University of Southern Queensland

Faculty of Health Engineering & Sciences

MUSIC Model Accuracy in Predicting Stormwater Quality

A dissertation submitted by

Wade Daniel Fletcher

in fulfilment of the requirements of

ENG4111 and ENG4112 Research Project

towards the degree of

Bachelor of Engineering (Civil Engineering)

Submitted: October, 2013

ABSTRACT

This dissertation investigates the use of stormwater treatment devices for urban catchments within Australia. The primary goal of the dissertation is to assess the accuracy of MUSIC modelling of stormwater pollutant generation and pollutant reduction to assess the effectiveness of the devices it is used to design.

A bio-filtration and detention basin with a moderately sized urban catchment was selected as the test site. The inlet into the existing basin was sampled over 6 months, during several storms, with flow depths measured and water samples taken at 6 minute intervals. These water samples were then analysed at a local laboratory and the results compared to the MUSIC model that was set up to replicate the basin catchment. These samples and discharges were then compared against the results of a MUSIC model of the site catchment. A pollutant trap was constructed at the basin inlet to collect gross pollutants to check the accuracy of the gross pollutants generation within MUSIC.

Given the limitations in time and funding it was not possible to provide a definitive answer as to the accuracy of flow, pollutant generation and pollutant reduction predictions by MUSIC. The level of modelled gross pollutants was reasonably accurate in relation to the volumes that were collected on site. On average the mass of the gross pollutants were 35% less than what was predicted by the MUSIC model but this was to be expected as not all the sediment or organics were captured.

Sampled inflow TSS and TP pollutant levels were generally below the modelled values. Inflow TN values were the least accurate of all the pollutants especially after periods of prolonged rain where the modelled TN concentrations were well above what was sampled.

On average sampled TN and TP inflow concentrations were 61% and 48% lower respectively than the modelled concentrations. The average sampled concentration of inflow TSS was 56% lower than the corresponding concentration modelled by MUSIC. It should be noted that the storm events that were sampled were smaller than an average storm. Previous research also found that there was a tendency by the MUSIC software to overestimate the pollutant concentrations for smaller storms.

It should also be kept in mind that due to finding and time constraints the sampling in this project assesses the instantaneous concentration not the annual loads. Therefore there is a greater margin for error. In order to determine the accuracy of annual loads of

pollutant generation and pollutant reduction it is recommended that more detailed research is undertaken over an extended period.

The setup of the bio-filtration basin was not considered to be adequate enough to provide for an accurate assessment of the modelled pollutant reduction. Results of the sampled outflow show a minimal reduction in pollutants and the condition of the samples basin should be kept in mind.

By better understanding the accuracy of stormwater pollutant modelling and variations due to a range of factors it is hoped that better design methodology and design guidelines can be adopted for the treatment of stormwater pollutants. This will hopefully benefit councils, engineers and developers as well as the community and environment by providing a cleaner and more sustainable water supply for centuries to come.

University of Southern Queensland
Faculty of Health Engineering & Sciences

ENG4111 & ENG4112 *Research Project*

LIMITATIONS OF USE

The Council of the University of Southern Queensland, its Faculty of Health, Engineering and Surveying, and the staff of the University of Southern Queensland, do not accept any responsibility for the truth, accuracy or completeness of material contained within or associated with this dissertation.

Persons using all or any part of this material do so at their own risk, and not at the risk of the Council of the University of Southern Queensland, its Faculty of Health, Engineering and Surveying or the staff of the University of Southern Queensland.

This dissertation reports an educational exercise and has no purpose or validity beyond this exercise. The sole purpose of the course pair entitled "Research Project" is to contribute to the overall education within the student's chosen degree program. This document, the associated hardware, software, drawings, and other material set out in the associated appendices should not be used for any other purpose: if they are so used, it is entirely at the risk of the user.

Executive Dean, Faculty of Health, Engineering and Sciences

CANDIDATES CERTIFICATION

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not being previously submitted for assessment in any other course or institution, except where specifically stated.

Mr Wade Daniel Fletcher
Student Number: 0050044296

Signature

13th October 2013

Date

ACKNOWLEDGEMENTS

I would like to acknowledge all those who have made it possible for me to complete this research project. In particular I would like to acknowledge Dr Ian Brodie, of the University of Southern Queensland for his supervision and guidance throughout this project.

I would also like to express my gratitude to those who have provided financial assistance to make this project possible. Thank you to Lismore City Council and Mr Nick Stephens for providing funding for the testing of stormwater samples. Thank you to Environmental Analysis Laboratory and Mr Graham Lancaster for also providing discounted rates for the testing of stormwater samples. Thank you to eWater for the provision of a licensed copy of MUSIC modelling software.

Appreciation is also due to my business partner, Mr Jakob Pfaeffli of CivilTech Consulting Engineers, for his knowledge and expertise in engineering matters particularly relating to stormwater modelling and treatment.

Most importantly, thank you to my wife for her support and encouragement & understanding throughout this research project and over the past 9 years of part time study and full time work. Without this help and encouragement, I doubt I would have made it this far.

WADE FLETCHER

University of Southern Queensland

October 2013

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES & GRAPHS

NOMENCLATURE AND ACRONYMS

The following abbreviations have been used throughout the text and bibliography:

ARI	Average Recurrence Interval
BASIX	Building Sustainability Index (NSW)
BOM	Bureau of Meteorology
DCP	Development Control Plan
EAL	Environmental Analysis Laboratory
EPA	Environmental Protection Authority
FAWB	Facility for Advancing Water Biofiltration
GP	Gross Pollutants
GPT	Gross Pollutant Trap
ha	Hectare
LCC	Lismore City Council
mg/L	Milligrams per litre.
mm/hr	Millimetres per hour.
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NRLG	Northern Rivers Local Government
NSW	New South Wales
ppm	Parts per million
QLD	Queensland
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
USQ	University of Southern Queensland

CHAPTER 1 - INTRODUCTION

Water is one of the most important substances on earth. All plants and animals must have water to survive. If there was no water there would be no life on earth. "

(Department of Health, 2013)

1.1 Aims and specific objectives

The importance of water has been well known for thousands of years. Without it human life would cease to exist. However, over the past century there has been a substantial increase in human population, an increase in pollutant generation which is often coupled with an increase in clean water demand and a decrease in rainfall and runoff.

In the past few decades there has been a substantial push to reverse this worsening of stormwater quality by seeking to return the runoff flows to near pre urban development conditions. The main goals are to reduce the stormwater volumes to pre development levels and reduce specific pollutant loads to a level that is not so detrimental to the aquatic life of our creeks, rivers and oceans.

Perhaps one of the most common and effective ways to treat stormwater runoff from residential, commercial, industrial or even agricultural land is by the use of a bio-filtration or bio-retention basin.

Simply put, a bio-filtration basin is a stormwater detention basin with a filter media layer in the base to filter sediment and pollutants from stormwater before discharging it downstream. These basins are typically planted with suitable species of sedges and grasses which aid in the removal of pollutants such as phosphorous and nitrogen. The basin typically also has a series of mid-flow pipes and a spillway which aid in reducing the peak flow volume discharging from the site which in turn reduces erosion and pollution problems downstream.

In the past decade there has been a significant push within cities to reduce the impact of stormwater by reducing the volume and pollutants discharging from a development. This understanding of the importance of stormwater treatment has filtered down to regional councils and is slowly being implemented by smaller rural councils.

Many regional and rural councils typically adopt the guidelines, policies and treatment targets set by industry leading councils such as Brisbane City Council and Melbourne

Water. Lismore City Councils stormwater guidelines are primarily controlled by their DCP Ch22 Water Sensitive Design (Lismore City Council DCP)Additional information on stormwater detention, rainfall data and general stormwater design is provided in the Northern Rivers - Local Government Development Design Specification, D5 Stormwater Drainage Design (Lismore City Council NRLG) which is co-written by Lismore City Council. While there are generally adequate stormwater management plans in place there seems to be a lack of knowledge of the modelling process and a lack of research into accuracy of stormwater pollutant modelling software such as the Model for Urban Stormwater Improvement Conceptualisation or MUSIC. MUSIC modelling is the main software used by local councils in assessing stormwater pollutant levels for Development Applications and Construction Certificates.

This research project sought to provide a clearer understanding of the accuracy of stormwater modelling on stormwater pollutants and stormwater flow volumes. The primary objectives of this research project were to:

- Model a developed catchment and bio-retention basin for inflow and outflow pollutant levels and compare them with laboratory analysed stormwater samples for accuracy.
- Measure the stormwater volumes generated by the catchment and to compare them for accuracy against the flow volumes generated by MUSIC.
- Capture and measure gross pollutants and compare the volume with the MUSIC model volumes.

Secondary objectives of the research were to assess the effects of a bio-filtration basin on stormwater flows and to review the importance of the first flush in stormwater management plans. However, due to time constraints during the research project these objectives were not assessed.

This research project will hopefully assist Lismore City Council (LCC) with the development of Northern Rivers specific MUSIC source nodes. This research project will enable council to assess the effectiveness of different treatment devices and enable council funds to be more effectively targeted to specific treatment goals and ensure council design guidelines are reflective of "real world" results.

1.2 Background information

Prior to commencing the field work and modelling of the proposed stormwater treatment device a literature review will be undertaken to identify existing studies, their results, research contradictions and any gaps in available research and knowledge. The literature review will also increasing the authors general understanding of the topic and terminology and allow the author to avoid common mistakes and provide suitable methodology for any field or laboratory work.

The reasons for conducting a literature review include:

- Identifying existing research into MUSIC modelling accuracy;
- Identify current stormwater treatment devices and their treatment effectiveness;
- Determining the best methodology for water sampling and collection and measuring of gross pollutants;
- Providing an understanding of the extent of research into stormwater treatment and the accuracy of MUSIC modelling;
- Allowing common research and field work mistakes to be avoided.

The literature review is detailed in Chapter 2 of this report and will be updated throughout the course of this research project.

1.3 Assessment of consequential effects, implications & ethics

A key consideration of all research or projects should be to "Identify sustainability, safety and ethical issues" that are associated with that project.

1.3.1 Safety

Safety not only relates to the person conducting research but also members of the public that may be affected by it. Specific safety concerns relating to the field work for this project have been addressed in the risk assessment in section 1.5. Most safety concerns can be substantially reduced by adequate use of PPE and the application of common sense.

Any hazards that are created during the field work component were barricaded off and removed upon completion. All local and affected residents were advised of the proposed works by a letter one week prior to commencement. Ultimately, it is hoped, the recommendations and conclusions of this research paper may lead to improved stormwater treatment devices and cleaner, safer water ways for all.

1.3.2 Ethical responsibility

The Code of Ethics set forth by the Institution of Engineers (EA 2010), Australia, outlines the following key principals:

- to demonstrate integrity by being honest and trust worthy and to respect the dignity of all persons;
- to practice competently by maintaining skills and knowledge;
- to exercise leadership, support diversity and to uphold the reputation of the practice of engineering;
- and finally to promote sustainability, engage with the community and to consider the needs of future generations.

Throughout this project all of these key principals were adhered to. All results and interpretation of data were objective and fair with the primary aims being the promotion of sustainable processes to increase my engineering skills and knowledge.

1.3.3 Sustainability

The main purpose of good stormwater management practices is the sustainability of our river systems, habitat, water source and ultimately human life. By better understanding the impact of human development and the effectiveness of stormwater treatment devices such as bio-retention basins we can provide for a more sustainable way of life.

Throughout this research full consideration was given to sustainability and the environment. All sampling containers were recycled, travelling by vehicle was limited where possible and all gross pollutants collected were separated into rubbish, organic and recycling to be disposed of at the LCC waste and recycling centres. Collected sediment was placed outside of stormwater flow paths so it would not enter the bio-filtration basin or downstream receiving creek.

1.4 Project methodology & justification

The primary tasks for this research project are listed in the Project Specification attached in Appendix A. As mentioned in Section 1 the aims and objectives of this research project were to:

- Model a developed catchment and bio-retention basin for inflow and outflow pollutant levels and compare them with laboratory analysed stormwater samples for accuracy.
- Measure the stormwater volumes generated by the catchment and to compare them for accuracy against the flow volumes generated by MUSIC.
- Capture and measure gross pollutants and compare the volume with the MUSIC model volumes.

The proposed research project was first discussed with several USQ staff members and possible problems were resolved and improvements made to the tasks and methodology. In late 2012, with the basic project outline selected, sponsorship was sought from local councils, water testing labs and local businesses to provide funding for the testing of stormwater samples. As mentioned, funding has been provided by LCC and discounted testing by Environmental Analysis Laboratory (EAL).

The next step in the research project was to select a suitable site to monitor the full range of pollutants and flows. LCC provided a full register of stormwater treatment devices under their control including wetlands, grassed swales, bio-filtration and rains gardens. A ranking matrix was set up to select the most suitable site from these devices. The selection process will look at the location of the device, treatment potential, safety, proximity to BOM rainfall stations, ability to measure pollutants and flow, catchment suitability and available engineering details and models.

This matrix selection process assessed the following sites: (Refer Appendix D)

- A series of bio-filtration basins and swales located at the Goonellabah Sports and Aquatic Centre.
- A small bio-filtration basin located at Joy Street, Goonellabah. This basin catchment is relatively new, small and undeveloped.

- A midsized bio-filtration basin located at the end of Waratah Way, Goonellabah. This basin catchment was well established with only 2 buildings under construction. The basin has been operational for over 10 years.
- A series of rainwater gardens in the Lismore CBD which treated commercial runoff through bio-filtration.
- A bio-filtration basin located at Nesbitt Park.
- A vegetated swale known as Gasworks channel located in downtown Lismore.

The site that was chosen for testing was the bio-filtration basin at Waratah Way (refer Figure 1.1). The basin is easy to access and located close to the authors place of work, is safe for testing and had little impact on the general public, has a single inflow and outflow point and was able to be modified to collect and measure gross pollutants. On the downside the basin was overgrown, had a large build-up of sediment especially at the headwall inlet and was mainly grassed as opposed to being vegetated with suitable plant species (refer Plate 1). While not the perfect site the selection matrix showed that this was the most suitable of the sites available within Lismore City Council.

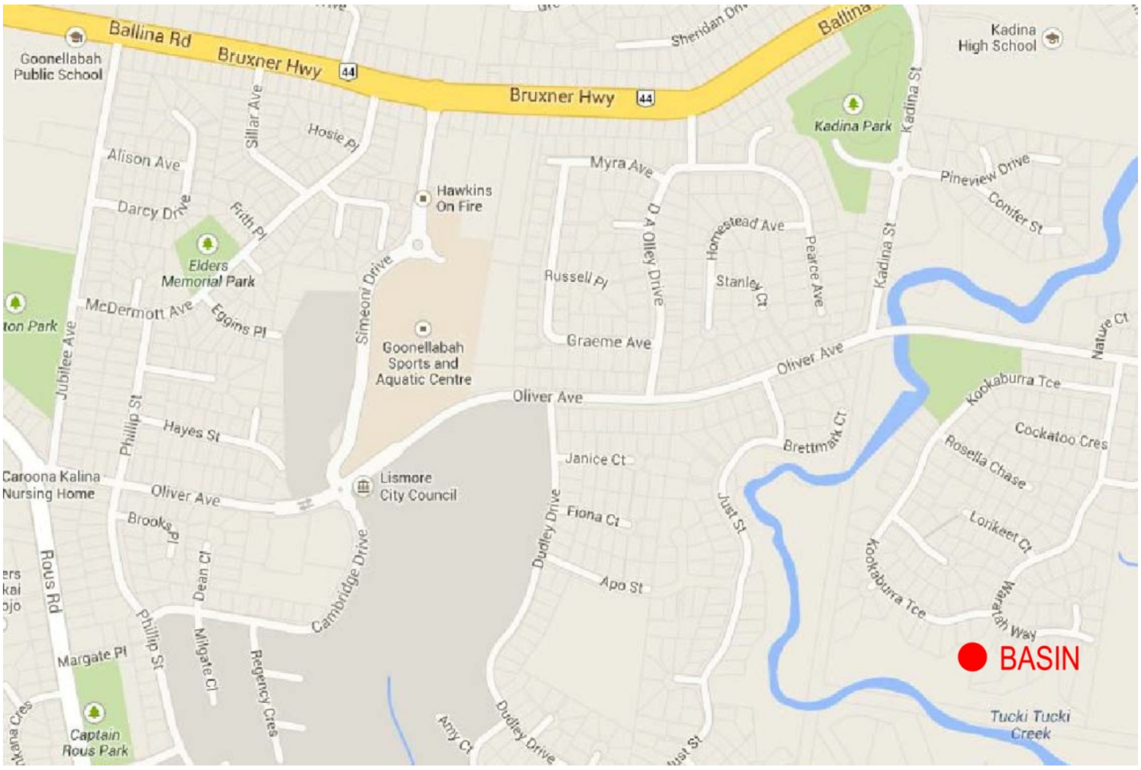


Figure 1.1: Basin locality plan

(Map sourced from Google Maps 26.08.2013)

Plate 1.1: Existing overgrown headwall, Waratah Way basin

With the site chosen, testing equipment was organised through EAL in order to be prepared to sample during subsequent rainfall events. The site was cleared of any rubbish, sediment cleared from headwalls and neighbours were advised of the pending work.

The existing 750 diameter headwall (refer Plate 1.1) did not have any form of gross pollutant capture device installed. The option of installing an "off the shelf" gross pollutant device such as an Ecosol NetTech or ski-jump was investigated and discussed with council. It was agreed that the cost of device would be too great for the purpose of this research project. In addition council already has a net-tech GPT installed for the purpose of monitoring gross pollutant levels and GPT effectiveness. While not critical to the projects conclusion the author decided to construct a GPT to better assess the full range of pollutants modelled by MUSIC.

Plate 1.2: Constructed GPT and cleaned out headwall, Waratah Way basin

A temporary gross pollutant trap was constructed by the author at the headwall outlet into the basin on the 16th of March 2013 (refer Plate 1.2). The GPT consisted of a 50mm steel rail across the top of the headwall and a star picket across the bottom supported by a series of star pickets driven into the existing sediment for support. This rail and star pickets support a piece of SL82 mesh cut to fit the width of the headwall. To the SL82 mesh 2 layers of 5cm x 1mm chicken wire were fixed by hand with 2mm wire. The chicken wire was fixed to the base of the concrete headwall with a series of small ramsets. Safety caps on the star pickets and safety tape were installed around the GPT by LCC staff. The gross pollutants caught by this device were collected and weighed at regular intervals, determined by the rainfall, to determine the loadings over a period of time.

