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The Northern Road Upgrade Mersey Road, Bringelly to Glenmore Parkway, Glenmore Park

NSW Environmental Impact Statement / Commonwealth Draft Environmental Impact Statement

Appendix K – Technical working paper: Flooding and hydrology

June 2017

THE NORTHERN ROAD UPGRADE
(BETWEEN MERSEY ROAD, BRINGELLY AND A LOCATION 600 m NORTH OF CHAIN-O-PONDS ROAD, MULGOA)

TECHNICAL WORKING PAPER:
FLOOD RISK ASSESSMENT

March 2017

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NOTE ON FLOOD FREQUENCY

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

Annual Exceedance Probability (AEP) per cent	Average Recurrence Interval (ARI) years
0.5	200
1	100
5	20
20	5

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

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

GLOSSARY OF TERMS AND ABBREVIATIONS

Term	Meaning
Afflux	Increase/decrease in water level resulting from a change in conditions. The change may relate to the watercourse, floodplain, flow rate, tailwater level etc.
AEP	Annual Exceedance Probability. 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 500 cubic metres per second 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 500 cubic metres per second or larger events occurring in any one year (see also average recurrence interval).
ALS	Airborne Laser Scanning. A type of aerial survey used to measure the elevation of the ground surface.
AHD	Australian Height Datum. A common national surface level datum approximately corresponding to mean sea level.
ARI	Average Recurrence Interval. The average period in years between the occurrence of a flood of a particular magnitude or greater. In a long period of say 1,000 years, a flood equivalent to or greater than a 100 year ARI event would occur 10 times. The 100 year ARI flood has a one per cent chance (i.e. a one-in-100 chance) of occurrence in any one year (see annual exceedance probability). The frequency of floods is generally referred to in terms of their AEP or ARI. In this technical working paper the frequency of floods generated by runoff from the study catchments is referred to in terms of their ARI, for example the 100 year ARI flood.
ARR	Australian Rainfall and Runoff (Institute of Engineers Australia, 1998).
BoM	Bureau of Meteorology
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
DECC	Department of Environment and Climate Change (now OEH).
DECCW	Department of Environment, Climate Change and Water (now OEH).
DoP	Department of Planning (now DP&E)
DPE	Department of Planning and Environment (formerly DoP)
DSC	Dam Safety Committee

Term	Meaning
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving (e.g. 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 area	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.
Flood prone land	Land susceptible to flooding by the Probable Maximum Flood. Note that the flood prone land is synonymous with flood liable land.
Flood storage area	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.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event (i.e. flood prone land).
Floodplain Risk Management Plan	A management plan developed in accordance with the principles and guidelines in the NSW Floodplain Development Manual (FDM), (DIPNR, 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.
Floodway area	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.
FPA	Flood Planning Area. The area of land inundated at the Flood Planning Level.
FPL	Flood Planning Level. A combination of flood level and freeboard selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans. Typically equal to the 100 year ARI flood level plus a freeboard of 0.5 metres.

Term	**Meaning**
Freeboard	A factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted Flood Planning Level and the peak height of the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as "greenhouse" and climate change. Freeboard is included in the Flood Planning Level.
GSDM	Generalised Short Duration Method. A method for estimating the Probable Maximum Precipitation for catchments up to 1,000 square kilometres in area.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to the NSW Floodplain Development Manual (FDM), (DIPNR, 2005) the hazard is flooding which has the potential to cause damage to the community.
Headwater	The upper reaches of a drainage system.
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	The 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.
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.
Merits based approach	The merits based 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.
OEH	Office of Environment and Heritage (formerly DECCW)
Overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
Peak discharge	The maximum discharge occurring during a flood event.
Peak flood level	The maximum water level occurring during a flood event.

Term	Meaning
PMF	Probable Maximum Flood The flood that occurs as a result of the Probable Maximum Precipitation (PMP) on a study catchment. The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation 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 (i.e. the floodplain).
PMP	Probable Maximum Precipitation. The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a catchment hydrologic model which simulates the conversion of rainfall to runoff.
PRM	Probabilistic Rational Method
Probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RL	Reduced Level. The reduced level is the vertical distance between an elevation and an adopted datum plane such as the Australian Height Datum (AHD).
Roads and Maritime	NSW Roads and Maritime Services
Runoff	The amount of rainfall which actually ends up as stream flow, also known as rainfall excess.
Stage	Equivalent to water level (both measured with reference to a specified datum)
SW	Sydney Water
Flow Velocity	A measure of how fast water is moving (e.g. metres per second [m/s]).
Water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.

EXECUTIVE SUMMARY

ES1.1 Background and study area

NSW Roads and Maritime Services (Roads and Maritime) is seeking approval to upgrade about 16 km of The Northern Road between Mersey Road, Bringelly and Glenmore Parkway, Glenmore Park (project) (refer **Figure 1.1** for route).

This technical working paper forms part of the Environmental Impact Statement (EIS) that has been prepared for the project and deals with the potential flood risks associated with the section that runs from Mersey Road to a location 600 m north of Chain-O-Ponds Road, Mulgoa. The flood risk assessment was based on design floods with average recurrence intervals (ARI's) of 2 year, 10 year and 100 year, as well as the Probable Maximum Flood (PMF). This technical working paper also sets out the findings of an assessment of the potential impact a partial blockage of the transverse drainage and future climate change would have on flooding behaviour in the vicinity of the project. The findings of a similar flood risk assessment which was undertaken for the section of the project which runs between a location 600 m north of Chain-O-Ponds Road and Glenmore Parkway are presented in a technical work paper which is contained in Appendix K.2 of the EIS.

The project would comprise a new six-lane divided road that would be built to the west of the existing two-lane road where it runs between Mersey Road and Elizabeth Drive, Luddenham, while the existing two-lane road would be upgraded to a six-lane divided road where it runs between Elizabeth Drive and a location 600 m north of Chain-O-Ponds Road. Provision would also be incorporated in the median for an additional travel lane in each direction if required in the future.

The section of the project that runs from Mersey Road to Elizabeth Drive runs through the catchments of Badgerys Creek, Duncans Creek and Cosgroves Creek, while the section which runs between Elizabeth Drive and a location 600 m north of Chain-O-Ponds Road generally follows a natural ridgeline which forms the catchment divide between an unnamed tributary of South Creek (Unnamed Tributary of South Creek), Mulgoa Creek and Blaxland Creek. **Figure 1.1** shows the extent of the aforementioned catchments in the vicinity of the project, while **Figure 4.1** (4 sheets) shows the extent of the catchments which contribute runoff to the existing transverse drainage along the section of The Northern Road which would be upgraded as part of the project.

ES1.2 Pre-project flooding behaviour

Flooding behaviour in the vicinity of the project where it runs between Mersey Road and Elizabeth Drive was defined using the TUFLOW two-dimensional (in plan) hydraulic modelling software, with the inflow hydrographs used as input to the model generated using the RAFTS sub-model contained in the DRAINS rainfall-runoff modelling software.

Figures 4.2 to **4.17** show flooding behaviour in the vicinity of the project corridor where it runs through the Cosgroves Creek, Duncans Creek and Badgerys Creek catchments for design storms of 2 year, 10 year and 100 year ARI, as well as the PMF.

The floodplains of both Duncans Creek and Cosgroves Creek are relatively narrow and well defined where the project runs through the upper reaches of the two catchments, with high hazard flooding conditions generally confined to the inbank area of the watercourses, as well as the network of dams which have been constructed along the various drainage lines.

While the Badgerys Creek floodplain is relatively wide in the vicinity of the project corridor, the present investigation found that the existing transverse drainage on the main arm of the creek has a hydrologic standard of greater than 100 year ARI.

Flooding along the section of the project corridor which runs between Elizabeth Drive and a location 600 m north of Chain-O-Ponds Road is generally limited to ponding along the upslope side of the existing two-lane road in the vicinity of the existing transverse drainage. Flow conveyed in the transverse drainage generally discharges directly to a series of natural grass lined depressions that drain to adjacent dams. The exception is in the Commonwealth Department of Defence's (DoD's) Defence Establishment Orchard Hills (DEOH) site, where flow conveyed in the adjacent transverse drainage discharges through the perimeter security fence and across the associated access road, before joining flow in a series of ill-defined drainage lines, several of which comprise natural grass lined depressions.

It is noted that runoff from the project corridor in the vicinity of the Littlefields Road intersection contributes to flow that discharges to the base of two deep open trenches within which two large diameter pipes are located (refer drainage lines BLC DL03 and BLC 05 on **Figure 4.1**, sheet 1). The two large diameter pipes form part of the greater Sydney water supply system and transfer raw water from Warragamba Dam to Prospect Reservoir. While runoff generated by the upslope catchments is conveyed to the base of the open trenches via a series of concrete lined batter chutes, the relatively flat grade along the line of the two pipelines results in the prolonged ponding of water around the base of the support structures, which in turn has resulted in bank slumping. Prolonged ponding along the southern side of the pipeline corridor on Drainage Line BLC 03 has also resulted in major slumping of the open trench within which the southern water supply pipeline is located.

ES1.3 Potential project related impacts

The project has the potential to impact flooding behaviour and scour potential outside the project corridor should appropriate mitigation measures not be incorporated into its design. The project also has the potential to impact the rate and volume of runoff discharging to the network of dams which are located downstream of the project corridor. **Table 5.1** in **Chapter 5** of this technical working paper describes the potential impacts of the project on flooding behaviour and scour potential, as well as measures that could potentially mitigate each identified impact.

Flooding also has the potential to impact on the project, which could be further exacerbated by a partial blockage of the transverse drainage or an increase in rainfall intensity associated with future climate change. The potential impacts of flooding therefore need to be taken into consideration when developing the proposed transverse drainage and flood mitigation strategy for the project.

ES1.4 Proposed transverse drainage and flood mitigation strategy

A strategy has been developed which is aimed at mitigating the impact of the project on flooding behaviour and scour potential, as well as providing a minimum 100 year ARI level of flood immunity to the new northbound and southbound carriageways (transverse drainage and flood mitigation strategy). The key features of the transverse drainage and flood mitigation strategy are shown on **Figures 6.1** and **6.2** and include:

- The upgrade of existing transverse drainage where the existing two-lane road would be widened to six lanes.
- The provision of new transverse drainage where the new six-lane road would be constructed to the east and west of the existing two-lane road.
- The diversion of flow generated by the new six-lane road away from the two drainage lines which discharge to the base of the open trenches within which the two water supply pipelines are located (i.e. away from drainage lines BLC DL03 and BLC DL05). This approach would require the following:
  - The provision of a new piped trunk drainage line which would convey runoff generated by a section of the new pavement in an easterly direction within the Sydney Water Supply Pipeline corridor where it would discharge to the DEOH site (Commonwealth land) along drainage line BLC DL06. Note that it is proposed to adjust the alignment of the perimeter security fence adjacent to the outlet of the new trunk drainage line in order to improve the angle at which flow discharges to drainage line BLC DL06.
  - The diversion of flow from a section of the new six-lane road west along Littlefields Road where it would discharge to an existing dam which is located on the southern side of the road adjacent to the limit of works.
- The lowering of road levels where the project crosses the Badgerys Creek floodplain. Lowering the road would significantly reduce the impact the project would have on flooding behaviour during floods that exceed the capacity of the transverse drainage.
- The provision of a flood relief channel on the southern overbank of Badgerys Creek immediately upstream of the road embankment. The flood relief channel would prevent the project from increasing peak flood levels in existing development for events up to 100 year ARI.
- The provision of easements where concentrated flow from the new pavement drainage system would discharge to a minor drainage line.[1] At these locations, the easement would extend from the project corridor to the first existing dam.
- The provision of new grass lined channels with low flow inverts where the project would result in a significant increase in the rate of flow discharging to a minor drainage line. At these locations, the channel would extend from the project corridor to the first existing dam. An easement would also be created over the channel to facilitate future access for maintenance.

[1] Note that the provision of easements would be limited to those sections of the project where runoff from the new pavement does not discharge to a defined watercourse.

- The provision of three permanent ponds adjacent to the transverse and pavement drainage outlets that border the DEOH site on Commonwealth land.
- The provision of scour protection measures on the inlet and outlet of the new transverse drainage.
- The removal of the earth embankments comprising the two large dams which are located on either side of Adams Road in the Cosgroves Creek catchment and the reinstatement/creation of the drainage line.
- The abandoning of several dams which would be located beneath the footprint of the new road embankment where the project runs through the Cosgroves Creek, Duncans Creek and Badgerys Creek catchments.
- The partial infilling of several dams located in the Duncans Creek catchment.
- The upgrade of the spillways of existing dams where the project would increase the frequency and/or the depth of overtopping of the earth embankment. The identification of the dams that would require their spillways to be upgraded would be undertaken at detailed design stage.

ES1.5 Post-project flood risk assessment

Figures 7.1 to **7.28** show flooding behaviour in the vicinity of the project under post-project conditions for design events of 2, 10 and 100 year ARI, as well as the PMF, while **Table 7.1** summarises the residual impacts of the project on the individual receiving drainage lines assuming the implementation of the transverse drainage and flood mitigation strategy described in **Chapter 6** of this technical work paper.

The key findings of the present investigation in regards the residual impacts of the project on flooding and drainage patterns were as follows:

- The project would result in an increase in both the rate and volume of runoff discharging to a number of receiving drainage lines. Changes in catchment hydrology are attributable to:
  - the increase in impervious area associated with the construction of the new northbound and southbound carriageways;
  - the provision of an efficient pavement drainage system which would control runoff discharging from the new carriageways; and
  - the diversion of surface runoff toward adjacent drainage lines.
- While peak flood levels would be increased as a result of the project for events up to 100 year ARI, affected areas are limited to undeveloped pastoral land.
- Due to the relatively steep sided nature of the drainage lines that cross the project corridor, increases in peak flood levels attributable to the project do not translate into a significant increase in the spatial extent of flood affected land for events up to 100 year ARI.

- The project would increase the scour potential in the drainage lines which run through DEOH site on Commonwealth land. The increase in scour potential would extend only a short distance from the corridor as the increase in peak flow attributable to the project as a percentage of the total flow reduces in the downstream direction due to the discharge of additional catchment runoff to the affected drainage line.
- The removal of the two large dams which are located on either side of Adams Road in the Cosgroves Creek catchment would result in an increase in peak flows (and flood levels) along the main arm of the creek downstream of the project corridor for events with ARI's up to 100 years (refer **Figures 7.5**, **7.6** and **7.7**). While no existing development would be impacted by the project as far downstream as Elizabeth Drive, the increase in the rate of flow is likely to increase the scour potential within the inbank area of the watercourse. The resulting increase in flow would also reduce the hydrologic standard of the existing transverse drainage located along Elizabeth Drive.
- The project would result in significant increases in peak flood levels along its upstream side during a PMF event. While the affected areas generally comprise undeveloped pastoral land, four existing dwellings that are located on the Badgerys Creek floodplain would be affected (refer Dwellings D1, D2, D3 and D4 on **Figure 7.27**). Given the relatively short catchment response time to intense rainfall events and the fact that depths of inundation would be increased by up to 2 m during a PMF event, the project would result in a significant increase in the flood risk in the affected properties.

  While further design development would need to be undertaken at detailed design stage, it is recommended that the road be lowered from its current level where it crosses the Badgerys Creek floodplain. **Figure 7.29** shows the resulting flooding behaviour, while **Figure 7.30** shows the impact the project would have on peak PMF levels when compared to present day (i.e. pre-project) conditions should the road be lowered from its current level.

  If the road were to be lowered from its current level, then the impact of the project on existing development would be limited to two of the four aforementioned dwellings (refer Dwellings D1 and D2 on **Figure 7.30**). Furthermore, increases in the depth of above-floor inundation in the two affected dwellings would be limited to a maximum of 0.2 metres during a PMF event. Based on this finding, adoption of a lowered road option would result in only a minor increase in flood risk given the very low probability of occurrence of a PMF event and the relatively small increase in the depth of above-floor inundation in the two dwellings.

The impact of a partial blockage of the proposed transverse drainage on flooding behaviour would be typically confined to land located immediately upstream of The Northern Road (refer **Figures 7.31**, **7.32** and **7.33**). Flooding conditions would not be exacerbated in the vicinity of any existing dwellings. A minimum 100 year ARI level of flood immunity would also be maintained to both carriageways of The Northern Road.

The assessment of increases in rainfall intensity associated with future climate change on flooding behaviour found that a 30 per cent increase in the intensity of 100 year ARI rainfall would result in an increase in peak flood levels along the project corridor by a maximum of 500 mm, but typically 50 mm or less. A 100 year ARI level of flood immunity would still be maintained to both carriageways of The Northern Road.

1 INTRODUCTION

1.1 Overview of The Northern Road Upgrade

The Australian and NSW governments are planning to upgrade The Northern Road as part of the Western Sydney Infrastructure Plan (**WSIP**), a 10 year, $3.6 billion road investment program (**The Northern Road Upgrade**). The Northern Road Upgrade will deliver new and upgraded roads to support integrated transport in the region and capitalise on the economic benefits from developing a western Sydney airport at Badgerys Creek. It will also improve safety, increase road capacity and reduce congestion and travel times in the future. The Northern Road Upgrade extends from The Old Northern Road, Narellan to Jamison Road, Penrith and has been divided into the following six sections:

- The Old Northern Road, Narellan to Peter Brock Drive, Oran Park, which covers about 3.3 km.
- Peter Brock Drive, Oran Park to Mersey Road, Bringelly, which covers about 10 km.
- Mersey Road, Bringelly to Eaton Road, Luddenham, which covers about 5.5 km.
- Eaton Road to Littlefields Road, Luddenham, which covers about 4.5 km.
- Littlefields Road, Luddenham to Glenmore Parkway, Glenmore Park, which covers about 6 km.
- Glenmore Parkway, Glenmore Park to Jamison Road, Penrith, which covers about 4 km.

NSW Roads and Maritime Services (**Roads and Maritime**) is seeking approval to upgrade about 16 km of The Northern Road between Mersey Road, Bringelly and Glenmore Parkway, Glenmore Park (**the project**).

This technical working paper presents the findings of a flood risk assessment that was undertaken for a 12.2 km long section of the project where it runs from Mersey Road, Bringelly to a location 600 m north of Chain-O-Ponds Road, Mulgoa. A companion technical working paper has also been prepared which deals with the 3.8 km long section of the project where it runs from a location 600 m north of Chain-O-Ponds Road, Mulgoa to Glenmore Parkway, Glenmore Park.

1.2 Overview of the project

The project comprises the following key features:

- A six-lane divided road between Mersey Road, Bringelly and Bradley Street, Glenmore Park (two general traffic lanes and a kerbside bus lane in each). The wide central median would allow for an additional travel lane in each direction in the future, if required.
- An eight-lane divided road between Bradley Street, Glenmore Park and about 100m south of Glenmore Parkway, Glenmore Park (three general traffic lanes and a kerbside bus lane in each direction separated by a median).
- About eight kilometres of new road between Mersey Road, Bringelly and just south of the existing Elizabeth Drive, Luddenham, to realign the section of The Northern Road that currently bisects the Western Sydney Airport site and to bypasses Luddenham.

- About eight kilometres of upgraded and widened road between the existing Elizabeth Drive, Luddenham and about 100m south of Glenmore Parkway, Glenmore Park.
- Closure of the existing The Northern Road through the Western Sydney Airport site.
- Tie-in works with the following projects:
  - The Northern Road Upgrade, between Peter Brock Drive, Oran Park and Mersey Road, Bringelly (to the south).
  - The Northern Road Upgrade, between Glenmore Parkway, Glenmore Park and Jamison Road, South Penrith (to the north).
- New intersections including:
  - Traffic light intersection connecting the existing The Northern Road at the southern boundary of the Western Sydney Airport, incorporating a dedicated u-turn facility on the western side.
  - Traffic light intersection for service vehicle access to the Western Sydney Airport, incorporating 160m of new road connection to the airport boundary.
  - Traffic light intersection connecting the realigned The Northern Road with the existing The Northern Road (west of the new alignment) south of Luddenham.
  - An un-signalised (give way controlled) intersection connecting the realigned The Northern Road with Eaton Road (east of the new alignment, left in, left out only).
  - A four-way traffic light intersection formed from the realigned Elizabeth Drive, the realigned The Northern Road and the existing The Northern Road, north of Luddenham.
  - A traffic light intersection at the Defence Establishment Orchard Hills entrance, incorporating a u-turn facility.
- New traffic light signals at four existing intersections:
  - Littlefields Road, Luddenham
  - Kings Hill Road, Mulgoa
  - Chain-O-Ponds Road, Mulgoa
  - Bradley Street, Glenmore Park incorporating a u-turn facility.
- Modified intersection arrangements at:
  - Dwyer Road, Bringelly (left in, left out only)
  - Existing Elizabeth Drive, Luddenham (left out only)
  - Gates Road, Luddenham (left in only)
  - Longview Road, Luddenham (left in, left out only)
  - Grover Crescent south, Mulgoa (left in only)
  - Grover Crescent north, Mulgoa (left out only).

- Dedicated u-turn facilities at:
  - The existing The Northern Road at Luddenham, southwest of Elizabeth Drive.
  - The existing Elizabeth Drive, Luddenham around 800m east of The Northern Road.
  - Chain-O-Ponds Road, Mulgoa.
- Twin bridges over Adams Road, Luddenham.
- Local road changes and upgrades, including:
  - Closure of Vicar Park Lane east of the realigned The Northern Road, Luddenham.
  - Eaton Road cul-de-sac west of the realigned The Northern Road, Luddenham.
  - Eaton Road cul-de-sac east of the realigned The Northern Road, Luddenham.
  - Elizabeth Drive cul-de-sac about 300m east of The Northern Road with a connection to the realigned Elizabeth Drive, Luddenham.
  - Extension of Littlefields Road east of The Northern Road, Mulgoa.
  - A new roundabout on the Littlefields Road extension, Mulgoa.
  - A new service road between the Littlefields Road roundabout and Gates Road, including an un-signalised intersection (give way controlled) at Gates Road, Luddenham.
  - Extension of Vineyard Road, Mulgoa between Longview Road and Kings Hill Road.
  - A new roundabout on the Vineyard Road extension at Kings Hill Road, Mulgoa.
- A new shared path on the western side of The Northern Road and pedestrian paths on the eastern side of The Northern Road where required.
- Drainage infrastructure upgrades.
- Operational ancillary facilities including:
  - Heavy vehicle inspection bays for both northbound and southbound traffic, adjacent to Grover Crescent, Mulgoa and Longview Road, Mulgoa respectively.
  - An incident response facility located on the south-western corner of the proposed four-way traffic light intersection at Elizabeth Drive, Luddenham.
- New traffic management facilities including Variable Message Signs (VMS).
- Roadside furniture and street lighting.
- Utility services relocations.
- Changes to property access along The Northern Road (generally left in, left out only).
- Establishment and use of temporary ancillary facilities and access tracks during construction.
- Property adjustments as required.
- Survey and clearance of undetonated explosive ordinance (UXO) within the Defence Establishment Orchard Hills as required.

1.3 Project location

Figure 1.1 (2 sheets) shows the extent of the project where it runs between Mersey Road, Bringelly and Glenmore Parkway, Glenmore Park. The section of the project that runs from Mersey Road, Bringelly to Elizabeth Drive, Luddenham is located within the Liverpool local government area (**LGA**), while the section that runs from Elizabeth Drive, Luddenham to Glenmore Parkway, Glenmore Park is located within the Penrith LGA. Note that this report deals with sections of the project that run through both LGA's.

1.4 Secretary's Environmental Assessment Requirements

The Secretary's Environmental Assessment Requirements (**SEARS**) for the project were issued on 9 March 2016 by the Department of Planning and Environment (**DPE**). The requirements relevant to flooding are as follows:

> *"identification of potential impacts and benefits of the proposal on existing flood regimes, consistent with the Floodplain Development Manual (Department of Natural Resources, 2005), with an assessment of the potential changes to flooding behaviour (levels, velocities and direction) and impacts on bed and bank stability, through flood modelling, and proposed management and mitigation measures;"*

This technical working paper forms part of the Environmental Impact Statement (**EIS**) that is currently being prepared for the project. The key objectives of the flood risk assessment were to:

- Identify the flood risk to the project in its as-built form (i.e. post construction) over the full range of potential flood events.
- Identify the potential impacts of the project on flooding behaviour in areas outside the project corridor.
- Identify measures aimed at reducing the flood risk to the project.
- Identify measures aimed at mitigating the impacts of the project on flooding behaviour in areas outside the project corridor.

1.5 Study area

The section of the project extending from Mersey Road to a location about 600 m north of Chain-O-Ponds Road is located within the following six catchments:

- Badgerys Creek – Mersey Road to a location 1.5 km north of Dwyer Road
- Duncans Creek – a location 1.5 m north of Dwyer Road to Adams Road
- Cosgroves Creek – Adams Road to Elizabeth Drive
- Unnamed tributary of South Creek – eastern side of the project corridor between Elizabeth Drive and a location 1.5 km south of Gates Road
- Blaxland Creek - eastern side of the project corridor between a location 1.5 km south of Gates Road and a location 600 m north of Chain-O-Ponds Road
- Mulgoa Creek - western side of the project corridor between Elizabeth Drive and a location 600 m north of Chain-O-Ponds Road

Figure 1.1 shows the extent of the project corridor within each of the above six catchments. Badgerys Creek, Cosgroves Creek, the unnamed tributary of South Creek and Blaxland Creek all drain in an easterly direction and form part of the larger South Creek catchment, while Duncans Creek and Mulgoa Creek drain in a westerly direction and discharge directly to the Nepean River.

Hydrologic modelling was carried out to define peak flows and discharge hydrographs for a range of design storms within the study catchments shown in **Figure 1.1**. The discharge hydrographs were then used as input to hydraulic models that were developed to define flooding patterns in the vicinity of the project corridor under both pre- and post-project conditions.

1.6 Report structure

Chapter 2 sets out the flood related statutory and policy context for The Northern Road Upgrade, as well as several industry guidelines that are relevant to the flooding investigation. This chapter also sets out how the relevant government policies and industry guidelines have been taken into account as part of the assessment.

Chapter 3 sets out the methodology that has been adopted in the definition of flooding behaviour in the vicinity of the project and also in identifying the impact it would have on flooding behaviour. Also presented in this chapter of the technical working paper is the methodology which has been adopted for assessing the impact a partial blockage of major hydraulic structures and also future climate change (increases in rainfall intensity only) would have on flooding behaviour under post-construction conditions. The methodology adopted for assessing measures aimed at mitigating the impact of the project on flooding and also the impact flooding has on the project is also presented in this chapter of the technical working paper.

Chapter 4 contains a brief description of the catchments through which the project runs. This chapter of the technical working paper also provides a description of flooding behaviour in the vicinity of the project under present day (i.e. pre-project) conditions.

Chapter 5 provides a description of the potential flood and scour related impacts of the project should appropriate mitigation measures not be incorporated into its design.

Chapter 6 provides details of the proposed transverse drainage and flood mitigation strategy that is aimed at mitigating the potential flood and scour related impacts of the project described in **Chapter 5**.

Chapter 7 presents the findings of an assessment which was undertaken into the residual flooding related impacts of the project following implementation of the proposed transverse drainage and flood mitigation strategy. Also presented in this chapter of the report are the key findings of an analysis which was undertaken to test the sensitivity of flooding behaviour to:

- a partial blockage of major hydraulic structures; and
- potential changes in rainfall intensity associated with future climate change.

Chapter 8 contains a list of references cited in this technical working paper.

Appendix A of this technical working paper contains background to the development and testing of the flood models that were used to define flooding behaviour in the vicinity of the project.

Appendix B contains a sketch showing the proposed security measure which would be installed at the location where concentrated flow would discharge through the DEOH security fence on Commonwealth land.

Appendix C contains a table which provides a comparison of peak flows at key locations under pre- and post-project conditions.

The scales on figures referred to in this technical working paper are applicable when printed at A3 size. The figures referred to in the main body of this technical working paper are located after **Chapter 8** of this technical working paper.

2 STATUTORY AND POLICY CONTEXT

2.1 Relevant Government policies and industry guidelines

Government policies and guidelines that have been considered as part of the current assessment (arranged in date order) include:

- *Flood Prone Land Policy* (NSW Government).
- Section 117(2) Local Planning Direction 4.3 Flood Prone Land (NSW Government).
- Planning circular PS 07-003 *New guideline and changes to section 117 direction and (Environmental Planning and Assessment Regulation on flood prone land* (NSW Government).
- *Guideline on Development Controls on Low Flood Risk Areas* (NSW Government).
- *Environment Protection and Biodiversity Act 1999* (Commonwealth Government)
- *Australian Rainfall and Runoff* (AR&R) (Institution of Engineers Australia (IEAust), 1998).
- *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method* (Bureau of Meteorology (BoM), 2003).
- *Floodplain Development Manual* (Department of Infrastructure, Planning and Natural Resources (DIPNR), 2005).
- *Floodplain Risk Management Guideline – Practical Considerations of Climate Change* (Department of Environment and Climate Change (DECC), 2007).
- *Liverpool Local Environmental Plan 2008*.
- *Penrith Local Environmental Plan 2010*.
- *AR&R Revision Projects – Project 11 – Blockage of Hydraulic Structures* (Engineers Australia (EA), 2013),
- *Guidelines for the Content of a Draft Environmental Impact Statement – The Northern Road Upgrade: Mersey Road, Bringelly to Glenmore Parkway, Glenmore Park* (Commonwealth Government)

2.2 Commonwealth Government Guidelines

Following the determination that the project has the potential to have a significant impact on matters of national environmental significance that are protected under Part 3 of the *Environment Protection and Biodiversity Act 1999* (those being *Listed threatened species and communities* (sections 18 and 18A); and *Commonwealth land* (sections 26 and 27A)), the Minister for the Environment and Heritage issued a set of guidelines for the preparation of the EIS (refer *Guidelines for the Content of a Draft Environmental Impact Statement – The Northern Road Upgrade: Mersey Road, Bringelly to Glenmore Parkway, Glenmore Park*).

2.3 Floodplain Development Manual

The Floodplain Development Manual (**FDM**) incorporates the NSW Government's Flood Prone Land Policy, the primary objectives of which are to reduce the impact of flooding and flood liability on owners and occupiers of flood prone property and to reduce public and private losses resulting from floods, whilst also recognising the benefits of use, occupation and development of flood prone land.

The FDM forms the NSW Government's primary technical guidance for the development of sustainable strategies to support human occupation and use of the floodplain, and promotes strategic consideration of key issues including safety to people, management of potential damage to property and infrastructure, and management of cumulative impacts of development. Importantly, the FDM promotes the concept that proposed developments be treated on their merit rather than through the imposition of rigid and prescriptive criteria.

Flood and floodplain risk management studies undertaken by local councils as part of the NSW Government's Floodplain Management Program are carried out in accordance with the merits based approach promoted by the FDM. A similar merits based approach has been adopted in the assessment of the impacts the project would have on existing flood behaviour and also in the development of a range of potential measures which would be aimed at mitigating its impact on the existing environment.

2.4 State Government planning directions and guidelines

In January 2007 the NSW Department of Planning (DOP) issued Planning circular PS 07-003 "*New guideline and changes to section 117 direction and (Environmental Planning and Assessment Regulation on flood prone land*" which provided an overview of its new guideline to the FDM titled Guideline on Development Controls on Low Flood Risk Areas and changes to the Environmental Planning and Assessment Regulation 2000 and section 117 Direction on flood prone land. More specifically, the circular provided advice on a package of changes concerning flood-related development controls on residential development on land above the 100 year ARI flood and up to the Probable Maximum Flood (**PMF**). These areas are sometimes known as low flood risk areas.

Guideline on Development Controls on Low Flood Risk Areas confirmed that unless there are exceptional circumstances, councils should adopt the 100 year ARI flood as the basis for deriving the Flood Planning Level (**FPL**) for residential development. In proposing a case for exceptional circumstances, a council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. The guideline also notes that, unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land above the residential FPL (low flood risk areas). However, the guideline does acknowledge that controls may need to apply to critical infrastructure (such as hospitals) and consideration given to evacuation routes and vulnerable developments (like nursing homes) in areas above the 100 year ARI flood.

In July 2007 the NSW Government's Minister for Planning issued a list of directions to local councils under section 117(2) of the Environmental Planning and Assessment Act 1979. Direction 4.3 - Flood Prone Land applies to all councils that contain flood prone land within their LGA and requires that:

- A draft Local Environmental Plan (**LEP**) shall include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the FDM (including the *Guideline on Development Controls on Low Flood Risk Areas*).
- A draft LEP shall not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.

- A draft LEP shall not contain provisions that apply to the flood planning areas which:
  - permit development in floodway areas,
  - permit development that will result in significant flood impacts to other properties,
  - permit a significant increase in the development of that land,
  - are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or
  - permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.
- A draft LEP must not impose flood related development controls above the residential flood planning level for residential development on land, unless a council provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).
- For the purposes of a draft LEP, a council must not determine a flood planning level that is inconsistent with the FDM (including the Guideline on Development Controls on Low Flood Risk Areas) unless a council provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

Based on the above requirements, the assessment of the impacts the project would have on existing flood behaviour and also the future development potential of flood affected land outside the project corridor relates to all storms with ARI's up to 100 years in the case of residential type development (and by default commercial and industrial type development) and for storms with ARI's greater than 100 years in the case of critical infrastructure (such as hospitals) and vulnerable developments (such as aged care facilities). The key findings of the assessment in this regard are set out in **Section 6.2**.

2.5 State Government Floodplain Risk Management Guidelines

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

The NSW Government's *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC, 2007) recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent. Under present day climatic conditions, increasing the 100 year ARI design rainfall intensities by 10 per cent would produce about a 200 year ARI flood; and increasing those rainfalls by 30 per cent would produce about a 500 year ARI flood. On current projections the increase in rainfalls within the design life of the project is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit.

The *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC, 2007) also contains guidance on strategies which are aimed at managing the impact of future climate change on both existing and proposed development. The guideline includes several examples on how to deal with the ramifications of future climate change which are dependent on location and the potential to effectively and practically manage its impact.

2.6 Local Government Flood Related Planning Controls

2.6.1 Liverpool LGA

The *Liverpool Local Environment Plan 2008* (Liverpool City Council (**LCC**), 2008)) aims to make local environmental planning provisions for land in Liverpool in accordance with the relevant standard environmental planning instrument under section 33A of the Environmental Planning and Assessment Act 1979 No. 203 (**the Act**)..

Clause 7.8 of LCC, 2008 titled "Flood planning" states the following:

"(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account floodplain risk management studies and plans adopted by the Council and projected changes as a result of climate change, including sea level rise and rainfall intensity,

(c) to avoid significant adverse impacts, including cumulative impacts, on flood behaviour and the environment.

(2) This clause applies to land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding, and

(f) is consistent with any relevant floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual.

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual, unless it is otherwise defined in this Plan."

Clause 7.8A of LCC, 2008 titled “Floodplain risk management” states the following:

“(1) The objectives of this clause are as follows:

(a) in relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding in events exceeding the flood planning level,

(b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

(2) This clause applies to land between the flood planning level and the level of a probable maximum flood, but does not apply to land at or below the flood planning level.

(3) Development consent must not be granted to development for any of the following purposes on land to which this clause applies unless the consent authority is satisfied that the development is consistent with any relevant floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual, and will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land:

(a) caravan parks,

(b) child care centres,

(c) correctional centres,

(d) emergency services facilities,

(e) group homes,

(f) hospitals,

(g) residential care facilities,

(h) respite day care centres,

(i) tourist and visitor accommodation.

(4) In this clause:

probable maximum flood has the same meaning as it has in the Floodplain Development Manual.

Note. The probable maximum flood is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation.

It is noted that the Flood planning land map for the Liverpool LGA does not show land in the vicinity of the project as lying at or below the FPL. This is probably due to LCC not having completed detailed flood studies in this area.

2.6.2 Penrith LGA

The *Penrith Local Environment Plan 2010* (Penrith City Council (**PCC**), 2010)) aims to make local environmental planning provisions for land within the Penrith LGA by providing a mechanism and framework for the management, orderly and economic development, and conservation of land in Penrith.

Clause 7.2 of PCC, 2010 titled "Flood Planning", which applies to land at or below the flood planning level or land located within the "Flood planning area" identified on the Flood planning land map, sets out the following requirements in relation to flooding:

"(3) Development consent is required for any development on land to which this clause applies.

(4) Development consent must not be granted for development on land that is at or below the flood planning level unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) if located in a floodway, is compatible with the flow conveyance function of the floodway and the flood hazard within the floodway, and

(c) is not likely to adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(d) is not likely to significantly alter flow distributions and velocities to the detriment of other properties or the environment, and

(e) is not likely to adversely affect the safe and effective evacuation of the land and the surrounding area, and

(f) is not likely to significantly detrimentally affect the environment or cause avoidable erosion, destruction of riparian vegetation or affect the restoration and establishment of riparian vegetation, or a reduction in the stability of river banks or waterways, and

(g) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding, and

(h) incorporates appropriate measures to manage risk to life from flood, and

(i) is consistent with any relevant floodplain risk management plan.

(5) Development consent must not be granted for development on land identified as "Flood planning land" on the Clause Application Map, unless the consent authority is satisfied that the development will not adversely affect the safe and effective evacuation of the land and the surrounding area.

(6) A word or expression used in this clause has the same meaning as it has in the NSW Government's Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.

(7) In this clause:
flood planning level means the level of a 1:100 ARI (average recurrence interval) flood event plus 0.5 metres freeboard."

The above approach is consistent with the NSW Government's *Guideline on Development Controls on Low Flood Risk Areas*, which confirms that unless there are exceptional circumstances, councils should adopt the 100 year ARI flood as the basis for deriving the FPL for residential development.

It is noted that the Flood planning land map for the Penrith LGA does not show land in the vicinity of the project as lying at or below the FPL. This is probably due to PCC not having completed detailed flood studies in this area.

Chapter 6 provides details of the transverse drainage and flood mitigation strategy that has been developed for the project in recognition of the above government requirements and industry guidelines, while **Chapter 7** describes the residual impact the project would have on flooding behaviour following its implementation.

3 ASSESSMENT METHODOLOGY

3.1 Key tasks

The key tasks comprising the flooding investigation are broadly described below:

- Develop hydrologic and hydraulic models in order to define flood behaviour in the vicinity of the project corridor.
- Run the flood models and prepare exhibits showing flooding behaviour under present day (pre-project) conditions for the 2 year, 10 year and 100 year ARI events, as well as the Probable Maximum Flood (PMF).
- Assess the impacts the project could potentially have on flooding behaviour should appropriate mitigation measures not be incorporated into its design.
- Assess the impact flooding could potentially have on the project should appropriate mitigation measures not be incorporated into its design.
- Develop a preferred set of measures which are aimed at mitigating the impacts of the project on flooding, as well as mitigating the impacts of flooding on the project.
- Assess the residual impact the project would have on flooding behaviour assuming the preferred set of flood mitigation measures is incorporated into its design.
- Assess the impact a partial blockage of major hydraulic structures would have on flooding behaviour under post-construction conditions.
- Assess the impact future climate change would have on flooding behaviour under post-construction conditions.

The following sections of this technical working paper set out the methodology that was adopted in the assessment of flooding behaviour under present day (i.e. pre-project) and post-project conditions. Further discussion on the measures that would be required to mitigate the impact of the project on flooding behaviour is contained in **Chapter 6** of this technical working paper.

3.2 Definition of present day flooding behaviour

In order to define the nature of flooding in the vicinity of the project it was necessary to develop a set of computer based flood models. The RAFTS sub-model incorporated in the DRAINS rainfall-runoff modelling software package was used to generate discharge hydrographs for a range of design storm events. The discharge hydrographs were then used as input to a hydraulic model that was developed using the TUFLOW two-dimensional (in plan) hydraulic modelling software to define flooding patterns in the vicinity of the project.

Flooding behaviour in the vicinity of the project corridor was defined for events with ARI's of between 2 and 500 years[2], as well as the PMF. A brief description of flooding behaviour in the vicinity of the project under present day (pre-project) conditions is presented in **Chapter 4** of this technical working paper.

[2] Design storms with ARI's of 200 and 500 years formed the basis of the assessment into the potential impacts of future climate change on flooding behaviour given they are analogous to a 10 and 30 per cent increase in the intensity of 100 year ARI rainfall under current climatic conditions, respectively

3.3 Sensitivity analyses

The sensitivity of the hydraulic model was tested to variations in hydraulic roughness to give some guidance on the freeboard which might be adopted in the design of the project. Runs of the hydraulic model were undertaken assuming a 20 per cent increase in hydraulic roughness (compared to the best estimate values given in **Table A3.1** in **Appendix A** of this technical working paper). The findings of the sensitivity analysis in relation to the resulting changes in flooding behaviour are presented in **Section A3.5** in **Appendix A** of this technical working paper.

3.4 Comparison with findings of previous studies

No detailed investigations are available that define flooding behaviour along the project corridor.

3.5 Provisional flood hazard

Flood hazard categories may be assigned to flood affected areas in accordance with the procedures outlined in the FDM. Flood prone areas may be provisionally categorised into *Low Hazard* and *High Hazard* areas depending on the depth of inundation and flow velocity. Flood depths as high as one metre, in the absence of any significant flow velocity, could be considered to represent Low Hazard conditions. Similarly, areas of flow velocities up to two metres per second, but with small flood depths of less than 0.2 metres could also represent Low Hazard conditions.

Figures showing Provisional Flood Hazard areas for the 100 year ARI event have been prepared as part of the current investigation based on Diagram L2 in the FDM (refer **Section 4.4** for further details).

The Flood Hazard assessment presented herein is based on considerations of depth and velocity of flow and is *provisional* only. As noted in the FDM, other considerations such as the rate of rise of floodwaters and access to high ground for evacuation from the floodplain should also be taken into consideration before a final determination of Flood Hazard can be made. These factors are generally taken into account during the preparation of a Floodplain Risk Management Study and Plan for an area.

3.6 Minimum hydrologic standards

The transverse drainage for the project is to provide a minimum 100 year ARI level of flood immunity to the new southbound and northbound carriageways. Scour protection measures are to be incorporated at the inlets and outlets of the upgraded transverse drainage to reduce the risk of scour for storms with ARI's up to 50 years, and to prevent damage of the individual structures for storms with ARI's up to 100 years.

3.7 Potential impacts of the project on flooding behaviour

A qualitative assessment was undertaken into the impacts the project could potentially have on flooding behaviour and the scour potential within the receiving drainage lines should appropriate mitigation measures not be incorporated into its design. The findings of the assessment are set out in **Sections 5.2** and **5.3** of this technical working paper.

3.8 Potential impacts of flooding on the project

A qualitative assessment was undertaken into the impacts flooding could potentially have on the project should appropriate mitigation measures not be incorporated into its design. The findings of the assessment are set out in **Section 5.4** of this technical working paper.

3.9 Assessment of potential flood mitigation measures

A range of measures were assessed which are aimed at mitigating the potential impacts of the project on flooding and the scour potential in the receiving drainage lines, as well as mitigating the potential impacts of flooding on the project.

The mitigating effects of these measures were assessed by altering the structure of the hydrologic and hydraulic models to incorporate details of the project. Background to the changes that were made to the structure of the models is contained in **Section A3.6** in **Appendix A** of this technical working paper.

3.10 Residual impacts of the project on flooding behaviour

The results of modelling the 2 year, 10 year and 100 year ARI events, together with the PMF event under post-project conditions were used to prepare a series of afflux diagrams showing the residual impact of the project on flooding behaviour following implementation of the preferred set of flood mitigation measures.[3] A discussion on the residual impacts of the project on flooding behaviour is contained in **Section 7.2** of this technical working paper.

3.11 Residual impacts of flooding on the project

The results of the modelling described in **Section 3.10** were also used to assess the residual impacts of flooding on the project following implementation of the preferred set of flood mitigation measures. This included a review of the freeboard which would be available to the main carriageways during a 100 year ARI event. The findings of this assessment are presented in **Section 7.3** of this technical working paper.

3.12 Impact of a partial blockage of major hydraulic structures on flood behaviour

Engineers Australia's guideline *AR&R Revision projects – project 11 – Blockage of Hydraulic Structures* (EA, 2013) includes guidance on modes of blockage which are likely to be experienced for different hydraulic structures.

In regards to pipe and culvert structures, the guideline recommends the adoption of a 20 per cent blockage factor where the height of a hydraulic structure is less than three metres or its width is less than five metres. The structure of the hydraulic model was adjusted to include a 20 per cent blockage factor which was applied to all major hydraulic structures.

The findings of the blockage related impact assessment are contained in **Section 7.4** of this technical working paper.

[3] In the context of technical working paper, afflux is the difference in peak flood levels caused by changes to the floodplain. For example, due to the construction of the road embankment across the floodplain of Badgerys Creek.

3.13 Impact of future climate change on flooding behaviour

Section 2.5 of this technical working paper provides background to the derivation of the adopted percentage increase in 100 year ARI design rainfall intensities which were used to assess the potential impact of future climate change on flooding behaviour in the vicinity of the project. Further details on the findings of the climate change impact assessment are contained in **Section 7.5** of this technical working paper.

4 EXISTING ENVIRONMENT

4.1 General

This chapter of the technical working paper provides a brief description of the catchments that contribute runoff to the existing transverse drainage which are located along the section of The Northern Road that extends from Mersey Road to a location 600 m north of Chain-O-Ponds Road. For discussion purposes, this section of The Northern Road is simply referred to as "The Northern Road".

The location of key features referred to in the following discussion are referenced by their position relative to the master control string for the road design. The location of each key feature relative to the master control string is referred to herein as its "Design Road Chainage" (**DRC**).

4.2 Catchment description

The section of The Northern Road that runs between the village of Luddenham and a location 600 m north of Chain-O-Ponds Road generally follows a natural ridgeline that forms the catchment divide between Mulgoa Creek, Duncans Creek, Cosgroves Creek, an unnamed watercourse and Blaxland Creek (refer **Figure 1.1** (2 sheets)). Mulgoa Creek and Duncans Creek drain in a westerly direction and discharge directly to the Nepean River, while Cosgroves Creek, the unnamed watercourse and Blaxland Creek drain in an easterly direction where they discharge to South Creek, a major tributary of the Hawkesbury-Nepean River.

