University of Southern Queensland
Faculty of Engineering and Surveying

Modelling Tamworth Regional Council Stormwater Network

A dissertation submitted by

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ABSTRACT

Over the last few decades the world's population has dramatically increased. The population increase has lead to rapid urbanisation, which has resulted in many complex problems relating to the management of stormwater. Stormwater needs to be thoroughly investigated in urban areas to reduce flooding in urban centres, and deterioration of water quality in rivers and streams. In urban areas, drainage systems are responsible for managing urban stormwater. The focus of this project was therefore to undertake modelling of a segment of the urban drainage network, to extrapolate problem areas and to implement possible augmentation works to improve flood immunity.

Tamworth is the focus area of the study. The city is located in Northern New South Wales and has a long history of extensive urban drainage problems. Along with high rainfall, in which the city has experienced four flash floods, Tamworth Regional Council has highlighted the urgent need for urban stormwater modelling.

For design and analysis of an effective economic urban drainage system, a computer-based stormwater-modelling package will be used. DRAINS is a Stormwater Drainage System design and analysis program that will be used for the investigation of the urban drainage network. DRAINS uses both hydrologic and hydraulic modelling to assess the urban drainage network.

The analysis undertaken to assess the segment of the urban drainage network of the city of Tamworth will have the potential to serve as a standard to which Council has to refer for future drainage augmentation works. The information collected and the conclusion drawn will be used to identify potential flood hazard zones. Recommendations will be implemented on possible augmentation works to the network to improve flood immunity to an acceptable standard.

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CERTIFICATION OF REPORT

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

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NOMENCLATURE

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

A	Area (m^2)
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AMC	Antecedent Moisture Condition
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
AutoCAD	Release 14.01, 1982-1998 AutoDesk Inc USA
C	Runoff Coefficient
CBD	Central Business District
D	Diameter (m)
g	Gravitational Acceleration (m^2/s)
GDH	Geocentric Datum of Australia
GIS	Geographical Information System
GPS	Global Positioning System
HGL	Hydraulic Grade Line
h_L	Head Loss (m)
I	Intensity (mm/h)
IFD	Intensity Frequency Duration
ILLUDAS	Illinois Urban Drainage Area Simulator
K	Pipe Wall Roughness (mm)
Km	Kilometres
k_L	Head Loss Coefficient (dimensionless)
k_U	Head Loss Coefficient
PC	Personal Computer
OH & S	Occupational Health and Safety
Q	Discharge (m^3/s)
QQS	Quality Quantity Simulator
QUDM	Queensland Urban Drainage Manuel
RCBC	Reinforced Concrete Box Culverts

RL	Relative Level
Re	Reynolds Number
RTK	Real Time Kinematic
S	Energy Line Slope
SWMM	Stormwater Management Model
TRC	Tamworth Regional Council
μ	Kinematic Viscosity [(1.14 x (m^2/s) at 15^{o}C]
v	Velocity (m^2/s)
v_o	Full-pipe velocity in the outlet pipe from the pit (m/s)

CHAPTER 1

INTRODUCTION

1.1. Introduction

> Stormwater drainage is an often overlooked and misunderstood aspect of the public works infrastructure. The more visible elements of public works, such as roads, bridges, traffic signs, to name but a few, are seen in our everyday lives, while storm water drainage structures are largely hidden from the public view. However, this lack of visibility does not lessen the importance of our drainage system (Customer Service is our primary focus, 2004).

Stormwater is an integral part of the water cycle. When rain falls, a portion of the water is used directly by plants; some remains on the surface or is held in the soil as groundwater and the remainder flows over the surface. This overland flow is called stormwater. It usually moves overland as sheet flow or as channel (concentrated) flow. All stormwater eventually discharges into a receiving water body (Willing, 2000).

In the natural environment, stormwater collects in creeks and streams where it usually flows to rivers. However, in the built environments, underground pipes and concrete channels have replaced the natural watercourses. Altering the movement of the stormwater, urbanisation has created many more impervious surfaces, such as roads and roofs. This has reduced the amount of rainwater that seeps into the ground. The removal of vegetation and its replacement with urban development also causes a reduction in the amount of rainwater that can be taken up by plants. The increase in the area of impervious surfaces act to collect, concentrate and quickly transport water from even low rainfall events to discrete discharge points. Typical discharge points include stormwater outlets. Hence, the volumes as well as frequencies of discharges are dramatically increased due to the built environments.

In natural systems, sediments, nutrients and other materials are collected by stormwater as it passes over the surface. The environment has evolved to cope with certain amounts of this material. The continual change in the quality and quantity of stormwater means that the natural environments are in a state of what is termed 'dynamic equilibrium' (Willing, 2000).

Human activity can significantly change this dynamic equilibrium through changing the characteristics of stormwater flows through the environment.

1.2. The Issue

Intensive impermeable surfaces, which are common in the majority of urban catchments in the Tamworth area, have caused a significant impact on the urban drainage infrastructure. Along with intensive rainfall the current urban drainage infrastructure is usually under-capacity.

A search for a feasible solution to the problem must include a comprehensive hydrological and hydraulic analysis of the entire drainage network. This will establish a correct causal relationship to understand the deficiencies in the urban drainage system. It is then possible to implement the most technically feasible and cost efficient solution to the problem.

1.3. Drainage model/ economic analysis

An urban drainage model comprises a hydrological model and a hydraulic model. The hydrologic model determines the runoff that occurs following a particular rainfall event. The primary output from the hydrologic model is hydrographs at varying locations along the waterways to describe the quantity, rate and timing of stream flow that results from rainfall events. These hydrographs then become a key input into the hydraulic model. The hydraulic model simulates the movement of floodwaters through waterway reaches, storage elements, and hydraulic structures. The hydraulic model calculates flood levels and flow patterns for the urban stormwater network (Case Study - Johnstone River Flooding Flood Model Development and Calibration, 2004).

Failure in adequate drainage can cause serious consequences on the urban environment such as damage to property through erosion and internal damage to homes. While it is not entirely possible to prevent drainage inadequacies, an effective model and economic analysis can minimise the major problem areas.

The stormwater drainage investigations that have been conducted in Tamworth are now outdated. This has provided the impetus to conduct a research investigation to model the stormwater drainage network. The model will simulate the current drainage network and will determine whether the current infrastructure is under capacity.

1.4. Project Objectives

The objectives for this particular project are described in APPENDIX A. In essence the project consists of:

- Research background information and literature related to urban drainage. This includes urban water drainage requirements and historical performance of Tamworth's urban drainage infrastructure.
- Prepare and conduct a detailed drainage model of the selected catchments in the Tamworth area. Identify areas of inadequate urban drainage infrastructure and use the model to simulate various augmentation works.
- Provide recommendations on a suitable augmentation strategy supported by an economic analysis

1.5. Dissertation Overview

This project is divided into several chapters, including:

1. Description of Study Area
2. Review of Previous Engineering Studies
3. Description of Selected Stormwater Drainage Models
4. Formulation of DRAINS Model
5. Investigation of Flood Mitigation Options
6. Discussion and Recommendations
7. Summary and Conclusion

CHAPTER 2

DESCRIPTION OF STUDY AREA

2.1. Introduction

Tamworth has long had a history of flash flooding throughout the past century. In the last four years Tamworth has endured four flash floods, two of which have prompted the State Government to render the area a State of Emergency (Keith, 2004). Due to these recent flooding events and other minor storm events, Tamworth Regional Council has decided that the urban drainage system is inadequate. However, if the recent flooding level exceeds design capacity, this is not a fault of the system.

Apart from field demonstrations to visually assess the performance of the drainage infrastructure, there is a strong need to further examine modelling the drainage network in an effort to identify for the residents the lack of drainage infrastructure in the Tamworth region. At present, there is a need for the development of a quick, accurate and reliable means of modelling Tamworth's drainage network to complete other expensive and time consuming studies undertaken by consultants.

2.2. Focus Area

Tamworth is located 408km by road northwest of Sydney and has a population of 35, 465 (ABS, 2001). A locality plan is shown in Figure 2-1. Tamworth Regional Council administers both the urban centre of Tamworth and the surrounding rural area. The Peel River bisects the city and is one of the major tributaries of the Namoi River in the Murray/Darling drainage basin. The north-eastern half of Tamworth city backs onto steep slopes that begin the New England Tablelands. The eastern half of the city has steeper slopes than the western side of the city and this causes many of the drainage issues in the Tamworth region. The soil type, which is found within the Tamworth region, is hard clay with low infiltration.

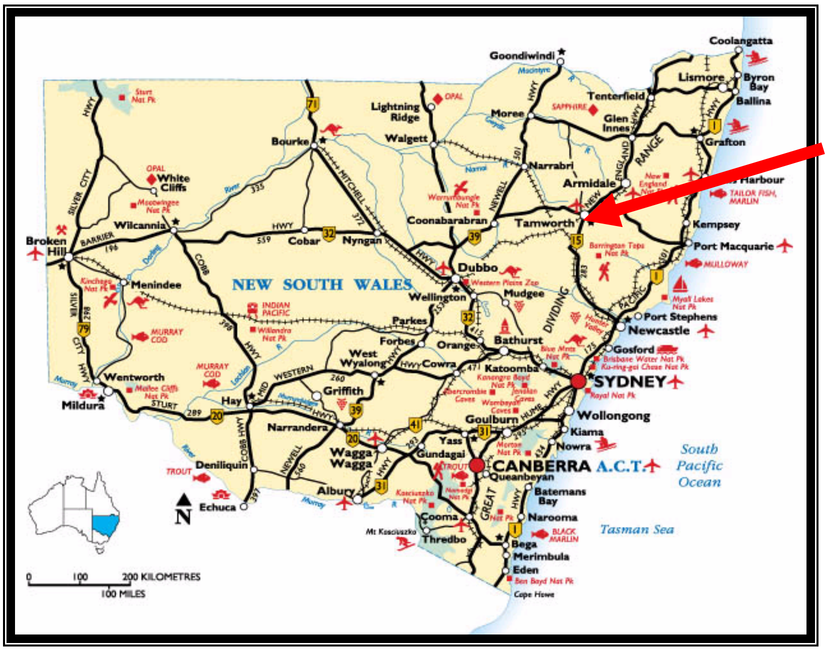


Figure 2-1 –Location of Tamworth

2.3. Focus Area – East Tamworth

The focus area for this study is East Tamworth. East Tamworth is one of the oldest areas in the Tamworth region. It was one of the first parts of the city to have stormwater drainage installed. This being the case, as further development in this area has caused the drainage infrastructure to become inadequate. Throughout the history of the Tamworth region there have been two studies undertaken in this area due to the inadequate drainage. Today all of the recommended works suggested by the drainage studies have been completed. Even though all the recommended works have been completed, the further development of East Tamworth has caused an increased strain on the urban drainage system.

The last study, which was undertaken in the East Tamworth area, was 25 years ago. Willing & Partners Consulting Engineers carried out the drainage study titled - “Report on Drainage Study for East Tamworth (1980)”. As the drainage infrastructure has degraded over the years due to further development, the need for an investigation into stormwater drainage was apparent.

The town map in Figure 2.2 shows the focus area for this study. The focus of the investigation will concentrate in the area highlighted in Figure 2-2. The study area is bounded by, Raglan, Carthage, Bourke and Roderick Streets.

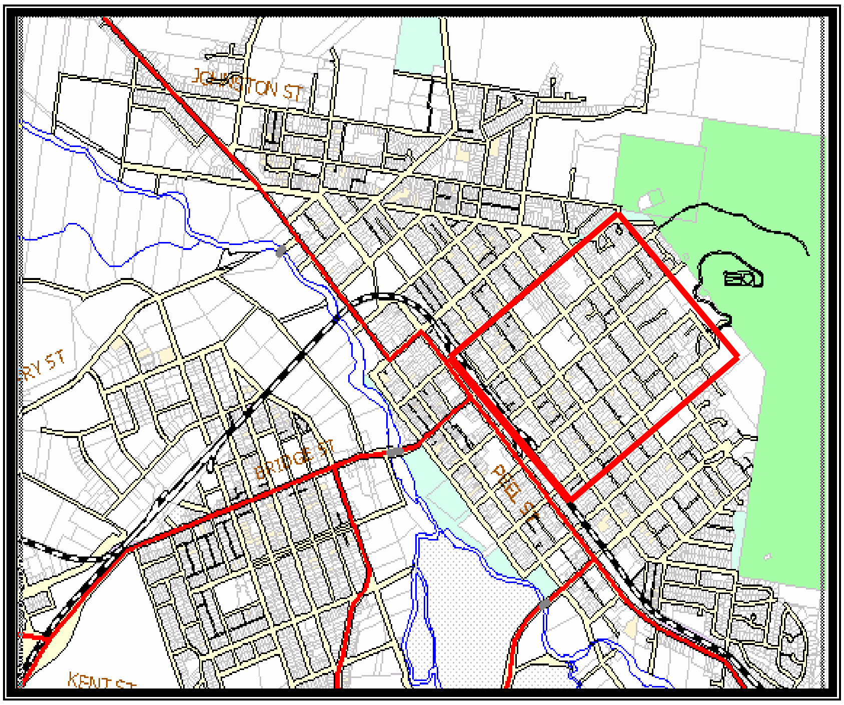


Figure 2-2 – Drainage Study Focus Area

A catchment is the area contributing flow to a point on a drainage system (CIRIA, 2004). The study will include sub-catchments 22 and 25. This can be seen in Figure 2-3. These sub-catchments will be analysed and then prioritised according to which catchment needs remedial action. An economic analysis will also be undertaken to study the effect of various augmentation works including provisions of grass swales and/or infiltration drains, increase in number and/or size of gully pits and pipelines.

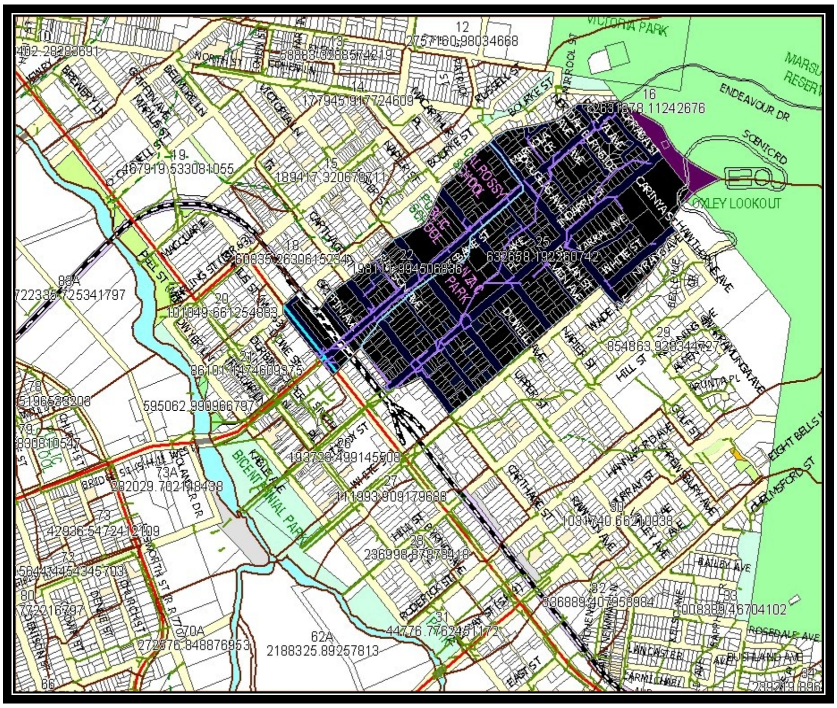


Figure 2-3 – Overall Catchment Area

An analysis of the complaint database has revealed some interesting aspects that have further strengthened the case for a new drainage study to be undertaken. These complaints have occurred over a period of six years and all complaints were related to flood damage and drainage implications. The general nature of the complaints was the flooding of private premises. There were some critical aspects that residents had in relation to the financial cost of damage to their property. In most cases, insurance covered the majority of these residents. The complaints data has then been taken and illustrated on a street map to pinpoint exactly where the major drainage problems are occurring. From Figure 2-4it is apparent that there are small clusters of problems in East Tamworth and these areas will be looked at closely to see whether these drainage issues can also be simulated from a model.

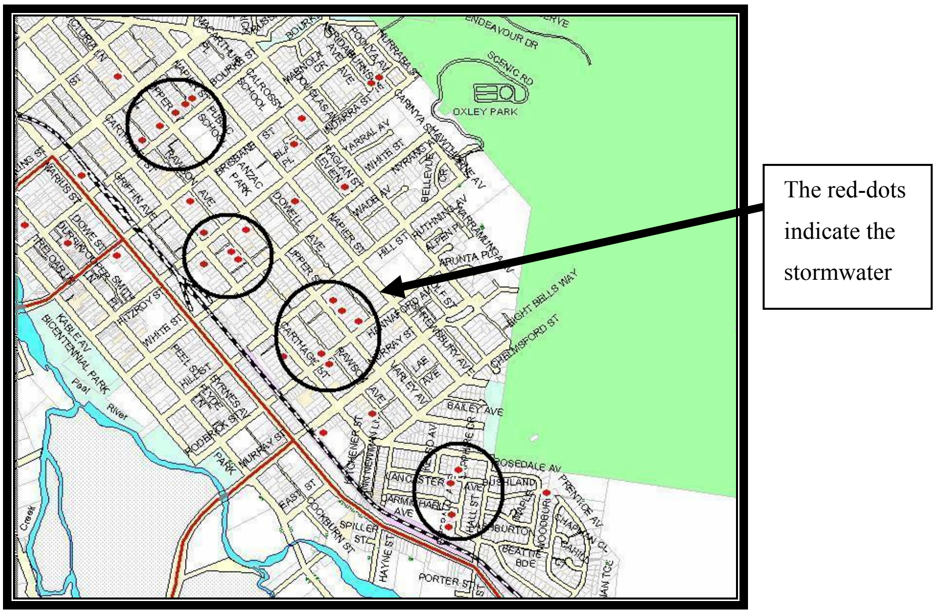


Figure 2-4 – East Tamworth Complaint Analysis

2.4. Conclusion

The analysis of the data from resident complaints has outlined the need for this research project to investigate a drainage study in the East Tamworth area. Two sub-catchments have been identified and the stormwater drainage model will be used to determine if the infrastructure in the East Tamworth area is under or over capacity.

CHAPTER 3

REVIEW OF PREVIOUS ENGINEERING

STUDIES

3.1. Introduction

Investigation into the urban stormwater drainage of Tamworth has revealed that thorough stormwater analysis needs to be undertaken in the East Tamworth area (Keith, 2004). At present, there have been four urban drainage investigations in the history of Tamworth Regional Council. The results and conclusions drawn from these studies are important when modelling an urban drainage network. Understanding from these past investigations is crucial when implementing flood mitigation options.

3.2. Urban Drainage Investigations

Sinclair Knight and Partners completed the first study back in 1972. They investigated the urban drainage in East Tamworth and in particular they investigated the urban drainage near the Central Business District (CBD). The focus area for this study can be seen in Figure 3.1. The second investigation was completed by Willing and Partners consulting engineers in 1980. The study was to develop an adequate stormwater drainage system for the present and future urban development of the city. A recent investigation into a stormwater management plan was conducted by Willing and Partners Consulting Engineers in 2000. Last year a Council employee, Ben Keith preliminary modelled many of Tamworth's sub-catchments. In the preliminary modelling of Tamworth sub-catchments, he estimated pit invert levels, Reduced Levels and made numerous assumptions. These assumptions included, ponding volume, base inflow and blocking factor. This study determined the critical factors that the computer software modelling package DRAINS requires in order for Council to use in evaluation of their current and or in design of new infrastructure of drainage.

3.3. Report on drainage study of East Tamworth – 1972

Sinclair Knight and Partners conducted a drainage study in 1972 in the East Tamworth area. The study has revealed an unusually high frequency of flooding in the lower part of the town between Peel Street and the Peel River, as shown in Figure 3-1.

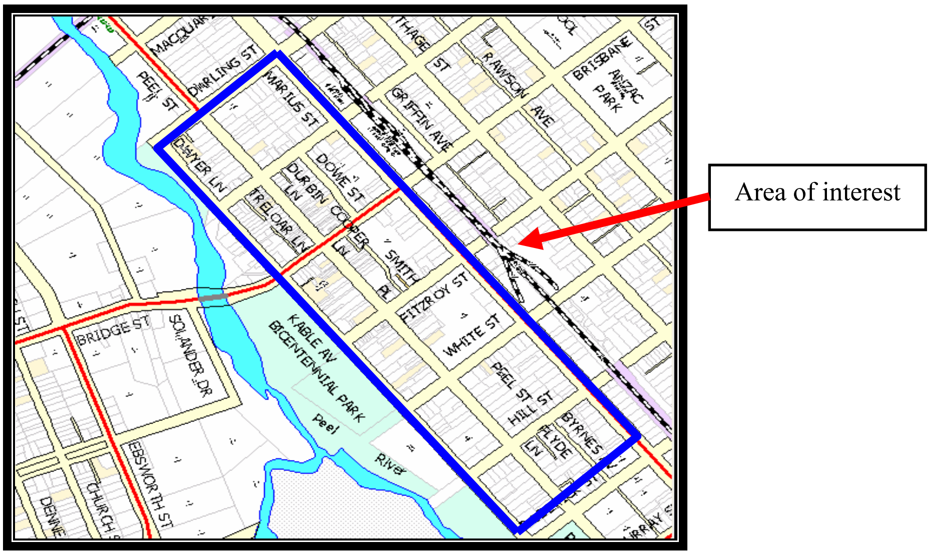


Figure 3-1 – Sinclair Knight and Partners focus area

East Tamworth drainage problems can be principally attributed to the interference with the natural drainage by the Peel River when it is in flood. The Peel River drains an area of 3082 square kilometres. At most times it is a slow moving stream occupying the centre of its channel some seven meters below the levee bank. Following heavy rain on the catchment, the Peel River rises quickly and is only prevented from entering the lower levels of the city by the levee banks. Some drainage pipes from Tamworth pass through the levee bank and are fitted with valves to prevent backflow of the river during flood periods. When the Peel River floods and the river level is above gauge reading of 4.26 metres, gravity drainage of the low area of town ceases (Sinclair Knight and Partners, 1972). This causes flooding of the lower part of town and this flooding was the catalyst of the report.

3.3.1. Recommendations

Sinclair Knight and Partners recommends the use of pressure drains and a pumped storage scheme. In the suburban areas, conventional pipe drains protect houses. The stormwater network has been designed for a one in five year storm. The pipes discharge directly into the Peel River. Overflow from the suburban area is carried to the river by pressure mains duplicating the lower part of the main drains from the suburban drains. These pressure drains form adequate static head (pressure) to force water into the river system, even in flood. The pressure drains that have been constructed from the study are shown in Figure 3-2 and Figure 3-3.

Figure 3-2 – Pressure Drains Inlet Located at Fitzroy and Marius Street

Figure 3-3 – Pressure Drains Outlet Located at Fitzroy and the Peel River

3.4. Willing and Partners Consulting Engineers – 1980

Willing and Partners Consulting Engineers conducted a drainage study in 1980. The study found that in general, the existing drainage facilities in East Tamworth are inadequate and require upgrading. Works in these areas would be extensive and quite costly. There are two major features principally associated with the drainage problems of East Tamworth. These two problems are the natural drainage by the Peel River when it is in flood, and the inadequate drainage system within the catchment.

During periods of high river level, drainage pipelines passing through the levee bank are unable to gravitate to the River. Gravity drainage of the low commercial area ceases when a gauge reading of 4.27m is recorded. At this level the floodgates on these pipelines must be closed to prevent river water entering the commercial area. The rain that falls on the commercial area or catchments discharging through the commercial area (with the exception of the runoff into the pressure drains) causes flooding of these low-lying areas (Willing, 1980).

The steep slopes in the East Tamworth contribute significantly to the runoff through the suburban area of the catchments. The degree of flooding within the suburban area is generally limited, due to its proximity to main natural drainage paths flowing through several properties.

East Tamworth is a difficult area to provide an adequate stormwater drainage network, due to the steep natural hillsides at the head of most of the catchments. Pressure drains from the higher suburban areas and a pumped storage system for the low-lying commercial areas can rectify the flooding in the area. Hence, the general design concept is to minimise the amount of pumped storage required by discharging as much stormwater as possible through pressure tunnels and the existing Rifle Range Gully Channel and Long Gully Channel. The location of Rifle Range Gully Channel and Long Gully Channel can be seen in Figure 3-4.

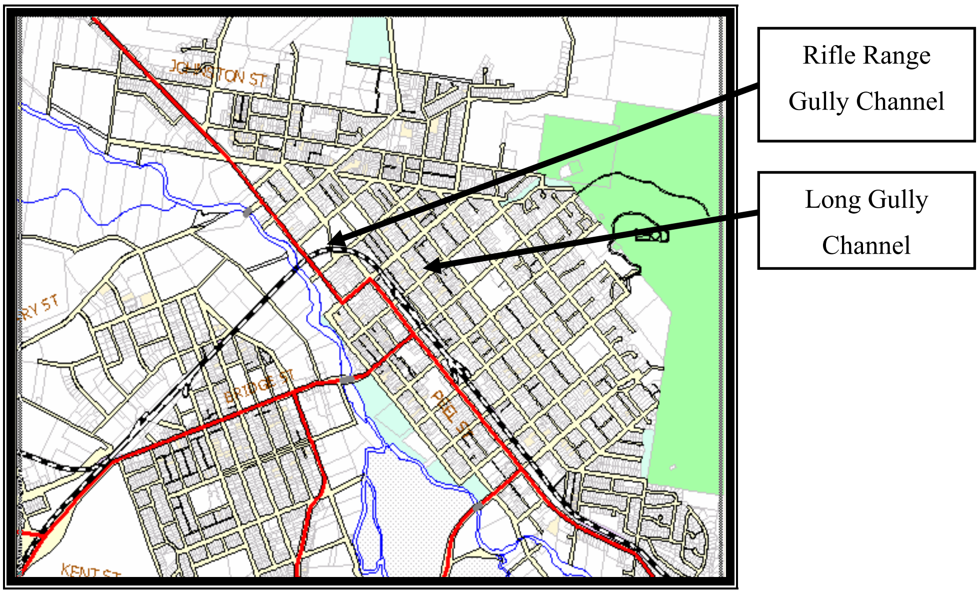


Figure 3-4 – Location of the Rifle Range Gully and Long Gully Channels

3.5. Tamworth Urban Area Stormwater Management Plan - 2000

Willing and Partners Consulting Engineers conducted a stormwater management plan in 2000 and the purpose of this management plan was to deal with drainage infrastructure but also predominantly on the stormwater quality entering the Cockburn and Peel Rivers. The town map in Figure 3-5 indicates the location of the Peel and Cockburn Rivers in relation to the town.

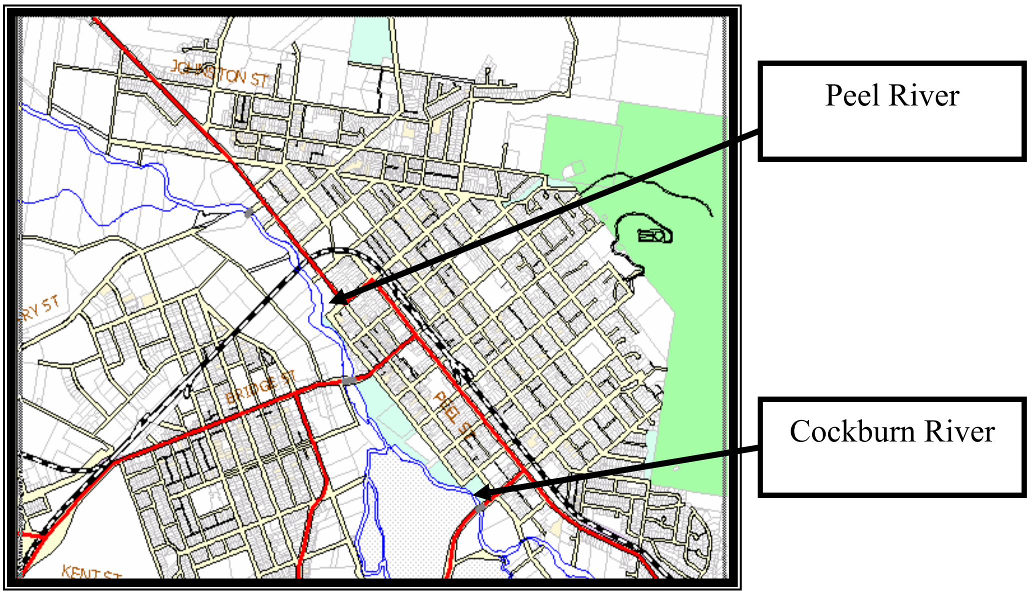


Figure 3-5 – Location of Peel and Cockburn Rivers

The primary goal of the Stormwater Management Plan was to facilitate the co-ordinated management of stormwater within a catchment to achieve ecological sustainability, and to achieve social and economic benefits from sound stormwater management practices (Willing, 2000). Once the values of the catchment have been identified, a stormwater management plan can then be implemented to safeguard these values. Identifying possible problems that may compromise these values is another facet of the stormwater management plan. The values, objectives, issues and management options were defined as follows:

Catchment Values: those aspects or components of the Tamworth urban catchments, or the natural or built environment that are valued by the community.

Stormwater Management Objectives: to enhance and protect the identified values in the Tamworth urban catchments.

Stormwater Issues: are factors that currently prevent, or may prevent, the adopted management objectives being satisfied.

Management Options: are non-structural actions and structural measures that can be implemented to meet the stormwater management objectives and thereby protect/enhance the values the community regards as important.

(Willing, 2000)

3.5.1. Recommendations

These are summarised in Figure 3-6.

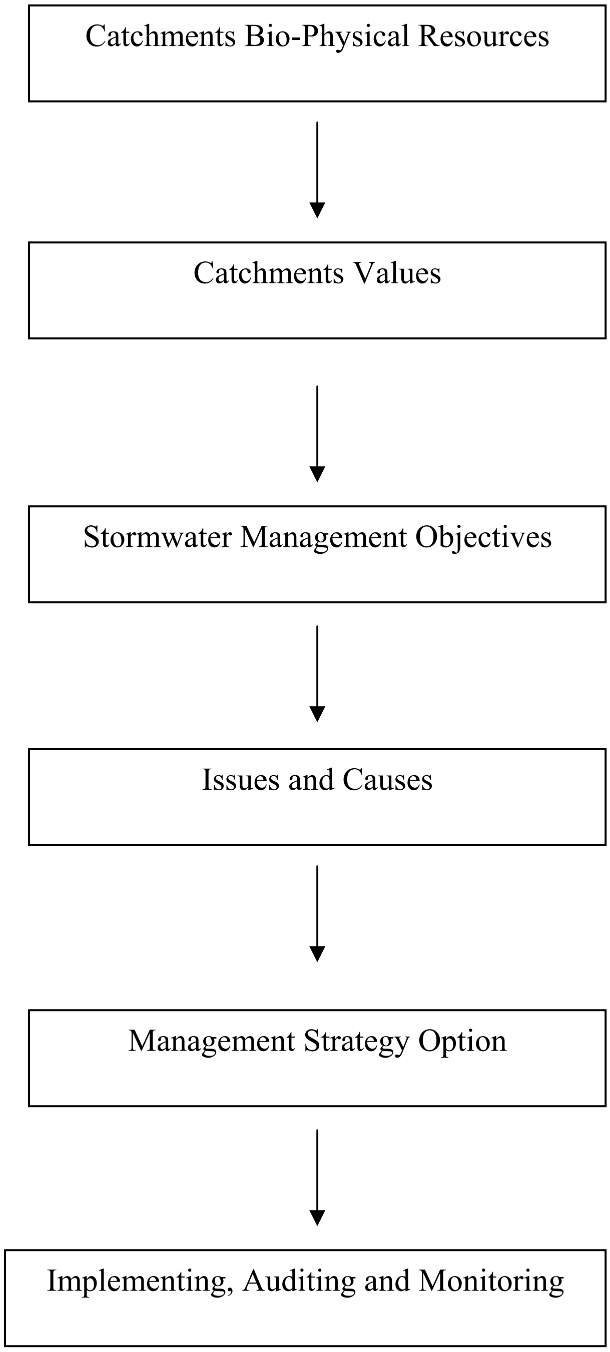


Figure 3-6– Tamworth Urban Area Stormwater Management Plan (Willing & Partners 2000, p. 16)

3.6. Tamworth Stormwater Drainage Analysis - Ben Keith

Tamworth Regional Council's preliminary action in investigating the urban drainage network was to model the catchments using DRAINS. This enabled Council to perform quick and easy analysis of each catchment.

