M2 Upgrade Environmental Assessment

Hills M2

23 April 2010

Environmental Assessment

Surface Water Assessment

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Prepared for

Hills M2

Prepared by

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Table of Contents

Terminology List

Terminology	Description
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500m3/s has an AEP of five per cent, it means that there is a five per cent chance (that is one in 20 chance) of a 500m3/s or larger flood event occurring in any one year (see also average recurrence interval).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as or larger then the selected event for example, floods with a discharge as great as or greater than the 20 year ARI flood will occur, on average, once in every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site location. It always relates to an area above a specific location.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving, for example metres per second (m/s).
Emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
Flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
Floodplain	Area of land that is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
Floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
Floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in the NSW Floodplain Development Manual (2005). Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
Flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
Flood planning area	The area of land below the FPL and thus subject to flood related development controls.
Flood planning levels (FPLs)	Are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and

Terminology	Description
	incorporated in management plans.
Flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
Flood prone land	Land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk is divided into 3 types, existing, future and continuing risks. They are described below: • Existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. • Future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. • Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
Flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
Habitable room	In a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to the NSW Floodplain Development Manual (2005) the hazard is flooding which has the potential to cause damage to the community.
Hydraulics	The term given to the study of water flow in waterways, in particular the evaluation of flow parameters such as water level and velocity
Hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
Hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
Local drainage	Smaller scale problems in urban areas.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purposes of the NSW

Terminology	Description
	Floodplain Development Manual (2005) major drainage involves: • The floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • Water depths generally in excess of 0.3m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • Major overland flowpaths through developed areas outside of defined drainage reserves; and/or • The potential to affect a number of buildings along the major flow path.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into council plans, policy, and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local flood risk management policy and EPIs.
Minor, moderate and major flooding	Both the SES and the BoM use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: • Minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. • Moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. • Major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
Modification measures	Measures that modify either the flood, the property or the response to flooding.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable maximum precipitation	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
Probability	A statistical measure of the expected chance of flooding (see AEP).

Terminology	Description
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the NSW Floodplain Development Manual (2005) it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Stage	Equivalent to water level (both measured with reference to a specified datum).
Stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
Survey plan	A plan prepared by a registered surveyor.
Water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
Note: project description terminology is contained in the project description.	

Executive Summary

Existing Environment

Transverse Drainage:- The M2 Motorway traverses through three main catchment areas of Darling Mills Creek, Devlins Creek and Terrys Creek whilst a number of smaller tributaries located towards the eastern end of the M2 (including Mars, University, Shrimptons and Porters Creeks) also form part of the Lane Cove River catchment. Within the limits of proposed widening works the motorway is crossed by some 26 local drainage lines which are served by transverse drainage structures comprising a combination of large concrete arches and box or pipe culverts. Large multi span bridge structures situated several metres above the normal water level are used to cross the three main creek waterways.

For the purposes of this study, existing flood conditions in the 100 year ARI design event have been estimated for the seven (7) transverse culvert structures which are to be extended due to the widening works, and a long reach of Devlins Creek that runs parallel to the motorway in an easterly direction and incorporates or influences the hydraulic behaviour of a number of culvert structures. Along the entire length of the reach modelled, the flood extent is typically contained within the riparian bush zone.

At University Creek, the existing flood behaviour in the vicinity of the M2 motorway appears to be influenced by a number of man made features. Flows from the upper catchment are initially controlled by a large diameter pipe and inlet structure immediately upstream of Talavera Road. The pipe flows are conveyed under the road and a building on the property located upstream of the M2, to discharge into an open channel near the inlet of the existing motorway culvert (Culvert 35). The hydraulic analyses indicate that the 100y ARI flood levels in this area may be higher than the adjoining motorway, which would therefore be overtopped in the existing situation.

At Shrimptons Creek, hydraulic modelling results indicate that the existing property access bridge, located just upstream of the motorway boundary, is constricting the waterway and controlling flood levels in this area.

Water Quality:- Between July and December 1994 (prior to the original motorway construction), samples were taken from sites downstream of the motorway to establish background Total Suspended Solids (TSS) averages for wet (128 mg/l) and dry (8 mg/l) conditions. Subsequent long term sampling results (post M2 construction) for wet events have calculated the median and average values to range between 5mg/l to 13mg/l (median) and 11mg/l to 32mg/l (average). Comparison of these results for the two alternative periods suggests that construction of the existing motorway has not had any significant impact on the water quality of downstream receiving waters.

Within the limits of the proposed project widening, there are thirty one (31) water quality basins originally provided to treat the low flow runoff draining from the existing motorway pavement surface via the stormwater pipe drainage networks. Low flow runoff (first flush) or contaminated spills washed from the road surface are directed through bifurcation pits that divert the water into the basins for containment and treatment. The first flush of runoff typically contains the higher concentration of sediments and larger particulate matter (waste materials from vehicles such as brake pad wear and metals). These settle out of the water when temporarily stored in the basin. Fluid type materials washed from the surface (such as fuels and oils) are less dense and float on the water surface allowing them to also be contained in the basin by use of special outlet arrangements.

The water sampling of the existing basins suggest that pollutants are being retained and the basins are therefore performing their intended function in helping to protect the quality of the receiving waters.

Receiving Environment - Native aquatic submerged and emergent vegetation is not abundant within the creeks of the study area. This is likely to be as a result of the chiefly rocky substrate found here, high water velocity during heavy rainfall and competition from introduced species. No assemblages of native aquatic plants were found that could be described as native vegetation communities. No aquatic plant species of conservation significance were recorded or considered likely to occur within the M2 corridor or surrounds. A variety of aquatic weeds (e.g. Water Milfoil (*Myriophyllum aquaticum*) and Watercress (*Rorippa nasturtiumaquaticum*)) are found along the waterways of the study area. Of these, three species are listed as noxious weeds: Long-leaf Willow Primrose (*Ludwigia longifolia*), Ludwigia (*Ludwigia peruviana*), and Sagittaria (*Sagittaria platyphylla*).

Prior to residential development in surrounding areas, the creeks of the locality are likely to have supported a diverse community of insects, fish, frogs, birds and mammals. The creeks are degraded to varying degrees as a result of a number of factors including increased erosion due to the concentration of stormwater flows, weed invasion, polluted catchment runoff and the presence of exotic fish species. As a result of this condition, frogs, fish and aquatic invertebrates that are sensitive to these forms of disturbance are unlikely to persist in these waterways. Nonetheless, a variety of disturbance tolerant fauna species remain.

The present condition of the creeks of the M2 corridor varies from highly modified to near-natural. The section of Darling Mills Creek crossed by the M2 corridor appears to be in relatively moderate condition, with low turbidity, little evidence of sedimentation and a low level of weed invasion. This area is likely to be inhabited by many species of native fish, the Eastern snake-necked Tortoise (*Chelodina longicollis*) the following frog species: the Green Stream Frog (*Litoria phyllochroa*), Peron's Tree Frog (*Litoria peronii*), Striped Marsh Frog (*Limnodynates peronii*) and Common Eastern Froglet (*Crinia signifera*).

The other creeks of the study area are more disturbed and are likely to contain a lower diversity and abundance of fish and frog species with the Plague Minnow becoming increasingly dominant in more disturbed areas.

Obstructions to fish movement within the M2 Corridor exist where waterways pass beneath the Motorway via culverts. Other barriers to fish passage include the retarding basin wall near Loyalty Road, North Rocks and weirs on the Lane Cove River). No threatened or protected aquatic invertebrate or fish species have been recorded in the waterways of the M2 Corridor. Introduced fish species recorded in the locality include Goldfish (*Carassius auratus*), Common Carp (*Cyprinus carpio*) and Plague Minnow (*Gambusia holbrooki*). Goldfish and Common Carp are not likely to be abundant in the small rocky streams of the study area however the Plague Minnow is found in all of the creeks, especially in disturbed areas. This species is listed as a Key Threatening Process due to its detrimental impacts upon tadpoles and frog eggs.

Impact assessment – Transverse Drainage

Operation:- The varying nature and extent of the proposed widening along the route means that only seven (7) of the twenty-six (26) existing transverse culvert drainage structures are affected by the widening to such an extent that they require physical extension. The lengths of these extensions vary from a minimum of 2.4m to a maximum of 17.1m (both for the same Culvert 35) with the remainder generally falling in the range of 4.9m to 8.5m.

Each of the affected structures has been modelled to establish 100 year ARI flood levels as well as outlet velocities for both the existing and proposed conditions. Modelling results show that there are no significant increases in flood levels which would potentially impact on upstream or adjoining properties. Culvert 26 is the only location where a potential impact has been identified and this is limited to a maximum increase of only 0.02m which should not adversely affect any of the surrounding properties. At University Creek (Culvert 35), the proposed channel works would reduce flood levels in this reach (between 1.0 to 1.5m) thereby improving the existing situation and reducing the risk of the motorway being overtopped by floodwaters.

It is not proposed to alter the waterway area (cross-sectional dimensions) of the existing culvert structures and as such the changes in outlet velocity are typically less than 0.1m/s. Such small changes are considered to be negligible relative to the velocities already prevailing at the existing outlets and in the adjoining downstream creek sections. The only exception is for University Creek where increasing the length of the relatively steep existing culvert grade with improvements to the channel upstream has increased the outlet velocity.

In addition to the individual transverse culvert crossings, the motorway is to be widened along the reach running parallel to Devlins Creek. For the reach between Chainage 10580 to 11100 downstream of Murray Farm Road, the proposed design concept is to construct the carriageway supported on piers and as a structurally cantilevered section to overhang the creek. This concept has been hydraulically modelled and found to have minimal impact (<0.01m) on flood levels.

Construction: - The proposed widening works would involve site establishment and preparation works as well as earthworks and drainage works. The disturbance of the areas surrounding the works would increase the susceptibility of the site to erosion problems occurring. Management techniques employed to control and deal with runoff from the site works during construction also have the potential to concentrate flows and increase erosion leading to water quality issues for the receiving waters downstream.

As the existing culvert structures are the only means to convey upstream catchment flows across the motorway, facilitation of the construction works is likely to result in some temporary obstruction of the waterway flow path. This obstruction may be caused by temporary bunding or diversions of the waterway, the placement of construction equipment or materials within the flow area, stockpiles or access roads and work platforms. There is the potential for such obstructions to result in the redistribution or concentration of flows (increased velocities) and depending on the circumstances this may increase flood levels upstream and temporarily impact on adjoining properties.

Mitigation Measures – Transverse Drainage

Operation: - The options for managing potential increases in upstream flood levels are largely constrained by the existing size and location of the previously constructed transverse culvert structures. The typical presence of retaining walls and a narrow corridor width is also a limiting factor. The concept design therefore generally proposes to construct new, or modify existing, retaining walls over any inlets/outlets affected by the widening works to minimise the need for extending the culvert structure. This approach should ensure there would be minimal additional upstream impacts (increase in flood levels) created and the need for disturbance of the surrounding environment is also reduced.

For the few culvert structures that are to be extended and may cause flood level impacts, the proposed mitigation measures include keeping the length of required extensions to an absolute minimum and modifying the inlet details to ensure hydraulic efficiencies are optimised and upstream impacts are minimised.

Energy dissipaters and scour protection measures downstream of extended culvert outlets would be modified and/or reconstructed as required to suit the new outlet conditions. Depending on the extent or nature of modification to the existing outlet structures, these scour protection works would largely reproduce the existing measures, which generally comprise either concrete dissipaters, rock mattress and/or dumped rock rip rap.

At University Creek (Culvert 35) the proposed works include replacing the existing overgrown gabion and rock mattress lined channel, which runs eastwards along the upstream (westbound) side of the motorway, with a concrete lined channel. The new channel would provide greater flow capacity than is currently available which should be sufficient to mitigate the impacts of the proposed widening as well as improve the existing flood situation by reducing the potential for overtopping of the motorway. An open traffic barrier, such as wire rope or guard rail, would be utilised along this reach to allow for potential overtopping of the motorway in the larger flood events. Special attention would be afforded to transitioning the channel into the culvert inlet in order to ensure any hydraulic losses (increases in water level) are minimised and the potential culvert performance is optimised. Increased velocities within the channel and at the culvert outlet would require additional consideration, such as energy dissipation, during detail design to reduce the hazard and prevent scouring of the downstream reaches.

Where piers are required for widening of any of the main bridges (Darling Mills, Devlins or Terrys Creeks), these are to be generally located out of the main creek waterway and are unlikely to create additional hydraulic impacts. Appropriate scour protection in the form of dumped rock rip rap would be provided where required.

Construction: - A Soil and Water Management sub-plan would be developed as part of an overall Construction and Environment Management Plan (CEMP) to document the relevant issues and proposed mitigation measures for dealing with potential impacts during the construction phase. These measures would include minimising the area disturbed, the erection of silt fencing, placement of hay bales, temporary and permanent sediment basins, temporary diversion berms and other similar erosion control measures implemented on large earthworks projects. It is also proposed that disturbed areas be re-vegetated as the works progress and that any scour protection measures required for the operational phase would be installed as soon as practical.

Impact assessment – Water Quality

Operation:- During the operational phase, the main potential water quality impacts attributable to the widening works would be an increase in pollutants associated with changes in the contributing catchment characteristics (i.e. increase in percentage of imperviousness or the overall total surface area resulting in larger volumes of runoff to be treated). The nature of pollutants associated with the motorway function and contained in this runoff include: gross pollutants, sediments and suspended solids, nutrients, heavy metals, organics, oils and surfactants, contaminant/accident spills. Minimising the transfer and discharge of these pollutants from the motorway to the waterways is the key objective for the operational phase.

In order to assess the potential impacts associated with the motorway widening, preliminary computer modelling using the MUSIC software (Version 3, 2005) has been undertaken for a selection of the existing basins affected by the works. Nine (9) basins were selected to provide a representative sample of the range of changes in contributing catchment areas including all of those with the largest percentage increases. For the twenty two (22) other basins they are either not affected by the widening works or the increase in area is less than 10% (typically <5%). Changes of less than 5 or 10% are generally within the order of accuracy for the modelling approach and assumptions with the resulting relative impacts mostly smaller. The changes are therefore not considered significant and can be readily addressed and dealt with during the detailed design phase.

