

Water Cycle Management Report

Vineyard Precinct
Post-Exhibition
October 2017

NSW Department of Planning & Environment

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NSW Department of Planning & Environment

10 Valentine Ave,
Parramatta NSW 2150

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1 Introduction

1.1 Objective of report

This report undertaken by Mott MacDonald (MM) details the procedures used and results obtained from analyses undertaken in developing the water cycle management strategy for the Vineyard precinct and to support the master planning by providing engineering input to assist in the development of an Indicative Layout Plan (ILP). The strategy has been developed using an integrated approach to flood risk management and urban design based on water sensitive urban design principles, meeting relevant standards.

1.2 Scope of Work

The purpose of the analyses was to:

- establish a water cycle management strategy based on water sensitive urban design principles;
- provide input into the development of the riparian corridors assessment;
- provide input into the development of the riparian land management and planning controls;
- undertake a hydrologic, hydraulic and water quality assessment of the precinct as an integrated approach to flood risk and water cycle management;
- develop a flood evacuation strategy to assist the State Emergency Services in directing residents of the precinct to during large storm events; and
- undertake design and cost analysis of water cycle infrastructure for precinct master planning.

The following analyses have taken into consideration the economical, engineering, environmental and social aspects of the planning proposal under the draft ILP. Particular emphasis has been placed on protecting the environment and enhancing the biodiversity of the receiving water bodies and surrounding environment by implementing water sensitive urban design and best management practices.

The following methodology has been adopted in order to assess the above scope of work:

1. Collate existing site data;
2. Review design controls and requirements;
3. Review previous studies;
4. Undertake hydrologic catchment analysis to compare existing site flows to proposed flows and determine stormwater detention strategies;
5. Undertake hydraulic modelling to assess the impact the proposed development has on surrounding environs; and
6. Assess the impact the proposed development has on regional water quality and develop water quality treatment strategies.

2 The Physical Environment

2.1 The Site

The Vineyard Precinct is located centrally in the northern most portion of the North West Priority Growth Area (NWPGA) and is bounded by Commercial and Menin Roads to the north, Boundary Road to the east, Windsor and Bandon Roads to the south and topography based boundary (slope transition) to the west. The site is bordered by three other growth precincts, Box Hill to the east and Riverstone and Riverstone West to the south. Although the site is wholly within Hawkesbury City Council (HCC) Local Government Area (LGA) it is bordered by the Blacktown City Council and Hills Shire Council as shown below in Figure 2.1.

The overall site comprises 590 hectares of primary production and rural small holdings zoned land under the Hawkesbury Local Environmental Plan (2012). It is approximately 4km wide in a west-east direction and ranges from approximately 1-2km long in a north-south direction.

Figure 2.1: Site Location



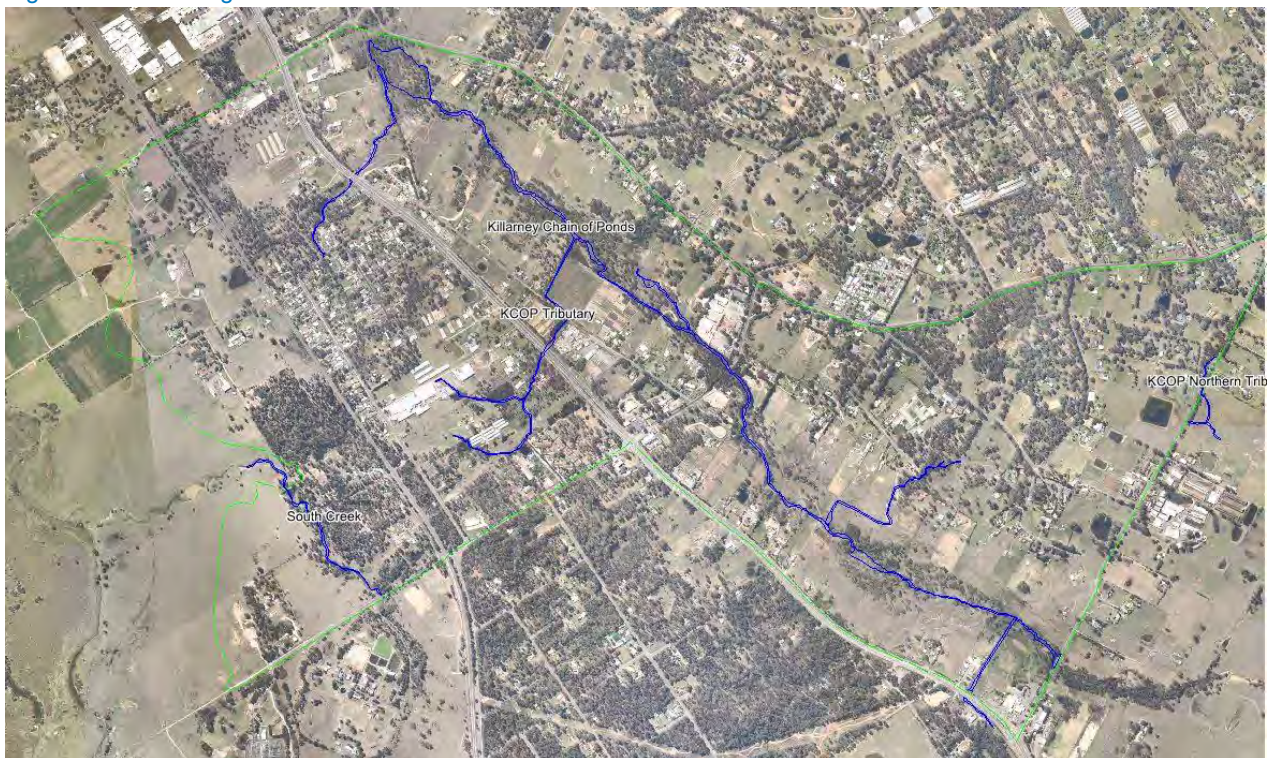
Source: Nearmap 2014

2.2 Data

2.2.1 Topography and Geology

The precinct is located within the South Creek sub-catchment of the Hawkesbury-Nepean River and consists of undulating terrain with elevations approximately ranging from 8-65m AHD. The site features an extensive flat depression along the entire central portion of the site associated with the Killarney Chain of Ponds, with a notably steep slope on the northern side of the precinct to Chapman & Menin Roads. A major ridgeline runs in a north-south direction in the western portion of the precinct, with areas along the western boundary falling away to South Creek in the west.

Figure 2.2: Existing Creeks



2.2.2 Developed Layout – Indicative Layout Plan (ILP)

The ILP has been developed using a holistic approach giving consideration to existing site conditions, environmental, indigenous heritage, non-indigenous heritage and cultural constraints, existing and proposed servicing infrastructure, housing demands, traffic conditions in and around the precinct, approved ILP's of surrounding precincts and costs associated with preparing the site.

An additional driver of the indicative layout plan is the arterial road network. A preliminary road hierarchy plan supplied by ARUP has allowed the development of a flood evacuation plan and improved compatibility with water-cycle and flood hazard management principles. According to the road hierarchy plan Windsor Road will function as the major north-south thoroughfare, with Chapman/Bandon, Commercial and Boundary Roads identified as future arterial, sub-arterial and collector roads for travel through the development. Design of local and collector roads will be guided by the information in this and other reports, and be documented in the Indicative Layout Plan.

A common objective of the Water Cycle Management Strategy and the Infrastructure and Development Staging Plan is to precede the planning process and feed robust engineering information into planners to enable a considered Indicative Layout Plan.

2.2.3 Rainfall Data

2.2.3.1 Rainfall Records

The water quality analysis required historical rainfall data recorded by a pluviograph station. The Richmond pluviograph recording station which is situated approximately 10km west of the subject site is the recommended rainfall data that is to be used by Council. Historical rainfall records for the area were obtained from the Bureau of Meteorology as follows:

Table 2.1: Richmond Pluviograph Data

Station No.	Location	Records	Data Interval
0607033	Richmond	1988 - 1994	6 minute

Source: Bureau of Meteorology

2.2.3.2 Intensity-Frequency-Duration (IFD)

Rainfall intensities were calculated within the XP-RAFTS model using the automatic storm generator tool. The tool requires input of the nine raw coefficients which were obtained from the Bureau of Meteorology's IFD calculator, based on the geographical coordinates.

Table 2.2 below provides a summary of the coefficients used.

Table 2.2: Bureau of Meteorology – IFD Coefficients

Intensity (mm/hr)			
50 year 1 hour	58.5	2 year 1 hour	30.05
50 year 1 hour	13.04	2 year 1 hour	6.72
50 year 1 hour	4.57	2 year 1 hour	1.86
Geographic Factors			
f50	15.82	f2	4.3
Location Skew			
0.02			

Source: Bureau of Meteorology

2.3 Additional Information used in the Assessment

2.3.1 Drainage Information

The flooding conditions on the site have potential to become worse under a developed scenario due to increases in impervious areas. A number of existing roads may be directly impacted as a result. Windsor Road, owned by the Roads and Maritime Services (RMS), is an arterial road and is required to maintain service up to and including the 500 year storm event.

Information on existing drainage culverts beneath Windsor Road have been provided by RMS. Where information was not available, including on other roads within the precinct, site inspections were undertaken to measure culvert information, including size, type and approximate length.

2.3.2 Cadastre

Existing cadastre and lot information, along with notable easements including Endeavour Energy and TransGrid overhead transmission line easements were provided by the Department of Planning and Environment. Information was provided in GIS format.

2.3.3 Creek Categories

Information on the existing creek locations and alignments, categories and riparian setbacks was provided by Ecological Australia.

3 Design Controls

3.1 Growth Centres Development Code (October 2006)

This code establishes the process of precinct planning for the growth centres including a framework for the development of the Indicative Layout Plan. This document ensures that the technical analyses necessary to produce specific planning controls are carried out within the context of the formulation of an Indicative Layout Plan so that the appropriate infrastructure will support future development.

3.2 State Environmental Planning Policy (Sydney Region Growth Centres) 2006

This legislation provides a set of controls on the planning process and on the development of land within the growth centre to ensure that changes to land use can be achieved with positive economic, cultural and ecological effects, improving the amenity of the growth centre area for future development. Of particular relevance to this report, the legislation ensures the availability of effective flood evacuation routes, limits any development with detrimental flood hazard impacts and maintains the overall sustainability of the water cycle.

3.3 NSW Floodplain Development Manual (April 2005)

The NSW Government's *Floodplain Development Manual – the Management of Flood Liable Land (2005)* is concerned with the management of the consequences of flooding as they relate to the human occupation of urban and rural developments. The manual outlines the floodplain risk management process and assigns roles and responsibilities for the various stakeholders.

The manual applies to the development, in particular in Appendix L – *Hydraulic and Hazard Categorisation* for ensuring safe overland flow paths are provided (see Figure L1 below).

