Appendix E

Flooding and drainage investigation

FLOODING AND DRAINAGE INVESTIGATION

MR 178 NARELLAN ROAD UPGRADE – CAMDEN VALLEY WAY TO BLAXLAND ROAD

VOLUME 1 – MAIN REPORT

May 2013

FINAL REPORT

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ABBREVIATIONS

AHD	Australian Height Datum
ALS	Airborne Laser Scanning (survey data)
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff, 1998 Edition
BLP	Brick Lined Pipe
CC	Camden Council
CCC	Campbelltown City Council
DRC	Design Road Chainage
GPT	Gross Pollutant Trap
LESCA	Local Erosion and Sediment Control Area
LGA	Local Government Area
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
RL	Reduced Level
RMS	NSW Roads and Maritime Services
RUSLE	Revised Universal Soil Loss Equation
SCA	Sydney Catchment Authority
SWMP	Soil and Water Management Plan

S1 SUMMARY OF KEY FINDINGS AND RECOMMENDATIONS

An investigation was carried out by Lyall & Associates Consulting Water Engineers on behalf of the NSW Roads and Maritime Services (RMS) to assess requirements for the control of stormwater runoff along the 6.8 kilometre length of Narellan Road between Camden Valley Way and Blaxland Road. This report deals with issues relating to both the construction and operational phases of the proposed road upgrade.

Figures 5.1 to **5.5** (bound in **Volume 2** of the report) show the layout of the cross and pavement drainage lines comprising the recommended drainage strategy for the Narellan Road upgrade. **Table B1** in **Annexure B** provides a description of the works comprising the recommended drainage strategy.

Figures 6.1 to **6.5** (bound in **Volume 2** of the report) show key elements of the recommended strategy to control erosion and sediment-laden runoff during construction of the road upgrade.

The key findings of the investigation as they relate to **present day conditions** were as follows:

- The hydrologic standard of existing cross drainage located along the length of the road corridor varies substantially, with surcharging of the existing road expected to occur during storms with equivalent average recurrence intervals (ARI's) ranging between about 2 and 100 years.
- Insufficient information was available at the time of writing to determine the hydrologic standard of existing cross drainage located near Camden Bypass and under Camden Valley Way. It will be necessary for RMS to undertake detailed survey of this drainage infrastructure prior to commencing detail design of the road upgrade.
- It will also be necessary for RMS to undertake additional survey to confirm details of existing pavement drainage systems along Narellan Road between Hartley Road and Camden Bypass prior to commencing detail design of the road upgrade.
- Existing water quality controls that treat runoff from the road corridor are limited to a gross pollutant trap and wetland located immediately upstream of Gilinganadum Dam within The Australian Botanic Garden, Mount Annan (Botanic Garden).

The key findings and recommendations of the investigation as they relate to the **operational phase** of the project were as follows:

<u>Cross Drainage</u>

- The recommended drainage strategy would improve the hydrologic standard of Narellan Road to a minimum of 10 year ARI along its length between Camden Valley Way and Blaxland Road, which is consistent with that of the proposed pavement drainage system. *[Note that the hydrologic standard of Narellan Road is typically greater than 10 year ARI, and exceeds 100 year ARI in several locations.]*

  The recommended drainage strategy will also minimise the adverse flood-related impacts of the road upgrade works on existing development and the existing drainage lines into which the new and upgraded pavement drainage systems will discharge.
- Upstream of the road corridor, flood levels will not be increased as a result of the road upgrade works. This is a result of the minor nature of the works, which will not change the existing hydraulic control formed by the current vertical alignment of the road.

- A flood study investigation is presently being undertaken on behalf of Camden Council for the Narellan Creek catchment. It is understood that the scope of this investigation includes detailed two-dimensional (in plan) hydraulic modelling to describe flooding patterns in the catchments which drain to the cross drainage of Narellan Road. Whilst a draft report for this study was not available at the time of writing, the findings of this study (if available) should be taken into consideration when preparing the detail design for the road upgrade works.

Pavement Drainage

- RMS' desired 10 year ARI hydrologic standard for the new pavement drainage system is generally achievable along the length of Narellan Road to be upgraded.

  It is noted that further investigations will be required as part of detail design to confirm the above finding, with the benefit of additional survey, between Hartley Road and Camden Bypass. Potential constraints imposed on piped drainage lines as a result of elevated tailwater conditions will also need to be considered during detail design, in particular where the pavement drainage system connects directly into existing cross drainage structures.
- Existing drainage patterns along the road corridor will generally be maintained as part of the road upgrade. The impact of the proposed road upgrade works on peak flows in receiving drainage lines will be minor, and will not contribute to an increased risk of flooding in adjacent development, nor to an increased risk of scour along these drainage lines.
- Minor redistributions of flow will occur downstream of the road corridor in the following two locations:
  - Peak flows downstream of cross drainage structure X2 at **Design Road Chainage** (**DRC**) **6575** will be increased, whilst flows downstream of cross drainage structure X1 at **DRC 6680** will be reduced.
  - Peak flows downstream of cross drainage structure X8 at **DRC 4150** will be increased, whilst flows downstream of cross drainage structure X7 at **DRC 4360** will be reduced.

  However, in both locations the proposed flow redistributions will not adversely impact existing development and will not reduce the yield of any existing water storages.

Water Quality

- The road upgrade works, which generally involve minor widening of existing road pavement, represent only a minor change to the existing characteristics of the catchments through which the road corridor passes. Opportunities for the treatment of stormwater runoff captured by new and upgraded pavement drainage systems are also limited by both space constraints and by the configuration of existing road drainage systems.
- The recommended drainage strategy incorporates measures to minimise the impact of the road upgrade works on the following two sensitive receiving water bodies:
  - Existing dam within Nos. 168 – 192 Narellan Road circa **DRC 6100**; and
  - Gilanganadum Dam within the Botanic Garden circa **DRC 4150**.

The recommended drainage strategy also avoids discharge of runoff from the road corridor into the Upper Canal, a key element of Sydney Catchment Authority's water supply network.

Residual Property Impacts

- The recommended drainage strategy would minimise the adverse flood-related impacts of the road upgrade works on existing development and the existing drainage lines into which the new and upgraded cross and pavement drainage systems will discharge.
- Residual drainage-related property impacts relate to:
  - new channel works and associated easement within Nos. 168 – 192 Narellan Road (opposite TAFE Access Road); and
  - minor increases in peak flow rates in several receiving drainage lines along the length of the proposed road upgrade works, which do not increase the risk of flooding in adjacent development.

The key findings and recommendations of the investigation as they relate to the **construction phase** of the project were as follows:

- Large scale sediment retention basins do not necessarily need to form part of the *Soil and Water Management Plan* (or similar) for the road upgrade project in order to comply with the guidelines set out in *"Soils and Construction – Managing Urban Stormwater"* Volume 1 (Landcom, 2004) and Volume 2D (DECC, 2008). Rather, it is recommended that localised erosion and sediment control measures, including temporary sediment sumps where practicable, form the basis of the erosion and sediment control strategy that will need to be developed as part of final design and/or construction documentation for the road upgrade works.
- **Figures 6.1** to **6.5** show the locations where a series of smaller temporary sediment sumps could be built to control runoff from disturbed areas during construction. The location of the sumps was determined based on a review of the available contour data and an assessment of the likely location where runoff from the road corridor will discharge to receiving drainage lines during the construction phase of the project.

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1 INTRODUCTION

1.1 Background

Roads and Maritime Services (RMS) is currently developing a concept design for the proposed upgrade of the 6.8 kilometre (km) length of Narellan Road between Camden Valley Way, Narellan and Blaxland Road, Campbelltown. **Figure 1.1** shows the extent of the proposed road upgrade works.

The objective of this present investigation was to undertake an assessment of drainage requirements associated with the road upgrade (both during the construction and operational phases of the road upgrade), and to prepare preliminary designs for the upgrade of existing road drainage systems. This work will inform further development of the concept road design and preparation of an environmental assessment for the upgrade works.

In the absence of existing hydrologic models for the catchments which lie upstream of Narellan Road, catchment modelling using the DRAINS rainfall-runoff software was undertaken to define peak flood flows arriving at the road corridor at the locations of existing cross drainage. The DRAINS model was also used to investigate the impact that the proposed road upgrade would have on peak flows in existing drainage lines downstream of Narellan Road, and to assist in the development of a strategy for discharging runoff from the upgraded roadway to these receiving drainage lines.

The DRAINS model was also used to assess the capacity of existing minor cross drainage structures along the route of the proposed road upgrade, and to investigate potential upgrade of selected structures. Existing HEC-RAS hydraulic models were available for three major existing cross drainage structures located between the Camden Bypass and the Upper Canal, and these were utilised for the purpose of this present investigation.

1.2 Study Tasks

The study tasks were broadly as follows:

- Site inspection to ground-truth existing drainage arrangements, confirm additional survey requirements and identify relevant site constraints.
- Review previous studies and available data along the route of the proposed road upgrade works.
- Liaise with Camden Council (CC), Campbelltown City Council (CCC) and Sydney Catchment Authority (SCA) to obtain relevant drainage information.
- Hydrologic analysis of catchments upstream of the road corridor to determine peak flow rates approaching existing cross drainage along the route. Hydrologic modelling also included catchments which lie downstream of the road corridor so that impacts on peak flow rates as a result of the road upgrade could be determined along the receiving drainage lines.
- Hydraulic analyses of existing cross drainage structures along Narellan Road to determine the current hydrologic standard of these crossings.

- Develop a strategy for discharging runoff from the new pavement drainage system aimed at mitigating the impacts of the road upgrade works on existing development. A concept layout for the new pavement drainage system was developed to show the indicative location of inlet pits and piped drainage lines that will be required to capture and convey runoff from the upgraded section of road to receiving drainage lines.
- Develop a strategy to control erosion and sediment-laden runoff during construction of the road upgrade.

1.3 Outline of Report

Section 2 of this report contains a description of existing road drainage systems along the length of Narellan Road to be upgraded, including both cross and pavement drainage systems. A brief description of the catchments which presently contribute runoff to these road drainage systems is also provided. **Annexure A** contains several photographs that show elements of the existing drainage system and receiving drainage lines along the length of Narellan Road that will be upgraded.

Section 3 contains an overview of the methodology and findings of an investigation undertaken to assess peak flow rates at key locations along the length of the road upgrade works under present day conditions. This section also presents the findings of an investigation which was carried out to assess the hydrologic standard of existing cross drainage along Narellan Road.

Section 4 provides a brief description of the proposed road upgrade works.

Section 5 presents the recommended strategy for managing runoff along the upgraded sections of Narellan Road and for its discharge into receiving drainage lines. Note that **Table B1** in **Annexure B** describes the recommended drainage works and proposed adjustments to existing road drainage systems. This section also deals with the impact the road upgrade works will have on drainage patterns along the length of the road corridor, and provides a summary of residual drainage-related property impacts should the recommended drainage strategy be implemented.

Section 6 outlines the findings of a preliminary assessment of measures which will be required to control runoff from the road corridor during the construction phase of the project. Preliminary advice in relation to the locations where the implementation of temporary sediment sumps would assist in this regard is also contained in this section of the report. **Annexure B** contains a table that summarises the estimated average annual soil loss from disturbed areas along the length of the road corridor, and was used to assist in development of the erosion and sediment control strategy.

Section 7 contains a list of references used during the course of the investigation.

Volume 2 of the report contains all referenced figures and appendices.

Appendix A contains several drawings showing details of existing water quality control measures for road runoff discharging to Gilinganadum Dam within The Australian Botanic Garden, Mount Annan (Botanic Garden).

1.4 Available Data

The following data were made available by RMS for this present investigation:

- Aerial photography covering the study area.
- Airborne laser scanning (ALS) survey data covering the study area.
- Detailed ground survey information along the route of the proposed road upgrade works.
- Detailed survey of a number of existing cross drainage structures and piped drainage systems located along the road corridor.
- Strategic road design model and staging plan for proposed upgrade works.
- GIS datasets including property boundary information.

The following additional information was obtained from other sources (as noted) over the course of the investigation:

- Plan showing selected details of an existing stormwater drainage structures within Blair Athol Estate and existing piped drainage under the adjacent section of Narellan Road (sourced from CCC).
- GIS datasets showing selected details of the existing stormwater drainage structures within Camden Local Government Area (LGA) and existing piped drainage under the section of Narellan Road passing through the Camden LGA (sourced from CC).
- Plan showing selected details of an existing stormwater drainage structure under the Upper Canal that controls the flow of runoff to cross drainage structures under Narellan Road (sourced from SCA).

Hydrologic and hydraulic models developed as part of the Upper Nepean Tributary Flood Study (LMCE, 1999) were also utilised for the purpose of this present investigation. The objective of this study in relation to Narellan Road was to define flow conditions at major creek crossings, including the main arm of Narellan Creek and a number of its larger tributaries, arising from a Probable Maximum Flood (PMF) event. Further details of the study and its application to this present investigation are provided in subsequent sections of this report.

A flood study investigation is presently being undertaken on behalf of CC for the Narellan Creek catchment. It is understood that the scope of this investigation includes detailed two-dimensional (in plan) hydraulic modelling to describe flooding patterns in the catchments which drain to the cross drainage of Narellan Road. Whilst a draft report for this study was not available at the time of writing, the findings of this study (if available) should be taken into consideration when preparing the detail design for the road upgrade works.

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2 EXISTING ROAD DRAINAGE SYSTEMS

2.1 General

This section of the report contains a description of existing road drainage systems along the length of Narellan Road to be upgraded, including both cross and pavement drainage systems. A brief description of the catchments which presently contribute runoff to these road drainage systems is also provided. [1]

Figure 2.1 shows the extent of the catchments which drain to fifteen existing cross drainage structures under Narellan Road, and one existing cross drainage structure under the northbound exit ramp at the Hume Highway interchange, and should be referred to when reading the following sections of the report. **Figures 2.2** to **2.6** show further details of existing road drainage systems along the length of the road corridor and should also be referred to when reading the following sections of the report.

Table 2.1 over provides a summary of the existing cross drainage structures along the route of the proposed road upgrade.

Annexure A contains several photographs that show elements of the existing drainage system and receiving drainage lines along the length of Narellan Road to be upgraded, and references to these photographs are contained in the following sections (and **Table 2.1**) where appropriate.

2.2 Catchment Overview

The 6.8 km length of Narellan Road to be upgraded runs through the catchments of two major creek systems. A ridge that runs generally north-south around 500 metre (m) west of the Hume Highway forms the catchment divide between these two systems.

To the west of the ridge, the road corridor is located within the Narellan Creek system, which forms part of the larger Nepean River system. The main arm of Narellan Creek and two of its smaller tributary arms known as Tributary 2 and Tributary 5, as well as a number of piped drainage lines, cross the road corridor from south to north within this catchment (refer **Figure 2.1**). The Upper Canal, a key element of SCA's water supply network, is used to transfer raw water from dams on the upper Nepean River to its water filtration plant at Prospect, also crosses the road corridor within this catchment.

To the east of the ridge, Narellan Road is located within the Bow Bowing Creek system, which forms part of the larger Georges River system. There are no major creek crossings along this section of road corridor, as it runs along a smaller ridgeline between two tributary arms of Bow Bowing Creek (refer **Figure 2.1**).

[1] Note that for the purpose of this report, the locations of key features are identified by their position along Narellan Road as defined by its Design Road Chainage (DRC). Note also that the discussion of road drainage systems commences at the eastern limit of the road upgrade, moving in a westerly direction (i.e. the discussion runs in the direction of decreasing DRC). This convention has also been adopted when describing the concept drainage and erosion and sediment control strategies in Sections 5 and 6 of the report, respectively.

