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Faculty of Engineering and Surveying

Diversion of Stormwater First Flush: An Alternative Method of Managing Pollution to Urban Waterways

A dissertation submitted by

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Abstract

The problem of stormwater runoff as a major contributor to urban waterway pollution is increasingly being recognised throughout the industry. Additionally, the stormwater first flush, either the initial period of runoff during a storm event or a seasonal first flush occurring after a long dry period, can contain higher pollutant loadings than the remainder of the stormwater runoff. In order to address these problems, a move towards sustainable development and effects based management is emerging, which leads to the need for efficient and effective methods of managing pollution within a catchment.

This dissertation looks at the diversion of stormwater first flush into the existing wastewater network as an alternative option to that of the containment of wastewater overflows for managing pollution to urban waterways. A high level desktop assessment of the Norman Creek catchment in Brisbane was undertaken to investigate the concept of the stormwater first flush diversion into the existing wastewater network.

It was found that a total of 23 extended dry periods occurred from January 2013 to July 2015, and all of these were found to be followed by a small storm event. This could be thought of as 23 small seasonal first flush events. Five of these storm events were simulated in a calibrated wastewater network model to assess areas within the network that may have spare capacity. A more detailed assessment was then undertaken to identify three potential diversion locations. The inflow expected from a stormwater diversion into the wastewater network was simulated with the addition of fixed 100 L/s, 200 L/s and 500 L/s inflows at each of the selected diversion locations in the model.

The model results indicated there is existing capacity within the Norman Creek wastewater network for flows of up to 200 L/s to be diverted from the stormwater system into the existing wastewater network at two of the diversion locations, and up to 100 L/s may be acceptable at the third location.
List of Abbreviations
ADWF – Average dry weather flow
ANZECC – Australia and New Zealand
BCC – Brisbane City Council
BOD – Biological oxygen demand
BOM – Bureau of Meteorology
CALTRANS – California Department of Transportation
DO – Dissolved oxygen
dwf – Dry weather flow
EP – Equivalent persons
EPP Water – Environmental Protection (Water) Policy 2009
GIS – Geographic information system
HGL – Hydraulic grade line
I/I – Infiltration and inflow
L/EP/day – Litres/ equivalent person/ day
NRDC – Natural Resources Defence Council
NWQMS – National Water Quality Management Strategy
PWWF – Peak wet weather flow
RDII – Rainfall dependant infiltration and inflow
SEQ – South East Queensland
TSS – Total suspended solids
UCLA – University of California at Los Angeles
UQ – University of Queensland
US-EPA – Environmental Protection Agency (United States)
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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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1 Introduction

One cause of pollution to waterways and poor river quality is the pollution attributed to stormwater runoff. Urban stormwater runoff is increasingly being recognised as one of the most significant contributors to water pollution (NRDC, 1999; LeBoutillier, Kells, & Putz, 2000; US-EPA, 1997; EPP Water, 2010). The management of stormwater has traditionally been focused on reducing or eliminating flooding in urban areas. Rainfall and the resulting runoff is generally diverted into, and through, the stormwater system as quick as possible in order to reduce quantity and velocity problems (NRDC, 1999). Little consideration was given for the effect on the quality of the waterway; however, focus is beginning to shift to include water quality aspects of the stormwater discharge.

The initial period of stormwater runoff can contain significantly higher pollutant loadings than the remainder of the runoff. This is known as stormwater first flush (Bertrand-Krajewski, Chebbo, & Saget, 1998; Lee, Bang, Ketchum, Choe, & Yu, 2002). Building on the first flush concept, extended periods with no rainfall can cause significant pollutant build-up to occur over a catchment. The initial storm event after this dry period can be associated with having increased pollutant concentrations present in the resulting stormwater discharge. This phenomenon can be described as a seasonal first flush (Lee, Laua, Kayhanian, & Stenstrom, 2004).

Stormwater is generally discharged directly into a waterway and, in terms of water quality, is seldom managed. Therefore, it makes sense to investigate the containment and treatment of stormwater first flush in order to reduce pollution to urban waterways.

This dissertation looks at the diversion of stormwater first flush as an alternative to the containment of wastewater overflows for managing pollution to urban waterways.

The focus area of the dissertation is the Norman Creek Catchment located in Brisbane.

1.1 Background

A traditional view towards managing urban waterway pollution focused on overflows from wastewater networks. Over time, significant work to improve wastewater networks and meet conveyance capacity or spill frequency targets has reduced overflows. However, unacceptable levels of pollution are still being observed in urban waterways. Further reductions of wastewater overflows potentially have very
high costs and may provide little benefit to the waterway since they may not be directly based on environmental or social metrics.

Urban stormwater runoff is increasingly being recognised as one of the most significant contributors to water pollution (US-EPA, 1997). Additionally, the effects of stormwater pollution can be exacerbated during the initial stages of a storm event, or when small storm events occur after long dry spells, with the rainfall runoff containing a higher pollutant loading (Lee, et al., 2004). These occurrences can be described as “stormwater first flush”. Diversion of stormwater first flush may provide an alternate, cost effective solution to waterway pollution, instead of further reducing wastewater overflows.

1.2 Progression of Wastewater Overflow Management

Water utilities traditionally designed wastewater infrastructure to convey a peak wet weather flow (PWWF) without spilling to the environment. The PWWF is quite often based on a factor of the average dry weather flow (ADWF), with the ADWF representing the amount of wastewater generated within a catchment during a standard dry dry (no rainfall). This is a historical approach to managing wastewater overflows that is still adopted by many utilities, particularly throughout Queensland and other parts of Australia.

This design standard for sizing wastewater infrastructure has been progressed around the world to focus on spill volumes and spill frequency, basically allowing a certain amount of overflow from the network before it is considered to be a problem. This is an improvement on the multiples of DWF management approach as it recognises that, in some cases, the wastewater overflow may not be causing a significant problem to the receiving environment.

These management approaches promote the idea that wastewater overflows are the main contributor to waterway pollution; above a certain criteria, all overflows from the wastewater network must be contained. They can be considered as outputs approaches.

The effects based management approach is outcomes focused, using data collected in the field to set goals based on specific drivers relevant to the waterway catchment area. It aims to individually assess wastewater overflows and consider the actual effect on the waterway, such as poor river quality during minor storms or aesthetic impact due to solids/fungus, in order for the source of the problems to be found. This leads to the design of beneficial and cost-effective solutions to resolve the identified
problems. A number of larger water utilities are beginning to move towards an effects based management approach to wastewater overflows.

1.3 Project Aims

This project aims to identify stormwater first flush as a significant contributor to urban waterway pollution. Research will be based around wastewater network overflows, stormwater discharges, and the stormwater first flush phenomenon. The diversion of stormwater first flush will be introduced as a method of managing pollution to urban waterways; alternative to the traditional focus of containing wastewater overflows.

A high level desktop assessment to determine the viability of a stormwater diversion option within the Norman Creek catchment will be undertaken. Historic data will be utilised to increase the relevance of the dissertation results. The following steps were taken for the desktop assessment:

- Assessment of rainfall data to select specific storm events.
- Analysis of the impact of selected storm events on the wastewater network to determine the remaining capacity in the wastewater network.
- Determine and assess potential locations for diversion of stormwater into the wastewater network.
- Report on conclusions from the dissertation.

![Figure 1-1: Progression of Wastewater Overflow Management](image)
2 Background Information

The following background information that is relevant to this dissertation was researched and is summarised in the following sections:

- Wastewater network overflows.
- Urban stormwater discharge and first flush.
- Relevant case studies.

2.1 Wastewater Network Overflows

Overflows from the wastewater network exert physical, chemical and biological effects on the receiving environment (NWQMS, 2004). This may lead to human health, environmental and aesthetic impacts. The severity of these impacts is largely dependent on the environment that the discharges occur in.

Sewer overflows will likely contain raw sewage, and as such, may carry disease causing organisms known as pathogens. These pathogens include bacteria, viruses, protozoa and fungi. Faecal coliforms or enterococci are commonly used as indicators of pathogen pollution. The associated diseases may range in severity from gastroenteritis to serious illnesses like cholera, dysentery or hepatitis. People can be exposed to the pathogens by:

- Direct contact to a sewer overflow in parks or streets; or waters related to swimming and boating activities.
- Overflows into drinking water sources.
- Consumption of shellfish harvested from areas contaminated by overflows. (NWQMS, 2004)

Significant environmental impacts may arise from sewer overflows, which may contain a range of pollutants as summarised in Table 2-1.

Table 2-1: Pollutants Found in Stormwater Discharges and Sewer Overflows

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Examples</th>
<th>Sources</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediments</td>
<td>Sand, soil, silt</td>
<td>Streets, lawns, atmospheric deposition, construction activities</td>
<td>Detrimental effects on aquatic insect habitats</td>
</tr>
<tr>
<td>Pollutant</td>
<td>Examples</td>
<td>Sources</td>
<td>Impacts</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------</td>
<td>---------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Nitrogen, Phosphorous</td>
<td>Fertilisers, atmospheric deposition, vehicle exhaust, animal waste, detergents</td>
<td>Eutrophication; Stimulates growth of algae and undesirable aquatic plants, micro-organisms, and invertebrates (e.g. mosquitos)</td>
</tr>
<tr>
<td>Metals</td>
<td>Zinc, cadmium, copper, chromium, arsenic, lead</td>
<td>Vehicles, atmospheric deposition, corroding metal surfaces, industrial areas</td>
<td>Toxic to fish and aquatic insects</td>
</tr>
<tr>
<td>BOD</td>
<td>Grass clippings, leaves, hydrocarbons, human and animal waste</td>
<td>Lawns/gardens, commercial landscaping, human/animal wastes</td>
<td>Reduces dissolved oxygen (DO) levels, affecting fish, insects and micro-organism productivity</td>
</tr>
<tr>
<td>Pathogens</td>
<td>Viruses, bacteria, protozoa</td>
<td>Lawns, roads, leaky sewers and sewer cross-connections, septic systems, human/animal wastes</td>
<td>Serious illness can develop if contact occurs</td>
</tr>
<tr>
<td>Gross pollutants</td>
<td>Rubbish, toilet paper, sanitary items</td>
<td>Households, roads, public places</td>
<td>Impacts the visual amenity of the waterway and can be hazardous to wildlife</td>
</tr>
</tbody>
</table>

Sourced from (NRDC, 1999; NWQMS, 2004; US-EPA, 1999)

Overflows within sewerage networks will usually occur during one of two distinct scenarios:

- **Dry-weather flow** – no impact from rainfall on the network, consists mainly of raw sewage.
- **Wet-weather flow** – Large amounts of rainfall is present in the sewers.