South of Luddenham, The Northern Road continues to follow the natural ridgeline that forms the catchment divide between Cosgroves Creek and Duncans Creek before crossing through the Badgerys Creek catchment.

Figure 4.1 (4 sheets) shows the extent of the catchments that contribute runoff to the existing transverse drainage along The Northern Road, while details of the individual structures are given in **Table 4.1** over the page. The catchments that contribute runoff to the existing transverse drainage of The Northern Road have generally been cleared of native vegetation, with the predominant ground cover being grass.

Commercial and residential development is limited to the village of Luddenham, with the remainder of the land bordering the road corridor comprising either rural holdings or the Commonwealth Department of Defence's (**DoD's**) Defence Establishment Orchard Hills (**DEOH**) site.

The main water supply lines for Sydney, which comprise 3.2 m and 2.4 m diameter steel pipes, run in an east-west direction and cross The Northern Road a short distance north of the Gates Road intersection. While the obvert level of the two pipes is located about 13 m below natural surface where they cross The Northern Road, the two pipes become exposed a short distance to the east and west of the road corridor where they are located in a series of relatively deep open trenches. The condition of these trenches is affected by catchment runoff which discharges to their base via a series of concrete lined chutes, further discussion on which is contained in **Section 4.3.1** of this technical working paper.

TABLE 4.1
DETAILS OF EXISTING TRANSVERSE DRAINAGE

Catchment	Cross Drainage Structure Identifier[1]	Design Road Chainage	Dimensions / Type[2] (mm)	Upstream Invert Level (m AHD)	Downstream Invert Level (m AHD)	Contributing Catchment Area (ha)
Blaxland Creek	BLC_EXD01	DRC 9680	1 off 450 RCP	86.82[3]	86.49[3]	1.08
	BLC_EXD02	DRC 10320	1 off 525 RCP	90.81	90.29	1.29
	BLC_EXD03	DRC 10680	1 off 450 RCP[3]	80.86	80.70	5.28
	BLC_EXD04	DRC 12320	1 off 600 RCP	75.45	74.89	2.87
	BLC_EXD05	DRC 12970	1 off 450 RCP	77.56	77.16	0.86
Mulgoa Creek	MC_EXD01	DRC 8790	1 off 375 RCP	Unknown	Unknown	0.42
	MC_EXD02	DRC 9080	1 off 375 RCP	Unknown	Unknown	0.40
	MC_EXD03	DRC 9160	1 off 450 RCP	Unknown	Unknown	0.19
	MC_EXD04	DRC 9280	1 off 450 RCP	Unknown	Unknown	0.15
	MC_EXD05	DRC 11240	1 off 525 RCP	84.45	83.99	1.77
	MC_EXD06	DRC 11900	1 off 450 RCP	82.00	81.76	1.12
	MC_EXD07	DRC 11980	1 off 450 RCP	77.83	77.7[3]	13.7
	MC_EXD08	DRC 12000	1 off 450 RCP	79.73	79.58	1.83
	MC_EXD09	DRC 12960	1 off 450 RCP[3]	76.03	75.81	3.47
	MC_EXD10	DRC 13190	2 off 450 RCP's	74.94	74.81	2.00

Refer over for footnotes to **Table 2.1**.

TABLE 4.1
DETAILS OF EXISTING TRANSVERSE DRAINAGE

Catchment	Cross Drainage Structure Identifier(1)	Design Road Chainage	Dimensions / Type(2) (mm)	Upstream Invert Level (m AHD)	Downstream Invert Level (m AHD)	Contributing Catchment Area (ha)
Unnamed Tributary of South Creek	UT_EXD01	DRC 8430	1 off 450 RCP	90.95(3)	90.75	1.72
Duncans Creek	DC_EXD01	DRC 3060	1 off 600 RCP	81.60(3)	80.04(3)	2.37
	DC_EXD02	DRC 5380	1 off 600 RCP	95.40(3)	94.37(3)	3.93
	DC_EXD03	DRC 5380	1 off 375 RCP	94.93(3)	94.08(3)	1.68
	DC_EXD04	DRC 5370	1 off 450 RCP	96.56(3)	95.45(3)	1.38
	DC_EXD05	DRC 5460	Unknown			0.55
Badgerys Creek	BC_EXD01	DRC 30	1 off 525 RCP	86.39(3)	86.32(3)	0.10
	BC_EXD02	DRC 360	1 off 450 RCP	80.1(3)	79.73(3)	1.54
	BC_EXD03	DRC 630	2 off 4200 x 2100 RCBC's	75.0(3)	74.72(3)	304
	BC_EXD04	DRC 880	3 off 900 RCP's	77.5(3)	77.39(3)	45.8

(1) Refer **Figure 4.1** (4 sheets) for locations of Transverse Drainage Identifiers.

(2) RCP = Reinforced Concrete Pipe RCBC = Reinforced Concrete Box Culvert.

(3) Assumed dimension/elevation.

4.3 Description of existing drainage system

4.3.1 Blaxland Creek Catchment

As mentioned, The Northern Road generally follows the natural ridgeline that forms the catchment divide between Blaxland Creek and Mulgoa Creek. As a result, the catchments that contribute flow to the existing transverse drainage are relatively small, as shown on **Figure 4.1**, sheets 1 and 2.

The drainage lines that cross The Northern Road in the Blaxland Creek catchment either directly or indirectly discharge to the DEOH site that is located on Commonwealth land to the east of the project corridor and north of the Sydney Water Supply Pipeline corridor.

It is noted that flow conveyed in drainage lines BLC DL03 and BLC DL05 discharges to the base of the open trenches in which the two aforementioned water supply pipelines are located. It is further noted that flow conveyed in drainage line BLC DL03 discharges to the base of the open trench in which the southern water supply pipeline is located, while drainage line BLC DL05 discharges to the base of the open trench in which the northern water supply pipeline is located.

Runoff discharging to the pipeline corridor along drainage lines BLC DL03 and BLC DL05 is conveyed to the base of the open trenches via a series of concrete lined chutes. An access road is located at the top of each chute, beneath which is located a reinforced concrete pipe. The reinforced concrete pipe located at the top of the chute on drainage line BLC DL03 has been set above natural surface levels on its upstream side, which results in the prolonged ponding of catchment runoff along the southern side of the pipeline corridor.

The two water supply pipelines are founded on a series of concrete support plinths, with the underside of each pipe located about 0.5 m above the base of each trench. The base of the open trenches fall in an easterly direction at a relatively flat grade, resulting in rather wet conditions persisting around the concrete support plinths.

The prolonged ponding of runoff at the inlet of the concrete lined chute on drainage line BLC DL03 combined with the rather wet conditions in the base of the two open trenches has resulted in bank slumping at several locations along the length of the two pipelines. While Water NSW has undertaken remedial works at a number of locations, continual slumping of the trench batters poses an ongoing problem for the authority.

4.3.2 Mulgoa Creek Catchment

Similar to Blaxland Creek, the catchments that contribute flow to the drainage lines that cross The Northern Road are relatively small, as shown on **Figure 4.1**, sheets 1 and 2. Most of the drainage lines that cross the road corridor run through large-lot rural residential properties, within which a series of farm dams are located. The farm dams typically comprise an earth embankment that has been built across the natural depression which forms each drainage line. The spillways associated with the farm dams are typically ill-defined and generally comprise a short section of lowered earth embankment. None of the spillways observed from the road corridor were lined.

4.3.3 Unnamed Tributary of South Creek Catchment

There is only one transverse drainage structure that controls runoff from a catchment which contributes flow to the unnamed tributary of South Creek (refer transverse drainage structure UT EXD01 on **Figure 4.1**, sheet 2). Runoff from the catchment which lies on the western (upslope) side of the road contributes to flow in an existing farm dam which is located a short distance from the road corridor on its eastern side.

4.3.4 Cosgrove Creek Catchment

While there are no existing transverse drainage structures located along the section of The Northern Road that would be upgraded as part of the project, runoff from the existing two-lane road does contribute to flow in the various drainage lines which drain in an easterly direction toward South Creek. Runoff from the urbanised parts of Luddenham that lie on the eastern side of The Northern Road also contributes to flow in Cosgroves Creek, as well as drainage lines CC DL02 and CC DL03.

There are a relatively large number of farm dams located along the various drainage lines east of the road corridor, as shown on **Figure 4.1**, sheets 2 and 3. It is noted that the project would impact a number of these dams where it would run to the east of Luddenham. Further discussion on the impact the project could potentially have on these dams is contained in **Chapter 5** of this technical working paper, while **Chapter 6** describes the measures that would be implemented in order to mitigate the project related impacts on the affected dams.

4.3.5 Duncans Creek Catchment

While there may be a number of existing transverse drainage structures located along The Northern Road where it runs along the natural ridgeline that forms the divide between the Duncans Creek and Cosgroves Creek catchments, the route of the upgraded section of road lies further to the west, as shown on **Figure 4.1**, sheet 3.

The proposed route of the project crosses a number of existing drainage lines along which a series of both small and large dams are located. The proposed route also lies a short distance to the east (upslope) of Willowdene Avenue, beneath which a series of transverse drainage structures are located.

4.3.6 Badgerys Creek Catchment

The proposed route of the project crosses a number of minor drainage lines west (upslope) of the existing road corridor, as shown on **Figure 4.1**, sheets 3 and 4. These drainage lines are ephemeral in nature and only flow when initial infiltration losses in the upslope catchment are satisfied.

The project corridor rejoins the existing two-lane road where The Northern Road crosses the main arm of Badgerys Creek. The existing transverse drainage structure on Badgerys Creek controls a catchment within which the principal land use is large-lot rural residential development. While the main arm of the creek is relatively incised in the vicinity of the project corridor, its cross sectional area reduces significantly a short distance to the east (downstream) in the vicinity of its confluence with drainage line BC DL02.

4.4 Description of existing flood behaviour

4.4.1 Blaxland Creek Catchment

While the section of The Northern Road that runs along the catchment divided between Blaxland Creek and Mulgoa Creek is not affected by mainstream or major overland flow, there is the potential for catchment runoff to pond adjacent to the inlet of the existing transverse drainage. For example, the owner of the property that lies on the western side of the road corridor adjacent to the inlet of transverse drainage structure BLC EXD04 has observed water ponding in the existing low point formed by the road embankment on several occasions.

4.4.2 Mulgoa Creek Catchment

Similar to the Blaxland Creek catchment, flooding problems are likely to be limited to catchment runoff ponding along the upslope side of the two-lane road. It is noted that drainage swales have been constructed along the western side of the road corridor in the vicinity of the Chain-O-Ponds Road intersection, along which several pipes are located where it is crossed by local access driveways.

4.4.3 Unnamed Tributary of South Creek Catchment

Similar to the Blaxland Creek and Mulgoa Creek catchments, flooding problems are likely to be limited to catchment runoff ponding along the upslope side of the two-lane road adjacent to the inlet of transverse drainage structure UT EXD01.

4.4.4 Cosgrove Creek Catchment

While the existing road corridor follows the natural ridgeline which forms the catchment divide between Cosgroves Creek and Duncans Creek (and therefore would be subject to similar issues to those described above), detailed flood modelling was undertaken to define the nature of flooding along the drainage lines that would be crossed by the project, which is located east of the existing road corridor and therefore further downstream along the respective drainage lines.

Figures 4.2, **4.3**, **4.4** and **4.5** respectively show flooding behaviour in the vicinity of the project corridor under pre-project conditions for design storms with ARI's of 2 year, 10 year and 100 year, together with the PMF.

While depths of ponding exceed 1 m in the various farms dams, flow in the various drainage lines between each water storage is generally relatively shallow for events up to 100 year ARI. There are also no existing dwellings that are presently impacted by flooding for events up to the PMF.

Figure 4.6 shows that high hazard flooding is generally confined to the farm dams and the incised reaches of the drainage system which are typically located downstream of the project corridor for events up to 100 year ARI.

4.4.5 Duncans Creek Catchment

Figures 4.7, **4.8**, **4.9** and **4.10** respectively show flooding behaviour in the vicinity of the project corridor under pre-project conditions for design storms with ARI's of 2 year, 10 year and 100 year, together with the PMF.

Flooding behaviour in the Duncans Creek catchment is similar to that described above for the Cosgroves Creek catchment, with relatively shallow flow occurring along the various drainage lines where they run between the existing farm dams. It is noted that the project would impact several farm dams where the depth of ponding would be greater than 1 m.

The aerial photography that has been used to compile the figures in this report shows the presence of a building that is located immediately downstream of an existing dam in Lot 13 DP 258581 on drainage line DC DL06 (refer **Figures 4.7** to **4.11** for location). However, a review of Google Maps™ shows that the building has recently been relocated closer to Willowdene Avenue to higher ground. It is also noted that the dwellings located in Lot 11 DP248069, Lot 104 DP884343 and Lot 105 DP884343 (refer **Figures 4.7** to **4.11** for location), while above the adjacent peak 100 year ARI flood level, are impacted by a PMF event.

While high hazard conditions are generally confined to the existing dams and the incised reaches of the drainage system for events up to 100 year ARI (ref. **Figure 4.11**), the confined nature of the floodplain in several areas results in hazardous flooding conditions being present across the full width of the flood affected area (for example, along drainage line DC DL07 between the project corridor and Willowdene Avenue).

4.4.6 Badgerys Creek Catchment

Figures 4.12, **4.13**, **4.14** and **4.15** respectively show flooding behaviour in the vicinity of the project corridor under pre-project conditions for design storms with ARI's of 2 year, 10 year and 100 year, together with the PMF, while **Figure 4.16** shows design water surface profiles along the main arm of the creek in the vicinity of the road crossing.

While the Badgerys Creek floodplain is relatively wide in the vicinity of where The Northern Road crosses the main arm of the creek, depths of flow on its overbank are relatively shallow for events up to 100 year ARI.

The transverse drainage structure on the main arm of Badgerys Creek has sufficient capacity to convey flows without surcharge of the existing road for events up to 100 year ARI.

Dwellings located on the western (upstream) side of the road corridor in Lot 93 DP654182 and Lot 94 DP654182 are marginally affected by a 100 year ARI flood event (refer inset on **Figure 4.14**), while the dwellings located in Lot 91 DP27550 and Lot 95 DP27550 are located on the edge of the floodplain.[4] It is noted that the dwelling located in Lot 94 DP654182 would be surrounded by floodwater during events as frequent as 2 year ARI (refer inset on **Figure 4.12**) and that depths of flow in the vicinity of the dwelling would increase to just over 1 m during a PMF event (refer inset on **Figure 4.15**). Similar depths of inundation would also be experienced in the vicinity of the dwelling located in Lot 91 DP27550 during a PMF event.

Similar to the other catchments, high hazard flooding conditions are generally confined to the farm dams and the incised reaches of the drainage system for events up to 100 year ARI (refer **Figure 4.17**).

[4] Defined by the extent of the PMF (refer inset on **Figure 4.15**).

5 ASSESSMENT OF POTENTIAL PROJECT RELATED IMPACTS

5.1 Overview

This chapter of the technical working paper describes the potential impacts of the project on flooding behaviour and the scour potential within the receiving drainage lines. Also included in this chapter is a description of the potential impacts of flooding on the project. Note that the following assessment assumes that no mitigation measures are incorporated into the design of the project.

5.2 Potential impacts of the project on flooding behaviour

Table 5.1 over the page summarises the potential impacts of the project on flooding behaviour in areas which lie outside the project corridor should appropriate mitigation measures not be incorporated into its design.

For ease of reference, a brief description of measures that would mitigate the project related impacts are also set out in **Table 5.1**. **Chapter 6** of this technical working paper contains a detailed description of the transverse drainage upgrade and flood mitigation measures which are referred to in **Table 5.1**.

5.3 Potential impacts of the project on scour potential

The project has the potential to cause scour in the receiving drainage lines due to the following reasons:

- increases in the rate of flow (and hence the depth and velocity of flow) associated with:
    - the enlargement of transverse drainage structures;
    - the discharge of runoff from the widened carriageway; and
    - changes in the distribution of flow along the project corridor;
- increases in the velocity of flow where it discharges from pipe outlets or newly lined sections of channel; and
- the concentration of flow resulting from the formalisation of the drainage system within the project corridor.

Increases in the rate of flow in the receiving drainage lines could result in a lowering of the stream bed through a process of headwater erosion, as well as a possible widening of the watercourse through a process of bank erosion. The lining of channels and the concentration of flow could also result in localised scour in the receiving drainage lines at the downstream limit of the drainage works.

Measures such as dumped rock rip rap protection would need to be incorporated in the design of the project in order to reduce the scour potential in the receiving drainage lines, further details on which are contained in **Chapter 6** of this technical working paper.

TABLE 5.1
SUMMARY OF POTENTIAL PROJECT RELATED IMPACTS

Catchment	Potential Project Related Impact	Potential Mitigation Measure
Blaxland Creek	➢ An increase in the rate and volume of runoff discharging to the open trenches in which the water supply pipelines are located could increase the likelihood of bank instability and also cause added wetting up of the ground around the concrete support plinths.	➢ Divert pavement runoff away from the drainage lines which discharge directly to the open trenches (i.e. away from drainage lines BLC03 and BLC05), or alternatively, divert drainage line BLC05 further east along the corridor to a location where the pipeline is not located in an open trench.
	➢ Increases in the rate of flow could cause scour in the receiving drainage lines.	➢ Divert pavement runoff away from affected drainage lines, or alternatively construct permanent ponds in project corridor to dampen the effects of the project on catchment hydrology.
	➢ Increases in the volume of flow would cause existing dams to fill more frequently, while increases in the rate of flow could cause scour of their earth embankments.	➢ Affected dams should be inspected during detailed design and measures implemented to prevent an increase in the head of water over the spillway. The spillways of affected dams should also be armoured to reduce the risk of increased scour.
	➢ Reductions in the volume of flow would cause existing dams to fill less frequently, reducing the available yield.	➢ Compensatory measures to be arranged with each affected dam owners.
	➢ Increases in the volume of flow discharging to a drainage line has the potential to cause wetting up of an area, resulting in it becoming inaccessible for maintenance.	➢ Construct a low flow channel between the outlet of the new pavement drainage system and a defined watercourse or dam.
	➢ Runoff discharging to the DEOH site on Commonwealth land could damage the access road which would be constructed along the new security fence.	➢ Provide a concrete causeway at the locations where concentrated flow would cross the access road.

Cont'd Over

TABLE 5.1 (Cont'd)
SUMMARY OF POTENTIAL PROJECT RELATED IMPACTS

Catchment	Potential Project Related Impact	Potential Mitigation Measure
Mulgoa Creek	➢ Increases in the rate of flow could cause scour in the receiving drainage lines.	➢ Divert pavement runoff away from affected drainage lines, or alternatively construct permanent ponds in project corridor to dampen the effects of the project on catchment hydrology.
	➢ Increases in the volume of flow would cause existing dams to fill more frequently, while increases in the rate of flow could cause scour of their earth embankments.	➢ Affected dams should be inspected during detailed design and measures implemented to prevent an increase in the head of water over the spillway. The spillways of affected dams should also be armoured to reduce the risk of increased scour.
	➢ Reductions in the volume of flow would cause existing dams to fill less frequently, reducing the available yield.	➢ Compensatory measures to be arranged with each affected dam owners.
	➢ Increases in the volume of flow discharging to a drainage line has the potential to cause wetting up of an area, resulting in it becoming inaccessible for maintenance.	➢ Construct a low flow channel between the outlet of the new pavement drainage system and a defined watercourse or dam.
Unnamed Tributary of South Creek	➢ Same as stated above for the Mulgoa Creek catchment.	➢ Same as stated above for the Mulgoa Creek catchment.
Cosgroves Creek	➢ Same as stated above for the Mulgoa Creek catchment.	➢ Same as stated above for the Mulgoa Creek catchment.
	➢ Removal of existing dams would increase the rate of flow discharging downstream due to the removal of temporary storage.	➢ Reconstruct the dams immediately adjacent to the project corridor.
	➢ A partial infilling of existing dams would increase the rate of flow discharging downstream due to the removal of temporary storage.	➢ Enlarge the dams outside of the project corridor to replace the displaced storage.

Cont'd Over

TABLE 5.1 (Cont'd)
SUMMARY OF POTENTIAL PROJECT RELATED IMPACTS

Catchment	Potential Project Related Impact	Potential Mitigation Measure
Duncans Creek	➢ Same as stated above for the Cosgroves Creek catchment. ➢ Construction of the road embankment through existing dams could potentially increase peak flood levels on the upstream side of the project corridor. ➢ Flooding conditions could be exacerbated in the vicinity of existing dwellings that are located in Lot 11 DP248069, Lot 104 DP884343 and Lot 105 DP884343.	➢ Same as stated above for the Cosgroves Creek catchment. ➢ Configure transverse drainage to mitigate impacts of project on peak flood levels upstream of project corridor. ➢ Maintain existing flow regime downstream of the project corridor for events larger than 100 year ARI.
Badgerys Creek	➢ Same as stated above for the Mulgoa Creek catchment. ➢ Flooding conditions could be exacerbated in the vicinity of the two existing dwellings that are partially affected by flooding during a 100 year ARI event (refer dwellings identified in inset of **Figure 4.14** in Lot 93 DP654182 and Lot 94 DP654182). ➢ Potentially life-threatening flooding could be experienced in Lot 93 DP654182 due to the road embankment forming an obstruction to flow during a partial blockage of the transverse drainage or more extreme floods, both of which would lead to several metres of water ponding above the floor level of the existing dwelling.	➢ Same as stated above for the Mulgoa Creek catchment. ➢ Provide sufficient waterway area under The Northern Road, including flood relief channel along western (upstream) side of project corridor. ➢ Lower the road embankment or alternatively enlarge the waterway area beneath The Northern Road. Alternatively, provide a flood free egress route to a location which lies above the PMF.

5.4 Potential impacts of flooding on the project

While the existing two-lane road generally runs along the natural ridgeline which forms the catchment divide along most of its length, unless sufficient waterway area is provided at the locations where the various drainage lines cross the project corridor there is the potential for the new road to be inundated during storms with ARI's less than 100 years.

A partial blockage of the transverse drainage by debris could result in floodwater surcharging onto the road during storms with ARI's less than 100 year ARI, while increases in rainfall intensity associated with future climate change could also result in the more frequent surcharge of the transverse drainage. There is also the potential for floodwater to erode the road embankment where it crosses major watercourses.

6 ASSESSMENT OF POTENTIAL TRANSVERSE DRAINAGE AND FLOOD MITIGATION MEASURES

6.1 Overview

This chapter sets out the details of measures that are aimed at mitigating the flooding and drainage related impacts of the project. Included in this chapter are the findings of detailed flood modelling which was undertaken to identify the residual flooding and drainage related impacts of the project following the incorporation of a preferred set of transverse drainage and flood mitigation measures into its design. **Chapter 7** of this report sets out the findings of a flood risk assessment that was undertaken assuming the proposed transverse drainage and flood mitigation strategy is incorporated into the design of the project.

6.2 Proposed transverse drainage and flood mitigation strategy

As set out in **Section 3.9**, the mitigating effects of a range of measures were assessed using the hydrologic and hydraulic models that were representative of post-project conditions. Based on the findings of the assessment, a preferred set of transverse drainage upgrade and flood mitigation measures were identified for incorporation into the design of the project.

Figure 6.1 (4 sheets) shows the extent of the catchments which would contribute flow to the new transverse drainage, while **Figure 6.2** (12 sheets) shows the key features of the proposed transverse drainage and flood mitigation strategy for the project. **Table 6.1** over page provides details of the individual transverse drainage structures that would form part of the strategy.

The key features of the proposed transverse drainage and flood mitigation strategy are broadly as follows:

- Existing transverse drainage would be upgraded where the existing two-lane road would be widened to six lanes, while new transverse drainage would be provided where the new section of road would be constructed to the west of the existing two-lane road.
- Permanent ponds would be constructed along the eastern side of The Northern Road on drainage to control runoff discharging to drainage lines BLC DL07, BLC DL08 and BLC DL09, where runoff from the project corridor would discharge directly to the OHDE (refer **Figure 6.2**, sheets 1 and 2). The ponds are aimed at reducing the volume of runoff which would discharge to the OHDE during relatively frequent storm events through the retention of runoff and evaporation. Energy dissipation measures and level spreaders are to be provided on the spillway of the ponds in order to reduce the risk of scour in the receiving drainage lines. Security measures similar to that shown in the sketch in **Appendix B** would be required where drainage lines BLC DL07, BLC DL08 and BLC DL09 cross the project boundary. The ponds would also need to be fenced off to prevent access by the general public.
- Drainage channels are to be provided extending from the project boundary to the first farm dam on a number of drainage lines where peak flows would be increased in privately owned land. Easements for drainage are to be provided along each channel to facilitate future maintenance.

- While several options were assessed for mitigating the potential impact of the project on flow discharging to the open trenches containing the Sydney Water Supply pipelines via drainage lines BLC DL03 and BLC DL05, following a site inspection and detailed assessment of the available options using ground survey the following option was considered to provide the most cost effective means of mitigating the impact of the project on the receiving drainage lines:
  - The diversion of runoff from a section of the new six-lane road, as well as a small presently undeveloped catchment which is located on the western (upslope side) of the project corridor in a westerly direction along Littlefields Road, where it would discharge to drainage line MC DL09 near the limit of the proposed road works. The extent of the road catchment which would be controlled by the drainage system is shown on **Figure 6.2**, sheets 2 and 3).
  - The provision of a new piped trunk drainage line which would convey runoff generated by a section of the new pavement in an easterly direction within the Sydney Water Supply Pipeline corridor where it would discharge to the DEOH site along drainage line BLC DL06 on Commonwealth land, as shown on **Figure 6.2**, sheet 2. Note that it is proposed to adjust the alignment of the perimeter security fence adjacent to the outlet of the new trunk drainage line in order to improve the angle at which flow discharges to drainage line BLC DL06. Energy dissipation measures and a flow spreader would be provided at the outlet of the new drainage line where flow would discharge to drainage line BLC DL06. The pipe is to convey flows for all storms up to 100 year ARI.
- Drainage channels would be provided extending from the project boundary to the first farm dam on drainage lines MC DL16, MC DL15, MC DL12, BLC DL05, BLC DL03, BLC DL02, UT DL01, CC DL06, CC DL02, CC DL06 and CC DL03, where peak flows would be increased in privately owned land. Easements for drainage are to be provided along each channel to facilitate future maintenance.
- A flood relief channel would be provided along the western side of the project corridor immediately south of the Badgerys Creek crossing. The flood relief channel in combination with 1 off 1200 x 900 RCBC beneath the access driveway in Lot 93 DP654182 would mitigate the impacts of the project on flooding behaviour in existing development for events up to 100 year ARI.
- Drainage measures would be incorporated in the design of the 3 m wide access track which would be constructed along the eastern side of the OHDE boundary fence. The measures would need to prevent damage to the access track where it crosses any concentrated flow path. The preferred approach would be to construct a concrete causeway incorporating a low flow pipe arrangement.
- The earth embankments of the two large dams, which are located on either side of Adams Road in the Cosgroves Creek catchment, would be removed and drainage lines would be reinstated/created as shown on **Figure 6.1**, sheet 5.
- Several dams that are located beneath the footprint of the new road embankment where the project runs through the Cosgroves Creek, Duncans Creek and Badgerys Creek catchments would be either demolished or partially infilled.

- Energy dissipation and scour protection measures would be provided at the outlets of each individual pavement and transverse drainage line. Scour protection measures would also need to be incorporated on the inlet of the upgraded transverse drainage in order to prevent damage to the structure during major flood events. It is envisaged that scour protection measures would take the form of dumped rock riprap or reno mattress. **Table 6.1** provides the indicative length of the rock or mattress layer that is required at the inlet and outlet of each transverse drainage structure.
- The upgrade of the spillways of existing dams where the project would increase the frequency and/or the depth of overtopping of the earth embankment. The identification of the dams that would require their spillways to be upgraded would be undertaken at detailed design stage.

TABLE 6.1
DETAILS OF UPGRADED TRANSVERSE DRAINAGE

Catchment	Transverse Drainage Structure Identifier[(1)]	Design Road Chainage	Dimensions / Type[(2)] (mm)	Upstream Invert Level (m AHD)	Downstream Invert Level (m AHD)	Contributing Catchment Area (ha)	Peak 100 year ARI Flood Level at Inlet (m AHD)	Maximum 100 year ARI Barrel Velocity (m/s)	Minimum Road Level Adjacent to Inlet (m AHD)	Scour Protection Requirements[(3,4)] (mm)
Blaxland Creek	BLC-PXD01	DRC 10160	2 off 750 mm RCP's	80.25	80.10	6.314.09	81.16	2.71	81.80	3000 [Inlet] 4000 [Outlet]
	BLC-PXD02	DRC 10600	1 off 750 mm RCP	81.27	81.20	1.91	82.56	1.72	83.04	3000 [Inlet] 4000 [Outlet]
	BLC-PXD03	DRC 10650	1 off 1050 mm RCP	81.10	81.00	4.63	82.26	2.61	83.22	5500 [Inlet] 5500 [Oulet]
	BLC-PXD04	DRC 12310	2 off 750 mm RCP's	75.8	73.5	2.17	76.35	3.15	78.63	3000 [Inlet] 4000 [Outlet]
Mulgoa Creek	MC-PXD01	DRC 11240	1 off 525 RCP	87.5	82.74	0.48	87.85	3.5	88.80	2000 [Inlet] 4000 [Oulet]
	MC-PXD02	DRC 12000	3 off 900 mm RCP's	77.73	77.60	11.7	78.48	2.03	79.40	3000 [Inlet] 5000 [Outlet]
	MC-PXD03	DRC 12050	1 off 750 mm RCP	80.50	78.95	1.32	81.03	4.42	82.30	3000 [Inlet] 4000 [Outlet]
	MC-PXD04	DRC 12050	1 off 675 mm RCP	80.59	79.68	0.78	81.20	3.37	81.85	3000 [Inlet] 4000 [Outlet]
	MC-PXD05	DRC 12980	2 off 675 mm RCP's	75.33	75.20	3.32	75.93	2.76	76.96	3000 [Inlet] 4000 [Outlet]
Unnamed Tributary of South Creek	UT-PXD01	DRC 8420	1 off 750 mm RCP	90.45	89.20	1.38	91.92	2.57	92.51	3000 [Inlet] 4000 [Outlet]

Refer over for footnotes to **Table 6.1**.

TABLE 6.1 (Cont'd)
DETAILS OF UPGRADED TRANSVERSE DRAINAGE

Catchment	Transverse Drainage Structure Identifier[(1)]	Design Road Chainage	Dimensions / Type[(2)] (mm)	Upstream Invert Level (m AHD)	Downstream Invert Level (m AHD)	Contributing Catchment Area (ha)	Peak 100 year ARI Flood Level at Inlet (m AHD)	Maximum 100 year ARI Barrel Velocity (m/s)	Minimum Road Level Adjacent to Inlet (m AHD)	Protection Requirements[(3,4)] (mm)
Cosgroves Creek	CC-PXD01	DRC 6100	1 off 3000 x 900 RCBC	74.45	74.3	21.3	75.39	2.47	75.57	3000 [Inlet] 3000 [Outlet]
	CC-PXD02	DRC 6190	3 off 1650 RCP's	74.3	72.45	55.0	75.79	2.31	82.67	8500 [Inlet] 8500 [Outlet]
	CC-PXD03	DRC 6660	3 off 2400 x 1200 RCBC's	71.08	69.75	89.5	72.21	2.54	77.88	3000 [Inlet] 4800 [Outlet][(5)]
	CC-PXD04	DRC 7080	2 off 900 RCP's	81.18	78.50	7.35	82.19	1.92	83.32	3000 [Inlet] 5000 [Outlet
	CC-PXD05	DRC 7620	2 off 900 RCP's	86.95	84.78	4.22	87.71	1.56	89.86	3000 [Inlet] 5000 [Outlet]
Duncans Creek	DC-PXD01	DRC 2190	2 off 900 RCP's	87.42	87.02	3.78	88.07	1.50	89.02	3000 [Inlet] 5000 [Outlet]
	DC-PXD02	DRC 2250	3 off 900 RCP's	86.32	84.80	16.7	86.95	1.47	89.34	3000 [Inlet] 5000 [Outlet]
	DC-PXD03	DRC 2620	1 off 750 RCP	85.73	83.62	0.82	86.13	1.13	86.87	3000 [Inlet] 4000 [Outlet]
	DC-PXD04	DRC 2840	2 off 1200 RCP's	80.83	77.76	18.5	81.69	1.73	83.83	6100 [Inlet] 6100 [Outlet]
	DC-PXD05	DRC 3250	2 off 1500 RCP's	68.15	65.00	28.6	69.25	1.97	76.44	7300 [Inlet] 7300 [Outlet]
	DC-PXD06	DRC 3800	2 off 1200 RCP's	75.05	71.00	16.1	75.94	1.76	81.67	6100 [Inlet] 6100 [Outlet]

Refer over for footnotes to **Table 6.1**.

TABLE 6.1 (Cont'd)
DETAILS OF UPGRADED TRANSVERSE DRAINAGE

Catchment	Transverse Drainage Structure Identifier(1)	Design Road Chainage	Dimensions / Type(2) (mm)	Upstream Invert Level (m AHD)	Downstream Invert Level (m AHD)	Contributing Catchment Area (ha)	Peak 100 year ARI Flood Level at Inlet (m AHD)	Maximum 100 year ARI Barrel Velocity (m/s)	Minimum Road Level Adjacent to Inlet (m AHD)	Protection Requirements(3,4) (mm)
Duncans Creek	DC-PXD07	DRC 4450	3 off 1800 x 1200 RCBC's	75.26	74.66	64.5	76.33	2.64	82.01	3000 [Inlet] 4800 [Outlet](5)
	DC-PXD08	DRC 4700	3 off 1350 RCP's	75.12	74.66	45.0	76.48	2.54	80.39	6700 [Inlet] 6700 [Outlet]
	DC-PXD09	DRC 5120	2 off 1200 RCP's	88.50	80.25	12.1	89.31	1.66	91.73	6100 [Inlet] 6100 [Outlet]
	DC-PXD10	DRC 5230	2 off 750 RCP's	94.80	94.00	1.96	95.44	1.51	97.21	3000 [Inlet] 4000 [Outlet]
Badgerys Creek	BLC-PXD01A	DRC 350	2 off 450 RCP's	80.25	79.97	-	80.69	1.25	81.11	2000 [Inlet] 2000 [Outlet]
	BLC-PXD01B	DRC 550	1 off 3600 x 1200 RCBC	76.42	76.22	-	77.54	1.80	78.99	3000 [Inlet] 4800 [Outlet](5)
	BC-PXD01	DRC 640	3 off 3000 x 2400 RCBC's	75.10	74.90	302	76.99	1.83	79.81	3000 [Inlet] 9600 [Outlet](5)
	BC-PXD02	DRC 700	1 off 450 RCP	77.79	77.25	0.40	78.41	1.85	78.35	2000 [Inlet] 2000 [Outlet]
	BC-PXD03	DRC 880	3 off 750 RCP's	77.50	77.10	45.6	78.57	2.51	78.66	3000 [Inlet] 4000 [Outlet]
	BC-PXD04	DRC 920	3 off 2100 x 1200 RCBC's	79.20	78.80	41.0	79.89	2.12	81.99	3000 [Inlet] 4800 [Outlet](5)
	BC-PXD05	DRC 1280	3 off 1200 x 600 RCBC's	83.05	82.45	13.7	83.71	2.08	84.56	1800 [Inlet] 1800 [Outlet]

(1) Refer **Figures 6.1** (4 sheets) and **6.2** (10 sheets) for locations of Transverse Drainage Identifiers.
(2) RCP = Reinforced Concrete Pipe RCBC = Reinforced Concrete Box Culvert.
(3) The dimension given in the table is the indicative length of scour protection as measured from the face of the headwall.
(4) Unless otherwise stated, scour protection requirement derived from Roads and Maritime's standard drawings.
(5) Source: CC, 2014.

7 POST-PROJECT FLOOD RISK ASSESSMENT

7.1 Overview

This chapter of the technical working paper deals with the key findings of the investigation in terms of the residual impact the project would have on flooding behaviour should the transverse drainage and flood mitigation strategy that is set out in **Chapter 6** of this technical working paper be implemented. Also set out in this chapter is an assessment of the impact flooding would have on key components of the project, such as the level of flood immunity of the main carriageways. The findings of an assessment into the impact a partial blockage of major hydraulic structures and future climate change would have on flooding behaviour under post-project conditions are also presented.

The figures referred to in this chapter show the impact the project would have on flooding behaviour in terms of changes in peak flood levels (commonly referred to as “afflux”). A positive afflux represents an increase and conversely a negative afflux represents a decrease in peak flood levels when compared to pre-project conditions. Differences in peak flood levels of ±0.01 metres (equal to 1 centimetre or 10 millimetres) are considered to be within the accuracy of the hydraulic model. The project is therefore considered to have a negligible or nil effect on flooding behaviour in areas where an afflux of ±0.01 metres is shown to be present. The figures also show the extent of additional land which would be inundated by floodwater, and conversely the extent of land which would be rendered flood free, as a result of the project.

7.2 Residual impact of the project on catchment hydrology and flooding behaviour

Figures 7.1 to **7.28** show flooding behaviour under post-project conditions, as well as the residual impacts of the project following implementation of the proposed transverse drainage and flood mitigation strategy in the Cosgrove Creek, Duncans Creek and Badgerys Creek catchments for design storms of 2 year, 10 year and 100 year ARI, together with the PMF.

Table 7.1 at the end of this chapter summarises the residual impacts of the project on catchment hydrology and flooding behaviour in the catchments through which it runs, while **Table C1** in **Appendix C** provides a comparison of peak flows at various locations along the receiving drainage lines under pre- and post-project conditions.

The key findings of the present investigation in regards the residual impacts of the project on flooding and drainage patterns were as follows:

- The project would result in an increase in both the rate and volume of runoff discharging to a number of receiving drainage lines. Changes in catchment hydrology are attributable to:
  - the increase in impervious area associated with the construction of the new northbound and southbound carriageways;
  - the provision of an efficient pavement drainage system which would control runoff discharging from the new carriageways; and
  - the diversion of surface runoff toward adjacent drainage lines.
- While peak flood levels would be increased as a result of the project for events up to 100 year ARI, affected areas are limited to undeveloped pastoral land.

- Due to the relatively steep sided nature of the drainage lines that cross the project corridor, increases in peak flood levels attributable to the project do not translate into a significant increase in the spatial extent of flood affected land for events up to 100 year ARI.

- The project would result in significant increases in peak flood levels along its upstream side during a PMF event. While the affected areas generally comprise undeveloped pastoral land, four existing dwellings that are located on the Badgerys Creek floodplain would be affected (refer Dwellings D1, D2, D3 and D4 on **Figure 7.27**). Given the relatively short catchment response time to intense rainfall events and the fact that depths of inundation would be increased by up to 2 m during a PMF event, the project would result in a significant increase in the flood risk in the affected properties.

  While further design development would need to be undertaken at detailed design stage, it is recommended that the level of the road be lowered where it crosses the Badgerys Creek floodplain. **Figure 7.27** shows the resulting flooding behaviour, while **Figure 7.30** shows the impact the project would have on peak PMF levels when compared to present day (i.e. pre-project) conditions should the road be lowered from its current level.

  If the road were to be lowered from its current level, then the impact of the project on existing development would be limited to two of the four abovementioned dwellings (refer Dwellings D1 and D2 on **Figure 7.30**). Furthermore, increases in the depth of above-floor inundation in the two affected dwellings would be limited to a maximum of 0.2 metres during a PMF event. Based on this finding, adoption of a lowered road option would result in only a minor increase in flood risk given the very low probability of occurrence of a PMF event and the relatively small increase in the depth of above-floor inundation in the two dwellings.

- The project would increase the scour potential in the drainage lines which run through DEOH site on Commonwealth land. The increase in scour potential would extend only a short distance from the corridor as the increase in peak flow attributable to the project as a percentage of the total flow reduces in the downstream direction due to the discharge of additional catchment runoff to the affected drainage line.

- The removal of the two large dams which are located on either side of Adams Road in the Cosgroves Creek catchment would result in an increase in peak flows (and flood levels) along the main arm of the creek downstream of the project corridor. While no existing development would be impacted by the project as far downstream as Elizabeth Drive, the increase in the rate of flow is likely to increase the scour potential within the inbank area of the watercourse. The resulting increase in flow would also reduce the hydrologic standard of the existing transverse drainage located along Elizabeth Drive.

7.3 Residual impact of flooding on the project

<u>Storms up to 100 year ARI</u>

Implementation of the transverse drainage and flood mitigation strategy set out in **Chapter 6** of this technical working paper would ensure that the required 100 year ARI level of flood immunity is achieved.

As flow velocities in the vicinity of The Northern Road are relatively mild and depths of inundation are typically less than 2 m, damage to the road embankment should not occur provided suitable scour protection measures are incorporated in areas of the project that are subject to flooding. Depending on flow velocities, such measures could involve grass or rock lining. Suitable scour protection measures would also need to be incorporated in the inlet and outlet of transverse drainage to prevent damage to road infrastructure.

Probable maximum flood

Surcharge of the road would occur during a PMF event, with the full width of the road formation inundated by floodwater between about **DRC 5200** and Glenmore Parkway. While depths of flow along the northbound and southbound carriageways would be relatively shallow along most of its length (generally in the range 50-300 millimetres), damage could be expected to occur to the road during an extreme storm event.

7.4 Impact of a partial blockage of major hydraulic structures on flooding behaviour

Figures 7.31, **7.32** and **7.33** show the impact a partial blockage of the proposed transverse drainage in the Cosgrove, Duncans and Badgerys Creek catchments, respectively would have on flooding behaviour for the 100 year ARI.

Increases in peak flood levels would be typically confined to land located immediately upstream of The Northern Road with the maximum increase in peak flood level occurring on the main arm of Badgerys Creek to a maximum of 200 mm. Flooding conditions would not be exacerbated in the vicinity of any existing dwellings. While a minimum 100 year ARI level of flood immunity would be maintained to both carriageways of The Northern Road, a partial blockage to transverse drainage structure BLC PXD02 would lead to surcharge of the local access road that lies to the east of The Northern Road at DRC 10600.

7.5 Impact of future climate change on flooding behaviour

Figures 7.34, **7.35** and **7.36** show the impact a potential increase of 10 per cent in 100 year ARI design rainfall intensities would have on flooding behaviour in the vicinity of the project where it runs through the Cosgrove, Duncans and Badgerys Creek catchments, respectively. Corresponding results of a 30 per cent increase in 100 year ARI design rainfall intensities are presented in **Figures 7.37**, **7.38** and **7.39**.

Table 7.2 at the end of this chapter summarises the impact a 10 and 30 per cent increase in 100 year ARI rainfall intensities would have on flooding behaviour in the vicinity of the project corridor.

A 30 per cent increase in the intensity of 100 year ARI rainfall would result in an increase in peak flood levels along the project corridor by a maximum of 300 mm, but typically 50 mm or less. A 100 year ARI level of flood immunity would still be maintained to both carriageways of The Northern Road.

TABLE 7.1
SUMMARY OF RESIDUAL IMPACTS OF THE PROJECT ON CATCHMENT HYDROLOGY AND FLOODING BEHAVIOUR

Catchment	Drainage Line	Land Ownership	Approximate Change in Peak Flow at Project Boundary(1) (%)	Proposed Mitigation Measures	Residual Impacts
Blaxland Creek	BLC DL01	P	-6 to -8	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • The adjacent dam is likely to fill and overtop less frequently due to the reduction in the volume of runoff.
	BLC DL02	P	>+100	• A new channel would be constructed between the outlet of the new drainage system and the adjacent dam. • A new easement would be created along the line of the channel to facilitate future maintenance. • During detail design an assessment would need to be undertaken into the impact the project would have on the characteristics of flow over the spillway of the affected dams. Adjustments would need to be made to the spillway of affected dams that would include their armouring using dumped rock rip rap.	• There would be an increase in the rate and volume of runoff discharging to the existing dam that is located a short distance to the east of the project corridor. • There is likely to be an increase in the potential for scour to occur along the receiving drainage line downstream of the aforementioned dam to the confluence with drainage line BLC DL01. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • The aforementioned dam is likely to fill and overtop more frequently due to the increase in the volume of runoff. • No existing development would be affected by the increased rate of flow in the receiving drainage line.
	BLC DL03	P	+76 to +86	• A new channel would be constructed between the outlet of the new drainage system and the adjacent dam. • A new easement would be created along the line of the channel to facilitate future maintenance. • Scour protection would be provided on the outlet of transverse drainage structure BLC PXD01.	• The increase in the rate of flow in the receiving drainage line would be offset by the reduction in the rate of flow in drainage line BLC DL04. As a result, there would be a minor reduction in both the rate and volume of runoff discharging to the adjacent dam. • No existing development would be affected by the increased rate of flow in the receiving drainage line.
	BLC DL04	P	-53 to -62	• No mitigation measures are proposed at this location.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor.
	BLC DL05	P	+5 to +24	• An easement would be created over the existing drainage line extending north (downstream) to the adjacent dam. This would facilitate access for future maintenance should the project result in scour along the drainage line. • Scour protection would be provided on the outlet of transverse drainage structures BLC PXD02 and BLC PXD03.	• There is likely to be an increase in the potential for scour to occur along the receiving drainage line downstream of the aforementioned dam to the confluence with drainage line BLC DL01. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • The adjacent dam is likely to fill and overtop more frequency due to the increase in the volume of runoff. • No existing development would be affected by the increased rate of flow in the receiving drainage line.
	BLC DL06	COM	0	• While there would be no increase in the rate of flow at the project boundary, scour protection measures would be provided at the outlet of the new pipe drainage system which would control runoff from the new carriageways and discharge it to drainage line BLC DL06 further to the east.	• There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff.
	BLC DL07	COM	>+100	• A permanent pond incorporating an armoured spillway would be constructed on the eastern side of the project corridor on drainage line BLC DL07. The pond will reduce the rate and volume of runoff discharging to the receiving drainage line during relatively frequent storm events.	• There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • No existing development would be affected by the increased rate of flow in the receiving drainage line.
	BLC DL08	COM	+135 to +186	• A permanent pond incorporating an armoured spillway would be constructed on the eastern side of the project corridor on drainage line BLC DL08. The pond will reduce the rate and volume of runoff discharging to the receiving drainage line during relatively frequent storm events. • Scour protection would be provided on the outlet of transverse drainage structure BLC PXD04.	• There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • No existing development would be affected by the increased rate of flow in the receiving drainage line.