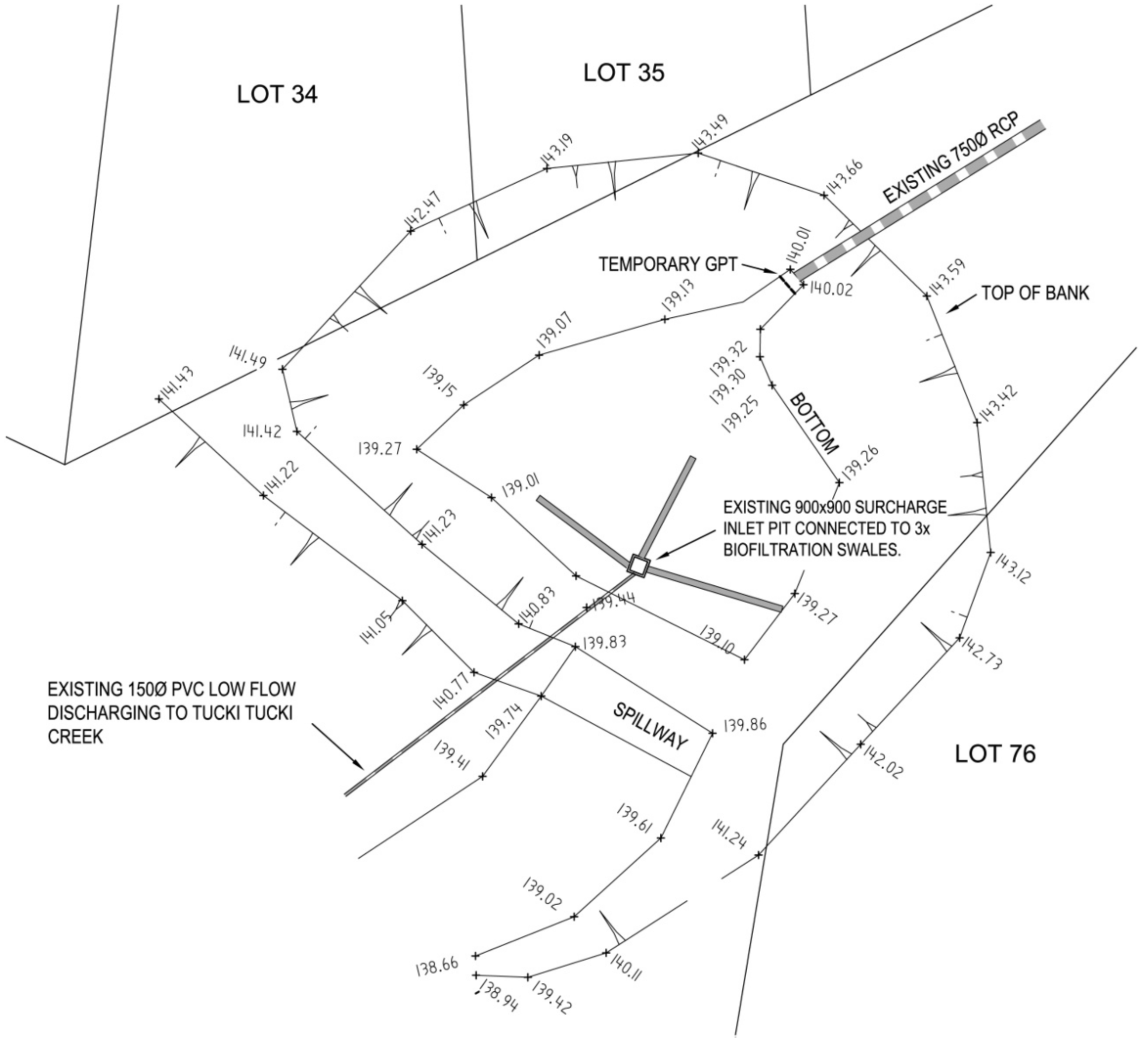


Figure 1.2: Basin layout plan

(Survey data provided by Aspect north)

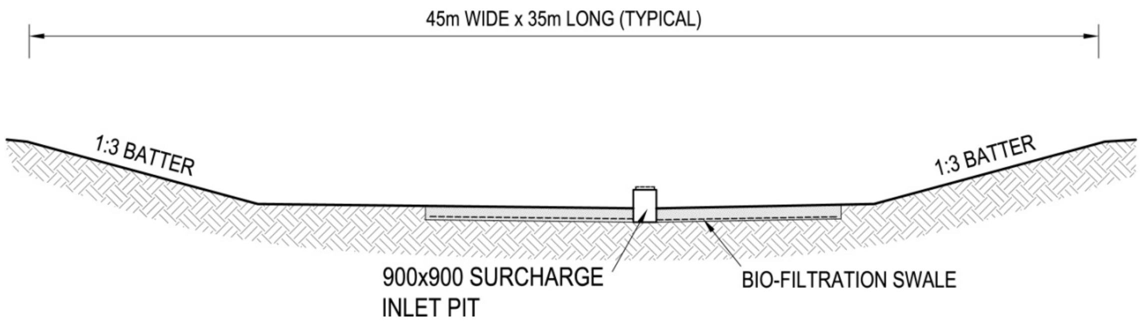


Figure 1.3: Basin typical section

The proposed site and catchment (refer Figure 1.4) is located at the end of Waratah Way, Goonellabah NSW. The basin catchment is 3.94 hectares and drains into Tucki

Tucki Creek before flowing to the Wilson and Richmond Rivers. The catchment and bio-filtration basin was investigated and modelled with MUSIC 5 to determine the pollutant levels generated for Total Nitrogen (TN), Total Phosphorous (TP), Total Suspended Solids (TSS) and Gross Pollutants (GP) as well as the stormwater flows. The model also provides a reduction rate for pollutants and out flows.

Figure 1.4 : Basin catchment plan & 1m contours

(Aerial photo sourced from NSW Sixviewer site, 1m existing contours extracted from Lismore City Councils GIS database)

Total Nitrogen (TN) is defined as "the the sum of nitrate-nitrogen (NO3-N), nitrite-nitrogen (NO2-N), ammonia-nitrogen (NH3-N) and organically bonded nitrogen" (ASA analytics Nitrogen). Excessive amounts of TN in water courses can lead to algae blooms through eutrophication. When the algae dies and decays it depletes the amount of dissolved oxygen in the water. This then impacts on animal and plant life within the rivers, creeks and oceans. The main sources of nitrogen are fertilisers and organic matter which is often used on lawns and gardens.

Total Phosphorous (TP) is defined as "the sum of reactive, condensed and organic phosphorous" (ASA analytics Phosphorous). As TP is a nutrient responsible for plant growth its impact on water quality is the same as TN. Excessive TP in a water system causes algae blooms which ultimately decay and deplete the dissolved oxygen in water. The removal of TP and TN nutrients is best done with wetlands of biofiltration basins.

Total Suspended Solids (TSS) refers to matter that is suspended or dissolved in water (Boulder Council). While TSS solids can be captured with a 0.45 micron filter paper, the total dissolved solids (TDS) cannot. However TDS are mainly salts which are typically low in stormwater samples. The combined TSS + TDS gives the total solids found in a water sample. TSS affects the specific conductance and turbidity of water. TSS can be effectively removed with sediment basins, wetlands, bio-filtration basins and even grassed swales and buffer strips.

Gross Pollutants (GP) are defined as large debris from urban catchments that includes plastic bottles, organics such as leaves and lawn clippings, coarse sediment, cigarette butts, metal cans and domestic plastics (Gosford GPT). While gross pollutants can be captured by basins and wetlands they tend to be flushed through the system and into creeks and rivers during large rainfall events. Gross pollutants are relatively easy to remove with end of line GPTs or pit based GPTs but require regular maintenance and the removal of gross pollutants to remain operational.

The actual methodology of sampling the stormwater was done in the following steps:

- Rainfall intensity was measured and recorded at the site every 6 or 12 minutes for the duration of the event. If rainfall last longer than 2 hours the sampling was generally stopped due to time and financial constraints.
- Samples of stormwater were taken at the inlet headwall and outlet headwall typically every 12 minutes. The procedure for sampling was discussed with EAL and is outlined in Section 2.3 of this report.
- Flow depths at the inlet and outlet headwalls were recorded every 12 minutes and the Manning's formula used to estimate the flow in and out of the bio-retention basin. In addition to this the velocity of the stormwater was estimated by timing debris within the water as it passed known lengths of pipe.

- Additional grab sampling of other treatment devices within Lismore was also carried out. This sampling consisted of a single inflow and outflow sample. Collecting these samples for other devices such as wetlands, vegetated swales and rain gardens was done to provide important data to LCC on the effectiveness of different stormwater treatment devices. This will hopefully help in the further development of their stormwater management guidelines.

A total of 4 storms were measured and sampled, three of these were samples for the biofiltration basin at Waratah Way (Refer Appendix C). These samples were stored in a fridge and transported to EAL for testing within the allocated time limit of 48 hours.

The BOM was not able to provide up to date 6 minute rainfall data to use with the MUSIC model. As such a 6 minute rainfall intensity hydrograph was manually created for the model. This was done by recording the actual rainfall depths on the site every day. Details of the type of rain and when it fell were noted. The BOM provides 30 minute weather information including rainfall intensities at the Lismore Airport which remain online for 4 days. As the airport is several kilometres from the subject treatment basin the intensities were scaled up or down to match the daily rainfall levels being recorded on site. Existing daily rainfall data from Elders weather and the BOM web sites was used to create "lead in" rainfall data prior to the sampling dates to allow an accurate "warm up" period for the model to run. This warm up period ensures that the MUSIC model is functioning correctly at the time of the sampled events and not simply represented as a dry basin within the model.

Two issues were encountered with the creation of the 6 minute rainfall hydrograph. The first was that the collection of 30 minute BOM rainfall data only commenced in March. Therefore the only available rainfall data was daily rainfall depths that were measured at the Lismore Airport. These daily rainfall figures were manually converted into 6 minute rainfall data to represent a typical Northern Rivers wet season. The effect of different types of events in the "warm up" period was assessed and found to be insignificant. The second issue that was encountered was that the BOM weather station at the Lismore Airport was down between the 8th of May 2013 and the 2nd of June 2013. To overcome this problem additional rainfall recordings were taken onsite to enable more accurate 6 minute rainfall data to be produced. Again, the type of rainfall preceding the sampling date was found to have a minimal effect upon the MUSIC model. Typically sampling was done at the start of a rain event to ensure that the first flush pollutants were captured.

The MUSIC model was then run and pollutant loadings determined for each measured storm by way of the time series graph function. The accuracy of the pollutant generation and pollutant reduction for all pollutants was then able to be analysed. TN, TP and TSS were reported in mg/L by EAL while gross pollutants were measured in kg. The source loads, residual loads and reductions were then used to determine the accuracy of the treatment train effectiveness function within MUSIC 5. Additional detail on the setup of the MUSIC model is provided in section 3.

The source nodes that were used for the MUSIC model were supplied by the Tweed Shire Council (TSC SW Quality). The Tweed Source node will be compared with the default MUSIC source nodes and source nodes from Brisbane City Council (BSC Modelling Guidelines). The accuracy of each individual parameter in the source nodes will not be tested as it is beyond the scope of this project.

1.5 Resource planning

All projects require certain levels of resources which may include staff and personnel, technical support or equipment suppliers. The resource requirements for this research project are listed below.

1.5.1 Staff and personnel requirements

Personnel involved in this research included but were not limited to:

- Wade Fletcher - As the author of this research project I was responsible for the project performance and completion of the required tasks. This was achieved by following the project timeline and keeping close communication with my course supervisor and support staff.

- Dr. Ian Brodie - As a USQ staff member and the supervisor of this research project Ian was my major point of contact for this research project. Communication with the course supervisor was carried out via email.

- Anton Nguyen - Was the primary contact within LCC. Anton provided access to council’s records, stormwater treatment devices, equipment and services. Communication with LCC took place either by phone or email with a log being kept of all communications.

- Graham Lancaster - Was the primary contact at EAL. Graham was responsible for the testing of stormwater samples and the provision of testing equipment and bottles for the project. Communication with Graham was carried out via email.

1.5.2 Equipment and technological support

A range of equipment and technological support was required to complete this research project. LCC provided access to stormwater treatment devices, old engineering details and models as well as equipment for sampling. EAL was supplied stormwater collection bottles for testing of TN, TP and TSS. The Bureau of Meteorology website was used as access to 30 minute rainfall intensities (BOM Lismore Airport) which was used to build a custom 6 minute rainfall data intensity table. Access to MUSIC software has be provided by eWater through USQ at the start of the project. At the start of the second semester the MUSIC licence was changed to VPN based licence. This licence was not able to be accessed properly so a copy of MUSIC was purchased by the author.

1.5.3 Financial backing

Lismore City Council agreed to fund the cost of the stormwater testing by EAL. The cost was subject to the number of tests performed and originally estimated to be 40 to 60 tests at $50 each equating to $2000 to $3000. The final number of samples tested did not reach this amount primarily due to the weather and lack of rainfall.

Environmental Analysis Laboratory (EAL) agreed to sponsor the research project by way of substantially reduced water testing rates.

eWater, as the developer of MUSIC, initially provided access to the latest version of MUSIC 5 with a standalone licence. This was later be upgraded to a VPN based licence which did not work.

A range of alternate sampling sites, research funding and stormwater testing facilities were investigated in case there were interruptions to the proposed agreements. The most critical item for the success of the project was the rainfall. While there was heavy rainfall in January, February and early March prior to the commencement of sampling there was minimal rainfall for the rest of March and into April. Heavier rainfall that fell from April to June tended to be over several days as opposed to isolated events. Rainfall over several days wasn't considered suitable for sampling as the pollutant levels would be significantly reduced due to the "first flush" effect. As such the number of samples taken was about half what was originally envisaged.

1.6 Project timeline

A project timeline is an important planning tool for any project. Project timelines are able to identify the critical path and individual tasks that may delay a project. They are important in assessing which tasks are completed, which are behind schedule and which need to be started. A well prepared and up to date project timeline enables a project manager to quickly identify any problems that may arise and allows them to take action.

A project timeline was prepared as part of this report. It detailed the individual tasks along with their start and completion dates. A copy of the project timeline for the initial project specification is attached in Appendix B. This timeline was adjusted throughout both semesters as work progressed and as priorities on the research project change.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

A literature review is essential to helping a researcher identify existing studies, their results, research contradictions and any gaps in available research. A literature review also helps in increasing a researchers general understanding of a topic and terminology, allows the researcher to avoid common mistakes and provide suitable methodology for any field or laboratory work.

Completing a literature review will help determine the extent of existing research into stormwater modelling accuracy, show existing results or lack of data, provide information on stormwater sampling methodology as well as provide background knowledge on this subject.

Bio-filtration devices are one of the most popular treatment devices because of their flexibility in size, location and appearance and their pollutant reduction performance (Hatt et. al 2008). Bio-filtration can be used as rain gardens, roadside buffer strips or designed to treat residential, industrial or even agricultural catchments. Bio-filtration also improves water runoff quality by planted filtration media as well as fine filtration, extended detention and biological uptake (Melbourne Water, 2005).

2.2 Existing research into MUSIC modelling accuracy

A report by Dotto, Deletic and Fletcher analysed the accuracy of the MUSIC model in relation to flow and pollutant generation. The primary aim of their research was too "increase our understanding of the uncertainties of the parameters in models that are currently being used for assessment of stormwater quantity and quality." More specifically they were seeking to find a relationship between "model uncertainty and the data availability for calibration and validation".

Dotto et al (2008) concluded that in relation to flow modelling by MUSIC "the rainfall/runoff model was satisfactory calibrated to both catchments when the Bayesian approach was applied". However they did recommend that an additional six months of calibration and 6 months of validation data be collected above their sampling period of

6 months. The sampling being done by this research project is not adequate to supplement the sampling by Dotto as it is over a short time period, has a small number of samples and does not sample all events. It should, however, confirm the general results as discussed by Dotto.

In relation to pollutant modelling by MUSIC, Dotto found varying levels of accuracy with a larger number of rainfall events and higher volumes producing better results. They recommended that "further work is necessary to evaluate the impact of data on calibration and validation in the case of water quality models."

Dotto also found that of the 13 calibration parameters in MUSIC the results were only sensitive to two parameters being Effective Impervious Area (EIA) and routing parameter K. It was suggested that the other 11 be fixed as default. No recommendations were made in relation to the pollutant generation parameters. The current version of MUSIC still has 13 flow calibration parameters available. The scope of this research project did not allow for further investigation of these parameters.

It should be noted that at the time of this research the latest version of MUSIC was version 3 which has since had substantial updates made to calculation methods. The current version of MUSIC is 5.1 which will be used for modelling in this research.

Research by Bratieres et.al. (2008) noted that despite the popularity of bio-filters worldwide there was "only limited data available on their performance in pollutant removal". He also noted that most field and laboratory studies showed poor TN removal, moderate to good TP removal while TSS removal was consistently higher than 90%.

Imteaz et. al (2012) researched the accuracy of modelling stormwater systems using MUSIC. They noted that there has been an increasing number of initiatives to manage urban stormwater runoff in a more sustainable way but that "there is considerable lacking in regards to quality assessment of different modelling tools". They also noted that "MUSIC has not been rigorously tested in regards to its pollutant treatment performances".

Imteaz et. al (2012) found that MUSIC predictions for TSS and TP concentrations in Brisbane were very close to the sampled levels. However, they found that MUSIC overestimated the flow reductions and the TN removal efficiency. In Melbourne they found that general flow and TSS reductions were fairly accurate but TP and TN reductions did not match the model. Reasons given for these discrepancies and differences between locations included nutrient leaching and the different rainfall levels for the different seasons. Flow estimation by MUSIC was found to be fairly accurate but it was recommended that additional sampling and research be conducted.

Research into the effectiveness of biofilters by Bratieres (2008) showed a mean TN removal of 46% and an average removal of 80% of TP. FAWB (2008) found that correctly designed and maintained biofiltration basins should be able to remove up to 50% of TN, 80% of TP and 90% of TSS.

2.3 Stormwater sampling methodology

The methodology used by Dotto, Deletic and Fletcher involved 1 minute rainfall logging over a 2 year period with discrete sampling during rainfall events of TSS, TP and TN pollutants at two sites around Melbourne. Between 10 and 24 pollutant samples were per event with between 27 and 50 events being sampled at their primary site. No collection or testing of gross pollutants were undertaken for this research.

The research conducted by FAWB at the Monash University (Bratieres et.al. in 2008) involved 125 bio-filtration columns set up to analyse the influence of vegetation type, filter type and depth, filter area and pollutant inflow levels. Inflow and outflow samples were collected and tested for TN, TP and TSS along with other pollutants and heavy metals. While useful as background information these results do not assess the effectiveness of a "real world" catchment and treatment basin.

The methodology used by Imteaz et. al (2012) for testing bio-filtration accuracy with MUSIC involved adjusting the MUSIC default parameters to generate the same inflow concentrations as used in their experiment. This research will not adjust the MUSIC parameters but seek to compare the inflow and outflow pollutant concentrations calculated by MUSIC compared with the inflow and outflow concentrations as sampled and measured in the field.

The most detailed information on water monitoring and sampling was found in the Monitoring and Sampling Manual 2009 published by the QLD Department of Environment and Heritage Protection (QLD EH&P 2009). The key components of stormwater sampling that are outlined in the Monitoring and Sampling Manual 2009 includes:

- Understanding that sound sampling design is essential. This includes understanding that water quality varies with time and location.
- The sampling method can depend on the purpose and objectives of water samples.
- The system that is to be sampled will also determine the best approach to sampling design and a good understanding of the ecosystem will help.
- What, where, when and how to sample stormwater.
- Sampling can be done by using a sampling pole and bottle or an auto sampler.
- Field equipment that is recommended for stormwater sampling includes sample carrier boxes, marking pens, camera, labels, sample bottle and a method of keeping samples cool.
- Surface water should be collected using gloves, bottles should be labelled prior to collection, and samples should be taken in the centre of the channel with the mouth of the bottle 10cm below the surface.
- Avoid scraping the sides of drains or disturbing sediment.
- Avoid contamination of samples by not smoking, not over filling bottles or rinsing bottles.
- Each sample should be named, include the date, time & location.

These guidelines were used as a guide to the correct sampling methodology to be used for this research project.

2.4 Soil filter media in bio-filtration systems

The Facility for Advancing Water Bio-filtration (FAWB) provided guidelines for soil filter media within bio-retention systems in March 2008. The recommended filter media profile was 400-600mm deep with a 100mm thick transition layer and a drainage layer with 50mm under pipe coverage. Based on a temperate climate it was suggested that a typical bio-retention basin should be 2% of the catchment area with infiltration ranging from 100-300mm/hr to sustain plant life. It was suggested that the filter media was to consist of material ranging from silt or fine sand and gravel up to course gravel. The majority of the media (50-90%) was to be fine to course sand. These parameters were consistent with bio-filtration parameters specified in other research papers by Bratieres et. al. 2008 and Hatt et. al. 2008.

