Waterfield Street Drainage Study

FINAL REPORT

- Final
- 18 July 2008

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1. Introduction

1.1. Background

Moreland City Council has commissioned Sinclair Knight Merz (SKM) to assess the existing drainage system around the Coburg shopping centre, specifically the area bounded by Munro St, Sutherland St, Sydney Rd, and O'Hea St.

This study has been prompted by two key issues. Firstly, the Coburg Library on the corner of Waterfield and Victoria Sts has been flooded on more than one occasion as a result of surface flows in Victoria St flowing through the front door of the building. Council would like to better understand the level of flooding risk for this valuable asset. Secondly, a large part of the Coburg shopping centre has been purchased by council, predominantly between Waterfield Street and Coburg Railway Station, with the intention of allowing major redevelopment of the area. Flooding of the Coburg library has indicated that there are flooding problems in this area, so council would like to better understand the flooding characteristics of the Coburg shopping centre so that any future redevelopment is better informed about the likely flows that will need to be catered for. In addition, Council would like to know if there are any flooding issues in the Coburg shopping centre which can be fixed relatively simply.

This drainage study focuses on the redevelopment areas between Waterfield St and Coburg Railway Station, and also on the Coburg Library site which has recently been subject to flooding. Options for improving the drainage in these particular locations are provided, along with some guidance of costs involved in any drainage works, and some broad indications of how these costs could be passed on to the Waterfield St redevelopment.

This project follows on from an initial proposal, which was submitted to Moreland City Council in August 2006, for a drainage analysis in the vicinity of Coburg Library. However, since then that proposal has been expanded to include the proposed redevelopment in Waterfield St, and other drainage issues identified upstream of the Harding Street main drain.

1.2. Project Aims

The objectives of this drainage study are to:

- Investigate the capacity of the existing system of pits and pipes upstream of the shopping centre.
- To identify key flow paths and areas of inundation within the detailed study area (Coburg Shopping Centre) including flood levels adjacent to key buildings including the Coburg Library.

- To identify opportunities to upgrade the drainage system to improve existing levels of flood protection within the Coburg Shopping Centre.

1.3. Tasks involved in study

The Coburg drainage study includes the following tasks:

- Review of existing underground services located using a MOCS search of the Coburg shopping centre.
- Detailed site survey of existing overland flow paths and street geometries throughout the Coburg shopping centre. This task also includes surveying of several key pipe invert locations.
- Hydrological analysis using RORB in order to estimate inflows for the Coburg shopping centre.
- Hydraulic analysis for upstream tributaries including rational method calculations, hydraulic grade line analysis, and assessment of inlet pit capacities.
- Detailed hydraulic analysis of Coburg shopping centre using XP Storm
- Identification, costing and assessment of upgrade opportunities within the Coburg shopping centre.
- Discussion of possible development contributions schemes to allow the costs of some drainage works to be passed on to developers involved in the redevelopment of the Coburg Shopping Centre.

2. Study Area

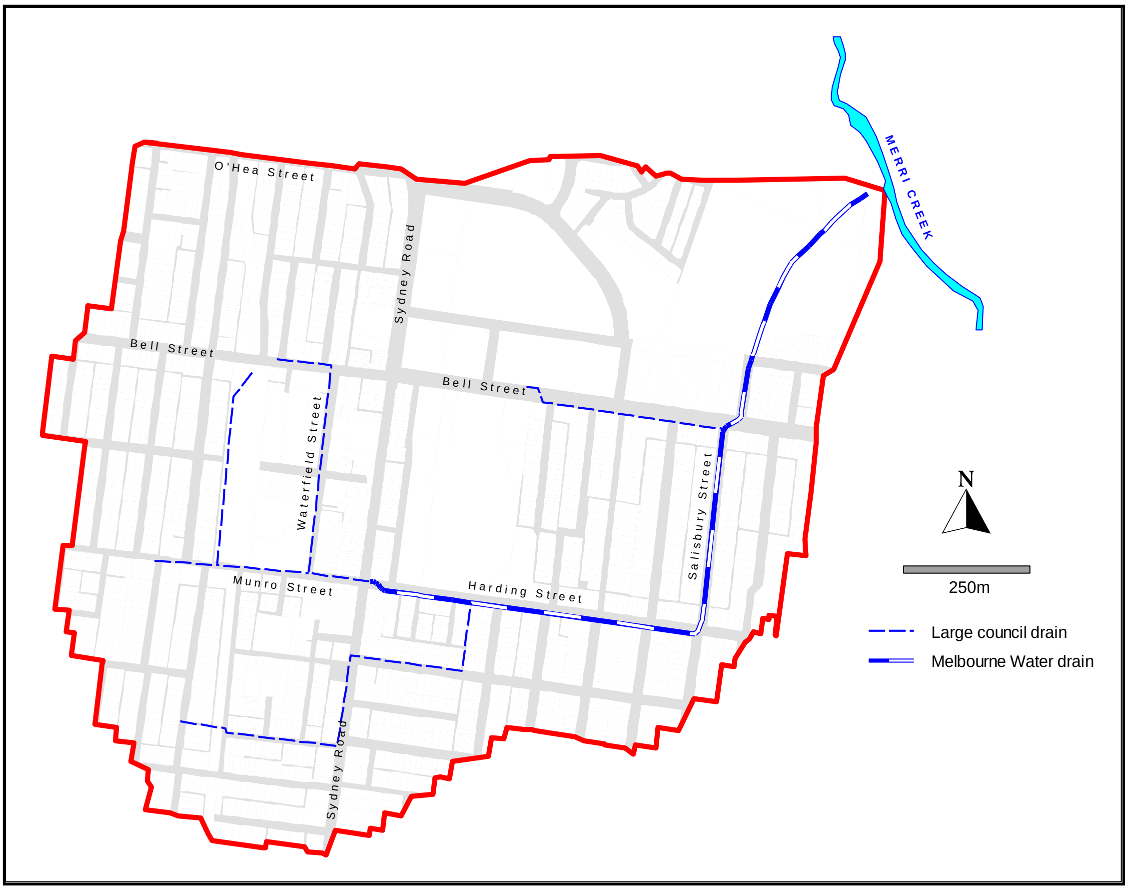
2.1. The Harding Street catchment

The study area is part of the Harding Street catchment, a small tributary of Merri Creek approximately 7.5 km north of Melbourne CBD.

The Harding Street catchment covers 175 ha, as shown in the figure below. It begins to the west of Sydney Road, covering the area between O'Hea Street and Munro Street. Council drains pass flow through the Coburg shopping centre to Munro St, and then across Sydney Rd to Harding St. Downstream of this point, the drain is managed by Melbourne Water. The Harding St drain flows east along Harding St, then north along Salisbury St, through McDonald Reserve and Coburg High School to Merri Creek.

The catchment is almost entirely residential and commercial, except for Coburg Cricket Ground and McDonald Reserve.

■ **Figure 2-1: Harding Street catchment**

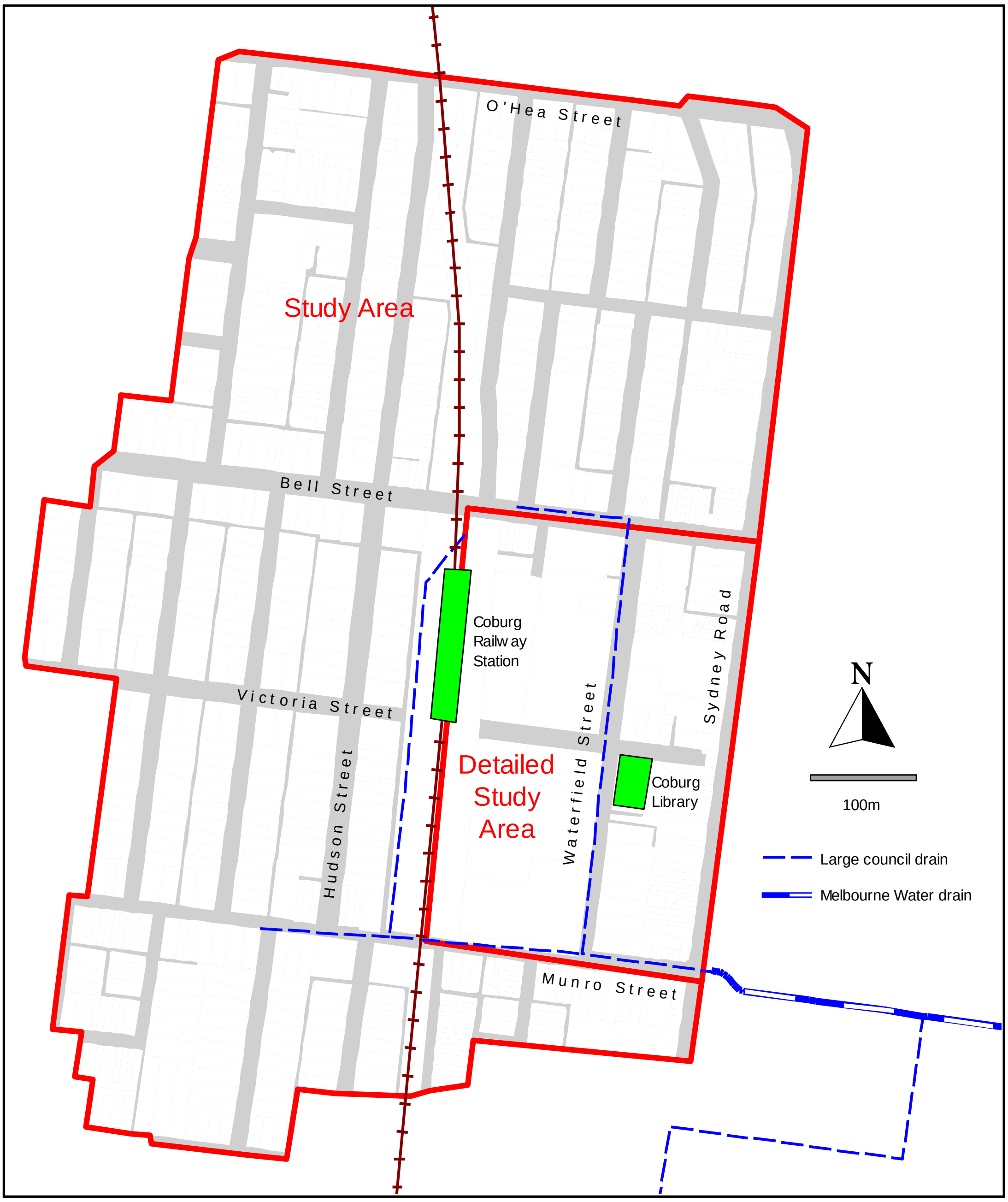


2.2. The study area

The study area is shown below. It includes the area upstream of the Harding St Main Drain (Melbourne Water asset), bounded by Sydney Road, Munro Street, Sutherland St, Kendall St, and O'Hea St.

In addition, more detailed hydraulic analyses have been undertaken for the main commercial area, roughly bounded by Sydney Road, Munro St, the railway, and Bell St.

■ **Figure 2-2: Study Area**



3. Survey

3.1. MOCS Search

A MOCS search was undertaken within the detailed study area to identify the location of existing infrastructure that may affect the feasibility of proposed drainage upgrade options. Table 3-1 describes the services in the study area. Overall, proposed drainage upgrade options will need to take these services into consideration.

■ **Table 3-1: Description of Services within Coburg Shopping Centre**

Asset Owner	Description of Assets
Visionstream, Ncc – Vic	Low risk of the works affecting the Nextgen Network – optical fibre cable. Cable runs east of Sydney road along Russell Street and is not in study area.
Yarra Trams and Swanston Trams	Trams along Sydney Road
Alinta AE	Minor Electricity Cables throughout study area
Telstra (Coburg)	Minor telecommunication cables throughout study area and some major optic fibres along main roads including: Bell Street, Victoria Street, Munro Street and Sydney Road.
Tenix Maintenance Services (gas)	High Pressure gas mains (140kPa – 515kPa) throughout the study area
Yarra Valley Water (Ltd.)	Water mains and waste water mains throughout the study area
Melbourne Water	Drainage pipeline along Harding Street but not in study area
Moreland City Council	Drainage pipelines throughout the area

3.2. Existing data

Spatial data was provided by Melbourne Water including 1m contours over the study area and the location of Harding Street drainage pipeline. There were also some 0.1 m natural surface contours provided by Melbourne Water from Flood Plain Mapping, however this only covered a small section near the Sydney Road and Harding Street intersection. Moreland City Council provided the location of the inlet pits and council drains including some diameters of pipes but no invert levels. A site inspection showed that some of the locations of the inlet pits were inaccurate and raised questions about the location of some of the pipes.

Overall, the extent of the data was insufficient for a detailed hydraulic analysis and hence a detailed site survey capturing key invert levels and key surface features was required.

3.3. Site survey

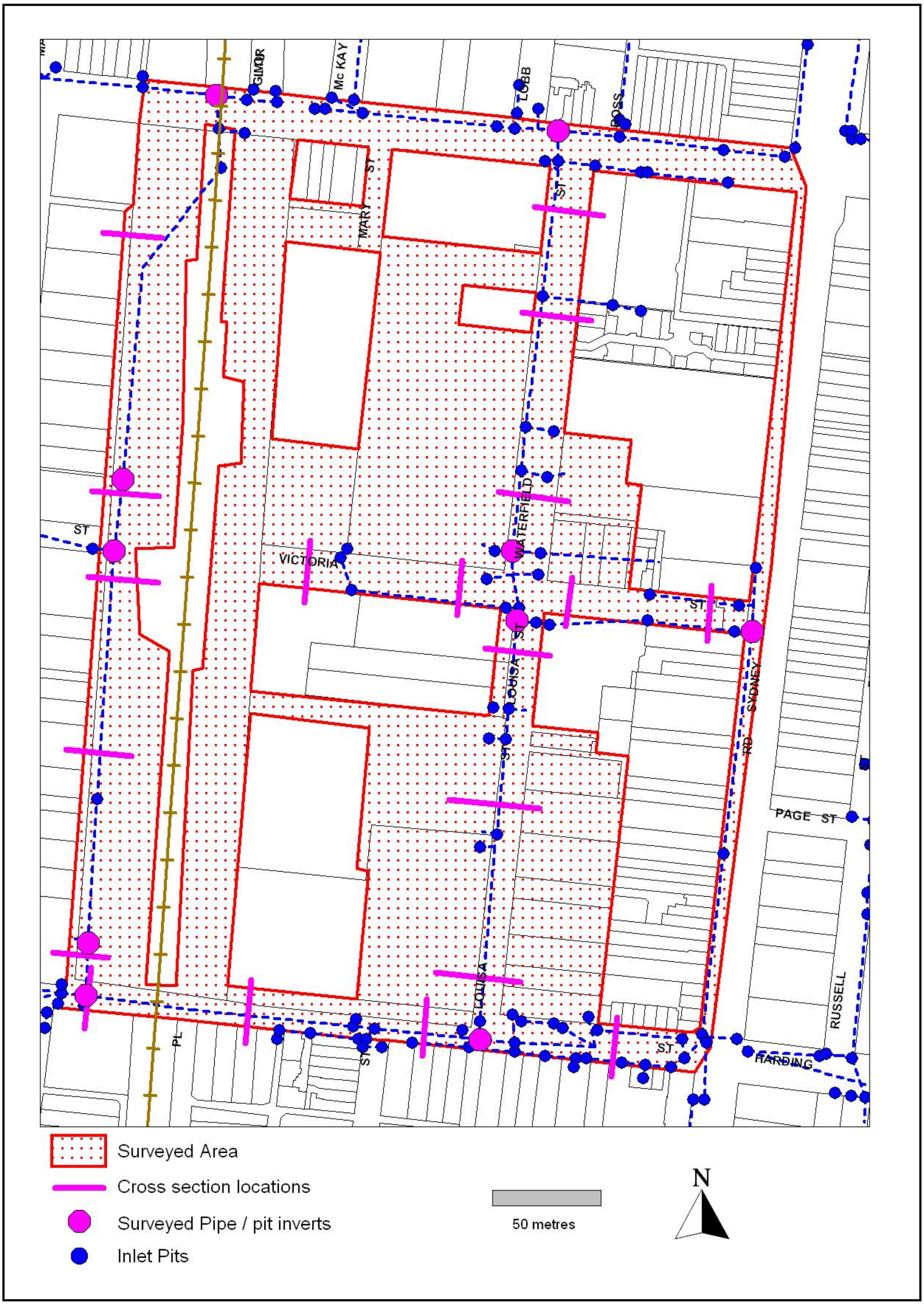
A detailed site survey was undertaken to better understand the likely direction of surface flow within the detailed study area around the Coburg shopping centre. This task included the detailed site survey of the following:

- Pipe invert levels at selected locations;
- Some cross sections of streets at key locations including edge of buildings, top of gutter, gutter invert and several points across the road; and
- Feature survey of public access areas (car parks, roads and reserves) around central Coburg. Particular attention was given to drainage paths, change of grade and change of surface (grass/asphalt).

Figure 3-1 shows a map of the surveyed area, cross sections and locations of surveyed pipe inverts. Not all pipe inverts were required due to the nature of the analysis, but some indicative levels along larger pipes were necessary. Note that Moreland City Council also lifted pit lids at the downstream end of Munro Street.

The results of the feature survey and pipe inverts are shown in Appendix A.

SKM



■ **Figure 3-1: Map of Surveyed Area**

4. Hydrology

4.1. Introduction

The peak 1 year, 5 year, 20 year and 100 year Average Recurrence Interval (ARI) flows for existing conditions were calculated using the hydrological model RORB (Monash University, 2007). A brief discussion of RORB is provided in Appendix B.

An existing RORB model for the entire Harding Street catchment was developed for Melbourne Water in 2006. Based on this model, another RORB model was created for the study area only (including Coburg Shopping Centre and tributaries upstream). However, this new model included many more subareas, and delineation of catchment boundaries was improved on the basis of site observation.

The new model was "calibrated" by adjusting the model parameters until the peak 100 year ARI flow at the corner of Sydney Rd and Harding St was the same in both the old and new models. The new model was then run for the 1 year, 5 year, 20 year and 100 year ARI events and the hydrographs at numerous locations in the study area were extracted and used as inflows for the detailed hydraulic modelling.

4.2. Modelling Approaches

The RORB model was developed by adopting the upper sub-areas from the Harding Street Model. Firstly, the catchment boundary was reviewed and adjusted so that it was consistent with contour information, council drain alignments and residential property boundaries. Then the RORB sub-areas were sub-divided to increase the level of detail captured by the RORB model. All pipes and reaches flowing down roadways and other paved areas were assumed to be lined in the RORB model.

Parameters for the one defacto storage present in the model were checked against available contour information. More detail on this is provided in Appendix B. The results of these checks showed that the storage parameters in the existing model were appropriate, therefore, the storage and its parameters were adopted from the Harding Street model for this investigation.

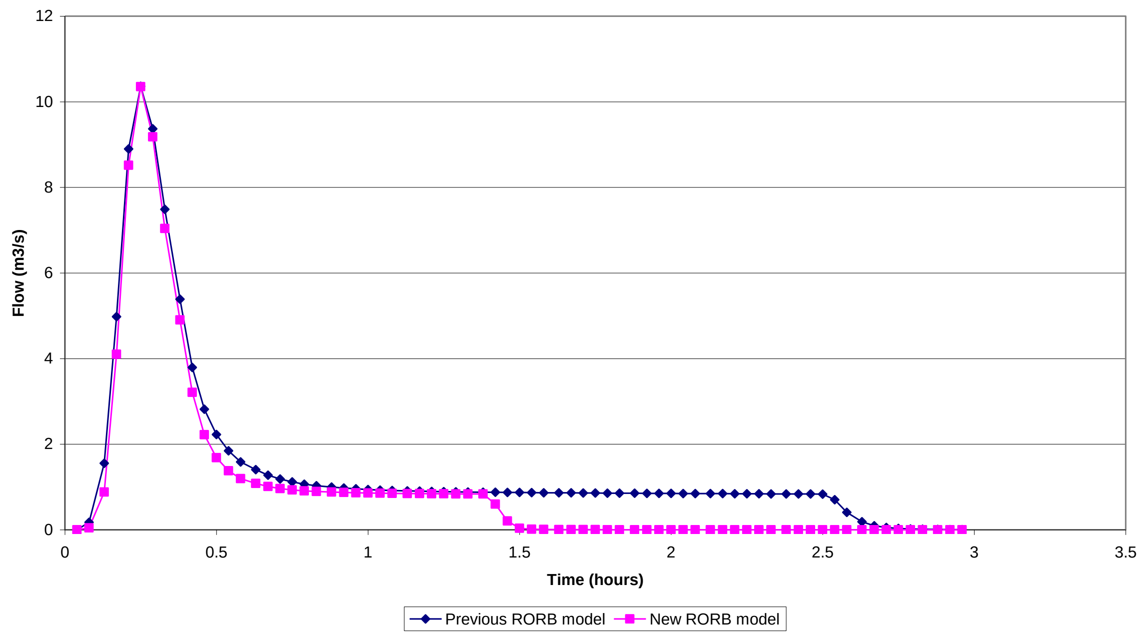
4.3. Adopted Parameters

For this catchment, "calibration" of the new RORB model was undertaken by adjusting the routing parameter (k_c) until the peak flow at the catchment outlet (corner Munro Street and Sydney Road) matched the peak flow for the same location in the old model.

The adopted parameters for the RORB model are shown in Table 4-1 and the hydrographs for the old and new model at the corner of Sydney Rd and Harding St are shown in Figure 4-1.