Refer over for footnotes to **Table 7.1**.

TABLE 7.1 (Cont'd)
SUMMARY OF RESIDUAL IMPACTS OF THE PROJECT ON CATCHMENT HYDROLOGY AND FLOODING BEHAVIOUR

Catchment	Drainage Line	Land Ownership	Approximate Change in Peak Flow at Project Boundary[1] (%)	Proposed Mitigation Measures	Residual Impacts
Blaxland Creek	BLC DL09	COM	+331 to +411	• A permanent pond incorporating an armoured spillway would be constructed on the eastern side of the project corridor on drainage line BLC DL09. The pond will reduce the rate and volume of runoff discharging to the receiving drainage line during relatively frequent storm events. • The existing channel downstream of the pond would be improved and a new drainage structure provided where it crosses an existing access road.	• There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • No existing development would be affected by the increased rate of flow in the receiving drainage line.
	BLC DL10	COM	0	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor.
Mulgoa Creek	MC DL01	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor.
	MC DL02	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor.
	MC DL03	P	-28 to -41	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • The adjacent dam is likely to fill and overtop less frequently due to the reduction in the volume of runoff.
	MC DL04	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • The project would not have a significant impact on the frequency of filling and overtopping of the adjacent dam.
	MC DL05	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • The project would not have a significant impact on the frequency of filling and overtopping of the adjacent dam.
	MC DL06	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • The project would not have a significant impact on the frequency of filling and overtopping of the adjacent dam.
	MC DL07	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • The project would not have a significant impact on the frequency of filling and overtopping of the adjacent dam.
	MC DL08	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • The project would not have a significant impact on the frequency of filling and overtopping of the adjacent dam.

Refer over for footnotes to **Table 7.1**.

TABLE 7.1 (Cont'd)
SUMMARY OF RESIDUAL IMPACTS OF THE PROJECT ON CATCHMENT HYDROLOGY AND FLOODING BEHAVIOUR

Catchment	Drainage Line	Land Ownership	Approximate Change in Peak Flow at Project Boundary[1] (%)	Proposed Mitigation Measures	Residual Impacts
Mulgoa Creek	MC DL09	P	+23 to +42	• A new channel would be constructed between the outlet of the new drainage system and the adjacent dam. • During detail design an assessment would need to be undertaken into the impact the project would have on the characteristics of flow over the spillway of the affected dams. Adjustments would need to be made to the spillway of affected dams that would include their armouring using dumped rock rip rap.	• There would be an increase in the rate and volume of runoff discharging to the existing dams that are located on the southern side of Littlefields Road. • There is likely to be an increase in the potential for scour to occur along the receiving drainage line downstream of the aforementioned dams. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • The aforementioned dams are likely to fill and overtop more frequently due to the increase in the volume of runoff. • The hydrologic standard of the existing transverse drainage structure under Queenshill Drive would be reduced due to the increase in the rate of flow along the drainage line. • No existing development would be affected by the increased rate of flow in the receiving drainage line.
	MC DL10	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor.
	MC DL11	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor.
	MC DL12	P	-4 to +5	• An easement would be created over the existing drainage line extending north (downstream) to the adjacent dam. This would facilitate access for future maintenance should the project result in scour along the drainage line. • Scour protection would be provided on the outlet of transverse drainage structure MC PXD01.	• The risk of scour in the receiving drainage line is relatively low given the minor increase in the rate of flow attributable to the project • The project would not have a significant impact on the frequency of filling and overtopping of the adjacent dam. • No existing development would be affected by the increased rate of flow in the receiving drainage line.
	MC DL13	P	-19 to -24	• A new channel would be constructed between the outlet of the new drainage system and the adjacent dam. • Scour protection would be provided on the outlet of transverse drainage structure MC PXD02.	• The adjacent dams are likely to fill and overtop less frequently due to the reduction in the volume of runoff.
	MC DL14	P	+51 to +107	• A short section of new channel would be constructed between the outlet of the new drainage system and the adjacent dam. • During detail design an assessment would need to be undertaken into the impact the project would have on the characteristics of flow over the spillway of the affected dams. Adjustments would need to be made to the spillway of affected dams that would include their armouring using dumped rock rip rap. • Scour protection would be provided on the outlet of transverse drainage structure MC PXD04.	• The adjacent dams are likely to fill and overtop more frequently due to the increase in the volume of runoff. • There is likely to be an increase in the potential for scour to occur along the receiving drainage line between the existing dams. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff.
	MC DL14a	P	-50 to -60	• No mitigation measures are proposed on the receiving drainage line.	• The project would not have a significant impact on the frequency of filling and overtopping of the adjacent dams.

Refer over for footnotes to **Table 7.1**.

TABLE 7.1 (Cont'd)
SUMMARY OF RESIDUAL IMPACTS OF THE PROJECT ON CATCHMENT HYDROLOGY AND FLOODING BEHAVIOUR

Catchment	Drainage Line	Land Ownership	Approximate Change in Peak Flow at Project Boundary[1] (%)	Proposed Mitigation Measures	Residual Impacts
Mulgoa Creek	MC DL15	P	-5 to + 15	• An easement would be created over the existing drainage line extending north (downstream) to the adjacent dam. This would facilitate access for future maintenance should the project result in scour along the drainage line. • Scour protection would be provided on the outlet of transverse drainage structure MC PXD05.	• The risk of scour in the receiving drainage line is relatively low given the minor increase in the rate of flow attributable to the project. • The project would not have a significant impact on the frequency of filling and overtopping of the adjacent dam. • No existing development would be affected by the increased rate of flow in the receiving drainage line.
	MC DL16	P	-14 to -23	• An easement would be created over the existing drainage line extending north (downstream) to the adjacent dam. This would facilitate access for future maintenance should the project result in scour along the drainage line.	• The project would not have a significant impact on the frequency of filling and overtopping of the adjacent dam. • The adjacent dam is likely to fill and overtop less frequently due to the reduction in the volume of runoff.
Unnamed Tributary of South Creek	UT DL01	P	+38 to +69	• A new channel would be constructed between the outlet of the new drainage system and the adjacent dam. • During detail design an assessment would need to be undertaken into the impact the project would have on the characteristics of flow over the spillway of the affected dams. Adjustments would need to be made to the spillway of affected dams that would include their armouring using dumped rock rip rap.	• There would be an increase in the rate and volume of runoff discharging to the existing dam that is located a short distance to the east of the project corridor. • There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • The aforementioned dam is likely to fill and overtop more frequently due to the increase in the volume of runoff. • No existing development would be affected by the increased rate of flow in the receiving drainage line.
	UT DL02	P	+106 to +179	• A new channel would be constructed between the outlet of the new drainage system and the adjacent dam. • During detail design an assessment would need to be undertaken into the impact the project would have on the characteristics of flow over the spillway of the affected dams. Adjustments would need to be made to the spillway of affected dams that would include their armouring using dumped rock rip rap.	• There would be an increase in the rate and volume of runoff discharging to the existing dam that is located a short distance to the east of the project corridor. • There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • The aforementioned dam is likely to fill and overtop more frequently due to the increase in the volume of runoff. • No existing development would be affected by the increased rate of flow in the receiving drainage line.

Refer over for footnotes to **Table 7.1**.

TABLE 7.1 (Cont'd)
SUMMARY OF RESIDUAL IMPACTS OF THE PROJECT ON CATCHMENT HYDROLOGY AND FLOODING BEHAVIOUR

Catchment	Drainage Line	Land Ownership	Approximate Change in Peak Flow at Project Boundary[1] (%)	Proposed Mitigation Measures	Residual Impacts
Cosgroves Creek	Cosgroves Creek	P	+38 to +40	• Scour protection would be provided on the outlet of transverse drainage structure CC PXD02.	• There would be an increase in peak flood levels downstream of the project corridor in the range 0-300 mm extending to a location downstream of Elizabeth Drive for events up to 100 year ARI. The increase in peak flow is largely attributable to the removal of the two large dams which are located on either side of Adams Road (i.e. because they presently act to attenuate peak flows by virtue of runoff discharging to the large storage areas). • There would only be a minor increase in the extent of land affected by flooding downstream of the project corridor extending to a location downstream of Elizabeth Drive for events up to 100 year ARI. • There would be a minor reduction in the hydrologic standard of the existing transverse drainage structure under Elizabeth Drive due to the increase in the rate of flow along the creek. • No existing development would be affected by the increased rate of flow in the receiving drainage line upstream of Elizabeth Drive. • There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • While the project would result in a significant increase in the depth and extent of flooding on the western (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.
	CC DL01	P	+25 to +33	• A new channel would be formed following the demolition and removal of the large farm dam that is located on the southern side of Adams Road. The new channel forming the receiving drainage line would be sized to convey flow generated by the upstream catchment, as would transverse drainage structure CC PXD01. • Scour protection would be provided on the outlet of transverse drainage structure CC PXD01.	• The demolition and removal of the large dam would result in an increase in peak flows in Cosgroves Creek.
	CC DL02	P	+7 to +9	• An easement would be created over the existing drainage line extending north (downstream) to the adjacent dam. This would facilitate access for future maintenance should the project result in scour along the drainage line. • Scour protection would be provided on the outlet of transverse drainage structure CC PXD03.	• The risk of scour in the receiving drainage line is relatively low given the minor increase in the rate of flow attributable to the project • The project would not have a significant impact on the frequency of filling and overtopping of the adjacent dam. • No existing development would be affected by the increased rate of flow in the receiving drainage line. • While the project would result in a significant increase in the depth and extent of flooding on the western (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.
	CC DL03	P	-	• No mitigation measures are proposed on the receiving drainage line.	• The project would not have an impact on the receiving drainage line.

Refer over for footnotes to **Table 7.1**.

TABLE 7.1 (Cont'd)
SUMMARY OF RESIDUAL IMPACTS OF THE PROJECT ON CATCHMENT HYDROLOGY AND FLOODING BEHAVIOUR

Catchment	Drainage Line	Land Ownership	Approximate Change in Peak Flow at Project Boundary[1] (%)	Proposed Mitigation Measures	Residual Impacts
Cosgroves Creek	CC DL04	P	0 to +33	• Scour protection would be provided on the outlet of transverse drainage structure CC PXD04. • During detail design an assessment would need to be undertaken into the impact the project would have on the characteristics of flow over the spillway of the affected dams. Adjustments would need to be made to the spillway of affected dams that would include their armouring using dumped rock rip rap.	• There would be an increase in the rate and volume of runoff discharging to the existing dams that are located immediately downstream of transverse drainage structure CC PXD04. • There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • The aforementioned dams are likely to fill and overtop more frequently due to the increase in the volume of runoff. • No existing development would be affected by the increased rate of flow in the receiving drainage line for events. • While the project would result in a significant increase in the depth and extent of flooding on the western (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.
	CC DL05	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor.
	CC DL06	P	+56 to +100	• A new channel would be constructed between the outlet of the new drainage system and the adjacent dam. • During detail design an assessment would need to be undertaken into the impact the project would have on the characteristics of flow over the spillway of the affected dams. Adjustments would need to be made to the spillway of affected dams that would include their armouring using dumped rock rip rap.	• There would be an increase in the rate and volume of runoff discharging to the existing dams that is located a short distance to the south of the project corridor. • There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • The aforementioned dams are likely to fill and overtop more frequently due to the increase in the volume of runoff. • No existing development would be affected by the increased rate of flow in the receiving drainage line.
	CC DL07	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor.
Duncans Creek	DC DL02	P	Minor Reduction	• Scour protection would be provided on the outlet of transverse drainage structures DC PXD01 and DC PXD02.	• There would be a minor reduction in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • While the project would result in a significant increase in the depth and extent of flooding on the eastern (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.

Refer over for footnotes to **Table 7.1**.

TABLE 7.1 (Cont'd)
SUMMARY OF RESIDUAL IMPACTS OF THE PROJECT ON CATCHMENT HYDROLOGY AND FLOODING BEHAVIOUR

Catchment	Drainage Line	Land Ownership	Approximate Change in Peak Flow at Project Boundary(1) (%)	Proposed Mitigation Measures	Residual Impacts
Duncans Creek	DC DL03a	P	>+100	• Scour protection would be provided on the outlet of transverse drainage structure DC PXD03. A new channel would be constructed between the outlet of the new drainage system and the adjacent dam. • During detail design an assessment would need to be undertaken into the impact the project would have on the characteristics of flow over the spillway of the affected dams. Adjustments would need to be made to the spillway of affected dams that would include their armouring using dumped rock rip rap.	• There would be an increase in the rate and volume of runoff discharging to the existing dam that is located a short distance to the west of the project corridor. • The increase in the rate of flow discharging to the dam would increase peak flood levels in the range 0-50 mm for events with ARI's up to 100 years. • There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • The aforementioned dam is likely to fill and overtop more frequently due to the increase in the volume of runoff. • No existing development would be affected by the increased rate of flow in the receiving drainage line. • While the project would result in a significant increase in the depth and extent of flooding on the eastern (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.
	DC DL03	P	-6 to -17	• Scour protection would be provided on the outlet of transverse drainage structure DC PXD04.	• The project would not have a significant impact on the frequency of filling and overtopping of the adjacent dam as it would receive additional runoff from drainage line DC DL03a. • The project would result in an increase in peak flood levels on the eastern (upstream) side of the project corridor in the range 0-200 mm for events with ARI's up to 100 years. • Due to the relatively steep sided nature of the drainage line, increases in peak flood levels in this range would not result in a significant increase in the extent of flood affected land. • While the project would result in a significant increase in the depth and extent of flooding on the eastern (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.
	DC DL04	P	-60 to -67	• No mitigation measures are proposed on the receiving drainage line.	• The adjacent dam is likely to fill and overtop less frequently due to the reduction in the volume of runoff.
	DC DL05	P	+6 to +17	• Scour protection would be provided on the outlet of transverse drainage structure DC PXD05.	• There would be a minor increase in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • There would be a minor reduction in the hydrologic standard of the existing transverse drainage structure under Willowdene Avenue due to the increase in the rate of flow along the receiving drainage line. • No existing development would be affected by the minor increase in the rate of flow in the receiving drainage line. • While the project would result in a significant increase in the depth and extent of flooding on the western (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.

Refer over for footnotes to **Table 7.1**.

TABLE 7.1 (Cont'd)
SUMMARY OF RESIDUAL IMPACTS OF THE PROJECT ON CATCHMENT HYDROLOGY AND FLOODING BEHAVIOUR

Catchment	Drainage Line	Land Ownership	Approximate Change in Peak Flow at Project Boundary(1) (%)	Proposed Mitigation Measures	Residual Impacts
Duncans Creek	DC DL06	P	+6 to +16	• Scour protection would be provided on the outlet of transverse drainage structure DC PXD06. • A new channel would be constructed between the outlet of the new drainage system and the adjacent dam. • During detail design an assessment would need to be undertaken into the impact the project would have on the characteristics of flow over the spillway of the affected dams. Adjustments would need to be made to the spillway of affected dams that would include their armouring using dumped rock rip rap.	• There would be a minor increase in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • The adjacent dam is likely to fill and overtop more frequently due to the increase in the volume of runoff. • There would be a minor reduction in the hydrologic standard of the existing transverse drainage structure under Willowdene Avenue due to the increase in the rate of flow along the receiving drainage line. • The increase in the rate of flow discharging to the receiving drainage line would increase peak flood levels in the range 0-100 mm for events with ARI's up to 100 years. • No existing development would be affected by the minor increase in the rate of flow in the receiving drainage line. • While the project would result in a significant increase in the depth and extent of flooding on the western (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.
	DC DL07	P	0 to +9	• Scour protection would be provided on the outlet of transverse drainage structure DC PXD07. • During detail design an assessment would need to be undertaken into the impact the project would have on the characteristics of flow over the spillway of the affected dams. Adjustments would need to be made to the spillway of affected dams that would include their armouring using dumped rock rip rap.	• The project would result in an increase in peak flood levels on the eastern (upstream) side of the project corridor of greater than 500 mm for events with ARI's up to 100 years. • Due to the relatively steep sided nature of the drainage line, increases in peak flood levels in this range would not result in a significant increase in the extent of flood affected land. • There would be a minor increase in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • The adjacent dam is likely to fill and overtop more frequently due to the increase in the volume of runoff. • Peak flood levels downstream of the project corridor would be increased in the range 0-100 mm during events with ARI's up to 100 years. • No existing development would be affected by the minor increase in the rate of flow in the receiving drainage line. • While the project would result in a significant increase in the depth and extent of flooding on the western (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.
	DC DL08	P	Minor Increase	• Scour protection would be provided on the outlet of transverse drainage structure DC PXD08. • During detail design an assessment would need to be undertaken into the impact the project would have on the characteristics of flow over the spillway of the affected dams. Adjustments would need to be made to the spillway of affected dams that would include their armouring using dumped rock rip rap.	• The project would result in an increase in peak flood levels on the eastern (upstream) side of the project corridor in the range 0-50 mm for events with ARI's up to 100 years. • Due to the relatively steep sided nature of the drainage line, increases in peak flood levels in this range would not result in a significant increase in the extent of flood affected land. • There would be a minor increase in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • The adjacent dam is likely to fill and overtop more frequently due to the increase in the volume of runoff. • While the project would result in a significant increase in the depth and extent of flooding on the western (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.

Refer over for footnotes to **Table 7.1**.

TABLE 7.1 (Cont'd)
SUMMARY OF RESIDUAL IMPACTS OF THE PROJECT ON CATCHMENT HYDROLOGY AND FLOODING BEHAVIOUR

Catchment	Drainage Line	Land Ownership	Approximate Change in Peak Flow at Project Boundary(1) (%)	Proposed Mitigation Measures	Residual Impacts
Duncans Creek	DC DL09	P	0 to +32	• Scour protection would be provided on the outlet of transverse drainage structure DC PXD09. • The existing dam would be demolished and removed and a new channel constructed linking with the existing drainage line.	• There would be a minor increase in the rate and volume of flow in the receiving drainage line downstream of the project corridor. • There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • While the project would result in a significant increase in the depth and extent of flooding on the western (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.
Badgerys Creek	Badgerys Creek	P	+2	• Lowering of road levels where the project crosses the Badgerys Creek floodplain. • Scour protection would be provided on the outlet of transverse drainage structure BC PXD01. • A flood relief channel would be constructed along the western (upstream) side of the project corridor on the southern side of Badgerys Creek to mitigate the impacts of the project on flooding behaviour in existing development for floods with ARI's up to 100 years.	• The project would result in significant increases in peak flood levels along its upstream side during a PMF event. While the affected areas generally comprise undeveloped pastoral land, four existing dwellings that are located on the Badgerys Creek floodplain would be affected (refer Dwellings D1, D2, D3 and D4 on **Figure 7.27**). Given the relatively short catchment response time to intense rainfall events and the fact that depths of inundation would be increased by up to 2 m during a PMF event, the project would result in a significant increase in the flood risk in the affected properties. • Lowering the road from its current level would reduce the impact the project would have on depths of above-floor inundation in the abovementioned dwellings. **Figure 7.30** shows that lowering the road would limit the impact of the project to two of the four abovementioned dwellings, with the increase in the depth of above-floor inundation also limited to a maximum of 0.2 metres during a PMF event (refer Dwellings D1 and D2 on **Figure 7.30**). • Based on the above, the project would result in only a minor increase in flood risk should the road be lowered from its current level given the very low probability of occurrence of a PMF event and the relatively small increase in the depth of above-floor inundation in the two dwellings.
	BC DL01	P	-	• No mitigation measures are proposed on the receiving drainage line.	• The project would not have an impact on the receiving drainage line.
	BC DL02	P	+8 to +18	• Scour protection would be provided on the outlet of transverse drainage structures BC PXD03 and BC PXD04. • A new channel would be constructed between the outlet of transverse drainage structure BC PXD04 and the inlet of transverse drainage structure BC PXD04.	• There would be an increase in peak flood levels downstream of the project corridor in the range 0-200 mm extending to a location downstream of main arm of Badgerys Creek. • No existing development would be affected by the minor increase in the rate of flow in the receiving drainage line for events up to 100 year ARI. • While the project would result in a significant increase in the depth and extent of flooding on the western (upstream) side of the project corridor during a PMF event, the affected area comprises undeveloped pastoral land.
	BC DL03	P	+67 to +68	• Scour protection would be provided on the outlet of transverse drainage structure BC PXD05. • A new channel would be constructed downstream of transverse drainage structure BC PXD05.	• There would be an increase in peak flood levels downstream of the project corridor in the range 0-200 mm extending to a location downstream of main arm of Badgerys Creek. The increase in peak flow is due to the discharge of runoff from the road cutting which would be located to the north. • There is likely to be an increase in the potential for scour to occur along the receiving drainage line. The risk of scour would be partially mitigated by an increase in vegetation growth that will occur as a result of the increase in the volume of runoff. • The project would result in a significant increase in the depth and extent of flooding on the western (upstream) side of the project corridor during a PMF event. The affected area comprises undeveloped pastoral land.
	BC DL04	P	-	• No mitigation measures are proposed on the receiving drainage line.	• The project would not have an impact on the receiving drainage line.
	BC DL05	P	Minor Reduction	• No mitigation measures are proposed on the receiving drainage line.	• The project would not have a significant impact on the receiving drainage line.

1. Range based on change in peak flows for design storms with ARI's of 2, 10, 100 years. Refer **Table C1** in **Appendix C** for individual values.

TABLE 7.2
SUMMARY OF CLIMATE CHANGE RELATED IMPACTS
100 YEAR ARI

Catchment	10 per cent increase in design rainfall intensities	30 per cent increase in design rainfall intensities
Blaxland Creek, Mulgoa Creek and Unnamed Tributary of South Creek	➢ Increases in peak flood levels would typically be 100 mm or less but will reach a maximum of about 200 mm upstream of transverse drainage structures BLC PXD01 and MC PXD05. ➢ The increases in peak flood levels would not be sufficient to cause surcharge of the main carriageways.	➢ Increases in peak flood levels would typically be 200 mm or less but will reach a maximum of about 300 mm upstream of transverse drainage structure BLC PXD02, and a maximum of about 500 mm upstream of transverse drainage structures BLC PXD01 and MC PXD05. ➢ The increases in peak flood levels would not be sufficient to cause surcharge of the main carriageways.
Cosgroves Creek	➢ While increases in peak flood levels would typically be 50 mm or less, there would be an increase in peak flood level upstream of transverse drainage structure CC PXD02 by a maximum of about 200 mm. ➢ The increases in peak flood levels would not be sufficient to cause surcharge of the main carriageways.	➢ Increases in peak flood levels would be typically 100 mm or less but will reach a maximum of about 300 mm upstream of transverse drainage structures CC PXD03 and CC PXD02. ➢ The increases in peak flood levels would not be sufficient to cause surcharge of the main carriageways.
Duncans Creek	➢ Increases in peak flood levels would typically be 50 mm or less but will reach a maximum of about 100 mm upstream of transverse drainage structures DC PXD04 and DC PXD06, and a maximum of about 200 mm upstream of transverse drainage structures DC PXD05, DC PXD07 and DC PXD08. ➢ The increases in peak flood levels would not be sufficient to cause surcharge of the main carriageways.	➢ Increases in peak flood levels would typically be 100 mm or less but will reach a maximum of about 200 mm upstream of transverse drainage structures DC PXD04 and DC PXD06, a maximum of about 300 mm upstream of transverse drainage structures DC PXD05 and DC PXD07, and a maximum of about 500 mm upstream of DC PXD08. ➢ The increases in peak flood levels would not be sufficient to cause surcharge of the main carriageways.
Badgerys Creek	➢ While increases in peak flood levels would typically be 50 mm or less, there would be an increase in peak flood level on the main arm of Badgerys Creek by a maximum of about 200 mm. ➢ The increases in peak flood levels would not be sufficient to cause surcharge of the main carriageways.	➢ Increases in peak flood levels would typically be 100 mm or less but will reach a maximum of about 200 mm upstream of transverse drainage structure BC PXD04 and a maximum of about 500 mm on the main arm of Badgerys Creek. ➢ The increases in peak flood levels would not be sufficient to cause surcharge of the main carriageways.

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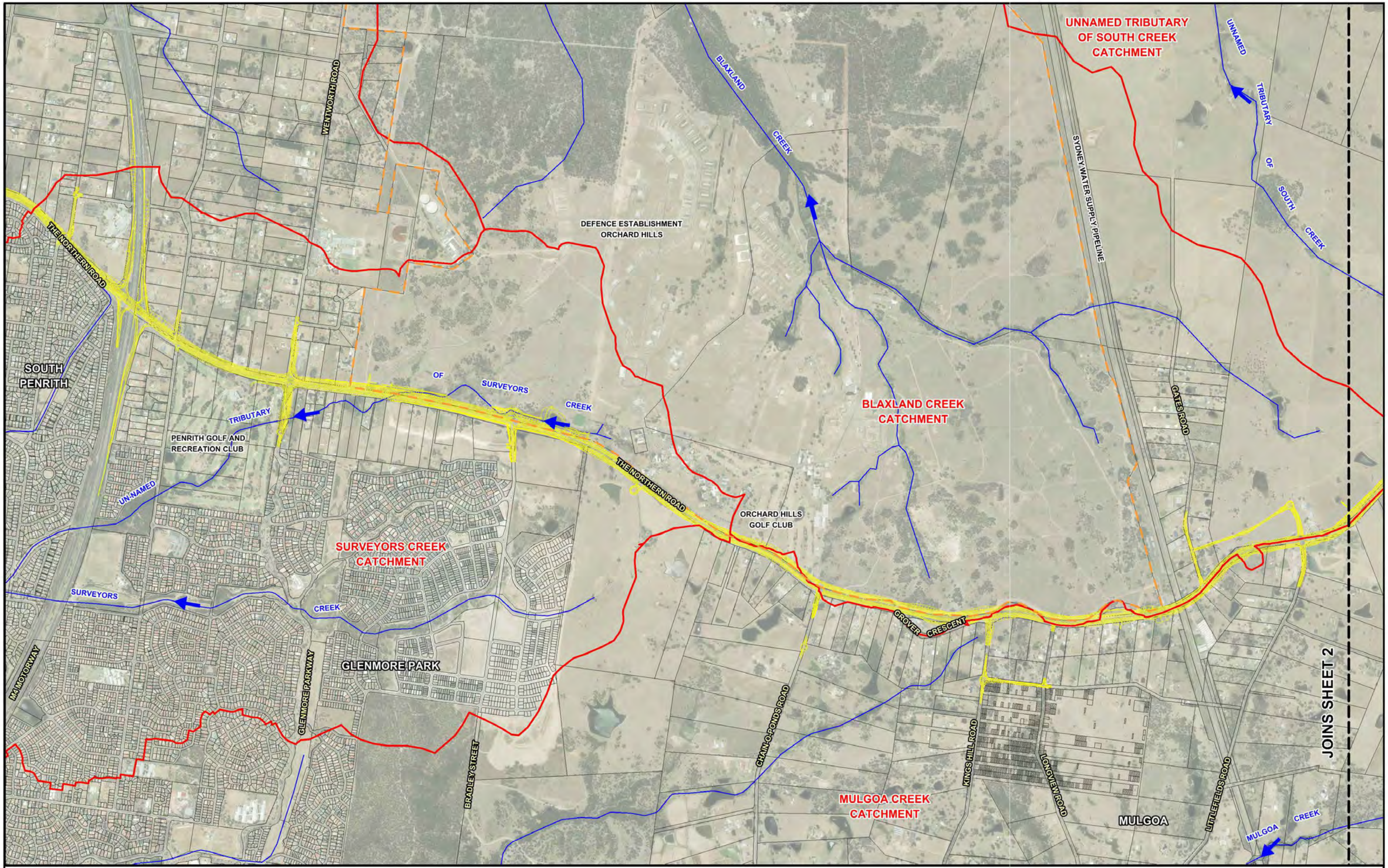
FIGURES



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LEGEND

- Catchment Boundary
- Defence Restricted Area Boundary
- Design Strings

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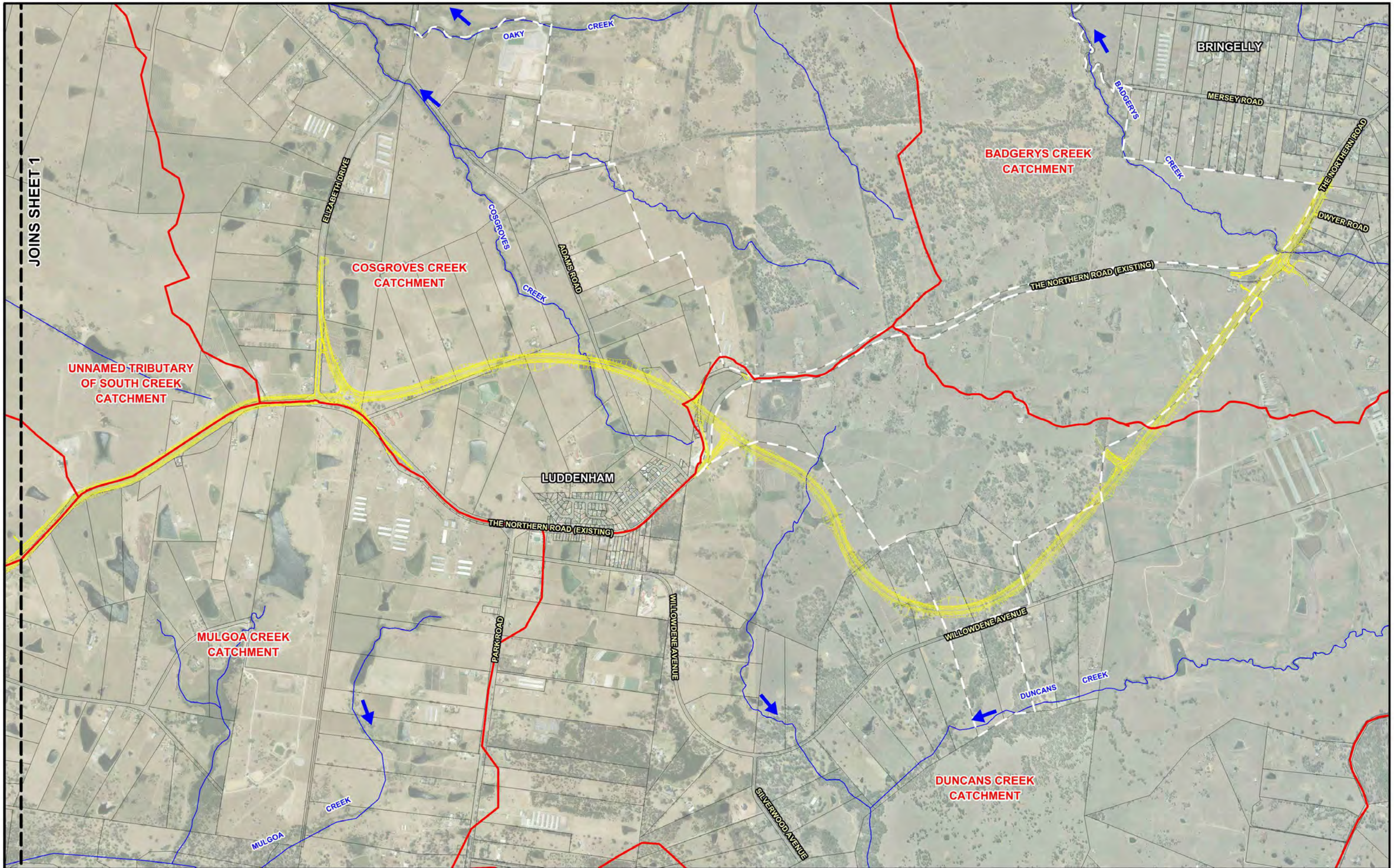
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 1.1
Sheet 1 of 2

LOCATION AND CATCHMENT PLAN



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LEGEND

Catchment Boundary

Proposed Western Sydney Airport Boundary

Design Strings

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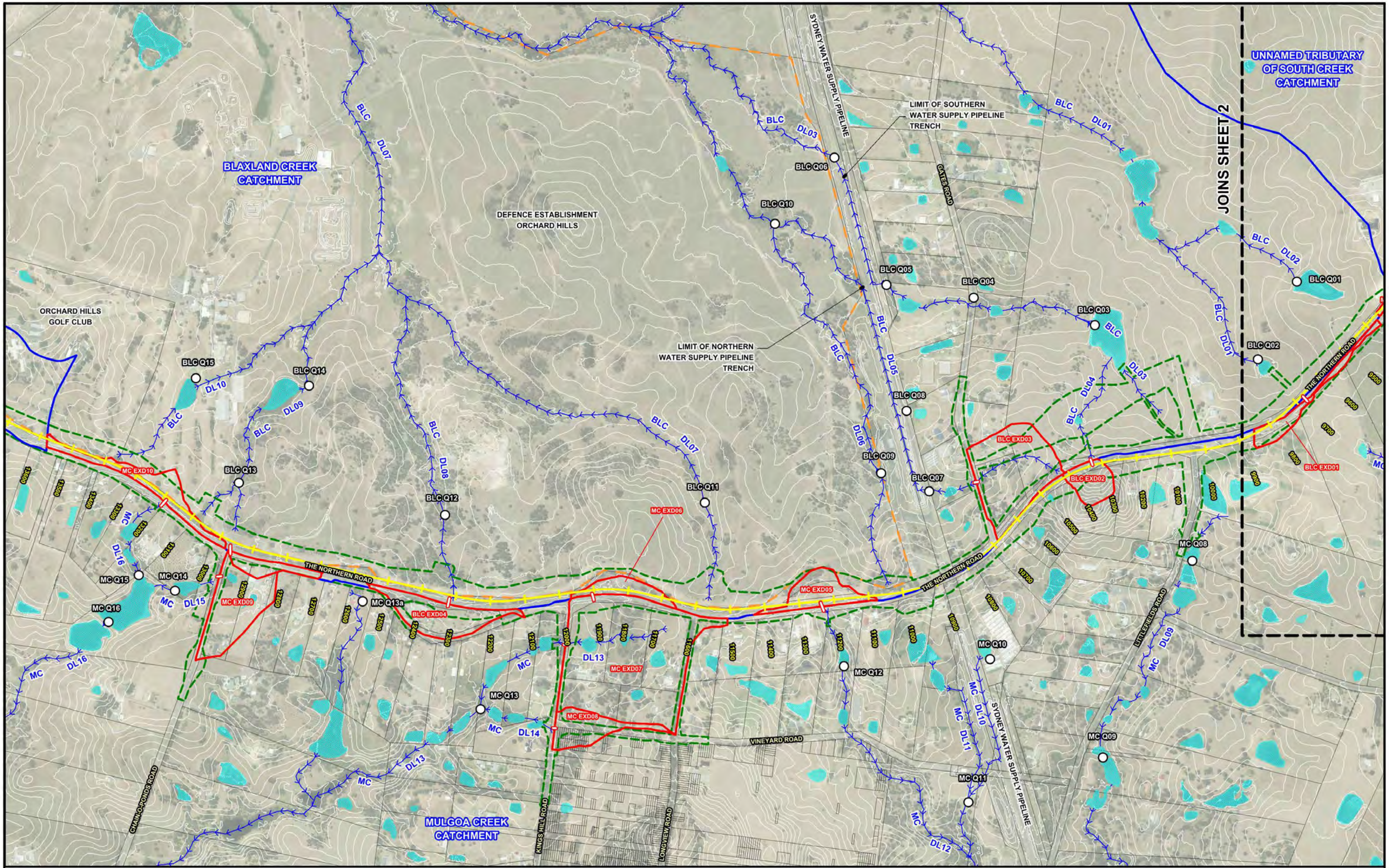
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 1.1
Sheet 2 of 2

LOCATION AND CATCHMENT PLAN



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LEGEND

MC EXD05	Existing Transverse Drainage Structure and Identifier	MC EXD05	Extent of Catchment Draining into Existing Transverse Drainage Structure and Identifier
	Design Road Control String and Chainage	BLC Q12	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Existing Dam		Defence Restricted Area Boundary
	Existing Drainage Lines		Project Boundary
	Catchment Boundary		

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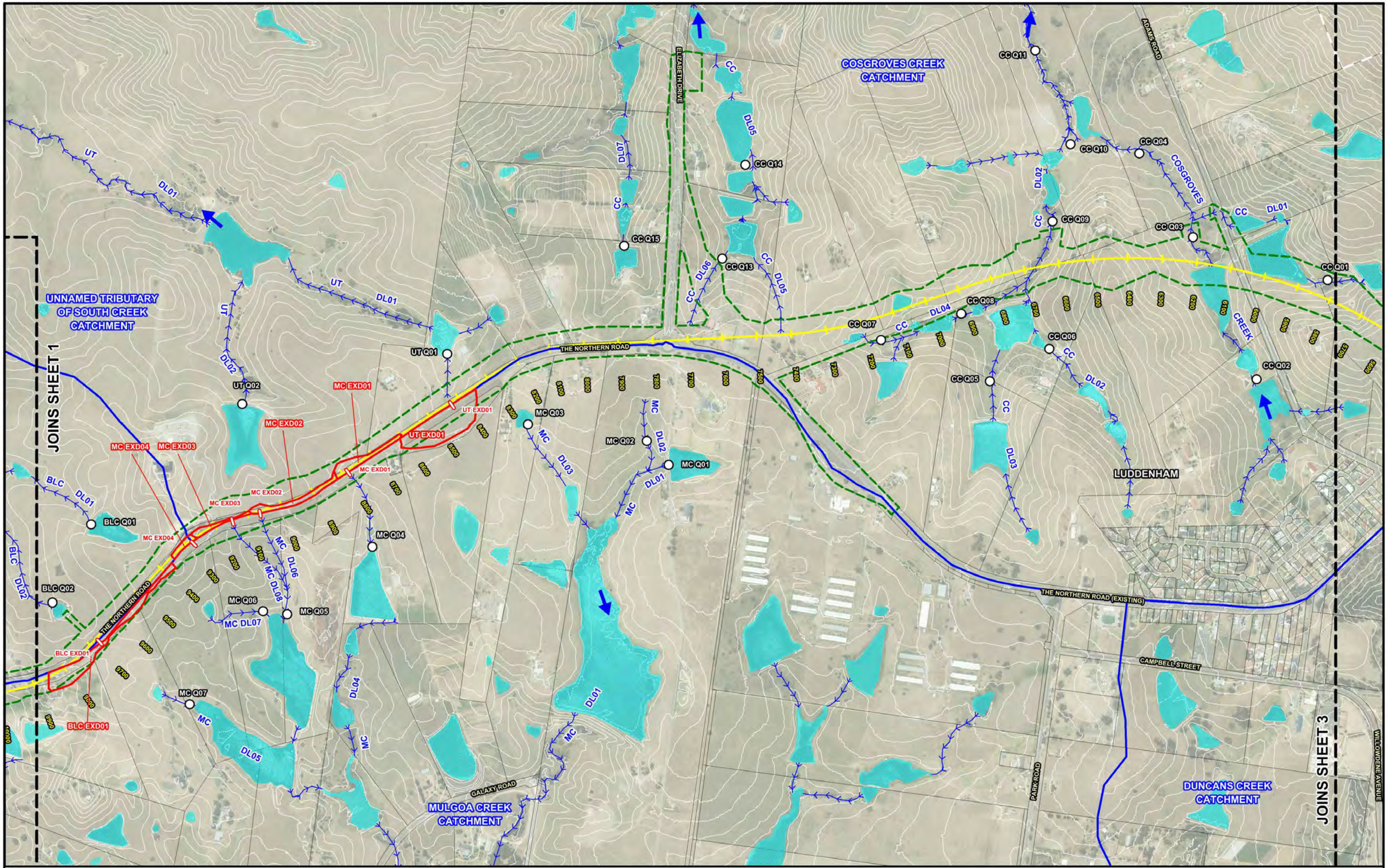
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.1
Sheet 1 of 4

TRANSVERSE DRAINAGE CATCHMENT PLAN
PRE-PROJECT CONDITIONS



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Scale: 1:10,000

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MC EXD01 — Existing Transverse Drainage Structure and Identifier

Design Road Control String and Chainage

Existing Dam

Existing Drainage Lines

MC EXD01 — Extent of Catchment Draining into Existing Transverse Drainage Structure and Identifier

MC Q04 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D)

Proposed Western Sydney Airport Boundary

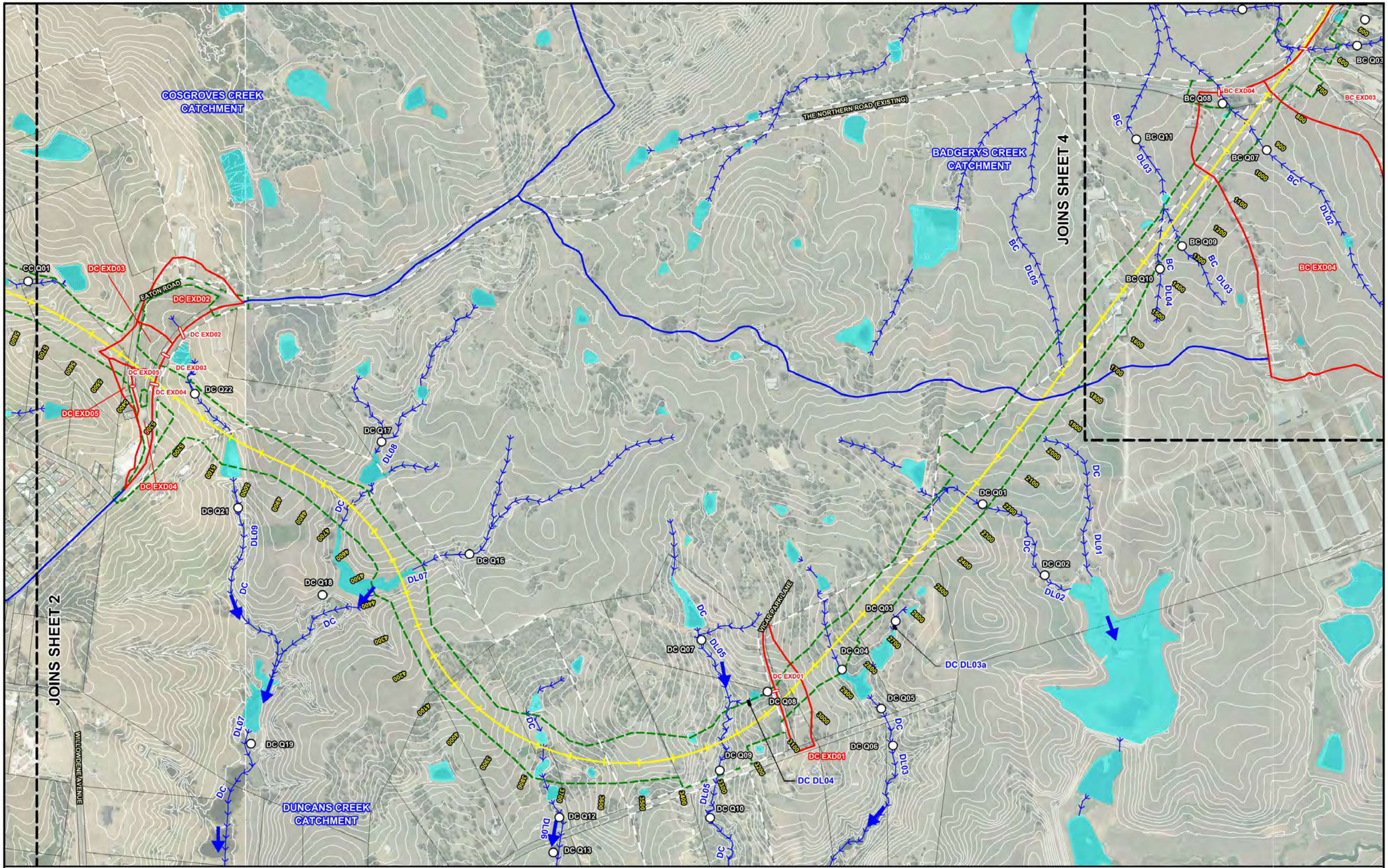
Project Boundary

Catchment Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.1
Sheet 2 of 4

TRANSVERSE DRAINAGE CATCHMENT PLAN
PRE-PROJECT CONDITIONS



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Scale: 1:10,000

LEGEND

DC EXD03	Existing Transverse Drainage Structure and Identifier
	Design Road Control String and Chainage
	Existing Dam
	Existing Drainage Lines
DC EXD03	Extent of Catchment Draining into Existing Transverse Drainage Structure and Identifier
DC Q02	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Proposed Western Sydney Airport Boundary
	Project Boundary
	Catchment Boundary