Figure 3.1: Velocity Depth Relationships, FDM

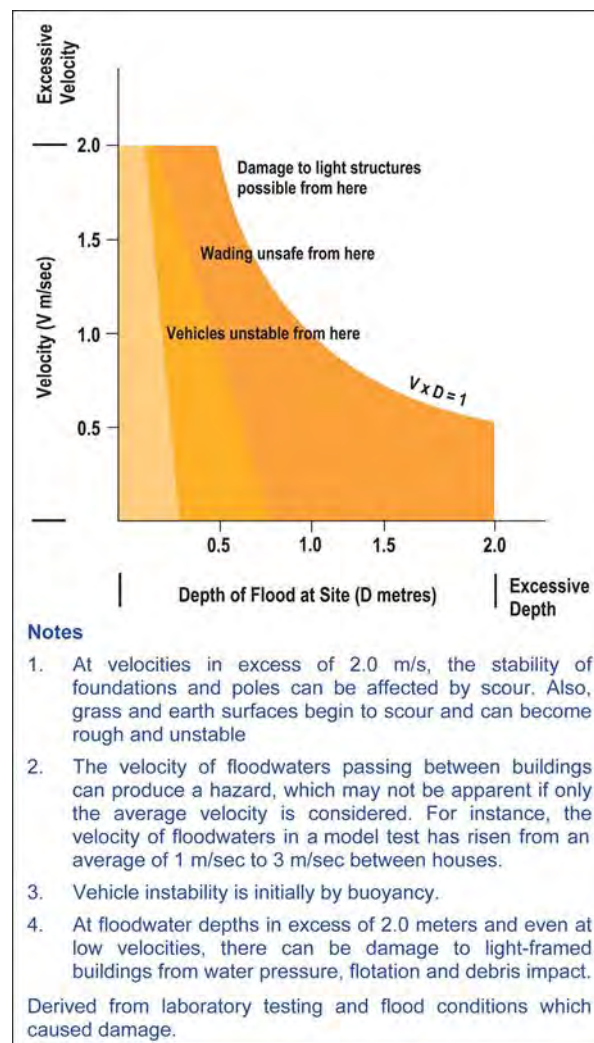


FIGURE L1 - Velocity & Depth Relationships

Source: NSW Floodplain Development Manual, 2004 (Dept. of Infrastructure, Planning & Natural Resources)

3.4 Floodplain Risk Management Guideline: Practical Consideration of Climate Change – Department of Environment and Climate Change (2007)

This guideline is designed to be used in addition to the Floodplain Development Manual (2005) and provides recommendations and methodologies for examining flood risk to developments in light of the projected impacts of climate change on sea levels and design rainfall events. The report recommends that sensitivity analysis is undertaken to using 10, 20 and 30% increases to rainfall intensities.

3.5 Stream Classifications for the North West Priority Growth Area

The NSW Office of Water supplies stream order classification for the identification and management of river ecosystems. The classifications of streams and the associated controls on development activities aim to preserve riparian buffer zones which contribute to the improvement in the health of river ecosystems and the reduction of erosion and potential flooding. Additional information was provided by Ecological Australia.

3.6 Australian Rainfall and Runoff – Volume 1 (2001)

Prepared by the Institution of Engineers, Australia Australian Rainfall and Runoff – *A Guide to Flood Estimation* was written to “provide Australian designers with the best available information on design flood estimation”. It contains procedures for estimating stormwater runoff for a range of catchments and rainfall events and design methods for urban stormwater drainage systems.

According to the document, good water management master planning should take into account:

- hydrological and hydraulic processes;
- land capabilities;
- present and future land uses;
- public attitudes and concerns;
- environmental matters;
- costs and finances; and
- legal obligations and other aspects.

3.7 NSW Department of Environment and Heritage

The NSW Department of Environment and Heritage, formerly The Department of Environment and Climate Change (DECC), and the NSW Environment Protection Authority (EPA) has developed a set of guidelines known as the Managing Urban Stormwater (MUS) series. The set of guidelines includes:

- Managing Urban Stormwater: Council Handbook;
- Environmental targets;
- Managing Urban Stormwater: Source Control;
- Managing Urban Stormwater: Soils & Construction; and
- Managing Urban Stormwater: Harvesting and Reuse.

3.7.1 Managing Urban Stormwater: Environmental Targets

The NSW Department of Environment and Climate Change (DECC) encourages the principle of no net deterioration of water quality. Under its former name, the NSW EPA, the DECC published *Managing Urban Stormwater: Environmental Targets*, outlining recommended environmental targets for stormwater management in new urban developments. Among its recommendations are the following stormwater treatment objectives:

Table 3.1: Stormwater Treatment Objectives for New Urban Areas

Pollutant	Adopted Treatment Objective
Gross Pollutant	90% retention of the annual average load for particles 0.5mm or less
Suspended Solids	85% retention of the annual average load
Total Phosphorous	65% retention of the annual average load
Total Nitrogen	45% retention of the annual average load

Source: *Managing Urban Stormwater: Environmental Targets*

3.7.2 Managing Urban Stormwater: Source Control

The DECC guide, *Managing Urban Stormwater: Source Control* recommends the control of stormwater pollution at the source, rather than more traditional “end of line” systems that are unsightly and require high levels of ongoing maintenance. In this document, Water Sensitive Urban Design (WSUD) is described as “minimising the impacts of development on the total water cycle and maximising the multiple benefits of a stormwater system”. It lists the main objectives of WSUD as:

- preservation of existing topographic and natural features;
- protection of surface water and groundwater sources;
- integration of public open space with stormwater drainage corridors, maximising public access; and
- passive recreational activities and visual amenity.

The broad principles of WSUD are listed as:

- minimising impervious area;
- minimising use of formal drainage systems (e.g. pipes);
- encouraging infiltration (where appropriate); and
- encouraging stormwater re-use.

3.7.3 Managing Urban Stormwater: Soils and Construction

Managing Urban Stormwater – Soils and Construction (4th edition, March 2004) are guidelines produced by the NSW Department of Housing to help mitigate the impacts of land disturbance activities on landforms and receiving waters by focusing on the removal of suspended solids in stormwater runoff from construction sites.

According to the guide, effective soil and water management during construction involves the following key principles:

- assess the soil and water implications of development at the subdivision or site planning stage (including salinity and acid sulphate soils);
- plan for erosion and sediment control concurrently with engineering design and before the land disturbance begins;
- minimise the area of soil disturbed;
- conserve topsoil for subsequent rehabilitation/revegetation;
- control surface runoff from upstream areas, as well as through the development site;
- rehabilitate disturbed lands as quickly as possible; and
- maintain soil and water management measures appropriately during, and after the construction phase until the disturbed land is fully stabilised.

3.8 Hawkesbury City Council (HCC) Control Documents

3.8.1 Hawkesbury City Council DCP 2002

An integral part of the master planning process for developments, the *Hawkesbury City Council DCP 2002* provides the necessary controls for the redevelopment of the site. Particular water management requirements include:

- compliance with Council's Development Control Plan (DCP);
- compliance with the demands of the BASIX system; and
- adoption of the principles of WSUD (including a water cycle management plan).

3.8.2 Hawkesbury City Council DCP – Appendix E Civil Works Specification

Council's *Appendix E – Civil Works Specification* sets out their requirements for the design of stormwater drainage for urban and rural areas. Part 1, the design specification, outlines the broad objectives of the policy of:

- retention of the natural stormwater system where possible;
- a high level of safety for all users;
- acceptable levels of amenity and protection from the impact of flooding;
- consideration given to the effect of floods greater than the design flood;
- a controlled rate of discharge to reduce downstream flooding impacts;
- protection of the environment from adverse impacts as a result of the development;
- maintenance of and enhancement of the regional water quality;
- sustainability of infrastructure; and
- economy of construction and maintenance.

The policy also provides detailed requirements for the hydrologic and hydraulic design and analyses of the developed water management system including standard calculation factors and drawings.

3.9 Additional References

It is noted that Hawkesbury City Council currently do not have specific statutory requirements for target pollutant removal rates for a new development. In lieu of more detailed data, it was agreed that the pollutant removal objectives and modelling parameters as outlined in Blacktown City Council's DCP and WSUD Handbook will be utilised for the precinct.

3.9.1 Blacktown City Council Developer Handbook for Water Sensitive Urban Design

Council's *Developer Handbook for Water Sensitive Urban Design* sets out their requirements for the design of water quality management systems to assist in mitigating the impact of urban development on local waterways within the area. The handbook also provides Council's modelling guidelines for the use of MUSIC modelling software.

4 Water Quantity Modelling

The assessment of water quantity was completed through hydrological modelling. This was carried out using the XP-RAFTS software package (XP Software, 2009) which is a non-linear runoff routing model that generates runoff hydrographs from rainfall. Computer based models of the existing and developed catchments were constructed and design storms applied to give estimates of the 2, 20, 100, 200 and 500 year ARI discharges. Assessment of these models then allowed the sizing and configuration of proposed basins and the documentation of their requirements to ensure the post developed scenario resulted in no worsening of flows to that of the existing. This is so as to not adversely impact on surrounding areas as a result of increased storm runoff in the proposed scenario. Assessments were also undertaken to considering Climate Change and the Probable Maximum Flood (PMF).

Outputs from these models were utilised in the hydraulic model (to be discussed in a later section of this report) to determine flooding extents, flow velocities and hazard categories for the Vineyard precinct.

4.1 Review of Previous Studies

4.1.1 Water Sensitive Urban Design and Flooding – Riverstone and Alex Avenue Precincts, GHD 2008

In 2008, GHD developed an XP-RAFTS model of the Riverstone catchment area for the Riverstone and Alex Avenue precincts and prepared a report detailing a water cycle management plan for the subject area.

The area included in this modelling comprised two distinct catchments, one catchment discharging to South Creek and the other to First Ponds Creek. The hydrologic analysis of the First Ponds Creek catchment provided runoff flow rates which could be referenced for discussion of modelling parameters and the comparison of flow regimes with subsequent modelling undertaken by MM for the Vineyard precinct.

An existing scenario was modelled hydraulically for comparison with a developed scenario which incorporated information from the draft indicative layout plan for the future development of the Riverstone and Alex Avenue precincts. Recommendations were made as to locations and sizing of online and offline basins to attenuate the post development flows back to the flow rates determined in the existing scenario model.

Results were compared between the GHD and MM modelling as part of the verification process which will be discussed in further detail in Section 4.7.

4.1.2 Water Cycle Management – Box Hill/Box Hill Industrial Precinct, JWP 2011

To support the Indicative Layout Plan for the adjacent Box Hill/Box Hill Industrial Precinct JWP developed a one and two-dimensional flood model and produced a Water Cycle Management strategy report. The report detailed a number of amendments to the flow regime of Killarney Chain of Ponds including basins, to manage the water cycle and address both quality and quantity targets for the precinct. The report identified areas where filling of the precinct could be achieved to maximise the developable land while addressing flood risk.

The hydrologic and hydraulic modelling discussed in the JWP report has provided flow rates at various points along the Killarney Chain of Ponds and First Ponds Creek which have been referenced in this report in terms of a comparison of modelling parameters and calibration of models.

It is important to note that the water quantity target in the developed scenario for the Box Hill/Box Hill Industrial precinct places a limit on the developed flow such that no increase to peak flow rates will occur in comparison to the existing scenario. This target is also applicable for precincts further upstream flowing into the Box Hill/Box Hill Industrial precinct. Considering this restraint on developed flows, the peak flow rates in the existing case are considered to yield the “worst case” upstream flows from the Vineyard precinct.

4.2 Modelling Approach

Two distinct modelling approaches were adopted to assess both the existing and proposed development catchments contributing to the Vineyard precinct. These approaches are outlined below;

- **Precinct models (for existing and proposed scenarios);**
 - Local Precinct hydrological models were developed to model the flows generated by the catchment areas within the Vineyard precinct. These models are referred to as the ‘Precinct’ models as they ignore upstream flows from the Riverstone, Riverstone East and Box Hill/Box Hill Industrial growth precincts. They ultimately only account for localised storms applied within the precinct boundary. They are useful for isolating and determining the effects the proposed development has on runoff within the precinct. These models form the basis of the pre-to-post hydraulic assessment and govern the detention basin sizing for the precinct only. Once the Precinct models are developed and detention basins sized the external upstream catchments are added to the model to create the regional models (refer below)
- **Regional models (for existing and proposed scenarios);**
 - The regional model incorporates upstream flows as described above. This gives a more realistic representation of flooding regime through the entire Killarney Chain of Ponds catchment (including the upstream First Ponds Creek).