Dry-weather sewer overflows generally occur only if there is a major infrastructure failure, such as a break in a sewer main or a power outage at a pumping station. There is little or no additional flow in the network that is attributable to rainfall, and overflows consist largely of raw sewage. The pollutant concentrations associated with a dry-weather overflow can be much greater than wet-weather overflows and stormwater discharge.
A wet-weather sewer overflow is caused by infiltration and inflow (I/I) into the sewerage network. Groundwater infiltration occurs through faulty connections and damaged pipes. Direct inflow from rainfall can be caused by damaged manholes and illegal connections from household gutters.

### 2.2 Urban Stormwater Discharges

Urban stormwater runoff is increasingly being recognised as one of the most significant contributors to water pollution (NRDC, 1999; LeBoutillier, Kells, & Putz, 2000; US-EPA, 1997; EPP Water, 2010).

The management of stormwater has traditionally been focused on reducing or eliminating flooding in urban areas. Rainfall and the resulting runoff is generally diverted into, and through, the stormwater system as quick as possible in order to reduce quantity and velocity problems (NRDC, 1999). Little consideration was given for the effect on the quality of the waterway; however, focus is beginning to shift to include water quality aspects of the stormwater discharge.

The impervious nature of an urban rainfall catchment poses a great risk to waterways. Not only are higher flows present in the waterway during rainfall, but the increased area for pollutants to collect, accumulate and be washed off leads to high levels of pollution caused by the stormwater discharge. The impacts of urban stormwater pollution may:

- Pollute drinking water sources.
- Fill in navigable waterways with contaminated sediment, leading to increased dredging and spoil disposal costs.
- Contaminate commercial fisheries and the aquatic habitat.
- Pollute beaches and recreational waters.
- Contribute to the eutrophication of a water body.

The pollutants attributable to stormwater discharge and sewer overflows can be similar, and are summarised in Table 2-1.

#### 2.2.1 Stormwater First Flush

The initial period of stormwater runoff can contain significantly higher pollutant loadings than the remainder of the storm event related runoff. This is known as stormwater first flush (Bertrand-Krajewski, Chebbo, & Saget, 1998; Lee, Bang, Ketchum, Choe, & Yu, 2002).

Stormwater first flush is a complex phenomenon that varies significantly between catchments. The term “first flush” is not clearly defined and has caused confusion.
and debate amongst water professionals for many years (Bertrand-Krajewski, Chebbo, & Saget, 1998). In general terms, stormwater first flush indicates that the initial rainfall and resulting runoff contains the main proportion of pollutants.

However, it is not clear at what point a first flush phenomenon is observed – e.g. 50% of total pollutants from a storm event in the first 25% of rainfall? Bertrand-Krajewski, et al. (1998) proposed arbitrary values of 80% of total pollutants within the first 30% (or 30/80 first flush) of total rainfall in order for a first flush phenomenon to be considered to be occurring.

This isn’t to say that every catchment experiences a 30/80 first flush, but this can be a good guideline for determining if a catchment experiences a significant first flush phenomenon after assessing water quality monitoring data. The catchment variables that affect the accumulation and build-up of pollutants in a stormwater discharge are extremely complex and not yet fully understood.

It is important to note that this dissertation is not about predicting pollutant loadings within a specific catchment; nor is it trying to quantify the reduction in pollution associated with diverting stormwater first flush. It is presenting the widely accepted idea that stormwater first flush is detrimental to the environment; reducing the stormwater pollution may provide a better value outcome than simply eliminating sewer overflows.

2.2.2 Seasonal First Flush

Climatic conditions, such as long wet or dry periods, may greatly impact pollutant emissions from urban stormwater discharges. A long dry period causes significant pollutant build-up to occur over a catchment. The initial storm event after this dry period can be associated with having increased pollutant concentrations present in the resulting stormwater discharge. This phenomenon can be described as a seasonal first flush (Lee, Laua, Kayhanian, & Stenstrom, 2004).

In some climates, wet and dry seasons are very well defined, that is, the majority of rainfall across a year will only occur in a few months. The remaining months can consist of relatively small storms occurring after long dry periods. The resulting pollutant concentrations in the urban stormwater discharge caused by these storms can be high. The relationship between the pollutant build-up and time between storm events is shown in Figure 2-1.
The total rainfall associated with these smaller storm events can be relatively minor compared with a large storm event. It can also be considered that the total rainfall from an entire small storm event may be similar (and in most cases less than) the rainfall attributed to the standard stormwater first flush (the initial period of stormwater runoff).

As such, small storm events will be considered to fall into the category of first flush, and will form the basis for assessing the potential for diversion of stormwater first flush into the wastewater network in this dissertation.

2.3 Summary of Stormwater Discharge and Sewer Overflows

The I/I component of wet-weather sewer overflows is significant and should be carefully analysed when looking at the impacts on the environmental values of the overflow location. The large additional flows into the wastewater system caused by the storm event will dilute the pollutant loadings from the sewage. The increased rainfall leads to an increase in stormwater discharge volume, which frequently contains higher pollutant loadings than sewer overflows.

However, a definitive comparison between both stormwater discharges and sewer overflows is difficult to make due to the variability in pollutant concentrations from both (NWQMS, 2004). Ideally, a monitoring program would be set up for a specific location with known issues. The water quality data obtained through the monitoring program would then be used to create a realistic water quality model. Using the
water quality model, pollutant loadings attributable to the stormwater runoff/discharge and sewer overflows could be calculated.

Setting up a monitoring program, assessing the water quality data, creating stormwater and wastewater quality models, and determining specific loadings for a certain catchment can be a lengthy and extremely difficult process (Liu, Egodawatta, & Goonetilleke, 2011; Gunawardena, Egodawatta, Ayoko, & Goonetilleke, 2011; LeBoutillier, Kells, & Putz, 2000; Thomson, et al., 2000).

A summary of typical pollutant loadings found in urban stormwater discharge and domestic wastewater is provided in Table 2-2. It can be seen from this table that there is considerable variance in pollutants associated with both wastewater and stormwater. It can also be seen that, depending on the situation, either stormwater runoff or wastewater may be the main contributor to waterway pollution in terms of having the greatest pollutant loading.

Table 2-2: Typical Pollutant Concentrations in Urban Stormwater Runoff and Domestic Wastewater

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Units</th>
<th>Range</th>
<th>Typical</th>
<th>Range</th>
<th>Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>20 - 2,890</td>
<td>150</td>
<td>100 - 350</td>
<td>200</td>
</tr>
<tr>
<td>Total Phosphorous</td>
<td>mg/L</td>
<td>0.02 - 4.30</td>
<td>0.36</td>
<td>4 - 15</td>
<td>8</td>
</tr>
<tr>
<td>Total Nitrate</td>
<td>mg/L</td>
<td>0.4 - 20.0</td>
<td>2</td>
<td>20 - 85</td>
<td>40</td>
</tr>
<tr>
<td>Lead</td>
<td>mg/L</td>
<td>0.01 - 1.2</td>
<td>0.18</td>
<td>0.02 - 0.94</td>
<td>0.1</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
<td>0.01 - 0.40</td>
<td>0.05</td>
<td>0.03 - 1.19</td>
<td>0.22</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>0.01 - 2.9</td>
<td>0.02</td>
<td>0.02 - 7.68</td>
<td>0.28</td>
</tr>
<tr>
<td>Faecal Coliform</td>
<td># per 100mL</td>
<td>400 - 50,000</td>
<td>$10^6$-$10^8$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sourced from (US-EPA, 1999)

The similarities between both the stormwater runoff and wastewater, along with the potential severity of stormwater first flush, provide a compelling argument for the diversion, containment and treatment of stormwater first flush.

2.4 Case Studies

It was not feasible to conduct any form of environmental monitoring as part of this project due to the extensive amount of time required for any such monitoring programs. Without having existing and specific data in regards to stormwater pollution within the Norman Creek study area, it was considered important to further justify the topic of diversion of stormwater first flush with information from previous
case studies. As such, two case studies were identified as being relevant to this project. There are likely many more relevant case studies, however these were the only two looked at in detail for the purposes of this thesis.

The first case study is of Lota Creek in Brisbane, Australia. Lota Creek is approximately 15 kilometres from the Norman Creek catchment. It looks at the impact of sewer overflows into the creek, however it identifies stormwater runoff to be the major cause of pollution to the creek.

The second case study is a report from the California Department of Transport (CALTRANS). It looks at the results of an extensive study into first flush pollutants. It is noted that the CALTRANS report is aimed at first flush from highways, however the concept can be broadened to apply to catchments with high proportions of impervious areas. The Norman Creek catchment also has a major highway/motorway running through it.

2.4.1 Lota Creek Case Study

The Lota Creek Case Study is a report for the Brisbane City Council (BCC) by Pollard et al. (2004) titled “The Impact of Sewage Overflows to an Urban Creek: A Case Study of Lota Creek in Brisbane”. The aim of this study was to determine impacts of sewage overflows and potential risks to public and ecosystem health in Lota Creek, Brisbane. While this was an intensive study of a single wet-weather event, sufficient hydrological detail – coupled to public and ecosystem health indicators – was obtained, allowing for the information to be translated into other similar coastal environments.

There is a belief that sewage overflows cause significant environmental harm. This leads to expectations for improved sewerage system performance. However this case study shows that stormwater is the main contributor to poor ecological health in the Lota Creek catchment.

