STORWATER AND ENVIRONMENTAL MANAGEMENT PLAN

BUFFER AREA 3 – WARRIEWOOD VALLEY
14-18 BOONDAH ROAD, WARRIEWOOD

August 2010

Report No. X08066_03C

Prepared for Meriton Apartments

BROWN CONSULTING

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STORMWATER AND ENVIRONMENTAL MANAGEMENT PLAN

BUFFER AREA 3 – WARRIEWOOD VALLEY

FOR MERITON APARTMENTS

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LIST OF ABBREVIATIONS

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
DIPNR	Department of Infrastructure, Planning and Natural Resources
DLWC	Department of Land and Water Conservation NSW
DEM	Digital Elevation Model
DTM	Digital Terrain Model
FPDM	Floodplain Development Manual
FPL	Flood Planning Level
FPMM	Floodplain Management Manual
FPRMS	Floodplain Risk Management Study
FSL	Flood Surface Level
GIS	Geographic Information System
ha	Hectare (Area = 10,000m^2)
LEP	Local Environmental Plan
LGA	Local Government Area
MGA	Map Grid Australia
m^3/s	Cubic meters per second
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCP	Reinforced Concrete Pipe
RCBC	Reinforced Concrete Box Culvert
RTA	Roads and Traffic Authority of NSW
SEPP	State Environmental Planning Policy
SMP	Stormwater Management Plan
TIN	Triangular Irregular Network

1 INTRODUCTION

Brown Consulting (NSW) Pty Ltd has been commissioned to provide a stormwater management plan for the application at 14-18 Boondah Road, Warriewood Valley in the Pittwater local government area. This report and its associated drawings provide a concept plan for the stormwater management of the proposed residential development.

The following drawings in **Appendix A** should be read in conjunction with this stormwater management plan:

A1	Existing 100 Year Flood Levels
A2	Existing PMF Flood Levels
A3	Existing 100 Year Flood Hazards
A4	Existing PMF Flood Hazards
A5	Stormwater Management Plan
A9	Developed 100 Year Flood Levels
A10	Developed PMF Flood Levels
A11	Developed 100 Year Flood Hazards
A12	Developed PMF Flood Hazards
A13	100 Year 2hr High Tailwater Flood Level Difference
A14	100 Year 2hr Low Tailwater Flood Level Difference
A15	100 Year 36hr High Tailwater Flood Level Difference
A16	100 Year 9hr Low Tailwater Flood Level Difference
A17	PMF 2hr High Tide Flood Level Difference

1.1 SITE LOCATION & DESCRIPTION

The site is located within the Warriewood Valley Urban Release Area known as Buffer Area 3 (formally Sector 14) within the lower reaches of Fern Creek. Fern Creek has been heavily modified as part of the residential development upstream of the site and flows into Warriewood Wetlands downstream of the site.

The site is currently occupied by a number of rural lots with residential dwellings, metal and concrete block sheds and stables, concrete and bitumen driveways and parking areas. The existing land use is predominately rural residential with horse/cattle paddocks, however industrial uses and agricultural plantation also exist within the site.

The vegetation within the site is made of maintained grassed areas within the residential lots, areas of dense Lantana and Poplar plantation with small pockets of bushland.

1.2 THE DEVELOPMENT PROPOSAL

The Application is for the construction of units in Buffer Area 3 Warriewood Valley. The development will utilise stormwater quality and quantity controls in accordance with industry 'best practice management', and more specifically to meet the objectives of Pittwater Council's "Water Management Specification". This will include stormwater reuse for each dwelling in accordance with the NSW government's BASIX, in addition to utilising stormwater treatments such as bioretention basins and pollutant traps. The development will also provide on-site detention to maintain existing flow regimes and provide additional flood storage to ensure no loss in floodplain volume for Fern Creek.

1.3 PREVIOUS STUDIES

1.3.1 Warriewood Valley Buffer Area 3 Water Management Report - Rezoning Application Stage (Aug 2005, Patterson Britton)

Patterson Britton & Partners prepared a Water Management Report for the Rezoning Application for a new residential subdivision. The report addressed impacts of the proposed development on water management issues including hydrological assessments, water quality assessments and management, flood attenuation and stormwater quantity management.

1.3.2 Warriewood Valley Flood Study (April 2005, Lawson and Treloar) Addendum 1 (July 2005, Cardno Lawson Treloar)

Candno Lawson Treloar undertook a flood study of the Warriewood Valley catchment to define the nature and extent of flooding. The runoff hydrographs for the study were estimated using the *XP-RAFTS* rainfall-runoff modelling package. The hydraulic modelling of Warriewood Valley catchment was undertaken using (*SOBEK*) an integrated 1D/2D hydraulic model developed by Delft Hydraulics. This model enables efficient integration between river hydraulics, where flow can be considered 1D, and the over bank floodplain where flows are best described by a 2D model.

The study produced flood levels and flood hazard mapping for a number of storm events ranging from the 5 year ARI to the PMF.

2 BACKGROUND

2.1 WARRIEWOOD VALLEY STORMWATER MANAGEMENT SPECIFICATION

This study has been developed in accordance with Pittwater Councils (2001) Stormwater Management Specification for the Warriewood Valley Urban Release Area. The key issues outlined by this specification include:

Stormwater Quantity Management

- Developed hydrograph must be within ±10% of the pre-developed hydrograph,
- Peak flow from the sector to be within ±5% of the peak flow given in Appendix A of Pitt Water Council specification.
- Developed peak flow to be no greater than pre-developed conditions,
- All OSD above ground structures to be located above the 100 year ARI flood level,
- Stormwater reuse to be utilised for the development

Flooding

- Estimation of flood levels for pre and post development,
- Floor levels to be +500 mm above the 1% AEP flood in Fern Creek,
- Water quality control devices to be above the 20% AEP flood level,
- Flood hazard and evacuation associated with the PMF to be considered if it flows through residential areas.

Stormwater Quality

- Load based modelling of pre and post development using a daily load model for 90th 50th and 10th percentile rainfall years,
- Ensure post developed pollutant loads do not exceed existing loads,
- Concept design of stormwater treatment facilities,

Water Balance

- Water balance modelling for pre and post development,

3 FLOOD MODELLING

The hydraulic modelling of the study area was undertaken using the SOBEK hydraulic model developed by Cardno Lawson Treloar for the Warriewood Valley flood study. SOBEK is an integrated 1D/2D hydraulic model that can model one dimensional flow characteristics such as creek sync channels in conjunction with two-dimensional flows across floodplains.

The hydraulic modelling examined a total of 7 flooding scenarios, being:

- 100 year ARI 2 hour duration with high tide in Narrabeen Lagoon
- 100 year ARI 2 hour duration with low tide in Narrabeen Lagoon
- 100 year ARI 36 hour duration with low tide in Narrabeen Lagoon
- 100 year ARI 9 hour duration with high tide in Narrabeen Lagoon
- PMF 2 hour duration with high tide in Narrabeen Lagoon
- PMF 2 hour duration with low tide in Narrabeen Lagoon
- PMF 90 minute duration with low tide in Narrabeen Lagoon

3.1 SURVEY & DIGITAL ELEVATION MODEL (DEM)

A Ground level survey of the site was undertaken by John B White Surveyors. The survey included spot levels throughout the site and identified existing building and structures, ponds and trees. A digital elevation model (DEM) incorporating 5m x 5m grids was produced of the study area using the survey data. This DEM was used as the 2D surface in SOBEK and nested into the existing DEM used in the Warriewood Valley flood study (Cardno Lawson Treloar).

3.2 BOUNDARY CONDITIONS

The upstream and downstream boundary conditions were the same as adopted in the Warriewood Valley flood Study. The downstream boundaries located within Narrabeen Lagoon were the constant water boundaries for both the high and low lagoon levels scenarios.

3.3 FRICTION COEFFICIENTS

The friction coefficients were the same as modelled in the Warriewood Valley Flood Study. The 2D modelling used a grid of Manning's roughness 'n' values that were estimated from landuse determined from aerial photography and site visits. The range of Manning's values used is shown in **Table 3.1** as presented in the Warriewood Valley Flood Study.

The proposed development will be located on fill areas will be located above the 100 year ARI flood level no specific Manning's value were adopted for those areas.

Table 3.1 Manning's Coefficients

Manning's Coefficient	Description of Landuse
0.16	Forest/Heavy Scrub.
0.20	Urban
0.015	Roads.
0.02	Open Spaces/Paddocks
0.01	Open Water

Source: Warriewood Valley Flood Study (Cardno Lawson Treloar 2005)

3.4 EXISTING FLOOD LEVELS

The existing flood levels for the 100 year ARI 2 hour duration storm event are presented in **Figure A1** (Appendix A). The flood levels within the site vary from 3.40 m AHD within Fern Creek at the western site boundary to 3.11m AHD within Warriewood Wetlands.

For both the high and low tide scenario's the flood levels are generated by the ponding levels within the Warriewood Wetlands/Narrabeen Lagoon. During the 100 year ARI event the flood levels within the wetlands drown out the majority of Fern Creek, with only the upper reaches (at the western site boundary) providing any flow conveyance.

The existing flood levels for the PMF 2 hr duration storm event are presented in **Figure A2** (Appendix A). For the PMF scenario the flooding is generated by the flood level of 4.59m AHD within Warriewood Wetlands (high level). Flows overtop Macpherson Street and flow along the western site boundary to the wetlands.

3.5 EXISTING FLOOD HAZARD

The existing flood hazard for the 100 year ARI and PMF storm events are presented in **figures A3** and **A4** respectively. The flood hazard was determined using the product of the flood velocity and depth. Results of modelling for the 100 year ARI event indicated a significant area with high hazard within Fern

Creek and low hazard across the flood plain. Modelling results indicated that the majority of the site would classified as high hazard for the PMF storm event, which is mostly due to the high flood depths associated with the PMF.

3.6 EXISTING FLOOD STORAGE

Based on the flood level rasters and existing survey information, a total flood storage of approximately 64,000m³ exists below the existing 100 year ARI flood level.

3.7 PROPOSED EARTHWORKS STRATEGY

The filling strategy adopted as part of this application was to fill land within the floodplain to a minimum level of RL 4.32 m. To ensure no net loss of floodplain storage below the 100 year ARI flood level, it is proposed to excavate non-filled areas within the floodplain to compensate for filled areas to provide the balance of floodplain storage (Figure 1).

The modelled fill/cut strategy results in no net loss in existing flood storage compared with the volume of floodplain storage in the developed scenario below the 100 year ARI flood level. The positive effects of this strategy is that flood sstorage is moved from areas high in the floodplain to a level lower in the floodplain. This provides greater flood storage for more frequent floods (say up to the 10 year ARI) than currently exists, and potentially reduces flood levels for those flood events.

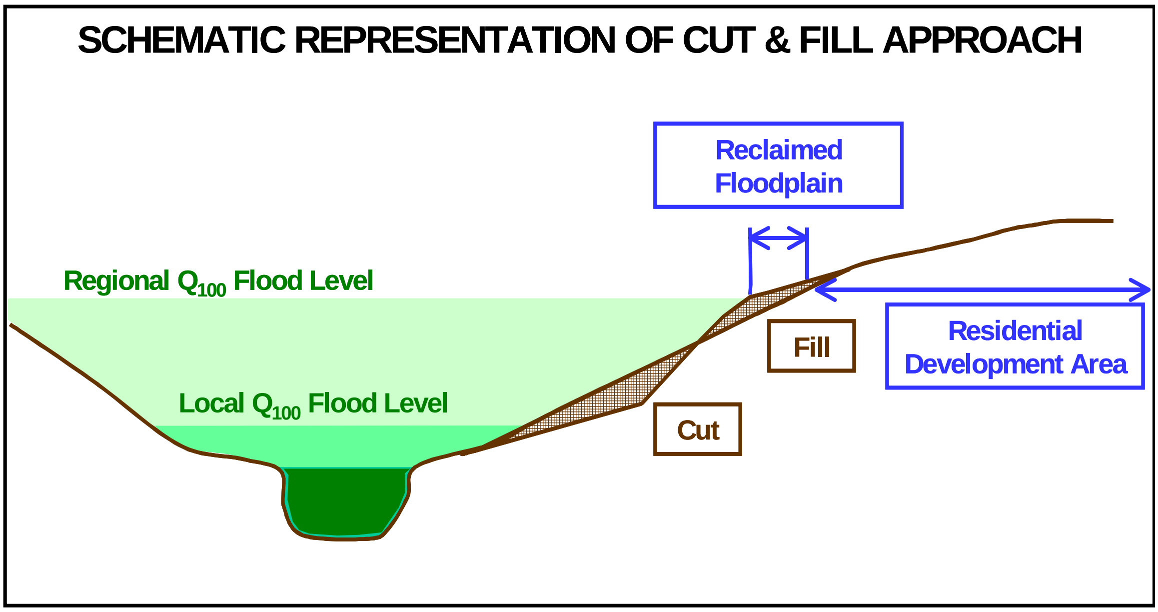

Figure 1 Schematic Representation of Cut and Fill Strategy

Floodplain storage is provided through the excavation of an area adjacent to the proposed fill platforms at a cut batter no greater than 1(V) in 4(H). The excavation area is setback within the site boundaries. The total surface area of the proposed flood storage (excavation) area is approximately 0.8 ha to achieve no decrease in flood storage for all events up to the 100 year ARI.

The proposed bulk earthworks strategy and typical cross sections are shown in **Appendix A**.

3.8 Hydraulic Modelling Results – Developed Scenario

A detail TIN was created in 12D of the proposed development and earthworks and converted to a raster grid (DEM) for use in the SOBEK model. The proposed terrain was nested into the existing DEM used in the Warriewood Valley flood study (Cardno Lawson Treloar) and modelled in SOBEK. The results of the hydraulic modelling are shown in **Appendix A** for both the high and low tailwater conditions.

3.9 FLOOD LEVEL DIFFERENCE

Figures A.13 - A.17 in Appendix A show the flood level difference resulting from the proposed development for the 100 year ARI and PMF storm events.

For the 100 year ARI the figures show the expected afflux is no greater the 0.02m however there is generally a flood level decrease to less then 0.01m increase throughout the majority of the site. Such a result is expected given that the area is dominated by regional flooding of Warriewood Wetlands/Narrabeen Lagoon.

For the PMF event there is an overall decrease in flood levels across the flood plain as a result of the additional flood storage in the low lying areas. A localised increase of up to 0.04m is experience within Boondah Road. The 2D hydraulic modelling also indicated an artificial flood increase greater then 0.05m within Macpherson Street upstream of the site as a result of the constriction of the flow path along the western site boundary.

As discussed the 2D hydraulic modelling of the concept design terrain was represented by a raster surface used in SOBEK. A raster is a regular grid of user defined size containing representative elevations, therefore there will always be some simplification of the terrain when converting a triangle TIN file to a grid. The 5m x 5m grid used for the study area did not accurately model the local overland flow path along the western boundary and therefore showed elevated flood levels. The flow path is designed for flow convenience and therefore best represents in a 1D model, **section 3.13** present the HEC-RAS 1D model developed for the flow path along the western boundary.

3.10 FLOOD HAZARD

Figures A11 and **A12** show the flood hazard mapping for the proposed development. The figures indicate the flood hazard is not aggravated as a result of the proposed development

3.11 FLOOD PLANING LEVEL

The flood planning level for the proposed development is 0.5m above the 100 year ARI flood level within Fern Creek. The flood planning level for the proposed development varies from 3.61m to 3.90m AHD. However the proposed minimum floor level has been set at 4.5m AHD, well above the flood planning level.

3.12 FLOOD EVACUATION

The modelling has shown that during the extreme events the site is predominately flood free with no dwelling subject to inundation. The primary flood evacuation for the site would be vertical evacuation therefore occupants remain inside the dwellings and move to the upper levels.

3.13 CLIMATE CHANGE

Cardno Lawson and Treloar undertook sensitivity analysis from two separate flood studies to estimate the likely climate change impact on the study site.

The scenarios assessed in the estimates are based on the DECC Practical Considerations of Climate Change Guidelines document released in 2007 and in accordance with NSW Sea Level Rise Policy. Three scenarios have been assessed, a low, medium and high scenario.

- Low Scenario – 0.18m increase in ocean levels, 10% increase in rainfall intensities
- Medium Scenario – 0.55m increase in ocean levels, 20% increase in rainfall intensities
- High Scenario – 0.91m increase in ocean levels, 30% increase in rainfall intensities

The current modelling utilised a peak flood level in Narrabeen Lagoon in a 100 year ARI event of 2.71m AHD, this level is based on a flood study undertaken by MHL in 1990. It is noted that this study did not incorporate climate change into the analysis.

A sensitivity analysis was undertaken on the ocean levels in a 100 year ARI event and the adopted design event assumed a 2 m AHD peak water level in the ocean. The sensitivity analysis included a peak ocean level of 2.7m AHD, 1.5m AHD and a normal tide level (0.6m AHD). This analysis has been used to estimate the effect of an increase in ocean levels as a result of climate change on the 100 year ARI flood level in the lagoon, assuming a linear interpolation between the sensitivity results. A 10% increase in rainfall intensities was assumed to result in a 10% increase in input flows to the Lagoon (and similarly for 20% and 30% scenarios), this is considered a conservative assumption. This analysis then provided the estimates on the Narrabeen Lagoon Levels in the 100 year ARI event under a low, medium and high scenario.

A sensitivity analysis was undertaken on flows and on downstream boundary levels as a part of the Warriewood Valley Flood Study. In both cases, variations of +/- 20% were undertaken. The sensitivity analysis on the downstream water levels allowed the estimate of likely effects of the higher Lagoon levels and increase in rainfall intensity on the study site.

The following increases in flood levels were provided by Cardno Lawson and Treloar to estimate the possible effect of climate change on flood levels within the development site.

Table 3.2 Increases in flood levels as a result of possible climate change

Climate Change Scenario	Increase in Flood Level (m)
Low	0.15
Medium	0.3
High	0.45

Source: Warriewood Valley Flood Study (Cardno Lawson Treloar)

Given the estimated increases in flood levels, it is expected that flood levels within the site would increase to 3.56m - 3.85m AHD as a result of the high climate change scenario (worse case) for the 100 Year ARI storm event. The proposed minimum floor levels have been set at 4.5m AHD, well above the expected 100 year ARI flood level which is increased as a result of climate change.

3.14 OVERLAND FLOW PATH ALONG WESTERN BOUNDARY

A minor overland flow path is proposed to pass along the western boundary to convey flows from Macpherson Street to Fern Creek during the PMF. The flowpath cross section has been based on the details provided with the Warriewood Valley Buffer Area 3 Water Management Report Rezoning Application Stage (Patterson Britton).

The modelling of the existing and developed scenario was undertaken using HEC-RAS (V3.1.3), a 1D hydraulic model developed by US Army Corps of Engineers. The upstream boundary condition was the inflow hydrograph taken from a measuring station within the SOBEK model for the PMF event and the downstream boundary condition is the water level control taken from the maximum flood level within the SOBEK model for the high and low tide scenario downstream of the flow path as modelled for the PMF event.

Table 3.3 PMF flood Levels with High Tide in the Overland Flow Path

Section	Existing PMF Flood Level (m, AHD)	Developed PMF Flood Level (m, AHD)	PMF Flood Level Increase (m, AHD)
140	5.38	4.62	-0.76
130	5.36	4.61	-0.75
120	5.3	4.61	-0.69
110	5.08	4.61	-0.47
100	4.71	4.6	-0.11
90	4.6	4.6	0
80	4.6	4.6	0
70	4.6	4.6	0
60	4.6	4.6	0
50	4.6	4.6	0
40	4.6	4.6	0
30	4.6	4.6	0
20	4.6	4.6	0
10	4.6	4.6	0

Table 3.4 PMF flood Levels with Low Tide in the Overland Flow Path

Section	Existing PMF Flood Level (m, AHD)	Developed PMF Flood Level (m, AHD)	PMF Flood Level Increase (m, AHD)
140	5.38	4.08	-1.3
130	5.36	4.26	-1.1
120	5.3	4.18	-1.12
110	5.08	4.12	-0.96
100	4.71	4.07	-0.64
90	4.56	4.04	-0.52
80	4.39	4.02	-0.37
70	4.06	4	-0.06

Section	Existing PMF Flood Level	Developed PMF Flood Level	PMF Flood Level Increase
60	4	4	0
50	4	4	0
40	4	4	0
30	4	4	0
20	4	4	0
10	4	4	0

The results of the HEC-RAS hydraulic modelling shows no increase in flood levels during the PMF event as a result of the proposed development.

4 WATER BALANCE MODELLING

A daily water balance model was developed for pre and post development of the site using MUSIC.

4.1 MODEL ASSUMPTIONS

This model used daily rainfall data from the Bureau of meteorology Station at Mona Vale to estimate daily runoff volumes. The period of record covered 31 years from January 1972 to the end of 2002. Evaporation data used were daily averages for each month.

For developed conditions, the rainwater reuse is proposed to be used for external purposes (irrigation and car wash bays). An annual water requirement was based on the 16 KL per 100m^2 of garden presented for Sydney by the National Water Commission (2008) R*equirements for Installation of Rainwater and Greywater Systems in Australia*. The annual demand was scaled according to the daily evapotranspiration data. The rainwater storage tanks can be located in the building basements and top-up from Sydney Water mains of up to 10% tank capacity is recommended.

4.2 WATER BALANCE SUMMARY

The music model was set up for the total development area and was split up into landuse source nodes including road corridors, roof areas and pervious areas with percentage impervious values of 78%, 90% and 5% respectively. The roof areas drain to the rainwater tanks with overflow directed to the bioretention basins. All over areas drain directly to the bioretention basins.

The water balance modelling estimated the following total rainfall depths for statistically representative rainfall years:

- 10th Percentile Rainfall Year 744 mm
- Average rainfall year 1,090 mm
- 90th Percentile rainfall year 1,537 mm

The water balance model results are shown in **Table 4.1**.

Table 4.1 Water Balance Modelling Results

	Pre-development Runoff	Post-Development Runoff with Stormwater Re-use
Site		
10^{th} Percentile Rainfall Year (m^3/s)	0	0
Average rainfall year (m^3/s)	0.00082	0.00080
90^{th} Percentile rainfall year (m^3/s)	0.00102	0.0013
Flow (ML/yr)	25.8	25.6

The model shows that development would not increase runoff volumes from that of existing conditions. This has been achieved by incorporating a stormwater reuse component for each dwelling.

In attempt to minimise reductions of environmental flows to Fern Creek and Warriewood Wetlands, rainwater reuse has been limited to runoff from roof areas. Within the site all roads and lot areas bypass the rainwater tanks and continue to flow to Fern Creek through the water quality treatment devices and on-site detention. The water balance modelling suggests that the environmental flows to Fern Creek will be maintained with associated rainwater reuse.

5 STORMWATER DRAINAGE CONCEPT PLAN (SDCP)

A requirement of Pittwater Council is to provide a Stormwater Concept Management Plan. This plan is shown in **Figure A5**, which identifies:

- Location & size of Stormwater Quality Improvement Devices (SQIDs)
- Location and size of the OSD systems,
- 1% AEP and PMF extents – post development
- Flood Storage – post development
- Surface overland flowpaths

6 STORMWATER QUALITY MANAGEMENT

6.1 MODELLING METHODOLOGY

Water quality modelling of the proposed development has been undertaken using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software package developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH). MUSIC enables the user to model the transfer of pollutants through a catchment and provides an aid in determining the treatment strategy required to meet the water quality objectives applicable to the site. The critical pollutants to be modelled are Gross Pollutants, Total Nitrogen (TN), Total Phosphorous (TP) and Total Suspended Solids (TSS).
The generation, transfer and removal of these critical pollutants will be modelled through the treatment strategy employed. Only the critical pollutants will be further addressed in this report, however the treatment devices will provide mitigation of other pollutant loads, such as heavy metals, since they are predominantly associated with fine sediment. The Primary Pollutant trap will intercept pollutants such as litter, rubbish, leaves etc therefore minimising the runoff of oxygen demanding substances.

The event mean concentrations (EMC) used were taken from the Warriewood Valley Water Management Specification, as shown in Table 6.1.

Table 6.1 Pollutant EMC Values & Runoff Coefficients

Landuse	TSS (mg/L)	TP (mg/L)	TN (mg/L)
Urban	100	0.3	1.5
Rural Residential	35	0.1	1
Horticultural	45	0.2	2.5
Pasture	15	0.04	0.5
Forest/Native Vegetation	10	0.03	0.32

Source: Warriewood Valley Water Management Specifications (2001)

6.2 MODELLING STORMWATER OF MANAGEMENT STRATEGIES

Pollutant export analysis has been undertaken for three scenarios using MUSIC. The three models are:

- Existing Scenario – Pre-developed site
- Developed Scenario – site developed as proposed, without any stormwater quality treatment; and
- Mitigated Scenario – site developed as proposed with stormwater quality treatment.