Due to a lack of drainage information, valid estimations and assumptions were used by Ben Keith when implementing these variables into DRAINS. These estimations and assumptions included;

- Invert Levels
- Pit Type
- Pit Family
- Ponding Volume
- Max Ponding Depth
- Base Inflow
- Blocking Factor
- Sub-Catchment Areas;
- Paved, Grassed and Supplementary Areas;
- Type of Pipe;
- Diameters;

These variables caused the model's accuracy to be uncertain, and as such, the model was tested for its accuracy. To test these variables, an accurate analysis of two different catchments was undertaken. To accurately model a catchment all the variables were eliminated. The variables were eliminated by fieldwork, when Work as Executed plans was unavailable. The effect the variables had on the model determined the deficiencies of this model.

The two fundamental factors that affected the results the most were, the reduced level (RL) and the invert level of each pit. Findings from the study revealed that not all variables have to be removed for the model to be sufficiently accurate. If the Reduced level and the invert level of each pit were surveyed, the results would be accurate enough for Council to use in evaluation of their current and or in design of new infrastructure

The information that is required to provide an adequate physical description of a catchment is shown in Table 3-1. The two catchments that were analysed were a large urban catchment and a small urban catchment. The present study concentrates on a drainage segment in East Tamworth and therefore this catchment can be regarded as a small urban catchment. From Table 3-1 it is evident that the crucial information that is necessary for this study is the R.L. and the invert levels.

Table 3-1 – Recommendation for modelling stormwater in Tamworth catchment (Keith 2004, p. 97)

Required Information	Large Urban > 150 nodes	Small Urban < 150 nodes
R.L.	Yes	Yes
Invert Levels	Yes	Yes
Sub-Catchment Details	Yes	No
Pit Information	No	No

3.7. Guidelines for the design of Drainage Systems

There are many factors that influence drainage standards

- The level of hydraulic performance required;
- Construction and operating costs;
- Maintenance requirements;
- Safety;
- Aesthetics;
- Regional planning goals; and
- Legal and statutory requirements

The majority of the drainage standards are usually expressed by an average recurrence interval (ARI) or annual exceedance probability (AEP). These two characteristics determine the magnitude of the rainfall or runoff event in which the drainage system can cope. The design of drainage systems is usually based on one level of operation, however, it best if the drainage system is designed for several performance levels. These levels include:

- A maintenance requirement – ARI of less than one year
- A convenience or nuisance-reduction requirement – ARI of one to ten years
- A flood damage prevention requirement – ARI of about hundred years.
- A disaster management requirement – This is for extreme circumstances such as probable maximum floods.

3.7.1. Design Standards

Recent surveys of government bodies and consultants have indicated that the most commonly used design ARI values for street drainage systems are:

- 20 or 50 years for intensely-developed business, commercial and industrial areas;
- 10 years for other business, commercial and industrial areas and intensely-developed residential areas; and
- 5 years for other residential areas and open spaces.

A 100 year ARI criterion for administrative definition of flood-prone areas has been adopted by several governments, and the same standard has been widely accepted for channel capacities and detention basins performance (Engineers Australia, 2001b).

3.7.2. Guidelines for Design of Drainage in the Tamworth Region

Tamworth Regional Council recommends that for the design of drainage systems, the design should be carried out in accordance with their "Design Manual". This "Design Manual" is intended to be used in conjunction with, and as a supplement to, the 2001 edition of "Australian Rainfall and Run-Off".

There are two types of drainage concepts that the Tamworth Regional Council uses for the design of drainage systems in the Tamworth Region. These two types of urban drainage design are deemed "Major/Minor" Systems drainage.

The "Minor" urban drainage system refers to the underground piped system, designed to an ARI, as determined in Table 3-2. For design purposes of the minor system, the elevation of the water in the pit is restricted to 150mm below the level of the invert of the gutter. This is commonly known as freeboard.

Table 3-2 – Design Average Recurrence Intervals for road drainage (Works & Technical Services Department Tamworth City Council 1993, p.24)

Land Use	A.R.I.
Rural	5 years
Rural Residential	5 years
Urban Residential	5 years
Commercial	10 years
Industrial	10 years

The "Major" urban drainage system refers to overland flow paths which are designed to convey major storm flows when the capacity of the minor system is exceeded (Works & Technical Services Department Tamworth City Council, 1993).

3.8. Conclusions

The drainage studies that were completed in the East Tamworth area indicate that there has been a past history of drainage problems in the area. After the first drainage study was undertaken, pressure tunnels were installed, to relieve East Tamworth of stormwater. After the second drainage study was completed, construction work continued. Today all of the recommended works have been completed. The last study that was undertaken was 25 years ago. Since this study an increased amount of development has taken place in the East Tamworth area. Council has not kept up their drainage infrastructure to manage with this increased amount of development and this is why Council are still having drainage problems in this area.

Lately Tamworth Regional Councils Customer Service Department has experienced increase in the amount of stormwater complaints in the East Tamworth area. This has caused Council to investigate these possible stormwater problems. These areas will be modelled and will enable Council to determine the most appropriate augmentation works. In addition, these drainage augmentation works will allow Council to further implement stormwater drainage construction works into their budget.

Tamworth Regional Council recommends in conjunction with Australian Rainfall and Runoff (ARR) that for the design of drainage in urban residential areas in Tamworth, be design with an ARI of 5 years.

It is intended that this study will markedly improve the East Tamworth stormwater drainage network. The test remains in implementing the most technically feasible and cost efficient solution to the stormwater drainage network

CHAPTER 4

DESCRIPTION OF SELECTED

STORMWATER DRAINAGE MODEL

4.1. Introduction

The analysis of urban drainage catchments incorporates two basic concepts. The first involves the examination of the hydrology of the area to determine flow quantities. The second uses hydraulics to determine pipe pressures and flood levels. Modelling an urban drainage catchment involves selecting a suitable computer-modelling package. An investigation into stormwater modelling software was undertaken. This was conducted to determine the most appropriate computer-modelling program for application in this study. The modelling software that will be used in this project is DRAINS. Understanding the hydrologic and hydraulic models that DRAINS uses is important for the analysis of urban catchment.

4.2. Hydrology

Hydrology is the science that deals with the properties, distribution and circulation of water on and below the earth's surface and in the atmosphere. The rainfall data that is used for design purposes, in terms of rainfall intensity and storm patterns, uses uniform rainfall intensities derived from intensity-frequency-relationship and a design temporal pattern at a particular location.

4.2.1. Average Recurrence Interval of a Design Storm

Drainage guidelines are expressed by an average recurrence interval (ARI) or annual exceedance probability (AEP). These two characteristics determine the magnitude of the rainfall and subsequent runoff event. The design average recurrence interval for the minor system in Tamworth is an ARI of 5. This was outlined in Section 3.7, Guidelines for Design of Drainage Systems.

4.2.2. Design IFD Rainfall

The design of any hydraulic structures requires the input data from IFD (Intensity-frequency-duration) design rainfall curves. These curves are derived from basic annual maximum rainfall data. This data ranges in durations from 5 minutes to seventy-two hours. The frequency analysis of rainfall data is used to design the capacity of a hydraulic structure and to evaluate the risk of over-topping or failure.

For any rainfall intensity data to be of practical significance, there must be accurate intensity-frequency-duration curves for any location in Australia.

4.2.3. Temporal Patterns

Rainfall temporal patterns are used as a method of estimating a unit hydrographs or runoff routing for the design of rural and urban flood estimation. These patterns are also used as a procedure for deriving a flood of selected probability of exceedance from a design rainfall of the same probability. Australia is divided into eight climatic zones, based on different temporal patterns and zones. Tamworth is located in Zone 2 and this can be seen in Figure 4-1.

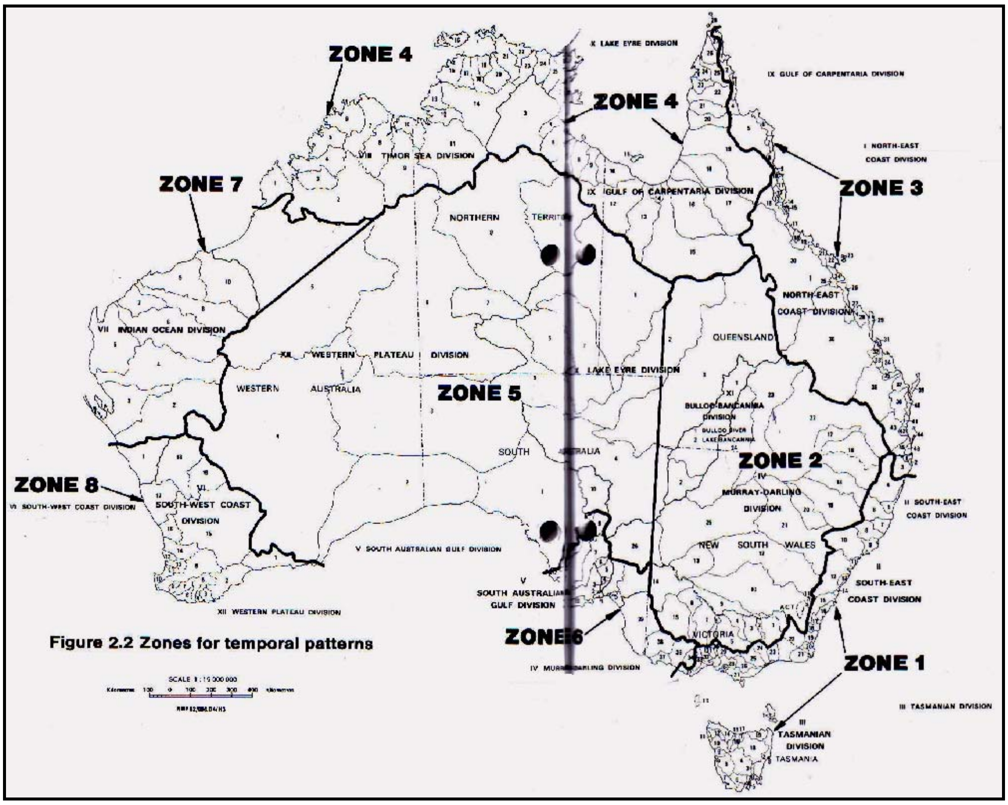


Figure 4-1 – The Temporal Patterns Zones (Engineers Australia 2001a, p. 35)

4.3. Parameters of the Model

Many simulation-modelling packages require a model to transform rainfall patterns to runoff hydrographs. The models that deal with this transformation are incorporated as part of the hydrological cycle known as the rainfall runoff process, shown in Figure 4-2.

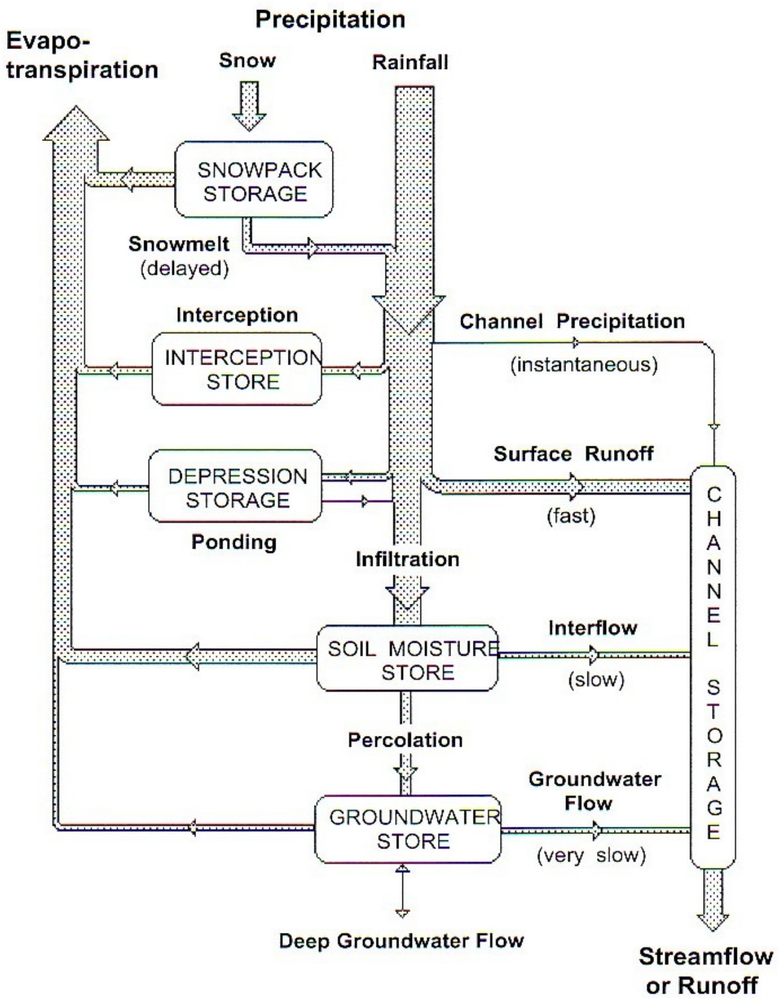


Figure 4-2 – The Rainfall-Runoff Process (O'Loughlin & Stack 2002, p. 6.5)

Urban stormwater design can be characterised by three drainage models:

- Simple models that produce a peak flow estimate.

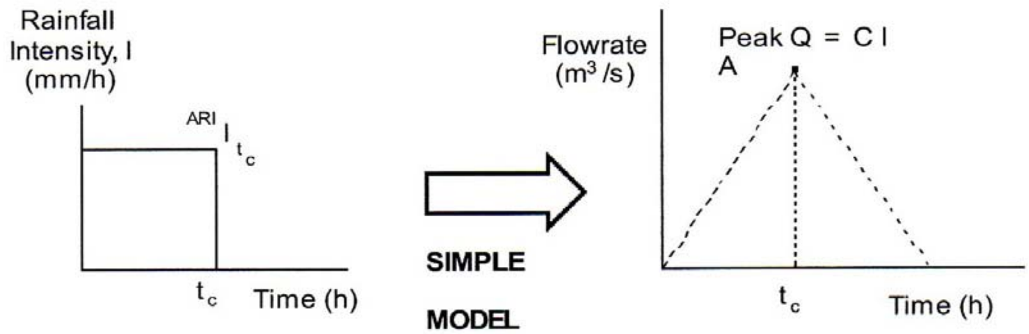


Figure 4-3 - Simple Rainfall Runoff Models (O'Loughlin & Stack 2002, p. 6.6)

- Simple hydrograph producing models.
- Complex models, producing continuous simulation of hydrographs.

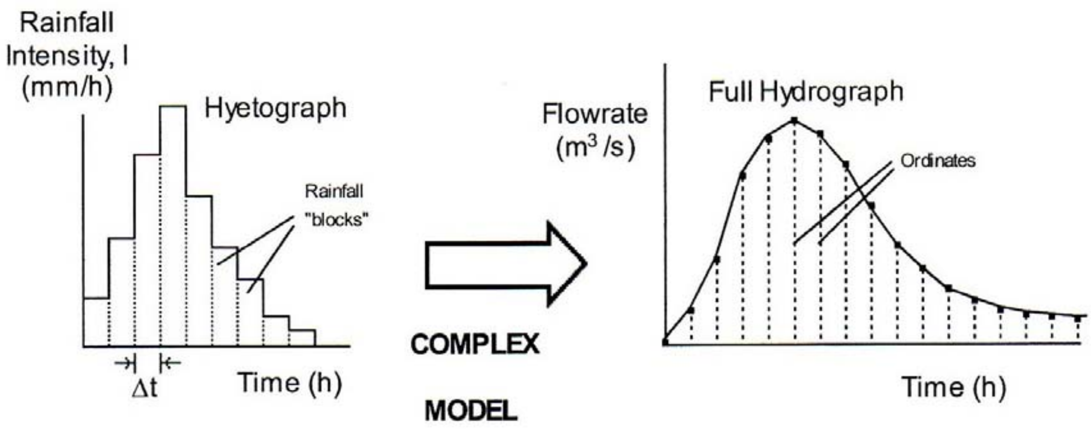


Figure 4-4 – Complex Rainfall Runoff Model (O'Loughlin & Stack 2002, p. 6.6)

Through the use of two models; loss and routing, it is possible to convert complex rainfall patterns into hydrographs of flow.

Loss models account for rainfall extractions, such as interception, depression storage, evaporation and infiltration. These extractions all prevent water from running off into pits. One such loss model is the Horton's infiltration relationship. This relationship describes the infiltration capacity of the soil. It also describes the decrease in capacity as more water is absorbed by the soil. It has the form of:

$$F = f_c + (f_0 - f_c)e^{kt}$$ **.. Eq. 4-1**

Where:

- f is the infiltration capacity (mm/h) at time t,
- f_0 and f_c are the initial and final constant rates of infiltration (mm/h)
- k is a shape factor (fixed at a value of 2 /h in Ilsax)
- t is the time from the start of rainfall (h).

Some routing models provide for spatially-variant rainfall. They have the ability to combine rainfall excess from different areas and allow for delaying effects, such as time of travel and storage.

These two models are able to determine the flows occurring during a particular rainfall event. The loss model describes how the infiltration properties of a catchment change as it become wet; rainfall excess can be determined and routed through a model.

The Rational Method has been the traditional method for calculating flow rates for urban drainage design. The formula is:

$$Q = C.I.A$$ .... **Eq. 4-2**

Where:

- Q is the design flowrate (m^3/s),
- C is the dimensionless runoff coefficient,
- I is a rainfall intensity (mm/h), and
- A is the catchment area (ha)

This method converts statistical rainfall intensity I, to a flow rate Q, using a runoff coefficient C and a catchment area A.

4.4. Hydraulics

There are three levels of hydraulic analysis available in the design and analysis of the urban stormwater drainage system. These include;

- Open channel flow assuming steady flow,
- Part or full-pipe flow calculations determining hydraulic grade lines (HGL) and water surface profiles,
- Full hydrodynamic modelling, using the St Venant Equations to employ finite difference solution of partial differential equations describing the conservation of mass and momentum. The St Venant equations are:

    The continuity equation:

$$v\frac{\partial A}{\partial x} + A\frac{\partial v}{\partial x} + b\frac{\partial h}{\partial t} = 0$$ .... **Eq. 4-3**

    The momentum equation:

$$g\frac{\partial h}{\partial x} + v\frac{\partial v}{\partial x} + \frac{\partial v}{\partial t} = g(i - j)$$ .... **Eq. 4-4**

When water flows in a pipe, energy is lost in a number of ways. Initially energy is lost from water entering a pipe. Further, energy is also lost due to friction and turbulence as water flows down the pipe. Water also possesses some kinetic energy after it reaches the downstream end of a pipe. This energy is lost by turbulence in the body of water into which the pipe discharges.

A pipe that is uniform in diameter, flowing at full capacity, the corresponding kinetic energy is constant along the pipe. The hydraulic grade line is therefore parallel to the total energy line if the flow is steady. This line is located at a distance of $v^2/2g$, metres below it. This separation is also known as the velocity head.

An application of the hydraulic grade line analysis requires a pit-to pit headloss formulation. This headloss formulation has two major components.

- Pipe friction headloss, h_f
- Pit energy headloss, h_w

The energy that is lost along a drainage line due to friction is found by multiplying the slope of the energy line between the inlet and exit, by the length of the pipe. The slope of the energy line is a function of the characteristics of the pipe and the properties of water. Darcy Weisbach and the Colebrook-White equations are two formulas used to relate these two characteristics. The Darcy Weisbach equation is shown in Eq. 4-5 and the Colebrook White equation is shown in Eq. 4-6.

$$h_f = \frac{\lambda L V^2}{2gD}$$ **.. Eq. 4-5**

Where:

- λ = k/d, where k is the pipe roughness (m/m), sometimes given as e
- L is length of pipe (m)
- V is velocity of water (m/s)
- g is the acceleration due to gravity (9.8 m/s^2)
- D is the diameter of the pipe (m)

$$\frac{1}{\sqrt{\lambda}} = -2\log\left[\frac{k}{3.7D} + \frac{2.51}{\mathrm{Re}\sqrt{\lambda}}\right]$$ **....................................... Eq. 4-6**

Where:

- λ = k/D, where k is the pipe roughness (m/m)
- L is length of pipe (m)
- V is velocity of water (m/s)

- $Re = VD/\mu.k$, where μ is Kinematic Viscosity of water (1.14 x (m^2/s) at 15°C)
- D is the diameter of the pipe (m)

At a pit the energy of water flowing in a pipe just downstream from the entrance is less than the energy of the water before it enters the pipe. This energy loss, h_w is caused by turbulence and pressure changes created as the water enters the pipe. The evaluation of these losses at a pit is complex, therefore a pit energy coefficient k_w attempts to simplify the energy loss processes at a pit. This effect is illustrated in Figure 4-5.

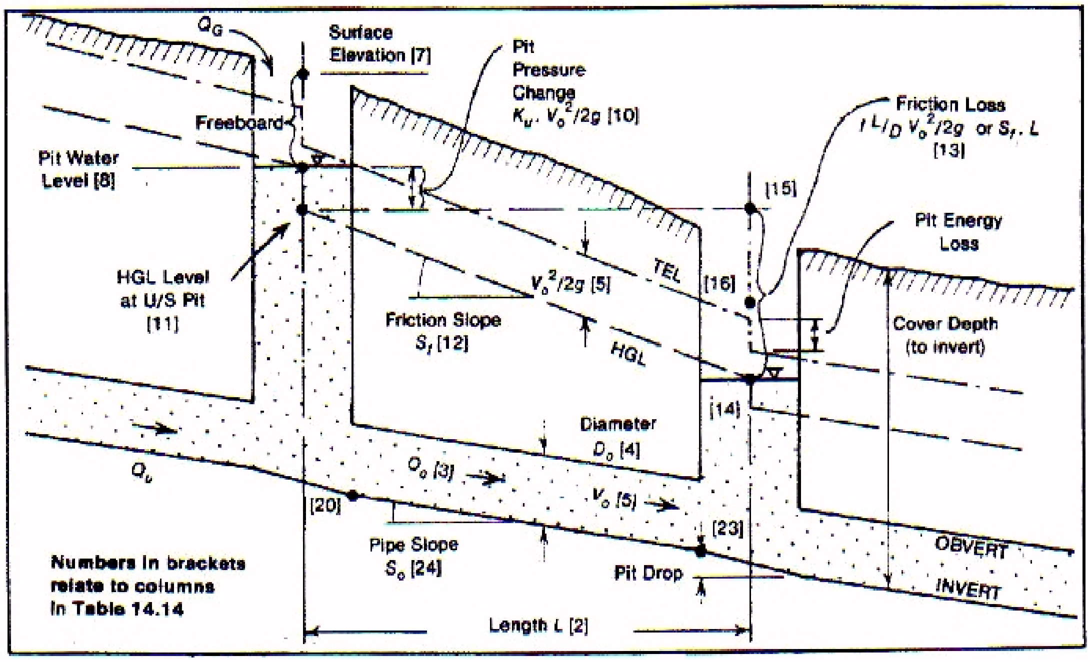


Figure 4-5 – Energy Level of Water Flowing in a Pipe (Engineers Australia 2001b, p. 42.)

4.5. Modelling Software

An investigation was undertaken into the software that is available to be utilised for this study. Programs that analyse stormwater catchments include DRAINS, Stormwater Management Model (SWMM; Huber and Dickinson 1988. Huber et al.1984. Rosener et al 1988) and MIKE SWMM. DRAINS was selected as the computer modelling package because of the ability to model complex urban catchments and as it was developed in conjunction with guidelines of Australian Rainfall and Runoff.

4.5.1. DRAINS

DRAINS has the ability to design and analyse urban stormwater drainage systems. It was designed to convert rainfall patterns to stormwater runoff hydrographs and route these through networks of pipes, channels and streams, integrating:

- Design and analysis tasks,
- Hydrology and hydraulics,
- Closed conduit and open channel systems,
- Stormwater detention systems,

4.5.2. SWMM

The Stormwater Management Model (Huber & Dickinson 1988, Huber et al.1984, Rosener et al 1988) is a comprehensive computer model for analysis of urban runoff. Single event and continuous event of sewers and natural drainage can be modelled for prediction of flows, stages and pollutant concentrations. SWMM can model all aspects of urban hydrologic and quality cycles. They include

- Surface and subsurface runoff
- Flow routing through drainage network
- Storage and treatment

4.5.3. MIKE STORM

MIKE SWMM combines two computer-modelling packages, MIKE 11 (Haveno et al., 1995) and SWMM (Huber & Dickinson, 1988. Huber et al.1984. Rosener et al 1988). MIKE 11 is used to model, rivers, estuaries, reservoirs and open channel systems. It uses a one-dimensional hydrodynamic model that applies the St. Venant equations. MIKE SWMM uses this uni-dimensional unsteady flow modelling from MIKE 11. This replaces the former EXTRAN module in SWMM. EXTRAN was used to rout inflow hydrographs through open channels and a pipe network system using explicit numerical solution. MIKE SWMM is able to perform hydrologic and hydraulic analysis of stormwater, which includes pipes, pumps, culverts and detention basins. One of MIKE SWMM strengths is the ability to 2-way link itself to GIS, AutoCAD and Asset Management Systems.

4.6. Historical Development of the DRAINS Program

The analysis of the drainage network in East Tamworth catchment will be modelled by a computer package called DRAINS. DRAINS was developed as a result of the following chain of proceeding models, seen in Figure 4-6.

TRRL Method (U.K., 1962)

↓

ILLUDAS (U.S., 1974)

↓

ILLUDAS-SA (South Africa, 1981)

↓

ILSAX (Australia, 1986)

↓

DRAINS (Australia, 1998)

Figure 4-6 – The Development Path of DRAINS

4.6.1. The U.K. TRRL Method

The TRRL (Watkins, 1962) method was developed in 1962. This method used a time area routing model combined with a design rainfall pattern to produce a flow hydrograph. The TRRL method was tested to determine the reliability and validity of the results by comparing flow estimates from rainfall and runoff data to calculated values from the TRRL method.

4.6.2. ILLUDAS and ILLUDAS - SA

The Illinois Urban Drainage Area Simulator, (ILLUDAS; Terstriep & Stall, 1974) was developed in 1974. This program is very versatile and many special features have been developed. The developers also conducted a number of tests on the models to test the reliability and validity of the results. This program was the basis for the Ilsax model.

4.6.3. ILSAX

The Ilsax program was developed in 1982 by Geoffrey O'Loughlin. The program was developed as an alternative stormwater model to the Rational Method. Ilsax program was developed in accordance with the guidelines in Australian Rainfall and Runoff, 1987 dealing with urban stormwater drainage.

4.6.4. DRAINS

DRAINS was developed as an extension to Ilsax and is a comprehensive, multi-purpose Windows program for designing and analysing catchments. DRAINS allows modelling using Ilsax and the Rational Method model hydrology. The program has the capability to conduct hydraulic modelling of pipes and open channels. The user can describe the drainage system graphically, using either drawing tools or transfers from drawing packages and spreadsheets. The stormwater runoff from catchment areas during storms is calculated and directs this through the drainage system.

4.7. Hydrologic Models used in DRAINS

There are two basic types of hydrologic drainage models used in DRAINS to analyse a drainage catchment. They are the Ilsax and the Rational Methods.

4.7.1. ILSAX

The Ilsax type model is the main hydrological model used to simulate an urban stormwater drainage system in DRAINS. Flow hydrographs from sub-catchments are calculated from routing and loss models. At the start of each storm, calculations are performed at specified times. These time intervals are small, generally less than one minute. A hydraulic grade line analysis performed throughout a drainage network at each time step and flow rates and water levels are consequently determined.

This model incorporates urban catchments, subdividing them into smaller sub-catchments associated with the type of drainage system. These sub-catchments can be classified into three surface types, paved, supplementary and grassed.

- Paved areas – impervious sub-catchment areas that are directly connected to the pipe network, these include road surfaces, driveways and roofs connected to street gutters.
- Supplementary areas – impervious sub-catchment areas that are not connected to the pipe network but drain onto pervious surface, which connect to this network. This includes tennis courts surrounded by lawns, house roofs draining onto pervious grounds.
- Grassed areas – pervious sub-catchment areas that are connected to the pipe network. This includes bare grounds and lawns.

These are shown schematically in Figure 4-7.

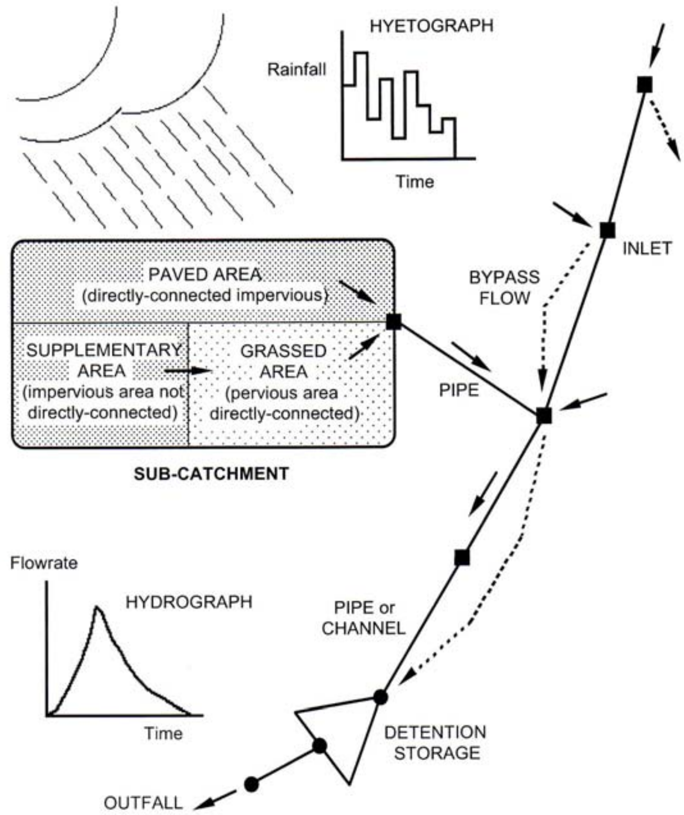


Figure 4-7 – The Layout of the Ilsax Model (O'Loughlin & Stack 2002, p. 6.8)

Runoff hydrographs are generated from inputted rainfall patterns using loss modelling combined with time-area routing to model the system behaviour (O'Loughlin & Stack, 2002). The model calculates runoff at the start of the storm and continues until the storm passes out of the catchment. Rainfall and runoff flow rates are calculated at intervals defined by each time step and the subsequent hydrographs are drawn.

Horton's infiltration model is used as a loss model to calculate losses for grassed or pervious areas and also subtracts depression storages from all surfaces. These parameters used in this model are determined from the soil type in the area. The soil type used in the Ilsax model follows the ILLUDAS model from which Ilsax was developed. There are four soil types:

- Type 1 – low runoff potential, high infiltration rates (sand and gravels),
- Type 2 – moderate infiltration rates and moderately well-drained,

- Type 3 – slow infiltration rates (may have layers that impede downward movement of water),
- Type 4 – soils with high runoff potential and very slow infiltration rates (consisting of clays with a permanent high water table and a high swelling potential).

Depression storage is another form of initial loss parameter. It is the depth of rainfall (mm) that is retained in depressions or puddles on the catchment surface and evaporated.

4.7.2. Time Area Method

The time-area method is the basis of the Ilsax model's hydrograph generation. This method is systematically presented in Figure 4-8.