The most northern section of proposed road upgrade works along the Hume Highway, involving extension of the southbound exit ramp, are located within the Biriwiri Creek catchment (refer **Figure 2.1**), which forms part of the Bow Bowing Creek system. *[Note that these works will be undertaken by RMS as an earlier, separate project to the remainder of the proposed road upgrade works – refer Chapter 4.]*

TABLE 2.1
SUMMARY OF EXISTING CROSS DRAINAGE

I.D.	Design Road Chainage	Location	Pipe / Culvert Dimensions (1) (mm)	Catchment Area (ha)	Description of Receiving Environment(2)
X1	6680	237 m west of Blaxland Road	1 off 825 RCP	7.3	Discharge to piped drainage system that runs north to Tributary 1 of Bow Bowing Creek (**Plate 1**).
X2	6575	325 m west of Blaxland Road	1 off 900 RCP / 1 off 1050 RCP	1.4	Discharge to open channel (**Plate 3**) feeding north into Tributary 1 of Bow Bowing Creek.
X3	6400	1000 m west of Blaxland Road	1 off 750 RCP	4.0	Discharge to informal drainage line across vegetated area (**Plate 4**). Drains to Tributary 1 of Bow Bowing Creek.
X4	6170	170 m east of TAFE Access Road	1 off 750 RCP	1.6	Discharge to informal drainage line across vegetated area (**Plate 5**). Drains to Tributary 1 of Bow Bowing Creek.
X5	6090	94 m east of TAFE Access Road	1 off 375 RCP	0.5	Discharge to densely vegetated drainage line (**Plate 6**). Drains to Tributary 1 of Bow Bowing Creek.
X6	4900	Hume Highway (northbound) entry/exit ramp	1 off 525 RCP	1.8	Discharge to piped drainage system that also receives runoff from Hume Highway and northbound entry/exit ramp. Drains to Tributary 2 of Bow Bowing Creek.
X7	4360	45 m west of Kenny Hill Road	1 off 1200 BLP	6.7	Discharge to grassed drainage line across north-western corner of No. 410 Narellan Road which feeds to catch drain along the upstream (eastern) side of the Upper Canal. Ultimately drains to Gilinganadum Dam (**Plates 9 to 12**).
X8	4150	200 m east of Mount Annan Christian College Access Road	1 off 900 RCP	11.7	Discharge via GPT to vegetated drainage line which feeds in to Gilinganadum Dam (**Plate 13**).
X9	3530	80 m west of Mount Annan Drive (Main Arm of Narellan Creek)	3 off 1700 RCP's	213	Discharge to grassed floodway that forms main arm of Narellan Creek (**Plate 14**).
X10	3350	250 m west of Mount Annan Drive	2 off 1200 RCP's	45.2	Discharge to Camden Council piped drainage system. Ultimately drains to main arm of Narellan Creek.
X11	3040	636 m east of Hartley Road	1 off 1050 RCP	6.7	Discharge to Camden Council piped drainage system. Ultimately drains to main arm of Narellan Creek.
X12	2900	500 m east of Hartley Road	1 off 750 RCP	3.6	Discharge to Camden Council piped drainage system. Ultimately drains to main arm of Narellan Creek.
X13	2050	340 m west of Hartley Road (Tributary 5 of Narellan Creek)	3 off 2140 x 2140 RCBC's	413	Discharge to existing creek that forms Tributary 5 of Narellan Creek (**Plate 15**).
X14	770	250 m west of Exchange Parade (Tributary 2 of Narellan Creek)	3 off 2100 x 2400 RCBC's	241	Discharge to existing creek that forms Tributary 2 of Narellan Creek (**Plate 16**).
X15	730	290 m west of Exchange Parade	unknown	17.2	Discharge to existing creek that forms Tributary 2 of Narellan Creek (**Plate 16**).
X16	100	Camden Valley Way, 50 m south of Narellan Road	1 off 600 RCP + 1 off 750 RCP	3.8	Discharge to vegetated channel that forms tributary arm of Narellan Creek (**Plate 17**).

(1) RCP – reinforced concrete pipe, BLP – brick lined pipe, RCBC – reinforced concrete box culvert.

(2) Refer **Annexure A** for plates.

Surrounding land use and development density varies substantially along the length of the road corridor, as indicated in the aerial photography visible in **Figure 2.1**. The western section of Narellan Road, between Camden Valley Way and Mount Annan Drive, passes through existing residential and commercial/industrial development in the suburbs of Narellan, Smeaton Grange, Narellan Vale, Currans Hill and Mount Annan. However, to the east of Mount Annan Drive the areas adjacent to the road corridor are largely rural in nature and much less intensely developed.

The following sections of the report provide a more detailed description of existing road drainage systems along the length of Narellan Road.

2.3 Blaxland Road to TAFE Access Road

Existing road drainage systems along this length of Narellan Road are shown on **Figure 2.2**.

2.3.1 Cross Drainage

There are five existing cross drainage structures along Narellan Road between Blaxland Road and the TAFE Access Road, all of which drain from south to north towards Tributary 1 of Bow Bowing Creek.

Cross drainage structure X1 is located at **DRC 6680** and comprises an 825 mm diameter reinforced concrete pipe (RCP). The structure controls runoff from a 7.3 ha catchment along the southern side of Narellan Road (refer catchment C3). Flows which surcharge the inlet of the cross drainage will track west along the southern kerbline of Narellan Road to the inlet of a 900 mm RCP (i.e. cross drainage structure X2) at the sag in the road corridor near **DRC 6600**. To the north of the road corridor, the pipe size increases to 900 mm diameter where it runs along an easement adjacent to the eastern boundary of an electrical substation. This pipe joins an existing piped drainage system that conveys low flows beneath Tributary 1 of Bow Bowing Creek, which has been formed into a grassed floodway where it runs through the surrounding residential development of Blair Athol (refer **Plate 1** in **Annexure A**).

Immediately to the west of the substation, cross drainage structure X2 conveys runoff across the road corridor at **DRC 6575**. The structure comprises a 450 mm RCP from the upstream headwall to the westbound kerbline, a 900 mm RCP from the westbound kerbline to the central median, and a 1050 mm RCP from the central median to the headwall located on the northern side of the road corridor. The 1050 mm RCP controls a total catchment area of 1.4 ha (refer catchment C4). Bypass flows from the inlet of the 450 mm RCP south of the southern kerbline are directed east to the inlet of cross drainage structure X1 at **DRC 6680**.

Cross drainage structure X2 also controls runoff from a 270 m long section of Narellan Road, further details of which are provided in the following section. The structure discharges into an excavated channel (refer **Plate 3**) that conveys runoff to Tributary 1 of Bow Bowing Creek a short distance downstream (north) of Narellan Road.

Further west along the road corridor at **DRC 6400**, cross drainage structure X3 controls a catchment of around 4 ha along the southern side of Narellan Road (refer catchment C5), including a 230 m long section of the westbound carriageway. This structure comprises a single 750 mm RCP and discharges to an informal drainage line (refer **Plate 4**) that feeds into Tributary 1 of Bow Bowing Creek a short distance downstream (north) of Narellan Road.

Cross drainage structure X4 is located at **DRC 6170** and also comprises a single 750 mm RCP. This structure controls a catchment of 1.6 ha along the southern side of the road corridor above the hinge point of the batter (refer catchment C6). This structure also controls runoff generated along an 80 m long section of the westbound carriageway. Cross drainage structure X4 discharges runoff into an informal drainage line (refer **Plate 5**) that feeds into Tributary 1 of Bow Bowing Creek a short distance downstream (north) of Narellan Road.

At **DRC 6090** cross drainage structure X5, comprising a single 375 mm RCP, crosses Narellan Road. This pipe controls a 0.5 ha catchment (refer catchment C7) along the southern side of the road corridor. Whilst predominantly grassed, this catchment also includes a 60 m long section of pavement along the westbound carriageway. The inlet of cross drainage structure X5 comprises a single SA2 type pit located along the westbound kerbline. The structure discharges to a densely vegetated drainage line (refer **Plate 6**) that directs runoff into an existing dam within Nos. 168 – 192 Narellan Road a short distance downstream (north) of the road corridor.

2.3.2 Pavement Drainage

Runoff generated from the intersection of Blaxland Road / Gilchrist Drive and Narellan Road is split into two catchments (refer Catchments C1 and C2). Runoff from Blaxland Road and the eastbound carriageway of Narellan Road west of the intersection is collected in a minor piped drainage system located along the northern kerb return and conveyed to CCC's local drainage system (refer location F2). A single 450 mm RCP under Blaxland Road controls runoff from the eastern portion of catchment C2.

During storm events which exceed the capacity of the pavement drainage system, bypass flows will be directed east along the northern side of Narellan Road and then proceed uncontrolled along an access road that commences at around **DRC 7000**. Runoff along this access road will feed directly to Bow Bowing Creek.

Runoff generated from Gilchrist Drive and Narellan Road east of the intersection is collected in a piped drainage system located along the westbound lane of Narellan Road. This system discharges to a grassed drainage line (refer location F1) which continues south-east towards Bow Bowing Creek.

Within catchment C3, runoff generated by the eastbound carriageway of Narellan Road is collected by a 375 mm piped drainage line located under the median. This piped drainage line connects into cross drainage structure X1. Two SF type pits along the median control runoff from the superelevated eastbound carriageway, with bypass flows following the prevailing grade of the pavement to the west to cross drainage structure X2.

Runoff generated on the westbound carriageway within catchment C3 falls towards the southern side of the road corridor, where the lack of kerb and gutter allows runoff to sheet off the pavement. Runoff is then directed to the inlet headwall of cross drainage structure X1.

As previously mentioned, cross drainage structure X2 controls runoff from a 270 m long section of Narellan Road between about **DRC 6400** and **DRC 6670**. Runoff generated from the westbound carriageway is collected at a single SA2 type pit located at the sag of the westbound kerbline (refer **Plate 2**). Runoff generated on the superelevated eastbound carriageway is collected by four SF type pits located along the central median, which are connected to the cross drainage via a single 375 mm diameter piped drainage line.

Runoff generated on the westbound carriageway within catchment C5 is controlled by a 375 mm diameter piped drainage line and four SA2 type pits located along the westbound kerbline. This system continues north across the road corridor as cross drainage structure X3 at **DRC 6400**. The pavement drainage system at this location also controls runoff from the batter slope adjacent to Narellan Road. Bypass flows will follow the prevailing grade of the pavement to the east to cross drainage structure X2.

Runoff generated on the westbound carriageway within catchment C6 is controlled by a single SA2 type pit in the southern kerbline, which connects into cross drainage structure X4 at **DRC 6170**. Bypass flows will follow the prevailing grade of the pavement to the east to cross drainage structure X3.

Runoff generated on the westbound carriageway within catchment C7 is controlled by a single SA2 type pit in the southern kerbline, which connects into cross drainage structure X5 at **DRC 6090**. Bypass flows will follow the prevailing grade of the pavement to the east to cross drainage structure X4.

There is no formal pavement drainage system in place to control runoff generated on the westbound carriageway between **DRC 5650** and **DRC 6090**, and on the eastbound carriageway between **DRC 5250** and **DRC 6550**. Runoff from these sections of the road corridor will sheet off the pavement and is largely uncontrolled between Narellan Road and the receiving drainage lines.

On the southern side of the TAFE Access Road intersection at **DRC 6000**, runoff generated on a short section of the westbound carriageway through the intersection drains to the south along the TAFE Access Road. Runoff along the various internal access roads within the grounds of the TAFE College / University of Western Sydney is controlled by an existing piped drainage system, details of which are not presently available, ultimately feeding into Tributary 2 of Bow Bowing Creek.

2.4 TAFE Access Road to Gilinganadum Dam

Existing road drainage systems along this length of Narellan Road are shown on **Figure 2.3**.

2.4.1 Cross Drainage

There are three existing cross drainage structures between the TAFE Access Road and Gilinganadum Dam.

Cross drainage structure X6 conveys runoff from west to east under the Hume Highway northbound entry/exit ramp just south of Narellan Road at **DRC 4900**. **Plate 7** shows the inlet headwall to the 525 mm RCP, which controls a catchment area of 1.8 ha. The structure continues to the south as a 450 mm diameter piped drainage line, and controls runoff generated on sections of the entry and exit ramps, further details of which are provided in the following section.

At **DRC 4360** a 1200 mm diameter pipe (denoted herein as cross drainage structure X7) conveys runoff to the south across Narellan Road. The length of pipe visible from the inlet of the structure is brick-lined (refer **Plate 8**). This structure controls a catchment area of 6.7 ha along the northern side of the road corridor. Part of this catchment area is piped under Kenny Hill Road via minor piped drainage structures located between **DRC 4400** and **DRC 4450**.

Cross drainage structure X7 also controls runoff from a 250 m long section of the eastbound carriageway of Narellan Road, further details of which are provided in the following section.

Cross drainage structure X7 transitions to 2 off 750 mm RCP's at an unknown location under Narellan Road. The twin pipe outlet on the southern side of the road corridor was blocked by sediment and debris to half-pipe height at the time of inspection. The twin pipes discharge to an informal grassed drainage line across the north-western corner of No. 410 Narellan Road, which feeds into a grassed catch drain along the upstream (eastern) side of the Upper Canal (refer **Plate 9**). The catch drain feeds 2 off 375 mm RCP's that were observed on the upstream (eastern) side of the canal (refer **Plate 10**). Based on information supplied by SCA, these pipes discharge into a single 1200 mm RCP that crosses under the canal. The 1200 mm RCP discharges into a vegetated overland flow path that feeds down to Gilinganadum Dam within the Botanic Garden (refer **Plates 11** and **12**).

At **DRC 4150** a 900 mm RCP (denoted herein as cross drainage structure X8) also conveys runoff to the south across Narellan Road. This structure controls a catchment area of 11.7 ha that is predominantly rural in nature. The majority of this catchment is located to the north of the Upper Canal, which drains under the canal approximately 25 m north of the road corridor. Cross drainage structure X8 also controls runoff from a 170 m long section of the eastbound carriageway of Narellan Road, further details of which are provided in the following section.

Cross drainage structure X8 discharges into water quality control measures which are located on the southern side of the road corridor before runoff enters Gilinganadum Dam a short distance further downstream. These measures comprise a two-stage gross pollutant trap (GPT), incorporating a low-level 600 mm diameter Pratten-type trap and high-level 300 mm high trash rack, and linear wetland constructed in series (refer to **Plate 13**). **Appendix A** contains a number of design drawings showing details of the GPT and wetland.

2.4.2 Pavement Drainage

Within catchment C10, runoff generated on the superelevated westbound carriageway of Narellan Road is controlled by a 450 mm diameter piped drainage line located under the median. This drainage line discharges to the southern side of the road corridor at **DRC 5650** to grassed overland flow path that runs generally south, ultimately feeding into Tributary 2 of Bow Bowing Creek.

Catchment C12, approximately 2.1 ha in area and located on the Hume Highway southbound entry/exit loop ramps is controlled by a 375 mm diameter piped drainage line. This piped drainage line discharges on the southern side of the loop ramp (refer location F12) into an overland flow path which ultimately feeds into Tributary 2 of Bow Bowing Creek.

Bypass flows from the pavement drainage system within Catchment C12 will follow the prevailing grade of the exit loop ramp and discharge to the existing pit and pipe system draining the Hume Highway southbound carriageway.

Catchment C11, which lies along the northern side of Narellan Road at the Hume Highway interchange is drained by a combined cross and pavement drainage system that routes runoff to the east across the highway corridor. This system discharges into Tributary 1 of Bow Bowing Creek via a 1200 mm RCP located under the Hume Highway southbound exit ramp (refer location F13).

To the north-east of Catchment C11, a number of catchments that lie along the western side of the Hume Highway are drained to the east under the highway via existing piped drainage systems. These piped drainage systems also drain lengths of both highway carriageways before discharging into Tributary 1 of Bow Bowing Creek (refer locations F14 and F15) and a tributary arm of Biriwiri Creek (refer locations F16 and F16a).

Catchment C13, which lies along the southern side of Narellan Road at the Hume Highway interchange, is also drained by a combined cross and pavement drainage system that routes runoff to the east across the highway corridor. This system discharges into Tributary 2 of Bow Bowing Creek via a 750 mm RCP located under the Hume Highway southbound entry ramp (refer location F11).

Runoff generated on the eastbound carriageway between about **DRC 4360** and **DRC 4610** is controlled by a 375 mm diameter piped drainage system, which connects into cross drainage structure X7. Bypass flows will follow the prevailing grade of the pavement to the west.

Runoff generated on the eastbound carriageway between about **DRC 4200** and **DRC 4360** is collected by a 375 mm RCP discharging to the northern side of Narellan Road and the inlet of cross drainage structure X8. Bypass flows will follow the prevailing grade of the northern kerbline to the west.

Runoff generated on the westbound carriageway between about **DRC 4150** and **DRC 4610** is controlled by a single SA2 type pit connecting into a 375 mm RCP, which drains to the GPT on the southern side of the road corridor adjacent to Gilinganadum Dam. Bypass flows will follow the prevailing grade of the southern kerbline to the west.

2.5 Gilinganadum Dam to Hartley Road

Existing road drainage systems along this length of Narellan Road are shown on **Figure 2.4**.

2.5.1 Cross Drainage

There are four existing cross drainage structures along the road corridor between Gilinganadum Dam and Hartley Road.