Models defining the existing catchment characteristics were initially set up for each of the selected basins to establish a baseline performance representative of current motorway conditions. The models were then modified to reflect any change in percentage imperviousness or increase in catchment area and thus quantify what potential impacts might be created by the widening works alone. Further model changes were then introduced to demonstrate the resultant treatment effectiveness (reduction in potential pollutant load impacts) following implementation of proposed basin modification works. The proposed works primarily involve changes to the inlet and outlet details in order to better utilise the existing storage volume available. All of the basins currently have a 1m freeboard above the top water level (TWL - the normal operating level for capturing and treating the low flow events) and at least 0.5m freeboard above the maximum water level (MWL – the highest water level reached in the basin before excess overflows are discharged directly from the basin itself). Initial modelling results suggest that increasing the ponded (extended) depth by approximately 0.2m to 0.3m would cater for the treatment of the extra runoff volumes generated by the upgrade.

The modelling results demonstrated that the existing basins are providing treatment for Total Suspended Solids (TSS) and Total Phosphorus (TP) that is in accordance with the stormwater treatment objectives for NSW outlined in Australian Runoff Quality (ARQ Table 1.2), these being: TSS reduction of 80%, TP reduction of 45%, TN reduction of 45%, Gross Pollutants 100%. The existing basins do not meet the pollutant reduction targets for Total Nitrogen (TN) (range of pollutant removal is 14 to 24 %). It will not be practicable to achieve the TN target due to the size of basin that would be required being larger than the space available.

Following the proposed widening of the motorway, the modelling results suggest that except for Total Nitrogen (TN), the existing basins would still have sufficient capacity/performance to be able to satisfy the treatment objectives of Australian Runoff Quality (ARQ) without any significant modification. After the motorway upgrade, TN pollutant loads are reduced in the order of 15 – 25 and this is also consistent with the existing level of treatment efficiencies (i.e. the current TN pollutant removal rates are not worsened).

With regards to spill incidents, the owners of the motorway Hills M2 Motorway indicated that there have not been any major spill incidents to threaten the surrounding environment since operations began. There have been some minor instances of contaminants falling from trucks (such as chemicals or paints) and the small oil & fuel leaks resulting from motor vehicle accidents. All such spills/incidents are quickly dealt with by the M2 response team which has a special action plan and spill containment kit to deploy so that the potential for any contaminants to reach the drainage system and downstream environment is minimised. As a further safeguard, the motorway drainage systems have been designed to direct any low flows, including fluid spills or wash down volumes, into the water quality basins where the contaminated runoff can be retained and appropriately dealt with. The potential for spill incidents to impact on the downstream ecosystem is therefore considered to be relatively low.

Construction: - The main potential impacts on water quality are more likely to occur during the construction phase when the underlying soils are exposed due to clearing of the works areas. This is primarily associated with increased erosion and sedimentation issues which are influenced by the severity of a storm event, the slope and footprint of disturbed area in conjunction with the management measures being implemented. Erosion and sediment loads would gradually diminish after construction as the disturbed areas are remediated and the revegetation of batters (or other stabilisation measures) start to establish and hold the soils in place. The key objective is to minimise erosion of disturbed earthworks areas and to contain any sediments on-site.

Other potential construction impacts include: building waste and litter; acids and chemicals from washing processes; accidental spills of construction fuels or chemical materials; and disturbance of contaminated soils.

Mitigation Measures – Water Quality

As a general guiding principle for design and construction, water quality mitigation and management measures would be implemented in accordance with the RTA's *Water Policy and Code of Practice for Water Management (1999)* and *Managing Urban Stormwater - Soils and Construction (Landcom 2004 – often referred to as The Blue Book)*. A summary of measures likely to be implemented for both the construction and operational phases is provided below

Operation: - appropriate energy dissipation and scour protection measures would be provided at bridge waterways and culvert inlets/outlets as necessary. Permanent scour protection requirements particularly at culvert outlets would be implemented as soon as practical and where feasible. Surface areas disturbed by the construction works would be re-established with landscaping.

The existing water quality basins would be modified as required to account for any significant changes in contributing catchment area or to meet the target pollutant reduction criteria. Basin 30b which is located just to the east of the Norfolk Tunnel would additionally be modified to incorporate measures for dealing with tunnel wash down water from maintenance activities.

Operational procedures would be reviewed to ensure the incident response plan is updated to address any changes or issues attributable to the upgrade works and also, adequately incorporates the latest environmental procedures and technologies for dealing with accidental contaminant spills. Maintenance plans and schedules would also be reviewed and updated as appropriate.

Construction: - the control and mitigation of potential surface water quality impacts during construction would be defined in a Soil and Water Management Plan (SWMP) prepared as part of the overall Construction Environmental Management Plan (CEMP). The SWMP would be developed to incorporate “best practice” controls and measures in accordance with “The Blue Book” and the Plan would be continually updated to suit the changing needs as the project works progress.

1.0 Introduction

1.1 Overview

This report provides an assessment of the surface water management issues associated with construction and operation of the proposed M2 Motorway Upgrade. The assessment includes identifying potential impacts and mitigation measures pertaining to flooding, stormwater and water quality. Detailed descriptions of the proposed upgrade works and M2 environs are provided within the main body of the Environmental Assessment (refer Sections 1, 4 and 7).

The objectives of this assessment include:

- Define the existing environment with respect to surface water aspects such as:
  - The interaction of the motorway and its transverse culvert drainage structures on flooding for surrounding areas.
  - The quality of surface water runoff from the motorway and the receiving water environment.
- Quantify the nature and extent of potential impacts due to both the construction and operational phases of the project.
- Identify appropriate mitigation measures to address and ameliorate any impacts.

1.2 Assessment Scope

General construction impacts associated with the M2 Motorway Upgrade are a key issue that must be addressed in the Environmental Assessment, as outlined in the Director-General's Requirements for the proposal. In particular the Environmental Assessment must include consideration of and a management framework for erosion, sedimentation, water quality and riparian management issues in and around watercourse crossings. This technical study has been prepared to satisfy that assessment requirement.

This technical study includes:

- A description of the hydrologic and hydraulic context of the existing motorway, including existing water quality and aquatic ecology in the receiving waters;
- A description of the existing motorway stormwater collection and treatment systems, including proposed modifications and the likely impacts to treatment effectiveness and water quality;
- A description of transverse drainage devices installed along the motorway and the proposed modification to these structures, including an assessment of the potential impacts associated with the proposed modifications;
- An identification and assessment of sources of polluted water at project sites during construction and on surface roads and in tunnels during operation and appropriate mitigation strategies to prevent potential water quality impacts; and,
- An assessment of the likely ground stability impacts during construction with specific focus on riparian zones and identification of appropriate mitigation strategies to minimise the potential for erosion and sedimentation issues in the downstream receiving waters.

1.3 Policy Framework

The relevant legislative requirements and government policies applicable to the surface aspects of the proposed upgrade works include:

- Water Act 1912.
- Water Management Act 2000.
- Fisheries Management Act 1994.
- NSW State Rivers and Estuaries Policy.
- NSW Floodplain Development Manual 2005.

2.0 Background

2.1 Geology

Within the length of the motorway corridor there are two major geological formations being Hawkesbury Sandstone and the overlying Ashfield Shale member of the Wianamatta Group. The interface between the two formations may be marked by the presence of the Mittagong Formation.

Hawkesbury Sandstone is a medium to coarse grained quartz sandstone with minor lenses of shale and laminate.

The Wianamatta Group Shales comprise Ashfield and Bringelly Shale Formations. The Ashfield Shale consists of black to dark grey shale and laminate. Bringelly Shale is comprised of shale, calcareous claystone, laminate and fine to medium-grained lithic-quartz sandstone.

The Mittagong Formation is comprised of alternating bands (and lenses) of sandstone and black siltstone of variable thickness. The quartz sandstone is of a finer grain than the Hawkesbury Formation.

The Hawkesbury Sandstone relief tends to be fairly rugged with rolling to very steep hills with steep or benched side slopes. Relief in the Ashfield Shale is generally undulating with rounded ridges and hill crests.

2.2 Soils

There are five major soil landscapes occurring throughout the corridor. The Glenorie Landscape (*gn*) is the main soils developed on the Wianamatta Group Shales. Typically these soils have a depth of up to 2m approximately with the topsoil consisting of a friable dark brown loam. Also on Wianamatta Group Shales there are some small areas of soils in the West Pennant Hills Landscape (*wp)* which are generally less than 2m in depth.

The Lucas Heights Landscape (*lh*) is typically found on the Mittagong Formation with the depth commonly less than 1m and a high soil erosion hazard.

In the southern section of the Lane Cove River valley and in the upper valley of Terrys Creek, the soils are shallow (less than 1m) and fall within the Gymea Landscape (*gy*). The erosion hazard is high to extreme.

In the northern section as well as the rugged valleys of Devlins Creek, the soils are mostly within the Hawkesbury Landscape (*ha*) and less than 0.5m depth. These shallow soils in conjunction with the steep terrain have an extreme erosion hazard.

2.3 Aquatic Environment

The M2 Motorway traverses through three main catchment areas of Darling Mills Creek, Devlins Creek and Terrys Creek whilst a number of smaller tributaries located towards the eastern end of the M2 (including Mars, University, Shrimptons and Porters Creeks) also form part of the Lane Cove River catchment. Within the limits of proposed widening works the motorway is crossed by some 26 local drainage lines which are served by transverse drainage structures comprising a combination of large concrete arches and box or pipe culverts. Large multi span bridge structures situated several metres above the normal water level, are used to cross the three main creek waterways.

Native aquatic submerged and emergent vegetation is not abundant within the creeks of the study area. This is likely to be as a result of the chiefly rocky substrate found here, high water velocity during heavy rainfall and competition from introduced species. The only commonly encountered native aquatic plants were Bull Rush (*Typha orientalis*) and knotweeds (*Persicaria spp*.), which were found in small patches along the creeks, chiefly in disturbed areas.

The detention basins within the M2 corridor contain an artificial assemblage of emergent native aquatic plants including Tall Spike-Rush *Eleocharis sphacelata*, Marsh Club-rush (*Bolboschoenus fluviatilis*) and Jointed Twig-rush (*Baumea articulata*) which were planted when the basins where constructed.

No assemblages of native aquatic plants were found that could be described as native vegetation communities. No aquatic plant species of conservation significance were recorded or considered likely to occur within the M2 corridor or surrounds. A variety of aquatic weeds (e.g. Water Milfoil (*Myriophyllum aquaticum*) and Watercress (*Rorippa nasturtiumaquaticum*)) are found along the waterways of the study area. Of these, three species are listed as noxious weeds. Noxious aquatic species recorded include:

- Long-leaf willow primrose (*Ludwigia longifolia*)
- Ludwigia (*Ludwigia peruviana*), and
- Sagittaria (*Sagittaria platyphylla*).

Prior to residential development in surrounding areas, the creeks of the locality are likely to have supported a diverse community of insects, fish, frogs, birds and mammals. The creeks are degraded to varying degrees as a result of a number of factors including increased erosion due to the concentration of stormwater flows, weed invasion, polluted catchment runoff and the presence of exotic fish species. As a result of this condition, frogs, fish and aquatic invertebrates that are sensitive to these forms of disturbance are unlikely to persist in these waterways. Nonetheless, a variety of disturbance tolerant fauna species remain.

The present condition of the creeks of the M2 corridor varies from highly modified to near-natural. The section of Darling Mills Creek crossed by the M2 corridor appears to be in relatively moderate condition, with low turbidity, little evidence of sedimentation and a low level of weed invasion. This area is likely to be inhabited by many species of native fish. It is also likely to be inhabited by the introduced fish, the Plague Minnow (*Gambusia holbrooki*) though the population density of this species is likely to be relatively low due to the higher water quality and intact riparian vegetation which favour native fish species. The Eastern snake-necked Tortoise (*Chelodina longicollis*) is also likely to be found here. Recent frog surveys conducted along this section of Darling Mills Creek detected the Green Stream Frog (*Litoria phyllochroa*), Peron's Tree Frog (*Litoria peronii*), Striped Marsh Frog (*Limnodynates peronii*) and Common Eastern Froglet (*Crinia signifera*).

The other creeks of the study area are more disturbed and are likely to contain a lower diversity and abundance of fish and frog species with the Plague Minnow becoming increasingly dominant in more disturbed areas.

Obstructions to fish movement within the M2 Corridor exist where waterways pass beneath the Motorway via culverts. During low flow conditions, the streams of water flowing through the culverts are broad but very shallow and may limit the passage of some fish species. Higher water velocity and turbulence during rainfall events and a lack of pooled areas for fish to rest between bouts of swimming may also limit fish movement through the culverts. The extremely low light level within culverts may also create a non-physical barrier for some fish species that may avoid dark areas during daylight hours (Fairfull and Witheridge 2003). Larger in stream structures (e.g. the retarding basin wall near Loyalty Road, North Rocks and weirs on the Lane Cove River) lower in the catchments of these creeks are also potential barriers to fish passage.

No threatened or protected aquatic invertebrate or fish species have been recorded in the waterways of the M2 Corridor. Introduced fish species recorded in the locality include Goldfish (*Carassius auratus*), Common Carp (*Cyprinus carpio*) and Plague Minnow (*Gambusia holbrooki*). Goldfish and Common Carp are not likely to be abundant in the small rocky streams of the study area however the Plague Minnow is found in all of the creeks, especially in disturbed areas. This species is listed as a Key Threatening Process due to its detrimental impacts upon tadpoles and frog eggs.

2.4 Existing M2 Motorway Design

The original design of the existing M2 Motorway was undertaken in 1995-96 with construction completed and the motorway opened to traffic in May 1997.

Detailed information pertaining to the assumptions and basis for the original Motorway design of drainage elements are limited. Copies of the design drawings and some work as executed information have been obtained but the supporting design calculations, reports or technical models were not available for review. The investigations undertaken for this current assessment have therefore relied upon the limited details that were already available along with some new information specifically gathered while developing the widening concept.

2.5 Survey Information

The following survey information was initially available for the purposes developing the design concept and associated investigations:

- 2m topographical mapping contours for the surrounding region.
- Photogrammetric survey within the corridor, excluding the pavement area, obtained from Ausimage (SKM).

- Detail survey of the Motorway surface between the existing barriers, not including eastbound pavement between Pennant Hills Road and Murray Farm Road obtained by surveyors for the M2 Upgrade Project team in November 2008, and from previous studies.
- Additional survey obtained by surveyors for the M2 Upgrade Project team in January 2009 to specifically assist with the hydraulic investigations and the detail design process in general.

