Appendix L

KING GEORGES ROAD INTERCHANGE UPGRADE

FLOODING AND DRAINAGE INVESTIGATION

VOLUME 1 – MAIN REPORT

AUGUST 2014

FINAL REPORT

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FOREWORD

The King Georges Road Interchange Upgrade project forms part of the larger WestConnex project, a program of around 33 km of interconnected works designed to improve road connections between Western Sydney and the Port Botany/Sydney Airport precinct, provide better connections along the M4 and M5 Motorway corridors and allow urban revitalisation along Parramatta Road.

This study deals with flooding and drainage issues associated with the King Georges Road Interchange Upgrade project, the extent of which is shown on **Figure 1.1** in **Volume 2** of this report.

Hydrologic and hydraulic models have been established of the catchments draining across and through the project for the purpose of assessing flood related impacts on the project works and changes in flood behaviour on the surrounding environment. Models have also been prepared to assess requirements for the upgrade of the existing motorway drainage system in the vicinity of the intersection. The development of these models has been based on concept road design models developed by the WestConnex Delivery Authority.

During detailed design, the designers of the King Georges Road Interchange project will need to review the concept road design in light of the recommendations contained in this report to ensure the intent of the proposed measures is maintained in the final design of the road works.

The hydrologic and hydraulic models developed as part of the present investigation provide a suitable basis for further development of the concept design during the detailed design phase. However, the designers of the King Georges Road Interchange Upgrade will need to review proposed detailed design arrangements in the context of the model extents, details and input data described in this report to ensure that the models are suitable for the purpose intended.

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NOTE ON FLOOD FREQUENCY

The frequency of floods is generally referred to in terms of their Annual Exceedance Probability (AEP) or Average Recurrence Interval (ARI). For example, for a flood magnitude having 5% AEP, there is a 5% probability that there will be floods of greater magnitude each year. As another example, for a flood having a 5 year ARI, there will be floods of equal or greater magnitude once in 5 years on average. The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) %	Average Recurrence Interval (ARI) years
0.2	500
0.5	200
1	100
5	20
10	10
20	5

In this report the frequency of floods generated by runoff from the study catchments is referred to in terms of their ARI, for example the 100 year ARI flood.

The report also refers to the Probable Maximum Flood (PMF). This flood occurs as a result of the probable maximum precipitation (PMP) on the study catchments. The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a catchment hydrologic model which simulates the conversion of rainfall to runoff. The PMF is defined as the upper limiting value of floods that could reasonably be expected to occur.

ABBREVIATIONS

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ALS	Airborne Laser Scanning (type of aerial survey)
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff, 1998 Edition
BoM	Bureau of Meteorology
CRCP	Continuous Reinforced Concrete Pavement
DECC	Department of Environment and Climate Change (now OEH)
DECCW	Department of Environment, Climate Change and Water (formerly, DECC, but now OEH)
GSDM	Generalised Short Duration Method
KGRIU	King Georges Road Interchange Upgrade
MC	Motorway Chainage
OEH	Office of Environment and Heritage (formerly DECCW)
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
RL	Reduced Level
Roads and Maritime	Roads and Maritime Services (formerly Roads and Traffic Authority (RTA))
SMCMA	Sydney Metropolitan Catchment Management Authority
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WDA	WestConnex Delivery Authority

S1 SUMMARY

S1.1 Background and Scope of Investigation

An investigation was carried out by Lyall & Associates (**L&A**) on behalf of the WestConnex Delivery Authority (**WDA**) to assess requirements aimed at addressing flooding and drainage issues associated with the planned King Georges Road Interchange Upgrade (**KGRIU**) project. **Figure 1.1** in **Volume 2** of this report shows the extent of the KGRIU project which spans the eastern end of the M5 South West Motorway and the western end of the M5 East Motorway.

The scope of the investigation comprised the following broad tasks:

- Review of available drainage plans and reports.
- Review and update of the existing catchment hydrology.
- Development of TUFLOW and HEC-RAS models of the Wolli Creek floodplain.
- Define flood behaviour in terms of flows, levels and velocities for floods ranging between 100 and 500 year ARI, as well as for the PMF.
- Development of a DRAINS model of the existing pavement drainage system controlling runoff from the motorway corridor in the vicinity of the KGRIU project.
- Assessment of the impacts the KGRIU project will have on flooding patterns.
- Assessment of the impacts future climate change could have on flooding patterns affecting the KGRIU project.
- Assessment of the requirements for the upgrade of the existing pavement drainage system, including water quality control measures of both the M5 East Motorway and M5 South West Motorway as part of the KGRIU project.
- Assessment of requirements for the control of runoff during construction of the KGRIU project.

S1.2 Flooding and Drainage Patterns - Present Day Conditions

The key findings of the investigation as they relate to present day flooding and drainage patterns were as follows:

i. Runoff from the section of M5 East and M5 South West motorways which will be upgraded as part of the KGRIU project discharges to the catchments of Salt Pan Creek, a tributary of the Georges River and Wolli Creek, a tributary of the Cooks River. The location of the catchment divide is shown on **Figure 1.1**.

ii. Flooding patterns along the motorway corridor where it runs through the Wolli Creek catchment have been defined using a RAFTS rainfall-runoff model that was developed during the planning phase of the original M5 East Motorway project and a TUFLOW model which was developed as part of the present investigation. **Figure 2.1** shows the layout of the RAFTS model, whilst **Figure 2.2** shows design discharge hydrographs at key locations along the main arm of Wolli Creek for 100 and 500 year ARI events, as well as the PMF. **Figure 2.3** (2 Sheets) shows the layout of the TULFOW model developed as part of the present investigation.

iii. Design water surface profiles along the southern side of the motorway corridor existing from Kooemba Road to Kingsgrove Road are shown on **Figure 2.4**, whilst 100 year ARI flooding patterns are shown on **Figure 2.5**.

iv. Existing residential and commercial/industrial development located on the southern side of the M5 East Motorway corridor was found to be subject to flooding at the 100 year ARI level (**Figure 2.5**).

v. The catchment hydrology undertaken during the planning of the original M5 East Motorway project adopted the approach to the derivation of PMP estimates set out in BoM, 1994. **Figure 2.6** shows flooding patterns in the vicinity of the motorway corridor derived from flows based on the approach which has now been superseded by BoM, 2003.. **Figure 2.7** shows flooding patterns in the vicinity of the motorway corridor based on the BoM, 2003 approach to deriving PMP estimates.

vi. Application of the methodology presented in BoM, 2003 to the RAFTS model which was developed during the planning of the original M5 East Motorway project results in a 5-9 per cent increase in the peak flow estimates for the PMF event (refer **Table 2.1**). This has resulted in an increase in peak flood levels along the M5 East Motorway corridor of up to 500 mm when compared with flows based on BoM, 1994 (refer **Figure 2.8**).

vii. Runoff from the section of the M5 East Motorway which will be impacted by the KGRIU project is controlled by a pavement drainage system (**Drainage Line A**) which discharges to an existing water quality pond that is located on the southern side of the motorway corridor between Kirrang Street and Kooemba Road (**Water Quality Pond 1** on **Figure 3.1**, Sheet 2 of 2).

viii. A section of Drainage Line A will surcharge during events as frequent as 5 year ARI where it runs along the median immediately west of the King Georges Road overpass. This surcharge is due to insufficient capacity in the existing 375 mm diameter pipe. Stormwater will also pond across the eastbound off-ramp at the location of the sag at about Motorway Chainage (**MC**) 1760 in a 20 year ARI event (**Figure 3.1**, Sheet 1 of 2).

ix. The trunk main of Drainage Line A comprises a 1500 mm diameter pipe which is located beneath the westbound carriageway west of the Cooloongatta Road overpass. The investigation found that this pipe has sufficient capacity to convey peak flows up to 100 year ARI (**Figure 3.1**, Sheet 2 of 2).

x. Widths of flow of over 3 m are present in a 20 year ARI event along both sides of the motorway. However, given the wide shoulder areas, the intrusion of flow into the trafficable lanes is minimal at the 20 year ARI level.

xi. Surcharge of the local stormwater drainage system which controls runoff from the highly urbanised catchment which lies to the north of the motorway corridor and west of King Georges Road was found to occur for events as frequent as 2 year ARI (**Figure 3.1**, Sheet 1 of 2). Stormwater which surcharges the drainage system in the western kerbline of King Georges Road north of the overpass will flow in a southerly direction across both the exit of the eastbound off-ramp and the entry of the westbound on-ramp before ponding in the sag in King Georges Road south of the overpass. Stormwater ponding on the western side of the road corridor will inundate the northbound lanes of King Georges Road to a maximum depth of about 400 mm before flowing in an easterly direction, where it will join flow in the concrete lined channel which runs to the south of Water Quality Pond 1.

xii. Stormwater will pond along the northern side of the noise wall between King Georges Road and Allambee Crescent due to a lack of inlet capacity along the trunk drainage line which runs along the northern side of the motorway corridor between King Georges Road and the Canterbury Golf Course (**Drainage Line C**) during storm events which surcharge the local stormwater drainage system. **Figure 3.1**,Sheet 2 of 2 shows the location of the ponding area. Depths of ponding in this area reach up to about 600 mm before stormwater commences to flow in an easterly direction along the shared path. Stormwater surcharging the ponding area would be joined by overland flow discharging from Booragull Street and the western side of Cooloongatta Road, before turning south and discharging to the southern side of the motorway corridor via the Cooloongatta Road overpass.

S1.3 Flooding and Drainage Patterns – Post-Upgrade Conditions

The key findings and recommendations of the investigation as they relate to post-upgrade conditions were as follows:

i. The footprint of the KGRIU project lies on land which is not affected by main stream flooding up to the PMF event. The construction of the KGRIU project will therefore not result in a loss of floodplain storage or conveyance in in the receiving drainage lines.

ii. The KGRIU project will result in a minor increase in peak flows discharging to the existing 1350 mm diameter pipe which crosses the motorway corridor west of the Penshurst Road underpass. Existing development will not be impacted as a result of this minor increase in peak flows due to floodwater being confined to the road reserve of Penshurst Road and Windara Reserve (refer **Table 4.1** for comparison of peak flows).

iii. The KGRIU project will result in a reduction in peak flows in the concrete lined channel which runs to the south of Water Quality Pond 1 (refer **Table 4.1**). The principal reason for this is the reduction in surcharge flows associated with improved inlet capacity along Drainage Line C.

iv. Peak flows will be increased in the concrete lined channel which runs from the outlet of Drainage Line C to the inlet of an existing transverse drainage structure (**XD1**) that crosses the motorway corridor at about MC2850 (refer **Table 4.1**). The reason for this is the reduction in surcharge flows associated with improved inlet capacity along Drainage Line C. Whilst the concrete lined channel has sufficient capacity to convey post-upgrade peak flows up to the 100 year ARI, there will be an increase in the magnitude of flow which discharges in an easterly direction along the northern side of the motorway corridor during storms which surcharge the inlet of transverse drainage structure XD1. The increase in flow discharging along the northern side of the motorway will not impact existing development and will rejoin flow in the main arm of Wolli Creek in the vicinity of the Kindilan Street underpass.

v. Changes in flooding behaviour along the motorway corridor due to possible increases in rainfall intensities associated with future climate change will not impact the KGRIU project given it is located on land which lies above the PMF.

vi. It will be necessary to incorporate additional capacity in the median of the westbound carriageway immediately west of the King Georges Road overpass due to there being insufficient capacity in the piped drainage system at this location (**Figure 4.1**, Sheet 1 of 2). Because the original M5 East Motorway project was constructed using a Continuous Reinforced Concrete Pavement (CRCP), it is recommended that a shallow reinforced concrete trench type drain is constructed directly beneath the F-type barrier at this location. The trench type drain would need to link with the existing median inlet pits and provide additional capacity during storms when the Hydraulic Grade Line rises to the surface of the pavement.