It should be noted that the updated version of the MUSIC program (v.3.01) was used for the modelling.

6.2.1 Source Nodes

For modelling with MUSIC, subject sites have to be classified into different land uses that are represented as source nodes. The source nodes that have been used in the modelling are Agriculture and Urban. Each are used for various land uses within the site for the existing and developed scenarios. The two types of source nodes used in the MUSIC modelling have used the following total impervious percentages:

- Agriculture - An impervious percentage of 5% was used for the existing scenario and areas of open space
- Urban – An impervious percentage of 80% was used for road carriage ways, 90% for roof areas, and 5% for pervious areas.

Soil properties for each source node are set as defaults use by MUSIC for the two respective source node types. Mean estimation and serial autocorrelation set to zero has also been adopted.

6.2.2 Drainage Links

No routing has been adopted for all drainage links within each model. This assumption is due to the type of SQID's modelled and the limited overland flow lengths. It is believed this assumption will produce more conservative results.

6.3 RESULTS FOR THE EXISTING & DEVELOPED SCENARIO'S

Table 6.2 and 6.3 summarises the results of the existing and developed (without mitigation) scenario pollutants loads generated from the site.

Table 6.2 Existing pollutant Loads

Percentile Year	TSS Conc. (mg/L)	TP Conc. (mg/L)	TN Conc. (mg/L)
Site A			
10th	25.1	0.131	1.18
mean	25.5	0.132	1.19
90th	25.1	0.132	1.19
Mean Annual Loads (kg/Yr)	448	1.68	16
Site B			
10th	25.1	0.131	1.18
mean	25.5	0.132	1.19
90th	25.1	0.132	1.19
Mean Annual Loads (kg/Yr)	339	1.27	12.1

Table 6.3 Developed (no mitigation) pollutant Loads

Percentile Year	TSS Conc. (mg/L)	TP Conc. (mg/L)	TN Conc. (mg/L)
Site A			
10th	12.6	0.151	1.5
mean	29.1	0.175	1.91
90th	98.9	0.28	2.09
Mean Annual Loads (kg/Yr)	1660	5.26	29.6
Site B			
10th	12.6	0.151	1.5
mean	29.1	0.176	1.86
90th	98.9	0.29	2.09
Mean Annual Loads (kg/Yr)	1110	2.94	16.4

The objective of the stormwater quality treatment strategy is to treat stormwater to an acceptable level such that pollutant loads are no worse then existing runoff quality conditions.

6.4 PROPOSED STORMWATER TREATMENT STRATEGY – SITE A

The water quality treatment for Site A will consist of:

- Stormwater re-use of dwelling roof runoff by utilising rainwater tanks,
- Primary pollutant trap capable of removing gross pollutants, sediment and oils to pre-treat road and lot drainage, and
- A bioretention basin which will receive flows from the pollutant traps.

The estimates of pollutant loads from Site A with stormwater treatment are shown in **Table 6.4**.

Table 6.4 Site A - Pollutant Loads with Stormwater Treatment

Percentile Year	TSS Conc. (mg/L)	TP Conc. (mg/L)	TN Conc. (mg/L)
10th	0	0	0
mean	0.88	0.031	0.67
90th	2.61	0.063	1.25
Mean Annual Loads (kg/Yr)	40.5	0.96	14.9
Existing Mean	25.5	0.132	1.18

6.4.1 Bioretention Basin Concept Design

Bioretention Basin Sizing

Filter Media depth	600 mm
Filter Media Surface Area	752 m^2
Extended Detention Depth	300 mm

Filter Media Specification

Filter Media Type	Loamy Sand (0.45 mm)
Hydraulic Conductivity	180 mm/h
Sub-surface Drain Type	Ag Drain (min 0.5% grade) 100 & 150mm slotted pipe

Surface Treatment on Filter Media

Plants selected for use in bioretention systems need to be able to tolerate periods of inundation, as these systems can be expected to have a proportion of the soil profile saturated for several days. The selection of a loamy sand soil with a hydraulic conductivity in the range of 100-200mm/h will normally ensure soils are not waterlogged, which has been accommodated in the concept design.

Plants with extensive fibrous root systems are generally preferred as they prevent the filter media from clogging. Plants with a spreading, rhizomatous or suckering habit are also preferred. The filter must be planted to ensure it does not clog, and a stone layer at the surface could be used if required, although no mulch should be placed on the filter.

Sub-surface Drainage

100 mm & 150mm Ag drain will be placed in a 150-200 mm thick fine gravel layer below a 100 mm thick sand transition layer located immediately below the filter media. The grading of the transition layer should be:

- 1.4 mm 100% passing
- 1.0 mm 80%
- 0.7 mm 44%
- 0.5 mm 8.4% passing

The maximum spacing of the Ag drain is to be maximum 2 m spacing centre to centre.

The proposed bioretention filter will incorporate a ***HPDE or Bentofix liner*** or equivalent beneath the gravel layer to ensure no infiltration into the surrounding soil occurs.

6.5 PROPOSED STORMWATER TREATMENT STRATEGY – SITE B

The water quality treatment for Site B will consist of:

- Stormwater re-use of dwelling roof runoff by utilising rainwater tanks,
- Primary pollutant trap capable of removing gross pollutants, sediment and oils to pre-treat road and lot drainage, and
- A bioretention basin which will receive flows from the pollutant traps.

The estimates of pollutant loads from Site B with stormwater treatment are shown in **Table 6.5**.

Table 6.5 Site B - Pollutant Loads with Stormwater Treatment

Percentile Year	TSS Conc. (mg/L)	TP Conc. (mg/L)	TN Conc. (mg/L)
10th	0	0	0
mean	1.04	0.036	0.69
90th	3.27	0.087	1.25
Mean Annual Loads (kg/Yr)	31.1	0.69	10.2
Existing Mean	25.5	0.132	1.19

6.5.1 Biofiltration Basin Concept Design

Biofiltration Basin Sizing

Filter Media depth	600 mm
Filter Media Surface Area	545 m^2
Extended Detention Depth	300 mm

Filter Media Specification

Filter Media Type	Loamy Sand (0.45 mm)
Hydraulic Conductivity	180 mm/h
Sub-surface Drain Type	Ag Drain (min 0.5% grade) 100 & 150mm slotted pipe

Surface Treatment on Filter Media

Plants selected for use in bioretention systems need to be able to tolerate periods of inundation, as these systems can be expected to have a proportion of the soil profile saturated for several days. The selection of a sandy loam soil with a hydraulic conductivity in the range of 100-200mm/h will normally ensure soils are not waterlogged, which has been accommodated in the concept design.

Plants with extensive fibrous root systems are generally preferred as they prevent the filter media from clogging. Plants with a spreading, rhizomatous or suckering habit are also preferred. The filter must be planted to ensure it does not clog, and a stone layer at the surface could be used if required, although no mulch should be placed on the filter.

Sub-surface Drainage

100 mm & 150mm Ag drain will be placed in a 150-200 mm thick fine gravel layer below a 100 mm thick sand transition layer located immediately below the filter media. The grading of the transition layer should be:

- 1.4 mm 100% passing
- 1.0 mm 80%
- 0.7 mm 44%
- 0.5 mm 8.4% passing

The maximum spacing of the Ag drain is to be maximum 2 m spacings centre to centre.

The proposed bio-filtration filter will incorporate a ***HPDE or Bentofix liner*** beneath the gravel layer to ensure no infiltration into the surrounding soil occurs.

6.6 MAINTENANCE

The pollutant traps shall be inspected every three months to establish the frequency of cleaning required. At a minimum the traps will require cleaning every six months.

The bioretention basins will be self cleaning when planted appropriately and fitted with a back flush system (pipe riser). Maintenance will be limited to landscaping and weed control.

6.7 MOSQUITO RISK

Mosquitoes require still permeant water bodies to lay eggs. As the bioretention basins do not hold water and will be self draining, the risk of mosquito breeding is considered minimal to none.

6.8 WATER QUALITY MONITORING

Water quality monitoring was undertaken as part of the rezoning application and details are presented in the Warriewood Valley Buffer Area 3 Water Management Report Rezoning Application (Patterson Britton, 2005).

7 ONSITE DETENTION REQUIREMENTS

The Warriewood Valley Water Management Specification provides site storage requirements (SSR) and permissible site discharge (PSD) for Sector 14 (buffer area 3). These were estimated from the *XP-RAFTS* modelling undertaken by Lawson & Treloar for Pittwater Council. These factors were determined as being:

- SSR 519 m^3/ha
- PSD for 1% AEP 2 hr Storm 109 l/s/ha

The PSD and SSR were verified using the *RAFTS* hydrological component of the *DRAINS* model. This software has a more advanced detention basin modelling component than *XP-RAFTS* that allows multiple orifices to be modelled and hydrographs examined. Initial and continuing losses adopted were those used in the Narrabeen Creek Flood Study by Lawson & Treloar Pty Ltd for Pittwater Council.

7.1 ONSITE DETENTION REQUIREMENTS - SITE A

The hydrological parameters adopted for the existing catchment conditions were the same as for the RAFTS modelling undertaken by Lawson & Treloar, being:

Existing Mannings ‘n’	0.05
Developed Mannings ‘n’	0.025 -0.035
Contributing catchment area	2.92 ha

The OSD system will utilise 1750 m^3 of storage located in a bio-filtration basin.

Basin A

The concept outlet arrangement from the Site A OSD outlet is:

- Orifice 328 mm at centre RL 2.83 m
- Outlet using a 525 mm RCP at IL 2.57 m
- Basin Base level RL 3.17 m
- 100 Year ARI top water level RL 4.17 m

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7.1.1 Freeboard

Floor levels for properties adjacent to the OSD basin have been set at least 0.3m above the 1 in 100 year ARI flood level. An emergency spillway has been provided discharging to Fern Creek with ample capacity to cater for all flows off the site.

7.2 ONSITE DETENTION REQUIREMENTS - SITE B

Site B catchment was modelled in *DRAINS* using the *RAFTS* hydrological component. A total catchment of 2.209ha is proposed to drain to the basin. The OSD system will utilise 620 m^3 of storage located in a bioretention basin and 410 m^3 located in tanks within the buildings.

The model parameters included;

Existing Mannings 'n'	0.05
Developed Mannings 'n'	0.025 -0.035
Contributing catchment area	2.92 ha

Basin B

The concept outlet arrangement from the Site B OSD outlet is:

- Orifice 330 mm at centre RL 2.77 m
- Outlet using a 525 mm RCP at IL 2.51 m
- Basin Base level RL 3.11 m
- 100 Year ARI top water level RL 4.6 m

7.2.1 Freeboard

Floor levels for properties adjacent to the OSD have been set at least 0.3m above the 1 in 100 year ARI flood level. An emergency spillway has been provided discharging to Fern Creek with ample capacity to cater for all flows off the site.

7.3 SUMMARY OF RESULTS

The OSD system will utilise 2780 m^3 of storage located in a bio-filtration basin and tanks. The *DRAINS* modelling results indicate that the development of the Site (with OSD) would not increase the peak flow compared with existing conditions. Results of modelling are shown in **Table 7.1**.

Table 7.1 Summary of Peak Flows

ARI Storm	Existing Conditions	PSD*	Developed With OSD
100	0.908	0.559	0.556

*PSD from the Warriewood Valley Urban Release Area Water Management Specification (2001)

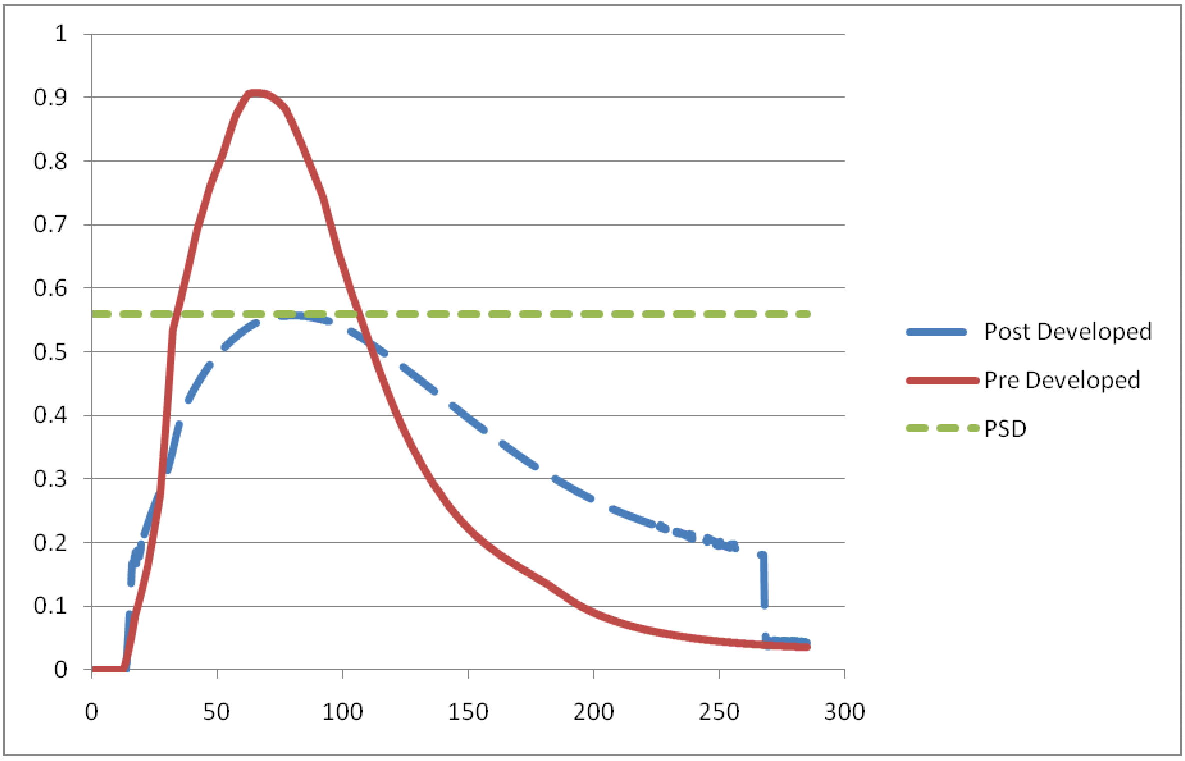


Figure 2 100 year ARI Storm Hydrograph

8 ENVIRONMENTAL MANAGEMENT

The development exists upstream of the Warriewood Wetlands. As part of the proposal the 25m Core Riparian Zone (CRZ) and the 25m Asset Protection Zone including the 10m vegetation buffer for the wetlands have been identified.

A Vegetation Management Plan has been produced for the proposed development area (not as part of this report). The plan identifies the removal of exotic species of vegetation and replaced with native vegetation within the CRZ and Asset Protection Zone.

9 CONCLUSIONS

The stormwater management plan for buffer area 3 Warriewood Valley has been prepared in accordance with Pittwater Councils Water Management Specification. The stormwater components used in the development will meet the principle objectives being:

- Ensuring that peak flows are maintained at a rate not exceeding that of existing conditions,
- Improving water quality of stormwater discharging from the site such that pollutant loads are no worse than that of existing conditions,
- Ensuring that the average annual flows from the site are no greater than that of existing conditions,
- Promoting WSUD in the design,

Extensive landscaping to the proposed drainage lines and public domain will complement the stormwater drainage design. The use of indigenous vegetation will assist in enhancing the biodiversity of habitat along the drainage reserves.

10 REFERENCES

Cardno Lawson and Treloar (2005) Warriewood Valley Flood Study

Institution of Engineers Australia (2004) Australian Runoff Quality – DRAFT.

Melbourne Water (2004). WSUD Engineering Procedures: Stormwater DRAFT.

NSW EPA (1997a). Managing Urban Stormwater: Council Handbook.

NSW EPA (1997b). Managing Urban Stormwater: Treatment Techniques.

Patterson Britton (2005) Warriewood Valley Buffer Area 3 Water Management Report Rezoning Application Stage

Pittwater Council (2001). Warriewood Valley Urban Land Release Water Management Specification. Prepared by Lawson & Treloar Pty Ltd.

Sydney Water (2003) Water Supply Code of Australia WSA03-2002

Sydney Water (2006) Sewerage Code of Australia WSA02-2002

11 GLOSSARY OF TERMS

Afflux	The rise in water level upstream of a hydraulic structure such as a bridge or culvert, caused by losses incurred from the hydraulic structure.
Australian Height Datum	National survey datum corresponding approximately to mean sea level.
Annual Exceedance Probability	The chance of a flood of a given size or larger occurring in any one year, generally expressed as percentage probability. For example, a 100 year ARI flood is a 1% AEP flood. An important implication is that when a 1% AEP flood occurs, there is still a 1% probability that it could occur the following year.
Average Recurrence Interval	Is the long term average number of years between the occurrence of a flood as big as, or larger than the selected flood event.
Catchment	The catchment at a particular point is the area of land which drains to that point.
Design floor level	The minimum (lowest) floor level specified for a building.
Design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100 year or 1% probability flood). The design flood may comprise two or more single source dominated floods.
Development	Existing or proposed works which may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.
Discharge	The rate of flow of water measured in terms of volume over time. It is not the velocity of flow which is a measure of how fast the water is moving rather than how much is moving. Discharge and flow are interchangeable.
Digital Terrain Model	A three-dimensional model of the ground surface that can be represented as a series of grids with each cell representing an elevation (DEM) or a series of interconnected triangles with elevations (TIN).
Effective warning time	The available time that a community has from receiving a flood warning to when the flood reaches their location.
Flood	Above average river or creek flows which overtop banks and inundate floodplains.
Flood awareness	An appreciation of the likely threats and consequences of flooding and an understanding of any flood warning and evacuation procedures. Communities with a high degree of flood awareness respond to flood warnings promptly and efficiently, greatly reducing the potential for damage and loss of life and limb. Communities with a low degree of flood awareness may not fully appreciate the importance of flood warnings and flood preparedness and consequently suffer greater personal and economic losses.
Flood behaviour	The pattern / characteristics / nature of a flood.
Flooding	The State Emergency Service uses the following definitions in flood warnings:

	Minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges
	Moderate flooding: low-lying areas inundated requiring removal of stock and/or evacuation of some houses. Main traffic bridges may be covered.
	Major flooding: extensive rural areas are flooded with properties, villages and towns isolated and/or appreciable urban areas are flooded.
Flood frequency analysis	An analysis of historical flood records to determine estimates of design flood flows.
Flood fringe	Land which may be affected by flooding but is not designated as a floodway or flood storage.
Flood hazard	The potential threat to property or persons due to flooding.
Flood level	The height or elevation of flood waters relative to a datum (typically the Australian Height Datum). Also referred to as "stage".
Flood liable land	Land inundated up to the probable maximum flood – flood prone land.
Floodplain	Land adjacent to a river or creek which is inundated by floods up to the probable maximum flood that is designated as flood prone land.
Flood Planning Levels	Are the combinations of flood levels and freeboards selected for planning purposes to account for uncertainty in the estimate of the flood level.
Flood proofing	Measures taken to improve or modify the design, construction and alteration of buildings to minimise or eliminate flood damages and threats to life and limb.
Floodplain Management	The coordinated management of activities which occur on flood liable land.
Floodplain Management Manual	A document by the NSW Government (2001) that provides a guideline for the management of flood liable land. This document describes the process of a floodplain risk management study.
Flood source	The source of the flood waters.
Floodplain Management Standard	A set of conditions and policies which define the benchmark from which floodplain management options are compared and assessed.
Flood standard	The flood selected for planning and floodplain management activities. The flood may be an historical or design flood. It should be based on an understanding of the flood behaviour and the associated flood hazard. It should also take into account social, economic and ecological considerations.
Flood storages	Floodplain areas which are important for the temporary storage of flood waters during a flood.
Floodways	Those areas of the floodplain where a significant discharge of flow occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if they are partially blocked, would cause significant redistribution of flood flows, or a significant increase in flood levels.
Freeboard	A factor of safety usually expressed as a height above the flood standard. Freeboard tends to compensate for the factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.

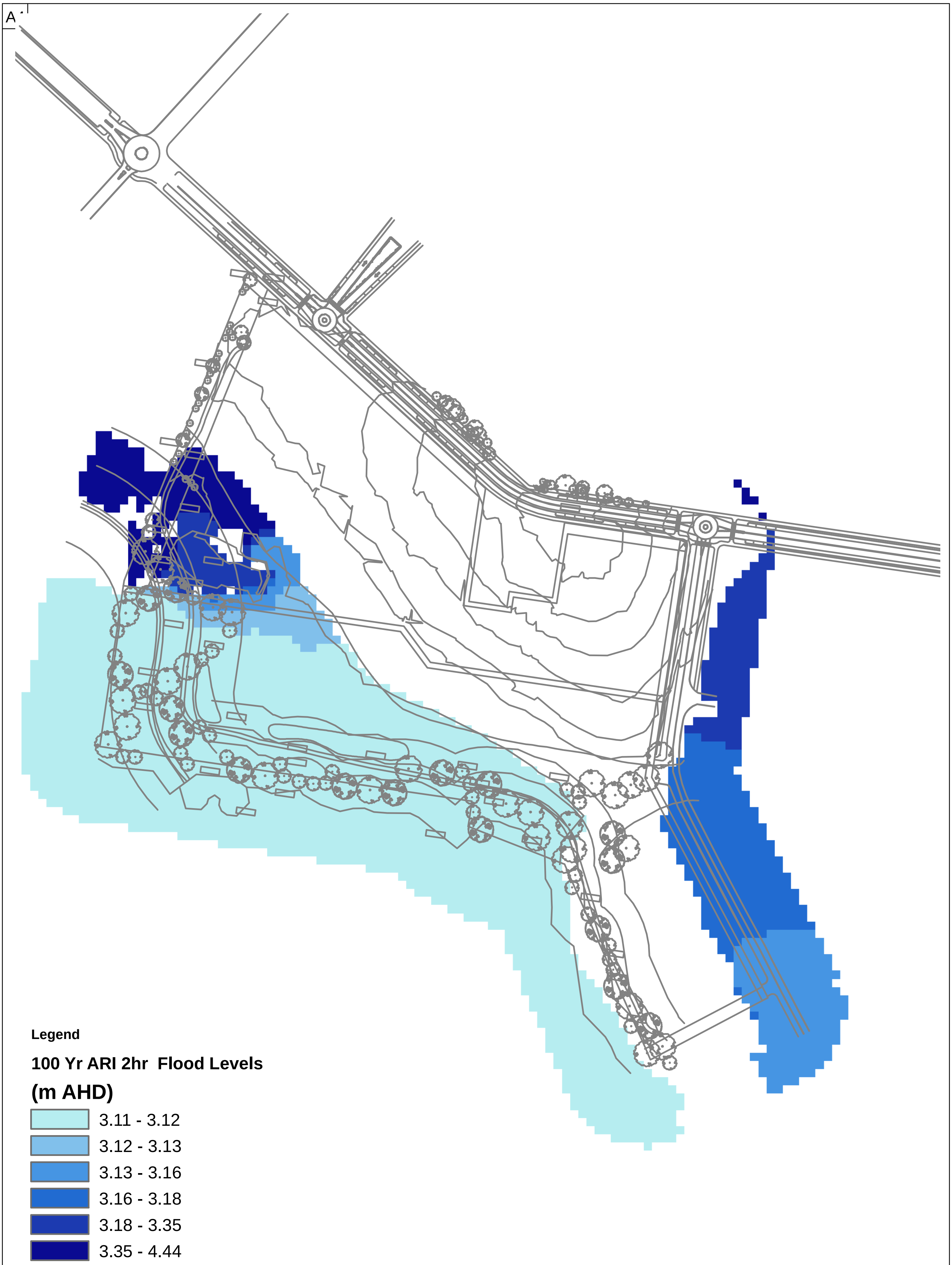
Geographical Information System	A form of computer software developed for mapping applications and data storage. Useful for generating terrain models and processing data for input into flood estimation models.
High hazard	Danger to life and limb; evacuation difficult; potential for structural damage, high social disruption and economic losses. High hazard areas are those areas subject to a combination of flood depth and flow velocity that are deemed to cause the above issues to persons or property.
Historical flood	A flood which has actually occurred – Flood of Record.
Hydraulic	The term given to the study of water flow in rivers, estuaries with coastal systems.
Hydrograph	A graph showing how a river or creek's discharge changes with time.
Hydrology	The term given to the study of the rain-runoff process in catchments.
Low hazard	Flood depths and velocities are sufficiently low that people and their possessions can be evacuated.
Management plan	A clear and concise document, normally containing diagrams and maps, describing a series of actions that will allow an area to be managed in a coordinated manner to achieve defined objectives.
Map Grid Australia	A national coordinate system used for the mapping of features on a representation of the earths surface. Based on the geographic coordinate system 'Geodetic Datum of Australia 1994'.
Peak flood level, flow or velocity	The maximum flood level, flow or velocity occurring during a flood event.
Probable Maximum Flood	An extreme flood deemed to be the maximum flood likely to occur at a particular location.
Probable Maximum Precipitation	The greatest depth of rainfall for a given duration meteorologically possible over a particular location. Used to estimate the probable maximum flood.
Probability	A statistical measure of the likely frequency or occurrence of flooding.
Riparian Zone	Areas that are located adjacent to watercourses. Their definition is vague and can be characterised by landform, vegetation, legislation or their function.
Runoff	The amount of rainfall from a catchment which actually ends up as flowing water in the river of creek.
Stage	Equivalent to water level above a specific datum- see flood level.
Stage hydrograph	A graph of water level over time.
Triangular Irregular Network	A mass of interconnected triangles used to model three-dimensional surfaces such as the ground (see DTM) and the surface of a flood.
Velocity	The speed at which the flood waters are moving. Typically, modelled velocities in a river or creek are quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section.