2.4.1.1 Lota Creek Case Study: Methodology

The study was conducted in the lower Lota catchment waterways. Overflow monitors were installed on the seven overflow structures in the study area, shown in Figure 2-2. Samples were collected both manually and by auto-samplers during four situations:

- Ambient dry weather event – No rain or overflow in the study area.
- Dry weather with overflow event – Equipment failure as the only cause of overflow.
- Wet weather with overflow event – Water infiltration of sewerage network was the only cause of overflow.
• Wet weather without overflow event – Stormwater not influenced by sewerage overflow.

Figure 2-2: Lota Creek Case Study - Study Area (Pollard, Leeming, Bagraith, Greenway, & Ashbolt, 2004)

The pollutants in the sewage of Lota were characterised to determine its physical, chemical, toxicological and microbiological character. The analytes included: organic and inorganic nutrients, sterol biomarkers, microbial faecal indicators, pathogens indicators (bacteria, viruses, protozoa), toxicants, metals, exotic chemicals, radioisotopes and endocrine disrupters. Pollutants common to both stormwater and sewage were identified to distinguish the impacts of the overflow during the wet-weather event.

Pollard et al. (2004) then determined the ambient water-quality of Lota’s waterways in relation to the pollutants found in the untreated sewage. Wet weather events were infrequent (one in two years), so repetitive event sampling was not possible. Six of the seven overflow structures that were monitored for two years had no impact on the local waterway because they did not overflow.

After the ambient water-quality of the receiving waterway was identified, the changes in the potential risk to ambient public health caused by the overflow events were
assessed. The public health hazard in the waterway was assessed based on human faecal contamination and related pathogenic indicators and faecal sterol biomarkers. Trigger values for the relevant indicators were identified from the ANZECC (2000) and BCC water quality guidelines and objectives for aquatic ecosystem protection. The changes to ambient physical and chemical conditions caused by the overflow and pollutants were compared to the trigger values. The impacts and hazards of both dry and wet-weather overflows were considered within the study. A summary of the concerns and observations arising from the study are provided in Table 2-3.
Table 2-3: Lota Creek Case Study – Research Summary

<table>
<thead>
<tr>
<th>Concern</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Public Health</strong></td>
<td></td>
</tr>
<tr>
<td>Risk to public health from human enteric bacteria and viruses</td>
<td>Faecal coliforms high but low risk from human faecal contamination</td>
</tr>
<tr>
<td><strong>Loss of amenity for recreational activities</strong></td>
<td>Faecal coliforms high but low risk from human faecal contamination</td>
</tr>
<tr>
<td><strong>Ecosystem Health</strong></td>
<td></td>
</tr>
<tr>
<td>Impacts of increased turbidity, nutrients: nitrogen, phosphorus and dissolved organic carbon and to the water column</td>
<td>None</td>
</tr>
<tr>
<td>Reduced oxygen concentrations in the water column</td>
<td>Low in some locations</td>
</tr>
<tr>
<td><strong>Toxicants</strong></td>
<td></td>
</tr>
<tr>
<td>Adding hormone disruptors to the water column</td>
<td>Inconclusive (below detection limit)</td>
</tr>
<tr>
<td>Adding metals to the water column</td>
<td>Not measured</td>
</tr>
<tr>
<td>Likely cumulative effects</td>
<td>Low based on dry weather re-suspension of sediments</td>
</tr>
</tbody>
</table>

**BST** = Bowering Street tributary  
**Enteric** = of the intestine  
**Faecal coliform** = Thermotolerant coliform  
**Sourced from** (Pollard, Leeming, Bagraith, Greenway, & Ashbolt, 2004)
2.4.1.2 Lota Creek Case Study: Summary

During the dry and wet weather overflow event the faecal indicators increased well above the ambient conditions. They increased above the public health guidelines for primary contact. During the dry weather overflow event (no rainfall) only human faecal contamination was identified. It was found that during the wet weather overflow, stormwater contributed 80% of the faecal contamination.

During the wet-weather overflow event, inorganic (e.g. nitrogen and phosphorus) and organic nutrients and suspended solids in the overflow effluent were rapidly diluted in the sewerage network and in the waterway. Concentrations were either below those associated with a healthy aquatic ecosystem and/or below those of the stormwater concentrations. Possible adverse impacts of chemical and physical stressors on ecosystem health were due primarily to stormwater run-off and not the sewage overflow.

The main finding from Pollard et al. (2004) was that stormwater impacts on ecosystem health were much greater than those of the sewage overflow effluent and, given a choice of managing these sources of contaminants, a priority would be for protecting ecosystem health – that is to say priority would be for managing stormwater pollution. The environmental concern for waterway pollution should shift from managing sewage overflows to managing stormwater runoff since stormwater has been found to be the main source of environmental pollution during wet-weather overflows.

2.4.2 CALTRANS Case Study

Stenstrom & Kayhanian (2005) prepared a report for the California Department of Transportation (CALTRANS) titled “First Flush Phenomenon Characterization”. This was an extensive study aimed at characterising and quantifying the first flush of highway pollutants from three sites near the University of California at Los Angeles (UCLA). The study was conducted over four years from 1999 to 2003.

This study has identified several types of first flushes that all indicate discharge of greater concentrations or mass in the early part of a storm event. It has also identified the existence of a seasonal first flush. It indicates that the existence of a first flush may present alternative opportunities for stormwater pollutant reduction strategies.
2.4.2.1 CALTRANS Case Study: Methodology

The CALTRANS case study was a four year stormwater monitoring study aimed at investigating the first flush phenomenon. It involved a lengthy data collection process and a highly detailed investigation of the data.

Three highly urbanised sites were utilised for the study (Sites 7-201, 7-202 and 7-203), as shown in Figure 2-3. Each site was instrumented with rainguages, flow meters and automatic composite samplers (taking grab samples).

Grab samples of the stormwater runoff during a storm event were taken at each site. During the first year of the study, five samples were taken during the first hour of runoff followed by two or three more samples during the following hours. For the remainder of the study, five samples were again collected in the first hour of runoff, followed by one sample per hour for the next seven hours of runoff. For shorter or longer storms, slightly less or slightly more samples, as required, were obtained.

A large number of water quality parameters including nutrients, metals, DO, solids and oil were routinely monitored throughout the entire study. All analysis was performed in accordance to the relevant guidelines. The results and findings of the study were then reported on.

Figure 2-3: CALTRANS First Flush Report – Study Area (Stenstrom & Kayhanian, 2005)
2.4.2.2 CALTRANS Case Study: Summary

An extensive monitoring and assessment process was undertaken and the results and conclusions identified the existence of the first flush phenomenon within the study area. The first flush phenomenon can be seen in Figure 2-4. Grab samples obtained during a storm event can be seen against a timeseries of the discharge.

Figure 2-4: CALTRANS Case Study - First Flush Phenomenon

Stenstrom & Kayhanian (2005) concluded that:

The existence of a first flush, either a storm or a seasonal first flush, may present opportunities for managers and regulators to affect better pollutant reduction programs. Treating early runoff that has higher contaminant concentrations may be a better policy than treating a similar fraction of the entire runoff volume... The Department's future development programs to reduce pollutants from stormwater may take advantage of first flush for removal of specific contaminate at local watershed basis. (p. 64)
3 What is the Stormwater Diversion?

The idea of the stormwater first flush diversion is to reduce the pollutant load impact on the waterway. This is done by diverting a portion of the stormwater discharge from the stormwater system into the wastewater system via a diversion structure, as shown in Figure 3-1. The higher pollutant loadings associated with the stormwater first flush are then contained in, and conveyed through, the wastewater system with the aim of being treated at the wastewater treatment plant.

![Figure 3-1: Diversion of Stormwater First Flush](image)

Sewers have generally been designed and constructed with a minimum capacity of 5xADWF. This is intended to provide enough capacity to convey or contain additional flows within the system during storm events. Due to the complex and unpredictable nature of RDII into the wastewater system, flows within the sewers during a storm event will quite often be below the maximum capacity of the sewer.

It can also be expected that during the first flush, or when a smaller storm is concurrent with a seasonal first flush, the RDII response within the wastewater system will be such that there is available capacity. Now, keeping in mind the significant issues identified with stormwater first flush, it can be seen that an excellent opportunity exists to manage pollution within a catchment by diverting the stormwater into the wastewater network and utilising this available capacity.

A stormwater diversion option could be seen as a more cost-effective option for the overall management of pollution to the waterway within the catchment. It can be an innovative option that aims to maximise the use of our existing infrastructure. It is also important to note that a stormwater diversion alone may not be the best option for managing pollution within a catchment. It should be seen as another tool in the shed that can be adopted as an alternative method to reducing the identified pollution.
4 Methodology

A specific methodology for managing pollution through the diversion of stormwater into the wastewater network is not available since it is a relatively new concept. As part of this dissertation, a detailed methodology has been undertaken and could be adopted (with some modifications) for any similar studies in the future.

The initial stage of the project involved selecting the study area and gathering the available data. Discussion with colleagues around pollution problems that are experienced in waterways in South East Queensland (SEQ) and target areas for the local government indicated that Norman Creek would be ideal to look at in more detail.

Ideally, the following data would have been available for this project:

- Rainfall data collected at five minute or less intervals from multiple raingauges across the catchment.
- Stormwater and wastewater data consisting of recently calibrated hydraulic models and GIS information of the existing infrastructure.
- Calibrated hydrologic/runoff model for the catchment.

The rainfall data was assessed in terms of quality and statistics and rainfall trends were identified. All relevant storm events were identified and the storm events used for assessment were selected. The rainfall data associated with the selected storms required setting up in a specific format to be used with the hydraulic models.

The wastewater network model obtained for this dissertation was calibrated in 2011. It consisted of trunk infrastructure only (225 mm sewers and above) and covered the S1 wastewater catchment in Brisbane. The rainfall data was entered into the model and scenarios for each storm event were created and modelled. Results from the models were in the form of flows, caused by dry weather flow (DWF) and the rainfall dependant infiltration and inflow (RDII), within each sewer.

This dissertation focused on determining the remaining capacity in the wastewater network. The capacity of the sewers was initially assumed as the theoretical pipe full flow, which provides contingency in case of sewers filling above pipe full and backing up the system. This was acceptable for an initial assessment of capacity which was utilised to identify potential diversion locations.