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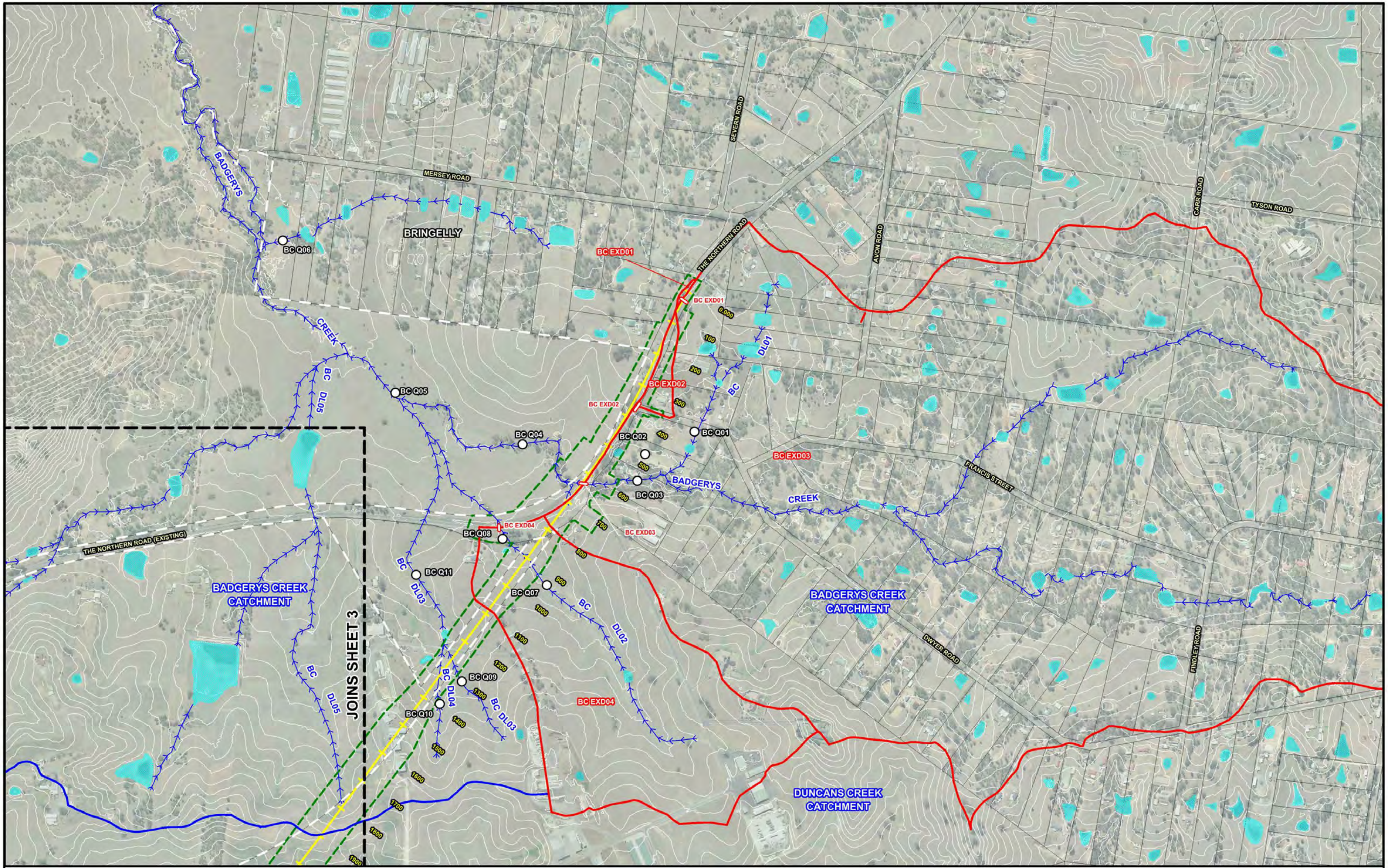
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.1
Sheet 3 of 4

TRANSVERSE DRAINAGE CATCHMENT PLAN
PRE-PROJECT CONDITIONS



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Scale: 1:10,000

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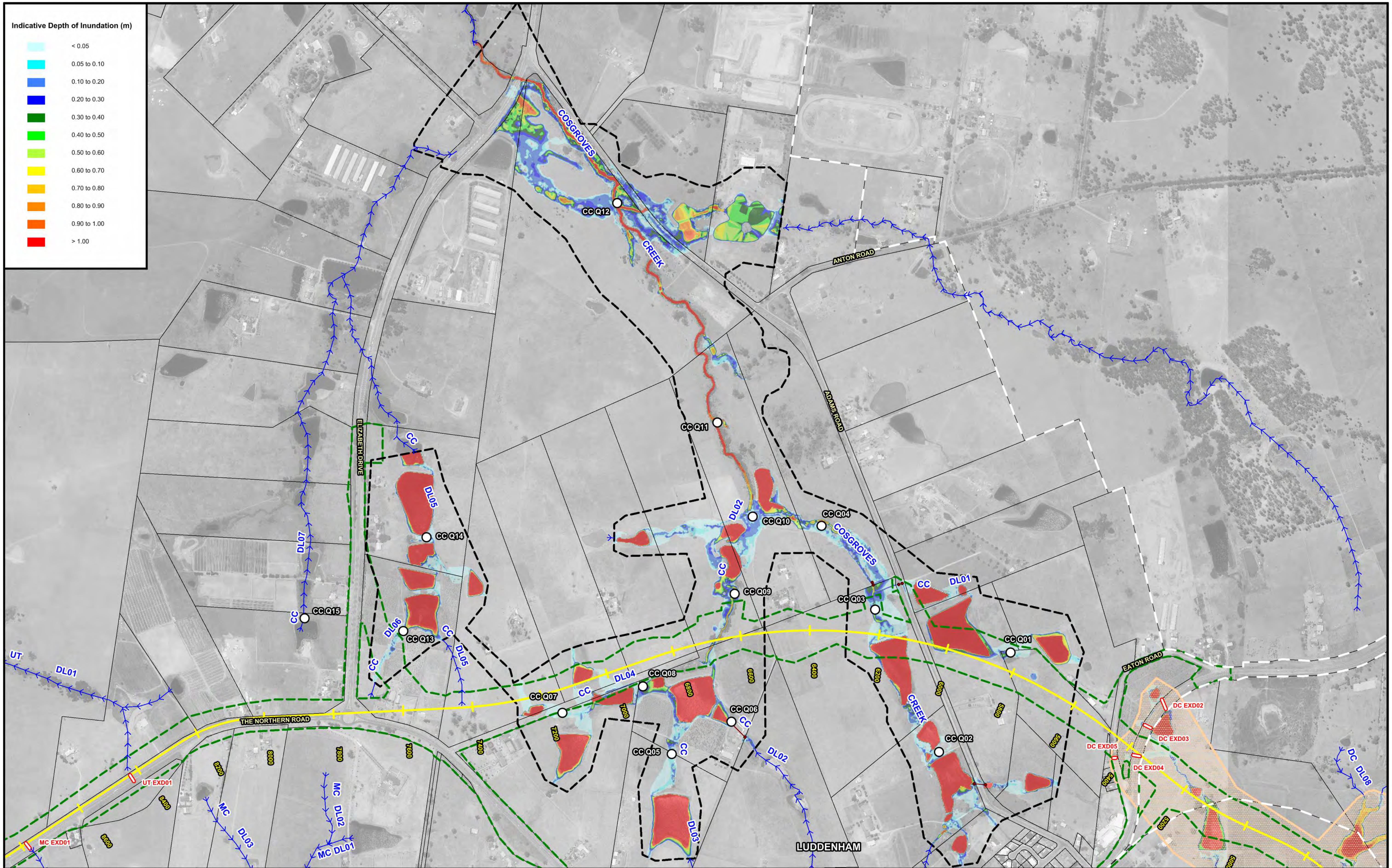
LEGEND

BC EXD03	Existing Transverse Drainage Structure and Identifier	BC EXD03	Extent of Catchment Draining into Existing Transverse Drainage Structure and Identifier
	Design Road Control String and Chainage	BC Q07	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Existing Dam		Proposed Western Sydney Airport Boundary
	Existing Drainage Lines		Project Boundary
	Catchment Boundary		

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.1
Sheet 4 of 4

TRANSVERSE DRAINAGE CATCHMENT PLAN
PRE-PROJECT CONDITIONS



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LEGEND

Design Road Control String and Chainage
Extent of Duncans Creek TUFLOW Model (Refer Figure 4.7 for TUFLOW Model Results)
Modelled Stormwater Drainage Network
Project Boundary
DC EXD05 Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)
CC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
Two-Dimensional Model Extent
Proposed Western Sydney Airport Boundary

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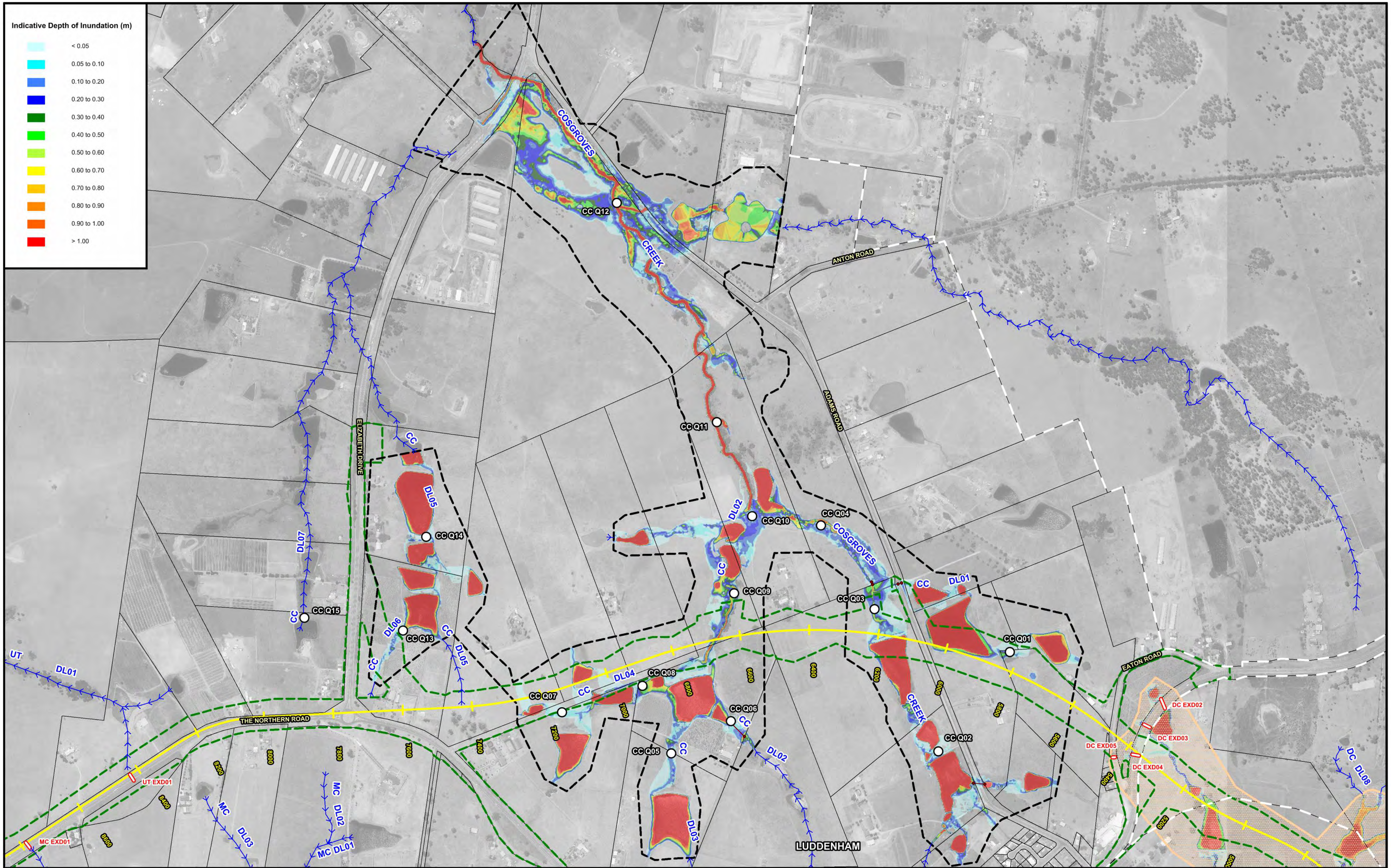
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.2

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - COSGROVES CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 2 YEAR ARI



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Scale: 1:10,000

LEGEND

Design Road Control String and Chainage	Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)
Extent of Duncans Creek TUFLOW Model (Refer Figure 4.8 for TUFLOW Model Results)	Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
Modelled Stormwater Drainage Network	Two-Dimensional Model Extent
Project Boundary	Proposed Western Sydney Airport Boundary

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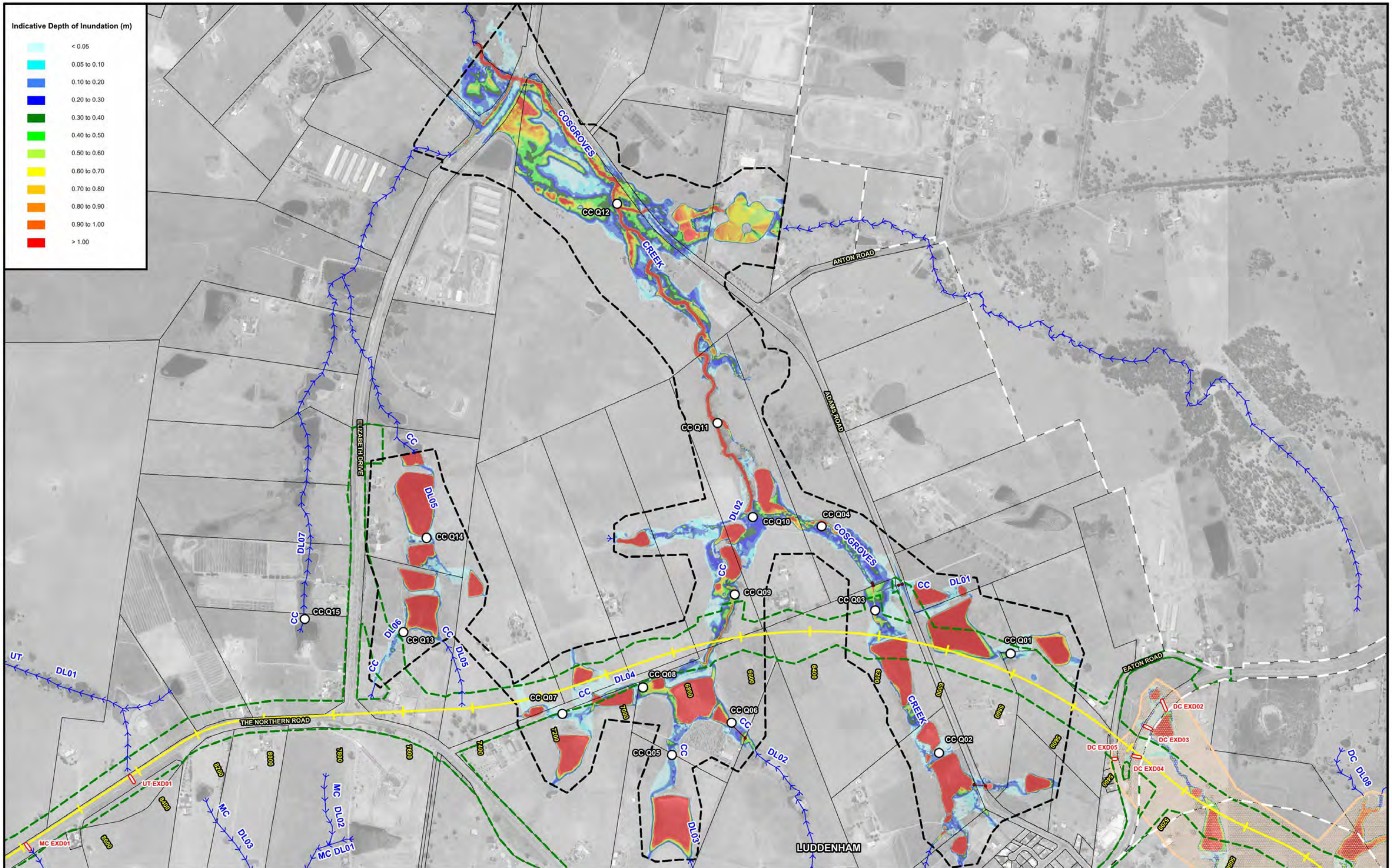
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.3

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - COSGROVES CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 10 YEAR ARI



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Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 4.9 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Project Boundary

DC EXD05 Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)

CC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

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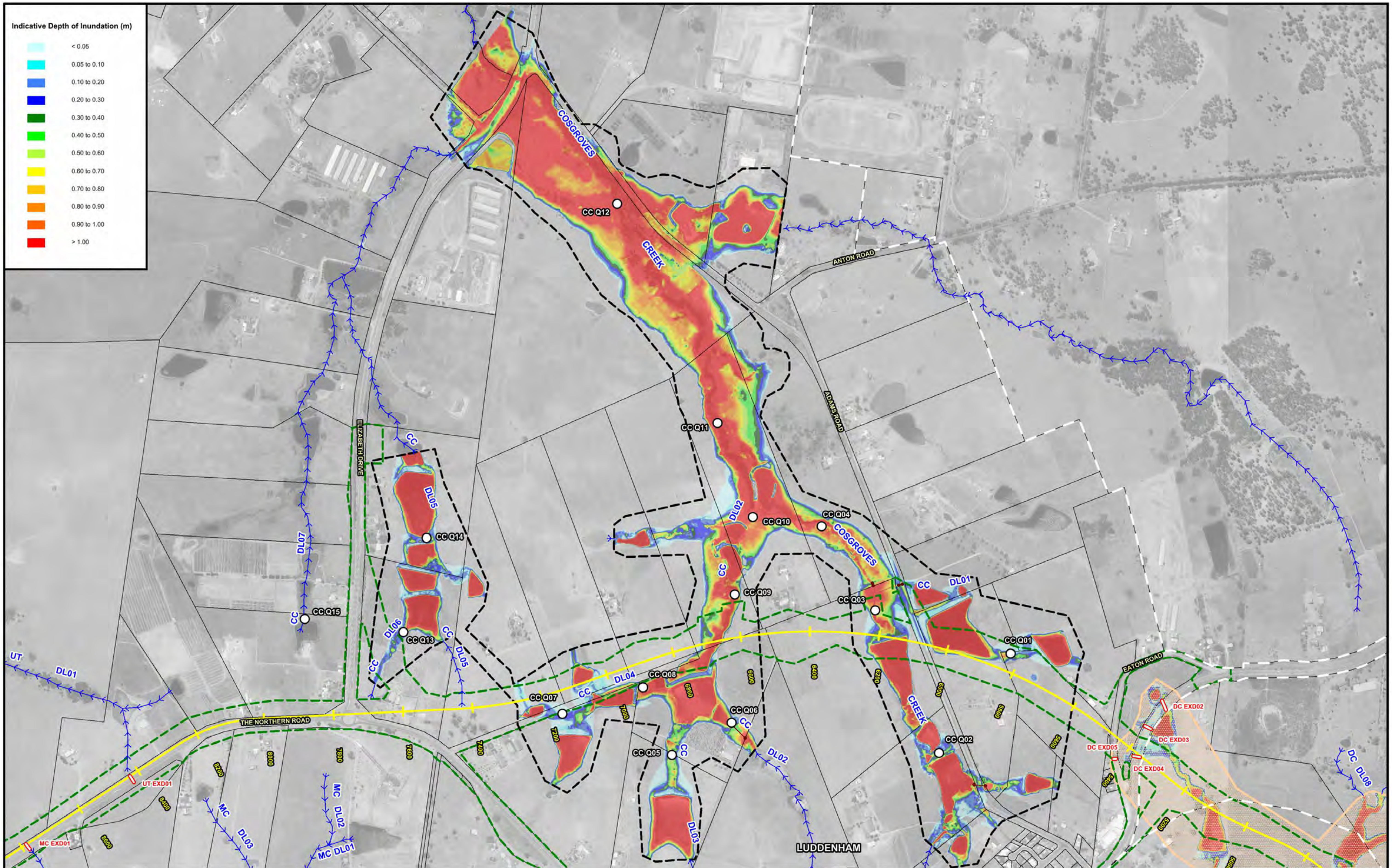
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.4

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - COSGROVES CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 100 YEAR ARI



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Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 4.10 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Project Boundary

DC EXD05 Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)

CC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

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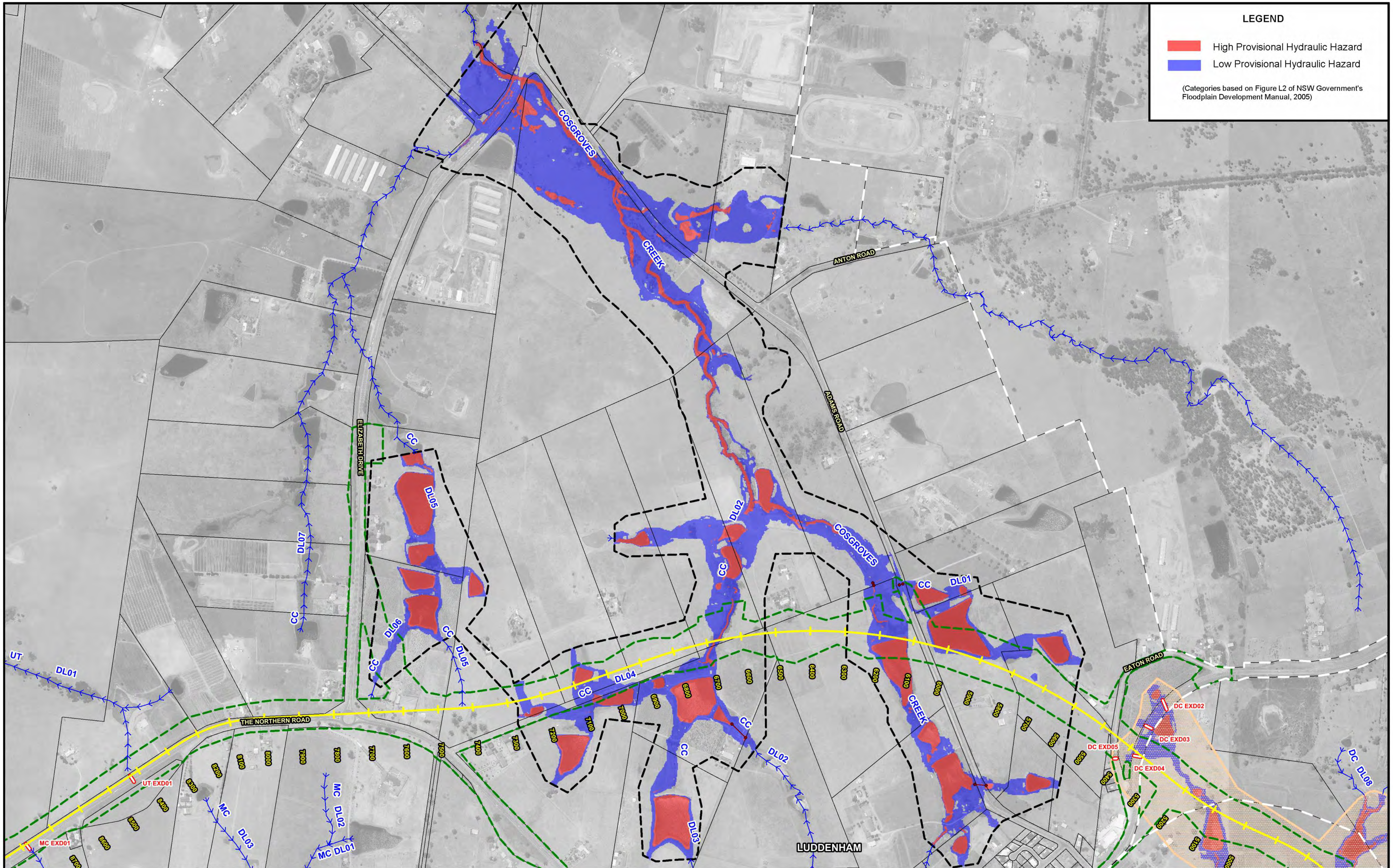
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.5

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - COSGROVES CREEK CATCHMENT
PRE-PROJECT CONDITIONS - PMF



LEGEND	
Design Road Control String and Chainage	Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)
Extent of Duncans Creek TUFLOW Model (Refer Figure 4.11 for TUFLOW Model Results)	Two-Dimensional Model Extent
Modelled Stormwater Drainage Network	Proposed Western Sydney Airport Boundary
Project Boundary	

100 0 100 200 300 m

Scale: 1:10,000

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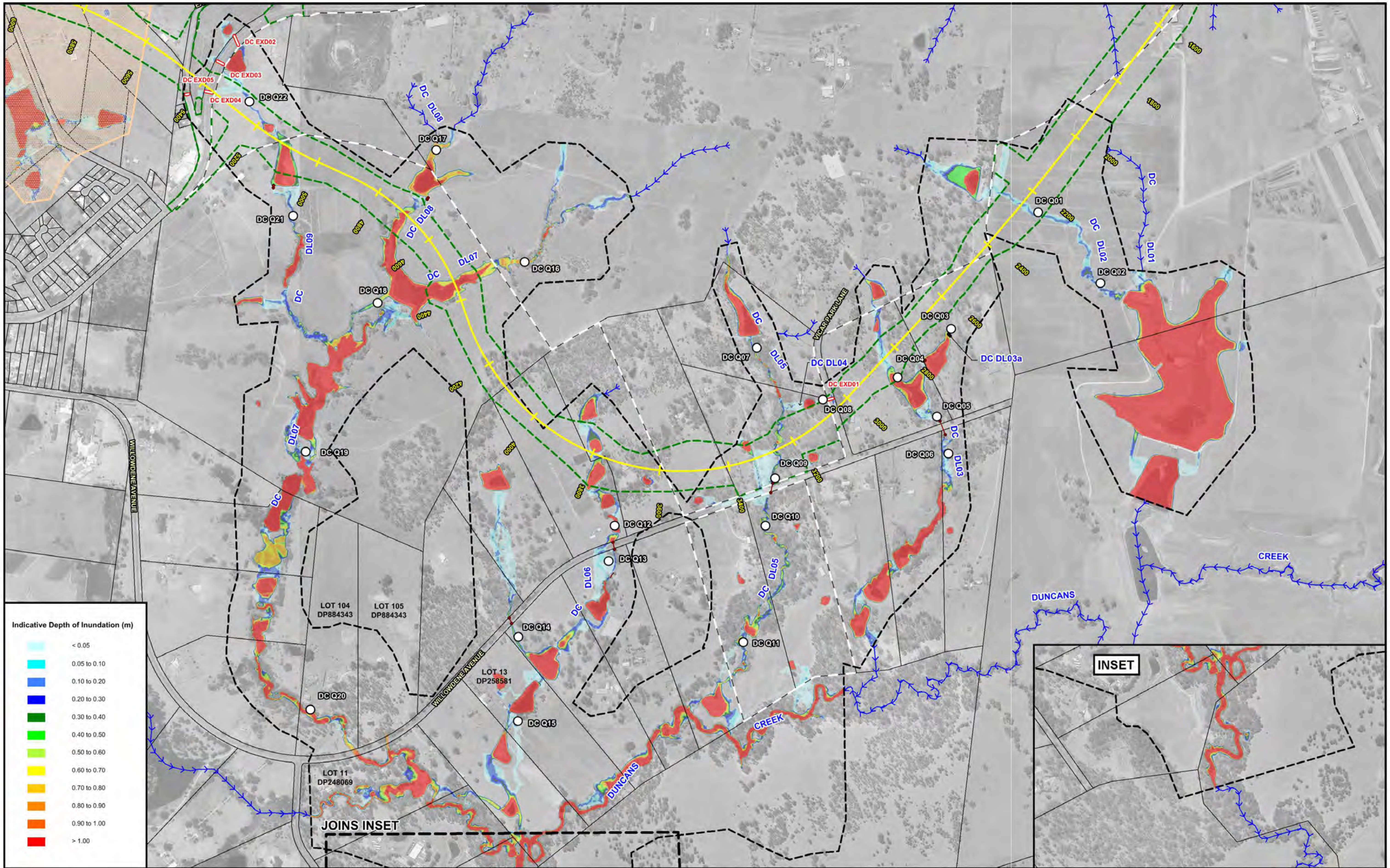
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.6

PROVISIONAL FLOOD HAZARD IN VICINITY OF PROJECT - COSGROVES CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 100 YEAR ARI



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Scale: 1:10,000

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LEGEND

Design Road Control String and Chainage

Extent of Cosgroves Creek TUFLOW Model (Refer Figure 4.2 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Project Boundary

DC EXD01 — Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)

DC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

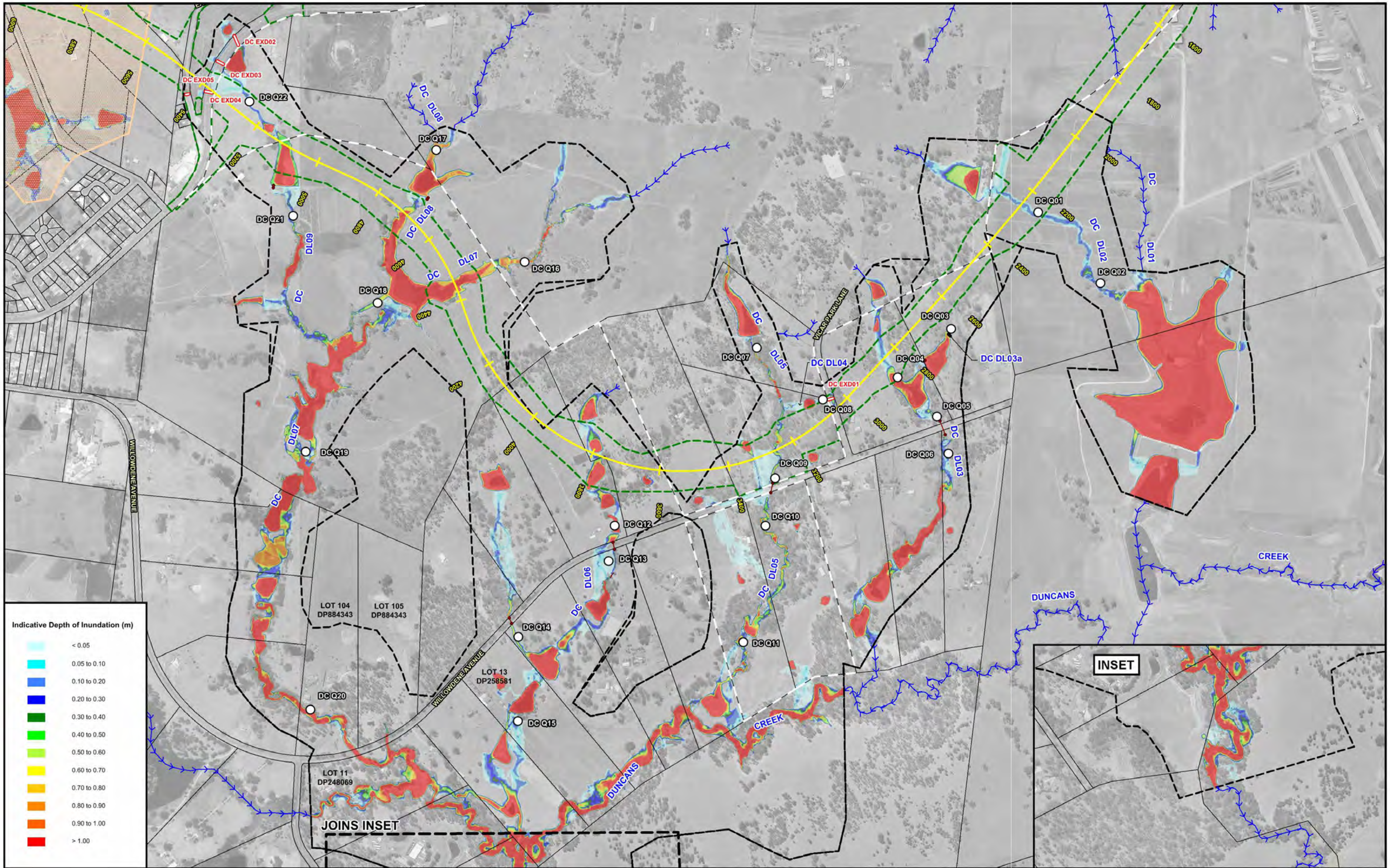
Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.7

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - DUNCANS CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 2 YEAR ARI



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100 0 100 200 300 m

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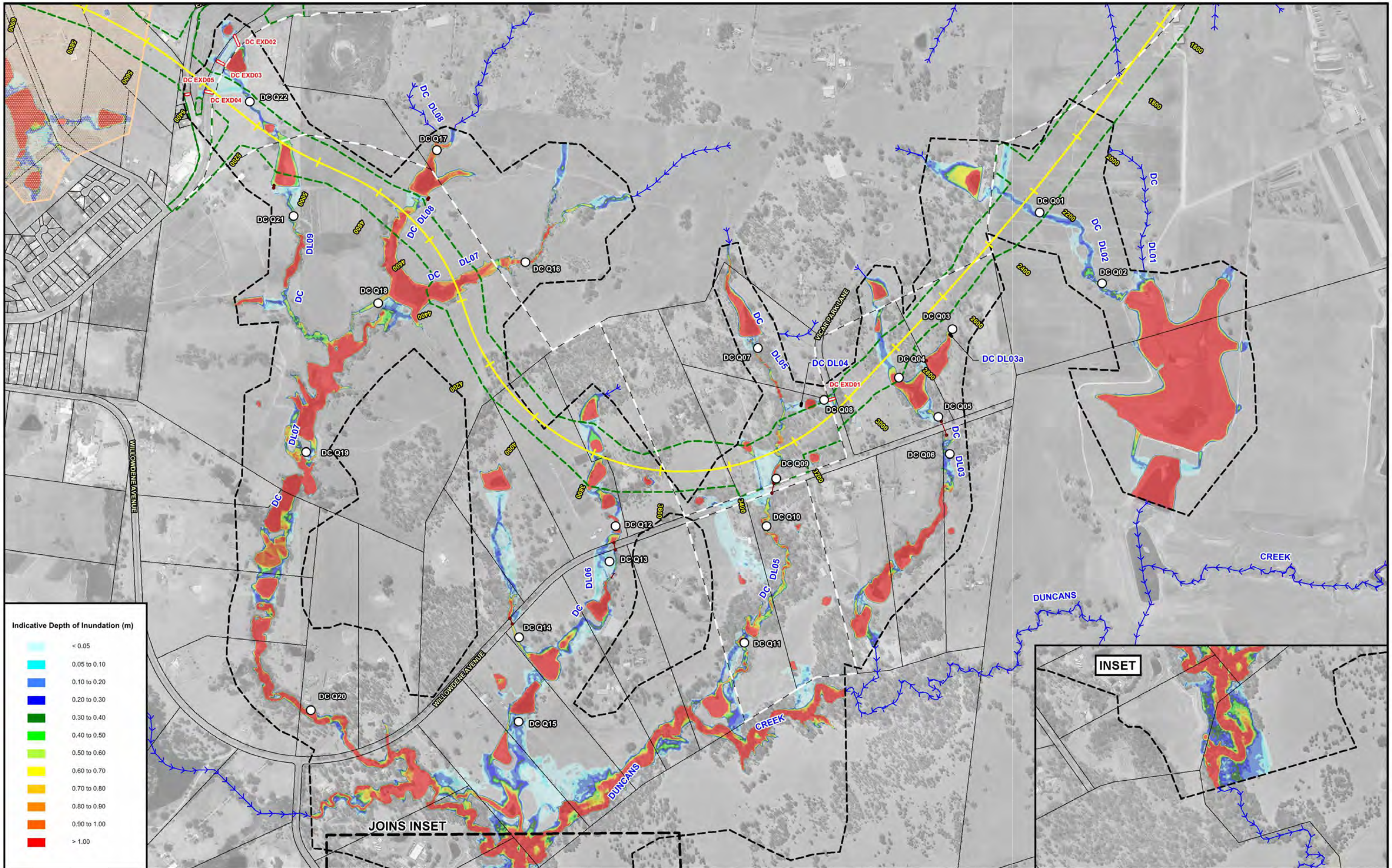
LEGEND

- Design Road Control String and Chainage
- Extent of Cosgroves Creek TUFLOW Model (Refer Figure 4.3 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Project Boundary
- DC EXD01 — Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)
- DC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.8

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - DUNCANS CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 10 YEAR ARI



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Scale: 1:10,000

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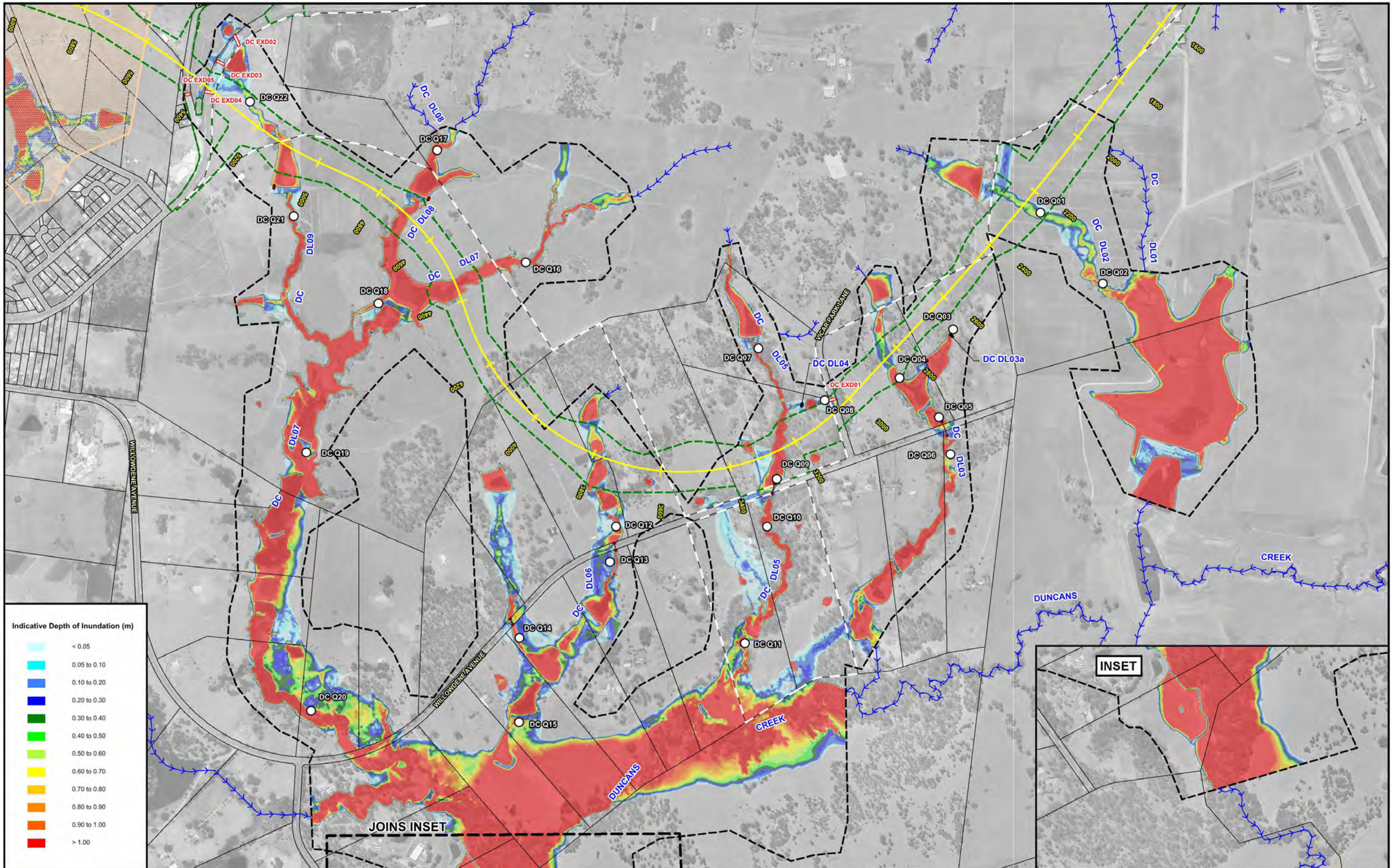
LEGEND

- Design Road Control String and Chainage
- Extent of Cosgroves Creek TUFLOW Model (Refer Figure 4.4 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Project Boundary
- DC EXD01 — Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)
- DC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.9

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - DUNCANS CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 100 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

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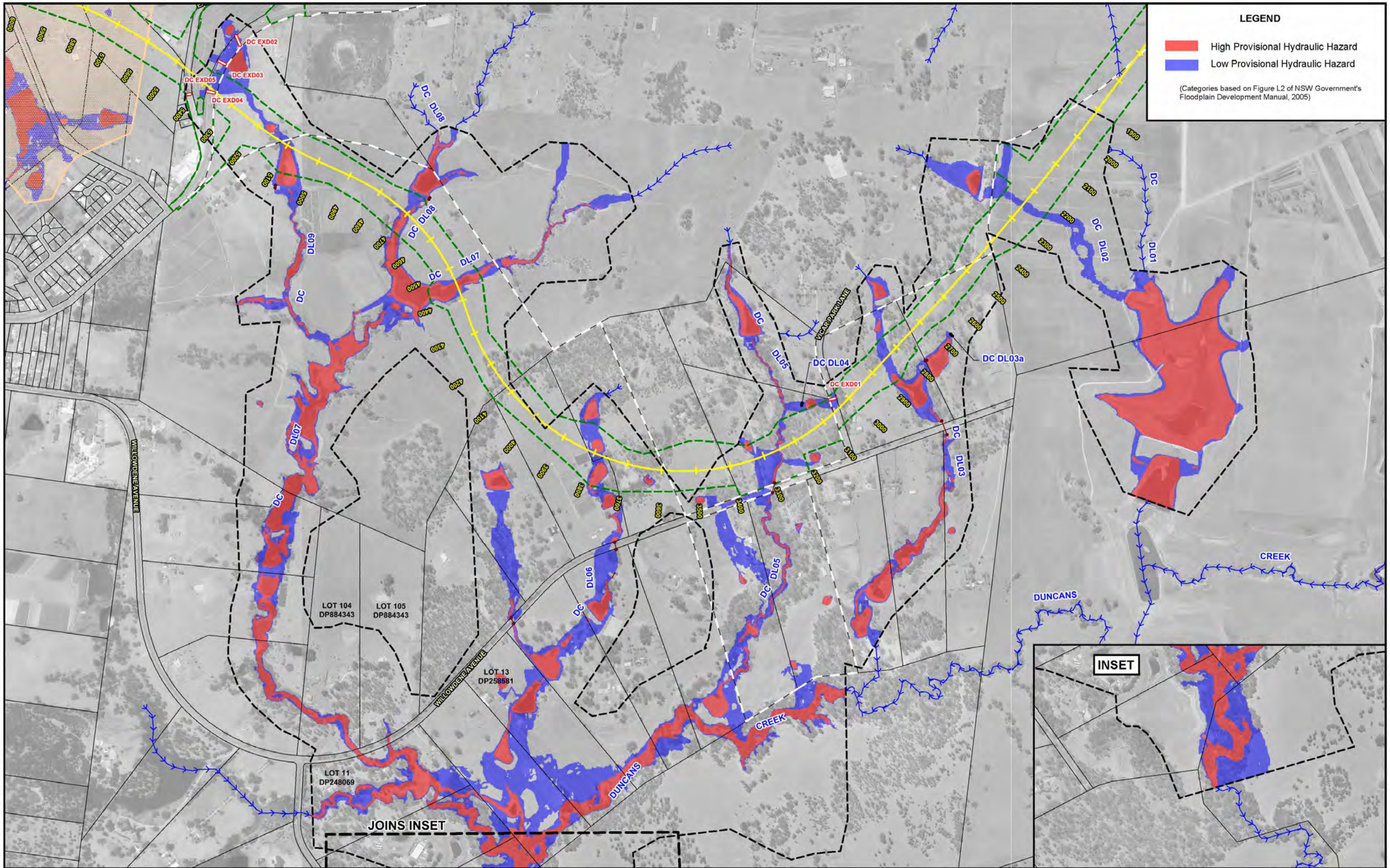
LEGEND

- Design Road Control String and Chainage
- Extent of Cosgroves Creek TUFLOW Model (Refer Figure 4.5 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Project Boundary
- DC EXD01 — Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)
- DC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.10

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - DUNCANS CREEK CATCHMENT
PRE-PROJECT CONDITIONS - PMF



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Cosgroves Creek TUFLOW Model (Refer Figure 4.6 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Project Boundary

DC EXD01 Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

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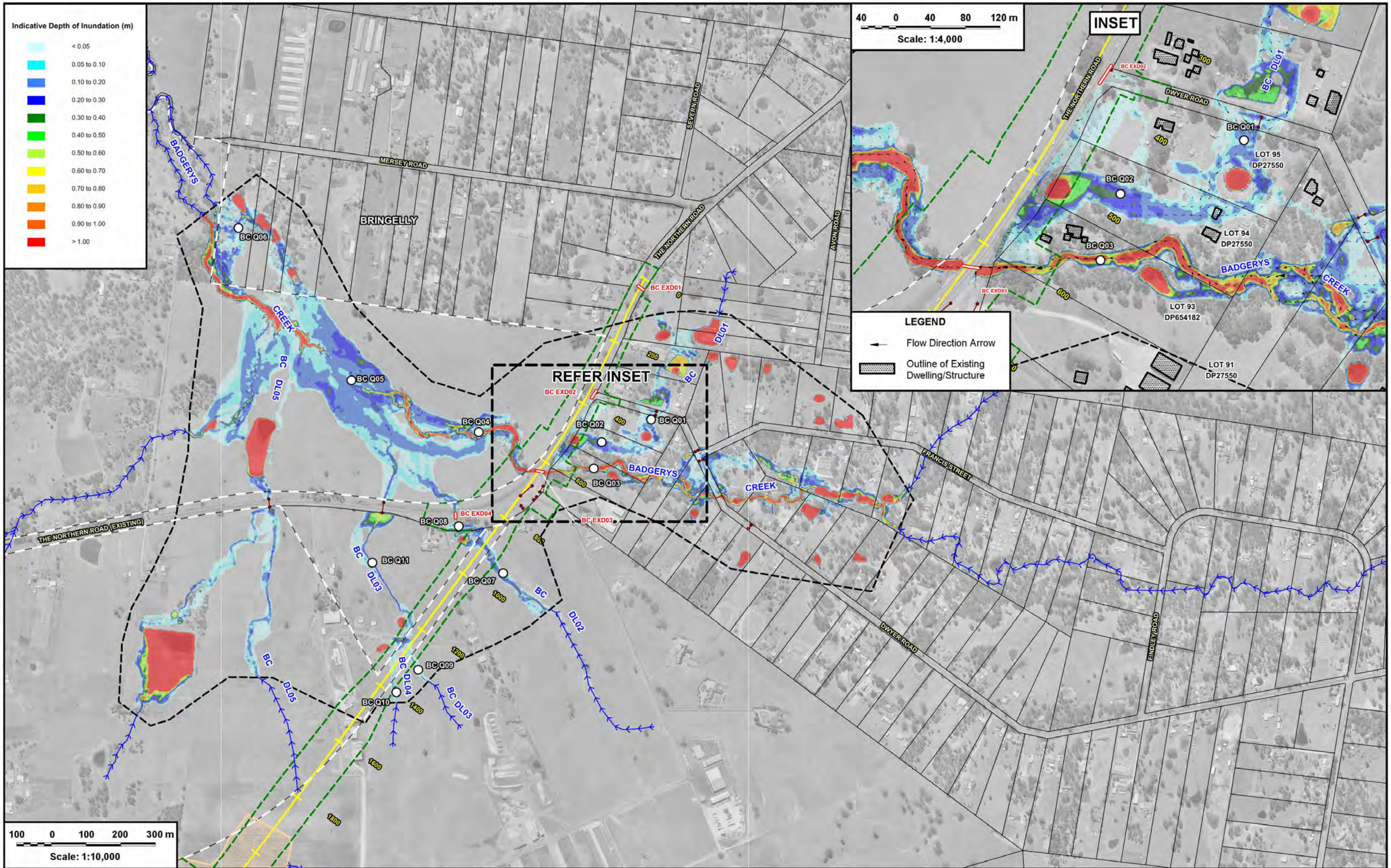
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.11