12 APPENDICES

Appendix A	Figures
Appendix B	Council Checklist
Appendix C	HEC RAS results
Appendix D	Drains Results
Appendix E	MUSIC Results

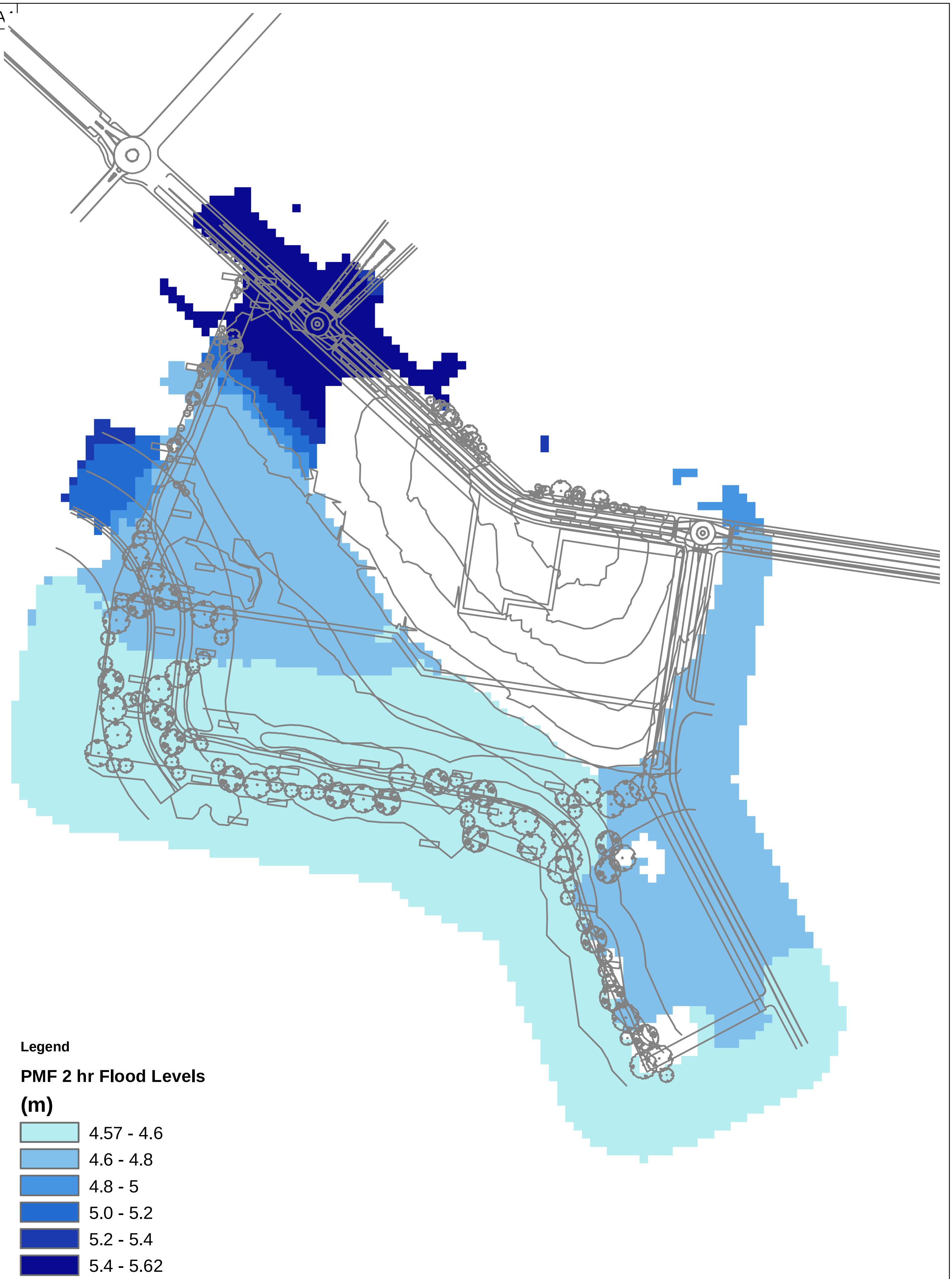
APPENDIX A

DRAWINGS



BROWN
CONSULTING

Project : Macpherson Street Warriewood	Scale : 1:3000	
Drawing Title : **FIGURE A1 EXISTING 100 Y 2Hr ARI FLOOD LEVEL MAP**	Drawn : TE	
	Checked : RP	
	Job No : X08066	



BROWN CONSULTING

Project : Macpherson Street Warriewood

Drawing Title :

FIGURE A2
EXISTING PMF 2Hr ARI
FLOOD LEVEL MAP

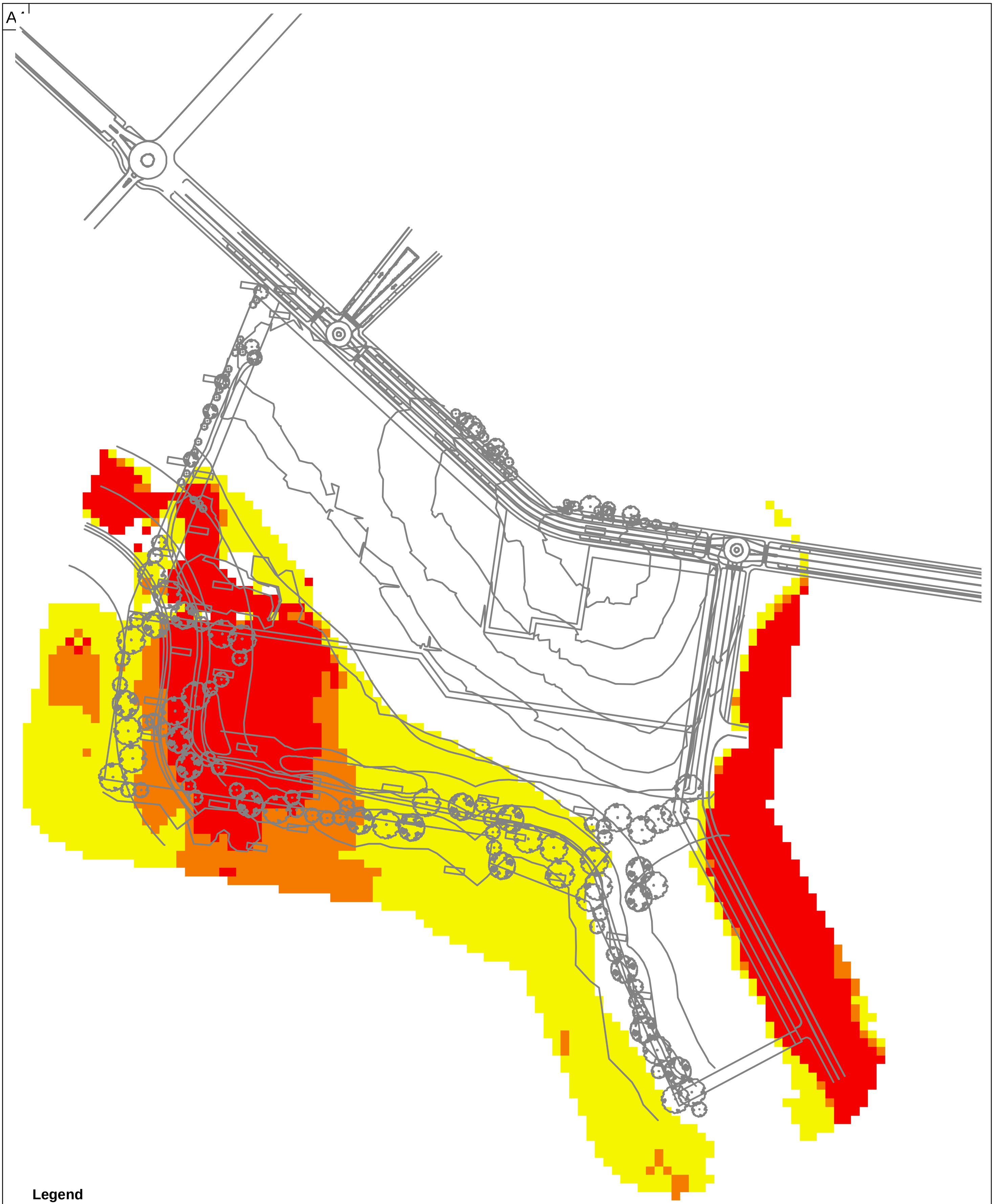
Scale : 1:3000

Drawn : TE

Checked : RP

Job No : X08066

Map Document: (G:\0004 - Macquarie\X04452.03 - Pacific Highway W2B - Concept Design\Current-BC\GIS\Report Figures-Concept Design\Fig A7.mxd)



Legend

100 Y ARI 2hr Flood Hazard

- 0 - 0.04
- 0.04 - 0.06
- >0.06

BROWN
CONSULTING

Project :	Macpherson Street Warriewood
Drawing Title :	FIGURE A3 EXISTING 100 Y 2Hr ARI FLOOD HAZARD MAP
Scale :	1:3000
Drawn :	TE
Checked :	RP
Job No :	X08066

Map Document: (G:\0004 - Macquarie\X04452.03 - Pacific Highway W2B - Concept Design\Current-BC\GIS\Report Figures-Concept Design\Fig A7.mxd)

Legend

PMF 2hr Hazard

- 0 - 0.04
- 0.04 - 0.06
- >0.06

BROWN CONSULTING

Project : Macpherson Street Warriewood

Drawing Title :

FIGURE A4
EXISTING PMF 2Hr ARI
FLOOD HAZARD MAP

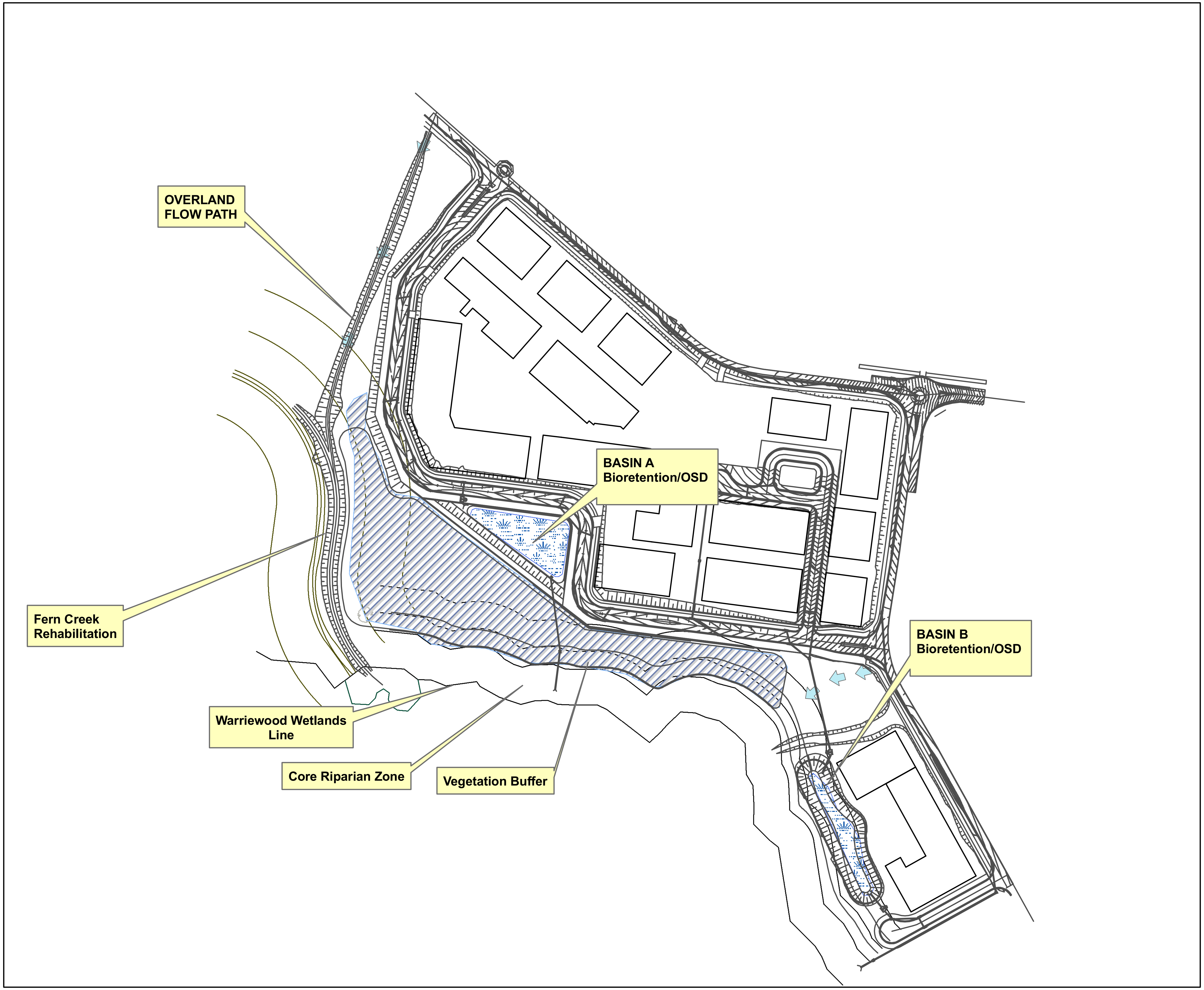
Scale : 1:3000

Drawn : TE

Checked : RP

Job No : X08066

Map Document: (G:\0004 - Macquarie\X04452.03 - Pacific Highway W2B - Concept Design\Current-BC\GIS\Report Figures-Concept Design\Fig A7.mxd)



BROWN CONSULTING

Legend

Legend

- Flow Path
- Bio Retention
- Flood Storage Area

Details

Issue	Amendment	Date
A	Development Application	Oct 08
B	Development Application	Feb 10

Project

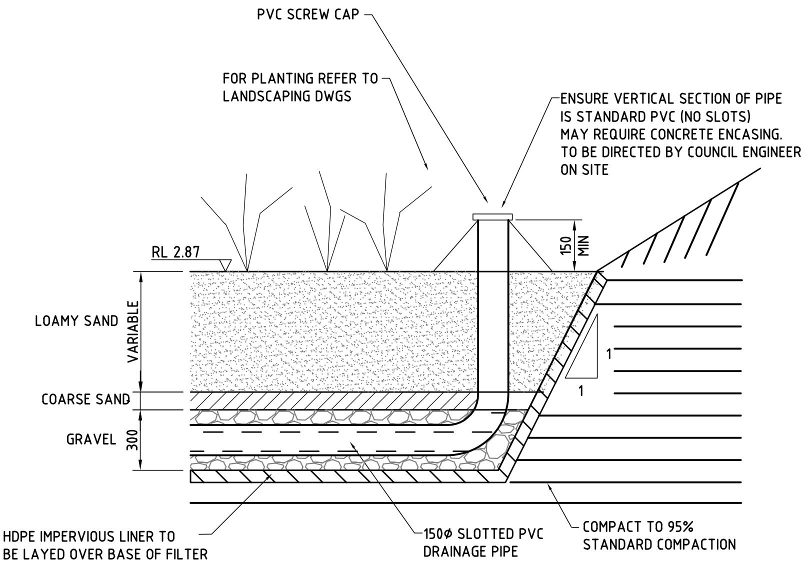
14-18 BOONDAH ROAD,
WARRIEWOOD

Drawing Title

FIGURE A5
STORMWATER MANAGEMENT PLAN

Scale 2,000
Drawn TE
Checked PB
Job No X08066
Drawing Number A5
Issue

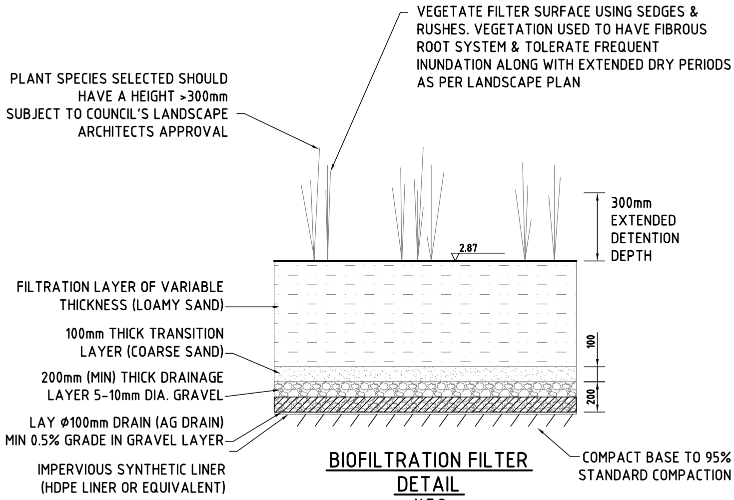
A4



DETAIL

BACKFLUSH/END CAP CONNECTION

N.T.S



BIOFILTRATION FILTER DETAIL

N.T.S

BIOFILTRATION FILTER MEDIA NOTES:

1. TRANSITION LAYER IS TO BE 100mm THICK USING COARSE SAND.
   TRANSITION LAYER SPECIFICATION (NOTE: ALLOW +/- 10% TOLERANCE)
   % PASSING 1.4mm 100%
   1.0mm 80%
   0.7mm 44%
   0.5mm 8.4%
2. FILTER MEDIA TO MEET THE FOLLOWING REQUIREMENTS :
   LOAMY SAND OR EQUIVALENT MATERIAL (HYDRAULIC CONDUCTIVITY 80-120mm/h)
   FREE OF RUBBISH & DELETERIOUS MATERIAL D_{50}= 0.45mm
3. THE HDPE LINER SHALL BE JOINED USING DOUBLE SIDED BUTYL TAPE IN ACCORDANCE
   WITH THE MANUFACTURERS INSTRUCTIONS

Brown Consulting (NSW) Pty Ltd
Level 2, 2 Burbank Place Norwest Business Park NSW Australia 2153
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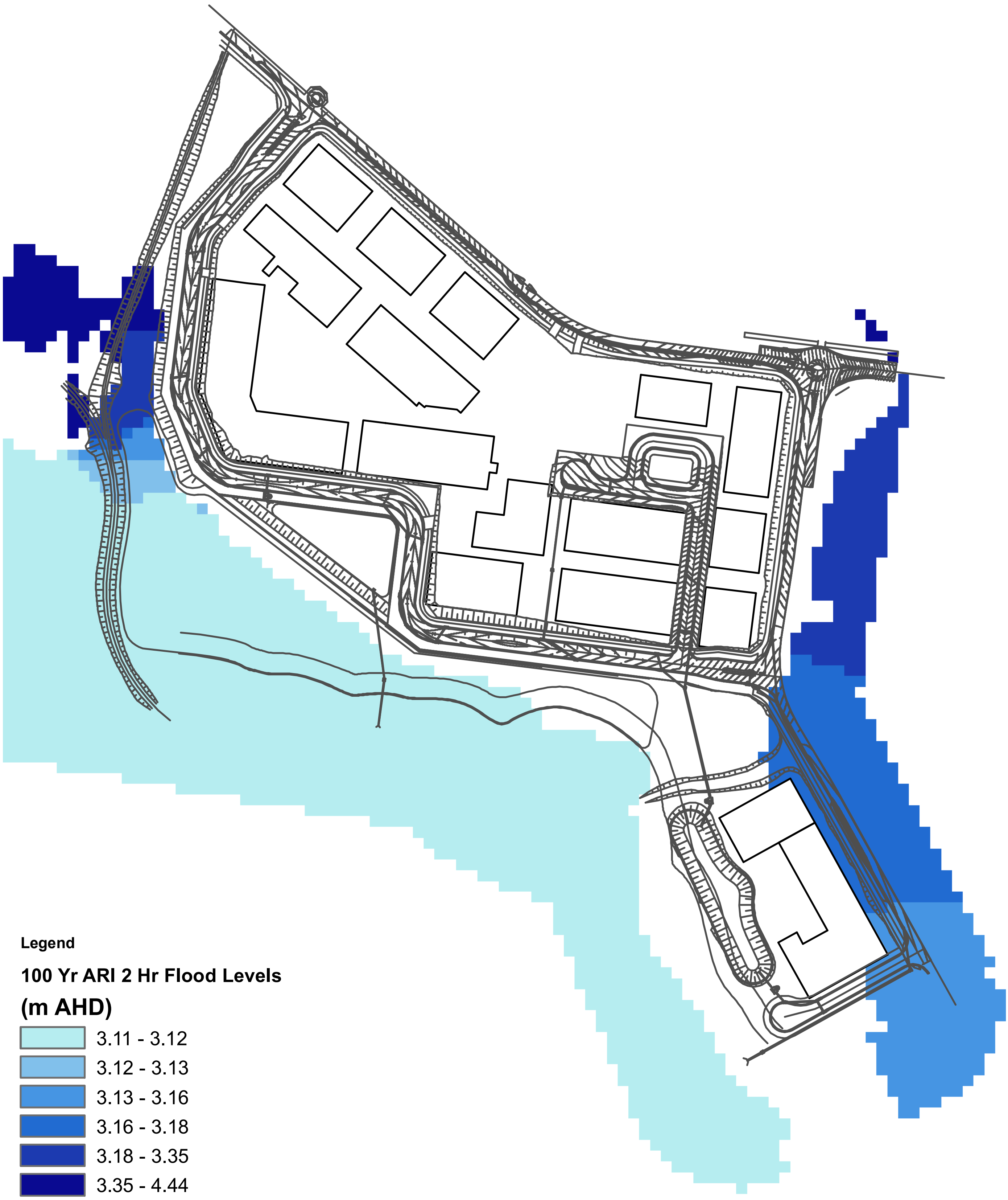
BROWN
Sydney
Canberra
Brisbane
Melbourne
Singapore

Client :	MERITON
Project :	14-18 BOONDAH RD WARRIEWOOD
Drawing Title :	FIGURE A8 BIORETENTION DETAILS
Designed :	TE
Drawn :	JT
Checked :	
Authorised for Issue :	
Scale :	N.T.S
Drawing No. :	X08066-003
Job No :	X08066



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Project : Macpherson Street Warriewood

Drawing Title :

FIGURE A 9
PROPOSED 100 Y 2Hr ARI
FLOOD LEVEL MAP

Scale : 1:3000

Drawn : TE

Checked : RP

Job No : X08066

Map Document: (G:\0004 - Macquarie\X04452.03 - Pacific Highway W2B - Concept Design\Current-BC\GIS\Report Figures-Concept Design\Fig A7.mxd)