- **Table 4-1: RORB Calibration Parameters**

Parameter	Value
k_c	1.00
m	0.8
IL	15 mm
RoC	0.6
d_{av}	0.63



- **Figure 4-1: Comparison of Hydrographs for the new model against the old model at the corner of Sydney Rd and Harding St.**

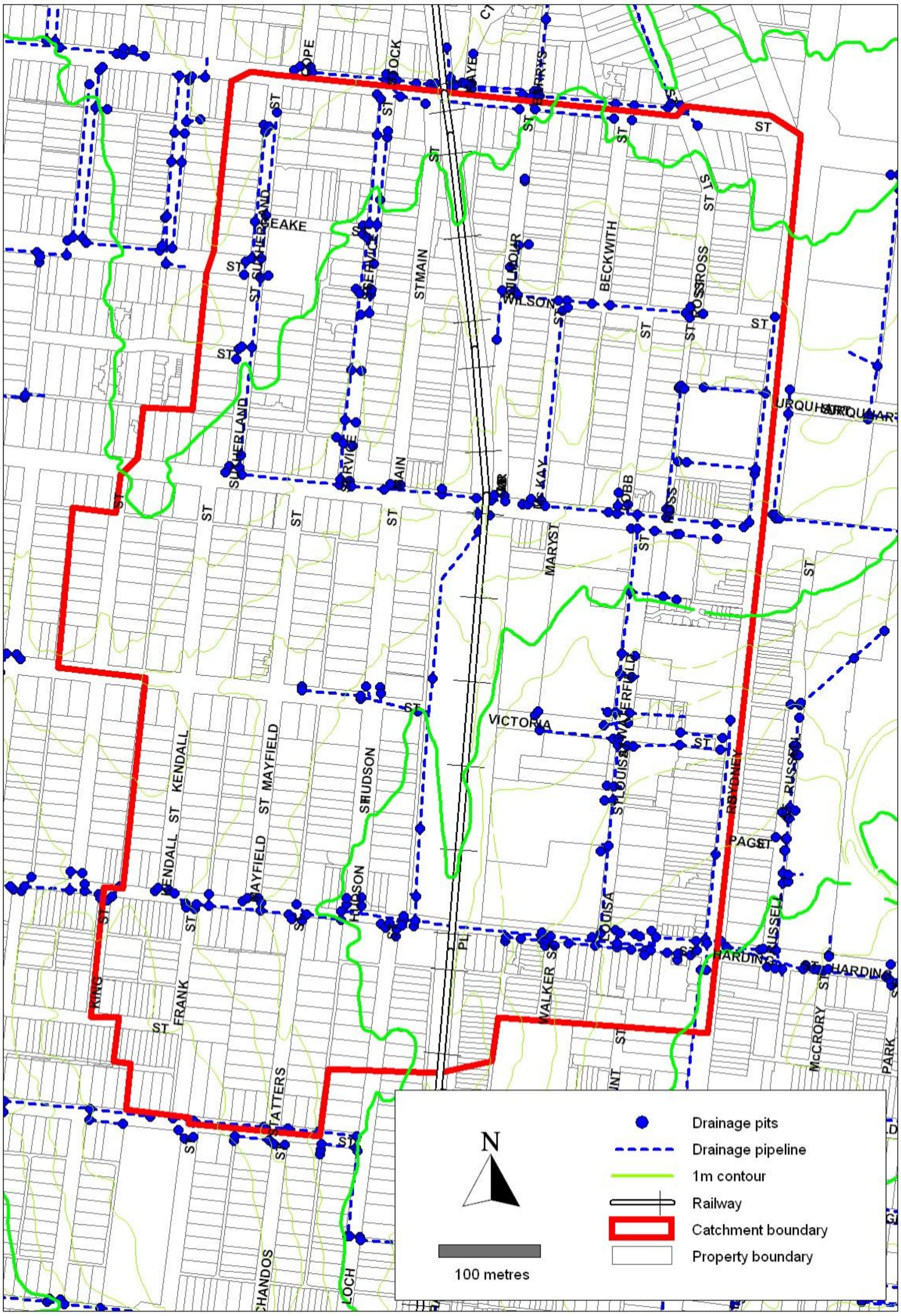
5. Hydraulic analysis of upstream tributary system

5.1. Details of existing system

The drainage system within the catchment has been split into separate systems for the purposes of the hydraulic analyses, and throughout this report the upstream tributaries will be referred to as:

- Munro Street;
- Victoria Street;
- McKay Street;
- Service Street;
- Sutherland Street; and
- Sydney Road/Bell Street.

This section of the report outlines the analysis of the upstream tributary drainage system only. More detailed analysis of the Coburg Shopping Centre is given in the following section.



- **Figure 5-1: Map of showing Upstream Tributaries**

5.2. Method of analysis

5.2.1. Rational Method

The rational method is the simplest and most widely used method for calculation of peak discharge from a catchment. The calculation method adopted for this study has been based on the method described in the Melbourne Water Land Development Manual. The basic equation is as follows:

$$Q = C.I.A/360$$

Where:

Q = peak flow in cumecs, corresponding to the average recurrence interval under consideration;

C = runoff coefficient, (fraction impervious multiplied by the frequency factor adopted from Harding Street Redevelopment Drainage Scheme);

I = rainfall intensity in mm/hour, corresponding to t_c, the time of concentration of the catchment, and the average recurrence interval under consideration; and

A = catchment area in hectares.

The rational method was applied to each of the drainage systems described in Section 5.1 for the

- 1 year ARI event;
- 5 year ARI event;
- 20 year ARI event; and
- 100 year ARI event.

The 100 year ARI event is required for planning purposes. New piped drainage systems in residential areas are typically designed for a 5 year ARI event as recommended in the Melbourne Water Land Development Manual (MWC 2004), although this standard varies between councils around the Melbourne metropolitan area. In older suburbs such as Coburg, the original design standard was typically much lower than 5 year ARI.

In addition, councils may apply different standards to development of commercial and industrial areas compared to residential areas. The standard is generally based on considerations of public safety and potential flood damage, suggesting that a higher standard may apply around a busy shopping area such as Coburg where significant vehicle and pedestrian traffic may be affected, say a 10 year ARI event.

To calculate flows at certain points within each system, each drain was separated into sections at selected pit locations, normally chosen so that they were upstream of a junction. In this way, peak flows could be calculated for each selected pit location, and for each of the four chosen ARI's.

5.2.2. Hydraulic Grade Line (HGL)

HGL analysis was undertaken to understand the capacity of the existing drainage system, in particular to determine the ARI of an event which would cause the underground drainage system to surcharge, resulting in overland flow.

For the HGL analysis, drain diameters, inverts, ground surface levels and pipe lengths were adopted either from drainage system information provided by Moreland City Council where available, or in some cases the ground surface levels were estimated using 1m contour information provided by Melbourne Water.

The flows were set to the maximum pipe capacity by factoring the 5 year ARI flows until the HGL level was just below the ground surface level.

Note that the flow in the HGL analysis was calculated downstream of the pit. Therefore, at the last pit in the drainage system, flow cannot be calculated and has been left blank in the results table.

5.2.3. Inlet Pit Capacities

An analysis of the street drainage inlets was undertaken to understand whether there is sufficient inlet capacity for the existing drainage system. If inlet capacity is too low, then surface flooding may occur when there is still some remaining capacity in the pipe.

This analysis was undertaken by inspecting all inlets in the study area and estimating the shoulder crossfall and slope of the road. For each section of drainage (as defined for the rational method calculations), the average flow per pit was calculated by dividing the HGL flow by the number of pits in the respective section. The flow width was then calculated using Manning's equation, and the inlet pit capacity was calculated using standard charts Vicroads Manual Road Design Guidelines for Drainage (VicRoads 1999).

It was assumed that all pits were side entry pits. No allowance was made for blockages.

If the total pit capacity was less than the HGL flow for each section of drainage, this was assumed to indicate that the inlet pit capacity was insufficient. Note that in the results table, if an inlet pit capacity is documented as sufficient, it only means it is sufficient for the capacity of the existing drainage system. It may not be sufficient for the full 5 year ARI design event, but there is no need to provide inlet pit capacity in excess of the pipe capacity.

5.3. Results

Table 5-1 summarises the results for the hydraulic analysis. The dark cells highlight sections of pipe that are not sufficient at the specified ARI. They also highlight inlet pit capacities that are insufficient for the existing drainage system. Overall, the following observations can be made:

- The maximum capacity of the pipes at Munro Street and Sutherland Street is greater than the 5 year ARI event;
- The maximum capacity of all other pipes is less than the 5 year ARI event;
- The maximum capacity of Victoria Street, McKay Street and Service Street drainage systems is less than the 1 year ARI. The maximum capacity of Sydney Road/Bell Street drainage system is slightly less than the 1 year ARI;
- The inlet pit capacity is insufficient at Victoria Street due to the very large area upstream of the first inlet pit.

Plots of the HGL analysis are shown in Appendix C.

Table 5-1: Summary of results of rational method calculations, HGL at point of failure, and sufficiency of inlet pit capacities

Location	Discharge (cumecs)						% of 5 year ARI	Pit Inlet Capacity
	Pit Number	1 Year ARI	5 Year ARI	20 Year ARI	100 Year ARI	Pipe Capacity		
Munro St	21691	0.04	0.06	0.09	0.16	0.06		sufficient
	21709	0.13	0.18	0.30	0.52	0.19		sufficient
	21730	0.22	0.29	0.48	0.85	0.31		sufficient
	21750	0.35	0.47	0.78	1.36	0.50		sufficient
	21807	1.72	2.31	3.82	6.67		106%	
Victoria St	20210	0.36	0.49	0.82	1.44	0.31		insufficient (there are no pits upstream of this point and there is a large area upstream)
	20236	1.01	1.37	2.27	3.99		63%	
McKay St	20373	0.06	0.08	0.13	0.23	0.02		sufficient
	20308	0.12	0.17	0.28	0.50	0.04		sufficient
	20280	0.28	0.39	0.65	1.15	0.09		sufficient
	20278	0.32	0.44	0.73	1.29	0.10		sufficient
	20341	0.53	0.72	1.19	2.09		22%	
Service St	18807	0.01	0.01	0.02	0.03	0.01		sufficient
	18794	0.15	0.20	0.32	0.56	0.12		sufficient
	20194	0.28	0.37	0.60	1.03	0.22		sufficient
	20228	0.51	0.66	1.09	1.86	0.39		sufficient
	20248	0.65	0.84	1.37	2.34		59%	
Sutherland St	18775	0.02	0.02	0.03	0.06	0.02		sufficient
	18761	0.07	0.09	0.15	0.25	0.10		sufficient
	20177	0.18	0.23	0.37	0.63	0.25		sufficient
	20192	0.25	0.32	0.52	0.89	0.36	110%	
Sydney Rd/Bell St	20416	0.05	0.06	0.10	0.18	0.04		sufficient
	20403	0.08	0.11	0.18	0.31	0.07		sufficient
	20401	0.11	0.15	0.25	0.45	0.10		sufficient
	20351	0.17	0.23	0.39	0.68	0.15		sufficient
	20341	0.78	1.05	1.75	3.04		66%	

(orange)	If flow at ARI is greater than failure point of HGL
(grey)	Total inlet pit capacity is insufficient
(light orange)	HGL flow is not calculated for end pit

5.4. Suggested system augmentation works

It is recommended that pipes in Victoria Street, McKay Street, Service Street and Sydney Road/Bell Street be upgraded to at least have a capacity for a 5 year ARI event.

However, it is recognised that the majority of streets in the Coburg area are likely to have similar ARI drainage capacities, and so any improvement in street drainage will need to be prioritised throughout the Moreland municipal area based on severity of property flooding, risks to public safety, and consequences of flooding.

Undertaking these upgrades may cause a minor increase in peak flows further downstream. However the time of concentration in these upstream sections of pipe are very short, and so any increase in the piped flow in these areas will only have a marginal impact on overall peak flows further downstream.

6. Hydraulic analysis of Coburg Shopping Centre Drainage System

6.1. Introduction

A detailed analysis of the Coburg shopping centre drainage system was undertaken using XP-storm (formerly known as Extran). XP-storm is a quasi 2 dimensional modelling package which is ideally suited to hydraulic studies in urban catchments as it can model both piped and overland flows simultaneously.

This analysis has been based on the current drainage network and includes:

- Mapping of flood extents showing problem areas of inundation
- Options to alleviate maximum flow and levels at problem areas
- Initial qualitative analysis of peak flow and depths for the various options

Hydraulic analysis of upstream tributaries was previously discussed in Section 5. Overall, it was found that the maximum capacity of the drainage network of upstream tributaries is less than the 5 year ARI and sometimes less than the 1 year ARI.

It should be noted that, in accordance with normal practice, all analysis of the drainage system in this area is based on the assumption that all flow paths, including pipes, channels, and gutters, are clean and free of blockages. However, commercial areas such as Coburg tend to produce significant levels of litter, and site observation and council feedback suggests that litter is a major issue in this catchment. Litter can block drains and gutters causing additional flooding problems, however due to the random, unpredictable nature of this problem, no allowance has been made in this study for blockages due to litter.

6.2. Details of existing system

The existing system modelled in XP Storm includes the area bounded by Bell St, Sydney Road, the laneway west of the railway line and Munro Street. This includes all pipes in this area as shown in Figure 3-1 with the exception of one pipe along Victoria Street from Waterfield Street to Sydney Road. The survey showed that this pipe does not exist and has been mapped in MapInfo incorrectly.

There are also a couple of small channels in the catchment. There is a 300mm deep x 400 mm wide channel along the laneway west of the railway line upstream of Victoria Street (refer to photo on title page of report). There is also a small trapezoidal channel east of the railway line.

However, from a site inspection it was decided that this channel was not active as it was in degraded condition. It is more likely that flow would travel overland across the carpark.

Figure 6-1 shows the overland flow paths throughout the Coburg Shopping Centre and was developed according to contour lines. It also shows the channel and banks indicating the potential width of the flow path. The locations of the cross sections were chosen to capture any change of geometry. They were generally spaced at frequent intervals and normally upstream and downstream of a corner or bend in the flow path. Cross sections were positioned close together for areas where the direction of the flow path was uncertain. These include the railway line at Bell Street, the railway line at Munro Street and the intersection of Waterfield Street and Victoria Street (near the Coburg Library).

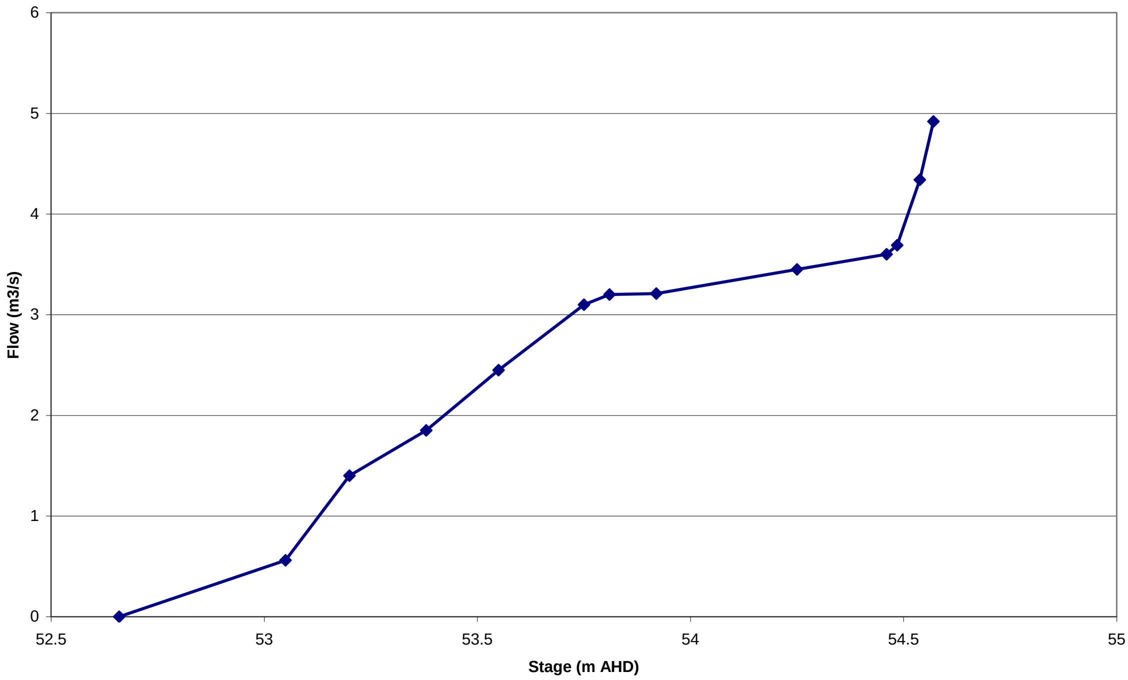
Figure 6-1 also shows the locations of inflow hydrographs adopted from RORB.

- **Figure 6-1: Map of Coburg Shopping Centre with Overland Flow Paths, Surveyed Cross Sections and Inflows from RORB**

6.3. Model Setup

The existing drainage network and overland flow paths were modelled in XP Storm. Pipe diameters and inverts at key locations were based on the detailed site survey. Cross sections of existing flow paths including street geometries were also based on the detailed site survey. Inflows at key locations in the catchment for each storm event were adopted from the RORB model and are shown in Appendix D.

The outlet in the study area is located on the corner of Sydney Road and Munro Street. Since the outlet is located at the upstream end of the Harding Street drain, the boundary condition at this location was based on a rating curve. This rating curve was developed by extracting the stage discharge relationship for the same location (just downstream of Sydney Road) in the Melbourne Water Harding Street XP storm model. The final stage discharge relationship used at the outlet is shown in Figure 6-2.



- **Figure 6-2: Stage Discharge Relationship used at the Outlet in XP Storm**

There are a number of locations within the study area where the setup of the model was particularly critical to ensuring an accurate representation of the flow. These locations include:

- **The Waterfield Street and Victoria Street intersection (location of Coburg library) -** There is a deep gutter on the north-west corner at the intersection of Waterfield Street and

Victoria Street. When the pipe is at full flow, this gutter holds the flow until the water level rises above the road crest and then continues along Waterfield Street. Therefore, in XP Storm the road crest has been set up as a defacto weir.

- **Munro Street upstream of the railway -** As mentioned in Appendix B, the railway line crossing Munro Street is on an embankment and will prevent any overland flow draining from west to the east of the catchment. Therefore the runoff from the western part of the catchment is restricted to either flowing through the council drain under the railway or flowing further along the railway line out of the study area into the neighbouring catchment. Flow out of the study area has been modelled as a loss in the XP storm model.
- **The split of flow over the railway at Bell Street -** The railway line crossing Bell Street is relatively flat. It is difficult to determine whether the flow will:
  - cross the railway; or
  - stay on the western side of the railway and subsequently flow through the carpark; or
  - do both.

  To capture this in the XP Storm model, the cross sections across the railway have been divided into two to represent the east and west side of the railway line. These have been linked to one another, so that the model can compute which direction the flow will go.

In addition, feedback from Moreland City Council suggested that the section of Sydney Road south of Munro Street may be acting as storage. The topography along this section is very flat and has a low point approximately 150 m south of Munro Street. This has been modelled in XP Storm by including the cross-section in the reach upstream of the outlet. However it should be noted that a wide, flat storage at this point in the drainage system will not affect upstream flows or velocities, but it may have an effect on expected peak flows in the Harding Street Main Drain downstream of Sydney Road.

The remainder of the model was set up in the conventional way with nodes representing inlet pits, connecting to pipes and the overland flow.

6.4. Results

Plans showing flood extents and flood depths are given in Appendix E.

7. Existing drainage issues around Coburg shopping centre

Based on the flood extents shown in Appendix E the particular problem areas in the existing drainage network include:

- Potential flooding of residential properties upstream of the railway on Munro Street;
- Large flows along Waterfield Street (from the Coburg library to Munro Street) and along Munro Street (from Waterfield Street to the outlet);
- Ponding and uncontrolled overland flow across the carpark west of Waterfield Street and north of Victoria Street); and
- Uncontrolled flow at the Bell Street rail crossing.

The area west of the railway line on Munro Street is considered problematic. This is because the railway acts as an embankment and the water can only pass downstream through one council drain. The council drain along Munro Street under the railway is 0.825 m and has a maximum capacity of 1.46 cumecs for a 100 year ARI. There is a maximum flow of approximately 8.3 cumecs upstream of the railway. Some of this additional flow that cannot fit in the pipe will be stored in the defacto retarding basin, however, once this is full the flow will encroach on surrounding residential properties and eventually flow along Loch Street and along the railway at the rear of Loch Street properties towards another council drain south of the study area. The size and capacity of this drain is not known. From a site inspection and anecdotal evidence, it is likely that high water levels occur regularly along the laneway and it can reasonably be concluded that residential properties in this area are likely to be subject to regular flooding.

The areas that experience the highest velocity and flows are along Waterfield Street (from the Coburg library to Munro Street) and along Munro Street (from Waterfield Street to the outlet). These flows pose a risk to pedestrians and drivers. The only known area that experiences flooding above floor level is the Coburg library, although other unreported properties may be subject to similar severity of inundation.

The carpark east of Waterfield Street and North of Victoria Street currently experiences uncontrolled sheet flow. Under existing conditions, it is not considered dangerous as it travels at low velocities. If redevelopment occurs, however, it is recommended that this uncontrolled flow be eliminated, particularly if the flow increases. The flow may increase due to redevelopments upstream such as at the Bell Street railway line and is discussed further below.

There is also a low point in the car park north east of the junction of Waterfield Street and Victoria Street that causes ponding up to depths of approximately 0.5 m. This may cause risk to pedestrians or cars parked within the vicinity.

The direction of flow from Bell St west of the railway crossing is pertinent to the rest of the study area. Currently the flow splits both east and west of the crossing. If this area is redeveloped in future, it is critical to understand the downstream impacts of changing this flow split.

- If flow is directed west of the railway line, it will result in a larger flood extent at Munro Street upstream of the railway and may increase the number of residential properties prone to flooding.
- If flow is directed to the east side of the railway line, flows across the carpark will increase, the severity of flooding of the Coburg library will increase ,and flow along Waterfield Street will increase.

Therefore, these issues would need to be addressed if redevelopment occurs at the railway crossing on Bell Street.

In order to address these issues, several options have been developed and tested in the XP Storm model.

8. Potential augmentation options

Based on the flood extents shown in Appendix E the problem areas in the existing drainage network include:

- Potential flooding of residential properties upstream of the railway on Munro Street ;
- Large flows along Waterfield Street (from the Coburg library to Munro Street) and along Munro Street (from Waterfield Street to the outlet);
- Ponding and uncontrolled overland flow across the carpark west of Waterfield Street and north of Victoria Street);
- Uncontrolled flow at the Bell Street rail crossing.

In order to address these issues, several options have been developed and tested in the model. Each option has been isolated to determine its effectiveness before being combined with other options.

This process of developing options has taken into consideration that the Coburg shopping centre may undergo redevelopment in the near future, and a bypass (intended to be undertaken by VicRoads) has been removed from the public acquisition overlay to the north of Bell Street.

The options tested in this study are as follows :

- Option 1 – Pipe augmentation along Munro Street
- Option 2 – Relandscaping defacto retarding basin upstream of the Munro Street railway crossing
- Option 3 – Effects of controlled flows east and west of Bell Street railway crossing
- Option 4 – Storages underneath the existing car parks
- Option 5 – Pipe augmentation through the existing car parks
- Option 6 – Reprofiling Waterfield Street
- Option 7 – Pipe augmentation along Waterfield Street
- Combined Option 1 – Combining options 1, 5, and 7
- Combined Option 2 – Combining options 1 and 4

Costing

Cost estimates of the redevelopment works are shown for each option. The adopted cost rates are generally in accordance with recommended rates from Melbourne Water, which are used for the Redevelopment Services Schemes and adjusted as necessary to make an allowance for specific issues. Table 8-1 shows the typical cost factors applied depending on the condition of each section.