PROVISIONAL FLOOD HAZARD IN VICINITY OF PROJECT - DUNCANS CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 100 YEAR ARI



LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 4.7 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Project Boundary

BC EXD01 Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)

BC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

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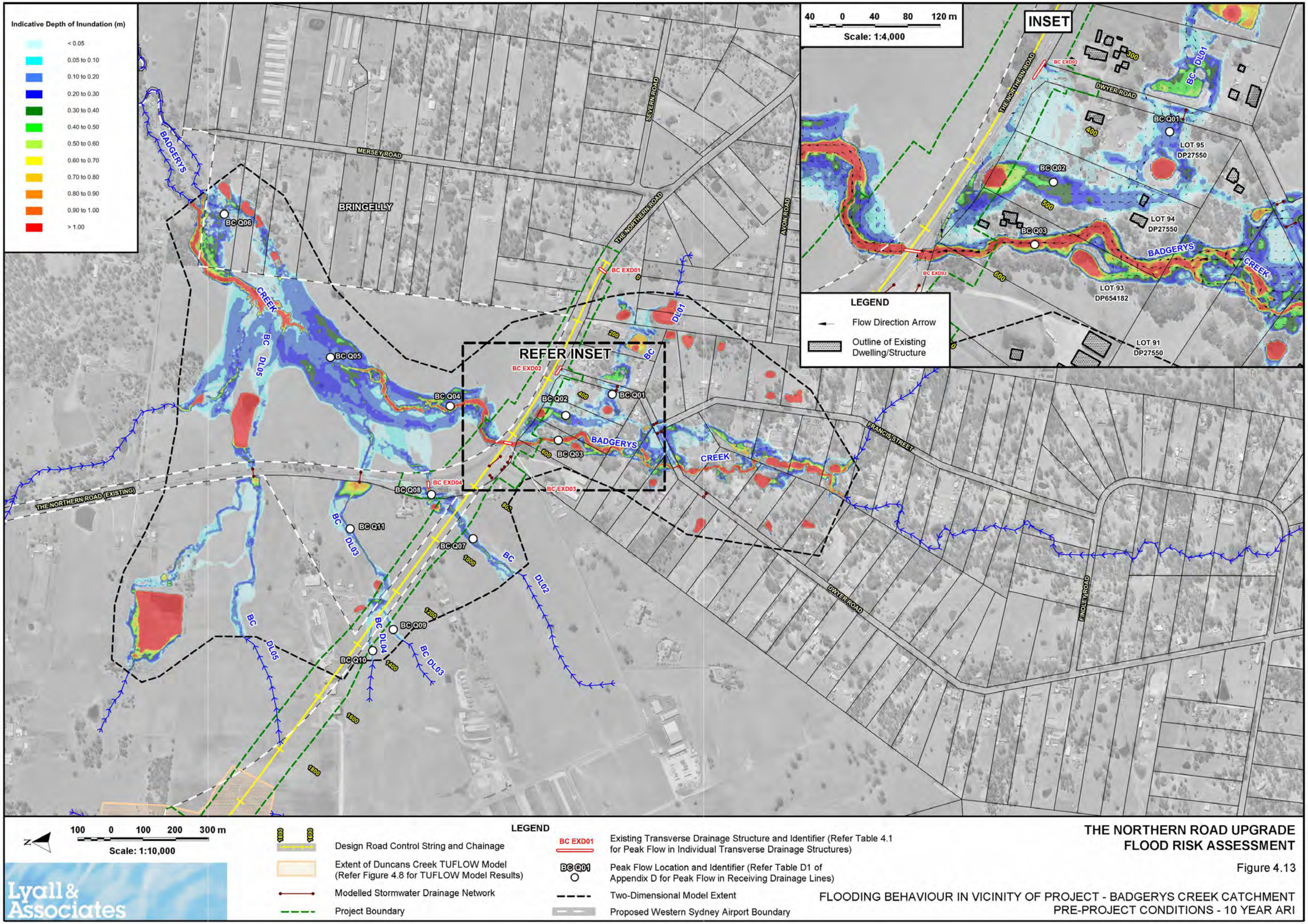
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.12

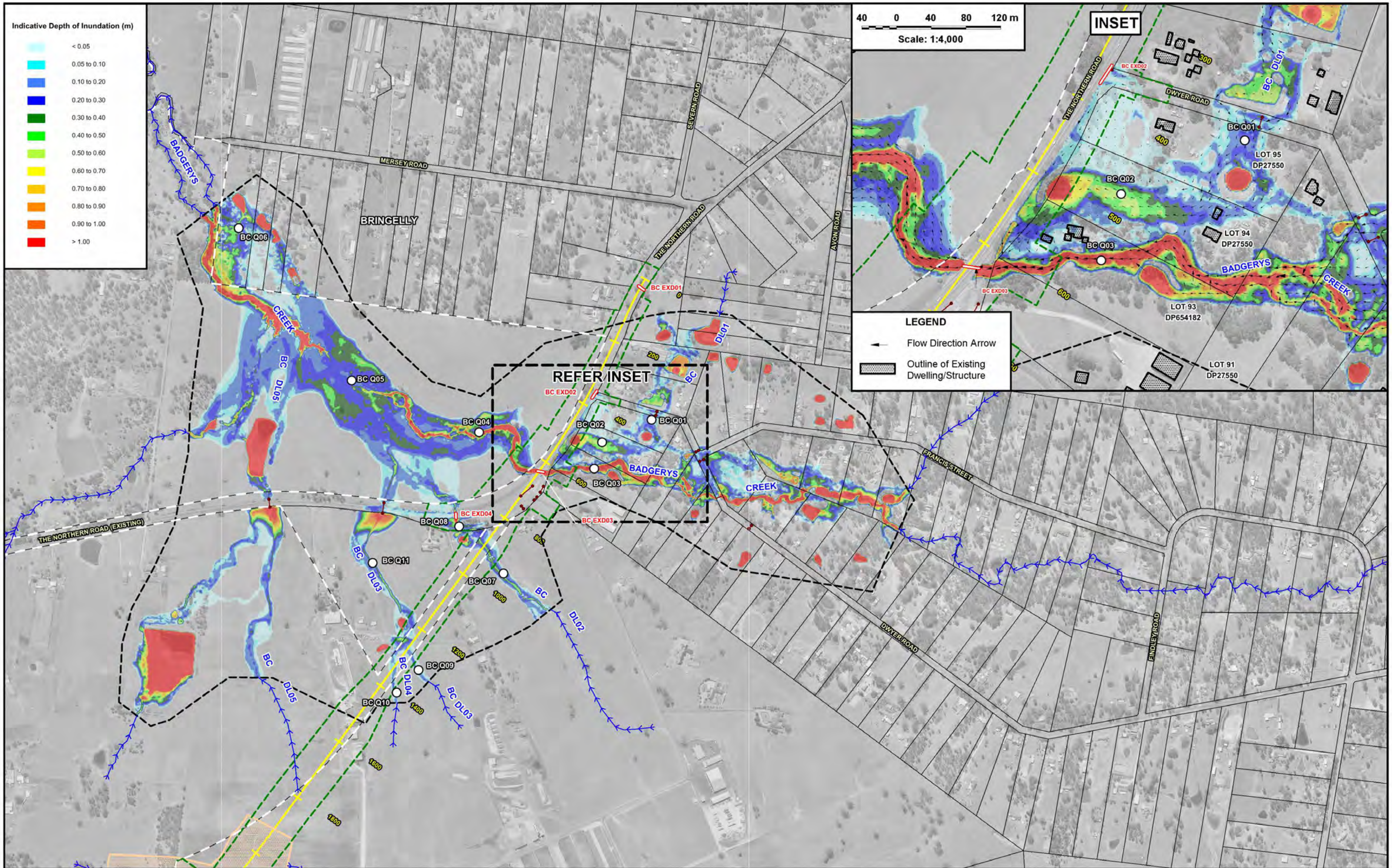
FLOODING BEHAVIOUR IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 2 YEAR ARI



THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.13

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 10 YEAR ARI



100 0 100 200 300 m
Scale: 1:10,000

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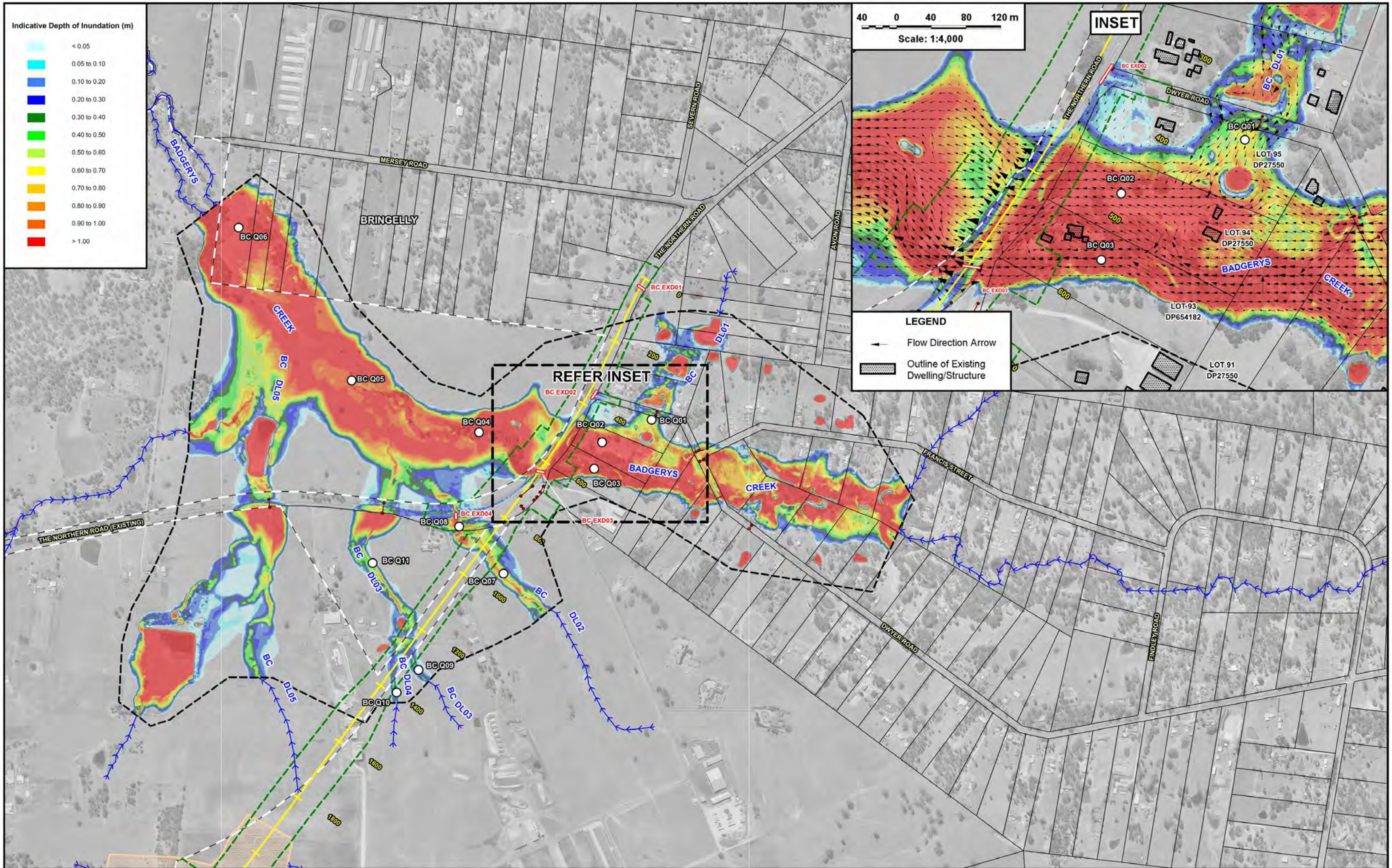
LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 4.9 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Project Boundary
- BC EXD01 — Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)
- BC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.14

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 100 YEAR ARI



Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 4.10 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Project Boundary

BC EXD01 — Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)

BC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

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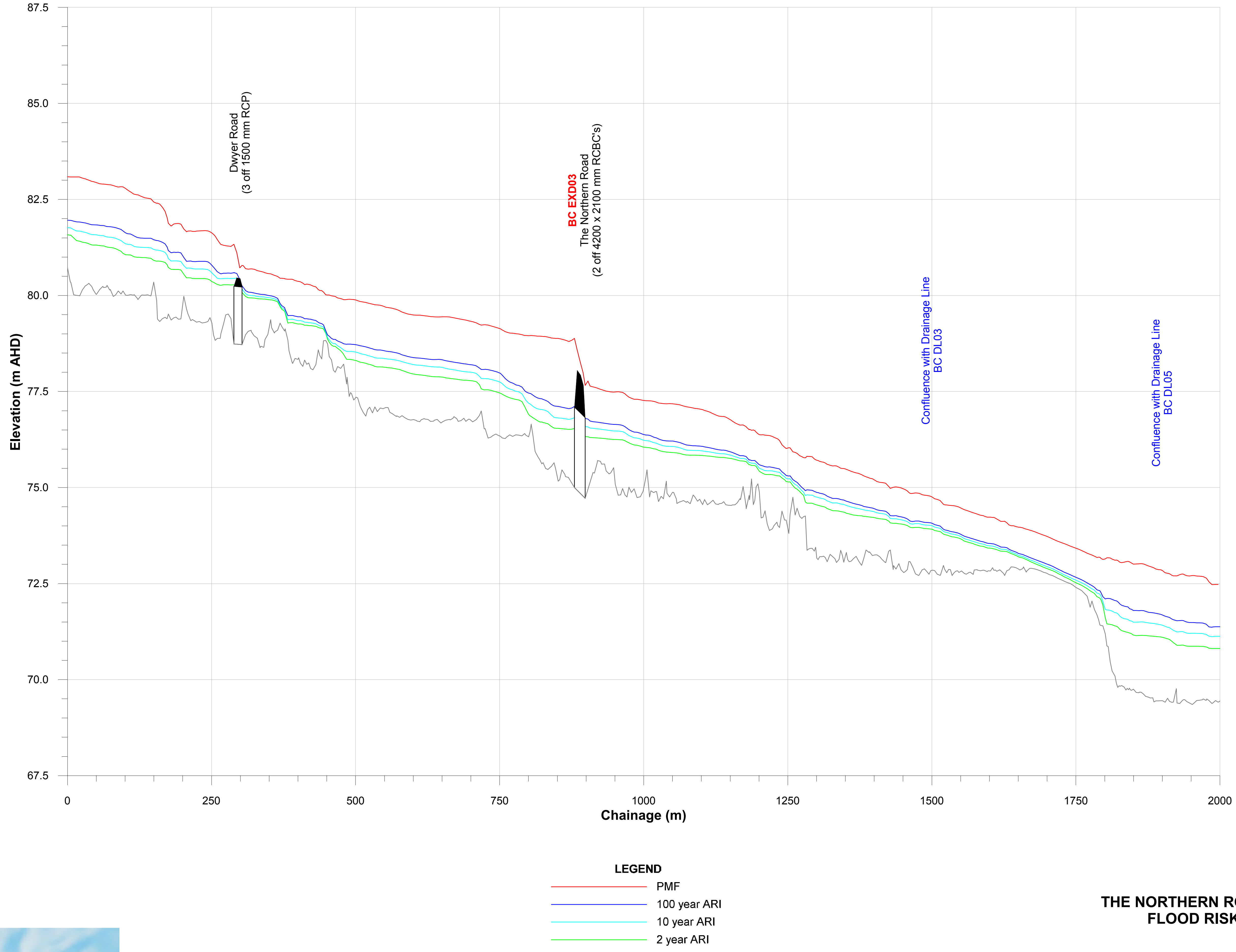
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.15

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT
PRE-PROJECT CONDITIONS - PMF



THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.16

DESIGN WATER SURFACE PROFILES - BADGERYS CREEK CATCHMENT
PRE-PROJECT CONDITIONS

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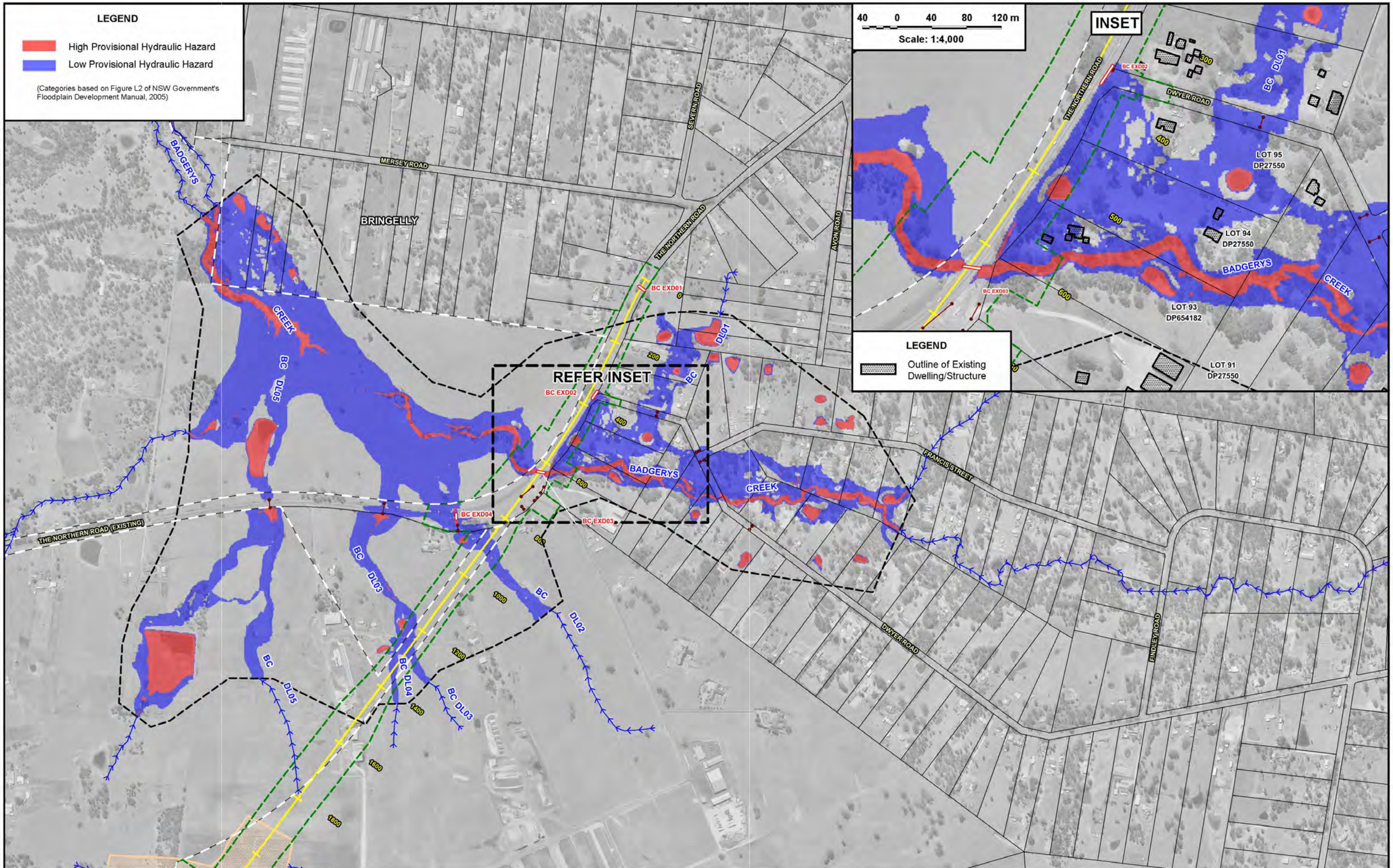

100 0 100 200 300 m
Scale: 1:10,000

LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 4.12 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Project Boundary
- BC EXD01 Existing Transverse Drainage Structure and Identifier (Refer Table 4.1 for Peak Flow in Individual Transverse Drainage Structures)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary

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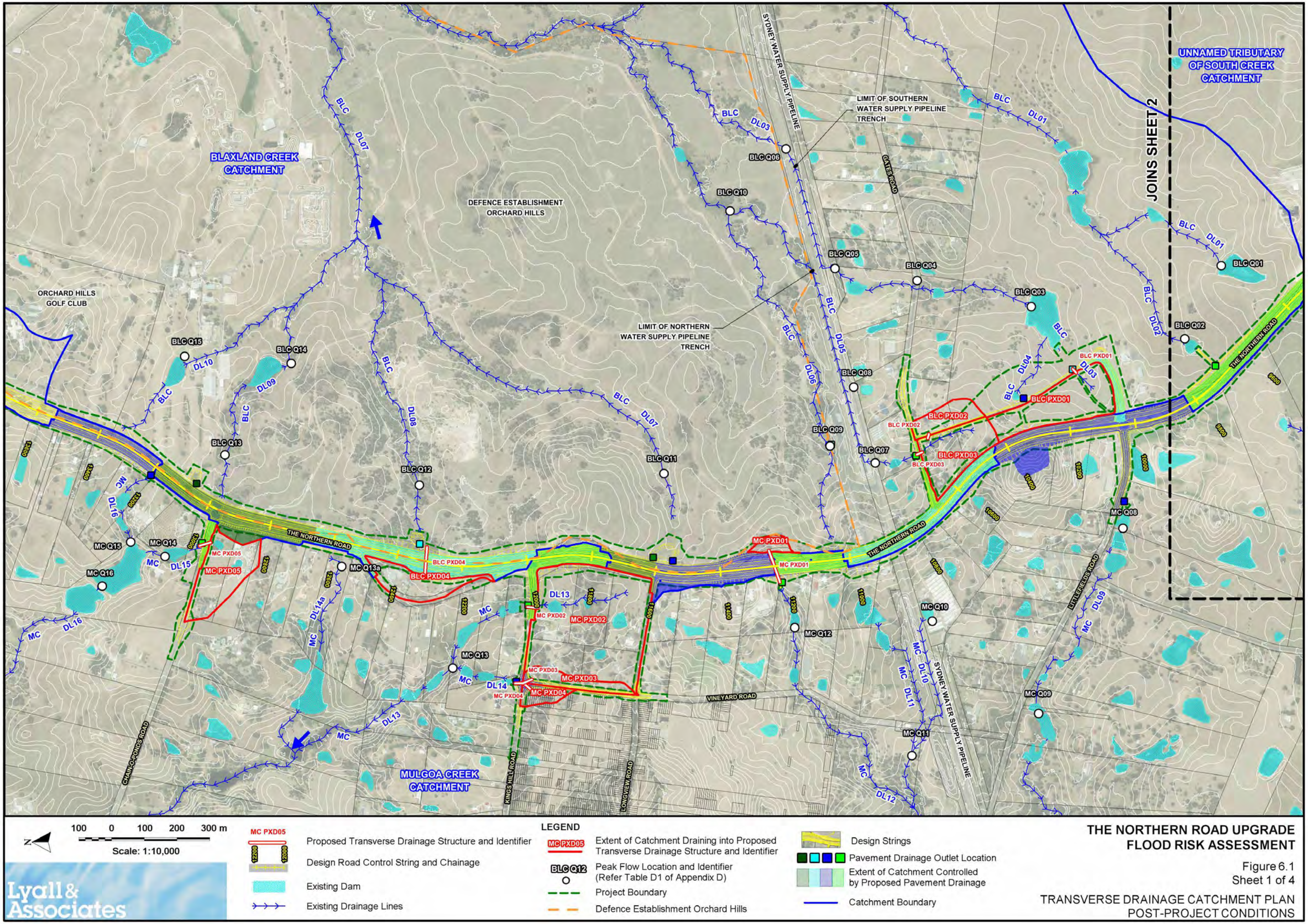
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 4.17

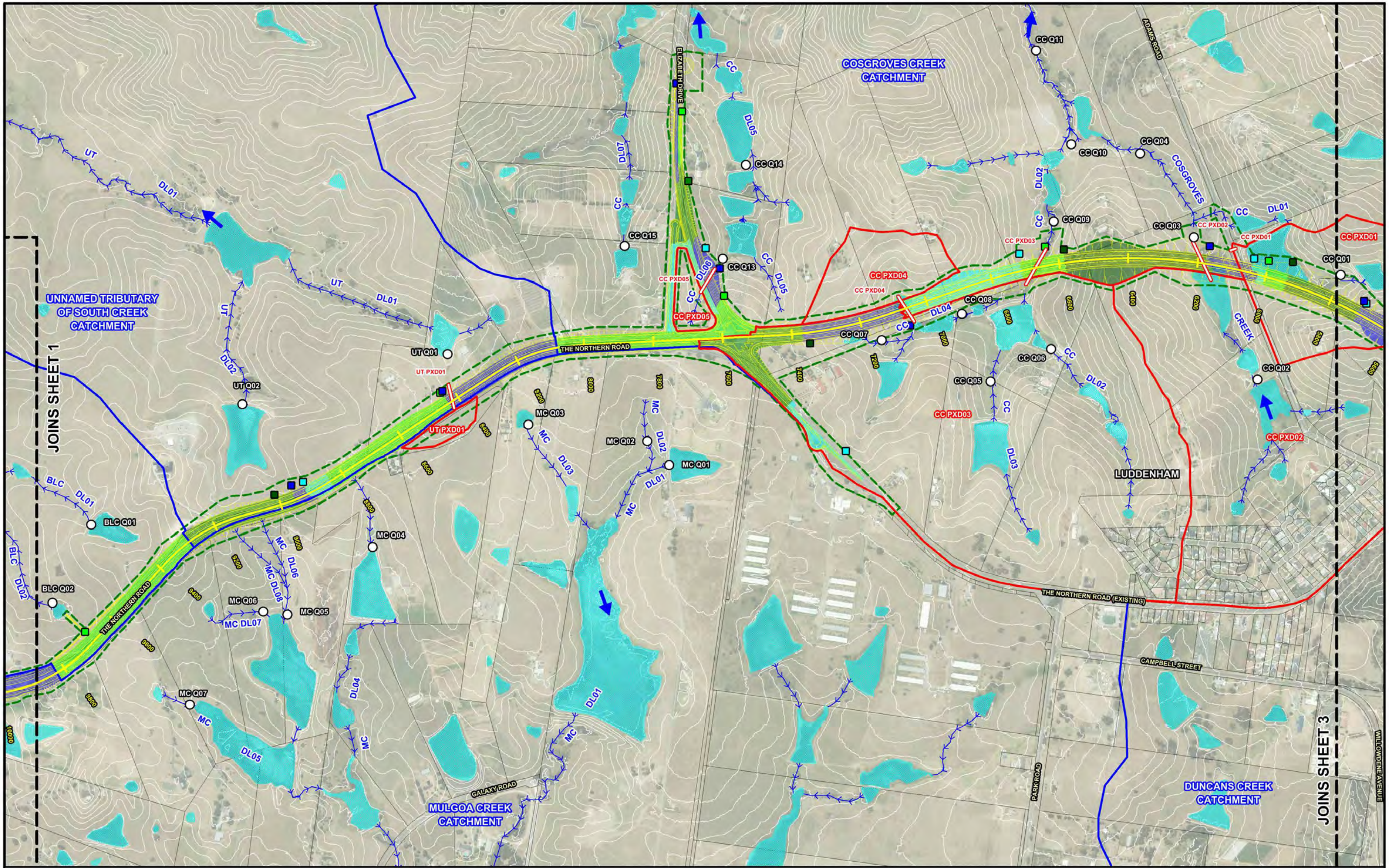
PROVISIONAL FLOOD HAZARD IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT
PRE-PROJECT CONDITIONS - 100 YEAR ARI



THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.1
Sheet 1 of 4

TRANSVERSE DRAINAGE CATCHMENT PLAN
POST-PROJECT CONDITIONS



Scale: 1:10,000

100 0 100 200 300 m

LEGEND

MC PXD01	Proposed Transverse Drainage Structure and Identifier
	Design Road Control String and Chainage
	Proposed Western Sydney Airport Boundary
	Existing Dam
	Existing Drainage Lines
MC PXD01	Extent of Catchment Draining into Proposed Transverse Drainage Structure and Identifier
MC Q04	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Project Boundary
	Design Strings
	Pavement Drainage Outlet Location
	Extent of Catchment Controlled by Proposed Pavement Drainage
	Catchment Boundary

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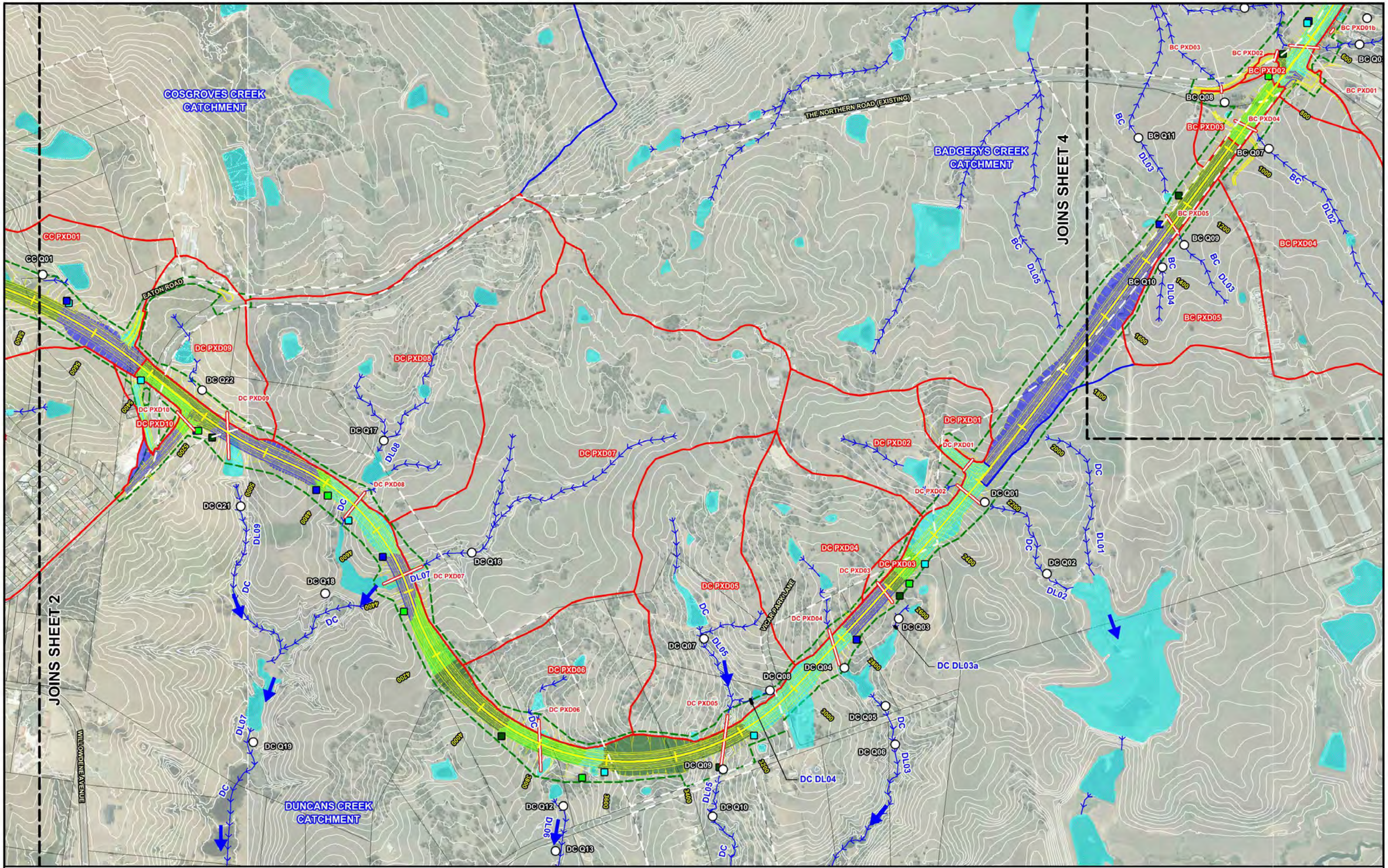
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.1
Sheet 2 of 4

TRANSVERSE DRAINAGE CATCHMENT PLAN
POST-PROJECT CONDITIONS



100 0 100 200 300 m

Scale: 1:10,000

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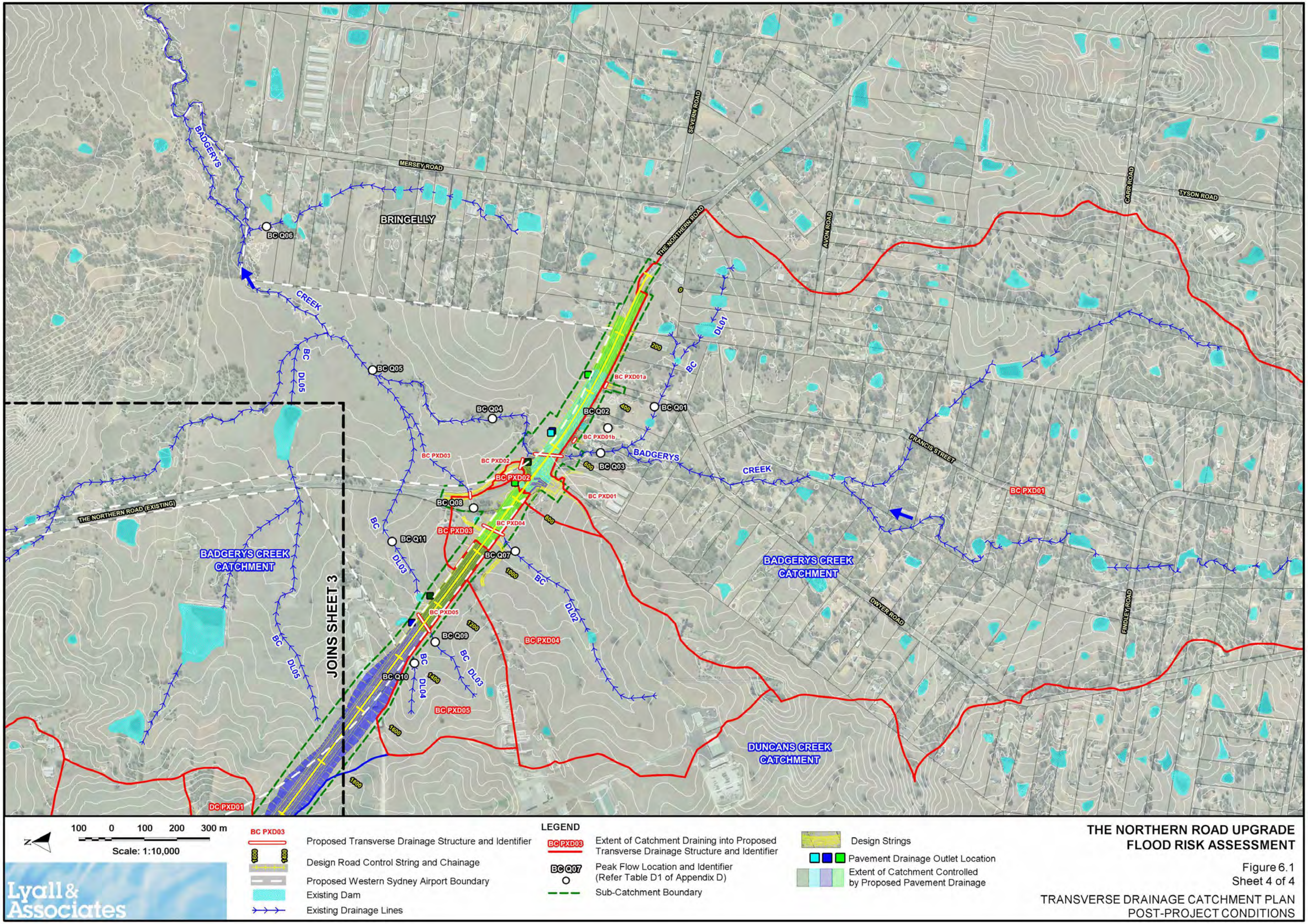
LEGEND

DC PXD03	Proposed Transverse Drainage Structure and Identifier
	Design Road Control String and Chainage
	Proposed Western Sydney Airport Boundary
	Existing Dam
	Existing Drainage Lines
DC PXD03	Extent of Catchment Draining into Proposed Transverse Drainage Structure and Identifier
DC Q02	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Project Boundary
	Design Strings
	Pavement Drainage Outlet Location
	Extent of Catchment Controlled by Proposed Pavement Drainage
	Catchment Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.1
Sheet 3 of 4

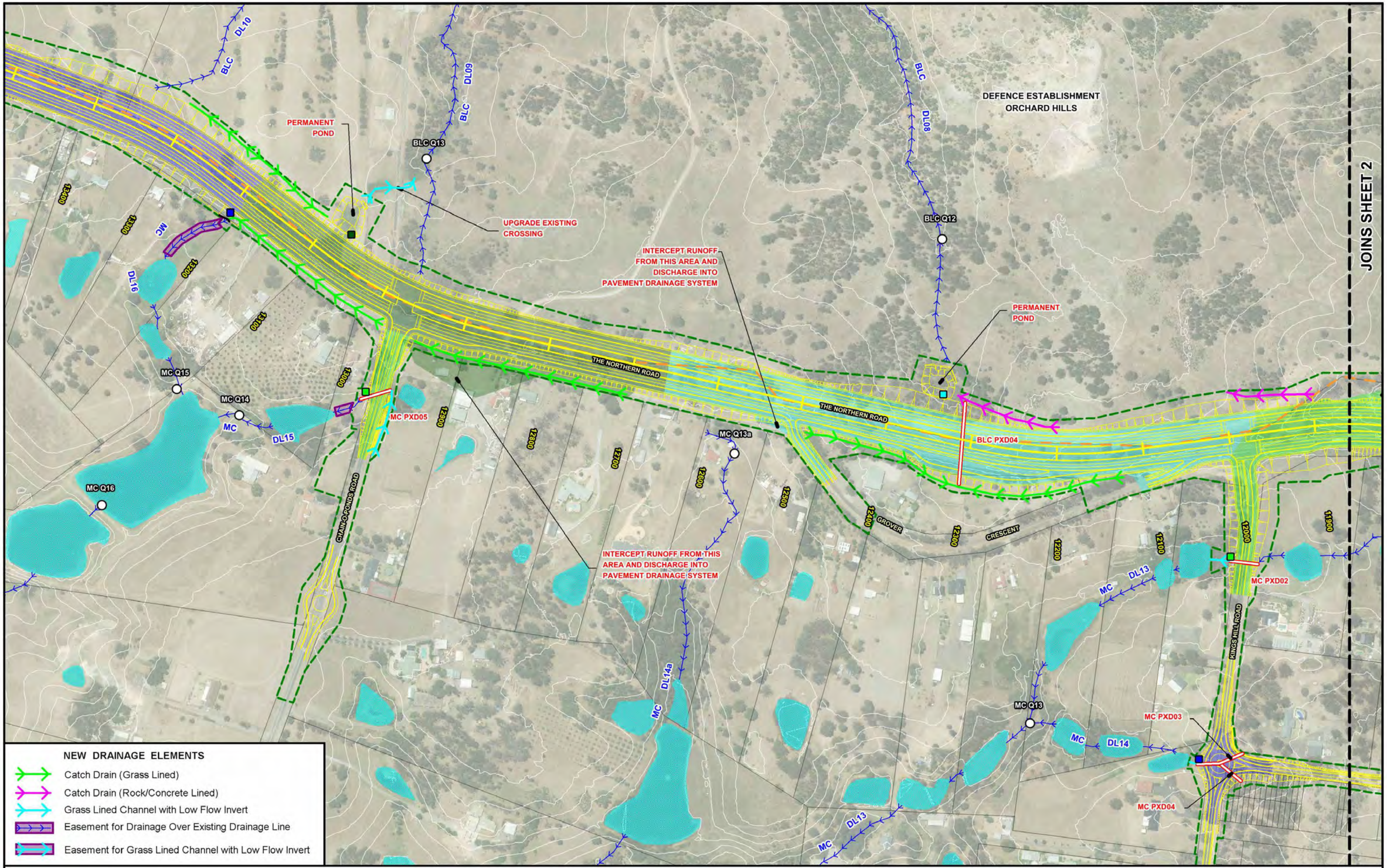
TRANSVERSE DRAINAGE CATCHMENT PLAN
POST-PROJECT CONDITIONS



THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.1
Sheet 4 of 4

TRANSVERSE DRAINAGE CATCHMENT PLAN
POST-PROJECT CONDITIONS



N

40 0 40 80 120 m

Scale: 1:4,000

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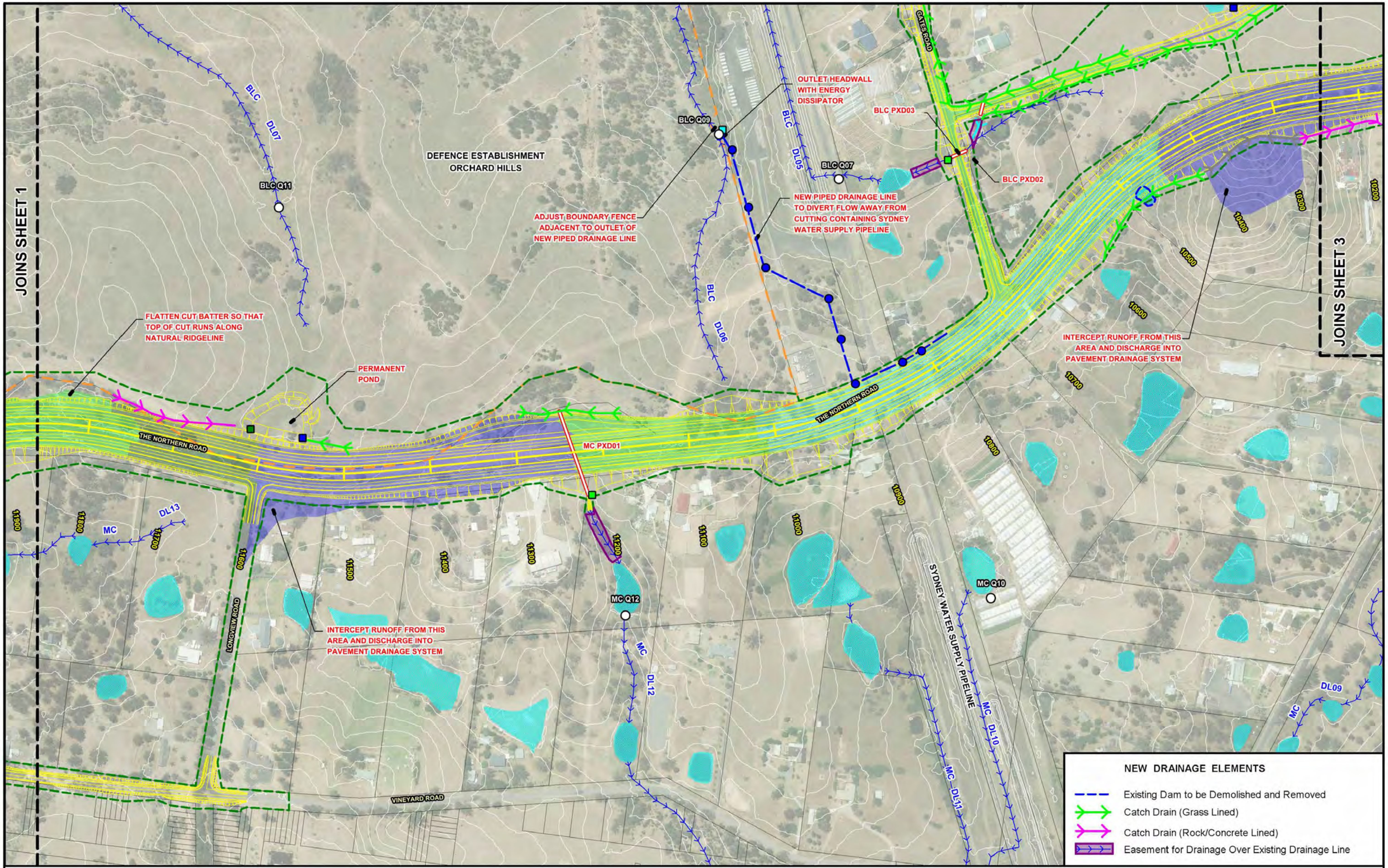
LEGEND

MC PXD02	Proposed Transverse Drainage Structure and Identifier (1)	MC Q14	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Design Road Control String and Chainage		Project Boundary
	Existing Dam		Existing Drainage Line
	Defence Establishment Orchard Hills	(1)	Unless otherwise shown, Transverse Drainage Requirements at driveways and internal access roads not shown
	Design Strings		Pavement Drainage Outlet Location
	Extent of Catchment Controlled by Proposed Pavement Drainage		