vii. Due to the adoption of narrower shoulders, it will be necessary to install a similar trench type drain arrangement directly beneath the King Georges Road overpass and also to its west along the northern side of the eastbound carriageway (**Figure 4.1**, Sheet 1 of 2). As there are no kerb inlet pits in these locations, new grated inlet structures similar to the opening on an F–Type barrier pit will need to be incorporated in the design of the trench drain arrangement.

viii. Existing constraints in the capacity of Drainage Line A downstream of the existing sag in the eastbound off-ramp will result in the occurrence of minor ponding across the widened off-ramp during a 20 year ARI event. A new 450 mm diameter pipe discharging to an existing 375 mm diameter pipe has been incorporated in the pavement drainage strategy, aimed at minimising the hydraulic losses in this section of the drainage system (**Figure 4.1**, Sheet 1 of 2).

ix. Whilst additional inlet capacity has been provided on both sides of King Georges Road north of the overpass, stormwater will still flow in a southerly direction across the exit of the eastbound off-ramp and the entry to the westbound on-ramp during storms larger than about 5 year ARI (**Figure 4.1**, Sheet 1 of 2).

x. Whilst the width of the shoulders on the off- and on-ramps west of the King Georges Road overpass will increase to 2.5 m, it will be necessary to install a minor pit and pipe system west of the crest in the motorway located at about MC 1650. This will require a new outlet headwall arrangement to be provided on the northern side of the motorway at about MC 1550 (**Figure 4.1**, Sheet 1 of 2).

xi. There is sufficient residual capacity within the 1500 mm diameter trunk line which runs in an easterly direction from the sag beneath the Cooloongatta Road overpass to Water Quality Pond 1 to convey flows up to the 100 year ARI under post-upgrade conditions (**Figure 4.1**, Sheet 2 of 2).

xii. Additional inlet capacity will need to be provided on the northern side of the motorway between King Georges Road and Allambee Crescent to prevent surcharge of the existing ponding area for events up to 100 year ARI (**Figure 4.1**, Sheet 2 of 2).

xiii. It is not proposed to incorporate a drainage system in the Penshurst Road bridge widening works, as the widths of flow along the edge of the motorway will not exceed 2 m in the critical 20 year ARI event.

xiv. An aquaplaning check found that there are two locations where the depth of sheet flow will exceed the threshold value of 4 mm (refer **Table 5.1** for details). The first location is around MC 1560 on the westbound carriageway, where the estimated maximum depth of sheet flow was 4.6 mm (refer flowpath W2 on **Figure 4.1**, Sheet 1 of 2). The second location is around MC 2630-2640 on the eastbound carriageway, where the estimated maximum depth of sheet flow was 4.5 mm (refer flowpaths E1, E2 and E3 on **Figure 4.1**, Sheet 2 of 2).[1]

S1.4 Operational Phase Water Quality Considerations

The key findings and recommendations of the investigation as they relate to water quality issues associated with the operational phase of the project were as follows:

[1] Note that the second non-conformance is located immediately to the east of the KGRIU project and is associated with the future widening of the motorway as part of the larger WestConnex project.

i. Given the minor nature of the road works west of King Georges Road, it is not proposed to incorporate any new water quality control measures along the section of motorway which runs through the Salt Pan Creek catchment.

ii. Runoff from the majority of the motorway which is affected by the KGRIU project is controlled by Water Quality Pond 1, the key features of which are shown on **Figure 6.1** and several design drawings contained in **Appendix D**.

iii. Reductions in pollutant loads achieved by the treatment measures that are incorporated in Water Quality Pond 1 are less than the targets which have been adopted by Rockdale City Council (RCC) for the discharge of stormwater to Wolli Creek from new large-scale developments.

iv. Following a review of the preliminary study findings, Roads and Maritime advised that Water Quality Pond 1 should be upgraded to achieve RCC's reduction targets for the <u>incremental increase</u> in pollutant load attributable to the KGRIU project. MUSIC modelling shows that this outcome can be achieved by converting the 140 m^2 open water area into a biofiltration system.

S1.5 Construction Phase Water Quality Considerations

The key findings and recommendations of the investigation as they relate to water quality issues associated with the construction phase of the project were as follows:

i. Disturbed areas will be limited to the northern and southern sides of the existing carriageway (refer **Figure 7.1**, 2 Sheets).

ii. Given the steep nature of the existing landscaped batters, there is the potential for increased sediment loads to be generated from the motorway corridor following clearing and grubbing activities. It will therefore be necessary to stage the clearing and grubbing of these areas in order to reduce the annual average sediment load discharging to the receiving drainage lines to less than the threshold design value of 150 m^3 for large-scale sediment retention basins.

iii. Provided the works are suitably staged, then local erosion control measures need only be implemented during construction of the KGRIU project, with Water Quality Pond 1 acting as a final "polishing pond" for runoff prior to its discharge to Wolli Creek.

1 INTRODUCTION

1.1 Background

The KGRIU project forms part of the larger WestConnex project, a program of around 33 km of interconnected works designed to improve road connections between Western Sydney and the Port Botany/Sydney Airport precinct, and provide better connections along the M4 and M5 Motorway corridors.

This study deals with flooding and drainage issues associated with both the construction and operational phases of the KGRIU project.

1.2 Project Overview

The KGRIU project will generally involve upgrading of the existing M5 East Motorway dual carriageways to retain two through lanes in each direction and accommodate its possible future widening as part of the larger WestConnex project. The eastern end of the project will tie into the existing M5 East Motorway near Kooemba Road in the suburb of Beverly Hills, whilst the western end of the project will tie into the M5 South West Motorway west of the Penshurst Road overpass in the suburb of Narwee.

To the west of King Georges Road, widening and lengthening of the eastbound off-ramp and westbound on-ramp will be required to make provision for the increased traffic movements which will occur following the completion of the larger WestConnex project. To the east of King Georges Road, the eastbound on-ramp will be extended by shifting the merge point further to the east and a new bridge span constructed to the north of the existing Cooloongatta Road overbridge. Similarly, the westbound off-ramp diverge will be shifted further to the east and a new bridge span constructed to the south of the existing Cooloongatta Road overbridge.

1.3 Scope of Present Investigation

The scope of the present investigation was broadly as follows:

1. **Review of Available Drainage Plans and Reports**. This task mainly comprised the review (**Review**) of as-built drawings provided by Roads and Maritime to determine the location and extent of existing drainage infrastructure along the M5 East and South West Motorways. The review extended to existing pavement drainage, as well as existing spill containment and water quality control measures.

   Several reports dealing with flooding and drainage in relation to the original M5 East Motorway were also provided by Roads and Maritime. However, these reports were all prepared during the project planning phase and so pre-date the final design of the transverse and pavement drainage systems which were ultimately constructed.

2. **Review and Update Existing Catchment Hydrology**. Investigations undertaken during the planning of the original M5 East Motorway developed catchment hydrologic models based on the RAFTS approach. These models were reviewed as part of the present investigation and updated principally to reflect more recent changes which have been made by the Bureau of Meteorology (BoM) to the methodology for deriving PMP estimates.

3. **Develop TUFLOW Model of Wolli Creek Floodplain**. Using available LiDAR and ground survey data, as well as information contained on the detailed design and “as-built” drawings, a 1D/2D hydrodynamic model of Wolli Creek and its floodplain was developed extending from King Georges Road to a location downstream of Bexley Road. The TUFLOW

software was used for the present investigation. TUFLOW dynamically links one-dimensional drainage elements such as pipes and open channels with a two-dimensional domain, which is typically used to model the passage of the flood wave across a floodplain.

4. Develop DRAINS Model of Existing Pavement Drainage System. Using information contained on the as-built drawings, a catchment-based rainfall-runoff model was set up to represent the pavement drainage lines which comprise the existing motorway pavement drainage system. The DRAINS computer modelling software, which converts rainfall to runoff and carries out a Hydraulic Grade Line analysis along piped reaches of the drainage system, was used for this purpose. The extents of the catchments which drain to the cross drainage lines were determined from contour and road design information provided by Roads and Maritime. The DRAINS model which was developed to assess the hydrologic standard of the existing pavement drainage system also incorporated an existing 1350 mm diameter pipe which crosses the motorway corridor west of the Penshurst Road underpass.

5. Assess Impacts of KGRIU on Flooding Patterns. The results of the TUFLOW model for present day conditions confirmed that the KGRIU project lies outside the extent of the PMF on Wolli Creek. As a result there was no need to adjust the model to reflect the proposed road works.

6. Assess Possible Impacts of Future Climate Change on Flooding Behaviour. Scientific evidence shows that climate change will lead to sea level rise and potentially increase flood producing rainfall intensities. Whilst sea level rise will not impact flooding behaviour in the vicinity of the KGRIU project, potential increases in rainfall intensity could increase peak flows in Wolli Creek and the existing transverse drainage structures of the M5 East Motorway. Based on guidelines issued by the Office of Environment and Heritage (OEH), an assessment was made of the impact of possible increases in 100 year ARI rainfall intensity on the level of flood immunity afforded to the upgraded interchange.

7. Assess Requirements for Upgrading the Existing Motorway Drainage System. An assessment was undertaken of the impact of the KGRIU project on the hydrologic standard of the existing pavement drainage system and on depths of sheet flow across the upgraded motorway pavement. Requirements for the upgrade of the existing pavement drainage system to meet current Roads and Maritime standards were assessed and a pavement drainage strategy developed for the KGRIU project. Requirements were also assessed for upgrading the existing water quality control pond into which the pavement drainage system of the M5 East Motorway presently discharges.

8. Assess Requirements for the Upgrading of Existing Water Quality Control Measures. An assessment was undertaken of the impact of the KGRIU project on the quality of stormwater discharging to both Wolli Creek and Salt Pan Creek. Requirements were assessed for the upgrade of Water Quality Pond 1 to offset the increase in pollutant load resulting from the KGRIU project.[2]

9. Assess Requirements for the Control of Runoff During Construction of the KGRIU Project. Using data contained in the publication "*Soils and Construction – Managing Urban Stormwater*" (Landcom, 2004), an assessment was made of measures which will need to be implemented during construction of the KGRIU project to reduce erosion potential and hence sediment load in runoff discharging to Wolli Creek.

[2] The assessment included an allowance for future widening of the motorway associated with the WestConnex M5 project.

1.4 Outline of Report

Chapter 2 of this report contains a brief description of the catchments through which the M5 South West and M5 East Motorways run. Also presented are the findings of the Review and the changes that were made to the input data of the original RAFTS models of the Wolli Creek catchment, principally to reflect the change made by BoM in the methodology for deriving PMP estimates (BoM, 2003). Background to the development of the TUFLOW hydraulic model of Wolli Creek and its floodplain are presented, including a description of flooding behaviour under present day conditions.

Chapter 3 presents the findings of the investigation to assess the hydraulic capacity of the existing pavement drainage system, to confirm (or otherwise) its ability to cater for the proposed road works. The "as-built" drawings prepared as part of the original M5 East Motorway construction and the detailed design drawings for the widening of the M5 South West Motorway were relied upon for information on the existing pavement drainage system, since no detail survey of the motorway drainage system is presently available. The investigation included an assessment of the hydraulic capacity of a single transverse drainage structure which crosses the motorway corridor west of the Penshurst Road underpass in the Salt Pan Creek catchment.

Chapter 4 contains a discussion on the findings of the investigation into the impacts the KGRIU project will have on flooding patterns in the Wolli Creek and Salt Pan Creek catchments. Also presented are details of the pavement drainage strategy which has been developed for the KGRIU project.