A review of the above survey information has indicated that there are still some areas of insufficient detail (such as confirming existing basin and culvert inlet/outlet details) and further survey is to be obtained to address this issue prior to detail design commencing.

2.6 Water Quality Data

As part of the original approval conditions for the M2 Motorway, a water quality monitoring program was initiated in 1997-98 following the commencement of operation in May 1997. The objectives of the monitoring program were to examine water quality to check for conformance with recommended quality limits and to quantify any changes in water quality so as to identify long term impacts which might be associated with construction. Since that time, water quality data has been collected and analysed by HLA-Envirosciences at sixteen (16) locations on tributary waterways upstream and downstream of the M2 corridor (refer Figures 1 to 5). The samples are collected following noteworthy storm events (where rainfall is greater than 10mm in the 24 hour period prior to sampling) and analysed for Total Suspended Solids (TSS). Suspended solids loadings are used as an important indicator in relation to nutrient transport and aesthetic appearance. Appendix A tabulates and charts the sampling data obtained for numerous events dating back as far as January 1998. The calculated long term average and median values for each of the sites are also included.

It should be noted that sites M2-1 through to M2-8 downstream of the motorway (refer figures 1 to 5) are the same sampling locations used by a Bill Rooney between July and December 1994 (prior to construction) to establish background averages for wet (128 mg/l) and dry (8 mg/l) conditions.

In addition to the ongoing event monitoring, water from a selection of water quality basins located along the corridor has also been sampled in May-June 2007 and July 2008 for a broader range of constituent pollutants. The objectives of this monitoring program were to examine the water quality in selected basins along the motorway and to conduct compliance sampling for licensing requirements. A comparison of results is included in Appendix A and discussed further in Section 4.1.

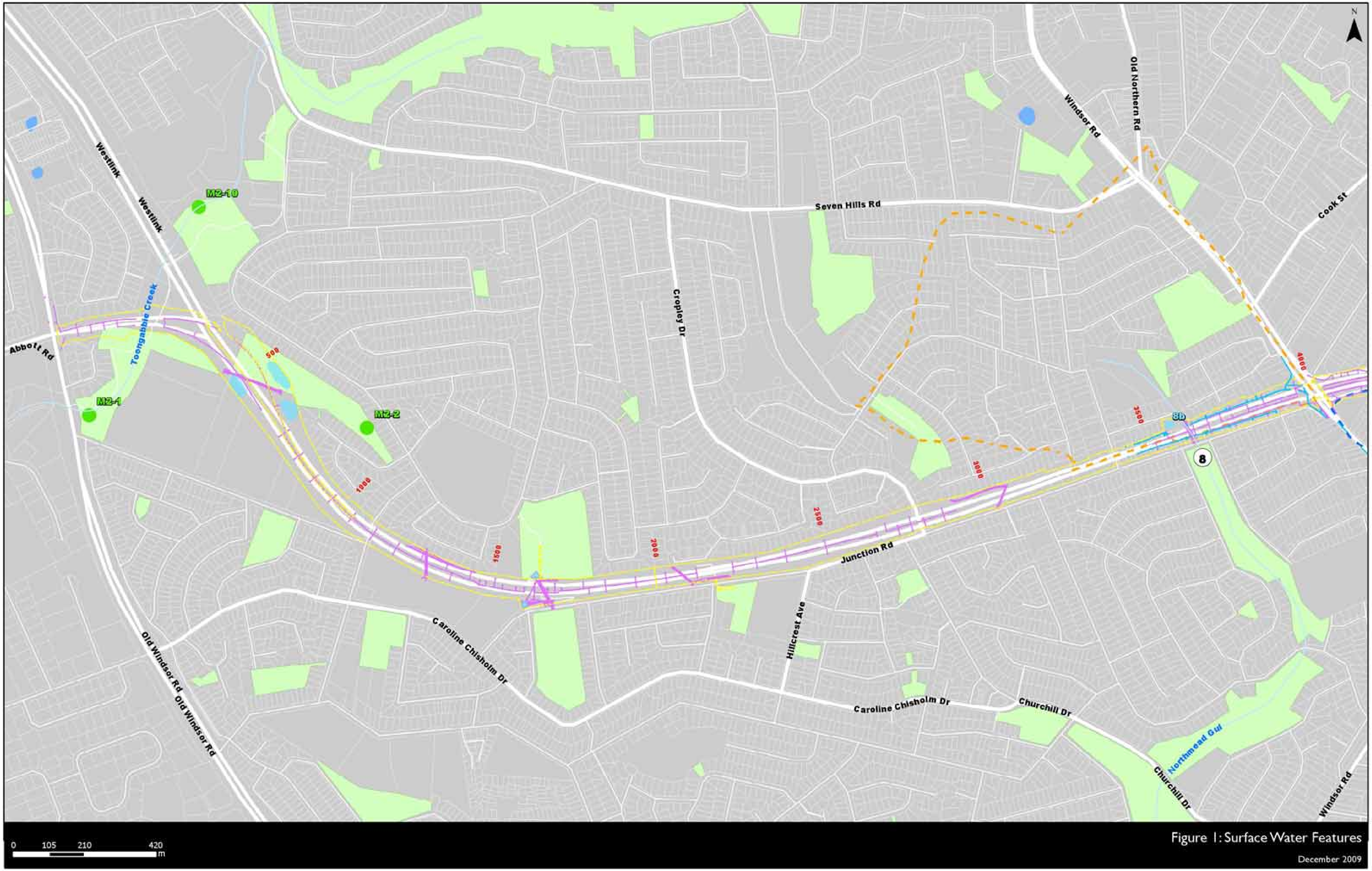


Figure 1: Surface Water Features

December 2009

Lease Boundary
Existing Basin
Proposed Basin
Proposed Culvert
Sampling Sites
Drainage Design
Existing Drainage
13 Culvert Name

Catchment Areas
Darling Mills Creek
Devlins Creek
Mars Creek
Northmead Gully
Shrimptons Creek
Terrys Creek