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.2
Sheet 1 of 10

PROPOSED TRANSVERSE DRAINAGE AND FLOOD MITIGATION STRATEGY



Scale: 1:4,000 (40 0 40 80 120 m)

LEGEND

MC PXD01	Proposed Transverse Drainage Structure and Identifier (1)
	Design Road Control String and Chainage
	Existing Dam
	Defence Establishment Orchard Hills
MC Q12	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Project Boundary
	Existing Drainage Line
(1)	Unless otherwise shown, Transverse Drainage Requirements at driveways and internal access roads not shown
	Design Strings
	Pavement Drainage Outlet Location
	Extent of Catchment Controlled by Proposed Pavement Drainage

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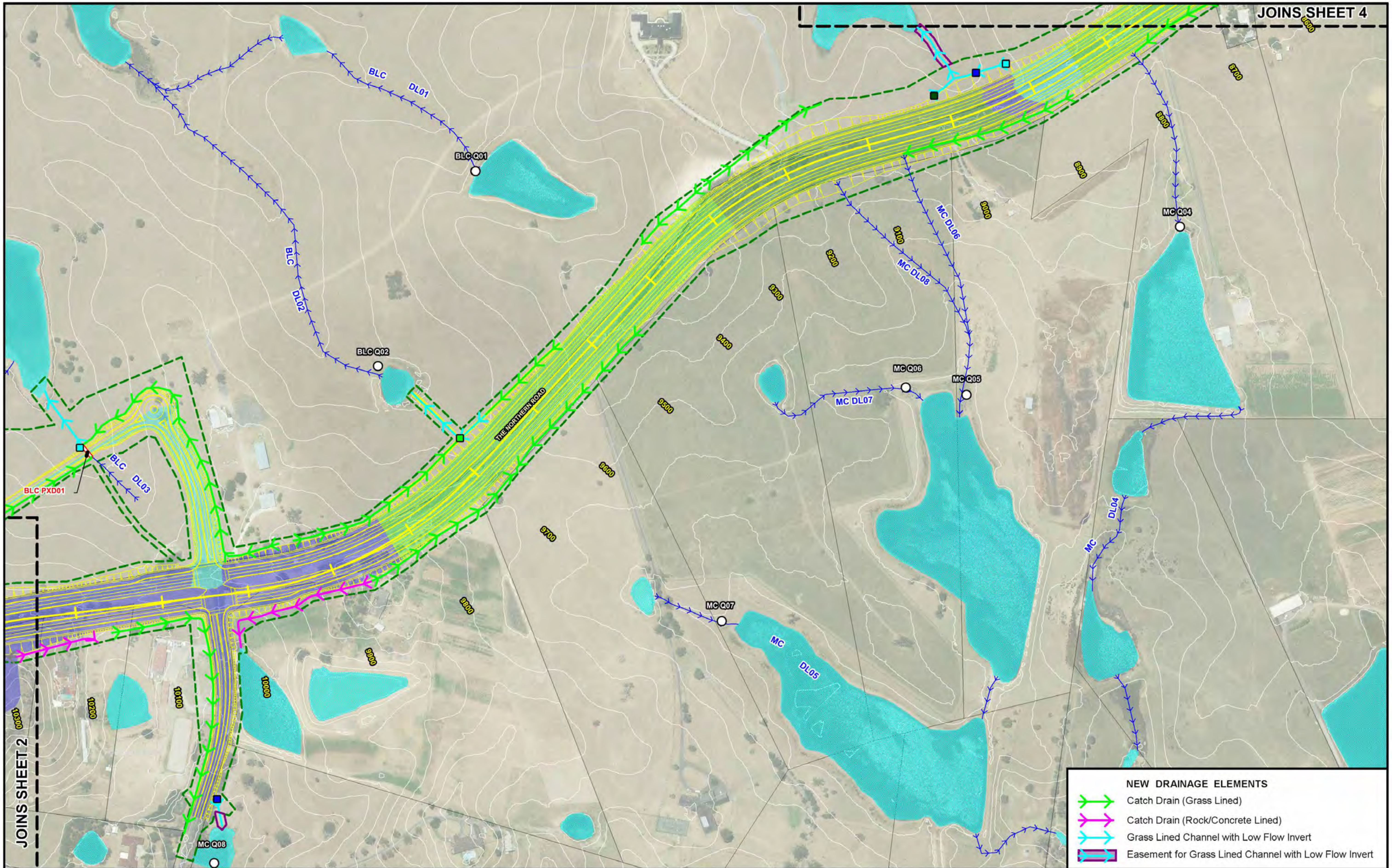
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.2
Sheet 2 of 10

PROPOSED TRANSVERSE DRAINAGE AND FLOOD MITIGATION STRATEGY



N

40 0 40 80 120 m

Scale: 1:4,000

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LEGEND

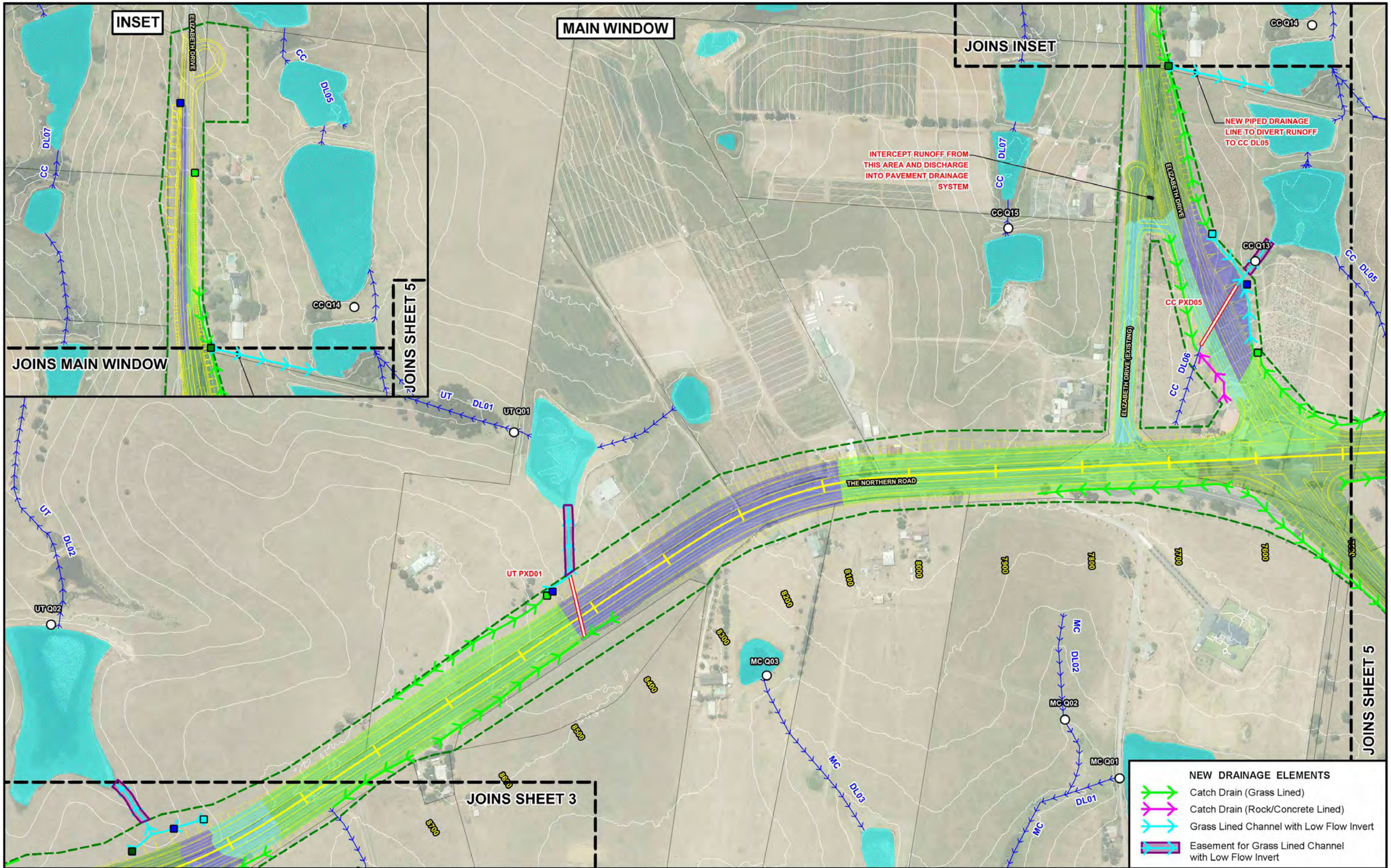
BLC PXD01	Proposed Transverse Drainage Structure and Identifier (1)	MC Q04	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
9600 9700	Design Road Control String and Chainage		Project Boundary
	Existing Dam		Existing Drainage Line
	Design Strings		Pavement Drainage Outlet Location
	Extent of Catchment Controlled by Proposed Pavement Drainage		

(1) Unless otherwise shown, Transverse Drainage Requirements at driveways and internal access roads not shown

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.2
Sheet 3 of 10

PROPOSED TRANSVERSE DRAINAGE AND FLOOD MITIGATION STRATEGY



Scale: 1:4,000 (40 0 40 80 120 m)

LEGEND

CC PXD05	Proposed Transverse Drainage Structure and Identifier (1)
	Design Road Control String and Chainage
	Existing Dam
CC Q13	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Project Boundary
	Existing Drainage Line
(1)	Unless otherwise shown, Transverse Drainage Requirements at driveways and internal access roads not shown
	Design Strings
	Pavement Drainage Outlet Location
	Extent of Catchment Controlled by Proposed Pavement Drainage

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THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.2
Sheet 4 of 10

PROPOSED TRANSVERSE DRAINAGE AND FLOOD MITIGATION STRATEGY

N

40 0 40 80 120 m

Scale: 1:4,000

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LEGEND

CC PXD03 — Proposed Transverse Drainage Structure and Identifier (1)

7200 / 7100 — Design Road Control String and Chainage

Existing Dam

CC Q07 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D)

Project Boundary

Existing Drainage Line

(1) Unless otherwise shown, Transverse Drainage Requirements at driveways and internal access roads not shown

Design Strings

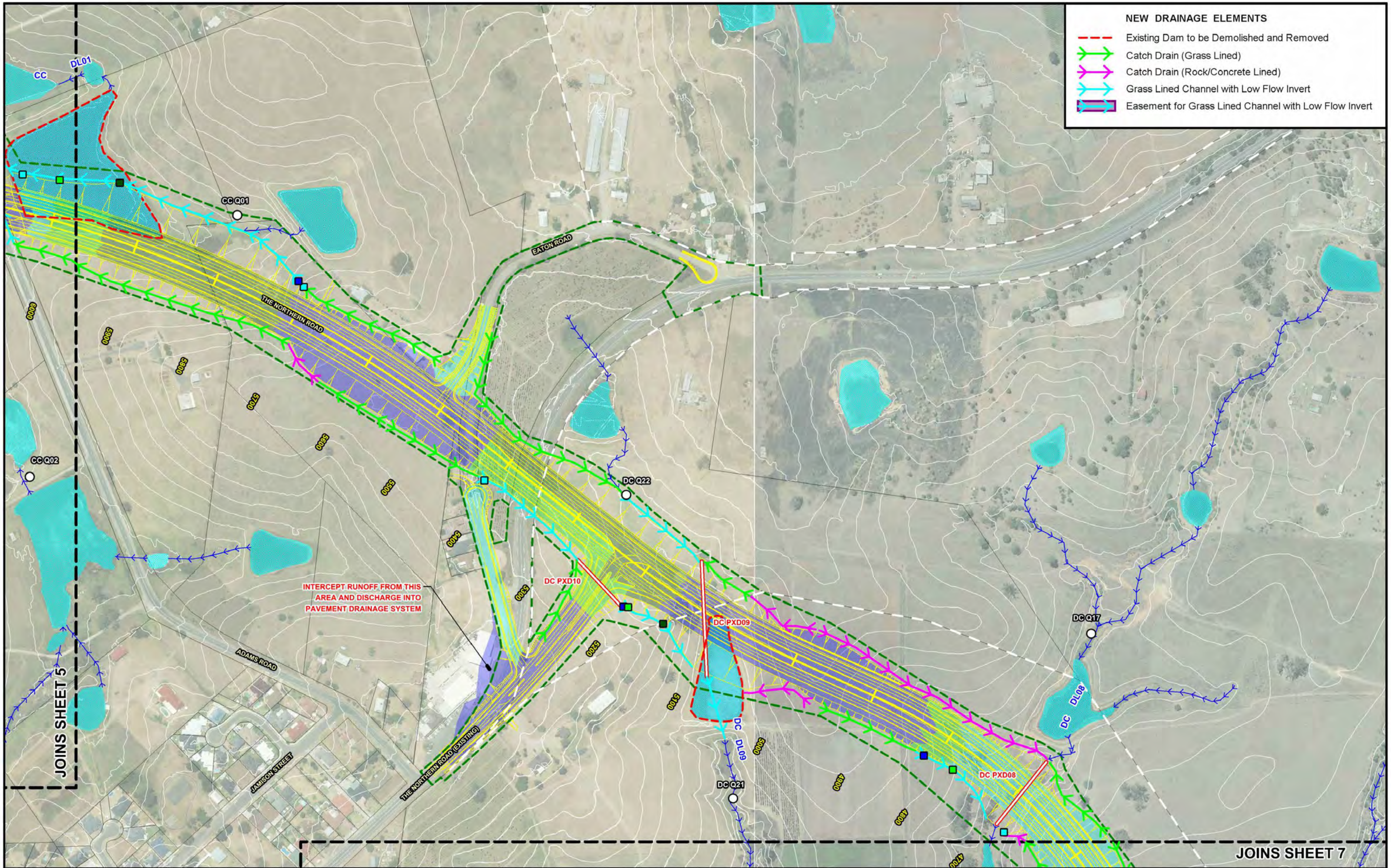
Pavement Drainage Outlet Location

Extent of Catchment Controlled by Proposed Pavement Drainage

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.2
Sheet 5 of 10

PROPOSED TRANSVERSE DRAINAGE AND FLOOD MITIGATION STRATEGY



Scale: 1:4,000 (40 0 40 80 120 m)

LEGEND

DC PXD09	Proposed Transverse Drainage Structure and Identifier [1]	DC Q22	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Design Road Control String and Chainage		Project Boundary
	Existing Dam		Existing Drainage Line
	Proposed Western Sydney Airport Boundary	(1)	Unless otherwise shown, Transverse Drainage Requirements at driveways and internal access roads not shown
	Design Strings		Pavement Drainage Outlet Location
	Extent of Catchment Controlled by Proposed Pavement Drainage		

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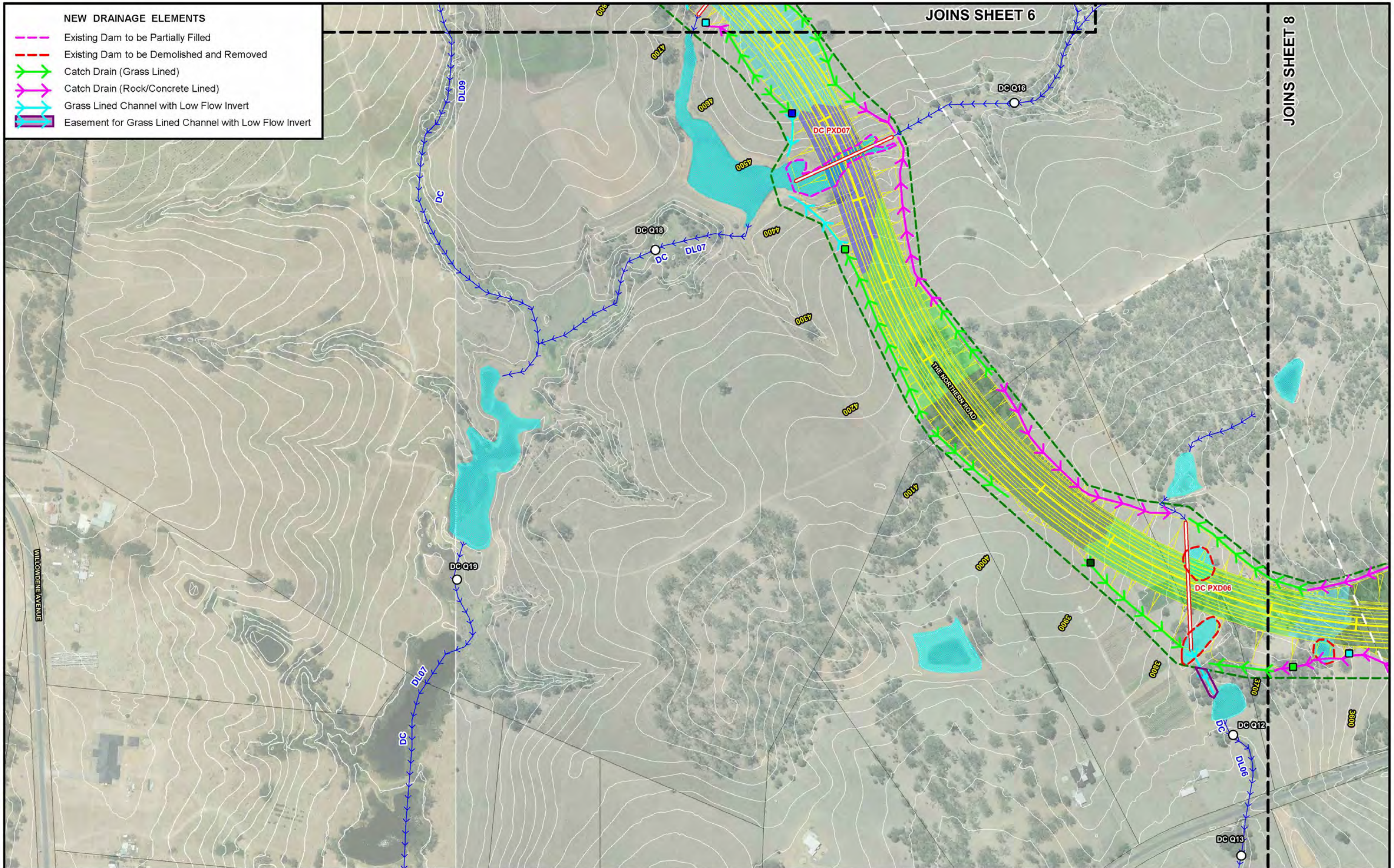
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.2
Sheet 6 of 10

PROPOSED TRANSVERSE DRAINAGE AND FLOOD MITIGATION STRATEGY



40 0 40 80 120 m

Scale: 1:4,000

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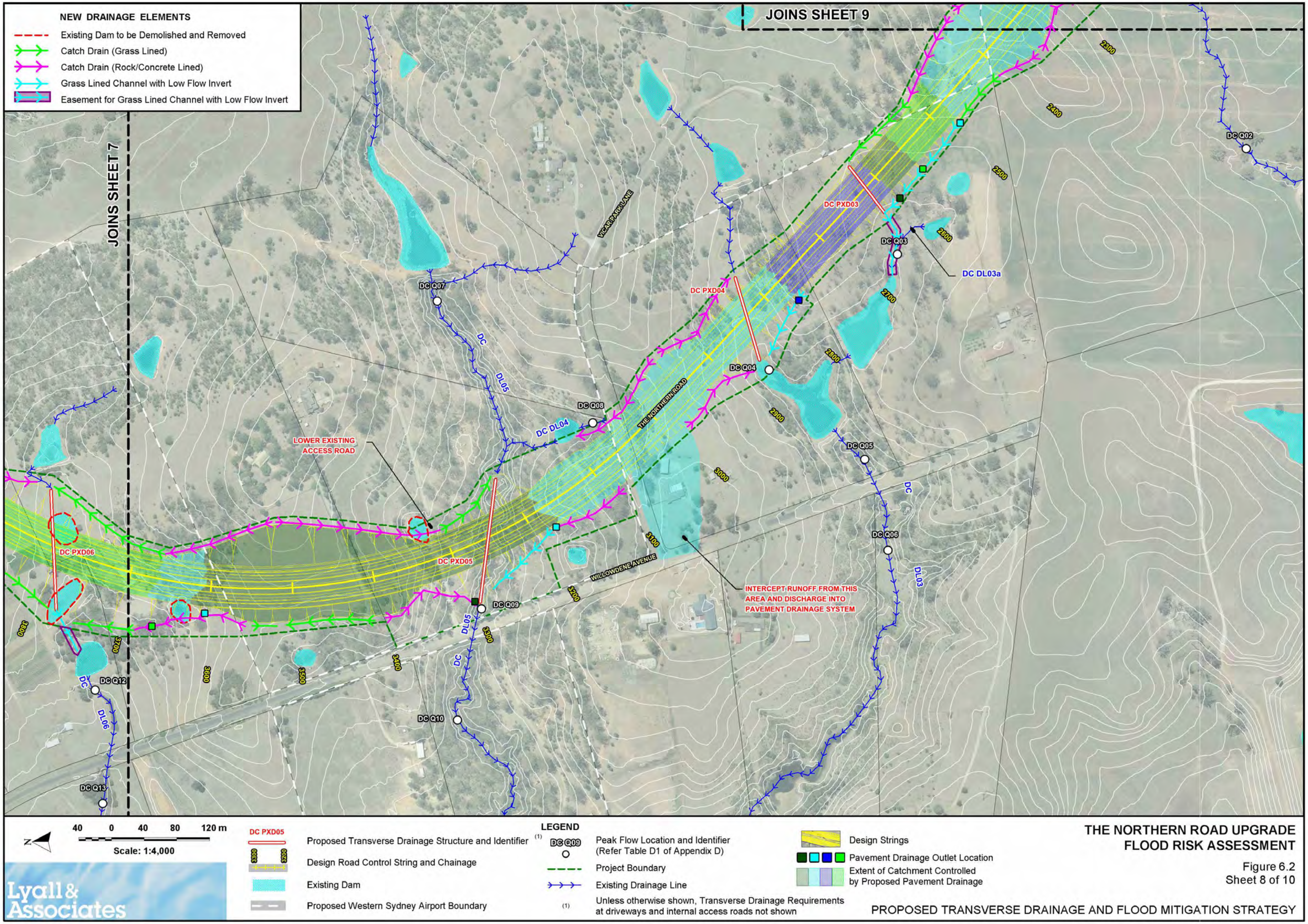
LEGEND

DC PXD06	Proposed Transverse Drainage Structure and Identifier [1]
3800 3700	Design Road Control String and Chainage
	Existing Dam
	Proposed Western Sydney Airport Boundary
DC Q12	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Project Boundary
	Existing Drainage Line
(1)	Unless otherwise shown, Transverse Drainage Requirements at driveways and internal access roads not shown
	Design Strings
	Pavement Drainage Outlet Location
	Extent of Catchment Controlled by Proposed Pavement Drainage

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.2
Sheet 7 of 10

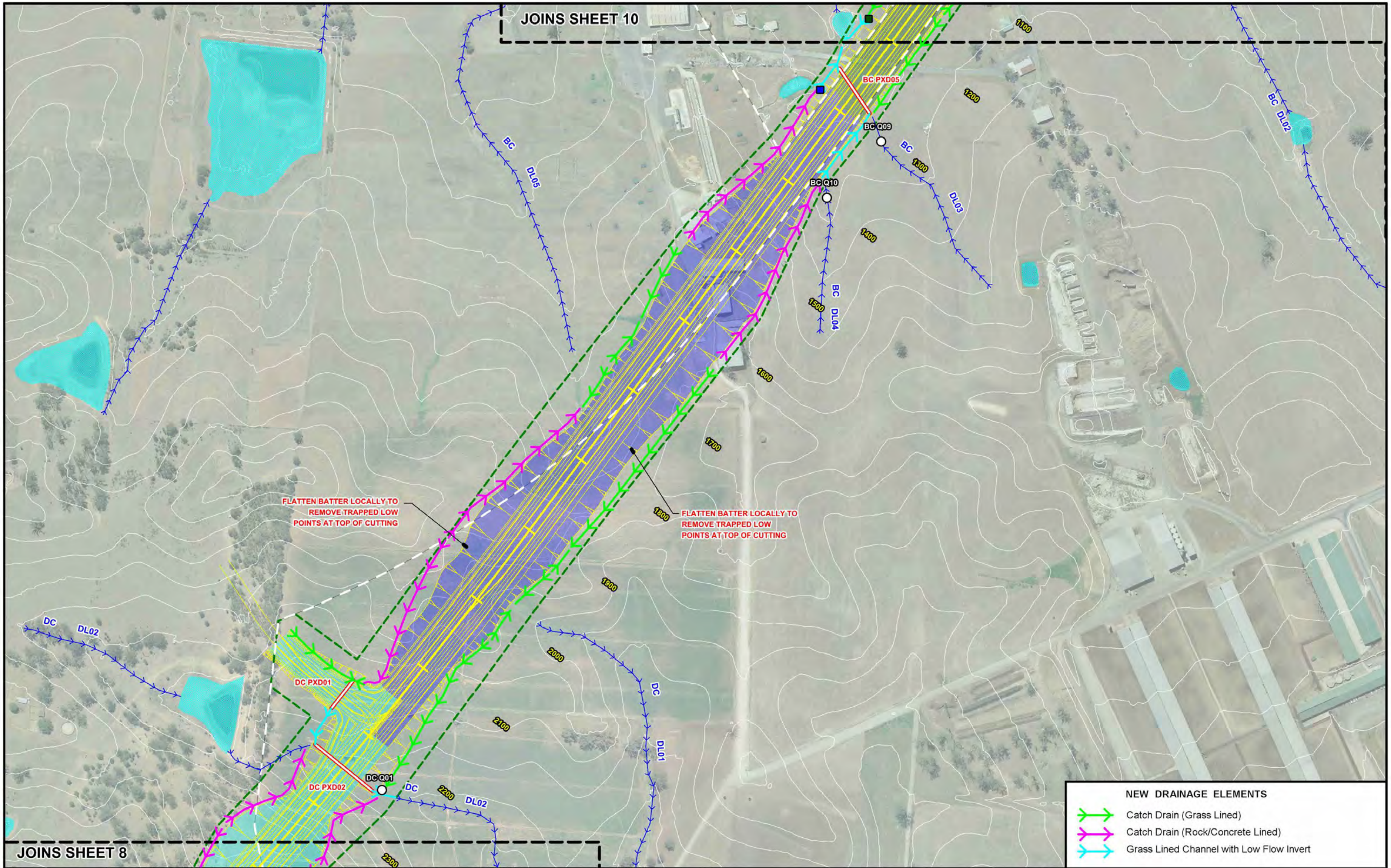
PROPOSED TRANSVERSE DRAINAGE AND FLOOD MITIGATION STRATEGY



THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.2
Sheet 8 of 10

PROPOSED TRANSVERSE DRAINAGE AND FLOOD MITIGATION STRATEGY



40 0 40 80 120 m

Scale: 1:4,000

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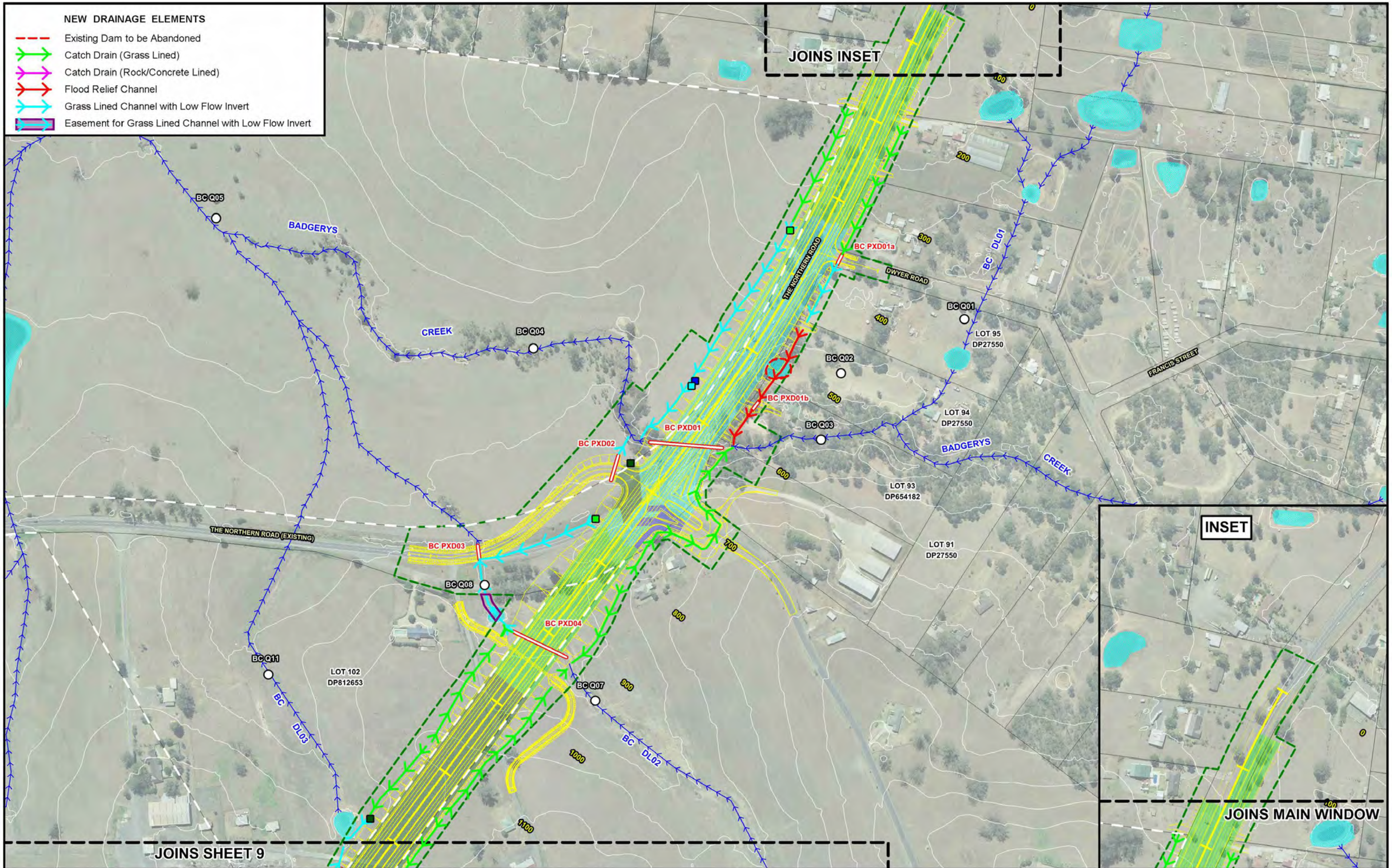
LEGEND

DC PXD02	Proposed Transverse Drainage Structure and Identifier (1)	DC Q01	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)		Design Strings
2300	Design Road Control String and Chainage		Project Boundary		Pavement Drainage Outlet Location
	Existing Dam		Existing Drainage Line		Extent of Catchment Controlled by Proposed Pavement Drainage
	Proposed Western Sydney Airport Boundary	(1)	Unless otherwise shown, Transverse Drainage Requirements at driveways and internal access roads not shown		

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.2
Sheet 9 of 10

PROPOSED TRANSVERSE DRAINAGE AND FLOOD MITIGATION STRATEGY



40 0 40 80 120 m

Scale: 1:4,000

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LEGEND

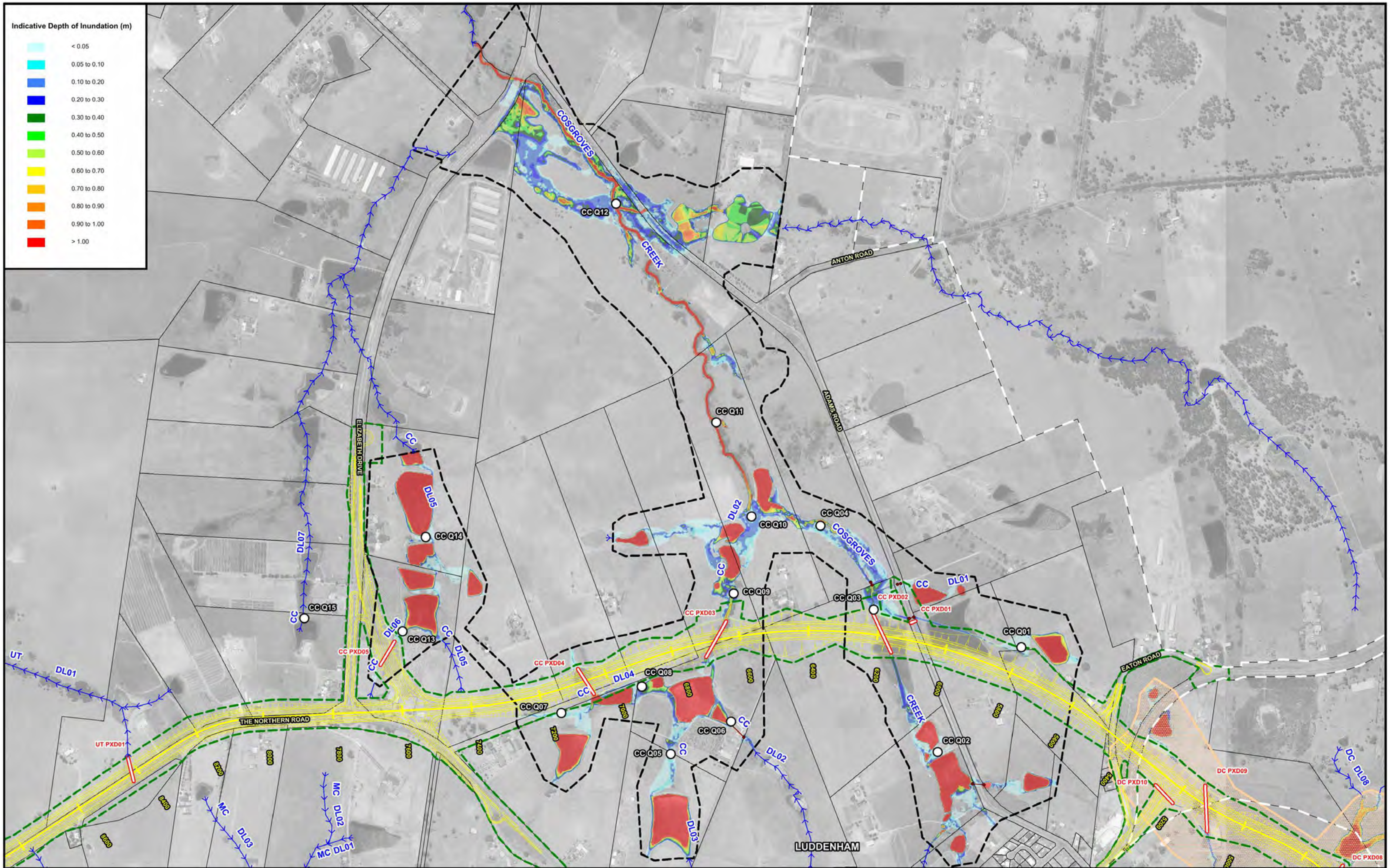
BC PXD01	Proposed Transverse Drainage Structure and Identifier (1)	BC Q01	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Design Road Control String and Chainage		Project Boundary
	Existing Dam		Existing Drainage Line
	Proposed Western Sydney Airport Boundary	(1)	Unless otherwise shown, Transverse Drainage Requirements at driveways and internal access roads not shown

Design Strings
Pavement Drainage Outlet Location
Extent of Catchment Controlled by Proposed Pavement Drainage

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 6.2
Sheet 10 of 10

PROPOSED TRANSVERSE DRAINAGE AND FLOOD MITIGATION STRATEGY



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.10 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

Project Boundary

CC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

CC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

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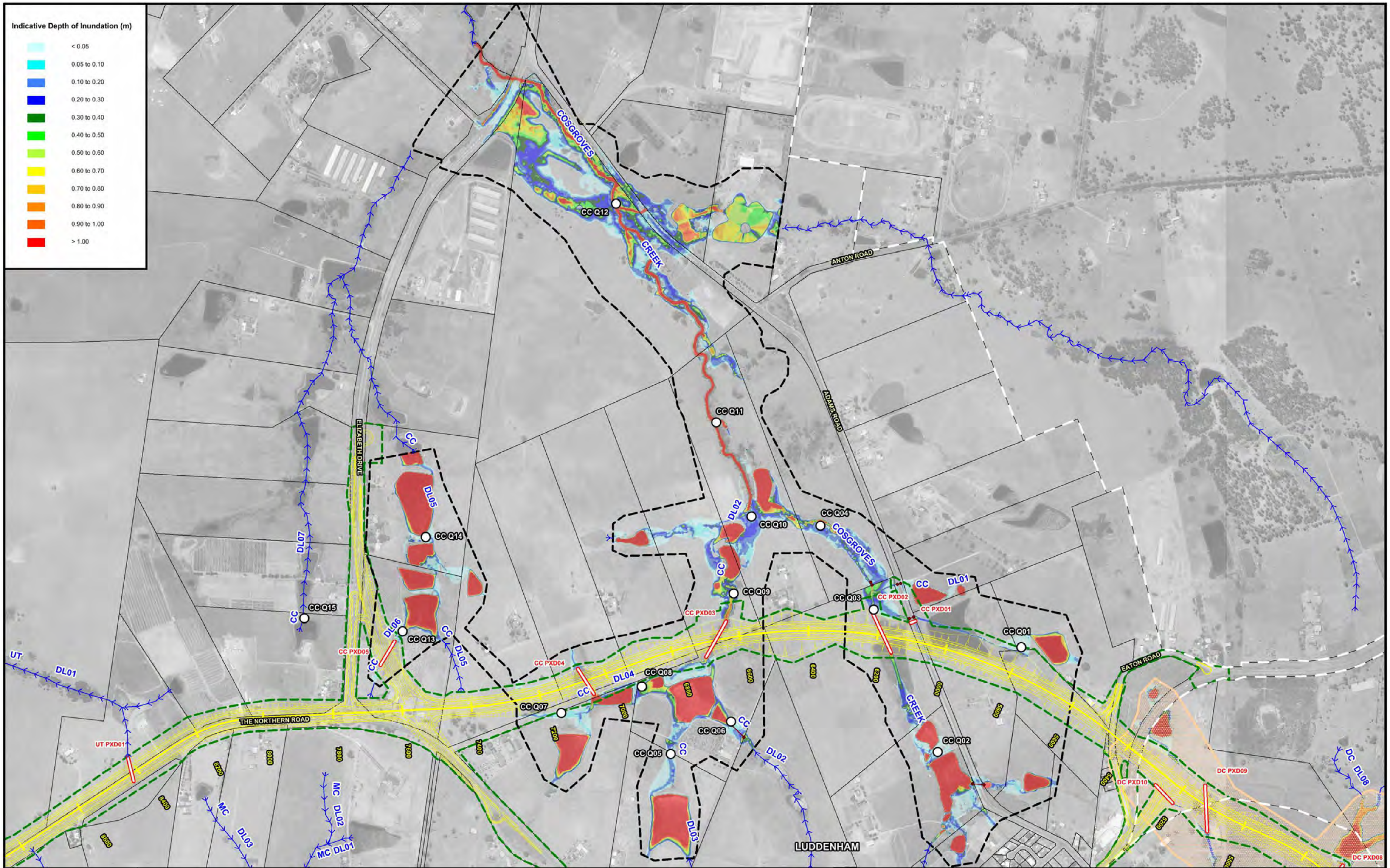
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.1

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - COSGROVES CREEK CATCHMENT
POST-PROJECT CONDITIONS - 2 YEAR ARI



LEGEND

Design Road Control String and Chainage	Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures) (CC PXD01)
Extent of Duncans Creek TUFLOW Model (Refer Figure 7.11 for TUFLOW Model Results)	Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines) (CC Q01)
Modelled Stormwater Drainage Network	Two-Dimensional Model Extent
Design Strings	Proposed Western Sydney Airport Boundary
Project Boundary	

100 0 100 200 300 m

Scale: 1:10,000

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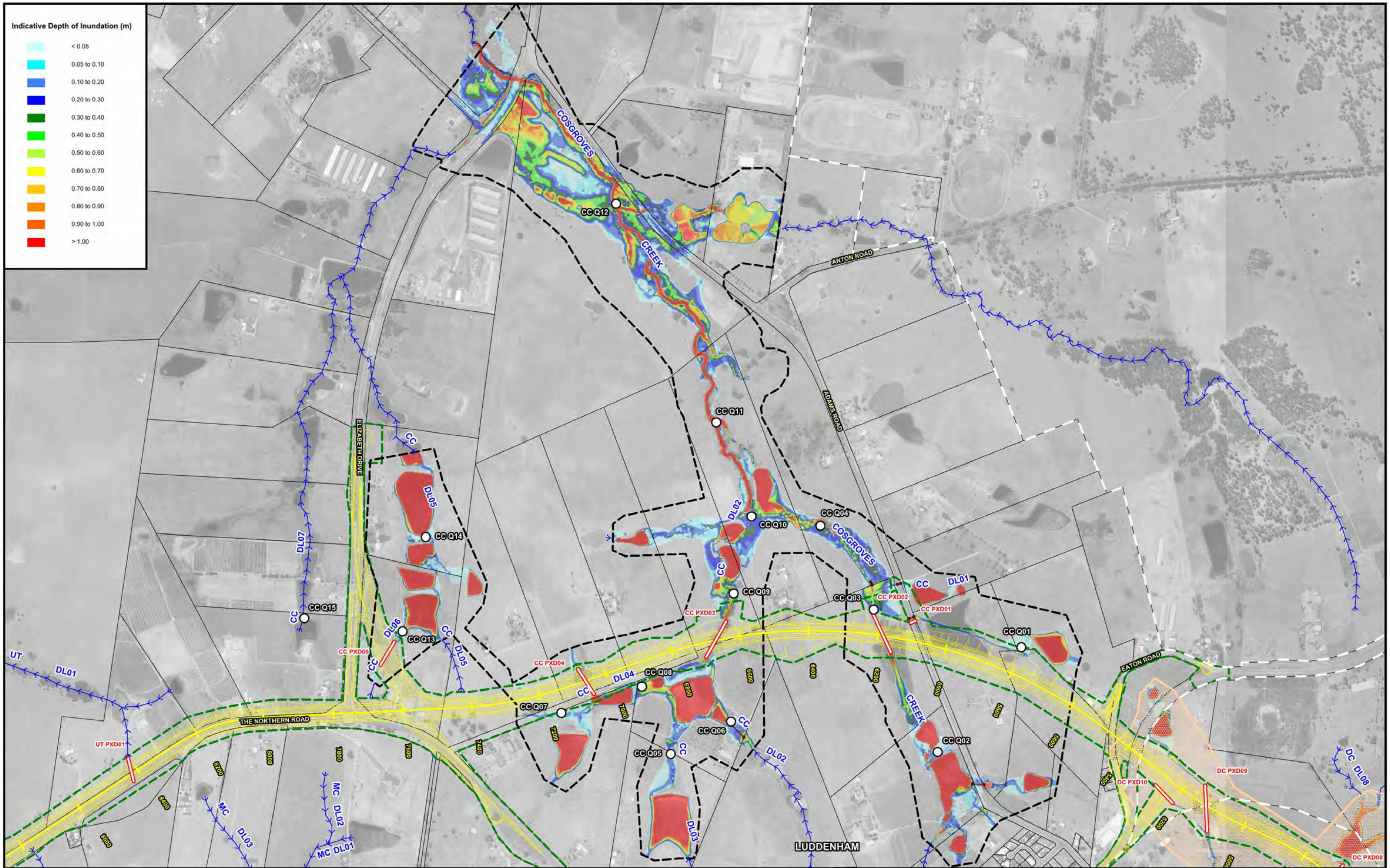
THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

Figure 7.2

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - COSGROVES CREEK CATCHMENT
POST-PROJECT CONDITIONS - 10 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.12 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

Project Boundary

Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

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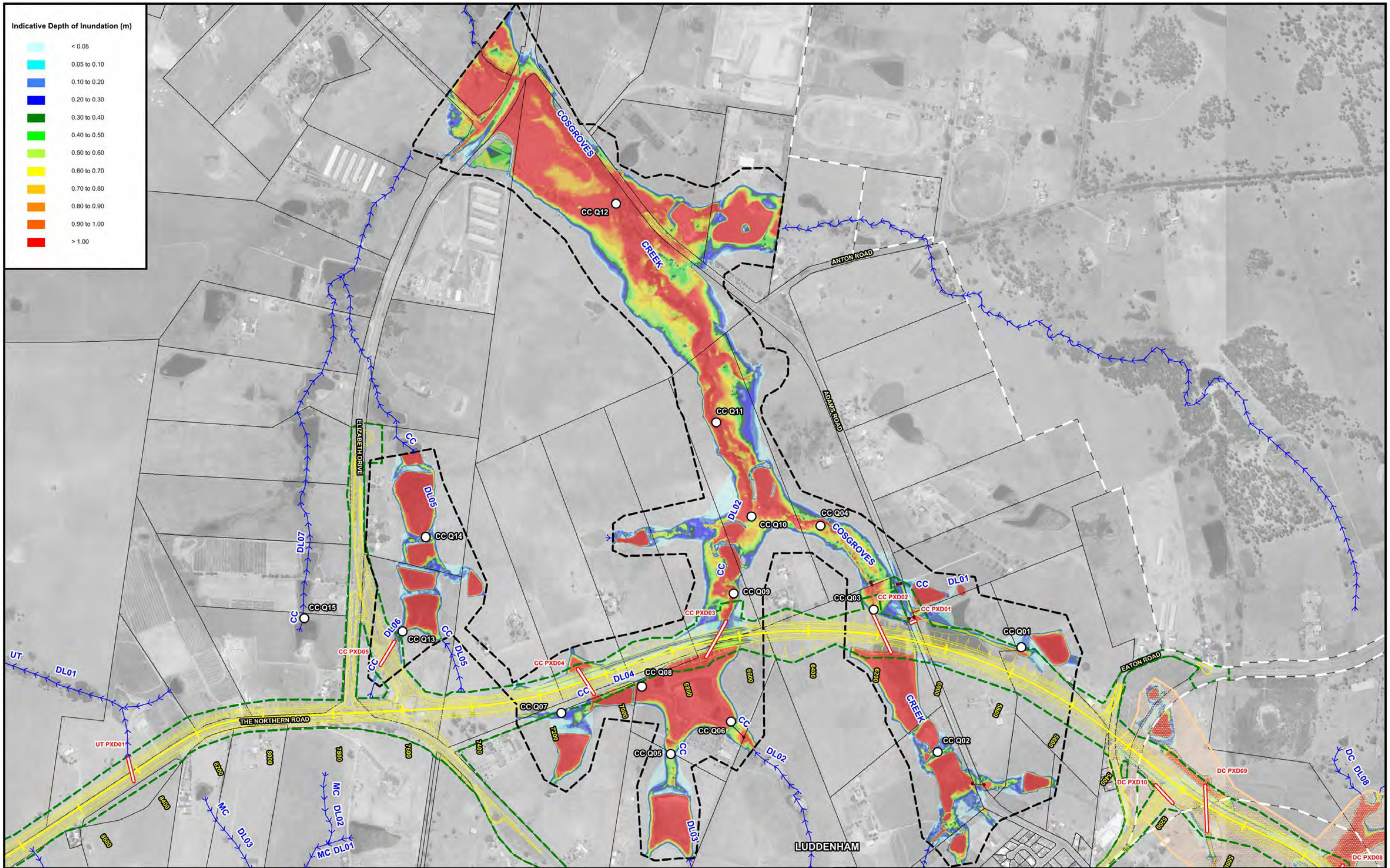
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.3