Narellan Road crosses the main arm of Narellan Creek at **DRC 3530**. The creek runs generally to the north and is conveyed under the existing six lane carriageway in 3 off 1700 mm RCP's (herein referred to as cross drainage structure X9). The structure controls a catchment area of 2.1 km^2. This catchment is rural in nature, with a large portion comprising the Botanic Garden. Downstream (north) of Narellan Road, the main arm of Narellan Creek continues as a grassed floodway through residential areas of Currans Hill (refer **Plate 14**).

Flooding conditions along the main arm of Narellan Creek were investigated as part of the Upper Nepean Tributary Flood Study (LMCE, 1999). Further details of the study and its application to this present investigation are provided in **Chapter 3** of this report.

Further to the west between **DRC 2900** and **DRC 3350**, runoff from catchments along the southern side of Narellan Road is controlled by cross drainage structures X10, X11 and X12. All three structures discharge into CC's piped drainage system downstream (north) of Narellan Road, which ultimately drains into the main arm of Narellan Creek.

Cross drainage structure X10 located at **DRC 3350** comprises 2 off 1200 mm RCP's, and controls a predominantly residential catchment area of around 45 ha. The catchment also includes a 580 m long section of the westbound carriageway of Narellan Road.

Cross drainage structure X11 located at **DRC 3040** comprises a single 1050 mm RCP, and controls a predominantly residential catchment area of around 6.7 ha.

Cross drainage structure X12 located at **DRC 2900** comprises a single 750 mm RCP, and controls a predominantly residential catchment area of around 3.6 ha.

Cross drainage structures X10, X11 and X12 also receive runoff from the road corridor via separate pavement drainage lines, further details of which are provided in the following section.

Flows surcharging from cross drainage structures X11 and X12, as well as from X9 on the main arm of Narellan Creek, will flow towards the sag in the road corridor near **DRC 3350**, adjacent to cross drainage structure X10. Runoff will then pond in the road corridor behind a large acoustic earth embankment and fence that runs along the northern side of Narellan Road until sufficient capacity is available within the piped drainage system that runs downstream (north) from cross drainage structure X10. The hydraulic control along the top of the embankment (i.e. the minimum crest elevation) is around RL 99.0 m AHD, located between **DRC 3350** and **DRC 3400**. Ponding to this level would flood both carriageways of Narellan Road. Flows overtopping the embankment would flow north through residential properties prior to rejoining the main arm of Narellan Creek north of Outram Place.

2.5.2 Pavement Drainage

Within catchment C15, runoff generated on both carriageways of Narellan Road is controlled by a series of pavement drainage lines located under both kerblines and the central median. These drainage lines connect to twin 450 mm RCP's crossing under Mount Annan Drive immediately south of Narellan Road, which discharge to a roadside channel that conveys runoff to the inlet of cross drainage structure X9 at **DRC 3550**. Runoff generated within catchment C16 is also conveyed to the inlet of cross drainage structure X9 via a separate 375 mm diameter pavement drainage line.

Runoff generated on a short length of road corridor immediately west of Mount Annan Drive is controlled by a series of SA2 type pits and 375 mm diameter piped drainage that are directly connected into cross drainage structure X9.

A number of modifications were made to pavement drainage arrangements along the 700 m long section of Narellan Road between about **DRC 2800** and **DRC 3500** as part of maintenance works undertaken by RMS in mid-2012. At cross drainage structure X10, a new piped drainage line and SF type pits have been constructed under the central median and connected into the cross drainage, with an additional lane and F-type barriers replacing the previous depressed median. Similar works involving the construction of a new piped drainage line and SF type pits have been undertaken in the central median further west at cross drainage structure X12.

Between the crest in the road corridor near **DRC 2900** and the Hartley Road / Waterworth Drive intersection, runoff generated on Narellan Road is controlled by separate pavement drainage systems located under the northern and southern kerblines.

To the south of Narellan Road (refer catchment C18), the pavement drainage system crosses east to west under Waterworth Drive as a 600 mm RCP before discharging to a roadside channel that feeds in to Tributary 5 of Narellan Creek.

To the north of Narellan Road, the pavement drainage system crosses east to west under Hartley Road as a 600 mm RCP and continues along the northern side of the road corridor for around 350 m before discharging directly to Tributary 5 on the downstream (northern) side of the road.

2.6 Hartley Road to Exchange Parade

Existing road drainage systems along this length of Narellan Road are shown on **Figure 2.5**.

2.6.1 Cross Drainage

Narellan Road crosses Tributary 5 of Narellan Creek at **DRC 2050**. The creek runs generally to the north and is conveyed under the existing six lane carriageway, as well as the adjacent Smeaton Grange Road, via a three cell reinforced concrete box culvert (RCBC) system with each cell measuring 2140 mm wide by 2140 mm high (herein referred to as cross drainage structure X13). The structure controls a 4.1 km^2 catchment that is predominantly residential in nature.

Flooding conditions along Tributary 5 of Narellan Creek were also assessed by LMCE (1999), with further details of the study and its application to this present investigation provided in **Chapter 3** of this report.

Downstream of cross drainage structure X13, Tributary 5 continues as a well-vegetated creekline (refer **Plate 15**) before joining the main arm of Narellan Creek on its left (southern) bank around 400 m to the north of the Narellan Road.

2.6.2 Pavement Drainage

Runoff generated on the westbound carriageway of Narellan Road between **DRC 2400** at Waterworth Drive and **DRC 2100** is controlled by two short sections of pavement drainage that discharge to Tributary 5 of Narellan Creek upstream of cross drainage structure X13 (refer catchments C19 and C20).

Further west, the connectivity of the existing pavement drainage system controlling runoff from the westbound carriageway between **DRC 1600** and **DRC 2000** is unknown. However, it is believed that this system discharges to the inlet of cross drainage structure X13.

Runoff generated on the eastbound carriageway between **DRC 1600** and **DRC 2000** is controlled by a series of inlet pits located along the northern side of the road corridor. These pits form part of a pavement drainage system running along Smeaton Grange Road, which drains to Tributary 5 of Narellan Creek downstream of cross drainage structure X13.

2.7 Exchange Parade to Camden Valley Way

Existing road drainage systems along this length of Narellan Road are shown on **Figure 2.6**.

2.7.1 Cross Drainage

Narellan Road crosses Tributary 2 of Narellan Creek at **DRC 770**. The creek runs generally to the north and is conveyed under the existing four lane carriageway, as well as the southern entry ramp to the Camden Bypass, via a three cell RCBC with each cell measuring 2100 mm wide by 2400 mm high (herein referred to as cross drainage structure X14). The structure controls a 2.4 km^2 catchment that is predominantly residential in nature.

Flooding conditions along Tributary 2 of Narellan Creek were also assessed by LMCE (1999), with further details of the study and its application to this present investigation provided in **Chapter 3** of this report.

A short distance to the west at **DRC 730** a pipe of unknown diameter crosses the road corridor (herein referred to as cross drainage structure X15). Whilst survey of the pit on the upstream (southern) side of Narellan Road suggests a pipe size of 600 mm diameter, this was unable to be confirmed at the pipe outlet due to the presence of extensive blackberry vegetation. The connectivity of existing pavement drainage lines along Narellan Road to cross drainage structure X15 is also currently unknown. The cross drainage controls a catchment area of 17.2 ha along the southern side of the road corridor (refer catchment C22). Whilst the catchment is predominantly residential in nature, it also includes part of the Camden Bypass road corridor and a 450 m long section of Narellan Road.

Downstream of cross drainage structures X14 and X15, Tributary 2 continues as a well-vegetated creekline (refer **Plate 16**) which ultimately joins the main arm of Narellan Creek downstream (north) of Camden Valley Way.

To the south of Narellan Road, two pipes comprising cross drainage structure X16 (1 off 600 mm RCP and 1 off 750 mm RCP) drain under Camden Valley Way from east to west. The pipes discharge into a vegetated channel (refer **Plate 17**), and control runoff from a 3.8 ha catchment that includes the length of Narellan Road between Camden Valley Way and **DRC 300**, as well as residential areas along the southern side of the road corridor (refer catchment C23).

2.7.2 Pavement Drainage

Runoff generated on the westbound carriageway between **DRC 750** and **DRC 1600** (refer catchment C21) is controlled by a pavement drainage system that discharges immediately upstream of the inlet to cross drainage structure X14.

The section of eastbound carriageway between **DRC 1000** and **DRC 1600** drains to a series of grassed swales located along the northern side of the road corridor. At Exchange Parade, runoff enters a piped drainage system that conveys flows to the north, ultimately discharging to Tributary 2 of Narellan Creek downstream (north) of Narellan Road.

Runoff generated on the eastbound carriageway between **DRC 750** and **DRC 1000** drains to a grassed swale that discharges to Tributary 2 of Narellan Creek immediately downstream (north) of cross drainage structure X14.

Between **DRC 300** and **DRC 750**, runoff generated on both carriageways of Narellan Road is controlled by a pavement drainage system discharging to cross drainage structure X15, which also outlets to Tributary 2 of Narellan Creek on the northern side of the road corridor.

Between Camden Valley Way and **DRC 300**, runoff generated on both carriageways of Narellan Road is controlled by a pavement drainage system discharging to cross drainage structure X16, which outlets on the western side of Camden Valley Way (refer location F27). Runoff is then conveyed generally north-west via a vegetated channel to the inlet of a three cell 2100 mm wide by 600 mm high RCBC that drains under The Northern Road approximately 250 m west of Camden Valley Way.

To the west of Camden Valley Way, Narellan Road continues as The Northern Road. Runoff generated along the length of The Northern Road between Camden Valley Way and **DRC 0** is controlled by a pavement drainage system discharging adjacent to the outlet of the above-mentioned 3 off 2100 x 600 mm RCBC's.

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3 ASSESSMENT OF PRESENT DAY FLOODING CONDITIONS

3.1 General

The assessment of runoff characteristics from the catchments which contribute flows to the network of piped and channel drainage systems along the road corridor was based on:

- a RAFTS hydrologic model developed as part of the Upper Nepean Tributary Flood Study (LMCE, 1999), for the main arm of Narellan Creek and its major tributaries; and
- a DRAINS hydrologic model developed as part of this present investigation, for the remaining sections of the road corridor.

The DRAINS model was also used to assess the impact the road upgrade works will have on peak flows in several receiving drainage lines downstream of Narellan Road, further details of which are presented in **Section 5**.

The extent of the various catchments that contribute flow to the existing drainage systems which cross Narellan Road are shown on **Figure 2.1**.

The following sections of the report contain a brief description of the adopted catchment modelling approach, present peak flow estimates that were adopted for the purpose of this present investigation, and summarise the results of an assessment of the hydraulic capacity of existing cross drainage along the length of the proposed road upgrade works.

3.2 Catchment Hydrology

3.2.1 Existing RAFTS Model

The hydrologic modelling carried out as part of LMCE, 1999 was focused on the PMF event, with limited information available for floods of lesser magnitude. However, design rainfall intensities for the 100 year ARI event were found to be imbedded in the existing RAFTS model. This enabled peak flows for this event to be determined at each of the three large drainage structures that cross the road corridor on the main arm of Narellan Creek and on its Tributaries 2 and 5 (i.e. for cross drainage structures X9, X13 and X14).

The model structure and linkages upstream of Narellan Road were briefly reviewed and generally found to be suitable for application to this present investigation. **Figure 2.1** shows the location of a number of existing stormwater detention basins within residential development along the southern (upstream) side of Narellan Road where it runs through the Camden LGA, all of which had been previously built into the RAFTS model.

Model parameters were generally retained from the earlier study with the exception of rainfall losses, which were previously excluded (i.e. zero losses were applied) as a result of its focus on extreme rainfall associated with the PMF event. Adopted loss parameters for this present investigation comprised initial losses of 1 mm and 10 mm for paved and grassed areas, and continuing losses of zero and 2.5 mm per hour for the same, respectively.

3.2.2 DRAINS Model Development

DRAINS is a simulation program which converts rainfall patterns to stormwater runoff, and then routes flows through networks of piped drainage systems, culverts, storages and open channels. It develops hydrographs and calculates hydraulic grade lines throughout the drainage network, enabling users to analyse the magnitude of overflows and stored water for established drainage systems. It is applicable to both rural and developed catchments, or any combination of the two, and is therefore well suited to this present investigation.

The DRAINS model included all of the catchments which contribute runoff to existing cross and pavement drainage systems (as separate but lumped sub-catchments) along the length of Narellan Road to be upgraded.

Sub-catchment boundaries were digitised based on available contour information, which comprised (in order of accuracy, from highest to lowest) ground survey along the road corridor, ALS data and 2 m contour data.

Aerial photography and site observations were used to assess the degree of urbanisation which is present in the study catchments.

Rainfall intensities for the 1, 2, 5, 10, 20 and 100 year ARI events were derived using procedures outlined in Australian Rainfall and Runoff (ARR) (IEAust, 1998).

In the absence of gauged streamflow data that could otherwise be used to calibrate the DRAINS model, peak flows arriving at the road corridor were tuned as close as was practicable to peak flow estimates derived using rational method procedures consistent with guidance provided in ARR. Assessment of peak flows generated by catchments that are predominantly undeveloped was carried out using the Probabilistic Rational Method developed for use in eastern NSW, whilst those catchments in which significant development has occurred were assessed using a more traditional deterministic rational method approach.

Adopted DRAINS model parameters comprised initial losses of 1 and 5 mm for paved and grassed areas, respectively. The soil type was set equal to 3, which corresponds with a soil of comparatively high runoff potential. An antecedent moisture condition of 3 was adopted, which reflects rather wet conditions prior to the occurrence of design storm events.

3.2.3 Peak Flow Estimates for Present Day Conditions

Table 3.1 at the end of this chapter gives peak flow rates generated by the RAFTS and DRAINS models (as applicable) for each of the catchments upstream of Narellan Road and Camden Valley Way that contribute runoff to existing cross drainage structures along the route of the proposed road upgrade.

Note that peak flow rates generated by the DRAINS model at key locations in receiving drainage lines under present day conditions are contained in **Table 5.2**.

3.3 Assessment of Existing Cross Drainage Systems

Table 3.1 over also summarises the results of an assessment of the capacity of existing cross drainage structures along the route of the proposed road upgrade, in terms of the ARI at which surcharging of the adjacent trafficable lane will occur.

For cross drainage structures X9, X13 and X14 the assessed capacity was determined based on hydraulic analyses undertaken using HEC-RAS hydraulic models developed by LMCE, 1999 for the main arm of Narellan Creek and its Tributaries 2 and 5. Flow rates applied to the HEC-RAS models were adjusted to simulate peak 100 year ARI flows arriving at Narellan Road, with flow rates upstream and downstream of the road corridor prorated based on the previous PMF flow distributions along each watercourse.

The hydrologic standard of Narellan Road at the location of these three major cross drainage structures was found to be in excess of 100 year ARI.

For all other cross drainage locations, the DRAINS model established to represent present day conditions along the road corridor was used for this assessment (refer **Table 3.1** for results of the assessment).

TABLE 3.1
PEAK FLOWS AND ASSESSED CAPACITY OF EXISTING CROSS DRAINAGE STRUCTURES

I.D.	Design Road Chainage	Pipe / Culvert Dimensions (mm)	Peak Flows (m^3/s) (1, 2)					Assessed Capacity (ARI)
			2 year ARI	5 year ARI	10 year ARI	20 year ARI	100 year ARI	
X1	6680	1 off 825 RCP	1.33	1.86	2.17	2.63	3.37	2 – 5 year
X2	6575	1 off 1050 RCP	0.17	0.55	0.87	1.37	3.12	~ 50 year
X3	6400	1 off 750 RCP	0.46	0.73	0.90	1.14	1.60	10 – 20 year
X4	6170	1 off 750 RCP	0.19	0.37	0.47	0.62	0.79	> 100 year
X5	6090	1 off 375 RCP	0.09	0.15	0.17	0.20	0.24	> 100 year
X6	4900	1 off 525 RCP	0.17	0.30	0.38	0.51	0.71	2 – 5 year
X7	4360	1 off 1200 BLP	0.62	1.03	1.26	1.62	2.19	> 100 year
X8	4150	1 off 900 RCP	0.91	1.62	2.02	2.68	3.97	10 – 20 year
X9	3530	3 off 1700 RCP's	Not analysed				19.5	> 100 year
X10	3350	2 off 1200 RCP's	3.47	4.61	5.17	5.78	6.74	50 – 100 year (4)
X11	3040	1 off 1050 RCP	0.92	1.30	1.52	2.02	3.20	50 – 100 year (4)
X12	2900	1 off 750 RCP	0.63	0.88	1.02	1.24	1.58	10 – 20 year (4)
X13	2050	3 off 2140 x 2140 RCBC's	Not analysed				29.1	> 100 year
X14	770	3 off 2100 x 2400 RCBC's	Not analysed				38.5	> 100 year
X15	730	unknown	1.53	2.36	2.85	3.57	4.89	Unable to be determined (3)
X16	100	1 off 600 RCP + 1 off 750 RCP	0.66	0.90	1.05	1.25	1.55	Unable to be determined (3)

(1) Peak flows include bypass flows from adjacent cross drainage systems where applicable. Peak flows quoted to more than one decimal place for ease of comparison where flows are relatively small.