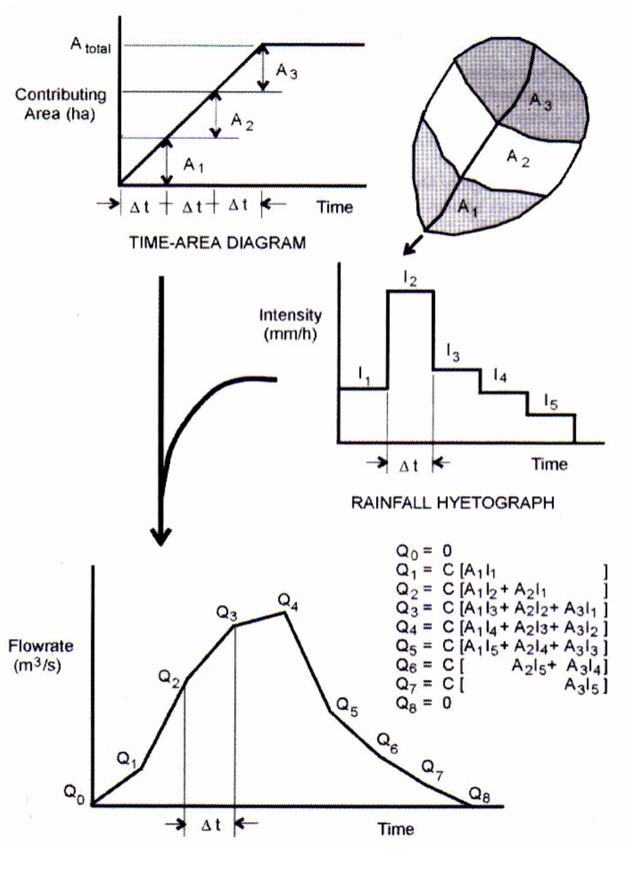


Figure 4-8 – Time-Area Calculations (O'Loughlin & Stack 2002, p. 6.10)

Assume that the rainfall hyetograph has had losses removed and therefore represents rainfall excess. The hyetograph is divided into time steps of Δt. After a storm commences on a catchment that has a time of entry of 5Δt, the initial flow Q_0 is zero.

After one time step Δt, only one sub-area contributes to the flow at the outlet. Therefore, the flowrate at the end of the first time step can be approximated by:

$$Q_1 = cA_1 I_1$$

.... **Eq. 4-7**

- C = conversion factor from mm/h to m^3/s.
- I_1 = average rainfall intensity during the first time step.

After the second time step, there are now two sub area contributions to the outlet flow. The flowrate Q_2 due to the second area of rainfall falling on the catchment nearest to the outlet node and runoff from the first block on the second sub-area can be approximated by:

$$Q_2 = c[A_1 I_2 + A_2 I_1]$$

.... **Eq. 4-8**

- C = conversion factor from mm/h to m^3/s.
- I = average rainfall intensity during the second time step.

This process continues until the entire hyetograph is routed through the catchment. The hydrographs builds up to a peak and then recede once rainfall stops and the catchment drains. The time area routing relies on times of travel as the main component used in routing.

4.7.3. The Rational Method

The Rational Method is one of the oldest and most widely used procedures in calculating the rate of surface runoff resulting from a storm. It is the most commonly used peak flow hydrological model in urban catchments. This method suffers from the limitation that it does not calculate flow hydrographs, and is gradually being superseded by hydrograph producing methods.

4.8. Pipe System Hydraulics used in DRAINS

There are two types of hydraulic analysis that the DRAINS program can perform. These two types of analysis are: Analysing the pipe network and designing the pipe network based on given rainfall data. In analysis runs, DRAINS determines the flow into pits, possible bypass flows and the flow along pipes. At the same time DRAINS retraces this path from a specified tailwater level at the systems outfall, determining hydraulic grade lines and water levels in pits. The tailwater levels calculations proceed down through the drainage network until the tailwater level is reached. This level can be specified by the user in the Outlet Node property sheet or if it freely discharges to the atmosphere DRAINS assumes to be the pipe's normal depth or critical depth for supercritical flow. The pipe friction and pit pressure changes and both part-full and full-pipe flows are taken into consideration when being modelled. This analysis indicates areas where flooding occurs and the drainage network can be easily changed with additional runs made to assess improvements.

In design runs, DRAINS implements particular pipe sizes and invert levels to prevent spilling from pits. The DRAINS program determines the pipe sizes and invert levels by calculating the peak flows from the subsequent hydrographs and designing for these in a downwards pass followed by an upward one.

4.8.1. Pipe Friction Equations

For circular pipes the velocity of the water in the pipes is calculated from combining the Darcy-Weisbach and Colebrook-White equation. This combination yields an explicit expression for V and is shown in Eq. 4-9 below.

$$V = -0.87\sqrt{2g.D.S}\,\log_e\left(\frac{K}{5.7D} + \frac{2.51\mu}{D\sqrt{2g.D.S}}\right)$$ **......................... Eq. 4-9**

Where:

- g is the gravitational acceleration (m/s^2), generally 9.8 m/s^2 at sea level
- D is the diameter (m)
- S is the energy line slope (m/m)
- K is the pipe wall roughness (mm),
- μ is the kinematic viscosity (taken as $1.14 \times 10^{-6} m^2/s$ at 15^oC)

4.8.2. Pit Pressure Changes

An important aspect in determining pipe system behaviour accurately is the head losses and changes to the energy grade line and hydraulic grade line at the pits and junctions. For full pipe flow Figure 4-9 shows how these are represented by two functions of the pit outlet velocity V_0.

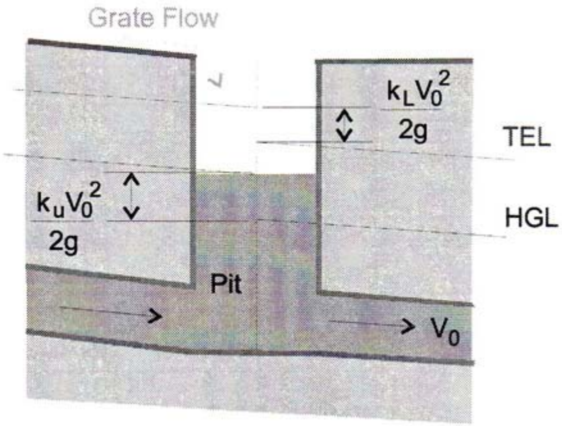


Figure 4-9 – Pit Energy Losses and Pressure Changes (O'Loughlin & Stack 2002, p. 6.40)

The Energy Line will drop by the amount of head loss for the pit. The head loss for the pit is given by Eq. 4-10:

$$h_L = k_L \frac{V_o^2}{2g} \qquad \textbf{Eq. 4-10}$$

Where:

- h_L is the head loss
- k_L is the coefficient (dimensionless)
- V_o is the full-pipe velocity in the outlet pipe from the pit (m/s), and
- g is the acceleration due to gravity (9.8 m/s^2)

The pressure change for each pit is expressed by Eq. 4-11:

$$h_u = k_u \frac{V_o^2}{2g} \qquad \textbf{Eq. 4-11}$$

Where:

- h_u is the head loss (m), and
- k_u is the head loss coefficient

4.9. Summary

Urban stormwater models must be capable of simulating flows over impervious and pervious areas through channels, pipe networks and through storages. After reviewing other modelling software it is hypothesised that Ilsax and DRAINS software will be the prime software used in the analysis of the urban drainage network. Modelling these drainage networks in a computer-modelling package DRAINS will enable Council to simulate a real world situation. DRAINS uses two different models to analyse the drainage of catchments. These two models include the Ilsax and Rational Models. The Ilsax is a medium level rainfall runoff model, which combines a Horton loss model with time area routing in a complex way. The Rational method, models the urban drainage network from calculating the peak flow rate. DRAINS uses hydraulics to determine water levels in each pit. It calculates HGL from preceding tailwater levels in the catchment.

CHAPTER 5

FORMULATION OF THE DRAINS MODEL

5.1. Introduction

This chapter will describe the data collection and data reduction methodologies that were employed in order to evaluate and present the data that was collected from the Catchments to be analysed in DRAINS. In addition, the model will be calibrated and a sensitivity analysis will also be investigated.

5.2. Data Collection

The researcher organised a surveyor to come up and gather some field data. This involved conducting several meetings to discuss the type of data that was needed to be collected in order for the analysis to be undertaken. The reason for gathering this field data was because the data could not be obtained accurately enough from Tamworth Regional Councils Geographical Information System. This data collection involved personal interaction with residents, due to many pits being located in residents' backyards. This interaction involved speaking to residents and informing them of the purpose for this data collection. The surveyor that conducted this survey was Kurt Suttor, from Pipeline Construction Services. The data collection was undertaken in East Tamworth in early May. Figure 5-1, shows the surveyor setting up for his data collection during this time period. In addition to positional coordinates and invert levels the following data will be collected:

- Pipe diameters
- Pipe type – concrete, PVC, clay, fibre cement, cast iron
- Reduced Level
- Invert Level
- Length and grade of kerb inlet lintels
- Upstream and downstream nodes

Data is recorded using pocket PC and this data is downloaded to a desktop computer and exported to Microsoft Access database for further processing

.

Figure 5-1 – Surveyor preparing to survey Tamworth Regional Council Stormwater Network

5.3. Field Methodology

The aim of the survey was to establish the horizontal and vertical location of stormwater structures and provide depths to inlet and outlet pipes at the structures. Detailed plans provided by the researcher allowed less problematic and more accurate data collection to be conducted by Pipeline Construction Services. This data is provided to Tamworth Regional Council (TRC) to generate stormwater catchment models for flow analysis. The co-ordinates are reported in Geocentric Datum of Australia (GDA) format for horizontal position and Australian Height Datum (AHD) for vertical position with survey tolerances required for the flow study models. The survey is carried out in two stages to utilise survey resources more efficiently. This method requires a minimum of two visits to each structure.

5.3.1. Internal Survey

The stormwater structure is located and identified with the aid of existing TRC GIS maps. The access chamber lid or grate is raised to allow measurements of internal dimensions and depths to pipe inverts. Access chambers are generally not entered. During the survey there were problems associated with lifting of certain concrete access chambers lids. The surveyor could not lift these lids manually and therefore, TRC maintenance crews assisted in lifting of these lids with mobile cranes.

Measurements to pipe inverts are made using graduated fibreglass rods. The depth measurements are taken from a locally marked reference point, generally at the centre of a chamber lid or the lintel edge at centre of grate. This data is later reduced to provide the vertical depth to the pipe invert. During the survey, there were pipes blocked due to saltation. Consequently, TRC maintenance crews assisted in flushing of certain segments of pipe network. If there is a requirement to enter the access chamber to acquire the survey data it is done in accordance with OH&S Confined Space regulations.

5.3.2. Equipment

The position of the Stormwater Structure is determined by the use of Real Time Kinematic Global Positioning System (RTK GPS). RTK GPS involves a base station and a rover. The base station is set up either over a known point or locally calibrated to known points with known co-ordinates satisfying the order of accuracy required for the survey. Before the survey could be conducted the researcher and the surveyor looked at possible locations around the city for this base station. This base station was eventually positioned on top of a water reservoir. Both the base station and the rover have a GPS receiver collecting data simultaneously. The base station transmits the difference between the GPS co-ordinates and the known co-ordinates to the rover by radio communication at one sec intervals and so providing real time co-ordinates at the rover.

The GPS data is recorded using a hand held electronic data collector running GPS data acquisition software. The software allows for inclusion of feature codes and attributes. The software also verifies the accuracy of the GPS data to predefined parameters. If the analysis of the data falls outside of the parameters the surveyor is warned and can choose to reject the data and re-read. The point of survey is the reference point established during the internal survey. Logging of the GPS data in Tamworth can be seen in Figure 5-2 below.

Where GPS signals are not available due to obstruction by trees, buildings and the like, reference marks are established near the structure for follow up survey using conventional survey equipment. This equipment includes surveyor's levels or total stations.

The GPS data is downloaded to a computer and integrated with internal survey data. The data is checked for accuracy and integrity prior to export to Excel format for delivery to TRC. Figure 5-2 shows the surveyor collecting stormwater data using GPS equipment.

Figure 5-2 – Surveyor conducting GPS survey of the stormwater network

5.3.3. Accuracy

The accuracy of the survey data collected to provide the x y z coordinate position of structure reference point will fall within the range of +/- 200mm Horizontal and +/- 50mm Vertical.

5.4. Data Reduction Methodologies

Importing the data into DRAINS requires the use of a compatible program such as Microsoft Excel. Indeed, DRAINS can import/export files from/to an excel spreadsheet. Excel has a number of advantages and disadvantages when using it as a dedicated data entry package for use in conjunction with DRAINS. The advantages include:

- Create data for nodes, pits, pipes, prismatic channels and overflow routes into DRAINS.
- Manipulate any numerical data for these objects.
- Import new data for pipes, prismatic channels and overflow routes within Excel, and incorporate this data into DRAINS.

The disadvantages include:

- Import data for non-prismatic channels, multi channels, detention basins, bridges or culverts into DRAINS.
- Construct new nodes or pits
- Import rainfall data

5.5. Catchments Details

A catchment is an area in which all surface water drains to a common point. Tamworth city's entire drainage catchment is 915 hectares in size. There are 107 sub-catchments within Tamworth city's overall catchment. These sub-catchment areas range in size from 0.5 hectares (CBD) to up to 270 hectares (outskirts of the city). The two sub catchments that were selected for the analysis is illustrated in APPENDIX B.

5.6. Variables used in the Formulation of the Model

The formulation of the DRAINS Model involves importing model parameters/physical characteristics into the computer package. These parameters for each sub-catchment include pit details, sub-catchment detail and pipe details. This data for Catchment 22 and 25 can be seen in APPENDIX D and APPENDIX E.

5.6.1. Pit Details

The pit details are a physical characteristic of data that is imported into DRAINS for analysis. These characteristics and reasoning for selection of certain physical characteristics are detailed below.

- Pit type – there are two types of pits found in a catchment. The two types of pits are on-grade and sag pits. On-grade pits are located on slopes, while sag pits are in hollows or depressions. Upon consultation with Council Assets Engineer, 90% of Tamworth's pits in Catchment 22 and 25 are on-grade pits and this will be assumed for all pits in these catchments (Chan, KK 2005, personal communication, 6 January).
- Pit family and size – the pit family is the slope of the pit from the upstream to downstream. The pit size indicates size of the inlet of the pit. Upon inspection of the pits in Catchment 22 and 25, the majority of the pits were, NSW RTA Pits – 3% slope. The pit size was also inspected at the same time and the majority of these pits were a SA2– 3% slope. The dimensions of this inlet pit are shown in Figure 5-3.

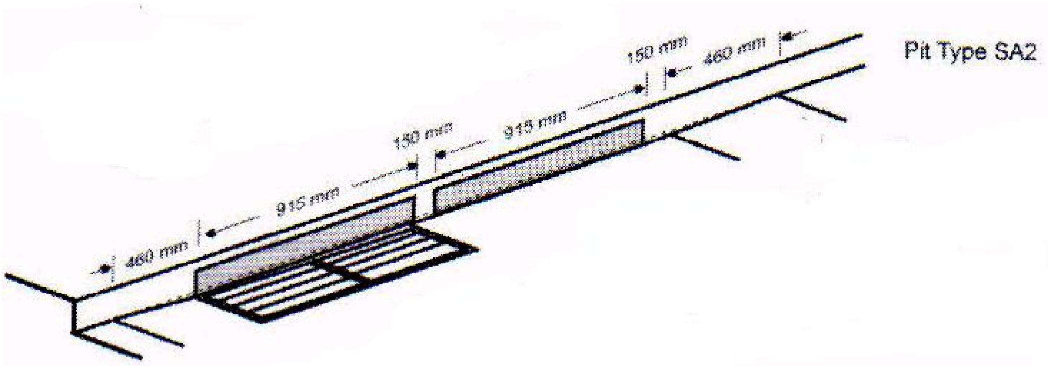


Figure 5-3 – NSW Road and Traffic Authority Inlets with depression Grates (O'Loughlin & Stack 2002, p. 6.35)

A typical inlet pit in this catchment is shown in Figure 5-4.

Figure 5-4 – A typical inlet pit in East Tamworth

- Pressure Change Coefficient – the pressure change coefficient allows for part-full flows to be adjusted if required. There are theoretical relationships for pressure changes based on conservation of momentum calculations, but these do not cover all cases. Generally, 1.5 will be a conservative value for k_u in flow through pits (O'Loughlin & Stack, 2002). A value of 1.5 will therefore be assumed as the pressure change coefficient. Headwalls use an entry loss coefficient in the same way as pit pressure coefficients. Entrance loss factors, are detailed in Table 5-1. All the headwalls in the Catchments 22 and 25 are projecting from fill, with a square cut end. Hence, the K value is 0.5.

Table 5-1 – Entry Loss Factors (O'Loughlin & Stack 2002, p. 6.30)

Circular Concrete Pipes	K Value
Projecting from, socket end	0.2
Projecting from fill, square cut end	0.5

- Reduced Level – the surface level (AHD) of the pit. Pipeline Construction Services has taken the levels and are accurate to within 50mm.
- Base Inflow – base inflow is when an external inflow is discharged into a pipe or channel from sources as groundwater infiltration. There is no data on

base inflow. Therefore, there will be an assumption made that base inflow equals 0.

- Blockage Factor – The blockage factor of a pit is the reduction in the capacity of the pit due to blockages from debris. The blockage factor ranges from zero for no debris in the pit, to one where the pit is completely blocked and stormwater being diverted downstream. Tamworth Regional Council recommends that an average blocking factor of 0.2 be used for drainage systems in the Tamworth area (Keith, 2004).
- X, Y coordinates – These coordinates allow the pits to be located in DRAINS. Pipeline Construction Services has obtained these coordinates and they are accurate to within 200mm. A DXF background file from AutoCAD is also inserted into DRAINS to allow for analysis.

5.6.2. Sub-catchment Details

The sub-catchment details are another physical characteristic of data that is imported into DRAINS for analysis. These characteristics and reasoning for selection of certain physical characteristics are detailed below:

- A sub-catchment name and area (ha)
  - These sub-catchment boundaries areas were estimated from cadastral information from GIS database.
- The percentage areas impervious, pervious and supplementary
  - The percentage impervious and pervious was estimated from experience, advice and observation of the urban catchments. The percentage impervious was estimated at being 70% and percentage pervious was estimated at being 30%.
- The corresponding times of concentration
  - The time of concentration for each sub-catchment is effectively the same as the times or concentration or times of travel used in the Rational Method. The Queensland Urban Drainage Manual (QUDM; Neville Jones & Associates et al., 1992) recommends a simplified procedure for setting inlet times, using the values in Table 5-2.

Table 5-2 – Recommended Standard Inlet Time of Concentration to First Inlet (QUDM 1992, p.5-15)

Location	Time (Minutes)
Road surface and paved areas	5
Urban and residential areas where average slope of land is greater than 15%	5
Urban and residential areas where average slope of land is greater than 10% and up to 15%	8
Urban and residential areas where average slope of land is greater than 6% and up to 10%	10
Urban and residential areas where average slope of land is greater than 3% and up to 6%	13
Urban and residential areas where average slope of land is up to 3%	15

Note: The average slopes referred to are the slopes along the predominant flow paths for the catchment in its developed state.

5.6.3. Pipe Details

The pipe details are another physical characteristic of data that is imported into DRAINS for analysis. These characteristics and reasoning for selection of certain physical characteristics are detailed below:

- Invert Level –level (AHD) to the bottom of the pipe outlet. Pipeline Construction Services has taken these invert levels.
- Roughness –a pipe roughness of 0.15mm for reinforced concrete pipes will be used in accordance with recommendations by Hydraulics Research (1983) and the Standards Association of Australia (1978). This is shown in Table 5-3.

Table 5-3 – Recommended Colebrook-White Roughness, k (O'Loughlin & Stack 2002, p. 6.39)

Pipe Material	Hydraulics Research Recommendations: k values (mm) for pipe condition:			SAA Recommendations: for concentrically-jointed, clean pipes
	Good	Normal	Poor	
Concrete				
Precast, with "O"Ring Joints	0.06	0.15	0.6	0.03 to 0.15
Spun precast, with "O" Rings	0.06	0.15	0.3	
Monolithic construction, against steel forms	0.3	0.6	0.15	
Monolithic construction, against rough forms	0.6	1.5	-	
Asbestos Cement	0.015-0.03			0.015 to 0.06
UPVC				
Chemically-cemented joints		0.03		0.003 to 0.015
Spigot and Socket Joint		0.06		

- Lengths and Diameters of each pipe are other physical properties used in DRAINS.

5.6.4. Overflow routes

Overflow routes define the path taken by stormwater flows that bypass on-grade pits. These routes were determined from cadastral information. An estimated travel time must be used for these overflow routes (O'Loughlin & Stack, 2002). These travel times will be investigated to determine how sensitive they are to resultant HGL.

5.7. Defining the Ilsax Model

The Ilsax model is defined in the drainage project menu, where the user selects the type of hydrologic model that they want to use to analyse the pipe network. This can be seen in Figure 5-5 below.

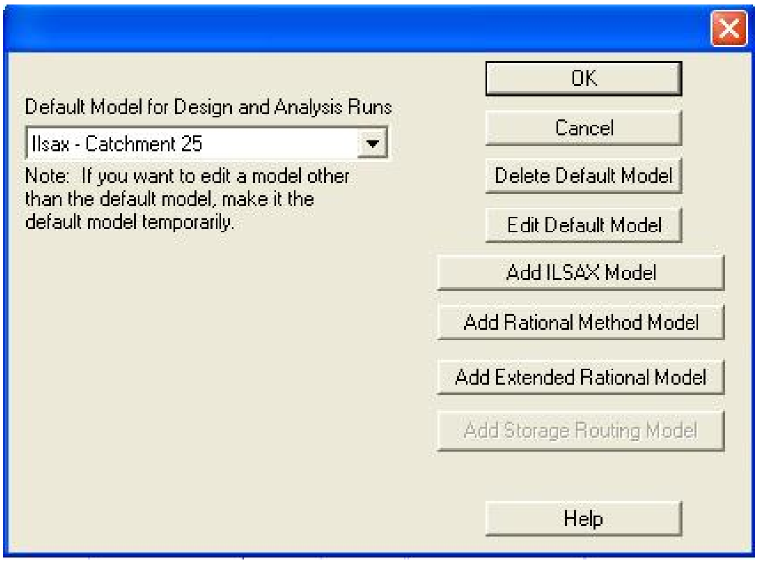


Figure 5-5 – Drainage Project Menu

The Ilsax Hydrological model uses a loss model involving depression storages and the Horton infiltration model for pervious areas. Suggested values for depression storage are 1mm for paved and supplementary areas and 5mm for grassed areas (O'Loughlin & Stack, 2002). The soil type, which is found within the Tamworth region, is hard clay with low infiltration. This was outlined in Section 2.2, Focus Area. Therefore, the type of soil that will be used in the analysis of the urban drainage network of the city of Tamworth is a Type 3 soil. This soil type has predetermined characteristics that DRAINS uses in the Horton infiltration model. This menu can be seen in the Figure 5-6 below.

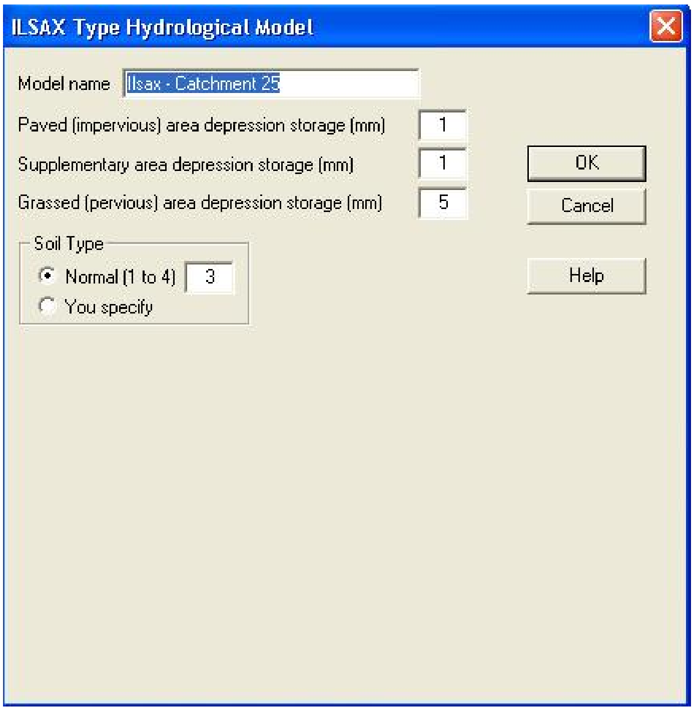


Figure 5-6 – Ilsax type hydrological Model

5.7.1. Rainfall Patterns

Varying rainfall patterns can be modelled when using the Ilsax hydrological model. For most analysis tasks in Australia, the rainfall data required will come from the Engineers Australia (2001a) – 'Australian Rainfall and Runoff'. This option allows for the estimation of a unit hydrographs through use of temporal patterns and also the design standard for the given storm event. (ARI) The IFD data for Tamworth was calculated using the algebraic method.

In order for DRAINS to analyse a network, the following information must also be entered.

- The antecedent moisture condition or catchment wetness prior to the start of the storm – see note 1
- The storm total duration (minutes)
- The time interval for the inputted hyetograph values (minutes)
- Intensities (mm/hr)

The rainfall data property sheet is shown in Figure 5-7 below.

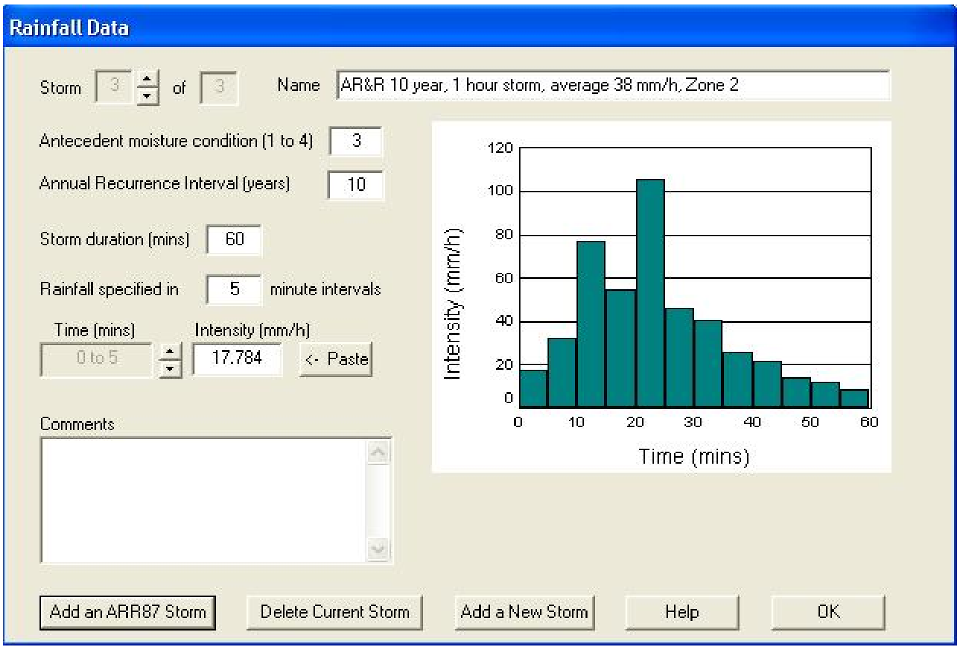


Figure 5-7 – Rainfall Data Property Sheet

NOTE:

Antecedent Moisture Condition (AMC) is a parameter used in the loss portion of the model to determine the moisture condition of the soil at the start of a storm. This parameter can have a significant effect on the flow rates generated by the Ilsax model. The AMC number can be represented on an infiltration curve. This is evident in Figure 5-8 below. Figure 5-8 illustrates the rate at which rainwater can penetrate the soil. During a storm event, the soil will become saturated and the infiltration will decrease allowing for greater runoff. This curve accounts for the four soil types and include:

1. Type A – low runoff potential, high infiltration rates,
2. Type B – moderate infiltration rates and moderately well-drained,
3. Type C – slow infiltration rates,
4. Type D – soils with high runoff potential and very slow infiltration rates

These soil types are used in conjunction with AMC, which fix the points on the infiltration curve.

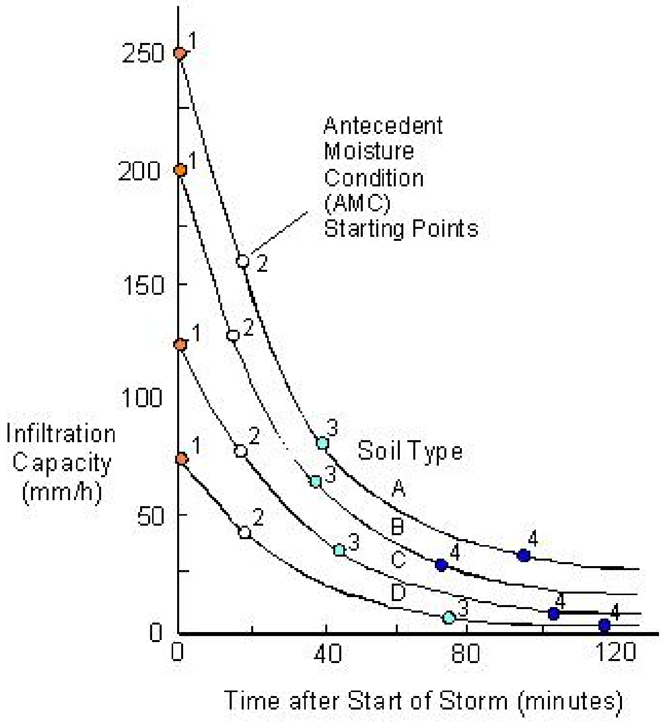


Figure 5-8 – Antecedent Moisture Condition (O'Loughlin & Stack 2002, p. 6.17)

Research has been undertaken on DRAINS and other related models and it has proved to be reasonably accurate to relate the AMC value of 1 to 4 to the rainfall in the previous 5 days (O'Loughlin & Stack, 2002). This can be seen in Table 5-4.

Table 5-4 – AMC value in relation to rainfall in 5 days preceding the storm (O'Loughlin & Stack 2002, p. 6.18)

Number	Description	Total Rainfall in 5 days preceding the storm (mm)
1	Completely dry	0
2	Rather dry	0 to 12.5
3	Rather wet	12.5 to 25
4	Saturated	Over 25

5.8. Calibration of the Model

Calibration of the Ilsax hydrological model will be conducted against the Rational Method model. This is a requirement for many Local Authorities and it stems from the Queensland Urban Drainage Manual, which states,

> Ilsax is a suitable for use in urban catchments but requires calibration with available flow data. Where this is not available it is recommended that the hydrograph obtained be adjusted to conform to the peak discharge derived for the same catchment using the Rational Method (Stack, 2005, p.1).

For the present study there is no data available for calibration of the Ilsax model. Therefore, the hydrograph must be adjusted to produce the same peak discharge as the Rational Method. The parameters that can be adjusted in the Ilsax model are: depression storage, the soil type and the Antecedent Moisture Condition. These parameters can be adjusted to meet the desired peak flow for each sub-catchment. However, if two adjacent sub-catchments have different characteristics (time of concentration) then to produce the same peak flow rates the Ilsax model would have to be adjusted for both catchments. This would not be realistic as generally the soil type and moisture condition would be the same for both catchments.

The Rational Method Model for a sub-catchment is Qpeak = CIA. The highest Qpeak comes from using higher rainfall intensities. IFD data indicates that the shorter duration storms have a higher average intensity (I). However the use of the full area (A) limits the storm duration to no less than the time of concentration for the catchment. The intensity from the Rational Method formula is calculated from IFD data and certain storm duration must be assumed in the process. The Rational Method calculates runoff from a sub-catchment with pervious and impervious areas having different times of concentration. This indicates that the model assumes a constant intensity rainfall pattern within the storm. Thus, the Rational Method model can be classified according to:

- No initial losses
- No storage routing effect

- Some continuing loss

Where Continuing Loss = Rainfall Rate – Runoff Rate

The Continuing Loss used in the Rational Method Model appears to be proportional to rainfall intensity. However this loss could be regarded as constant, due to the rainfall intensity being constant. This aspect serves as the fundamental reason why the Rational Method Model and Ilsax Model are completely different. This demonstrates the difficulty in calibrating an Ilsax model to produce similar results to the Rational Method. Hence, changing the Ilsax model and produce an Extended Rational Method Model is necessary if it is required to be calibrated against the Rational Model.

The Extended Rational Model would have either no initial loss or an on-going loss that is constant to rainfall intensity. The latter is preferred, as it seems physically more realistic. This model uses the runoff coefficient (like the Rational Method) in place of the depression storage, Antecedent Moisture Condition and the soil type. The continuing loss of the model would be calculated as (1 – C).I, where I is the average intensity of the storm. Since the model applies the same runoff coefficients as the Rational Method, this model does not require calibration against Rational Method peak flow rates. It will always produce the same peak flow from a sub-catchment as the Rational Method, provided that the same storms are used as in the Rational Method. (i.e. if constant intensity storms with durations corresponding to the times of concentration of the drainage system sub-catchments are used). In normal use, application of such storms would not be used. However, varying intensity storms with patterns taken from Australian Rainfall and Runoff, 2001 or historical data would be used (Stack, 2005).