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - COSGROVES CREEK CATCHMENT
POST-PROJECT CONDITIONS - 100 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

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LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.13 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

Project Boundary

CC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

CC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

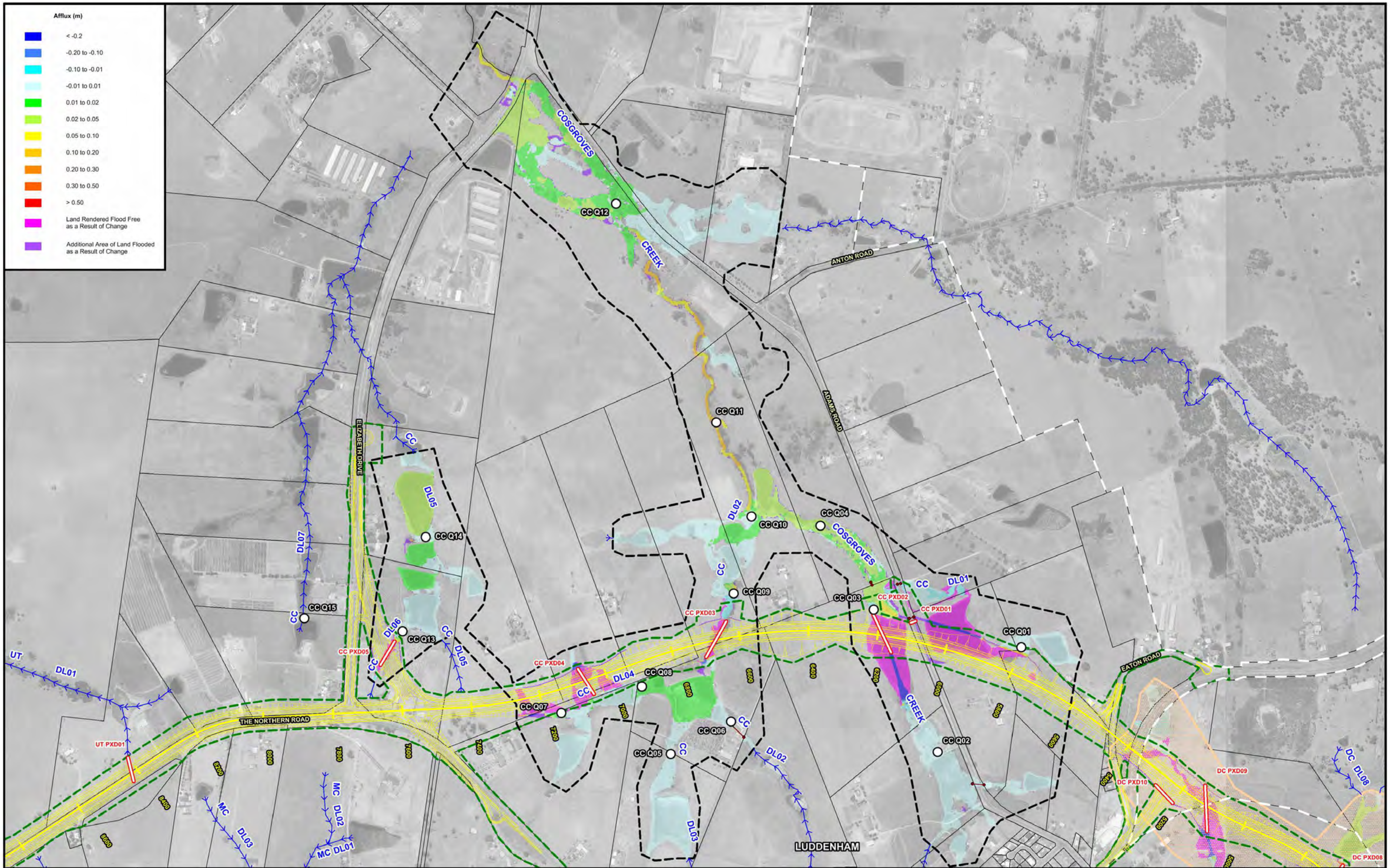
Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

Figure 7.4

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - COSGROVES CREEK CATCHMENT
POST-PROJECT CONDITIONS - PMF



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 7.14 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- CC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary
- Project Boundary
- CC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

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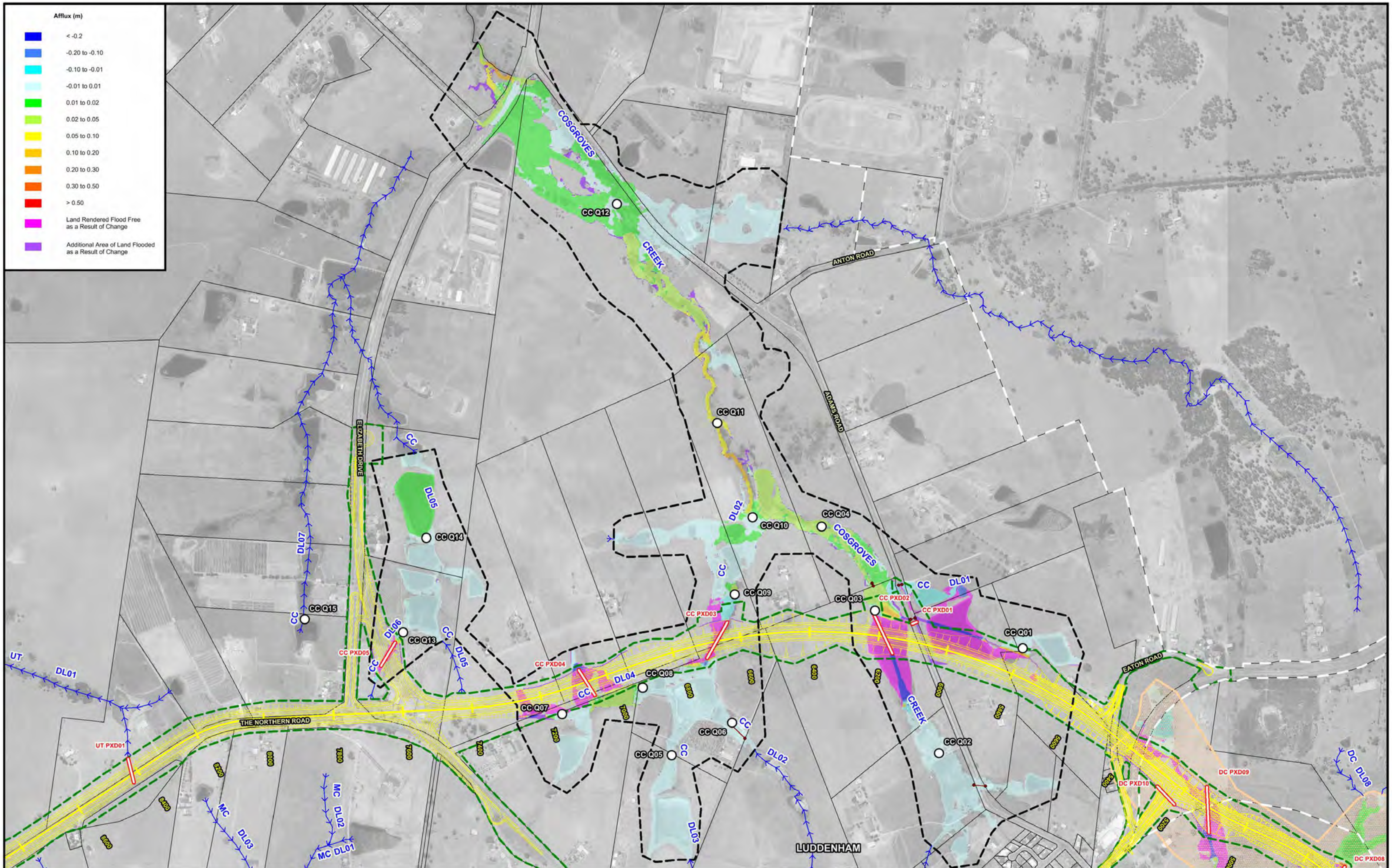
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.5

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
COSGROVES CREEK CATCHMENT - 2 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

Lyall & Associates

LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.15 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

CC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

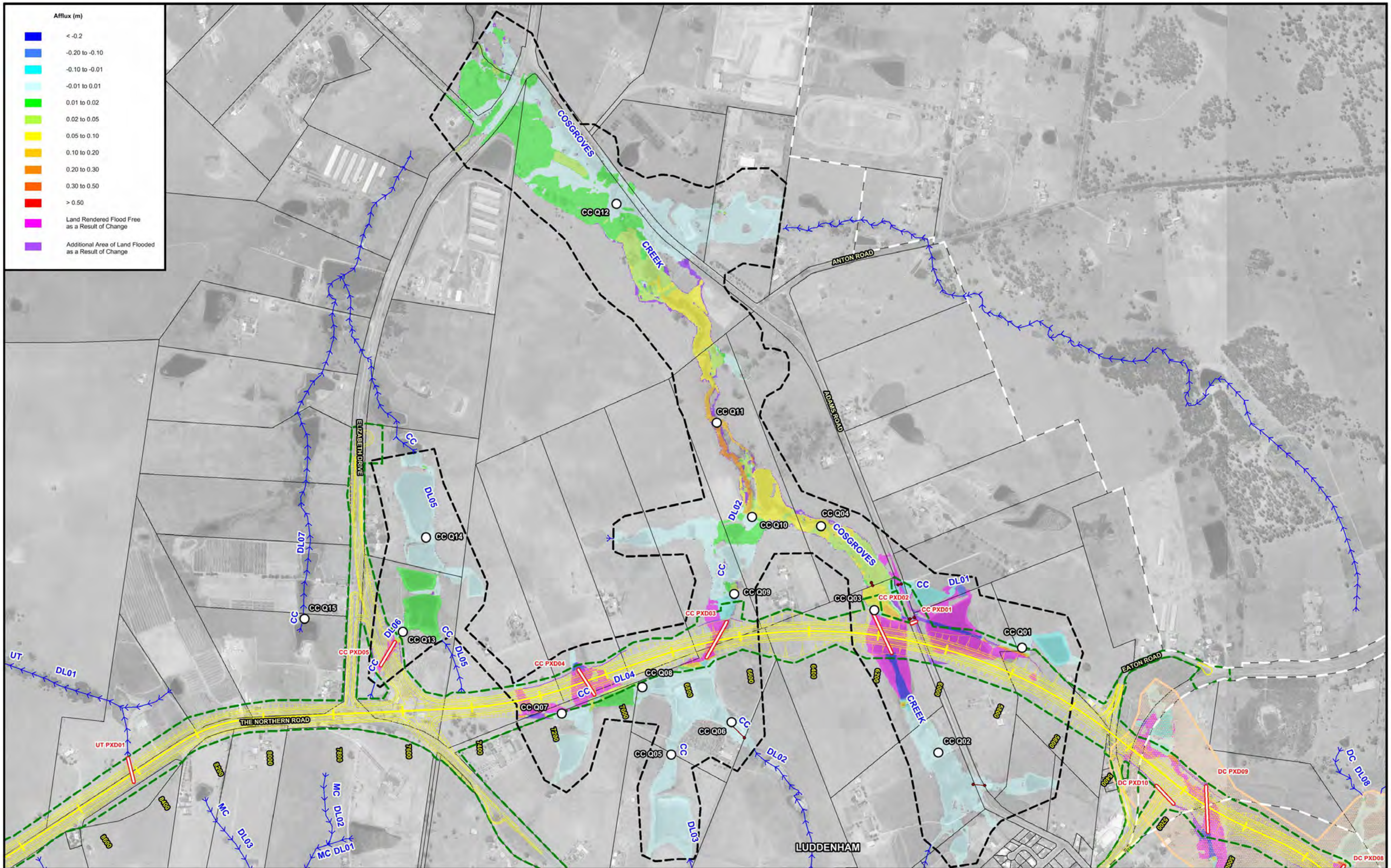
Project Boundary

CC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.6

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
COSGROVES CREEK CATCHMENT - 10 YEAR ARI



N
100 0 100 200 300 m
Scale: 1:10,000

LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 7.16 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- CC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary
- Project Boundary
- CC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

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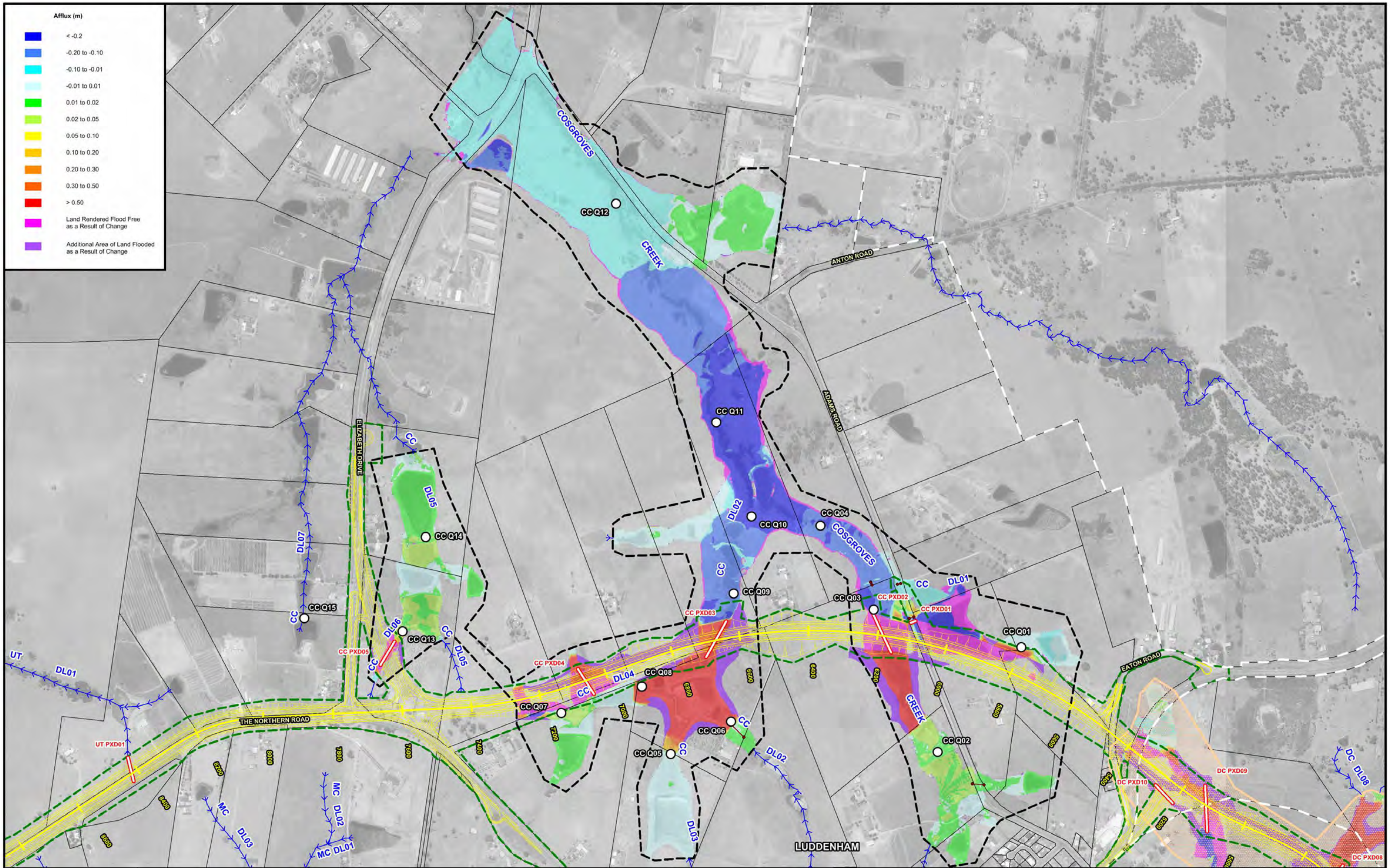
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.7

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
COSGROVES CREEK CATCHMENT - 100 YEAR ARI



LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.17 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

CC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

Project Boundary

CC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

100 0 100 200 300 m

Scale: 1:10,000

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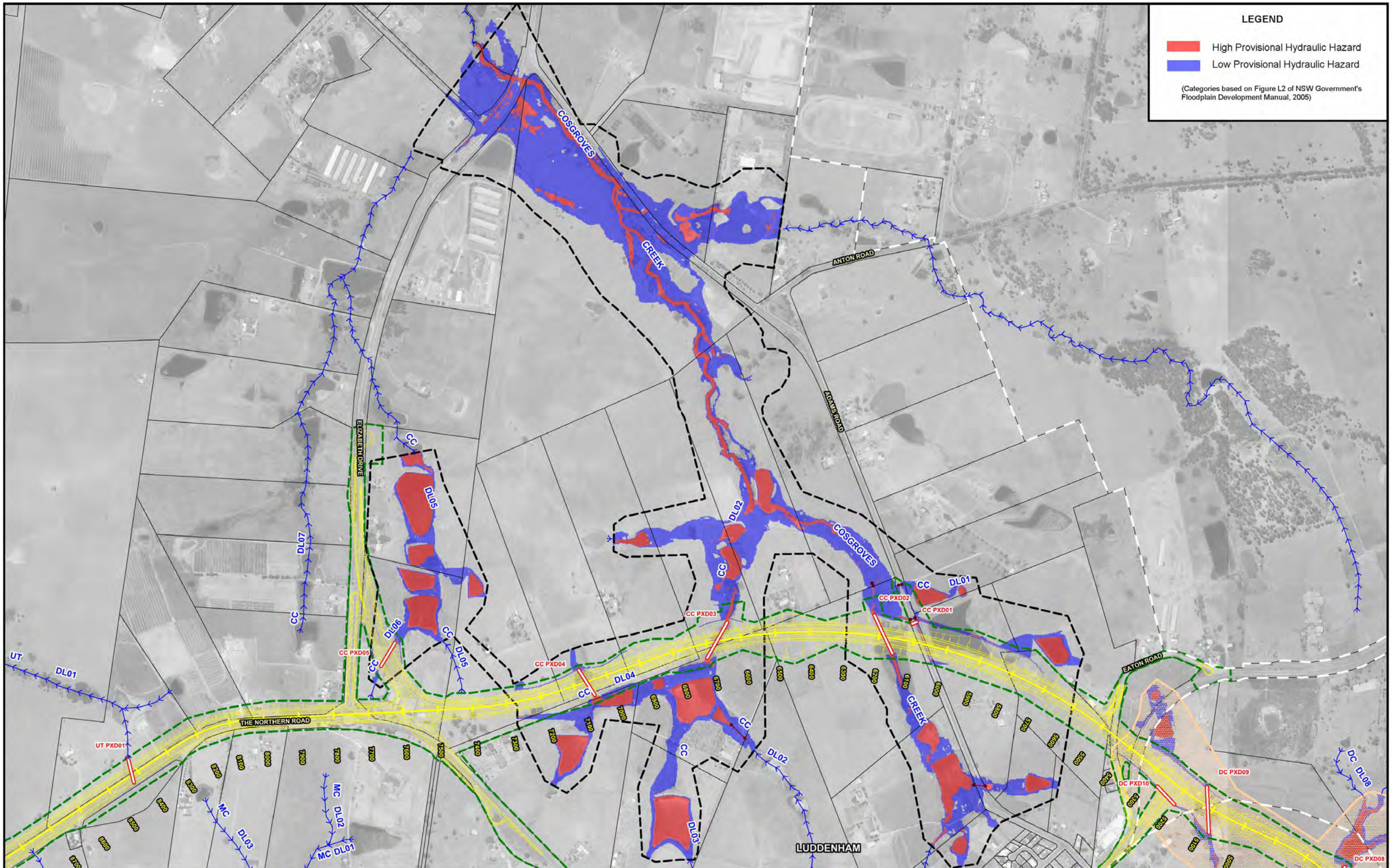
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.8

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
COSGROVES CREEK CATCHMENT - PMF



Scale: 1:10,000 (100 0 100 200 300 m)

LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 7.18 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- Project Boundary
- CC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary

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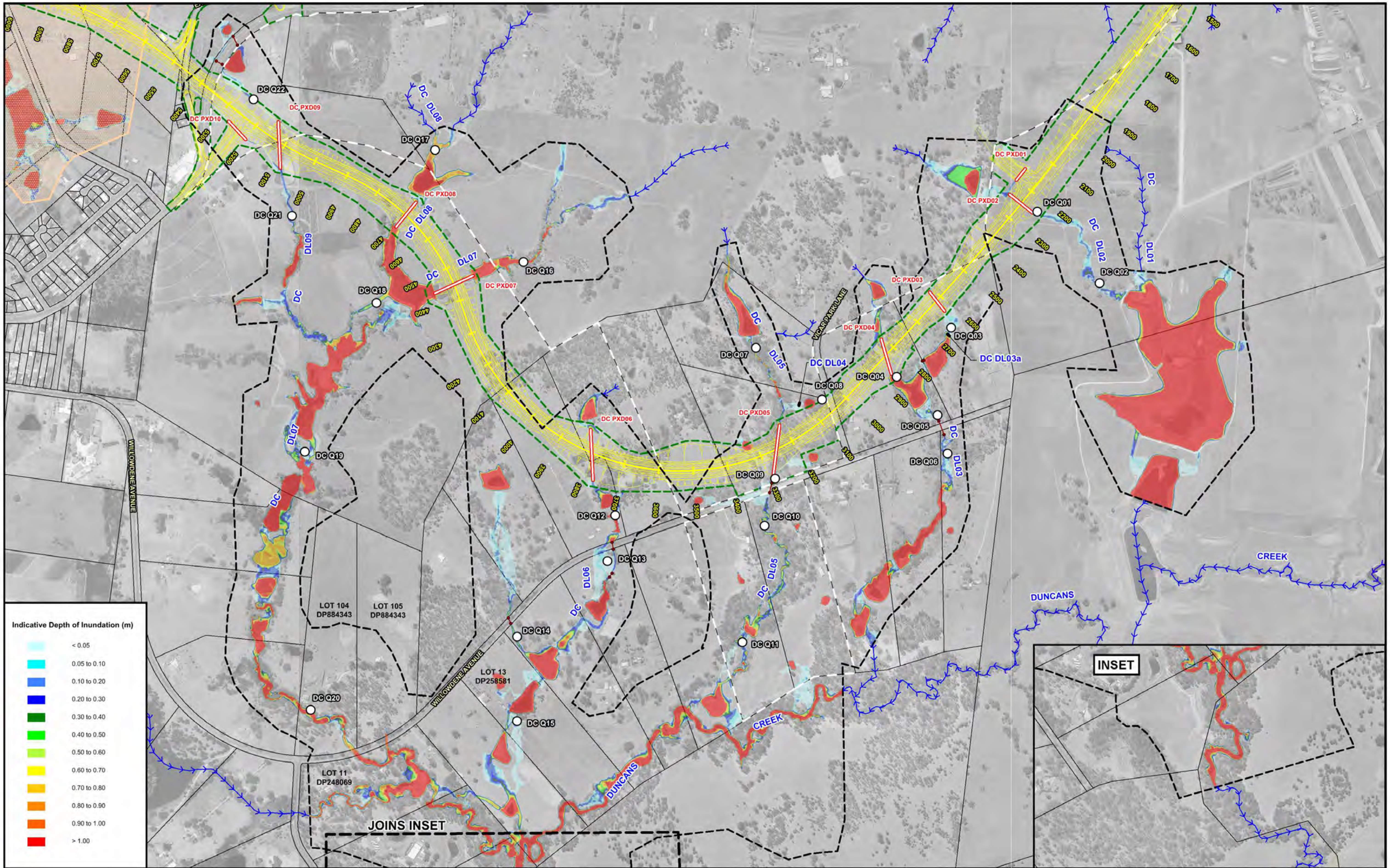
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.9

PROVISIONAL FLOOD HAZARD IN VICINITY OF PROJECT - COSGROVES CREEK CATCHMENT
POST-PROJECT CONDITIONS - 100 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

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LEGEND

Design Road Control String and Chainage

Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.1 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

Project Boundary

DC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

DC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

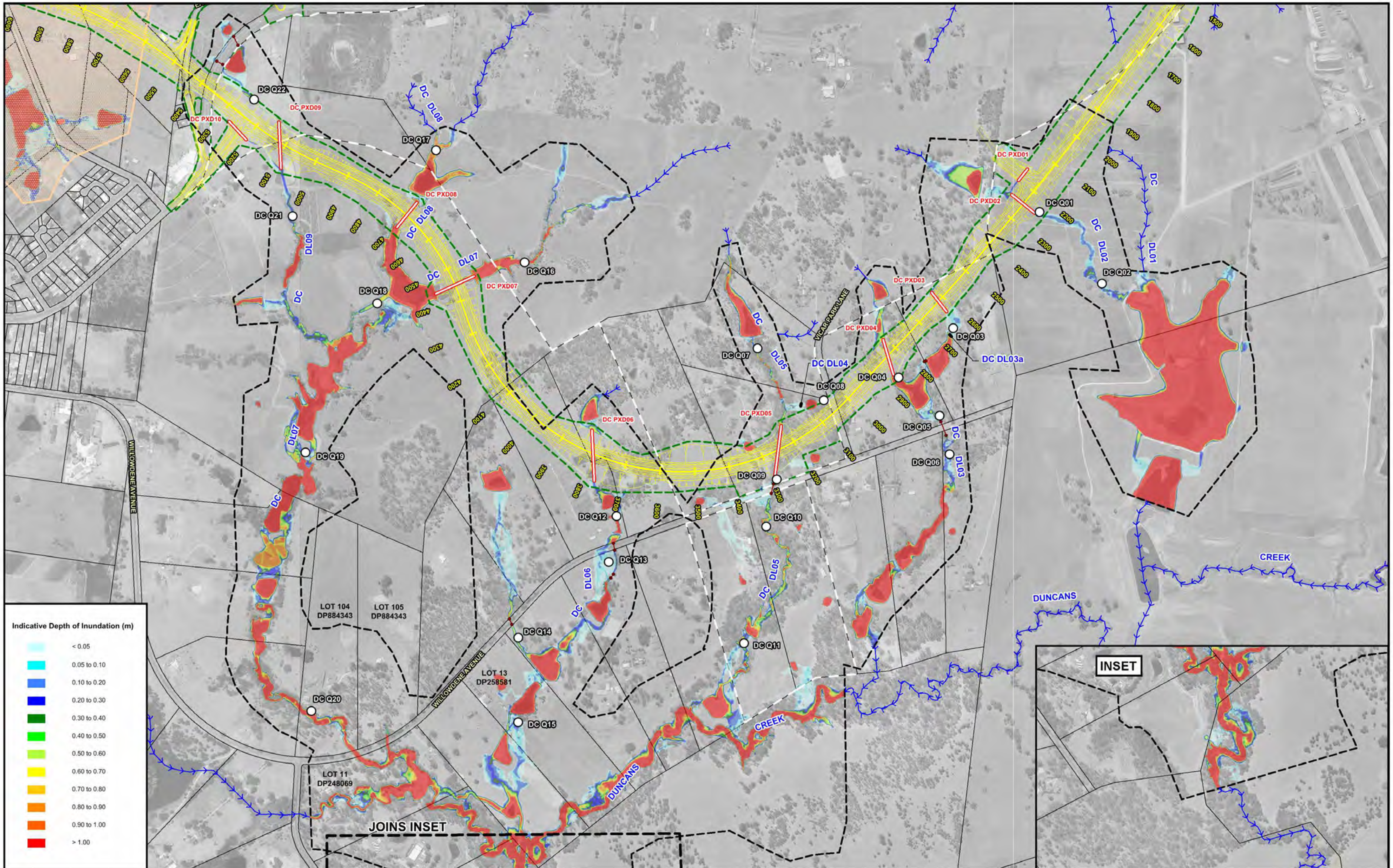
Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

Figure 7.10

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - DUNCANS CREEK CATCHMENT
POST-PROJECT CONDITIONS - 2 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

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LEGEND

Design Road Control String and Chainage

Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.2 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

Project Boundary

DC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

DC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

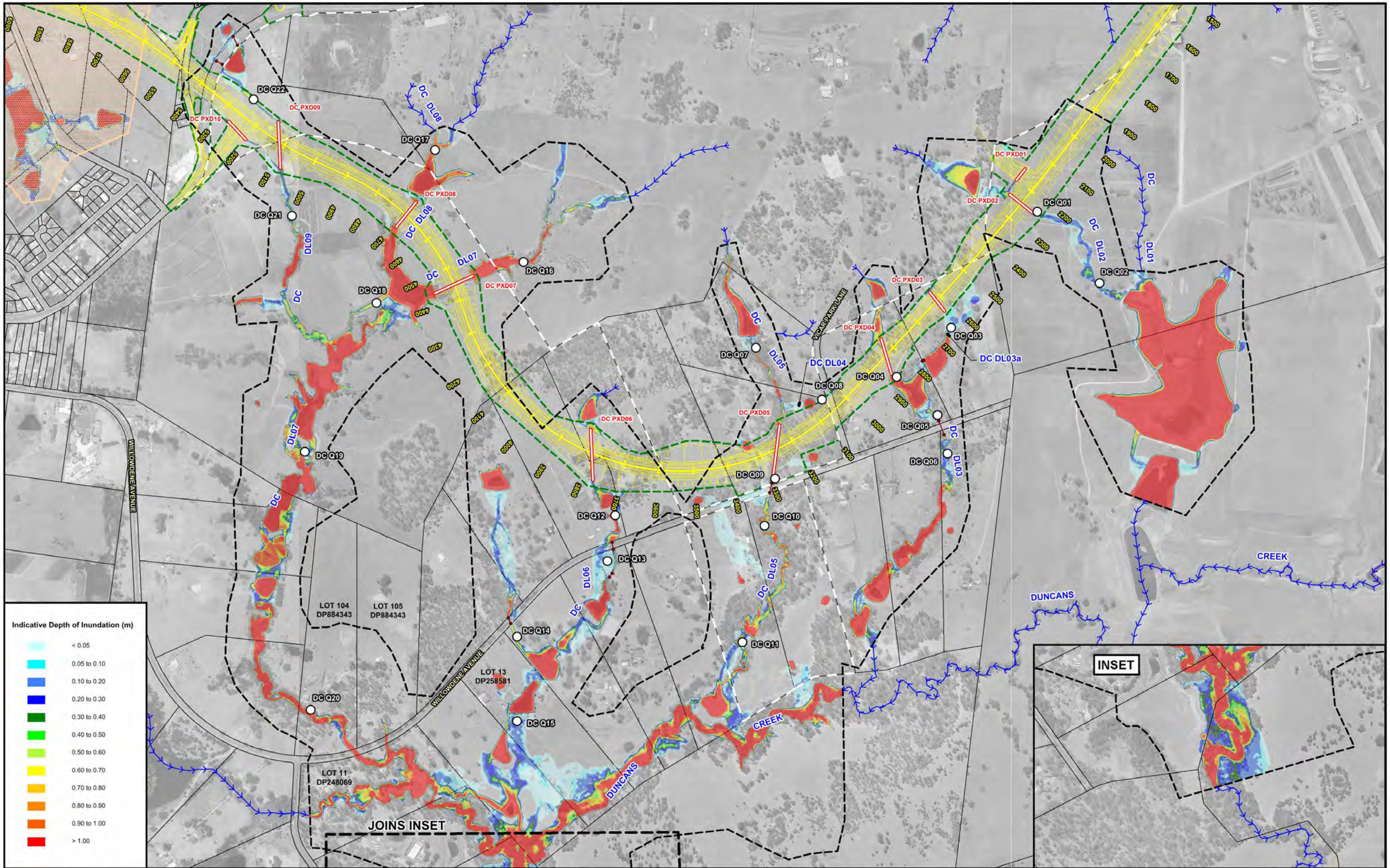
Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.11

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - DUNCANS CREEK CATCHMENT
POST-PROJECT CONDITIONS - 10 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

- Design Road Control String and Chainage
- Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.3 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- Project Boundary
- DC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- DC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary

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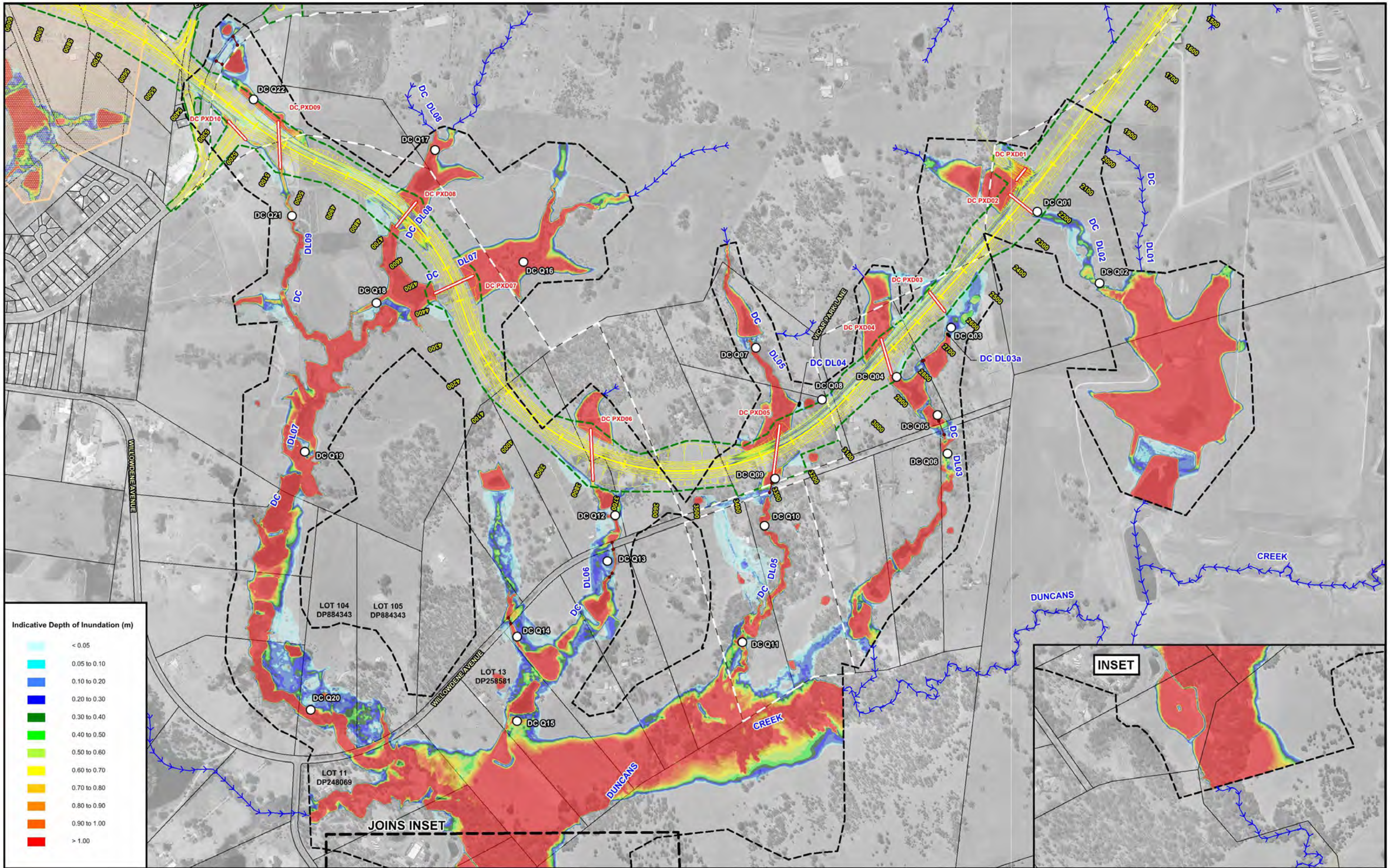
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.12

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - DUNCANS CREEK CATCHMENT
POST-PROJECT CONDITIONS - 100 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.4 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

Project Boundary

DC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

DC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

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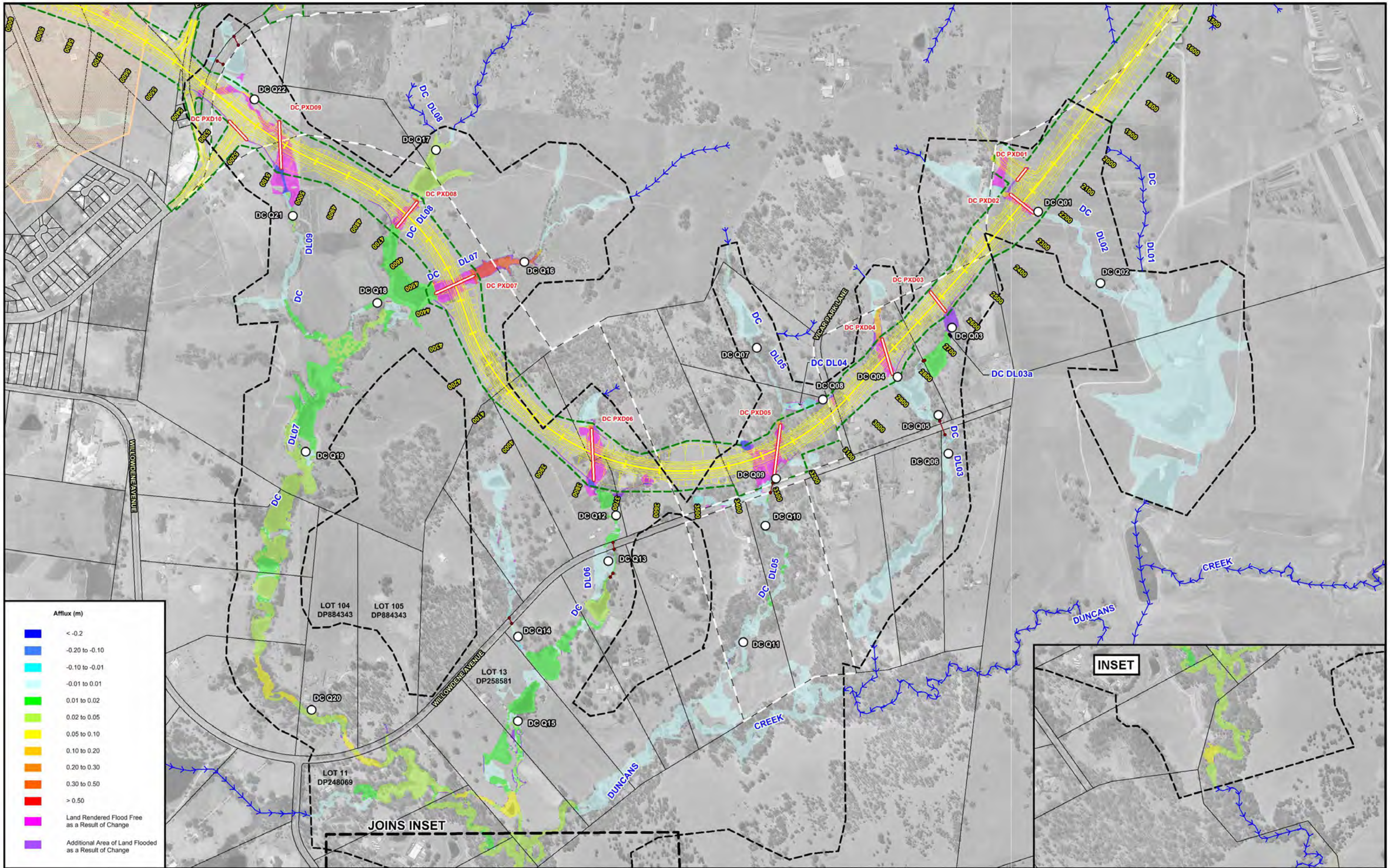
THE NORTHERN ROAD UPGRADE FLOOD RISK ASSESSMENT

Figure 7.13

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - DUNCANS CREEK CATCHMENT
POST-PROJECT CONDITIONS - PMF



Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.5 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

DC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

Project Boundary

DC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

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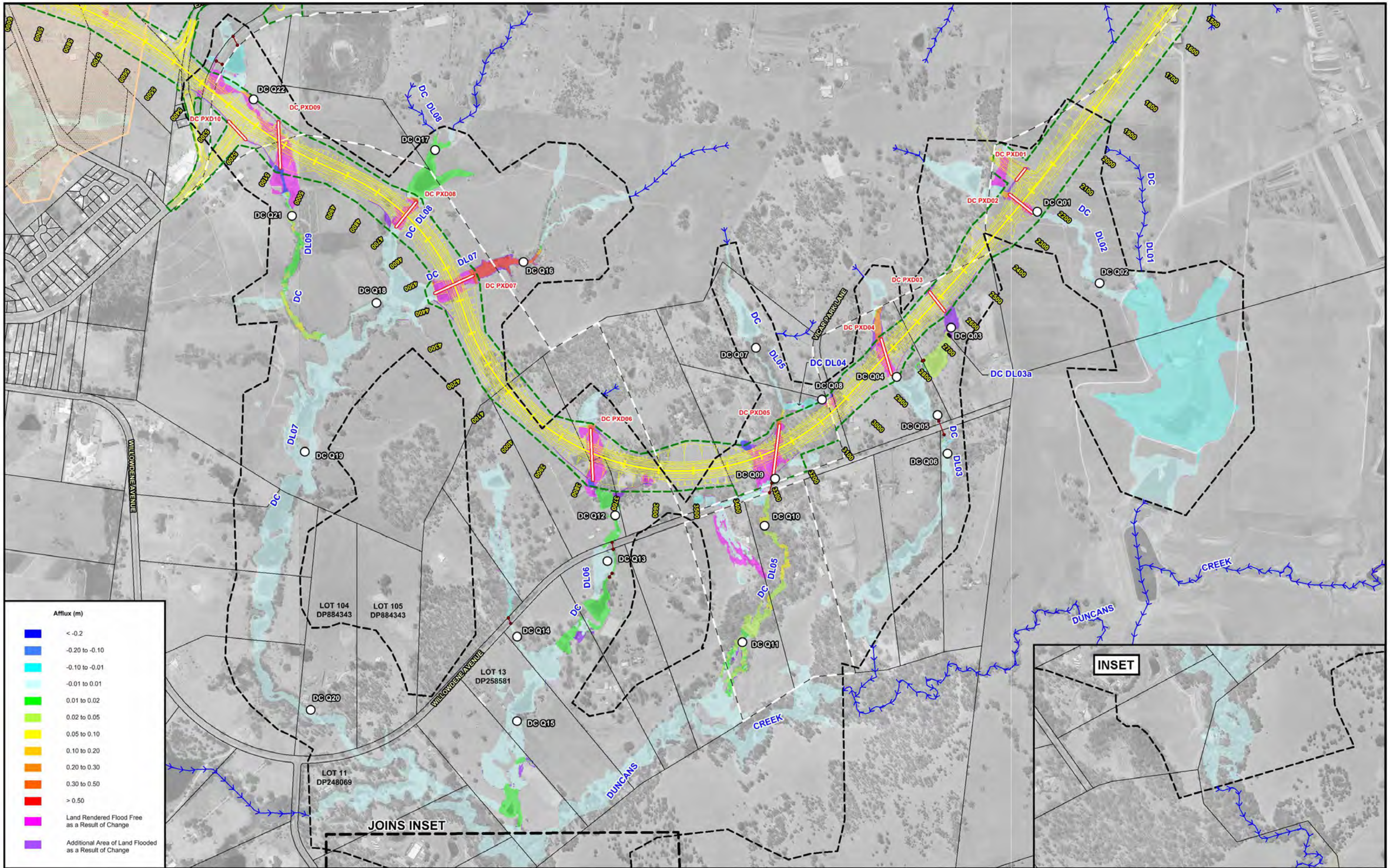
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.14

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
DUNCANS CREEK CATCHMENT - 2 YEAR ARI



LEGEND

- Design Road Control String and Chainage
- Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.6 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- DC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary
- Project Boundary
- DC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