It was noted by FAWB (June 2008) that the hydraulic conductivity of media started at the design rate, decreased over the first 6 months before increasing back to the design rate over the next 12 months. This reduction was due to media compaction and clogging prior to the root system gaining full depth and size to improve infiltration rates.

Research by Hatt et. al. (2008) indicates the importance of the infiltration rate of the bio-filtration media. It was noted that "higher infiltration rates may lead to higher effluent concentrations" and that higher hydraulic capacity can enable either higher annual flows to be treated or smaller sized treatment devices to be used but that "there appears to be a trade-off between hydraulic capacity and pollutant removal". The actual media to be selected will always depend on the treatment objectives and the space available for treatment.

2.5 Leaching, plant species and other considerations

Numerous research papers, both field and lab based, indicated the presence of nutrient leaching in bio-filtration basins. This occurs where nutrients are absorbed into the filter media only to be remobilised after a period of dry weather. Leaching of nutrients was discussed by Bratieres et. al. (2008), Imteaz et. al. (2012), Hatt et. al. (2008) and by the FAWB (June 2008). Imteaz noted that "in the experiments, leaching from the filter material itself might be the reason for having higher nutrients (TP and TN) concentrations in the outflows from the bio-retention system".

FAWB (June 2008) noted that most soils will naturally leach nitrogen and that the "extent of leaching is influenced by the presence of organic matter". They also noted that "there is a strong correlation between the number of dry days prior to a storm event and leaching of nitrogen from soil filter media". It was suggested that filter media that is low in nutrients should be used and that leaching is influenced by the presence of organic material. The possibility of leaching is noted and will be considered when assessing the stormwater sampling results for this research project.

Research into the ideal plant species was conducted by FAWB (June 2008). They found that of the 5 plant species they tested *Carex appressa* was the best for the removal of TP and TN nutrients. It was suggested that this was because of the rapidly spreading roots. Other plant species that had high nutrient removal rates included *Melaleuca ericifolia*, *Juncus amabilis* and *Juncus flavidis* while *Dianella* was found to be poor at nutrient uptake and removal. These findings were backed up by field scale research by Hatt et. al. (2008) which showed that *Carex appressa* had better Nitrogen uptake than *Dianella*. The subject site at Waratah way does not contain any of these recognised plant species and is typically grassed with Kikuyu grass.

Taebi et. al. (2004) researched the effects of the first flush of a storm upon the pollution load of urban stormwater runoff. They found that the effects of the first flush were the most noticeable for TSS while discharge loads of TN were approximately uniform. Taebi did not monitor levels of TP or gross pollutants but it is likely that TP levels would be uniform while gross pollutants would likely be increased during the first flush period. Taebi also found that the first flush load of TSS "increases, when the intensity and duration of a rainfall event increases". Taebi developed an equation which predicts the total load of TSS transported with the first 20% of runoff with respect to total depth of rainfall and total time of rainfall duration.

2.6 Gross pollutant research and testing methodology

Rushton et. al. (2007) divided gross pollutants into 3 categories being litter (paper, plastic, metal etc), organics (leaves, grass, twigs etc) and course sediments. Rushton also mentioned three categories of stormwater monitoring ranging from minimal monitoring up to research and design monitoring. For this research project the implementation of minimal monitoring will be sufficient with the following Level 1 minimal monitoring methodology to be adopted for the sampling of gross pollutants.

- Measure and record rainfall
- Record interval between collection events
- Record weight of 3 categories of gross pollutants

2.7 Literature review conclusion

The literature review demonstrates the increasing emphasis on stormwater management over the past decade. Existing research provides adequate information on the effectiveness of stormwater treatment including bio-filtration basins as well as the importance of parameters such as filter media type and plant species.

However, there does appear to be a shortage of research into the accuracy of stormwater pollutant modelling especially with the latest version of MUSIC. Given that MUSIC is the main stormwater pollutant modelling within Australia it would be valuable to understand how the pollutant load generation and pollutant reduction of a MUSIC model compare with the pollutant loads and reductions of a functioning catchment and treatment basin.

In the research papers into the accuracy of MUSIC modelling by Imteaz et. al (2012) and Dotto et al (2008) no research was done into the gross pollutant generation by catchments. I was unable to find any other research into the accuracy of the gross pollutant loads generated by MUSIC. As part of this research project I will compare the model against the actual levels of gross pollutants generated by the chosen catchment to gain a better idea of the accuracy of MUSICS gross pollutant load. However, because this research project is only partly focused on gross pollutants and is limited to one catchment further research into this area is recommended.

This research project highlighted problems that could be faced during the research project as well as methodology for sampling and modelling which will be essential to the success of the project. It also highlighted a shortage of research around not only MUSIC modelling but also gross pollutant generation levels. This background information was a great assistance in the collection and documentation of my research.

CHAPTER 3 – STORMWATER MODELLING

3.1 The subject site

The stormwater sampling location is located at the end of Waratah Way, Goonellabah NSW. The basin catchment is 3.94 hectares and drains into Tucki Tucki Creek before flowing to the Wilson and Richmond Rivers. The basin is in land zoned Residential under the Lismore Local Environmental Plan (LEP) 2012. The catchment is entirely urban development consisting typically of brick and tile houses on 600 to 900 square metre blocks. At the commencement of sampling in March there were 3 houses within the catchment that were under construction. These houses were complete by the end of the sampling period in early August. The 3 construction sites were monitored throughout sampling to assess the impact on water quality particularly in relation to sediment. All builders employed adequate sediment fence, shake down grids and pit inlet filters and the impact upon the results was considered to be minimal.

3.2 Stormwater treatment objectives

Water Sensitive Urban Design (WSUD) assesses the impact of the stormwater runoff from an urban development and seeks to implement design measures to reduce the impact of stormwater intensification and the increase of pollutants. Stormwater intensification occurs because of the increase of impervious surfaces such as roads, buildings and driveways. The increase in pollutants comes from the increased ability for pollutants to wash of instead of being absorbed by grass and vegetation as well as an increase in human and animal activity.

Melbourne Water (Melbourne Water bio-retention) outlines three key principles involved in the WSUD approach. These are:

- The protection of waterways and associated ecosystems;
- Managing stormwater within the landscaped environment rather than allowing it to discharge directly to waterways. This is done by reducing the flows from the development and reducing the pollution within the flow;

- Providing addition amenities to the local communities while reducing the cost associated cost to the developer. This can be done by using existing gullies and creeks as well as reducing the required size of storm water pipes and pits.

The specific stormwater treatment objectives for Lismore City Council are outlined in their DCP Ch22 Water Sensitive Design. The objectives of DCP Ch22 for developments larger than 2500m² relate to the reduction of reticulated water usage, stormwater quality and stormwater quantity.

The required reduction of reticulated water usage for a residential development is set at 40%. The intent of this is to increase the reuse of reticulated water and therefore decrease the need to upgrade the bulk water network. This is in line with the requirements by BASIX whereby each house that is constructed in NSW is required to be designed to achieve a 40% reduction of water usage. This is done through the use of rainwater storage tanks, low flow taps and fittings and low water use lawns and gardens. Due to the requirements of BASIX the reduction of reticulated water usage does not need to be considered with the design of a subdivision.

The reduction of stormwater quantity is required for both environmental protection and infrastructure protection. The environment is protected by reducing flows which in turn reduces the erosion of waterway banks and beds leading to a reduction in the levels of sediment and silt. The protection of infrastructure is achieved by reducing pipe and basin velocities and volumes. DCP22 requires post development 1 year Annual Recurrence Interval (ARI) discharges to equal too or less than the pre development 1 year ARI discharges while infrastructure protection flows must be reduced to less than the pre development 10 year ARI discharges. However, the NRLG requires all stormwater events from 1 year ARI to 100 year ARI with durations ranging from 5 minutes up to 3 hours to be reduced to the equivalent predevelopment flow. Typically rainwater tanks are installed on each lot to detain the shorter heavier storms. Larger end of line detention basins are installed to detain longer events with lower rainfall intensities but larger overall volumes of water. This research project does not go into a detailed study of the rainfall runoff volumes or the effects of the existing basin on peak stormwater discharges.

The performance criteria for SW quality by LCC are located in Chapter 22.4 Table 1

- Total Suspended Solids must have a 75% reduction of mean annual loads compared to the base line. Base line data is taken as the average pollutant generation over the 10 year period as modelled from the supplied rainfall data.
- Total Phosphorous must have a 65% reduction of mean annual loads compared to the base line.
- Total Nitrogen must have a 40% reduction of mean annual loads compared to the base line.
- Gross Pollutants must have a 75% reduction of mean annual loads compared to the base line.

Pollutant levels and reduction effectiveness are typically measured by MUSIC in kg per hectare per year averaged over the 10 years of rainfall data. To gather this sort of data would cover a long period of time and cost a substantial amount of money. Neither of these were available for this research project. The sampling and modelling for this research project was therefore assessed at an instantaneous point and measured in mg/L. This is further discussed in Chapter 4.1.

3.3 Weather data

The weather data that is inputted into a MUSIC model is the rainfall every 6 minutes and the evapro-transpiration data.

3.3.1 Rainfall data

MUSIC requires 6 minute time step rainfall data which is collected and supplied at numerous locations around Australia by the BOM. MUSIC 5 provides free access to pluviograph rainfall data from 1600 sites across Australia for licensed users (eWater pluviograph). The sites that are closest to Goonellabah are the Lismore Airport and the Alstonville Tropical Fruit Research station. The Lismore Airport site was used because it was closer and the BOM website provided 30 minute weather data for this location.

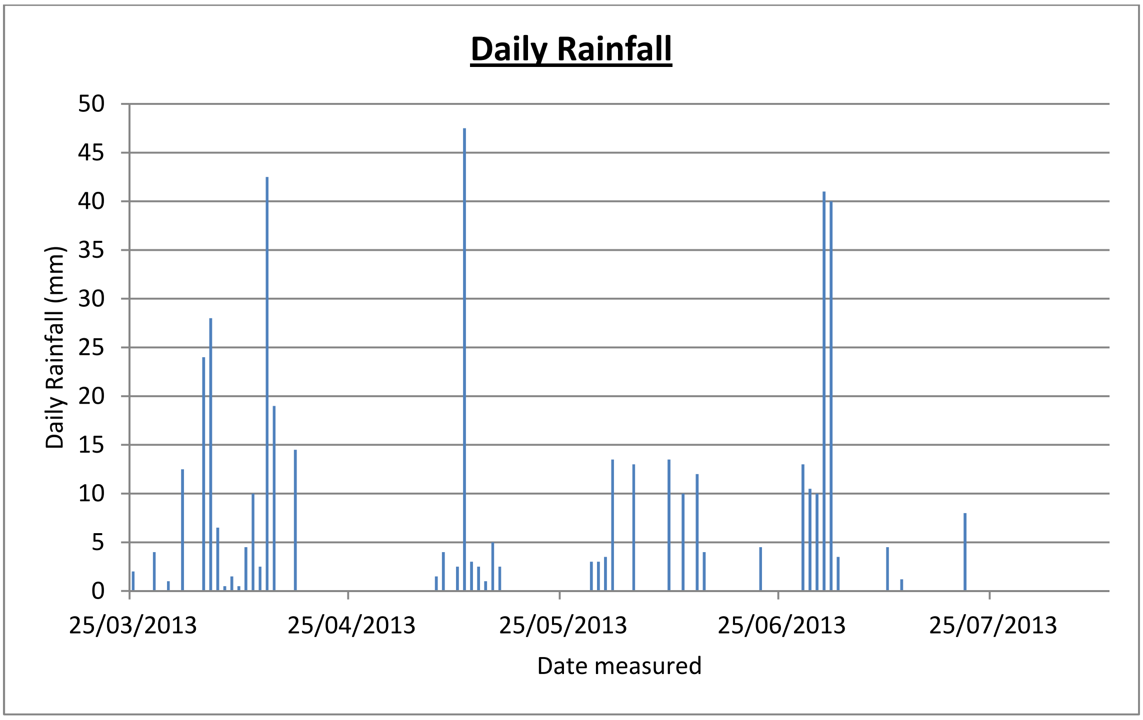
Typically a minimum data set covering a 10 year period of recorded rainfall is used to allow for the warm-up period and cover a representative range of events. Typically the date of this data isn't critical as it is being used to calculate annual pollutant loads.

The BOM was not able to provide current 6 minute rainfall data. For the purpose of this research project it was important to get accurate rainfall data for the duration of the storm being sampled and for the preceding day. The best way to achieve this was by using the following combined data for a period from 1st of January 2013 to 11th of August 2013:

- The rainfall data from the 1st of January to the 6th of April was sourced from the BOM daily rainfall records for the Lismore Airport (BOM Lismore Daily). These rainfall figures where manually divided into 6 minute rainfall values using a text editor to create a txt file acceptable to MUSIC. Actual 6 minute rainfall figures for years prior to 2010 where reviewed to achieve a similar type of rainfall pattern. Isolated rainfall events were assumed to be more intense storms while rainfall events that spanned several days were assumed to have lower intensity rain periods. Testing of the rainfall data showed that there was very little impact in relation to the intensity of the rainfall in the "warm up" period. The more important factor was the amount of rain that fell but even the impact of this was only minor on the end results.
- The rainfall data from the 7th of April to the 7th of May was sourced from the BOM 30 minute rainfall records for the Lismore Airport (BOM Lismore Airport). This data was only for 4 days so regular collection of this data was required. During this period the daily rainfall figures at Waratah Way were collected. This enabled the 30 minute rainfall values to be scaled to match what was measured on site. This was done because the Lismore Airport weather station is located 7.5km from the site. While steady rainfall was similar there were cases where there was considerable difference in the rainfall of storms recorded at Waratah Way. Once the 30 minute rainfall data was scaled it was then manually divided into 5 varying amounts based on a typical hyetograph profile to achieve 6 minute rainfall data formatted for MUSIC.
- From the 8th of May to the 2nd of June the Lismore weather station was off line and no 30 minute rainfall data was available. To overcome this manual recording at Waratah Way was increased from daily to 3-4 times a day. In addition to this notes were made on the start and finish time of rain and the type of rainfall. From this information 6 minute rainfall data was created.

- The Lismore Airport weather station came back online on the 3rd of June and 30 minute rainfall records were collected and edited as discussed above. The collection of this rainfall data continued until the 11th of August

The combination of theses 3 sources of daily rainfall data is shown in Figure 3.2.



Graph 3.1: Daily rainfall measured onsite

Stormwater samples of the biofiltration basin inflow and outflow were taken for three main events (Refer Appendix C). These events were:

Event 1:

Date:	24.03.2013
Sampling Times:	6:00pm to 6:30pm
Inflow Samples:	1, 2 and 3
Outflow Samples:	1A, 2A and 3A
Maximum Intensity:	1.5 mm/6 min
Storm Duration:	24 minutes
Total Rainfall:	2.5 mm

Event 2:

Date:	12.04.2013
Sampling Time:	9:30am to 9:48am

Inflow Samples	1A and 2A
Outflow Samples	1B and 2B
Maximum Intensity:	1 mm/6 min
Storm Duration:	54 minutes
Total Rainfall:	6.5 mm

Event 3:

Date:	13.04.2013
Sampling Time:	9:36am to 10:12am
Inflow Samples	1A and 2A
Outflow Samples	2A and 2B
Maximum Intensity:	1.7 mm/6 min
Storm Duration:	1:40 hours
Total Rainfall:	12 mm

Event 3 was sampled 1 day after sampling of event 2 was undertaken. This enabled the research to see the pollutant levels that are generated by a secondary rainfall event on a "clean" catchment. Samples J1 and J2 relate to the inflow and outflow of the minor bio-filtration basin located at Just Street. The results of this additional treatment device are discussed in Chapter 5. The raw results of these samples are attached in Appendix C. Detailed comparison of these sampling results and the MUSIC model is discussed in Chapter 4.

An additional storm was sampled at a vegetated swale in Lismore known as Gasworks Channel and the major bio-filtration basin at Just Street. This was done to compare the effectiveness of different types of treatment devices. The sampling and results of these additional types of treatment devices is discussed in Chapter 5.

Event 4:

Date:	20.07.2013
Time:	12:30pm
Gasworks Channel Samples	Gas 1 and Gas 2
Major Just St Basin	J1 and J2

3.3.2 Evapro-transpiration data

Monthly Average Areal Potential Evapro-Transpiration figures measure the amount of water removed by a vegetated area by the process of both evaporation and transpiration which is the uptake of water by vegetation (BOM Evapro-transpiration). These figures are provided by the BOM for South Grafton and Tweed which are located 100km to the north and south of Lismore respectively. To get evapro-transpiration data suitable for the Lismore region an average of the BOM supplied data for South Grafton and Tweed was calculated. The figures used for this MUSIC model are as follows:

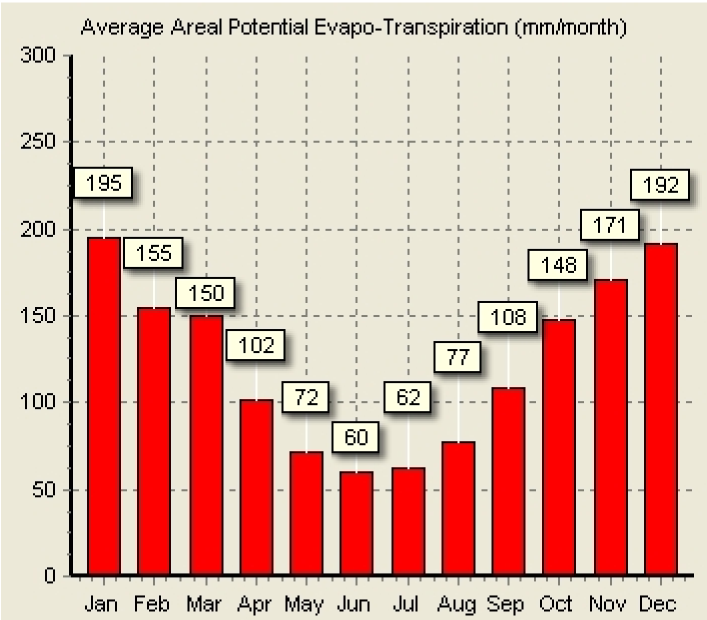


Figure 3.1: Evapro-transpiration rates

The evapro-transpiration values are combined with the rainfall data in the MUSIC meteorological template to generate a 6 minute template time step to enable the MUSIC model to be setup and run.