▪ **Table 8-1: Cost Factors to apply to Greenfields Reimbursement Rates**

Condition	Greenfields Factor	
	Typical Range	Median
Greenfield	1	1
Reserve	1.1 – 1.3	1.2
Minor Road	1.2 – 1.6	1.4
Developed Private Properties	1.5 – 2	1.8
Major Road	1.5 – 3	2.5
Pipe Jacking	2.2 – 5	4

The following assumptions have been made as part of the cost estimate:

- Relocation of services such as water, wastewater, gas, electricity, and telephony has not been included in cost estimates. This is partly because the cost of relocation of minor services is often relatively small, but also because the exact relocations required depends on the exact alignment chosen. Where significant services will be encountered, such as train and tram rails, these have been included in costings.
- Additional costs of works under rail or tram tracks are often significant, so these have been taken into account.
- Sections that have been tunnelled have been assigned a cost factor of 5.
- Tunnelling shafts are assumed to be $25,000 per metre depth. An arbitrary depth of 6 metres has been assumed.
- For major roads, a cost of $100,000 per road has been assumed for traffic management plans.
- An estimated railway management/compensation fee of $500,000 has been assumed each time the proposed works crosses the railway line. It has been assumed that the railway line will not remain in operation during construction, as there is a risk that the depth of the pipe is not sufficient to tunnel/pipe jack while the line is still in operation. This assumes that the railway line is closed so that works can be done over a weekend.

The cost for the railway management/compensation has been based on a weekend closure of the Upfield Line. It would include:

- Gaining approvals from Victrack, Connex and MainCo and their supervision costs
- Cost of redirecting passengers by bus around the closure site
- Cost of compensation that Connex has to pay the State Government for delays to customers travel times

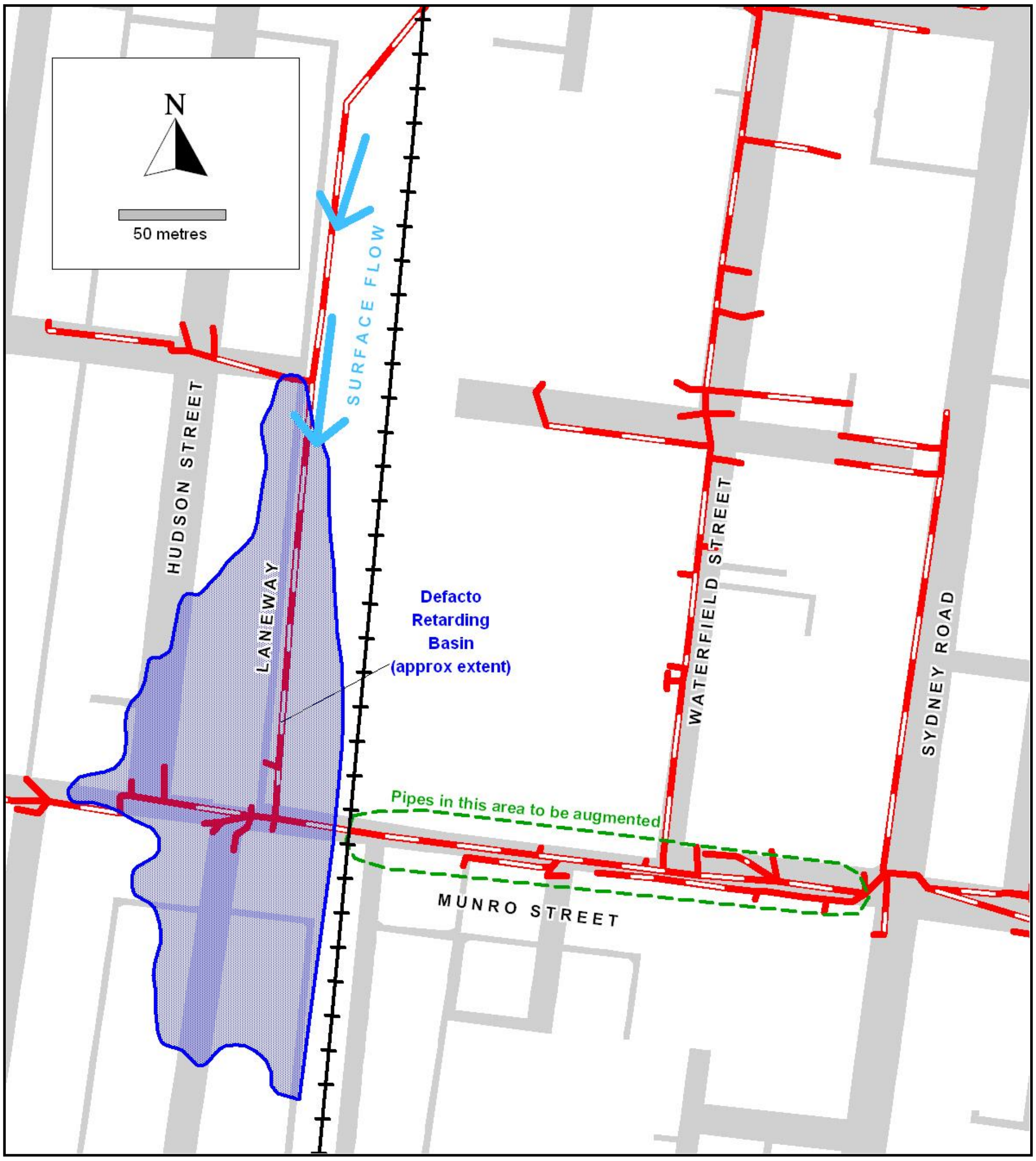
Note that this does not include any rectification to the rail line should it be damaged during construction.

The scope and quality of the works has not been fully defined and therefore the estimates are not warranted by SKM. These estimates are typically developed based on supplied costs for common items from Melbourne Water and SKM experience. The accuracy of the estimates is not expected to be better than say ± 50% for the items described in this report. A functional design is recommended for more detailed budget setting purposes.

8.1. Option 1 – Pipe Augmentation along Munro Street

This option investigated pipe augmentation along Munro Street to relieve the deep flooding upstream of the Munro Street railway crossing (refer to Figure 8-1). In this way, the deep water which builds up on the west side of the railway can be alleviated by piping more water along Munro St, away from the problem area. The total amount of flow entering this area is approximately 8.3 cumecs and the existing 0.825 m pipe under the railway can only carry approximately 1.46 cumecs. Pipe augmentation was sized in order to decrease levels in the defacto retarding basin while maintaining or decreasing overland flow along Munro Street.

- **Figure 8-1: Schematic layout of option 1**



8.1.1. Option 1 Hydraulic Results

Pipe augmentation was sized in order to decrease levels in the defacto retarding basin while maintaining or decreasing overland flow along Munro Street. This involved varying the size of the pipe so that it was increased under the railway and along Munro Street to 1.65 m until the intersection with Waterfield Street and increasing the remaining pipe to the outlet to 1.95 m. This combination increased capacity of the pipe under the railway to 7.6 cumecs. This slightly decreased the overland flow along Munro Street and decreased the levels in the defacto retarding basin. The results are shown in Table 8-2.

- **Table 8-2: Results of Pipe Augmentation for 100 Year ARI Event**

Scenario	Maximum Elevation in Defacto Storage (m AHD)	Capacity of Pipe under the railway line	Overland Flow upstream of Outlet	Level at outlet on Munro Street
Baseline	59.56 m	1.46 cumecs	7.13 cumecs	54.45 m AHD
Pipe Augmentation	59.03 m	7.60 cumecs	6.48 cumecs	54.57 m AHD

Note that any increase in piped flows along Munro Street would feed additional piped flows directly into the Harding Street Main Drain managed by Melbourne Water, which starts at the intersection of Munro Street and Sydney Road. However the Harding Street Main Drain was originally designed assuming the Munro Street defacto retarding basin was not present, and this same assumption was used by Melbourne Water when undertaking the drainage survey and flood mapping in 1998 (CMPS&F 1998). This means that much of the published flood information for this drain already assumes these additional piped flows along Munro Street are occurring.

Additional piped flow in Munro Street is likely to cause additional surface flooding along the Harding Street Main Drain alignment, on top of that already experienced. It is recommended that Moreland City Council discuss flood mitigation options along this drain alignment with Melbourne Water.

8.1.2. Option 1 Costs

Cost estimates of the proposed works for option 1 are shown in Table 8-3. This assumes tunnelling shafts of 6 m depth in order to tunnel under the railway line. Overall, the capital cost of works for this option is estimated at $3.5 million including design and contingency.

Note that tunnelling is still required even when the railway has been closed because Victrack generally does not allow trenching across railway lines. During tunnelling, VicTrack prefer to close the railway unless the tunnel is very deep; deeper than 6m as proposed in this case. This is for construction safety reasons, and also the potential risks and liability involved in passenger trains passing over an active construction site.

Additional costs of construction under the Sydney Road tram tracks is difficult to estimate directly, and has therefore been included as a higher construction cost factor of 5, reflecting the highly complex construction environment near this junction.

- **Table 8-3: Costs of Proposed Works for Option 1**

Total Cost	$ 2,648,293
Total Cost With Design & Contingency	$ 3,515,129

Location (Downstream to Upstream)	Works Description	Pipeline Diameter	Length (m)	Factor	Factored Unit Cost ($/m)	Cost ($)	TOTAL Cost With Design & Contingency ($)
Munro St (under railway)	Pipe Augmentation	1650	76	5.00	$ 5,065	$ 384,940	$ 540,263
Munro St (under railway)	u/s tunnelling shaft		6		$ 25,000	$ 150,000	$ 210,525
Munro St (under railway)	d/s tunnelling shaft		6		$ 25,000	$ 150,000	$ 210,525
Munro St (under railway)	Railway Management					$ 500,000	$ 500,000
Munro St (railway to Waterfield St)	Pipe Augmentation	1650	107	3.00	$ 3,039	$ 325,173	$ 456,380
Munro St (Waterfield St to Outlet)	Pipe Augmentation	1950	122	5.00	$ 7,690	$ 938,180	$ 1,316,736
Munro St (Waterfield St crossing Sydney Rd to Outlet)	Traffic Management Plan					$ 100,000	$ 140,350
Munro St (Waterfield St crossing Sydney Rd to Outlet)	Junction pits x 2			2.00	$ 50,000	$ 100,000	$ 140,350

8.1.3. Option 1 Feasibility

The main construction feasibility issue along Munro Street includes limited space for additional services. Existing services include:

- railway line;
- tram tracks on Sydney road;
- existing drainage pipeline;
- major optic fibres;
- high pressure gas mains;
- water mains;
- waste water mains; and
- minor electricity cables.

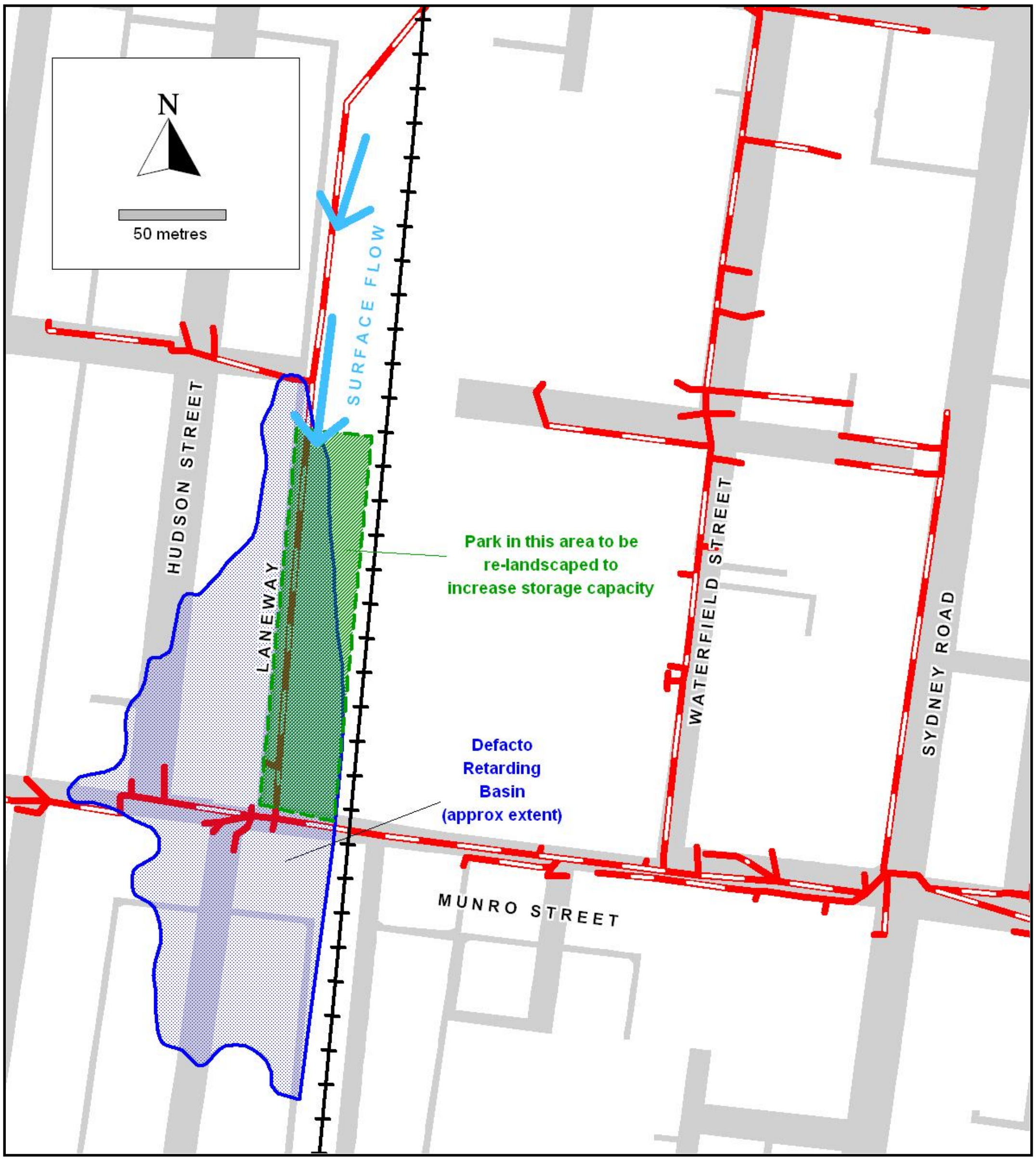
The proposed works for this option include tunnelling under the railway line, which makes this option very costly. It also includes crossing the tram tracks on Sydney Road, which is potentially complex and may affect the timing of construction (e.g. may need to construct during night time or on the weekend to minimise disruption to public transport). To determine whether there is adequate space for the proposed works for this option, further investigation will be required at the functional design stage. Relocation of some of the services listed above may need to be taken into consideration, however **this has not been included in the costs** at this stage of the project except for the railway and tram tracks.

8.2. Option 2 – Relandscaping Defacto Retarding Basin

This option investigated increasing the size of the defacto retarding basin upstream of the railway on Munro Street (refer to Figure 8-2). This would allow additional water to be stored in the park area, consequently reducing the volume of water which would spill out on to neighbouring streets and properties.

The defacto retarding basin was sized through trial and error to determine the size required to decrease the water levels in the defacto retarding basin.

- **Figure 8-2: Schematic layout of option 2**



8.2.1. Option 2 Hydraulic Results

It was found that a storage with a surface area of greater than 30 ha would begin to lower the water level in the defacto retarding basin. This area assumes that the maximum depth of the storage coincided with the invert of the existing drain passing under the railway. The results are shown in Table 8-4.

- **Table 8-4: Results of Enlarging Defacto Retarding Basin for 100 year ARI event**

Scenario	Maximum Elevation in Defacto Storage (m AHD)	Overland Flow upstream of Outlet
Baseline	59.56 m	7.13 cumecs
Relandscaping Defacto Storage to 40 ha	59.52 m	7.03 cumecs

Note that this option results in marginally lower flows at the downstream end of the study area. This would result in a very small reduction in flood levels along the alignment of the Harding Street Main Drain.

8.2.2. Option 2 Feasibility

From aerial photography the maximum area of storage available is less than 1.5 ha. According to the model, this size does not have a significant effect on the water levels and is not considered a cost effective option. Therefore, enlarging the defacto retarding basin to 30 ha is not considered feasible and consequently a cost has not been provided for this option.

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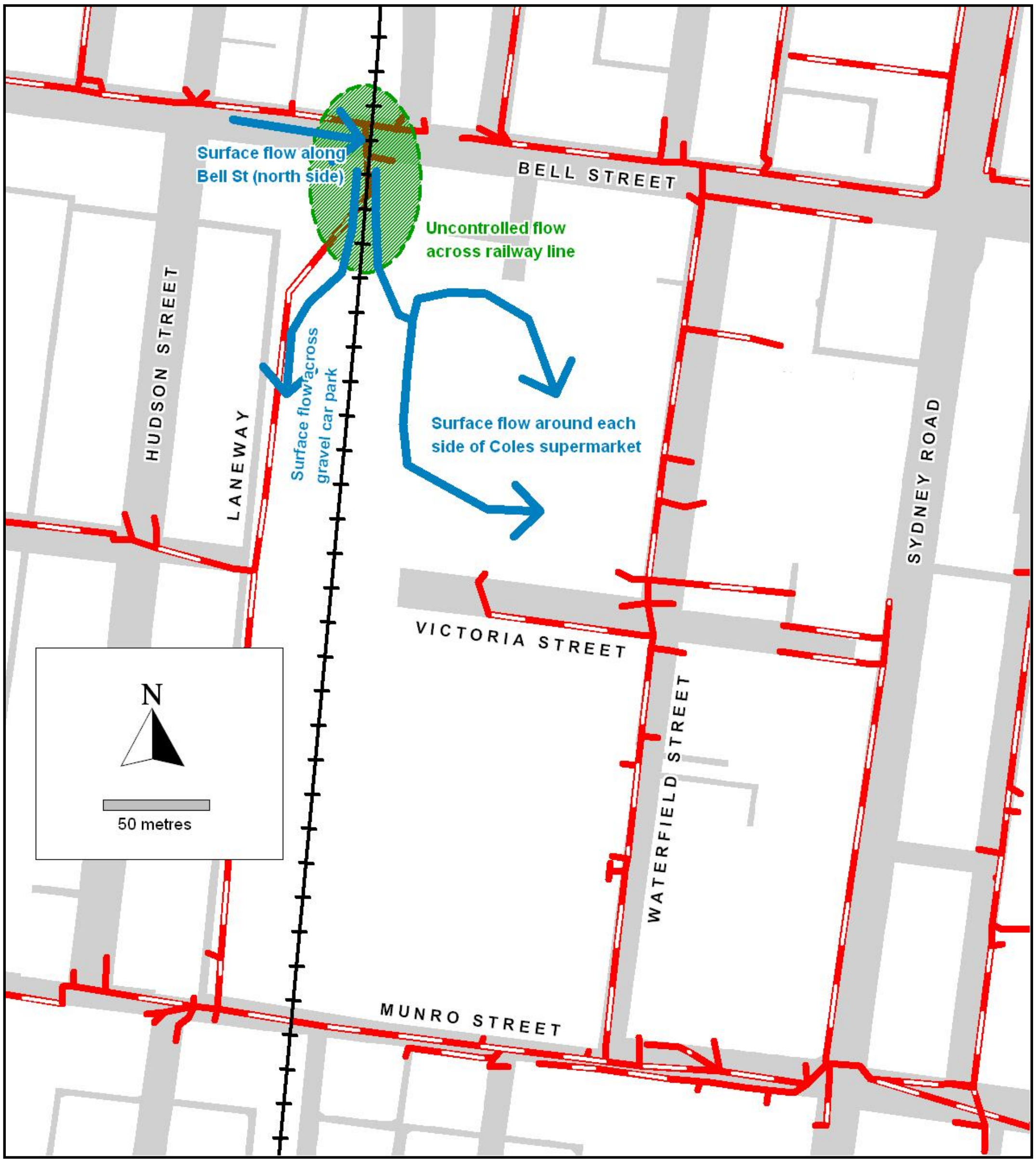
8.3. Option 3 – Controlled Flows East and West of Bell Street Railway Crossing

This option investigated the impact when all flow is diverted along the east side of railway or when all the flow is diverted west of the railway (refer to Figure 8-3). This option was tested to demonstrate the risks that should be considered if redevelopment occurs near the railway line at Bell Street. For example, if redevelopment occurred which diverted more flow across the railway, flows through the carpark to Waterfield Street would be increased, exacerbating existing problems. Likewise, if flow was diverted west of the railway, flow entering the defacto retarding basin upstream of Munro Street would be increased, exacerbating existing flooding in this area.

▪ **Figure 8-3: Schematic layout of option 3**



8.3.1. Option 3 hydraulic results

Table 8-5 shows a summary table of the results of flow being directed east or west of the railway line at Bell Street.

▪ **Table 8-5: Results when flow is directed east or west of railway**

Scenario	Overland Flow west of Railway (cumecs)	Overland Flow east of Railway (cumecs)	Overland Flow at Outlet (cumecs)	Water Level at Library (m AHD)
Baseline	1.71	1.76	7.13	57.92
Direct all flow west of railway	2.96	0.57	6.03	57.87
Direct all flow east of railway	0.60	2.78	8.13	57.97

Diverting all Flow West of Railway at Bell Street

Overall, if flow is directed along the west side of the railway line the hydraulic results show that:

- the flow along the west side of the railway is increased from 1.71 cumecs to 2.96 cumecs. This will amplify the issues upstream of the railway on Munro Street.
- Flows entering the storage will increase from 8.3 cumecs to 9.5 cumecs (these values include inflows from Bell Street, Victoria Street and Munro Street). This increase in flow would increase the flood extent and may increase the number of properties prone to flooding.

Therefore, if all flow is directed west of the railway, options need to be developed to cope with the additional flow and address the issues outlined previously in Section 7.

Diverting all Flow East of Railway at Bell Street

Overall, if flow is directed along the east side of the railway line the hydraulic results show that flow is increased from 1.76 cumecs to 2.78 cumecs. Directing the flow to the east of the railway has the following impacts:

- It will help alleviate the issues upstream of the railway on Munro Street; however
- It will increase uncontrolled flow across the car park;
- It will increase flows along Waterfield Street and along Munro Street towards the outlet; and
- It will also increase water levels at the Coburg Library and other buildings in the vicinity.

Therefore, if all the flow is directed across the railway, options need to be developed to cope with the additional flow and address the issues outlined previously in Section 7.

8.4. Option 4 – Storages underneath the Car Park

This option investigated the storage required to decrease the peak flows along Waterfield Street and along Munro Street towards the outlet. A storage would reduce peak flows by only allowing flows up to the pipe capacity to pass. All other flows are held in the storage area until the storm has passed. This eliminates surface flooding immediately downstream of the storage, and reduces surface flooding further downstream.