(2) Peak flows for cross drainage structures X9, X13 and X14 based on RAFTS model, whilst peak flows for all other cross drainage based on DRAINS model – refer **Section 3.1**.

(3) Insufficient information was available to assess the hydrologic standard of this existing cross drainage system.

(4) Assessment does not account for tailwater influences from the existing piped drainage system downstream of the road corridor, details of which were not available for this present investigation.

4 PROPOSED ROAD UPGRADE WORKS

4.1 General

The proposed road upgrade works will ultimately provide a six lane divided road along the 6.8 km length of Narellan Road between Camden Valley Way, Narellan and Blaxland Road, Campbelltown. Major elements of the upgrade works, based on the concept road design model provided by RMS in mid-February 2013, will include:

- widening of existing four lane sections of Narellan Road to six lanes;
- widening of existing bridges over the Upper Canal and the Hume Highway;
- widening of the existing Hume Highway southbound exit ramp to Narellan Road (westbound);
- realignment of the existing Hume Highway southbound exit ramp to Narellan Road (eastbound); and
- upgrade of a number of intersections.

Table 4.1 over provides a summary of the proposed road upgrade works.

In general, both the horizontal and vertical alignments of the proposed road upgrade works will closely follow that of the existing road. The one major exception to this occurs in the case of the realigned southbound exit ramp from the Hume Highway to Narellan Road (eastbound), which will be located up to 75 m east of the existing ramp.

4.2 Staging of the Road Upgrade

RMS is planning to progressively undertake the proposed road upgrade works in the following three stages:

- Stage A — Hume Highway (East) to 400 m east of University / TAFE access road
- Stage B — Botanic Gardens Access to Hume Highway interchange and 400 m east of University / TAFE access road to Gilchrist Drive / Blaxland Road
- Stage C — Camden Valley Way to Botanic Gardens Access

It is understood that the extension of the Hume Highway southbound exit ramp by approximately 500 m to the north will be undertaken by RMS as an earlier, separate project to the remainder of the proposed road upgrade works.

TABLE 4.1
KEY ELEMENTS COMPRISING NARELLAN ROAD UPGRADE

Section	Start Chainage	End Chainage	Description
Blaxland Road to TAFE Access Road	DRC 7087	DRC 6000	• Addition of a third lane to the eastbound carriageway between **DRC 6150** and **DRC 6800** as well as subsequent minor earthworks and driveway reconstruction associated with the road widening. • Upgrade of the University / TAFE access road intersection, including provision of a fourth leg at the intersection to provide access into Nos. 168-192 Narellan Road (Maryfields Recovery Centre). • Removal of the concrete median and replacement with dedicated turning lane for westbound traffic turning right onto Blaxland Road. This work also involves widening the eastbound carriageway between Blaxland Road and **DRC 7087**.
TAFE Access Road to Gilinganadum Dam	DRC 6000	DRC 4150	• Removal of the grassed median and reconstruction of lane widening along eastbound carriageway between **DRC 3980** and **DRC 4900**. • Existing bridge over the Upper Canal at **DRC 4250** to be widened towards the median. • Reconstruction of the existing eastbound shoulder for use as a trafficable lane between **DRC 4150** and **DRC 4750**. • Construction of a heavy vehicle inspection bay alongside the westbound carriageway between **DRC 4540** to **DRC 4700**. • Construction of an incident response facility immediately south of Narellan Road circa **DRC 5450**. • Realignment of the existing carriageway on the westbound approach to the Hume Highway Interchange including the addition of a left turn lane to enter the southbound carriageway of the Hume Highway. • Widening of the existing southbound exit loop ramp from the Hume Highway to Narellan Road (westbound) to include an additional lane. This work required works to reshape the existing batter slopes. • Inclusion of an eastbound right turning lane to enter the southbound carriageway of the Hume Highway. • Widening of the existing bridge over the Hume Highway Interchange. • Realignment of both northbound and southbound exit ramps from the Hume Highway to Narellan Road. • Addition of a third lane to both carriageways between **DRC 5425** and **DRC 6000**.
Gilinganadum Dam to Hartley Road	DRC 4150	DRC 2400	• Upgrade of the Hartley Road intersection including the addition of a new left turn lane for eastbound traffic on Narellan Road, as well as providing an acceleration/merging lane for traffic turning left from Waterworth Drive. The works also involve an additional right turn lane for westbound traffic. • Upgrade of the Tramway Drive intersection, including the relocation of the bus bay and of eastbound right turn lane.
Hartley Road to Exchange Parade	DRC 2400	DRC 1000	• Reconstruction of the westbound shoulder between **DRC 1700** and **DRC 2050**. • Construction of an additional westbound lane between **DRC 975** and **DRC 1700**, and reconstruction of the westbound shoulder between **DRC 1450** and **DRC 1700**.
Exchange Parade to Camden Valley Way	DRC 1000	DRC 0	• Reshaping the intersection of Narellan Road and Camden Valley Way to provide an additional right turn lane for westbound traffic and subsequent construction of eastbound lane, and construction of a left turn lane for traffic entering Somerset Avenue.

5 PROPOSED DRAINAGE STRATEGY

5.1 General

A strategy aimed at mitigating the adverse impacts of the road upgrade works on existing development and the drainage lines into which the upgraded pavement drainage system will discharge was developed as part of this present investigation. In developing the strategy, the impact of the road upgrade works on both nuisance and major flooding was taken into account.

Table B1 in **Annexure B** presents the recommended drainage strategy for the sections of Narellan Road that are proposed to be upgraded. **Figures 5.1** to **5.5** show the recommended drainage strategy along the road corridor and should be referred to when reading **Table 5.1** and the following sections of the report.

In general terms, stormwater runoff from the new and widened sections of road pavement will be controlled by new piped pavement drainage systems discharging to existing drainages lines located downstream of the road corridor. RMS advised that where runoff currently 'sheets off' the existing pavement (i.e. is not controlled by existing kerb/gutter or piped drainage) it is desirable to retain this arrangement provided any adverse impacts can be avoided or otherwise mitigated.

To assist in future development of the detailed design of the road upgrade, a concept layout for upgraded cross and pavement drainage systems was also prepared as part of this present investigation (refer **Section 5.2**). **Section 5.3** outlines key design considerations that were taken into account in assessing drainage upgrade requirements along the length of Narellan Road, and identifies a number of issues that will require further consideration as part of future detail design of the road upgrade.

This chapter also deals with the findings of the investigation into the impact the proposed road works will have on drainage patterns along the length of the road upgrade (refer **Section 5.4**). **Section 5.5** provides a summary of residual drainage-related property impacts should the recommended drainage strategy be implemented by RMS.

5.2 Concept Drainage System Layout

Figures 5.1 to **5.5** show the indicative location of inlet pits and piped drainage lines that will be required to capture and convey runoff from the upgraded sections of pavement along Narellan Road to receiving drainage lines. **Table 5.1** over provides a summary of the elements comprising the concept drainage system.

Note also that at each outlet to upgraded cross and pavement drainage systems it is recommended that appropriate energy dissipation and scour protection measures are incorporated.

It is recommended that RMS undertake further design development to confirm the size of pipes and number of pits required to control runoff from the upgraded sections of road, as those shown on **Figures 5.1** to **5.5** are indicative only. Potential constraints imposed on piped drainage lines as a result of elevated tailwater conditions will also need to be considered, in particular where the pavement drainage system connects directly into existing cross drainage structures. The sizing of catch/table drains shown on **Figures 5.1** to **5.5** will also need to be undertaken during detail design of the road upgrade works.

TABLE 5.1
SUMMARY OF ELEMENTS COMPRISING
CONCEPT PAVEMENT DRAINAGE SYSTEM [1]

Drainage Element	Diameter (mm) / Pit Type [2]	Total Pipe Length (m) / No. of Pits/Headwalls
Reinforced Concrete Pipe	375	3,673
	450	762
	525	585
	600	203
	675	29
	750	2
	1200	10
Pit / Headwall	SA2	94
	SF	14
	SO	29
	MGSG	4
	Junction	2
	Headwall	2
	Special	1
	Inline Pollution Control Device	1

(1) **Figures 5.1** to **5.5** show the recommended pavement drainage strategy for the upgraded length of Narellan Road.

(2) Refer RMS standard drawings for pit/headwall details.

5.3 Design Considerations

5.3.1 General

The following sections provide a summary of key design parameters and assumptions made for the purpose of this present investigation. A number of recommendations are also provided to assist in future design development for the road upgrade.

5.3.2 Design Development

Assessment of drainage requirements was undertaken based on RMS' concept road design model current in mid-February 2013. It is understood that further design development has since occurred, including incorporation of the following:

- a new shared path along the southern side of the road corridor;
- a new incident response facility immediately south of Narellan Road circa **DRC 5450**; and
- changes to proposed intersection treatments at Kenny Hill Road (circa **DRC 4400**) and the TAFE Access Road (circa **DRC 6000**).

Whilst these refinements are unlikely to have a significant impact on existing flooding patterns or flow conditions in receiving watercourses due to their relatively minor nature, further investigation will be required by RMS as part of detail design to assess their impact on drainage requirements for the road upgrade works, and to develop strategies to mitigate any adverse drainage and flood-related impacts that are identified.

5.3.3 Hydrologic Standard for the Road Upgrade

The adopted hydrologic standard for the concept pavement drainage system was an ARI of 10 years under present day climatic conditions, as nominated by RMS. A maximum gutter flow width of 1.5 m was generally adopted for pit spacing purposes, unless a smaller width of flow was warranted to avoid flows encroaching on trafficable lanes.

Upgrade of existing cross drainage systems was generally not considered as part of the concept drainage strategy, as the substantial extent of works that would typically be required to install larger capacity pipes or culverts across the road corridor is not consistent with the relatively minor surface works proposed as part of the road upgrade project. However, measures have been recommended to improve the hydrologic standard of Narellan Road where relatively frequent surcharging of the westbound carriageway currently occurs near cross drainage structure X1 at **DRC 6680**, as works can be implemented upstream of the road corridor to avoid the need for opening up sections of existing road pavement (refer **Figure 5.1** and **Table B1** in **Annexure B** for further details). These measures would improve the hydrologic standard of Narellan Road to a minimum of 10 year ARI, which is consistent with that of the proposed pavement drainage system. _[Note that the hydrologic standard of Narellan Road is typically greater than 10 year ARI, and exceeds 100 year ARI in several locations.]_

5.3.4 Water Quality Control Measures

Opportunities for the treatment of stormwater runoff captured by new and upgraded pavement drainage systems along the length of the road upgrade works are limited by both space constraints within the existing road corridor and by the configuration of existing road drainage systems. Furthermore, the proposed road upgrade, which generally involves minor widening of existing road pavement, represents only a small increase in the overall imperviousness of the road corridor.

The approach adopted for assessment of water quality control requirements was to identify those receiving drainage lines with a relatively high sensitivity to potential water quality issues, and to then identify what additional measures (if any) would be required to ensure that the road upgrade works would not compromise the existing use or environmental value of those drainage lines.

Review of the environmental sensitivity of receiving drainage lines along the length of the proposed road upgrade identified two water bodies with relatively high sensitivity. These water bodies, as well as the measures incorporated into the proposed drainage strategy to mitigate potential water quality issues associated with the discharge of road runoff, are as follows (refer **Figures 5.1** and **5.2**, and **Table B1** in **Annexure B** for further details):

- Existing dam within Nos. 168 – 192 Narellan Road circa **DRC 6100**
  - Drainage channel downstream of new piped outlet to be vegetated to provide additional water quality improvement prior to discharge to existing dam.
- Gilanganadum Dam within the Botanic Garden circa **DRC 4150**
  - Inline pollution control device (e.g. Humes HumeCeptor unit) targeting hydrocarbons and sediments to control runoff from proposed heavy vehicle inspection bay on westbound carriageway circa **DRC 4530**; and
  - All runoff from the road corridor discharging to Gilanganadum Dam to be controlled by existing GPT and linear wetland on southern side of Narellan Road circa **DRC 4150**.

Note that the Upper Canal, which crosses Narellan Road at **DRC 4250**, was also identified as a watercourse with relatively high sensitivity. The canal does not currently receive runoff from the road corridor. This will be maintained as part of the road upgrade, with runoff from the upgraded road corridor to be piped across the canal via a new piped crossing strapped to the underside of the new shared path bridge to the south of the westbound carriageway.

5.3.5 Impact of Future Development Upslope of the Road Corridor

For the catchments which lie upstream of Narellan Road and contribute runoff to the various cross drainage structures that cross the road corridor, it was assumed that measures will be incorporated into future development which will control the rate of flow discharging to the road corridor to no larger than present day conditions.

5.3.6 Culvert Blockage

The proposed road upgrade works are not considered to increase the risk of blockage of existing cross drainage structures. Note also that no allowance for the partial blockage of the inlet of existing cross drainage structures was made in the assessment of the hydrologic standard of the road corridor at these structure locations (refer **Section 3.3**).

5.3.7 Utilities

It should be noted that the location of underground utilities within the road corridor have been determined by desktop review only, and only in a number of selected locations. Detailed investigations will need to be carried out during the preparation of the detail design for the road upgrade works in order to ensure there is no conflict between proposed drainage structures and either existing or proposed utilities.

5.3.8 Potential for Aquaplaning

The potential for aquaplaning on widened sections of carriageway will need to be assessed as part of detail design of the road upgrade works, in conjunction with the development of vertical alignments for the new sections of pavement.

Based on RMS' design criteria, the design of the road and pavement drainage system will need to ensure that depths of sheet flow across the road surface do not exceed 5 mm during a storm with an intensity of 50 mm/hr.

5.4 Impact of Proposed Road Upgrade on Drainage Patterns

5.4.1 General

The DRAINS model which was used to derive peak flows under present day conditions was adjusted to reflect the changes which will occur to the surface of the road corridor as a result of the road upgrade. Links within the DRAINS model were also altered to reflect changes that will occur in drainage patterns as a result of the installation of new and upgraded cross and pavement drainage systems along the length of the road upgrade.

Table 5.2 at the end of this chapter shows the impact the road upgrade will have on peak flows in selected receiving drainage lines for storms with ARI's ranging between 1 and 100 years. Note that the locations referred to in **Table 5.2** are shown on **Figures 2.2** to **2.6** and **Figures 5.1** to **5.5**.

Table 5.3, also located at the end of this chapter, shows the impact the road upgrade will have on peak flows arriving at the inlet of the cross drainage structures along its length. Note that the structure identifiers referred to in **Table 5.3** are shown on **Figures 2.2** to **2.6** and **Figures 5.1** to **5.5**.

The following sections provide a summary of drainage-related impacts along the length of proposed road upgrade works.

5.4.2 Blaxland Road to TAFE Access Road

Proposed adjustments to existing road drainage systems along the length of Narellan Road between the eastern extent of road upgrade works at **DRC 7087** and the TAFE Access Road near **DRC 5700** are shown on **Figure 5.1**, and summarised in **Table B1** in **Annexure B**.

The first outlet would discharge directly into the grassed drainage line running south-east towards the main arm of Bow Bowing Creek (refer location F1). Peak flows at the outlet would be increased by a maximum of 11 per cent for events up to 100 year ARI as a result of extending the existing pavement drainage system to control runoff from part of the eastbound carriageway of Narellan Road west of Blaxland Road. Note that peak flows entering CCC's piped drainage system to the north of Blaxland Road (refer location F2) would be slightly reduced as a result of these works.

The third outlet would discharge to CCC's piped drainage system that runs to the north along the eastern side of the electrical substation near **DRC 6650** (refer location F3).

Peak flows discharging to the 900 mm RCP downstream of cross drainage structure X1 would be reduced for all events up to and including 100 year ARI, as a result of the proposed construction of an earth bund and feeder line upstream (south) of Narellan Road to divert runoff approaching the inlet of X1 towards cross drainage structure X2. As a consequence, peak flows discharging from the fourth outlet (refer location F4) would be increased, by between 20 and 80 per cent for the 1 and 100 year ARI events, respectively. However, note that further downstream of both outlets along Tributary 1 of Bow Bowing Creek (refer location F3a), the impact of the proposed road upgrade works on peak flows is negligible.