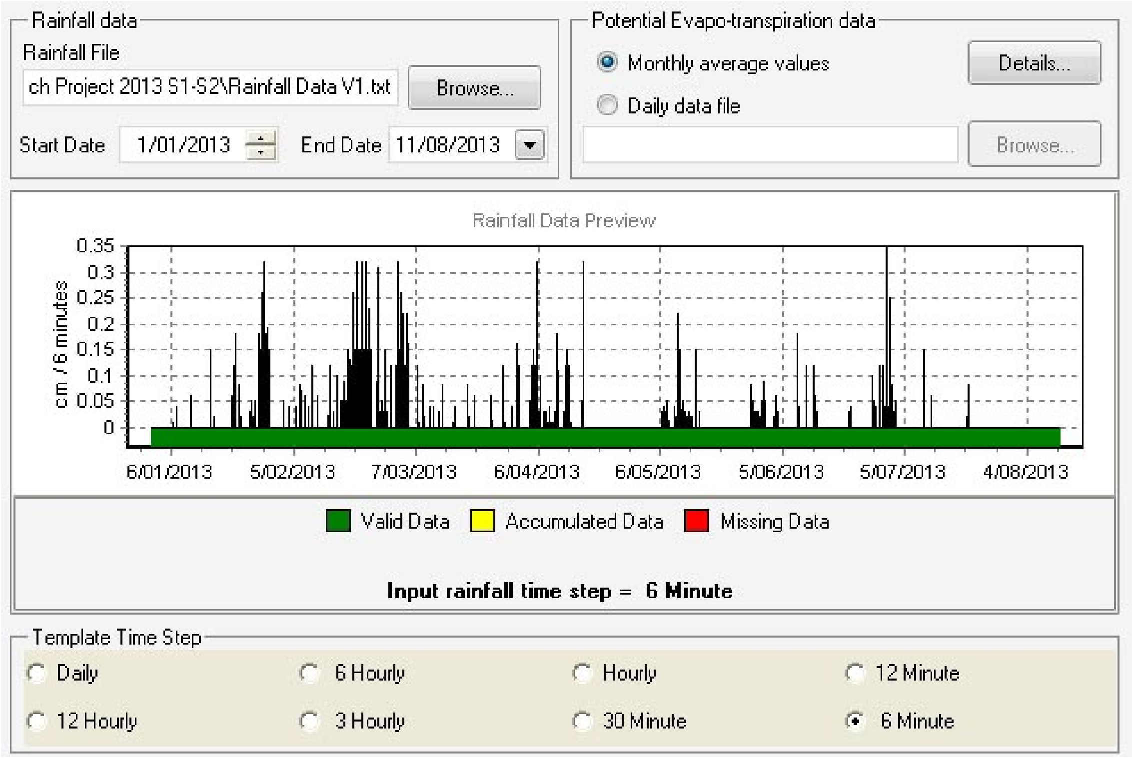


Figure 3.2: MUSIC meteorological template builder

3.4 MUSIC modelling setup

The setup of a MUSIC model typically involves a series of source nodes connecting to a treatment train. Normally the existing and proposed site conditions are modelled to gain an indication of the increase of stormwater pollutants relating to a proposed development. From this a treatment train can be designed and adjusted until it complies with the relevant stormwater quality targets.

The MUSIC model required for this research paper was somewhat different in that the catchment was already developed and the treatment devices were already operational. The selection and setup of the source node parameters along with the calculation of the catchment area and fraction impervious are discussed in section 3.4.1. The setup of the bio-retention treatment node and calculation of parameters including basin volume, filter depth, filter area and hydraulic conductivity is calculated below in section 3.4.2.
With the MUSIC model setup it was then possible to model the basin inflow and outflow relating to flow, TSS, TP, TN and GP and to validate the accuracy of the model.

3.4.1 Source node parameters

Source nodes are used to define the different types of land use including urban, agricultural and forest. Each source node calculates different levels of pollutant concentrations depending upon the intensity of the rainfall data file and other parameters. The parameters which are normally adjusted in a source node are the catchment area and the fraction impervious. It is possible to adjust the rainfall runoff parameters, pervious area properties, ground water properties and the base flow parameters for each pollutant but this normally requires substantial field testing.

MUSIC provides default source nodes for urban, agricultural and forest but many metropolitan councils often develop their own source nodes based on their climate, soil and runoff conditions. Lismore Council has adopted the use of the Tweed source nodes for their catchments. Table 3.2 below shows the differences in mean annual pollutant loads between the default, Brisbane and Tweed source nodes with a 3.94ha catchment using the rainfall data measured on site.

	Flow (ML/yr)	**TSS** (kg/yr)	**TP** (kg/yr)	**TN** (kg/yr)	**GP** (kg/yr)
Default MUSIC Urban Source Node	67.7	12500	26.5	190	1300
Brisbane Urban Source Node	67.4	13000	25.6	138	1290
Tweed Urban Source Node	67.9	7020	17	105	1310

Table 3.2: Source Node - Mean annual load comparison

The MUSIC model for this research project was setup with a Urban Tweed source node. The catchment was analysed with LPI contours and Mapinfo cadastre in AutoCAD and determined to be 3.94ha. By overlaying the cadastre and contours on a scaled sixviewer aerial the fraction impervious is calculated as 47% which includes all roof area, footpaths and road pavement. Using deposited plans from the LPI and high resolution aerial photos the accuracy of the catchment area was considered to be sufficient. The exact catchment boundaries were verified by site inspection and found to be accurate. Minor variations in catchments due to the drainage of roof water were considered to be minimal and were ignored. No agricultural or forest source nodes are required for this model.

Figure 3.3: MUSIC modelling schematic of subject site

3.4.2 Gross pollutant trap parameters

A gross pollutant trap (GPT) is typically the first treatment node at the start of a treatment train. GPTs are designed to capture larger pollutants such as plastics, metals, organics and sediment. The most common gross pollutants in an urban catchment include plastic bottles, organics such as leaves and lawn clippings, cigarette butts, metal cans and domestic plastics (Gosford SC GPT). Gross pollutant traps can either be pit filter baskets or end of line treatment devices. End of line treatment devices such as ski jumps or Ecosol NetTech GPTs are often favoured because they provide a single maintenance point. For GPTs to be effective they must be emptied at regular intervals.

The outlet headwall into the subject basin did not have any form of GPT installed and there was no evidence of GPTs inside the stormwater inlet pits within the basins catchment. Typically heavier gross pollutants and sediments will settle inside the basin while lighter pollutants such and bottles, cans and bags will be flushed through in the next major rainfall event. The existing headwall had a significant build-up of sediment and grass up to 300mm deep. This sediment and grass had to be removed from the headwall and downstream channel before a temporary GPT could be constructed as discussed in section 1.4

As this device was custom made the MUSIC model GPT node was created using the default parameters for reduction of pollutant concentrations.

3.4.3 Bio retention basin parameters

A bio-retention basin is designed to reduce the flow velocities discharging downstream and to improve the quality of the water runoff (Melbourne Water WSUD). Bio-retention basins are especially effective in removing nitrogen and phosphorous using uptake through specifically chosen plants and sedges.

Bio-retention basins are divided into 7 main categories including inlet properties, storage properties, filter and media properties, infiltration properties, lining properties, vegetation properties and outlet properties.

Works as executed survey, shown in Figure 1.2, was obtained from old Aspect North data bases for the purpose of calculating areas and volumes of the basin. This survey was completed in 2002 but is still accurate for the purposes of this research. The top of the basin is typically 30m long and 28m wide with an 11m wide spillway at RL139.85. There is a 900 x 900 surcharge inlet pit located at the end of the basin which is connected to 3 bio-filtration trenches typically 10m long and 0.45m wide. The pit discharges through a low flow 150mm uPVC pipe.

The following bio-retention basin properties were used to create the bio-retention treatment node in MUSIC.

Inlet Properties

- Low Flow By-Pass 0.0 m^3/s
- High Flow By-Pass 5.0 m^3/s

There is no low flow system included in the design of this basin. The grassed spillway is designed to act as the high flow bypass with an estimation made of its capacity from the survey levels.

Storage

• Extended Detention Depth	0.66 m
• Surface Area	587 m

The surface area and storage volume of the basin were calculated with CivilCAD. As the storage is the critical factor in pollutant reduction the depth was adjusted to give the correct storage volume of 387 m^3.

Filter and Media Properties

• Filter Area	11.7 m
• Unlined Filter Media Perimeter	52 m
• Saturated Hydraulic Conductivity	500 mm/hour
• Filter Depth	0.6 m
• TN Content of Filter Media	800 (mg/kg)
• Orthophosphate Content of Filter Media	80 (mg/kg)

Filter area, perimeter and filter depth were calculated from the provided survey data. The saturated hydraulic conductivity was calculated manually using a clear tube and watch. The results of this sample varied from 380mm/hr to 650mm/hr at different locations with an average value being adopted. This value correlated with the MUSIC default for course sand. Default media values for TN and Orthophosphate were adopted. These values are in the middle of the typical range.

Infiltration Properties

• Exfiltration rate	36 mm/hr

The exfiltration rate is adopted from the MUSIC recommended value for clayey sand.

Infiltration Properties

The basin isn't lined.

Vegetation Properties

The latest release of MUSIC allows the used to specify if the basin is vegetated with effective nutrient removal plants, vegetated with ineffective nutrient removal plants or unvegetated. The basin is currently vegetated with grass which isn't considered effective at removing TP and TN nutrients.

Outlet Properties

- Overflow Weir Width 11 m
- An underdrain is present.
- No submerged zone with carbon is present.

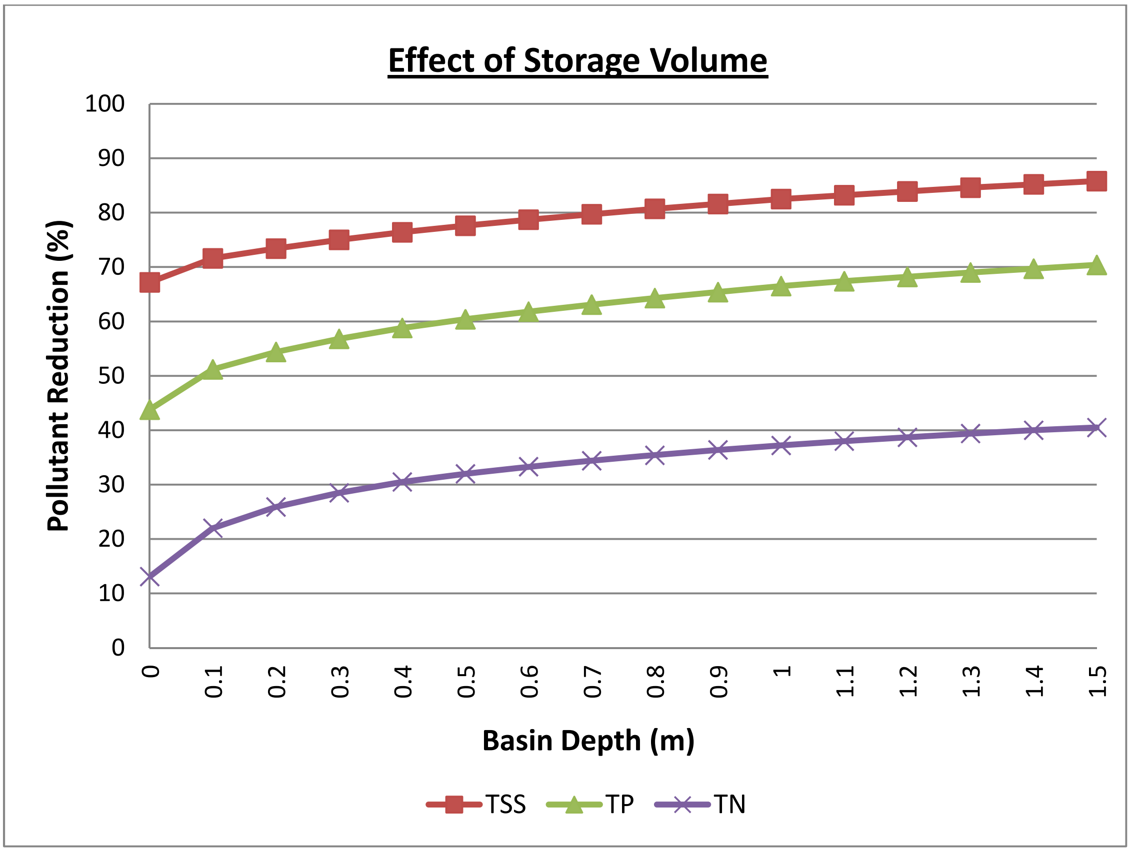
3.5 Effects of individual MUSIC parameters on a model

To better understand the effect of the parameters of a bio-retention treatment node a range of parameters were adjusted manually from low to high values and the results were graphed. This procedure was not applied to the parameters of the source nodes but only the critical parameters of the bio-retention treatment node. The parameters that were assessed were the basin storage, the filter area, the hydraulic conductivity and the filter depth. Typically only one parameter was adjusted at a time to provide for consistent results from which to assess the parameters effect. The model for checking the parameters was not based on Waratah Way but was a bio-retention basin from another site which had more typical filter to catchment areas.

The bio-retention basin was $1000m^2$ in area with a storage depth of 1m. The filter media had an area of $100m^2$, a depth of 0.6m and a hydraulic conductivity of 100 mm/hr. The Tweed urban residential catchment node had an area of 5.86ha and was 40% impervious. 10 years of 6 minute rainfall data from Alstonville weather station was used to run the model.

3.5.1 Basin Storage Volume

The basin storage volume is controlled in MUSIC by adjusting either the extended detention depth or the surface area. The extended attention depth was adjusted from 0m deep up to 2m deep in intervals of 0.1m. The effect on the pollutant reduction percentage with an increasing storage volume is shown below in Graph 3.2.



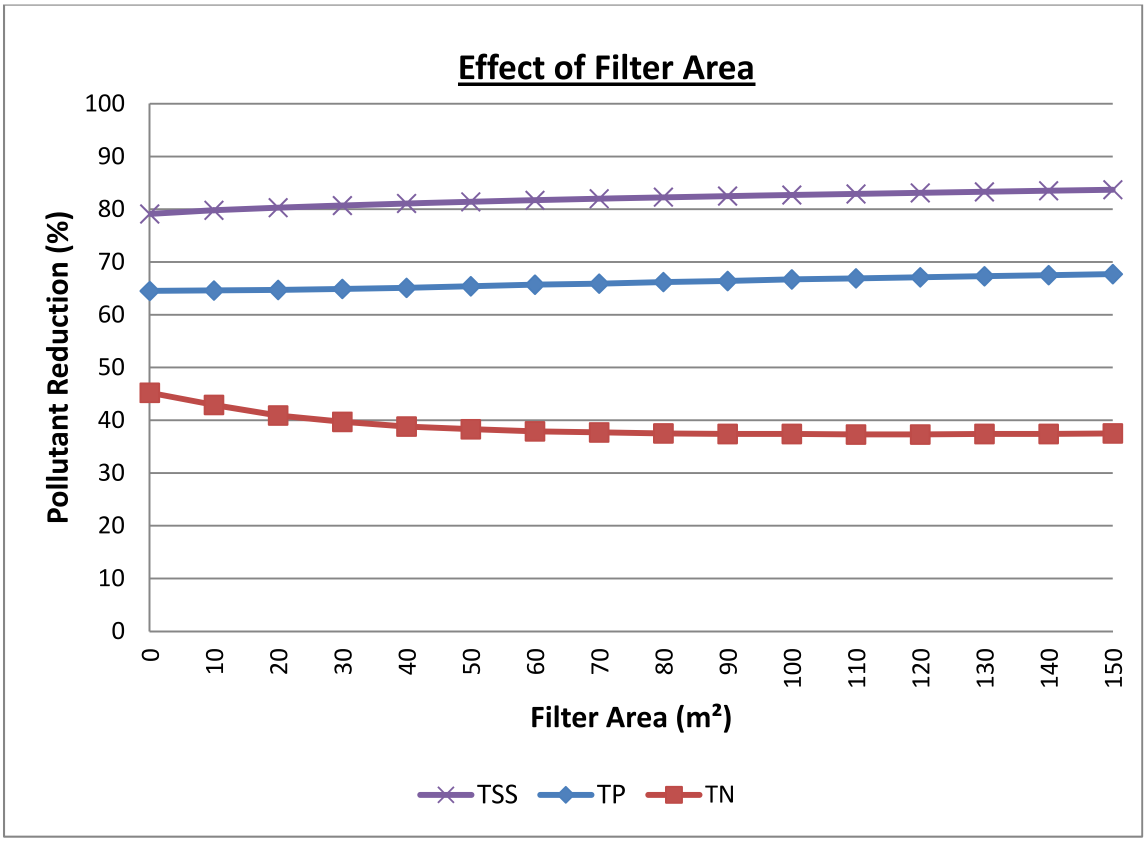
Graph 3.2: Effect of basin storage volume on stormwater treatment.

As can be seen above, the greater the volume of a detention basin the greater the removal percentage of TSS, TN & TP. Initially the reductions are most noticeable but as the basin gets larger the increases get smaller which is to be expected. As a bio-retention basin gets larger it is able to contain and treat larger and larger events. The ultimate basin size would contain and treat all events but this would obviously come at a considerable cost and require a large area of land and is not required under WSUD practices.

3.5.2 Filter Area

The filter area depends on the amount of land available and the volumes of water to be treated. To assess the effect of the filter area on pollutant reduction percentages the area was adjusted from 10m² to 150m² in increments of 10m². The effect on the pollutant reduction percentage with an increasing filter area is shown below in Graph 3.3.

Graph 3.3 shows a relatively linear increase in pollutant reduction of TSS and TP as the filter area increases. However TN reductions are the highest with a small filter area which rapidly drops before levelling out and then increasing later on. This model behaviour was not expected and further investigation into this could be warranted.



Graph 3.3: Effect of filter area on stormwater treatment.

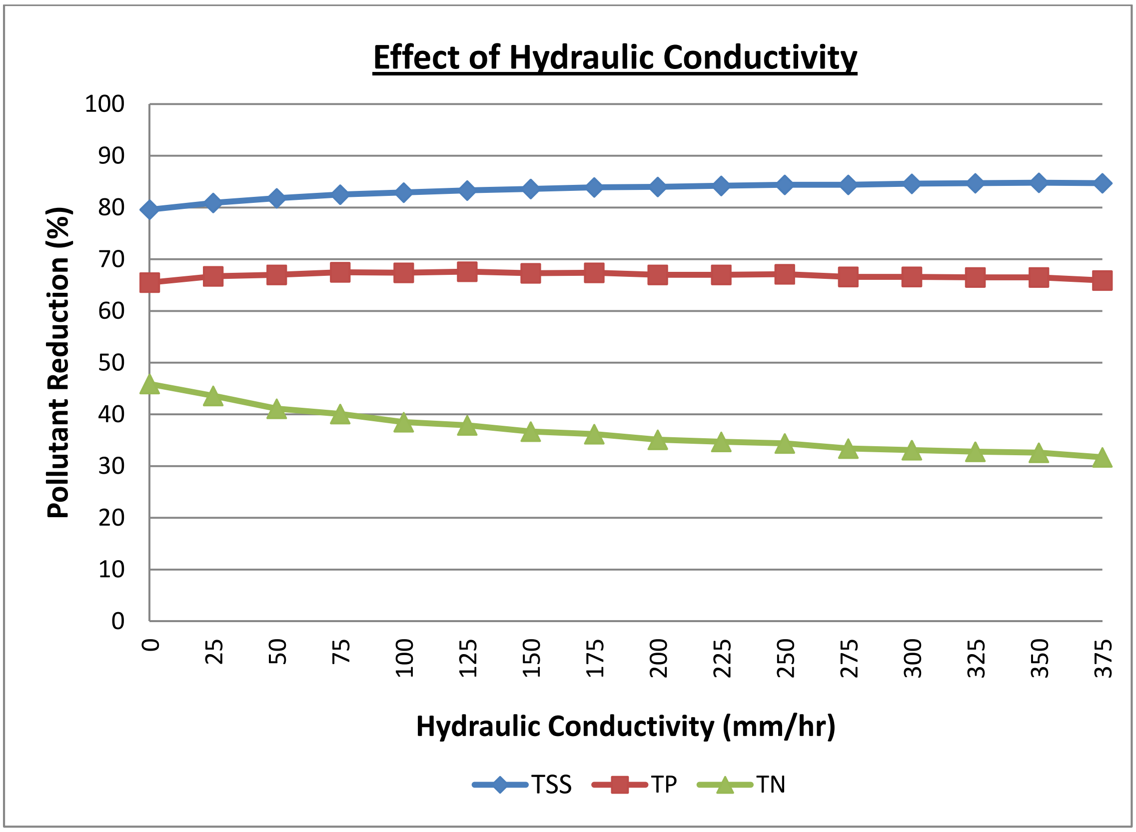
3.5.3 Hydraulic Conductivity and Particle Size

Hydraulic conductivity is the ability of soil to transmit water when submitted to a hydraulic gradient (Web EAD). The hydraulic conductivity of media is directly linked to the size of the particle.