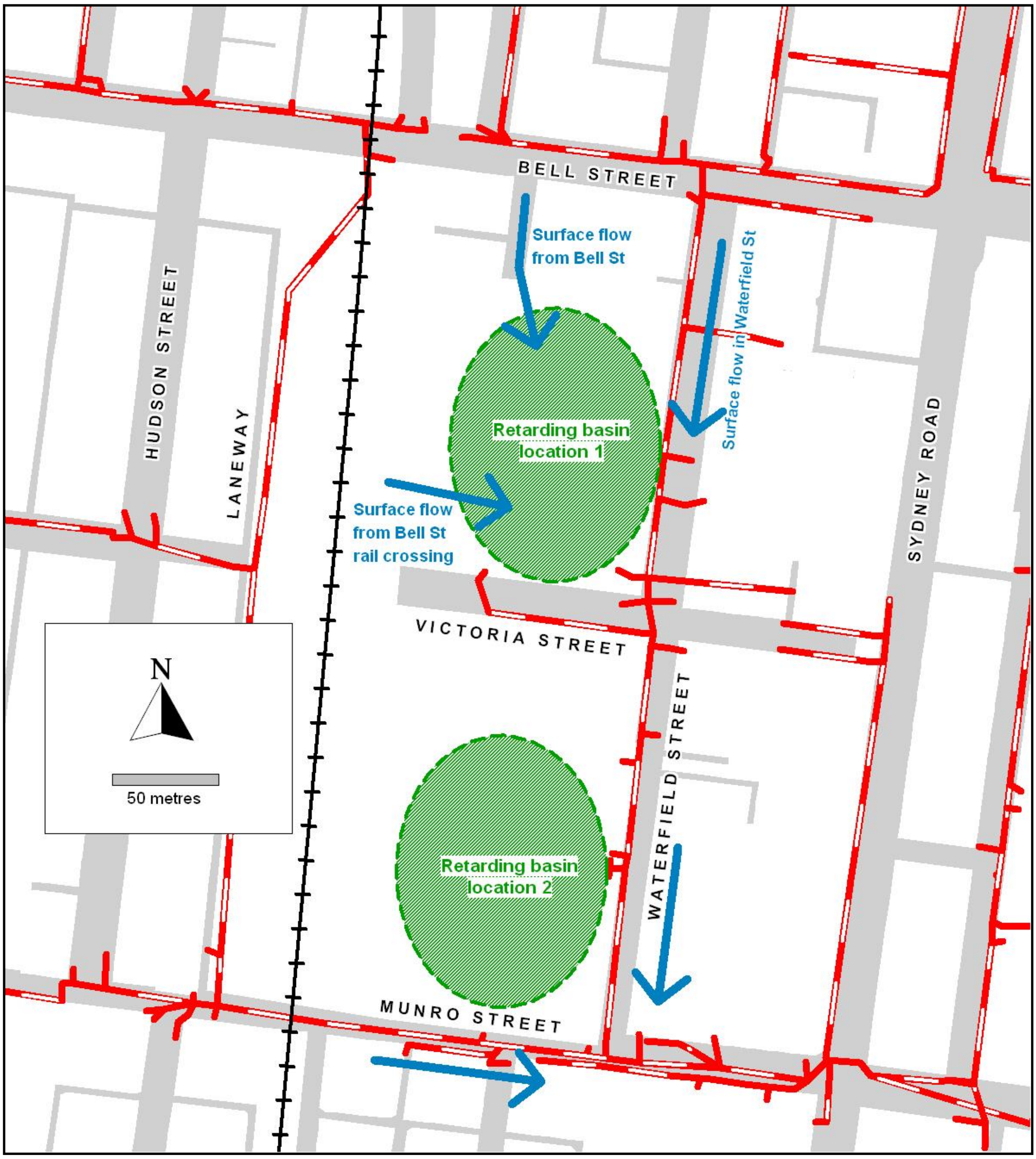
Potential storage locations are available throughout the car park. There would be an opportunity to install storages prior to any redevelopment works. Two locations for the storage were trialled: north of Victoria Street and south of Victoria Street (refer to Figure 8-4).

A storage located north of Victoria Street could be designed so that overland flow upstream of the carpark and at the northern end of Waterfield Street could be diverted through the storage. This would decrease the amount of overland flow across the car park, decrease the water levels near the library and decrease the peak flow near the outlet.

A storage located south of Victoria Street would capture the overland flow along Waterfield Street downstream of the library and the overland flow along Munro Street upstream of Waterfield Street. This would decrease the peak flow near the outlet, however, it would not impact on areas upstream of the storage. For example, the water levels at the library will not decrease, and there will still be uncontrolled overland flow across the car park.

The main requirement for the storage is to ensure that the base of the storage is sloped towards the storage outlet. Pumps would not be required as long as the base of the storage is not below the invert of the outlet pipe.

▪ **Figure 8-4: Schematic layout of option 4**



8.4.1. Option 4 – Hydraulic Results

Storage North of Victoria Street

The first storage was placed at a node upstream of the library and captured all overland flows along Waterfield Street upstream of the library and through the carpark. The larger the storage the larger the decrease in flow and water levels near the library and at the outlet

For the storage to hold all of the overland flow from upstream of the library in a 100 year ARI event, it needs to be approximately 33,750 m^3. For this analysis the dimensions 2.5 ha x 1.35 m deep were used. The assumed storage depth of 1.35 is feasible, and is based on the existing pipe invert on the upstream side of Victoria Street.

When the storage is 33,750 m^3, the maximum water level in a 100 year event just reaches the door sill level of the library. The storage is capturing most of the overland flow upstream of the library, however some overland flow results from the limited capacity of the pipe on Waterfield Street causing the flow to exit through the pits just outside the library. Increasing the pipe size from 0.675 m to 0.825 m immediately upstream and downstream of the pit outside of the library reduces the maximum water level in the 100 year ARI event so that it is below the door sill level of the library.

This option significantly decreases the peak flow upstream of the outlet from 7.1 cumecs to 2.5 cumecs. This will make a significant improvement in flooding issues along the alignment of the Harding Street Main Drain.

Storage South of Victoria Street

Another storage was investigated in the car park south of Victoria Street. The only issue that this storage addressed was the large overland flows along Munro Street downstream of Waterfield Street.

Initially, this storage was sized so that it reduced the overland flow along Munro Street downstream of Waterfield to at least the crown level of the road for all cross sections. To do this a storage of 65,250 m^3 (4.5 ha x 1.45 m deep) was calculated, however, this reduced the overland flow at the outlet to 0.72 cumecs, which is excessive. A storage of 36,250 m^3 (2.5 ha x 1.45 m deep) reduced the flow upstream of the outlet to 3.2 cumecs, which is a less extreme reduction in flow and reduces the water level to below the pavement.

In comparison to the storage north of Victoria Street, the storage south of Victoria Street is less effective. Even with a slightly larger storage, the overland flow upstream of the outlet is greater than the storage in the north. Additionally, this storage does not alleviate the water levels at the library.

The reason that this storage was not as effective in reducing the flow upstream of the outlet is because the pipes along Munro Street were always full so that the water in the storage was forced to spill as overland flow rather than flow through the pipes.

This option significantly decreases the peak flow upstream of the outlet from 7.1 cumecs to 3.2 cumecs. This will make a significant improvement in flooding issues along the alignment of the Harding Street Main Drain.

- **Table 8-6: Results of Storage Located in the Carpark Upstream of the Library**

Scenario	Peak overland flow along Waterfield Street near Library (cumecs)	Peak water level near library (m AHD)	Peak flow upstream of the Outlet (cumecs)
Base Case	5.7 cumecs	57.92 m AHD	7.1 cumecs
Storage (33,750 m^3) located north of Victoria Street	1.7 cumecs	57.76 m AHD	2.5 cumecs
Storage (33,750 m^3) and increased pipes to 0.825 m located north of Victoria Street	0.8 cumecs	57.70 m AHD	2.5 cumecs
Storage (36,250 m^3) located south of Victoria Street	5.7 cumecs	57.92 m AHD	3.2 cumecs

Due to the effectiveness of the storage beneath the car park north of Victoria Street, this option has been costed and feasibility addressed in the following sections.

8.4.2. Option 4 Costs

The cost of the storage depends on the type of redevelopment that will occur, and the method of construction. Several different options for constructing a storage were considered:

- If a multiple story car park or building was constructed, there would be an opportunity to have a built in storage at the bottom level. This could consist of a raised floor slab with a cavity of approximately 1.4 m deep, similar to adding a "half storey" at the bottom of the building. The cost of such a storage is virtually impossible to estimate for the purposes of this study, as it depends on construction methods and the relative size of the development. It could be anything from \$1 million to \$30 million, or potentially more or less than that.
- If development consisted of a single level open car park, a built-in underground storage could be constructed. One approach would be to construct a series of large pipes beneath the car park. These would act as a storage when the pipe in Waterfield Street is full. It could then

backflow into the series of pipes in the car park rather than spill over onto the street. Assuming an array of 1.35m diameter concrete pipes, the cost of the storage would be of the order of $25 million. Corrugated iron pipes could also be used, but any cost benefit through using cheaper pipes may be lost due to the greater cover requirements for this type of material.

- Alternatively, a built-in storage could be constructed using a modular “off the shelf” system. A cost estimate for such a storage was provided by Humes Water Solutions. They suggested a product called the Hume Stormtrap, which is a detention storage system costing $300 per cubic metre and an additional $200 per cubic meter for installation. Therefore, for a volume of 33,750 m^3, the total capital cost is estimated at $16.9 million.

8.4.3. Feasibility of Option 4

The main issues with this option include the cost and the amount of space available.

The redevelopment of central Coburg provides an opportunity to include the drainage and mitigation works as a condition of development. This would be realistic provided that the cost of the additional drainage is not excessive compared to the cost of overall site development and the potential for financial returns from the site. This is discussed further in Section 9.

According to the modelling, a total volume of 33,750m^3 is required to prevent flooding of the library in a 100 year event. In the car park north of Victoria Street a total surface area of approximately 1 ha is available (150 m long x 72 m wide). Therefore, an average depth of 3.4 m is required to achieve the volume calculated by the modelling. However, if the storage is designed to use gravity drainage, the depth available is approximately 1.4 m near the outlet. This results in a total volume of 16,200 m^3 that is available for storage. This does not take into consideration whether depths across the car park could vary.

Therefore, storage of 33,750 m^3 is not feasible under existing conditions.

In any case, this option shows that it is highly effective in reducing flows downstream of the storage. Although there may not be sufficient space to fit storage of 33,750 m^3, there would be sufficient space for storage to cater for the 1 year, 5 year, 20 year ARI events. Additionally, the proposed redevelopment of the Coburg shopping centre could provide the opportunity to increase the available storage volume to further help mitigate a 100 year ARI event. **However it should be noted that a storage sized for a 20 year ARI event may provide little or no benefit in a 100 year ARI event.** This is because once a retarding basin is full, it ceases to have any effect on downstream flows.

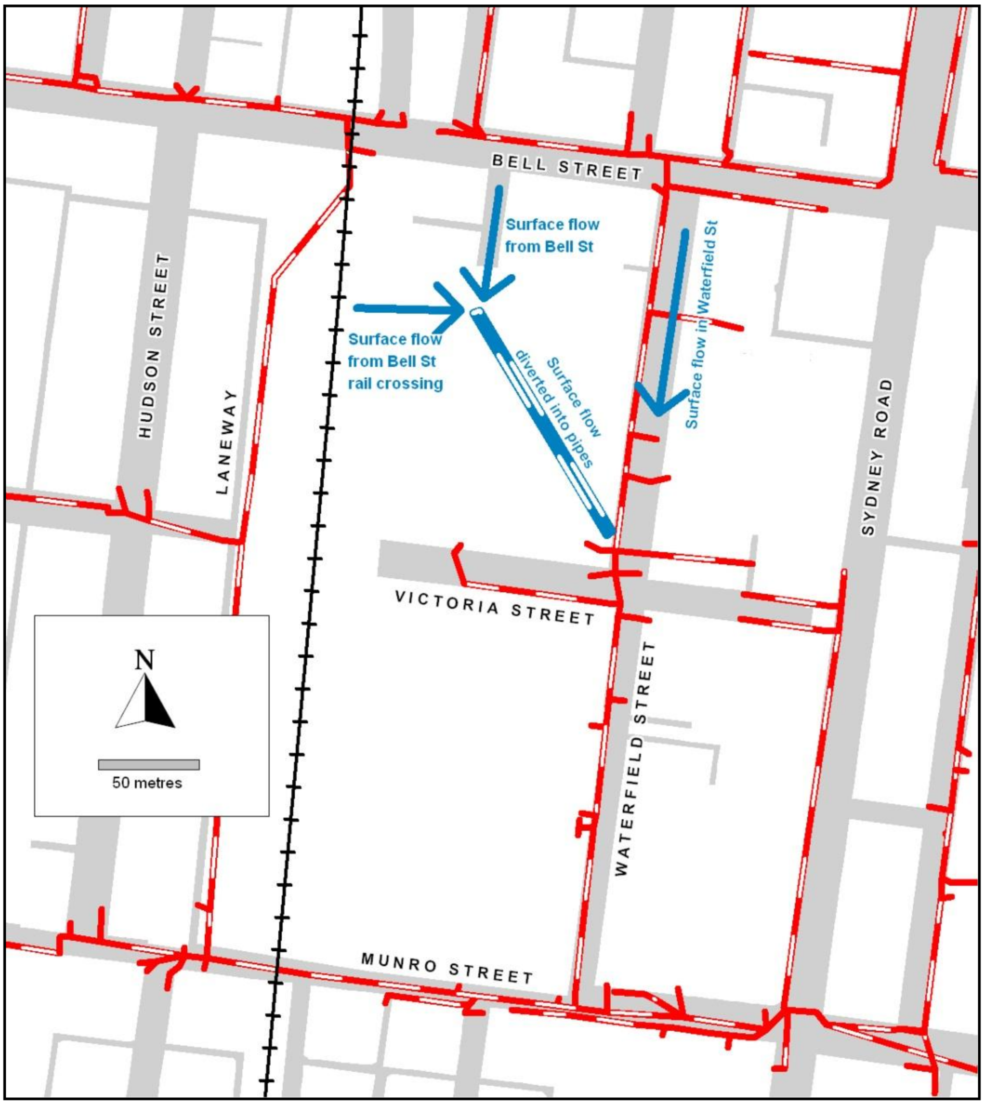
In terms of existing services, there is a Yarra Valley Water wastewater pipeline around the perimeter of the northern car park that needs to be taken into consideration.

8.5. Option 5 – Pipe Augmentation through Car Park

This option investigated the pipe size required to take all of the peak flow across the carpark in a 100 year ARI event (refer to Figure 8-5). This would minimise the uncontrolled sheet flow and ponding across the car park. Also, if this area is redeveloped in future, uncontrolled surface flow may not be desirable, depending on the exact nature of the redevelopment. As a result, some kind of pipe or channel augmentation may be required.

Two pipes were modelled together for this scenario. One pipe was modelled from the north-west corner of the carpark to the corner of Victoria and Waterfield Street. The other pipe was modelled from the west side of the catchment, intersecting with the other pipe at the low point in the car park.

- **Figure 8-5: Schematic layout of option 5**



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8.5.1. Option 5 – Hydraulic Results

Table 8-7 shows the results of pipe augmentation through the car park. Pipes of 0.750 m diameter have the capacity to take nearly all the flow (except from the west of the catchment, which has an overland flow of 0.25 cumecs).

Overall, the results show that pipe augmentation will decrease overland flow throughout the carpark, however, it will increase flow along Waterfield Street and Munro Street near the outlet. This indicates that this option needs to be considered in conjunction with another option in order for it to benefit the catchment. This may include works downstream of the carpark, such as further pipe augmentation along Waterfield Street or reprofiling of Waterfield Street. These will be investigated in options 6 and 7.

In addition, the increased flow at the downstream end of the study area means that there will be an increase in flood levels along the alignment of the Harding Street Main Drain. If any increase in flows in this drain are considered, it is recommended that potential flood mitigation options for Harding Street Main Drain be discussed with Melbourne Water. This might involve increasing the capacity of the existing drain, either through replacement with a larger drain or duplication, or surface mitigation measures such as detention basins or road remodelling.

Table 8-7: Results of Pipe Augmentation through Car Park for 100 Year ARI

Scenario	Overland Flow across Carpark from North West Corner	Overland Flow across Carpark from West Side	Overland Flow across car park in south east corner	Overland flow along Waterfield Street near Library	Water level near library	Flow upstream of the Outlet
Base Case	0.4 cumecs	1.8 cumecs	1.7 cumecs	5.7 cumecs	57.92 m AHD	6.1 cumecs
Pipe Augmentation (0.750)	0.0 cumecs	0.3 cumecs	0.0 cumecs	6.0 cumecs	57.94 m AHD	7.6 cumecs

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8.5.2. Option 5 – Costs

Cost estimates of the proposed works for option 5 are shown in Table 8-8. Overall, the capital cost of works for this option is estimated at $0.32 million including design and contingency.

- **Table 8-8: Costs of Proposed Works for Option 5**

Total Cost	$ 203,391
Total Cost With Design & Contingency	$ 315,969

Location (Downstream to Upstream)	Works Description	Pipeline Diameter	Length (m)	Factor	Factored Unit Cost ($/m)	Cost ($)	TOTAL Cost With Design & Contingency ($)
North West corner to South East Corner of Car Park	Pipe Augmentation	750	139	1.40	$ 433	$ 60,131	$ 93,414
West side to Intersection with other pipe	Pipe Augmentation	750	100	1.40	$ 433	$ 43,260	$ 67,204
South east corner of car park	Junction pits x 2			2.00	$ 50,000	$ 100,000	$ 155,350

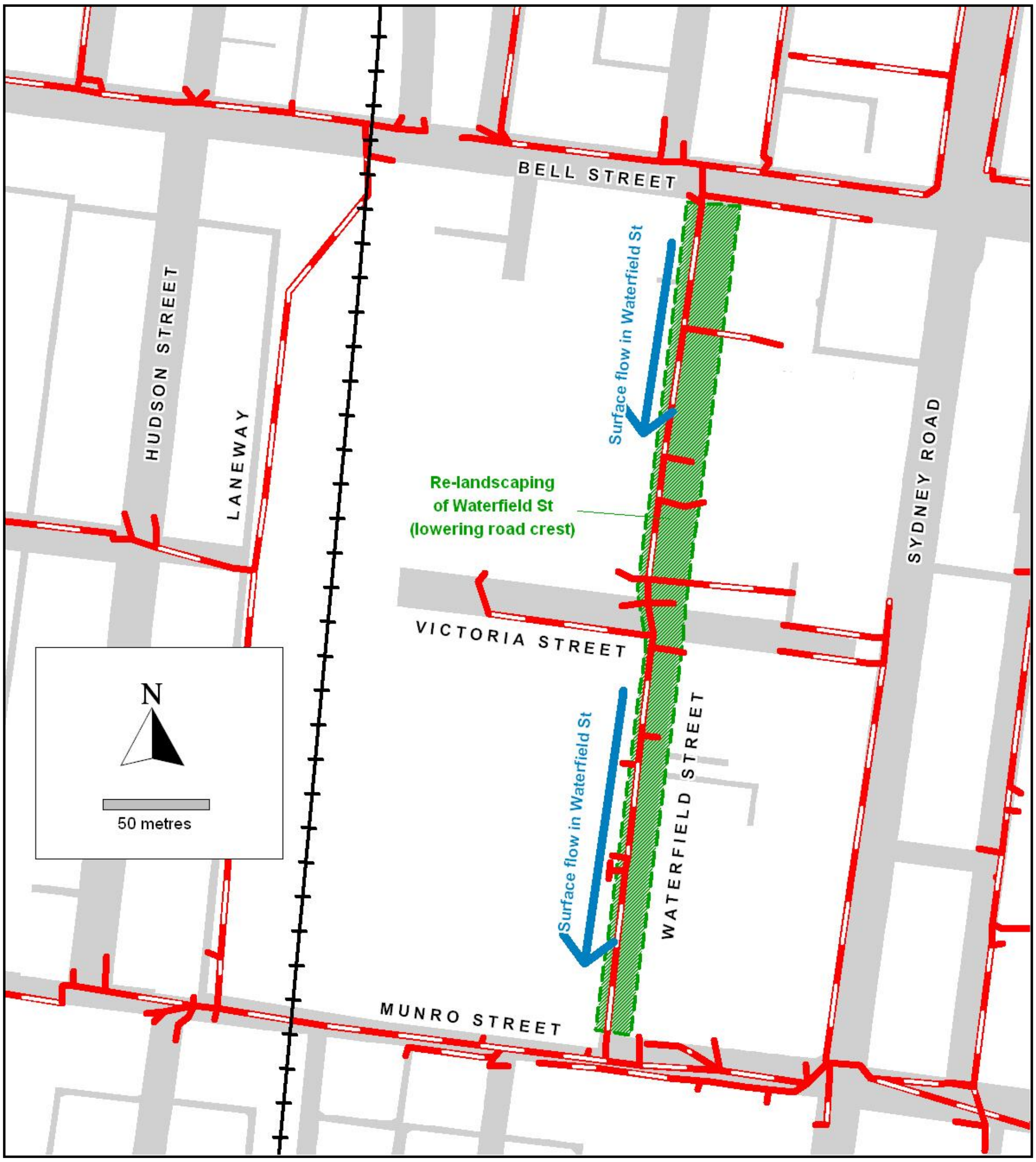
8.5.3. Option 5 - Feasibility

This option is considered feasible as there are minimal services within the area. The main concern is a wastewater pipeline around the perimeter of the northern car park belonging to Yarra Valley Water that needs to be taken into consideration. The proposed redevelopment of the Coburg shopping centre would provide a good opportunity for implementing this option.

8.6. Option 6 – Reprofiling Waterfield Street

This option investigated reprofiling Waterfield Street so that the street has a flatter crown, thereby creating more storage for overland flow (refer to Figure 8-6). Currently, along Waterfield Street north of the library, the road crown is typically 200mm higher than the top of the kerb, with an average camber of nearly 5%. This is unnecessarily steep, and could be reduced to 1% or 2% in some areas. This was modelled in XP Storm by changing the cross-sections for each overland flow reach along Waterfield Street.

- **Figure 8-6: Schematic layout of option 6**



8.6.1. Option 6 – Hydraulic Results

Table 8-9 shows the results of reprofiling Waterfield Street in a 100 year event. Overall, the flow along Waterfield Street and Munro Street increases. The flow along Victoria Street decreases slightly and therefore the water level near the library also decreases. The impact of this option is minimal and therefore has not been costed.

If the road camber is reduced too much this could affect street drainage in smaller ARI events. There needs to be sufficient slope available to force surface flow into side entry pits, and to keep any surface flow concentrated in gutters to avoid any safety issues.

In addition, the marginal increase in flow at the downstream end of the study area means that there will be a very small increase in flood levels along the alignment of the Harding Street Main Drain. If any increase in flows in this drain are considered, it is recommended that potential flood mitigation options for Harding Street Main Drain be discussed with Melbourne Water. This might involve increasing the capacity of the existing drain, either through replacement with a larger drain or duplication, or surface mitigation measures such as detention basins or road remodelling.