Chapter 5 presents the findings of the investigation to assess the depth of sheet flow across the upgraded motorway pavement at various critical locations.

Chapter 6 presents the findings of the investigation to assess the impact of the KGRIU upgrade on the quality of stormwater discharging to both Wolli Creek and Salt Pan Creek. A review of the existing level of treatment afforded by Water Quality Pond 1 is provided, along with recommendations for its upgrade as part of the KGRIU project.

Chapter 7 provides a summary of the approach to be adopted in developing the proposed erosion and sediment control strategy for the construction phase of the KGRIU works. This includes requirements for local erosion and sediment control measures along the length of the road upgrade.

Chapter 8 contains a list of documents which were referenced as part of the investigation.

Annexure A sets out the RAFTS model parameters which were adopted for generating design discharge hydrographs for input to the TUFLOW hydraulic model.

Figures referred to in this report are bound in a separate volume (**Volume 2**) which also contains the following appendices:

- **Appendix A** contains a number of "as-built" drawings showing the layout of the existing transverse drainage structures which are located along the M5 East Motorway.
- **Appendix B** contains a number of "as-built" drawings showing the layout of the existing pavement drainage system of the M5 East Motorway in the vicinity of the KGRIU project.

- **Appendix C** contains a number of detailed design drawings showing the layout of the existing pavement drainage system of the M5 South West Motorway in the vicinity of the KGRIU project.
- **Appendix D** contains a number of "as-built" drawings showing details of Water Quality Pond 1.

1.5 Available data

In addition to the as-built drawings and reports relating to the existing motorway pavement drainage system referred to above, the following data were also made available by Roads and Maritime for this present investigation:

- Aerial photography covering the study area.
- LiDAR survey data covering the study area.
- Detailed ground survey information in selected locations within the motorway corridor and also within the inbank area of Wolli Creek between King Georges Road and Bexley Road.
- Previous reports prepared during the planning phase of the original M5 East Motorway project.
- RAFTS model files developed during the planning phase of the original M5 East Motorway project.
- Proposed horizontal and vertical alignment of the KGRIU project, in the form of a 3D road design models.
- Various GIS datasets including property boundary information.
- "As-built" drawings of the existing M5 East Motorway drainage system and detailed design drawings of the existing M5 South West Motorway drainage system.

2 FLOODING ASSESSMENT – PRESENT DAY CONDITIONS

2.1 General

This chapter contains a brief description of the catchments through which the M5 South West and M5 East Motorway run. It also deals with the definition of present day flooding patterns along the section of the M5 East Motorway where it runs between King Georges Road and Kingsgrove Road in the Wolli Creek catchment. It also includes an assessment of the hydrologic standard of the existing transverse drainage along this section of the motorway.

The findings of an investigation into the hydrologic standard of the existing transverse drainage which crosses the motorway corridor west of the Penshurst Road underpass in the Salt Pan Creek catchment are presented in **Chapter 3**.

2.2 Catchment Description

2.2.1 Salt Pan Creek

The M5 South West Motorway runs in an east west direction through the Salt Pan Creek catchment, a tributary of the Georges River. The section of the M5 South West Motorway which will be widened as part of the KGRIU project lies in the upper reaches of the Salt Pan Creek catchment, as shown on **Figure 1.1**. The catchment through which the motorway runs is completely urbanised with a drainage system comprising piped and open channel reaches.

A single transverse drainage structure located at Motorway Chainage (**MC**) 1440 controls runoff from an 11.7 ha urbanised catchment which lies to the north of the motorway corridor. The location of the transverse drainage structure is shown on **Figure 1.1** (refer transverse drainage structure **XD0**). Further discussion on flooding and drainage patterns along the section of the M5 South West Motorway which will be widened as part of the KGRIU project is contained in **Chapter 3**.

2.2.2 Wolli Creek

The M5 East Motorway runs in an east to west direction through the Wolli Creek catchment, which is completely urbanised with a drainage system comprising piped and open channel reaches. **Figure 2.1** shows the location of the M5 East Motorway and the division of the overall catchment into sub-areas which was used in catchment modelling (RAFTS) to determine discharge hydrographs. The main arms on the southern side of the M5 East Motorway are channelised to the east of Beverly Hills Park, where a concrete stormwater channel continues to Bexley Road. Immediately downstream of Bexley Road the creek enters a densely vegetated steep walled valley which significantly restricts creek flows (**Figure 2.3**, Sheet 2 of 2). The catchment area at Bexley Road is 11.5 km^2.

Hyder Consulting prepared the design of the original M5 East Motorway project and its drainage system, including modifications to the open channel section of Wolli Creek between Kingsgrove Road and Bexley Road, as well as the cross drainage lines which convey runoff into the creek from areas north of the road. Detailed design drawings showing the adjustments that were made to the existing drainage system as part of the construction of the original M5 East Motorway (plan view only) are contained in **Appendix A**.

The drainage system was designed to convey flows up to the 100 year ARI magnitude. Several underpasses were also provided between King Georges Road and Bexley Road (including Kingsgrove Road itself) which provide additional capacity to convey flows greater than 100 year ARI magnitude.

2.3 Wolli Creek Catchment Hydrology

2.3.1 Background to Hydrologic Model Development

Wolli Creek catchment has a history of flooding which had been investigated in several detailed flood studies undertaken in the last 25 years. The most recent investigations were undertaken by Willing and Partners (WP) for the design of the M5 East Motorway project and used a hydrologic catchment model based on the RAFTS approach (WP, 1999 and 2000).

In RAFTS, the catchment is sub-divided into a number of sub-catchments and connected to represent the layout of the drainage system. Rainfall on each sub-catchment is adjusted to allow for infiltration and other losses. The resulting sub-area rainfall-excess is converted into a hydrograph and progressively added to runoff from the other areas in the drainage system, with the combined flow being routed through the system to the outlet.

In addition to rainfall losses, the model requires other parameters relating to the time of travel of the floodwave through the drainage system. Ideally these parameters are derived by calibrating the model to historic storm events and using the calibrated model for the estimation of design flood events. However, there are no historic streamflow data available for Wolli Creek and consequently, WP used values which had been adopted in flood investigations in the Sydney region.

Two RAFTS models were developed by WP during the detailed design of the original M5 East Motorway project. The first was used to generate discharge hydrographs for design storms up to 500 year ARI (**WP RAFTS Model**), whilst the second was used to generate discharge hydrographs for the PMF (**WP PMF RAFTS Model**).[3]

The structure of the WP RAFTS Model was reviewed and was considered appropriate for adoption in this present study, with the exception that the lag time in the concrete lined section of channel which runs between Kingsgrove Road and Bexley Road was adjusted based on the results of the TUFLOW modelling (refer **Section 2.4**). Further details on the process adopted for deriving design storms and their application to the model to generate design discharge hydrographs are contained in **Annexure A** of this report.

2.3.2 Probable Maximum Precipitation

The flooding investigations that were undertaken as part of the detailed design of the original M5 East Motorway project derived estimates of probable maximum precipitation (PMP) based on the Generalised Short Duration Method (GSDM) as described in the BoM's Bulletin 53 (BoM, 1994). In 2003, BoM issued an update of Bulletin 53 which incorporated a revised method of spatial distribution of rainfall and updated moisture factors (BoM, 2003).

For the present investigation, estimates of probable maximum precipitation (PMP) were derived using the methodology prescribed in BoM, 2003. This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 km^2 in area and storm durations up to 6 hours.

The steps involved in assessing revised PMP estimates for the Wolli Creek catchment are briefly as follows:

[3] It is noted that the structure of the WP PMF RAFTS Model differs from that of the WP RAFTS Model. The reasons for these structural differences are not known.

- Calculate PMP for a given duration and catchment area using depth-duration-area envelope curves derived from the highest recorded US and Australian rainfalls.
- Adjust the PMP estimate according to the percentages of the catchment which are meteorologically rough and smooth, and also according to elevation adjustment and moisture adjustment factors.
- Assess the design spatial distribution of rainfall using the distribution for convective storms based on US and world data, but modified in the light of Australian experience.
- Derive storm hyetographs using the temporal distribution contained in Bulletin 53, which is based on pluviographic traces recorded in major Australian storms.

No PMP ellipses are presented WP, 1999 and WP, 2000. It was therefore necessary to rely on the input data that is contained in the WP PMP RAFTS Model for assigning revised PMP rainfall depths to the sub-catchments in the model. In addition to updating the PMP depth estimates in the model (**Adjusted WP PMF RAFTS Model**), the lag time in several of the model links was also adjusted (refer **Annexure A** for details).

2.3.3 Design Discharge Hydrographs

The Adjusted WP PMF RAFTS Model was run with the parameters given in **Annexure A** to obtain design hydrographs for input to the TUFLOW hydraulic model. **Table 2.1** over page gives peak flows at key locations along the main arm of Wolli Creek and at inflow points to the TUFLOW hydraulic model for design storms with ARI's of 100, 200 and 500 years, as well as the PMF.

For comparative purposes, peak flow estimates for the PMF event based on the methodology set out in BoM, 1994 are also presented in **Table 2.1**. The revised methodology of BoM, 2003 for deriving PMP estimates has led to a 5% increase at Kingsgrove Road, and about a 9% increase at Bexley Road in the peak flow estimate for the PMF event. The peak flows on Wolli Creek between Beverly Hills Park and Bexley Road range between 3.5 and 3.7 times the magnitude of the 100 year ARI peak. These values are at the lower limit of expected values for small urbanised catchments.

Discharge hydrographs generated by the Adjusted RAFTS Model may be compared with the TUFLOW discharge hydrographs, which are also shown on **Figure 2.2**. The estimates of peak overland flow discharge derived by TUFLOW are less than those derived by RAFTS. This difference is attributed to the attenuating effects of the storage which is present on the floodplain and which is incorporated into the two-dimensional model domain of TUFLOW, but is not specifically modelled by RAFTS.

Comparison of the discharge hydrographs presented on **Figure 2.2** for pre- and post- upgrade conditions shows that the loss of floodplain storage associated with the WestConnex M5 project will not have a significant effect on peak flows in Wolli Creek. The impact of the road works on peak flood levels along Wolli Creek is discussed in **Chapter 4** of this report.

Given the uncertainties associated with the background to the development of the WP PMF RAFTS Model, leading to the possible underestimation of peak flows, it is recommended that a new hydrologic model be developed and used to derive discharge hydrographs and peak flow estimates for the PMF event as part of the detailed design of the WestConnex M5 project.[4]

[4] This recommendation does not apply to the detailed design of the KGRIU project as it is located on land which lies above the PMF.