Soil Type	Median Particle Size (mm)	Saturated Hydraulic Conductivity	
		(mm/hr)	(m/s)
Gravel	2	36000	1×10^{-2}
Coarse sand	1	3600	1×10^{-3}
Sand	0.7	360	1×10^{10}
Sandy loam	0.45	180	5×10^{-5}
Sandy clay	0.01	36	1×10^{-5}

Table 3.3: Hydraulic conductivity vs median particle size *(MUSIC)*

To assess the effect of the saturated hydraulic conductivity on pollutant reduction percentages the conductivity was adjusted from 25 mm/hr to 375 mm/hr in increments of 25mm/hr. The median particle size was adjusted as per Table 3.3 to give a representative result of the effects of filter media ranging from sandy clay to sandy loan and onto sand. The effect on the pollutants with an increasing saturated hydraulic conductivity and particle size is shown below in Graph 3.4.

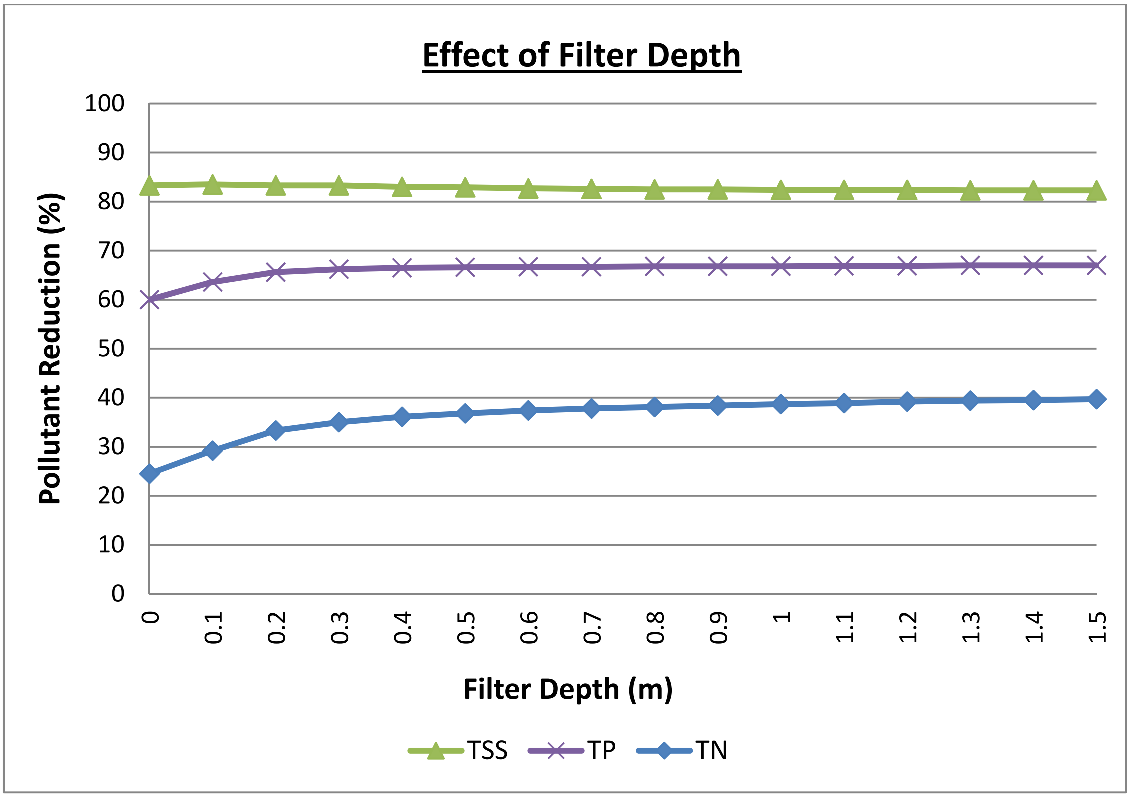


Graph 3.4: Impact of hydraulic conductivity on stormwater treatment.

The effects of the conductivity and particle size parameters vary for all three pollutants. TN reduction is best achieved with a low level of hydraulic conductivity. This is most likely due to extended detention times allowing for nutrient uptake by the plants within the basin. TP reduction gradually increases up to a hydraulic conductivity rate of 250 mm/hr but starts to decline after this. TSS reduction gradually increases up to a hydraulic conductivity rate of 1100 mm/hr (not shown in this graph) but starts to decline after this. The coarser the filter particle size the larger the volume of water that can be treated for TSS. However, as demonstrated by the MUSIC model, once the hydraulic conductivity passes 1100 mm/hr (the equivalent of sand) the effectiveness of the removal of TSS is reduced.

3.5.4 Filter Depth

To assess the effect of the filter depth on pollutant reduction percentages the depth was adjusted from 0.1m to 1.5m in increments of 0.1m. The effect on the pollutants with an increasing filter depth is shown below in Graph 3.5.



Graph 3.5: Effect of filter depth on stormwater treatment.

Graph 3.5 shows little impact on the reduction of TSS as the filter depth increases. The impact on TP removal increases rapidly at first before slowing up and levelling out once the filter depth was above 0.6m. The impact on TN removal also increases rapidly at first before slowing up and levelling out once the filter depth was above 0.8m.

From this brief study of the four major parameters the following is suggested as a preliminary guide for the design of a bio-retention basin but ultimately each basin needs to be designed to suit each individual site and the required objectives.

- The hydraulic conductivity should generally range from 150 mm/hr to 300 mm/hr. This can be reduced to aid the removal of TN but this may need to be accompanied with an increased basin size for the removal of TSS.
- Ideally the minimum filter depth should be 0.6m however once the depth gets above 0.9m deep the increase in pollutant reduction is minimal.
- The filter area needs to be sized to suit the catchment and target objectives. The MUSIC model shows that larger filter areas may be less effective in removing TN which should be investigated further.
- The larger the basin volume the greater the removal of all three pollutants will be and the greater storage there is available for sediments.

These outcomes are generally in line by research undertaken by the Facility for Advancing Water Bio-filtration (FAWB) in March 2008 which recommended a filter media depth of 400-600mm deep with a 100mm thick transition layer and a drainage layer with 50mm under pipe coverage. They also recommended the conductivity rate stay between 100-300 mm/hr as a balance between plan survival and minimising the required basin area.

CHAPTER 4 – SAMPLING RESULTS & COMPARISONS

4.1 MUSIC modelling results

As mentioned, pollutant levels and reduction effectiveness are typically measured in kg per hectare per year averaged over the 10 years of rainfall data. To gather this sort of data would cover a long period of time and cost a substantial amount of money. Neither of these were available for this research project.

MUSIC software allows the user to review instantaneous pollutant levels for a 6 minute period. This is done using the "time series graph" function within MUSIC. Pollutant levels for each 6 minute period is shown in milligrams per litre (mg/L) which is equivalent to parts per million (ppm). By measuring the rainfall exactly in 6 minute blocks and noting the exact time that each sample it was hoped that there would be a correlation between the modelling results and the stormwater samples.

Individual rainfall events are detailed in section 3.3.1. The following tables refer to the rainfall event and the sample. For example, event 1-S2 refers to the first storm and the second sample taken during that storm.

4.1.1 Total Suspended Solids modelling results

The individual inflow and outflow modelled results for the Total Suspended Solids is shown below in mg/L.

Event	Inflow	Outflow
1-S1	102	2
1-S2	128	2
1-S3	7	2
2-S2	92	2
2-S2	7	2
3-S1	67	20
3-S2	108	18

Table 4.1: Modelled TSS results (mg/L)

4.1.2 Total Nitrogen modelling results

The individual inflow and outflow modelled results for the Total Nitrogen is shown below in mg/L.

Event	Inflow	Outflow
1-S1	102	2
1-S2	128	2
1-S3	7	2
2-S2	92	2
2-S2	7	2
3-S1	67	20
3-S2	108	18

Table 4.2: Modelled TN results (mg/L)

4.1.3 Total Phosphorous modelling results

The individual inflow and outflow modelled results for the Total Phosphorous is shown below in mg/L.

Event	Inflow	Outflow
1-S1	0.23	0.46
1-S2	0.42	0.46
1-S3	0.08	0.46
2-S2	0.07	0.46
2-S2	0.03	0.46
3-S1	0.28	0.17
3-S2	0.26	0.2

Table 4.3: Modelled TP results (mg/L)

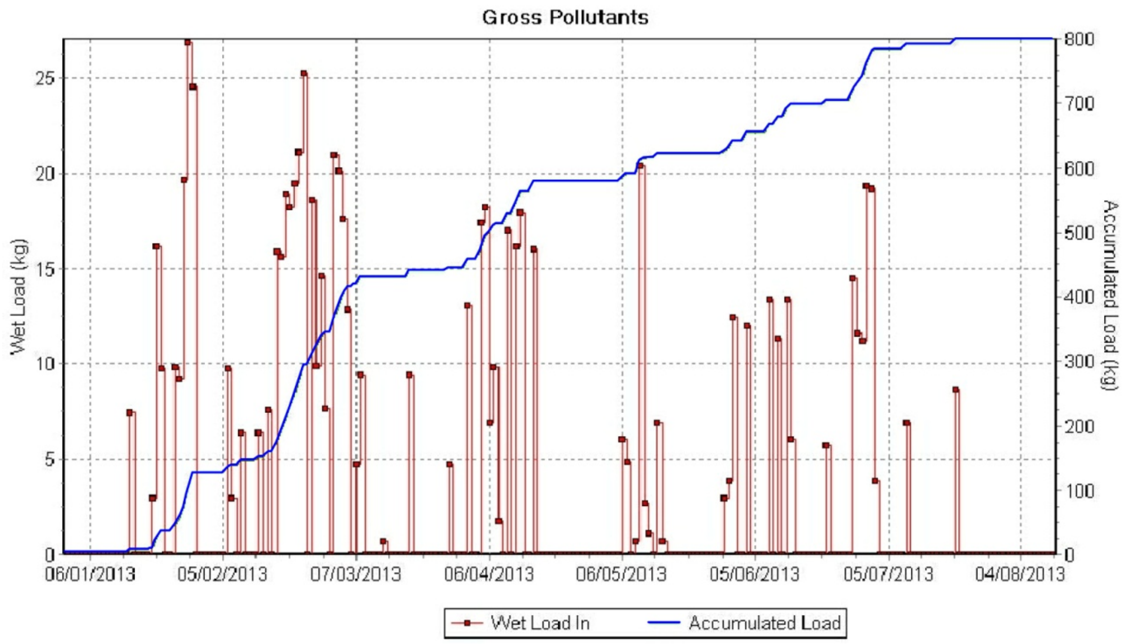
It is noted that the outflow values for a lot of the storms are very similar. The most likely explanation for this is that the intensity of the sampled storms is very similar and that the infiltration rate through the modelled media is generally the same rate throughout the event.

4.1.4 Gross Pollutants modelling results

The gross pollutant trap was constructed on the 16th of March. The gross pollutants were then measured on 4 occasions on the 24th of May, 9th of April, 27th of April and the 6th of July typically following a period of rainfall. MUSIC allows the user to export pollutant data in excel compatible form. This data was then used to calculate the total pollutant mass for the periods matching the gross pollutant dates discussed above. The modelled gross pollutant wet weight for these collection periods is:

Collection Date	GP Weight (kg)
24 March	9.4
9 April	72.0
27 April	67.2
6 July	204
Total	**353.4**

Table 4.4: Modelled GP wet weight over sampling collection periods (kg)



Graph 4.1: Daily & cumulative modelling results

4.2 Stormwater quality sampling results

4.2.1 Total Suspended Solids sampling results

The individual inflow and outflow sampling results for the Total Suspended Solids is shown below in mg/L.

Event	Inflow	Outflow
1-S1	83	26
1-S2	18	18
1-S3	6	8
2-S2	39	11
2-S2	5	10
3-S1	6	1
3-S2	2	2

Table 4.5: Sampled TSS results (mg/L)

4.2.2 Total Nitrogen sampling results

The individual inflow and outflow sampling results for the Total Nitrogen is shown below in mg/L.

Event	Inflow	Outflow
1-S1	1.19	1.07
1-S2	0.5	0.71
1-S3	0.64	0.71
2-S2	0.35	0.21
2-S2	0.12	0.21
3-S1	0.43	0.32
3-S2	0.42	0.37

Table 4.6: Sampled TN results (mg/L)

4.2.3 Total Phosphorous sampling results

The individual inflow and outflow sampling results for the Total Phosphorous is shown below in mg/L.

Event	Inflow	Outflow
1-S1	0.12	0.07
1-S2	0.04	0.06
1-S3	0.04	0.05
2-S2	0.08	0.04
2-S2	0.03	0.04
3-S1	0.05	0.05
3-S2	0.05	0.04

Table 4.7: Sampled TP results (mg/L)

4.2.4 Gross Pollutants sampling results

As mentioned the gross pollutant trap was constructed on the 16th of March. The gross pollutants were then measured on 4 occasions on the 24th of May, 9th of April, 27th of April and the 6th of July typically following a period of rainfall. The collected gross pollutants were separated manually into three categories being organics (grass & leaves), litter (plastics, paper and metal) and sediment (coarse and fine). The sampled gross pollutant wet weight for each of these categories during the specified collection periods is:

Collection Date	Coarse Sediment	Organics	Plastic, Paper & Metals	Total
24/03/2013	1.9	0.4	0.1	2.4
9/04/2013	61	2.9	0.5	64.4
27/04/2013	38	1.2	0.3	39.5
6/07/2013	120	1.8	0.9	122.7
Total	**220.9**	**6.3**	**1.8**	**229**

Table 4.8: Sampled GP results wet weight (kg)

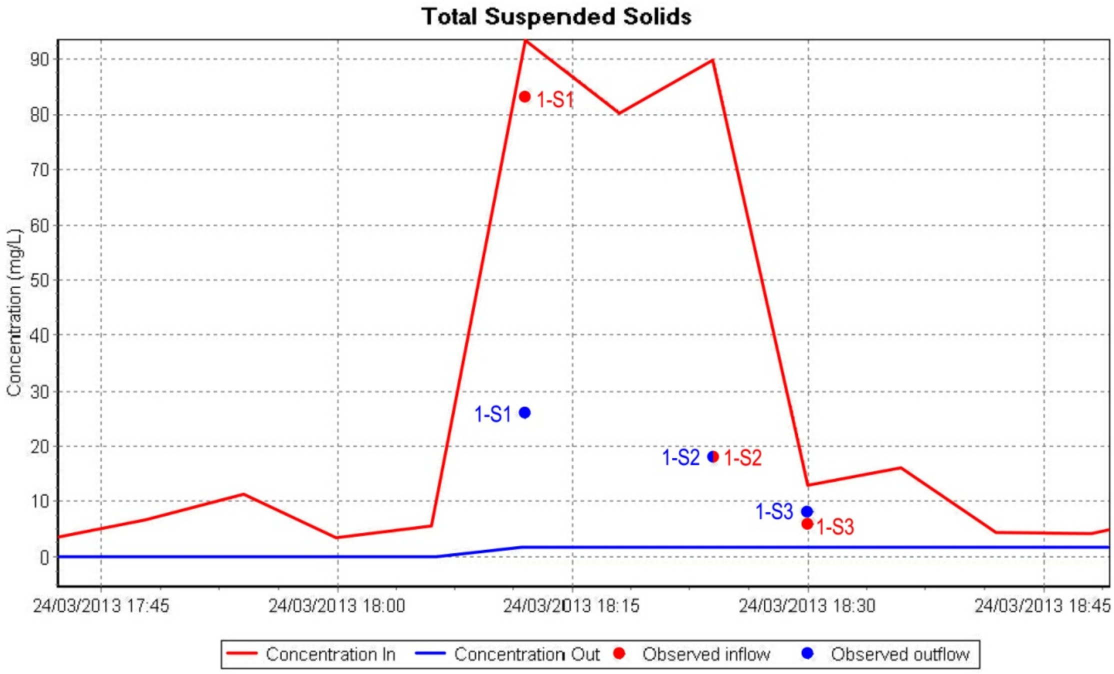
4.3 Stormwater quality comparisons

Comparisons of the stormwater pollutant modelling results and stormwater pollutant sampling results are shown below in tables and graphs. The graphs have been generated through the MUSIC time series graph option. TSS, TN & TP pollutant levels are instantaneous values shown in mg/L while the values of the gross pollutants are shown as wet weight in kilograms.

4.3.1 Total Suspended Solids quality comparisons

	Inflow TSS (mg/L)		**Outflow TSS** (mg/L)	
Event	**Modelled**	**Sampled**	**Modelled**	**Sampled**
1-S1	102	83	2	26
1-S2	128	18	2	18
1-S3	7	6	2	8
2-S2	92	39	2	11
2-S2	7	5	2	10
3-S1	67	6	20	1
3-S2	108	2	18	2

Table 4.9: TSS comparison of modelled and sampled concentrations (mg/L)



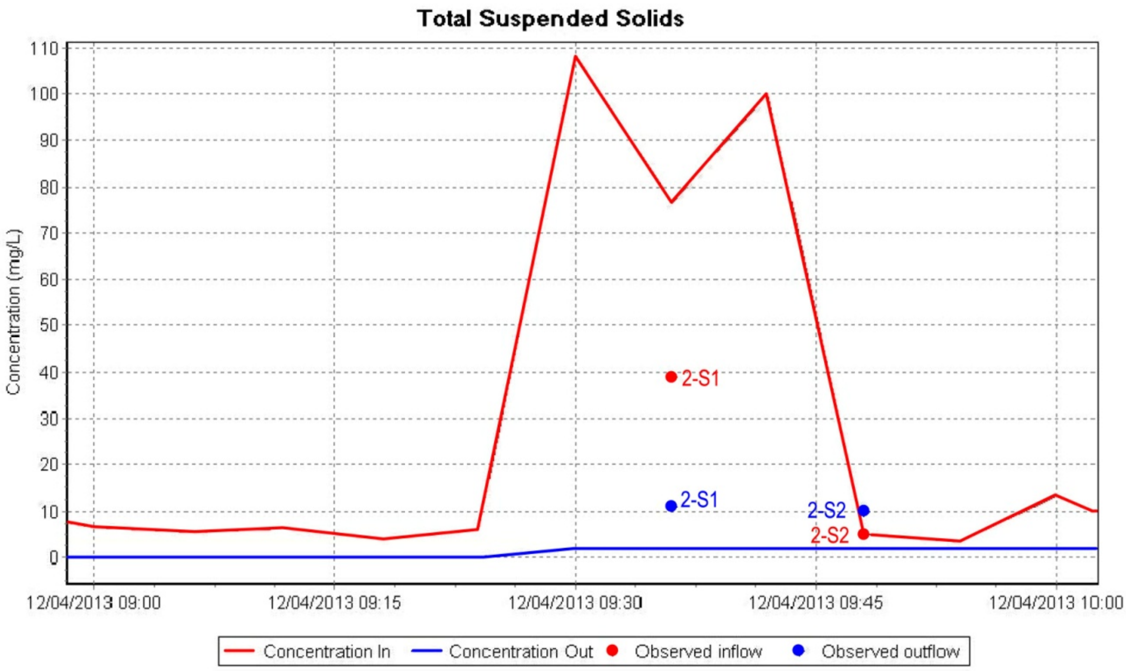
Graph 4.2: Storm 1 TSS comparison of modelled & sampled concentrations (mg/L)

Sampled inflow concentrations are shown as red points.