The fifth outlet would discharge into the existing drainage line downstream of cross drainage structure X3 (refer location F5). It is recommended that the new pavement drainage line controlling runoff along the northern kerbline is discharged at a separate piped outlet adjacent to the cross drainage headwall. Peak flows downstream of the new outlet location would not be significantly affected, as runoff generated on the eastbound carriageway between **DRC 6200** and **DRC 6400** will presently sheet off the pavement towards the same drainage line.

The sixth outlet would discharge into the existing drainage line downstream of cross drainage structure X4 (refer location F6). Runoff discharging from the road corridor at this location would include that which currently discharges at location F7, with the existing cross drainage structure X5 to be abandoned.

Peak flows downstream of the outlet at F6 would be increased as a result of the additional length of westbound carriageway controlled by cross drainage structure X4, with increases ranging between 17 and 45 per cent for events up to the 100 year ARI. However, note that a short distance further downstream of the outlet along Tributary 1 of Bow Bowing Creek (refer location F7a) the impact of the proposed road upgrade works on peak flows is negligible.

On the northern side of the road corridor at **DRC 6000**, a new pavement drainage outlet would be required to control runoff from the proposed U-Turn facility opposite the TAFE Access Road. A new vegetated drainage channel approximately 25 m long would be required to drain the new piped outlet into the adjacent dam. An easement approximately 3 m wide would also be required through Nos. 168 – 192 Narellan Road over the length of channel works to be located outside the proposed road acquisition boundary to enable future maintenance of the channel by RMS.

On the southern side of the intersection, runoff from a short section of the westbound carriageway through the intersection will continue to drain to the south along the TAFE Access Road (refer locations F8 and F9). Runoff along the various internal access roads within the grounds of the TAFE College / University of Western Sydney is controlled by an existing piped drainage system.

West of the TAFE Access Road, runoff from both carriageways of Narellan Road will continue to sheet off the pavement onto adjacent grassed roadside areas.

5.4.3 TAFE Access Road to Gilinganadum Dam

Proposed adjustments to existing road drainage systems along the length of Narellan Road between the TAFE Access Road near **DRC 5700** and Gilinganadum Dam at **DRC 4150**, as well as the Hume Highway southbound carriageway and exit ramps, are shown on **Figure 5.2** and summarised in **Table B1** in **Annexure B**.

The first outlet along Narellan Road at **DRC 5650** would discharge to a grassed overland flow path that runs generally south from the road corridor. This flow path ultimately feeds in to Tributary 2 of Bow Bowing Creek with the grounds of the University of Western Sydney. Peak flows leaving the road corridor (refer location F10 on **Figure 5.1**) would be essentially unchanged by the proposed works.

Outlets from the three upgraded piped drainage systems controlling runoff from the various sections of pavement at the Hume Highway interchange would discharge directly to existing drainage lines feeding into Tributaries 1 and 2 of Bow Bowing Creek (refer locations F11, F12 and F13). Impacts of the proposed road upgrade works on peak flows downstream of these outlets are negligible, due to the minor nature of the proposed works.

Widened sections of pavement along the upgraded southbound exit ramp of the Hume Highway (i.e. to the north of Narellan Road) would be drained to three existing outlets (refer locations F15, F16 and F16a). A new pavement drainage line located along the widened eastern kerbline would connect into an existing piped drainage system controlling runoff from the highway corridor, and discharging into a tributary arm of Bow Bowing Creek at location F15. Further north along the highway, widened sections of pavement would drain into a tributary arm of Biriwiri Creek between locations F16 and F16a. Impacts of the proposed road upgrade works on peak flows downstream of these outlets are negligible, due to the minor nature of the proposed works.

Along the northern side of Narellan Road immediately west of the Hume Highway, runoff from the eastbound carriageway would be discharged at two locations near **DRC 4880** and **DRC 5000**. Runoff would then enter the existing piped drainage system crossing under the highway from west to east, which ultimately outlets at location F13.

At cross drainage structure X7, the existing pavement drainage system controlling runoff from a 250 m long section of the eastbound carriageway of Narellan Road would be abandoned in favour of a new pavement drainage system, incorporating a new piped crossing of the Upper Canal, directing runoff to the outlet of cross drainage structure X8. As a result, peak flows downstream of cross drainage structure X7 (refer location F17) would be reduced by the road upgrade works by between 10 and 15 per cent for all events up to 100 year ARI. A short distance further downstream of location F17, peak flows crossing under the Upper Canal would also be reduced, to a slightly lesser extent, as a result of the road upgrade.

Downstream of cross drainage structure X8, combined flows from the cross drainage and new pavement drainage system outlet (refer location F18) would be directed towards Gilanganadum Dam via the existing GPT, which would need to be reconfigured to accommodate the new pavement drainage outlet. Peak flows entering the GPT and downstream linear wetland would be increased by between 9 and 16 per cent for events ranging between 1 and 100 year ARI as a result of the road upgrade works, primarily as a result of the redirection of flows away from the outlet at F17.

Note that the impact of redirecting runoff from the road corridor towards the existing GPT and wetland on the operation of these water quality control devices is considered to be minor. Analyses undertaken as part of this present investigation have assessed that bypass of the low-level Pratten trap will occur once flows exceed about 0.41 m^3/s, and that the peak 1 year ARI flow will be increased from 0.43 m^3/s to 0.49 m^3/s as a result of the road upgrade works (refer location F18). This indicates that a minor reduction in treatment capability will occur, with an increase in the frequency of bypass from around once per year to around once per six months.

However, at a bypass frequency of once per six months the device would still treat over 90 per cent of the average annual volume of runoff discharging from the road corridor, noting also that this treatment capability falls within the generally accepted target range for design of water quality control measures.

5.4.4 Gilinganadum Dam to Hartley Road

Proposed adjustments to existing road drainage systems along the length of Narellan Road between Gilinganadum Dam at **DRC 4150** and Hartley Road at **DRC 2350** are shown on **Figure 5.3**, and summarised in **Table B1** in **Annexure B**. It is recommended that upgraded sections of pavement drainage be discharged at four locations along this section of the road corridor (refer locations F19, F19a, F20 and F21). Note that all four locations are existing piped drainage system outlets.

The first two outlets would discharge directly into the main arm of Narellan Creek (refer locations F19 and F19a). The outlet of the extended pavement drainage system at F19 would discharge immediately upstream (south) of cross drainage structure X9, whilst the new pavement drainage line discharging at F19a would connect into the cross drainage under the widened northern kerbline of Narellan Road, which in turn discharges to Narellan Creek immediately north of Outram Place.

The third outlet would discharge into the existing drainage channel immediately upstream of the inlet to cross drainage structure X10 (refer location F20). Runoff discharging from the cross drainage is conveyed to the main arm of Narellan Creek approximately 250 m to the north via CC's existing piped drainage system.

By inspection of the minor nature of proposed road works draining to these three outlets and the relatively large catchments that generate runoff arriving at the upstream (southern) side of the road corridor in this area, the impact of the proposed road upgrade on peak flows along the receiving drainage lines is considered to be negligible.

The fourth outlet would discharge directly into Tributary 5 of Narellan Creek where it runs along the western side of Waterworth Drive (refer location F21).

Peak flows discharging from the upgraded pavement drainage system at F21 would be increased by between 7 and 10 per cent for all events up to and including 100 year ARI. However, the increase in peak flow in Tributary 5 of Narellan Creek a short distance downstream of the outlet would be negligible because of the much larger flows in the watercourse generated by the catchment upstream (south) of the road corridor.

5.4.5 Hartley Road to Exchange Parade

Proposed adjustments to existing road drainage systems along the length of Narellan Road between Hartley Road at **DRC 2350** and Exchange Parade at **DRC 1000** are shown on **Figure 5.4**, and summarised in **Table B1** in **Annexure B**. It is recommended that upgraded sections of pavement drainage be discharged at three locations (refer locations F22, F23 and F24) along this section of the road corridor. Note that all three locations are existing piped drainage system outlets.

The first two outlets would discharge directly into Tributary 5 of Narellan Creek where it runs along the southern side of the road corridor (refer locations F22 and F23). Peak flows discharging from the upgraded piped drainage systems at these locations would be increased by a maximum of 2 per cent for all events up to and including 100 year ARI.

The third outlet would discharge directly into Tributary 5 of Narellan Creek adjacent to the outlet headwall of cross drainage structure X13, on the downstream (northern) side of the road corridor (refer location F24).

By inspection of the minor nature of proposed road works draining to these outlets and the relatively large catchment that contributes runoff to Tributary 5 where it crosses Narellan Road, the impact of the proposed road upgrade on peak flows along Tributary 5 is considered to be negligible.

Note that additional survey will be required prior to detailed design of the road upgrade works to confirm the configuration of existing road drainage systems between **DRC 1600** and **DRC 2050**, and their suitability to control runoff from the widened westbound carriageway that is proposed along this length of Narellan Road.

5.4.6 Exchange Parade to Camden Valley Way

Proposed adjustments to existing road drainage systems along the length of Narellan Road between Exchange Parade at **DRC 1000** and the western extent of the road upgrade at **DRC 0** are shown on **Figure 5.5**, and summarised in **Table B1** in **Annexure B**. It is recommended that upgraded sections of pavement drainage be discharged at three locations (refer locations F25, F26 and F27) along this section of the road corridor. Note that all three locations are existing piped drainage system outlets.

The first two outlets would discharge directly into Tributary 2 of Narellan Creek (refer locations F25 and F26). The outlet at F25 would discharge immediately upstream (south) of cross drainage structure X14, whilst the outlet at F26 would discharge to Tributary 2 adjacent to the outlet headwall of the cross drainage.

Peak flows discharging from the upgraded pipe drainage system at F25 would be increased by a maximum of 6 per cent for all events up to and including 100 year ARI. However, by inspection of the minor nature of proposed road works draining to Tributary 2 of Narellan Creek and the relatively large catchment that contributes runoff to this watercourse where it crosses Narellan Road, the impact of the proposed road upgrade on peak flows along Tributary 2 is considered to be negligible.

Additional survey will be required prior to detailed design of the road upgrade works to confirm the configuration of existing road drainage systems and connection to CC's piped drainage system that runs along the southern side of Narellan Road. Further hydraulic analyses will also be required to confirm that CC's piped drainage system has sufficient capacity to accept the increased flows that will result from the minor pavement widening that is proposed between **DRC 1000** and **DRC 1600**.

The third outlet would discharge to the vegetated channel extending north-west from Camden Valley Way (refer location F27). The proposed road upgrade works in the vicinity of the Camden Valley Way intersection are also of a relatively minor nature, which is reflected in the DRAINS model results under post-road upgrade conditions. Peak flows conveyed in the existing piped drainage system crossing Camden Valley Way and discharging to the channel will be increased by a maximum of 1 per cent for events up to and including 100 year ARI.

Note that should RMS wish to determine the current hydrologic standard of cross drainage structures X15 and X16 then additional survey would also be required to confirm the configuration of these piped crossings, in order to support the necessary hydraulic analyses.

5.5 Summary of Drainage-Related Property Impacts

Existing drainage patterns along the road corridor will generally be maintained as part of the road upgrade. The impact of the proposed road upgrade works on peak flows in receiving drainage lines will be minor, and will not contribute to an increased risk of flooding in adjacent development, nor to an increased risk of scour along these drainage lines.
Minor redistributions of flow will occur downstream of the road corridor in the following two locations:

- Peak flows downstream of cross drainage structure X2 at **DRC 6575** will be increased, whilst flows downstream of cross drainage structure X1 at **DRC 6680** will be reduced (refer locations F4 and F3 on **Figure 5.1**, respectively).
- Peak flows downstream of cross drainage structure X8 at **DRC 4150** will be increased, whilst flows downstream of cross drainage structure X7 at **DRC 4360** will be reduced (refer locations F18 and F17 on **Figure 5.2**, respectively).

However, in both locations the proposed redistribution of flow will not adversely impact existing development and will not reduce the yield of any existing water storages.

Channel works will be required outside the existing road corridor in one location only (Nos. 168 – 192 Narellan Road – refer **Figure 5.1**), in order to convey flows from a new piped drainage system controlling runoff from the proposed U-Turn facility opposite the TAFE Access Road into the adjacent dam. An easement (approx. 3 m wide x 25 m long) will be required through Nos. 168 – 192 Narellan Road over the length of channel works to be located outside the proposed road acquisition boundary.

Upstream of the road corridor, flood levels will not be increased as a result of the road upgrade works. This is a function of the minor nature of the proposed works that will not change the current vertical alignment of the road (i.e. will not change the hydraulic control formed by the existing road profile).

TABLE 5.2
IMPACT OF ROAD UPGRADE ON PEAK FLOWS IN RECEIVING DRAINAGE LINES [(1)]

Location Identifier [(2)]	1 year ARI				2 year ARI				5 year ARI				20 year ARI				100 year ARI			
	Present Day	Post Upgrade	Difference[(3)]		Present Day	Post Upgrade	Difference[(3)]		Present Day	Post Upgrade	Difference[(3)]		Present Day	Post Upgrade	Difference[(3)]		Present Day	Post Upgrade	Difference[(3)]	
	(m^3/s)	(m^3/s)	(m^3/s)	(%)	(m^3/s)	(m^3/s)	(m^3/s)	(%)	(m^3/s)	(m^3/s)	(m^3/s)	(%)	(m^3/s)	(m^3/s)	(m^3/s)	(%)	(m^3/s)	(m^3/s)	(m^3/s)	(%)
F1	0.17	0.19	0.02	11%	0.24	0.27	0.03	10%	0.34	0.37	0.03	10%	0.47	0.51	0.04	9%	0.61	0.66	0.05	8%
F2	0.13	0.11	-0.01	-10%	0.19	0.17	-0.02	-9%	0.28	0.26	-0.03	-9%	0.41	0.38	-0.04	-9%	0.52	0.48	-0.04	-8%
F3	0.94	0.87	-0.07	-7%	1.36	1.20	-0.16	-12%	1.57	1.51	-0.07	-4%	1.57	1.72	0.14	9%	1.57	1.73	0.16	10%
F3a	3.42	3.50	0.08	2%	6.78	6.97	0.18	3%	11.54	11.78	0.24	2%	18.37	18.73	0.35	2%	26.35	26.85	0.50	2%
F4	0.18	0.36	0.18	99%	0.29	0.54	0.25	87%	0.89	0.84	-0.05	-6%	2.19	2.03	-0.16	-7%	3.39	3.20	-0.19	-6%
F4a	3.03	3.13	0.10	3%	6.31	6.49	0.18	3%	10.92	11.15	0.23	2%	17.55	17.87	0.33	2%	25.08	25.63	0.54	2%
F5	0.30	0.30	0.01	2%	0.51	0.52	0.01	1%	0.70	0.71	0.01	1%	0.69	0.70	0.01	1%	0.70	0.72	0.02	2%
F6	0.07	0.10	0.03	45%	0.19	0.26	0.07	34%	0.37	0.46	0.09	24%	0.62	0.74	0.11	18%	0.79	0.92	0.13	17%
F7	0.03	0	-0.03	-100%	0.06	0	-0.06	-100%	0.08	0	-0.08	-100%	0.11	0	-0.11	-100%	0.12	0	-0.12	-100%
F7a	2.33	2.41	0.08	3%	4.94	5.04	0.10	2%	8.67	8.77	0.10	1%	14.12	14.39	0.27	2%	20.79	20.85	0.07	0%
F8	0.02	0.02	0.00	0%	0.02	0.02	0.00	0%	0.02	0.02	0.00	0%	0.03	0.03	0.00	0%	0.04	0.04	0.00	0%
F9	0.01	0.01	0.00	0%	0.02	0.02	0.00	0%	0.02	0.02	0.00	0%	0.03	0.03	0.00	0%	0.03	0.03	0.00	0%
F10	0.10	0.11	0.01	8%	0.16	0.17	0.01	5%	0.24	0.25	0.01	3%	0.35	0.36	0.01	2%	0.47	0.47	0.00	1%
F11	0.62	0.63	0.01	1%	1.38	1.39	0.00	0%	2.33	2.34	0.01	0%	3.79	3.77	-0.02	-1%	5.53	5.49	-0.04	-1%
F12	0.21	0.21	0.00	0%	0.30	0.28	-0.02	-7%	0.31	0.29	-0.02	-7%	0.33	0.31	-0.02	-7%	0.34	0.32	-0.02	-7%
F13	0.93	0.98	0.04	5%	1.74	1.82	0.08	5%	2.71	2.93	0.22	8%	4.16	4.44	0.28	7%	5.66	5.94	0.29	5%
F17	0.36	0.31	-0.06	-15%	0.76	0.67	-0.09	-12%	1.26	1.11	-0.15	-12%	1.91	1.71	-0.20	-11%	2.55	2.29	-0.26	-10%
F18	0.43	0.49	0.06	13%	0.96	1.06	0.10	10%	1.71	1.86	0.16	9%	2.72	3.03	0.31	11%	2.97	3.45	0.48	16%
F19	0.30	0.27	-0.03	-8%	0.49	0.44	-0.04	-9%	0.75	0.68	-0.07	-9%	1.21	1.06	-0.15	-12%	2.82	2.50	-0.33	-12%
F21	0.12	0.14	0.01	10%	0.19	0.20	0.02	9%	0.27	0.29	0.02	8%	0.38	0.41	0.03	8%	0.50	0.53	0.04	7%
F22	0.04	0.04	0.00	0%	0.05	0.05	0.00	2%	0.06	0.07	0.00	2%	0.09	0.09	0.00	1%	0.10	0.10	0.00	1%
F23	0.05	0.05	0.00	2%	0.06	0.06	0.00	2%	0.08	0.09	0.00	1%	0.11	0.11	0.00	1%	0.14	0.14	0.00	1%
F25	0.19	0.20	0.01	6%	0.28	0.30	0.02	5%	0.42	0.44	0.02	5%	0.61	0.63	0.02	4%	0.83	0.86	0.03	3%
F27	0.92	0.93	0.01	1%	1.36	1.38	0.01	1%	1.91	1.93	0.02	1%	2.68	2.70	0.02	1%	3.40	3.42	0.02	1%

(1) Peak flows have been quoted to more than one decimal place for comparative purposes only.