A stormwater hydraulic model and a hydrologic/runoff model were unable to be obtained for this dissertation. The best available data was in the form of PDF maps of the stormwater network. These were geocoded into GIS software to provide a
spatial relationship with the wastewater network. The quality of the stormwater data meant that it could only be used to identify potential diversion locations. No assessment of stormwater discharge or flows within the stormwater network was undertaken.

Potential locations for the diversion of stormwater into the wastewater network were identified. Inflows of 100 L/s, 200 L/s and 500 L/s at the selected diversion locations were simulated to represent varying amounts of diverted stormwater. However, due to a lack of available data, only a high level assessment of each location could be undertaken. The detailed feasibility of each diversion point was not considered as part of this dissertation.

4.1 Study Area – Norman Creek Catchment

The Norman Creek catchment is located in Brisbane, Queensland, Australia. It has an area of approximately 30 km². A map of the catchment is shown in Figure 4-1. It is bordered to the south by Toohey Mountain and Mount Gravatt; to the east by Holland Park and Camp Hill; to the west by Annerley and Highgate Hill; and to the North by Kangaroo Point and Norman Park. It forms part of the Lower Brisbane catchment and drains to the Brisbane River.

The Norman Creek catchment has many tributaries including Ekibin Creek, Sandy Creek, Coorparoo Creek and Kingfisher Creek. The catchment stretches across the suburbs of East Brisbane, Woolloongabba, Highgate Hill, Coorparoo, Camp Hill, Greenslopes, Annerley, Holland Park, Mount Gravatt, Holland Park West and Tarragindi.
4.2 Climate Information

Brisbane has a subtropical climate. It is generally warm or hot with temperatures averaging 30°C through summer (December to February). The winter months (June/July/August) are generally dry with temperatures averaging 21°C. Rainfall throughout winter averages 45 mm per month, which is approximately one third of the rainfall during summer (BOM, Bureau of Meteorology, 2015).

A distinct wet season occurs in Brisbane, with severe thunderstorms and cyclones often experienced. Heavy rainfall can occur during the wet season and frequent showers, with only a small number of dry days between, are typical of the Brisbane summer.

During the dry season, it is common for long periods with little to no rainfall occurring. Storm events are also smaller and less intense than in the wet season.
4.3 Assessment of Available Data

An initial assessment indicated that data available for this dissertation was limited to the following:

• Rainfall data from BOM raingauges or other source.
• Stormwater data – maps of existing and future trunk infrastructure.
• Wastewater data – hydraulic model calibrated in 2011.

Detailed assessment of the data is discussed in the following sections.

4.4 Assessment of Rainfall Data

Ideally, rainfall data would be obtained from multiple raingauges spread across the catchment. It would capture rainfall volumes (as a depth) on a frequent basis, such as one or two minute intervals. Using multiple raingauges within close proximity of the catchment, with rainfall collected at frequent intervals would minimise the spatial and temporal variations that are inherent during a storm event. The rainfall time series data can then be utilised for modelling purposes and calculating runoff volumes. A map of the raingauges that were potentially available to source data from is shown in Figure 4-2.

There are four raingauges owned by the Bureau of Meteorology (BOM) that are spread across the Norman Creek catchment. Three of the BOM raingauges only collect daily rainfall totals (Mt Gravatt Alert, 040790; Greenslopes Private Hospital, 040383; and Brisbane RPA Hospital, 040767). These three raingauges are of no use for this dissertation. The other BOM raingauge (Brisbane, 040913) collects rainfall totals at a two minute interval; only daily rainfall data was freely available. For this dissertation, it was deemed unnecessary to obtain rainfall data from the BOM Brisbane raingauge due to cost constraints around obtaining two minute interval data. It is however noted that this raingauge is in the ideal position to provide rainfall data for assessment of the Norman Creek catchment, if more accurate results were required.

The UQ Raingauge, located to the west of the Norman Creek catchment, was selected to obtain rainfall data for this dissertation. The UQ raingauge records rainfall totals at a one minute interval and is in close enough proximity to provide good approximations of the rainfall across the catchment. The data is also freely available from the UQ weather station website (University of Queensland, 2015).
4.4.1 UQ Raingauge Data Quality

Rainfall data used for this dissertation was obtained from the UQ raingauge (UQ weather station). The data is free to obtain and rainfall totals are provided at one minute intervals. The raingauge isn’t in an ideal location in relation to the Norman Creek catchment; however it is more than suitable for the purposes of this dissertation.

The UQ weather station records over 30 different types of data, such as wind and temperature, in addition to rainfall total and intensity. The data is archived and available dated back to January 2003. Any period of rainfall data could be analysed for the purposes of this dissertation. It was considered that at least two years of rainfall data would be sufficient, and the period from January 2013 to July 2015 was selected.
One minute data and daily summaries from the UQ weather station for the selected 31 month period were downloaded from the archives in a text file format. Both one minute data and daily summaries were downloaded as separate files for individual months. The different types of data were separated into columns within the text files. It was necessary to convert the data into an excel format in order to assess statistics and create model import files.

It is noted that a significant amount of time is generally required to manipulate and assess large amounts of data such as one minute rainfall data. This is inherent in many projects and is usually unavoidable. It was no different for this dissertation, and the following steps were taken to manipulate and assess the rainfall data in an efficient manner:

- A VBA macro was created in excel to convert the text files to excel files and delete the unnecessary data fields, leaving only rainfall totals and intensity.
- Daily summaries were combined into a single spreadsheet to form a time series for each year.
- Errors were identified in the one minute rainfall data where the dates were incorrectly formatted after converting to excel files. The day and month were automatically switched during conversion for any days before the 13th of each month.
- Another VBA macro was created to obtain statistics for select storm events. This was necessary to analyse the relevant one minute data excel files for selected storm events.

The overall quality of the rainfall data was considered to be good, with only seven days of rainfall unavailable due to system errors or faulty readings across the 31 month period.

### 4.4.2 Rainfall Statistics

The rainfall is shown graphically in Figure 4-3 and a summary of the rainfall statistics is provided in Table 4-1. A summary of the daily rainfall across the whole period is also provided in Appendix C. The following criteria were adopted when considering rainfall statistics and storm events:

- **Dry Day** < 0.5 mm of rainfall.
- **Very Wet Day** > 10 mm of rainfall.
- **Small Storm Event** < 10 mm of rainfall.
- **Dry Period** = 5 or more consecutive Dry Days.
- **Extended Dry Period** = 10 or more consecutive Dry Days.
Figure 4-3: Daily Rainfall Data from UQ Raingauge
Table 4-1: Rainfall Statistics from UQ Raingauge

<table>
<thead>
<tr>
<th>Year</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>All Data</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Days with Rainfall Data</td>
<td>360</td>
<td>363</td>
<td>212</td>
<td>935</td>
</tr>
<tr>
<td># of Dry Days</td>
<td>260 (72%)</td>
<td>283 (78%)</td>
<td>153 (72%)</td>
<td>696 (74%)</td>
</tr>
<tr>
<td># of Wet Days</td>
<td>100 (28%)</td>
<td>80 (22%)</td>
<td>59 (28%)</td>
<td>239 (26%)</td>
</tr>
<tr>
<td># of Very Wet Days</td>
<td>18 (5%)</td>
<td>15 (4%)</td>
<td>12 (6%)</td>
<td>45 (5%)</td>
</tr>
<tr>
<td># of Dry Periods</td>
<td>19</td>
<td>25</td>
<td>10</td>
<td>54</td>
</tr>
<tr>
<td># of Days in Dry Periods</td>
<td>217 (60%)</td>
<td>224 (62%)</td>
<td>114 (54%)</td>
<td>555 (59%)</td>
</tr>
<tr>
<td># of Small Storm Events Following Dry Periods</td>
<td>17 (89%)</td>
<td>23 (92%)</td>
<td>8 (80%)</td>
<td>48 (89%)</td>
</tr>
<tr>
<td># of Extended Dry Periods</td>
<td>8 (42%)</td>
<td>9 (36%)</td>
<td>6 (60%)</td>
<td>23 (43%)</td>
</tr>
<tr>
<td># of Days in Extended Dry Periods</td>
<td>150 (42%)</td>
<td>118 (33%)</td>
<td>87 (41%)</td>
<td>355 (38%)</td>
</tr>
<tr>
<td># of Small Storm Events Following Extended Dry Periods</td>
<td>8 (100%)</td>
<td>9 (100%)</td>
<td>6 (100%)</td>
<td>23 (100%)</td>
</tr>
</tbody>
</table>

In the 31 month period beginning in January 2013, it was found that only 5% of the total number of days could be considered as very wet days (>10 mm rainfall); on average, 95% of the year consists of small storm events or no rainfall at all.

A total of 54 different dry periods were observed which covered approximately 60% of the whole dataset. Approximately 90% of them were followed by a small storm event.

Now the interesting statistic: A total of 23 extended dry periods, accounting for 355 days out of 935 (or 38%), were found to all be followed by a small storm event. This indicates that, on average, over one third of the time available for pollution build up to occur in an urban watershed is followed by a small storm event.

It presents an excellent opportunity to manage a portion of the pollution attributed to the extended period of build up through the diversion of storm water first flush into the wastewater network (in particular seasonal first flush).

4.4.3 Selection of Storm Events

Based on previous studies, the Brisbane wastewater network is anticipated to have spare capacity during smaller storm events with a total rainfall of less than 10 mm. As such, the selection of storm events to test this hypothesis was focused on these small storm events. A total of 23 separate small storm events following extended dry periods were identified. A summary of these can be found in Appendix C.
The following criteria were also considered when selecting the storm events that would be further assessed:

- Total rainfall greater than 2 mm.
- Peak intensity greater than 30 mm/hr.
- Preceding dry period of 2 or more weeks.
- Storm events spread across the whole period of data.

Storm events with a total rainfall less than 2 mm were ignored. These storms would be expected to have either similar or less impact than the slightly larger storms. A similar rationalisation was taken for selecting events larger than 30 mm/hr.