TABLE 2.1
SUMMARY OF PEAK FLOWS
(m^3/s)

Location	TUFLOW Inflow Hydrograph Identifier(1)	Design Storm Event (year ARI)			PMF	
		100(4)	200(4)	500(4)	BOM, 1994(2)	BOM, 2003(3)
King Georges Road	WC01	8.6	10	11	22	23
Kirrang Street	WC02	8.4	9.8	11	19	20
Canterbury Golf Course	WC03	2.9	3.4	3.7	6.1	6.3
Rosebank Avenue	WC04	8.2	9.7	11	19	20
Amtree Street	WC05	7.8	9.3	10	19	20
Beverly Hills Park	WC06	156	185	205	534	561
Garema Circuit	WC07	6.9	8.2	9.0	17	18
	WC08	0.8	0.9	1.0	1.7	1.8
Smith Reserve	WC09	27	32	36	64	67
West of Forrester Street	WC10	0.9	1.1	1.2	2.1	2.2
Forrester Street	WC11	0.9	1.1	1.2	2.1	2.2
Sheffield Street	WC12	0.5	0.5	0.6	1.0	1.1
Richland Street	WC13	13	16	18	34	35
Kingsgrove Road	-	250	295	325	836	875
Kingsgrove Memorial Reserve	WC14	32	38	42	72	76
West of Arinya Street	WC15	2.7	3.2	3.6	5.9	6.1
Arinya Street	WC16	2.4	2.8	3.1	4.8	5.0
Pangee Street	WC17	4.5	5.2	5.7	9.2	9.7
Giraween Street	-	265	315	345	883	937(4)
Bobadah Street	WC18	4.0	4.7	5.1	8.2	8.6
South of Beaconsfield Avenue	WC19	1.5	1.8	2.0	3.1	3.2
Gilchrist Park	WC20	18	22	24	43	45
Bexley Road	WC21	18	22	25	43	45
Kingsgrove Avenue Reserve	-	280	330	360	930	1010(4)
Bexley Road	-	280	330	360	938	1022(4)

1. Refer **Figure 2.3** for location of TUFLOW model inflow boundaries.
2. Peak flows presented for PMP rainfall depths for 60 minute storm duration.
3. Unless otherwise noted, critical PMP storm is of 60 minutes duration.
4. Peak flows are for critical storm of 90 minutes duration.

2.4 Hydraulic Modelling of Design Floods – Wolli Creek Catchment

2.4.1 Background to Hydraulic Model Development

Previous studies undertaken during the investigation and design of the M5 East Motorway used the HEC-2 (WP, 1995) and XP-EXTRAN (WP, 2000) software packages to define flooding behaviour along the main arm of Wolli Creek. Since the preparation of these earlier studies, more sophisticated modelling techniques have been developed which more accurately simulate the passage of a flood wave through the drainage system.

For the purpose of the present investigation, the TUFLOW software was used to convert the design discharge hydrographs generated by the WP RAFTS Model and the Adjusted WP PMF RAFTS Model into two-dimensional (in plan) flooding patterns. The layout of the TUFLOW model is shown on **Figures 2.3** (2 Sheets).[5] Further background to the development of the TUFLOW model of Wolli Creek, including details of the existing cross drainage along the motorway are contained in **Annexure B** of this report.

2.4.1 Description of Flooding Behaviour

Figure 2.4 shows design water surface profiles along the main arm of Wolli Creek and one of its tributaries extending from a location adjacent to Water Quality Pond 1 to a location approximately 80 m downstream of Kingsgrove Road. **Figure 2.5** shows flooding patterns in the vicinity of the KGRIU project for the 100 year ARI event. Minor surcharge of transverse drainage structure XD1 will occur in a 100 year ARI event, when a peak flow of 1.6 m^3/s will discharge in an easterly direction toward the Kindilan Street underpass. Floodwater which surcharges the inlet of transverse drainage structure XD1 will pond along the northern side of the motorway before discharging to inlet pits located on cross drainage structures XD1A and XD2.

Surcharge of the existing concrete lined channel which runs to the south of Water Quality Pond 1 is surcharged by a 100 year ARI event east (downstream) of Kooemba Street (refer **Figure 2.5**). As a result, two existing residential properties that are located on the southern side of the motorway corridor on Tallawalla Street are subject to flooding at the 100 year ARI level. The presence of colorbond fencing that extends from Tallawalla Street to the motorway boundary will result in increased depths of inundation on the western (upstream) side of the two affected properties and divert flood flows into Tallawalla Street. Floodwater which surcharges the channel at this location flows in an easterly direction, where it does not fully re-enter the channel system until a location opposite the Kindilan Street underpass.

Flooding will be experienced in commercial and industrial development located between Beverly Hills Park and Kingsgrove Road, as a result of floodwater surcharging the main arm of Wolli Creek in a 100 year ARI event. Depths of inundation in several properties will exceed 1 m.

The transverse drainage structures which lie immediately to the east of the Kindilan Street underpass (refer XD3, XD4, XD5, XD6 and XD7 on **Figure 2.5**) have sufficient capacity to convey peak 100 year ARI flows generated by the local catchments which drain from the north.

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[5] Whilst the hydraulic model extends east to a location downstream of Bexley Road, only those results of the modelling which are relevant to the KGRIU project are presented in this report.

Figures 2.6 and **2.7** show flooding patterns for PMF flows derived using the methodology set out in BoM, 1994 and BoM, 2003, respectively. **Figure 2.8** shows the impact of the increase in the estimate of PMF flows on peak flood levels along Wolli Creek.

Major ponding of floodwater will occur along the northern side of the motorway corridor between about MC 2650 and the Kindilan Street underpass during a PMF event. Flows based on BoM, 2003 result in an increase in peak flood levels in the range 0-200 mm in this area.[6]

[6] The presence of the noise wall which runs behind the F-type barrier kerb on the northern side of the corridor prevents a minor surcharge of flow which would otherwise occur onto the surface of the motorway at about MC 2950 during a PMF event.

3 PAVEMENT DRAINAGE ASSESSMENT – PRESENT DAY CONDITIONS

3.1 Brief Description of Existing Pavement Drainage System

The original detailed design and "as-built" drawings were relied as part of the present investigation, as there is detailed survey data available of the existing motorway drainage system. **Appendices B** and **C** contain a selected set of drainage plans which show the extent of the existing pavement drainage system along the M5 East Motorway and M5 South West Motorway, respectively.

Figure 3.1 (2 Sheets) shows the extent of the existing motorway drainage system in the vicinity of the KGRIU project, as determined from the available drawings. Note that the extent of the local stormwater drainage system which contributes to flow in several of the receiving drainage lines is not shown on the figure.

Runoff from the majority of the motorway corridor over the length of the KGRIU project is controlled by a single pavement drainage system (**Drainage Line A**). Drainage Line A extends from the existing crest in the motorway west of the King Georges Road Overpass to a location east of Kooemba Road, a distance of about 1.2km. Runoff controlled by Drainage Line A discharges to Water Quality Pond 1 which is located on the southern side of the corridor at about MC 2650.

The "as-built" drawings show that Drainage Line A comprises a 1500 mm diameter pipe where it runs against the grade in the motorway from the location of the existing sag beneath Cooloongatta Road overpass to Water Quality Pond 1. As a result, the invert level of the pipe adjacent to Water Quality Pond 1 is over 5 m below that of the existing pavement.

The "as-built" drawings also show that Drainage Line A includes a minor piped drainage system that captures runoff from a section of the M5 East Motorway east of Water Quality Pond 1. This pipe drainage system is located at a depth of over 4 m due to its running against the grade of the existing pavement.

A relatively large urbanised catchment drains toward the motorway corridor on its northern side. The "as-built" drawings show that a large trunk drainage line comprising a maximum 1800 mm diameter pipe was installed along the northern side of the M5 East Motorway behind the existing noise wall (**Drainage Line C**). Whilst there was limited inlet capacity to the 1800 mm diameter pipe incorporated in the original design of the M5 East Motorway, the design drawings show that provisions were incorporated in the design for the future upgrade of the local stormwater drainage system by others.

A review of the available LIDAR survey data shows that there is a relatively large urbanised catchment which lies to the north of the motorway corridor and west of King Georges Road. The "as-built" drawings show that there is limited inlet capacity located in the western kerbline of King Georges Road between the overpass and Shorter Avenue. Furthermore, it appears that a single pipe of unknown diameter, which crosses King Georges Road immediately south of Shorter Avenue, controls runoff from a 3 ha highly urbanised catchment (refer **Figure 3.1**, Sheet 1 of 2).[7]

[7] The "as-built" drawings show that this drainage line comprises a 600 mm diameter pipe where it connects to Drainage Line C. For the purpose of the present investigation it has been assumed that this drainage line comprises a 450 mm diameter pipe where it crosses King Georges Road immediately south of Shorter Avenue.

Runoff from the westbound on-ramp to the motorway is controlled by a minor piped drainage system which drains toward the sag in King Georges Road south of the overpass. Runoff draining to the sag is conveyed in the easterly direction where it discharges to a concrete lined channel which runs to the south of Water Quality Pond 1.

West of the crest in the motorway at about MC 1650, the detailed design drawings show that there are two minor drainage lines which control runoff from the surface of the M5 South West Motorway. A tailout drain was also observed in the field on the northern side of the motorway at about MC 1600. It is noted that a median inlet, which is shown on the "as-built" drawings to be located where the existing westbound carriageway transitions from super-elevation to normal crossfall, could not be observed in the field.

The detail design drawings also show a 1350 mm diameter pipe crosses the motorway corridor west of the Penshurst Road underpass at MC 1440 (shown as transverse drainage structure **XD0** on **Figure 1.1**). **Figure 3.1**, Sheet 1 of 2 shows the location where the 1350 mm diameter pipe crosses the motorway corridor and the extent of the upstream catchment. Runoff conveyed in the 1350 mm diameter pipe discharges to a vegetated channel which runs in a westerly direction on the southern side of the motorway. Runoff which originates from the motorway corridor west of the crest at about MC 1650 ultimately discharges to the main arm of Salt Pan Creek which is lcoated about 2.7 km to the west.

3.2 Hydrologic and Hydraulic Modelling

The assessment of the hydraulic capacity of the existing pavement drainage system was undertaken using the DRAINS modelling software. DRAINS converts storm rainfall to runoff and routes flows through networks of pipes and 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.

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

Adopted DRAINS model parameters comprised initial rainfall losses of 1 mm and 10 mm for paved and grassed areas, respectively. An antecedent moisture condition of 3 was adopted, reflecting rather wet conditions prior to the occurrence of the storm and the soil type was set equal to 3, which corresponds with a soil of comparatively high runoff potential.

As no survey of the current motorway drainage system is presently available, details of the existing pavement drainage lines were taken from the detailed design and "as-built" drawings. Contour sets derived from LiDAR survey data and the latest road design model were used in combination with the detailed design and "as-built" drawings to define the sub-catchments draining to the existing pavement drainage system.

3.3 Capacity of Existing Pavement Drainage System

The investigation found that the 1500 mm diameter pipe which runs from the sag beneath the Cooloongatta Road overpass to Water Quality Pond 1 has sufficient capacity to convey peak flows up to 100 year ARI event, with the pipe only running partially full for events up to this return period.

The investigation also found that Drainage Line A will surcharge during events as frequent as 5 year ARI event, where it runs along the median immediately west of the King Georges Road overpass, due to insufficient capacity in the existing 375 mm diameter pipe. Stormwater would pond across the eastbound off-ramp at the location of the sag at about MC 1760 in a 20 year ARI event.

Widths of flow of over 3 m are present in a 20 year ARI event along both sides of the motorway. However, given the wide shoulders which run along the edges of both carriageways, the intrusion of flow into the trafficable lanes would be minimal.

Surcharge of the local stormwater drainage system which controls runoff from the highly urbanised catchment which lies to the north of the motorway corridor and west of King Georges Road was found to occur for events as frequent as 2 year ARI. Stormwater which surcharges the drainage system in the western kerbline of King Georges Road north of the overpass will flow in a southerly direction across both the exit of the eastbound off-ramp and the entry of the westbound on-ramp, before ponding in the sag in King Georges Road south of the overpass. Stormwater ponding on the western side of the road corridor will inundate the northbound lanes of King Georges Road to a maximum depth of about 400 mm, before flowing in an easterly direction where it will join flow in the concrete lined channel which runs to the south of Water Quality Pond 1.