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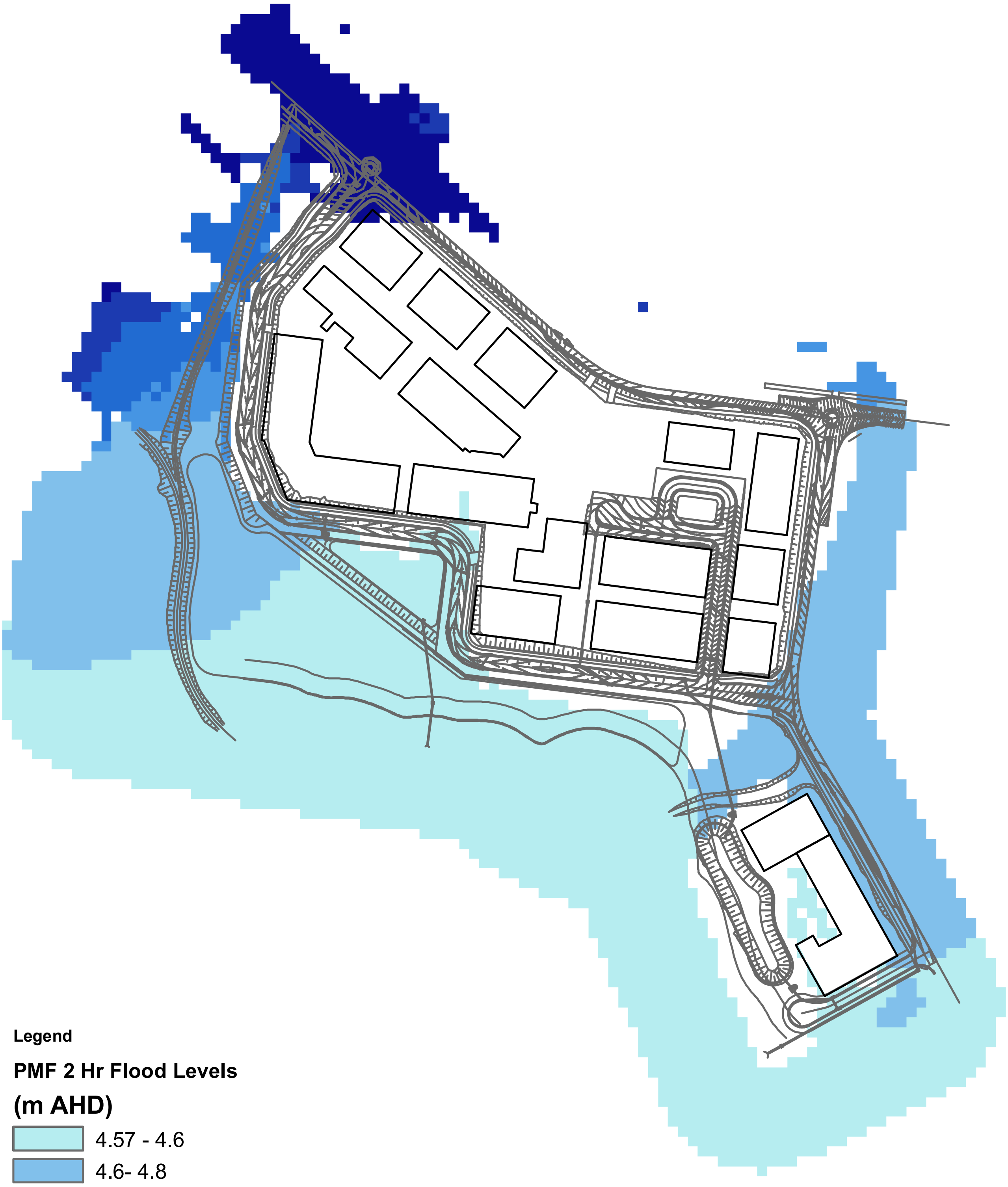


Legend

PMF 2 Hr Flood Levels

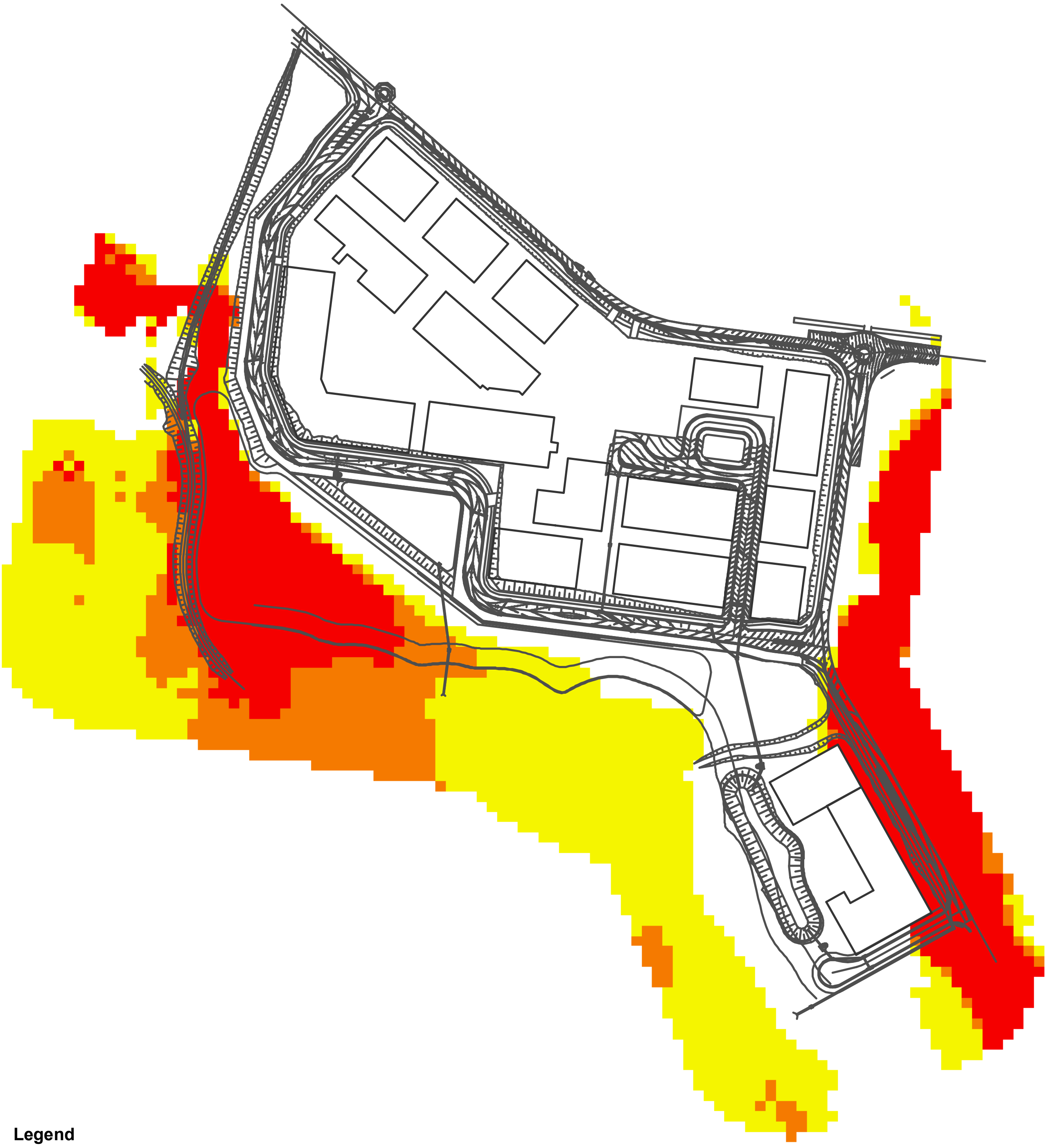
(m AHD)

- 4.57 - 4.6
- 4.6- 4.8
- 4.80 - 5
- 5.0 - 5.2
- 5.2 - 5.3
- 5.3 - 5.62

BROWN CONSULTING

Project : Macpherson Street Warriewood	Scale : 1:3000	
Drawing Title : **FIGURE A 10 PROPOSED PMF 2Hr ARI FLOOD LEVEL MAP**	Drawn : TE	
	Checked : RP	
	Job No : X08066	

Map Document: (G:\0004 - Macquarie\X04452.03 - Pacific Highway W2B - Concept Design\Current-BC\GIS\Report Figures-Concept Design\Fig A7.mxd)



Legend

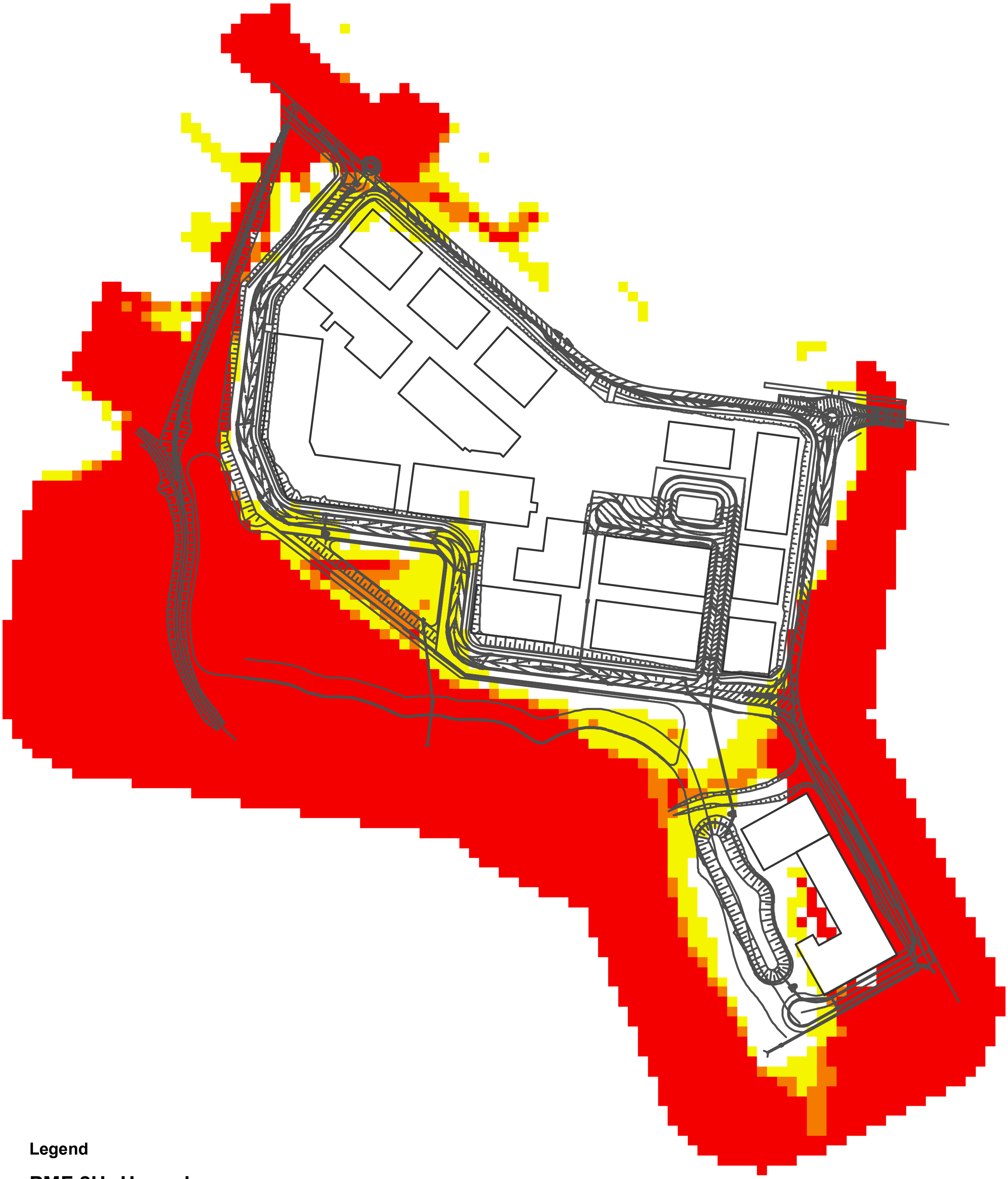
100 Y 2hr Hazard

- Low Hazard
- Medium Hazard
- High Hazard

BROWN CONSULTING

Project : Macpherson Street Warriewood	Scale : 1:3000	
Drawing Title : **FIGURE A11 DEVELOPED 100 Y 2Hr ARI FLOOD HAZARD MAP**	Drawn : TE	
	Checked : RP	
	Job No : X08066	

Map Document: (G:\0004 - Macquarie\X04452.03 - Pacific Highway W2B - Concept Design\Current-BC\GIS\Report Figures-Concept Design\Fig A7.mxd)



Legend

PMF 2Hr Hazard

- Low Hazard
- Medium Hazard
- High Hazard

BROWN CONSULTING	Project : Macpherson Street Warriewood	Scale : 1:3000
	Drawing Title : **FIGURE A12 DEVELOPED PMF 2Hr ARI FLOOD HAZARD MAP**	Drawn : TE
		Checked : RP
		Job No : X08066

Legend

100 Yr 2hr Flood Level Difference (m)

- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - 0
- 0 - 0.01
- 0.01 - 0.05

BROWN CONSULTING

Project : Macpherson Street Warriewood

Drawing Title :

FIGURE A13
100 Y 2Hr ARI HIGH TIDE
FLOOD LEVEL DIFFERENCE MAP

Scale : 1:3000

Drawn : TE

Checked : RP

Job No : X08066

Map Document: (G:\0004 - Macquarie\X04452.03 - Pacific Highway W2B - Concept Design\Current-BC\GIS\Report Figures-Concept Design\Fig A7.mxd)

A

Legend

100 Yr 2hr Flood Level Difference (m)

- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - 0
- 0 - 0.01
- 0.01 - 0.05

BROWN CONSULTING

Project :	Macpherson Street Warriewood
Drawing Title :	FIGURE A14 100 Y 2Hr ARI LOW TIDE FLOOD LEVEL DIFFERENCE MAP
Scale :	1:3000
Drawn :	TE
Checked :	RP
Job No :	X08066

Map Document: (G:\0004 - Macquarie\X04452.03 - Pacific Highway W2B - Concept Design\Current-BC\GIS\Report Figures-Concept Design\Fig A7.mxd)

Legend

100 Yr 36hr Flood Level Difference (m)

- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - 0
- 0 - 0.01
- 0.01 - 0.05

BROWN CONSULTING	Project : Macpherson Street Warriewood	Scale : 1:3000
	Drawing Title : FIGURE A15 100 Y 36Hr ARI LOW TIDE FLOOD LEVEL DIFFERENCE MAP	Drawn : TE
		Checked : RP
		Job No : X08066

Map Document: (G:\0004 - Macquarie\X04452.03 - Pacific Highway W2B - Concept Design\Current-BC\GIS\Report Figures-Concept Design\Fig A7.mxd)

A

Legend

100 Yr 9hr Flood Level (m)

-0.4 - -0.3

-0.3 - -0.2

-0.2 - 0

0 - 0.01

0.01 - 0.05

BROWN CONSULTING

Project : Macpherson Street Warriewood

Drawing Title :

FIGURE A16
100 Y 9Hr ARI LOW TIDE
FLOOD LEVEL DIFFERENCE MAP

Scale : 1:3000

Drawn : TE

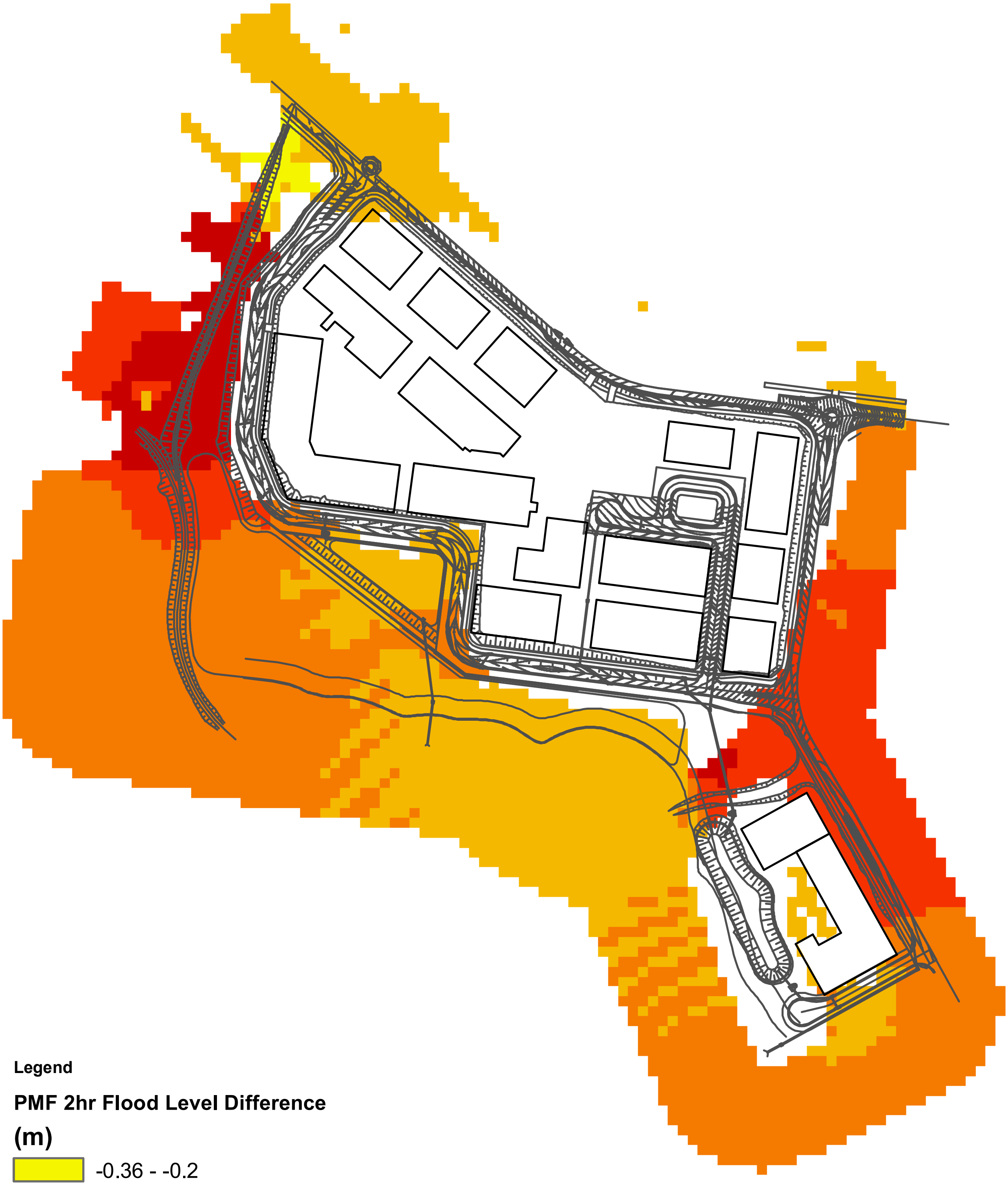
Checked : RP

Job No : X08066

N

Map Document: (G:\0004 - Macquarie\X04452.03 - Pacific Highway W2B - Concept Design\Current-BC\GIS\Report Figures-Concept Design\Fig A7.mxd)

A



Legend

PMF 2hr Flood Level Difference (m)

- -0.36 - -0.2
- -0.2 - 0
- 0 - 0.01
- 0.01 - 0.05
- 0.05 - 0.47

BROWN CONSULTING

Project :	Macpherson Street Warriewood
Drawing Title :	FIGURE A17 PMF HIGH TIDE FLOOD LEVEL DIFFERENCE MAP
Scale :	1:3000
Drawn :	TE
Checked :	RP
Job No :	X08066

Map Document: (G:\0004 - Macquarie\X04452.03 - Pacific Highway W2B - Concept Design\Current-BC\GIS\Report Figures-Concept Design\Fig A7.mxd)

APPENDIX B

COUNCIL CHECK LIST

DOCUMENTATION CHECKLIST - DEVELOPMENT APPLICATION

(Detach and include with submissions)

Section	Item	Requirement	Check (√)
4.1	Water Cycle Assessment - Water Balance Modelling Pre & Post Development	++++++++++	√
4.1.1	Stream Gauging, infiltration testing and use of local rainfall data for modelling	♦♦♦♦♦♦♦♦	-
4.2.1	Water Quality Monitoring Plan	♦♦♦♦♦♦♦♦	-
4.2.1	Water Quality Monitoring Sites Shown on Plan (at least three)	♦♦♦♦♦♦♦♦	-
4.2.1, 2, C	Water Quality Monitoring Data	♦♦♦♦♦♦♦♦	-
4.2.1, 2, C	Assessment and interpretation of water quality monitoring data	♦♦♦♦♦♦♦♦	-
4.2.1, 2, C	Assessment and interpretation of water quality monitoring data from SQID's		
4.3	Water Quality Management Assessment - Load Modelling Pre and Post Development	++++++++++	√
4.3.1, 3	Justification of assumptions for Event Mean Concentrations	♦♦♦♦♦♦♦♦	√
4.3.2	Identification of and details for Stormwater quality facilities	□□□□□□□□□□□	√
4.3.2, 4.4.5	Mosquito Risk Assessment for both Watercourse and Water Quality/Quantity features	♦♦♦♦♦♦♦♦	√
4.3.6, 4.6.5	Inspection and Cleaning Reports for SQID's and OSD		
4.3.6	Management Plan for Stormwater Quality Improvement Devices	♦♦♦♦♦♦♦♦	√
4.3.5	Environmental Management Plan (Soil and Water Aspects)		
4.3.4	Erosion and Sediment Control Plan		
4.4.3, 4, 5	Existing and Proposed Creek Corridor in plan with cross/long sections with flood levels	♦♦Note 1♦♦	√
4.4.4	Proposed Creek Corridor Planting Schedule	□□□Note 1□□□	
4.4.5	Creek Corridor Vegetation Monitoring and Management Plan	Note 1	
4.4.5	Vegetation and Creek Maintenance and Monitoring Reports		
4.5	Flood Analysis – existing and design conditions		√
4.5.2	Compliance of structures and creek corridor with flood planning levels	□□□□□□□□□□□	√
4.5.4	Details of Interim Flood Protection Works	□□□□□□□□□□□	√
4.6.3	Design Storm Hydrological Modelling of Site - Pre and Post Development	++++++++++	√
4.6.3	On-Site Detention Facilities	□□□□□□□□□□□	√
4.6.4	Stormwater Retention Facilities	□□□□□□□□□□□	√
4.7	Stormwater Concept Drainage Plan	♦♦♦♦♦♦♦♦	√

KEY:

	Preliminary Calculations/Assessment Required		*Work as Executed Plans*
□□□□□□□□	*Concept Design Required*	♦♦♦♦♦♦	*Required/Reviewed/Updated*
+++++++	*Detailed Assessment/Calculations/Design*		*Not required*

Note 1 Even if the works are not to be constructed by the Applicant on the land to be transferred to Council under the Material Public Benefit Option in the Section 94 Plan, preliminary investigation for Rezoning and concept design at DA stage is required

Completed by Principal Certifier:

Name:...................................... TROY EYLES
Title:.. ENGINEER
Organisation: .... BROWN CONSULTING

Signature: ....
Date:..