The longer the dry period is prior to the storm, the greater the pollutant build up. This will lead to higher concentrations of pollutants in the runoff to the stormwater system. These longer dry periods were focused on for this dissertation; however capturing and diverting stormwater after any length of dry period would likely reduce pollution to the waterway.

The selected storm events range from 2.6 mm up to 9.6 mm total rainfall. A summary of each event is provided in Table 4-2. Event 15 is expected to have the least available capacity remaining in the wastewater system since it has the highest peak and average intensity.

**Table 4-2: Selected Storm Events**

<table>
<thead>
<tr>
<th>Event #</th>
<th>4</th>
<th>6</th>
<th>15</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Rainfall (mm)</td>
<td>9.6</td>
<td>4.4</td>
<td>5.8</td>
<td>2.6</td>
<td>6.8</td>
</tr>
<tr>
<td>Date</td>
<td>16/09/2013</td>
<td>29/10/2013</td>
<td>25/09/2014</td>
<td>27/10/2014</td>
<td>18/03/2015</td>
</tr>
<tr>
<td>Start Time</td>
<td>8:25 AM</td>
<td>1:40 PM</td>
<td>3:55 PM</td>
<td>4:55 PM</td>
<td>9:05 AM</td>
</tr>
<tr>
<td>End Time</td>
<td>12:00 AM</td>
<td>6:05 PM</td>
<td>4:20 PM</td>
<td>5:05 PM</td>
<td>10:25 AM</td>
</tr>
<tr>
<td>Duration (hrs)</td>
<td>15.6</td>
<td>4.4</td>
<td>0.4</td>
<td>0.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Preceding Dry Days</td>
<td>32</td>
<td>26</td>
<td>16</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Peak Intensity (mm/hr)</td>
<td>53.4</td>
<td>65.8</td>
<td>88.0</td>
<td>42.6</td>
<td>27.2</td>
</tr>
<tr>
<td>*Average Intensity (mm/hr)</td>
<td>3.4</td>
<td>5.0</td>
<td>23.7</td>
<td>22.7</td>
<td>6.3</td>
</tr>
</tbody>
</table>

*Average Intensity is calculated based on the UQ Weather Stations “Rainfall Intensity” readings. The UQ Weather station determines when no rainfall is occurring during the storm event, and the average intensity is then calculated by ignoring the time of no rainfall.*
4.5 Stormwater Data

There was not much information on the stormwater network that was freely available. It would have been ideal to have a stormwater model to use for this dissertation. This would have allowed for assessment of flows within the stormwater network, providing reasonably accurate results on the proportion of stormwater flows able to be diverted into the wastewater network.

The next best form of stormwater data would have been a GIS layer of the stormwater infrastructure. The Brisbane City Council (BCC) was contacted in order to obtain this information. The response from BCC regarding collection of a stormwater GIS layer came too late to be useful for this dissertation. It would also have come at a reasonably high cost.

Since the main focus of this dissertation was determining capacity in the wastewater network, obtaining and assessing accurate stormwater data was considered unnecessary. The stormwater data was only required for use in identifying potential diversion locations. This was only a very high level assessment, so the general location of stormwater infrastructure in relation to the wastewater network was required.

The stormwater data utilised for this dissertation was obtained from the Brisbane City Plan 2014 interactive mapping online tool (Brisbane City Council, 2014). This online tool was used to obtain the locations of existing and future stormwater trunk infrastructure.

4.6 Wastewater Network Assessment

The wastewater network associated with the Norman Creek catchment forms part of the Brisbane S1 sewer catchment. The majority of the Norman Creek catchment drains through the syphon at Kangaroo Point. A small area to the north-east drains to the Scott Street pumping station. The Caswell Street pumping station operates as a wet weather pumping station, operating only once the syphon has been overloaded due to high flows and backing up has occurred through the system up to a certain level. These pumping stations lift the wastewater into the downstream S1 sewer network, which is then gravitated and pumped to the Luggage Point Treatment Plant. The wastewater infrastructure within the Norman Creek catchment can be seen in Figure 4-4.

Note that the limit of this dissertation is the Kangaroo Point syphon, Caswell Street and Scott Street pumping stations. The network downstream from here is not considered.
4.6.1 Wastewater Model

A hydraulic model of the wastewater network was available for this project, consisting of the following details:

- Mike URBAN format.
- Included only trunk infrastructure with 225 mm diameter sewers and larger.
- Calibrated in 2011

The model had previously been calibrated in 2011 and was initially set up with population and infrastructure relating to the year 2011. No further information was available and it was outside the scope of this project to update the model to existing conditions. Even with this limitation, the model was still considered to be suitable for
this dissertation and the results will be valid. This is due to the dissertation only being a very high level assessment with the aim of determining the viability of the concept of stormwater first flush diversions into the wastewater network. The use of an older model will fulfil this aim, however it would obviously be recommended that a more detailed assessment, using the latest up-to-date data, be undertaken in order to determine the feasibility of implementing stormwater diversions at particular locations.

4.6.2 Model Setup

The only changes made to the model were in relation to the specific modelling scenarios and to the storm event rainfall data. These are detailed in the following sections.

No other changes were made to the following key model parameters:

- Model equivalent population (EP) = 746,741 EP. Note that this includes the whole of the S1 wastewater catchment.
- An average dry weather flow (ADWF) of 210 L/EP/day with calibrated diurnal profiles.
- Evaporation rates as shown in Table 4-3.

Table 4-3: Modelled Evaporation Rates

<table>
<thead>
<tr>
<th>Month</th>
<th>Evaporation Rate (mm/h)</th>
<th>Month</th>
<th>Evaporation Rate (mm/h)</th>
<th>Month</th>
<th>Evaporation Rate (mm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.3204</td>
<td>May</td>
<td>0.1476</td>
<td>September</td>
<td>0.2232</td>
</tr>
<tr>
<td>February</td>
<td>0.288</td>
<td>June</td>
<td>0.126</td>
<td>October</td>
<td>0.2772</td>
</tr>
<tr>
<td>March</td>
<td>0.252</td>
<td>July</td>
<td>0.1332</td>
<td>November</td>
<td>0.2628</td>
</tr>
<tr>
<td>April</td>
<td>0.1908</td>
<td>August</td>
<td>0.1944</td>
<td>December</td>
<td>0.3276</td>
</tr>
</tbody>
</table>

4.6.2.1 Modelling Scenarios

A total of 20 scenarios were required to initially be modelled. Following the identification of diversion locations, a further 9 scenarios were modelled. A summary of the modelled scenarios can be found in Appendix D.

Each of the five selected storm events required the following four scenarios to be set up and modelled:

- Runoff hotstart scenario – Simulation starts 3 months before actual storm event and ends 1 month before. Used to provide initial conditions for the runoff scenario.
- Runoff scenario – Simulation starts 1 month before storm event and ends 1 day after storm event. Used to provide RDII component of flows during the storm event.
• Network hotstart scenario – Simulation starts 12 hours before storm event and ends 1 hour after the storm event. Used to provide initial conditions for the network scenario.

• Network scenario – Simulation starts and ends either side of the storm event. Used in conjunction with the runoff scenario to obtain the wastewater network flows.

A considerable amount of effort was required in setting up and running each of the modelling scenarios. Frequent model crashes occurred and model run times would take up to 2 hours each.

4.6.2.2 Storm Event Model Import

The selected storm events were imported into the model as total rainfall in millimetres at 1 minute frequencies.
5 Results

The results obtained for this dissertation were focused on identifying the possibility of diverting stormwater first flush into the wastewater network. The limited availability of data made it difficult to obtain any sort of useful results regarding first flush in terms of the initial period of runoff from a storm event. As such, the focus of the results from this dissertation was on the first flush associated with a storm event following an extended dry period, known as the seasonal first flush.

The wastewater model was used to identify the remaining system capacity during selected storm events. An initial assessment of the system was based on the capacity of the system being when a pipe is flowing full. While this is useful to identify parts of the system that may have capacity and should be further investigated, it does not provide a definitive answer to how much capacity is remaining in the system since:

- Sewers may surcharge (pipes run full with manholes filling above pipe obverts). The additional hydraulic head can lead to flows greater than the pipe full flow. Some sewers, such as siphons, are designed to operate surcharged under normal conditions.
- Downstream constraints may actually control the capacity. A sewer that is predicted to have flows at 50% of its pipe full flow may be constrained by a downstream sewer that, with the same flow, is operating near or above 100% of its pipe full flow.
- It does not account for storage within the system. Flows within the system in reality are dynamic, meaning they can vary greatly with time; very high flows are often observed immediately following rainfall with low flows generally observed throughout an average day. The system may have available capacity to store additional flow above pipe full flow without any negative impacts.

It was important to keep these considerations in mind when looking at the remaining capacity in the system during the storm events. Therefore, an initial assessment was undertaken to determine the worst case storm event and identify locations for potential diversions.

Following the identification of diversion locations, several more scenarios were simulated to represent varying amounts of diverted stormwater at each location. This allows for the consideration of pipes running full and system storage. The results obtained from this final assessment were used to determine potentially acceptable diversion flow limits along with associated pollutant loads.
5.1 Initial Assessment

The initial assessment of the remaining capacity of the wastewater network in the Norman Creek catchment involved identifying the storm event which had the greatest impact on the system. Three sewers were randomly selected across the catchment in order to get an idea of the RDII impact from each storm event. The maximum flows predicted within each of the three sewers during each storm event are shown in Table 5-1. The flow profiles in each sewer across a day for the selected storm events are shown in Figure 5-1.