(2) Refer **Figures 5.1** to **5.5** for reference to Location Identifier.

(3) Note that a positive value represents an increase in peak flow when compared to present day conditions.

TABLE 5.3
IMPACT OF ROAD UPGRADE ON PEAK FLOWS ARRIVING AT INLET TO CROSS DRAINAGE STRUCTURES [(1) (2)]

I.D.	Design Road Chainage	Pipe / Culvert Dimensions (mm)		2 year ARI				5 year ARI				10 year ARI				20 year ARI				100 year ARI			
				Present Day	Post Upgrade	Difference(3)		Present Day	Post Upgrade	Difference(3)		Present Day	Post Upgrade	Difference(3)		Present Day	Post Upgrade	Difference(3)		Present Day	Post Upgrade	Difference(3)	
		Present Day	Post Upgrade	(m^3/s)	(m^3/s)	(m^3/s)	(%)	(m^3/s)	(m^3/s)	(m^3/s)	(%)	(m^3/s)	(m^3/s)	(m^3/s)	(%)	(m^3/s)	(m^3/s)	(m^3/s)	(%)	(m^3/s)	(m^3/s)	(m^3/s)	(%)
X1	6680	1 off 825 RCP	Earth bund and 525 mm piped feeder line for X2 to be constructed, resulting in partial diversion of flows from X1 to X2	1.33	1.33	0.00	0%	1.86	1.86	0.00	0%	2.18	2.18	0.00	0%	2.63	2.63	0.00	0%	3.36	3.36	0.00	0%
X2	6575	1 off 1050 RCP		0.17	0.41	0.24	137%	0.75	0.68	-0.07	-10%	1.28	1.04	-0.24	-19%	2.00	1.77	-0.23	-11%	3.19	2.93	-0.26	-8%
X3	6400	1 off 750 RCP	No change	0.46	0.46	0.00	0%	0.73	0.73	0.00	0%	0.90	0.90	0.00	0%	1.14	1.14	0.00	0%	1.59	1.59	0.00	0%
X4	6170	1 off 750 RCP	No change [4]	0.19	0.26	0.07	34%	0.37	0.46	0.09	24%	0.48	0.57	0.10	20%	0.62	0.74	0.11	18%	0.79	0.92	0.13	17%
X5	6090	1 off 375 RCP	Existing cross drainage structure to be removed [4]	0.09	0	-0.09	-100%	0.15	0	-0.15	-100%	0.17	0	-0.17	-100%	0.20	0	-0.20	-100%	0.24	0	-0.24	-100%
X6	4900	1 off 525 RCP	No change	0.17	0.17	0.00	0%	0.30	0.30	0.00	0%	0.38	0.38	0.00	0%	0.51	0.51	0.00	0%	0.71	0.71	0.00	0%
X7	4360	1 off 1200 BLP	No change	0.62	0.62	0.00	0%	1.03	1.03	0.00	0%	1.26	1.26	0.00	0%	1.61	1.61	0.00	0%	2.19	2.19	0.00	0%
X8	4150	1 off 900 RCP	No change	0.90	0.90	0.00	0%	1.62	1.62	0.00	0%	2.02	2.02	0.00	0%	2.68	2.68	0.00	0%	3.96	3.96	0.00	0%
X9	3530	3 off 1700 RCP's	No change	Not Analysed																19.5	Refer Note 5		
X10	3350	2 off 1200 RCP's	No change	3.23	3.25	0.02	1%	5.07	5.09	0.02	0%	5.45	5.48	0.03	1%	5.91	5.96	0.04	1%	6.97	6.99	0.02	0%
X11	3040	1 off 1050 RCP	No change	0.92	0.92	0.00	0%	1.30	1.30	0.00	0%	1.53	1.53	0.00	0%	1.90	1.90	0.00	0%	2.75	2.75	0.00	0%
X12	2900	1 off 750 RCP	No change	0.63	0.63	0.00	0%	0.88	0.88	0.00	0%	1.02	1.02	0.00	0%	1.23	1.23	0.00	0%	1.58	1.58	0.00	0%
X13	2050	3 off 2140 x 2140 RCBC's	No change	Not Analysed																29.1	Refer Note 5		
X14	770	3 off 2100 x 2400 RCBC's	No change	Not Analysed																38.5	Refer Note 5		
X15	730	unknown	No change	1.53	1.53	0.00	0%	2.36	2.36	0.00	0%	2.85	2.85	0.00	0%	3.57	3.57	0.00	0%	4.88	4.88	0.00	0%
X16	100	1 off 600 RCP + 1 off 750 RCP	No change	0.66	0.66	0.01	1%	0.90	0.91	0.01	1%	1.05	1.05	0.01	1%	1.25	1.26	0.01	1%	1.55	1.56	0.01	1%

(1) Peak flows have been quoted to more than one decimal place for comparative purposes only.

(2) Peak flows for cross drainage structures X9, X13 and X4 based on RAFTS model, whilst peak flows for all other cross drainage structures based on DRAINS model – refer **Section 3.1**.

(3) Note that a positive value represents an increase in peak flow when compared to present day conditions.

(4) Existing cross drainage structure X5 to be removed, with flows diverted to cross drainage structure X4. Note that increased flows bypassing inlet of cross drainage structure X4 will not encroach into trafficable lanes for storms less than 10 year ARI.

(5) By inspection of the minor nature of proposed road works draining to cross drainage structures X9, X13 and X14, and the relatively large catchments that generate runoff arriving at the inlet of these structures, the impact of the proposed road upgrade on peak flows is considered to be negligible.

6 EROSION AND SEDIMENT CONTROL STRATEGY

6.1 General

A strategy aimed at mitigating the adverse impacts of the construction phase of the road upgrade on water quality in receiving drainage lines and watercourses was developed as part of this present investigation.

Figures 6.1 to **6.5** show the recommended erosion and sediment control strategy along the route of the proposed road upgrade and should be referred to when reading the following sections of the report. The strategy addresses the increase in potential for both erosion and sediment mobilisation within the construction corridor, and transport of this sediment into downstream watercourses via sediment-laden runoff leaving areas disturbed by the road works.

A preliminary assessment was undertaken to determine the average annual volume of sediment which could be "washed off" the road corridor if appropriate measures are not implemented by the Contractor during the construction phase of the project. Based on the findings of this assessment, it was concluded that large scale sediment retention basins do not necessarily need to form part of the *Soil and Water Management Plan* (SWMP) (or similar) for the road upgrade works. Rather, the provision of a series of smaller temporary sediment sumps positioned at key locations along the road corridor would be sufficient to manage runoff from disturbed areas during construction.

It is recommended that the strategy presented in this section of the report be used as the starting point for the preparation of the SWMP that will need to be developed as part of final design and/or construction documentation for the road upgrade works. However, it should be recognised that ultimate requirements for controlling erosion and sediment during construction will be dictated by final design of the road upgrade works, proposed construction methods, staging and site management practices, all of which are yet to be finalised.

The strategy has been developed based on the principles and design guidelines set out in the following documents:

- *Soils and Construction – Managing Urban Stormwater* series (herein referred to as the *"Blue Book"*), comprising:
  - Volume 1 (Landcom, 2004)
  - Volume 2D – Main Roads (DECC, 2008);
- *RMS Erosion and Sedimentation Management Procedure* (RMS, 2008); and
- *RMS QA Specification G38* (RMS, 2011).

6.2 Key Elements of the Strategy

The primary principles for effective erosion and sediment control are firstly to minimise erosion, and then to capture sediment from disturbed areas where erosion cannot be prevented.

Whilst this present investigation deals primarily with the control of sediment, and the structural measures that will be required to capture "on-site" water and bypass "off-site" water through the construction site, a range of erosion control principles will need to be incorporated into the future SWMP including:

- appropriate location and treatment of site access and stockpile sites;
- conservation of existing topsoil for later site rehabilitation;
- minimisation of disturbed areas, and stabilisation using batter blanketing, surface mulching or vegetation;
- scour protection along drainage lines through the site;
- separation of clean and dirty water wherever possible, and the diversion of clean water from upslope areas through the construction site;
- site maintenance requirements; and
- progressive site rehabilitation.

6.2.1 Local Erosion and Sediment Control Measures

The *Blue Book* allows for localised erosion and sediment control measures to be used in the absence of large scale sediment retention basins where the average annual soil loss from a disturbed area, as derived by application of the Revised Universal Soil Loss Equation (RUSLE), is less than 150 m^3/annum.[2]

To demonstrate that large scale sediment retention basins do not necessarily need to form part of the SWMP for the road upgrade project, the road corridor was divided into a number of discrete areas (denoted hereon as “local erosion and sediment control areas”, or LESCA’s) and the average annual soil loss from each computed by application of the RUSLE. The extent of each LESCA was derived based on a review of the available contour data and an assessment of the likely location where runoff from the road corridor will discharge to receiving drainage lines during the construction phase of the project.

Figures 6.1 to **6.5** show the extent of the LESCA’s along the route of the road upgrade, as well as the estimated average annual soil loss from each. **Table 6.1** over summarises the parameters which are constant in the RUSLE for the site, whilst **Table C1** in **Annexure C** gives the average annual soil loss derived for each LESCA, as well as the RUSLE parameters which are unique to each.

By inspection of the values given in **Table C1** in **Annexure C** (and also shown on **Figures 6.1** to **6.5**), it can be seen that the estimated average annual soil loss from each LESCA does not exceed the threshold value of 150 m^3. The implementation of effective localised erosion and sediment control measures aimed at minimising the volume of sediment which is transported from disturbed areas will therefore be key to the control of sediment from the road corridor in the absence of any large scale sediment retention basins. Measures would include use of the following practices and smaller scale elements:

- staging of works to minimise the extent of disturbance at any one time;
- temporary stabilisation or revegetation/rehabilitation works to reduce the extent of disturbed surfaces;
- application of temporary surface treatments or blanketing on exposed earth surfaces;
- sediment barriers and sumps, in series where necessary;
- vegetative buffer strips; and

[2] For further details of the RUSLE, refer Appendix A of Landcom, 2004.

- stabilised drainage lines incorporating rock check dams at regular intervals.

Note also that whilst the proposed shared path along the southern side of the road corridor is not accounted for in the above assessment (i.e. the additional area that would need to be disturbed in order to construct the path is not incorporated into each LESCA), the impact of the path footprint would be only minor and would not result in the estimated average annual soil loss from any LESCA exceeding the threshold value of 150 m^3.

TABLE 6.1
CONSTANT PARAMETERS ADOPTED FOR APPLICATION TO THE RUSLE

Parameter	Value	Comment
Rainfall Intensity for 2 year ARI, 6 hour duration design storm	9.6 mm/hr	Based on design rainfall data adopted for the purpose of this present investigation
Rainfall Erosivity Factor (R)	2059	Based on 2 year ARI, 6 hour duration design storm
Soil/sediment Type	C C/D B/C	Blacktown Soil Landscape Luddenham Soil Landscape Theresa Park Soil Landscape
Soil Erodibility Factor (K)	0.038	Taken from Table C21 in Appendix C of Landcom, 2004
Erosion Control Practice Factor (P)	1.3	Representative of compacted and smooth surface conditions on site
Cover Factor (C)	1.0	Representative of bare earth conditions on site.

6.2.2 Temporary Sediment Sumps

Figures 6.1 to **6.5** show the locations where temporary sediment sumps could be built to control runoff from disturbed areas during construction.

The location of the sumps was determined based on a review of the available contour data and an assessment of the likely location where runoff from the road corridor will discharge to receiving drainage lines during the construction phase of the project. Ultimate requirements for temporary sediment sumps along the length of road corridor will be dictated by final design of the road upgrade, proposed construction methods and staging plans, and site management practices.

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7 REFERENCES

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Landcom (2004). "*Managing Urban Stormwater – Soils and Construction*". Volume 1, 4^{th} Edition.

LMCE (1999). *"Upper Nepean River Tributary Flood Studies, Volume 2 – Stage 3".* Report prepared for Camden Council by Lyall & Macoun Consulting Engineers.

RMS (2011). *"QA Specification G38"*, Edition 1, Revision 3.

RMS (2008). *"Erosion and Sedimentation Management Procedure"*. RMS Procedure PN143P, Version 2 dated November 2008.

SCS, 1990. *"Soil Landscapes of the Wollongong Port Hacking 1:100,000 Sheet Map"*.

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ANNEXURE A

PLATES SHOWING ELEMENTS OF EXISTING DRAINAGE SYSTEM

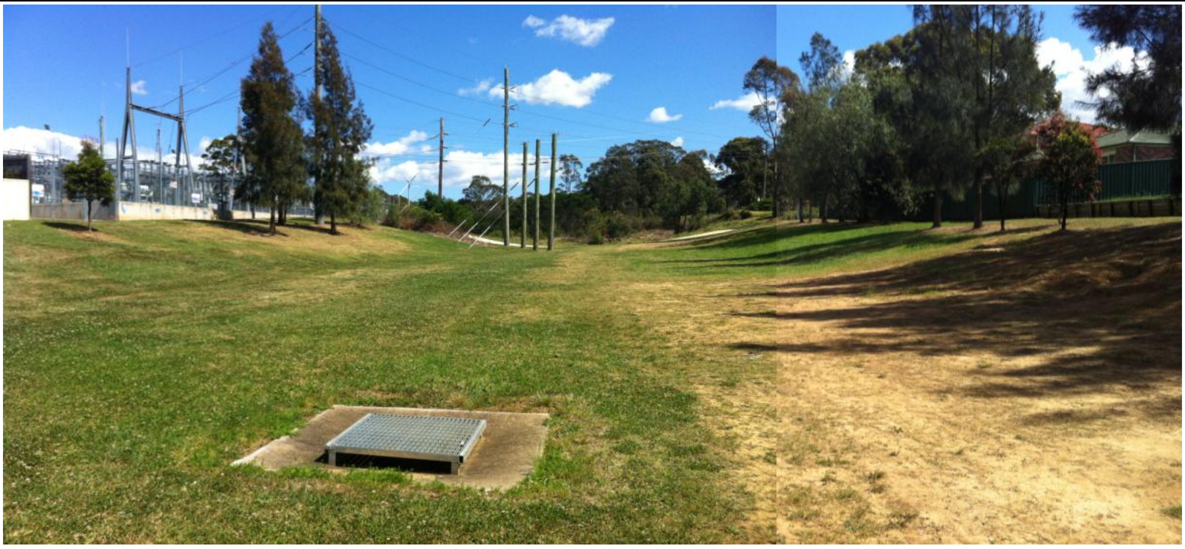


Plate 1 – Looking west (upstream) along Tributary 1 of Bow Bowing Creek where it runs as a grassed floodway through the surrounding residential development of Blair Athol. Inlet pit receiving runoff from Catchment C3 (and cross drainage structure X1) in foreground. Electrical substation located adjacent to Narellan Road in background on left.