APPENDIX C

HEC RAS RESULTS

HIGH TAILWATER PMF

EXISTING

HEC-RAS Plan: Plan 01 River: FP Reach: 10 Profile: PF#1

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
10	150	PF#1	4.82	4.57	5.38	4.99	5.39	0.000175	0.32	27.26	55.18	0.12
10	140	PF#1	4.82	4.83	5.38		5.38	0.000572	0.41	19.3	55.4	0.19
10	130	PF#1	4.82	4.96	5.36		5.37	0.002221	0.67	12.58	55.62	0.36
10	120	PF#1	4.82	4.97	5.3		5.33	0.008304	0.98	7.24	41.97	0.65
10	110	PF#1	4.82	4.68	5.08	5.08	5.2	0.019021	1.7	3.57	23.45	1.01
10	100	PF#1	4.82	4.41	4.71	4.76	4.94	0.046507	2.28	2.27	7.51	1.53
10	90	PF#1	4.82	4.18	4.55	4.52	4.7	0.024972	1.77	2.82	8.12	1.14
10	80	PF#1	4.82	3.98	4.6		4.61	0.001811	0.71	10.99	39.44	0.34
10	70	PF#1	4.82	3.75	4.6		4.6	0.000191	0.32	26.66	56.93	0.12
10	60	PF#1	4.82	3.53	4.6		4.6	0.000036	0.18	45.21	56.78	0.05
10	50	PF#1	4.82	3.25	4.6		4.6	0.000013	0.12	62.49	57.36	0.03
10	40	PF#1	4.82	3.11	4.6		4.6	0.000007	0.1	75.2	57.54	0.03
10	30	PF#1	4.82	2.95	4.6		4.6	0.000005	0.09	84.46	62.7	0.02
10	20	PF#1	4.82	2.87	4.6		4.6	0.000004	0.08	92.27	65.01	0.02
10	10	PF#1	4.82	2.76	4.6	2.98	4.6	0.000003	0.08	101.9	73.53	0.02

DEVELOPED

HEC-RAS Plan: Plan 01 River: FP Reach: 10 Profile: PF#1

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
10	150	PF#1	4.82	3.73	4.62	4.33	7.24	1.000898	2	0.61	4.58	6.62
10	140	PF#1	4.82	3.66	4.62	4.26	4.66	0.001449	0.98	6.6	10.53	0.34
10	130	PF#1	4.82	3.58	4.61		4.64	0.001051	0.88	7.38	10.67	0.29
10	120	PF#1	4.82	3.5	4.61		4.63	0.000784	0.8	8.15	10.82	0.25
10	110	PF#1	4.82	3.42	4.61		4.63	0.00061	0.74	8.98	11.54	0.23
10	100	PF#1	4.82	3.35	4.6		4.62	0.000463	0.67	10.01	11.82	0.2
10	90	PF#1	4.82	3.27	4.6		4.62	0.000395	0.65	11.23	16.15	0.19
10	80	PF#1	4.82	3.19	4.6		4.61	0.000272	0.56	12.67	14.19	0.16
10	70	PF#1	4.82	3.12	4.6		4.61	0.000198	0.5	14.55	15.24	0.14
10	60	PF#1	4.82	3.04	4.6		4.61	0.000161	0.46	15.8	16.19	0.12
10	50	PF#1	4.82	2.96	4.6		4.6	0.00008	0.34	22.15	20.03	0.09
10	40	PF#1	4.82	2.88	4.6		4.6	0.000049	0.27	28.02	23.81	0.07
10	30	PF#1	4.82	2.81	4.6		4.6	0.000018	0.17	42.62	29.47	0.04
10	20	PF#1	4.82	2.73	4.6		4.6	0.000014	0.16	46.66	31.13	0.04
10	10	PF#1	4.82	2.65	4.6	3.18	4.6	0.00002	0.19	43.42	36.28	0.04

LOW TAILWATER PMF

EXISTING

HEC-RAS Plan: Plan 01 River: FP Reach: 10 Profile: PF#1

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
10	150	PF#1	4.82	4.57	5.38	4.99	5.39	0.000175	0.32	27.26	55.18	0.12
10	140	PF#1	4.82	4.83	5.38		5.38	0.000572	0.41	19.31	55.4	0.19
10	130	PF#1	4.82	4.96	5.36		5.37	0.002219	0.66	12.58	55.62	0.36
10	120	PF#1	4.82	4.97	5.3		5.33	0.008282	0.98	7.25	42.01	0.65
10	110	PF#1	4.82	4.68	5.08	5.08	5.2	0.019021	1.7	3.57	23.45	1.01
10	100	PF#1	4.82	4.41	4.71	4.76	4.94	0.046507	2.28	2.27	7.51	1.53
10	90	PF#1	4.82	4.18	4.56	4.53	4.7	0.023213	1.73	2.89	8.17	1.1
10	80	PF#1	4.82	3.98	4.39	4.39	4.49	0.017061	1.44	4.19	27.1	0.94
10	70	PF#1	4.82	3.75	4.06	4.11	4.23	0.045285	1.93	3.1	24.77	1.45
10	60	PF#1	4.82	3.53	4	3.83	4.01	0.001962	0.74	12.03	47.53	0.35
10	50	PF#1	4.82	3.25	4		4	0.000168	0.3	28.1	57.36	0.11
10	40	PF#1	4.82	3.11	4		4	0.000052	0.18	40.7	57.54	0.06
10	30	PF#1	4.82	2.95	4		4	0.000035	0.17	46.85	62.7	0.05
10	20	PF#1	4.82	2.87	4		4	0.000024	0.15	53.57	64	0.05
10	10	PF#1	4.82	2.76	4	2.98	4	0.00002	0.15	58.29	71.91	0.04

DEVELOPED

HEC-RAS Plan: Plan 01 River: FP Reach: 10 Profile: PF#1

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
10	150	PF#1	4.82	3.73	3.98	4.33	7.24	1.000898	2	0.61	4.58	6.62
10	140	PF#1	4.82	3.66	4.08	4.26	4.67	0.071071	3.53	1.56	6.64	2
10	130	PF#1	4.82	3.58	4.26	4.18	4.38	0.007366	1.69	3.69	9.73	0.71
10	120	PF#1	4.82	3.5	4.18		4.3	0.007118	1.68	3.73	9.8	0.7
10	110	PF#1	4.82	3.42	4.12		4.23	0.006237	1.61	3.92	10.01	0.66
10	100	PF#1	4.82	3.35	4.07		4.17	0.005425	1.53	4.14	10.05	0.62
10	90	PF#1	4.82	3.27	4.04		4.12	0.004054	1.39	4.59	10.14	0.54
10	80	PF#1	4.82	3.19	4.02		4.08	0.002942	1.25	5.34	11.84	0.47
10	70	PF#1	4.82	3.12	4		4.05	0.002044	1.09	6.26	12.61	0.39
10	60	PF#1	4.82	3.04	4		4.03	0.001386	0.95	7.19	12.75	0.33
10	50	PF#1	4.82	2.96	4		4.01	0.000599	0.67	10.94	17.02	0.22
10	40	PF#1	4.82	2.88	4		4.01	0.000325	0.52	14.5	20.45	0.16
10	30	PF#1	4.82	2.81	4		4.01	0.000086	0.28	25.55	27.67	0.09
10	20	PF#1	4.82	2.73	4		4	0.000061	0.25	28.74	28.8	0.07
10	10	PF#1	4.82	2.65	4	3.18	4	0.00012	0.36	23.16	31.34	0.1

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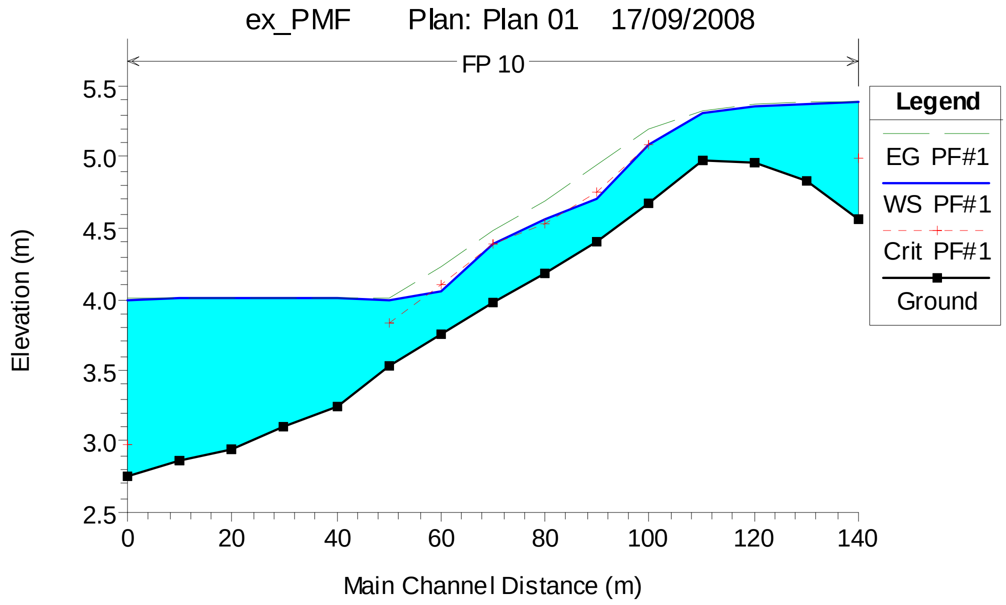

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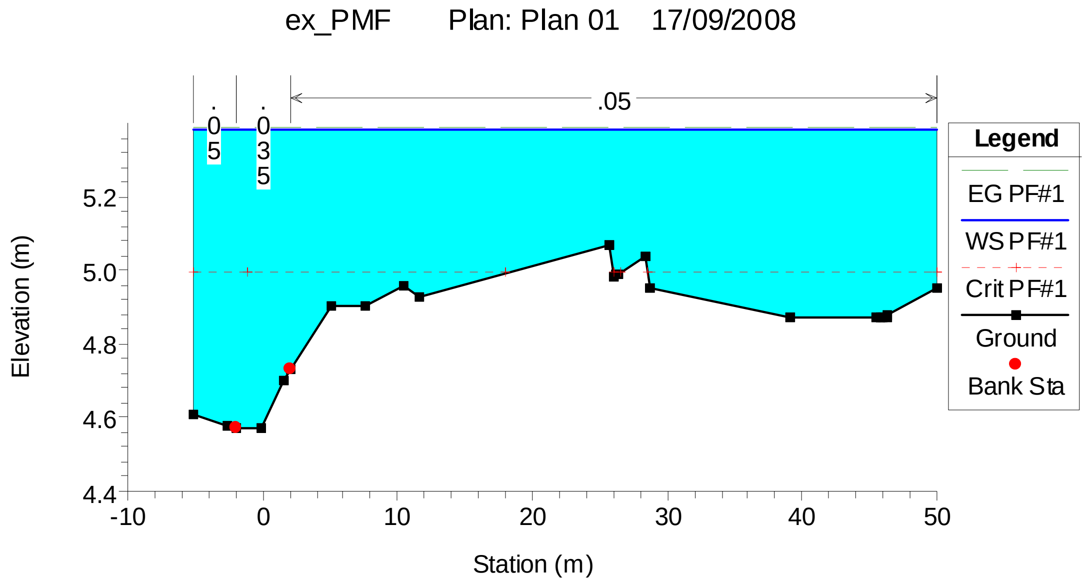

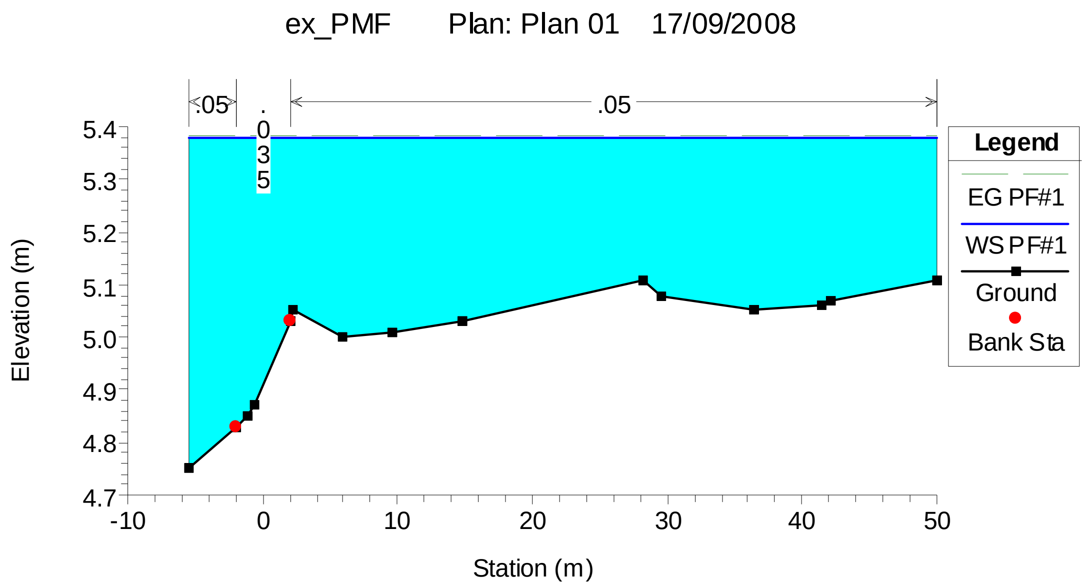
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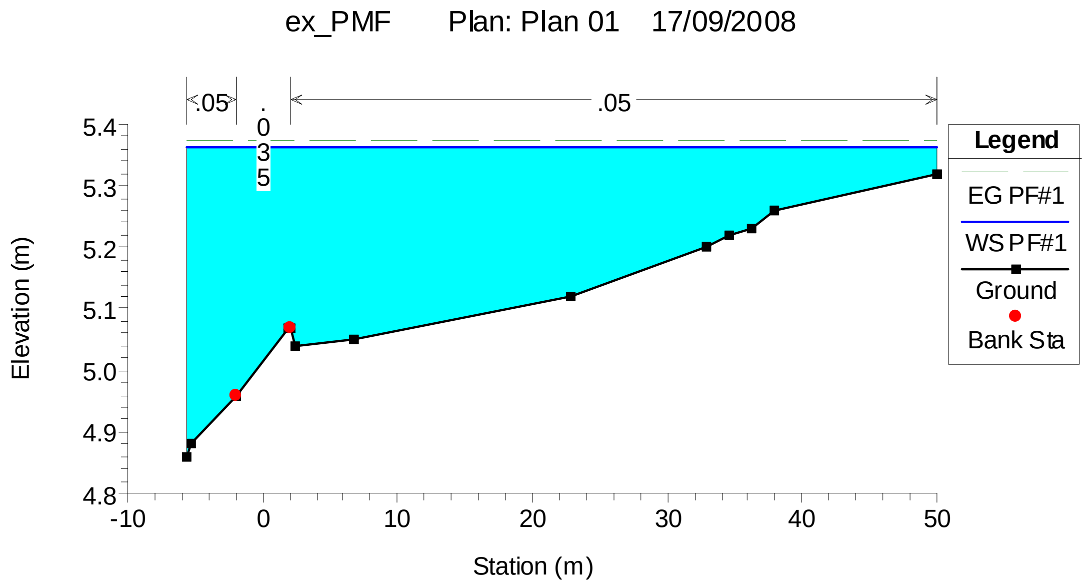
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Bank Sta
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Station (m)
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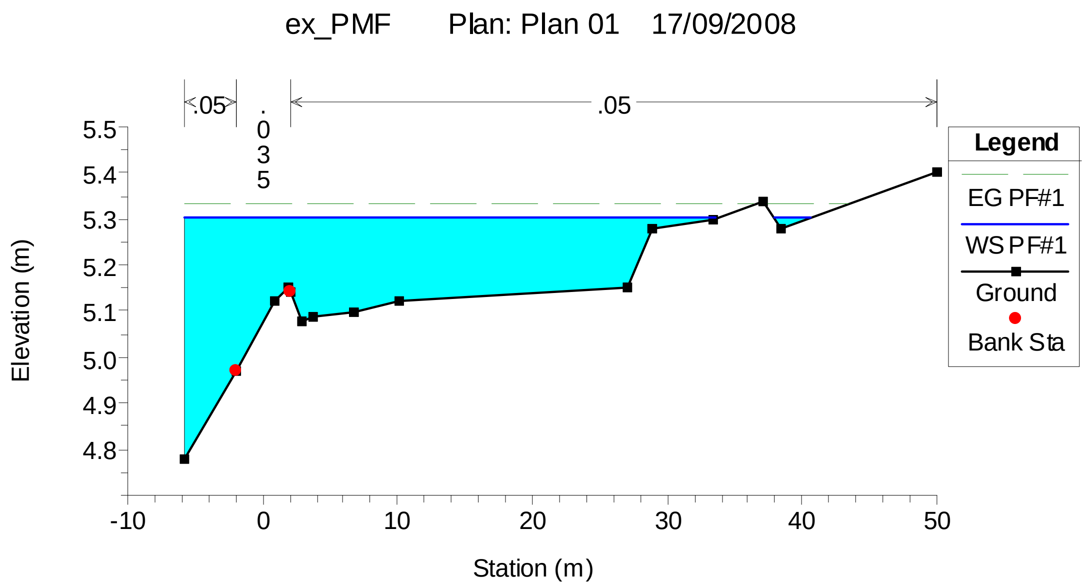
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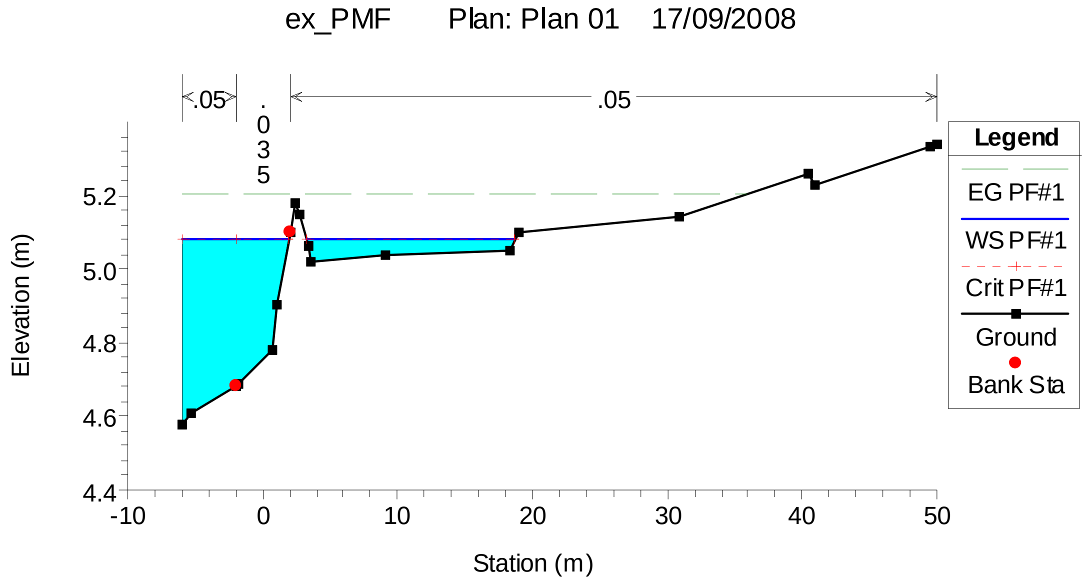
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Bank Sta
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Station (m)
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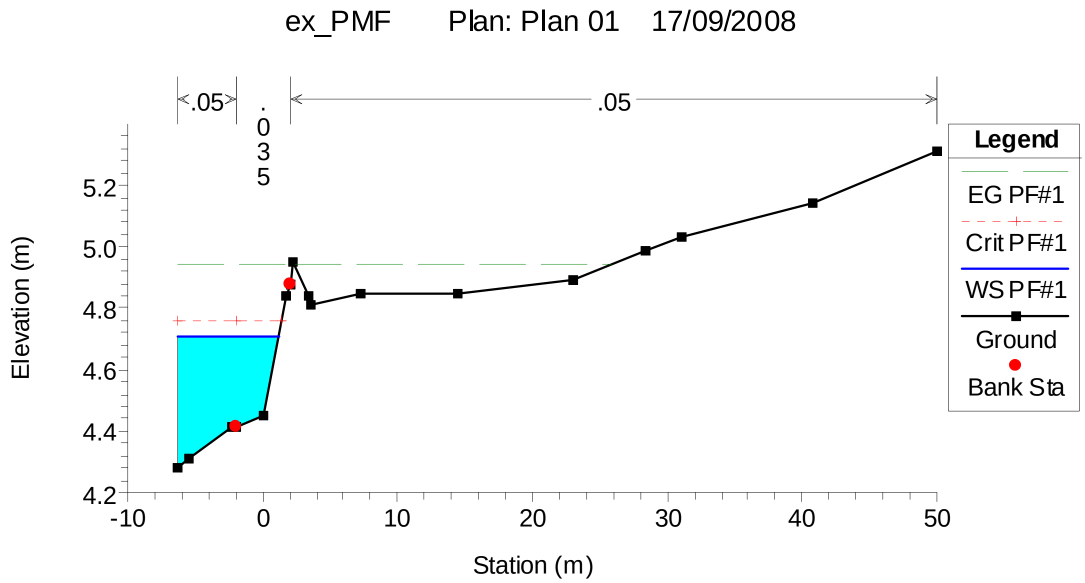
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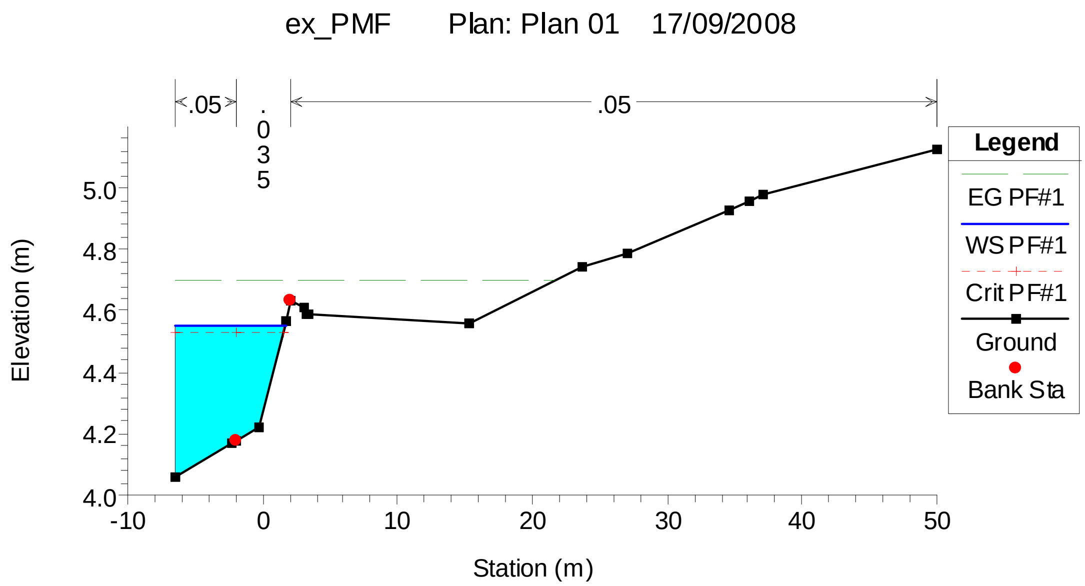
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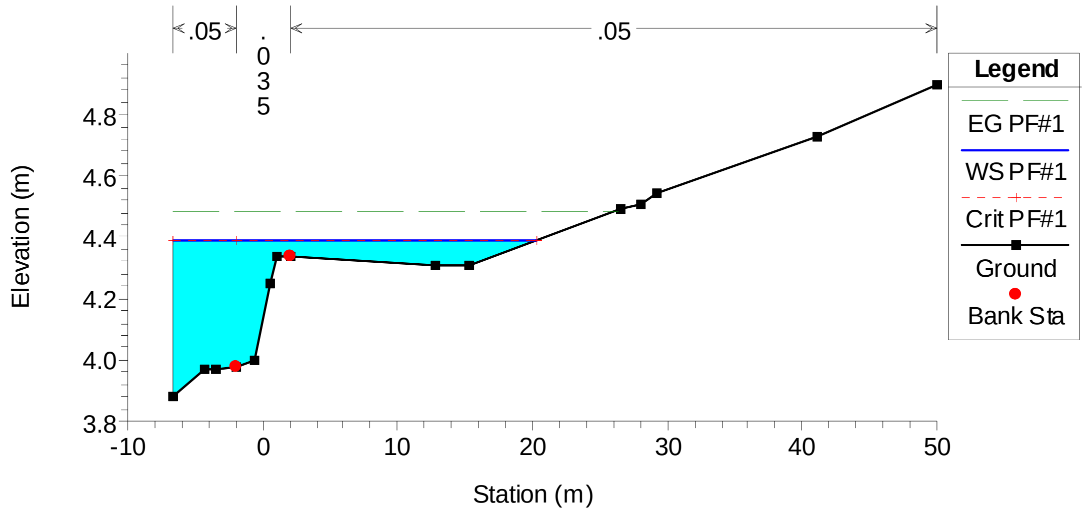

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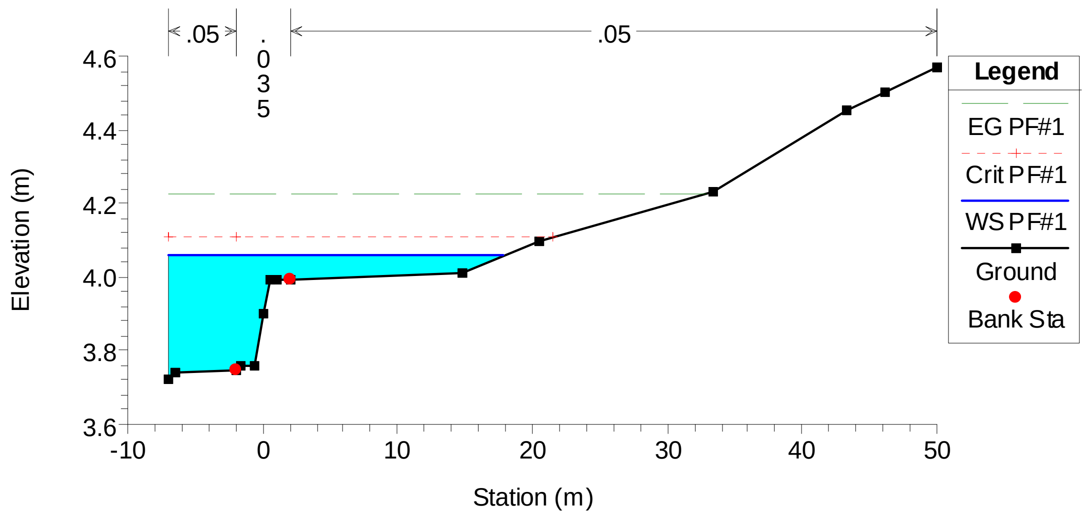