The Extended Rational Method is similar to the Modified Rational Method that is used in the United States. The difference between these two models is that the Extended Rational Method assumes a constant continuing loss instead of the continuing loss proportional to rainfall intensity in which the other model uses. These two models produce identical results for a constant intensity storm. However the results differ for storms with variable rainfall intensities. The constant continuing loss is adopted as being a more accurate description of actual processes (Stack, 2005).

5.8.1. Calibration of the model in DRAINS

To apply the Extended Rational method in DRAINS a pervious area coefficient must be entered. This coefficient is calculated from the Australian Rainfall and Runoff and is based on the 10 year ARI, 1-hour rainfall intensity for the site. The calculation of this coefficient can be seen in APPENDIX C and is calculated from Eq. 5.1 below.

$$C_{10} = 0.1 + 0.0133\left(10I_{1} - 25\right)$$

.. Eq. 5-1

Where:

- ${}^{10}I_1 > 25$mm/hr & < 70mm/h

An analysis was undertaken to determine if the Extended Rational Method and the Ilsax method would produce similar discharge hydrographs. The analysis that was undertaken was on Catchment 22. After the analysis was undertaken the discharge hydrographs were compared for both the major and minor storm. The pipe that was chosen for comparison was selected randomly from the network. Figure 5-9 below indicates the pipe were the hydrographs were taken for comparison.

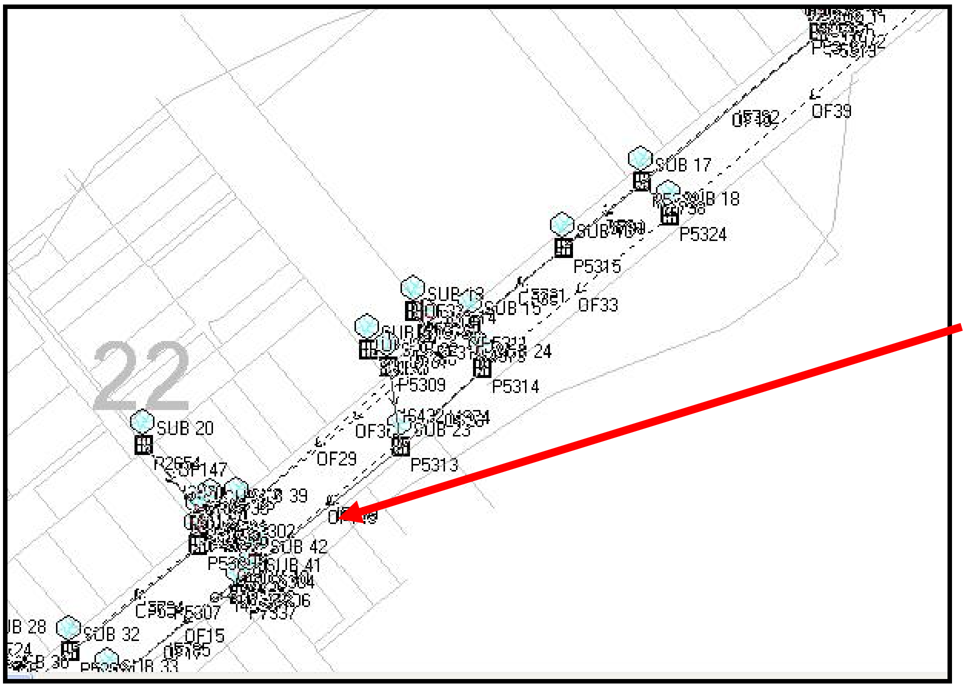


Figure 5-9 – Demonstrates the pipe that was used for the comparison

5.8.2. Calibration Results

The graphs of the minor storm analysis were undertaken to show a statistical representation of the discharges in the pipe. The following graphical representations of the two discharge hydrographs are illustrated in Figure 5-10. The red hydrograph represents the Extended Rational Method and the black hydrograph represents the Ilsax model.

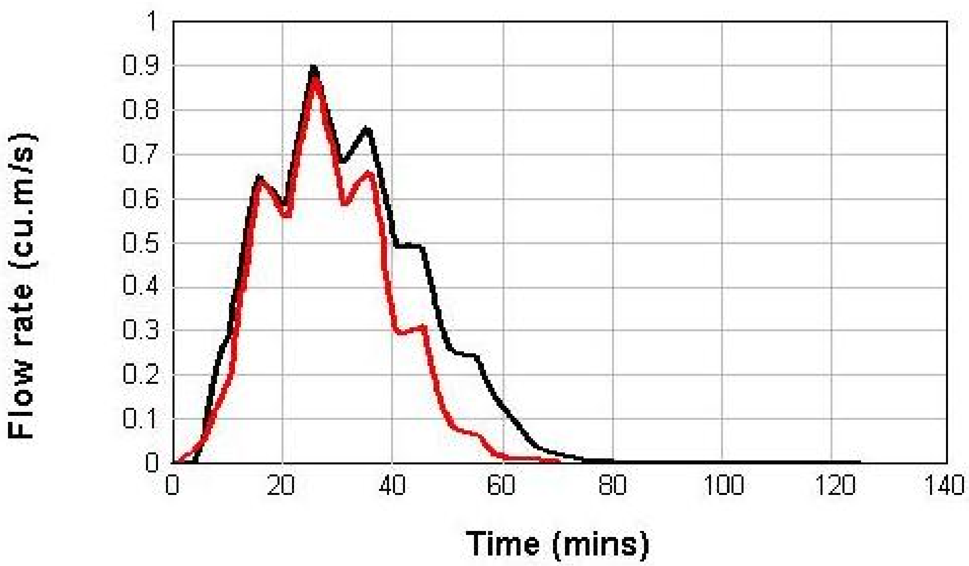


Figure 5-10 – Discharge Hydrograph for Minor Design

As is evident in Figure 5-10, the discharge hydrographs of the Extended Rational Method and the Ilsax method show a similar peak hydrograph. This was generally to be expected.

The graphs of the major storm analysis were also undertaken to confirm that the relationship also adheres to a major storm. The two discharge hydrographs are illustrated in Figure 5-11. The red hydrograph again represents the Extended Rational Method and the black hydrograph represents the Ilsax model.

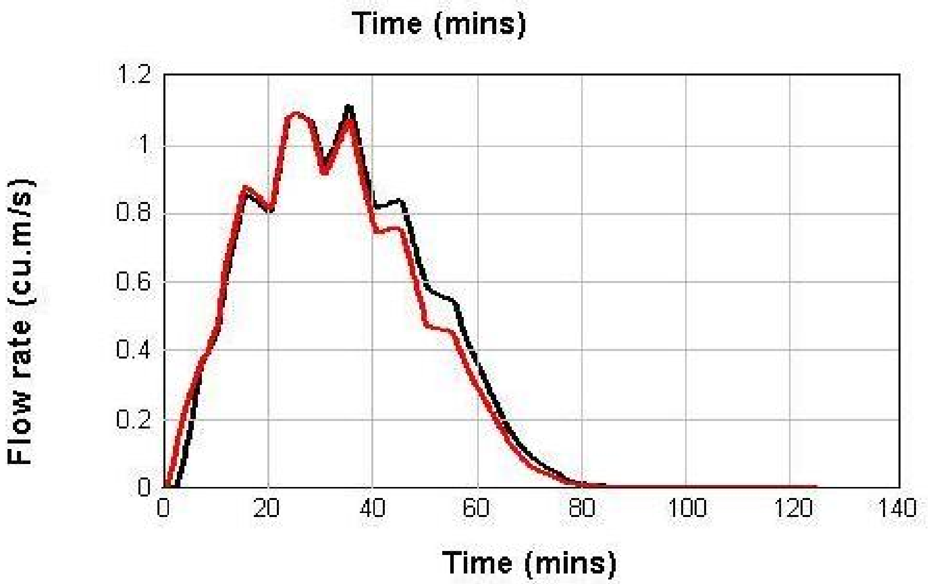


Figure 5-11 – Discharge Hydrograph for Major Design

As is again evident in Figure 5-11, the discharge hydrographs of the Extended Rational Method and the Ilsax method show a similar peak discharge hydrograph. These hydrographs were expected after conducting the minor storm analysis and producing similar discharge hydrographs.

5.9. Sensitivity Analysis

A sensitivity analysis was performed to demonstrate the resultant effects of ill-selected parameters that could be entered into DRAINS. The input values that were entered into DRAINS were selected using experience, advice and observation. Therefore, these values have the potential to be incorrect. The differences in Hydraulic Grade Lines are compared to determine the expected change in outcome for a given change in the input.

DRAINS models system behaviour from generating runoff hydrographs from inputted rainfall patterns using loss modelling combined with time-area routing to model the system behaviour (O'Loughlin & Stack, 2002). This loss model subtracts depression storages from all surfaces and calculates addition losses from Horton infiltration procedures. The time of travel or time of concentrations is the main parameter used in the routing model. Therefore, varying these model/physical characteristics will determine how sensitive the model is. Further, this will demonstrate how the model will react to ill-selected parameters.

Antecedent Moisture Condition (AMC) was the first physical characteristic, used in the initial loss model, which was analysed to determine its sensitivity. The value that was selected for analysis was an AMC of 4. This value indicates that there has been approximately 25mm of rainfall in the preceding 5 days. A change in AMC would result in varying the surface inflow and therefore alter the volume of runoff captured by the stormwater drain. A value of 1 was selected as a comparison of AMC. This value indicates that there has been no rainfall in the preceding 5 days. Figure 5-12 shows graphically differences in Hydraulic Grade Lines (HGL) at each pit in Catchment 22.

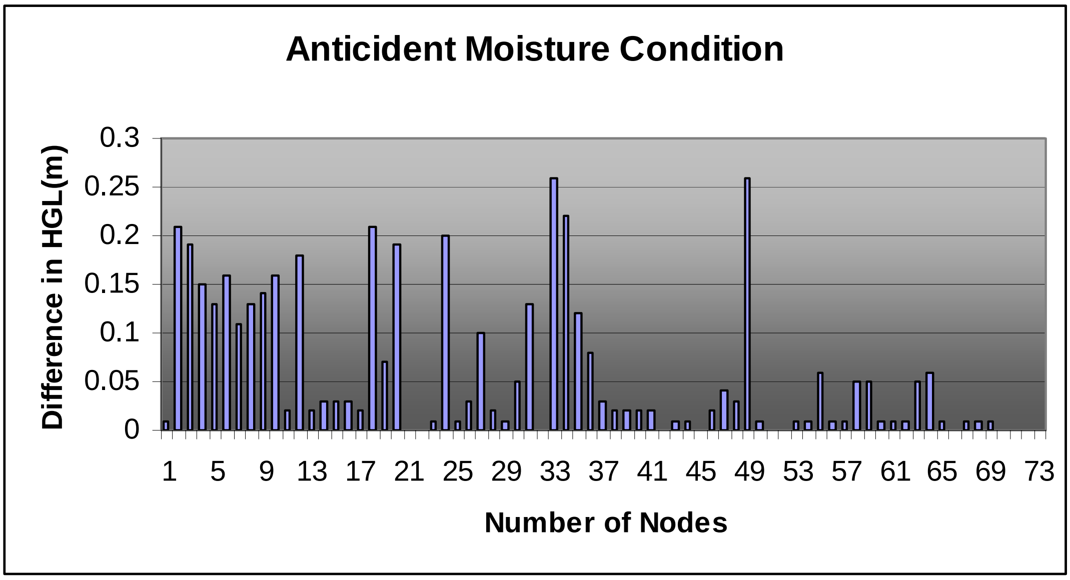


Figure 5-12 – Sensitivity of the model to varying antecedent moisture condition

From the graph, it is apparent that the AMC is a sensitive physical characteristic. As a result, the AMC characteristic used in the initial loss model has a great effect on the HGL at each pit.

Soil type was another physical characteristic, used in the initial loss model, which was analysed to determine its sensitivity. The two soil types that were compared were a Type 1 Soil against a Type 4 Soil. These two types of different soils were chosen as the Type 1 soil has a low runoff potential with high infiltration rates, while the Type 4 soil has a high runoff potential and a very slow infiltration rate. Figure 5-13 illustrates how the variations in the soil types affect the Hydraulic Grade Line (HGL).

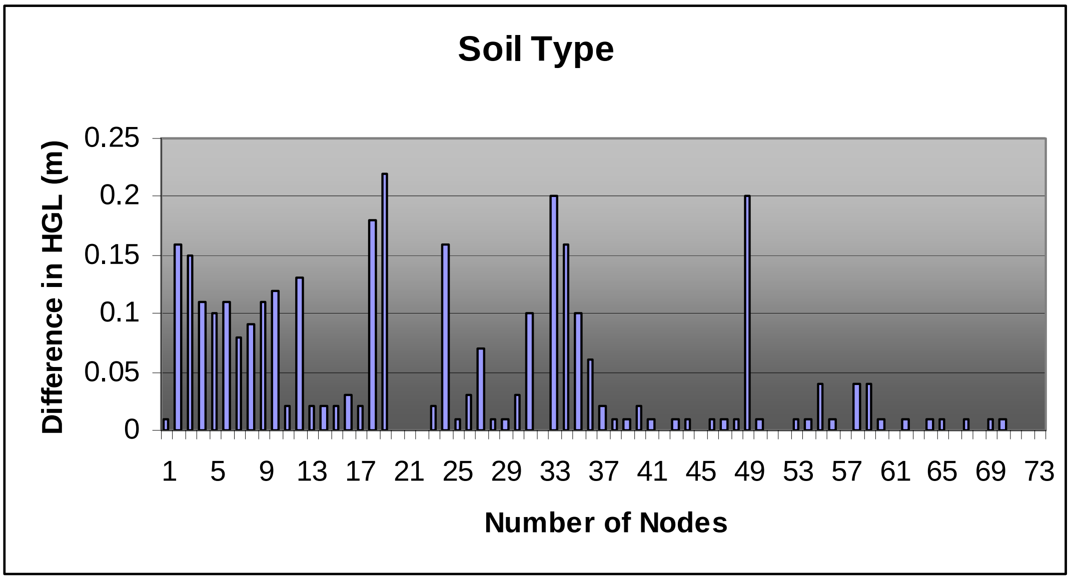


Figure 5-13 – Sensitivity of the model to varying soil types

From the graph it is quite evident that the soil type is a sensitive characteristic used in the initial loss model. This indicates that the Horton infiltration parameters in the initial loss model have a pronounced effect on the HGL at each pit. The reason for the difference is largely due to the properties of the different soil types.

Depression storage was the last physical characteristic, used in the initial loss model, which was analysed to determine its sensitivity. The values that are recommended are 1mm for paved and supplementary areas and 5mm for grassed areas. However, the values for paved and supplementary can range from 0 to 5mm and the grassed area value can range from 2mm to 10mm. The values that were used to determine the sensitivity were 5mm for paved and supplementary areas and 10mm for grassed areas. The differences in Hydraulic Grade Lines (HGL) values were calculated to illustrate the sensitivity of the model to this parameter. Figure 5-14 illustrates the variations in the initial loss value and the affect this has on the surface inflow into the stormwater pits.

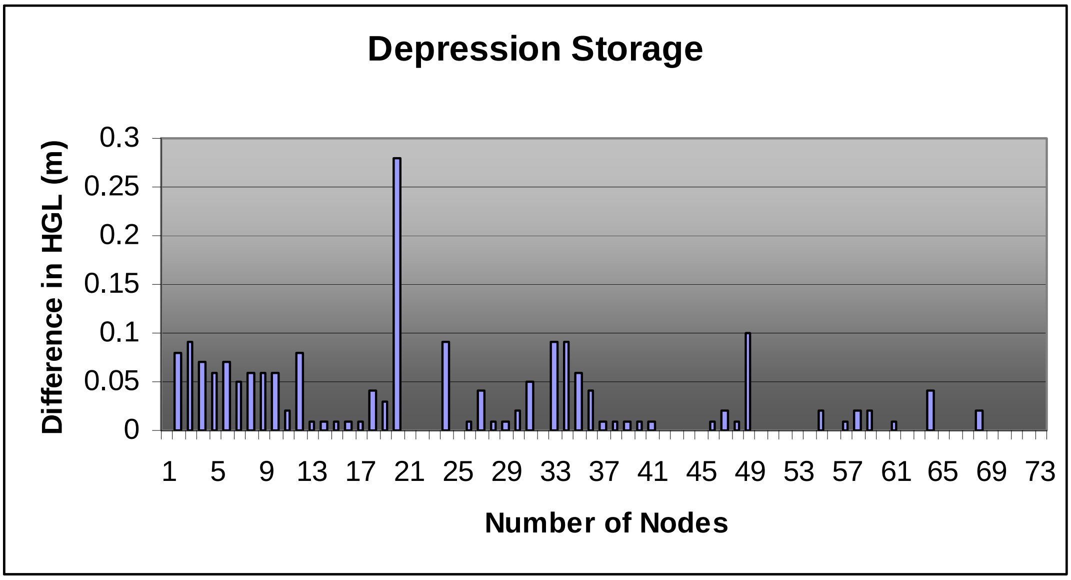


Figure 5-14 – Sensitivity of the model to varying depression storage coefficients

From the graph it appears that the depression storage is not as sensitive as the other parameters. Therefore, depression storage parameter in the initial loss model does not have great effect on the HGL at each pit.

The main parameter used in the routing model is the time of travel. These values were obtained from the Queensland Urban Drainage Manual (QUDM; Neville Jones & Associates et al., 1992). This manual recommends a simplified procedure for setting inlet times. These inlet times were varied by two minutes and Figure 5-15 illustrates the difference in Hydraulic Grade Lines (HGL) for each pit.

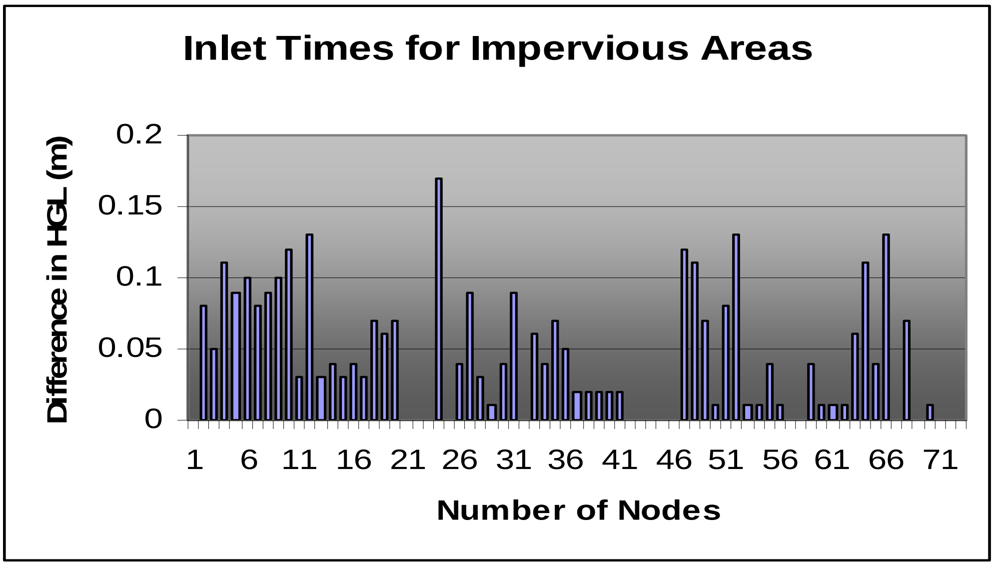


Figure 5-15 – Sensitivity of the model to varying inlet times, for impervious areas

From the graph it seems that the standard inlet times are a sensitive parameter, used in the routing model. This parameter has an immense effect on the HGL at each pit, with variations of up to 0.17m.

In addition to the model/physical characteristics used in the sensitivity analysis, an investigation into the sensitivity of the estimated times of travel for overflow routes was also undertaken. The results from Catchment 22, showed similar trends to the results obtained from Catchment 25. Therefore, only a selection of results from Catchment 25 is shown in Table 5-5.

Table 5-5 – Results from analysis of travel times for overflow routes

Pit	Time of Travel (m)	Hydraulic Grade Line (mm)
P5272	5	402.5
	10	402.5
	20	402.5
P5540	5	462.7
	10	462.7
	20	462.7
P2553	5	427.5
	10	430.5
	20	430.5

These results indicate that the estimated travel times for each pit do not have a great effect on the HGL of each pit. Therefore, this demonstrates that each pit is not sensitive to the times of travel for overflow routes. In addition, a reason why the travel times are estimated could be due to them having minimal effect on the HGL.

5.10. Conclusion

This chapter has investigated the data collection and data reduction methodologies used for the DRAINS program. Further, different input variables, used in the analysis of an urban drainage catchment were examined. The DRAINS model has been calibrated against the Extended Rational Method producing similar peak discharge hydrographs. Moreover, a sensitivity analysis has also been conducted to determine how responsive these variables are to the resultant Hydraulic Grade Lines. The physical characteristics of Antecedent Moisture Condition and soil type, used in the initial loss model, are sensitive physical characteristics used in this loss model. It is also important to note that the time of travel used in the routing model is another sensitive parameter used in this model.

CHAPTER 6

INVESTIGATION OF FLOOD MITIGATION OPTIONS

6.1. Introduction

The purpose of this chapter is to identify areas of inadequate flood immunity and use the model to simulate the effect of various augmentation works including provisions of grass swales and/or infiltration drains, increase in number and/or size of gully pits and pipelines. The data was prepared using the methodologies discussed in the previous chapter.

6.2. Overall Catchment

The urban drainage catchment was analysed in DRAINS to determine the adequacy of the stormwater network. The Ilsax model was the hydrological model chosen to undertake this analysis. Both catchments were analysed with a design ARI of 5. This was outlined in Section 3.7, Design Guidelines. These catchments were analysed with various storms for given ARI. The storm that caused the drainage system to be inadequate was a storm with duration of 5 minutes and an average intensity of 133mm/hr. The Antecedent Moisture Condition that was selected in the analysis for both catchments was an AMC of 4. This indicates that the catchment has received at least 25mm of rain in the preceding 5 days. Therefore, the soil was saturated, which will increase runoff into the drains.

The two suburban catchments incorporate a school, parks and gardens and a road network. Both catchments back onto the steep slopes of the Northern Tablelands. The catchments that were analysed have the following characteristics.

- Area – 83.07 ha
- Number of Pits - 195
- Number of Pipes – 221

The location of both catchments can be seen in Figure 6-1.

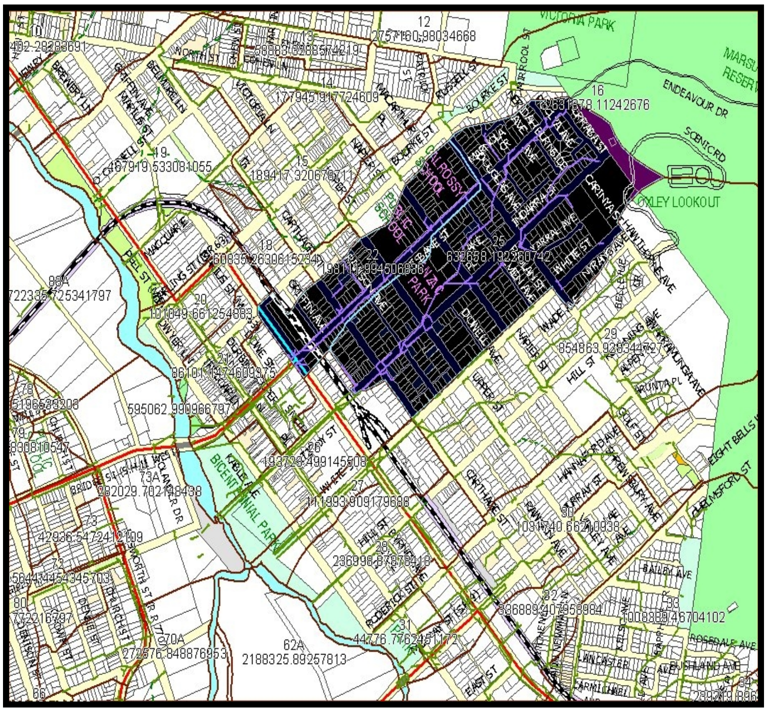


Figure 6-1 – Overall Catchment Area

6.3. Analysis of Catchment 22

The catchment is located on the outskirts of the C.B.D and is on the northern side of the city. The location of the catchment is shown in Figure 6-2. This catchment is adjacent to Catchment 25; the other catchment that is being analysed in this study. This catchment incorporates suburban housing, a school and a road network. Compared with other catchments in the area, this one is relatively small and encompasses the following characteristics.

- Number of Pits - 73
- Number of Pipes - 70

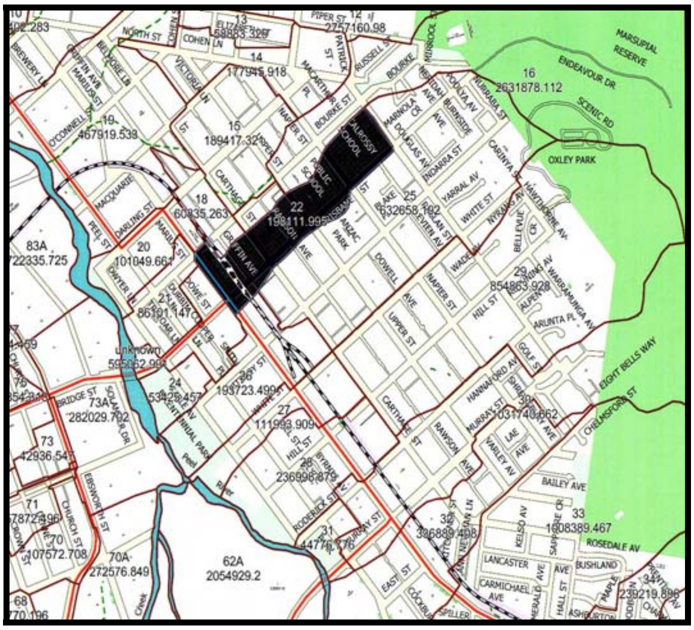


Figure 6-2 – Catchment 22 Area

6.4. Results

The minor storm event that occurred in Catchment 22 indicates that there was no water up welling from any pit in Catchment 22. For design purposes, freeboard is limited to 0.15m. This was outlined in Section 3.7, Design Guidelines for the Tamworth Region. Freeboard was also adequate for all pits in Catchment 22. This report can be seen in Figure 6-3. Further, more detailed results can be seen in APPENDIX F.

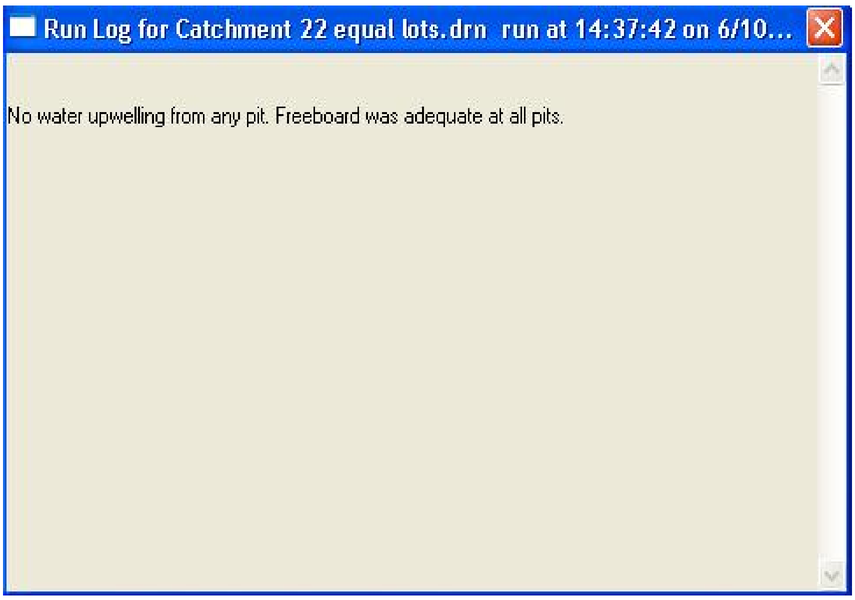


Figure 6-3 – Run Log for Catchment 22 Minor Design

From the results it is evident that the drainage system is not under capacity and therefore no initial augmentation works need to be considered

6.5. Analysis of Catchment 25

This catchment is also located on the outskirts of the C.B.D and is also on the northern side of the city. The location of this catchment is shown in Figure 6-4. The catchment area consists of suburban housing, parklands and a road network. This catchment features include:

- Number of Pits - 138
- Number of Pipes - 132

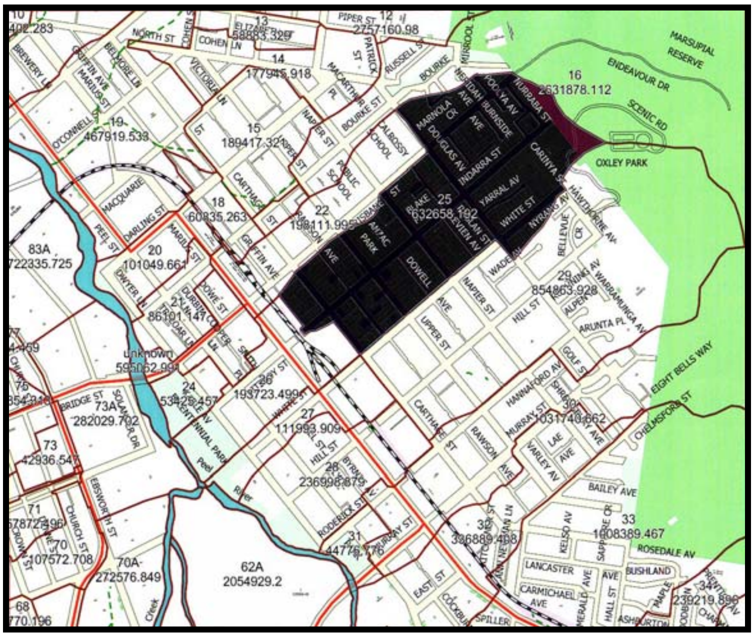


Figure 6-4 – Catchment 25 Area

6.6. Results

The minor storm event that occurred in Catchment 25 demonstrates that there is water up welling from one pit in this catchment. There are also two other pits where freeboard was less than 0.15m. These pits were looked at in more detail to determine if augmentation works need to be undertaken in these areas. A DRAINS report can be seen in Figure 6-5. In addition, more detailed results can be seen in APPENDIX G.

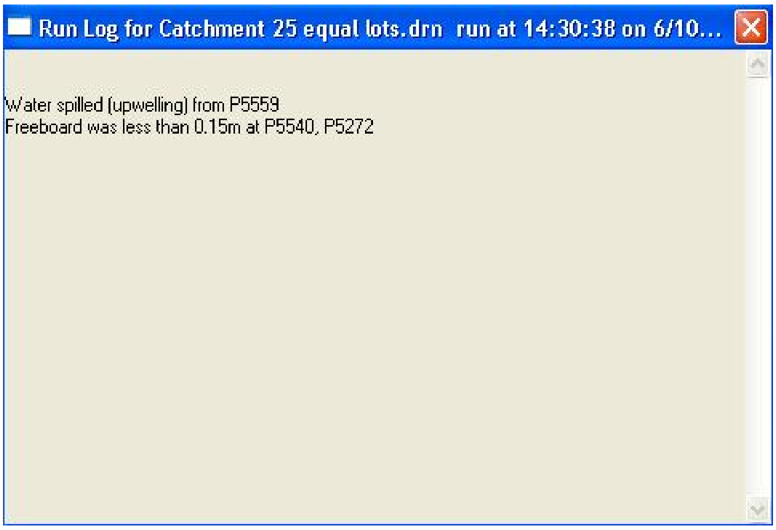


Figure 6-5 – Run Log for Catchment 25 Minor Design

There have been various stormwater problems identified within Catchment 25. These problems have been addressed, with various augmentation strategies developed and implemented.

6.7. Results Option 1

The first area that was identified to be under capacity is shown in Figure 6-6. This drainage line is 7.25m long and is a 750mm reinforced concrete pipe. This area is at the top of catchment 25 and incorporates pit P5559.