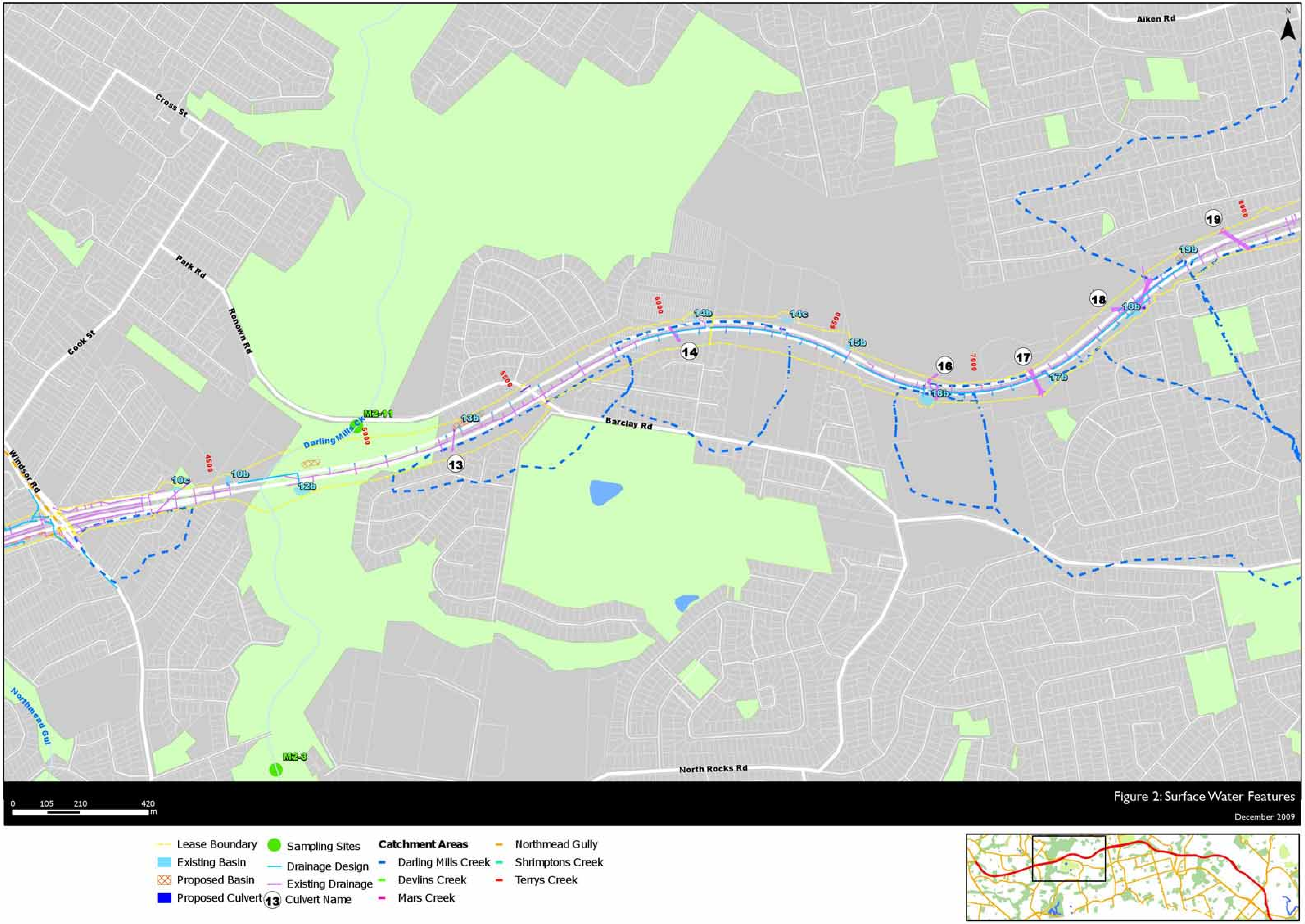


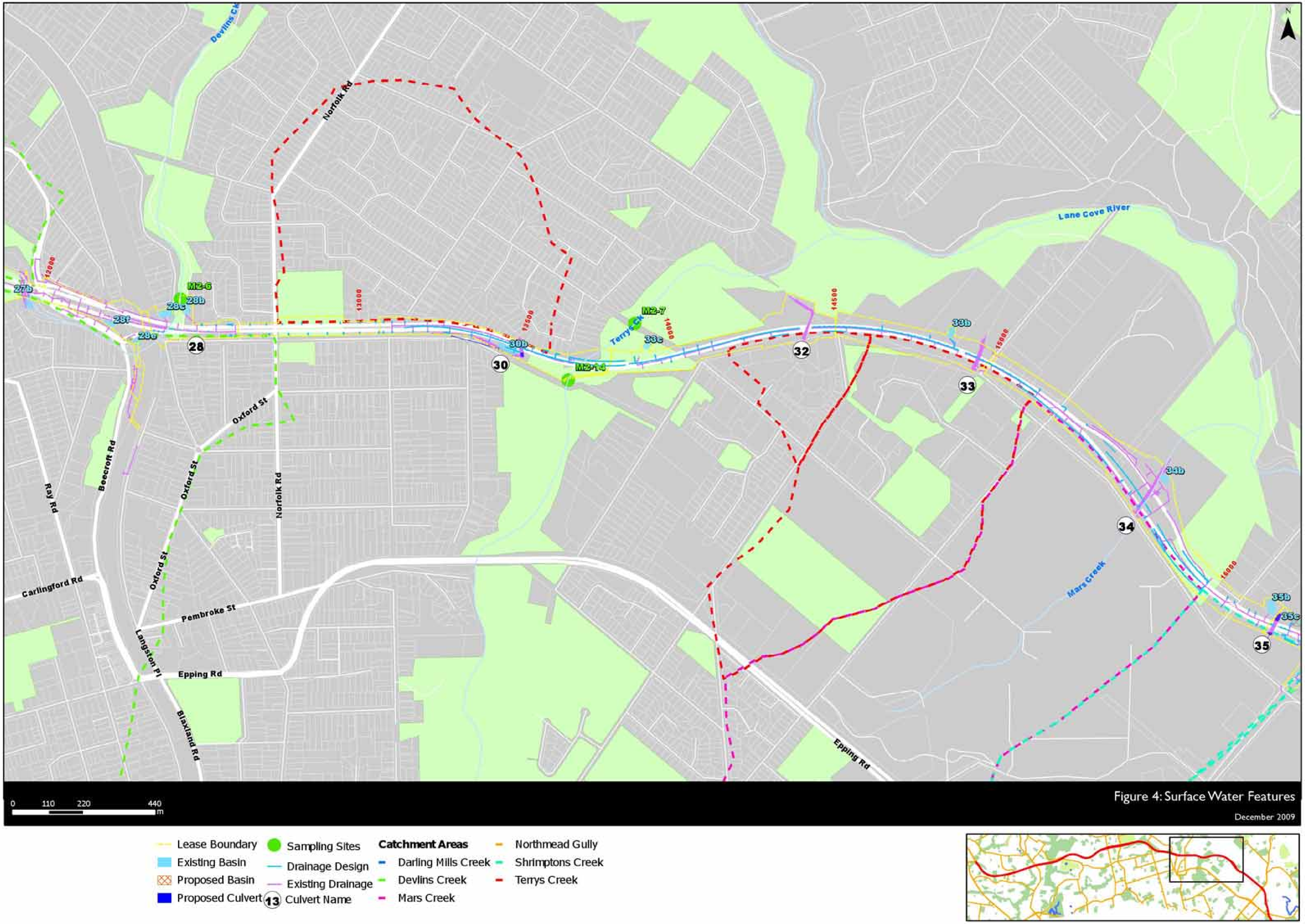
Figure 2: Surface Water Features

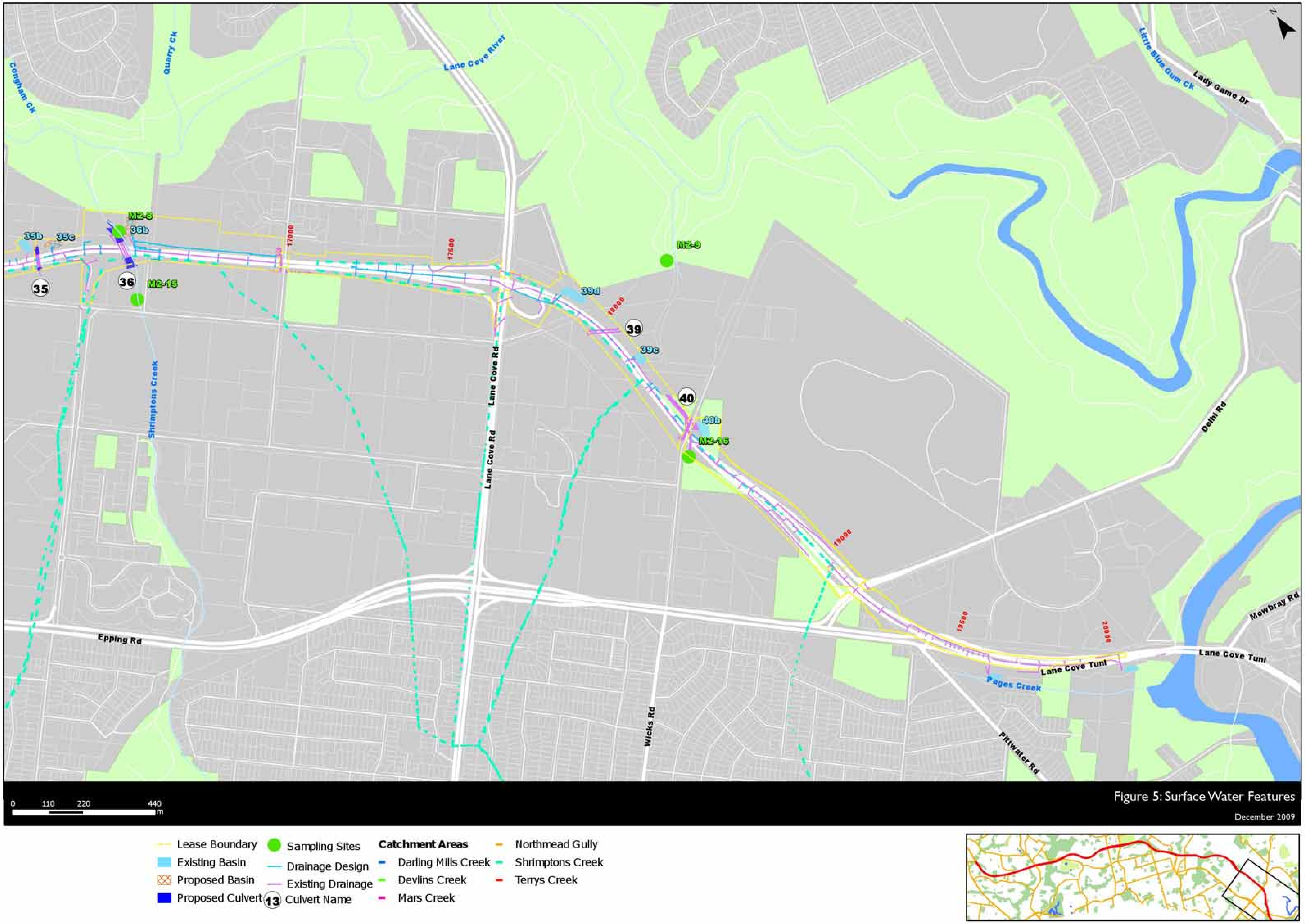
December 2009

Figure 3: Surface Water Features

December 2009

Lease Boundary	Sampling Sites	**Catchment Areas**	Northmead Gully
Existing Basin	Drainage Design	Darling Mills Creek	Shrimptons Creek
Proposed Basin	Existing Drainage	Devlins Creek	Terrys Creek
Proposed Culvert	(13) Culvert Name	Mars Creek	


Devlins Ck
Norfolk Rd
Lane Cove River
Terrys Ck
M2-6
M2-7
M2-14
27b
28b
28c
28f
28e
28
30b
30
33b
33c
32
33
34b
34
35b
35c
35
12000
13000
13500
14000
14500
15000
16000
Oxford St
Beecroft Rd
Ray Rd
Norfolk Rd
Carlingford Rd
Pembroke St
Langston Pl
Epping Rd
Blaxland Rd
Mars Creek
Epping Rd
0 110 220 440 m
Figure 4: Surface Water Features
December 2009
Lease Boundary
Existing Basin
Proposed Basin
Proposed Culvert
Sampling Sites
Drainage Design
Existing Drainage
13 Culvert Name
Catchment Areas
Darling Mills Creek
Devlins Creek
Mars Creek
Northmead Gully
Shrimptons Creek
Terrys Creek



Congham Ck
Quarry Ck
Lane Cove River
Little Blue Gum Ck
Lady Game Dr
M2-8
35b
35c
36b
M2-9
M2-15
35
36
17000
17500
39d
18000
39
39c
40
40b
M2-16
Shrimptons Creek
Lane Cove Rd
Delhi Rd
19000
Epping Rd
Mowbray Rd
19500
20000
Lane Cove Tunl
Pages Creek
Wicks Rd
Pittwater Rd
0 110 220 440 m
Figure 5: Surface Water Features
December 2009
Lease Boundary
Existing Basin
Proposed Basin
Proposed Culvert
Sampling Sites
Drainage Design
Existing Drainage
13 Culvert Name
Catchment Areas
Darling Mills Creek
Devlins Creek
Mars Creek
Northmead Gully
Shrimptons Creek
Terrys Creek

2.7 Proposed Upgrade Drainage Works

A brief description of the proposed upgrade works pertaining to surface water drainage elements within each of the Precincts is outlined below. A description of the M2 Precinct environs is available in Section 4 of the Environmental Assessment report. It should be emphasised that some of the ultimate drainage design details (particularly the basins) have not been finalised due to insufficient detail survey making it difficult to confirm the size and functionality of the existing basins. Additional survey information is being obtained to allow further investigations and enable the consideration of alternative design solutions for the various site specific conditions. The ultimate details would then be finalised as part of the detailed design process which would be completed prior to construction commencing. Some of the basin works described below may therefore be subject to change. However, it is not envisaged that such changes are likely to be significant relative to the scale of works currently proposed but rather they would be limited to additional earthworks in lieu of simply adjusting the inlet and outlet arrangement.

Prior to construction commencing, it is also proposed that the existing basins would be drained to allow for cleaning and de-silting to ensure the full capacity and effectiveness was available. A similar maintenance exercise would then be undertaken at the completion of construction so that the basins would be properly prepared for their ongoing operational conditions.

Precinct 1 – Abbott Road to Windsor Road

Drainage works for Precinct 1 predominantly involve the adjustment of existing, and provision of additional, inlet pits with associated pipes to drain the pavement area of the new west facing ramps. This longitudinal drainage system would drain to the existing water quality basin 8b located around Chainage 3580 on the eastbound side of the motorway (refer Figure 1). It is proposed to modify the existing basin inlet and outlet to provide for changes to the drainage system. Alternatively, some earthworks may be required to increase the storage volume. There are no transverse culvert works proposed or required within Precinct 1

Precinct 2 – Windsor Road to Pennant Hills Road

An existing 1200mm diameter pipe culvert at Chainage 5250 (Culvert 13 – refer Figures 2 & 6) is to be extended approximately 6m on the downstream outlet (eastbound) side to accommodate the proposed road widening. The works would incorporate a new headwall into the proposed retaining wall for the widening works with new energy dissipation and scour protection.

At Chainage 7560 it is proposed to extend the inlet of an existing 1500x1200 box culvert (Culvert 18 – refer Figures 2 & 7) by up to 5m on the westbound side, along with replacement of the inlet scour protection.

Figure 6 Culvert 13 – Chainage 5250

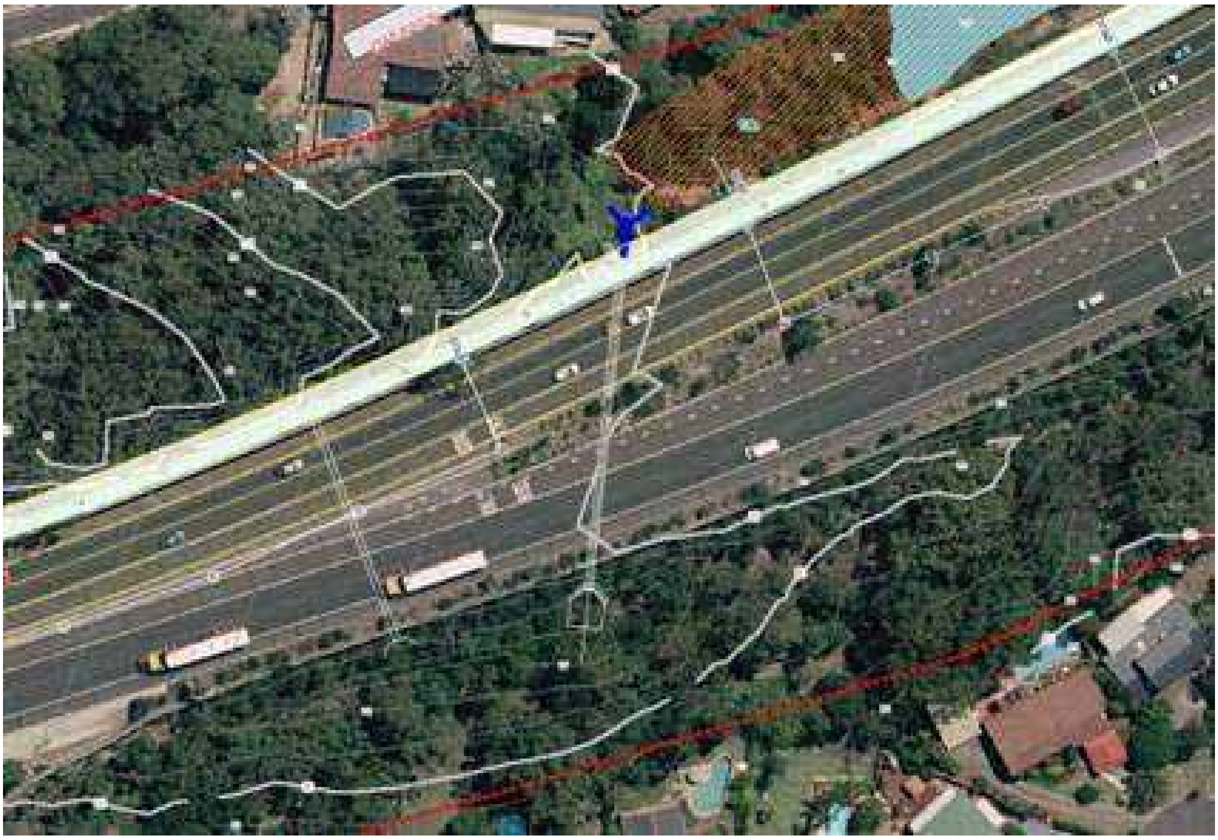


Figure 7 Culvert 18 – Chainage 7560

A new culvert parallel to the motorway is proposed at the Barclay Road overbridge (chainage 5520 to 5550 – refer Figure 2) which would provide connectivity of catch drains being relocated at the top of the cutting on the east bound (northern) side due to the road widening.

Within Precinct 2, there are eleven (11) existing water quality basins which would require modification works to provide additional volume for treatment purposes. The additional volumes potentially required vary considerably from nothing up to approximately 600m^3. The existing motorway corridor is typically constrained in terms of width or available land space, which severely limits the opportunity for increasing basin footprints. Wherever possible or practical, it is therefore generally proposed to modify the basin inlet/outlet arrangements (by changing the inlet/outlet levels, dimensions or similar) to better utilise any spare volume capacity that currently exists as freeboard (up to 1m of airspace above the top water level). This approach would be dependent on the existing levels of key basin features compared to the elevation of the motorway and drainage system upstream. It is envisaged that earthworks would be required in some locations to obtain additional storage volume. As a general design principle such earthworks would be minimised to avoid impacts on the surrounding vegetation.

It is possible that a new basin may be required on the eastbound side around Chainage 4800 (refer Figure 2) to remove the need for upgrading the drainage system across the motorway and then having to also enlarge the existing basin 12b on the westbound side.

Precinct 3 – Pennant Hills Road to Beecroft Road

Within Precinct 3, Devlins Creek runs parallel to the motorway for significant portions and crosses the M2 back and forth through large precast concrete arch structures on 3 occasions. Only the existing 12.4mx4m structure at Chainage 10550 (Culvert 23 – refer Figures 3 & 8) would be affected by the widening works and would require extension by approximately 4.9m. A gabion wall and open channel immediately downstream of the outlet would require re-construction or modification to suit. At Chainage 11640 there is a tributary creek served by a 4x1350mm diameter RCP (Culvert 26 – refer Figures 3 & 9) which would require extending up to 6m at the inlet and reconstruction of the existing scour protection.

Figure 8 Culverts 23, 24a & 24 - Chainage 10500-1120

Figure 9 Culverts 24, 25 & 26 - Chainage 11100-11700

Two (2) of the four (4) existing water quality basins are likely to require earthworks to create additional storage volume (23b & 27b). The existing basin 22b at Chainage 9730 could be significantly impacted (reduced) due to the widening works. If it is not possible to achieve the appropriate storage volume through earthworks modifications, it may be necessary to extend a retaining wall to remove the need for a batter slope and thereby minimise the footprint and impact of the widening. Basin 25b at Chainage 11310 (refer Figure 3) appears to already have sufficient storage volume but may require modification of the inlet and outlet.

Precinct 4 – Norfolk Tunnel (including approaches to Terrys Creek)

Within the vicinity of the bend in Somerset Street (at the projected intersection with Gloucester Road), the motorway widening is likely to impact on the existing local street drainage system. The works would involve relocation or reconfiguration of parts of the local street pit and pipe elements away from the motorway footprint.

The 3 cell 2400x1800 box culvert outlet located around Chainage 13500 is to be extended approximately 8m on the westbound side (Culvert 30 – refer Figures 4 & 10). Works would involve reconstructing the outlet scour protection measures as well as 30m of the existing concrete/rock mattress open channel which receives flows from the local road drainage system.

There are only two (2) water quality basins in Precinct 4. The existing volume for basin 28f at Chainage 12230 (Figure 4) appears to be sufficient, however if minor augmentation is required then this could be achieved through modification of the inlet and outlet. Otherwise there appears to be space available to enlarge the footprint by earthworks. Basin 30b at Chainage 13470 (Figure 4) is located at the end of the Norfolk Tunnel drainage system. The road widening is proposed to pass over the basin on a cantilevered roadway so that there is no impact (reduction) on the existing basin volume. The basin inlet/outlet is proposed to be modified to better utilise the spare volume available. Additional modifications to the basin would also be required to capture and treat the tunnel wash down water prior to discharge. Depending on the quality of the water this would be discharged manually either to the nearby sewer system or local drainage path down to Terrys Creek.