Table 5-1: Maximum Flow During Storm Events in Sample of Sewers

<table>
<thead>
<tr>
<th>Event #</th>
<th>Sewer LS163607 Maximum Flow (L/s)</th>
<th>Sewer LS123248 Maximum Flow (L/s)</th>
<th>Sewer GM13B_4 Maximum Flow (L/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWF</td>
<td>145</td>
<td>31</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>162</td>
<td>90</td>
<td>33</td>
</tr>
<tr>
<td>6</td>
<td>150</td>
<td>56</td>
<td>29</td>
</tr>
<tr>
<td>15</td>
<td>207</td>
<td>98</td>
<td>32</td>
</tr>
<tr>
<td>17</td>
<td>166</td>
<td>77</td>
<td>30</td>
</tr>
<tr>
<td>18</td>
<td>238</td>
<td>100</td>
<td>34</td>
</tr>
</tbody>
</table>
Figure 5-1: Flows During Storm Events in a Sample of Sewers
It is clear that Event 18 causes the greatest impact on the system, with the maximum sewer flows occurring during this storm event. This is partly due to the majority of rainfall that fell during Event 18 coinciding with the morning ADWF peak. Event 4 had a higher total rainfall than Event 18; however the rainfall was spread across the whole day with a more intense period around 10pm following the night time ADWF peak.

The other three selected storm events (Event 6, 15 and 17) each had higher peak intensities but lower total rainfall than Event 18. Event 6 had the least impact on the system since it consisted of two smaller bursts of rainfall between the morning and night time ADWF peaks. Events 15 and 17 occurred during the night time peak with Event 15 having a considerable RDII impact on the system caused by its large amount of total rainfall and high peak intensity.

It is noted that across all the selected storm events, the maximum flows within each of the selected sewers are less than half their full pipe flow capacities (see Table 5-2 and Table 5-3). This provides a good indication that there may be available capacity within the wastewater network during a small storm event to divert a portion of the stormwater runoff and warrants the further assessment being undertaken.

Table 5-2: Pipe Capacity in Sample of Sewers

<table>
<thead>
<tr>
<th>Sewer LS163607 Capacity (L/s)</th>
<th>Sewer LS123248 Capacity (L/s)</th>
<th>Sewer GM13B_4 Capacity (L/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>555</td>
<td>220</td>
<td>133</td>
</tr>
</tbody>
</table>

Table 5-3: Remaining Capacity in Sample of Sewers

<table>
<thead>
<tr>
<th>Event #</th>
<th>Sewer LS163607 Remaining Capacity (L/s)</th>
<th>Sewer LS123248 Remaining Capacity (L/s)</th>
<th>Sewer GM13B_4 Remaining Capacity (L/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWF</td>
<td>410 (74%)</td>
<td>189 (86%)</td>
<td>105 (79%)</td>
</tr>
<tr>
<td>4</td>
<td>393 (71%)</td>
<td>130 (59%)</td>
<td>100 (76%)</td>
</tr>
<tr>
<td>6</td>
<td>405 (73%)</td>
<td>164 (74%)</td>
<td>104 (78%)</td>
</tr>
<tr>
<td>15</td>
<td>348 (63%)</td>
<td>122 (55%)</td>
<td>101 (76%)</td>
</tr>
<tr>
<td>17</td>
<td>389 (70%)</td>
<td>143 (65%)</td>
<td>103 (78%)</td>
</tr>
<tr>
<td>18</td>
<td>317 (57%)</td>
<td>120 (54%)</td>
<td>99 (74%)</td>
</tr>
</tbody>
</table>

Event 18 was selected for further assessment since it was predicted to have the greatest impact on the wastewater system in the Norman Creek catchment. It is anticipated that by assessing the worst case storm event, the results can be translated to the storm events with lesser RDII impact on the system, along with other similar storms that were not assessed as part of this dissertation.
5.1.1 Identifying Diversion Locations

Several diversion locations were identified by assessing the ratios of the maximum flow predicted within each pipe (Qmax) across the system against the theoretical pipe full flows (Qmanning – pipe full flow is calculated by Mike URBAN using the Manning’s formula). The ratios are known as Qmax/Qmanning. Figures of Qmax/Qmanning for each storm event can be found in Appendix E.

Event 18 has been selected to use for further assessment; however the Qmax/Qmanning figures for all storm events can be used to assist in determining parts of the system that may have more capacity remaining than other parts. Several locations for potential diversions, along with comments, are summarised in Table 5-4 and shown in Figure 5-2.

Varying amounts of inflow at locations 2, 3 and 6 will be assessed to simulate diversion of stormwater first flush into the wastewater network.

Table 5-4: Summary of Potential Diversion Locations

<table>
<thead>
<tr>
<th>Location #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>450/525 mm diameter sewer line draining from Kangaroo Point. Appears to have considerable spare capacity with maximum flows during Event 18 remaining below 50% of the pipe full flow. However, the maximum flows within these sewers are hindered due to being laid at a very flat gradient. This may limit the benefit gained from diverting the stormwater first flush. The operation of the system downstream of this sewer line is unclear. There is a siphon that runs under the Brisbane River, as well as mains that run to/from Caswell Street pumping station. Due to the limited understanding of the downstream system, this location was not considered for further assessment. It is noted that the stormwater network at this location drains a highly urbanised area, including two major roads. Pollutant build up may be more significant than at other locations, and as such, further investigation into diverting stormwater first flush at this location would be recommended with the availability of better quality data.</td>
</tr>
<tr>
<td>2</td>
<td>450 mm diameter sewer line draining from the Woolloongabba area. May have considerable spare capacity with Qmax/Qmanning ratios remaining below 50%. Appears to be considerable capacity downstream with a 675 mm diameter sewer and a 900 mm diameter interceptor sewer draining flows directly to Caswell Street pumping station. The stormwater network at this location drains from a highly urbanised area, including several major roads and intersections (Ipswich Road, Stanley Street and Vulture Street), and part of the Pacific Motorway. This appears to be an ideal location for diverting stormwater first flush. Further assessment of a potential connection into the 900 mm diameter interceptor sewer will be undertaken.</td>
</tr>
<tr>
<td>Location #</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>3</td>
<td>600 mm diameter overflow relief sewer line from Wembley Park to Caswell Street. This sewer line was predicted to operate only during Event 18, indicating the potential for capacity to receive flows from the diversion of stormwater first flush. The location and operation of the stormwater system in this area is unclear due to the limited amount of available data. It appears that there is limited opportunity for a diversion structure to be installed in a location that collects a significant amount of stormwater runoff and allows for a feasible connection to the wastewater network. However, there may be an opportunity for a beneficial connection at the upstream end of the overflow line, and as such, further assessment of a stormwater diversion at this location will be undertaken.</td>
</tr>
<tr>
<td>4</td>
<td>300/375 mm diameter sewer line draining from the Greenslopes area. There appears to be limited capacity predicted by the model during storm events 4, 15 and 18. This location was not considered any further for the purposes of this dissertation.</td>
</tr>
<tr>
<td>5</td>
<td>225/300/375 mm diameter sewer lines draining the east of the Norman Creek catchment. There appears to be limited capacity predicted by the model during all storm events. This location was not considered any further for the purposes of this dissertation.</td>
</tr>
<tr>
<td>6</td>
<td>525/600 mm diameter Norman Creek main sewer line collecting wastewater flows from the south of the Norman Creek catchment. Appears to be considerable spare capacity predicted by the model during all events, with the majority of flows from the south of Norman Creek catchment being conveyed by the duplicate 525 mm diameter sewer line. There is likely to be a good opportunity to connect the channelized section of Norman Creek (running through Ekibin Park) to the 525 mm diameter sewer. Further assessment of diverting stormwater flows at this location will be undertaken.</td>
</tr>
<tr>
<td>7</td>
<td>Wastewater system draining from the south east of the Norman Creek catchment. There appears to be limited capacity predicted by the model in each of the sewer lines draining this area of the catchment. However, the main constraint for this part of the system is the 525 mm diameter sewer, immediately downstream of where the 375 mm and 525 mm diameter sewer lines converge. As such, this location was not considered further as part of this dissertation.</td>
</tr>
</tbody>
</table>

*Green shading indicates locations that are assessed further as part of this dissertation. Locations which were not considered further are denoted by red shading.*
Figure 5-2: Potential Diversion Locations
5.2 Final Assessment of Diversions

The locations identified in section 5.1.1 were used for the final assessment of stormwater first flush diversions into the wastewater network. These included location 2, 3 and 6. The following methodology was used for the final assessment:

- Set up a total of 9 separate model scenarios that include RDII from Event 18 across the catchment and background DWF.
- Simulate the inflow from a stormwater diversion with the addition of fixed 100 L/s, 200 L/s and 500 L/s inflow at the selected diversion location.
- Assess the remaining capacity in the network in terms of manhole surcharges, controlled overflows and longitudinal profiles.

The results for each of the selected diversion locations are discussed in the following sections.
5.2.1 Diversion Location 2

The potential for diverting stormwater flows into the 450 mm diameter Woolloongabba Sub Main at Lerna Street (at the upstream end of Kingfisher Creek) was assessed. The location of the diversion is shown in Figure 5-3.

![Figure 5-3: Diversion Location 2](image)

Three scenarios were modelled in Mike URBAN to simulate 100 L/s, 200 L/s and 500 L/s constant inflows into the wastewater network from the stormwater channel. The maximum predicted HGL (for the long section shown in Figure 5-3) is shown in Figure 5-4. The thin, upper line represents the ground profile and the lower, parallel blue lines represent the sewer main. The thick red line is the maximum HGL caused by the 500 L/s inflow; thick green line is the maximum HGL caused by the 200 L/s inflow; thick blue line is the maximum HGL caused by the 100 L/s inflow.
Figure 5-4: Longitudinal Profile Showing Maximum HGLs for Diversion Location 2

A constant 500 L/s stormwater diversion into the wastewater network at this location appears to be unacceptable. The capacity of the downstream sewers is unable to convey the additional flow, causing backing up and significant flooding from the manholes upstream of the diversion location. It is noted that an existing internal weir at manhole MH162019, a short distance downstream from the diversion location, flows into the 900 mm diameter Norman Creek Interceptor Sewer (Section 2). This sewer appears to have sufficient capacity to convey at least up to the 200 L/s diversion inflows. No further optimisation of the potential diversion location, including modelling inflows directly into the manhole MH162019, was considered for this dissertation. As such, a constant 500 L/s stormwater diversion into the wastewater network is considered to be unacceptable.