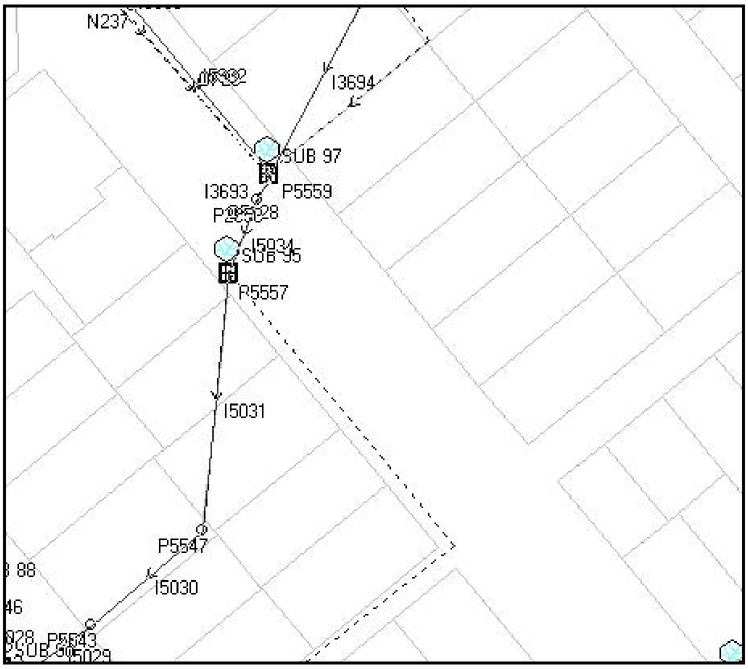


Figure 6-6 – Drains Map of identified problem area, Option 1

The complaint records supported the problems identified by DRAINS. From Figure 6-7 it is evident that directly across the road from the pit there have been stormwater complaints. This area has many silky oak trees littering the pavement and inlets with its leaves. This causes the water to bypass the overflow route and into residents premises. In addition, these areas do not have a prominent crown on the road and causing water to flow directly across the road.

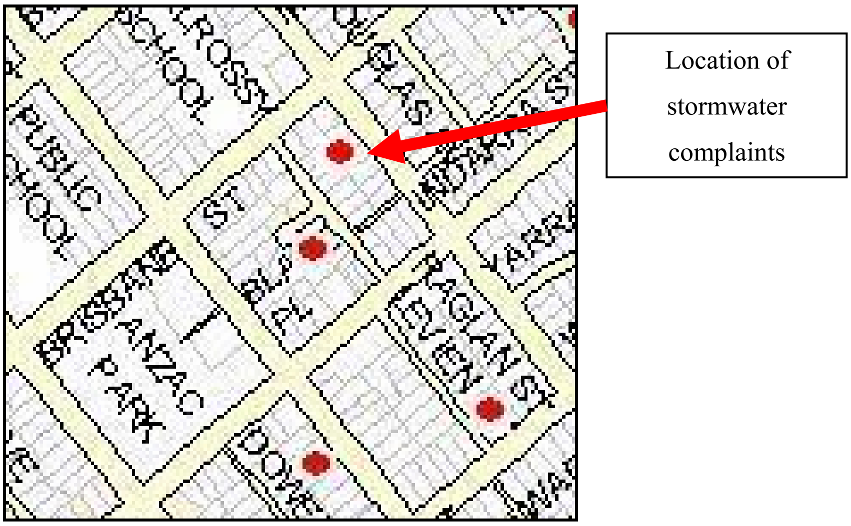


Figure 6-7 – Complaint Analysis Map

The long section of pits (P5559 & P2553) and the joining pipe is illustrated in Figure 6-8. This long section indicates that this pit is surcharging onto the road and therefore freeboard is 0mm.

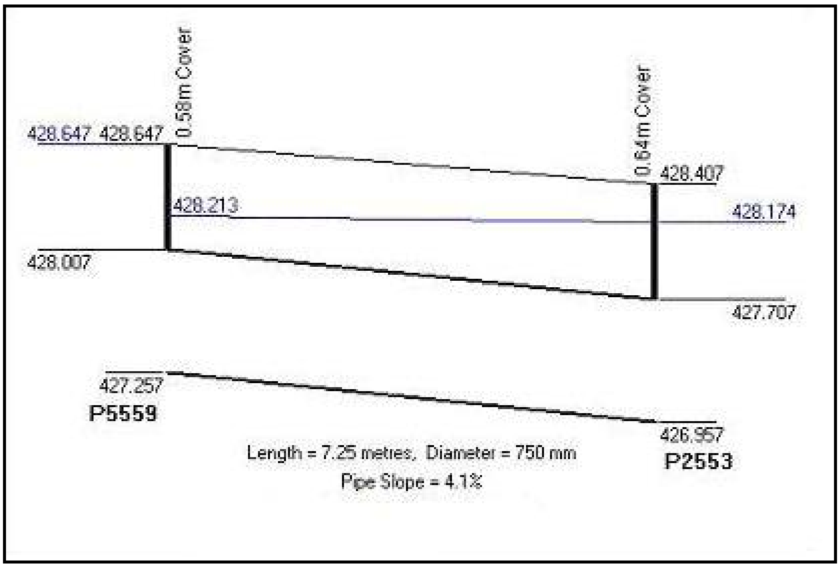


Figure 6-8 – Long Section of identified problem area

6.7.1. Augmentation Works – Option 1

With the current stormwater system being inadequate, the proposed design to improve the stormwater system is to construct a new line containing reinforced concrete boxed culverts. Reinforced concrete box culverts are an economical solution where limited cover or hydraulic capacity has dictated the design criteria. The long section of this augmentation works can be seen in Figure 6-9. This augmentation works consist of laying 25.45m of reinforced box culvert. Furthermore, this long section demonstrates that freeboard is now adequate at P5559 with freeboard now being 228mm.

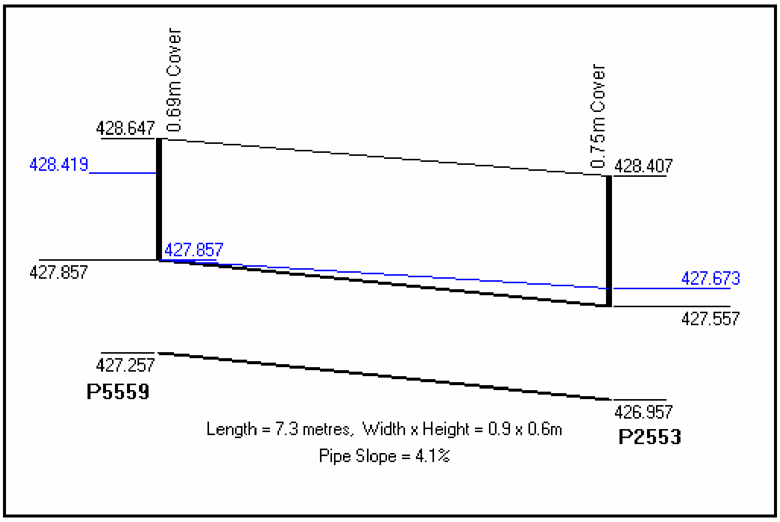


Figure 6-9 –Effect of Reinforced Concrete Box Culvert on HGL

Other proposed augmentation works were considered, however these augmentation works consisted of increasing the pipe to extreme sizes. Hence, these works were not considered in the analysis, as they were already not economically viable.

6.8. Results Option 2

The second area that was identified to be under capacity is shown in Figure 6-10. This drainage line is 10.6m and the pipe is a 375mm diameter reinforced concrete pipe. This area is again at the top of Catchment 25 and incorporates the pit P5540.

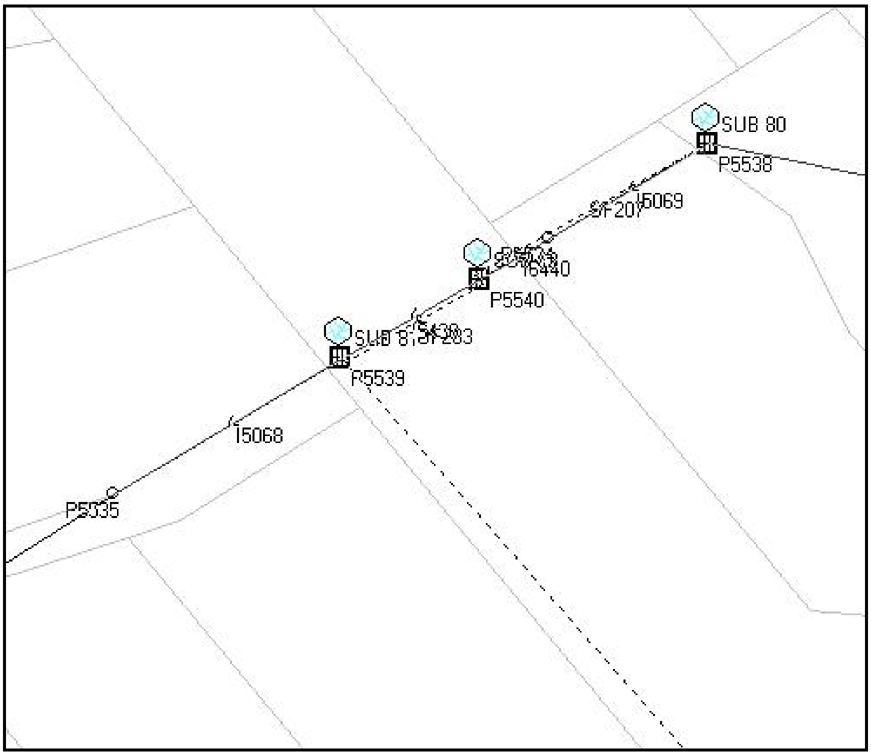


Figure 6-10 – Drains Map of identified problem area, Option 2

From Section 2.3, Focus Area for the Study, where an analysis of the complaint database was undertaken, it can be seen that there has been stormwater damage from houses across the road from this pit. This can be seen in the complaint analysis map in Figure 6-11. Despite there being an overflow route across the road, at times this is ineffective because of the leaf litter on the road. This could cause the water to make its way up the layback of the driveway and into the property of the house.

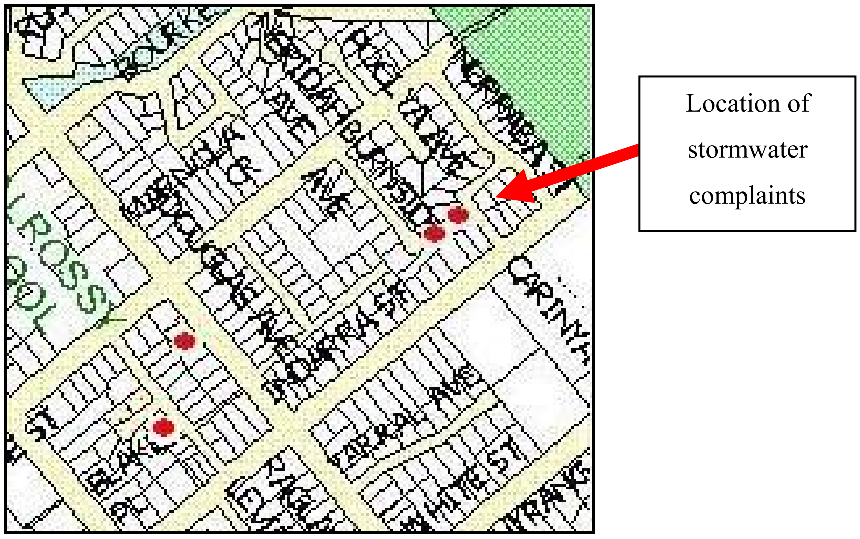


Figure 6-11 – Complaint Analysis Map

The long section of pits (P5540 & P5539) and the joining pipe is illustrated in Figure 6-12 below. This long section, demonstrates that there is 149mm of freeboard. This indicates that for this section of pipe the network is under capacity.

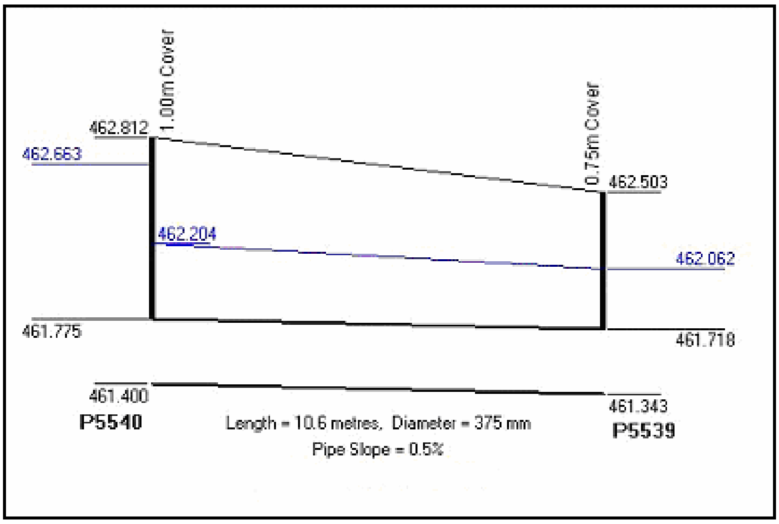


Figure 6-12 – Long Section of identified problem area

6.8.1. Augmentation Works – Option 2

The objective of the augmentation works is to provide suitable strategy for the identified problem area in Catchment 25. There were two options that were considered for the works. The first option was to place another identical 375mm pipe parallel to the existing pipe. This would make use of the existing pipe and therefore this pipe would not need to be replaced. DRAINS was used to analyse this augmentation works. This augmentation works consist of laying 10.6m of 375mm reinforced concrete pipe. The results of the augmentation works indicate that the two identical pipes have lowered the Hydraulic Grade Line and freeboard is now 601mm. This is illustrated in the Figure 6-13.

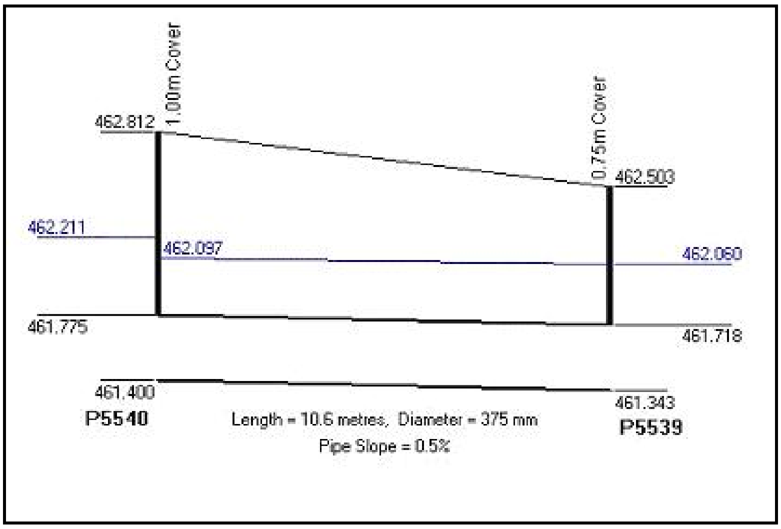


Figure 6-13 – Effect of pipe duplication on HGL

The second option that was investigated was to replace the existing line with a larger diameter concrete pipe. DRAINS was also used to determine this diameter pipe and selected a 450mm diameter concrete pipe. The results from the simulation demonstrate that using a pipe that is greater in diameter has reduced the freeboard to 476mm. Therefore, this system is now adequate for the design storm. The long section of the augmentation works can be seen in Figure 6-14.

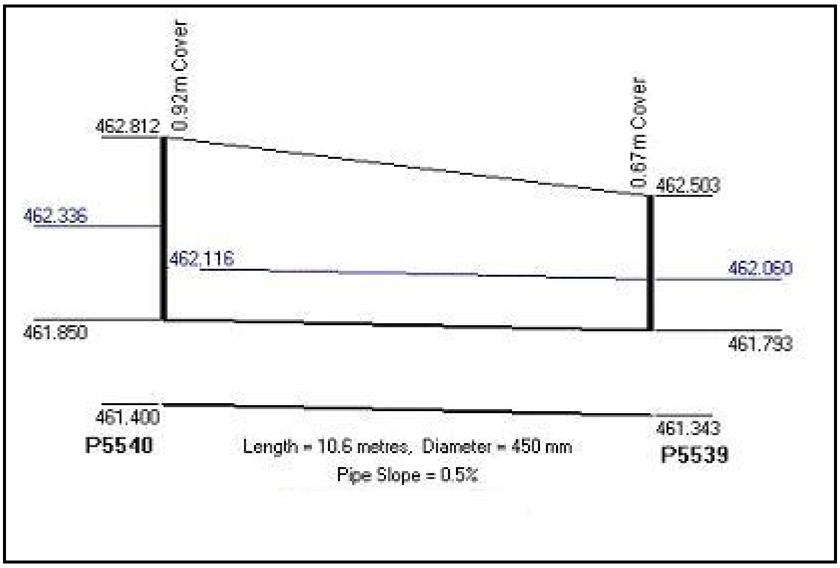


Figure 6-14 – Effect of a 450mm diameter reinforce concrete pipe on HGL

6.9. Results Option 3

The last area that was identified to be under capacity is shown in Figure 6-15. This drainage line is 63.6m and the pipe is a 300mm diameter reinforced concrete pipe. This pipe is in the middle of Catchment 25 and incorporates the pit P5572.

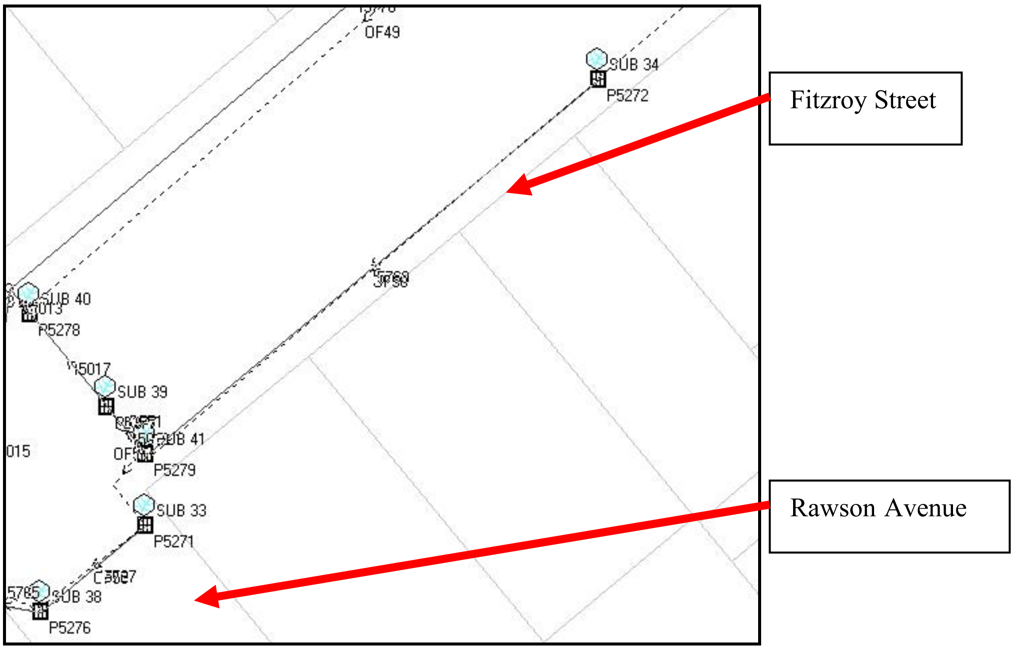


Figure 6-15 – Drains Map of identified problem area, Option 3

This problem that was identified from the DRAINS analysis, is supported by complaint analysis. This was outlined in Section 2.3, Focus Area for the Study. Upon inspection of the identified problem area, residents claimed that during a storm event, their property would frequently be flooded by stormwater. Anecdotal evidence suggests that water flows down Fitzroy Street and bypassed the overflow route due leaf litter blocking the pit. The water then flows down Rawson Avenue and into their property. Residents are now cleaning these drainage pits to minimise this stormwater damage. This can be seen quite clearly on complaint analysis map in Figure 6-16.

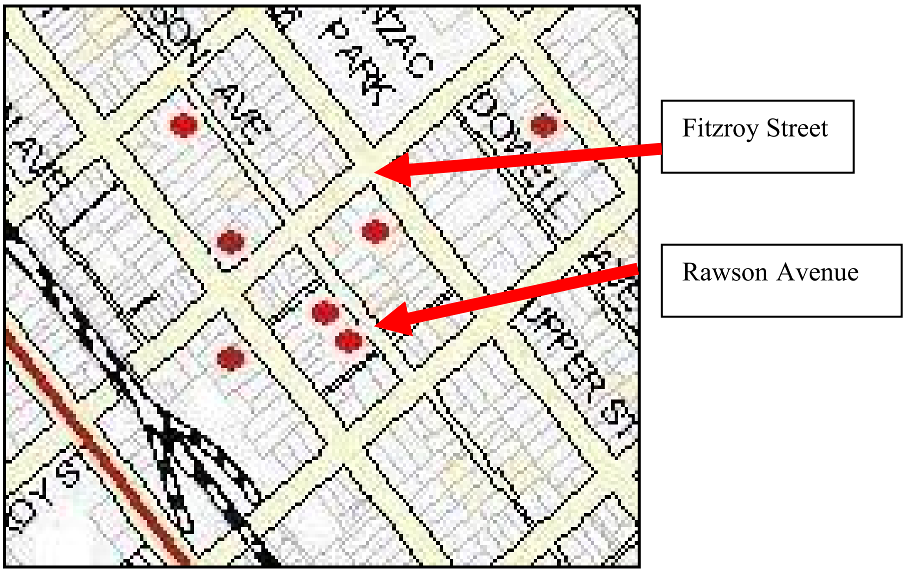


Figure 6-16 – Complaint Analysis Map

The long section of pits (P5572 & P5279) and the joining pipe is illustrated in Figure 6-17 below. This long section, demonstrates that there is 89mm of freeboard. This demonstrates that for this section of pipe the network is under capacity.

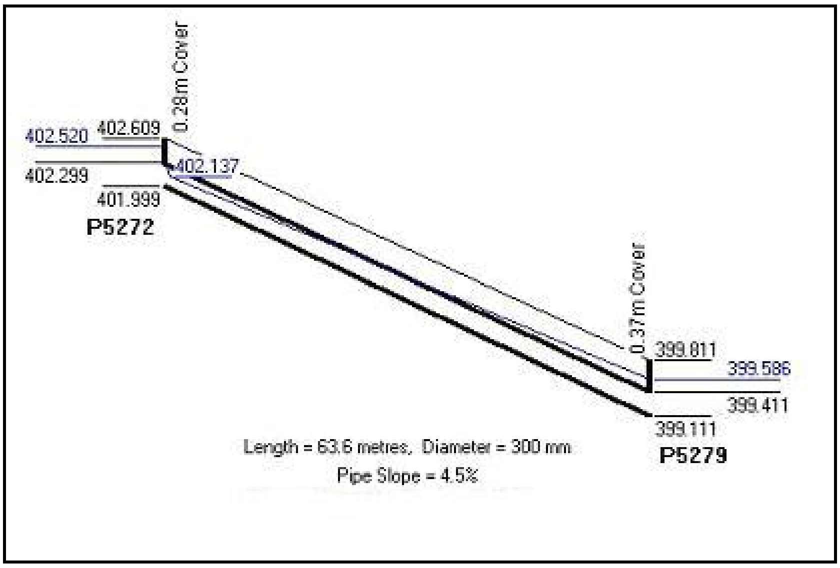


Figure 6-17 – Long Section of identified problem area

6.9.1. Augmentation Works – Option 3

One proposed design to improve the stormwater system in this area is to re-lay the pipe network using the same pipe diameter however lowering the pipe so that there is now 0.48m of cover. After the analysis by DRAINS freeboard is now adequate with freeboard being 290mm. The long section of this augmentation works can be seen in

Figure 6-18. This augmentation works consists of laying 63.6m of 300mm diameter pipe.

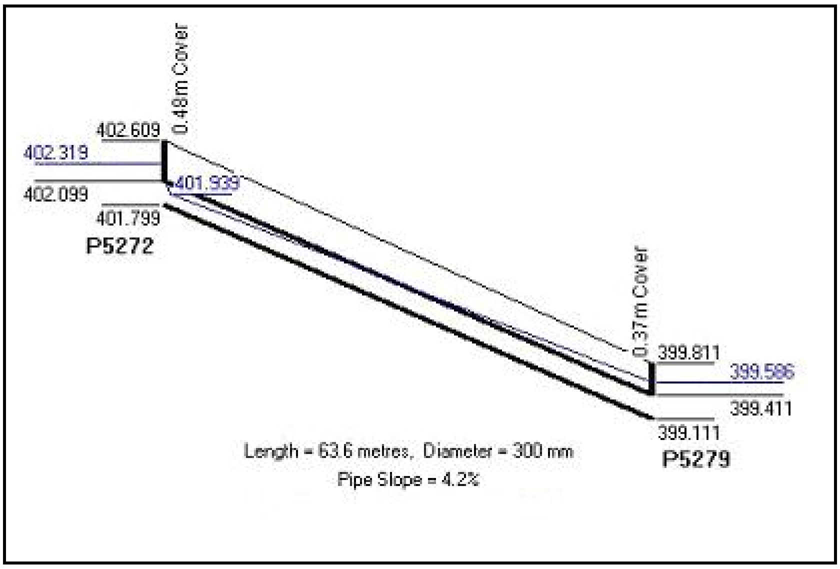


Figure 6-18 – Lowering the 300mm pipe to give a cover of 0.48 m

The other proposed design to improve the stormwater system in this area is to construct another pipe duplicate the existing pipe network. The long section of this augmentation works can be seen in Figure 6-19. This augmentation work consists of laying 63.6m of 300mm reinforced concrete pipe. By installing a new pipe parallel to the existing pipe, freeboard has been lowered to 323mm. This area of the network is now not under capacity.

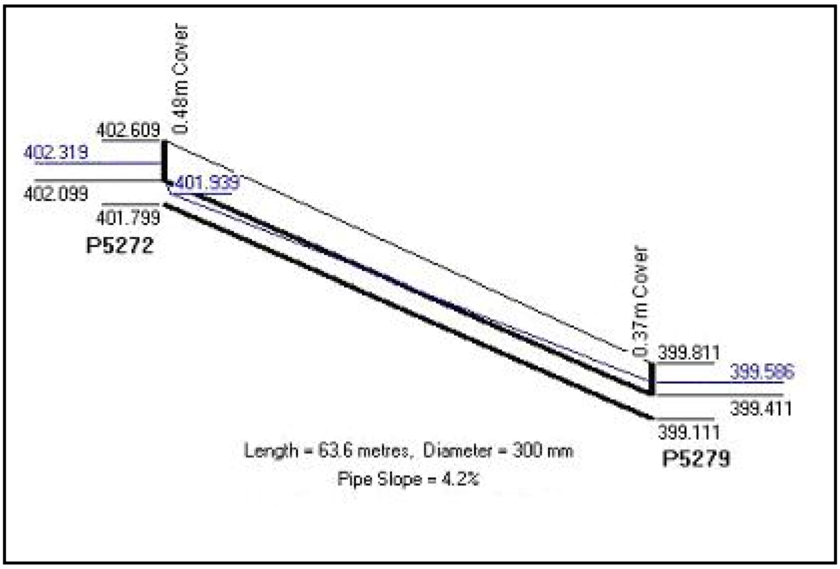


Figure 6-19 – Effect of pipe duplication on HGL

6.10. Conclusion

This chapter has identified areas of inadequate flood immunity and the DRAINS model has simulated the effect of various augmentation works. These augmentation works are summarised in Table 6-1.

Table 6-1 – Summary of Augmentation Works

	Augmentation Works
Option 1	Reinforced concrete box culvert – 900*600
Option 2	Duplicate 375mm concrete pipe
	450mm concrete pipe
Option 3	Duplicate 300mm concrete pipe
	Lower existing pipe to 48mm

In the following chapter, recommendations will be proposed based on an economic analysis to determine the most suitable augmentation works for the network.

CHAPTER 7

RECOMMENDATIONS

7.1. Introduction

This chapter will provide recommendations on a suitable augmentation strategy, supported by an economic analysis.

7.2. Cost Guide

The following is a general cost guide that will be used to determine the cost of the five proposed augmentation works for Tamworth. The cost guide has been obtained from Toowoomba City Council. This Table can be seen in APPENDIX H. This cost guide involves all the activities associated with construction of various sizes of pipes. Table 7-1 illustrates the costs per metre for construction of different diameters of reinforced concrete pipe and reinforced concrete box culvert.

Table 7-1 – Construction costs per metre of pipe

Item	Average Cost ($)
300	360
375	380
450	400
525	440
600	490
675	520
750	600
825	700
900	750
1050	900
RCBC 900 * 650	720
Manholes	4550

7.3. Cost of each Alternative

For each alternate method an economic analysis was conducted to determine the most cost effective solution for each augmentation works.

7.3.1. Catchment 25 – Option 1

This option consisted of laying 25.5m of 1900 * 650mm reinforced concrete box culverts. At present, this segment of the network consists of a 750mm pipe running across the road and therefore the manholes will need to be replaced if box culverts were to be used. A summary of the economic analysis is shown below.

- Reinforced Concrete Box Culverts

1)	Construction of new 1900*650mm pipeline	$ 18 360
2)	Construction of two new manholes	$ 9 100
	Total	**$ 27 460**

7.3.2. Catchment 25 – Option 2

The second option consisted of laying 10.6m of either duplicating the 375mm pipe that is already in place or increasing the pipe size to 450mm. Currently, the stormwater drainage system consists of a 375mm pipe. If either of these works were implemented, both manholes would need to be replaced. A summary of the economic analysis is shown below.

- Identical 375mm pipes

3)	Construction of new 375mm pipeline	$ 4 028
4)	Construction of two new manholes	$ 9 100
	Total	**$ 13 128**

- Increasing Pipe Size to 450mm

1)	Construction of new 450mm pipeline	$ 4 770
2)	Construction of two new manholes	$ 9 100
	Total	**$ 13 870**

7.3.3. Catchment 25 – Option 3

This last option consisted of lowering the original pipe by 200mm and the other alternative was to duplicate the existing pipe. At present, there is a 300mm diameter pipe running beside road. Therefore, if these augmentation works were to be implemented, the manholes will need to be replaced. If the move to duplicate the existing 300mm diameter were adopted, both manholes would need to be replaced. However if the existing pipe were lowered, only one manhole would need to be replaced. A cost guide showing additional excavation cost is shown in Table 7-2 below, along with a summary of the economic analysis.

Table 7-2 – Additional Excavation Costs

Item	Average Cost ($) m^3
Fill Material	17
Excavation	5
Removal of Material	6.5
Compacted Fill	5

- Lowering the pipe by 200mm
  1) Construction of new 300mm pipeline $ 22 896
  2) Manhole $ 4 550
  3) Extra Excavation $ 335

Total **$ 27 781**

- Identical 300mm pipes
  1) Construction of new 300mm pipeline $ 22 896
  2) Construction of two new manholes $ 9 100

Total **$ 31 996**

7.4. Limitations

Two main limitations were identified within this project and they are summarised below.

7.4.1. Estimating the percentage of impervious and pervious areas

Estimating the areas of impervious and pervious areas were calculated from advice and known experience of the area. This could be improved by calculating actual areas of houses, driveways, and sheds and this would subsequently improve the estimates of actual areas.

7.4.2. Modelling Actual Physical properties

The DRAINS model is unable to model physical properties like unaligned kerb and gutter caused by uplift of trees. A picture illustrating this issue is shown in Figure 7-1. These areas need to be treated on an individual basis, which is out of the scope of the DRAINS program.

Figure 7-1 – Unaligned kerb and gutter in the East Tamworth area

7.5. Maintenance Issues

It has been brought to the attention of residents in the area, that there are ongoing maintenance issues associated with this section of the urban drainage network. These maintenance issues include:

- Thorough cleaning of the kerb and gutter and in particular the inlet pits of the drainage network
- Restoration of the kerb and gutter in the East Tamworth area. This includes realignment of the existing kerb and gutter. It is quite evident that this practice is currently taking place. However, ongoing financial assistance needs to be addressed in the stormwater budget. This restoration process can be seen in Figure 7-2.

Figure 7-2 – Realignment of existing kerb and gutter

7.6. Conclusion

This chapter has identified areas of inadequate flood immunity. These areas have had augmentation works simulated in the DRAINS model and the corresponding economic analysis has been undertaken. These costs were used as a guide to determine the most suitable and effective augmentation works for the area. The augmentation works that were selected based on this economic analysis was:

- Option 1 – 0.9 * 0.6 Reinforced Box Culverts

- Option 2 – Identical 375mm Reinforced Concrete Pipe
- Option 3 – Lowering the existing pipe

CHAPTER 8

SUMMARY AND CONCLUSIONS

8.1. Introduction

The purpose of this chapter is to address the objectives of the project and to draw conclusions from the analyses performed in the previous chapter. The opportunities for further research of stormwater modelling in Tamworth will also be discussed.