Figure 10 Culvert 30 – Chainage 13500

Precinct 5 – Terrys Creek to Lane Cove Tunnel

The upstream inlet of the existing 3 cell 2400x1800 box culvert for University Creek at Chainage 16220 (Culvert 35 – refer Figures 5 & 11) is to be extended approximately 2.4m on the westbound side and the downstream outlet is to be extended 17.1m under the new Christie Road onload ramp on the eastbound side. The associated widening of the embankment would require construction of a vertical retaining wall to limit the potential imposition (infilling) of an existing channel which runs along the upstream (westbound) side of the motorway. The channel of varying width is currently lined with gabions and rock mattresses which have become overgrown with weeds and other vegetation. It is proposed to reconstruct a new concrete channel with a more consistent and sightly increased waterway area to improve the hydraulic capacity and reduce flood levels through this area.

Figure 11 Culvert 35 – Chainage 16220

Figure 12 Culvert 36 – Chainage 16450

The Shrimptons Creek catchment drains to a large 20mx6m precast concrete arch under the motorway around Chainage 16450 (Culvert 36 – refer Figures 5 & 12). The widening works at this location include the provision of a westbound off ramp to Herring Road which would require extending the arch by 12m on the upstream side.

There are six (6) existing water quality basins in Precinct 5 with at least five (5) requiring some form of augmentation to achieve additional storage volume. It is proposed that this would be achieved through modification of the inlet and outlet arrangement for three (3) of the basins (33c, 34b & 35b) while earthworks would more likely be involved for the remaining two (35, & 36b). All of the basins are located on the eastbound side of the motorway in the Lane Cove River catchment.

3.0 Surface Water Catchment Assessment (Transverse Drainage)

3.1 Methodology

The assessment of local surface water catchments draining to and across/through the motorway has involved hydrologic modelling to determine peak flow estimates applicable for design and hydraulic modelling to quantify if the proposed upgrade works would impact on flood levels and velocities.

The hydrologic modelling of the urbanised catchments has been based on the XP-Rafts runoff-routing software. Models were established for the Devlins Creek, University and Shrimptons Creek catchments.

Hydraulic modelling has involved a combination of headwater calculations for the smaller culvert structures which primarily operate under inlet control, while detailed HEC-RAS modelling has been undertaken for the larger waterways where structures are more influenced by hydraulic gradients or potential downstream tailwater conditions. The waterways modelled include Devlins Creek, University Creek and Shrimptons Creek. The results output from the various hydraulic analyses are included in Appendix B.

It should be noted that the primary aim of the hydrologic/hydraulic analyses undertaken for this study was to establish the relative impacts of the proposed upgrade works. As such, the analyses and associated results are not purported to represent the type of rigorous investigations normally associated with a design flood study which defines design flood behaviour (such as absolute flood levels for planning purposes or design peak flows). The analyses and results are considered suitable for the intended purposes of quantifying the existing situation and the potential impacts attributable to the widening works.

Current scientific evidence suggests that the climate is changing and the effects of these changes need to be considered. Climate change is predicted to have an impact on variations in rainfall intensities as well as rises in sea levels. In this instance, the motorway corridor is situated at relatively high elevations and therefore is above the influence of any potential rise in sea level. With respect to variations in rainfalls, it is possible that these may increase or decrease and for the purposes of the current exercise the performance of the affected structures have also been conservatively assessed for up to a 20% increase in flows to identify any significant issues or risks should the future situation be different to existing or the assumed designed conditions.

3.2 Existing Environment

The M2 Motorway traverses through three main catchment areas of Darling Mills Creek, Devlins Creek and Terrys Creek whilst a number of smaller tributaries located towards the eastern end of the M2 (including Mars, University, Shrimptons and Porters Creeks) also form part of the Lane Cove River catchment. Within the limits of proposed widening works the motorway is crossed by some 26 local drainage lines which are served by transverse drainage structures comprising a combination of large concrete arches and box or pipe culverts. Large multi span bridge structures situated several metres above the normal water level are used to cross the three main creek waterways. These main creeks are all contained within well defined and incised valleys of predominantly bush vegetation. At Darling Mills Creek (approx. chainage 4570) the main watercourse and a tributary join together under one of the 33.75m bridge spans with piers located on the outside of the Y junction. Similarly at the Devlins Creek bridge (approx. chainage 9770), the main creek is joined by a small tributary watercourse before winding along the bridge alignment between and around the existing piers. An existing sewer line also closely follows the same channel alignments. The waterway channels are both relatively small and mostly lined with sandstone rocks with the general condition described as average to disturbed. The Terrys Creek bridge (approx. chainage 13670) comprises 33.75m spans with the piers located away from the creek banks. A summary of key details pertaining to the various existing structures is presented in Table 3-1.

The region surrounding the motorway is known to have experienced a number of historical floods with some of the more notable events occurring in November 1984, December 1989, twice in February 1990 and more recently February 2007. It appears there is limited data available from these events which would provide any quantitative value in assessing the performance of the existing structures or the relative impacts of the proposed upgrade works.

It is understood however, that the City of Ryde Council are currently in the process of preparing a detailed flood study which covers the tributaries within its jurisdiction. This includes Mars, University, Shrimptons and Porters Creeks. Details of this study were not available at the time of preparing this assessment.

For the purposes of this study, existing flood conditions in the 100 year ARI design event have been estimated for the seven (7) transverse culvert structures which are to be extended due to the widening works. A long reach of Devlins Creek extending from Beecroft Road to just upstream of Murray Farm Road and the upper M2 motorway crossing (culvert 23), effectively runs parallel to the motorway and incorporates or influences a number of culvert structures. Additionally, sections of the motorway adjacent to the creek are to be widened. Consequently this entire reach was modelled using HEC-RAS. The structures and adjoining reaches immediately upstream and downstream of the motorway at University (culvert 35) and Shrimptons Creeks (culvert 36) were modelled separately also using HEC-RAS. Culverts 13, 18, 26 and 30 were analysed using HY-8 culvert analysis software and the results are included in Appendix B.

The estimated 100 year ARI flood extent for the upper and lower reaches of Devlins Creek under existing conditions is presented in Figures 13 and 14. Along the entire length of the reach modelled, the flood extent is typically contained within the riparian bush zone which is bounded by the motorway embankment on one side and residential development on the other. Large precast concrete arch culvert structures are used for all of the main motorway crossings of Devlins Creek (Culverts 23, 24, 27 and 28) with only culvert 23 to be extended due to the widening works.

The existing flood behaviour for University Creek in the vicinity of the M2 motorway (refer Figure 15) appears to be influenced by a number of man made features. Flows from the upper catchment are initially controlled by a large diameter pipe and inlet structure immediately upstream of Talavera Road. The pipe flows are conveyed under the road and the building on the property located upstream of the M2 to discharge into an open channel near the inlet of the existing motorway culvert (Culvert 35). Excess flows that surcharge across Talavera Road, drop over a concrete weir (wall) where they are then directed overland through the property car park into another drop inlet structure and large box culvert which discharges into an overgrown gabion and rock mattress lined channel running eastwards alongside the westbound (southern) side of the motorway. The channel drops 1m into the motorway culvert inlet. Preliminary results of the hydraulic analyses have indicated that the 100y ARI flood levels in this area may be higher than the adjoining motorway which would therefore be overtopped in the existing situation. Further modelling is required to confirm the hydraulic conditions in this area.

At Shrimptons Creek, the buildings which are evident on the property immediately upstream of the motorway (refer Figure 15) have recently been demolished and the site is in the process of redevelopment. The hydraulic profile and results summarised in Appendix B indicate that the existing property access bridge, located just upstream of the motorway boundary, is constricting the waterway and appears to be controlling flood levels in this area. Downstream of the bridge as the channel drops quickly through the large arch culvert structure (nearly 3m in elevation difference from the bridge to the arch outlet), the steep nature causes flow in the reach to the inlet of the arch to become super-critical (i.e. below the normal water level based on the geometric properties of the waterway area). The 20mx6m arch itself has sufficient capacity to convey the 100y ARI design flow.

Table 3-1 Summary of Existing Transverse Drainage Structures

Culvert Ref ID GHD Design	Approx Chainage (m)	Catchment		No. Conduit Cells	Width (mm)	Height (mm)	Structure Type	Extension Length (m)		Comments
		Tributary Name	Area (ha)					Inlet	Outlet	
8	3620	Northmead Gully	71.40	2	2400	1800	BOX	-	-	No culvert extension works required
				1	1650		PIPE	-	-	
9	4300	Darling Mills Ck	4.73	1	750		PIPE	-	-	No culvert extension works required
	4570	Darling Mills Ck					Bridge			Additional piers are to be installed in-line with existing on the upstream side of the bridge. This may require the construction of one (1) and possibly two (2) pier(s) within the creek or its tributary. If this is necessary, it is proposed that the pier(s) would be streamlined and aligned with the flood flow. The Piers would not adversely increase hydraulic impacts (flood levels or velocities).
13	5250	Darling Mills Ck	10.55	1	1200		PIPE	6	-	New retaining wall to be constructed over outlet with rock mattress channel and gabion bank downstream to be reconstructed and extended
14	6020	Darling Mills Ck	16.11	2	1800		PIPE	-	-	No culvert extension works required
16	6850	Darling Mills Ck	9.17	1	2100		PIPE	-	-	No culvert extension works required
17	7180	Darling Mills Ck	55.69	1	9000	4000	Precast Concrete Arch	-	-	No culvert extension works required
18e	7565	Darling Mills Ck	159.02	3	3000	2400	BOX with a precast link slab	-	-	No culvert extension works required
18w	7560	Darling Mills Ck	12.51	1	1500	1200	BOX	4.9	-	Inlet rock mattress scour protection to be reconstructed.
19	7920	Darling Mills Ck	67.17	3	2400	1800	BOX with a precast link slab	-	-	No culvert extension works required
20	8340	Darling Mills Ck	4.33	1	1350		PIPE	-	-	No culvert extension works required
21	8500	Darling Mills Ck	6.9	1	1800		PIPE	-	-	No culvert extension works required

Culvert Ref ID GHD Design	Approx Chainage (m)	Catchment		No. Conduit Cells	Width (mm)	Height (mm)	Structure Type	Extension Length (m)		Comments
		Tributary Name	Area (ha)					Inlet	Outlet	
	9770	Devlins Ck					Bridge			Additional piers are to be installed in-line with existing in the middle and southern (westbound) side of the bridge structure. It is probable that this may require construction of one (1) and possibly two (2) pier(s) in or adjacent to a tributary channel or flow path joining with Devlins Ck The Piers would not adversely increase hydraulic impacts (flood levels or velocities).
23	10550	Devlins Ck	284	1	12400	4000	Precast Concrete Arch	-	4.9	Gabion wall and open channel downstream to be reconstructed. Low flow channel to be transitioned to existing creek with appropriate scour protection.
24a	10960	Devlins Ck	17.9	1	1800		PIPE	-	-	No culvert extension works required
24	11110	Devlins Ck	649	2	12400	4000	Precast Concrete Arch	-	-	No culvert extension works required
25	11350	Devlins Ck	16.3	2	1350		PIPE	-	-	No culvert extension works required
26	11640	Devlins Ck	30.91	4	1350		PIPE	6	-	Large area of rock mattress scour protection upstream of inlet to be reconstructed.
27	11930	Devlins Ck	752	1	18000	4500	Precast Concrete Arch	-	-	No culvert extension works required
28	12390	Devlins Ck	1007	1	21000	7300	Precast Concrete Arch	-	-	No culvert extension works required
30	13500	Terrys Ck	56.79	3	2400	1800	BOX with link slab	-	8.5	Existing concrete/rock lined open channel from local road drainage system to be reconstructed. Culvert outlet to be transitioned to downstream channel with scour protection measures
	13670	Terrys Ck					Bridge			Additional piers are to be installed in-line with existing on the downstream side of the bridge. The Piers would not adversely increase hydraulic impacts (flood levels or velocities).
32	14415	Terrys Ck	9.36	1	1500		PIPE	-	-	No culvert extension works required
33	14960	Terrys Ck	54.04	2	2400	1800	BOX	-	-	No culvert extension works required
34	15600	Mars Creek	96.87	3	2400	1800	BOX	-	-	No culvert extension works required

Culvert Ref ID GHD Design	Approx Chainage (m)	Catchment		No. Conduit Cells	Width (mm)	Height (mm)	Structure Type	Extension Length (m)		Comments
		Tributary Name	Area (ha)					Inlet	Outlet	
35	16220	University Ck	89.9	3	2400	1800	BOX with link slab	2.4	17.1	Culvert outlet to be extended under Christie Rd EB on-ramp and reconstruct energy dissipater. Minor inlet extension also required on WB side.
36	16450	Shrimptons Ck	560	1	approx. 20000	approx. 6000	Precast concrete arch units	12	-	Large arch structure – inlet to be extended under Herring Rd WB off-ramp
37	16980		49.45	1	1800		PIPE	-	-	No culvert extension works required
39	18000	Porters Ck	38.49	1	2400	1800	BOX	-	-	No culvert extension works required
40	18425		1.23	1	3600	2400	BOX	-	-	No culvert extension works required

SCALES AT A3 SIZE DRAWING
Horizontal 1:2500
Vertical 1:2500

Figure 13: Devlins Creek: 1 in 100y Flood Extent - Existing Conditions
December 2009