Due to a lack of inlet capacity along Drainage Line C, stormwater will ponding along the northern side of the noise wall between King Georges Road and Allambee Crescent during storm events which surcharge the local stormwater drainage system. Depths of ponding in this area would reach up to about 600 mm before stormwater would commence to flow in an easterly direction along the shared path. Stormwater surcharging the ponding area would be joined by overland flow discharging from Booragull Street and the western side of Cooloongatta Road, before turning south and discharging to the southern side of the motorway via the Cooloongatta Road overpass.

Further discussion on the impact of the KGRIU project on peak flows in the receiving drainage lines which drain to the east of King Georges Road is contained in **Chapter 4** of this report.

3.4 Capacity of Existing Transverse Drainage System West of Penshurst Road

The existing 1350 mm diameter pipe which crosses the motorway corridor west of the Penshurst Road underpass at MC1440 was found to have a hydrologic standard of about 100 year ARI.[8] However, it is noted that floodwater will pond beneath the motorway in Penshurst Road to depths exceeding 2 m during storms which surcharge the existing stormwater drainage system north of the motorway corridor. It is further noted that floodwater which surcharges the ponding area on Penshurst Road will discharge directly to Windara Reserve, which is located on the southern side of the motorway corridor. **Figure 3.1**, Sheet 1 of 2 shows the path overland flows will take during storms which surcharge the local stormwater drainage system.

Further discussion on the impact of the KGRIU project will have on peak flows in the receiving drainage lines draining to the west of King Georges Road is contained in **Chapter 4** of this report.

[8] This finding assumes that all of the runoff generated by the 11.7 ha catchment which lies to the north of the motorway corridor is capable of discharging to the inlet of the 1350 mm diameter pipe. In reality, flow surcharging the drainage system in John Mountford Reserve will bypass the inlet of the pipe.

4 FLOODING AND DRAINAGE ASSESSMENT – POST-UPGRADE CONDITIONS

4.1 Impacts of KGRIU Project on Flooding and Drainage Patterns

4.1.1 General

Table 4.1 over page gives peak flows at key locations in the receiving drainage lines under both pre- and post-upgrade conditions and should be referred to when reading the following section of the report.

4.1.2 Salt Pan Creek Catchment

The KGRIU project will result in a minor increase in peak flows discharging across the motorway corridor via both the existing 1350 mm diameter transverse drainage structure and the Penshurst Road underpass for events up to 100 year ARI (refer Peak Flow Identifier **SPC1** on **Figure 4.1**, Sheet 1 of 2). As flooding in this area is confined to the sag in Penshurst Road and Windara Reserve, the minor increase in peak flows will not have an impact on existing residential development.

The KGRIU project will have a minor impact on peak flows in the vegetated channel which runs through Windara Reserve for events up to about 20 year ARI. However, it will have no impact on the peak 100 year ARI flow (refer Peak Flow Identifier **SPC2** on **Figure 4.1**, Sheet 1 of 2).

4.1.3 Wolli Creek Catchment

By inspection of **Figure 2.7**, the works associated with the KGRIU project lie outside the extent of the PMF event. As a result, any changes to finished surface levels associated with the road works will not impact flooding patterns on Wolli Creek.

The investigation into the upgrade requirements for the pavement drainage system of the motorway (refer **Section 4.2** for details) showed that the road works will not have an impact on peak flows discharging to Wolli Creek via Drainage Line A for all events up to 100 year ARI.

The impact of the KGRIU project on peak flows in the receiving drainage lines which drain to the east of King Georges Road are summarised as follows:

- There will be no increase in peak flows discharging east from the sag in King Georges Road (refer Peak Flow Identifier **WC1** on **Figure 4.1**, Sheet 2 of 2). This is principally due to the proposed upgrade of the stormwater drainage system at the intersection of King Georges Road and the eastbound off-ramp, which has the effect of increasing the flow which is conveyed in Drainage Line C.
- Peak flows discharging across the Cooloongatta Road overpass will be reduced for events up to 100 year ARI (refer Peak Flow Identifier **WC2** on **Figure 4.1**, Sheet 2 of 2). This is due to the proposed improvements to the inlet capacity of Drainage Line C, principally in the vicinity of the ponding area located between King Georges Road and Allambee Crescent.
- There will be a reduction in peak flows in the tributary arm of Wolli Creek immediately upstream of the outlet of Drainage Line A for events up to 100 year ARI (refer Peak Flow Identifier **WC3** on **Figure 4.1**, Sheet 2 of 2). This is a result of the reduction which will occur in peak flows which presently discharge across the Cooloongatta Road overpass.

TABLE 4.1
IMPACT OF KGRIU PROJECT ON PEAK FLOWS[1,2]

Catchment	Location Identifier[3]	Location	Pre-Upgrade Conditions			Post-Upgrade Conditions			Difference[4]		
			5 year ARI	20 year ARI	100 year ARI	5 year ARI	20 year ARI	100 year ARI	5 year ARI	20 year ARI	100 year ARI
Wolli Creek	WC1	Tributary arm of Wolli Creek immediately east of sag in King Georges Road (piped + overland)	3.26	5.10	7.50	3.26	5.10	7.50	0	0	0
	WC2	Flow surcharging Drainage Line C and discharging across Cooloongatta Road overpass.	0.44	0.99	1.49	0.28	0.67	0.96	-0.16	-0.32	-0.53
	WC3	Tributary arm of Wolli Creek immediately upstream of outlet of Drainage Line A.	4.98	8.08	11.90	4.93	7.78	11.30	-0.05	-0.3	-0.60
	WC4	Drainage Line A – Outlet of 1500 mm diameter pipe at location of bifurcation pit controlling flow discharging to Water Quality Pond 1	1.59	2.24	2.83	1.78	2.41	2.87	0.19	0.17	0.04
	WC5	Drainage Line A - Outlet of 450 mm diameter pipe at location of bifurcation pit controlling flow discharging to Water Quality Pond 1	0.23	0.29	0.33	0.23	0.29	0.33	0	0	0
	WC6	Tributary arm of Wolli Creek immediately downstream of Kooemba Road.	10.00	15.90	22.40	10.00	15.60	21.80	0	-0.30	-0.60
	WC7	Drainage Line C - Outlet of 1800 mm diameter pipe at commencement of concrete lined channel running along northern side of motorway corridor.	3.39	4.55	5.37	4.77	6.26	7.14	1.38	1.71	1.77
	WC8	Inlet of transverse drainage structure XD1.	25.70	41.60	56.50	27.10	42.90	58.00	1.40	1.30	1.50
Salt Pan Creek	SPC1	Total flow discharging across motorway corridor at Penshurst Road (combination of flow in 1350 mm diameter transverse drainage structure and surcharge flow onto underpass).	4.53	6.15	7.45	4.55	6.20	7.51	0.02	0.05	0.06
	SPC2	Vegetated channel located in Windara Reserve west of Penshurst Road	6.78	9.38	11.30	6.87	9.45	11.30	0.09	0.07	0

1. Peak flows have been quoted to more than one decimal place for comparative purposes.
2. Peak flows are for design storm of 25 minutes duration which is generally critical for maximising flows in the vicinity of the KGRIU project.
3. Refer **Figure 4.1** (2 Sheets) for peak flow location and identifier.
4. Note that a positive value represents an increase in peak flow when compared to pre-upgrade conditions.

- Whilst there will be a minor increase in the peak flow discharging from the motorway drainage system to the tributary arm of Wolli Creek (refer Peak Flow Identifier **WC4** on **Figure 4.1**, Sheet 2 of 2), this will not result in an increase in peak flows in the receiving drainage line immediately downstream of Kooemba Road (refer Peak Flow Identifier **WC6** on **Figure 4.1**, Sheet 2 of 2). This is a result of the reduction which will occur in peak flows which presently discharge across the Cooloongatta Road overpass.

- There will be an increase in peak flows in the concrete lined channel into which Drainage Line C discharges for events up to 100 year ARI (refer Peak Flow Identifier **WC7** on **Figure 4.1**, Sheet 2 of 2). This is a result of the proposed improvements to the inlet capacity of the drainage line along its length.

  The concrete lined channel into which Drainage Line C discharges is 2.3 m in width and reduces in depth from 2.5 m at the outlet of the existing 1800 mm diameter pipe to 1.2 m over a distance of about 30 m. The design drawings show that the invert of the channel has been graded at 0.6%. Based on the above, the existing concrete lined channel has a minimum capacity of about 9 m^3/s, which is greater than the peak 100 year ARI flow discharging from Drainage Line C in a 100 year ARI event under post-upgrade conditions.

  Figure 2.5 shows that floodwater presently surcharges the inlet of transverse drainage structure XD1 in a 100 year ARI event, where it flows in an easterly direction along the northern side of the motorway corridor before discharging to the main arm of Wolli Creek via the Kindilan Street underpass. Whilst the proposed improvements to the inlet capacity of Drainage Line C will increase peak flows at the inlet of transverse drainage structure XD1 (refer Peak Flow Identifier **WC8** on **Figure 4.1**, Sheet 2 of 2) and hence the magnitude of the flow discharging to the main arm of Wolli Creek via the Kindilan Street underpass, flooding conditions in existing development will not be exacerbated as a result of the KGRIU project.[9]

4.2 Possible Effects of Future Climate Change on Flooding Behaviour

Scientific evidence shows that climate change will lead to sea level rise and potentially increase flood producing rainfall intensities. The significance of these effects on flood behaviour will vary depending on geographic location and local topographic conditions. Climate change impacts on flood producing rainfall events show a trend for larger scale storms and resulting depths of rainfall to increase, whilst future impacts on sea levels are likely to result in a continuation of the rise which has been observed over the last 20 years.[10]

OEH recommends that its guideline *Practical Considerations of Climate Change, 2007* be used as the basis for examining climate change induced increases in rainfall intensities in projects undertaken under the State Floodplain Management Program and the Floodplain Development Manual. The guideline recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on

[9] It is noted that the structure of the RAFTS model developed as part of the original design of the M5 East Motorway and subsequently adopted as part of the present investigation, did not include the surcharge flows which have been identified in King Georges Road and the Cooloongatta Road underpass. As a result, the peak flow discharging along the northern side of the motorway corridor east of transverse drainage structure XD1 is likely to be similar to that shown on **Figure 2.5** under post-upgrade conditions.

[10] Based on current projections, sea levels rise will not affect peak flood levels in the vicinity of the KGRIU and WestConnex M5 projects given the invert level of Wolli Creek upstream of Kingsgrove Road lies above RL 12 m AHD.

increases in rainfall intensities ranging between 10 and 30 per cent. On current projections, the increase in rainfalls within the design life of the KGRIU and WestConnex M5 projects is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit. Under present day climatic conditions, increasing the 100 year ARI design rainfall intensities by 10 per cent would produce a 200 year ARI flood; and increasing those rainfalls by 30 per cent would produce a 500 year ARI event.

Table 2.1 gives peak flows at selected location along Wolli Creek for both 200 and 500 year ARI events. As the analyses undertaken as part of the present investigation showed that both the KGRIU and WestConnex M5 projects will not be affected by a PMF event, then by inspection, potential increases in peak 100 year ARI flows (and hence peak 100 year ARI flood levels) in the range 10 to 30 per cent will not cause flooding of the upgraded section of motorway.

4.3 Pavement Drainage System Upgrade Requirements

In consultation with Roads and Maritime, it was determined that the principal criterion to be used in the development of the pavement drainage strategy for the KGRIU project was to ensure that the width of the trafficable lanes is not to be reduced to less than 2.5 m during the critical 20 year ARI event. Based on the understanding that the ultimate lane width will be 3.2 m and both kerb side and median shoulders will be 0.5 m in width, the maximum allowable width of flow in the critical 20 year ARI event equated to 1.2 m (i.e. 3.2 - 2.5 + 0.5 = 1.2 m).