Both the 100 L/s and 200 L/s stormwater diversions are predicted by the model to cause no uncontrolled manhole flooding or flows through controlled wastewater overflow structures. The predicted HGL profiles are similar, with the 200 L/s stormwater diversion causing the HGL upstream of the diversion location to rise by approximately 0.5 m.

The downstream head is controlled by the pump on settings at the Caswell Street pumping station and the capacity of the inverted syphon’s at Kangaroo Point. The additional flows into the wastewater network from the stormwater diversion cause backing at the inverted syphon. The HGL within the system builds up until the Caswell Street pumps turn on. The freeboard (depth from ground level to water surface) may be a concern upstream of the diversion location, with levels reaching approximately 0.5 m due to the constant 200 L/s diversion inflow. However, due to the current settings for the pump on levels at the Caswell Street pumping station
being at such a relatively high level, the predicted freeboards for stormwater
diversion inflows up to 200 L/s are considered acceptable.

The predicted results for the modelled diversion location 2 indicate that the
wastewater network may have sufficient capacity to accommodate a constant
stormwater first flush diversion inflow of up to 200 L/s.
5.2.2 Diversion Location 3

A potential location for a stormwater diversion was identified at the upstream end of the 600 mm diameter Wembley Park to Caswell Street overflow relief sewer. The sewer main runs underneath the concrete stormwater channel at the south-eastern corner of Wembley Park. The location of the diversion is shown in Figure 5-5.

Figure 5-5: Diversion Location 3

Three scenarios were modelled in Mike URBAN to simulate 100 L/s, 200 L/s and 500 L/s constant inflows into the wastewater network from the stormwater channel. The maximum predicted HGL (for the long section shown in Figure 5-5) is shown in Figure 5-6. The thin, upper line represents the ground profile and the lower, parallel blue lines represent the sewer main. The thick red line is the maximum HGL caused by the 500 L/s inflow; thick green line is the maximum HGL caused by the 200 L/s inflow; thick blue line is the maximum HGL caused by the 100 L/s inflow.

Figure 5-6: Longitudinal Profile Showing Maximum HGLs for Diversion Location 3
It is clear that a 500 L/s stormwater diversion at location 3 would be unacceptable due to uncontrolled flooding from several manholes. Backflow upstream from the modelled diversion inflow node also triggers a controlled overflow at the sewer overflow weir for both the 200 L/s and 500 L/s inflows. This indicates that a constant inflow of 200 L/s would also be unacceptable at location 3 with the current wastewater system configuration. The HGL for the 100 L/s constant inflow is predicted to remain below the ground level; no uncontrolled manhole spills or controlled overflows are predicted to occur.

It is interesting to note the high water levels (HGLs) observed at the downstream end of the longitudinal profile. This is due to the current operation of the downstream network and the Caswell Street pumping station. The Caswell Street pumping station currently operates as a wet weather pumping station with the pumps set to turn on only when a very high water level is reached. The capacity of the inverted syphon’s at Kangaroo Point is unable to handle the increased flows due to storm event 18 and the stormwater diversion inflow. The insufficient syphon capacity causes the HGL to build up until the Caswell Street pump on levels are reached. With both the syphon’s and Caswell Street pumps operating, there is enough capacity to draw the HGL down and convey up to at least the 100 L/s and 200 L/s stormwater diversion inflows.

Modifying the current operation of the system is outside the scope of this project. Therefore the existing wastewater system is predicted to be able to safely accommodate a constant stormwater diversion inflow of no more than 100 L/s at the identified location 3.
5.2.3 Diversion Location 6

The 525 mm diameter Norman Creek Main Sewer line, running along the western side of Ekibin Park parallel to a concrete channel section of Norman Creek, was identified to be a potential location for a stormwater diversion. The setup of the Mike URBAN model did not allow for an inflow to be modelled exactly at the identified diversion location. Instead, it was necessary to model the stormwater diversion inflow at a node a short distance upstream from the desired location. This was considered to have minimal effect on the results. The location of the diversion is shown in Figure 5-7.

Figure 5-7: Diversion Location 6

Three scenarios were modelled in Mike URBAN to simulate 100 L/s, 200 L/s and 500 L/s constant inflows into the wastewater network from the stormwater channel. The maximum predicted HGL (for the long section shown in Figure 5-7) is shown in Figure 5-8. The thin, upper line represents the ground profile and the lower, parallel blue lines represent the sewer main. The thick red line is the maximum HGL caused by the 500 L/s inflow; thick green line is the maximum HGL caused by the 200 L/s inflow; thick blue line is the maximum HGL caused by the 100 L/s inflow.
Similarly to the other diversion locations, the 500 L/s constant inflow at location 6 is predicted to cause unacceptable overflows, both from uncontrolled manhole spills and controlled spillage at the sewer overflow weir. The sewer overflow weir is activated due to backflow upstream from the modelled diversion inflow node.

Both the 100 L/s and 200 L/s diversion inflows are predicted to cause similar maximum HGLs within the wastewater system, with the latter less than 1 m higher at the modelled inflow node.

Again, the downstream HGL is controlled by the levels at the Caswell Street pumping station; the pumps are set to turn on at approximately 0.5 mAHD. When the pumps are operating, the HGL within the system is drawn down due to the pumps having sufficient capacity to convey the additional flows.

At manhole MH162041, there is a 600 mm diameter cross-connection between the 525 mm diameter Norman Creek Main Sewer and 600 mm diameter Norman Creek Interceptor Sewer lines. The slope of the HGL downstream of this point indicates that there may be sufficient capacity to convey flows greater than that predicted with the additional 200 L/s diversion inflows. This 600 mm diameter cross-connection runs under the concrete channel section of Norman Creek in Ekibin Park and may provide a better location for a stormwater diversion to be installed in terms of both proximity and hydraulics.

This dissertation has not explored the optimisation or detailed feasibility of the stormwater diversion locations. As such, a 500 L/s constant diversion inflow at the identified location 6 is predicted to be unacceptable. According to the model, a stormwater first flush diversion of up to 200 L/s may be possible at location 6.
6 Conclusion

The traditional management of stormwater and wastewater, and the pollution associated with each, is starting to be questioned. A move towards sustainable development and effects based management is emerging. Stormwater runoff is recognised as a significant contributor to pollution in urban waterways. It is also becoming more and more apparent that the stormwater runoff can be a larger source of pollution within a catchment than wastewater overflows. Stormwater first flush is considered to pose a significant impact in terms of increased pollutant loadings during storm events. The significance of the impacts of stormwater pollution and first flush pollution has been highlighted by the Lota Creek and CALTRANS case studies.

This dissertation has looked at the potential of an alternative method for managing the pollution to an urban waterway, being the diversion of stormwater first flush into the existing wastewater network. The stormwater first flush diversion would be expected to reduce the pollutant load impact on the waterway. It is potentially a more cost effective option, and may provide much larger benefits, than solely focusing on eliminating overflows from the wastewater network.

The concept of the stormwater first flush diversion was investigated as part of this dissertation by undertaking a high level desktop assessment of the Norman Creek catchment. Rainfall data from the UQ Raingauge, located to the west of the Norman Creek catchment, was assessed in order to identify storm events that may represent a seasonal first flush within the catchment. It was found that a total of 23 extended dry periods occurred from January 2013 to July 2015, and all of these were found to be followed by a small storm event. This could be thought of as 23 small seasonal first flush events. Five of these storm events were selected for further assessment.

A calibrated wastewater network model was utilised for the desktop assessment. The 5 storm events were simulated in the model to assess areas within the network that may have spare capacity. Storm event 18 was predicted to have the greatest impact on the wastewater network and was selected as the ideal storm to represent first flush conditions within the Norman Creek catchment. It is expected that the results from storm event 18 can be translated to other similar or smaller events.

Potential locations for the diversion of stormwater into the wastewater network were selected by identifying areas of the wastewater network that appeared to have spare capacity during the modelled storm events. The following 3 locations were identified for further assessment:
• Diversion location 2 – the 450 mm diameter Woolloongabba Sub Main at Lerna Street (at the upstream end of Kingfisher Creek.
• Diversion location 3 – the upstream end of the 600 mm diameter Wembley Park to Caswell Street overflow relief sewer at the south-eastern corner of Wembley Park.
• Diversion location 6 – the 525 mm diameter Norman Creek Main Sewer line, running along the western side of Ekibin Park parallel to a concrete channel section of Norman Creek.

The inflow expected from a stormwater diversion into the wastewater network was simulated with the addition of fixed 100 L/s, 200 L/s and 500 L/s inflows at each of the selected diversion locations. The inflows modelled were a constant flow, and can be thought of as a worst case scenario occurring within the system.

The model results indicated there is existing capacity within the Norman Creek wastewater network for flows of up to 200 L/s to be diverted from the stormwater system into the existing wastewater network at diversion location 2 and 6. Up to 100 L/s may be acceptable at diversion location 3.

It is expected that implementation of stormwater diversions at locations 2, 3 and 6, with the flows controlled up to the maximums identified, would be fully contained within the existing wastewater network and conveyed to the wastewater treatment plant during storm events similar to, or smaller than, storm event 18. The pollutants associated with the diverted stormwater runoff would be restricted from entering the waterway, and conveyed to the existing treatment plant.

6.1 Summary

The diversion of stormwater first flush into the existing wastewater network is an innovative option for managing pollution to urban waterways. This dissertation has successfully examined the concept of stormwater first flush diversion into wastewater systems as an option for pollutant control purposes. The potential for several viable diversion locations within the Norman Creek catchment were identified.

A more detailed investigation, utilising an effects based management approach, would be required before any significant recommendations could be made.

Stormwater pollution can pose a greater overall risk than sewer overflows; an effects based management approach towards the overall waterway pollution, with a potential management option being the diversion and containment of polluted stormwater, may provide far greater benefits than the traditional focus on solely eliminating sewer overflows.
6.2 Limitations

6.2.1 Quality of Data

The quality and availability of data was a hindrance throughout the project. There was minimal stormwater data available; no assessment of the stormwater system was undertaken as part of this dissertation. The online stormwater maps that were available were only useful to assist in identifying potential stormwater diversion locations.

