major flows. Ideally these systems should be designed to have a minimum slope of 1% to effectively convey the flows through the system and have low velocities to prevent scouring of plants. Bio-retention systems operates by filtering surface flows through the surface vegetation and then percolating runoff through prescribed filtration media that provide treatment through fine filtration, extended detention and some biological uptake (WSUD, 2006).

In this instance there is no underdrain proposed for the bio-retention system as infiltration and groundwater recharge is encouraged. Furthermore, the site topography does not allow for any additional pipe discharge as the existing levels does not permit flows lower than the invert of the bio-retention swale.

The main swales will be planted with appropriate plant species conducive to achieve maximum nutrient uptake, plants that will withstand high flows and inundations, and; plants that require minimal maintenance. For reference on suitable plant see table A.1 WSUD, 2006.

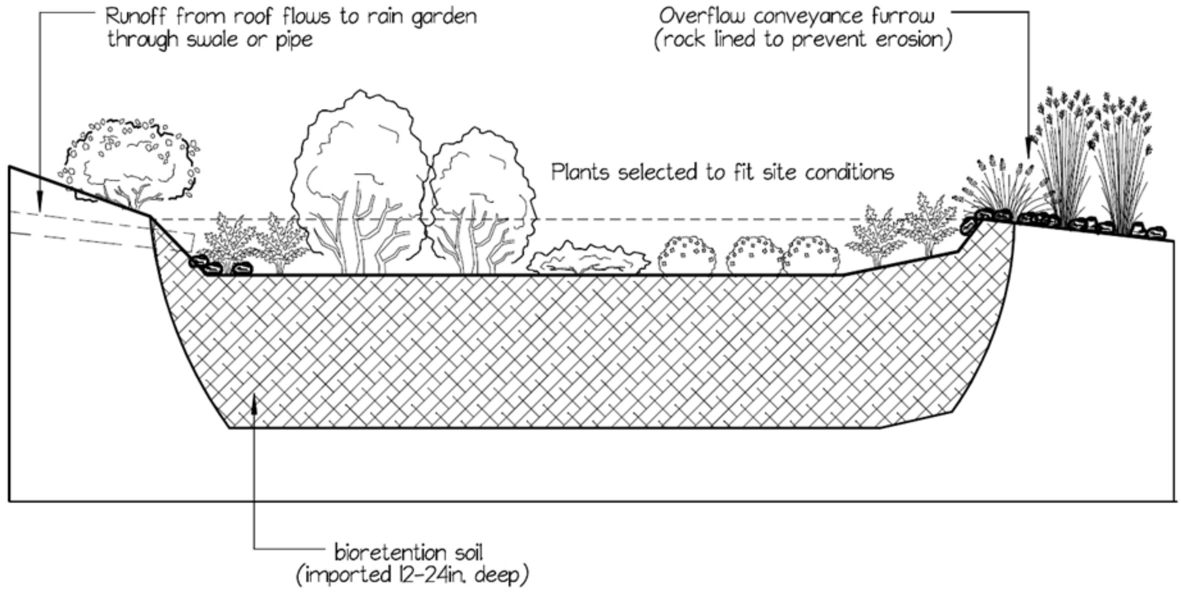


Figure 11 – typical cross section of a bio-retention swale proposed for the northern periphery of the site.

5.5.3 Level Spreader

It is proposed to provide a level spreader at the discharge of the two main south to north swales to change the concentrated flows into sheet flow. This is aimed at reducing the erosion potential at these locations as well as providing an opportunity for further infiltration by spreading the flow over larger area. A level spreader will also reduce the velocities of the flows and in doing so reduce the risk of damage to the environmentally sensitive area to the north.