The DRAINS model developed as part of the present investigation (refer **Section 3.2** for details) was used to develop the pavement drainage strategy for the KGRIU project, the layout of which is shown on **Figure 4.1** (2 Sheets).

The strategy was developed with the aim of not disturbing as far as is practicable the existing Continuous Reinforced Concrete Pavement (CRCP) which runs from a location immediately west of the King Georges Road overpass east to the limit of works. The strategy also aims to connect into the existing trunk line of Drainage Line A at the location of existing pits, rather than to construct new pits that would need to be up to 5 m deep. **Table 4.2** over page summarises the number of new pits (by type) and length of pipes (by diameter) which comprise the pavement drainage strategy for the KGRIU project.

The assessment found that there is sufficient residual capacity within the 1500 mm diameter pipe which drains the sag in the M5 East Motorway beneath the Cooloongatta Road overpass for surcharge not to occur in the widened sections of motorway.

It will be necessary to incorporate additional capacity in the median of the westbound carriageway immediately west of the King Georges Road overpass due to there being insufficient capacity within the piped drainage system at this location. Because the original M5 East Motorway project was constructed using a Continuous Reinforced Concrete Pavement (CRCP), it is recommended that a shallow reinforced concrete trench type drain be constructed directly beneath the F-type barrier at this location. The trench type drain would need to link with the existing median inlet pits and provide additional capacity during storms when the Hydraulic Grade Line rises toward the surface of the pavement. The trench drain arrangement would not need to extend east beneath the King Georges Road overpass as it was found that the existing 450 mm diameter pipe which is located in the median has sufficient capacity to convey the peak 20 year ARI flow.

TABLE 4.2
SUMMARY OF NEW ELEMENTS COMPRISING
PAVEMENT DRAINAGE STRATEGY FOR KGRIU PROJECT[1]

Drainage Element	Diameter (mm) / Pit Type[2]	Total Pipe Length (m) / No. of Pits/Headwalls
Reinforced Concrete Pipe	375	2595
	450	141
	525	132
	600	115
	675	100
	750	42
	825	26
	900	10
	1050	20
Pit/Headwall[2,3]	SA2 (MD.R11.B01.A)	61
	SAS (MD.R11.B01.A)	2
	S02 (MD.R11.B24.A)	14
	GP-TF-SG (MD.R11.B24.A)	143
	MGOS (MD.R11.B31.A)	4
	Headwall (MD.R11.A02.A)	2

1. **Figure 4.1** (2 Sheets) shows the layout of the new pavement drainage system.
2. Refer Roads and Maritime standard drawings for pit/headwall details.
3. Does not include existing pits which will need to be adjusted as part of road works.

Due to the adoption of narrower shoulders, it will be necessary to install a similar trench type drain arrangement directly beneath the King Georges Road overpass and also to its west along the northern side of the eastbound carriageway. As there are no kerb inlet pits in these locations, new grated inlet structures similar to the opening on an F–Type barrier pit will need to be incorporated in the design of the trench drain arrangement.

Existing constraints in the capacity of Drainage Line A downstream of the existing sag in the eastbound off-ramp mean that minor ponding will occur across the widened off-ramp during a 20 year ARI event. A new 450 mm diameter pipe discharging to an existing 375 mm diameter pipe has been incorporated in the pavement drainage strategy aimed at minimising the hydraulic losses in this section of the drainage system.

Whilst additional inlet capacity has been provided on both sides of King Georges Road north of the overpass, stormwater will still flow in a southerly direction across the exit of the eastbound off-ramp and the entry to the westbound on-ramp during storms larger than about 5 year ARI.

Additional inlet capacity has been provided on the northern side of the motorway between King Georges Road and Allambee Crescent sufficient that the existing ponding area will not be surcharged for events up to 100 year ARI.

Whilst the width of the shoulders on the off- and on-ramps west of the King Georges Road overpass will increase to 2.5 m, it will be necessary to install a minor pit and pipe system west of the crest in the motorway located at about MC 1650. This will require a new outlet headwall arrangement to be provided on the northern side of the motorway at about MC 1550. It is not proposed to incorporate a drainage system in the Penshurst Road bridge widening works as the widths of flow along the edge of the motorway will not exceed 2 m in the critical 20 year ARI event.

5 AQUAPLANING ASSESSMENT

5.1 Background

Pneumatic tyres on motor vehicles are intended to deform under load thus creating a flat contact area with the road pavement. On wet pavements, water must be expelled from this contact area because it reduces the available friction and aquaplaning may result if water remains trapped between the tyre and the pavement.

The greater the vehicle speed, the less time there is available to expel the water. This is the main reason for the decrease of friction with speed on wet pavements. Large, open flow channels provided by the tyre tread or by the pavement macro-texture allow better and faster drainage thereby reducing the dependence of skid resistance on vehicle speed.

Aquaplaning may therefore occur when the grooves in the tyres of a motor vehicle are unable to displace the water on the road surface at a sufficient rate for the tyres to maintain contact with the road pavement, and the tyres of the moving vehicle become completely separated from the road surface.

The risk of aquaplaning occurring is increased with increasing vehicle speed and depth of water present on the road surface. Speed is a significant factor in aquaplaning, with the risk of a vehicle losing traction greatly reduced for speeds below 80 km/hr.

A thick water film could be produced by high rainfall intensity, or ponding of water in wheelpath ruts. Critical locations for developing excessive water depths or ponding are curve transitions, where long flow paths, lengths and low crossfalls may occur.

5.2 Design Criteria

Roads and Maritime Technical Direction (draft) entitled *"Pavement Surface Water Depth Criteria"* (RTA, 2001) sets out the following criteria for assessing acceptable sheet flow conditions across a road surface:

For a 50 mm per hour rainfall design event:

- *the maximum water depths at any point on the pavement must not be more than 5 mm in the through lanes;*
- *the maximum water depths at any point on the pavement must not be more than 5 mm at intersections, and on the auxiliary lanes provided on the approach to an intersection; and*
- *the maximum change in the depth of flow across the pavement must not exceed 5 mm over any 10 metres.*

A more stringent requirement of limiting the maximum water depth to 4 mm where the design speed is 80 km per hour or higher is contained in the more recent publication *"Guide to Road Design Part 5: Drainage Design"* (Austroads, 2003).[11]

[11] It is noted that the designers of the original M5 East Motorway would have adopted the 5 mm threshold depth.

The relationship to be adopted for deriving depths of surface sheet flow over pavements is shown in **Equation 5.1** over, which is a metric version of a method originally developed by Gallaway et al (1979) for the US Federal Highway Administration:

$$d_w = \frac{0.10286 T_{xd}^{\;0.11} L^{0.43} I^{\;0.59}}{S^{0.42}} - T_{xd} \qquad \text{...Equation 5.1}$$

Where:

- d_w = surface water depth above the macrotexture asperities (mm),
- T_{xd} = pavement macrotexture depth (mm),
- L = drainage path length (m),
- S = average slope of the drainage path (%),
- I = rainfall intensity (mm/h).

5.3 Assessed Depths of Sheet Flow

The depth of sheet flow was computed at a number of critical locations along the KGRIU project based on *Equation 5.1*. These generally correspond to locations at which the pavement transitions between normal crossfall and superelevation, or where the flow path length will be significantly increased as a result of proposed pavement widening. **Figure 4.1** (2 Sheets) shows the location where aquaplaning checks have been undertaken as part of the present investigation.

Pavement macrotexture depths of 0.9 mm and 0.4 mm were used for the purpose of the present investigation. A value of 0.9 mm is representative of an open graded asphalt surface with some allowance built in for future wear (DTMR, 2010). A value of 0.4 mm was used as a lower bound to test the sensitivity of calculated sheet flow depths.

The results of the analysis (refer **Table 5.1** over page) show that depths of sheet flow will exceed the threshold value of 4 mm once the eastbound carriageway is widened between about MC 2634 and MC 2642 as part of the larger WestConnex project. The non-conformance is located at an a-typical pavement transition which occurs as a result of the crest in the motorway being located close to the switch between superelevation and normal crossfall.[12]

The results also show that the 4 mm threshold is currently exceeded on the westbound carriageway between about MC 1540 and MC 1600.[13] It is noted that depths of flow on the pavement at this location would actually be greater than that computed using *Equation 5.1*, as although shown on the design drawings (refer **Appendix B** for copy), there is no pit present in the median to intercept concentrated runoff which is flowing along the barrier kerb at the location where the pavement switches from superelevation to normal crossfall.

The results show that the computed depths of sheet flow are not sensitive to the adopted pavement macrotexture depth.

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[12] Note that the non-conformance is located immediately to the east of the KGRIU project and is associated with the future widening of the motorway as part of the larger WestConnex project.

[13] Note that on the new section of on-ramp, the depth of sheet flow along the same projected flow path was computed to be about 4.2 mm based on *Equation 5.1*. The reduced depth is a function of the slightly steeper grade of the pavement in this area.

TABLE 5.1
DEPTH OF SHEET FLOW OVER PAVEMENT SURFACE

Location[1]	Identifier [1]	Motorway Chainage	Assessed Flow Path Length (m)	Assessed Flow Path Slope (%)	Computed Depth of Sheet Flow (mm)	
					T_{xd} = 0.4 mm	T_{xd} = 0.9 mm
Eastbound Carriageway	E1[2]	2642	15	0.34	**4.32**	**4.26**
	E2[2]	2635	12.8	0.33	**4.07**	3.99
	E3[2]	2634	13.3	0.28	**4.47**	**4.43**
Westbound Carriageway	W1	2000	79	5.26	2.65	2.43
	W2	1540	91	1.84	**4.64**	**4.61**
Eastbound Off-Ramp	OR1	1975	39	2.20	2.85	2.65

1. Refer **Figure 4.1** (2 Sheets) for location of flow paths.
2. Flow path lengths assume extension of the motorway widening works east of the KGRIU project as part of the larger WestConnex project.

6 WATER QUALITY AND SPILL CONTAINMENT

6.1 Design Considerations

The Director General's requirements for the KGRIU project require an assessment of water quality impacts and mitigation measures to manage water pollution, with reference to relevant environmental water quality criteria, including the "*Australian and New Zealand Guidelines for Fresh and Marine Water Quality"* (ANZECC, 2000) and any applicable regional, local or site specific guidelines.

The ANZECC, 2000 guidelines provide a nationally consistent approach to water quality management based on the principle of ecological sustainable development of water resources. The guidelines contain a set of tools for the assessment and management of water quality across a range of water resource types and based on designated environmental values.

Within the broader catchment context, the ANZECC, 2000 guidelines have been used to develop the following catchment management plans:

- Cooks River Stormwater Management Plan (PPK, 1999)
- Botany Bay and Catchment Water Quality Improvement Plan (SMCMA, 2011)

A primary objective of SMCMA, 2011 was to establish stormwater pollution reduction targets (in terms of gross pollutants, total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN)) for all new development and re-development within the Botany Bay catchment to protect the condition of the bay, its estuaries and waterways. These pollutant reduction targets are presented in **Table 6.1** over page and have subsequently been included in a number of local council engineering specifications and planning policies, including "*Rockdale Technical Specification: Stormwater Management"* (RCC, 2011).

Pollution reduction targets recommended in "*Managing Urban Stormwater: Council Handbook (Revised Draft)"* (EPA, 2007) are also shown in **Table 6.1** over page. These targets are commonly adopted for new development across NSW in the absence of local guidelines such as that provided by SMCMA, 2011. For the purpose of the present investigation, the SMCMA, 2011 targets are considered more appropriate as they have been based on a catchment specific assessment of Botany Bay and its waterways. Furthermore, the set of targets shown in **Table 6.1** for large redevelopment type projects are considered to be applicable, given the scale of the KGRIU project.