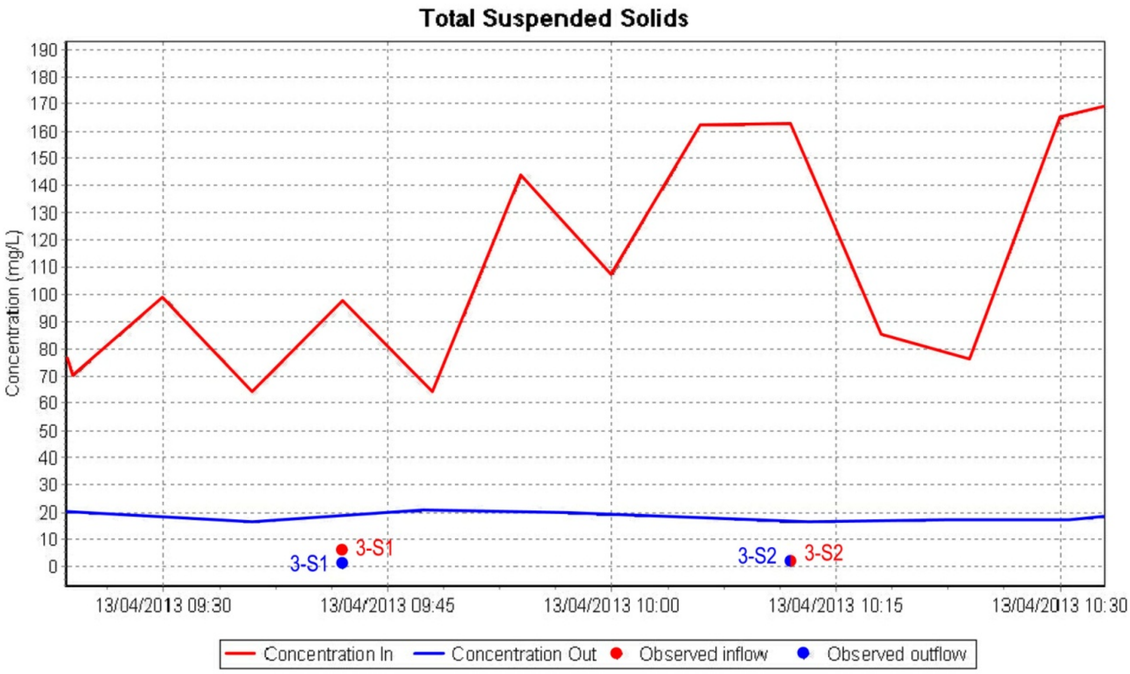
Sampled outflow concentrations are shown as blue points.

Modelled inflow concentrations are shown as a red line.

Modelled outflow concentrations are shown as a blue line.



Graph 4.3: Storm 2 TSS comparison of modelled & sampled concentrations (mg/L)

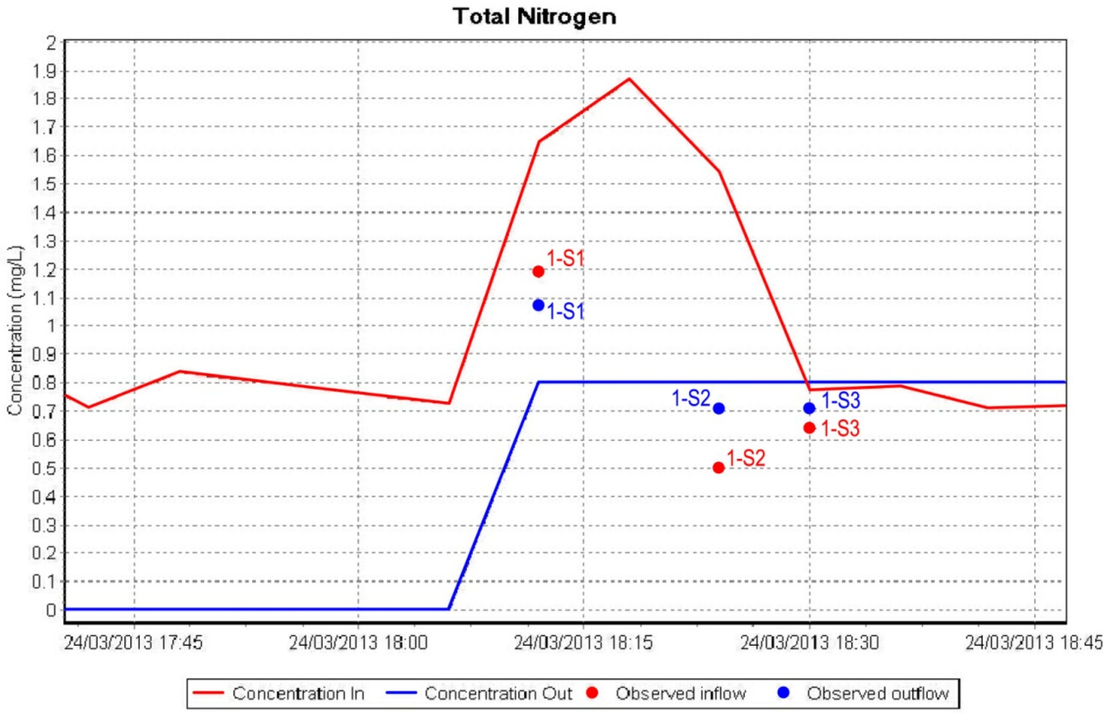


Graph 4.4: Storm 3 TSS comparison of modelled & sampled concentrations (mg/L)

4.3.2 Total Nitrogen quality comparisons

	Inflow TN (mg/L)		**Outflow TN** (mg/L)	
Event	**Modelled**	**Sampled**	**Modelled**	**Sampled**
1-S1	1.81	1.19	0.8	1.07
1-S2	1.5	0.5	0.8	0.71
1-S3	0.77	0.64	0.8	0.71
2-S2	1.62	0.35	0.8	0.21
2-S2	0.8	0.12	0.8	0.21
3-S1	1.71	0.43	1.4	0.32
3-S2	1.55	0.42	1.35	0.37

Table 4.10: TN comparison of modelled and sampled concentrations (mg/L)



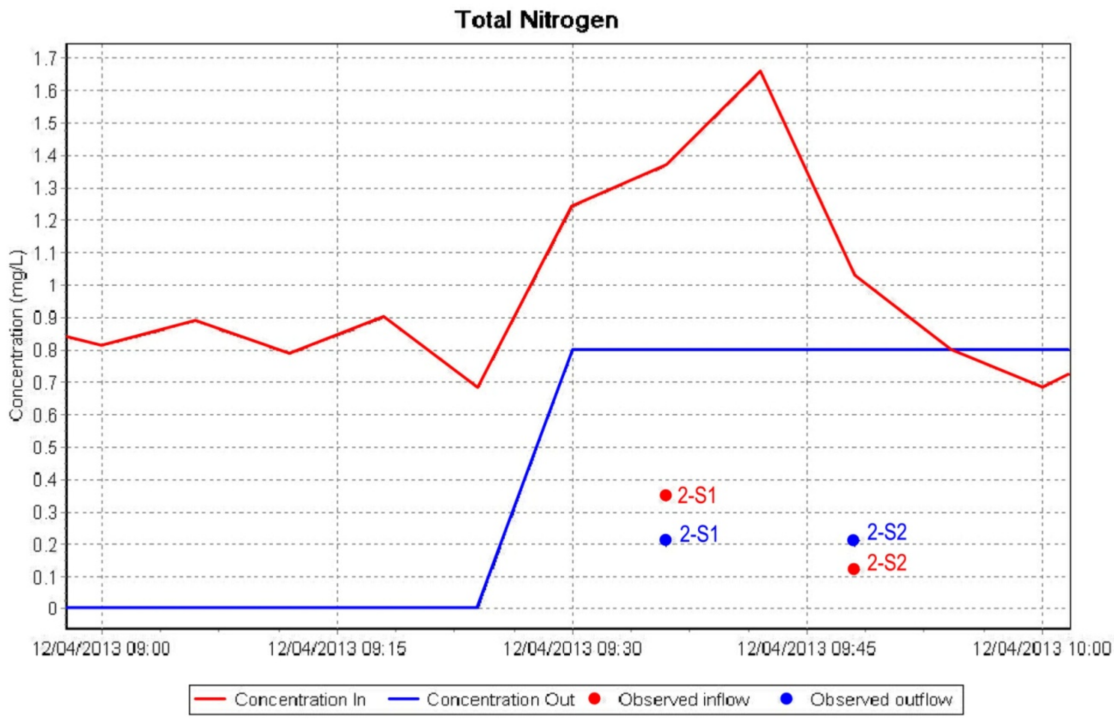
Graph 4.5: Storm 1 TN comparison of modelled & sampled concentrations (mg/L)

Sampled inflow concentrations are shown as red points.

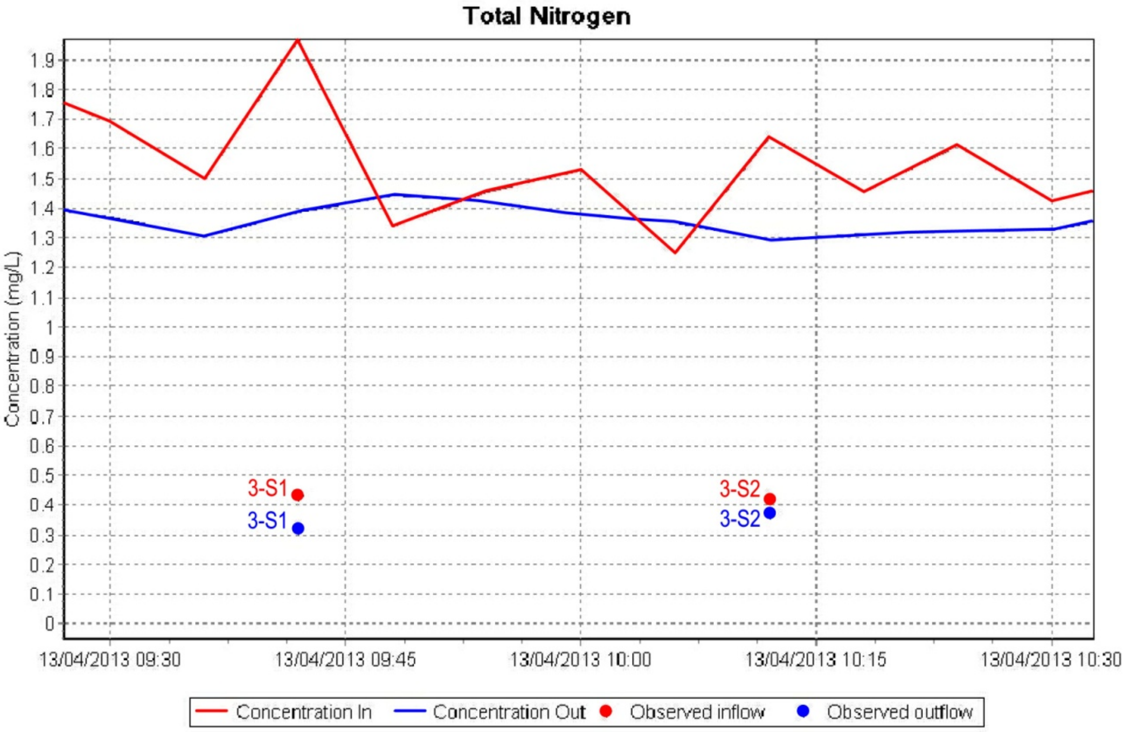
Sampled outflow concentrations are shown as blue points.

Modelled inflow concentrations are shown as a red line.

Modelled outflow concentrations are shown as a blue line.



Graph 4.6: Storm 2 TN comparison of modelled & sampled concentrations (mg/L)

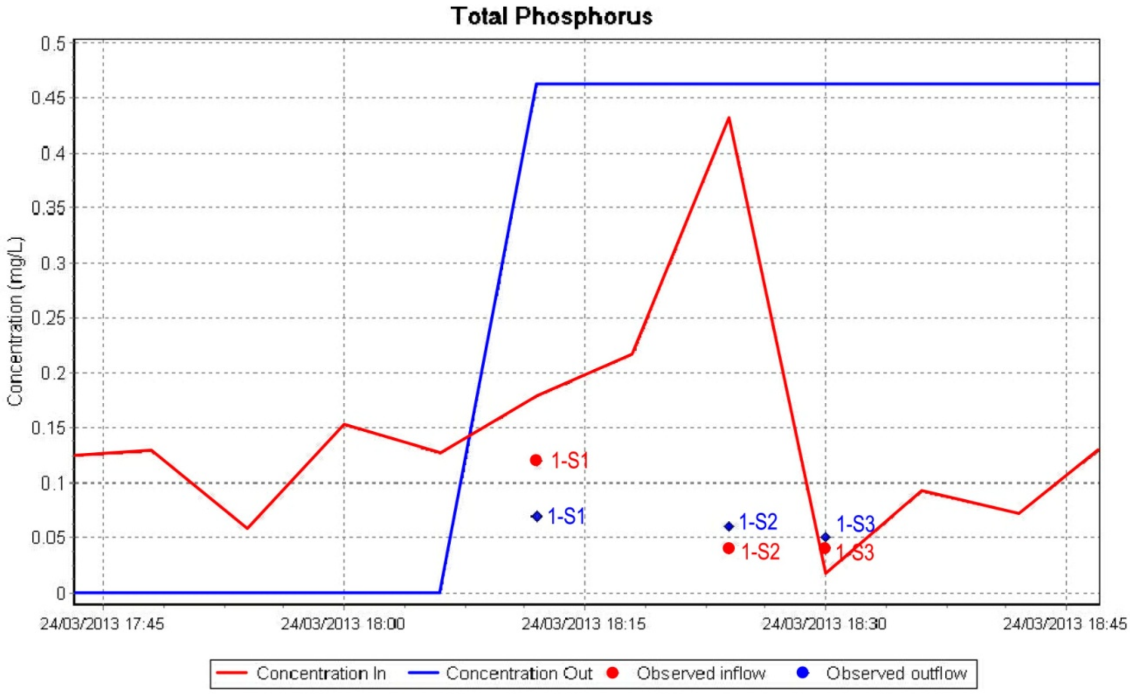


Graph 4.7: Storm 3 TN comparison of modelled & sampled concentrations (mg/L)

4.3.3 Total Phosphorous quality comparisons

	Inflow TP (mg/L)		**Outflow TP** (mg/L)	
Event	**Modelled**	**Sampled**	**Modelled**	**Sampled**
1-S1	0.23	0.12	0.46	0.07
1-S2	0.42	0.04	0.46	0.06
1-S3	0.08	0.04	0.46	0.05
2-S2	0.07	0.08	0.46	0.04
2-S2	0.03	0.03	0.46	0.04
3-S1	0.28	0.05	0.17	0.05
3-S2	0.26	0.05	0.2	0.04

Table 4.11: TP comparison of modelled and sampled concentrations (mg/L)



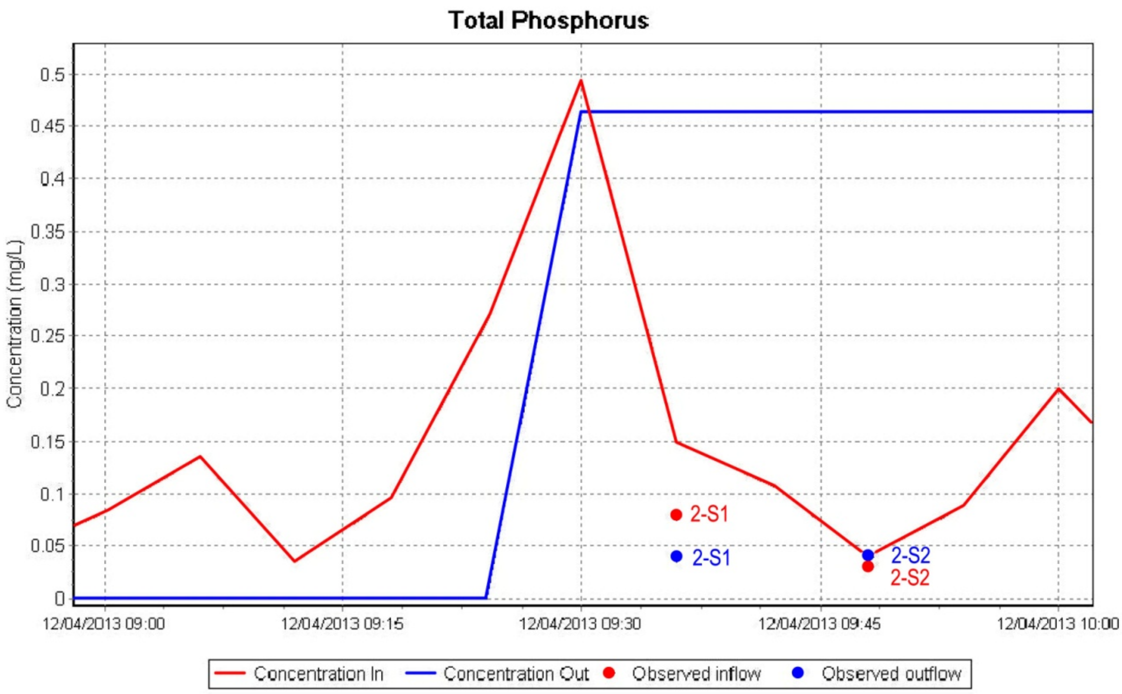
Graph 4.8: Storm 1 TP comparison of modelled & sampled concentrations (mg/L)

Sampled inflow concentrations are shown as red points.

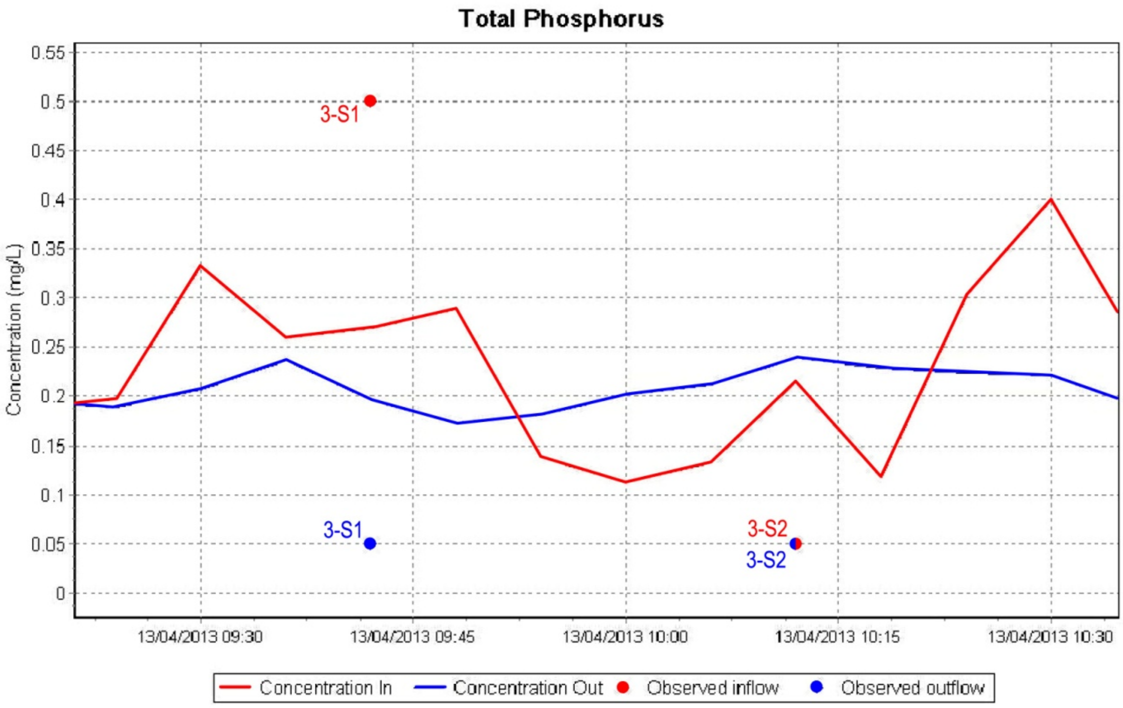
Sampled outflow concentrations are shown as blue points.

Modelled inflow concentrations are shown as a red line.

Modelled outflow concentrations are shown as a blue line.