- **Table 8-9: Results of Re-Landscaping Waterfield Street in 100 year Event**

Scenario	Overland flow along Waterfield Street near Library	Overland Flow along Victoria Street near Library	Water level near library	Flow upstream of the Outlet
Base Case	5.7 cumecs	1.1 cumecs	57.92 m AHD	7.1 cumecs
Reprofiling Waterfield Street	6.0 cumecs	0.8 cumecs	57.90 m AHD	7.2 cumecs

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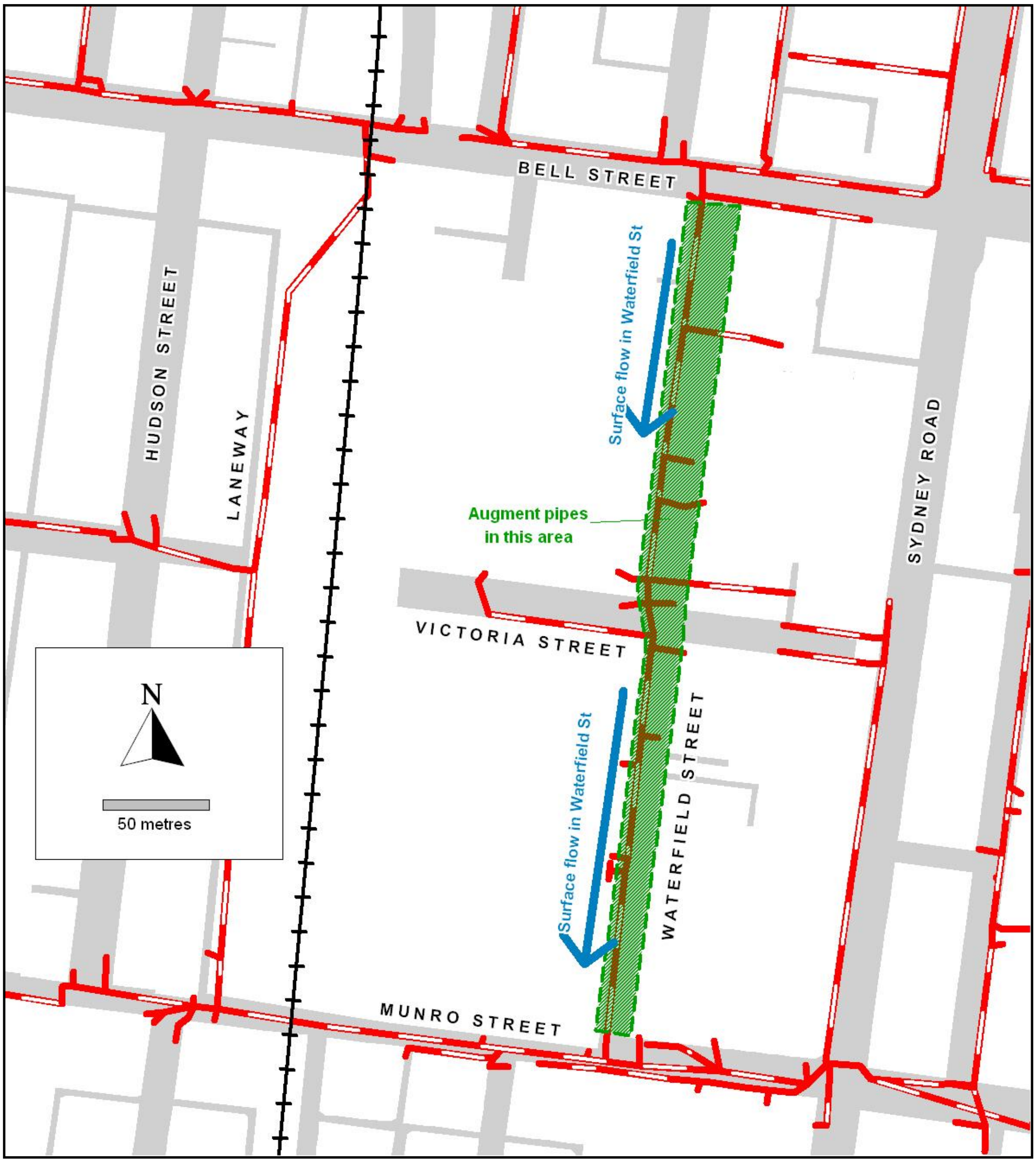
8.7. Option 7 – Pipe Augmentation along Waterfield Street

This option investigated pipe augmentation along Waterfield Street downstream of the library and along Munro Street (refer to Figure 8-7). The purpose of this option is to reduce water levels near the library and decrease overland flow along Waterfield and Munro Streets. The pipes were sized so that the water level at the library was less than the door sill level of 57.76 m AHD and so that the overland flow along Munro Street was reduced.

- **Figure 8-7: Schematic layout of option 7**



8.7.1. Option 7 – Hydraulic Results

Table 8-10 shows the results of enlarging the pipe along Waterfield Street and Munro Street for a 100 year event. Overall, the overland flow near the library was eliminated and the flow upstream of the outlet was reduced when:

- The existing pipe was enlarged from 0.65 m to 1.5 m along Waterfield Street from the library; and
- The existing pipe was enlarged from 1.05 m to 1.5 m along Munro Street, although this does require additional construction costs for pipe augmentations under the Sydney Road tram tracks.

This option significantly decreases the peak flow upstream of the outlet from 7.1 cumecs to 3.6 cumecs. This will make a significant improvement in flooding issues along the alignment of the Harding Street Main Drain.

Table 8-10: Results of Duplicating the Pipe along Waterfield Street and Munro Street

Scenario	Overland flow along Waterfield Street near Library	Overland Flow along Victoria Street near Library	Water level near library	Flow upstream of the Outlet
Base Case	5.7 cumecs	1.1 cumecs	57.92 m AHD	7.1 cumecs
Augmenting Pipe (1.5 m) along Waterfield and Munro Street	0.0 cumecs	0.0 cumecs	57.48 m AHD	3.6 cumecs

8.7.2. Option 7 – Costs

Cost estimates of the proposed works for option 7 are shown in Table 8-8. Overall, the capital cost of works for this option is estimated at $1.0 million including design and contingency.

Additional costs of construction under the Sydney Road tram tracks is difficult to estimate directly, and has therefore been included as a higher construction cost factor of 5, reflecting the highly complex construction environment near this junction.

■ **Table 8-11: Costs of Proposed Works for Option 7**

Total Cost	$ 659,730
Total Cost With Design & Contingency	$ 1,024,891

Location (Downstream to Upstream)	Works Description	Pipeline Diameter	Length (m)	Factor	Factored Unit Cost ($/m)	Cost ($)	TOTAL Cost With Design & Contingency ($)
Street to Munro Street)	Pipe Augmentation	675	193.52	3.00	$ 792	$ 153,268	$ 238,102
Munroe Street (from Waterfield Street to change in pipe size)	Pipe Augmentation	750	16	3.00	$ 921	$ 14,736	$ 22,892
Munroe Street (from change in pipe size ot outlet)	Pipe Augmentation	1050	119.56	5.00	$ 2,440	$ 291,726	$ 453,197
Munroe St (Waterfield St crossing Sydney Rd to Outlet)	Traffic Management Plan					$ 100,000	$ 155,350
Length of works	Junction pits x 3			3.00	$ 50,000	$ 100,000	$ 155,350

8.7.3. Option 7 – Feasibility

The main issue along Munro Street include limited space for additional services. Existing services include:

- Tram tracks on Sydney Road;
- the existing drainage pipeline;
- minor optic fibres along Waterfield Street;
- major optic fibres along Munro Street;
- minor electricity cables;
- high pressure gas mains;
- water mains; and
- waste water mains.

The proposed works for this option include crossing the tram tracks on Sydney Road, which is potentially complex and may affect the timing of construction (e.g. may need to construct during night time or on the weekend to minimise disruption to public transport). Further investigation may be required along Munro Street at the functional design stage to determine whether there is adequate space for the proposed works for this option. Relocation of some of the services may need to be taken into consideration, which **has not been included in the costs** at this stage of the project except for the tram tracks on Sydney Road.

Waterfield Street also contains many of the services listed above (except tram tracks) but the advantage of pipe augmentation along Waterfield Street is the road is bounded by car parks so there is more likely to be sufficient room for alternative alignments for the proposed works.

8.8. Combined Option 1

This option investigated the combination of some of the more effective options detailed above. These included:

- Pipe Augmentation along Munro Street (under railway) 1.65 m until intersection with Waterfield Street and 1.95m to outlet;
- Pipe Augmentation along Waterfield Street (individual option was 1.5m this was upgraded to 1.65m); and
- Pipe Augmentation through the car park (0.750 m).

8.8.1. Combined Option 1 – Hydraulic Results

Table 8-12 shows the results of combining three of the piped options. The combination of options addresses some of the issues in the catchment such as:

- Reduces the flood extent upstream of the railway on Munro Street;
- Controls flow through the car park;
- Decreases water levels near the library; and
- Decreases overland flow along Waterfield and Munro Street.

However, the combination of options mean that some of the pipes need to be resized as each option influences the results of the other options. Without changing the pipe size, the flows along Waterfield Street and particularly along Munro Street are increased.

Increasing the pipe size on Waterfield Street to 1.65 m removes the overland flow near the library. However, the overland flow upstream of the outlet does not decrease significantly from 7.1 cumecs to 6.1 cumecs, although even this modest decrease in flow will help to alleviate flooding problems along the Harding Street Main Drain alignment. The combination of piped options means that the peak flows are being routed too quickly through the catchment with less attenuation than if they travelled as overland flow.

▪ **Table 8-12: Results of Combining 3 of the Piped Options**

Scenario	Overland flow along Waterfield Street near Library	Overland Flow along Victoria Street near Library	Water level near library	Flow upstream of the Outlet
Base Case	5.7 cumecs	1.1 cumecs	57.92 m AHD	7.1 cumecs
Combination of Piped options	1.8 cumecs	8.7 cumecs*	58.44 m AHD*	8.4 cumecs
Piped options with increased pipe diameter on Waterfield Street to 1.65m	0.0	0.0	57.48 m AHD	6.1 cumecs

* Note that there is a large spike in the flow that impacts the results.

8.8.2. Combined Option 1 – Costs

Cost estimates of the proposed works for option 1 are shown in Table 8-13. Overall, the capital cost of works for this option is estimated at $4.8 million.

▪ **Table 8-13: Costs of Proposed Works for Combined Option 1**

Option	Cost	Total Cost with Design and Contingency
Pipe augmentation along Munro Street	$2.6 M	$3.5 M
Pipe augmentation along Waterfield Street	$0.7 M	$1.0 M
Pipe Augmentation through car park	$0.2 M	$0.3 M
TOTAL	**$3.5 M**	**$4.8 M**

8.8.3. Combined Option 1 – Feasibility

The main issue along Munro Street include limited space for additional services. Existing services include:

- railway line;
- tram tracks on Sydney road;
- existing drainage pipeline;
- minor optic fibres along Waterfield Street;

- major optic fibres along Munro Street;
- high pressure gas mains;
- water mains;
- waste water mains; and
- electricity cables,.

The proposed works for this option include tunnelling under the railway line, which makes this option very costly. It also includes crossing the tram tracks on Sydney Road, which is potentially complex and may affect the timing of construction (e.g. may need to construct during night time or on the weekend to minimise disruption to public transport). Further investigation may be required along Munro Street at the functional design stage to determine whether there is adequate space for the proposed works for this option. Relocation of some of the services may need to be taken into consideration, however, this **has not been included in the costs** at this stage of the project.

Waterfield Street also contains many of the services listed above (except tram tracks and railway line) but the advantage of pipe augmentation along Waterfield Street is the road is bounded by car parks so there is more likely to be sufficient room for alternative alignments for the proposed works.

8.9. Combined Option 2

In light of the results presented in Table 8-12, a different combination of options has been investigated. This includes:

- Pipe augmentation along Munro Street (under railway) 1.65 m until intersection with Waterfield Street and 1.95m to outlet ; and
- 33,750 m^3 of storage beneath car park north of Victoria Street (requiring a very extensive footprint area).

8.9.1. Hydraulic Results

Table 8-14 shows the results of combining the above options. The combination of options is highly effective at addressing most of the flooding issues in the catchment such as:

- Reduces the flood extent upstream of the railway on Munro Street;
- Controls flow and ponding through the car park;
- Decreases water levels near the library; and
- Decreases overland flow along Waterfield and Munro Street.

The flow upstream of the outlet is reduced significantly from 7.1 cumecs to 2.8 cumecs. This decrease in flow will significantly reduce flooding problems along the Harding Street Main Drain alignment.

Table 8-14: Results of Combined Option 2

Scenario	Water Level in Defacto Retarding Basin (m AHD)	Overland flow along Waterfield Street near Library	Water level near library (m AHD)	Flow upstream of the Outlet
Base Case	59.56 m AHD	5.7 cumecs	57.92 m AHD	7.1 cumecs
Storage (1.35m deep by 2.5 ha) located north of Victoria Street and pipe augmentation along Munro Street	59.03 m AHD	0.8 cumecs	57.70 m AHD	2.8 cumecs

8.9.2. Combined Option 2 – Costs

Cost estimates of the proposed works for option 1 are shown in Table 8-13. Overall, the capital cost of works for this option is estimated at $19.8 million.

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- **Table 8-15: Costs of Proposed Works for Combined Option 2**

Option	Cost	Total Cost with Design and Contingency
Pipe Augmentation along Munro Street	$2.6 M	$3.5 M
Storage beneath Car Park	Not known	$16.9 M
TOTAL	**Not known**	**$20.4 M**

8.9.3. Combined Option 2 – Feasibility

The main issue with this combined option is the extremely high cost of the storage and the space required for the storage.

As discussed in Section 8.4.3 the redevelopment of central Coburg provides an opportunity to include the drainage and mitigation works as a condition of development. This would be realistic provided that the cost of the additional drainage is not excessive compared to the cost of overall site development and the potential for financial returns from the site. This is discussed further in Section 9.

According to the modelling, a total volume of 33,750m^3 is required to prevent flooding of the library in a 100 year event. In the car park north of Victoria Street a total volume of approximately 16,200 m^3 is available for storage, therefore storage of 33,750 m^3 is not feasible under existing conditions. **It should be noted that a storage sized for a lesser ARI event will be proportionally cheaper, but it may provide little or no benefit in a 100 year ARI event.**

In any case, this option shows that it is highly effective in reducing flows downstream of the storage. Although there may not be sufficient space to fit storage of 33,750 m^3, there would be sufficient space for storage to cater for the 1 year, 5 year, 20 year ARI events and storage in this location of a smaller size would still help alleviate some of the flooding issues in a 100 year event. Additionally, the proposed redevelopment of the Coburg shopping centre could provide the opportunity to increase the available storage volume to further help mitigate a 100 year ARI event.

The main issue along Munro Street include limited space for additional services. Existing services include:

- railway line;
- tram tracks on Sydney road;
- existing drainage pipeline;
- major optic fibres;
- high pressure gas mains;

- water mains;
- waste water mains; and
- electricity cables.

The proposed works for this option include tunnelling under the railway line, which makes this option very costly. It also includes crossing the tram tracks on Sydney Road, which is potentially complex and may affect the timing of construction (e.g. may need to construct during night time or on the weekend to minimise disruption to public transport). To determine whether there is adequate space for the proposed works for this option, further investigation will be required at the functional design stage. Relocation of some of the services may need to be taken into consideration, however, this **has not been included in the costs** at this stage of the project.

9. Developer Contribution Strategies for Drainage and Flood Mitigation Works

There are three key issues which combine to make it difficult to create an equitable strategy for determining drainage works contributions:

- It is expected that the development of central Coburg will be on a large scale, and will cover most of the areas where flood mitigation works are required.
- It is expected that development works will be undertaken by several different organisations, and properties where mitigation works may be required are owned by several different owners.
- The drainage works are required to address pre-existing drainage problems, because central Coburg already has a very high impervious fraction, and development is not likely to change this. Developers are likely to resist having to contribute significant costs for drainage works required to fix flooding problems caused by others. Nevertheless, most developers would be willing to assist in some way, as the alleviation of flooding problems may increase the value of their property.

9.1. Types of strategies

There is a range of strategies available to determine appropriate developer contributions for drainage and flood mitigation works. Some of these strategies include:

- **Impervious fraction** – if a development is increasing the impervious fraction of a catchment, it must be increasing the volume of runoff within a catchment. A developer can then contribute toward the portion of the drainage works which are required to deal with the additional runoff. This can be implemented as part of a developer contribution plan included in the council planning scheme, or can simply be included as a requirement on any development permit in the area.

  This is the most common strategy for determining developer contributions toward drainage works. Melbourne Water has adopted this strategy for many drainage schemes around Melbourne, including both greenfield sites and redevelopment areas. However, this strategy is not appropriate in the current case because the impervious fraction of central Coburg is already extremely high, and further development is unlikely to change it.

- **Upstream works offset** – In some situations, it may be very difficult or expensive to construct drainage works within a development which help to mitigate the impact of the development on the drainage system. As an alternative, there may be opportunities to implement works upstream of a development which may have a similar effect, but are much cheaper. For example, if a development were to produce significant extra flood flows, it may be easier for the developer to construct retarding basins upstream of the development, so that the additional flows have no net effect.

This strategy is not appropriate in the current case because the proposed developments within Coburg are unlikely to actually increase flood flows, and there is virtually no land available upstream for additional drainage works.

- **On site land offset** – In some urban areas, large developments are required to include a given area of public open space. It may be possible to allow the developer to use this open space as a retarding basin, yet keep the land open to public use.

  This strategy may be possible in this case, but given the scale of the required retarding basins and the value of land in central Coburg, this strategy is unlikely to be feasible.

- **Land swap** – In some cases, a developer may own other land in a catchment which could be swapped to allow this land to be used for flood retardation or other flood mitigation works, and could also double as public open space.

  Given the relatively small catchment size in this case, it is unlikely that this strategy will be feasible.

9.2. Method of implementing drainage contribution charges

Contributions toward the costs of these drainage works can be obtained in a variety of different ways. The three most appropriate methods in this situation would be:

- Create a developer contribution plan, and incorporate that plan into the council planning scheme;
- Include the necessary charges as a requirement of planning / building permits within the study area; or
- Where a development covers a location where drainage works are required, include the actual works as a requirement of building permits, with the developer funding a proportion of the works equivalent to the contribution charges.

All of these options will require that detailed planning of the required works be undertaken to determine the necessary developer charges (VDPCD 2007), as follows:

Developer charge = Infrastructure cost x Developer funding proportion x Share of usage

Where Infrastructure cost = the total cost of the drainage works in the study area;
Developer funding proportion = proportion of the total infrastructure cost that council intends to recover through developer charges
Share of usage = the share of usage or benefit that can be attributed to any one development

Determining the total cost of the drainage works will require a more detailed design of the works, with costings prepared in more detail than was provided in this study. Potentially this could be undertaken in conjunction with developers, as the exact costs of the required drainage works in central Coburg will be heavily dependent on the detailed design of the proposed development works. For this reason, a collaborative approach with individual developers is essential.

Council needs to determine how much of the works should be funded by developments, and how much should be funded through other sources such as external grants.

In addition, the share of usage or benefit needs to be carefully considered. In the case of upgrades to drainage systems, the share of usage is usually determined based on proportion of additional drainage flow contributed by each new development. However, as previously noted the drainage problems in the study area are pre-existing, and any new development is unlikely to change total flows in the drainage system. Therefore the share of usage in this particular case should be based on proportion of existing flow contributed by each property.

Having determined the above details, council may wish to implement the contribution plan within the existing council planning scheme. There are specific guidelines published by the Victorian Department of Planning and Community Development specifying how a development contribution plan is to be prepared and implemented. These Development Contribution Guidelines are available online at www.dse.vic.gov.au.

In addition, Darebin City Council has implemented a large number of development contribution plans for a wide range of types of infrastructure. For details of these plans, refer to the Darebin website at www.darebin.vic.gov.au, or to the Darebin planning scheme at www.dse.vic.gov.au.

Implementing a contribution plan as part of the council planning scheme is likely to be the most robust approach, which may be of benefit should the charges be challenged in a VCAT hearing. However, council may choose to simply add the relevant charges as a condition of any development permit in the study area. Because such an approach is less likely to be supported in a VCAT hearing, a more collaborative approach with developers would be required, with all parties reaching agreement up-front on what drainage works are required and what proportion of the cost of the works should be covered by developers.

Whichever method of implementing contribution charges is adopted, collaboration with developers is important. A transparent, collaborative approach with the involvement of developers in the design process is likely to provide the potential for better, more cost-effective drainage solutions to be implemented which complement the proposed development of the area, rather than the drainage works becoming a constraint or limitation to development.

9.3. Discussion

Given the above issues, an appropriate strategy for determining drainage works contributions could be to use the **ratio of current impervious area** of the land being developed compared to the total current impervious area of the catchment upstream of the Harding Street Main Drain, starting from the junction of Harding Street and Sydney Road. This way if a property currently represents, say, 5% of the total impervious area upstream of the Harding Street Main Drain, then development of this property would require a contribution of 5% of the developer funded portion of the costs of drainage works in this area.

It may be possible for a developer to offset this contribution by reducing the impervious area of the fully developed property, through measures such as pervious paving or significant lawn / garden areas. By adding pervious surfaces to the development, the contribution could be proportionally reduced. In addition, the contribution could also be reduced if the developer undertakes some of the required drainage works on that property, with the contribution reduction equal to the cost of the works they have undertaken.

This option is realistic, provided the cost of the contribution is not excessive compared to the cost of overall site development and compared to the potential financial returns from the site.

It is recommended that this strategy be considered, and that council undertake a more rigorous economic study of potential contribution scheme strategies after functional design and costing of the drainage works is completed.

Also, if such a strategy is implemented, then it is recommended that a detailed analysis of the catchment should be undertaken to determine current impervious areas using high quality satellite imagery (such as DigitalGlobe) or remote sensing data. The impervious fraction estimates used for this study are based on planning scheme zones and site observations, and more detailed estimates should be obtained if they are to be adopted for calculating developer contributions.

10. Recommendations

10.1. Recommended Option A

If drainage augmentation works are undertaken in the Coburg shopping centre and cost **is not** a limiting factor, it is recommended that the following combined option be considered for implementation:

- Pipe augmentation along Munro Street (under railway);
- Retarding basin beneath the car park to the north of Victoria Street.

This option provides the best opportunity for reducing flood levels along Waterfield Street and Munro Street, reducing the potential for flood damage to properties in the area, especially the Coburg library, and properties upstream of the railway line on Munro Street. It also removes the uncontrolled flow and ponding that occurs in the car park.

The total cost of this option is $20.4 million including design and contingency. Details of cost estimates can be found in section 8.9. **It should be noted that a storage sized for a lesser ARI event will be proportionally cheaper, but it may provide little or no benefit in a 100 year ARI event.**

Any functional or detailed design of drainage augmentation works need to be undertaken in close consultation with both Moreland City Council and Melbourne Water.

10.2. Recommended Option B

If drainage augmentation works are undertaken in the Coburg shopping centre and cost **is** a limiting factor, it is recommended that the following combined option be considered for implementation:

- Pipe Augmentation along Munro Street (under railway) of 1.65 m until intersection with Waterfield Street and 1.95m to outlet;
- Pipe Augmentation along Waterfield Street of 1.65m; and
- Pipe Augmentation through the car park of 0.750 m.