Note that the Project Deed for the original M5 East Motorway project (constructed in 2000) required water quality ponds to have a minimum pond area corresponding to 2% of the contributing catchment area. The ability to retrofit water quality arrangements to meet current best practice guidelines for treatment of all runoff from the motorway (not just from the additional paved area associated with the upgrade works) may be constrained by the prevailing topography and limited corridor area as well as the configuration of existing road drainage systems.

Based on the above, upgrades to the existing water quality arrangements have been designed, as a minimum, to offset post-upgrade increases in pollutant loads compared with present day conditions. Further measures to meet the SMCMA, 2011 targets have also been considered within the limitations of the prevailing site constraints and are discussed in **Section 6.4**.

TABLE 6.1
POLLUTION REDUCTION TARGETS

Stormwater Pollutant	SMCMA, 2011		EPA, 2007
	Greenfield Development and Large Redevelopment(1)	Multi-Unit Dwellings, Commercial and Industrial Development, Small Re-developments	
Gross Pollutants	90%	90%	100% retention up to 3 month ARI peak flow
Total Suspended Solids (TSS)	85%	80%	85%
Total Phosphorus (TP)	60%	55%	65%
Total Nitrogen (TN)	45%	40%	45%

(1) Pollution reduction targets assessed as being applicable to the KGRIU project.

6.2 Existing Arrangements for Discharge of Pavement Drainage

Review of the as-built drainage drawings shows that existing water quality control measures within the M5 East Motorway corridor comprise a single water quality pond (**Water Quality Pond 1**) which incorporates provision for incident management storage and the capture of gross pollutants. **Figure 1.1** shows the location of Water Quality Pond 1, whilst several detailed design drawings showing key features of the structure are contained in **Appendix C** of this report.

Water Quality Pond 1 comprises a sediment storage zone, a macrophyte zone and an open water zone, as shown on **Figure 6.1**. A gross pollutant trap is also located at the inlet to the pond, whilst provision for spill containment is incorporated in the sediment storage zone. The measures incorporated in Water Quality Pond 1 provide a level of treatment that is broadly consistent with current Roads and Maritime practice for motorways in an urban environment.

6.3 Impacts of KGRIU Project on Water Quality

The main risk to water quality in the drainage lines downstream of road corridor is due to runoff from impervious areas which can transport contaminants that build-up on the road surface during dry weather. Contaminants in road surface runoff include suspended sediments, heavy metals, litter, nutrients such as nitrogen and phosphorus, oils and greases.

The KGRIU project will have a negligible effect on the quality of stormwater runoff within the Salt Pan Creek catchment, given the minor nature of the road widening works west of about MC 1650. However, the increase in impervious area associated with the KGRIU project has the potential for adverse impacts on the water quality in Wolli Creek due to an increase in the build-up and subsequent transport of contaminants during rainfall events. As a result, there will be a reduction in the level of treatment provided to runoff from the motorway by Water Quality Pond 1, prior to discharge into Wolli Creek.

To demonstrate the level of impact that the proposed road works will have on existing water quality in Wolli Creek, an investigation was carried out using the MUSIC rainfall-runoff modelling software. A MUSIC model was established to reflect the contributing catchment and water quality arrangement at Water Quality Pond 1 under present day conditions. Rainfall records from the Sydney Airport pluviograph recorder for the period 1962 to 2006 were selected for use in the investigation, and a six minute time step was adopted to best match the size and residence time of Water Quality Pond 1.

The sediment storage zone, macrophyte zone and open water zones shown in **Figure 6.1** were modelled as a treatment train to assess the performance of the water quality pond in retaining pollutants generated from the catchment. The model was then adjusted to reflect post-upgrade conditions by adjusting boundaries and per cent impervious area in the contributing catchment.

The changes in pollutant loads resulting from the road upgrade works are summarised in **Table 6.2** over page[14]. Water Quality Pond 1 provides 100% retention of gross pollutants under both present day and post upgrade conditions (**Column [B]**). It is predicted that TSS discharging from Water Quality Pond 1 will increase by 30 per cent, from an annual load of 2,790 kg to 3,650 kg (refer **Column [C]**). Similar relative increases are predicted to occur in TN and TP loads (**Columns [D]** and **[E]**).

6.4 Assessment of Mitigation Measures

Following a review of the preliminary study findings, Roads and Maritime advised that Water Quality Pond 1 should be upgraded to achieve the SMCMA, 2011 reduction targets for the <u>incremental increase</u> in pollutant load attributable to the KGRIU project. MUSIC modelling shows that this outcome can be achieved by converting the 140 m^2 open water area into a biofiltration system (refer **Table 6.2**).

[14]The assessment includes an allowance for future widening of the motorway associated with the WestConnex M5 project.

TABLE 6.2
SUMMARY OF WATER QUALITY PERFORMANCE FOR WATER QUALITY POND 1[(1,2)]

Scenario **[A]**	**Gross Pollutants (kg/year)** **[B]**	**TSS (kg/year)** **[C]**	**TP (kg/year)** **[D]**	**TN (kg/year)** **[E]**
Reduction Target (SMCMA, 2011)	90%	85%	60%	45%
Present Day Inflow to Pond	1,760	10,000	23.2	177
Present Day Outflow from Pond	0 *[100%]*	2,790 *[72%]*	10.4 *[55%]*	130 *[27%]*
Post-KGRIU Project Inflow to Pond	2,040	12,300	28	211
Incremental Increase in Pollutant Load Attributed to KGRIU Project	280 (2,040 – 1,760 = 280)	2,300 (12,300 - 10,000 = 2,300)	4.8 (28 – 23.2 = 4.8)	34 (211 – 177 = 34)
Total Allowable Pollutant Load from Pond Post-KGRIU Project[(3)]	**28** (0 + ((100 – 90) / 100) x 280 = 28)	**3,135** (2,790 + ((100 - 85) / 100) x 2,300 = 3,135)	**12.32** (10.4 + ((100 - 60) / 100) x 4.8 = 12.32)	**148.7** (130 + ((100-45) / 100) x 34 = 152.1)
Post-KGRIU Project Outflow from Pond (No Adjustments to Pond)[(4)]	0	3,650	13.2	159
Post-KGRIU Project Outflow from Pond (Conversion of 140 m^2 Open Water Area to Biofiltration System)[(4)]	**0**	**2,910**	**11.7**	**145**

(1) Refer **Figure 1.1** for location of Water Quality Pond 1.

(2) The assessment includes an allowance for future widening of the motorway associated with the WestConnex M5 project.

(3) Assumes reduction target is applied to incremental increase in pollutant load only.

7 EROSION AND SEDIMENT CONTROL STRATEGY

7.1 General

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

It is recommended that the strategy presented in this section of the report be used as a starting point for preparation of the Soil and Water Management Plan (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).
- *Roads and Maritime Erosion and Sedimentation Management Procedure* (Roads and Maritime, 2008).
- *QA Specification G38 – Soil and Water Management* (Roads and Maritime, 2014).

7.2 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 corridor, 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 any temporary drainage lines through the site;
- separation of on-site and off-site water wherever possible, and the diversion of clean water from upslope areas through the construction corridor;
- site maintenance requirements; and
- progressive site rehabilitation.

7.3 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) [15], is less than 150 m^3.

Figures 7.1 and **7.2** show the extent of land which will be disturbed during the construction phase of the project (excluding areas of existing pavement) and identifies the receiving drainage lines to which runoff from these areas will discharge. . **Table 7.1** summarises the parameters which are constant in the RUSLE for the site, whilst **Table 7.2** over page gives the average annual soil loss derived for each disturbed area, as well as the RUSLE parameters which are unique to each.

TABLE 7.1
CONSTANT PARAMETERS ADOPTED FOR APPLICATION TO THE RUSLE

Parameter	Value	Comment
Rainfall Intensity for 2 year ARI, 6 hour duration design storm	12.4 mm/hr	For upper reaches of Wolli Creek catchment.
Rainfall Erosivity Factor (R)	3316	Based on 2 year ARI, 6 hour duration design storm
Soil/sediment Type(1,2)	D D	Birrong Soil Landscape Blacktown Soil Landscape
Soil Erodibility Factor (K)(3)	0.047 0.038	Birrong Soil Landscape Blacktown Soil Landscape
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.

1. Refer **Figure 7.1** for extent of Birrong and Blacktown soil landscapes
2. The soil type along the motorway corridor may differ from that shown on the Soil Landscapes of the Sydney 1:100,000 Sheet (SCS, 1989) given the highly disturbed nature of the area.
3. Values taken from Table C20 in Appendix C of Landcom, 2004

The analysis showed that the average annual sediment load at any one outlet will not exceed the threshold value of 150 m^3, with the exception of the following:

- the total disturbed area contributing to flow in the vegetated channel which runs along the southern side of the motorway corridor west of the Penshurst Road underpass; and
- the total disturbed area contributing to flow discharging to Water Quality Pond 1.

It is noted that the values presented in **Table 7.2** represent the worst case scenario, where it is assumed that the clearing and grubbing of the steep batter areas along the Motorway is not staged. Further analysis showed that provided the works are staged such that the clearing and grubbing of the steep batter areas is limited to a maximum area of 4,000 m^2, then the average annual sediment load draining to the receiving drainage lines will not exceed 150 m^3.

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

TABLE 7.2
ESTIMATED AVERAGE ANNUAL SOIL LOSS FROM ROAD CORRIDOR

Description of Disturbed Area[1]	Soil Landscape	Slope Length (m)	Gradient (%)	LS Factor	Sediment Load (tonnes/ha/yr)	Area Contributing to On-site Water (ha)	Sediment Load (m^3/yr)
Disturbed area on northern side of Motorway east of Penshurst Road underpass draining to vegetated channel south of outlet headwall located at Station 1290.	Blacktown	10.0	50.0	3.33	546	0.928	33.7
Disturbed area on northern side of Motorway west of Penshurst Road underpass draining to vegetated channel south of outlet headwall located at Station 1290.	Birrong	10.0	50.0	3.33	674.71	0.111	49.9
Disturbed area on southern side of Motorway east of Penshurst Road underpass draining to vegetated channel south of outlet headwall located at Station 1290.	Blacktown	10.0	50.0	3.33	546	0.1065	38.7
Disturbed area on northern side of Motorway west of Penshurst Road underpass draining to vegetated channel south of outlet headwall located at Station 1290.	Birrong	10.0	50.0	3.33	674.71	0.113	50.8
Total Sediment Load in Runoff Contributing to Flow in Vegetated Channel South of Outlet Headwall Located at Station 1290							**173.1**
Disturbed area draining directly to concrete lined channel running south of Water Quality Pond 1.	Blacktown	15	50	3.33	546	0.206	75.0
Total Sediment Load in Runoff Contributing Directly to Flow in Concrete Lined Channel Running South of Water Quality Pond 1.							**75.0**
Disturbed area in north-west corner of KGRI draining to concrete lined channel downstream of Drainage Line C.	Blacktown	15	50	3.33	546	0.143	51.9
Disturbed area in north-east corner of KGRI draining to concrete lined channel downstream of Drainage Line C.	Blacktown	50	1	0.17	28	0.007	0.1
Disturbed area along realigned section of Drainage Line C immediately upstream of concrete lined channel.	Blacktown	200	1	0.24	39	0.173	4.5
Total Sediment Load in Runoff Contributing to Flow in Concrete Lined Channel Immediately Downstream of Drainage Line C							**56.5**

Cont'd Over

TABLE 7.2 (Cont'd)
ESTIMATED AVERAGE ANNUAL SOIL LOSS FROM ROAD CORRIDOR

Description of Disturbed Area[1]	Soil Landscape	Slope Length (m)	Gradient (%)	LS Factor	Sediment Load (tonnes/ha/yr)	Area Contributing to On-site Water (ha)	Sediment Load (m^3/yr)
Disturbed area on northern side of motorway corridor between about Stations 1650 and 1850 draining to Drainage Line A.	Blacktown	20	50	3.33	546	0.240	87.3
Disturbed area on northern side of motorway corridor between about Stations 2170 and 2600 draining to Drainage Line A.	Blacktown	10	50	3.33	546	0.619	225.1
Disturbed area on southern side of motorway corridor between about Stations 2170 and 2725 draining to Drainage Line A.	Blacktown	10	50	3.33	546	1.084	394.2
Total Sediment Load in Runoff Contributing to Flow Discharging to Water Quality Pond 1							**706.6**

1. Refer **Figure 7.1** for location of disturbed areas.

Given the relatively confined nature of the construction works (i.e. narrow sections of new pavement combined with resurfacing of existing pavement), the implementation of effective localised erosion and sediment control measures aimed at minimising the volume of sediment which is transported from disturbed areas will be key to the control of sediment from the road corridor. 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
- stabilised drainage lines incorporating rock check dams at regular intervals.