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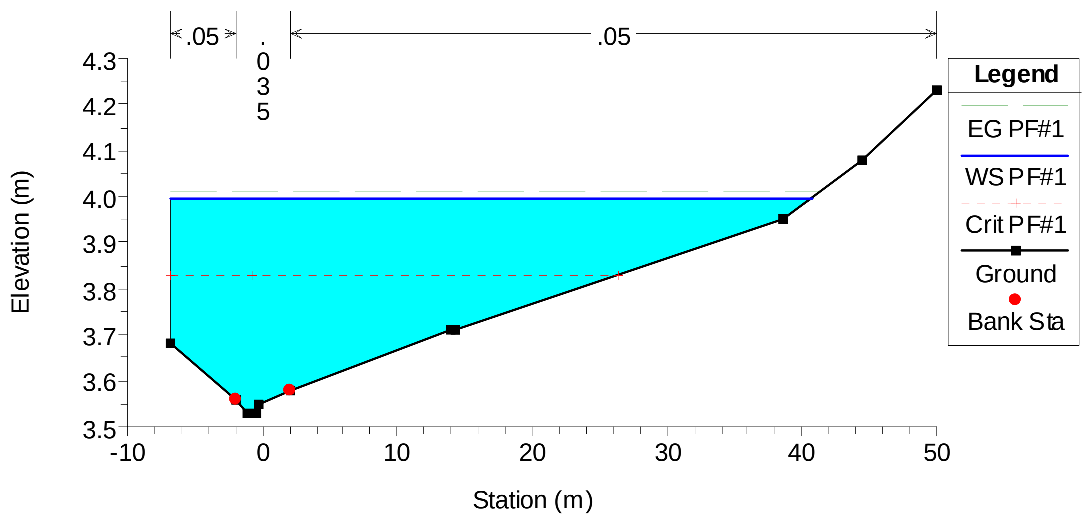

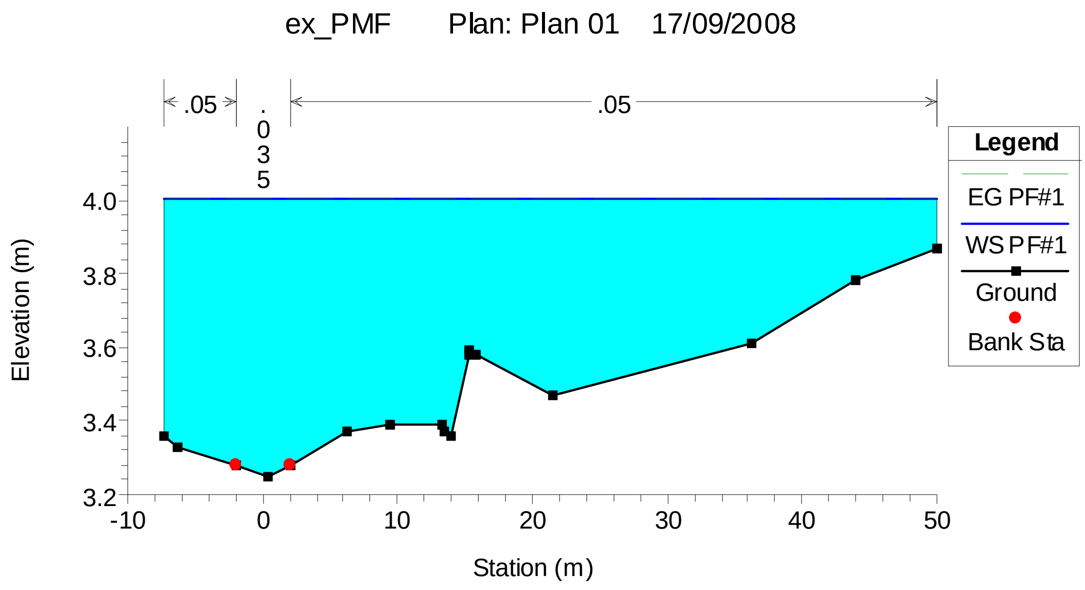
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Station (m)
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EG PF#1
WS PF#1
Ground
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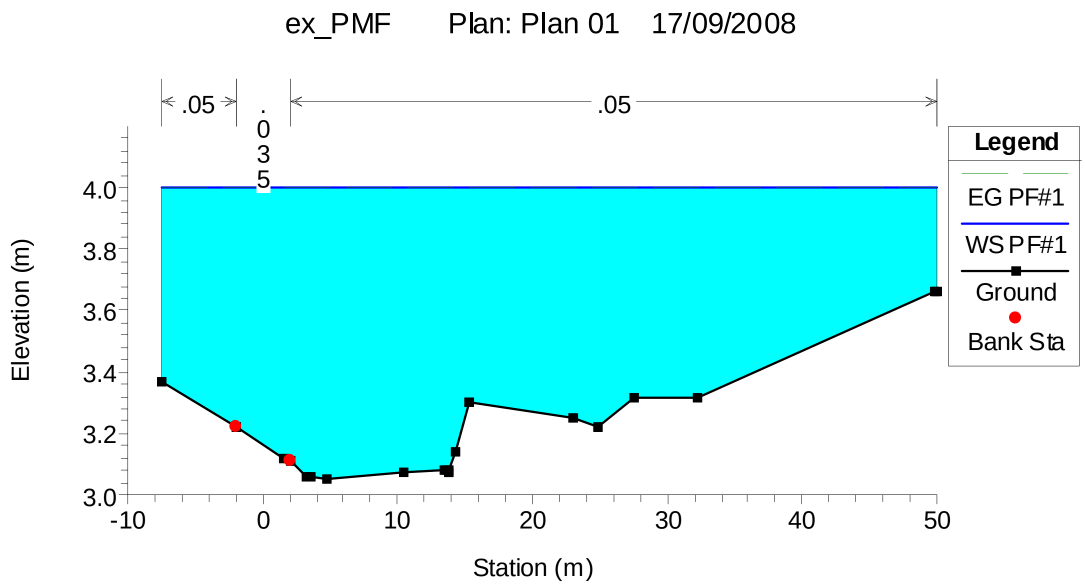
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Station (m)
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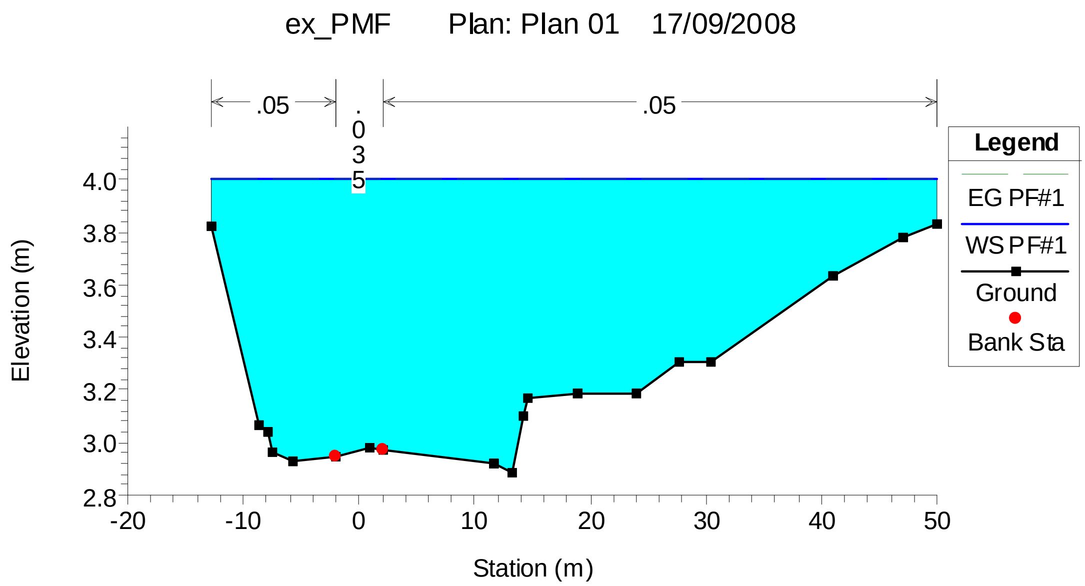
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Station (m)
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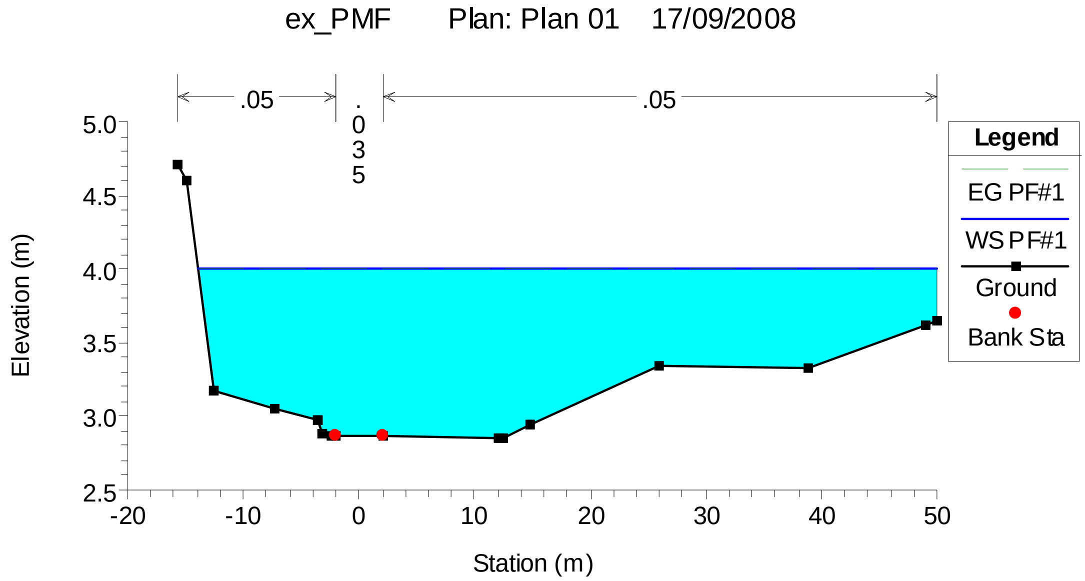
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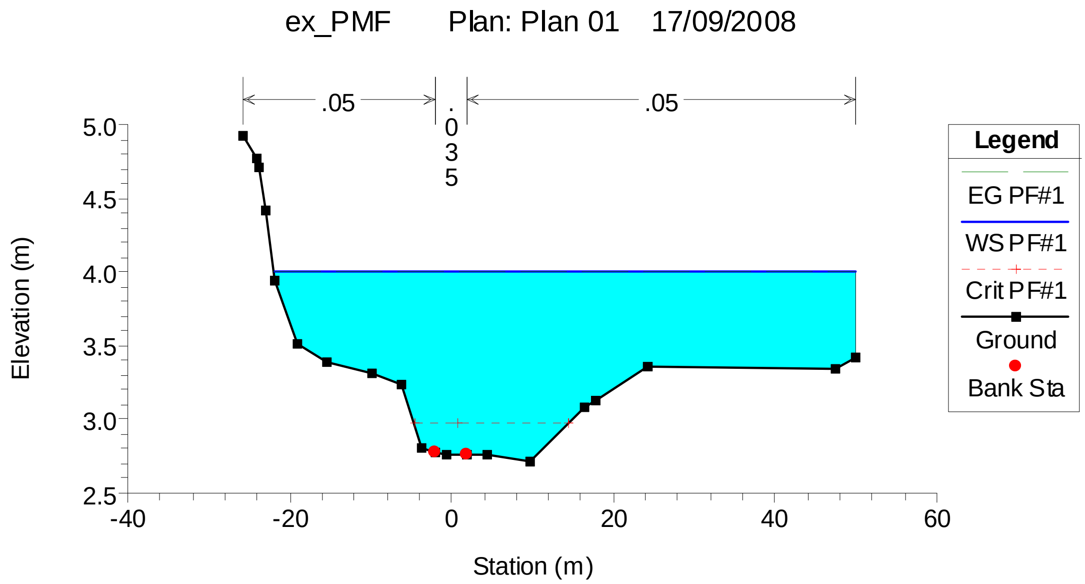
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.05
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.05
Legend
EG PF#1
WS PF#1
Crit PF#1
Ground
Bank Sta
Elevation (m)
Station (m)
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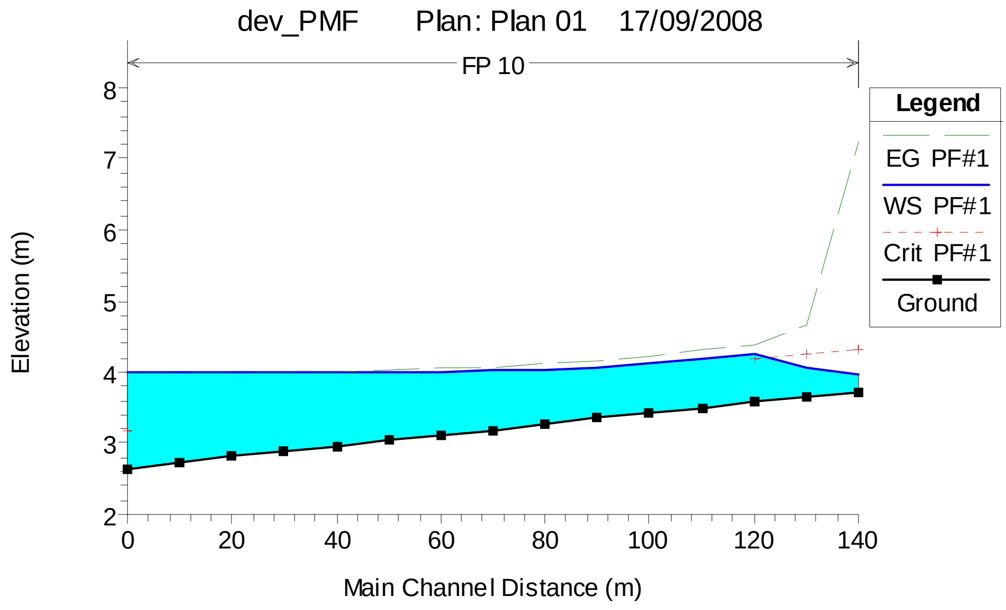
4.5
4.0
3.5
3.0
2.5
-40
-20
0
20
40
60

Developed

Long section



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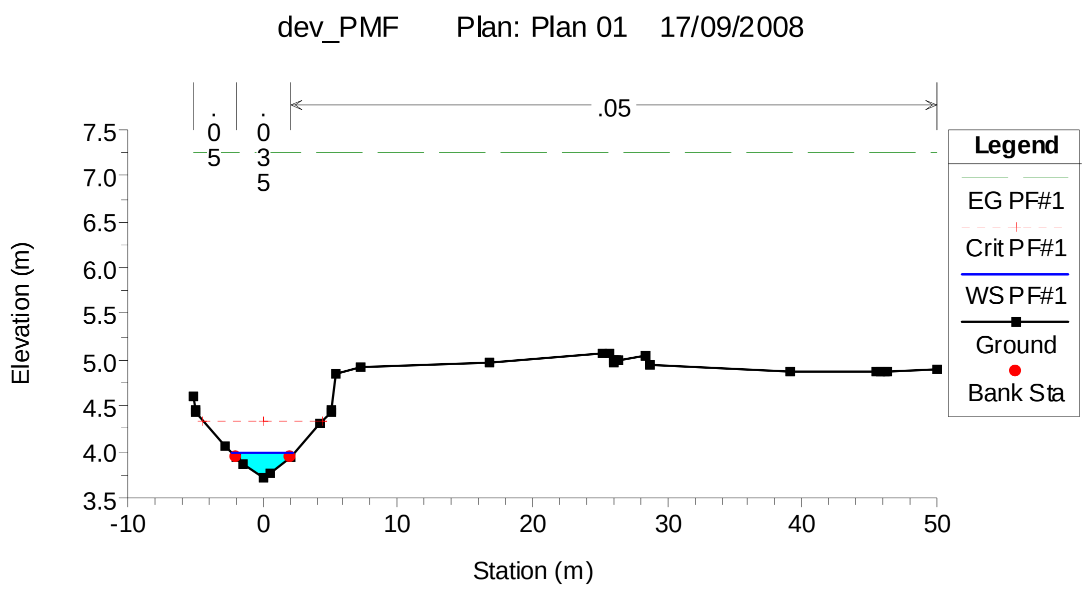