This option provides a reasonable opportunity for reducing flood levels along Waterfield Street and Munro Street, reducing the potential for flood damage to properties in the area, especially the Coburg library, and properties upstream of the railway line on Munro Street. It also reduces and controls the flow and ponding that occurs in the car park north of Victoria Street.

The total cost of this option is $4.8 million including design and contingency. Details of cost estimates can be found in section 8.8.

Any functional or detailed design of drainage augmentation works need to be undertaken in close consultation with both Moreland City Council and Melbourne Water.

10.3. Comparison of Hydraulic Results for Recommended Options

The hydraulic results for the recommended options are shown below.

Scenario	Overland flow along Waterfield Street near Library	Water level near library (m AHD)	Flow upstream of the Outlet
Base Case	5.7 cumecs	57.92 m AHD	7.1 cumecs
Recommended Option A	0.8 cumecs	57.70 m AHD	2.8 cumecs
Recommended Option B	0.0 cumecs	57.48 m AHD	6.1 cumecs

These results show that both options significantly reduce the peak flow and water level near the library in Waterfield Street. It should be noted that the scale of the reduction in water level is not critical, as both options reduce levels by more than 200mm which is sufficient to eliminate flooding of the library. In addition, both options reduce the peak flow at the model outlet, however the option including a large storage has a significantly larger impact in this respect.

Overall, Recommended Option A gives the best hydraulic results overall, but is significantly more expensive.

10.4. Other Issues to be Considered

It is recognised that the details of any drainage option implemented will depend on the nature of redevelopment which is planned for the Coburg shopping centre. Depending on the details of the redevelopment works, some of the above recommended options may no longer be viable, however it is recommended that all development works take into account the drainage issues which have been highlighted in this study, and aim to mitigate flooding along Waterfield and Munro Streets. In particular, the magnitude of 100 year peak flows throughout the study area need to be considered in any redevelopment design, including the likely magnitude of surface flows.

In addition, the impact of any works in the vicinity of the Bell St rail crossing be carefully considered, as this area is critical for determining levels of downstream flooding. The exact split of flow in this area can result in additional flows passing along the laneway to the Munro St rail crossing, and exacerbating flooding issues in this area, or can cause additional flows to pass behind the Coles supermarket in Waterfield St, exacerbating flooding along Waterfield St and Munro St.

It is strongly recommended that any redevelopment of the Coburg shopping centre include a detailed drainage strategy for the area, and must include details of works designed to control piped and overland flow magnitudes and flow paths, and demonstrates how these works will mitigate flooding issues in the area as identified in this report. This strategy must be prepared in close consultation with both Moreland City Council and Melbourne Water.

10.5. Consideration of litter and blockages

It should be noted that, in accordance with normal practice, all analysis of the drainage system in this area is based on the assumption that all flow paths, including pipes, channels, and gutters, are clean and free of blockages. However, commercial areas such as Coburg tend to produce significant levels of litter, and site observation and council feedback suggests that littler is a major issue in this catchment. Litter can block drains and gutters causing additional flooding problems, however due to the random, unpredictable nature of this problem, no allowance has been made in this study for blockages due to litter.

It is recommended that any drainage works in the Coburg area include litter traps and, if possible, water quality improvement works. An existing gross pollutant trap exists on Harding St just downstream of Sydney Road, and is managed by Melbourne Water, therefore any litter traps and water quality improvement works need to be designed to complement this existing infrastructure.

Also, it is recommended that any detailed design of drainage works in this area include an appropriate allowance for blockage due to litter.

10.6. Developer contributions

An appropriate strategy for determining drainage works contributions could be to use the **ratio of current impervious area** of the land being developed compared to the total current impervious area of the catchment upstream of the Harding Street Main Drain, starting from the junction of Harding Street and Sydney Road.

It is recommended that this strategy be considered, and that council undertake a more rigorous economic study of potential contribution scheme strategies after functional design and costing of the drainage works is completed.

Also, if such a strategy is implemented, then it is recommended that a detailed analysis of the catchment should be undertaken to determine current impervious areas using high quality satellite imagery (such as DigitalGlobe) or remote sensing data. The impervious fraction estimates used for this study are based on planning scheme zones and site observations, and more detailed estimates should be obtained if they are to be adopted for calculating developer contributions.

As above, it is strongly recommended that any redevelopment of the Coburg shopping centre include a detailed drainage strategy for the area. Refer to section 10.4.

11. References

City of Darebin, *Darebin Planning Scheme - Development Contributions Plan Overlay (including Schedule 1)*, January 2006.

Institution of Engineers, Australia (1997), *Australian Rainfall and Runoff – A Guide to Flood Estimation.*

Melbourne Water (2004). *Land Development Manual.* Melbourne Water, Victoria, 2004

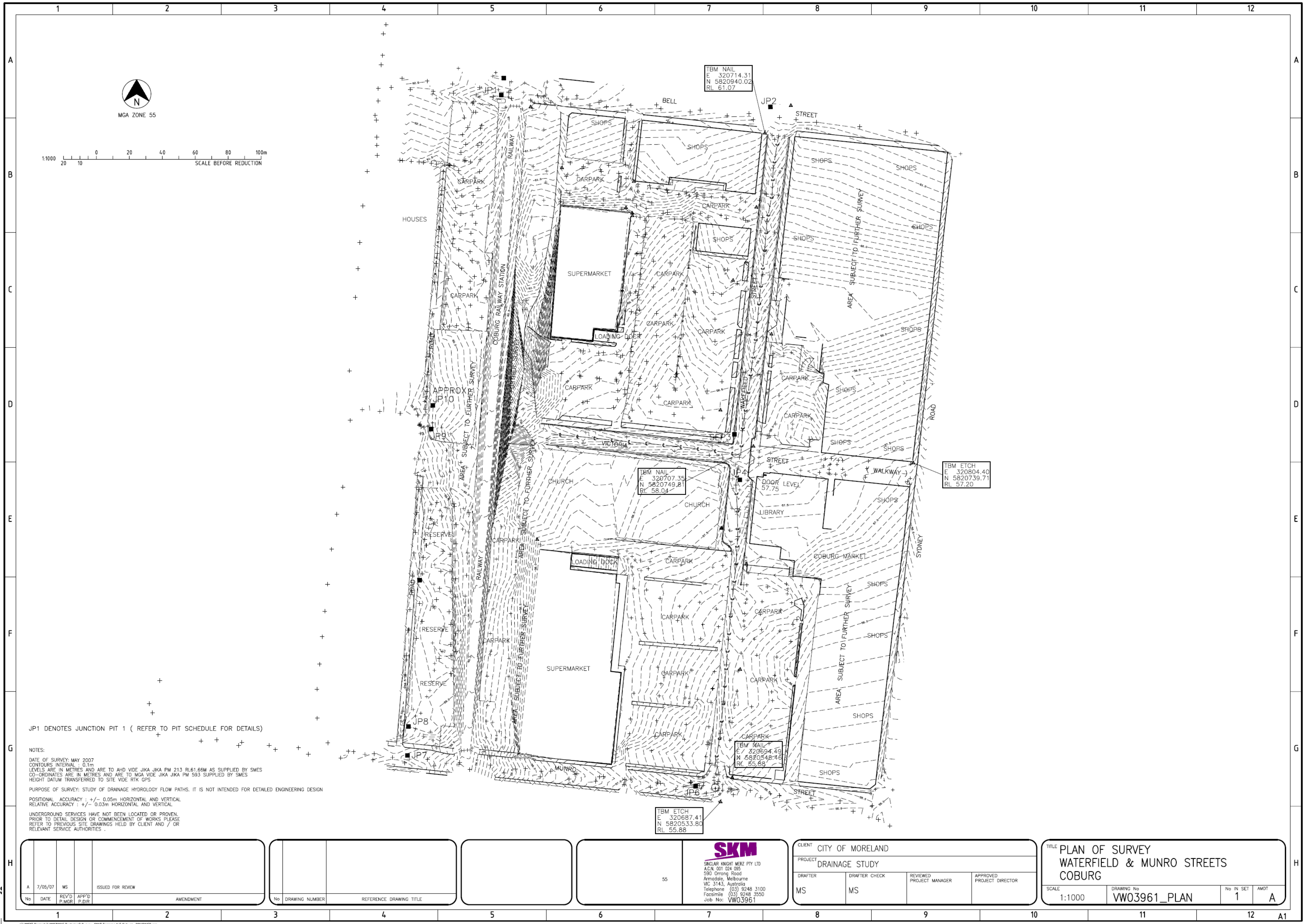
Monash University Department of Civil Engineering, in conjunction with Sinclair Knight Merz (2007), *RORB – Version 6, Runoff Routing Program User Manual,* by E.M. Laurenson, R.G. Mein, and R.J. Nathan, October 2007.

SKM (2006) *Harding Street Main Drain – Redevelopment Services Scheme Investigation*. SKM for Melbourne Water, August 2006

VicRoads (1999), Road Design Guidelines – Part 7 (Drainage), Rev 1.7, September 1999.

Victorian Department of Planning and Community Development (VDPCD), *Development Contribution Guidelines*, March 2007.

Appendix A Survey Results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BELL
STREET
JP1
JP2
SHOPS
CARPARK
HOUSES
SUPERMARKET
LOADING DOCK
COBURG RAILWAY STATION
RAILWAY
AREA SUBJECT TO FURTHER SURVEY
APPROX JP10
JP9
VICTORIA
STREET
WATERFIELD STREET
WALKWAY
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RL 57.20
TBM NAIL
E 320707.35
N 5820749.81
RL 58.04
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CHURCH
DOOR LEVEL 57.75
LIBRARY
COBURG MARKET
SYDNEY ROAD
RESERVE
JP8
JP7
MUNRO
STREET
JP6
TBM NAIL
E 320694.49
N 5820548.48
RL 55.68
TBM ETCH
E 320687.41
N 5820533.80
RL 55.88
JP1 DENOTES JUNCTION PIT 1 (REFER TO PIT SCHEDULE FOR DETAILS)
NOTES:
DATE OF SURVEY: MAY 2007
CONTOURS INTERVAL : 0.1m
LEVELS ARE IN METRES AND ARE TO AHD VIDE JIKA JIKA PM 213 RL61.66M AS SUPPLIED BY SMES
CO-ORDINATES ARE IN METRES AND ARE TO MGA VIDE JIKA JIKA PM 593 SUPPLIED BY SMES
HEIGHT DATUM TRANSFERRED TO SITE VIDE RTK GPS
PURPOSE OF SURVEY: STUDY OF DRAINAGE HYDROLOGY FLOW PATHS. IT IS NOT INTENDED FOR DETAILED ENGINEERING DESIGN
POSITIONAL ACCURACY : +/- 0.05m HORIZONTAL AND VERTICAL
RELATIVE ACCURACY : +/- 0.03m HORIZONTAL AND VERTICAL
UNDERGROUND SERVICES HAVE NOT BEEN LOCATED OR PROVEN.
PRIOR TO DETAIL DESIGN OR COMMENCEMENT OF WORKS PLEASE
REFER TO PREVIOUS SITE DRAWINGS HELD BY CLIENT AND / OR
RELEVANT SERVICE AUTHORITIES .
A 7/05/07 MS ISSUED FOR REVIEW
No DATE REV'D P.MGR APP'D P.DIR AMENDMENT
No DRAWING NUMBER REFERENCE DRAWING TITLE
55
SKM
SINCLAIR KNIGHT MERZ PTY LTD
A.C.N. 001 024 095
590 Orrong Road
Armadale, Melbourne
VIC 3143, Australia
Telephone (03) 9248 3100
Facsimile (03) 9248 3550
Job No: VW03961
CLIENT CITY OF MORELAND
PROJECT DRAINAGE STUDY
DRAFTER MS
DRAFTER CHECK MS
REVIEWED PROJECT MANAGER
APPROVED PROJECT DIRECTOR
TITLE PLAN OF SURVEY
WATERFIELD & MUNRO STREETS
COBURG
SCALE 1:1000
DRAWING No VW03961_PLAN
No IN SET 1
AMDT A
A1

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- **Table A-11-1: Surveyed Invert Levels at Selected Locations within Coburg Shopping Centre**

Number	Pit Type	Internal Size	Pit Top RL		Outlet	Inlet A	Inlet B	Inlet C
1	JP		61.65	Size	625	650		
				Depth	1.39	1.41		
2	JP		61.28	Size	600	525	525	
				Depth	1.66	1.55	1.54	
3	GP	800x700	57.86	Size	750	600	375	300
				Depth	1.41	1.29	1.30	0.95
4	JP	750x600	57.67	Size	675	675	300	
				Depth	1.67	1.67	1.40	
5	GP	700x600		Size	450	450		
				Depth	1.22	1.20		
6	JP	600x600	56.31	Size	750	750	300	
				Depth	1.75	1.76	1.30	
7	JP		59.04	Size	800	750	750	
				Depth	1.77	1.77	1.73	
8	JP	Large	58.80	Size	750	750	450	
				Depth	1.52	1.48	0.83	
9	JP	1.07x0.88	59.56	Size	750	750	600	
				Depth	1.25	1.20	1.23	
10	Open pit drain	300x400	61.55	Size	750	300x400 brick drain		
				Depth	1.08			

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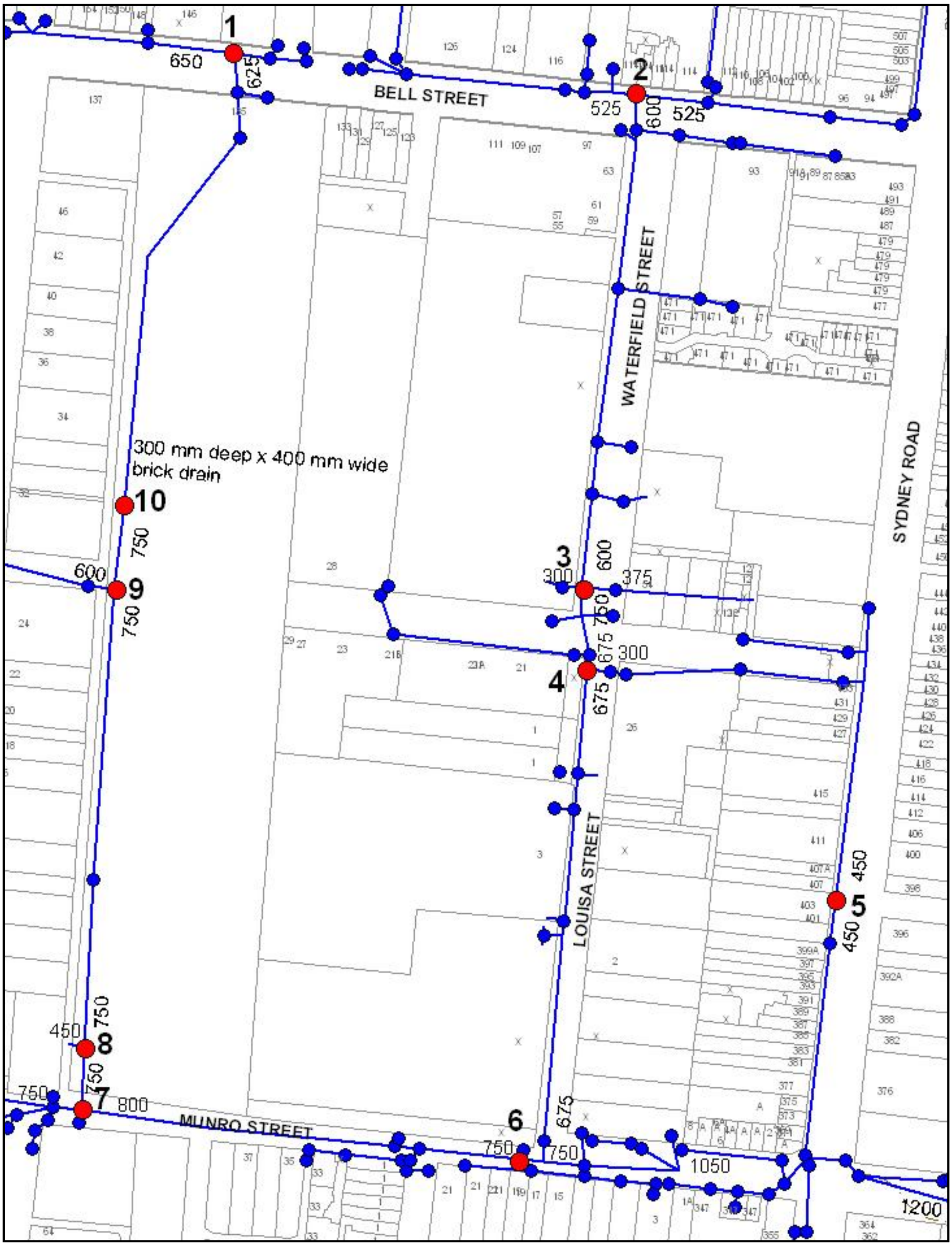

■ **Figure A-1: Locations of Surveyed Invert Levels and Pipe Diameters**

Appendix B RORB Modelling

B.1 RORB Overview

RORB is a non linear rainfall runoff and streamflow routing model for calculation of flow hydrographs in drainage and stream networks.

The model requires catchments to be subdivided into sub-areas, connected by a series of conceptual reach storages. Design storm rainfall is input to the centroid of each sub-area. Specified losses are then deducted, and the excess routed through the reach network.

Each reach is assumed to have storage characteristics as follows:

$$S = 3600kQ^m$$

Where S is storage (m^3);
Q is outflow discharge (m^3/s); and
k and m are dimensionless parameters.

The coefficient k is the product of two factors:

$$K = k_c.k_r$$

where k_c is an empirical coefficient applicable to the entire catchment, and
k_r is the relative delay time applicable to each reach.

The relative delay time for each reach, k_{ri}, is determined as follows:

$$k_{ri} = F_i*(L_i/d_{av})$$

where L_i is the reach length (km),
d_{av} is the average distance along the reach network from each subareas' centroid to the catchment outlet (km), and
F_i is an empirical factor, and a function of reach type as follows:

for natural reaches, F_i=1.0,
for excavated but unlined reaches, F_i=1/(3S_c0.25),
for lined or piped reaches, F_i=1/(9S_c0.5), and
for drowned reaches, F_i=0.0,

where S_c is reach slope (%).

The model is also able to simulate:

lakes, retarding basins and similar storages; and

concentrated and distributed inflows and outflows.

B.2 Design Rainfall Intensities

Design rainfall intensities were determined based on the methods prescribed in Book 2 of the 1997 Edition of Australian Rainfall and Runoff (Reference 7). The Intensity-Frequency-Duration (IFD) table used for the [waterway/drain name] catchment is shown as Table B-1, and is based on the following parameters:

1 HR DUR 2 ARI	19.1	mm/hr
12 HR DUR 2 ARI	3.9	mm/hr

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72 HR DUR 2 ARI	1.11	mm/hr
1 HR DUR 50 ARI	39.57	mm/hr
12 HR DUR 50 ARI	7.11	mm/hr
72 HR DUR 50 ARI	2.23	mm/hr
G (skewness)	0.35	mm/hr
F2 Geo factor 2 ARI	4.28	
F50 Geo factor 50 ARI	14.97	

- **Table B-1: Intensity-Frequency-Duration Table for Coburg**

Duration	Design Rainfalls for Average Recurrence Intervals (Years)								
	1 (mm/hr)	2 (mm/hr)	5 (mm/hr)	10 (mm/hr)	20 (mm/hr)	50 (mm/hr)	100 (mm/hr)	200 (mm/hr)	500 (mm/hr)
6m	44.4	59.3	81.9	97.4	118.0	147.7	172.6	199.8	239.6
10m	36.1	48.1	66.0	78.3	94.5	118.0	137.5	158.8	190.0
20m	26.0	34.5	47.0	55.4	66.6	82.7	96.1	110.6	131.7
30m	21.0	27.8	37.6	44.2	53.0	65.6	76.0	87.3	103.7
1hr	14.1	18.6	24.9	29.1	34.7	42.7	49.2	56.3	66.5
2hr	9.2	12.1	15.9	18.4	21.8	26.6	30.5	34.7	40.7
3hr	7.1	9.3	12.2	14.0	16.5	20.0	22.9	25.9	30.3
6hr	4.6	6.0	7.7	8.7	10.2	12.3	14.0	15.7	18.3
12hr	3.0	3.8	4.8	5.5	6.4	7.6	8.6	9.6	11.1
18 hr	2.3	2.9	3.7	4.2	5.0	5.9	6.7	7.6	8.7
24hr	1.9	2.4	3.1	3.5	4.1	5.0	5.7	6.4	7.4
36 hr	1.4	1.8	2.4	2.7	3.2	3.9	4.4	5.0	5.8
48hr	1.1	1.5	1.9	2.2	2.6	3.2	3.7	4.1	4.8
72hr	0.8	1.1	1.4	1.7	2.0	2.4	2.8	3.1	3.7

B.3 Storages

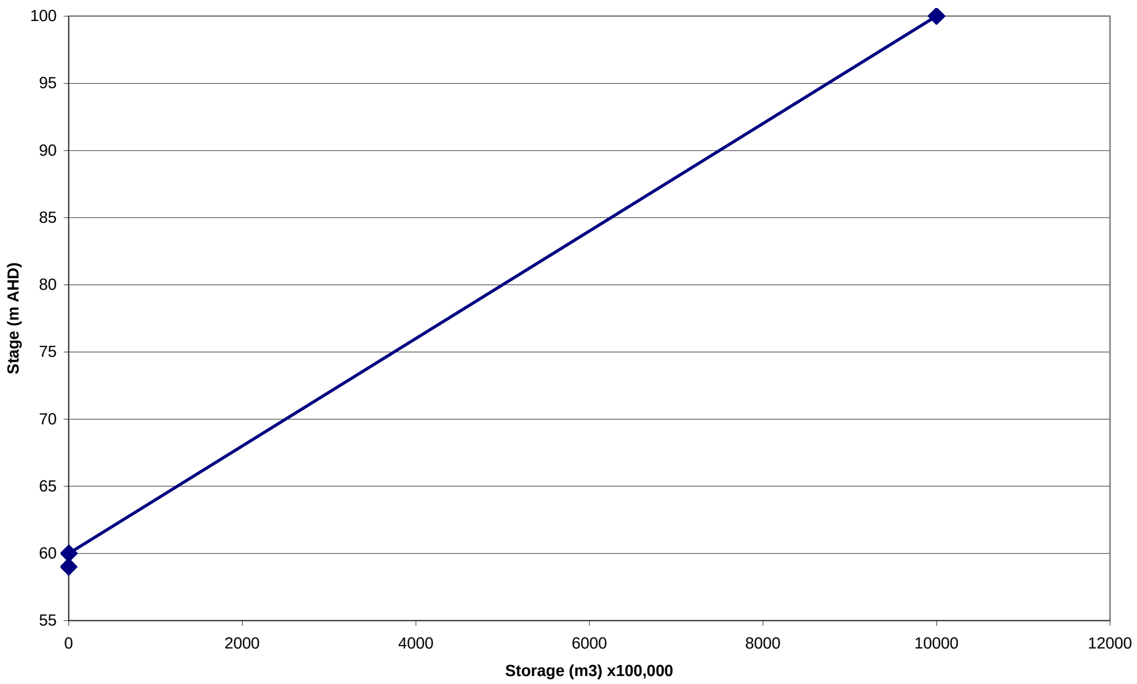
There is one defacto storage in the study area. This is located along the western side of the railway line upstream of Munro Street. This was modelled in the Harding Street RORB model. The storage is modelled in RORB using a weir and pipe formula and a stage storage relationship.