4.3 XP-RAFTS Parameters

The user data inputs required by XP-RAFTS include catchment areas and slopes, pervious and impervious areas, IFD rainfall statistics and hydrological losses. Guidelines for determining these parameters are provided in Australian Rainfall and Runoff (I.E Aust, 2001) and are broken up as follows:

4.3.1 Catchments and Slopes

A three-dimensional (3D) surface was produced from aerial survey (LiDAR) data supplied by the Department of Planning and Environment using 3D modelling software. An analysis was performed using the 3D surface, information gathered during site inspections and existing aerial imagery to determine catchment delineation and slope profiles across the precinct.

4.3.2 Impervious Catchment Areas

For the existing scenario modelling, an impervious fraction of 5% was applied to each of the sub-catchments for all undeveloped land areas. For the developed scenario, the values recommended in the BCC Growth Centre Precincts Development Control Plan 2010 were adopted since these reflect the developed land use as documented in the draft ILP and are generally preferred parameters. This included an 85% impervious fraction for the proposed development areas. Refer to Drawing 0210 in Appendix A which outlines the developable areas in which the 85% impervious fraction is applied.

4.3.3 Intensity-Frequency-Duration (IFD)

Rainfall intensities determined as described in Section 2.2.3.2.

4.3.4 Rainfall Losses

The loss model adopted to estimate rainfall excess in the development of design flow hydrographs was the Initial Loss-Continuing Loss model. Parameters have been adopted based on a combination of site investigations, modelling undertaken by others on surrounding precincts and best engineering practice.

The following initial loss-continuing loss parameters were utilised within the model:

- an Initial Loss of 15mm and a Continuing Loss of 2.0mm/hour for pervious areas; and
- an Initial Loss of 2.5mm and a Continuing Loss of 0.0mm/hour for impervious areas.

4.3.5 Land Use

Aerial photographs provided information on current land use for the modelling of runoff in the existing scenario. The draft Indicative Layout Plan supplied by Cox Richardson was used as the basis for land use in the developed scenario..

4.3.6 Hydraulic Roughness Parameters

Hydraulic roughness parameters for the catchments were estimated based upon site inspections and discussions with Hawkesbury City Council, and were applied in accordance with recommendations in AR&R. Manning's values were applied to the model based on the land use of each sub-catchment.

In the existing scenario, a Manning's roughness parameter of 0.04 was adopted for the pervious and 0.025 for the impervious portion component of all 'undeveloped' land,

The proposed scenario adopted the same parameters for the areas of unchanged land use (land remaining undeveloped) and new values were adopted for the land area that is proposed for new land uses. A Manning's roughness parameter of 0.035 was applied to the pervious component while 0.015 was applied to the proposed impervious component.

4.3.7 B-Multiplier

The b-multiplier (b) used in XP-RAFTS is the coefficient used to calibrate a model to fit observed rainfall and stream flow data/recorded floods. The existing and proposed models both adopted a default 'b' value of 1.0 and no further calibration was deemed necessary based on comparisons with other approved models.

4.4 XP-RAFTS Catchments

An overall catchment is divided into a network of sub-catchments joined by links. The links represent natural watercourses, artificial channels, roadways or pipes. Rainfall is applied to each sub-catchment. Losses (representing infiltration, interception, etc.) are subtracted from the rainfall and the excess is then converted into an instantaneous flow. This instantaneous flow is then routed through the sub-area storages to develop local sub-catchment hydrographs. Total flow hydrographs at various nodes in the drainage network are calculated by combining local hydrographs. Hydrographs are transported through the drainage network by time lagging or channel routing. Hydrographs may also be routed through the storage basins such as dams or detention basins.

4.5 Existing Catchment

The Vineyard precinct is 591 hectares, but also has contributing upstream areas, which give a total catchment size of approximately 930 hectares.

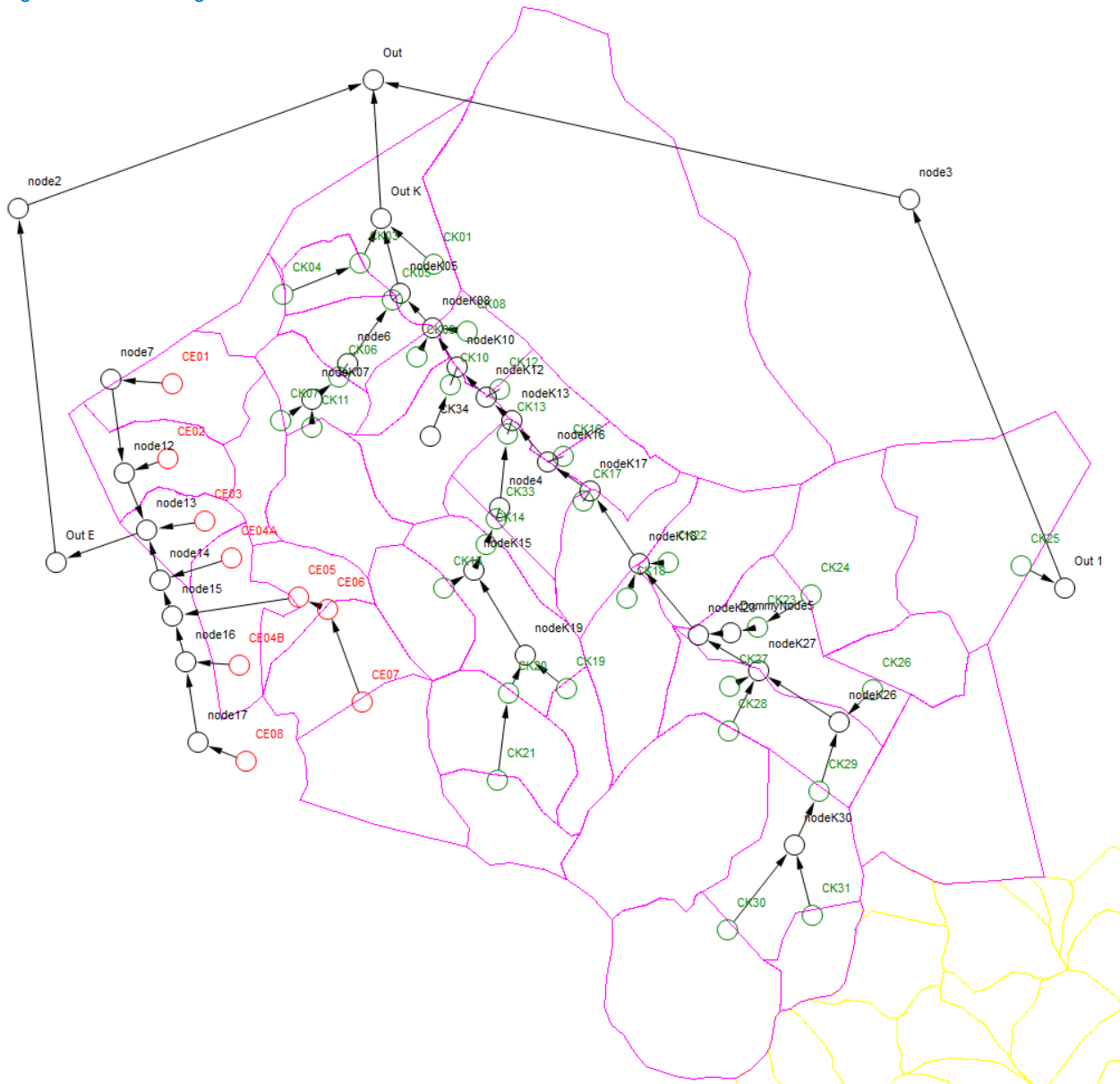
As described previously, the pre-developed precinct has an existing creek system which runs from south-east to north-west through the centre of the site, conveying runoff from the adjacent Box Hill and Riverstone East, and further upstream growth centre precincts to the Hawkesbury-Nepean River. This major water course, Killarney Chain of Ponds, has a series of smaller tributaries contributing runoff to the major channel, most of which will remain in the post-development scenario. A crest running south to north

through the western part of the precinct, following St James Road and continuing along Railway Road South splits a small portion of the precinct (approximately 15%) towards the west, which will drain to the Eastern Creek floodplain.

The Vineyard catchment has been divided into 41 sub-catchments. These sub-catchments range in size from 4.4 to 65.5 hectares (refer to Appendix B). The sub-catchments east of the natural ridgeline naturally adjoin the Killarney Chain of Ponds system at various points and eventually discharge to a large pond at the northern boundary of the Vineyard precinct. West of the ridgeline, the sub-catchments fall to the west and also find a series of small tributaries that discharge to Eastern Creek.

Drawing 0201 in Appendix A shows the existing catchment divisions, while Figure 4.1 represents the existing Precinct network within XP-RAFTS.

Figure 4.1: Existing Precinct XP-RAFTS Network



The pre-developed XP-RAFTS model was subsequently formulated by incorporating the following:

- “Catchment Nodes” were used to represent each of the 41 sub-catchments. Here, each node is representative of the catchment and is divided into both pervious and impervious values (Refer Appendix B);
- “Dummy Nodes” were used where two or more existing sub-catchments joined, which allowed both inflow and outflow hydrographs to be assessed.
- “Lag Links” were used as the links between the nodes and were modelled to provide the travel time (in minutes) for the peak flow to travel the length of this reach. The method for determining the lag link times is discussed in Section 4.6 below.

The following comments are also provided:

- No low flow pipe networks have been modelled in the XP-RAFTS model;
- Catchment CK25 bypasses the main channel system and drains to the East towards the Box Hill growth precinct. This has been included in the overall site discharge via a bypass node; and
- The model of the existing scenario has been modelled using two flow scenarios as described in section 4.2;

4.6 Lag Links and Model Calibration

Lagging links were developed (through the below iterations) to ensure a more accurate representation of hydrograph phasing was achieved in the model.

The procedure for determining the lag times was based on an iterative process which re-rationalised the links based on actual flow velocities generated by the catchment. The methodology is described below;

- Lag times (in minutes) were initially derived from conservative estimates of flow velocities through the active floodway and floodplain. The XP-RAFTS model was run with these estimations and the resulting flow hydrographs were then applied to the 2D TUFLOW hydraulic model (discussed in section 5);
- As TUFLOW determines storm flow runoff characteristics from the physical topography, stream flow velocities were able to be accurately measured along each of the major flow paths. After examining the flow velocities across the precinct, an average velocity of 0.52m/s was adopted; and
- The adopted precinct flow velocity (m/s) was then converted to a lag time (in minutes) for each lag link based on the known catchment flow path lengths (m). From this, revised XP-RAFTS lag link times were calculated and returned into the model.

4.7 Existing Model Verification

4.7.1.1 Previous Studies

Section 4.2 outlined the two flow scenarios that were modelled, these being Precinct and Regional. To accurately compare the GHD study (2008) with the model prepared as part of this assessment, all flows from the surrounding precincts were to be included. Thus, a comparison between the MM regional existing hydrologic results and previous modelling results extracted from the GHD existing model was carried out

as a validity check on the parameters used for input to the modelling. This comparison also serves to highlight the effect of various assumptions in the modelling parameters on the flow rates and flood levels.