Graph 4.9: Storm 2 TP comparison of modelled & sampled concentrations (mg/L)



Graph 4.10: Storm 3 TP comparison of modelled & sampled concentrations (mg/L)

4.3.4 GP wet weight comparison

The subject site did not have a GPT installed. As such a temporary GPT was constructed to capture the gross pollutants and sediments generated by the catchment. This allowed for an assessment of the total GP generation accuracy but not the GP removal accuracy of a standard GPT.

Collection Date	**Modelled GP Weight** (kg)	**Sampled GP Weight** (kg)
24 March	9.4	2.4
9 April	72	64.4
27 April	67.2	39.5
6 July	204	122.7
Total	**353.4**	**229**

Table 4.12: GP comparison of modelled and sampled weights (kg)

4.4 Stormwater flow volumes

The calculation of stormwater flow volumes by measuring the depth of flow and using the Manning's formula along with the pipe slope, co-efficient and pipe size to calculate the volume and velocity.

Upon comparing these manually calculated runoff volumes with discharge peaks calculated using the rational method it was quickly evident that the flows were far in excess of what they should have been. The most likely reason for this error was that the gross pollutant trap quickly became clogged with lawn clippings which created a tailwater effect, raised the depth of flow in the pipe and rendered the Manning's formula ineffective

From this point inlet flow volumes were assessed by measuring the depth in the pipe and estimating the velocity of the water by calculating the time gross pollutants took to travel one length of pipe. Obviously the accuracy of this method is not suitable to be included in a research and as such has been excluded. In general these approximate calculations indicated that the inflow volumes calculated by MUSIC are relatively accurate.

CHAPTER 5 – ADDITIONAL SAMPLING RESULTS

5.1 Alternate stormwater treatment devices

A secondary objective of this research project was to collect spot samples on several other stormwater treatment devices within Lismore City Council. The sampling was a single inlet and a single outlet sample to determine the levels of TSS, TP and TN . No rainfall data from any of these sites was collected neither were any MUSIC models created or gross pollutants collected.

Discussions with LCC support staff were undertaken to determine which devices would be tested. It was decided that a range of devices including bio-retention basins, vegetated swales, rain gardens and wetlands should be assessed.

5.1.1 Gasworks Channel vegetated swale

Gasworks Channel is a vegetated swale running from Keen Street (adjacent to Toyota servicing) to Junction Street before discharging into the Wilson River, Lismore. The channel is approximately 500m long and the catchment consists or mainly urban runoff with some light industrial and parkland. The inlet sample was taken at the upstream end near the GPTs while the downstream sample was taken beside Junction Street.

Treatment type	Vegetated Swale
Location	Junction Street, Lismore
Sample Date	20 July 2013

Sample Results	Inflow	Outflow	Change %
TSS	25 mg/L	61 mg/L	+144%
TN	0.10 mg/L	0.15 mg/L	+50%
TP	0.31 mg/L	0.53 mg/L	+71%

The stormwater samples show an increase of all pollutants in excess of 50%. It is noted that the levels of TSS are above expected levels which may be due to erosion of the vegetated swale. The increase in TN and TP values may be due to inflow of other pollution sources along the swale. Typically vegetated swales are efficient for the removal of TSS but will only remove small amounts of TN and TP.

Figure 5.1: Gasworks Channel locality plan

5.1.2 Just Street - Minor bio-retention basin

Just Street is located off Oliver Avenue in Goonellabah. The minor basin is located at the end of a developed urban catchment and includes several undeveloped blocks of land. The basin is located at the end of a 600 diameter pipe and included a concrete energy dissipater and riprap spillway discharging into Tucki Tucki Creek which is upstream of the Waratah Way catchment. An inflow sample was collected at the headwall while the outflow sample was collected at the end of the 150 diameter low flow outlet.

Treatment type	Small bio-retention basin
Location	Just Street, Goonellabah
Sample Date	13 April 2013

Sample Results	Inflow	Outflow	Change %
TSS	2 mg/L	<1 mg/L	> -50%
TN	0.04 mg/L	0.04 mg/L	0%
TP	0.13 mg/L	0.12 mg/L	-8%

The pollutant concentrations from the smaller bio-retention basin are especially low. The main reasons for this are that the rainfall was from a small storm and that the catchment is largely undeveloped as shown in Figure 5.1.

The stormwater samples show little change in the way of pollutant reduction for pollutant levels for all pollutants. The actual level of pollution in these samples was extremely low. These samples were taken after a few days of light to moderate rain therefore the catchment had effectively been cleaned of pollutants prior to these samples being taken.

Figure 5.2: Just Street Minor basin locality plan

5.1.3 Just Street - Major bio-retention basin

The major basin is located towards the end of the current Just Street development. The catchment if primarily urban however it is sparsely developed an is mostly grassed. The basin is located at the end of a small cell box culvert. The basin overflows over a low level concrete access before discharging down a riprap gabion mattress into Tucki Tucki creek which is upstream of the Waratah Way catchment. An inflow sample was collected at the headwall while the outflow sample was collected at the end of one of the 150 diameter low flow outlets.

Treatment type	Major bio-retention basin
Location	Just Street, Goonellabah
Sample Date	19 July 2013

Sample Results	**Inflow**	**Outflow**	**Change %**
TSS	11 mg/L	<1 mg/L	> -90%
TN	0.07 mg/L	0.02 mg/L	-71%
TP	1.49 mg/L	0.08 mg/L	-95%

The stormwater samples show an reduction of all pollutants ranging from 71% to 95%. These reduction levels are above design reduction levels which are primarily due to the small amount of rain that fell in this storm. It is noted that the level of TP in the inflow was well above normal levels. There was a build-up of sludge in the pipe which is likely to have contributed to this. The bio-filtration basin was extremely effective at removing all sampled pollutants.

Figure 5.3: Just Street Major basin locality plan

The results from these few samples showed how effective bio-retention basins can be in relation to grassed swales. The author was also aiming to sample wetlands and rain gardens in the CBD but a lack of rain meant that these samples could not be done.

CHAPTER 6 – RESEARCH FINDING & DISCUSSION

6.1 Research findings & discussion

With the sampling of stormwater pollutants and collection of gross pollutants complete these results were then compared with modelled pollutant concentrations to determine the accuracy of MUSIC.

6.2 MUSIC source node pollutant generation accuracy

Each inflow water sample was analysed in mg/L and compared against the modelled pollutant level for the corresponding time step. These corresponding values are shown in the tables below along with the pollutant difference in mg/L and the pollutant difference as a percentage. The actual difference is calculated by subtracting the sampled pollutant value from the modelled pollutant value i.e. 83-102 = -19mg/L. The percentage difference is calculated as (1-(sampled / modelled)) i.e. (1-(83/102)) x 100.

Given that the pollutant levels are being modelled in 6 minute time steps instead of the traditional yearly loads it is to be expected that there will be some samples that have a low level of accuracy. It is hoped that with enough samples this research project will be able show if MUSIC modelling software is relatively accurate.

6.2.1 Total Suspended Solids pollutant generation accuracy

Table 6.1 below shows that 3 samples are well below the corresponding modelled values. We can also see that 3 samples are relatively accurate being just below 100% of the modelled value. With the three extreme values removed the TSS concentration in the sampled stormwater inflows is now an average of 84% of the modelled values.

	Inflow TSS (mg/L)		Sample vs model differences	
Event - Sample	**Modelled**	**Sampled**	**Difference** (mg/L)	**Difference** (%)
1-S1	102	83	-19	-19%
1-S2	128	18	-110	-86%
1-S3	7	6	-1	-14%
2-S2	92	39	-53	-58%
2-S2	7	5	-2	-29%
3-S1	67	6	-61	-91%
3-S2	108	2	-106	-98%
Average	**73**	**23**	**-50**	**-56%**

Table 6.1: Accuracy of TSS concentration in inflow - sampled & modelled (mg/L)

6.2.2 Total Nitrogen pollutant generation accuracy

Table 6.2 below shows 2 samples just below the modelled concentration of pollutants. However the majority of the samples TN values are consistently 70-85% below the modelled TN values. It is unclear what is causing this and it is recommended that it should be investigated with more detailed sampling. Research by Dotto & Fletcher (2008) and Imteaz (2008) found that pollutant concentrations for smaller events were typically overstated by MUSIC but compensated for in larger storms. This was applicable to TSS, TN and TP. Given that the storms that were sampled by this research it is not surprising that the sampled concentrations are generally lower than the modelled concentrations.

	Inflow TN (mg/L)		Sample vs model differences	
Event - Sample	**Modelled**	**Sampled**	**Difference** (mg/L)	**Difference** (%)
1-S1	1.81	1.19	-0.62	-34%
1-S2	1.5	0.5	-1	-67%
1-S3	0.77	0.64	-0.13	-17%
2-S2	1.62	0.35	-1.27	-78%
2-S2	0.8	0.12	-0.68	-85%
3-S1	1.71	0.43	-1.28	-75%
3-S2	1.55	0.42	-1.13	-73%
Average	**1.39**	**0.52**	**-0.87**	**-61%**

Table 6.2: Accuracy of TN concentration in inflow - sampled & modelled (mg/L)

6.2.3 Total Phosphorous pollutant generation accuracy

Table 6.3 shows that there is no consistent pattern between the sampled and modelled values of inflow TP. While there are a couple of samples that are very close to the corresponding model value the majority are consistently well under those values. As with the TN sampling values it is unclear what is causing this and it is recommended that it should be investigated with more detailed sampling.

	Inflow TP (mg/L)		**Sample vs model differences**	
Event - Sample	**Modelled**	**Sampled**	**Difference** (mg/L)	**Difference** (%)
1-S1	0.23	0.12	-0.11	-48%
1-S2	0.42	0.04	-0.38	-90%
1-S3	0.08	0.04	-0.04	-50%
2-S2	0.07	0.08	0.01	14%
2-S2	0.03	0.03	0	0%
3-S1	0.28	0.05	-0.23	-82%
3-S2	0.26	0.05	-0.21	-81%
Average	**0.20**	**0.06**	**-0.14**	**-48%**

Table 6.3: Accuracy of TP concentration in inflow - sampled & modelled (mg/L)

6.2.4 Gross Pollutant generation accuracy

Table 6.4 below shows the accumulated weight of gross pollutants to each collection date from the GPT installation date of the 23rd of March. MUSIC does not provide a breakdown of the gross pollutants by weight therefore only the total values for each sampling period and the overall total values are compared. On average the collected or sampled volumes of gross pollutants were 35% less than the MUSIC model projected over the sampling period. While the GPT captured substantial amounts of sediment there would have been a considerable amount of suspended solid and sediment that was not captured. To counteract this there was evidence that some of the gross pollutant consisted of blue metal from house construction sites within the catchment. The gross pollutant modelling and collection indicated that the MUSIC model values of gross pollutants within the inflow are relatively accurate. If more accurate volumes of pollutants are required is recommended that more additional sampling be undertaken.

Collection Date	Modelled GP Weight (kg)	Sampled GP Weight (kg)	Sample vs model differences	
			Difference (kg)	Difference (%)
24-Mar	9.4	2.4	-7	-74%
9-Apr	72	64.4	-7.6	-11%
27-Apr	67.2	39.5	-27.7	-41%
6-Jul	204	122.7	-81.3	-40%
Total	**353.4**	**229**	**-124.4**	**-35%**

Table 6.4: Accuracy of GP weights in inflow - sampled & modelled (kg)

6.2.5 Stormwater flow generation accuracy

Measurements of stormwater flows into the basin were not considered accurate enough for research purposes and are therefore not discussed in detail in this section.

6.3 MUSIC treatment node accuracy

Each outflow water sample which has been analysed in mg/L was compared against the modelled pollutant level for the corresponding time step. These corresponding values are in the tables below along with the pollutant difference in mg/L and the pollutant difference as a percentage. The actual difference is simply calculated by subtracting the sampled pollutant value from the modelled pollutant value i.e. 83-102 = -19mg/L. The percentage difference is calculated as (1-(sampled / modelled)) i.e. (1-(83/102)) x 100.

6.3.1 Total Suspended Solids pollutant reduction accuracy

Table 6.5 shows that the majority of the modelled outflow has the same concentration while 2 values are significantly higher. It is unknown why these two vales are so much higher as there is no bypass flows from the basin. Aside from these 2 samples, all of the outflow samples have TSS levels that are typically 4-8 times larger than the corresponding model values. The bio-filtration system of this basin was built 10 years ago and was not designed or constructed to the current best practices. To better assess the accuracy of MUSIC treatment nodes of outflows it is recommended that additional sampling be done on a range of treatment devices.

	Outflow TSS (mg/L)		Sample vs model differences	
Event - Sample	**Modelled**	**Sampled**	**Difference** (mg/L)	**Difference** (%)
1-S1	2	26	24	1200%
1-S2	2	18	16	800%
1-S3	2	8	6	300%
2-S2	2	11	9	450%
2-S2	2	10	8	400%
3-S1	20	1	-19	-95%
3-S2	18	2	-16	-89%
Average	**7**	**11**	**4**	**424%**

Table 6.5: Accuracy of TSS concentration in outflow - sampled & modelled (mg/L)

6.3.2 Total Nitrogen pollutant reduction accuracy

Table 6.6 also shows that sampled nitrogen levels are typically lower than the modelled outflow levels. These values vary from just below to being substantially below the modelled values. Again, the design of the bio-retention basin may be a factor here and these results should be verified with further testing.

	Outflow TN (mg/L)		Sample vs model differences	
Event - Sample	**Modelled**	**Sampled**	**Difference** (mg/L)	**Difference** (%)
1-S1	0.8	1.07	0.27	34%
1-S2	0.8	0.71	-0.09	-11%
1-S3	0.8	0.71	-0.09	-11%
2-S2	0.8	0.21	-0.59	-74%
2-S2	0.8	0.21	-0.59	-74%
3-S1	1.4	0.32	-1.08	-77%
3-S2	1.35	0.37	-0.98	-73%
Average	**0.96**	**0.51**	**-0.45**	**-41%**

Table 6.6: Accuracy of TN concentration in outflow - sampled & modelled (mg/L)

6.3.3 Total Phosphorous pollutant reduction accuracy

Table 6.7 shows that sampled phosphorous levels are substantially lower than the modelled outflow levels. These sampled values are all consistently lower than the model and range from 70% lower up to 90% lower. Again, the design of the bio-retention basin may be a factor here and these results should be verified with further testing.

	Outflow TP (mg/L)		**Sample vs model differences**	
Event - Sample	**Modelled**	**Sampled**	**Difference** (mg/L)	**Difference** (%)
1-S1	0.46	0.07	-0.39	-85%
1-S2	0.46	0.06	-0.4	-87%
1-S3	0.46	0.05	-0.41	-89%
2-S2	0.46	0.04	-0.42	-91%
2-S2	0.46	0.04	-0.42	-91%
3-S1	0.17	0.05	-0.12	-71%
3-S2	0.2	0.04	-0.16	-80%
Average	**0.38**	**0.05**	**-0.33**	**-85%**

Table 6.7: Accuracy of TP concentration in outflow - sampled & modelled (mg/L)

6.3.4 Gross Pollutant reduction accuracy

Determining the accuracy of gross pollutant reduction of the effectiveness of commercially available gross pollutant traps was no part of the scope of this research project. As such a temporary gross pollutant trap was constructed to assess the catchment pollutant generation as discussed in section 6.2.4.

6.3.5 Stormwater flow reduction accuracy

Measurements of stormwater flows out of the basin were not considered accurate enough for research purposes and are therefore not discussed in detail in this section.

CHAPTER 7 – RESEARCH CONCLUSIONS

7.1 Achievement of Project Objectives

The primary objectives of this research project were to:

1. Model a developed catchment and bio-retention basin for inflow and outflow pollutant levels and compare them with laboratory analysed stormwater samples to assess the accuracy of MUSIC.
2. Measure the stormwater volumes generated by the catchment and to compare them for accuracy against the flow volumes generated by MUSIC.
3. Capture and measure gross pollutants and compare the volume with the MUSIC model volumes.

Detailed research findings and discussions in relation to **Objective 1** are outlined in Chapter 6. These findings can broadly be summarised as:

- Sampled TSS inflow pollutants expressed as concentrations were 14% to 98% less than the corresponding modelled MUSIC pollutant levels. On average the sampled TSS pollutant was 56% less than the MUSIC pollutant level;

- Sampled TN inflow pollutants expressed as concentrations were 17% to 85% less than the corresponding modelled MUSIC pollutant levels. On average the sampled TN pollutant was 61% less than the MUSIC pollutant level;

- Sampled TP inflow pollutants expressed as concentrations were 14% more to 90% less than the corresponding modelled MUSIC pollutant levels. On average the sampled TP pollutant was 48% less than the MUSIC pollutant level;

- Sampled TSS outflow pollutants expressed as concentrations were on average 4 times greater than the corresponding modelled MUSIC pollutant levels.

- Sampled TN outflow pollutants expressed as concentrations were 14% more to 74% less than the corresponding modelled MUSIC pollutant levels. On average the sampled TN pollutant was 41% less than the MUSIC pollutant level;

- Sampled TP outflow pollutants expressed as concentrations were 71% to 91% less than the corresponding modelled MUSIC pollutant levels. On average the sampled TSS pollutant was 85% less than the MUSIC pollutant level.

As mentioned in Chapter 6, research by Dotto & Fletcher (2008) and Imteaz (2008) found that pollutant concentrations for smaller events were typically overstated by MUSIC but compensated for in larger storms. This was applicable to TSS, TN and TP. Given that the storms that were sampled by this research it is not surprising that the sampled concentrations are generally lower than the modelled concentrations.

It can be seen in the detailed results in Chapter 6 there is a substantial variation in some of these sampling and modelling results due to the short sampling period. There are a range of factors which may have influenced the accuracy of the modelling and sampling which has been previously discussed. These factors should be kept in mind when reading this report.

Objective 2 was not completed as the measurements of stormwater flows into the basin were not considered accurate enough for research purposes. The reasons for this are discussed in more detail in section 4.4.

Detailed research findings and discussions in relation to **Objective 3** are discussed in section 6.2.4. The collection of gross pollutants and comparison found that the collected weight of gross pollutants was on average 35% less than the modelled weights. Given the size of the gross pollutant trap mesh there would have been considerable volumes of suspended solids and sediment that were not collected. It is therefore reasonable to assume that the amounts of GP that are modelled by MUSIC are quiet accurate.

Secondary objectives addressed as part of this research project included:

4. Addressing the effectiveness of alternate stormwater treatment devices;

5. Determining the influence of critical bio-filtration treatment node parameters.

Objective 4 is discussed in Chapter 5. Due to the limited amount of rainfall these was a lack of samples taken to be able to properly address this objective. From the samples that were collected it was evident that there was a substantial advantage to using bio-retention basins for the treatment of stormwater compared to using vegetated swales.

Objective 5 is covered in detail in section 3.5. By running a default model and adjusting a single parameter over a range of values we can graph the effect of that parameter on the treatment node which in this case was a bio-retention basin. The 4 parameters that were assessed included the hydraulic conductivity, the filter depth, the filter area and basin volume. From these results we were able to determine that the ideal bio-retention basin should have a hydraulic conductivity ranging from 150 mm/hr to 300 mm/hr and have a filter depth from 0.6m deep to 0.9m deep. In addition to this the basin volume and filter area should generally be as large as possible although the treatment improvements do reduce as they get bigger.

7.2 Further Work

This research paper was only made possible through the funding provided by Lismore City Council and Environmental Analysis Laboratory. However, due to the limited time frame and variable rainfall the number of samples taken was less than desired. Ideally a functioning basin would be modelled and sampled for all rainfall events for a complete year. This would enable the researcher to gain a clearer picture of the seasonal variations in pollutant loads as opposed to the short time periods used in this report.