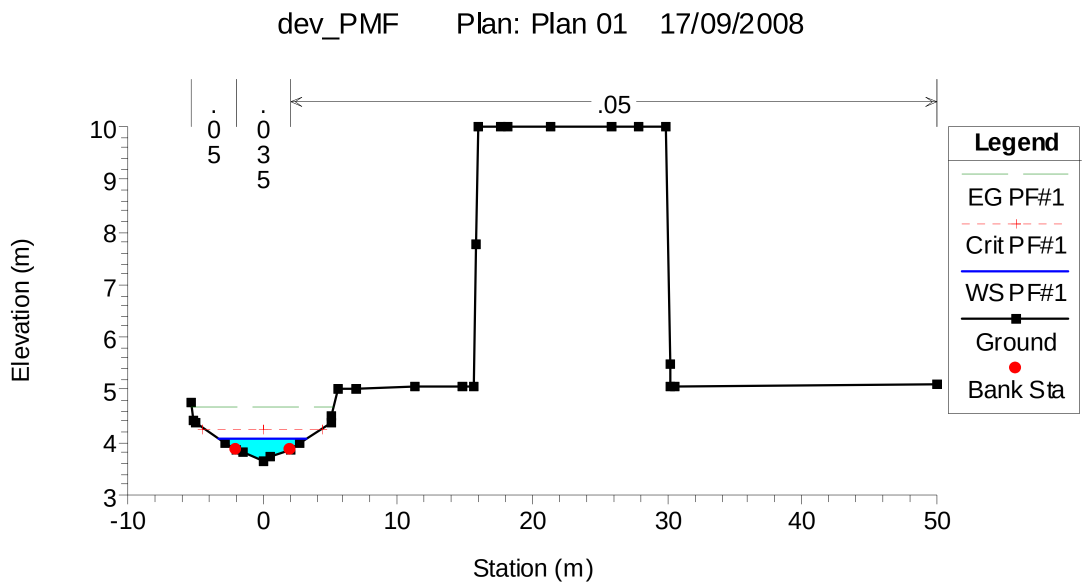
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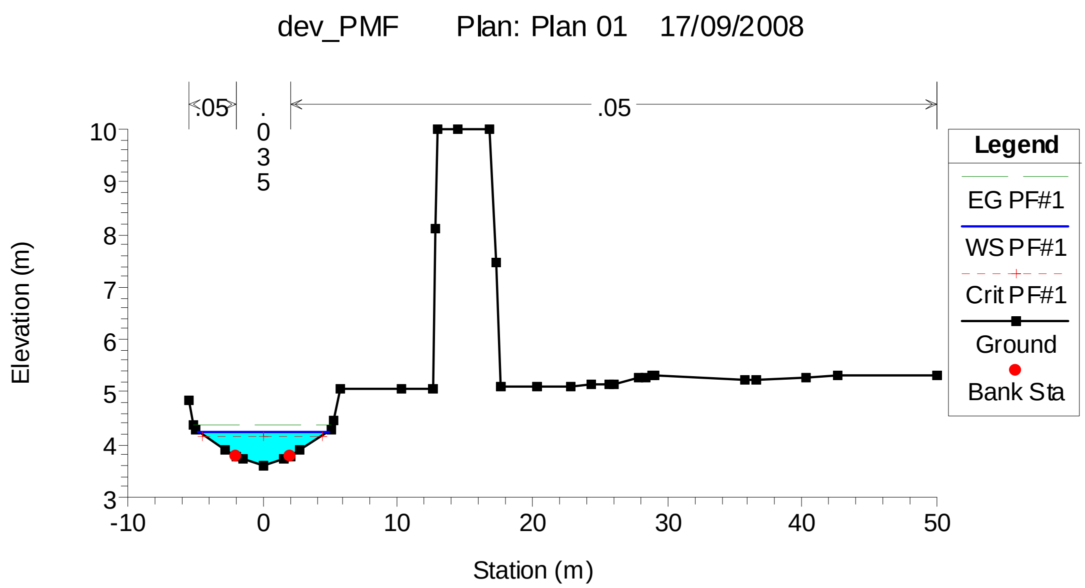
Elevation (m)
Station (m)
Legend
EG PF#1
Crit PF#1
WS PF#1
Ground
Bank Sta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.035
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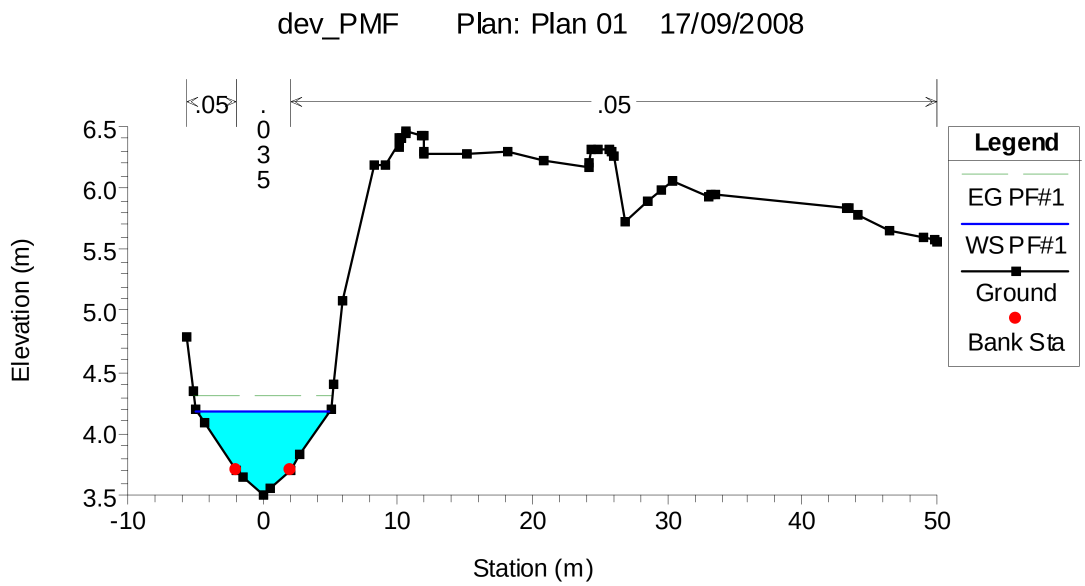
Elevation (m)
Station (m)
Legend
EG PF#1
WS PF#1
Crit PF#1
Ground
Bank Sta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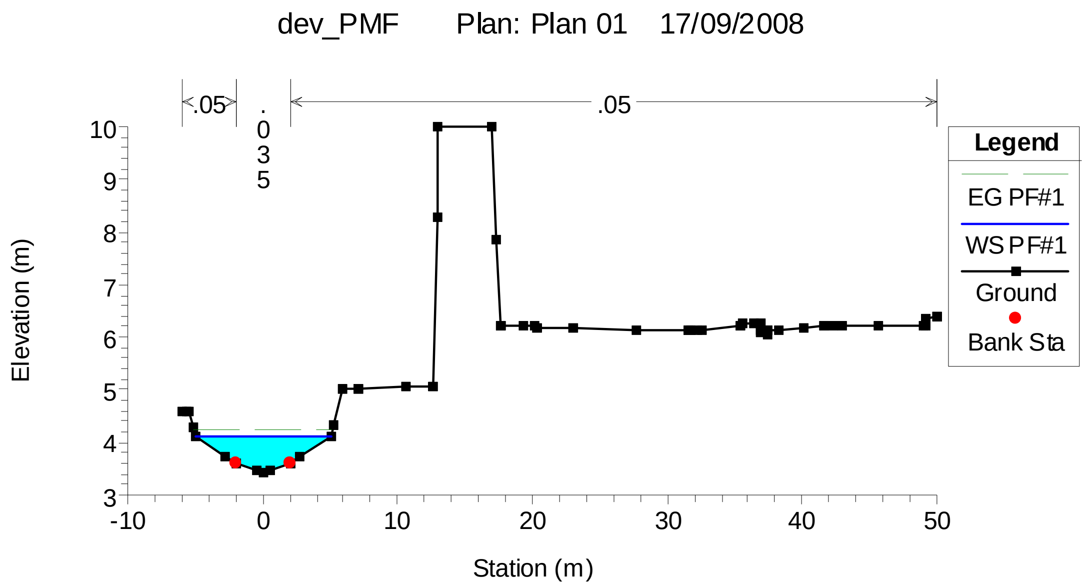
Elevation (m)
Station (m)
Legend
EG PF#1
WS PF#1
Ground
Bank Sta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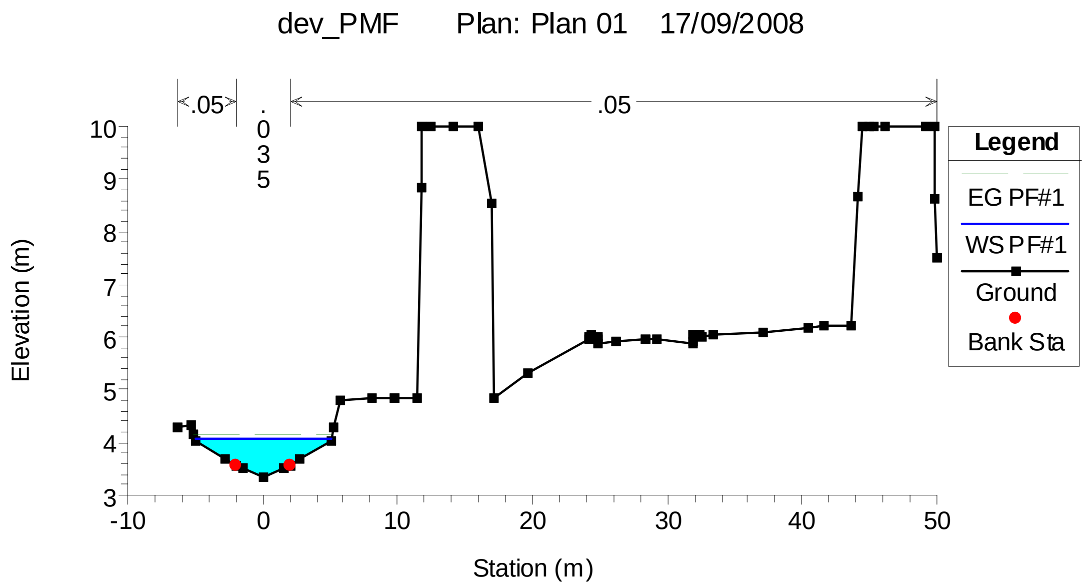
.035
.05
Elevation (m)
Station (m)
Legend
EG PF#1
WS PF#1
Ground
Bank Sta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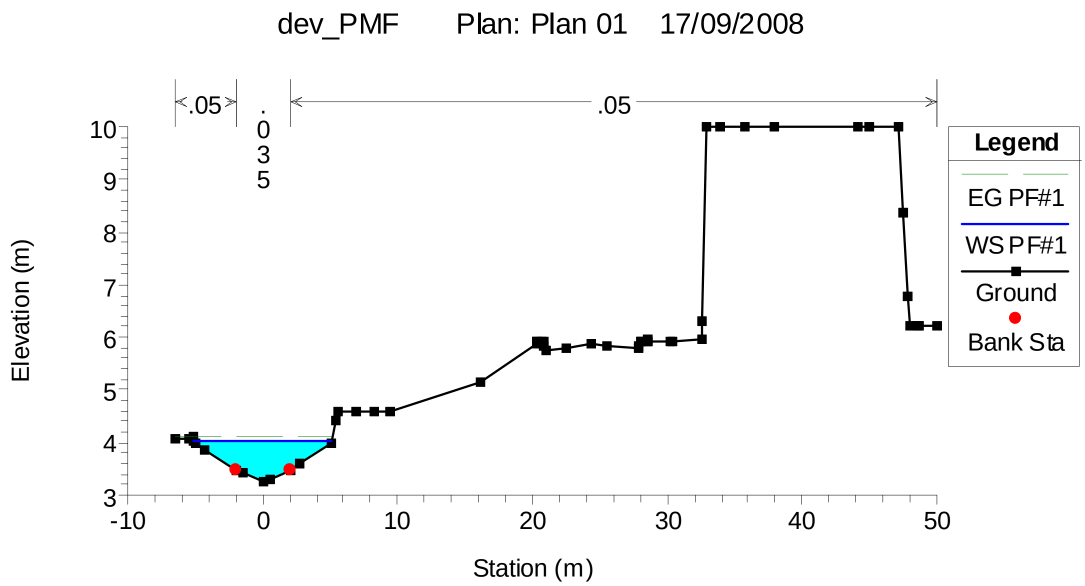
Elevation (m)
Station (m)
Legend
EG PF#1
WS PF#1
Ground
Bank Sta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.035
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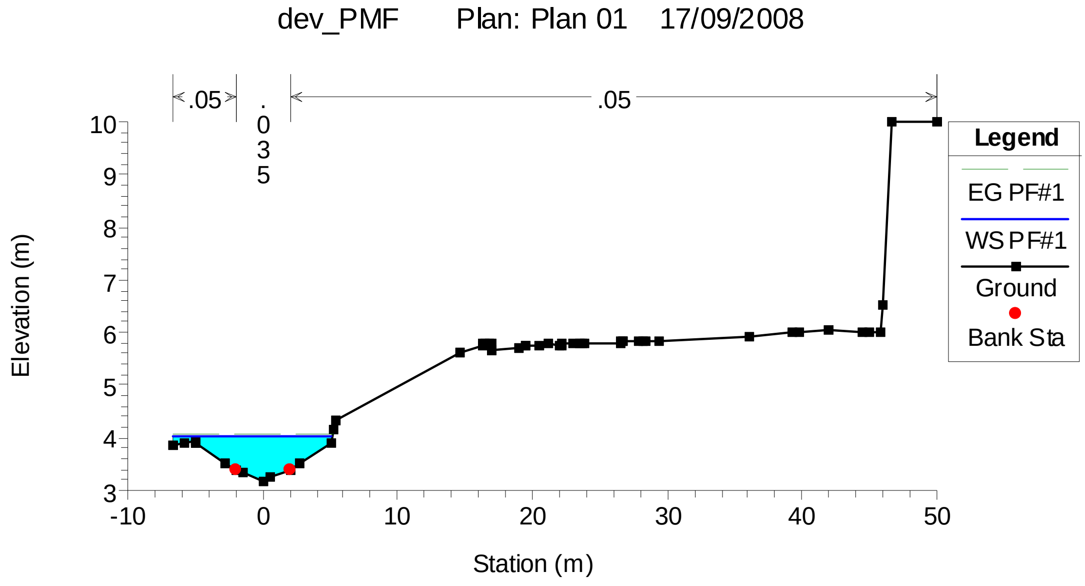
Elevation (m)
Station (m)
Legend
EG PF#1
WS PF#1
Ground
Bank Sta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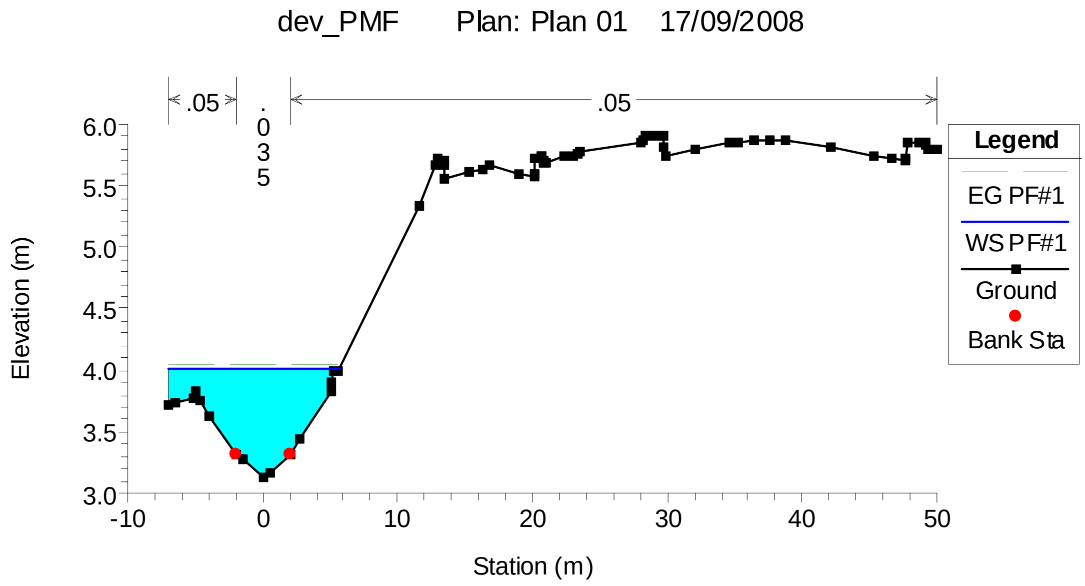
.035
.05
Legend
EG PF#1
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)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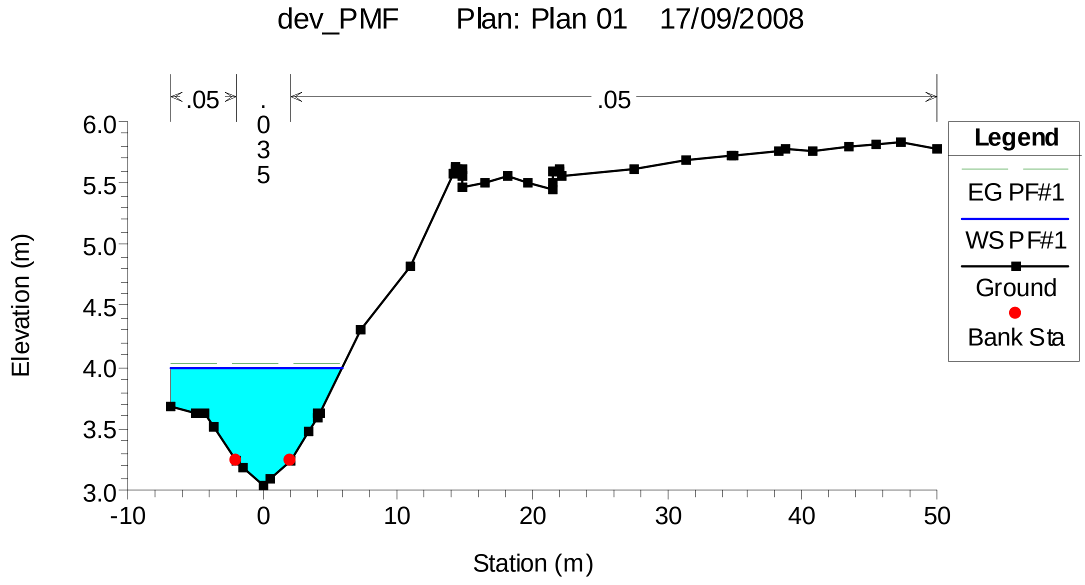
.035
.05
Legend
EG PF#1
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)


dev_PMF Plan: Plan 01 17/09/2008
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.035
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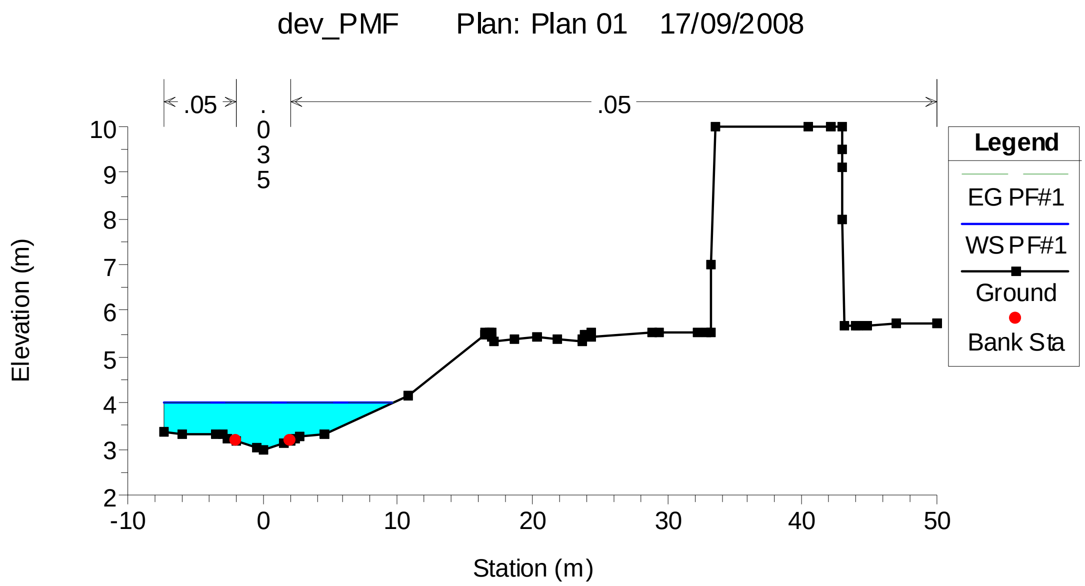
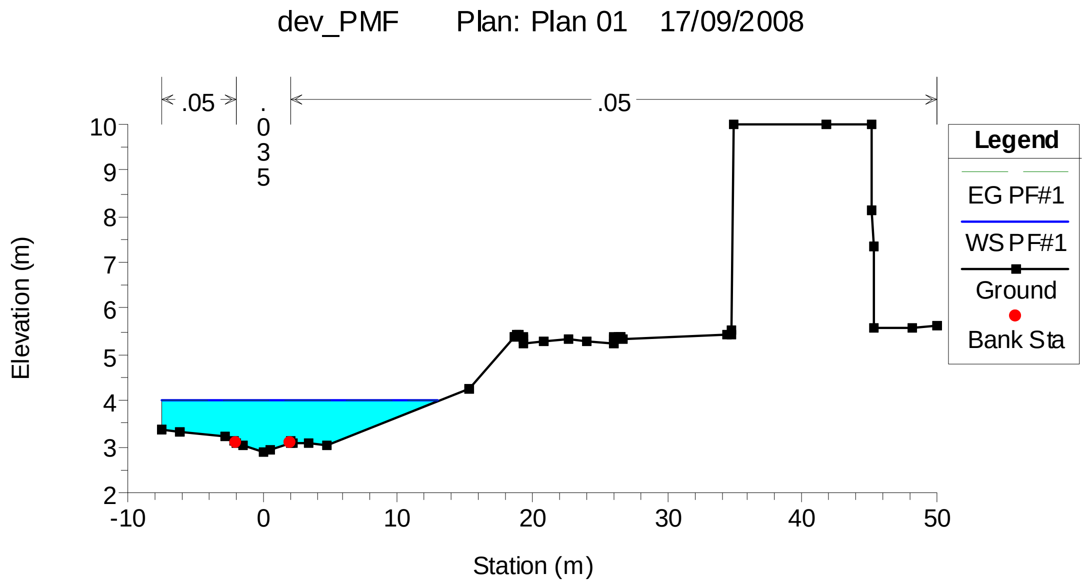
Legend
EG PF#1
WS PF#1
Ground
Bank Sta
Elevation (m)
Station (m)


dev_PMF Plan: Plan 01 17/09/2008
.05
.035
.05
Elevation (m)
Station (m)
Legend
EG PF#1
WS PF#1
Ground
Bank Sta


dev_PMF Plan: Plan 01 17/09/2008
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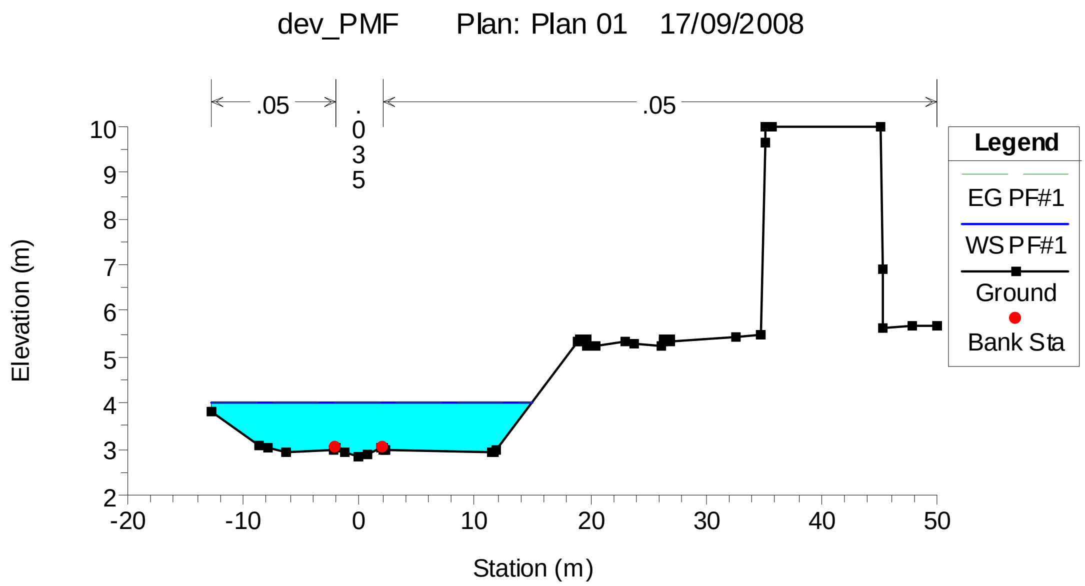
.035
.05
Elevation (m)
Station (m)
Legend
EG PF#1
WS PF#1
Ground
Bank Sta


dev_PMF Plan: Plan 01 17/09/2008
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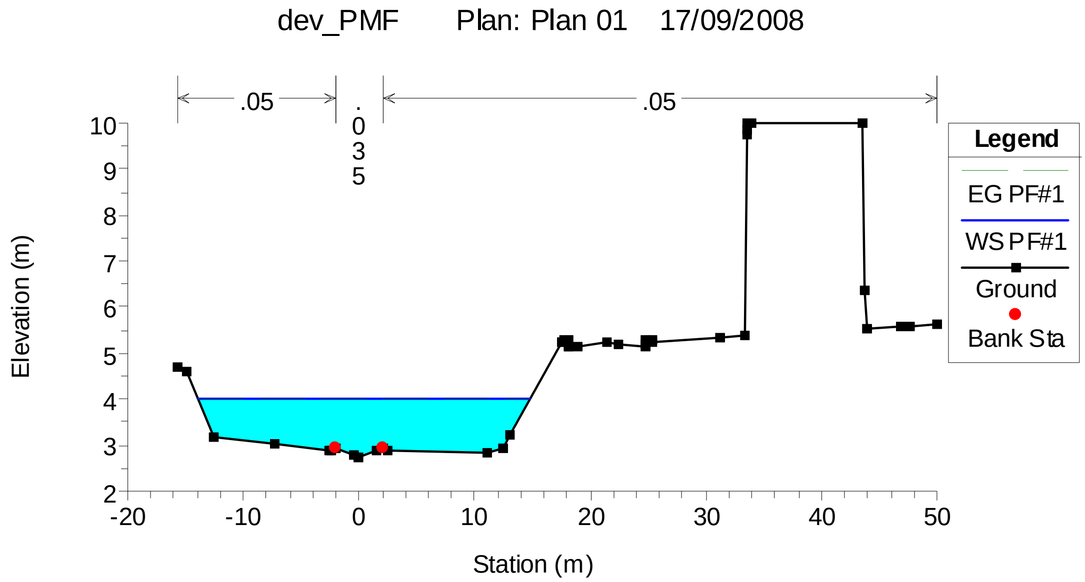
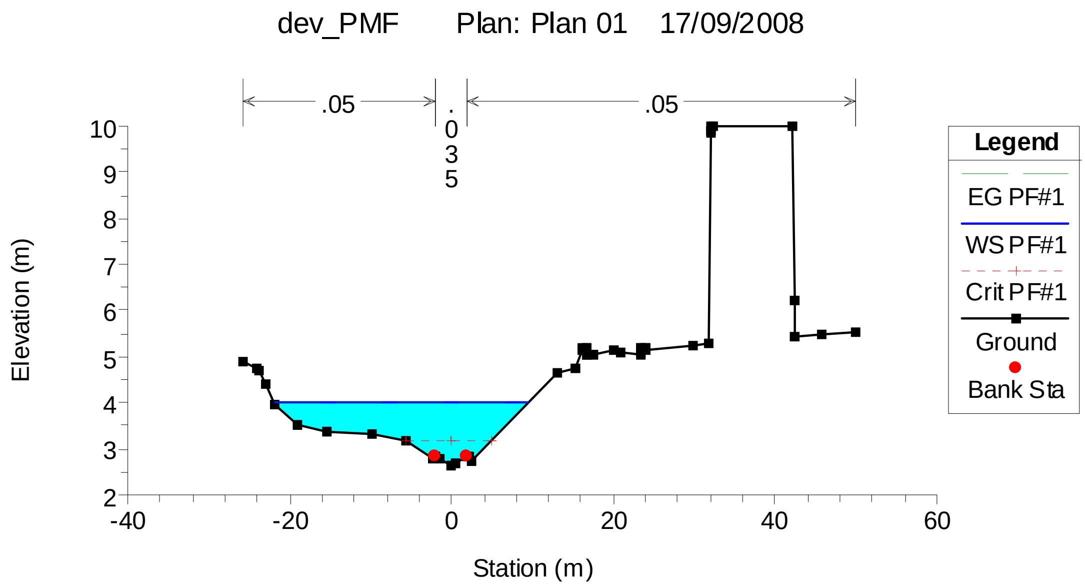
.035
.05
Elevation (m)
Station (m)
Legend
EG PF#1
WS PF#1
Ground
Bank Sta


dev_PMF Plan: Plan 01 17/09/2008
.05
.035
.05
Elevation (m)
Station (m)
Legend
EG PF#1
WS PF#1
Ground
Bank Sta


dev_PMF Plan: Plan 01 17/09/2008
.05
.035
.05
Elevation (m)
Station (m)
Legend
EG PF#1
WS PF#1
Crit PF#1
Ground
Bank Sta

APPENDIX D

DRAINS RESULTS

DATA

PIT / NODE DETAILS Version 9

Name	Type	Family	Size	Ponding Volume (cu.m)	Pressure Change Coeff. Ku	Surface Elev (m)	Max Pond Depth (m)	Base Inflow (cu.m/s)
Creek	Node					18		0
N183	Node							0
N193	Node					22		0
N278	Node							0
N282	Node					22		0
N287	Node							0
N293	Node							0
N309	Node							0
N358	Node							0
N359	Node							0
N361	Node							0
N362	Node							0
N368	Node							0
N369	Node							0

DETENTION BASIN DETAILS

Name	Elev	Volume	Init Vol. (cu	Outlet Typ	K	Dia(mm)	Centre RL	Pit Family
Basin A	2.57	1	0	Orifice		328	2.83	
	3.17	5						
	4.17	1750						
	5.17	4000						
Basin2	2.51	1	0	Orifice		330	2.77	
	3.11	10						
	4.6	1030						
	4.65	2000						

SUB-CATCHMENT DETAILS

Name	Pit or Node	Total Area	Impervious Area	Avg Slope(%)	Hydrological Model
Exist Cat 1	N183	2.92	3.9	5	RAFTS
Exist Cat 2	N278	2.209	26	5	RAFTS
Predev Cat	N287	2.92	1	1.4	RAFTS
Predev Cat	N293	2.209	1	1.4	RAFTS
Cat 2	N358	1.34	20	0.5	RAFTS
Cat 2 roof	N359	0.86	90	0.5	RAFTS
Cat 1	N361	1.978	20	0.5	RAFTS
Cat 1 road	N362	1.161	90	0.5	RAFTS

PIPE DETAILS

Name	From	To	Length (m)	U/S IL (m)	D/S IL (m)	Slope (%)	Type	Dia (mm)
Pipe56	Basin A	N193	30	2.57	2.27	1	Concrete, u	525
P69	Basin2	N282	30	2.51	2.21	1	Concrete, u	525

DETAILS of SERVICES CROSSING PIPES

Pipe	Chg (m)	Bottom Elev (m)	Height of S (m)	Chg (m)	Bottom Elev (m)	Height of S (m)	Chg (m)	Bottom Elev (m)

CHANNEL DETAILS

Name	From	To	Type	Length (m)	U/S IL (m)	D/S IL (m)	Slope (%)	Base Widtl (m)

OVERFLOW ROUTE DETAILS

Name	From	To	Travel Time (min)	Spill Level (m)	Crest Length (m)	Weir Coeff. C	Cross Section	Safe Depth Major Stor (m)
OF181	N183	N368	1				Pathway 4ı	0.3
OF175	Basin A	N193	1	4.18	5	1.7	Overflow	0.3
OF179	N193	N309	1				Pathway 4ı	0.3
OF220	N278	N368	1				Pathway 4ı	0.3
OF230	Basin2	N282	1	4.61	5	1.7	Overflow	0.3
OF235	N282	N309	1				Pathway 4ı	0.3
OF241	N287	N369	1				Overflow	0.3
OF244	N293	N369	1				Overflow	0.3
OF252	N309	Creek	1				Overflow	0.3
OF255	N358	Basin2	1				Overflow	0.3
OF257	N359	Basin2	1				Overflow	0.3
OF259	N361	Basin A	1				Overflow	0.3
OF260	N362	Basin A	1				Overflow	0.3
Exist of	N368	Creek	1				Overflow	0.3
Pre dev OF	N369	Creek	1				Overflow	0.3