The model parameters for this storage were reviewed against survey data to ensure that they were accurate and able to be adopted for this study. The survey indicated that the lowest contour is 58.81 m AHD and the height of the railway line is 59.74 m AHD, which is consistent with parameters in the model.

Figure B-1 shows the relationships between stage and storage used in the Harding Street RORB model. It shows the defacto storage was given an infinitely large stage storage relationship to model the fact that any stormwater on the western side of the catchment would pond until it is discharged through either of the council drains under the railway line. Based on a site inspection, it was determined that the railway line is on a slight embankment above the level of the surrounding area and hence will prevent any overland flow draining from west to the east of the catchment.

Therefore the runoff from the western part of the catchment is restricted to the two council drains under the railway line. One of the council drains goes under the railway line along Munro Street. The other council drain is located approximately 300 m further south and also goes under the railway line. This drain is not part of the Harding Street Catchment and therefore flow to this council drain will need to be modelled as a loss in the system in the detailed hydraulic modelling.

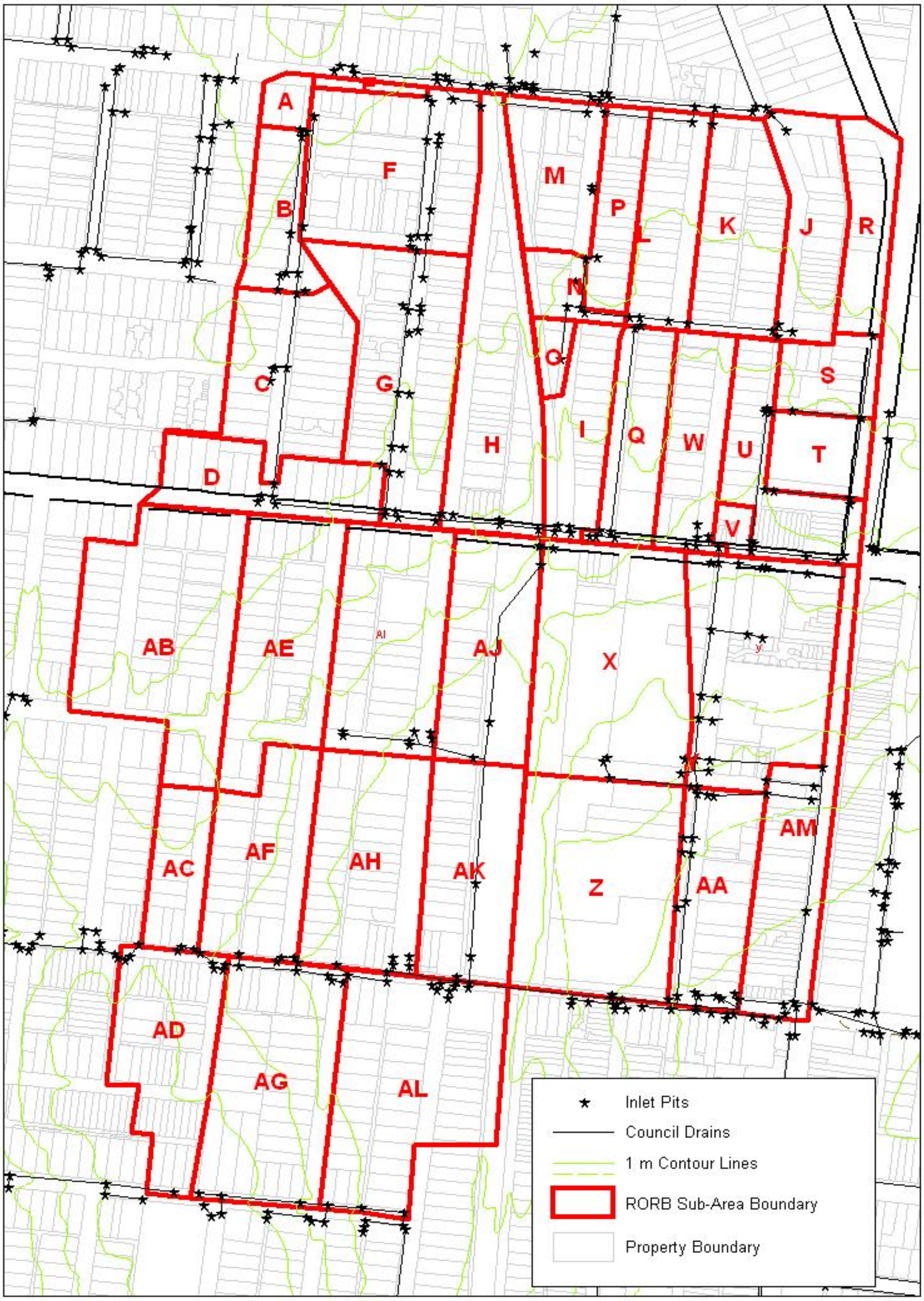
Based on this assessment the stage-storage and storage-discharge curves in the RORB model were adopted for this investigation.



▪ **Figure B-1: Stage Storage relationship used in RORB**

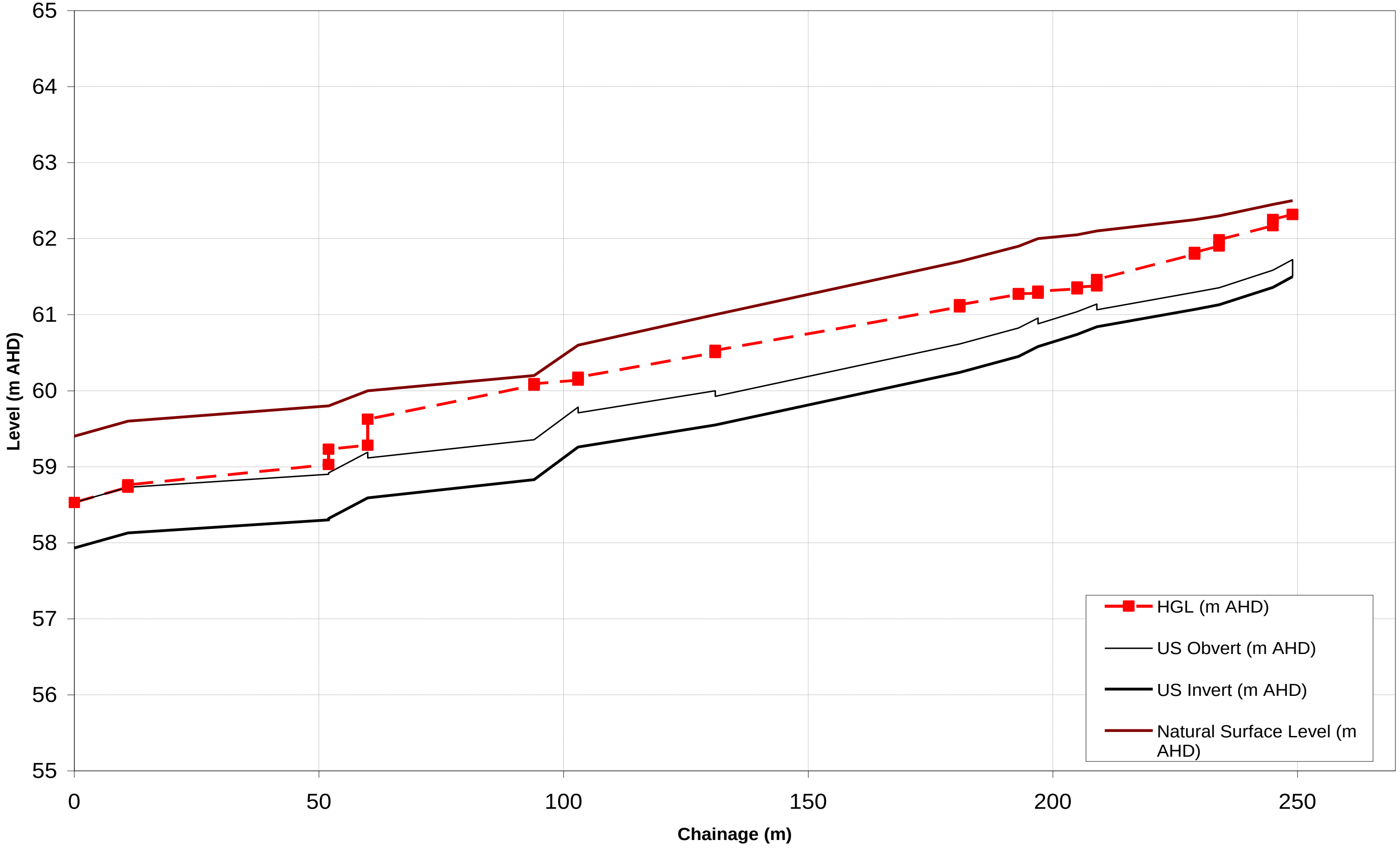
B.4 New Sub-Areas

The new sub-areas used in RORB for the study area are shown in Figure B-. The sub-areas from the Harding Street RORB model were sub-divided to increase the level of detail over the study area.

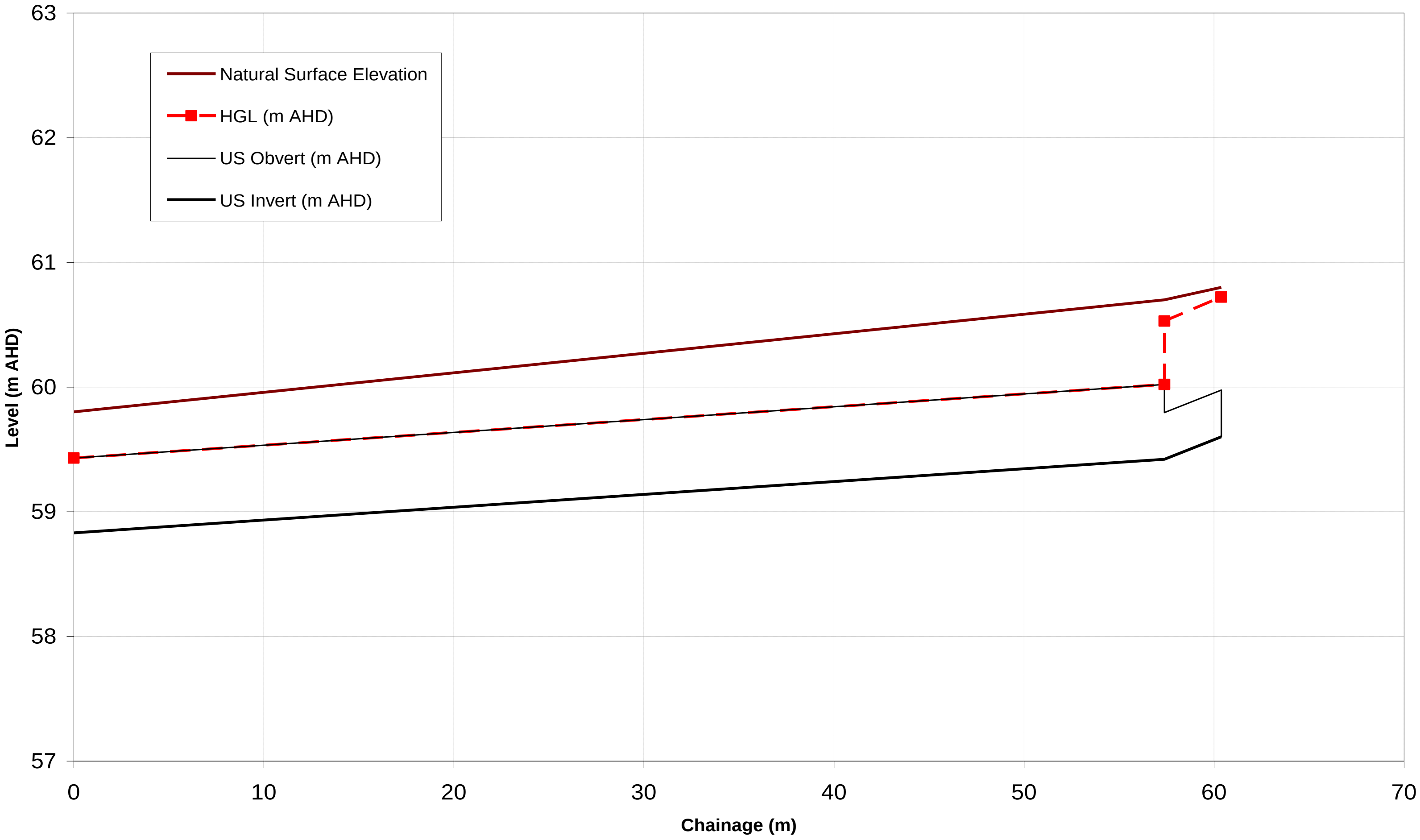


■ **Figure B-2: New RORB Sub-Areas for Study Area**

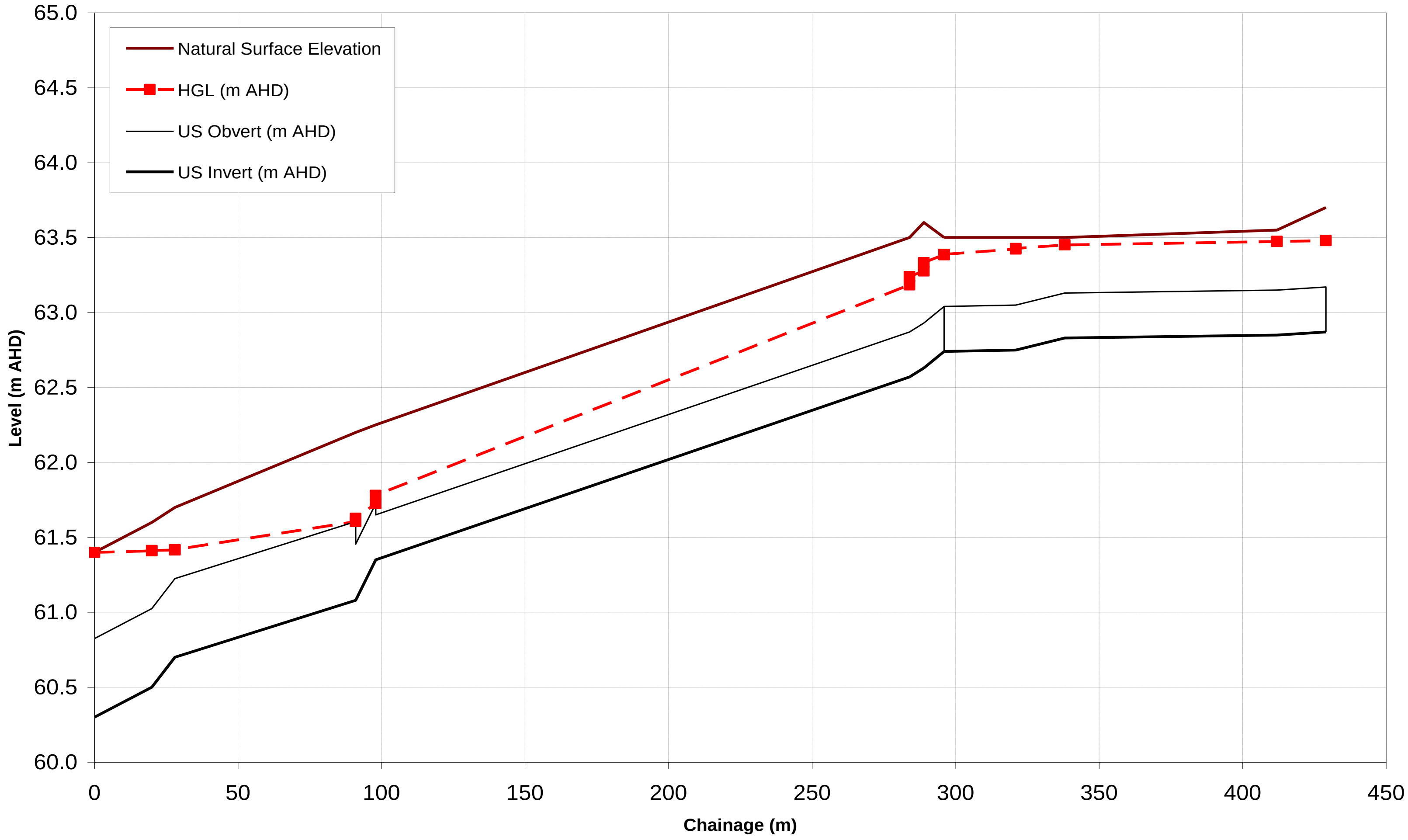
Appendix C Hydraulic Grade Line Analysis



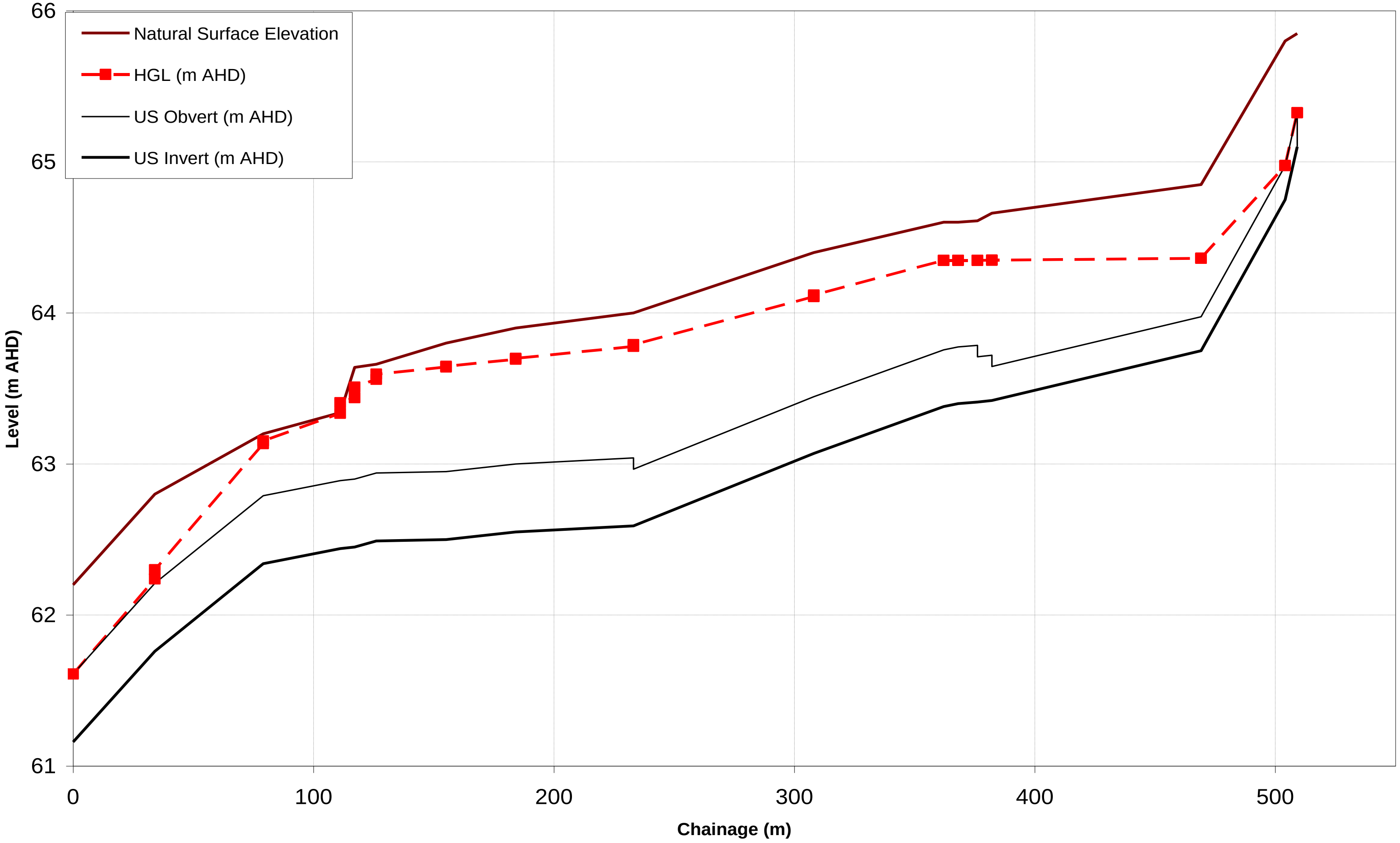
■ **Figure C-1: HGL of Munro Street**



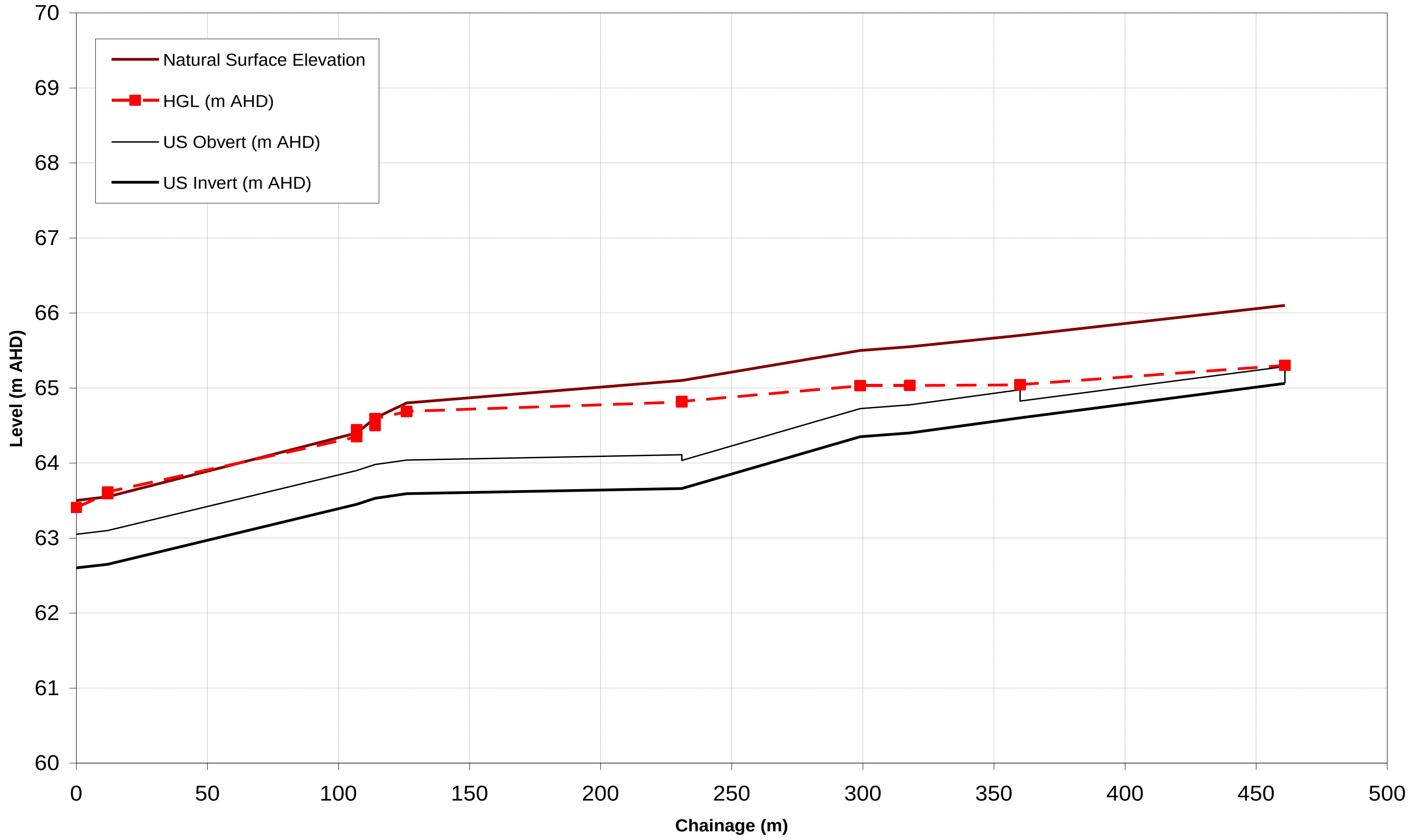
▪ **Figure C-2: HGL of Victoria Street**