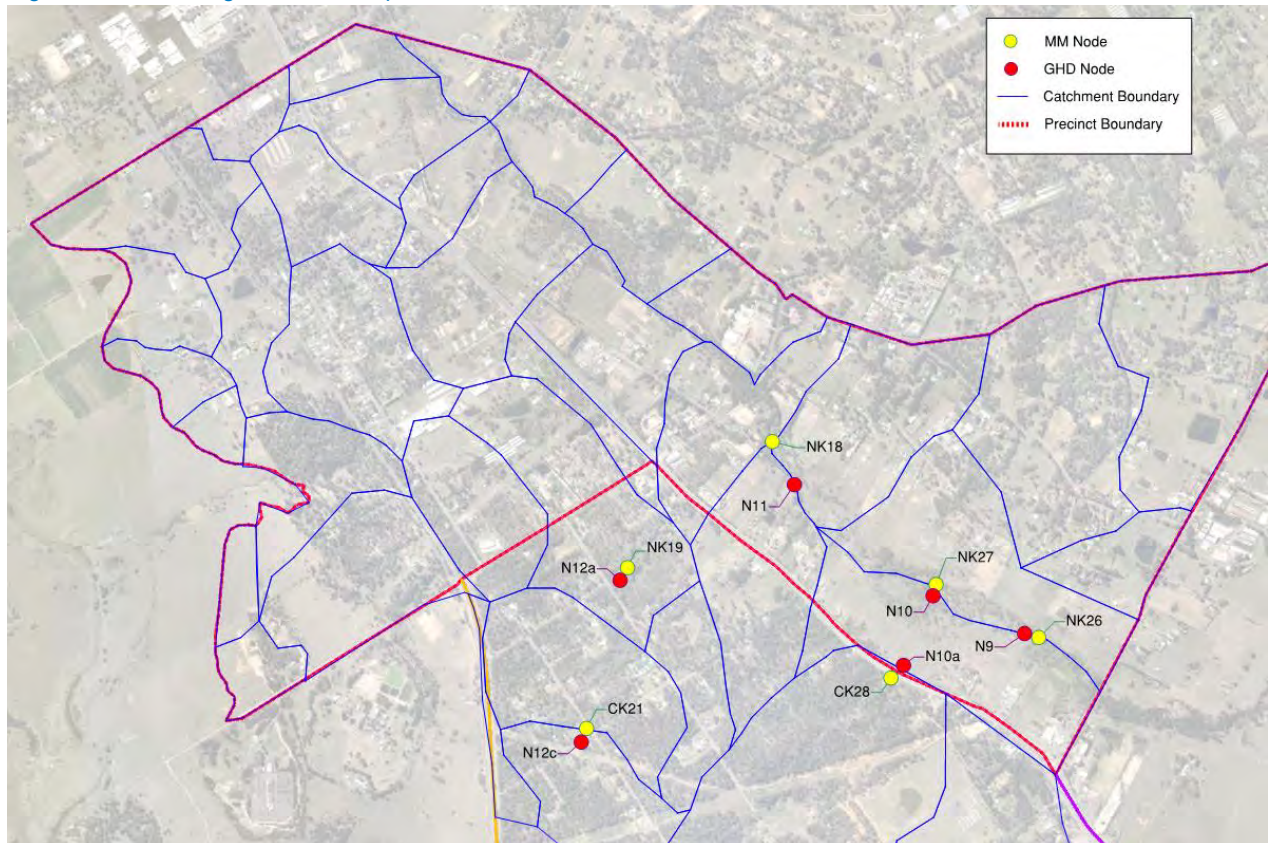
Peak hydrographs were compared in size and shape at suitable locations where node locations generally aligned between the two models. Figure 4.2 below shows the location of nodes in both models utilised for comparison. 100 year ARI peak flow rates have been extracted from both models and are listed in Table 4.1 below.

Table 4.1: Regional Hydrological model 100 year flow comparison - Existing Scenario

MM Node	GHD Node	MM flow rate (m3/s)	GHD flow rate (m3/s)	Description/Node Location
NK18	N11	211.603	227.262	Killarney Chain of Ponds
NK19	N12a	9.837	8.921	O'Connell Street
CK21	N12c	3.182	2.887	Hamilton Street
NK26	N9	197.521	214.150	Killarney Chain of Ponds
NK27	N10	204.115	222.381	Killarney Chain of Ponds
CK28	N10a	7.736	8.078	Windsor Road

From the above it can be seen that the flows from the GHD model are generally within 10% of the MM modelling. This could be explained as a result of different modelling methods, adopted catchment parameters, catchment divisions or rainfall data. Overall the variances are seen to be within an acceptable level of difference to use the existing precinct and regional model as a base to build the proposed precinct and regional models.

Figure 4.2: Existing Model – Comparison Locations



Source: Nearmap (2014), GHD (2008)

4.8 Developed Catchment

The existing catchment layout was used as a base to prepare the developed catchment layout. The Draft ILP provided by Cox Richardson (shown in Figure 4.3) was then used to tailor the catchments to suit the future layout. This resulted in a number of changed catchment areas, slopes, etc.

Water Cycle plans in Appendix A shows the proposed catchment divisions, while Figure 4.4 represents the proposed network in XP-RAFTS. Catchment areas, slopes and percentage impervious portions are tabulated in Appendix B.

The post-developed XP-RAFTS model was subsequently formulated by incorporating the same system of catchment nodes, dummy nodes and lag links as the existing model described in section 4.5. The proposed model however, included 'basin nodes' which were used to represent proposed detention basins used to ensure there is no increase to peak flows exiting the overall development.

Figure 4.3: Vineyard Draft ILP



Source: Cox Richardson

In addition to the comments provided in section 4.5, the following is to be noted of the proposed model.

- No detention basins have been provided immediately downstream of the proposed development adjacent to the north-eastern precinct boundary. Compensatory storage and flow attenuation has been provided in other locations within the precinct.

4.9 Management Strategies

4.9.1 Major/Minor System

The drainage system to be used in the developed scenario is the major/minor system. The minor system is designed to control nuisance flooding and enable effective stormwater management for the site. Council's standards require that the minor system be designed for a minimum 5 year ARI, but with more stringent requirements on specific areas dependant on land use. For the purpose of a high level assessment minor stormwater pit and pipe networks were not considered in the modelling however consideration was given to sizing of regional drainage elements such as detention basins for the 2yr, 20yr, 100yr, 200yr, 500yr, PMF and Climate Change.

The major drainage system incorporates overland flow routes through developed scenario roads and open spaces and has been assessed against the 100 year ARI design storm event, with general safety and flooding issues being addressed for events in excess of the 100 year ARI storm. The function of Windsor Road was also checked against flooding affectation in the 500 year event due to its role as an emergency evacuation route for the Riverstone, Box Hill and Vineyard area.

Inlet and culvert blockages were considered in the modelling with a 50% blockage factor across all culverts being applied in order to assess overland flow paths. Smaller culverts with a diameter less than or equal to 600mm were omitted from modelling in major events to simulate potential blockages of these structures. In determination of the sizing for drainage structures associated with arterial roads, 50% blockage was allowed for in the design capacity.

4.9.2 Design Discharges

Urban catchments generally experience higher discharge rates than rural ones due to the increase in impervious areas and the reduction of hydraulic resistance to flow paths. The detention strategy was developed to attenuate design flows such that there would be no increase in flow rates as a result of development in the 2 to 100 year ARI design flood events.

A range of storm durations from 25 minutes to 3 hours were modelled for each ARI, using AR&R temporal patterns, in order to identify the peak flow for each sub-catchment node. The design discharges for all of these events are shown in Appendix C.

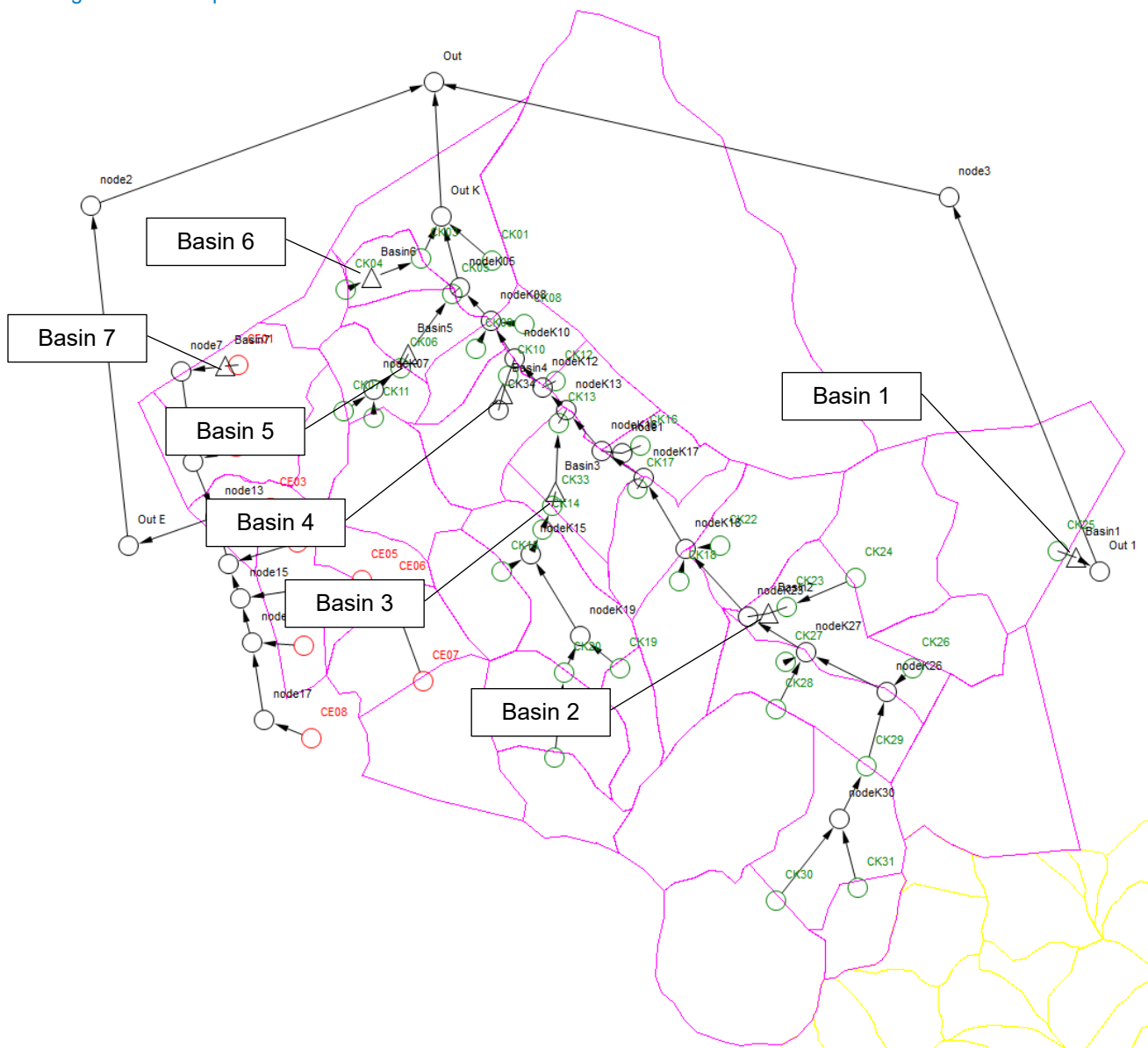
Extended duration storms were simulated for the 6 hour and 12 hour events to analyse any potential secondary peaks. These storms were run for the 2 year and 100 year to asses any impacts.