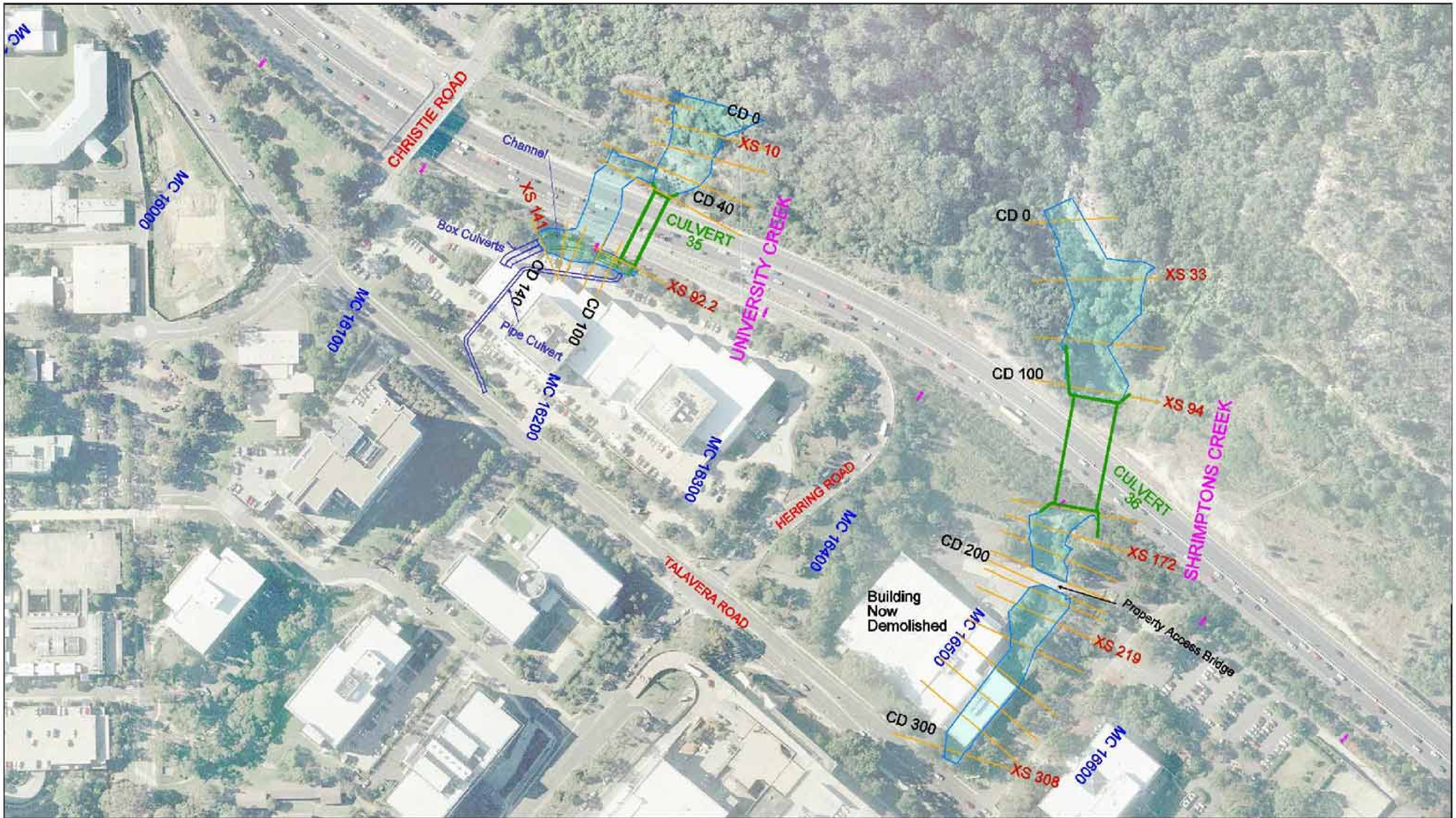
Legend

CD 12000	Channel Distance
XS 12040	Motorway Chainage
MC 12000	Channel Cross Section

Figure 14: Devlins Creek: 1 in 100y Flood Extent - Existing Conditions
December 2009

Legend

CD 12000	Channel Distance
XS 12040	Channel Cross Section
MC 12000	Motorway Chainage



SCALES AT A3 SIZE DRAWING
Horizontal 1:2000
Vertical 1:2000

Figure 15: University Creek and Shrimptons Creek: 1 in 100y Flood Extent - Existing Conditions
December 2009

Legend

CD 12000	Channel Distance
XS 12040	Channel Cross Section
MC 12000	Motorway Chainage

3.3 Impact Assessment

Construction: The proposed widening works would involve site establishment and preparation works as well as earthworks and drainage works. The disturbance of the areas surrounding the works would increase the susceptibility of the site to erosion problems occurring. Management techniques employed to control and deal with runoff from the site works during construction also have the potential to concentrate flows and increase erosion leading to water quality issues for the receiving waters downstream. Erosion and water quality issues are discussed in more detail in Section 4.

As the existing culvert structures are the only means to convey upstream catchment flows across the motorway, facilitation of the construction works is likely to result in some temporary obstruction of the waterway flow path. This obstruction may be caused by temporary bunding or diversions of the waterway, the placement of construction equipment or materials within the flow area, stockpiles or access roads and work platforms. There is the potential for such obstructions to result in the redistribution or concentration of flows (increased velocities) and depending on the circumstances this may increase flood levels upstream and temporarily impact on adjoining properties. Problems of a similar nature may be experienced at the Darling Mills and Devlins Creek bridge sites due to the construction of any piers which might be located within or immediately adjacent to the creek waterways. The hydraulic impacts for these sites should not be as significant as the culvert situation because of the larger waterway area available meaning the flows would not be as concentrated. Additionally, there are no adjoining properties at risk of damage from flooding.

Operation: The varying nature and extent of the proposed widening along the route means that only seven (7) of the twenty-six (26) existing transverse culvert drainage structures are affected by the widening to such an extent that they actually require physical extension. The lengths of these extensions vary from a minimum of 2.4m to a maximum of 17.1m (both for the same culvert 35) with the remainder generally falling in the range of 4.9m to 8.5m.

Each of the affected structures has been modelled to establish 100 year ARI flood levels for both the existing and proposed conditions. A summary of the flood level and velocity results is presented in Table 3-2.

Table 3-2 Hydraulic Impacts – 100 year ARI event

Culvert		Analysis	Design Flow	Upstream Flood Level (mAHD)		Relative Impact (m)	Outlet Velocity (m/s)		Relative Impact (m/s)
ID	Chainage		(m^3/s)	Existing	Proposed		Existing	Proposed	
13	5250	HY8	4.5	78.84	78.84	0.00	6.36	6.44	0.08
18	7560	HY8	5.3	73.05	73.05	0.00	6.66	6.66	0.00
23	10550	Hecras	110	85.56	85.56	0.00	1.34	1.34	0.00
		HY8		86.11	86.12	0.01	2.93	2.93	0.00
26	11640	HY8	14.8	78.81	78.83	0.02	2.58	2.58	0.00
30	13500	HY8	19.3	48.02	48.02	0.00	3.91	3.96	0.05
35	16220	Hecras	41	41.51	41.41	-0.10	2.96	4.49	1.53
36	16450	Hecras	190	32.91	32.91	0.00	3.68	3.68	0.00

As is evident from the results in Table 3-2, there are no significant increases in flood levels that would potentially impact on upstream or adjoining properties. At Culvert 26 a maximum increase in peak flood level of 0.02m is identified, which should not adversely affect any surrounding properties. Culvert 23 has been modelled using two techniques. A maximum increase of 0.01m is shown with one method (HY8) and no increase is shown with the other method (HECRAS). As with Culvert 26, this change is not likely to adversely affect any surrounding properties. At University Creek (Culvert 35), the proposed channel works (refer Section 2.6) would reduce flood levels in this reach (between 1.0 to 1.5m) thereby improving the existing situation and reducing the risk of the motorway being overtopped.

It is not proposed to alter the waterway area (cross sectional dimensions) of the existing culvert structures and as such the changes in outlet velocity are typically less than 0.1m/s. Such small changes are considered to be negligible relative to the velocities already prevailing at the existing outlets and in the adjoining downstream creek sections. The only exception is for University Creek where increasing the length of the relatively steep existing culvert grade with improvements to the channel upstream has increased the outlet velocity. An energy dissipater at the relocated outlet together with other possible detail design measures (channel and inlet configurations, grade changes, increased culvert roughness or downstream dimensions) would be provided to address this increase.

In addition to the individual transverse culvert crossings, the motorway is to be widened along the reach running parallel to Devlins Creek. For the reach between Chainage 10580 to 11100 the proposed design concept is to construct the carriageway supported on piers and as a structurally cantilevered section to overhang the creek. This concept has been modelled in HECRAS and found to have minimal impact (<0.01m) on flood levels.

For the main bridge crossings of Darling Mills and Devlins Creeks, there is a possibility that one or two piers will need to be placed within or immediately adjacent to the creek channel. The need and/or location for these piers is subject to structural and constructability considerations and alternative options are being considered as part of the detailed design development. It is unlikely that the piers would have significant hydraulic impacts (increases in water levels, or velocities) in the context of the overall creek waterway area available relative to the area or size of the one or two additional piers. Any impacts would be localised and contained to the area immediately surrounding the pier itself. As noted in Section 2 and elsewhere, the creek channels and banks are generally defined or formed through the underlying sandstone rock substrate. While some local geomorphological changes may be experienced with time, substantial scouring is less likely to occur.

3.4 Management of Impacts

Construction: Managing potential hydraulic impacts during construction needs to minimise the risks to the surrounding environment as well as the works themselves. Appropriate mitigation measures to be implemented will vary depending on the nature of the risks and sensitivity of the particular situation but would include consideration of the following:

- Temporary diversion or pumping of low flows around the works area.
- Minimising the need or extent of any obstructions required to be placed within the waterway area.
- Programming or staging any construction associated with creek/channel works or the transverse culverts to minimise the total time that works are undertaken in the vicinity of watercourses and thereby minimise the risk exposure.
- To better facilitate construction methods and reduce potential erosion/scour problems, permanent diversion of small channels in localised areas might be considered for situations where the permanent works (such as bridge piers) may be required to remain adjacent to or partially obstructing the waterway.
- Ensuring construction equipment (or excess material) is removed from the waterway or floodplain areas if wet weather is approaching and at the completion of each day’s work activity.
- Strategically placing temporary levees or bunds to contain potential impacts and minimise the risk to surrounding properties which might otherwise be affected.

Operation: The options for managing potential increases in upstream flood levels are largely constrained by the existing size and location of the previously constructed transverse culvert structures. The typical presence of retaining walls and a narrow corridor width is also a limiting factor. The concept design therefore generally proposes to construct new, or modify existing, retaining walls over any inlets/outlets affected by the widening works to minimise the need for extending the culvert structure. This approach should ensure there would be minimal additional upstream impacts (increase in flood levels) created and the need for disturbance of the surrounding environment is also reduced.

For the few culvert structures that are to be extended and may cause flood level impacts, the proposed mitigation measures include modifying the inlet details to ensure hydraulic efficiencies are optimised and therefore losses and upstream impacts are minimised; keeping the length of required extensions to an absolute minimum.

Energy dissipaters and scour protection measures downstream of the culvert outlets would be modified and/or reconstructed to suit. Depending on the extent or nature of modification to the existing outlet structures, these scour protection works would largely reproduce the existing measures which generally comprise either concrete dissipaters, rock mattress and/or dumped rock rip rap.

Just downstream of Murray Farm Road, between Chainage 10580 to 11100 (refer Figure 13), the motorway is to be widened on the westbound (southern) side where it would potentially impose on Devlins Creek and its floodplain which runs in parallel along the motorway corridor. In order to minimise impacts on the waterway area of the creek and floodplain, the concept design proposes to construct a concrete deck carriageway structure supported on piers (10880-11100) and as a cantilevered section (10580-10880) overhanging the floodplain area. Consequently there would be little to no change in flood behaviour along this reach.

At University Creek (Culvert 35), the property immediately upstream of the M2 motorway is currently affected by overland flooding from upstream and in a 100 year ARI event the M2 itself is at risk of being overtopped under existing conditions. The proposed works include replacing the existing overgrown gabion and rock mattress lined channel, which runs along the upstream (westbound) side of the motorway, with a concrete lined channel. The new channel would provide greater flow capacity than is currently available which would be sufficient to mitigate the impacts of the proposed widening as well as improve the existing flood situation. An open traffic barrier, such as wire rope or guard rail, would be utilised along this reach to allow for potential overtopping of the motorway in the larger flood events. Special attention would be afforded to transitioning the channel into the culvert inlet in order to ensure any hydraulic losses are minimised and the potential culvert performance is optimised. Increased velocities within the channel and at the culvert outlet would require additional consideration, such as energy dissipation, during detail design to reduce the hazard and prevent scouring of the downstream reaches.

Where piers are required for widening of any of the main bridges (Darling Mills, Devlins or Terrys Creeks) these are generally to be located out of the main creek waterway and are unlikely to create additional hydraulic impacts. Wherever possible the new piers would be aligned with the existing piers or creek channel and streamlined in shape to minimise the potential to interfere with stream flows. Appropriate scour protection in the form of dumped rock rip rap would be provided where required.

4.0 Water Quality

4.1 Existing Environment

The following observations in respect of the existing water quality conditions are made based on the available data summarised in Appendix A. As a general note, the data is quite variable but this is often typical of most water quality sampling data reflecting the stochastic nature of the rainfall-runoff processes.

Between July and December 1994 (prior to the original motorway construction), Bill Rooney sampled sites M2-1 through to M2-8 downstream of the motorway and established background TSS averages for wet (128 mg/l) and dry (8 mg/l) conditions. Subsequent long term sampling results (post M2 construction) by HLA Envirosciences (which follow wet events of rainfall greater than 10mm in preceding 24h) have calculated the median and average values to range between 5mg/l to 13mg/l (median) and 11mg/l to 32mg/l (average). Comparison of these results for the two alternative periods suggests that construction of the existing motorway has not had any significant impact on the water quality of downstream receiving waters.

Of the forty-seven (47) events which have been sampled at the 16 locations (some 752 samples in total), there are only thirteen instances (<2%) where the TSS has exceeded the background average of 128mg/l established prior to construction of the motorway. Excluding the results for Toongabbie Creek, which is outside the current limits or influence of proposed widening works, the number of exceedances is reduced to only ten (10) which resulted from five separate events. Only four of these results (0.5%) actually represent sampling sites nominated as being downstream of the motorway influence.

While TSS is only an indicator of potential contaminants and water quality, the long term monitoring results tend to suggest there appears to be minimal discharge or transfer of suspended solids from the motorway which could exacerbate sedimentation of the downstream receiving waters. The motorway activities are therefore having minimal impact on the general water quality of the various tributary watercourses through which it traverses.

Within the limits of the proposed project widening, some thirty one (31) water quality basins were originally provided to treat the low flow runoff draining from the existing motorway pavement surface via the stormwater pipe drainage networks. Low flow runoff (first flush) or contaminated spills washed from the road surface are directed through bifurcation pits which divert the water into the basins for containment and treatment. The first flush of runoff typically contains the higher concentration of sediments and larger particulate matter (waste materials from vehicles such as brake pad wear and metals) which tend to settle out of the water more readily when temporarily stored in the basin. Fluid type materials washed from the surface (such as fuels and oils) are less dense and tend to float on the water surface allowing them to also be contained in the basin by use of special outlet arrangements. The locations of the basins are shown on Figures 1 to 5 with estimated basin details summarised in Table 4-1. A copy of the original design details is included in Appendix C for reference.