8.2. Achievement of Objectives

Further development in the East Tamworth area i.e. greater impermeable surfaces, has caused the drainage infrastructure to be inadequate and outdated. This aspect formed the basis for this investigation. A complaint analysis was undertaken to depict various problematic areas in the East Tamworth area. This analysis was used to ascertain the sub-catchments used in the DRAINS analysis.

An extensive literature review was conducted using previous engineering studies based on research conducted in the Tamworth area. These investigations provided an insight into problematic areas in Tamworth and also hinted at possible solutions to these problems. All the studies have centred on the East Tamworth area. This area has been subject to several investigations, in which pressure tunnels were installed to rectify the stormwater problems.

The current design standard for urban stormwater drainage in the Tamworth area has also been reviewed. This involved investigating previous design standards used for Tamworth urban drainage infrastructure and comparing these, to the Australian Rainfall and Runoff, 2001. The current design standard for urban residential areas in Tamworth is an ARI of 5 years.

The computer package that was used to perform the analysis and design on the two catchments in East Tamworth was DRAINS. DRAINS is a Windows program, released by Watercom Pty Ltd, that converts rainfall patterns to runoff hydrographs and routes these through the stormwater system models set up by the user. The hydrology calculations used in the software program are based on Australian Rainfall and Runoff methods. This requires information on the rainfall intensities for varying durations based on a design ARI.

To determine the flow through the stormwater system, the software program, DRAINS, requires catchment information. For each catchment, the following information is required for DRAINS; size of the sub-catchment, fraction impervious (paved) and grassed areas and the time of entry for the paved and grassed areas.

The software program, DRAINS, can analyse and design stormwater models containing various stormwater infrastructure. Such components of a stormwater system as referred to above include pipes, pits, channels, culverts, bridges, and detention basins.

Ilsax Hydrological Model was calibrated against the Extended Rational Method. The results produced similar peak discharge hydrographs. This is a requirement from the Queensland Urban Drainage Manuel if the Ilsax Model is used. Further, a sensitivity analysis has also been conducted to determine how responsive the physical characteristics/model parameters are to the resultant Hydraulic Grade Lines. The Antecedent Moisture Condition, soil type and time of concentration are all sensitive physical characteristics/model parameters used DRAINS model.

Results from the DRAINS analysis indicate that there were three areas of inadequate drainage in the East Tamworth area. A series of augmentation works were then simulated to determine the effect of these works. This was followed by an economic analysis to establish the most cost effective solution to the given problem. The three augmentation works and their costs are outlined below:

- **Option 1** – 0.9 * 0.6 Reinforced Concrete Box Culverts
  Total Cost – **$27 460**

- **Option 2** – Duplicate 375mm Reinforced Concrete Pipe
  Total Cost – **$ 13 128**

- **Option 3** – Lowering the existing pipe
  Total Cost – **$ 27 781**

An allowance must be made in Council budget for the implementation of these three works. The most critical augmentation work that needs immediate attention is Option 1. The results from the analysis indicate that for the design storm, the pit will surcharge. Thus, these augmentation works need to be implemented immediately. The other two Options are not as critical as the first, however, for the design storm they are under capacity. These two Options should be implemented in the new financial year stormwater drainage budget.

8.3. Recommendations for future research

Two main recommendations for future research are forwarded below

8.3.1. Designing of Major System

The design of the major system consists of the disposal of a design flood of specified frequency. This water will be disposed through pavements, roadway reserves, open space floodway channels and detention basins. The major system design will identify areas of inadequate flood immunity and use a model to simulate the effect of various augmentation works including provisions of grass swales, trunk drainage and additional and/or larger detention basins.

8.3.2. Designing of Adjacent Catchments

Due to the complexity of the urban drainage catchments in Tamworth, it is necessary to undertake further hydrologic and hydraulic modelling of other segments of the urban drainage network. This will identify other areas of potential flood hazard zones and then make recommendations on possible augmentation works to the network to improve flood immunity to an acceptable standard.

8.4. Summary

This project has demonstrated that after modelling two segments of the urban drainage network, there are several potential flood hazard zones. Recommendations on possible augmentation works, supported by an economic analysis have been documented to improve flood immunity of the network.

REFERENCES

ABS. 2001, '*Basic Community Profile 1991 to 2001*', Australian Bureau of Statistics, 130057300 Tamworth, viewed 17 December 2004 <http://www.abs.gov.au/Ausstats/ABS@Census.nsf/0/AC84681A40AD7A5DCA256BBF00002FD6?Open>

Berk, K., Carey, 1998, *Data Analysis with Microsoft Excel,* Brooks and Cole, Melbourne

Case Study - *Johnstone River Flooding Flood Model Development and Calibration*, viewed 7 January 2005 <http://earthsci.org/J_Flood_4/flood/J_Flood_2>

DHI Water and Environment, '*Mike Storm - Stormwater Network Analysis*', viewed 20 January 2005 <http://www.dhiaust.com/general/StormA4.pdf>

Havno, K., M.N. and Dorge, J., 1995, Mike 11 – A Generalised River Modelling Package, '*Computer Models of Watershed hydrology*', Ed. V.P Singh, Water Resources Publications, Colorado, 733-782

Huber, W.C., Heaney, J.P, Nix, S.J., Dickinson, R.E. and Polmann, D.J, 1984, Stormwater Management Model, User's Manuel, Version 3, '*US Environmental Protection Agency*', Athens, Georgia, Report EPA/600/2-84-109a

Huber, W.C. & Dickinson, R.E., 1988, Storm Water Management Model, Version 4, User's Manuel *'US Environmental Protection Agency*', Athens, Georgia, Report EPA/600/3-88-001a

Keith, B, 2004, *Modelling Tamworth Regional Council's Stormwater Drainage System Using DRAINS*

Neville Jones & Associates Pty Ltd and Australian Water Engineering, 1992, *Queensland Urban Drainage Manual*, 2 volumes, prepared for the Queensland

Water Resources Commission, the Local Government Engineers' Association of Queensland and Brisbane City Council, Brisbane

O'Loughlin, G & Stack, B, 2002, *DRAINS User Manuel*, Watercom Pty Ltd.

Roesner, L.A., Aldrich, J.A. and Dickinson, R.E., 1988, Stormwater Management model, User's Manual, Version 4: Addendum I, EXTRAN, *US Environmental Protection Agency*, Athens, Georgia, Report EPA/600/3-88-001b

Sinclair Knight and Partners Consulting Engineers, 1972, *Report on Drainage study of East Tamworth*. Submitted to Council 10/4/1972

Stack, B, 2005. *Extended Rational Method Model*, Watercom Pty Ltd, viewed 1 September 2005 < http://www.watercom.com.au/ERM.pdf>

Stormwater Drainage Project, 2004, '*Customer Service is our primary focus'*, viewed 15 December 2004 <http://www.ci.greeley.co.us/2n/PageHome.asp?fkOrgID=89>

CIRIA, 2004, 'Sustainable drainage system: promoting a good practice', viewed 6 January 2005<www.ciria.org/suds/glossary.htm>

Terstriep, M.L. and Stall, J.B, 1974, *The Illinois Urban Drainage Area Simulator* ILLUDAS, Bulletin 58, Illinois State Water Survey, Urbana

Tamworth Regional Council 2005, '*Geographic Information System Map'*, viewed Dec 2004-Oct 2005 <gis.tamworth.nsw.gov.au>

The Australian Tourism Commission, 2005, '*New South Wales'*, viewed 17 December 2004 < http://www.ausplendour.com.au/english/nsw.htm>

Tamworth Regional Council (Thomas Baxter) 2005, '*Database for, Stormwater Pipe'*

Tamworth Regional Council (Thomas Baxter) 2005, '*Database for, Stormwater Node'*

Tamworth Regional Council (Thomas Baxter) 2005, '*Database for, Areas of Catchment'*

Tamworth City Council (Prepared by Works & Technical Services Department Tamworth City Council] 1993, *Engineering Guidelines for Subdivision & Developments, Guidelines for Stormwater Drainage Design*

The Department of Public Works Streets Division, *'STORMWATER DRAINAGE PLAN'* (March 1998), viewed 12 January 2005 <http://www.apwa.net/Documents/Accreditation/DRAINMAN.pdf>

The Institution of Engineers Australia, 2001a, *Australia Rainfall & Runoff*, Design Rainfall Considerations Vol 1, Book 2.

The Institution of Engineers Australia, 2001b, *Australia Rainfall & Runnof, Urban* Stormwater Management Vol 1, Book 8

U.S.A Environmental Protection Agency, Wednesday, December 17th, 2003, *SWMM*, viewed 20 January 2005 <http://www.epa.gov/ceampubl/swater/swmm/index.htm>

Watkins, L.H, 1962, *The design of Urban Sewer Systems Research into the Relation between rate of Rainfall and Rate of Flow in Sewers,* Technical Paper No. 5 U.K. Department of Scientific and Industrial Research, Road Research Laboratory

Willing and Partners Consulting Engineers, 1980, *Report on Drainage Study for Tamworth*. Submitted to Council 25/5/1980

Willing and Partners Consulting Engineers, 2000, *Tamworth's Stormwater Management Plan.* Submitted to Council 19/4/2000

APPENDIX A

PROJECT SPECIFICATION

University of Southern Queensland
Faculty of Engineering and Surveying

ENG 4111/2 Research Project

PROJECT SPECIFICATION AS AT OCTOBER 2005

FOR:	**Rodney Harrison**
TOPIC:	Modelling Tamworth Regional Council's Stormwater Drainage System Using DRAINS.
SUPERVISOR:	Ken Moore, University Southern Queensland
ENROLMENT:	ENG4111 – S1, D, 2005; ENG4112 – S2, D, 2005;
SPONSORSHIP:	Tamworth Regional Council
PROJECT AIM:	To undertake hydrologic and hydraulic modelling of a segment of the minor system of the urban drainage network of the city of Tamworth to identify potential flood hazard zones and to make recommendations on possible augmentation works to the network to improve flood immunity to an acceptable standard.

PROGRAMME: Issue B, 27th October 2005

1. Identify a suitable study area within the Tamworth urban drainage network compatible in extent and complexity with the DRAINS model and having regard to any historical evidence of inadequate flood immunity.
2. Review current standards and methods for engineering design of urban stormwater drainage systems.
3. Provide a detailed description of the DRAINS model including its theoretical basis, model parameters, data inputs and outputs and include comparisons with other accepted design/analysis methods.
4. Calibrate the model to the study area and verify the output using any available measured rainfall/runoff/ flood height data and/or comparison of peak discharge with another hydrological model. Include a sensitivity analysis of model parameters/physical characteristics.

5. Identify areas of inadequate flood immunity and use the model to simulate the effect of various augmentation works including provisions of grass swales and/or infiltration drains, increase in number and/or size of pipelines.
6. Provide recommendations on a suitable augmentation strategy supported by an economic analysis.

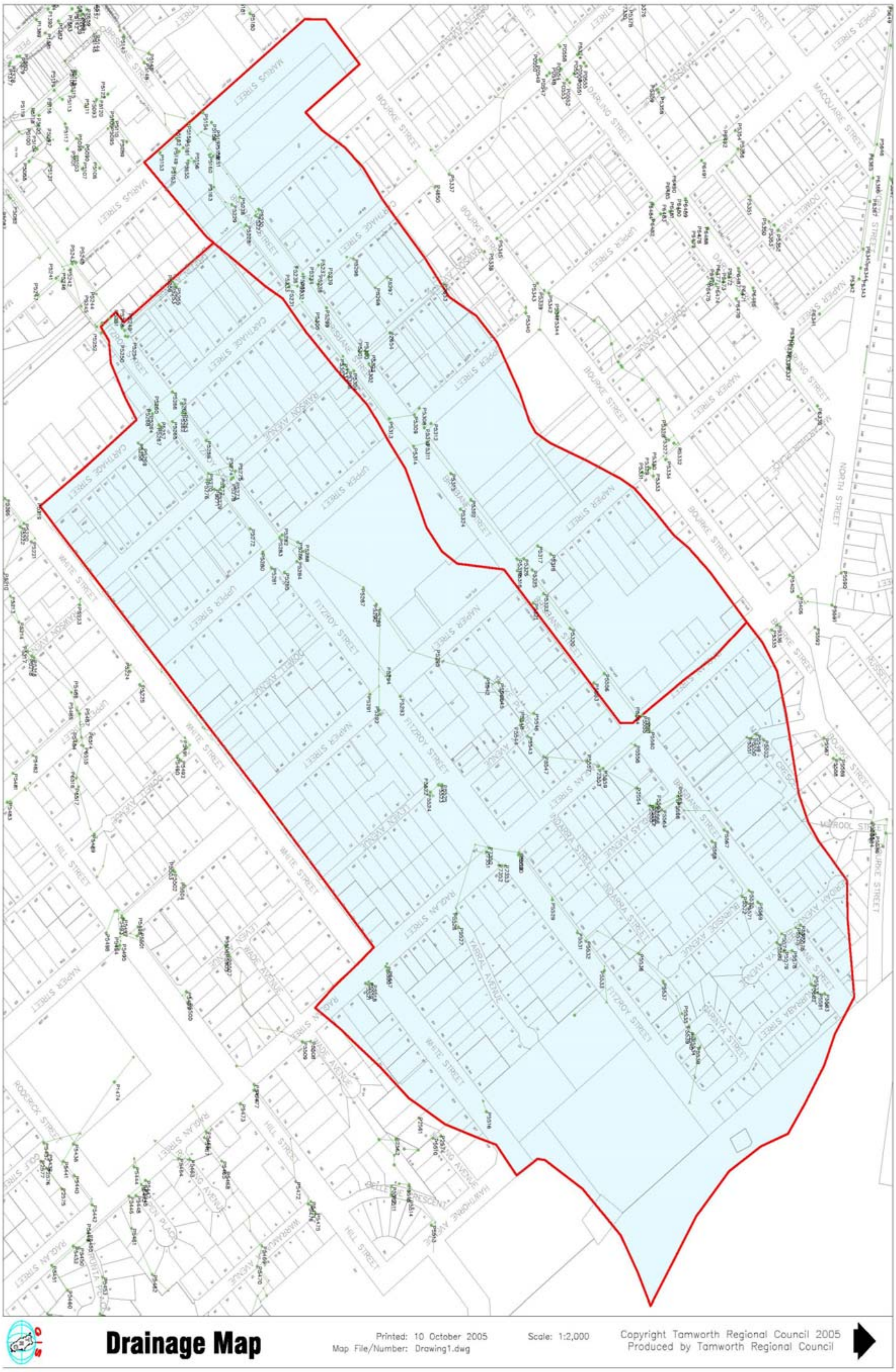
AGREED:

Riley Hue ________ (Student)   K.A.Z. Moore ________ (Supervisor)

25 / 10 / 05   25/10/05

APPENDIX B

GEOGRAPHIC INFORMATION SYSTEM MAP


Drainage Map
Printed: 10 October 2005
Map File/Number: Drawing1.dwg
Scale: 1:2,000
Copyright Tamworth Regional Council 2005
Produced by Tamworth Regional Council

APPENDIX C

CALCULATION OF C10 COEFFICIENT

LPIII Design Rainfall Intensities:

		DURATION					
		5min	6min	10min	20min	30min	1 hour
ARI	1	67.8	63.5	51.85	37.60	30.48	20.66
	2	88.5	82.9	67.5	48.76	39.43	26.61
	5	115.7	108.1	87.5	62.6	50.35	33.61
	10	133.2	124.3	100.3	71.5	57.2	37.97
	20	156.8	146.2	117.6	83.4	66.6	43.97
	50	189.6	176.7	141.7	100.0	79.6	52.2
	100	216.2	201.3	161.0	113.2	89.9	58.7

		3hour	6hour	12hour	24hour	48hour	72hour
ARI	1	10.52	6.81	4.42	2.65	1.54	1.08
	2	12.78	7.96	4.98	3.05	1.82	1.30
	5	14.06	8.03	4.60	2.97	1.87	1.38
	10	14.72	8.00	4.36	2.90	1.88	1.42
	20	15.96	8.31	4.35	2.96	1.98	1.52
	50	17.55	8.70	4.33	3.04	2.09	1.64
	100	18.73	8.98	4.32	3.10	2.17	1.73

*** All in mm/hr**

Design Aids:

Duration (min)	N
5	-0.058
6	0.000
7	0.050
8	0.099
9	0.140
10	0.181
11	0.217
12	0.252
13	0.283
14	0.314
15	0.343
16	0.370
17	0.395
18	0.420
20	0.467
25	0.568
30	0.654
35	0.728

(with 7, 9, 11, 13 and 17 min. values linearly interpolated)

N(7 min) = (0.099 + 0.000)/2
= 0.050

$I_D = I_L(I_U/I_L)^N$

* Seeing as all unknown values are between the standard durations of 6 min. and 1 hour:

I_U = 26.6 'hr (2 ARI) and 58.7 mm/hr (100 ARI)

I_L = 82.9 'hr (2 ARI) and 201.3 mm/hr (100 ARI)

Table_B1:	Duration (min)	N	ID (2 ARI)	ID (100 ARI)	t * 2I0.4	t * 100I0.4
	5	-0.058	88.5	216.2	30.05	42.94
	6	0.000	82.9	201.3	35.12	50.08
	7	0.050	78.4	189.4	40.06	57.02
	8	0.099	74.1	178.2	44.77	63.59
	9	0.140	70.7	169.4	49.43	70.11
	10	0.181	67.5	161.0	53.91	76.34
	11	0.217	64.8	154.2	58.35	82.52
	12	0.252	62.3	147.6	62.64	88.46
	13	0.283	60.1	142.0	66.91	94.38
	14	0.314	58.0	136.7	71.05	100.10
	15	0.343	56.1	131.9	75.13	105.73
	16	0.370	54.4	127.6	79.16	111.29
	17	0.395	52.9	123.7	83.16	116.80
	18	0.420	51.4	120.0	87.05	122.15
	20	0.467	48.8	113.2	94.68	132.62
	25	0.568	43.5	100.0	113.04	157.73
	30	0.654	39.4	89.9	130.45	181.42
	35	0.728	36.3	82.1	147.16	204.08

Runoff Coefficients:

$C'_{10} = 0.1 + 0.0133*(10I_1 - 25)$

$= 0.27$

$C_{10} = 0.9*f + C'_{10}*(1-f)$

$C_2 = 0.85*C_{10}$

$C_{100} = 1.2*C_{10}$

APPENDIX D

CATCHMENT 22 DATA

PIT / NODE DETAILS			Version 9							
Name	Type	Family	Size	Pressure Change Coeff. Ku	Surface Elev (m)	Blocking Factor	x	y	Bolt-down lid	id
P5318	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	420.05	0.2	303182	6559206	No	2
P5317	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	418.95	0.2	303172	6559189	No	1
P5326	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	418.63	0.2	303188	6559170	No	9
P5319	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	418.18	0.2	303188	6559161	No	10
P5322	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	413.50	0.2	303114	6559098	No	15
P5315	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	410.86	0.2	303081	6559071	No	14
P5311	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	408.63	0.2	303043	6559039	No	13
P5314	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	408.19	0.2	303048	6559021	No	21
P5313	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	406.17	0.2	303013	6558988	No	20
P5304	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	403.13	0.2	302954	6558939	No	36
P5307	Node				402.14		302936	6558925		68
P5305	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	399.87	0.2	302892	6558889	No	28
P5231	Node				397.64		302848	6558852		82
P5233	Node				397.40		302845	6558849		70
N104	Node				394.40		302775	6558791		231
N107	Node				392.50		302743	6558765		251
P5163	Node				391.40		302725	6558750		80
P5151	Node				389.80		302686	6558749		72
N142	Node				389.65		302683	6558746		361
N143	Node				388.00		302660	6558728		362
P5150	Node				386.35		302646	6558717		74
P5325	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	419.39	0.2	303202	6559181	No	3
P5321	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	422.80	0.2	303243	6559183	No	5
P5323	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	421.21	0.2	303232	6559197	No	4
P5553	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	427.24	0.2	303343	6559265	No	8
P5556	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	427.29	0.2	303331	6559279	No	7
P5320	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	424.00	0.2	303275	6559233	No	6
P5312	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	408.18	0.2	303019	6559044	No	11
P5310	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	407.97	0.2	303025	6559035	No	12

PIT / NODE DETAILS			Version 9							
Name	Type	Family	Size	Pressure Change Coeff. Ku	Surface Elev (m)	Blocking Factor	x	y	Bolt-down lid	id
P5309	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	407.53	0.2	303008	6559022	No	19
P5324	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	413.53	0.2	303126	6559084	No	16
P2654	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	403.19	0.2	302906	6558988	No	17
P2655	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	402.79	0	302932	6558957	No	31
P5300	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	402.79	0.2	302929	6558955	No	30
P5301	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	402.40	0.2	302929	6558947	No	29
P5299	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	399.59	0.2	302875	6558902	No	27
P5235	Node				397.53		302833	6558871		88
P5236	Node				396.76		302824	6558863		90
N113	Node				394.30		302758	6558809		277
N114	Node				393.75		302756	6558807		278
N133	Node				392.65		302728	6558784		324
P5308	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	407.70	0.2	303000	6559028	No	18
H0031	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	398.72	0.2	302812	6558930	No	22
P5296	Node				399.08		302814	6558939		98
P5237	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	397.72	0.2	302822	6558892	No	23
P5234	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	397.94	0.2	302839	6558880	No	25
P5239	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	398.53	0.2	302837	6558906	No	24
P5238	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	398.50	0.2	302846	6558891	No	26
P5303	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	402.96	0.2	302935	6558959	No	32
P5302	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	403.18	0.2	302945	6558960	No	33
P5306	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	402.71	0.2	302952	6558931	No	35
P7337	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	402.35	0.2	302946	6558926	No	34
P5230	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	394.00	0.2	302752	6558811	No	37
P5226	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	392.95	0.2	302737	6558785	No	38
P5229	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	392.80	0.2	302747	6558774	No	39
P5227	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	394.47	0.2	302761	6558806	No	40
P5228	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	394.15	0.2	302772	6558794	No	41
P5160	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	389.50	0.2	302684	6558744	No	42

PIT / NODE DETAILS			Version 9							
Name	Type	Family	Size	Pressure Change Coeff. Ku	Surface Elev (m)	Blocking Factor	x	y	Bolt-down lid	id
P5155	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	388.00	0.2	302692	6558715	No	43
N153	Node				387.80		302688	6558720		403
P5161	Node				387.47		302676	6558708		78
P5162	Node				386.32		302664	6558699		76
P5156	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	388.08	0.2	302693	6558723	No	44
P5153	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	386.88	0.2	302682	6558677	No	45
P5152	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	387.73	0.2	302707	6558697	No	46
P5149	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	387.67	0.2	302680	6558702	No	47
P5159	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	387.81	0.2	302644	6558747	No	48
N139	Node				388.00		302656	6558733		353
P5157	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	387.76	0.2	302663	6558750	No	49
P5154	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	386.71	0.2	302631	6558735	No	50
P5554	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	431.20	0.2	303384	6559322	No	51
P5316	Node				418.72		303203	6559161		66
P5232	Node				399.00		302848	6558863		86

SUB-CATCHMENT DETAILS								
Name	Pit or	Total	Paved	Grass	Supp	Paved	Grass	Supp
	Node	Area	Area	Area	Area	Time	Time	Time
		(ha)	%	%	%	(min)	(min)	(min)
SUB 3	P5318	0.45	70	30	0	5	13	0
SUB 2	P5317	0.15	70	30	0	5	13	0
SUB 10	P5326	0.08	70	30	0	5	13	0
SUB 11	P5319	0.08	70	30	0	5	13	0
SUB 17	P5322	0.60	70	30	0	5	13	0
SUB 16	P5315	0.50	70	30	0	5	13	0
SUB 15	P5311	0.50	70	30	0	5	13	0
SUB 24	P5314	0.23	70	30	0	5	13	0
SUB 23	P5313	0.23	70	30	0	5	13	0
SUB 42	P5304	0.38	70	30	0	5	13	0
SUB 33	P5305	0.23	70	30	0	5	13	0
SUB 4	P5325	0.45	70	30	0	5	13	0
SUB 6	P5321	0.38	70	30	0	5	13	0
SUB 5	P5323	0.15	70	30	0	5	13	0
SUB 9	P5553	0.23	70	30	0	5	13	0
SUB 8	P5556	1.00	70	30	0	5	13	0
SUB 7	P5320	1.00	70	30	0	5	13	0
SUB 13	P5312	0.50	70	30	0	5	13	0
SUB 14	P5310	0.50	70	30	0	5	13	0
SUB 22	P5309	0.30	70	30	0	5	13	0
SUB 18	P5324	0.15	70	30	0	5	13	0
SUB 20	P2654	0.38	70	30	0	5	13	0
SUB 36	P2655	0.08	70	30	0	5	13	0
SUB 35	P5300	0.38	70	30	0	5	13	0
SUB 34	P5301	0.08	70	30	0	5	13	0
SUB 32	P5299	0.30	70	30	0	5	13	0
SUB 21	P5308	0.30	70	30	0	5	13	0
SUB 25	H0031	0.38	70	30	0	5	13	0
SUB 27	P5237	0.45	70	30	0	5	13	0
SUB 29	P5234	0.08	70	30	0	5	13	0
SUB 28	P5239	0.08	70	30	0	5	13	0
SUB 30	P5238	0.08	70	30	0	5	13	0
SUB 37	P5303	0.30	70	30	0	5	13	0
SUB 39	P5302	0.08	70	30	0	5	13	0
SUB 41	P5306	0.08	70	30	0	5	13	0
SUB 40	P7337	0.08	70	30	0	5	13	0
SUB 43	P5230	0.45	70	30	0	5	13	0
SUB 49	P5226	0.15	70	30	0	5	13	0
SUB 50	P5229	0.15	70	30	0	5	13	0
SUB 51	P5227	0.15	70	30	0	5	13	0
SUB 52	P5228	0.60	70	30	0	5	13	0
SUB 54	P5160	0.60	70	30	0	5	13	0
SUB 56	P5155	0.08	70	30	0	5	13	0
SUB 57	P5156	0.08	70	30	0	5	13	0
SUB 59	P5153	0.08	70	30	0	5	13	0
SUB 60	P5152	0.08	70	30	0	5	13	0
SUB 61	P5149	0.08	70	30	0	5	13	0
SUB 65	P5159	0.38	70	30	0	5	13	0
SUB 66	P5157	0.38	70	30	0	5	13	0
SUB 67	P5154	0.38	70	30	0	5	13	0

PIPE DETAILS												
Name	From	To	Length	U/S IL	D/S IL	Slope	Type	Dia	Rough	Pipe Is	No. Pipes	Chg From
			(m)	(m)	(m)	(%)		(mm)				
I4971	P5318	P5317	20.1	418.37	417.16	6.00	Concrete	375	0.15	Existing	1	P5318
I5796	P5317	P5326	23.8	417.16	416.95	0.89	Concrete	450	0.15	Existing	1	P5317
I5797	P5326	P5319	9.5	416.95	416.47	5.05	Concrete	450	0.15	Existing	1	P5326
I5792	P5319	P5322	97	416.47	412.01	4.60	Concrete	525	0.15	Existing	1	P5319
I5790	P5322	P5315	42.6	412.01	409.44	6.03	Concrete	600	0.15	Existing	1	P5322
I5791	P5315	P5311	49.9	409.44	407.14	4.60	Concrete	600	0.15	Existing	1	P5315
I4973	P5311	P5314	19.1	407.14	406.33	4.24	Concrete	675	0.15	Existing	1	P5311
I4974	P5314	P5313	47.9	406.33	404.55	3.73	Concrete	675	0.15	Existing	1	P5314
I5789	P5313	P5304	77	404.55	401.29	4.23	Concrete	750	0.15	Existing	1	P5313
I5786	P5304	P5307	22.6	401.29	400.37	4.07	Concrete	750	0.15	Existing	1	P5304
I5785	P5307	P5305	56.9	400.37	398.27	3.69	Concrete	750	0.15	Existing	1	P5307
I5787	P5305	P5231	56.6	398.27	395.99	4.02	Concrete	750	0.15	Existing	1	P5305
I6483	P5231	P5233	5	395.99	395.64	7.14	Concrete	750	0.15	Existing	1	P5231
I5743	P5233	N104	91.5	395.64	393.00	2.88	Concrete	750	0.15	Existing	1	P5233
I5737	N104	N107	40	393.00	391.00	5.00	Concrete	750	0.15	Existing	1	N104
I5734	N107	P5163	24	391.00	390.24	3.17	Concrete	750	0.15	Existing	1	N107
I4948	P5163	P5151	39.1	390.00	387.74	5.77	Concrete	750	0.15	Existing	1	P5163
I5689A	P5151	N142	3.4	388.32	388.15	5.09	Box Culve	1.17W x 0.76H	0.15	Existing	1	P5151
I5689D	N142	N143	30	388.15	386.25	6.33	Box Culve	1.17W x 0.76H	0.15	Existing	1	N142
I5689C	N143	P5150	16.5	386.25	385.35	5.48	Box Culve	1.17W x 0.76H	0.15	Existing	1	N143
I5799	P5325	P5326	18.3	418.10	416.95	6.27	Concrete	375	0.15	Existing	1	P5325
I5794	P5321	P5323	19.4	420.50	419.54	4.95	Concrete	375	0.15	Existing	1	P5321
I5793	P5323	P5319	56.2	419.54	416.47	5.46	Concrete	375	0.15	Existing	1	P5323
II5931	P5553	P5556	18.2	426.38	425.88	2.75	Concrete	375	0.15	Existing	1	P5553
I5800	P5556	P5320	73.1	425.88	422.50	4.62	Concrete	375	0.15	Existing	1	P5556
I5795	P5320	P5323	56.2	422.50	419.54	5.27	Concrete	375	0.15	Existing	1	P5320
I4976	P5312	P5310	10.5	406.81	406.48	3.18	Concrete	450	0.15	Existing	1	P5312
I5788	P5310	P5309	21.4	406.48	405.76	3.33	Concrete	450	0.15	Existing	1	P5310
I6432	P5309	P5313	34.1	405.76	404.55	3.57	Concrete	450	0.15	Existing	1	P5309
I5798	P5324	P5322	19	412.53	412.01	2.77	Concrete	375	0.15	Existing	1	P5324

PIPE DETAILS												
Name	From	To	Length	U/S IL	D/S IL	Slope	Type	Dia	Rough	Pipe Is	No. Pipes	Chg From
			(m)	(m)	(m)	(%)		(mm)				
I3870	P2654	P2655	41	402.14	401.52	1.50	Concrete	375	0.15	Existing	1	P2654
I4961B	P2655	P5300	3.3	401.52	401.41	3.39	Concrete	375	0.15	Existing	1	P2655
I4960	P5300	P5301	8.32	401.41	401.00	4.88	Concrete	375	0.15	Existing	1	P5300
I5784	P5301	P5299	70	401.00	398.39	3.73	Concrete	375	0.15	Existing	1	P5301
I4957	P5299	P5235	52.9	398.39	395.61	5.26	Concrete	450	0.15	Existing	1	P5299
I5742	P5235	P5236	11.5	395.61	395.44	1.43	Concrete	600	0.15	Existing	1	P5235
I5741	P5236	N113	85.5	395.44	393.00	2.85	Concrete	600	0.15	Existing	1	P5236
I5736A	N113	N114	3.75	393.00	392.75	6.67	Concrete	600	0.15	Existing	1	N113
I5736B	N114	N133	36	392.75	391.25	4.17	Concrete	600	0.15	Existing	1	N114
I5732	N133	P5151	55	391.25	388.40	5.18	Concrete	600	0.15	Existing	1	N133
I4975	P5308	P5309	10.1	406.65	405.76	8.80	Concrete	375	0.15	Existing	1	P5308
Pipe23(	H0031	P5296	15	388.00	387.00	6.67	Concrete	375	0.15	Existing	1	H0031
I4953	P5237	P5234	20.8	396.60	396.26	1.65	Concrete	375	0.15	Existing	1	P5237
I4954	P5234	P5235	11.7	396.26	395.61	5.57	Concrete	450	0.15	Existing	1	P5234
I4956	P5239	P5238	17.3	397.41	397.22	1.09	Concrete	450	0.15	Existing	1	P5239
I4955	P5238	P5234	12.1	397.22	396.26	7.95	Concrete	450	0.15	Existing	1	P5238
I4961A	P5303	P2655	3.3	401.52	401.41	3.39	Concrete	375	0.15	Existing	1	P5303
I5783	P5302	P5301	21	401.56	401.00	2.65	Concrete	375	0.15	Existing	1	P5302
I4959	P5306	P7337	8	401.53	401.31	2.69	Concrete	375	0.15	Existing	1	P5306
I4958	P7337	P5307	10.5	401.31	400.37	8.96	Concrete	375	0.15	Existing	1	P7337
I4952	P5230	N114	5.25	393.00	392.75	4.76	Concrete	300	0.15	Existing	1	P5230
I4949	P5226	N133	9.75	391.90	391.25	6.67	Concrete	375	0.15	Existing	1	P5226
I4950	P5229	N107	9.75	391.80	391.00	8.21	Concrete	225	0.15	Existing	1	P5229
I5733	P5227	N113	3.2	393.40	393.30	3.13	Concrete	375	0.15	Existing	1	P5227
I5738	P5228	N104	4	393.20	393.00	5.00	Concrete	375	0.15	Existing	1	P5228
I6426	P5160	N142	2.75	388.32	388.15	6.18	Concrete	375	0.15	Existing	1	P5160
Pipe21:	P5155	N153	5	387.00	386.80	4.00	Concrete	375	0.15	Existing	1	P5155
I5691B	N153	P5161	16	386.80	386.12	4.25	Concrete	375	0.15	Existing	1	N153
I5687	P5161	P5162	15.2	386.12	384.62	9.90	Concrete	375	0.15	Existing	1	P5161
I5691A	P5156	N153	5.5	387.00	386.80	3.62	Concrete	375	0.15	Existing	1	P5156