4.9.3 Detention Basins

To manage the flood risk impact on downstream properties, detention basins will be constructed for water quantity management. Detention Basins were introduced in the hydrologic modelling for the developed

scenario to ensure that during the 2 to 100 year flood events no increase to the peak flows is to be experienced. A detention strategy was developed to determine the sizing and configuration of detention basins, optimising the flow regime to satisfy the requirements of maximum permitted flows as established through the modelling of the existing scenario.

Figure 4.4: Proposed Precinct XP-RAFTS Network



4.9.3.1 Basin Strategy

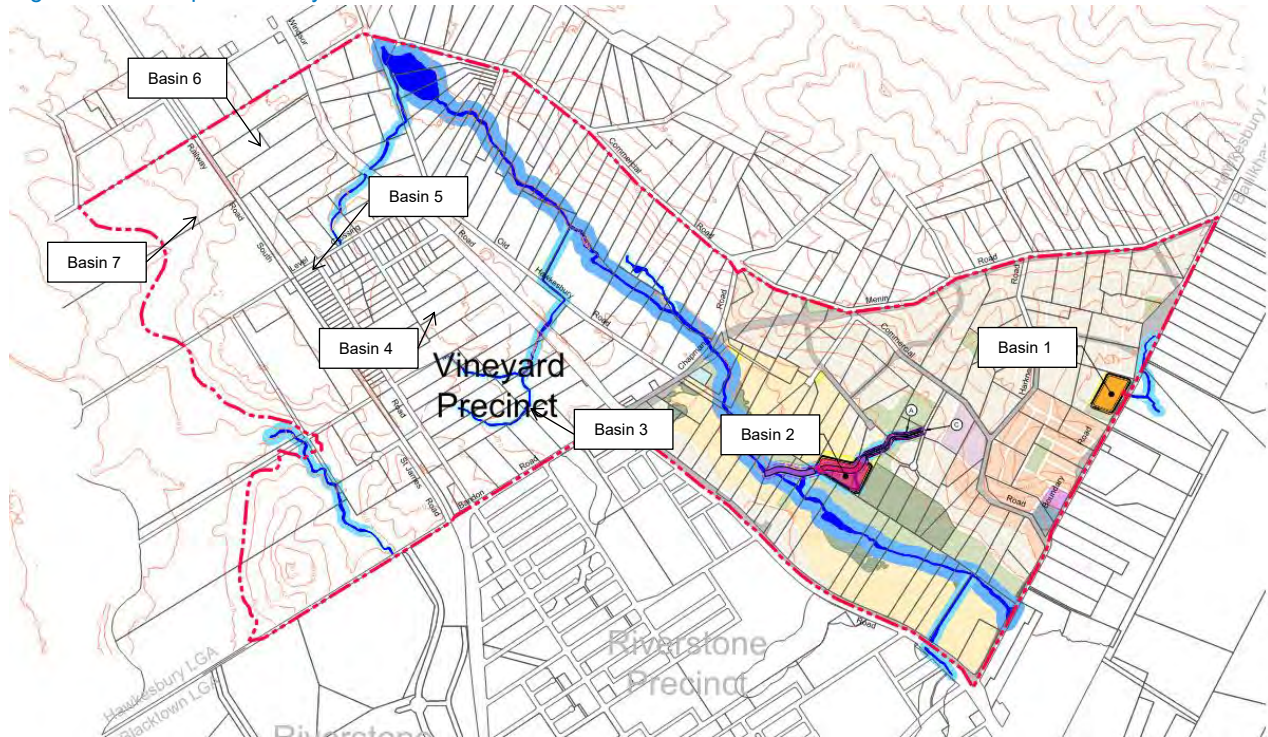
The detention strategy was developed by comparing precinct flows generated within the Vineyard precinct only, and does not include externally contributing precincts in order to assess the impacts directly attributable to the development. As a result of the increased flows in the proposed scenario, 7 new basins have been proposed to detain flows and decrease the peak flow rates generated by the proposed development. All basins were modelled with a stage-storage relationship. Basins 2, 3 & 5 have been designed to maintain the existing creek within the detention basin for the 2 year bank full flows, the outlet structure is then comprised of a staged weir (rather than a piped outlet) to maintain environmental flows to the creeks. All basins are proposed to be online to the existing creeks where possible, and within the 100 year flood extents so as to minimise the impact on developable area.

General principals adopted when locating and configuring the basins included the following:

- Locate basins to detain as much of the catchments runoff as possible, thereby minimising the overall number of basins required;
- Avoid existing vegetation where possible;
- Avoid areas that may be retained;
- Average storage depth of 1.2m within storage overbank areas;
- Average batter slopes of 1:6;
- Maintain the current flow regime to Windsor Rd;
- Maintain a natural creek flow continually through the basins where possible. This involved constricting the creek flow for minor storm events rather than damming the flow to require a low flow culvert/ piped outlet; and
- Staged weir outlet for larger storm events.

The volumes required were refined by manual iteration until results showed that the total flows generated from the post-developed scenario did not exceed those in the pre-developed. A summary of the proposed detention storages for the Vineyard precinct are shown in the table below. The basin locations are shown in Appendix A.

Figure 4.5: Proposed Vineyard Basin Locations



Source: Base layout By Cox Richardson

Table 4.2: Proposed Detention Basins

Basin	Size (m ³)	Average Depth (m)	Type of Basin	Location
1	15,100	1.2	Offline Basin	Eastern end of precinct; West of Boundary Road
2	22,500	1.2	Online Basin	Killarney Chain of Ponds; South of Commercial Road
3	4,200	1.2	Upstream of Windsor Road to eliminate need to upgrade culverts	North of Bandon Road; West of Windsor Road
4	5,600	1.2	Upstream of Windsor Road to eliminate need to upgrade culverts	South of Blackwood Road; West of Windsor Road
5	14,500	1.2	Upstream of Windsor Road to eliminate need to upgrade culverts	South of Level Crossing Road; West of Windsor Road
6	2,450	1.2	Upstream of Windsor Road to eliminate need to upgrade culverts	North Eastern edge of precinct; West of Windsor Road
7	4,800	1.2	Offline Basin	East of Railway Road South

4.10 Results

Table 4.3 below contains the 100 year existing peak flow rates, compared with the developed flows with and without detention basins for key locations across the precinct. It can be seen that developed peak flows are generally higher than the corresponding flows in the existing case, and that the detention basin strategy is necessary to limit the developed peak flows back to the corresponding existing peak flow rate. Similarly, the peak flow rate results from the 2 year event can be seen in Table 4.4.

Table 4.3: 100 year Existing and Developed precinct peak flow rates

Node	Existing precinct peak flow (m3/second)	Developed precinct peak flow (m3/second)	Developed precinct peak flow with detention (m3/second)
CK26	12.188	12.062	12.062
CK27	20.751	20.679	20.679
CK23	28.553	35.749	28.756
CK18	33.362	42.075	34.552
CK17	34.458	43.834	36.056
CK16	35.340	45.103	36.880
CK13	50.941	61.579	53.195
CK12	51.709	62.196	53.488
CK10	53.505	63.661	54.970
CK08	54.573	64.291	55.401
CK05	59.615	67.628	59.739
Out K	60.675	67.935	60.210

Table 4.4: 2 year Existing and Developed precinct peak flow rates

Node	Existing precinct peak flow (m3/second)	Developed precinct peak flow (m3/second)	Developed precinct peak flow with detention (m3/second)
CK26	1.376	3.674	3.674
CK27	1.911	1.911	1.911
CK23	3.316	10.195	10.195
CK18	1.490	1.490	1.490
CK17	1.106	1.106	1.106
CK16	1.794	3.398	3.398
CK13	6.118	7.700	6.144
CK12	1.030	1.854	1.854
CK10	1.554	2.558	1.454
CK08	0.841	1.111	1.111
CK05	3.805	8.530	3.701
Out K	21.631	23.868	21.205

The above results show that under the local flow scenario, there is generally no worsening of the flooding conditions when incorporating the proposed detention strategy. However, this scenario is unlikely to occur in a practical sense. As such, a comparison of flows at the outlet (node Out K) under the regional flow scenario has been shown in the below table to further highlight that the post developed flows are no worse than the existing.

Table 4.5: Regional Pre-Post Flow Comparison

Out K	Existing Flow (m ³ /s)	Proposed Flow (m ³ /s)
100 year	231.30	225.84
2 year	105.32	104.82

4.10.1 Probable Maximum Flood

The probable maximum flood event has been considered in the assessment to aid in the preparation of a flood evacuation plan. Probable Maximum Precipitation (PMP) was derived using the Bureau of Meteorology’s Generalised Short Duration Method (2003). A comparison of peak duration storm rainfall intensities is shown in the below table along with the resulting peak flows for the 100 year event and PMF at the main catchment outlet (node Out K)

Table 4.6: Comparison of the peak 100 year and PMF event

Node	100yr Intensity 6 hour duration (mm/hr)	100yr flow rate (m ³ /second)	PMF Intensity 2 hour duration (mm/hr)	PMF flow rate (m ³ /second)
Out K	22.17	230.91	255	1497

Based on the modelling, the peak PMF will be approximately 6.5 times greater in flows than the peak 100 year event at the outlet to the site. It is important to also note that the duration of the peak PMF is shorter than the 100 year peak duration by 4 hours.

4.10.2 Climate Change Assessment

Recommendations from the former Department of Environment and Climate Change document titled *Practical Consideration of Climate Change* guide the modelling of flood scenarios to include a “sensitivity check” incorporating data on the projected effects of climate change on sea levels and rainfall intensities. Multiple iterations of flood models can be produced using different climate change affected rainfall intensities. For the purpose of this report however, a sensitivity analysis has been undertaken by applying a 10%, 20% and 30% increase to rainfall intensity of the peak 100year ARI storm event.

Table 4.7 below compares 100 year flow rates for the developed scenario with corresponding flows adopting the increased rainfall intensity outlined above. As is evident, the increase to peak flow at the

outlet is proportional to the increase in rainfall intensity. Discussion and 2D modelling of the effect of the increased flows on flood levels are explained in the following section.

Table 4.7: Effects of climate change on 100yr flow rates – 360 minute storm duration

100 year 2 hour storm	Current	+10%	+20%	+30%
Rainfall Intensity (mm/hr)	22.17	24.39	26.60	28.82
Peak Flow (m ³ /s)	230.91	260.44	290.51	320.43
Percent Increase to Peak Flow	0%	10.01%	19.98%	30.00%

5 Hydraulics

5.1 Introduction

TUFLOW, a one and two-dimensional (2D) hydraulic modelling program has been utilised to perform a detailed assessment of the existing (pre-development) and proposed (post-development) flooding scenarios for the Vineyard precinct.

The objective of the flood assessment was to determine changes to flooding characteristics resulting from development of the precinct, and examine the performance of the water cycle management strategies discussed in section 4. The flooding characteristics examined in the analysis include water level, depth, velocity and hazard category.

Data supplied by Council, the Department of Planning and Environment and the Bureau of Meteorology was utilised along with information gathered through first hand observations of existing conditions.

5.2 Existing and Proposed Models

5.2.1 TUFLOW Software Package

The *TUFLOW* (2D component) software package computes flow paths by dividing the floodplain into a grid of individual cells. The flow of water between cells is then computed repeatedly at regular time steps by solving two dimensional shallow water equations to estimate the flood spread and flow. As each cell contains information on water levels, flows are routed in the direction that will naturally follow the modelled topography.