Due to time constraints, it was necessary to make the assumption that the calibrated wastewater network model was accurate. This may not be completely inaccurate, however considerable checks would usually be undertaken to ensure a good level of confidence in the models being used.

As noted previously in this dissertation, the model used was calibrated in 2011. Changes such as the following may have occurred since then:

- Populations may have increased, causing increased loadings on the wastewater system.
- The behaviours of the population within the catchment may have changed, leading to a reduction in water usage and thus, reduced loadings on the wastewater network.
- Infrastructure upgrades may have been commissioned, increasing the available capacity within the network.
- Changes to the hydrology caused by building developments and construction, combined with sewer maintenance and deterioration, may cause changes to the RDII impacts on the wastewater system.

Ideally, a more up to date model would be utilised for assessing the stormwater diversions.

The rainfall data obtained for this dissertation was measured at a location outside of the catchment. To increase the accuracy of the results, more detailed rainfall monitoring should be undertaken with multiple locations located within the Norman Creek catchment.

6.2.2 Only Existing Conditions Assessed

The model only contained a representation of existing conditions: 2011 population and existing infrastructure. This was considered to be more than adequate for this dissertation, since the purpose was to identify the potential for diversion of stormwater flows into the wastewater network. However, a more detailed
assessment would need to consider additional scenarios such as the predicted ultimate loadings on the network. The impact from larger storm events would also need to be considered, taking into account design storms of a specific return period.

6.2.3 Isolated Assessment of Only a Part of the Wastewater System

This dissertation was only concerned with the Norman Creek Catchment and the wastewater infrastructure associated with it. In order to reduce the workload to an acceptable volume for an undergraduate thesis, the wastewater network downstream from the study area was not considered. Instead, the Caswell Street pumping station was considered to provide a hydraulic break in the wastewater system. This is a realistic assumption and retains validity in the results. However an assumption is also made that the network downstream of the Caswell Street pumping station can satisfactorily convey the pumped flows. This may not be the case in reality and would need to be carefully considered before any conclusions could be deemed to be fully accurate.

Due to the way a wastewater system is designed, the downstream network should generally have capacity to convey the flows that are pumped from upstream. This is to say that if the additional inflows from the stormwater diversion can be satisfactorily conveyed to a wastewater pumping station, then the downstream system should have the capacity to convey flows all the way to a wastewater treatment plant.

6.2.4 Additional Load at Wastewater Treatment Plant

Additional loads due to the diversion of stormwater flows into the wastewater network, in terms of both higher flows and higher pollutant loadings, may have a considerable impact at the treatment plant. This should be seen as a ‘good problem’ to have since it would indicate a reduction in pollutants to the waterways, which is the purpose of diverting the stormwater first flush.

The consideration of the additional treatment loads is anticipated to be part of an effects based management approach. The stormwater diversion is an alternative method to managing pollution to the waterway; the benefits and impacts should be weighed up against other viable options. It is likely that other options, such as increased storage capacity within the wastewater network or upgrading the conveyance capacity of the system, will also lead to increased loadings at the treatment plant.

Nevertheless, this has not been considered for this dissertation, however would form an important part in the detailed assessment of stormwater diversions.
6.2.5 Assessment of Stormwater System

The available data relating to the stormwater systems was minimal, and as such, no assessment of the stormwater system was able to be undertaken. Therefore the capacity of the stormwater system to transfer flows to the diversion location has not been assessed. While this is not a big limitation for this dissertation since its purpose was predominantly to identify capacity in the wastewater system, it was considered to be worth mentioning as it should form a part of a more detailed assessment involving diversion of stormwater first flush into the wastewater network.
7 Further Study

This dissertation has provided a good insight into the potential for diversion of stormwater flows into the wastewater network. However, there is still much work that needs to be done before any concrete recommendations and conclusions can be made. A brief discussion of several topics that could be undertaken as further study is provided in the following sections.

7.1.1 Detailed Design of a Diversion System

An assumption is made throughout this dissertation, being that a diversion from the stormwater network into the wastewater network of any flow is possible, without any consideration of the design of such a structure or how it would operate. Further study into the design of a diversion system would be beneficial for gaining an understanding of the hydraulics of the diversion and the feasibility at potential diversion locations. It would be anticipated that a simple connection between the systems, via either a weir structure or a cross-connecting pipe, would be sufficient. Methods of controlling the flow would need to be designed, such that either a passive mechanical system or an automated electronic system have the capability of reducing or restricting diversion flows under specific conditions.

7.1.2 Integrated Modelling of the Wastewater and Stormwater Networks

This dissertation has only looked at the impact of fixed constant inflows into the wastewater network at several diversion locations in order to represent a diversion from the stormwater system. The accuracy and validity of the results could be improved with the use of a calibrated stormwater model. An integrated modelling approach, where both the wastewater and stormwater systems are simultaneously modelled, with the inclusion of stormwater diversion structures (modelled as weirs or pipes) will allow for a better understanding of the hydraulics surrounding each stormwater diversion. A realistic available flow from the stormwater network could be identified, along with the total proportions of diverted flow. In addition, using an integrated modelling approach with the inclusion of water quality within both systems would assist in optimising stormwater diversion control flowrates.

7.1.3 Quantify and Compare the Pollutant Loads to the Environment from Wastewater Overflows and Stormwater Discharge

An effects based management approach to managing pollution to a waterway requires understanding of the catchment as a whole, and all the various factors impacting on it. A large part of this is to understand the pollutant loads attributable to
the various sources impacting within the catchment. A significant amount of work is required to identify and quantify pollutants associated with various sources, such as stormwater runoff and wastewater overflows. However, without this knowledge, it is impossible to fully compare various options of managing the pollution.
8 Bibliography


Appendix A

Project Specification
FOR: PATRICK TUNNAH

TOPIC: MANAGING POLLUTION TO WATERWAYS USING AN EFFECTS BASED WASTEWATER PLANNING APPROACH AND DIVERSION OF STORMWATER “FIRST FLUSH” TO THE WASTEWATER SYSTEM

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ENROLMENT: ENG4111 – S1, 2015
ENG4112 – S2, 2015

PROJECT AIM: Determine the effects (environmental, social and economic) on a specific waterway in the Brisbane area caused by stormwater and separate sewerage system overflows. Then analyse the feasibility and likely benefits of diverting the stormwater “first flush” (the initial flow following rainfall in a stormwater system) into the wastewater collection system.

SPONSORSHIP: MWH Pty Ltd and Queensland Urban Utilities

PROGRAMME: Issue A, 18th March 2015

1. Research background information related to the following:
   - Waterway pollution
   - Assessment of waterway standards/values and performance
   - Stormwater (SW) discharge to the environment (in terms of quantity and quality)
   - SW first flush characteristics (how the first flush quality varies with the rest)
   - Impacts of wet weather wastewater (WW) discharge (network overflows) to the environment
   - SW/WW planning/design guidelines
   - Case studies of SW and WW discharges and their effects

2. Quick review of available data in order to select appropriate waterway catchment. Then collect the following data from BOM, government/ local council and other sources that is specific to selected waterway:
   - Stream flow and water quality
   - Rainfall
   - SW discharges, hydraulic and pollutant loadings
   - WW discharges, hydraulic and pollutant loadings
   - WW, SW and water quality models

NOTE: available data will have a large effect on the direction and content of this dissertation. Remaining tasks may be revised at this point.

3. Assess the existing capacity of the system using the design information.
4. Critically analyse the data obtained in 2 and 3 to identify and predict occurrence of overflow (from stormwater and wastewater outlets) and corresponding hydraulic and pollutant loading for a storm event of given intensity and duration.
5. Analyse the effects of hydraulic and pollutant loading triggered by a storm event (of given intensity and duration) in the river system using water quality models for scenarios described in step 4.
6. Define goals of managing the pollution to the waterway, based on specific drivers i.e. recreational uses, public health, aquatic habitat, visual aesthetics etc.
7. Analyse the diversion of SW first flush to the WW system as a solution to meeting the defined goals. Include the feasibility of this solution and the cost benefit compared with traditional solutions.
8. Submit an academic dissertation on the research.
Appendix B

CALTRANS Case Study Additional Information

The following graphs and tables have been sourced directly from Stenstrom & Kayhanian (2005). Figure 4.1 shows a cumulative pollutant mass verse cumulative flow volume example graph. A mass first flush (MFF) ratio with 45% of pollutant mass discharged within 10% of the flow would be shown as $\text{MFF}_{10} = 4.5$.

Table 4.1 lists the MFF ratios for $\text{MFF}_{20}$ (i.e. total pollutant mass discharged after 20% of total flow).

![Load-graph example of MFF calculation](image-url)
Table 4.1 shows the MFF\textsubscript{20} ratios for all three UCLA sites and the pooled data for all three sites, for 26 pollutants. They are ranked by magnitude. Generally the chemical oxygen demanding (COD) or organics indicating pollutants (DOC, O&G, TKN) have the highest MFF ratios. It should be expected that they have similar ratios, since they are highly correlated, as shown in the last chapter. The fact that their values are high suggests that they are washed or scoured from the sites early in the storm.

Table 4.1 Ranked mass first flush ratios for MFF\textsubscript{20}

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<th>Rank</th>
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<th>7-201 Median</th>
<th>Parameters</th>
<th>7-202 Median</th>
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Appendix C

Additional Rainfall Data

The following tables provide additional information for the rainfall data.

**TABLE C-1: Key to Daily Rainfall Tables**

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**TABLE C-2: 2013 Daily Rainfall**

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Appendix D

Mike URBAN Modelled Scenarios

Model Scenarios for Selected Storm Events

TABLE D-6: Model Scenarios for Selected Storm Events

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<td>End Time</td>
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Appendix E

Results from Selected Storm Events – Qmax/Qmanning
FIGURE E-1: Initial Results - Qmax/Qmanning - Event 4
FIGURE E-2: Initial Results - Qmax/Qmanning - Event 6
FIGURE E-3: Initial Results - Qmax/Qmanning - Event 15
FIGURE E-4: Initial Results - $Q_{\text{max}}/Q_{\text{Manning}}$ - Event 17