REFERENCES

AsaAnalytics, Total Nitrogen in Wastewater, Retrieved 28 July, 2013 from asaanalytics website, <http://www.asaanalytics.com/total-nitrogen.php>

AsaAnalytics, Total Phosphorous in Water or Wastewater, Retrieved 28 July, 2013 from asaanalytics website, <http://www.asaanalytics.com/total-phosphorous.php>

Austrac e-learning, *Applying risk appetite to risk assessment*, October 2011, Retrieved 10 April 2013 from Austrac e-learning website <http://www.austrac.gov.au/elearning_amlctf_programcourse/mod4/module_4_risk_16.html>

Bratieres K, Fletcher TD, Deletic A, Zinger Y, *Nutrient and sediment removal by stormwater biofilters: A large scale design optimisation study*, Monash University Victoria, February 2008

Brisbane City Council, Guidelines for Pollutant Export Modelling in Brisbane, Retrieved 28 July, 2013 from Brisbane City Council website, <http://www.brisbane.qld.gov.au/documents/building_development/pollutant%20export%20modelling%20guidelines%20v7_2.pdf>

Bureau of Meteorology, About Evapotranspiration, Retrieved 20 July, 2013 from BOM website, < http://www.bom.gov.au/watl/eto/about.shtml>

Bureau of Meteorology, Daily rainfall Lismore Airport AWS, Retrieved 20 July from BOM website,<http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=2013&p_c=677875&p_stn_num=058214>

Bureau of Meteorology, Latest weather observations for Lismore Airport, Retrieved 20 July, 2013 from BOM website, <http://www.bom.gov.au/products/IDN60801/IDN60801.94572.shtml>

City of Boulder, General information on Solids, Retrieved 28 July, 2013 from City of Boulder website, <http://bcn.boulder.co.us/basin/data/NEW/info/TSS.html>

CRCCH, MUSIC Version 3, *User guide, Cooperative Research Centre for Catchment Hydrology*.

Department of Health and Ageing, *Environmental Health Practitioner Manual*, November 2010, Retrieved 27 April, 2013 from Department of Health and Ageing website, <http://www.health.gov.au/internet/publications/publishing.nsf/Content/ohp-enhealth-manual-atsi-cnt-l~ohp-enhealth-manual-atsi-cnt-l-ch6~ohp-enhealth-manual-atsi-cnt-l-ch6.1>

Dotto CBS, Deletic A, Fletcher TD, *Analysis of uncertainty in flow and water quality from a stormwater model*, Monash University Victoria, 2008.

Engineers Australia, July 2010, *Our code of ethics*, <http://www.engineersaustralia.org.au/sites/default/files/shado/About%20Us/Overview/Governance/codeofethics2010.pdf> [accessed 14.04.2013]

Environmental Science Division, Hydraulic Conductivity, Retrieved 28 July, 2013 from EVS website, <http://web.ead.anl.gov/resrad/datacoll/conuct.htm>

eWater, Pluviograph Rainfall Data Tool, Retrieved 20 July, 2013 from eWater website, <http://www.ewater.com.au/products/ewater-toolkit/urban-tools/music/pluviograph-rainfall-data-tool/>

FAWB, *Advancing the design of stormwater biofiltration*, Facility for Advancing Water Biofiltration, www.monash.edu.au/fawb, June 2008

FAWB, *Guidelines for soil filter media in bioretention systems*, Facility for Advancing Water Biofiltration, www.monash.edu.au/fawb, March 2008

Gosford City Council, Gross pollutant traps, Retrieved 28 July, 2013 from Gosford City Council website <http://www.gosford.nsw.gov.au/environment/education/documents /fact-sheets-2/gross_pollutant_traps.pdf>

Hatt BE, Fletcher TD, Deletic A, *Hydraulic and pollutant removal performance of stormwater biofiltration systems at the field scale*, Monash University Victoria, December 2008.

Imteaz MA, Ahsan A, Rahman A, Mekanik F, *Modelling stormwater treatment systems using MUSIC: Accuracy*, University of Western Sydney, March 2012.

Lismore City Council, 2012, *DCP Ch22 Water Sensitive Design,* <http://www.lismore.nsw.gov.au/page.asp?f=RES-JOZ-62-56-37> [accessed 10.04.13]

Melbourne Water, Water Sensitive Urban Design, Retrieved 6 August, 2013 from Melbourne Water website, <http://wsud.melbournewater.com.au/content/treatment_ measures/bio-retention_systems.asp>

Melbourne Water, WSUD approach, Retrieved 6 August, 2013 from Melbourne Water website, <http://www.melbournewater.com.au/Planning-and-building/Stormwater-management/Water-Sensitive-Urban-Design/Pages/The-WSUD-approach.aspx>

Northern Rivers Local Government, 2003, *Stormwater Drainage Design,* <http://www.lismore.nsw.gov.au/content/planning/manuals/D05-Stormwater_Drainage _Design.pdf>, [accessed 20.07.13]

QLD SPA, Monitoring and Sampling Manual 2009, Retrieved 28 July, 2013 from QLD ENP website, <http://www.ehp.qld.gov.au/water/pdf/monitoring-man-2009-v2.pdf>

Rushton B, England G, Smith DD, *Proposed guidelines for monitoring stormwater gross solids,* ASCE, Florida, 2007

State of Washington Department of Ecology, March 2010, *How to do stormwater sampling - A guide for industrial facilities,* < https://fortress.wa.gov/ecy/publications/publications/ 0210071.pdf >, [accessed 27.04.13]

Taebi A, Droste RL, *First flush pollution load of urban stormwater runoff,* NRC Research, Canada, March 2004.

Tweed Shire Council, Stormwater Quality, Retrieved 28 July, 2013 from Tweed Shire Council website, <http://www.tweed.nsw.gov.au/planningdocs/pdfs/PlanningDocs/ D7%20Stormwater%20Quality%20v1.3.pdf>

Workplace Health and Safety Queensland, Risk Management, 2013, Retrieved 10 April, 2013 from WH&S QLD website, <http://www.deir.qld.gov.au/workplace/subjects/ riskman/fivesteps/index.htm>

WorkCover NSW, 2012, *A practical guide to basic risk management*, <http://www.workcover.nsw.gov.au/formspublications/publications/Documents/hazpak_making_your_workplace_safer_guide_0228.pdf>, [accessed 10.04.13]

APPENDIX A - Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR:	**Wade Daniel FLETCHER**
TOPIC:	STORMWATER TREATMENT EFFECTIVENESS MODELLED vs. ACTUAL POLLUTANT & FLOW QUANTITIES
SUPERVISOR:	Dr Ian Brodie
ENROLMENT:	ENG 4111 - S1, D, 2013 ENG 4112 - S2, D, 2013
SPONSORSHIP:	**Environmental Analysis Laboratory (EAL)** - Provision of testing of water samples at a discounted rate **Lismore City Council (LCC)** - Provision of funding for testing of water samples.
PROJECT AIM:	This project seeks to investigate the effectiveness of stormwater pollutant reduction and accuracy of modelling software compared to data collected from actual rainfall events.
PROGRAMME:	**Issue A, 29 April 2013**

1. Undertake a literature review of treatment performance and stormwater sampling methods.
2. Select suitable stormwater treatment device such as bio-retention basin, wetland or grassed swale in consultation with Lismore City Council staff.
3. Investigate the selected treatment device catchment and parameters to model the stormwater pollutant generation and reduction for a range of rainfall events using MUSIC 5 software.
4. Conduct field work to sample stormwater inflow and outflow from the selected treatment device(s) which can then be analysed by EAL for Total Nitrogen (TN), Total Phosphorus (TP) and Total Suspended Solid (TSS) pollutant levels.
5. Analyse the recorded rainfall data, device inflow and outflow pollutants against equivalent rainfall events to determine the accuracy of MUSIC 5 pollutant reduction modelling.
6. Complete and submit an academic dissertation with detailed research methodology, findings and conclusion.

As time and funding permits:

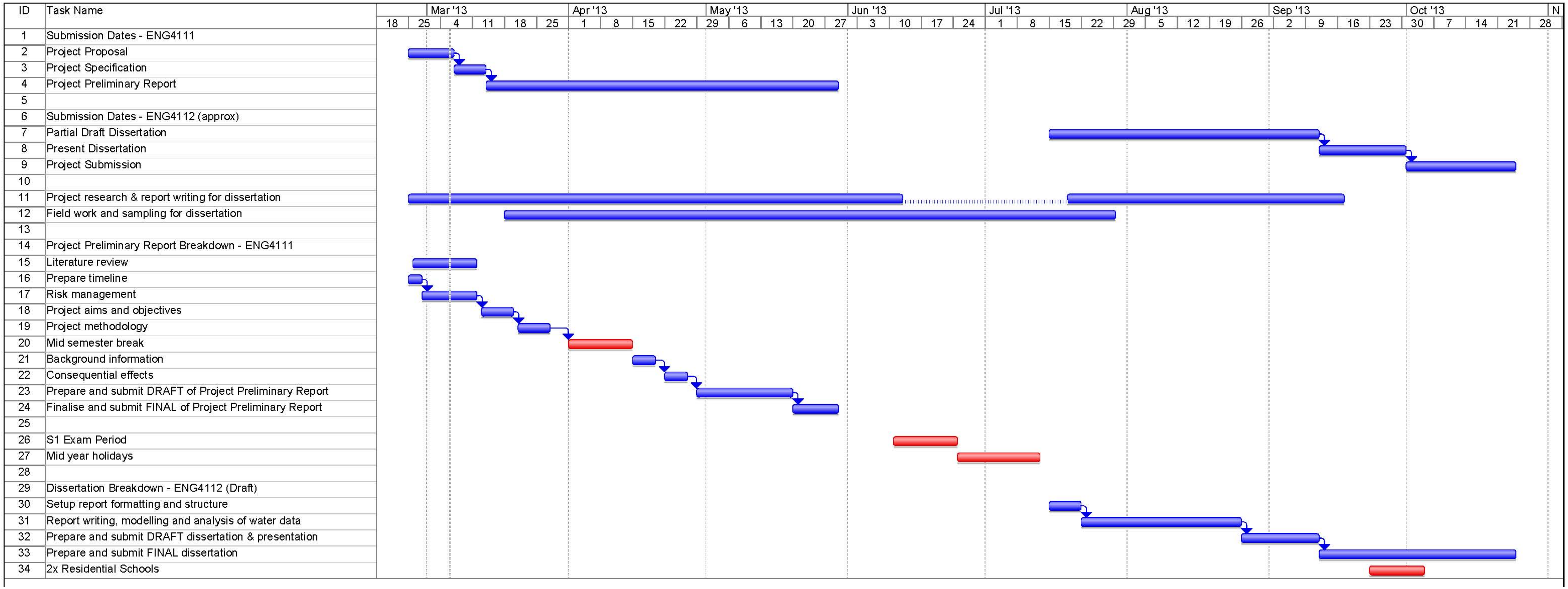
7. Model gross pollutant loads and measure by way of gross pollutant trap.

AGREED: ____________________ (Student) ____________________ (Supervisor)

Date: / / 2013 Date: / / 2013

Examiner/Co-examiner:____

APPENDIX B – Project Timeline



APPENDIX C – Raw Sampling Results

Storm 1 - 24.03.2013 at 6:00pm

RESULTS OF WATER ANALYSIS

6 samples supplied by CivilTech Consulting Engineers on the 25th March, 2013 - Lab. Job No. C5394
Analysis requested by Wade Fletcher.
(Po Box 1020, LISMORE NSW 2480).

PARAMETER	METHODS REFERENCE	Sample 1 1	Sample 2 1A	Sample 3 2	Sample 4 2A	Sample 5 3	Sample 6 3A
	Job No.	*C5394/1*	*C5394/2*	*C5394/3*	*C5394/4*	*C5394/5*	*C5394/6*
TOTAL SUSPENDED SOLIDS (mg/L)	GFC equiv. filter - APHA 2540-D	83	26	18	18	6	8
TOTAL PHOSPHORUS (mg/L P)	APHA 4500 P-H	0.12	0.07	0.04	0.06	0.04	0.05
TOTAL NITROGEN (mg/L N)	APHA 4500 N-C	1.19	1.07	0.50	0.71	0.64	0.71

Notes:

1. 1 mg/L (milligram per litre) = 1 ppm (part per million) = 1000 µg/L (micrograms per litre)= 1000 ppb (part per billion)
2. Analysis performed according to APHA, 2012, "Standard Methods for the Examination of Water & Wastewater", 22nd Edition, except where stated otherwise.
3. Analysis conducted between sample arrival date and Report provision date
4. ** denotes these test procedure or calculation are as yet not NATA accredited but quality control data is available
5. .. Denotes not requested

NATA
WORLD RECOGNISED ACCREDITATION
Accreditation No. 14960.
Accredited for compliance with ISO/IEC 17025.

checked: ....
Graham Lancaster
Laboratory Manager

Environmental Analysis Laboratory, Southern Cross University,
Tel. 02 6620 3678, website: scu.edu.au/eal

Storm 2 - 12.04.2013 at 9:30am

RESULTS OF WATER ANALYSIS

4 samples supplied by CivilTech Consulting Engineers on the 12th April, 2013 - Lab. Job No. C5733
Analysis requested by Wade Fletcher.
(Po Box 1020, LISMORE NSW 2480).

PARAMETER	METHODS REFERENCE	Sample 1 1A	Sample 2 1B	Sample 3 2A	Sample 4 2B
	Job No.	*C5733/1*	*C5733/2*	*C5733/3*	*C5733/4*
TOTAL SUSPENDED SOLIDS (mg/L)	GFC equiv. filter - APHA 2540-D	39	11	5	10
TOTAL PHOSPHORUS (mg/L P)	APHA 4500 P-H	0.08	0.04	0.03	0.04
TOTAL NITROGEN (mg/L N)	APHA 4500 N-C	0.35	0.21	0.12	0.21

Notes:

1. 1 mg/L (milligram per litre) = 1 ppm (part per million) = 1000 μg/L (micrograms per litre)= 1000 ppb (part per billion)
2. Analysis performed according to APHA, 2012, "Standard Methods for the Examination of Water & Wastewater", 22nd Edition, except where stated otherwise.
3. Analysis conducted between sample arrival date and Report provision date
4. ** denotes these test procedure or calculation are as yet not NATA accredited but quality control data is available
5. .. Denotes not requested

NATA
WORLD RECOGNISED ACCREDITATION
Accreditation No. 14960.
Accredited for compliance with ISO/IEC 17025.

checked: ....
Graham Lancaster
Laboratory Manager

Environmental Analysis Laboratory, Southern Cross University,
Tel. 02 6620 3678, website: scu.edu.au/eal

Storm 3 - 13.04.2013 at 9:36am

RESULTS OF WATER ANALYSIS

6 samples supplied by CivilTech Consulting Engineers on the 16th April, 2013 - Lab. Job No. C5766
Analysis requested by Wade Fletcher.
(Po Box 1020, LISMORE NSW 2480).

PARAMETER	METHODS REFERENCE	Sample 1 1A	Sample 2 1B	Sample 3 2A	Sample 4 2B	Sample 5 J1 WF	Sample 6 J2
	Job No.	*C5766/1*	*C5766/2*	*C5766/3*	*C5766/4*	*C5766/5*	*C5766/6*
TOTAL SUSPENDED SOLIDS (mg/L)	GFC equiv. filter - APHA 2540-D	6	1	2	2	2	<1
TOTAL PHOSPHORUS (mg/L P)	APHA 4500 P-H	0.05	0.05	0.05	0.04	0.04	0.04
TOTAL NITROGEN (mg/L N)	APHA 4500 N-C	0.43	0.32	0.42	0.37	0.13	0.12

Notes:

1. 1 mg/L (milligram per litre) = 1 ppm (part per million) = 1000 μg/L (micrograms per litre)= 1000 ppb (part per billion)
2. Analysis performed according to APHA, 2012, "Standard Methods for the Examination of Water & Wastewater", 22nd Edition, except where stated otherwise.
3. Analysis conducted between sample arrival date and Report provision date
4. ** denotes these test procedure or calculation are as yet not NATA accredited but quality control data is available
5. **.. Denotes not requested**

NATA
WORLD RECOGNISED ACCREDITATION
Accreditation No. 14960.
Accredited for compliance with ISO/IEC 17025.

checked: ....
Graham Lancaster
Laboratory Manager

Environmental Analysis Laboratory, Southern Cross University,
Tel. 02 6620 3678, website: scu.edu.au/eal

Storm 4 - 20.07.2013 at 12:30pm

RESULTS OF WATER ANALYSIS (Page 1 of 1)

4 samples supplied by CivilTech Consulting Engineers on the 22nd July, 2013 - Lab. Job No. C7664

Analysis requested by Wade Fletcher

PO Box 1020, LISMORE NSW 2480

PARAMETER	METHODS REFERENCE	Sample 1 J21	Sample 2 J22	Sample 3 Gas 1	Sample 4 Gas2
	Job No.	*C7664/1*	*C7664/2*	*C7664/3*	*C7664/4*
TOTAL SUSPENDED SOLIDS (mg/L)	GFC equiv. filter - APHA 2540-D	11	<1	25	61
TOTAL PHOSPHORUS (mg/L P)	APHA 4500 P-H	0.07	0.02	0.10	0.15
TOTAL NITROGEN (mg/L N)	APHA 4500 N-C	1.49	0.08	0.31	0.53

Notes:

1. 1 mg/L (milligram per litre) = 1 ppm (part per million) = 1000 μg/L (micrograms per litre)= 1000 ppb (part per billion)
2. For conductivity - 1 dS/m = 1 mS/cm = 1000 μS/cm
3. Analysis performed according to APHA, 2012, "Standard Methods for the Examination of Water & Wastewater", 22nd Edition, except where stated otherwise.
4. Analysis conducted between sample arrival date and Report provision date

NATA
WORLD RECOGNISED ACCREDITATION
Accreditation No. 14960.
Accredited for compliance with ISO/IEC 17025.

checked: ....
Graham Lancaster (Nata signatory)
Laboratory Manager

Environmental Analysis Laboratory, Southern Cross University,
Tel. 02 6620 3678, website: scu.edu.au/eal

APPENDIX D – Site Selection Matrix

		Site # 1 GSAC Bio-filtration		Site # 2 Joy Street Bio-filtration		Site # 3 Waratah Way Bio-filtration		Site # 4 CBD Rainwater Gardens		Site # 5 Nesbitt Park Bio-filtration		Site # 6 Gasworks Creek	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Travelling distance to site and ease of access	5%	4	0.2	4	0.2	5	0.25	3	0.15	3	0.15	3	0.15
Stormwater treatment potential of device	5%	5	0.25	4	0.2	3	0.15	4	0.2	4	0.2	3	0.15
Safety for tester and impact on general public	5%	4	0.2	3	0.15	4	0.2	3	0.15	5	0.25	2	0.1
Locality relative to BOM rainfall stations	5%	3	0.15	3	0.15	4	0.2	5	0.25	4	0.2	5	0.25
Ability to sample single inflow and outflow points for quality	20%	1	0.2	4	0.8	5	1	3	0.6	2	0.4	4	0.8
Ability to measure inflow and outflow volumes for flow and detention	15%	1	0.15	4	0.6	4	0.6	3	0.45	1	0.15	3	0.45
Importance of treatment and research information to Lismore City Council	10%	5	0.5	4	0.4	4	0.4	5	0.5	4	0.4	3	0.3
Importance of treatment type relative to existing available research data	15%	5	0.75	5	0.75	4	0.6	5	0.75	5	0.75	3	0.45
Availability of existing engineering and modelling information for specific site	5%	5	0.25	5	0.25	3	0.15	5	0.25	3	0.15	1	0.05
Catchment size and character suitability for flow and pollutant generation	10%	3	0.3	3	0.3	5	0.5	3	0.3	3	0.3	2	0.2
Ability to capture and measure gross pollutant levels.	5%	3	0.15	1	0.05	5	0.25	2	0.1	2	0.1	2	0.1
Total Score		**3.10**		**3.85**		**4.30**		**3.70**		**3.05**		**3.00**	