ESTRY (1D component) is a separate calculation engine which is incorporated into *TUFLOW* to handle flows through structures which cannot be accurately represented with grid cells. *ESTRY* is a network dynamic flow program suitable for mathematically modelling floods and tides (and/or surges) in a virtually unlimited number of combinations. By including non-linear geometry, *ESTRY* can provide an accurate representation of the way in which channel conveyance and available storage volumes vary with changing water depth. *ESTRY* has been developed in conjunction with *TUFLOW* to resolve complex 1D-2D flows across the floodplain interface.

The flood assessment was modelled using TUFLOW build 2013-12-AB.

5.2.2 Local and Regional Flood Events

Flood events were modelled for the 2, 20, 100, 200, 500 year Average Recurrence Intervals, the Probable Maximum Flood and Climate Change. These events were simulated in both the existing and developed scenarios. Downstream of the precinct the Killarney Chain of Ponds and Eastern Creek discharge to the Hawkesbury Nepean River. The close proximity to this major river system means that wider-scale regional flood events have backwater flooding effects within the Vineyard precinct. In order to fully assess potential flood risks across the Vineyard precinct it is important to consider flooding characteristics in both the

regional flood event over the wider Hawkesbury Nepean but also in the case of local storm events covering the precinct catchments and upstream in the Killarney Chain of Ponds catchment. It should be noted that the use of the term local flood in the hydraulic analysis is different to that used in the hydrological analysis discussed earlier.

The application of regional flood conditions to the modelling is discussed in section 5.2.5.3.

5.2.3 Hydrologic Data

Results of the Hydrological assessment were input into the existing and developed TUFLOW hydraulic models. As mentioned in the hydrological analysis, existing scenario upstream flows from Killarney Chain of Ponds and First Ponds Creek have been applied representing the maximum peak flow rates, as opposed to attenuated developed scenario flows which will be experienced once the upstream precincts are developed and proper water cycle management principles are implemented.

Existing scenario flow rates for First Ponds Creek have been extracted from the hydrological analysis and applied to the model as a hydrograph upstream of the confluence with Killarney Chain of Ponds. This approach is taken to ensure that all effects of this major confluence on the flow regime are represented in the model. The application of the hydrograph to the model is discussed in section 5.2.5.2.

Killarney Chain of Ponds flows were extracted from JWP's Box Hill/Box Hill Industrial Precincts modelling to ensure consistency in water-cycle management across neighbouring precincts and to accurately model upstream flows entering the precinct. As with the First Ponds Creek flows, this hydrograph has been applied to the model upstream of the confluence with First Ponds Creek, at the upstream boundary location discussed in section 5.2.5.2.

5.2.4 Digital Terrain Model

5.2.4.1 Survey data

The topography of the catchments and the creek alignments have been reproduced digitally, based on LiDAR (Light Detection and Ranging) information supplied by Council. A 5m x 5m grid was selected for the Digital Terrain Model (DTM) for use in TUFLOW. This grid resolution is judged appropriate for this model given the scale of the precinct and a general lack of clearly defined creek banks which could potentially demand a finer resolution.

5.2.4.2 Developed scenario modifications

For analysis of the developed scenario earthworks have been proposed to amend flow regimes within the upper reaches of streams (stream order 1) and overland flow paths in order to consolidate developable land and maximise the developable value of the precinct. Where small streams are to be re-trained as channels or flow paths as roads, 3D terrain modelling was carried out to create design surface levels applied directly to the DTM.

Where detention basins are proposed for the management of water quantity and quality, the grading of the basins has been created using 3D terrain modelling and applied to the DTM as surface levels. General design principles for the basins are as follows:

- In an attempt to maximise developable land the proposed detention basins have generally been located in areas that are outside local flooded areas but within regionally flooded areas. This is discussed in further detail in section 5.2.7.2.
- Nominal depth of 1.2m
- 1v:6h graded basin walls
- 2 year ARI flow channel cut through the basin.
- Modified v-notch stage-discharge outflow structures

Overflow structures for the basins have been modelled as one-dimensional structures in ESTRY and discussed in section 5.2.6.1.

5.2.5 Boundary Conditions

5.2.5.1 Precinct Catchments

The runoff volumes from catchments within the precinct have been determined through the hydrological modelling, and have been applied to the hydraulic model as hydrographs (flow vs time). With this approach the hydraulic model simulates the convergence of sub catchment rainfall at the lower portion of each sub-catchment where it enters more defined overland flow paths or streams. For the developed scenario some of these hydrographs have been directly applied to channel sections within the DTM to simulate the flow within a typical future road cross-section, or the discharge of formal road network drainage infrastructure to open drainage channels.

5.2.5.2 Upstream creek flows

First Ponds Creek crosses the model boundary near Windsor Road , one of two major flow paths from upstream catchments. The runoff volumes for the two upstream reaches of First Ponds Creek were calculated in the hydrological analysis discussed in section 5.2.3. These upstream flows have been applied as hydrographs upstream of the Schofields Rd structures.

Killarney Chain of Ponds enters the model within the Box Hill/Box Hill Industrial Precinct. As discussed in section 5.2.3 flow rates from previous models were considered, with the selected hydrograph being applied across the flood plain at the model boundary allowing TUFLOW to apply the flows to creek sections.

5.2.5.3 Downstream creek flows

Where flood events occur across the wider Hawkesbury Nepean catchment, backwater flooding is experienced through the Vineyard precinct. As such the downstream boundary conditions across Killarney

Chain of Ponds and towards Eastern Creek are configured as stable water levels at the predetermined regional flood level. Where precinct and upstream catchment flows reach the downstream boundary, levels are generated by TUFLOW through calculations of flow volumes through the floodway given predetermined topography from the digital terrain model.

An initial water level for local events was applied to the model as an antecedent condition, to reduce the impact of potential initial storage volumes in the creek sections. The 2 year ARI regional flood level was adopted for this condition since this reflects a bank full scenario at the lower reaches of the precinct and hydraulic model.

For the modelling of regional flood events, the initial tailwater level was matched to the adopted design-event flood levels for the Hawkesbury Nepean, supplied by Blacktown City Council. These are as follows:

- 2 year ARI – 11.1m AHD
- 20 year ARI – 13.7m AHD
- 100 year ARI – 17.3m AHD
- 200 year ARI – 18.6m AHD*
- 500 year ARI – 20.3m AHD
- PMF – 26.4m AHD

* the 200 year ARI flood level has been interpolated from the other ARIs, supplied by Council

5.2.5.4 Losses

Losses through evaporation and infiltration to the soil have been applied in the hydrological model for all catchment areas of the precinct. Further infiltration and evaporation has not been incorporated into the hydraulic model as these affects have been accounted for already in the hydrological analysis.

5.2.5.5 Existing Dam structures

Existing dams as surveyed have been examined for the sensitivity of surrounding flooding characteristics to water levels and potential storage volumes. The initial water level of existing dams has been applied to the model conservatively to reduce the risk of over-estimation of dam storage through flood events. This approach is consistent with previous studies of flooding in the area and is in line with best practices.

5.2.6 Hydraulic structures (1D ESTRY component)

Windsor Road traverses the length of the precinct and forces flows through formal drainage structures or to spill across the road surface. Roads and Maritime Services (RMS) cross drainage data for Windsor Road was provided by the Department of Planning and Environment for incorporation into the model as one-dimensional structures.

Where other formal drainage structures are located within the model extents information from site inspections have been used to generate an accurate one-dimensional hydraulic representation of these structures within the model.

Inlet and culvert blockages were considered in the modelling with a 50% blockage factor across all culverts being applied in order to assess overland flow paths. Smaller culverts with a diameter less than or equal to 600mm were omitted from modelling in major events to simulate potential blockages of these structures.

5.2.6.1 Detention basin outlet structures

The detention basin outlet structures designed integrally through the hydrological analysis have been incorporated into the TUFLOW model as ESTRY structures. The stage-discharge performance of the basins, as designed, has been replicated in TUFLOW by embedding the structures into the basin walls (within the DTM) creating both the low flow outlet and overflow weir sections. Detention basins pipe outlets were not considered to have a 50% blockage factor applied.

5.2.7 Water Cycle Management Strategies

A range of measures is proposed for the water cycle management of the Vineyard precinct. The following strategies were adopted,

- Detention basins have been modelled to assess the impacts of the increase in runoff from the proposed development and to test the efficiency of the basins in relation to geometric design and outlet function with tailwater effects.
- Opportunities have been explored to reduce the extent of flooding within the development thus increasing the developable area. This has generally only been applied where there are existing wide spread shallow flows. This has been achieved with localised filling and channel re-definition.
- Where it is possible to manage surface flows within the street drainage network they have been excluded from the TUFLOW modelling.

5.2.7.1 Creek re-alignment

In the developed scenario, the construction of a road network and associated piped drainage structures will capture rainfall and runoff flows from the upper portions of the precinct catchments. In order to consolidate the proposed development layout and maximise the development potential of the precinct, minor flow paths and streams have been either:

- realigned and channelized (where the existing stream-order of one applies); or
- removed and replaced with formal drainage structures.

Under existing conditions there are sections of the Eastern Creek tributaries, and Killarney Chain of Ponds and its tributaries that have been significantly altered by agricultural/industrial works such that in some locations there is little to none discernable creek channel. In these areas the existing flooding is quite widespread, this is particularly evident in the tributaries where there has been significant manipulation to the existing floodplain with farm dams and pastures, here flood depths are generally quite shallow and an upgraded creek section is proposed to better manage nuisance water and floodwaters. This in turn allows previously shallow flooded areas to be salvaged for development.

Where existing riparian corridors exist these have been maintained and creek embellishment works proposed (these works are only proposed to 1st order streams). The existing classification has been maintained while the flows have been channelised. The result is a formal drainage channel with riparian offsets, better streamlined for configuration of developable areas.

5.2.7.2 Detention Basins

Detention basins have been designed through the hydrological analysis of the developed scenario to attenuate developed scenario flows back to existing for events ranging from the 2 – 100year ARI. The performance of these detention basins can be observed in the attenuated flow rates discussed in the results section following and can be observed across the flood maps for 2 to 100year ARI events. The stage vs storage relationships for these facilities have been replicated in the TUFLOW model as discussed in section 5.2.4.2.

In an attempt to maximise developable land the proposed detention basins have generally been located in areas that are outside local flooded areas but within regionally flooded areas. In the event of a regional flood from the Hawkesbury river the resultant runoff from the development is minute in comparison to the Hawkesbury river flooding, and the Vineyard runoff has little to no impact on flood levels.

5.3 Results

5.3.1 Flood maps for design events

The following TUFLOW output maps are attached to this report as Appendix D:

- 2yr Existing Flood Extents/Depths – Local and Regional
- 2yr Proposed Flood Extents/Depths – Local and Regional
- 20yr Existing Flood Extents/Depths – Local
- 20yr Proposed Flood Extents/Depths – Local
- 100yr Existing Flood Extents/Depths – Local and Regional
- 100yr Proposed Flood Extents/Depths – Local and Regional
- 100yr Flood Difference maps from Existing to Proposed – Local and Regional
- 100yr Existing Flood FDM Hazard Maps – Local and Regional
- 100yr Proposed Flood FDM Hazard Maps – Local and Regional

- 100yr Climate Change maps (30% Increase in rainfall intensity) – Regional
- 100yr Flood Difference maps from Proposed to Proposed (with Climate Change) – Regional
- 200yr Proposed Flood Extents/Depths – Local and Regional
- 500yr Proposed Flood Maps - Local and Regional
- PMF Proposed Flood Maps - Local and Regional

5.3.2 Existing and developed scenario comparison

The existing site is heavily flooded due to a combination of large upstream catchments, flat floodplain areas around KCOP and high tailwater effects when the Hawkesbury River floods that effects KCOP and Eastern Creek. The flooding covers approximately 30-40% of the site in a 100 year event.