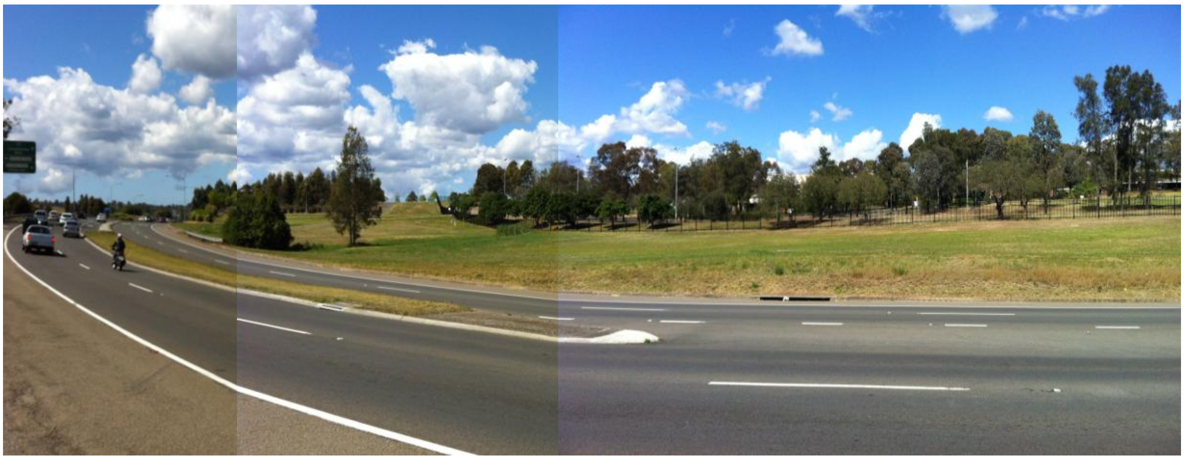


Plate 2 – Looking south at sag in Narellan Road near **DRC 6575**. Inlet pit along westbound kerbline, which forms part of cross drainage structure X2, in background.

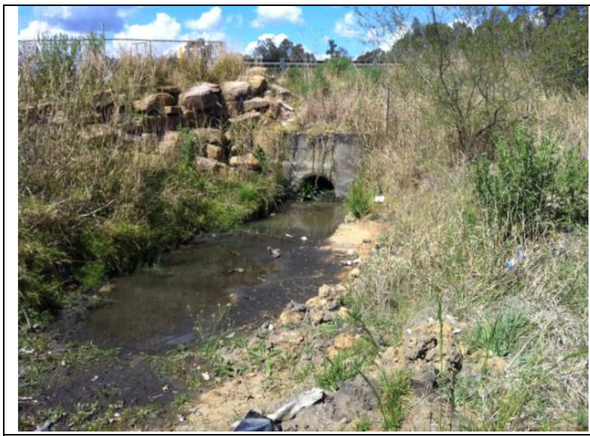


Plate 3 – Looking south at outlet of 1050 mm diameter pipe crossing Narellan Road at **DRC 6575** (cross drainage structure X2).

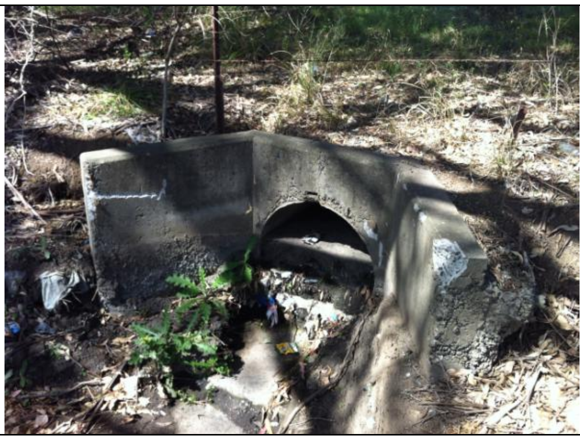


Plate 4 – Looking south at outlet of 750 mm diameter pipe crossing Narellan Road at **DRC 6400** (cross drainage structure X3).

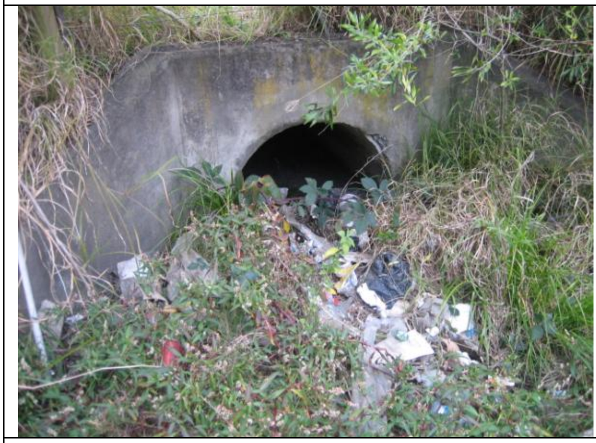


Plate 5 – Looking south at outlet of 750 mm diameter pipe crossing Narellan Road at **DRC 6170** (cross drainage structure X4).

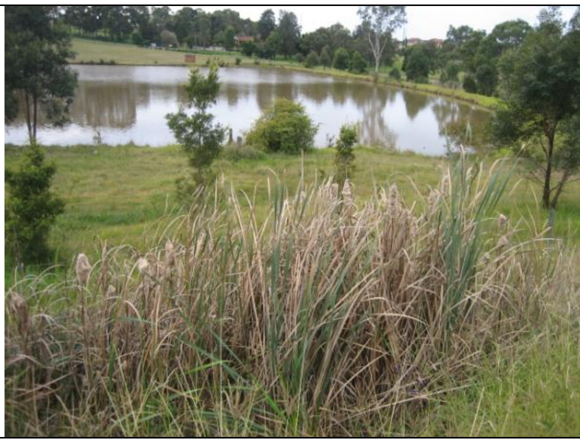


Plate 6 – Looking north from outlet of 375 mm diameter pipe crossing Narellan Road at **DRC 6094** (cross drainage structure X5).

Plate 7 – Looking north at inlet of 525 mm diameter pipe crossing the northbound exit ramp of the Hume Highway (cross drainage structure X6).

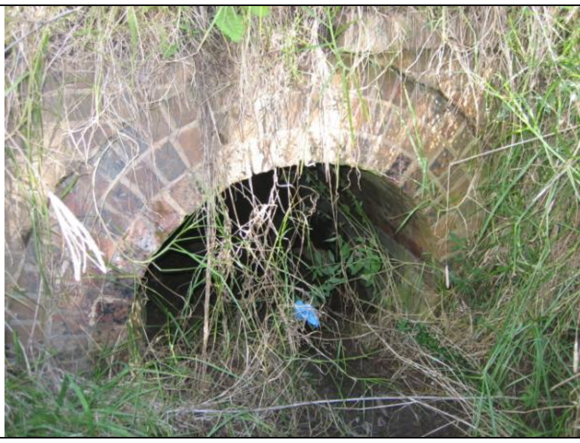


Plate 8 – Looking south at inlet of 1200 mm brick-lined culvert crossing Narellan Road at **DRC 4360** (cross drainage structure X7).

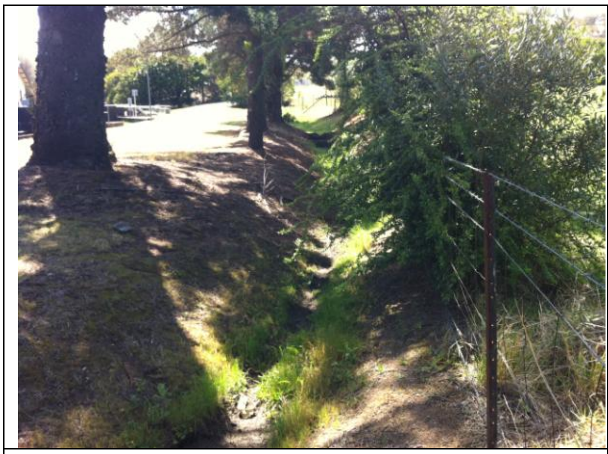


Plate 9 – Looking south-west at catch drain running along eastern side of the Upper Canal.

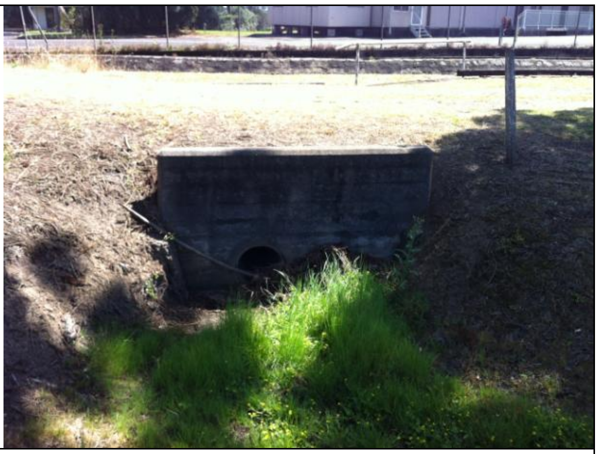


Plate 10 – Looking north-west at inlet of 2 off 375 mm diameter pipes on upstream (eastern) side of the Upper Canal.

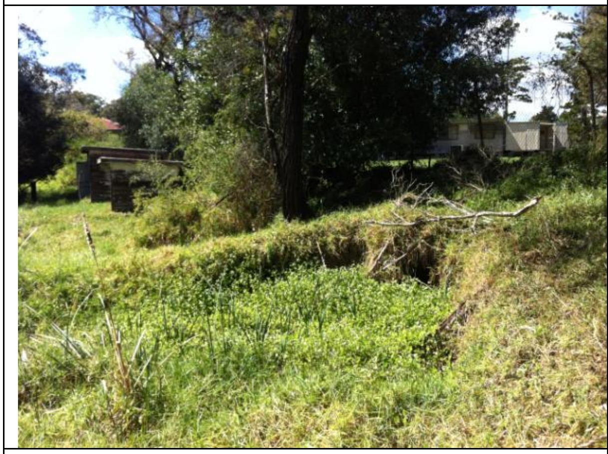


Plate 11 – Looking east at outlet of 1200 mm diameter pipe on western (downstream) side of the Upper Canal.

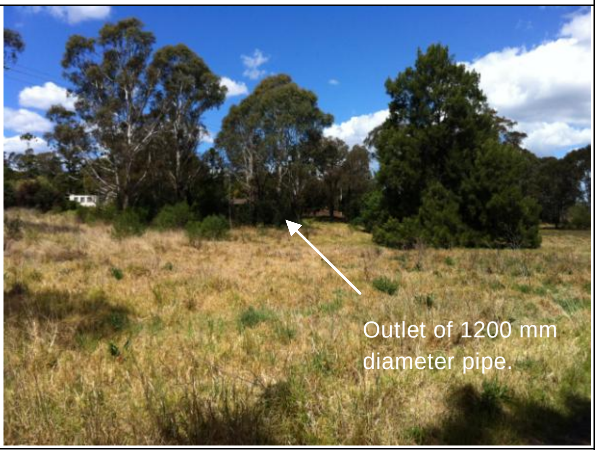


Plate 12 – Looking east towards outlet of 1200 mm diameter pipe on western (downstream) side of the Upper Canal. Vegetated overland flow path downstream of the piped outlet in foreground.

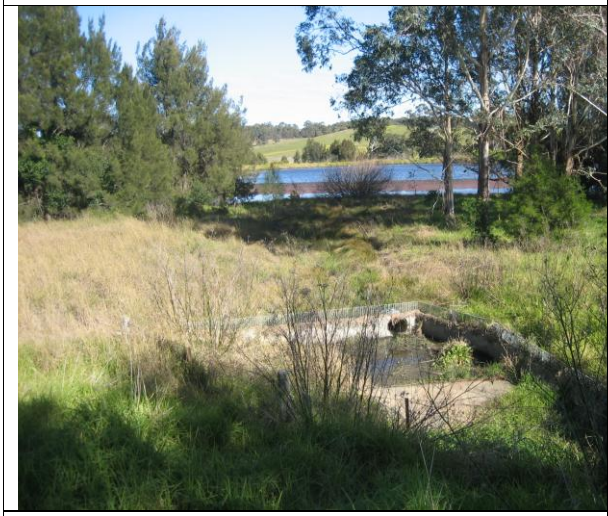


Plate 13 – Looking south from outlet of 900 mm diameter pipe (cross drainage structure X8) and 375 mm diameter pavement drainage line at **DRC 4150**. GPT in foreground and Gilinganadum Dam in background.

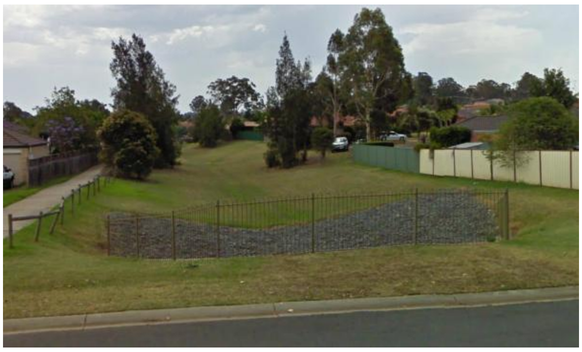
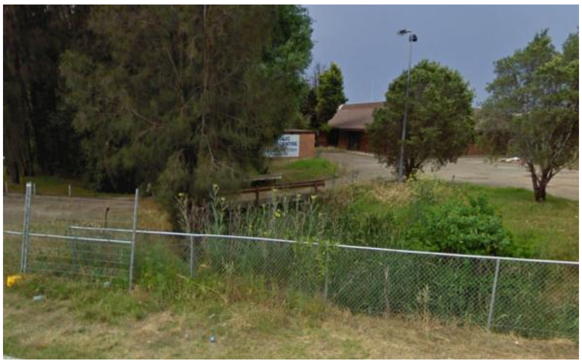
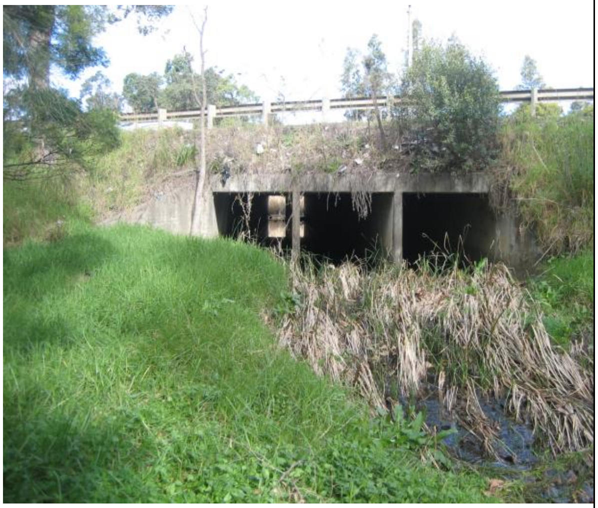


Plate 14 – Looking south along floodway that forms main arm of Narellan Creek at outlet of 3 off 1700 RCP's at **DRC 3530** (cross drainage structure X9).