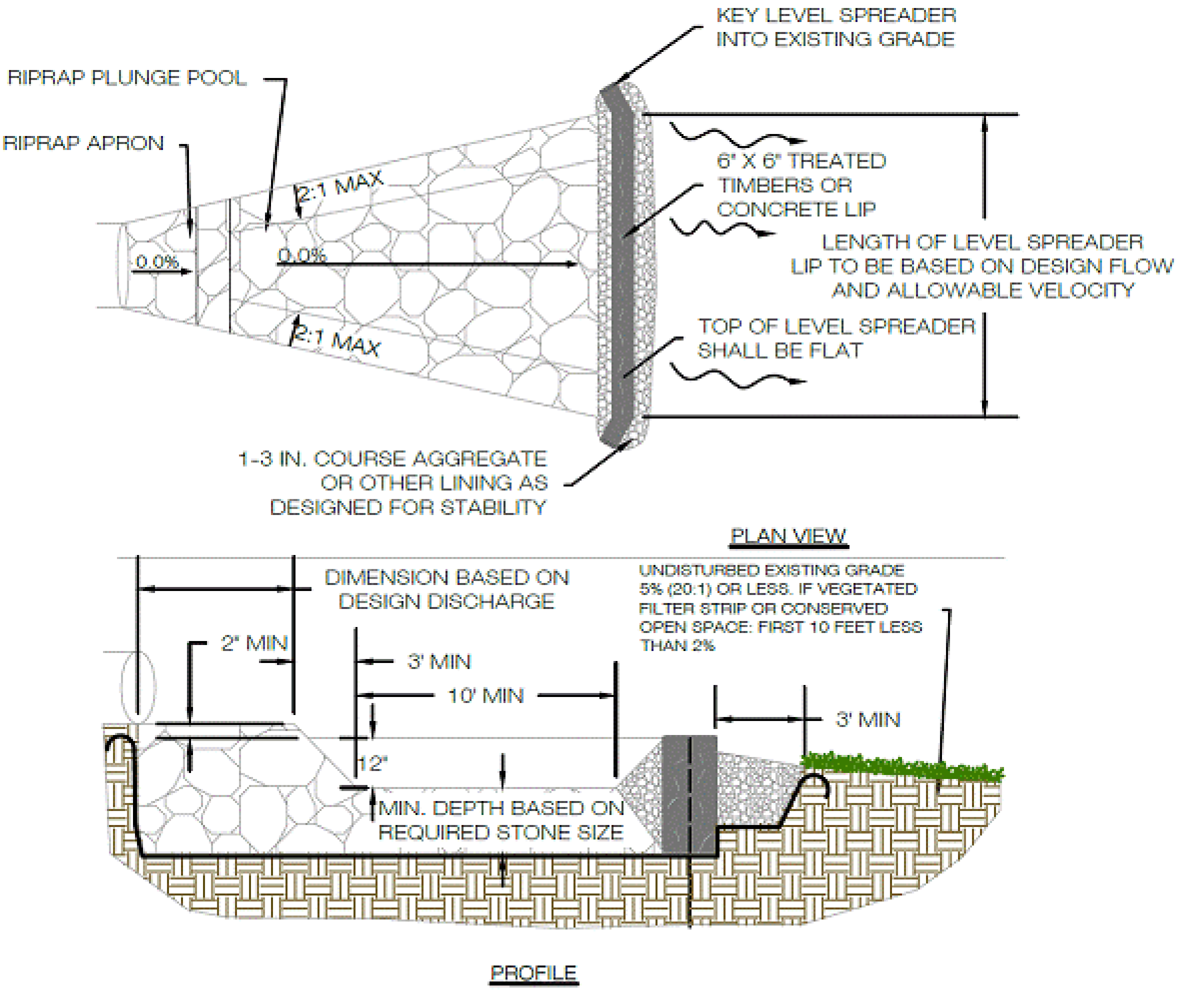


Figure 12 – typical level spreader proposed for the main swale outlet.

6. Conclusion

The amended stormwater quality treatment proposal will achieve a superior performance in terms of water quality treatment from the proposed development without compromising any of the Part 3A approved design aspects. Furthermore, the reduced maintenance requirements from a whole of system perspective must be seen as a positive for both the developer as well as the public authorities. Public health is always a concern and the removal of the constructed wetlands from the proposed system will reduce the potential for mosquito breeding, odour from stagnant water, public safety and the proliferation of aquatic weeds.

The amended design will also provide positive benefits from a groundwater recharge perspective and protect the conservation zone from potential high concentrated flows through the introduction of level spreaders.

From a design perspective, the proposed system is in keeping with current best practice and as such is recommended for implementation.

Appendix 1: Revised Subdivision Layout

Appendix 2: MUSIC Parameters