The existing Chapman Rd and Commercial Rd are heavily flooded under existing conditions where they cross KCOP. The existing drainage structures at both of these crossings do not have capacity to convey both the Local or Regional 2 year flood events. Upgrade of these structures to make them flood free in the 100 year event would require significantly raising and spanning large sections of the roadway which would impose significant cost to the development and likely cause further upstream flooding. As such this proposal does not suggest upgrade of these drainage structures. It is understood that RMS are currently exploring options for upgrades of Bandon/Chapman Road. Any flood impacts associated with these works will be assessed under a separate proposal.

Generally, flood mapping indicates that in the developed scenario the water cycle management strategies restrict developed flows back to the existing scenario flow rates. As can be seen in the attached flood maps flood hazards are generally not increased across the site, and in most cases are reduced.

For the 100 year event flood water levels were generally reduced or maintained. Localised areas of increase generally occur within the detention basins where they are manageable and velocities are low.

The results are consistent with the hydrologic modelling and there is no increased impact on neighbouring properties or downstream of the site.

As a result of the detention basins there is no flood worsening for all the Windsor Rd culverts.

5.4 Climate Change

As an extension of the climate change assessment undertaken in section 4.10.2 the proposed flow increases were run through the flood model to determine the associated impacts and increases in flood level. As a worst case scenario the 30% rainfall intensity climate change scenario was adopted.

The results of the study indicate that flood level increases are expected in the order of 0-200mm when compared with the proposed development base case. Under a 30% climate change increase scenario flood levels are similar in level to the 200yr event. It is anticipated that the increase in size and cost of

detention basins to accommodate this climate change scenario may outweigh the alternate impact of adopting a higher freeboard. It is recommended that detention basins are designed for the 100yr event at this stage. Future Development Applications should give practical consideration to a climate change event. Traditionally a 15% increase in rainfall intensity is adopted for climate change assessments.

5.5 PMF

The Peak PMF flood even has been simulated in the proposed flood model. In the PMF event the precinct experiences backwater flooding from the greater Hawkesbury-Nepean catchment which further amplifies the impacts of flooding particularly on the lower regions of the site towards the FPC/Windsor road crossing. As Windsor Rd is cut off by severe flooding at FPC, safe refuge and evacuation is generally achieved to the South of the site in Riverstone. The regional SES flood evacuation plan governs for the area however significant portion of the site remain unaffected by floodwaters and pedestrians should remain in these areas if possible. Properties along the Northern KCOP fringes that may be flood affected by the PMF event in the future will be able to safely evacuate to higher ground within Riverstone East Precinct. It is also recommended that proposed new schools act as localised refuge points in times of flooding to reduce the risk of cars travelling along Windsor Road.

A sample flood evacuation route map has been included in Appendix D. The 500 year flood level has been shown on this plan in order to highlight evacuation routes leading up to a potential PMF event.

5.6 Comparison of Modelled Results

Developed and existing scenario flow rates across the site determined through the hydraulic analysis were compared with the previous hydraulic models for Box Hill/Box Hill Industrial and Riverstone and Alex Avenue precincts discussed earlier. As indicated in the table below, the maximum 100 year developed scenario flow rate was compared with those from previous modelling for various locations across the precinct.

Figure 5.1: Flood Level Comparison Locations



Table 8.1: Peak Flood Scenarios – Flood Level (m AHD)

Location	100yr Existing Local	100yr Existing Regional	100yr Proposed Local	100yr Proposed Regional	100yr Proposed Climate Change +30% Local	100yr Proposed Climate Change +30% Regional
Killarney Chain of Ponds at Boundary Rd	19.86	19.86	19.87	19.87	20.05	20.05
Killarney Chain of Ponds Location 3	17.18	17.50	17.20	17.49	17.39	17.61
Killarney Chain of Ponds Location 2	15.24	17.31	15.24	17.31	15.45	17.32
Killarney Chain of Ponds Location 1	11.44	17.30	11.44	17.30	11.62	17.30
Killarney Chain of Ponds at Brennans Dam Rd	12.42	17.33	11.14	17.30	11.18	17.30

Table 5.2: Extreme Events Peak Water Level – (m AHD)

Location	500yr Proposed Local	500yr Proposed Regional	PMF Proposed Local	PMF Proposed Regional
Killarney Chain of Ponds at Boundary Rd	20.06	20.45	21.50	26.45
Killarney Chain of Ponds Location 3	17.41	20.31	19.04	26.43
Killarney Chain of Ponds Location 2	15.46	20.30	16.94	26.41
Killarney Chain of Ponds Location 1	11.64	20.30	13.41	26.40
Killarney Chain of Ponds at Brennans Dam Rd	11.19	20.30	15.68	26.40

5.7 Flood Planning Level

Flooding throughout the Vineyard precinct has been managed through implementation of detention basins. The difference in flood depth from the existing scenario is shown on Figure VY_DIF_100yr_360m_D in Appendix D.

Based on Hawkesbury Council's Floodplain Risk Management Study & Plan, the 100yr flood extents have been adopted as the flood planning level (FPL). It is proposed that this policy is maintained for the Vineyard Precinct. This will be reflected in the DCP.

The following definitions for the FPL will apply:

- **1% AEP existing regional flood depth** generally means the flood depth as shown in map titled *Vineyard ILP 1% AEP Existing Regional Flood Depth (Tail Water 17.3m AHD)*, drawing number VY_EXR_100yr_360m_D, dated 31/10/2017 contained in Appendix D.
- **1% AEP proposed regional flood depth** generally means the flood depth as shown in map titled *Vineyard ILP 1% AEP Proposed Regional Flood Depth (Tail Water 17.3m AHD)*, drawing number VY_PRR_100yr_360m_D, dated 31/10/2017 contained in Appendix D.
- **1% AEP flood planning level** generally means the following:
 - The 1% AEP proposed regional flood depth, or
 - Any other 1% AEP related flood depth adopted by Council for the purposes of the Vineyard precinct DCP.

Note: This report proposes a range of waterway realignments and stormwater management devices to achieve the *1% AEP proposed regional flood depth*. Such realignments and management devices will be built over time as funding and delivery arrangements permit. Where *the 1% AEP existing regional flood depth* is greater than the *1% AEP proposed regional flood depth*, developers will need to manage existing flooding onsite with temporary solutions until such time as the relevant realignments and management devices are realised. This may involve the installation of temporary works such as temporary on-site detention and temporary flood storage works and the delayed development of part of the subject site.

It should also be noted that over time the flood extents could change, particularly if alterations to the shape of detention basins are required. The final decision regarding adoption of flood planning levels will therefore reside with Council. Developers will need to liaise with Council during the Development Application phase to determine the applicable FPL for each site.

6 Water Quality Modelling

The stormwater management systems for the site shall comply with Hawkesbury City Council's Development Control Plan. Council's policy requires improved water quality of the stormwater flow from the developed site prior to discharge into the authority's drainage system.

To demonstrate compliance with these objectives, treatment removal loads were analysed from pre to post development scenarios using MUSIC (Model for Urban Stormwater Improvement Conceptualisation) software. Model development and results are discussed below.

6.1 MUSIC Methodology

MUSIC software allows the modeller to assess the effectiveness of the water quality devices by measuring against a "base" model (which assumes that no water quality treatment measures are installed). The developed site was compared with and without water quality treatment measures and subsequent pollutant reduction percentages calculated, based on the compared results.

It is noted that Hawkesbury City Council currently do not have any statutory requirements for target pollutant removal rates for a new development. As such, in lieu of more detailed data, it was agreed that the pollutant removal objectives and modelling parameters as outlined in Blacktown City Council's DCP and WSUD Handbook were to be utilised for the precinct.

Table 6.1: MUSIC Pollutant Reduction Targets

Pollutant	Minimum Removal Rate
Gross Pollutants (GP)	90%
Suspended Solids (TSS)	85%
Phosphorus	65%
Nitrogen	45%

Source: Blacktown City Council DCP, 2006

6.2 Model Parameters

6.2.1 Rainfall Data

Pluviograph data from Richmond (1881-2002) daily interval was utilised within the model. This data was considered appropriate as it is close to the site and contained periods of both dry and wet weather.

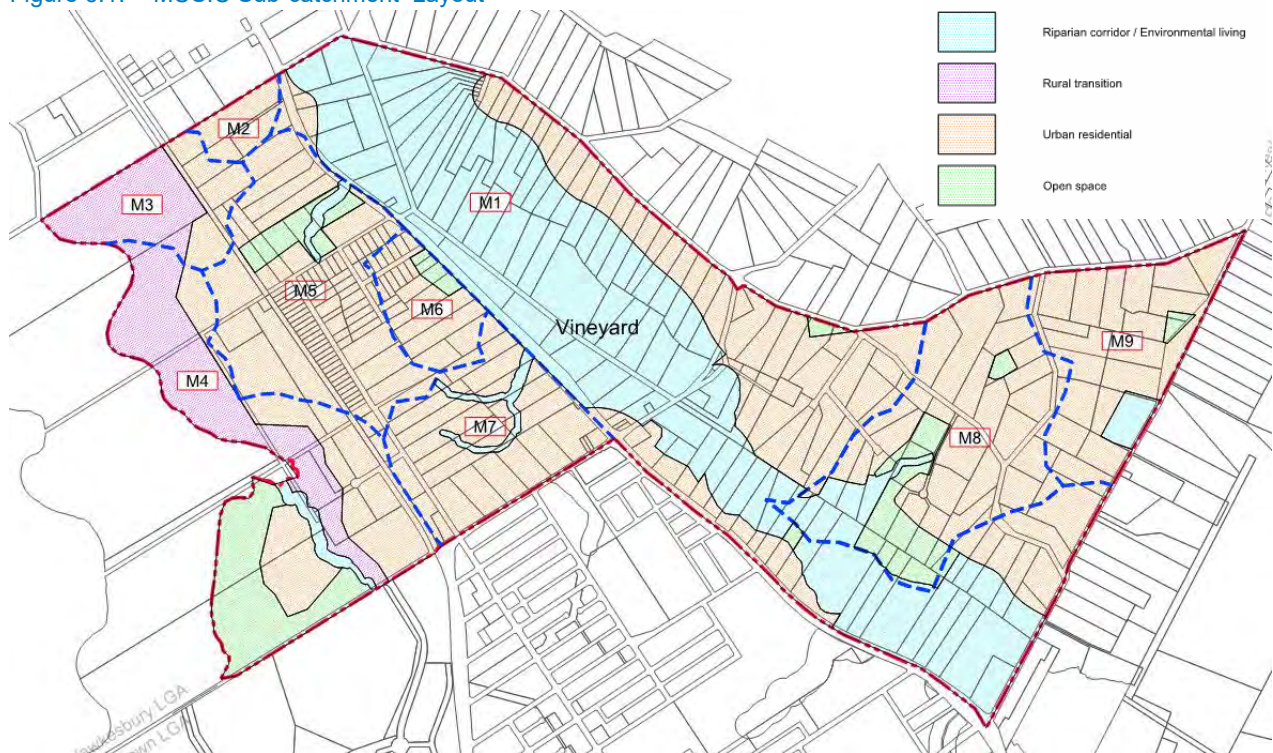
6.2.2 Base Catchment

The XP-RAFTS model developed for detailed analysis and design of the proposed water management system divided the site into approximately 41 sub-catchments. This level of detail is required at the design stage for the site hydrologic and hydraulic analyses. However, this level of detail is not necessary for water

quality modelling using MUSIC because the treatment devices capture runoff from large areas and sub-division of sub-catchments smaller than the treatment catchment will not achieve improved results.