The sampling of the existing water quality basins, which are meant to treat the “first flush” of runoff from the pavement surfaces, also suggest that the basins are performing their intended function in helping to protect the quality of the receiving waters. Water quality sampling results obtained in 2007 and 2008 for various basins are included in Appendix A.

The July 2007 HLA Envirosciences report found marginal exceedances of the ANZECC Freshwater criteria for zinc and copper at eight (8) of the ten (10) locations sampled. However, the report considered it was likely (but subject to further confirmation) that these exceedances were actually representative of regional water concentrations.

The July 2008 report by Sydney Environmental and Soil Laboratory Pty Ltd states that *“the waters sampled generally complied with the adopted guidelines”.* Possible explanations or reasons for any of the exceptions or exceedances noted were summarised as follows:

- Copper can be released into the environment by both natural sources (such as wind-blown dust, decaying vegetation, forest fires and sea spray) and human activities (including mining, metal production and phosphate fertilizer production).
- Cobalt which is most likely sourced from freely available particles not bound to soil or sediment particles.
- Tin which can enter waterways via a number of sources such as tin cans and organotin compounds which are often added to fungicides and insecticides.

- Beryllium which only marginally exceeded the guideline criteria is mostly found in soils within the environment.
- Zinc which is an abundant material that occurs naturally and is used in galvanising processes (including roof materials and gutters) as well as an activator in the rubber industry.
- Iron which is used in various alloys and applications including cars and is often naturally elevated in groundwater within sandstone layers.
- Polycyclic aromatic hydrocarbons (PAHs) which naturally occur in bush fires as well as oils with the most likely source being emitted from motor vehicle exhaust.

The elevated readings within the basins for some elements such as copper & zinc as well as the PAHs suggest that these pollutants are being captured and retained in the basins in accordance with the design functional intent.

The Hills M2 Motorway have indicated that the existing basins are generally working satisfactorily and aside from the ongoing build up of litter requiring regular cleaning, the basins have been drained and de-silted once in 2005 since the motorway became operational in 1997. The excavated sediment material was retained in a suitable storage area of the works depot within the motorway corridor.

With regards to spill incidents, the Hills M2 Motorway indicated that there has not been any major spill incidents to threaten the surrounding environment since operations began. There have been some minor instances of contaminants falling from trucks (such as chemicals or paints etc) and obviously some small oil & fuel leaks resulting from motor vehicle accidents. All such spills/incidents are quickly dealt with by the M2 response team which has a special action plan and spill containment kit to deploy so that the potential for any contaminants to reach the drainage system and downstream environment is minimised. As a further safeguard, the existing motorway drainage systems have been designed to direct any low flows, including fluid spills or wash down volumes, into the water quality basins where the contaminated runoff can be retained and appropriately dealt with.

Table 4-1 Water Quality Basin Details

Basin Ref ID GHD Design	Tributary Catchment	Basin Location Approx. Chainage		Contributing Catchment Area			Basin Volumes (m^3)		
				Existing (ha)	Proposed (ha)	% diff	GHD Design	Est. Available	Required
8B	Northmead Gully	3580	EB	2.06	3.12	51	1370	925	624
10C	*Darling Mills Ck*	*4390*	*EB*	*1.94*	*1.94*	*0*	*420*	*428*	*388*
10B	*Darling Mills Ck*	*4550*	*EB*	*1.50*	*1.50*	*0*	*290*	*445*	*300*
12B	Darling Mills Ck	4770	WB	2.88	3.18	10.4	480	746	636
E204	Darling Mills Ck	4780	EB		0.69				138
13B	Darling Mills Ck	5360	EB	3.50	3.95	13	775	207	790
14B	Darling Mills Ck	6100	EB	0.61	0.66	8	120	124	132
14C	Darling Mills Ck	6370	EB	0.95	0.99	4	240	349	198
15B	Darling Mills Ck	6570	EB	0.91	0.93	2	160	280	186
16B	Darling Mills Ck	6860	WB	0.93	0.98	5	180	457	196
17B	Darling Mills Ck	7230	WB	1.34	1.36	1	360	356	272
18B	Darling Mills Ck	7560	WB	2.89	2.97	3	590	643	594
19B	Darling Mills Ck	7850	EB	2.60	2.62	1	590	670	524
21B	*Darling Mills Ck*	*8440*	*EB*	*7.75*	*7.75*	*0*	*1700*		*0*
22B	Devlins Ck	9730	WB	3.94	4.07	3	500	642	814
23B	Devlins Ck	10510		2.76	2.92	12.9	490	547	576
25B	Devlins Ck	11310	EB	2.60	2.78	7	580	916	556

Basin Ref ID GHD Design	Tributary Catchment	Basin Location Approx. Chainage		Contributing Catchment Area			Basin Volumes (m^3)		
				Existing (ha)	Proposed (ha)	% diff	GHD Design	Est. Available	Required
27B	Devlins Ck	11900	WB	2.07	2.13	3	420	459	426
28F	Devlins Ck	12230	WB	1.71	1.68	-2	480	853	336
28E	*Devlins Ck*	*12320*	*WB*	*0.17*	*0.17*	*0*	*60*	*108*	*0*
28C	*Devlins Ck*	*12390*	*EB*	*1.48*	*1.51*	*2*	*410*	*286*	*0*
28B	Devlins Ck	12460	EB	0.83	0.83	0	180	410	0
30B	Terrys Ck	13470	WB	2.09	2.89	38	520	905	578
33C	Terrys Ck	13920	EB	2.03	2.31	14	320	852	462
33B	Terrys Ck	14860	EB	1.42	1.67	18	260	595	334
34B	Mars Ck	15620	EB	5.03	5.17	3	930	1260	1034
35B	University Ck	16190	EB	3.44	3.51	2	680	1250	702
35C	University Ck	16285	EB	1.01	0.97	43	230	237	318
36B	Shrimptons Ck	16500	EB	1.60	2.54	59	330	676	1092
39D	Porters Ck	17880	EB	5.44	5.56	2	920	3099	1112
39C	*Porters Ck*	*18155*	*EB*	*1.65*	*1.65*	*0*	*300*	*2135*	*0*
40B	*Porters Ck*	*18460*	*EB*	*2.62*	*2.62*	*0*	*660*	*1248*	*0*

- *Basins highlighted in italics are not directly affected by the widening works.*

4.2 Impact Assessment

Construction: Potential impacts on water quality are more likely to occur during the construction phase of the proposal than the operational phase. The proposed works would involve excavation in many locations, resulting in exposure of the underlying soils, which has the potential to lead to sediment transport, erosion and ultimately sedimentation in downstream water bodies. The potential for sediment transport and sedimentation issues would be influenced by factors such as severity of storm events, the slope and footprint of disturbed area and the management controls that are implemented.

Works involving excavations would have the greatest potential to result in sediment transport and sedimentation issues. Such works would include physical widening works, construction of new piers for bridges, retaining walls, installation of stormwater drainage infrastructure and the augmentation of culverts and water treatment basins. These construction activities pose the greatest risk where they occur near waterways, on steep slopes or on land subject to flow or flooding. A management framework and site specific controls would need to be developed and implemented during the construction phase of the project to reduce the risks of sedimentation in down gradient water bodies due to the proposed constructions works.

Environmental releases of potentially harmful chemicals and other substances may occur as a result of proposed construction, which would have the potential to impact upon water quality in receiving waters down gradient from motorway. Such potentially contaminating substances would include acids and chemicals from washing processes, construction fuels, oils, lubricants, hydraulic fluids and other chemicals. Release of these substances might occur due to spills, as a result of equipment refuelling, failure and maintenance, via treatment and curing processes for concrete, as a result of inappropriate storage, handling and use of the substances or from the disturbance and inappropriate handling of potentially contaminated soils. These substances have the potential to be picked up in surface water (run-off) and be transported down gradient from the proposed works locations. Water quality and associated ecological impacts could result if these contaminants end up in water bodies down gradient from the works areas. A management framework would be required to reduce the potential for environmental releases of potentially harmful chemicals and to reduce the risk of any such releases entering local waterways.

A description of specific locations and scenarios where there is the potential for disturbance of the soil and sediment liberation, release of potentially contaminating substances, off-site transport of sediment and pollutants and ultimately impacts to water quality in the down gradient environment as a result of proposed construction activities is outlined below. Details of appropriate management strategies to address the issues and reduce the risk of water quality impacts are provided for each scenario.

To assist the discussion, a preliminary assessment of areas more likely to be prone to erosion due to the construction works has been undertaken. Maps showing the results of the assessment are included in Appendix D with the potential risk categorised as either high or medium to low depending on the nature of the site conditions and the type of construction works being undertaken. The factors which have been considered include: ground conditions (rock or soil), erodibility, slope, extent of clearing required, location of works relative to sensitive receiving environments, piers/piling works, fill earthworks or retaining wall. In this instance, a significant proportion of the project involves widening of existing cut batters/faces. These cut batters are typically comprised of rock and the disturbed face will drain down to the motorway. The dirty water runoff can then be readily managed with a treatment train of appropriate measures to reduce the risk of sediments being transported to the downstream receiving environment.

During construction, soils will be disturbed and sediment will be liberated inside the motorway areas. There is also the potential for spills of potentially contaminating substances. Procedural and physical management measures would be implemented during construction to retain sediment and spills at the work locations. However, there is still a possibility that sediment and potentially contaminating substances could enter the motorway stormwater drainage system. In such situations, the stormwater would be collected and transferred to the existing water quality basins, which are designed to collect, retain and treat these types of pollutants. Under normal operating conditions, any pollutants from inside the motorway areas would therefore be collected and retained in the water quality basins, reducing the risk of water quality impacts in the receiving waters downstream of the motorway.

During significant rainfall events, the water quality basins have the potential to become completely filled to capacity. In such situations the basins are designed to surcharge into the downstream environment. During these occurrences pollutants from the motorway may bypass the basins themselves and be discharged into downstream drainage systems and ultimately into permanent water bodies, potentially affecting local water quality. However, any chemical contamination would be highly diluted due to the significant volumes of run off. In addition, it is likely that due to the urbanised nature of the surrounding catchments, the water quality of the runoff from the M2 Motorway would not be different from the quality of runoff from the existing urban catchments. Therefore it is anticipated that the contribution of the Motorway to pollutant loads in these receiving waters would be limited.

Potential water quality impacts may result from the proposed modifications of the existing water quality basins. The works proposed at these locations have the potential to cause disturbance to the ground surface in areas that do not drain to the basins themselves. Soil contamination could also occur in these areas from the excavators and other equipment required in the basin modification works. Sediment and any other pollutants from these areas would have the potential to enter watercourses and ultimately permanent water bodies down gradient from the works locations. The areas of disturbance at these locations would be anticipated to be quite small. In addition, these areas would have limited up-slope catchment areas, limiting the potential for surface water run-off. As such, the potential for large loads of sediments to be released from the areas of disturbance is considered to be quite low. Appropriate management strategies and plans would be required to limit the amount of soil disturbance, collect and retain sediment on-site and stabilise disturbed surfaces as soon as practicable following basin modification works. With suitable strategies in place it is anticipated that the potential for significant water quality impacts in the downstream aquatic environments during construction would be minimal.

As part of construction, works and storage areas are proposed in areas that do not drain to the motorway. Any sediment releases or potentially contaminating substances spilled in these locations would not be captured by the motorway stormwater collection system and water quality basins. These substances could potentially enter the local stormwater system, which drain to local watercourses, which could lead to water quality impacts in the downstream receiving waters. For these works and storage locations, appropriate management strategies would be required to limit area of disturbance, provide for secure and bunded storage of potentially contaminating substances, divert surface water from up-slope areas around the areas of disturbance, retain sediment on site and stabilise disturbed areas as soon as practicable following completion of construction at that location. Suitable protective measures and devices would also be required at any entry points to the stormwater system to prevent the ingress of sediment and other pollutants. With suitable strategies and protective measures in place, it is considered that the potential for water quality impacts in downstream, receiving waters associated with the construction works would be minimal.

The proposed construction and modification works at the transverse drainage structures that cross the motorway have the potential to impact upon downstream water quality. At these locations, surface water flows are concentrated, velocities can be high and water can therefore have a large erosive potential. The proposed modifications often are located directly in the flow areas of these watercourses. Disturbance to these areas has the potential to decrease ground stability. Combined with the high erosive potential of run-off passing through these culverts, there is the potential for scour and the release of large sediment loads into the downstream receiving environment at these locations, particularly during significant rainfall events.

Outlets to these structures would be designed with suitable scour protection, to create stable discharge points, reducing the risk of scour at the culvert and sedimentation of the down stream receiving waters. The protective measures would also reduce the velocities and the erosive potential of the water being discharged from the culverts. However, during and immediately following construction, there would be a period in between initial ground disturbance and the installation of effective scour protection when these locations would be vulnerable to scour. This could potentially lead to sedimentation in down gradient water bodies, particularly during significant rainfall events, and downstream water quality impacts.

Appropriate management strategies would be required to manage surface water and prevent scour and sedimentation associated with proposed works at the transverse culvert crossings. Each location would need to be assessed individually and a work plan developed to minimise potential scour issues. The management strategies to be considered would include staging of works to maintain flows in stable areas, monitoring of weather forecast and commencement of in channel works when dry weather is forecasted (if practicable). Whilst there is limited opportunity to undertake the proposed culvert modifications on a seasonal basis, there may be some scope to prioritising the proposed works at these locations at times when dry weather is predicted. This would help to reduce potential scour and sedimentation issues. Installation of suitable permanent scour protection measures as soon as possible following each culvert modification would also assist in reducing the risk of scour and sedimentation of downstream receiving waters. However, due to the locations of these works and the unpredictability of the weather some potential for water quality impacts due to these works will remain.

Proposed works in riparian areas associated with the widening and modification of the bridges over the major watercourse crossings also have the potential to impact upon water quality. Riparian vegetation would need to be cleared to create works areas at these locations. Tracks would need to be created through vegetated areas to access the proposed works locations. The removal of vegetation and the disturbance created when constructing the tracks and works areas would cause ground instability. The potential for sediment release would increase from these areas, particularly on sloped land. Due to the proximity of these areas to watercourses, the potential for sedimentation of these watercourses and other water quality impacts would be increased due to the proposed works.