<table>
<tr><td></td><td></td></tr>
<tr><td>Plate 15 – Looking south along Tributary 5 of Narellan Creek from outlet of 3 off 2140 x 2140 mm RCBC's at DRC 2050 (cross drainage structure X13).</td><td>Plate 16 – Looking south at outlet of 3 off 2100 x 2400 mm RCBC's at DRC 770 (cross drainage structure X14). Note cross drainage structure X15 also drains to this watercourse.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Plate 17 – Looking north along vegetated channel from outlet of cross drainage structure X16 at DRC 100.</td><td></td></tr>
</table>

ANNEXURE B

SUMMARY OF WORKS COMPRISING RECOMMENDED DRAINAGE STRATEGY

TABLE B1
RECOMMENDED DRAINAGE STRATEGY

<table>
<tr><th>Section</th><th>Summary of Works Comprising Recommended Drainage Strategy [(1)]</th></tr>
<tr><td>Blaxland Road to TAFE Access Road</td><td>
➢ Figure 5.1 shows the recommended drainage strategy where Narellan Road runs between the eastern extent of the proposed road upgrade at DRC 7087 and the TAFE Access Road near DRC 5700.
<u>Outlet at DRC 7020 (refer location F1)</u>
• Extend existing pavement drainage system across westbound carriageway and along median of eastbound right turn lane between DRC 6800 and DRC 6850.
<u>Outlet at DRC 6700 (refer location F3)</u>
• Construct new earth bund with min. crest elevation RL 77.3 m AHD immediately west of inlet to cross drainage structure X1, to increase the hydraulic capacity of this structure and reduce the frequency of surcharge onto the westbound carriageway.
Construct new 525 mm RCP piped ‘feeder line’ from the inlet of cross drainage structure X1 to cross drainage structure X2. Based on preliminary assessment, MGDG inlet and pipe invert levels of the feeder line to be constructed at RL’s 77.0 m AHD and 75.6 m AHD, respectively.
The new earth bund and feeder line will reduce the frequency of surcharge onto the westbound carriageway from the inlet of cross drainage structure X1 from 2 – 5 year ARI to 10 – 20 year ARI, and maximises use of the spare capacity that is presently available in cross drainage structure X2. [Note that on completion of these works, the hydrologic standard of the westbound carriageway will be in the range 10 – 20 year ARI for the combined cross drainage system comprising structures X1 and X2.]
<u>Outlet at DRC 6570 (refer location F4)</u>
• Construct new pavement drainage line connecting to cross drainage structure X2 to suit widened southern kerbline between DRC 6450 and DRC 6590.
• Extend existing median pavement drainage line controlling runoff from the eastbound carriageway between DRC 6600 and DRC 6630.
• Construct new catch drains along the top of the batter slope along the southern side of the road corridor to prevent runoff from flowing over the existing batter and onto the westbound carriageway.
• Modify existing SA2 type pit along the southern kerbline to accept new 525 mm RCP piped feeder line (refer above).
<u>Outlet at DRC 6400 (refer location F5)</u>
• Extend existing pavement drainage line to suit new southern kerbline between DRC 6200 and DRC 6340.
• Construct new pavement drainage line extending south along TAFE driveway to assist in controlling runoff approaching Narellan Road from the south. Connect to cross drainage structure X3.
• Construct new pavement drainage along northern kerbline between DRC 6210 and DRC 6400, to control runoff from the eastbound carriageway. Discharge at existing outlet headwall of cross drainage structure X3.
<u>Outlet at DRC 6170 (refer location F6)</u>
• Construct new pavement drainage line connecting to cross drainage structure X4 to suit new southern kerbline between DRC 6050 and DRC 6160. Reconstruct existing SA2 type pit to suit kerbline location.
<u>Outlet at DRC 6090 (refer location F7)</u>
• Demolish and remove (or alternatively abandon) existing cross drainage structure X5.
<u>Outlet at DRC 6040 (refer northern side of Narellan Road at proposed U-Turn facility opposite TAFE Access Road)</u>
• Construct new pavement drainage line to control runoff from proposed U-Turn facility, and discharge to existing dam within Nos. 168 – 192 Narellan Road via new vegetated drainage channel. Easement required through Nos. 168 – 192 Narellan Road where channel is located outside proposed road acquisition boundary.
<u>Outlet at DRC 5880 (refer northern side of Narellan Road at existing driveway)</u>
• Demolish and remove minor piped drainage line under existing driveway.
➢ Additional survey will be required prior to commencing detailed design of the road upgrade works to confirm pipe sizes and invert levels along the full length of cross drainage structure X2, to resolve inconsistencies noted in the existing drainage survey.
</td></tr>
</table>

(1) Note that at each outlet of upgraded cross and pavement drainage systems it will be necessary to incorporate appropriate energy dissipation and scour protection measures.

TABLE B1 (Cont'd)
RECOMMENDED DRAINAGE STRATEGY

Section	Summary of Works Comprising Recommended Drainage Strategy [(1)]
TAFE Access Road to Gilinganadam Dam	➢ **Figure 5.2** shows the recommended drainage strategy where Narellan Road runs between the TAFE Access Road near **DRC 5700** and Gilinganadum Dam at **DRC 4150**. Outlet at **DRC 5650** (refer location F10 on **Figure 5.1**) • Retain existing median pavement drainage line controlling runoff from westbound carriageway between **DRC 5350** and **DRC 5650**. Outlet at **DRC 5280** (refer location F13) • Extend existing 375 mm pavement drainage line to suit realigned Hume Highway southbound exit ramp. • Construct new pavement drainage line controlling runoff from eastbound carriageway (**DRC 5200** to **DRC 5650**) and realigned Hume Highway southbound exit ramp, and discharge on downstream (eastern) side of ramp at new combined outlet with extended 1200 mm RCP (refer next dot point). • Extend existing 1200 mm RCP to outlet on downstream (eastern) side of realigned Hume Highway southbound exit ramp. • Construct new pavement drainage line to suit widened northern kerbline between **DRC 4920** and **DRC 5000**. • Upgrade and extend existing pavement drainage line to suit widened northern kerbline between **DRC 4650** and **DRC 4880**. • Extend existing pavement drainage line to suit southern kerbline between **DRC 4700** and **DRC 4850**. Outlet at **DRC 5300** (refer location F12) • Upgrade and extend existing pavement drainage system along outer kerbline of Hume Highway southbound exit loop ramp, extending north to Narellan Road and west along westbound carriageway of Narellan Road to **DRC 5160**. Abandon existing pavement drainage line along westbound carriageway. • Construct new pavement drainage line along inner kerbline of Hume Highway southbound exit loop ramp. • Replace existing 375 mm RCP crossing the Hume Highway southbound entry ramp with new 600 mm RCP. Outlet at **DRC 5150** (refer to location F11) • Abandon existing cross drainage structure X6 and replace with new 525 mm RCP piped drainage line rerouting flows down the western side of the Hume Highway northbound exit ramp, and connect into existing Hume Highway drainage system. • Extend existing pavement drainage lines along both sides of Hume Highway northbound entry loop ramp, and connect to existing piped drainage system. • Construct new catch drains along the southern side of Narellan Road between **DRC 4610** and **DRC 4890** to control flows from upslope area and direct runoff to new piped inlet. Outlet at **DRC 4350** (refer to location F17) • Abandon existing pavement drainage system discharging into cross drainage structure X7. Seal off existing connection into cross drainage structure within median. Outlet at **DRC 4150** (refer to location F18) • Construct new catch drains along the southern side of Narellan Road between **DRC 4450** and **DRC 4610** to control flows from upslope area and direct runoff to new piped inlet. • Construct new pavement drainage system controlling flows along both carriageways of Narellan Road between **DRC 4150** and **DRC 4610**. Key features of the new pavement drainage system comprise the following: - New SO type kerb and pavement drainage line between **DRC 4530** and **DRC 4650** along southern kerbline of new heavy vehicle inspection bay. An inline pollution control device (e.g. Humes HumeCeptor unit) should be installed to target hydrocarbons and sediments that may be generated within the inspection bay. - New MGDG type pits to accept inflows from new catch drains along the southern side of the road corridor. - New pavement drainage line to cross over existing cross drainage structure X7 at **DRC 4350** along the southern kerbline. - New pavement drainage line to cross over Upper Canal (circa **DRC 4250**) via 600 mm diameter piped crossing strapped to underside of new shared path bridge. Pavement drainage line to divert back to southern kerbline west of Upper Canal. - Discharge new pavement drainage system adjacent to outlet from cross drainage structure X8 at **DRC 4150**. • Reconfigure existing gross pollutant trap at outlet of cross drainage structure X8 to accept flows from new 675 mm RCP pavement drainage outlet (and existing 900 mm RCP cross drainage line).

(1) Note that at each outlet of upgraded cross and pavement drainage systems it will be necessary to incorporate appropriate energy dissipation and scour protection measures.

TABLE B1 (Cont'd)
RECOMMENDED DRAINAGE STRATEGY

Section	Summary of Works Comprising Recommended Drainage Strategy [1]
Gilinganadum Dam to Hartley Road	➢ **Figure 5.3** shows the recommended drainage strategy where Narellan Road runs between Gilinganadum Dam at **DRC 4150** and Hartley Road at **DRC 2400**. Outlet at **DRC 3580** (refer location F19) • Extend existing pavement drainage line along northern kerbline between **DRC 3960** and **DRC 4080**. Outlet at **DRC 3530** (refer cross drainage structure X9) • Reconstruct existing pavement drainage line to suit widened northern kerbline between **DRC 3490** and **DRC 3610** (extending into Tramway Drive), and connect into cross drainage structure X9. Outlet at **DRC 3350** (refer cross drainage structure X10) • Extend existing pavement drainage line along southern kerbline between **DRC 3460** and **DRC 3510**. • Construct new table drain along the northern side of Narellan Road between **DRC 3350** and **DRC 3480** to control flows from widened eastbound carriageway and direct runoff to cross drainage structure X10. Outlet at **DRC 2390** (refer location F21) • Reconstruct existing pavement drainage line to suit widened southern kerbline between Waterworth Drive and **DRC 2790**, and connect to existing pavement drainage system in Waterworth Drive. • Reconstruct existing pavement drainage line to suit widened western kerbline of Waterworth Drive near **DRC 2400**, and connect to existing pavement drainage system. Outlet at **DRC 2030** (refer F24 on **Figure 5.4**) • Extend existing pavement drainage line along northern kerbline between **DRC 2630** and **DRC 2700**. • Reconstruct existing pavement drainage line to suit widened eastern kerbline of Hartley Road near **DRC 2400**, and connect to existing pavement drainage system.
Hartley Road to Exchange Parade	➢ **Figure 5.4** shows the recommended drainage strategy where Narellan Road runs between Hartley Road at **DRC 2400** and Exchange Parade at **DRC 1000**. Outlet at **DRC 2260** (refer location F22) • Reconstruct existing pavement drainage line to suit widened southern kerbline between **DRC 2260** and **DRC 2340.** Outlet at **DRC 2100** (refer location F23) • Reconstruct existing pavement drainage line to suit widened southern kerbline between **DRC 2160** and **DRC 2220.** Outlet at **DRC 820** (refer location F25) • Construct new pavement drainage lines (4 off) to suit widened southern kerbline between **DRC 1000** and **DRC 1570**, and connect to existing Camden Council piped drainage system. ➢ Additional survey will be required prior to commencing detailed design of the road upgrade works to confirm the configuration of existing road drainage systems along the westbound carriageway between **DRC 1000** and **DRC 2050**, and their connection to Camden Council's piped drainage system along the southern side of the road corridor.
Exchange Parade to Camden Valley Way	➢ **Figure 5.5** shows the recommended drainage strategy where Narellan Road runs between Exchange Parade at **DRC 1000** and Camden Valley Way at **DRC 0**. Outlet at **DRC 740** (refer location F26) • Reconstruct existing pavement drainage line to suit widened northern kerbline between **DRC 340** and **DRC 370**. Outlet at **DRC 50** (refer location F27) • Reconstruct existing pavement drainage lines (2 off) to suit widened northern kerbline between **DRC 250** and **DRC 300**, and between **DRC 180** and **DRC 200**. • Construct new pavement drainage lines (2 off) to suit new kerbline location at south-east corner of Camden Valley Way / Somerset Avenue intersection. ➢ Additional survey will be required to confirm the configuration of cross drainage structures X15 and X16 in order to support the necessary hydraulic analyses to determine their current hydrologic standard.

(1) Note that at each outlet of upgraded cross and pavement drainage systems it will be necessary to incorporate appropriate energy dissipation and scour protection measures.

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ANNEXURE C

TABLE SUMMARISING ESTIMATED AVERAGE ANNUAL SOIL LOSS FROM ROAD CORRIDOR

TABLE C1
ESTIMATED AVERAGE ANNUAL SOIL LOSS FROM ROAD CORRIDOR

LESCA No.	Local Identifier	Slope Length (m)	Gradient (%)	LS Factor	Sediment Load (tonnes/ha/yr)	Area Contributing to On-site Water (ha)	Sediment Load (m^3/yr)
1	-	10.7	4.7	0.36	36.6	0.092	**2.2**
2	-	32.0	3.9	0.54	54.9	0.839	**30.7**
3	-	3.7	3.4	0.21	21.4	0.102	**1.5**
4	-	7.0	7.0	0.53	53.9	0.070	**2.5**
5	-	44.1	4.5	0.76	77.3	0.139	**7.2**
6	-	30.6	3.3	0.45	45.8	0.403	**12.3**
7	7_a	6.0	50.0	2.75	279.7	0.096	17.9
	7_b	29.0	3.9	0.52	52.9	0.565	19.9
						Total	**37.8**
8	-	23.1	8.7	1.01	102.7	0.118	**8.1**
9	-	36.0	3.5	0.52	52.9	0.069	**2.4**
10	-	36.0	3.5	0.52	52.9	0.076	**2.7**
11	-	23.1	8.7	1.01	102.7	0.446	**30.6**
12	-	27.0	5.6	0.71	72.2	0.318	**15.3**
13	-	23.1	8.7	1.01	102.7	0.297	**20.4**
14	-	23.1	8.7	1.01	102.7	0.567	**38.8**
15	-	28.0	2.6	0.35	35.6	0.566	**13.4**
16	-	12.0	4.2	0.34	34.6	0.156	**3.6**
17	-	23.0	2.4	0.29	29.5	0.180	**3.5**
18	-	15.0	6.7	0.58	59.0	0.466	**18.3**
19	-	10.0	7.0	0.48	48.8	0.186	**6.0**
20	-	27.5	2.7	0.35	35.6	0.188	**4.5**
21	-	25.7	4.7	0.58	59.0	0.157	**6.2**
22	-	178.0	2.1	0.55	56.0	0.254	**9.5**
23	-	97.0	1.9	0.44	44.8	0.281	**8.4**

TABLE C1 (Cont'd)
ESTIMATED AVERAGE ANNUAL SOIL LOSS FROM ROAD CORRIDOR

LESCA No.	Local Identifier	Slope Length (m)	Gradient (%)	LS Factor	Sediment Load (tonnes/ha/yr)	Area Contributing to On-site Water (ha)	Sediment Load (m^3/yr)
24	-	55.0	6.5	1.55	157.7	0.064	**6.8**
25	-	126.0	2.5	0.64	65.1	0.114	**5.0**
26	-	220.0	2.0	0.61	62.1	0.214	**8.8**
27	-	257.0	2.5	0.88	89.5	0.364	**21.7**
28	-	336.0	2.9	1.22	124.1	0.200	**16.5**
29	-	47.0	4.2	0.73	74.3	0.197	**9.7**
30	-	48.0	1.6	0.27	27.5	0.351	**6.4**
31	-	9.0	3.0	0.23	23.4	0.027	**0.4**
32	-	53.0	3.8	0.69	70.2	0.132	**6.2**
33	-	36.5	6.8	1.04	105.8	0.155	**11.0**
34	34_a	24.6	3.0	0.38	38.7	0.570	14.7
	34_b	45.5	2.7	0.45	45.8	0.218	6.7
						Total	**21.3**
35	-	33.4	5.3	0.76	77.3	0.221	**11.4**
36	29_a	11.0	45.0	3.32	337.7	0.149	33.4
	29_b	22.0	3.4	0.39	39.7	0.530	14.0
						Total	**47.5**
37	-	47.6	2.4	0.40	40.7	0.450	**12.2**
38	-	19.0	3.9	0.44	44.8	0.388	**11.6**
39	-	19.0	3.9	0.44	44.8	0.230	**6.9**
40	-	26.5	3.8	0.48	48.8	0.433	**14.1**
41	-	18.6	4.0	0.42	42.7	0.579	**16.5**
42	-	14.3	3.5	0.32	32.6	0.275	**6.0**
43	-	90.0	2.8	0.64	65.1	0.358	**15.5**
44	-	23.5	3.2	0.39	39.7	0.415	**11.0**

TABLE C1 (Cont'd)
ESTIMATED AVERAGE ANNUAL SOIL LOSS FROM ROAD CORRIDOR

LESCA No.	Local Identifier	Slope Length (m)	Gradient (%)	LS Factor	Sediment Load (tonnes/ha/yr)	Area Contributing to On-site Water (ha)	Sediment Load (m^3/yr)
45	45_a	6.7	37.3	1.91	194.3	0.122	15.8
	45_b	13.3	5.6	0.46	46.8	0.281	8.8
						Total	**24.5**
46	-	30.9	2.4	0.33	33.6	0.254	**5.7**
47		13.0	3.2	0.29	29.5	0.026	**0.5**
48	-	21.4	2.8	0.33	33.6	0.198	**4.4**
49	-	15.0	1.7	0.24	24.4	0.082	**1.3**
50	-	17.4	2.8	0.33	33.6	0.292	**6.5**
51	-	26.4	1.9	0.29	29.5	0.155	**3.0**
52	-	40.3	3.7	0.58	59.0	0.838	**33.0**
53	-	34.7	4.3	0.63	64.1	0.736	**31.5**
54	-	30.9	2.4	0.34	34.6	0.588	**13.6**
55	-	11.0	2.3	0.21	21.4	0.094	**1.3**
56	-	24.1	2.1	0.28	28.5	0.344	**6.5**
57	-	14.5	3.4	0.32	32.6	0.209	**4.5**

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