The XP-RAFTS sub-catchments were therefore consolidated into 9 sub-catchment areas based on the proposed drainage system layout (refer Figure 6.1).

Figure 6.1: MUSIC Sub-catchment Layout



Catchments were then separated into four main components for the purposes of the MUSIC model, with the different land use categories measured as a percentage from the Master Plan documentation.

- Urban Residential Areas;
- Rural Transition;
- Urban Parkland; and
- Riparian Corridor zones.

Table 6.2: Area Breakdown per MUSIC Sub-Catchment

Catchment	Urban Residential (Ha)	Rural Transition (Ha)	Urban Parkland (Ha)	Riparian Zones (Ha)	Total
M1	83.26	-	3.53	159.80	246.59
M2	6.48	-	-	-	6.48
M3	9.00	14.82	-	-	23.82
M4	30.56	28.95	18.84	2.56	80.91
M5	56.31	-	5.05	1.48	62.84
M6	14.21	-	1.58	-	15.79
M7	38.71	-	-	2.82	41.53
M8	52.54	-	4.10	13.19	69.83
M9	42.50	-	-	0.69	43.19
Total	333.57	43.77	33.10	180.54	590.98

6.2.2.1 Urban Zones

The following methodology and parameters were incorporated in the MUSIC model to represent the new Urban Residential and Urban Parkland areas within the precinct:

- An 85% impervious fraction was adopted for the urban residential areas within the catchment in accordance with Blacktown City Council's MUSIC Modelling Guidelines (New Residential Lot including Half Road);
- In accordance with general engineering practice, a 5% impervious fraction was adopted for the new urban parkland zones;
- The rainfall runoff parameters utilised within the model were based on the recommended default values listed in Blacktown City Council's Developer Handbook for Water Sensitive Urban Design as shown below:

Table 6.3: Rainfall Runoff Parameters

Soil Properties	Default Urban Values
Rainfall threshold (mm)	1.4
Soil Capacity (mm)	170
Initial Storage (%)	30
Field Capacity (mm)	70
Infiltration Capacity Coefficient 'a'	210
Infiltration Capacity Coefficient 'b'	4.7
Initial Depth (mm)	10
Daily Recharge Rate (%)	50
Daily Base flow Rate (%)	4
Deep Seepage Rate (%)	0

- The following assumptions were made in regards to the proposed catchment densities:
 - Average No. Lots per Hectare = 20;
 - Average Lot size = 500m²;
 - Average dwelling size = 250m²; and
 - Average Road Area = 10% of Total Catchment Area.
- In accordance with BCC requirements, the urban residential zones within the precinct were then categorised into the following area types:
 - Roof;
 - Road;
 - Landscape; and
 - Other Impervious Areas
- The pollutant concentration parameters used within the model were based on the recommended model defaults for different land use categories as specified in Council’s WSUD Handbook. These are summarised in the following table:

Table 6.4: Post-Development Areas – MUSIC Node Classification

Land Use	MUSIC Node	Category*
Roof Areas	Roof	“Roof Area”
Road Areas	Road	“Road Area”
Other Impervious Areas	Imperv.	“Other Impervious Areas”
Landscape Areas	Perv.	“Pervious Areas”
Urban Parkland Areas	Perv.	“Pervious Areas”

Source: Blacktown City Council’s WSUD Handbook

6.2.2.2 Rural Transition Zones and Riparian Corridors

The following methodology and parameters were incorporated in the MUSIC model to represent the Rural Transition and Riparian Zones within the precinct:

- In accordance with general engineering practice, a 5% impervious fraction has been adopted;
- We note that Blacktown City Council currently do not have approved source nodes for non-urban land uses. As such, in lieu of more detailed data, the rainfall runoff parameters utilised within the model were based on the recommended default values listed in the Sydney Catchment Authorities NSW Draft MUSIC Modelling Guidelines (2010) for Rural and Riparian zones:

Table 6.5: Rainfall Runoff Parameters

Soil Properties	National Park / Riparian
Rainfall threshold (mm)	1.4
Soil Capacity (mm)	210
Initial Storage (%)	30
Field Capacity (mm)	80

Soil Properties	National Park / Riparian
Infiltration Capacity Coefficient 'a'	175
Infiltration Capacity Coefficient 'b'	3.1
Initial Depth (mm)	10
Daily Recharge Rate (%)	35
Daily Base flow Rate (%)	20
Deep Seepage Rate (%)	0

Source: NSW Draft MUSIC Modelling Guidelines 2010

- The pollutant concentration parameters used within the model were based on the recommended model defaults for different land use categories as specified in NSW Draft MUSIC Modelling Guidelines. These are summarised in the following table:

Table 6.6: Post-Development Areas – MUSIC Node Classification

Land Use	MUSIC Node	Category*
Rural Transition	Rural	"Rural Residential"
Riparian Corridor	Park	"Protected Land"

Source: NSW Draft MUSIC Modelling Guidelines 2010

6.2.3 Developed Catchment

The developed catchment model was identical to the base model in terms of catchment area and break-up of roof, paved and pervious areas, but included the water quality management strategies outlined below.

6.2.3.1 Management Strategies

Storm runoff generated within the precinct can be separated into 3 main streams:

- Roof or rainwater runoff, which can be captured and reused for toilet flushing or irrigation;
- Road and pavement runoff, which can be treated by GPT's or bio-retention devices; and
- Pervious surfaces will have reduced runoff due to a portion of infiltration, and water "lost" to groundwater.

The developed treatment train is as follows:

- Rainwater tanks are to be provided on the developed dwellings for at source treatment and re-use of roof water;
- Gross pollutant traps and trash racks to capture larger pollutants and sediments before discharge into the watercourse; and
- Bioretention "raingardens" to provide online treatment for effective removal of fine sediments and nutrients.

The possibility of using tree bays as an at source stormwater bio-retention device has not been considered as part of this proposal. The deviation of low flows from the road gutters into these tree bays would enable the at source water quality treatment of the low flows. This additional treatment would further improve any water quality results obtained during this modelling. The potential for this would be assessed as part of individual evaluation of each stage depending upon site parameters including road networks and grades.

With the rapidly evolving field of Water Sensitive Urban Design any developed measures should be reconsidered at the time of construction to ensure they are still industry best practice and suitable for the development however, at a minimum they should meet the requirements specified in this report.

6.2.3.2 Rainwater Tanks

In developing the MUSIC model for the proposed scenario, it is our understanding that a rainwater re-use tank is to be included for each individual lot within the precinct. The tanks will collect the 'clean' roof water from the new dwellings for re-use on site, with overflows directed to the public drainage network.

The following assumptions have been adopted for the rainwater tanks to be included within the precinct:

- 3,000L Tank per Lot;
- lot size of 250m²;
- 50% roof catchment split;
- Internal re-use rate = 0.2kL/day; and
- External re-use rate = 0.4kL/m²/year (distributed as PET - Rain).

It is noted that a more comprehensive assessment of the rainwater tanks will need to be undertaken during the detailed design stage and should also include a BASIX assessment to confirm the above assumptions.

6.2.3.3 Gross Pollutant Traps

For the purposes of MUSIC modelling on the Vineyard site, it was assumed that Gross Pollutant Traps (GPTs) would be located at the outflow from each discharge point into the watercourse. Additionally, GPTs are assumed upstream of any developed scenario water body or bio-retention devices to provide pre-treatment of gross pollutants and suspended solids.

Proposed positions of these Gross Pollutant Traps are shown in drawing 0221. Here, positioning has taken into consideration the developed catchments in order to maximise flows, with each GPT sized to treat runoff up to and including the 3 month ARI in accordance with general engineering practice.

The expected removal rates that were utilised within the water quality modelling process to represent the GPT units were based on Blacktown City Council's standard rates for a "Vortex" type GPT as shown below:

Table 6.7: GPT MUSIC Input Parameters

Pollutant	Input	Output
Total Suspended Solids (mg/L)	1,000	300
Total Phosphorus (mg/L)	5	3.5
Total Nitrogen (mg/L)	50	50
Gross Pollutants (kg/ML)	15	0

Source: Blacktown City Council

6.2.3.4 Bioretention “Raingardens”

Bioretention “Raingardens” are proposed to treat runoff from all sub-catchments within the precinct excluding M4. “Flow splitting” pits will direct flows up to and including the 3-month ARI runoff to the treatment facilities, while higher flows up to and including the 100-year ARI storm event will bypass the system and drain to a downstream OSD basin / watercourse.

In developing the MUSIC model for the post-developed site, the following assumptions have been made regarding the bioretention systems:

- Extended detention depth = 0.3m
- Filter depth = 0.6m
- Median particle diameter = 0.45mm; and
- Saturated hydraulic conductivity = 90 mm/hr.
- Exfiltration Rate = 0.5mm/hr.

The proposed positions of the Bio-retention “Raingardens” are shown in drawing 0221. Here, basins have been nominated as either an “online” or “offline” system, with consideration given to the location of the system in relation to the riparian zones and flooding regime for each watercourse.

Table 6.8: Bio-retention Summary

Catchment	Bio-retention Area (m ²)
M1	20,000
M2	850
M3	680
M4	-
M5	7,500
M6	2,000
M7	2,500
M8	7,000
M9	4,300
Total	44,830

6.3 Results

6.3.1 Base Model

In accordance with the industry standards and assessment processes the base water quality MUSIC model for the site was developed assuming that no water quality treatment measures would be installed. This model provides the basis for pollutant generation from the site and the measure for pollutant removal under "treated" conditions.

6.3.2 Developed Model

The "treated" site conditions model was developed incorporating the water quality treatment train as described above, with results compared against the base model to determine the pre-post pollutant concentration loads across the catchment.

Results of the MUSIC analysis indicate that, by including the nominated treatment train, the water quality improvement objectives set out in Blacktown City Council's DCP Part R: WSUD and Integrated Water Cycle Management and Hawkesbury City Council's DCP are achieved for the precinct.

Table 6.9: MUSIC Model Results – Whole Precinct

	Total Suspended Solids (kg/year)	Total Phosphorus (kg/year)	Total Nitrogen (kg/year)	Gross Pollutants (kg/year)
Generation	254,000	544	4,780	54,100
Output	36,700	184	2,580	2,280
REDUCTIONS	85.5	66.2	46.0	95.8
OBJECTIVES	85	65	45	90

As an exercise to assess the compliance of Stage 1 in the interim, against the water quality objectives, reduction rates have also been assessed at Chapman Road. The table below highlights that the target removal rates are achieved without the need for the downstream devices.

Table 6.10: MUSIC Model Results – Stage 1

	Total Suspended Solids (kg/year)	Total Phosphorus (kg/year)	Total Nitrogen (kg/year)	Gross Pollutants (kg/year)
Generation	86,300	183	1,600	18,500
Output	4,850	44	772	290
REDUCTIONS	94.4	75.9	51.7	98.4
OBJECTIVES	85	65	45	90