Site specific plans would be required at each location to manage and reduce the risk of water quality impacts associated with these works. The site-specific plans would include strategies such as the creation of exclusion zones to limit disturbance, works staging, specific activity procedures for vegetation clearing and access track creation, diversion of run-on from upslope areas around works areas, surface controls to promote ground stability, limit run-off lengths and reduce run-off velocities within the work sites, installation of devices to capture and retain sediment on-site and measures to re-establish ground stability as soon as practicable following the completion of construction. With appropriate strategies in place, the risk of sedimentation of the local waters in the vicinity of these works locations could be substantially reduced.

Operation: During the operational phase, the potential water quality impacts attributable to the widening works would be an increase in pollutants associated with changes in the contributing catchment characteristics (i.e. Increase in percentage of imperviousness or the overall total surface area resulting in larger volumes of runoff to be treated). The nature of pollutants associated with the motorway function and contained in this runoff include:

- Gross pollutants.
- Sediments and suspended solids.
- Nutrients.
- Heavy metals.

- Organics, oils and surfactants.
- Contaminant/accident spills.

Minimising the transportation and discharge of sediments, suspended solids, heavy metals and PAHs from the motorway is the key objective for the operational phase.

In order to assess the potential impacts associated with the motorway widening, preliminary computer modelling using the MUSIC software (Version 3, 2005) has been undertaken for a selection of the existing basins affected by the works. Nine (9) basins were selected to provide a representative sample of the range of changes in contributing catchment areas (refer Table 4-1 & 4-2) including all of those with the largest percentage increases. For the twenty two (22) other they are either not affected by the widening works or the increase in area is less than 10%.

Models defining the existing catchment characteristics were initially set up for each of the selected basins to establish a baseline performance representative of current motorway conditions. The models were then modified to reflect any change in percentage imperviousness or increase in catchment area and thus quantify what potential impacts might be created by the widening works alone.

The pollutant loads estimated from the MUSIC model for the current and proposed widened motorway conditions are summarised in Table 4-2. The base parameters adopted for purposes of the MUSIC modelling are presented in Appendix C along with more detailed results.

Table 4-2 Estimated Catchment Pollutant Loads (kg/year) – Pre and Post Widening

Basin	Chainage	Change in total Area %	Existing Catchments			Proposed Widened Catchments		
			TSS	TP	TN	TSS	TP	TN
8b	3580	51.5	5610	9.67	34.7	9600	16.2	56.1
12b	4770	10.4	8840	14.9	52	9760	16.6	57.5
13b	5360	12.9	10100	17.2	60.8	11000	18.5	66.7
23b	10510	5.8	9490	16	54.7	10100	16.9	57.6
25b	11310	5.9	8990	15.2	51.5	9690	16.3	55.3
30b	13470	38.3	7190	12.1	41.8	9930	16.7	57.2
33b	14860	17.6	4720	7.92	27.4	5630	9.48	32.6
35c	16285	43.3	3120	5.28	18.1	4660	7.84	26.9
36b	16500	58.8	5150	8.69	30.1	8040	13.6	47.4

Note: TSS = Total Suspended Solids, TP = Total Phosphorus, TN = Total Nitrogen

Further model changes were then introduced to demonstrate the resultant treatment effectiveness (reduction in potential pollutant load impacts) following implementation of proposed basin modification works. The proposed works primarily involve changes to the inlet and outlet details in order to better utilise the existing storage volume available. All of the basins currently have a 1m freeboard above the top water level (TWL - the normal operating level for capturing and treating the low flow events) and at least 0.5m freeboard above the maximum water level (MWL – the highest water level reached in the basin before excess overflows are discharged directly from the basin itself). Initial modelling results suggest that increasing the ponded (extended) depth by approximately 0.2m to 0.3m would generally cater for treating the increase in runoff volumes generated by the changes in catchment area. Given that a majority of basins are situated below the motorway level in downstream bushland areas, it should be feasible to accommodate such relatively small increases in depth without adversely affecting the hydraulic performance of the upstream drainage systems whilst still maintaining some freeboard of 0.2m to 0.3m.

A comparison of the treatment effectiveness results (% reduction of pollutant loads discharged) is included in Table 4.3 with more details available in Appendix C. Results for gross pollutants have not been included as the current and proposed basin arrangements provide 100% capture.

Table 4-3 Water Quality Treatment Train Effectiveness

Basin	% Reduction						Relative Difference %		
	Existing Basin			Proposed Basin					
	TSS	TP	TN	TSS	TP	TN	TSS	TP	TN
8b	85.4	68.8	20	85.4	68.9	18.7	0	0.1	-0.3
12b	80.3	64.5	16.1	80.9	64.6	16.4	0.6	0.1	0.3
13b	71.3	56.1	14.2	72.3	57	14.9	1.0	0.9	0.7
23b	77.2	61.8	15.9	77.6	62.1	16.2	0.4	0.3	0.3
25b	81.5	65.8	17.1	81.3	65.9	17	-0.2	0.1	-0.1
30b	84.8	68.6	17.6	84.8	68.8	17.4	0	0.2	-0.2
33b	85	69.1	21.1	84.9	69.1	20.6	-0.1	0	-0.5
35c	81.8	65.9	17.1	81.5	65.6	16.8	-0.3	-0.3	-0.3
36b	87.9	72.1	23.8	87.7	71.7	23.3	-0.2	-0.4	-0.5

Note: TSS = Total Suspended Solids, TP = Total Phosphorus, TN = Total Nitrogen

It is evident from the modelling results in Table 4-3 (and Appendix C) that the existing basins are performing well and except for TN appear to be achieving treatment efficiency levels (or percentage pollutant reductions) which are generally greater than or in accordance with the stormwater treatment objectives for NSW outlined in Australian Runoff Quality (ARQ Table 1.2) being:

- TSS reduction of 80%.
- TP reduction of 45%.
- TN reduction of 45% where practical to achieve.
- Gross Pollutants 100%.

The City of Ryde has also set out pollutant reduction objectives in the March 2009 Development Control Plan (DCP) for Water Sensitive Urban Design (WSUD) which targets 85% for TSS, 60% for TP, 45% for TN and 90% for gross pollutants. These objectives are greater than those required by ARQ but the modelling results suggest that with the exception of TN these values are also mostly being achieved under existing conditions. Following the proposed widening of the motorway, the modelling results suggest that the existing basins would still have sufficient capacity/performance to be able to satisfy the treatment objectives of ARQ without any significant modification.

There are some situations where a significant reduction in Total Nitrogen is not practical to achieve due to the size of basin which would be required. Nitrogen loads are often due to atmospheric fall-out rather than being sourced from motorway activities and typically large water surface areas (such as wetlands) are required for treatment purposes. In this instance, the potential size or footprint of basins are more often constrained by the prevailing topography and limited corridor area available whilst trying to minimise disturbance of the surrounding environment and established vegetation. A reduction in TN in the order of 15 – 25% has been found to be generally achievable given the prevailing constraints and this is also consistent with the existing level of treatment efficiencies (i.e. the current situation is not adversely affected).

Overall, the various analyses undertaken using MUSIC modelling indicate that the pollutant loads are proportionally related to the changes in catchment area. The results also show that these impacts are manageable through modifications to the existing basins and it is possible to achieve the treatment efficiency objectives required by ARQ. Additionally, the treatment performance levels achieved would be similar to the existing situation including TN.

4.3 Management of Impacts

As a general guiding principle for both design and construction, water quality mitigation and management measures would be implemented in accordance with the requirements of:

- *Water Policy and Code of Practice for Water Management (RTA 1999).*

- *Erosion and Sedimentation Management Procedures (RTA)*.
- *Managing Urban Stormwater - Soils and Construction Volumes 1 and 2 (often referred to as The Blue Book - Landcom 2004 and 2006)*.

A summary of measures likely to be implemented for both the construction and operational phases is provided below.

Construction: the control and mitigation of potential surface water quality impacts during the construction phase would be defined in a Soil and Water Management Plan (SWMP) prepared as part of the overall Construction Environmental Management Plan (CEMP). The SWMP would be developed to incorporate the most appropriate or "best practice" controls and measures in accordance with "The Blue Book" requirements and the Plan would be continually updated to suit the ever changing needs as the project works progress. Due consideration would also be given to the extent of works and situation relative to the sensitivity of the surrounding environment. Typical mitigation measures to be considered or implemented include:

- Minimising disturbed areas and re-vegetating or stabilising such areas as soon as practical as the works progress.
- Utilising cleared vegetation for mulching wherever possible to minimise erosion and filter runoff to trap coarse sediments.
- Installation of appropriate erosion control measures such as silt fencing, straw bales, check dams, temporary ground stabilisation, diversion berms or site regrading.
- Divert clean water runoff away from the works or disturbed areas wherever possible.
- Utilisation of existing water quality basins or installation of new temporary sediment basins as appropriate.
- Installation of any permanent scour protection measures required for the operational phase as soon as practical.
- Providing bunded areas for storage of hazardous materials such as oils, chemicals and refuelling areas.
- Any work platforms or access tracks required through waterway areas would be constructed of large clean rock material wrapped or underlain with geofabric.
- Employ a qualified soil conservation officer to advise on appropriate controls and to monitor the implementation and maintenance of such measures.
- Engage all site staff through tool box talks or similar with appropriate training on soil and water management practices.
- Work Method Statements would be prepared for all waterway works with particular emphasis on the early implementation of erosion and scour protection requirements.

Operation: appropriate energy dissipation and scour protection measures would be provided at bridge waterways and culvert inlets/outlets as necessary. Permanent scour protection requirements particularly at culvert outlets would be implemented as soon as practical. Surface areas disturbed by the construction works would be re-established with landscaping.

The existing water quality basins would be modified as required to account for any significant changes in contributing catchment area or to meet the target pollutant reduction criteria. Due to the constrained project corridor, and in an effort to minimise further disturbance of the established vegetation, wherever practical it is proposed to modify the inlet/outlet details of the existing basins to better utilise the storage volume already available by increasing the ponded (extended) depth. As discussed in Section 4.2, the majority of existing basins appear to have been designed with up to 1m of freeboard above the top water level (TWL) and 0.5m above the maximum water level (MWL). The required increases in depth are typically directly proportional to the percentage increase in catchment area. As indicated in Table 4-1, the change in contributing area is less than 15% for more than half of the existing basins and storage depths are in the order of 1m to 2m, so the required increase in depth would mostly be in the range of 0.15m to 0.3m which should not present any major problems or issues to achieve. In a number of instances however, it would be necessary to physically enlarge the basin to cater for the additional volume of runoff requiring treatment. A sensitivity analysis (refer Appendix C) has indicated that the increase in basin area required would also be directly proportional with the change in catchment area. In some instances the solution would involve a combination of increasing area and depth so as to minimise the actual disturbance footprint for the basin.

The preferred approach for modifying the various basins in each Precinct is indicated in Section 2.6. The actual solution would ultimately be determined during the detailed design phase once the additional survey information has been obtained and further modelling/investigations are undertaken.

The basins would be used to treat the low flow runoff "first flush" from the motorway pavement surfaces. Basin 30b which is located just to the east of the Norfolk Tunnel would additionally be modified to incorporate measures for dealing with tunnel wash down water from maintenance activities.

The spill containment capability afforded within the existing basins would be retained and upgraded or enhanced as appropriate to minimise the risk of accidental spills or contaminants discharging freely to the downstream environment. Operational procedures would be reviewed to ensure the relevant incident response plans are updated to address any changes or issues attributable to the upgrade works and also, adequately incorporates the latest environmental procedures and technologies for dealing with accidental contaminant spills. Maintenance plans and schedules would also be reviewed and updated as appropriate.

5.0 Conclusion

A detailed assessment of surface water issues incorporating transverse culvert structures and water quality has been undertaken to establish existing baseline conditions and to quantify the nature and extent of any potential impacts associated with the proposed widening works. Both the construction and operational phases of the project have been considered. Where impacts have been identified, a range of appropriate mitigation measures have been proposed to ensure such impacts are minimised.

From a drainage perspective the proposed upgrade works are not considered significant in the context of the existing motorway environment. Only seven (7) of the existing transverse culvert structures are to be extended with the majority in the range of 5m to 8m. Detailed hydraulic analyses (refer Table 3-2 for results summary) indicate that there are no significant increases in flood levels which would potentially impact on upstream or adjoining properties. Culvert 26 is the only location where a potential impact has been identified and this is limited to a maximum increase of only 0.02m which should not adversely affect any surrounding properties. At University Creek, the proposed channel works would reduce flood levels in this reach (between 1.0 to 1.5m) thereby improving the existing situation and reducing the risk of the motorway being overtopped.

Where culvert structures are to be extended, the proposed mitigation measures will include keeping the length of required extensions to an absolute minimum and modifying the inlet details to ensure hydraulic efficiencies are optimised and therefore losses and upstream impacts are minimised.

The existing water quality basins are currently performing well and have greater capacity available to ensure that there would be no worsening of the existing situation. The long term TSS monitoring results tend to support this assessment with minimal discharge or transfer of suspended solids from the existing motorway which could exacerbate sedimentation of the downstream receiving waters. Water sampling of the actual basins, which are meant to treat the “first flush” of runoff from the pavement surfaces, also suggest that pollutants are being retained and the basins are performing their intended function in helping to protect the quality of the receiving waters. The motorway activities are therefore having minimal impact on the general water quality of the various tributary watercourses through which it traverses. As a further safeguard against contaminated spills, the motorway drainage systems are designed to direct any low flows, including fluid spills or wash down volumes, into the water quality basins where the contaminated runoff or accident spills can be retained and appropriately dealt with.

Various analyses have been undertaken using MUSIC modelling which indicate that the pollutant loads from the motorway upgrade are proportionally related to the changes in catchment area. MUSIC modelling results have indicated that in the most part, these existing basins would be able to treat the additional runoff volumes though the implementation of modifications to either the inlet/outlet arrangements, the basin area & volume or a combination of both. The standard treatment efficiency objectives required by ARQ (except for TN) would be achieved and performance levels similar to the existing situation would be targeted.

All of the measures proposed to mitigate any surface water impacts associated with the upgrade works are generally in accordance with the existing drainage elements and measures which were constructed as part of the original M2 Motorway.

In the context of the existing motorway presence and its surface water functionality, it is considered that the impacts associated with the upgrade works are generally minimal.

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