As described in **Chapter 6**, Water Quality Pond 1 incorporates a large sediment settling and storage zone which will further assist in reducing the sediment load discharging from Drainage Line A to Wolli Creek.[16]

[16] Note that due to the large area of pavement which presently contributes to flow in Drainage Line A, there is insufficient volume available in Water Quality Pond 1 for it to be operated as a sediment retention basin capable of removing Type D soil particles.

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ANNEXURE A
ADOPTED RAFTS MODEL PARAMETERS

A1. Design Storms

A1.1 Rainfall Intensity

Design storms of return periods between 1 in 100 and 1 in 500 years were derived from Australian Rainfall & Runoff (ARR) (IEAust, 1998) for storm durations ranging between 30 minutes and 18 hours.

A1.2 Areal Reduction Factors

The rainfalls derived using the processes outlined in ARR, 1998 are applicable strictly to a point. In the case of a large catchment of over tens of square kilometres, it is not realistic to assume that the same rainfall intensity can be maintained over a large area, an areal reduction factor (ARF) is typically applied to obtain an intensity that is applicable over the entire area.

For this present study, ARR indicates that for a catchment area of 11.5 km^2, an ARF value of 1.0 should be applied to design rainfalls.

A1.3 Temporal Patterns

Temporal patterns for various zones in Australia are presented in ARR, 1998. These patterns are used in the conversion of a design rainfall depth with a specific ARI into a design flood of the same frequency. Patterns of average variability are assumed to provide the desired conversion. The patterns may be used for ARIs up to 500 years where the design rainfall data is extrapolated to this ARI.

A2. RAFTS Model Parameters

A2.1 Rainfall Losses

RAFTS requires losses to be applied to storm rainfall to determine the depth of surface runoff, as well as information on the time of travel of the flood wave through the catchment.

Infiltration losses are of two types: initial loss arising from water which is held in depressions which must be filled before runoff commences, and a continuing loss rate which depends on the type of soil and the duration of the storm event. The split catchment option was used for estimating hydrographs from each sub-catchment. This option separately models runoff from the pervious and impervious portions and combines them at the catchment outlet.

Losses from the impervious portion of the catchment are subject to less uncertainty resulting from antecedent rainfall conditions than from the pervious portion. Values of 1.5 mm for initial loss and zero continuing loss were adopted for impervious surfaces. The response of the model to initial losses from the pervious portion ranging between zero and 20 mm was tested for the 100 year ARI design storm event. The results showed that the peak discharge was not particularly sensitive to pervious initial loss, because about 50 per cent of the total catchment surface is impervious.

Loss values adopted for design flood estimation are shown in **Table A1** over.

TABLE A1
DESIGN LOSS VALUES

Type of Surface	Initial Loss (mm)	Continuing Loss (mm/h)
Pervious Areas	20	1.5
Impervious Areas	1.5	0

A2.2 Routing Parameters

During the early phases of the study it was found that the travel times in the WP RAFTS Model for the reach of Wolli Creek between Kingsgrove Road and Bexley Road were too long when compared to the results of the TUFLOW hydraulic model. The lag times in the WP RAFTS Model were therefore reduced based on an average flow velocity in the modelled reach of channel of 3 m/s (**Adjusted RAFTS Models**). **Figure 2.2** shows the relative timing of the discharge hydrograph which was generated by the Adjusted RAFTS Models and after it was routed through the TUFLOW hydraulic model.

Similar to the WP RAFTS Model, a Bx factor of 1.0 was incorporated in the Adjusted RAFTS Models.

A2.3 Surface Roughness Parameters

The WP RAFTS model developed as part of the detailed design of the original M5 East Motorway project contained Manning's n surface roughness values of 0.025 and 0.035 for the impervious and pervious portions of the catchment, respectively. No changes were made to these values as part of the present investigation.

ANNEXURE B
BACKGROUND TO TUFLOW MODEL DEVELOPMENT

B1. The TUFLOW Modelling Approach

TUFLOW solves the equations of flow at each point of a rectangular grid system which represent overland flow on the floodplain and along streets. The choice of grid point spacing depends on the need to accurately represent features on the floodplain which influence hydraulic behaviour and flow patterns (e.g. buildings, streets, changes in channel and floodplain dimensions, hydraulic structures which influence flow patterns, etc).

The basic equations of TUFLOW involve all of the terms of the St Venant equations of unsteady flow. Consequently the model is "fully dynamic" and once tuned will provide an accurate representation of the passage of the floodwave through the drainage system (both surface and piped) in terms of extent, depth, velocity and distribution of flow.

Pipe drainage and channel systems can be modelled as one-dimensional elements embedded in the larger two-dimensional domain which typically represents the wider floodplain. Flows are able to move between the one and two-dimensional elements of the model depending on the capacity characteristics of the drainage system being modelled.

B2. TUFLOW Model Setup

B2.1 Model Structure

The layout of the TUFLOW model developed as part of the present investigation is shown on **Figures 2.3** (2 Sheets). All of the features which influence the passage of flow were included in the TUFLOW model which comprises piped reaches on the main arms, cross drainage pipes, open channels which are modelled by cross sections normal to the direction of flow, as well as overland flow which is modelled by the rectangular grid. **Table B1** over gives details of the M5 East Motorway transverse drainage structures that were incorporated in the TUFLOW model.

In addition to the transverse drainage structures listed in **Table B1**, flood relief is also provided via the Karingal Street, Arinya Street and Lundy Avenue underpasses, details of which were also incorporated in the TUFLOW model.

Discharge hydrographs from the RAFTS sub-catchments were added as distributed flow at the model boundaries and at internal locations identified in the figure.

An important consideration of two-dimensional modelling is how best to represent the roads, fences, buildings and other features which influence the passage of flow over the natural surface. Two-dimensional modelling is very computationally intensive and it is not practicable to use a mesh of very fine elements without incurring very long times to complete the simulation, particularly for long duration flood events. The requirement for a reasonable simulation time influences the way in which these features are represented in the model.

After initial model testing, a 2 m grid spacing was found to provide the appropriate balance between the need to define features on the floodplain versus model run times. Grid elevations were based on available LiDAR survey data. Ridge and gully lines were added to the model where the grid spacing was considered too coarse to accurately represent important topographic features which influence the passage of overland flow, such as road centrelines and footpaths. It was important that the model recognised the ability of roads to capture overland flow and act as floodways.

TABLE B1
DETAILS OF M5 EAST MOTORWAY TRANSVERSE DRAINAGE STRUCTURES INCORPORATED INTO TUFLOW MODEL

Transverse Drainage Structure Identifier[1]	Dimensions (mm)[2]	Invert Level (m AHD)	
		Inlet on Northern Side of Motorway Corridor	Outlet to Wolli Creek
XD1	2 off 4200 x 1800 RCBC's	21.6	21.18
XD1A	1 off 1050 RCP	20.56	20.33
XD2	2 off 1200 RCP's	26.11	20.10
XD3	2 off 1200 RCP's	24.25	18.63
XD4	1 off 1800 RCP	20.25	15.88
XD5	1 off 1050 RCP	20.00	15.36
XD6	1 off 1050 RCP	15.90	15.03
XD7	1 off 1050 RCP	14.97	14.84
XD8	1 off 1050 RCP	14.80	13.81
XD9	2 off 2100 x 1800 RCBC's	13.87	13.57
XD10	1 off 1500 RCP	13.20	11.17
XD11	1 off 1350 RCP	11.55	10.50
XD12	1 off 1500 RCP	13.55	10.13
XD13	1 off 1500 RCP	14.57	9.51
XD14	1 off 1050 RCP	18.60	7.33
XD15	1 off 2400 RCP	5.63	5.21

1. Refer **Figure 2.3** for location of transverse drainage structures.
2. RCBC = Reinforced Concrete Box Culvert RCP = Reinforced Concrete Pipe

For modelling purposes it was assumed that the noise walls which run along both sides of the motorway corridor would prevent the influx of floodwater onto the motorway corridor at locations where the existing F-type barrier arrangement is overtopped. This assumption will need to be reviewed as part of any future design of the larger WestConnex project as it will be necessary to ensure that flooding of the motorway east of the KGRIU project will not occur at locations where floodwater will either pond up against or flow along the face of these structures.

The footprints of a large number of individual buildings located in the two-dimensional model domain were digitised and assigned a high hydraulic roughness value relative to the more hydraulically efficient roads and flow paths through allotments. This accounted for their blocking effect on flow whilst maintaining a correct estimate of floodplain storage in the model. It was not practicable to model the individual fences surrounding the many allotments in the study area. They comprised many varieties (brick, paling colorbond, etc) of various degrees of permeability and resistance to flow. It was assumed that there would be sufficient openings in the fences to allow water to enter the properties, whether as flow under or through fences and via openings at driveways.

B2.1 Model Parameters

The main physical parameter for TUFLOW is the hydraulic roughness. Hydraulic roughness is required for each of the various types of surfaces comprising the overland flow paths, as well as for the cross sections representing the geometric characteristics of the creek between King Georges Road and Bexley Road. In addition to the energy lost by bed friction, obstructions to flow also dissipate energy by forcing water to change direction and velocity and by forming eddies. Hydraulic modelling traditionally represents all of these effects via the surface roughness parameter known as "Manning's n". Flow in the piped system also requires an estimate of hydraulic roughness.

There are no historic flood level data available to assist with the tuning of the model for roughness. Assessment of Manning's n values for the cross sections comprising the concrete lined and unlined sections of Wolli Creek was relatively straightforward. Cross sections taken normal to the direction of flow have traditionally been used for one-dimensional modelling of waterways and there are numerous previous studies and references in the engineering literature relating various types of surfaces to hydraulic roughness.

Table B2 presents the "best estimate" of hydraulic roughness values adopted for design purposes. The adoption of a value of 0.02 for the surfaces of roads, along with an adequate description of their widths and centreline and kerb elevations, allowed an accurate assessment of their conveyance capacity to be made. Similarly the high value of roughness adopted for buildings recognised that they completely blocked the flow but were capable of storing water when flooded.

TABLE B2
"BEST ESTIMATE" OF HYDRAULIC ROUGHNESS VALUES
ADOPTED FOR TUFLOW MODELLING

Surface Treatment	Manning's n Value
Concrete channel	0.015
Asphalt or concrete road surface	0.02
Well Maintained Grassed Cover e.g. sporting oval	0.03
Unlined channel/Flow over Road Impeded by Handrail	0.05
Grass/Lawns/Macrophytes	0.06
Trees	0.08
Creek bank	0.10
Fences Houses	1
Buildings	10