RESULTS

DRAINS results prepared 13 August, 2010 from Version 2010.01

PIT / NODE DETAILS Version 8

Name	Max HGL	Max Pond HGL	Max Surfac Flow Arrivi (cu.m/s)	Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint
N193	2.53		0				
N282	2.49		0				

SUB-CATCHMENT DETAILS

Name	Max Flow (cu.m/s)	Due to Storm
Exist Cat 1	0.941	AR&R 100 year, 2 hours storm, average 63 mm/h, Zone 1
Exist Cat 2	1.2	AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1
Predev Cat	0.505	AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1
Predev Cat	0.404	AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1
Cat 2	0.395	AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1
Cat 2 roof	0.585	AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1
Cat 1	0.538	AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1

Cat 1 road 0.776 AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1

Outflow Volumes for Total Catchment (3.17 impervious + 12.4 pervious = 15.5 total ha)

Storm	Total Rainf	Total Runo	Imperviou	Pervious Runoff
	cu.m	cu.m (Runo	cu.m (Runo	cu.m (Runoff %)
AR&R 100	3445.5	1620.01 (4	128.39 (18	1491.62 (54.4%)
AR&R 100	5466.17	3553.51 (6	451.65 (40	3101.86 (71.3%)
AR&R 100	6994.63	4898.54 (7	577.60 (40	4320.94 (77.6%)
AR&R 100	8238.11	5962.98 (7	649.91 (38	5313.07 (81.0%)
AR&R 100	9326.17	6945.24 (7	766.60 (40	6178.64 (83.2%)
AR&R 100	10336.5	7885.06 (7	902.60 (42	6982.45 (84.8%)
AR&R 100	12706.9	10072.63 (	1200.20 (4	8872.43 (87.7%)
AR&R 100	14766.43	12436.62 (	1925.47 (6	10511.15 (89.4%)
AR&R 100	17509.87	16643.88 (	3966.35 (1	12677.53 (90.9%)
AR&R 100	19584.95	16509.35 (	2168.25 (5	14341.10 (92.0%)
AR&R 100	22849.11	13693.78 (	-3241.22 (-	16935.00 (93.1%)

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm
Pipe56	0.265	2.4	2.834	2.534	AR&R 100 year, 1.5 hours storm, average 75
P69	0.294	2.5	2.789	2.489	AR&R 100 year, 1.5 hours storm, average 75

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Chainage (m)	Max HGL (m)	Due to Storm

OVERFLOW ROUTE DETAILS

Name	Max Q U/S	Max Q D/S	Safe Q	Max D	Max DxV	Max Width	Max V	Due to Stor
OF181	0.941	0.941	1.931	0.187	0.32	4	1.72	AR&R 100
OF175	0	0	5.556	0	0	0	0	
OF179	0.265	0.265	1.931	0.113	0.12	4	1.05	AR&R 100
OF220	1.2	1.2	1.931	0.209	0.39	4	1.88	AR&R 100
OF230	0	0	5.556	0	0	0	0	
OF235	0.294	0.294	1.931	0.118	0.13	4	1.09	AR&R 100
OF241	0.505	0.505	5.556	0.089	0.09	7.57	1.05	AR&R 100
OF244	0.404	0.404	5.556	0.08	0.08	7.2	0.99	AR&R 100
OF252	0.556	0.556	5.556	0.094	0.1	7.74	1.08	AR&R 100
OF255	0.395	0.395	5.556	0.079	0.08	7.18	0.97	AR&R 100
OF257	0.585	0.585	5.556	0.096	0.11	7.83	1.1	AR&R 100
OF259	0.538	0.538	5.556	0.092	0.1	7.67	1.08	AR&R 100
OF260	0.776	0.776	5.556	0.11	0.13	8.37	1.2	AR&R 100
Exist of	2.037	2.037	5.556	0.175	0.28	10.71	1.6	AR&R 100
Pre dev OF	0.908	0.908	5.556	0.119	0.15	8.72	1.26	AR&R 100

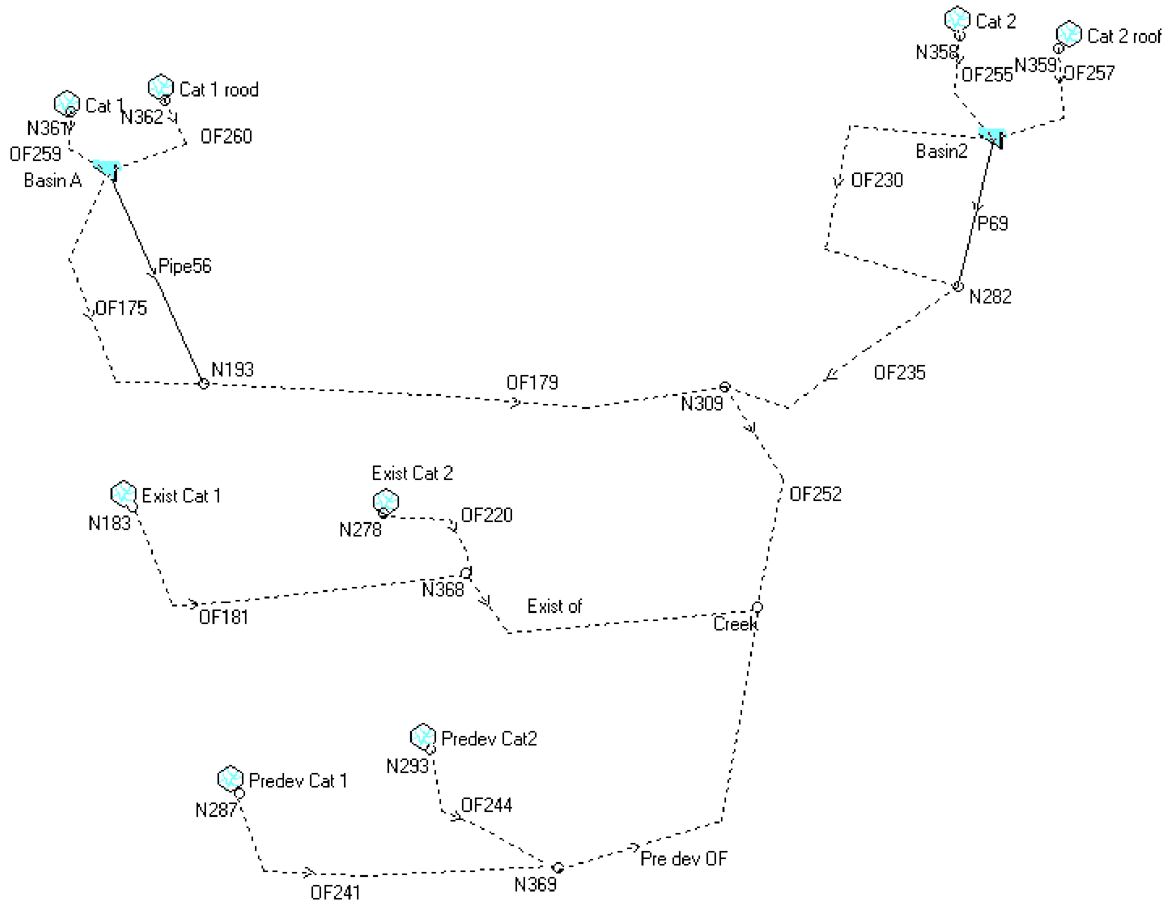
DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level

Basin A	4.18	1773.2	0.265	0.265	0
Basin2	4.41	901	0.294	0.294	0

CONTINUITY CHECK for AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1

Node	Inflow (cu.m)	Outflow (cu.m)	Storage Ch (cu.m)	Difference %
Creek	16632.2	16632.2	0	0
N183	3163.83	3163.83	0	0
Basin A	3388.06	3388.14	2.34	-0.1
N193	3388.14	3388.1	0	0
N278	2378.51	2378.51	0	0
Basin2	2365.99	2363.23	3.5	0
N282	2363.23	2363.21	0	0
N287	3054.88	3054.88	0	0
N293	2296.15	2296.15	0	0
N309	5749.08	5748.99	0	0
N358	1485.13	1485.13	0	0
N359	881.71	881.71	0	0
N361	2161.02	2161.02	0	0
N362	1228.66	1228.66	0	0
N368	5540.21	5540.16	0	0
N369	5348.89	5348.9	0	0


Cat 2
Cat 2 roof
N358
OF255
N359
OF257
Basin2
OF230
P69
N282
OF235
Cat 1
Cat 1 rood
N361
N362
OF260
OF259
Basin A
Pipe56
OF175
N193
OF179
N309
OF252
Exist Cat 1
N183
Exist Cat 2
N278
OF220
N368
Exist of
Creek
OF181
Predev Cat2
N293
OF244
Predev Cat 1
N287
OF241
N369
Pre dev OF

APPENDIX E

MUSIC RESULTS

Basin A

Existing

X08066_100806_exv4 - Ex Cat 1 - All Data Statistics

Outflow	mean	standard de	median	maximum	minimum	10 percentil	90 percentil
Flow (cubic metres/sec)	4.66E-04	7.23E-03	1.53E-04	0.784	2.22E-06	1.49E-05	5.80E-04
TSS Concentration (mg/L)	25.5	1.61	25.1	35	25.1	25.1	25.1
Log [TSS] (mg/L)	1.4	2.40E-02	1.4	1.54	1.4	1.4	1.4
TP Concentration (mg/L)	0.131	5.19E-03	0.132	0.132	0.1	0.132	0.132
Log [TP] (mg/L)	-0.884	1.92E-02	-0.88	-0.88	-1	-0.88	-0.88
TN Concentration (mg/L)	1.18	3.03E-02	1.19	1.19	1	1.19	1.19
Log [TN] (mg/L)	7.15E-02	1.19E-02	7.40E-02	7.40E-02	2.13E-05	7.40E-02	7.40E-02
TSS Load (kg/6 Minutes)	5.11E-03	9.11E-02	1.38E-03	9.87	2.01E-05	1.34E-04	5.25E-03
TP Load (kg/6 Minutes)	1.92E-05	2.60E-04	7.26E-06	2.82E-02	1.05E-07	7.05E-07	2.74E-05
TN Load (kg/6 Minutes)	1.82E-04	2.60E-03	6.53E-05	0.282	9.49E-07	6.34E-06	2.47E-04
Gross Pollutant Load (kg/6 Minu	9.94E-04	1.40E-02	0	1.03	0	0	0

Flow (ML/yr)	14.7
Total Suspended Solids (kg/yr)	448
Total Phosphorus (kg/yr)	1.68
Total Nitrogen (kg/yr)	16
Gross Pollutants (kg/yr)	87.1

Developed No Treatment

X08066_100806_dev_ notreatv4 - Cat 1 - All Data Statistics

Inflow	mean	standard de	median	maximum	minimum	10 percentil	90 percentil
Flow (cubic metres/sec)	5.95E-04	2.42E-03	3.40E-05	7.13E-02	0	9.14E-09	1.30E-03
TSS Concentration (mg/L)	29.1	33.4	12.6	100	0	12.6	98.9
Log [TSS] (mg/L)	1.29	0.357	1.1	2	1.06	1.1	2
TP Concentration (mg/L)	0.175	6.38E-02	0.151	0.3	0	0.151	0.298
Log [TP] (mg/L)	-0.761	0.116	-0.82	-0.523	-0.861	-0.82	-0.525
TN Concentration (mg/L)	1.91	0.395	2.09	2.09	0	1.5	2.09
Log [TN] (mg/L)	0.291	5.44E-02	0.32	0.32	0.176	0.178	0.32
TSS Load (kg/Day)	4.55	20.8	3.74E-02	616	0	9.32E-06	10.3
TP Load (kg/Day)	1.44E-02	6.24E-02	4.50E-04	1.85	0	1.12E-07	3.20E-02
TN Load (kg/Day)	8.10E-02	0.315	6.10E-03	9.25	0	1.55E-06	0.175
Gross Pollutant Load (kg/Day)	1.06	2.57	0	19.2	0	0	4.82
Outflow	mean	standard de	median	maximum	minimum	10 percentil	90 percentil
Flow (cubic metres/sec)	5.95E-04	2.42E-03	3.40E-05	7.13E-02	0	9.14E-09	1.30E-03
TSS Concentration (mg/L)	29.1	33.4	12.6	100	0	12.6	98.9
Log [TSS] (mg/L)	1.29	0.357	1.1	2	1.06	1.1	2
TP Concentration (mg/L)	0.175	6.38E-02	0.151	0.3	0	0.151	0.298
Log [TP] (mg/L)	-0.761	0.116	-0.82	-0.523	-0.861	-0.82	-0.525
TN Concentration (mg/L)	1.91	0.395	2.09	2.09	0	1.5	2.09
Log [TN] (mg/L)	0.291	5.44E-02	0.32	0.32	0.176	0.178	0.32
TSS Load (kg/Day)	4.55	20.8	3.74E-02	616	0	9.32E-06	10.3
TP Load (kg/Day)	1.44E-02	6.24E-02	4.50E-04	1.85	0	1.12E-07	3.20E-02
TN Load (kg/Day)	8.10E-02	0.315	6.10E-03	9.25	0	1.55E-06	0.175
Gross Pollutant Load (kg/Day)	1.06	2.57	0	19.2	0	0	4.82

Flow (ML/yr)	18.8	18.8	0
Total Suspended Solids (kg/yr)	1.66E+03	1.66E+03	0
Total Phosphorus (kg/yr)	5.26	5.26	0
Total Nitrogen (kg/yr)	29.6	29.6	0
Gross Pollutants (kg/yr)	386	386	0

Developed with Treatment

X08066_100806_dev_treatmentv4 - Bio-Retention (V3 Upgrade) - All Data Statistics

Inflow	mean	standard de	median	maximum	minimum	10 percentil	90 percentil
Flow (cubic metres/sec)	5.01E-04	2.36E-03	3.56E-05	7.03E-02	0	1.00E-08	7.57E-04
TSS Concentration (mg/L)	6.62	7.35	3.78	30	0	3.78	17.8
Log [TSS] (mg/L)	0.737	0.29	0.577	1.48	0.577	0.577	1.3
TP Concentration (mg/L)	0.107	4.50E-02	0.106	0.21	0	9.48E-02	0.159
Log [TP] (mg/L)	-0.934	8.73E-02	-0.975	-0.678	-1.03	-0.975	-0.773
TN Concentration (mg/L)	1.58	0.56	1.88	1.88	0	1.29	1.88
Log [TN] (mg/L)	0.238	6.01E-02	0.274	0.274	0.107	0.13	0.274
TSS Load (kg/Day)	0.638	4.5	1.32E-02	153	0	3.26E-06	0.773
TP Load (kg/Day)	6.35E-03	3.60E-02	3.50E-04	1.16	0	9.15E-08	8.81E-03
TN Load (kg/Day)	6.10E-02	0.274	5.51E-03	8.15	0	1.62E-06	9.78E-02
Gross Pollutant Load (kg/Day)	0.207	0.695	0	8.18	0	0	0.547
Outflow	mean	standard de	median	maximum	minimum	10 percentil	90 percentil
Flow (cubic metres/sec)	5.00E-04	2.21E-03	2.00E-05	6.46E-02	0	0.00E+00	8.93E-04
TSS Concentration (mg/L)	0.884	1.21	0.575	13.2	0	0	2.61
Log [TSS] (mg/L)	3.01E-02	0.319	-0.218	1.12	-0.24	-0.24	0.571
TP Concentration (mg/L)	3.11E-02	2.68E-02	4.25E-02	0.134	0	0	6.29E-02
Log [TP] (mg/L)	-1.31	9.61E-02	-1.37	-0.872	-1.43	-1.37	-1.12
TN Concentration (mg/L)	0.674	0.553	0.898	1.25	0	0	1.25
Log [TN] (mg/L)	3.74E-02	6.72E-02	9.25E-02	9.71E-02	-6.91E-02	-5.60E-02	9.71E-02
TSS Load (kg/Day)	0.111	1.19	1.20E-03	73.8	0	0.00E+00	0.14
TP Load (kg/Day)	2.63E-03	1.62E-02	8.01E-05	0.75	0	0.00E+00	4.06E-03
TN Load (kg/Day)	4.08E-02	0.186	2.04E-03	6.41	0	0.00E+00	7.37E-02
Gross Pollutant Load (kg/Day)	0	0	0	0	0	0	0

Flow (ML/yr)	18.8	15.8	15.9
Total Suspended Solids (kg/yr)	1.66E+03	40.5	97.6
Total Phosphorus (kg/yr)	5.26	0.96	81.8
Total Nitrogen (kg/yr)	29.6	14.9	49.7
Gross Pollutants (kg/yr)	386	0	100

Basin B

Existing

X08066_100806_exv4 - Ex Cat 2 - All Data Statistics

Outflow	mean	standard de	median	maximum	minimum	10 percentil	90 percentil
Flow (cubic metres/sec)	3.53E-04	5.47E-03	1.16E-04	0.593	1.69E-06	1.13E-05	4.39E-04
TSS Concentration (mg/L)	25.5	1.61	25.1	35	25.1	25.1	25.1
Log [TSS] (mg/L)	1.4	2.40E-02	1.4	1.54	1.4	1.4	1.4
TP Concentration (mg/L)	0.131	5.19E-03	0.132	0.132	0.1	0.132	0.132
Log [TP] (mg/L)	-0.884	1.92E-02	-0.88	-0.88	-1	-0.88	-0.88
TN Concentration (mg/L)	1.18	3.03E-02	1.19	1.19	1	1.19	1.19
Log [TN] (mg/L)	7.15E-02	1.19E-02	7.40E-02	7.40E-02	2.13E-05	7.40E-02	7.40E-02
TSS Load (kg/6 Minutes)	3.87E-03	6.89E-02	1.05E-03	7.47	1.53E-05	1.02E-04	3.97E-03
TP Load (kg/6 Minutes)	1.45E-05	1.97E-04	5.49E-06	2.13E-02	8.04E-08	5.34E-07	2.07E-05
TN Load (kg/6 Minutes)	1.38E-04	1.97E-03	4.94E-05	0.213	7.23E-07	4.80E-06	1.87E-04
Gross Pollutant Load (kg/6 Minu	7.52E-04	1.06E-02	0	0.776	0	0	0

Flow (ML/yr)	11.1
Total Suspended Solids (kg/yr)	339
Total Phosphorus (kg/yr)	1.27
Total Nitrogen (kg/yr)	12.1
Gross Pollutants (kg/yr)	65.9

Developed No Treatment

X08066_100806_dev_ notreatv4 - Cat 2 - All Data Statistics

Inflow	mean	standard de	median	maximum	minimum	10 percentil	90 percentil
Flow (cubic metres/sec)	3.99E-04	1.63E-03	2.35E-05	4.82E-02	0	6.25E-09	8.66E-04
TSS Concentration (mg/L)	29	33.4	12.6	100	0	12.6	98.9
Log [TSS] (mg/L)	1.29	0.357	1.1	2	1.05	1.1	2
TP Concentration (mg/L)	0.175	6.47E-02	0.151	0.3	0	0.151	0.298
Log [TP] (mg/L)	-0.761	0.116	-0.82	-0.523	-0.866	-0.82	-0.525
TN Concentration (mg/L)	1.9	0.413	2.09	2.09	0	1.5	2.09
Log [TN] (mg/L)	0.29	5.43E-02	0.32	0.32	0.176	0.178	0.32
TSS Load (kg/Day)	3.04	14	2.59E-02	416	0	6.55E-06	6.83
TP Load (kg/Day)	9.65E-03	4.21E-02	3.12E-04	1.25	0	7.87E-08	2.14E-02
TN Load (kg/Day)	5.45E-02	0.212	4.20E-03	6.25	0	1.09E-06	1.17E-01
Gross Pollutant Load (kg/Day)	0.709	1.73	0	13	0	0	3.23
Outflow	mean	standard de	median	maximum	minimum	10 percentil	90 percentil
Flow (cubic metres/sec)	3.99E-04	1.63E-03	2.35E-05	4.82E-02	0	6.25E-09	8.66E-04
TSS Concentration (mg/L)	29	33.4	12.6	100	0	12.6	98.9
Log [TSS] (mg/L)	1.29	0.357	1.1	2	1.05	1.1	2
TP Concentration (mg/L)	0.175	6.47E-02	0.151	0.3	0	0.151	0.298
Log [TP] (mg/L)	-0.761	0.116	-0.82	-0.523	-0.866	-0.82	-0.525
TN Concentration (mg/L)	1.9	0.413	2.09	2.09	0	1.5	2.09
Log [TN] (mg/L)	0.29	5.43E-02	0.32	0.32	0.176	0.178	0.32
TSS Load (kg/Day)	3.04	14	2.59E-02	416	0	6.55E-06	6.83
TP Load (kg/Day)	9.65E-03	4.21E-02	3.12E-04	1.25	0	7.87E-08	2.14E-02
TN Load (kg/Day)	5.45E-02	0.212	4.20E-03	6.25	0	1.09E-06	1.17E-01
Gross Pollutant Load (kg/Day)	0.709	1.73	0	13	0	0	3.23

Flow (ML/yr)	12.6	12.6	0
Total Suspended Solids (kg/yr)	1.11E+03	1.11E+03	0
Total Phosphorus (kg/yr)	3.52	3.52	0
Total Nitrogen (kg/yr)	19.9	19.9	0
Gross Pollutants (kg/yr)	259	259	0

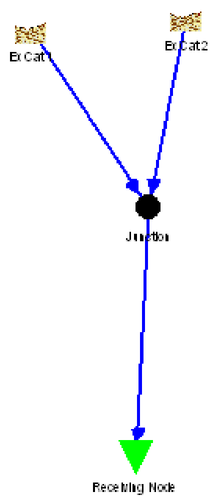
Developed with Treatment

X08066_100806_dev_treatmentv4 - Bio-Retention (V3 Upgrade) - All Data Statistics

Inflow	mean	standard de	median	maximum	minimum	10 percentil	90 percentil
Flow (cubic metres/sec)	3.41E-04	1.57E-03	2.77E-05	4.74E-02	0	0	5.67E-04
TSS Concentration (mg/L)	7.01	7.76	3.78	30	0	0	20.7
Log [TSS] (mg/L)	0.754	0.307	0.577	1.48	0.577	0.577	1.35
TP Concentration (mg/L)	0.108	4.71E-02	0.106	0.21	0	0	0.171
Log [TP] (mg/L)	-0.928	9.25E-02	-0.975	-0.678	-1.03	-0.975	-0.75
TN Concentration (mg/L)	1.56	0.573	1.88	1.88	0	0	1.88
Log [TN] (mg/L)	0.236	6.10E-02	0.274	0.274	0.107	0.129	0.274
TSS Load (kg/Day)	0.504	3.19	9.84E-03	106	0	0	0.763
TP Load (kg/Day)	4.62E-03	2.48E-02	2.62E-04	0.792	0	0	7.16E-03
TN Load (kg/Day)	4.17E-02	0.183	4.24E-03	5.51	0	0	7.16E-02
Gross Pollutant Load (kg/Day)	0.231	0.663	0	6.79	0	0	0.822
Outflow	mean	standard de	median	maximum	minimum	10 percentil	90 percentil
Flow (cubic metres/sec)	3.41E-04	1.48E-03	1.89E-05	4.43E-02	0	0	6.31E-04
TSS Concentration (mg/L)	1.04	1.34	0.575	12.8	0	0	3.27
Log [TSS] (mg/L)	7.50E-02	0.349	-0.209	1.11	-0.24	-0.24	0.599
TP Concentration (mg/L)	3.36E-02	2.79E-02	4.25E-02	0.132	0	0	7.01E-02
Log [TP] (mg/L)	-1.29	0.104	-1.37	-0.878	-1.42	-1.37	-1.11
TN Concentration (mg/L)	0.695	0.547	0.898	1.25	0	0	1.25
Log [TN] (mg/L)	3.68E-02	6.65E-02	8.91E-02	9.71E-02	-6.75E-02	-5.24E-02	9.71E-02
TSS Load (kg/Day)	8.51E-02	0.768	1.08E-03	49.1	0	0	0.137
TP Load (kg/Day)	1.91E-03	1.08E-02	7.31E-05	0.506	0	0	3.29E-03
TN Load (kg/Day)	2.78E-02	1.24E-01	1.91E-03	4.36	0	0	5.19E-02
Gross Pollutant Load (kg/Day)	0	0	0	0	0	0	0

Flow (ML/yr)	12.6	10.7	14.7
Total Suspended Solids (kg/yr)	1.11E+03	31.1	97.2
Total Phosphorus (kg/yr)	3.52	0.697	80.2
Total Nitrogen (kg/yr)	19.9	10.2	48.9
Gross Pollutants (kg/yr)	259	0	100

Existing



Proposed