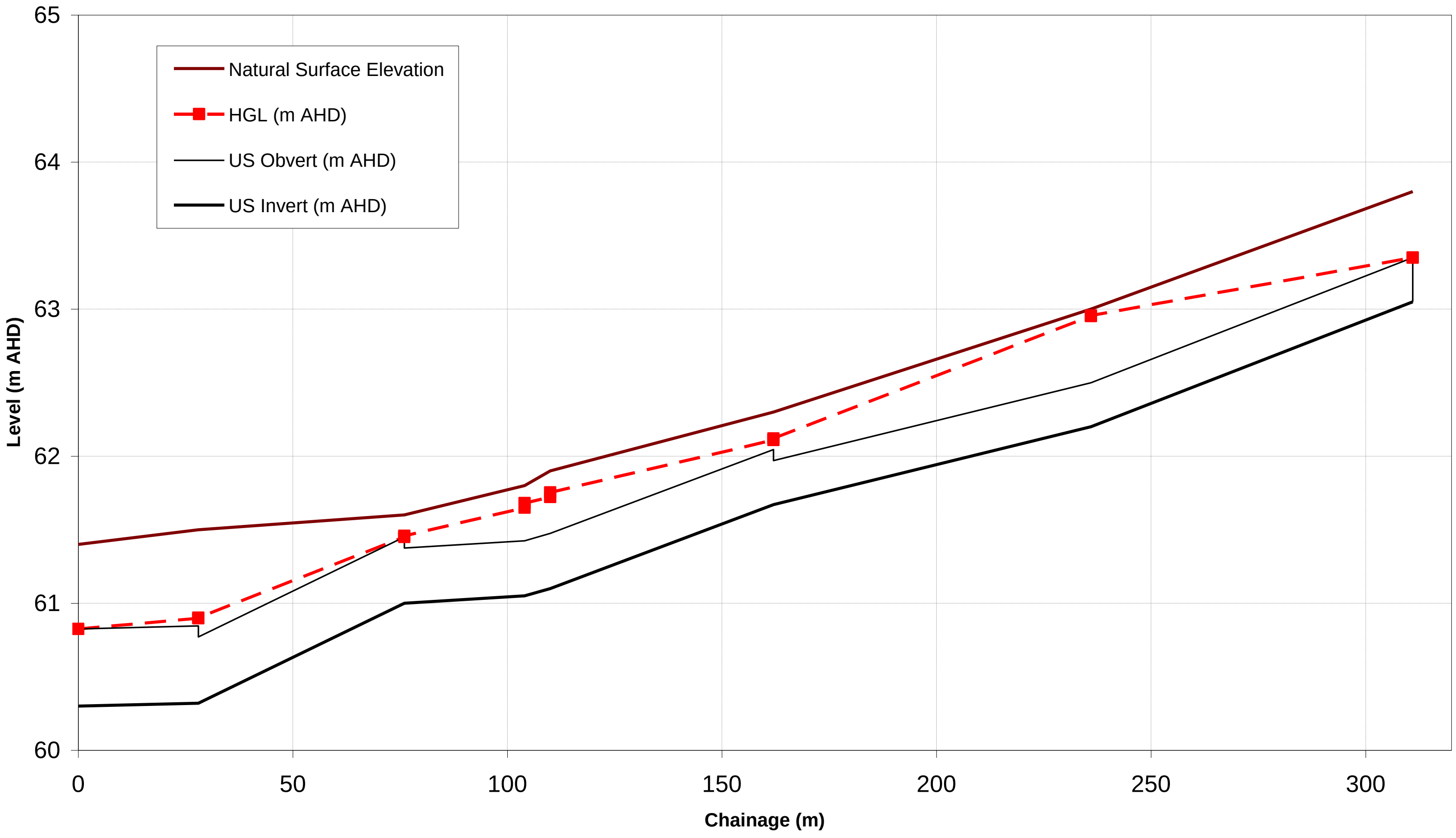
- **Figure C-3: HGL of McKay Street**



■ **Figure C-4: HGL of Service Street**



▪ **Figure C-5: HGL of Sutherland Street**



■ **Figure C-6: HGL of Sydney Road/Bell StreetSystem augmentation works**

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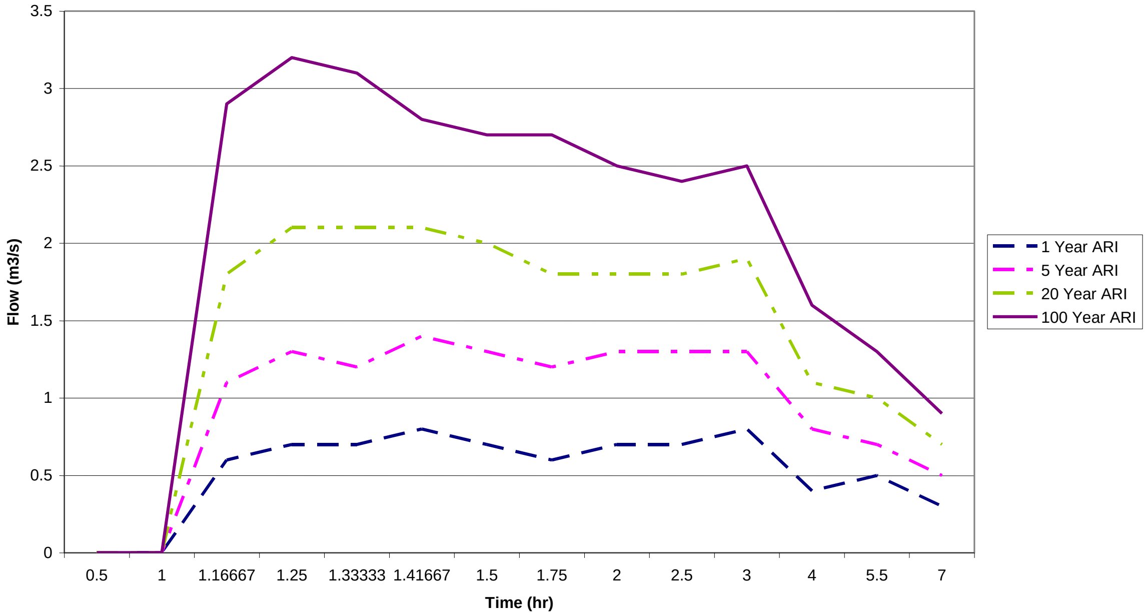
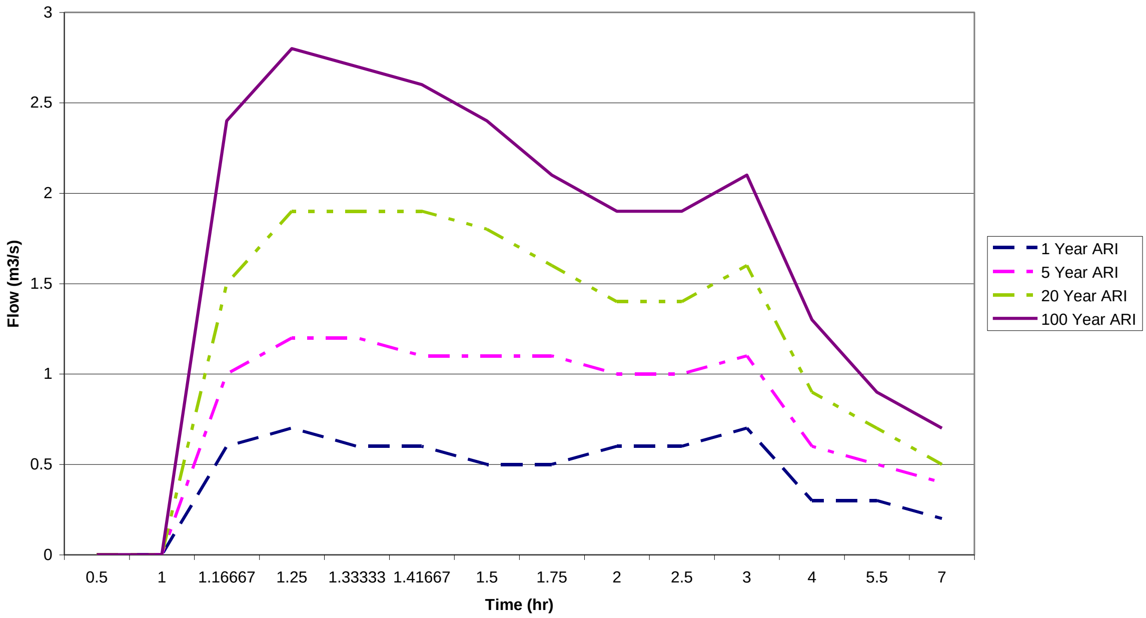
Appendix D XP Storm Inputs

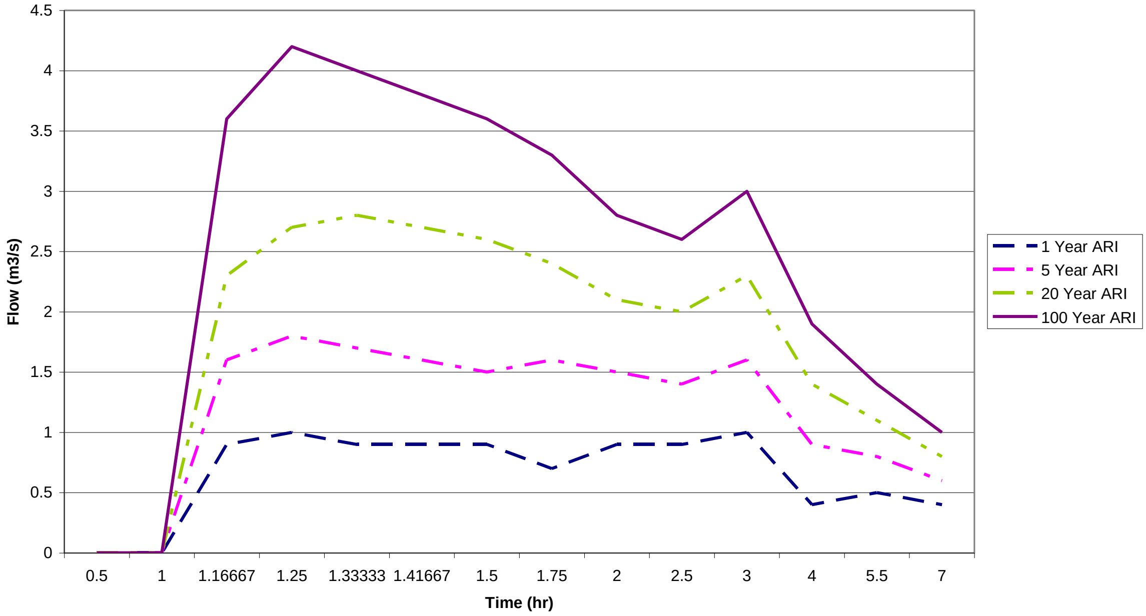
D.1 Hydrographs from RORB



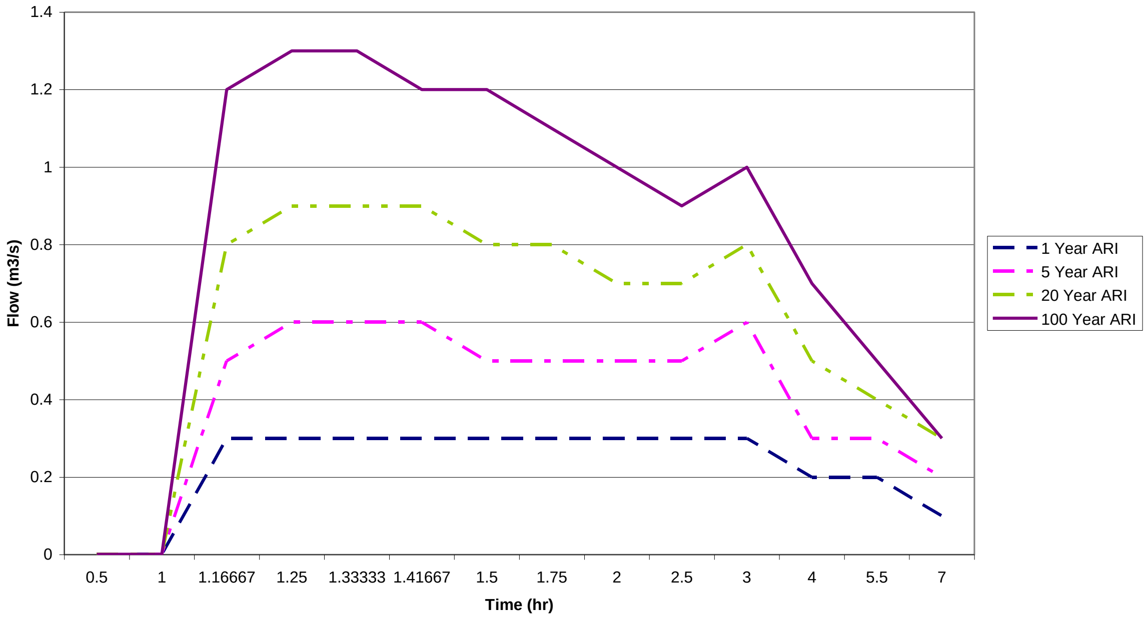
- **Figure D-1: RORB Hydrographs for the 1 Year, 5 Year, 20 Year and 100 Year Flows at Bell Street Upstream of the Railway Line**



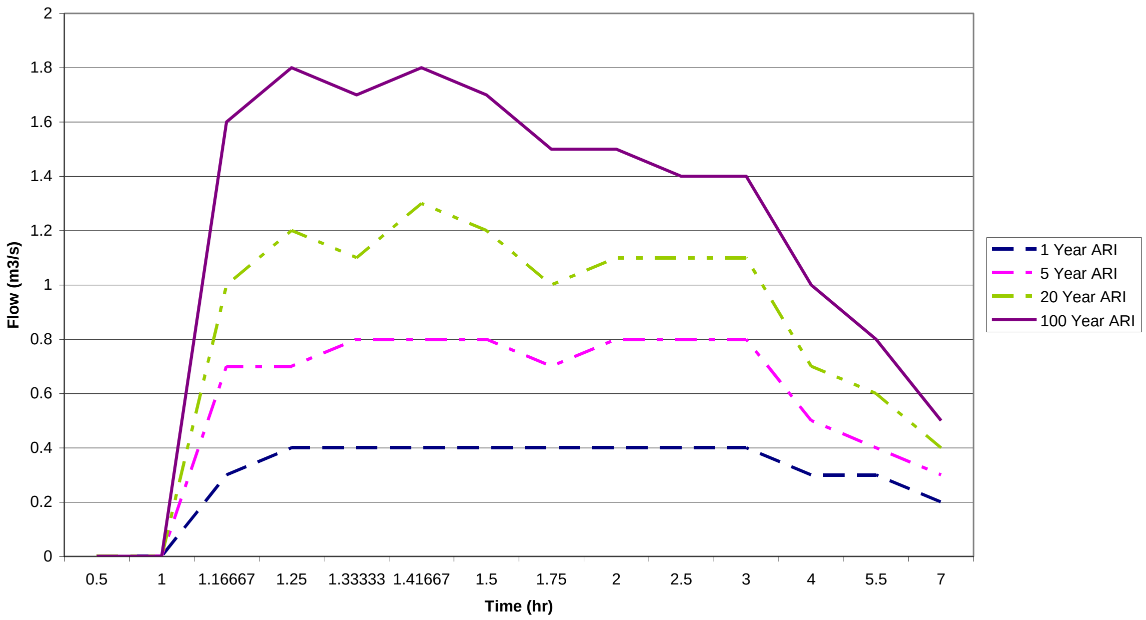
- **Figure D-2: RORB Hydrographs for the 1 Year, 5 Year, 20 Year and 100 Year Flows at Victoria Street**



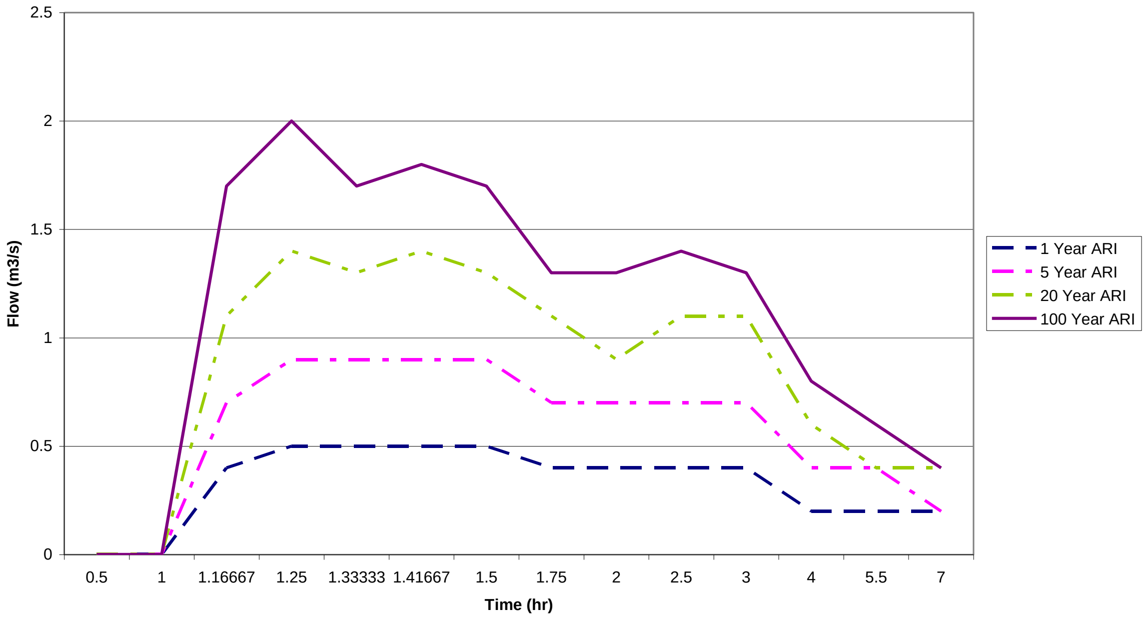
- **Figure D-3: RORB Hydrographs for the 1 Year, 5 Year, 20 Year and 100 Year Flows at Munro Street Upstream of Railway**



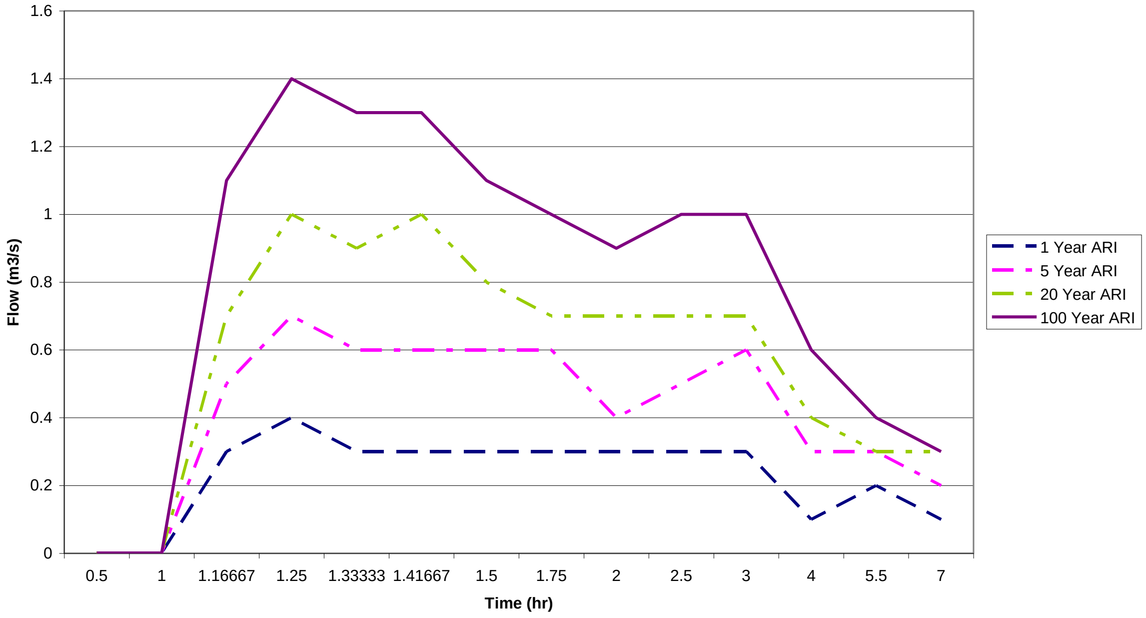
- **Figure D-4: RORB Hydrographs for the 1 Year, 5 Year, 20 Year and 100 Year Flows at Bell Street at the top of Waterfield Street**



- **Figure D-5: RORB Hydrographs for the 1 Year, 5 Year, 20 Year and 100 Year Flows at Bell Street at the downstream end of McKay Street**



- **Figure D-6: RORB Hydrographs for the 1 Year, 5 Year, 20 Year and 100 Year Flows for Sub-Areas X and Y**



- **Figure D-7: RORB Hydrographs for the 1 Year, 5 Year, 20 Year and 100 Year Flows for Sub-Areas Z and AA**

Appendix E Flood extents and depth plans