PIPE DETAILS

Name	From	To	Length (m)	U/S IL (m)	D/S IL (m)	Slope (%)	Type	Dia (mm)	Rough	Pipe Is	No. Pipes	Chg From
I4943	P5153	P5162	28.5	385.88	384.62	4.45	Concrete	300	0.15	Existing	1	P5153
I4945	P5152	P5149	26.8	386.68	386.39	1.07	Concrete	375	0.15	Existing	1	P5152
I4944	P5149	P5161	7.85	386.39	386.12	3.41	Concrete	375	0.15	Existing	1	P5149
I5685A	P5159	N139	18	386.80	386.25	3.06	Concrete	375	0.15	Existing	1	P5159
I5685B	N139	N143	6	386.50	386.25	4.17	Concrete	375	0.15	Existing	1	N139
I4947	P5157	N139	19.25	386.70	386.25	2.34	Concrete	375	0.15	Existing	1	P5157
I5690	P5154	P5150	23.5	385.64	384.64	4.25	Concrete	375	0.15	Existing	1	P5154
I5930	P5554	P5556	68.2	429.45	425.88	5.24	Concrete	375	0.15	Existing	1	P5554
I4972	P5316	P5319	14.5	417.75	416.47	8.84	Concrete	300	0.15	Existing	1	P5316
I5740	P5232	P5233	14.6	397.10	396.64	3.17	Concrete	300	0.15	Existing	1	P5232

APPENDIX E

CATCHMENT 25 DATA

PIT / NODE DETAILS			Version 9							
Name	Type	Family	Size	Pressure Change Coeff. Ku	Surface Elev (m)	Blocking Factor	x	y	Bolt-down lid	id
H0657	Headwall			0.5	448.13		303740	6559282		1
N251	Node				446.50		303722	6559281		534
P5533	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	445.14	0.2	303701	6559279	No	75
P5532	Node				441.35		303665	6559254		157
N257	Node				440.50		303651	6559243		559
N258	Node				436.25		303610	6559208		560
P5528	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	430.27	0.2	303554	6559163	No	70
H0001	Node				428.03		303545	6559105		746
H0658	Headwall			0.5	475.20		303865	6559395		2
P5538	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	466.28	0.2	303797	6559409	No	80
P5534	Node				462.95		303786	6559402		160
P5540	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	462.81	0.2	303781	6559399	No	82
P5539	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	462.50	0.2	303771	6559394	No	81
P5535	Node				459.00		303755	6559384		164
P5537	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	452.00	0.2	303715	6559359	No	79
P5536	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	447.24	0.2	303680	6559325	No	78
H0660	Headwall			0.5	422.19		303483	6559046		4
P5524	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	422.69	0.2	303479	6559043	No	66
P5522	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	422.54	0.2	303472	6559037	No	64
H0659	Node				418.73		303430	6559003		759
P5254	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	391.51	0.2	302911	6558633	No	17
P5250	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	391.62	0.2	302911	6558630	No	14
P5249	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	391.18	0.2	302903	6558629	No	13
P5248	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	391.13	0.2	302900	6558625	No	12
P5251	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	390.78	0.2	302891	6558617	No	15
N269	Node				389.00		302906	6558598		695
P5256	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	391.96	0.2	302842	6558693	No	18

PIT / NODE DETAILS			Version 9							
Name	Type	Family	Size	Pressure Change Coeff. Ku	Surface Elev (m)	Blocking Factor	x	y	Bolt-down lid	id
P5253	Node				391.93		302846	6558697		126
P5259	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	396.85	0.2	303041	6558740	No	21
P5263	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	396.17	0.2	303007	6558712	No	25
P5262	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	396.31	0.2	303006	6558707	No	24
P5261	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	396.05	0.2	302995	6558706	No	23
P5266	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	395.45	0.2	302980	6558694	No	28
P5260	Node				395.19		302996	6558672		133
P5265	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	396.26	0.2	303017	6558694	No	27
P5267	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	395.51	0.2	303023	6558677	No	29
P5257	Node				395.39		303021	6558675		129
P5264	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	395.32	0.2	303008	6558667	No	26
P5268	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	394.79	0.2	303003	6558664	No	30
P5269	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	394.89	0.2	303050	6558653	No	31
P5258	Node				394.77		303044	6558647		131
P5271	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	399.73	0.2	303101	6558751	No	33
P5276	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	399.15	0.2	303090	6558741	No	38
P5270	Node				399.23		303082	6558742		135
P5272	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	402.61	0.2	303151	6558799	No	34
P5279	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	399.81	0.2	303101	6558758	No	41
P5277	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	400.40	0.2	303097	6558763	No	39
P5278	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	400.21	0.2	303089	6558774	No	40
P5273	Node				400.07		303086	6558776		138
P5275	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	400.00	0.2	303079	6558779	No	37
P5274	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	399.67	0.2	303072	6558773	No	36
P5281	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	405.93	0.2	303200	6558828	No	43
P5280	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	404.69	0.2	303180	6558816	No	42
P5283	Node				404.07		303161	6558839		140

PIT / NODE DETAILS			Version 9							
Name	Type	Family	Size	Pressure Change Coeff. Ku	Surface Elev (m)	Blocking Factor	x	y	Bolt-down lid	id
P5285	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	406.37	0.2	303205	6558845	No	47
P5284	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	405.83	0.2	303192	6558862	No	46
P5288	Node				404.76		303179	6558872		144
P5286	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	404.55	0.2	303168	6558864	No	48
P5282	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	404.07	0.2	303158	6558842	No	44
P5291	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	415.35	0.2	303357	6558961	No	53
N209	Node				415.40		303347	6558974		395
N208	Node				415.20		303326	6558974		394
P5289	Node				415.00		303251	6558976		146
P5290	Node				414.40		303246	6558971		149
P5287	Node				412.00		303224	6558953		142
P5293	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	415.89	0.2	303360	6559003	No	55
N210	Node				415.35		303335	6558983		396
P5294	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	415.50	0.2	303334	6558989	No	56
P5516	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	463.98	0.2	303877	6559119	No	58
K0038	Node				462.50		303864	6559115		765
P5517	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	442.84	0.2	303701	6558985	No	59
P5520	Node				441.65		303696	6558983		153
K0039	Node				441.20		303692	6558985		753
P5518	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	443.49	0.2	303719	6558964	No	60
P5519	Node				443.23		303715	6558960		151
P5521	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	443.89	0.2	303717	6558955	No	63
P5525	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	422.91	0.2	303470	6559059	No	67
P5523	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	422.41	0.2	303470	6559054	No	65
P5527	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	435.50	0.2	303647	6559081	No	69
P5526	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	434.05	0.2	303630	6559079	No	68
P5529	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	436.16	0.2	303613	6559209	No	71

PIT / NODE DETAILS			Version 9							
Name	Type	Family	Size	Pressure Change Coeff. Ku	Surface Elev (m)	Blocking Factor	x	y	Bolt-down lid	id
P5531	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	440.89	0.2	303654	6559243	No	73
P5541	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	419.48	0.2	303343	6559136	No	83
N230	Node				419.75		303344	6559127		451
P5542	Node				419.30		303336	6559117		168
P5295	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	417.80	0.2	303313	6559052	No	57
P5546	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	422.97	0.2	303381	6559184	No	88
P5548	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	422.43	0.2	303389	6559166	No	90
P5545	Node				420.00		303352	6559137		186
P5552	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	439.90	0.2	303414	6559495	No	94
P5549	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	439.22	0.2	303407	6559485	No	91
P5550	Node				438.97		303412	6559479		188
P5551	Node				437.88		303411	6559472		190
P5558	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	431.43	0.2	303420	6559321	No	96
N237	Node				431.00		303418	6559315		477
P5559	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	428.65	0.2	303450	6559277	No	97
P2553	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	428.41	0.2	303447	6559271	No	8
P5557	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	428.22	0.2	303440	6559255	No	95
P5547	Node				425.00		303434	6559197		181
P5543	Node				423.52		303409	6559175		173
P5544	Node				422.80		303395	6559165		177
P5560	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	431.71	0.2	303403	6559340	No	98
N235	Node				431.50		303398	6559340		473
P5561	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	431.87	0.2	303395	6559340	No	99
P5563	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	433.25	0.2	303493	6559350	No	101
P5562	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	433.29	0.2	303497	6559345	No	100
P2555	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	432.48	0.2	303496	6559341	No	10
P2554	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	430.95	0.2	303474	6559323	No	9

PIT / NODE DETAILS			Version 9							
Name	Type	Family	Size	Pressure Change Coeff. Ku	Surface Elev (m)	Blocking Factor	x	y	Bolt-down lid	id
P5567	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	437.67	0.2	303526	6559441	No	105
N244	Node				436.40		303502	6559421		516
N245	Node				435.00		303502	6559388		517
P5566	Node				434.22		303489	6559378		192
P5564	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	433.30	0.2	303501	6559357	No	102
P2556	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	433.35	0.2	303498	6559348	No	11
P5571	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	445.73	0.2	303617	6559472	No	109
P5572	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	445.22	0.2	303609	6559466	No	110
P5570	Node				444.97		303601	6559475		194
P5568	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	438.26	0.2	303540	6559425	No	106
P5565	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	434.35	0.2	303484	6559378	No	103
P5576	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	452.83	0.2	303655	6559544	No	114
P5575	Node				452.00		303648	6559538		203
P5574	Node				450.71		303655	6559519		201
P5569	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	446.23	0.2	303616	6559487	No	107
P5577	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	452.88	0.2	303645	6559545	No	115
P7353	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	430.12	0.2	303571	6559145	No	124
P7352	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	429.70	0.2	303570	6559136	No	123
P7351	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	429.34	0.2	303554	6559119	No	122
P7484	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	448.74	0.2	303757	6559239	No	125
P5530	Node				430.33		303557	6559163		155
P5583	Node				461.08		303730	6559577		205
P5581	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	460.33	0.2	303729	6559568	No	119
P5582	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	459.83	0.2	303719	6559559	No	120
P5573	Node				459.18		303708	6559563		198
P5578	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	452.17	0.2	303677	6559533	No	116
P5579	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	451.51	0.2	303678	6559522	No	117

PIT / NODE DETAILS			Version 9							
Name	Type	Family	Size	Pressure	Surface	Blocking	x	y	Bolt-down	id
				Change	Elev (m)	Factor			lid	
				Coeff. Ku						
P5580	OnGrade	NSW RTA SA Inlet, 3% crossfall, 3% grade	SA2 - 3% long. grade	1.5	451.14	0.2	303667	6559513	No	118
H0705	OnGrade	NSW RTA SA Inlet, 3% crossfall, 5% grade	SA2 - 3% long. grade	1.5	416.13	0	303381	6558974	No	####

SUB-CATCHMENT DETAILS								
Name	Pit or	Total	Paved	Grass	Supp	Paved	Grass	Supp
	Node	Area	Area	Area	Area	Time	Time	Time
		(ha)	%	%	%	(min)	(min)	(min)
SUB 1	H0657	0.80	70	30	0	5	13	0
SUB 75	P5533	0.31	70	30	0	5	13	0
SUB 70	P5528	0.46	70	30	0	5	13	0
SUB 2	H0658	1.00	70	30	0	5	13	0
SUB 80	P5538	0.38	70	30	0	5	13	0
SUB 82	P5540	0.69	70	30	0	5	13	0
SUB 81	P5539	0.76	70	30	0	5	13	0
SUB 79	P5537	0.23	70	30	0	5	13	0
SUB 78	P5536	0.30	70	30	0	5	13	0
SUB 4	H0660	0.40	70	30	0	5	13	0
SUB 66	P5524	0.68	70	30	0	5	13	0
SUB 64	P5522	0.46	70	30	0	5	13	0
SUB 3	H0659	0.60	70	30	0	5	13	0
SUB 17	P5254	0.46	70	30	0	5	13	0
SUB 14	P5250	0.46	70	30	0	5	13	0
SUB 12	P5248	0.54	70	30	0	5	13	0
SUB 15	P5251	0.69	70	30	0	5	13	0
SUB 18	P5256	0.46	70	30	0	5	13	0
SUB 21	P5259	0.24	70	30	0	5	13	0
SUB 25	P5263	0.31	70	30	0	5	13	0
SUB 24	P5262	0.31	70	30	0	5	13	0
SUB 23	P5261	0.84	70	30	0	5	13	0
SUB 28	P5266	0.69	70	30	0	5	13	0
SUB 27	P5265	0.24	70	30	0	5	13	0
SUB 29	P5267	0.46	70	30	0	5	13	0
SUB 26	P5264	0.54	70	30	0	5	13	0
SUB 30	P5268	0.54	70	30	0	5	13	0
SUB 31	P5269	0.84	70	30	0	5	13	0
SUB 33	P5271	0.84	70	30	0	5	13	0
SUB 38	P5276	0.91	70	30	0	5	13	0
SUB 34	P5272	0.24	70	30	0	5	13	0
SUB 41	P5279	0.39	70	30	0	5	13	0
SUB 39	P5277	0.24	70	30	0	5	13	0
SUB 40	P5278	0.46	70	30	0	5	13	0
SUB 37	P5275	0.69	70	30	0	5	13	0
SUB 36	P5274	0.69	70	30	0	5	13	0
SUB 43	P5281	0.84	70	30	0	5	13	0
SUB 42	P5280	0.76	70	30	0	5	13	0
SUB 47	P5285	0.76	70	30	0	5	13	0
SUB 46	P5284	4.00	20	80	0	5	13	0
SUB 48	P5286	4.00	20	80	0	5	13	0
SUB 44	P5282	0.84	70	30	0	5	13	0
SUB 53	P5291	0.91	70	30	0	5	13	0
SUB 55	P5293	0.84	70	30	0	5	13	0
SUB 56	P5294	0.24	70	30	0	5	13	0
SUB 58	P5516	0.99	70	30	0	5	13	0
SUB 59	P5517	0.46	70	30	0	5	13	0
SUB 7	K0039	0.46	70	30	0	5	13	0

SUB-CATCHMENT DETAILS								
Name	Pit or	Total	Paved	Grass	Supp	Paved	Grass	Supp
	Node	Area	Area	Area	Area	Time	Time	Time
		(ha)	%	%	%	(min)	(min)	(min)
SUB 60	P5518	0.61	70	30	0	5	13	0
SUB 63	P5521	0.61	70	30	0	5	13	0
SUB 67	P5525	0.24	70	30	0	5	13	0
SUB 65	P5523	0.24	70	30	0	5	13	0
SUB 69	P5527	1.14	70	30	0	5	13	0
SUB 68	P5526	0.76	70	30	0	5	13	0
SUB 71	P5529	0.31	70	30	0	5	13	0
SUB 73	P5531	0.39	70	30	0	5	13	0
SUB 83	P5541	0.76	70	30	0	5	13	0
SUB 57	P5295	0.76	70	30	0	5	13	0
SUB 88	P5546	0.69	70	30	0	5	13	0
SUB 90	P5548	0.69	70	30	0	5	13	0
SUB 94	P5552	0.54	70	30	0	5	13	0
SUB 91	P5549	0.54	70	30	0	5	13	0
SUB 96	P5558	0.24	70	30	0	5	13	0
SUB 97	P5559	0.69	70	30	0	5	13	0
SUB 8	P2553	0.17	70	30	0	5	13	0
SUB 95	P5557	0.69	70	30	0	5	13	0
SUB 98	P5560	0.76	70	30	0	5	13	0
SUB 99	P5561	0.76	70	30	0	5	13	0
SUB 101	P5563	0.24	70	30	0	5	13	0
SUB 100	P5562	0.69	70	30	0	5	13	0
SUB 10	P2555	0.69	70	30	0	5	13	0
SUB 9	P2554	0.53	70	30	0	5	13	0
SUB 105	P5567	0.76	70	30	0	5	13	0
SUB 102	P5564	0.69	70	30	0	5	13	0
SUB 11	P2556	0.69	70	30	0	5	13	0
SUB 109	P5571	0.39	70	30	0	5	13	0
SUB 110	P5572	0.61	70	30	0	5	13	0
SUB 106	P5568	0.39	70	30	0	5	13	0
SUB 103	P5565	0.24	70	30	0	5	13	0
SUB 114	P5576	0.54	70	30	0	5	13	0
SUB 107	P5569	0.39	70	30	0	5	13	0
SUB 115	P5577	0.54	70	30	0	5	13	0
SUB 124	P7353	0.91	70	30	0	5	13	0
SUB 123	P7352	0.39	70	30	0	5	13	0
SUB 122	P7351	0.91	70	30	0	5	13	0
SUB 125	P7484	1.66	70	30	0	5	13	0
SUB 119	P5581	0.61	70	30	0	5	13	0
SUB 120	P5582	0.46	70	30	0	5	13	0
SUB 116	P5578	0.31	70	30	0	5	13	0
SUB 117	P5579	0.31	70	30	0	5	13	0
SUB 118	P5580	0.46	70	30	0	5	13	0
SUB 5	H0705	0.38	70	30	0	5	13	0

PIPE DETAILS													
Name	From	To	Length	U/S IL	D/S IL	Slope	Type	Dia	Rough	Pipe Is	No. Pipes	Chg From	At Chg
			(m)	(m)	(m)	(%)		(mm)					
I5064A	H0657	N251	17	447.10	445.50	9.41	Concrete	525	0.15	Existing	1	H0657	0
I5064B	N251	P5533	20	445.50	444.13	6.85	Concrete	525	0.15	Existing	1	N251	0
I5924	P5533	P5532	44.2	443.45	439.73	8.42	Concrete	525	0.15	Existing	1	P5533	0
I5062A	P5532	N257	15	439.73	439.00	4.86	Concrete	675	0.15	Existing	2	P5532	0
I5062B	N257	N258	53.5	439.00	435.00	7.48	Concrete	675	0.15	Existing	2	N257	0
I5062C	N258	P5528	75	435.00	429.00	8	Concrete	675	0.15	Existing	2	N258	0
I5780	P5528	H0001	60	429.00	427.50	2.5	Box Culve	1.5W x 0.5	0.15	Existing	1	P5528	0
I5070	H0658	P5538	67.7	474.39	464.54	14.54	Concrete	525	0.15	Existing	1	H0658	0
I5069	P5538	P5534	12.6	464.54	462.07	19.63	Concrete	375	0.15	Existing	1	P5538	0
I6440	P5534	P5540	6	462.07	461.40	11.17	Concrete	375	0.15	Existing	1	P5534	0
I6439	P5540	P5539	10.6	461.40	461.34	0.54	Concrete	375	0.15	Existing	1	P5540	0
I5068	P5539	P5535	19.3	461.34	459.00	12.14	Concrete	525	0.15	Existing	1	P5539	0
I5067	P5535	P5537	47.7	457.50	450.50	14.68	Concrete	750	0.15	Existing	1	P5535	0
I5926	P5537	P5536	47.9	450.50	446.00	9.39	Concrete	750	0.15	Existing	1	P5537	0
I5066	P5536	P5532	72.6	446.00	439.73	8.64	Concrete	750	0.15	Existing	1	P5536	0
I5919A	H0660	P5524	4	420.75	420.65	2.57	Box Culve	1.9W x 0.6	0.15	Existing	1	H0660	0
I5919B	P5524	P5522	10.1	420.60	419.90	6.93	Box Culve	1.9W x 0.6	0.15	Existing	1	P5524	0
I5918	P5522	H0659	53.8	419.90	417.92	3.69	Concrete	1800	0.15	Existing	1	P5522	0
I1112	P5254	P5250	5	390.50	390.30	4	Concrete	375	0.15	Existing	1	P5254	0
I5756	P5250	P5249	7.65	390.12	389.76	4.71	Concrete	300	0.15	Existing	1	P5250	0
I5757	P5249	P5248	4.75	389.76	389.54	4.72	Concrete	450	0.15	Existing	1	P5249	0
I5751	P5248	P5251	11.8	389.54	389.00	4.55	Concrete	450	0.15	Existing	1	P5248	0
I5754	P5251	N269	24.5	389.00	386.50	10.2	Concrete	450	0.15	Existing	1	P5251	0
I5752	P5256	P5253	5	391.21	391.08	2.7	Concrete	375	0.15	Existing	1	P5256	0
I5753	P5253	P5249	89	391.08	389.76	1.48	Concrete	375	0.15	Existing	1	P5253	0
I5759	P5259	P5263	44	396.11	395.39	1.65	Concrete	300	0.15	Existing	1	P5259	0
I5008	P5263	P5262	4.5	395.39	394.71	14.93	Concrete	300	0.15	Existing	1	P5263	0
I5009	P5262	P5261	12	394.71	393.45	10.54	Concrete	375	0.15	Existing	1	P5262	0
I5011	P5261	P5266	19.2	393.45	393.18	1.39	Concrete	450	0.15	Existing	1	P5261	0

PIPE DETAILS													
Name	From	To	Length	U/S IL	D/S IL	Slope	Type	Dia	Rough	Pipe Is	No. Pipes	Chg From	At Chg
			(m)	(m)	(m)	(%)		(mm)					
I5010	P5266	P5260	27.2	393.18	391.98	4.42	Concrete	450	0.15	Existing	1	P5266	0
I5758	P5260	N269	117	391.80	386.50	4.53	Concrete	1500	0.15	Existing	1	P5260	0
I5764	P5265	P5262	17.8	394.96	394.71	1.39	Concrete	375	0.15	Existing	1	P5265	0
I5763A	P5267	P5257	15.3	393.00	391.18	11.92	Concrete	375	0.15	Existing	1	P5267	0
I5763B	P5257	P5264	15.5	391.18	389.33	11.94	Concrete	375	0.15	Existing	1	P5257	0
I5761	P5264	P5268	11.7	389.54	389.33	1.79	Concrete	450	0.15	Existing	1	P5264	0
I5760	P5268	P5260	10.4	393.09	391.98	10.69	Concrete	375	0.15	Existing	1	P5268	0
I5012	P5269	P5258	8.25	393.96	393.77	2.33	Concrete	375	0.15	Existing	1	P5269	0
I5762	P5258	P5257	36.2	393.77	391.18	7.17	Concrete	375	0.15	Existing	1	P5258	0
I5767	P5271	P5276	15.1	396.24	395.96	1.91	Concrete	375	0.15	Existing	1	P5271	0
I5765	P5276	P5270	8.6	395.96	395.71	2.87	Concrete	375	0.15	Existing	1	P5276	0
I5768	P5270	P5260	111	395.71	391.98	3.36	Concrete	1500	0.15	Existing	1	P5270	0
I5769	P5272	P5279	63.6	402.00	399.11	4.54	Concrete	300	0.15	Existing	1	P5272	0
I5016	P5279	P5277	6.85	399.11	398.44	9.77	Concrete	375	0.15	Existing	1	P5279	0
I5017	P5277	P5278	13.2	398.44	397.32	8.49	Concrete	375	0.15	Existing	1	P5277	0
I5013	P5278	P5273	3.2	397.32	397.24	2.47	Concrete	375	0.15	Existing	1	P5278	0
I5015	P5273	P5270	34	397.24	395.71	4.51	Concrete	1500	0.15	Existing	1	P5273	0
I5766	P5275	P5274	8.7	398.42	398.29	1.54	Concrete	375	0.15	Existing	1	P5275	0
I5014	P5274	P5270	32.4	398.29	395.71	7.97	Concrete	375	0.15	Existing	1	P5274	0
I5018	P5281	P5280	22.9	404.77	403.44	5.79	Concrete	375	0.15	Existing	1	P5281	0
I5019	P5280	P5283	29.1	403.44	401.90	5.31	Concrete	375	0.15	Existing	1	P5280	0
I5770	P5283	P5273	97.5	401.90	397.24	4.78	Concrete	1500	0.15	Existing	1	P5283	0
I2021	P5285	P5284	22.5	405.00	404.43	2.52	Concrete	450	0.15	Existing	1	P5285	0
I5022	P5284	P5288	15.5	404.43	402.36	13.38	Concrete	450	0.15	Existing	1	P5284	0
I5774	P5288	P5283	36.9	402.36	401.90	1.24	Concrete	1350	0.15	Existing	1	P5288	0
I5020	P5286	P5282	23	403.60	402.30	5.66	Concrete	375	0.15	Existing	1	P5286	0
I5771	P5282	P5283	4.5	402.30	401.90	8.89	Concrete	375	0.15	Existing	1	P5282	0
I5779	P5291	N209	15.5	413.99	413.75	1.54	Concrete	375	0.15	Existing	1	P5291	0
I5778B	N209	N208	15.5	413.75	413.60	0.97	Box Culve	0.9W x 0.4	0.15	Existing	1	N209	0
I5778C	N208	P5289	75.5	413.60	413.50	0.13	Box Culve	0.9W x 0.4	0.15	Existing	1	N208	0

PIPE DETAILS													
Name	From	To	Length	U/S IL	D/S IL	Slope	Type	Dia	Rough	Pipe Is	No. Pipes	Chg From	At Chg
			(m)	(m)	(m)	(%)		(mm)					
I5775	P5289	P5290	8.25	413.50	412.70	9.7	Concrete	1200	0.15	Existing	1	P5289	0
I5773	P5290	P5287	26.8	412.70	410.00	10.07	Concrete	1200	0.15	Existing	1	P5290	0
I5772	P5287	P5288	93.6	410.00	402.36	8.16	Concrete	1200	0.15	Existing	1	P5287	0
I5777A	P5293	N210	31.5	414.80	414.00	2.54	Box Culve	0.9W x 0.4	0.15	Existing	1	P5293	0
I5777B	N210	N208	12	414.00	413.60	3.33	Box Culve	0.9W x 0.4	0.15	Existing	1	N210	0
I5776	P5294	N210	6	414.20	414.00	3.33	Concrete	300	0.15	Existing	1	P5294	0
I5917	P5516	K0038	15	463.00	461.80	8	Concrete	300	0.15	Existing	1	P5516	0
I4845	P5517	P5520	5	441.80	440.60	24	Concrete	225	0.15	Existing	1	P5517	0
I4844	P5520	K0039	5	440.60	440.20	8	Concrete	300	0.15	Existing	2	P5520	0
I4848	P5518	P5519	5.5	442.80	442.50	5.45	Concrete	375	0.15	Existing	1	P5518	0
I4846	P5519	P5520	30	442.50	440.60	6.33	Concrete	450	0.15	Existing	1	P5519	0
I4847	P5521	P5519	4.5	442.80	442.50	6.67	Concrete	300	0.15	Existing	1	P5521	0
I5920	P5525	P5523	5.25	422.00	421.70	5.71	Concrete	300	0.15	Existing	1	P5525	0
I5921	P5523	P5524	14.4	421.70	420.60	7.64	Concrete	300	0.15	Existing	1	P5523	0
I5073	P5527	P5526	17.5	434.50	433.05	8.29	Concrete	525	0.15	Existing	1	P5527	0
I5071	P5526	H0001	90	433.05	427.50	6.17	Concrete	525	0.15	Existing	1	P5526	0
I5923	P5529	N258	3	435.05	435.00	1.67	Concrete	300	0.15	Existing	1	P5529	0
I5061	P5531	N257	3	439.70	439.10	20	Concrete	300	0.15	Existing	1	P5531	0
I5027	P5541	N230	9.55	418.47	418.00	4.92	Concrete	375	0.15	Existing	1	P5541	0
I5026B	N230	P5542	13	418.00	417.50	3.85	Concrete	900	0.15	Existing	1	N230	0
I5025	P5542	P5295	68.6	417.50	415.80	2.48	Concrete	900	0.15	Existing	1	P5542	0
I5023	P5295	P5289	98.8	415.80	413.50	2.33	Concrete	900	0.15	Existing	1	P5295	0
I5028	P5546	P5548	19.2	420.61	420.10	2.65	Concrete	375	0.15	Existing	1	P5546	0
I5927	P5548	P5545	46.8	420.10	418.30	3.85	Concrete	750	0.15	Existing	1	P5548	0
I5026A	P5545	N230	13	418.30	418.00	2.31	Concrete	900	0.15	Existing	1	P5545	0
I5039	P5552	P5549	12.6	439.13	438.30	6.56	Concrete	375	0.15	Existing	1	P5552	0
I5038	P5549	P5550	8.4	438.30	438.07	2.79	Concrete	375	0.15	Existing	1	P5549	0
I5929	P5550	P5551	6.5	438.07	437.88	2.85	Concrete	450	0.15	Existing	1	P5550	0
I5935	P5558	N237	6	430.40	430.00	6.67	Concrete	375	0.15	Existing	1	P5558	0
I5932	N237	P5559	49	430.00	427.26	5.6	Concrete	375	0.15	Existing	1	N237	0

PIPE DETAILS													
Name	From	To	Length	U/S IL	D/S IL	Slope	Type	Dia	Rough	Pipe Is	No. Pipes	Chg From	At Chg
			(m)	(m)	(m)	(%)		(mm)					
I3693	P5559	P2553	7.25	427.26	426.96	4.14	Concrete	750	0.15	Existing	1	P5559	0
I5034	P2553	P5557	18.2	426.96	426.00	5.26	Concrete	750	0.15	Existing	1	P2553	0
I5031	P5557	P5547	58.3	426.00	423.64	4.05	Concrete	750	0.15	Existing	1	P5557	0
I5030	P5547	P5543	33	423.64	421.94	5.15	Concrete	750	0.15	Existing	1	P5547	0
I5029	P5543	P5544	17	421.94	421.07	5.16	Concrete	750	0.15	Existing	1	P5543	0
I5928	P5544	P5548	6.5	421.07	420.10	14.86	Concrete	750	0.15	Existing	1	P5544	0
I5933	P5560	N235	5	430.70	430.50	4	Concrete	375	0.15	Existing	1	P5560	0
I5934	N235	N237	32	430.50	430.00	1.56	Concrete	375	0.15	Existing	1	N235	0
I5033	P5561	N235	4	430.86	430.50	9	Concrete	225	0.15	Existing	1	P5561	0
I5936	P5563	P5562	6.5	432.67	431.47	18.38	Concrete	300	0.15	Existing	1	P5563	0
I3696B	P5562	P2555	4.5	431.50	431.00	11.11	Concrete	750	0.15	Existing	1	P5562	0
I3695	P2555	P2554	28	431.03	429.32	6.12	Concrete	750	0.15	Existing	1	P2555	0
I3694	P2554	P5559	51.5	429.32	427.26	4.01	Concrete	750	0.15	Existing	1	P2554	0
I5938	P5567	N244	31.1	436.67	435.40	4.09	Concrete	450	0.15	Existing	1	P5567	0
I5939	N244	N245	33.2	435.40	434.00	4.22	Concrete	450	0.15	Existing	1	N244	0
I5940	N245	P5566	16	434.00	433.12	5.5	Concrete	450	0.15	Existing	1	N245	0
I5941	P5566	P5564	23.6	433.26	432.33	3.95	Concrete	450	0.15	Existing	1	P5566	0
I5035	P5564	P2556	9.4	432.33	432.00	3.48	Concrete	450	0.15	Existing	1	P5564	0
I3696A	P2556	P5562	3.5	432.00	431.50	14.29	Concrete	750	0.15	Existing	1	P2556	0
I5944	P5571	P5572	10.6	444.16	443.82	3.27	Concrete	375	0.15	Existing	1	P5571	0
I5945	P5572	P5570	12.4	443.82	443.35	3.8	Concrete	375	0.15	Existing	1	P5572	0
I5946	P5570	P5568	78.8	443.35	436.56	8.61	Concrete	525	0.15	Existing	1	P5570	0
I5942	P5568	P5565	72.8	436.56	432.53	5.53	Concrete	525	0.15	Existing	1	P5568	0
I5937	P5565	P2556	33.4	432.53	431.85	2.04	Concrete	600	0.15	Existing	1	P5565	0
I5956	P5576	P5575	9.5	451.76	450.82	9.83	Concrete	300	0.15	Existing	1	P5576	0
I5951	P5575	P5574	20.5	450.82	449.81	4.92	Concrete	375	0.15	Existing	1	P5575	0
I5950	P5574	P5569	50.7	449.81	444.58	10.33	Concrete	450	0.15	Existing	1	P5574	0
I5943	P5569	P5570	19.4	444.58	443.35	6.34	Concrete	450	0.15	Existing	1	P5569	0
I5947	P5577	P5575	7	451.40	450.82	8.2	Concrete	375	0.15	Existing	1	P5577	0
I5783	P7353	P7352	8.5	429.41	429.00	4.82	Concrete	375	0.15	Existing	1	P7353	0

PIPE DETAILS													
Name	From	To	Length	U/S IL	D/S IL	Slope	Type	Dia	Rough	Pipe Is	No. Pipes	Chg From	At Chg
			(m)	(m)	(m)	(%)		(mm)					
I7582	P7352	P7351	24.7	428.20	428.00	0.81	Concrete	450	0.15	Existing	2	P7352	0
I5782A	P7351	H0001	17.5	428.50	427.50	5.71	Concrete	525	0.15	Existing	1	P7351	0
I7672	P7484	N251	54.5	447.70	444.50	5.87	Concrete	450	0.15	Existing	1	P7484	0
I1111	P5530	P5528	3	429.30	429.10	6.67	Concrete	300	0.15	Existing	1	P5530	0
I5036	P5583	P5581	9.3	459.30	458.90	4.3	Concrete	375	0.15	Existing	1	P5583	0
I5954	P5581	P5582	13.3	458.90	458.64	1.93	Concrete	375	0.15	Existing	1	P5581	0
I5955	P5582	P5573	12	458.64	458.07	4.79	Concrete	375	0.15	Existing	1	P5582	0
I5953	P5573	P5578	42.3	458.07	450.80	17.17	Concrete	375	0.15	Existing	1	P5573	0
I5952	P5578	P5579	11.1	450.80	450.40	3.6	Concrete	375	0.15	Existing	1	P5578	0
I5948	P5579	P5580	14.2	450.40	450.00	2.82	Concrete	375	0.15	Existing	1	P5579	0
I5949	P5580	P5574	13.1	450.00	449.81	1.42	Concrete	375	0.15	Existing	1	P5580	0
I6488	H0705	P5292	3.81	414.68	414.48	5.25	Concrete	450	0.15	Existing	1	H0705	0

APPENDIX F

CATCHMENT 22 RESULTS

PIT / NODE DETAILS				Version 7		
Name	Max HGL	Max Surface	Max Pond	Min	Overflow	Constraint
		Flow Arriving	Volume	Freeboard	(cu.m/s)	
		(cu.m/s)	(cu.m)	(m)		
P5318	418.76	0.097	0	1.28	0.039	Inlet Capacity
P5317	417.52	0.032	0	1.43	0.006	Inlet Capacity
P5326	417.47	0.04	0	1.16	0.008	Inlet Capacity
P5319	417.34	0.061	0	0.84	0.017	Inlet Capacity
P5322	412.9	0.129	0	0.61	0.061	Inlet Capacity
P5315	410.39	0.107	0	0.46	0.047	Inlet Capacity
P5311	408.09	0.107	0	0.55	0.047	Inlet Capacity
P5314	407.31	0.048	0	0.89	0.01	Inlet Capacity
P5313	405.65	0.048	0	0.51	0.01	Inlet Capacity
P5304	402.44	0.08	0	0.69	0.029	Inlet Capacity
P5307	400.69	0				
P5305	399.46	0.048	0	0.41	0.01	Inlet Capacity
P5231	396.27	0				
P5233	395.98	0				
N104	393.31	0				
N107	391.35	0				
P5163	390.3	0				
P5151	388.81	0				
N142	388.61	0				
N143	386.76	0				
P5150	384.71	0				
P5325	418.49	0.097	0	0.89	0.039	Inlet Capacity
P5321	420.89	0.08	0	1.91	0.029	Inlet Capacity
P5323	420.46	0.127	0	0.75	0.06	Inlet Capacity
P5553	426.76	0.048	0	0.48	0.01	Inlet Capacity
P5556	426.36	0.215	0	0.93	0.125	Inlet Capacity
P5320	423.17	0.215	0	0.83	0.125	Inlet Capacity
P5312	407.08	0.107	0	1.1	0.047	Inlet Capacity
P5310	406.97	0.107	0	1	0.047	Inlet Capacity
P5309	406.35	0.069	0	1.18	0.021	Inlet Capacity
P5324	412.9	0.032	0	0.63	0.006	Inlet Capacity
P2654	402.53	0.08	0	0.66	0.029	Inlet Capacity
P2655	402.04	0.03	0	0.75	0	None
P5300	401.95	0.08	0	0.84	0.029	Inlet Capacity
P5301	401.61	0.033	0	0.8	0.007	Inlet Capacity
P5299	399.01	0.064	0	0.58	0.019	Inlet Capacity
P5235	395.85	0				
P5236	395.64	0				
N113	393.16	0				
N114	392.95	0				
N133	391.45	0				
P5308	407.04	0.064	0	0.66	0.019	Inlet Capacity
H0031	388.39	0.08	0	10.33	0.029	Inlet Capacity
P5296	387.07	0				
P5237	396.92	0.097	0	0.8	0.039	Inlet Capacity
P5234	396.73	0.016	0	1.2	0.003	Inlet Capacity
P5239	397.63	0.03	0	0.9	0.006	Inlet Capacity
P5238	397.47	0.016	0	1.03	0.003	Inlet Capacity
P5303	402.06	0.064	0	0.91	0.019	Inlet Capacity

PIT / NODE DETAILS				Version 7		
Name	Max HGL	Max Surface	Max Pond	Min	Overflow	Constraint
		Flow Arriving	Volume	Freeboard	(cu.m/s)	
		(cu.m/s)	(cu.m)	(m)		
P5302	401.95	0.066	0	1.23	0.019	Inlet Capacity
P5306	401.7	0.016	0	1.01	0.003	Inlet Capacity
P7337	401.69	0.016	0	0.66	0.003	Inlet Capacity
P5230	393.35	0.097	0	0.65	0.039	Inlet Capacity
P5226	392.28	0.047	0	0.66	0.01	Inlet Capacity
P5229	392.12	0.063	0	0.68	0.018	Inlet Capacity
P5227	393.79	0.063	0	0.68	0.018	Inlet Capacity
P5228	393.6	0.129	0	0.54	0.061	Inlet Capacity
P5160	388.71	0.129	0	0.79	0.061	Inlet Capacity
P5155	387.13	0.016	0	0.87	0.003	Inlet Capacity
N153	386.85	0				
P5161	386.18	0				
P5162	384.68	0				
P5156	387.15	0.018	0	0.93	0.004	Inlet Capacity
P5153	386.15	0.016	0	0.74	0.003	Inlet Capacity
P5152	386.81	0.016	0	0.93	0.003	Inlet Capacity
P5149	386.77	0.016	0	0.9	0.003	Inlet Capacity
P5159	387.19	0.08	0	0.61	0.029	Inlet Capacity
N139	386.76	0				
P5157	387.09	0.08	0	0.67	0.029	Inlet Capacity
P5154	386.03	0.08	0	0.69	0.029	Inlet Capacity
P5554	429.45	0	0	1.75	0	None
P5316	417.75	0				

SUB-CATCHMENT DETAILS							
Name	Max	Paved	Grassed	Paved	Grassed	Supp.	Due to Storm
	Flow Q	Max Q	Max Q	Tc	Tc	Tc	
	(cu.m/s)	(cu.m/s)	(cu.m/s)	(min)	(min)	(min)	
SUB 3	0.097	0.091	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 2	0.032	0.03	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 10	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 11	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 17	0.129	0.121	0.01	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 16	0.107	0.101	0.008	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 15	0.107	0.101	0.008	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 24	0.048	0.045	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 23	0.048	0.045	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 42	0.08	0.076	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 33	0.048	0.045	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 4	0.097	0.091	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 6	0.08	0.076	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 5	0.032	0.03	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 9	0.048	0.045	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 8	0.215	0.202	0.016	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 7	0.215	0.202	0.016	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 13	0.107	0.101	0.008	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 14	0.107	0.101	0.008	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 22	0.064	0.061	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 18	0.032	0.03	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 20	0.08	0.076	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 36	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 35	0.08	0.076	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 34	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 32	0.064	0.061	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 21	0.064	0.061	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 25	0.08	0.076	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

SUB-CATCHMENT DETAILS							
Name	Max Flow Q (cu.m/s)	Paved Max Q (cu.m/s)	Grassed Max Q (cu.m/s)	Paved Tc (min)	Grassed Tc (min)	Supp. Tc (min)	Due to Storm
SUB 27	0.097	0.091	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 29	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 28	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 30	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 37	0.064	0.061	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 39	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 41	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 40	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 43	0.097	0.091	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 49	0.032	0.03	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 50	0.032	0.03	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 51	0.032	0.03	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 52	0.129	0.121	0.01	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 54	0.129	0.121	0.01	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 56	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 57	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 59	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 60	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 61	0.016	0.015	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 65	0.08	0.076	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 66	0.08	0.076	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

PIPE DETAILS					
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)	
I4971	0.057	3.7	418.442	417.519	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5796	0.083	0.7	417.483	417.47	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5797	0.153	1	417.356	417.339	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5792	0.46	5.2	416.693	412.896	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5790	0.552	5.9	412.223	410.394	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5791	0.611	5.5	409.684	408.087	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4973	0.671	5.4	407.399	407.307	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4974	0.708	5.3	406.604	405.654	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5789	0.955	5.9	404.842	402.435	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5786	1.005	5.9	401.596	400.688	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5785	1.029	5.8	400.688	399.464	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5787	1.065	6	398.587	396.311	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I6483	1.065	7.4	396.265	395.984	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5743	1.065	5.3	395.984	393.347	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5737	1.127	6.6	393.308	391.353	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5734	1.149	5.6	391.353	390.593	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4948	1.149	7	390.3	388.806	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5689A	1.569	2.8	388.806	388.633	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5689D	1.629	3.1	388.605	386.756	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5689C	1.723	2.9	386.756	385.852	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5799	0.057	3.7	418.171	417.47	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5794	0.051	3.3	420.574	420.458	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5793	0.294	5.1	419.734	417.339	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
II5931	0.038	2.5	426.453	426.355	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5800	0.128	3.8	426.007	423.171	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5795	0.217	4.6	422.666	420.458	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4976	0.061	1.2	406.975	406.971	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5788	0.121	3.4	406.601	406.351	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I6432	0.213	3.9	405.934	405.654	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

PIPE DETAILS					
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)	
I5798	0.026	0.2	412.899	412.896	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I3870	0.051	2	402.244	402.043	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4961B	0.113	1	401.962	401.954	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4960	0.164	2.2	401.648	401.605	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5784	0.19	3.9	401.173	399.007	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4957	0.235	4.6	398.551	395.85	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5742	0.331	3	395.85	395.686	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5741	0.331	4	395.643	393.202	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5736A	0.356	5.7	393.163	392.955	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5736B	0.412	4.8	392.955	391.455	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5732	0.436	5.3	391.449	388.806	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4975	0.046	4	406.713	406.351	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
Pipe230	0.051	3.7	388.068	387.068	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4953	0.057	1.4	396.749	396.735	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4954	0.096	4	396.35	395.85	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4956	0.024	1.5	397.476	397.466	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4955	0.027	2.8	397.269	396.735	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4961A	0.046	0.4	402.044	402.043	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5783	0.046	2.5	401.643	401.605	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4959	0.013	0.3	401.69	401.69	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4958	0.026	3.2	401.358	400.688	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4952	0.057	3.2	393.09	392.955	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4949	0.038	3.5	391.958	391.449	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4950	0.045	3.7	391.878	391.353	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5733	0.045	2.7	393.478	393.378	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5738	0.068	2.6	393.308	393.308	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I6426	0.068	0.7	388.607	388.605	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
Pipe211	0.013	1.9	387.043	386.854	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5691B	0.026	2.6	386.854	386.181	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

PIPE DETAILS					
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)	
I5687	0.051	4.4	386.181	384.676	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5691A	0.014	1.9	387.044	386.854	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4943	0.013	2.2	385.924	384.676	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4945	0.013	0.6	386.768	386.767	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4944	0.026	2.4	386.445	386.181	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5685A	0.051	2.7	386.885	386.756	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5685B	0.103	1.3	386.756	386.756	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4947	0.051	2.5	386.791	386.756	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5690	0.051	3.1	385.712	384.713	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5930	0	0	429.45	426.355	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4972	0	0	417.751	417.339	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

APPENDIX G

CATCHMENT 25 RESULTS

PIT / NODE DETAILS				Version 7		
Name	Max HGL	Max Surface	Max Pond	Min	Overflow	Constraint
		Flow Arriving	Volume	Freeboard	(cu.m/s)	
		(cu.m/s)	(cu.m)	(m)		
H0657	447.48	0.15		0.65		None
N251	445.64	0				
P5533	444.13	0.172	0	1.01	0.092	Inlet Capacity
P5532	439.9	0				
N257	439.16	0				
N258	435.16	0				
P5528	429.64	0.096	0	0.63	0.039	Inlet Capacity
H0001	427.81	0				
H0658	474.76	0.15		0.44		None
P5538	465.17	0.079	0	1.11	0.028	Inlet Capacity
P5534	462.71	0				
P5540	462.66	0.143	0	0.15	0.072	Inlet Capacity
P5539	462.06	0.158	0	0.44	0.082	Inlet Capacity
P5535	457.62	0				
P5537	451.31	0.048	0	0.69	0.01	Inlet Capacity
P5536	446.82	0.062	0	0.42	0.017	Inlet Capacity
H0660	421.85	1.257		0.34		None
P5524	421.82	0.141	0	0.87	0.07	Inlet Capacity
P5522	421.72	0.096	0	0.82	0.039	Inlet Capacity
H0659	418.17	0				
P5254	390.9	0.096	0	0.62	0.039	Inlet Capacity
P5250	390.62	0.096	0	1	0.039	Inlet Capacity
P5249	390.3	0.077	0	0.88	0.027	Inlet Capacity
P5248	390.15	0.112	0	0.98	0.05	Inlet Capacity
P5251	389.73	0.143	0	1.05	0.072	Inlet Capacity
N269	386.92	0				
P5256	391.61	0.096	0	0.36	0.039	Inlet Capacity
P5253	391.19	0				
P5259	396.53	0.208	0	0.32	0.12	Inlet Capacity
P5263	395.84	0.12	0	0.33	0.055	Inlet Capacity
P5262	395.27	0.064	0	1.04	0.019	Inlet Capacity
P5261	394.22	0.174	0	1.83	0.094	Inlet Capacity
P5266	393.94	0.143	0	1.51	0.072	Inlet Capacity
P5260	392.22	0				
P5265	395.29	0.05	0	0.97	0.011	Inlet Capacity
P5267	394.14	0.116	0	1.38	0.053	Inlet Capacity
P5257	394.1	0				
P5264	394.05	0.112	0	1.27	0.05	Inlet Capacity
P5268	393.89	0.144	0	0.9	0.073	Inlet Capacity
P5269	394.38	0.174	0	0.51	0.094	Inlet Capacity
P5258	394.15	0				
P5271	396.65	0.174	0	3.08	0.094	Inlet Capacity
P5276	396.5	0.189	0	2.65	0.105	Inlet Capacity
P5270	396.12	0				
P5272	402.52	0.36	0	0.09	0.24	Inlet Capacity
P5279	399.59	0.24	0	0.22	0.144	Inlet Capacity
P5277	398.92	0.033	0	1.49	0.007	Inlet Capacity
P5278	397.89	0.321	0	2.33	0.208	Inlet Capacity
P5273	397.59	0				

PIT / NODE DETAILS				Version 7		
Name	Max HGL	Max Surface Flow Arriving (cu.m/s)	Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint
P5275	398.83	0.143	0	1.17	0.072	Inlet Capacity
P5274	398.79	0.143	0	0.88	0.072	Inlet Capacity
P5281	405.33	0.679	0	0.6	0.508	Inlet Capacity
P5280	404.13	0.508	0	0.57	0.36	Inlet Capacity
P5283	402.23	0				
P5285	405.55	0.861	0	0.82	0.679	Inlet Capacity
P5284	404.98	0.302	0	0.85	0.194	Inlet Capacity
P5288	402.83	0				
P5286	404.08	0.401	0	0.47	0.272	Inlet Capacity
P5282	402.95	0.459	0	1.12	0.321	Inlet Capacity
P5291	414.57	1.041	0	0.78	0.861	Inlet Capacity
N209	414.2	0				
N208	414.1	0				
P5289	413.76	0				
P5290	412.96	0				
P5287	410.27	0				
P5293	415.2	0.174	0	0.69	0.094	Inlet Capacity
N210	414.1	0				
P5294	414.52	0.05	0	0.98	0.011	Inlet Capacity
P5516	463.42	0.206	0	0.56	0.118	Inlet Capacity
K0038	461.9	0				
P5517	442.4	0.206	0	0.45	0.118	Inlet Capacity
P5520	440.7	0				
K0039	440.3	0				
P5518	443.2	0.127	0	0.28	0.06	Inlet Capacity
P5519	442.61	0				
P5521	443.17	0.127	0	0.72	0.06	Inlet Capacity
P5525	422.36	0.11	0	0.55	0.048	Inlet Capacity
P5523	422.11	0.05	0	0.3	0.011	Inlet Capacity
P5527	435.04	0.237	0	0.46	0.142	Inlet Capacity
P5526	433.62	0.158	0	0.43	0.082	Inlet Capacity
P5529	435.38	0.064	0	0.78	0.019	Inlet Capacity
P5531	440.05	0.092	0	0.84	0.036	Inlet Capacity
P5541	418.88	0.158	0	0.6	0.082	Inlet Capacity
N230	418.34	0				
P5542	417.89	0				
P5295	417.1	0.158	0	0.7	0.082	Inlet Capacity
P5546	421.56	0.143	0	1.41	0.072	Inlet Capacity
P5548	421.51	0.152	0	0.92	0.078	Inlet Capacity
P5545	418.68	0				
P5552	439.53	0.112	0	0.37	0.05	Inlet Capacity
P5549	438.78	0.112	0	0.45	0.05	Inlet Capacity
P5550	438.2	0				
P5551	438.02	0				
P5558	430.79	0.083	0	0.64	0.03	Inlet Capacity
N237	430.15	0				
P5559	428.65	0.143	0	0	0.373	Outlet System
P2553	428.17	0.373	0	0.23	0.25	Inlet Capacity
P5557	427.28	0.25	0	0.94	0.152	Inlet Capacity

PIT / NODE DETAILS				Version 7		
Name	Max HGL	Max Surface	Max Pond	Min	Overflow	Constraint
		Flow Arriving	Volume	Freeboard	(cu.m/s)	
		(cu.m/s)	(cu.m)	(m)		
P5547	423.95	0				
P5543	422.25	0				
P5544	421.51	0				
P5560	431.11	0.158	0	0.6	0.082	Inlet Capacity
N235	430.69	0				
P5561	431.36	0.158	0	0.51	0.082	Inlet Capacity
P5563	432.99	0.05	0	0.26	0.011	Inlet Capacity
P5562	432.62	0.143	0	0.67	0.072	Inlet Capacity
P2555	432.21	0.155	0	0.27	0.08	Inlet Capacity
P2554	430.55	0.11	0	0.4	0.048	Inlet Capacity
P5567	437.14	0.158	0	0.53	0.082	Inlet Capacity
N244	435.49	0				
N245	434.08	0				
P5566	433.35	0				
P5564	433.12	0.143	0	0.17	0.072	Inlet Capacity
P2556	433.05	0.143	0	0.31	0.072	Inlet Capacity
P5571	444.55	0.081	0	1.18	0.029	Inlet Capacity
P5572	444.28	0.127	0	0.94	0.06	Inlet Capacity
P5570	443.56	0				
P5568	437.71	0.081	0	0.55	0.029	Inlet Capacity
P5565	433.68	0.05	0	0.67	0.011	Inlet Capacity
P5576	452.12	0.112	0	0.71	0.05	Inlet Capacity
P5575	450.95	0				
P5574	449.99	0				
P5569	445.63	0.081	0	0.59	0.029	Inlet Capacity
P5577	451.8	0.112	0	1.08	0.05	Inlet Capacity
P7353	429.83	0.202	0	0.28	0.115	Inlet Capacity
P7352	429.17	0.304	0	0.53	0.195	Inlet Capacity
P7351	429.13	0.195	0	0.21	0.11	Inlet Capacity
P7484	448.19	0.312	0	0.55	0.201	Inlet Capacity
P5530	429.64	0				
P5583	459.3	0				
P5581	459.19	0.127	0	1.13	0.06	Inlet Capacity
P5582	459.11	0.096	0	0.72	0.039	Inlet Capacity
P5573	458.15	0				
P5578	451.49	0.064	0	0.68	0.019	Inlet Capacity
P5579	451.25	0.064	0	0.25	0.019	Inlet Capacity
P5580	450.84	0.096	0	0.3	0.039	Inlet Capacity
H0705	415.21	1.368	0	0.93	1.218	Inlet Capacity

PIPE DETAILS							
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm		
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)			
SUB 1	0.15	0.13	0.03	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 75	0.064	0.063	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 70	0.096	0.093	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 2	0.15	0.13	0.03	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 80	0.079	0.077	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 82	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 81	0.158	0.154	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 79	0.048	0.047	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 78	0.062	0.061	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 4	0.083	0.081	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 66	0.141	0.138	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 64	0.096	0.093	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 3	0.125	0.121	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 17	0.096	0.093	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 14	0.096	0.093	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 12	0.112	0.109	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 15	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 18	0.096	0.093	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 21	0.05	0.049	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 25	0.064	0.063	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 24	0.064	0.063	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 23	0.174	0.17	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 28	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 27	0.05	0.049	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 29	0.096	0.093	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 26	0.112	0.109	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 30	0.112	0.109	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 31	0.174	0.17	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 33	0.174	0.17	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

PIPE DETAILS							
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm		
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)			
SUB 38	0.189	0.184	0.008	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 34	0.05	0.049	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 41	0.081	0.079	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 39	0.033	0.032	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 40	0.096	0.093	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 37	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 36	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 43	0.174	0.17	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 42	0.158	0.154	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 47	0.158	0.154	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 46	0.298	0.231	0.091	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 48	0.401	0.347	0.08	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 44	0.174	0.17	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 53	0.189	0.184	0.008	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 55	0.174	0.17	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 56	0.05	0.049	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 58	0.206	0.2	0.008	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 59	0.096	0.093	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 7	0.096	0.093	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 60	0.127	0.123	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 63	0.127	0.123	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 67	0.05	0.049	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 65	0.05	0.049	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 69	0.237	0.231	0.01	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 68	0.158	0.154	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 71	0.064	0.063	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 73	0.081	0.079	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 83	0.158	0.154	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 57	0.158	0.154	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

PIPE DETAILS							
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm		
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)			
SUB 88	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 90	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 94	0.112	0.109	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 91	0.112	0.109	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 96	0.05	0.049	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 97	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 8	0.035	0.034	0.001	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 95	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 98	0.158	0.154	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 99	0.158	0.154	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 101	0.05	0.049	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 100	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 10	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 9	0.11	0.107	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 105	0.158	0.154	0.007	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 102	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 11	0.143	0.14	0.006	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 109	0.081	0.079	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 110	0.127	0.123	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 106	0.081	0.079	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 103	0.05	0.049	0.002	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 114	0.112	0.109	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 107	0.081	0.079	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 115	0.112	0.109	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 124	0.189	0.184	0.008	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 123	0.081	0.079	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 122	0.189	0.184	0.008	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 125	0.312	0.303	0.013	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 119	0.127	0.123	0.005	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

PIPE DETAILS							
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm		
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)			
SUB 120	0.096	0.093	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 116	0.064	0.063	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 117	0.064	0.063	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 118	0.096	0.093	0.004	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
SUB 5	0.079	0.077	0.003	5	13	0	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

PIPE DETAILS					
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)	
I5064A	0.15	5.5	447.197	445.645	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5064B	0.261	5.4	445.645	444.275	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5924	0.307	6	443.6	439.899	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5062A	0.729	5.2	439.899	439.17	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5062B	0.78	6.2	439.156	435.158	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5062C	0.824	6.5	435.158	429.637	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5780	0.878	1.9	429.315	427.815	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5070	0.15	6.5	474.474	465.171	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5069	0.2	7.5	464.653	462.708	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I6440	0.2	1.8	462.708	462.663	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I6439	0.271	2.4	462.204	462.062	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5068	0.345	7.1	461.487	459.144	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5067	0.345	7.9	457.617	451.307	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5926	0.38	6.8	450.638	446.822	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5066	0.424	6.7	446.152	439.899	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5919A	1.257	1	421.814	421.819	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5919B	1.324	1.1	421.705	421.722	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5918	1.368	6.2	420.155	418.17	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I1112	0.057	1.9	390.62	390.62	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5756	0.114	1.9	390.36	390.3	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5757	0.172	1.1	390.161	390.151	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5751	0.233	2.7	389.777	389.73	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5754	0.304	6.4	389.153	386.918	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5752	0.057	2.7	391.306	391.191	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5753	0.057	2	391.191	390.3	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5759	0.088	2.4	396.264	395.841	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5008	0.101	5.7	395.475	395.269	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5009	0.17	5.6	394.832	394.218	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5011	0.25	1.6	394.029	393.943	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

PIPE DETAILS					
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)	
I5010	0.321	4.7	393.38	392.216	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5758	3.361	8.3	392.216	386.918	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5764	0.039	0.4	395.275	395.269	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5763A	0.064	0.6	394.115	394.105	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5763B	0.137	1.2	394.105	394.049	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5761	0.2	1.3	393.929	393.895	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5760	0.262	6.3	393.241	392.216	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5012	0.08	1.3	394.162	394.151	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5762	0.08	0.7	394.151	394.105	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5767	0.08	0.9	396.518	396.499	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5765	0.164	2.7	396.159	396.116	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5768	2.781	7.1	396.116	392.385	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5769	0.12	3.8	402.137	399.586	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5016	0.126	5.2	399.213	398.917	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5017	0.126	4.9	398.549	397.886	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5013	0.174	2	397.591	397.591	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5015	2.481	7.9	397.591	396.116	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5766	0.071	0.6	398.801	398.793	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5014	0.143	4.9	398.407	396.116	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5018	0.171	4.4	404.914	404.128	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5019	0.222	4.7	403.611	402.23	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5770	2.31	7.9	402.23	397.591	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I2021	0.182	3.3	405.173	404.984	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5022	0.183	6.5	404.537	402.831	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5774	1.95	4.3	402.831	402.372	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5020	0.128	4.1	403.722	402.947	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5771	0.208	5.5	402.442	402.23	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5779	0.182	1.9	414.298	414.2	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5778B	0.5	1.2	414.2	414.103	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

PIPE DETAILS					
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)	
I5778C	0.5	1.8	414.103	413.816	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5775	1.768	9.8	413.759	412.96	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5773	1.768	10	412.957	410.272	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5772	1.768	9.2	410.272	402.831	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5777A	0.08	1.1	414.882	414.103	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5777B	0.119	1.3	414.103	414.103	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5776	0.039	2.6	414.279	414.103	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5917	0.088	4.3	463.099	461.899	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4845	0.088	6.5	441.883	440.704	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4844	0.191	4.4	440.704	440.304	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4848	0.067	3.7	442.883	442.608	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4846	0.134	4.5	442.608	440.708	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I4847	0.067	3.8	442.889	442.608	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5920	0.062	2.3	422.121	422.113	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5921	0.086	2.3	421.859	421.819	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5073	0.095	4.6	434.579	433.622	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5071	0.17	4.8	433.166	427.815	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5923	0.046	2	435.158	435.158	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5061	0.056	5.8	439.758	439.158	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5027	0.075	3.6	418.562	418.344	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5026B	1.375	6.1	418.344	417.885	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5025	1.375	5.3	417.885	417.097	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5023	1.449	5.3	416.203	413.903	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5028	0.071	0.6	421.531	421.512	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5927	1.299	6.2	420.458	418.681	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5026A	1.299	5.1	418.681	418.381	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5039	0.062	3.9	439.206	438.775	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5038	0.124	3.1	438.45	438.216	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5929	0.124	3.2	438.202	438.017	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

PIPE DETAILS					
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)	
I5935	0.052	3.8	430.469	430.152	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5932	0.19	4.5	430.152	428.647	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I3693	1.074	2.4	428.213	428.174	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5034	1.097	4.2	427.386	427.279	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5031	1.162	6.2	426.331	423.972	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5030	1.162	6.7	423.952	422.254	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5029	1.162	6.7	422.254	421.512	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5928	1.162	4.2	421.512	421.512	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5933	0.075	3.3	430.798	430.691	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5934	0.151	2.7	430.691	430.191	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5033	0.075	4.4	430.96	430.691	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5936	0.039	5.2	432.716	432.624	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I3696B	0.976	2.2	432.235	432.213	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I3695	1.047	6.9	431.316	430.551	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I3694	1.106	6.1	429.645	428.647	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5938	0.075	3.4	436.761	435.489	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5939	0.075	3.4	435.489	434.089	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5940	0.075	3.8	434.082	433.35	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5941	0.075	3.3	433.35	433.124	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5035	0.146	0.9	433.06	433.046	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I3696A	0.869	2.2	432.637	432.624	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5944	0.052	1.7	444.286	444.28	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5945	0.119	3.5	443.947	443.558	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5946	0.566	6.9	443.558	437.706	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5942	0.617	6	436.811	433.683	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5937	0.655	2.3	433.273	433.046	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5956	0.062	4.5	451.832	450.947	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5951	0.125	3.9	450.947	449.992	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5950	0.397	6.8	449.992	445.632	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

PIPE DETAILS					
Name	Max Q	Max V	Max U/S	Max D/S	Due to Storm
	(cu.m/s)	(m/s)	HGL (m)	HGL (m)	
I5943	0.448	5.9	444.793	443.563	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5947	0.062	4.2	451.469	450.947	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5783	0.087	3.6	429.511	429.169	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I7582	0.179	0.6	429.145	429.129	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5782A	0.253	4.9	428.651	427.815	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I7672	0.111	4.2	447.799	445.645	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I1111	0	0	429.637	429.637	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5036	0	0	459.297	459.194	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5954	0.067	1	459.124	459.111	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5955	0.124	3.9	458.765	458.19	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5953	0.124	6.6	458.15	451.492	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5952	0.17	1.5	451.312	451.252	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5948	0.215	1.9	450.962	450.84	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I5949	0.272	2.8	450.303	450.117	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2
I6488	0.156	1.7	414.933	414.933	AR&R 5 year, 5 minutes storm, average 116 mm/h, Zone 2

APPENDIX H

ESTIMATED CONSTRUCTION COSTS

TOOWOOMBA CITY COUNCIL

DESIGN & SURVEY BRANCH

12 October 2005

Construction costs per metre of pipe

Item	Average Cost ($)
300	360
375	380
450	400
525	440
600	490
675	520
750	600
825	700
900	750
1050	900
RCBC 900 * 600	720
Manholes	4550

Additional excavation costs

Item	Average Cost ($) m^3
Fill Material	17
Excavation	5
Removal of Material	6.5
Compacted Fill	5

G.A. NATALIER
SUPERVISOR DESIGN