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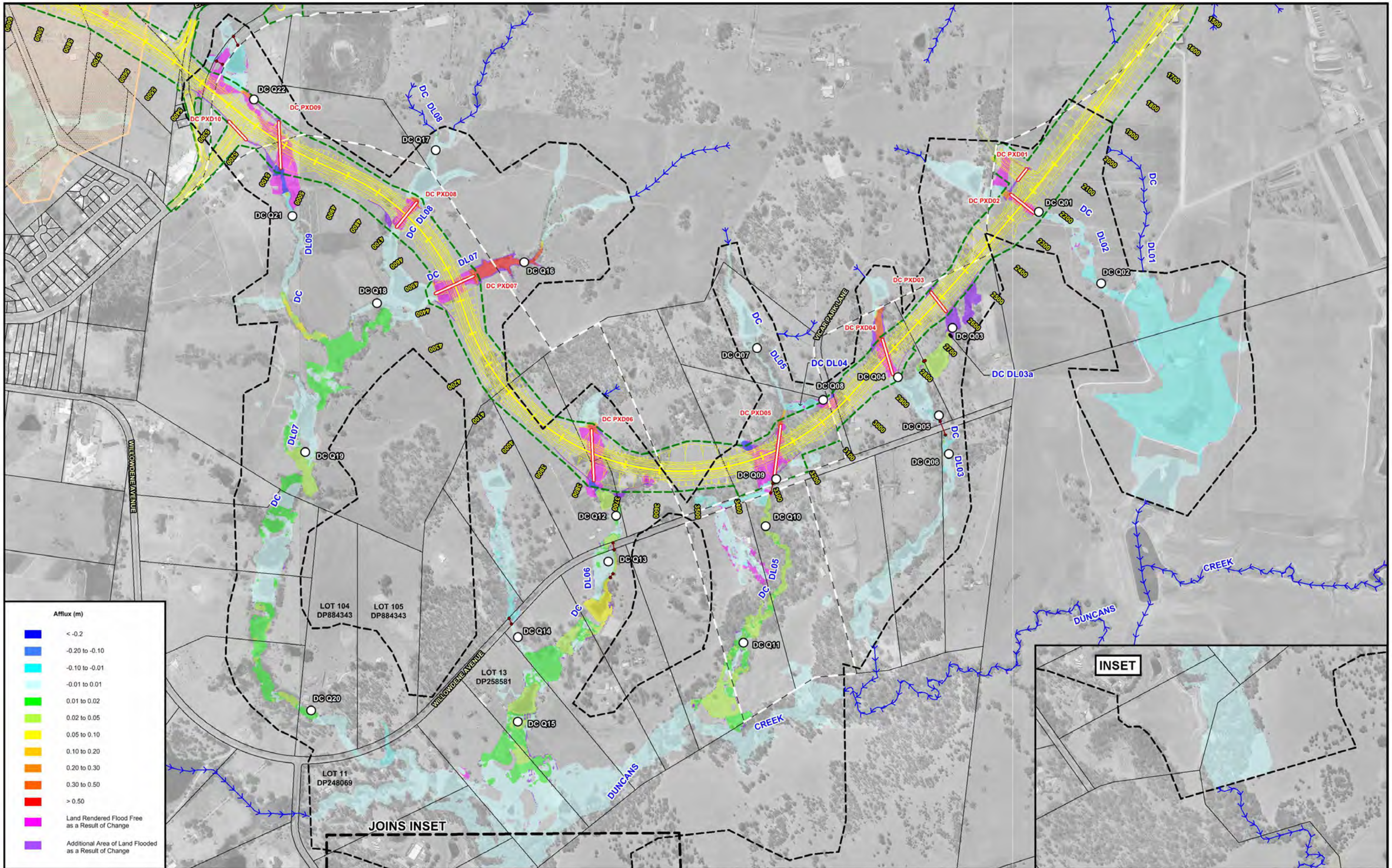
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.15

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
DUNCANS CREEK CATCHMENT - 10 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

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LEGEND

Design Road Control String and Chainage

Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.7 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

DC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

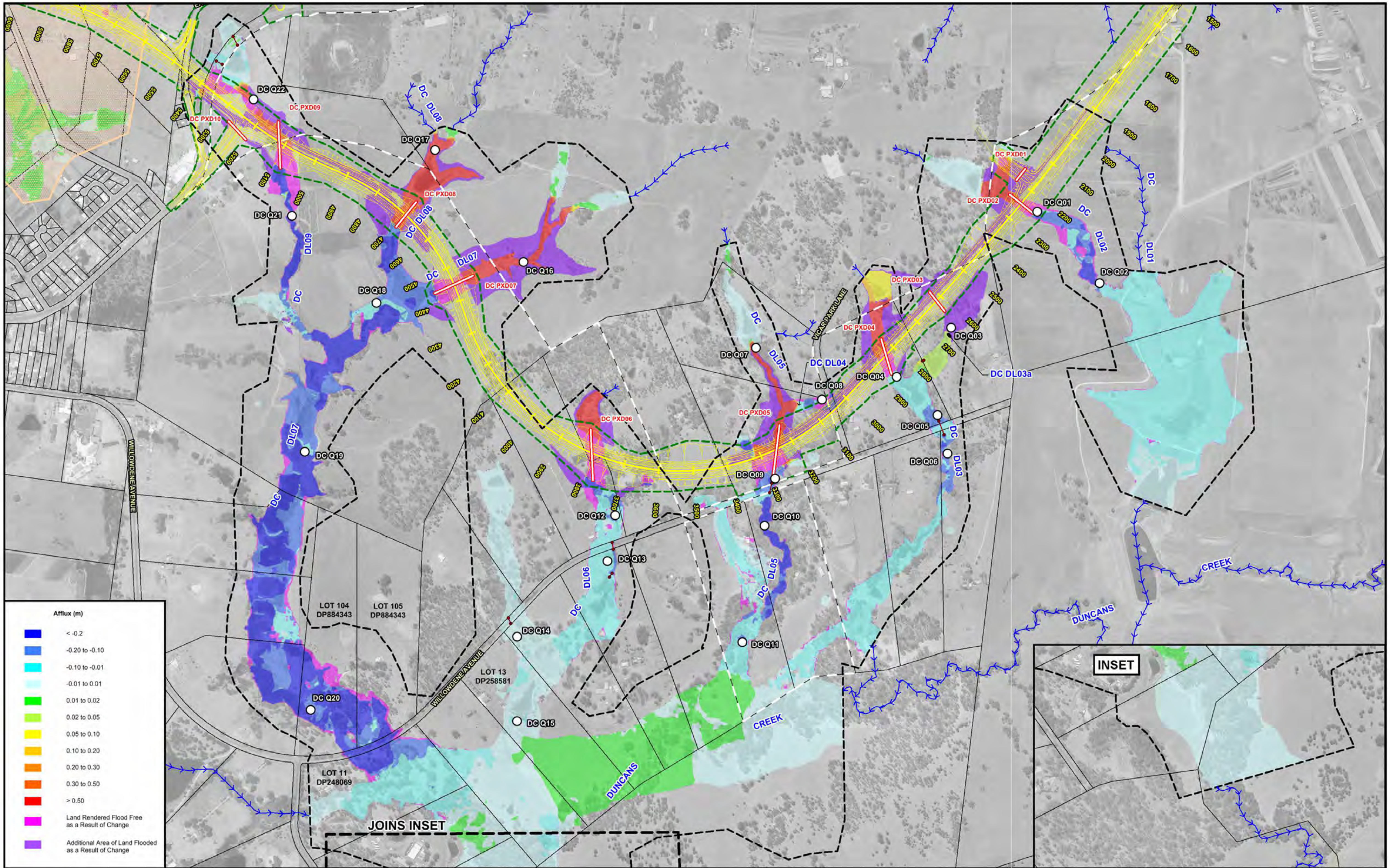
Project Boundary

DC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.16

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
DUNCANS CREEK CATCHMENT - 100 YEAR ARI



Scale: 1:10,000 (100 0 100 200 300 m)

LEGEND

- Design Road Control String and Chainage
- Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.8 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- DC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary
- Project Boundary
- DC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

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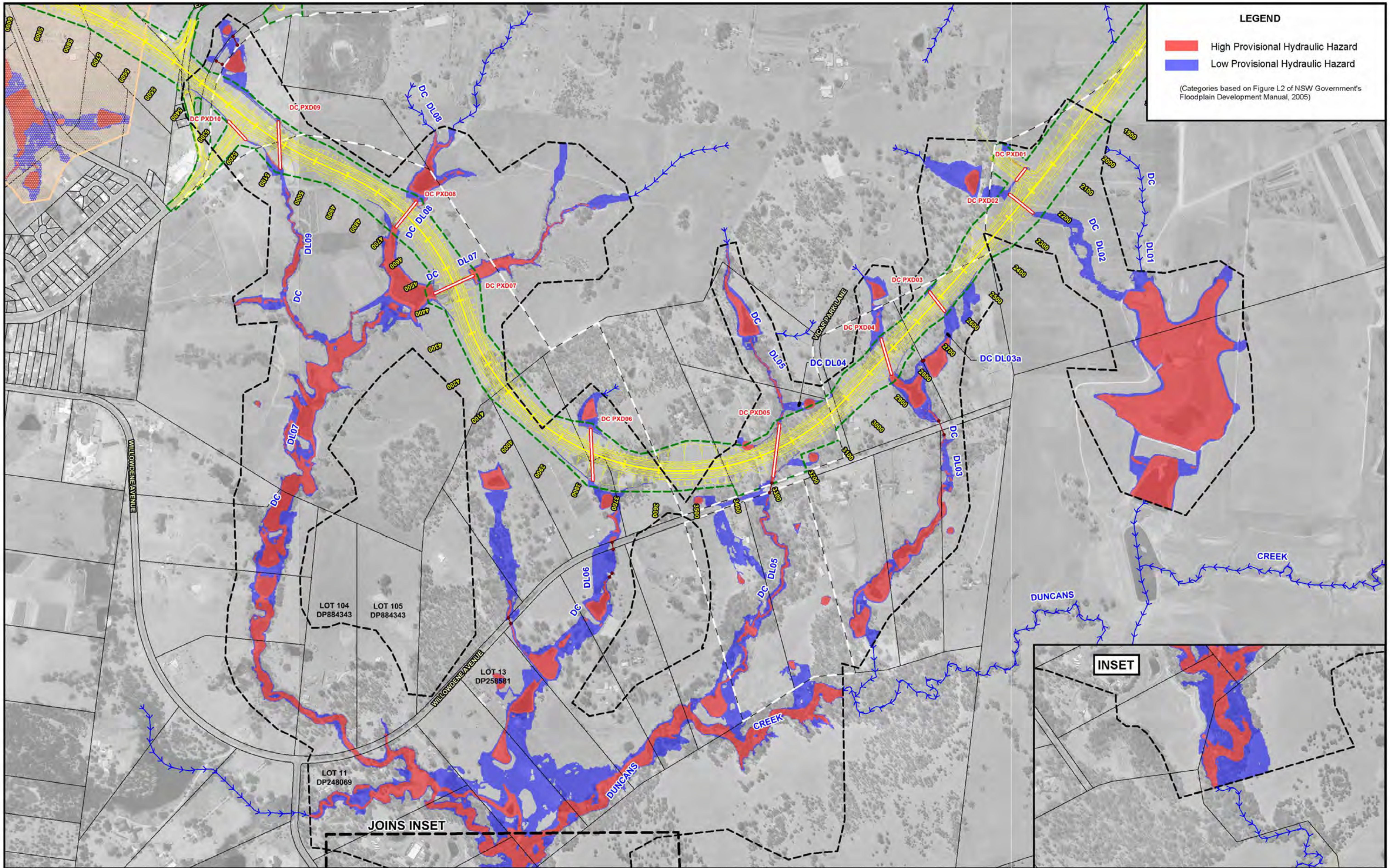
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.17

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
DUNCANS CREEK CATCHMENT - PMF



LEGEND

Scale: 1:10,000

100 0 100 200 300 m

- Design Road Control String and Chainage
- Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.9 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- Project Boundary
- DC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary

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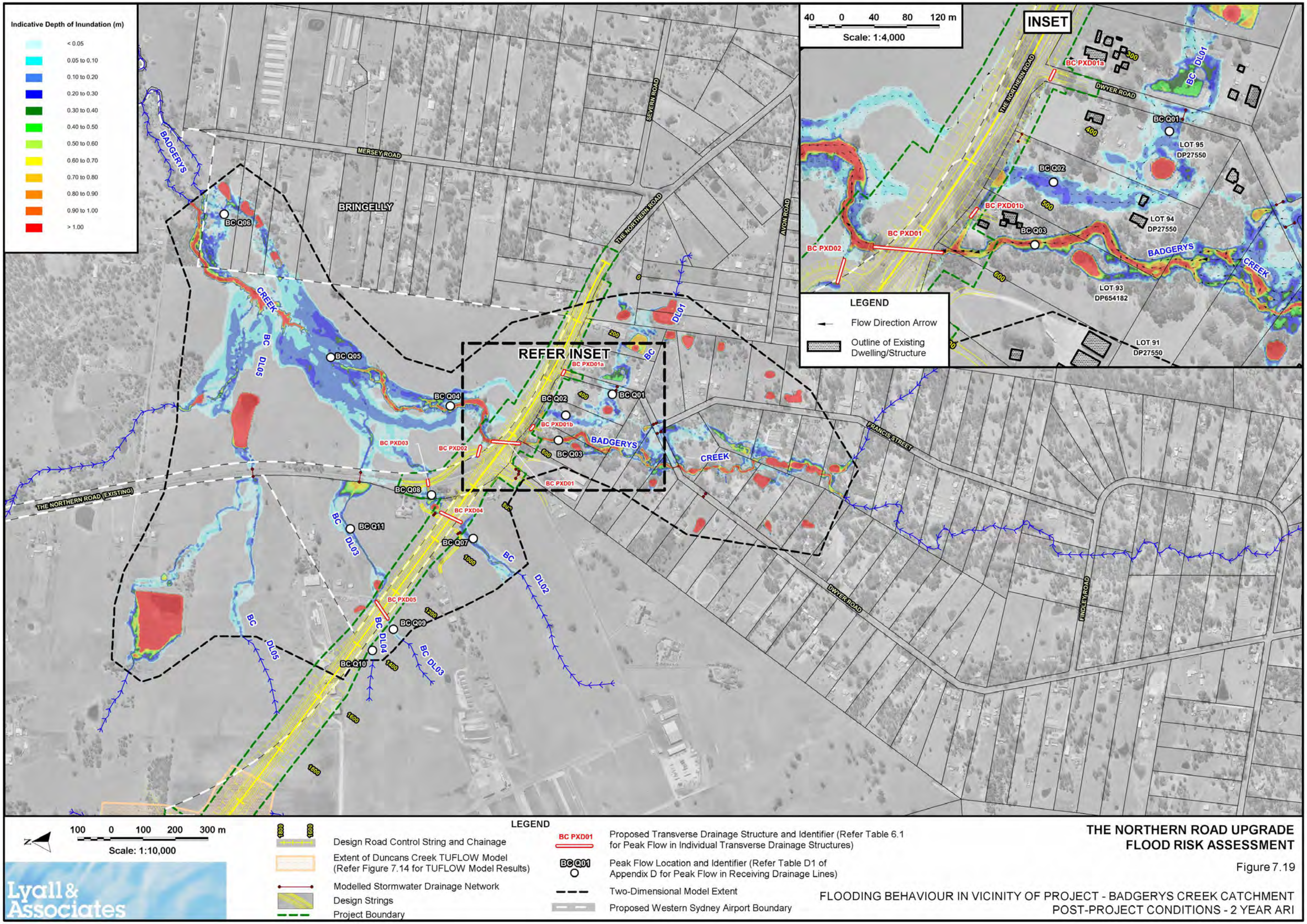
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.18

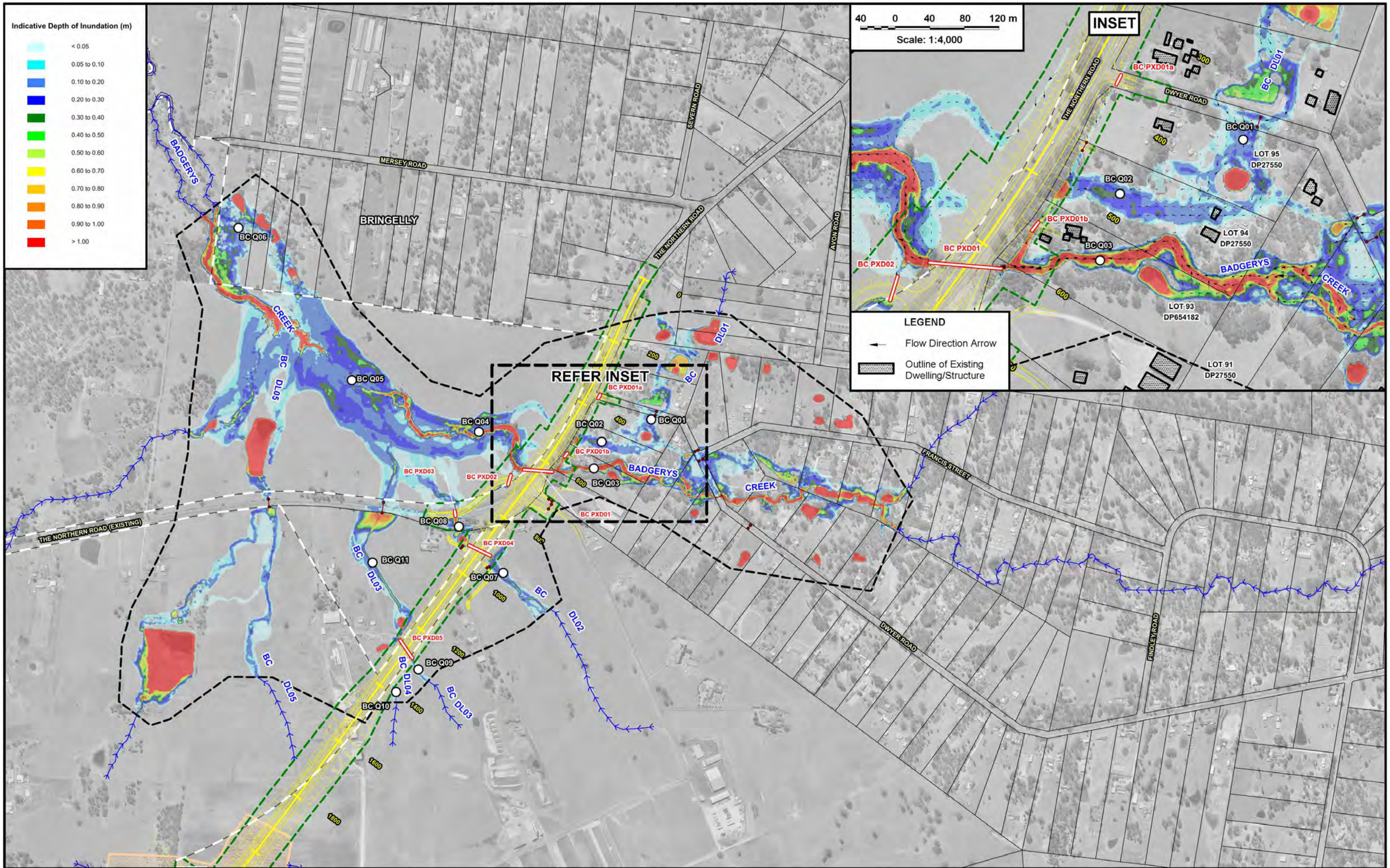
PROVISIONAL FLOOD HAZARD IN VICINITY OF PROJECT - DUNCANS CREEK CATCHMENT
POST-PROJECT CONDITIONS - 100 YEAR ARI



THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.19

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT
POST-PROJECT CONDITIONS - 2 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

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LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.15 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

Project Boundary

BC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

BC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

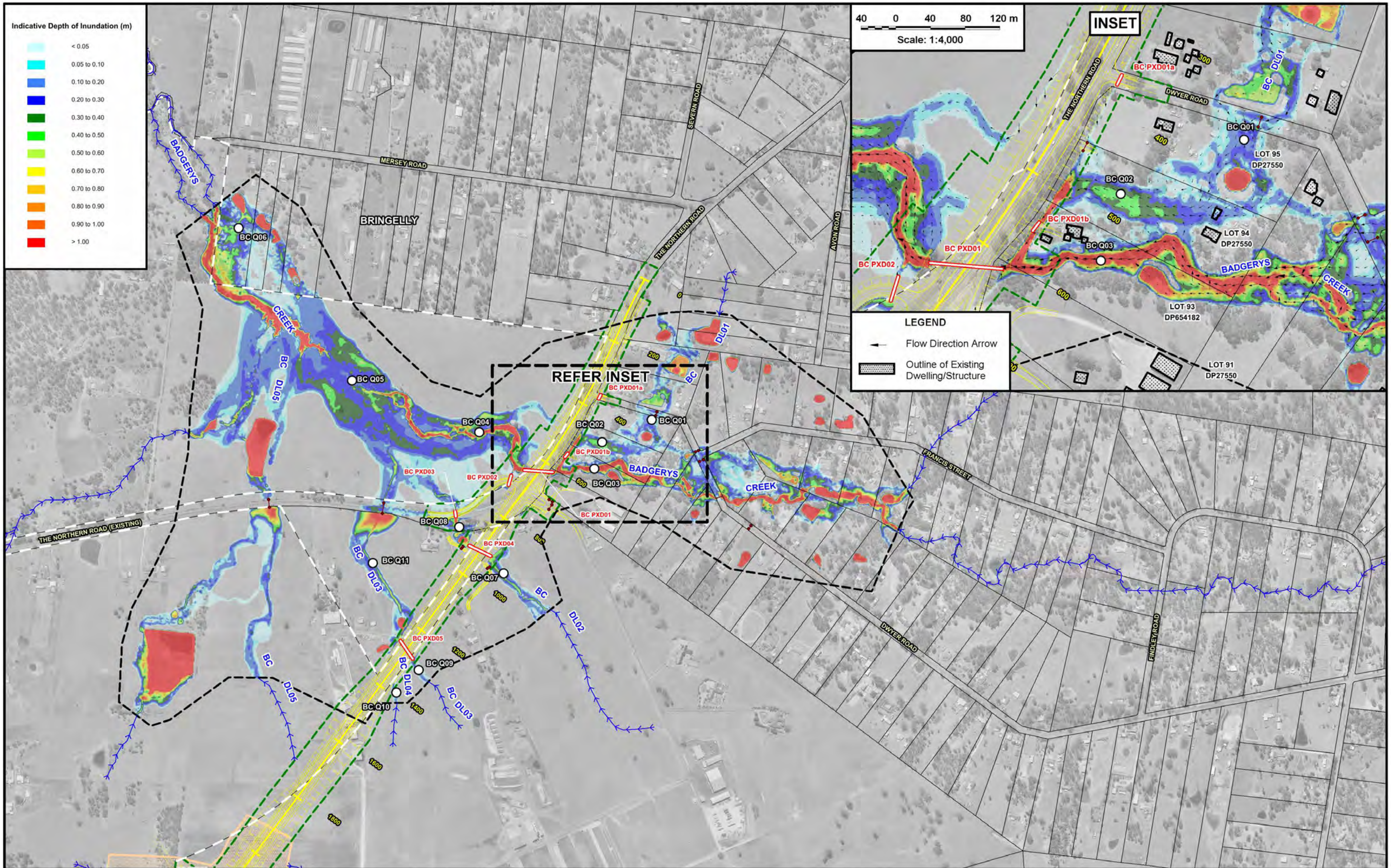
Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.20

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT
POST-PROJECT CONDITIONS - 10 YEAR ARI



Scale: 1:10,000

LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 7.16 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- Project Boundary
- BC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- BC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary

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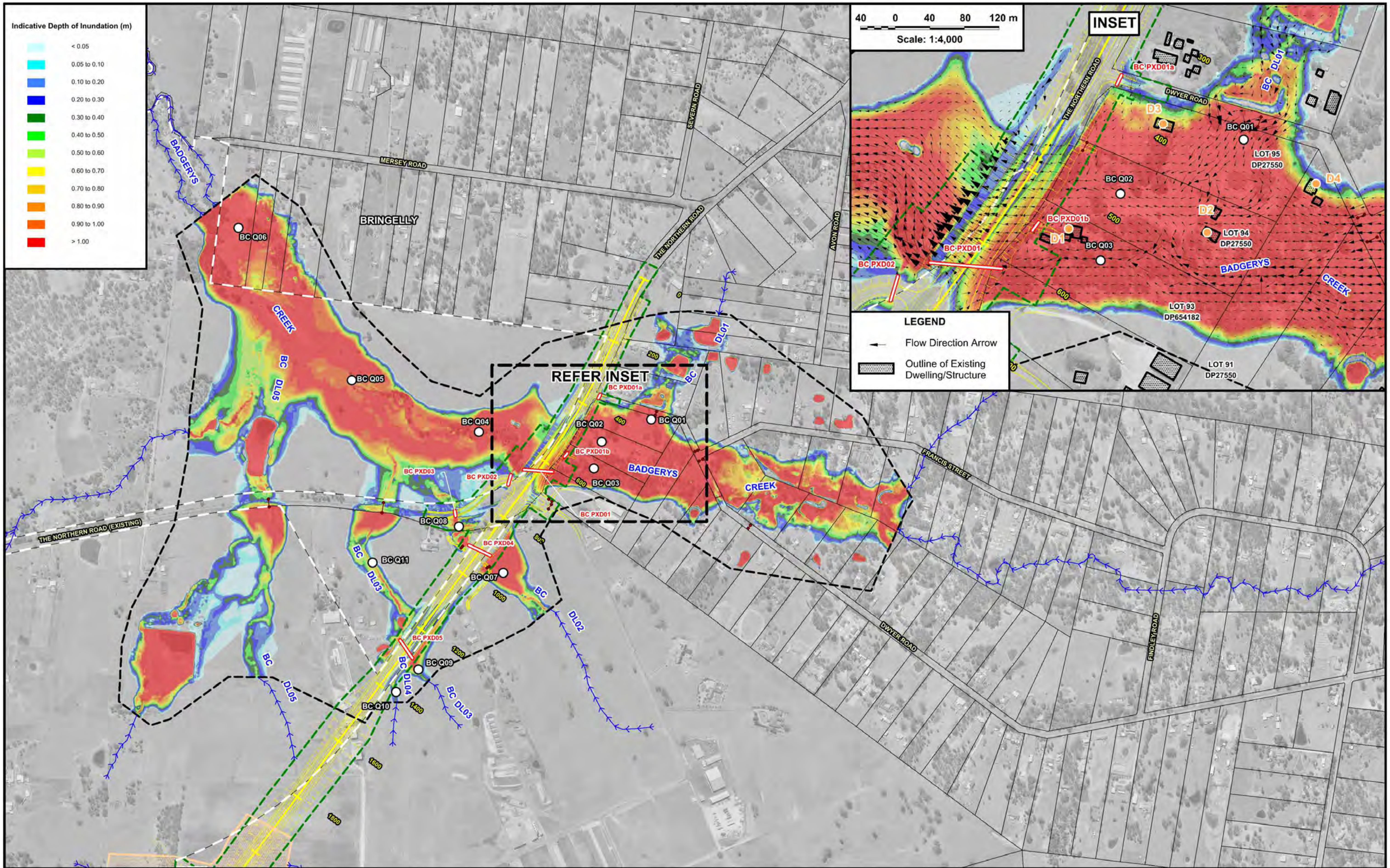
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.21

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT
POST-PROJECT CONDITIONS - 100 YEAR ARI



LEGEND

100 0 100 200 300 m

Scale: 1:10,000

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.17 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

Project Boundary

BC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

BC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

D1 — Dwelling Location and Identifier

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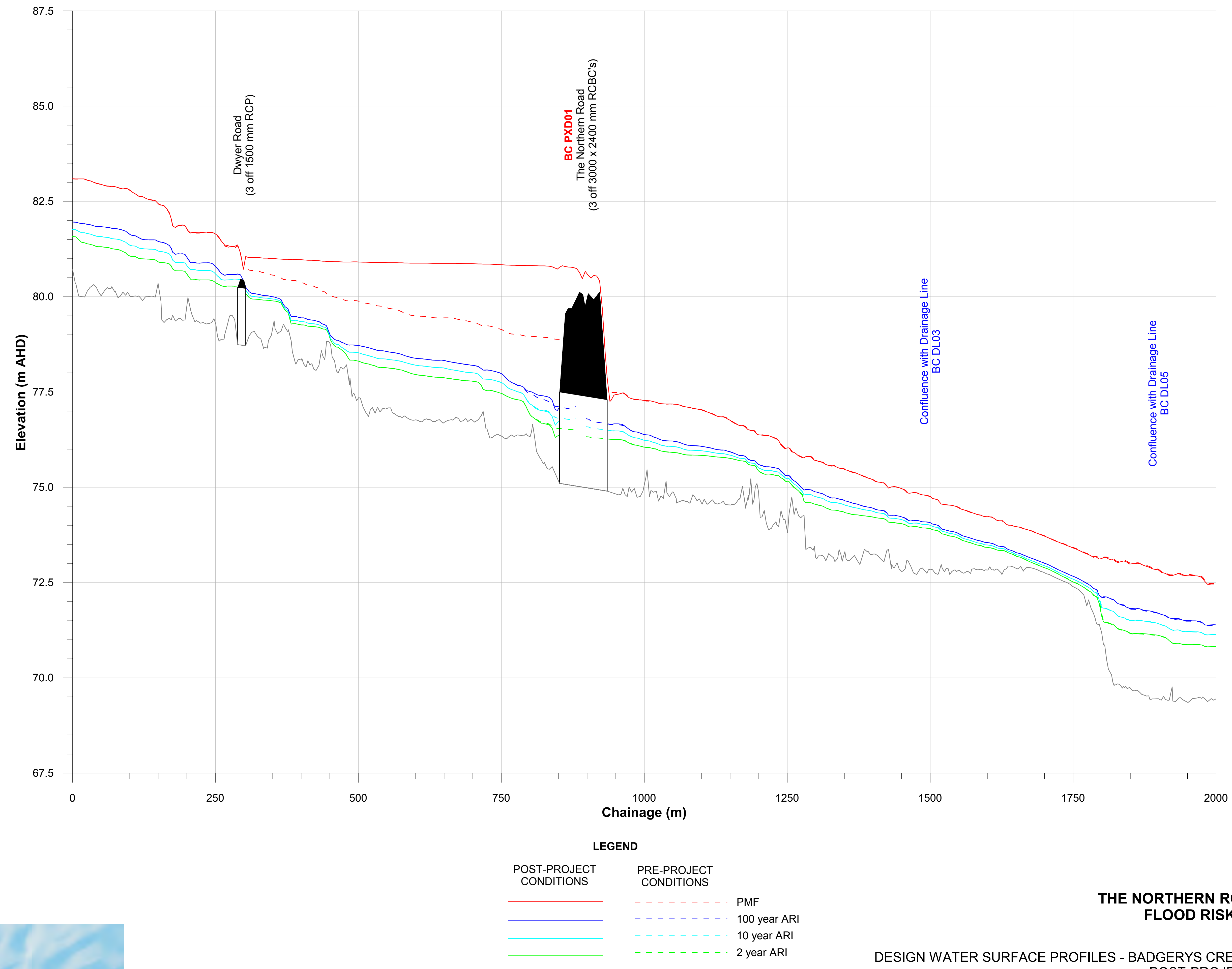
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.22

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT
POST-PROJECT CONDITIONS - PMF



THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.23

DESIGN WATER SURFACE PROFILES - BADGERYS CREEK CATCHMENT
POST-PROJECT CONDITIONS

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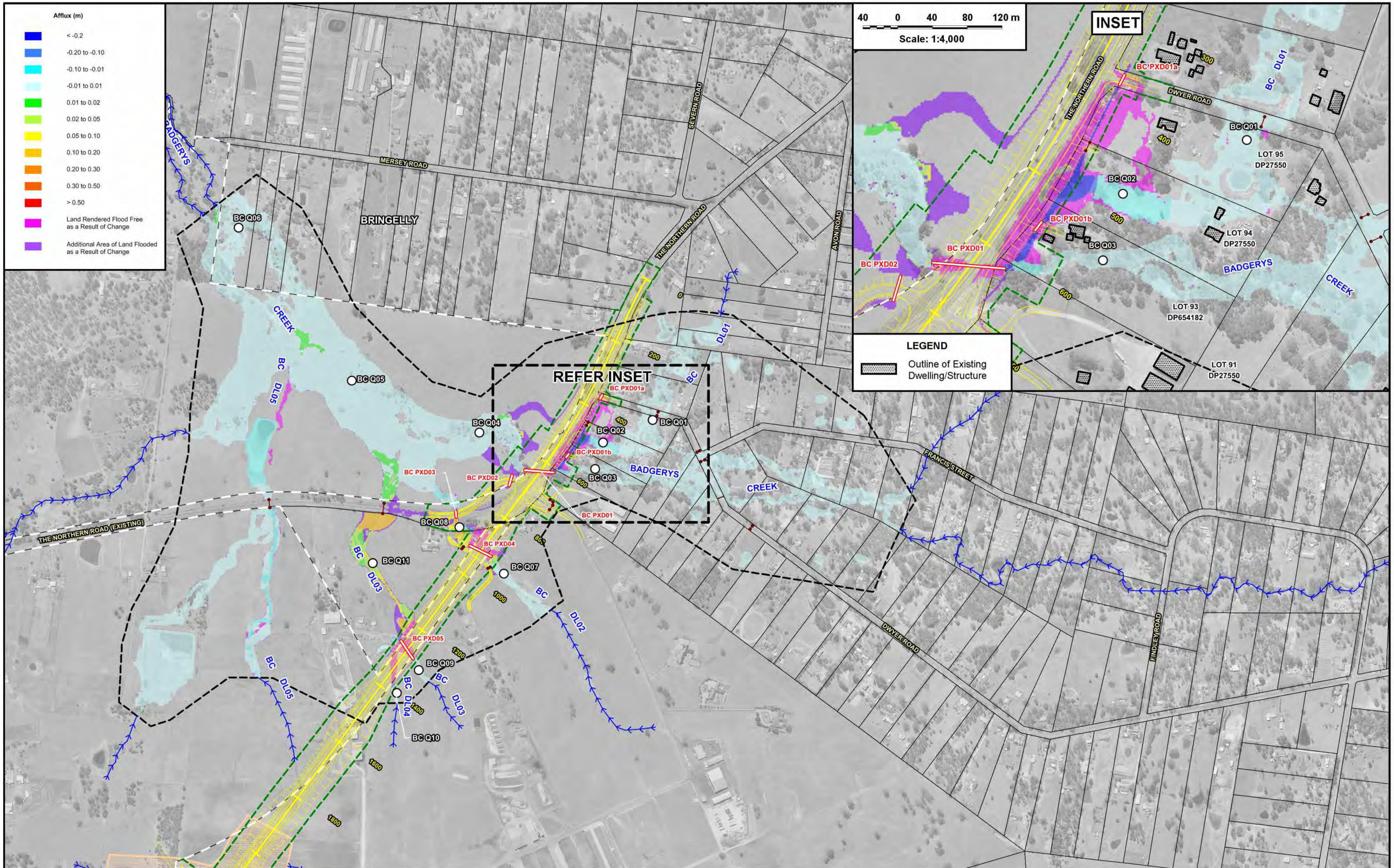

LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 7.17 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- Project Boundary
- BC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- BC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary

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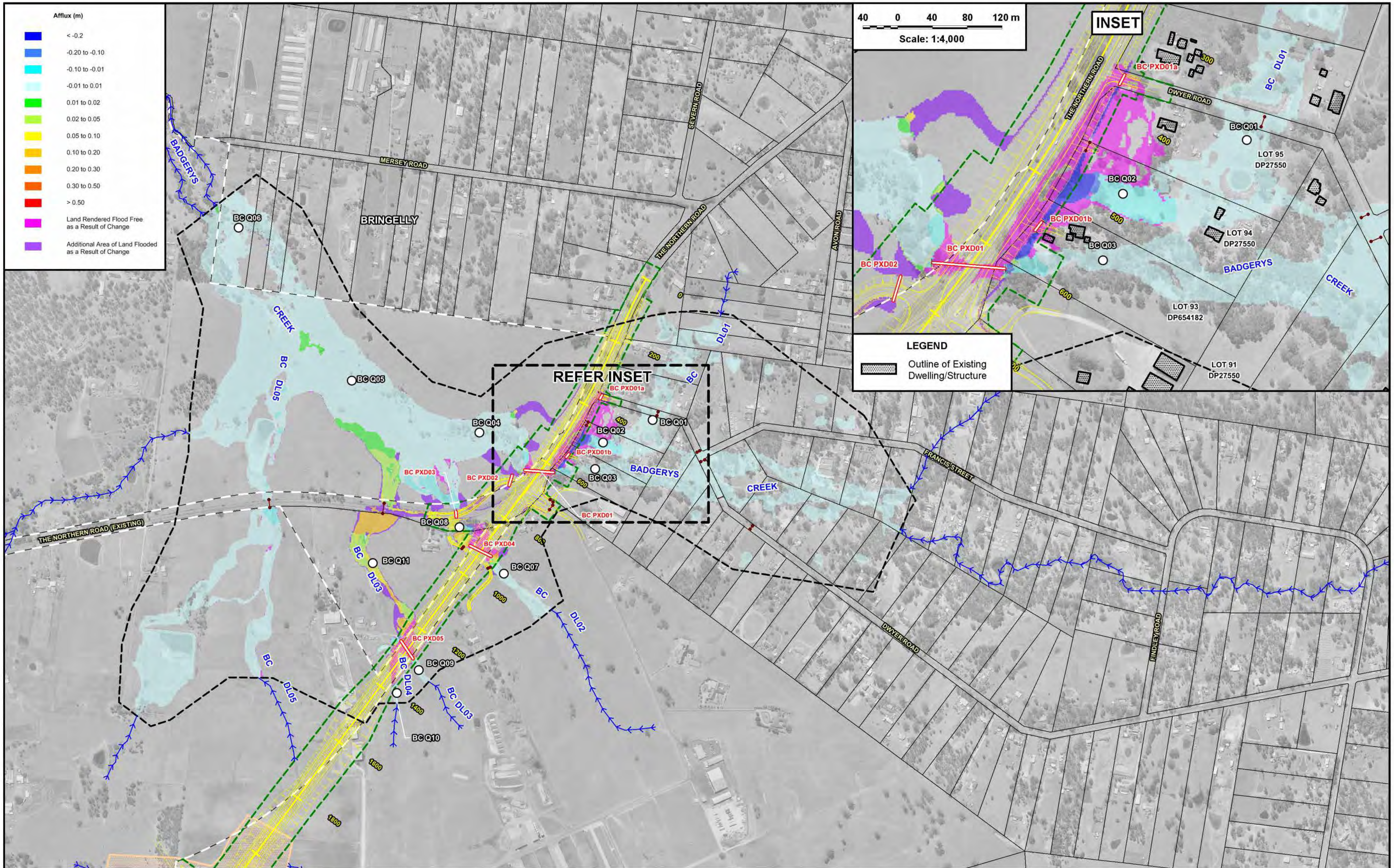
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.24

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
BADGERYS CREEK CATCHMENT - 2 YEAR ARI



LEGEND

Scale: 1:10,000

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 7.17 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- Project Boundary
- BC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- BC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary

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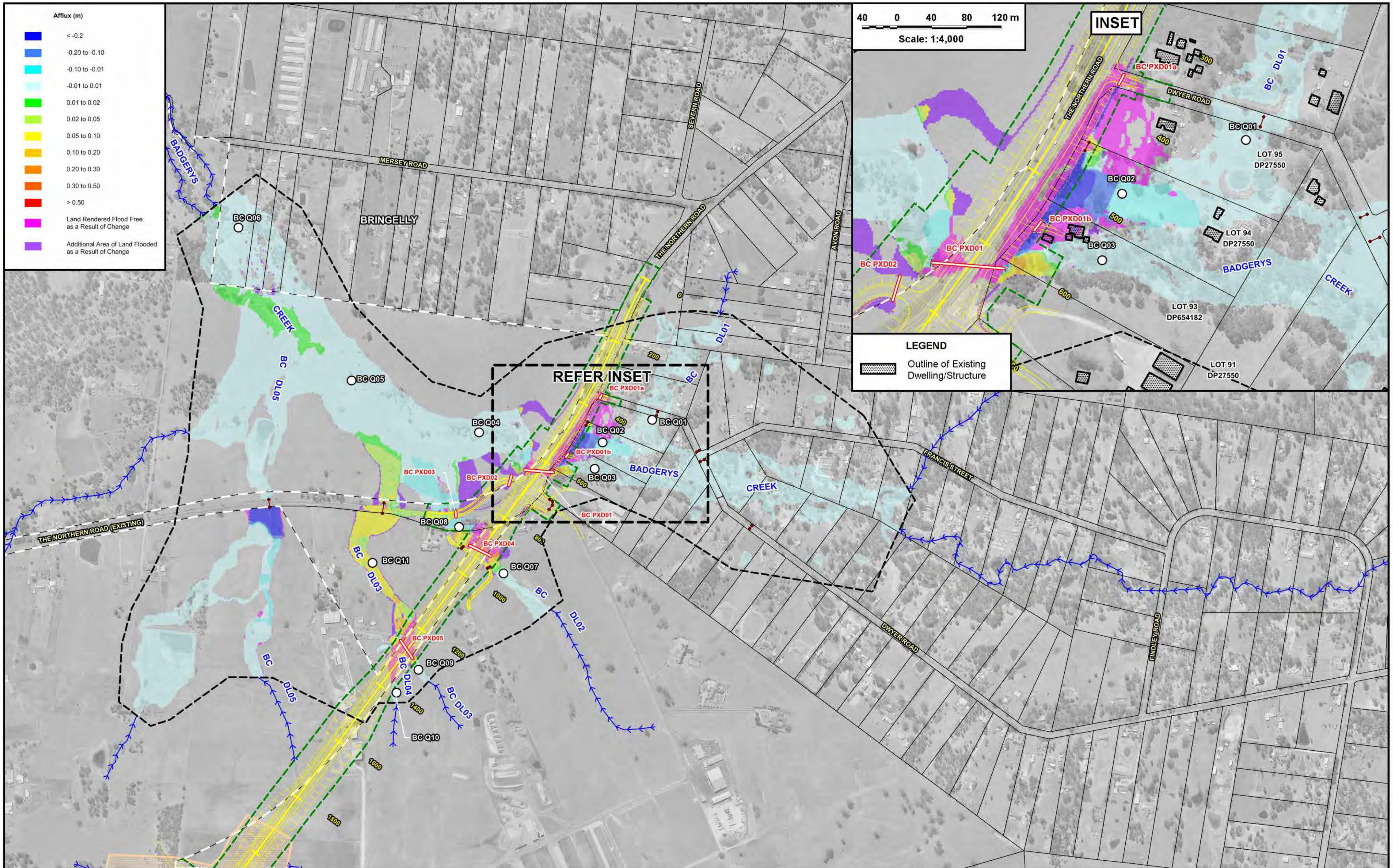
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.25

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
BADGERYS CREEK CATCHMENT - 10 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.17 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

Project Boundary

BC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

BC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

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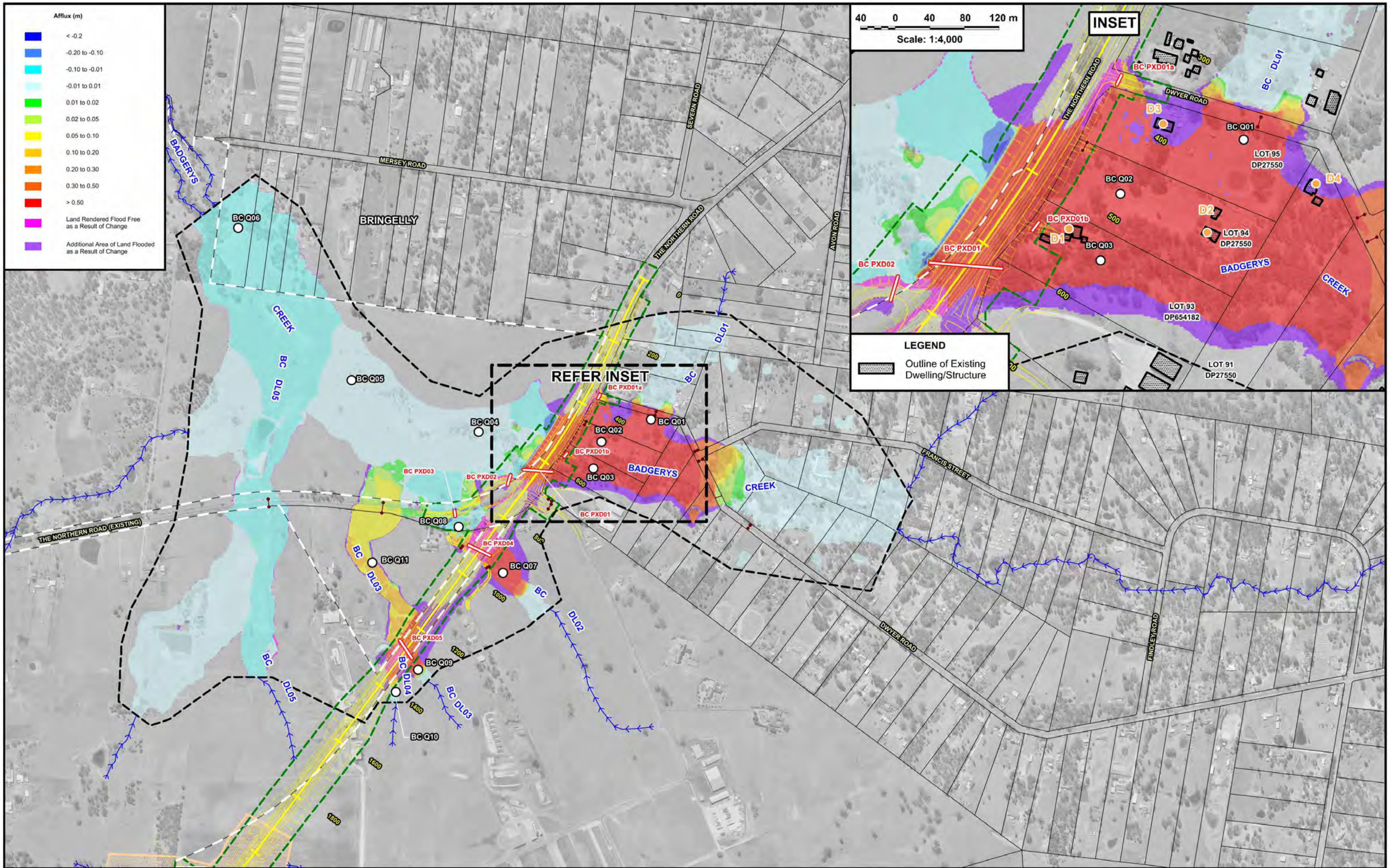
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.26

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
BADGERYS CREEK CATCHMENT - 100 YEAR ARI



100 0 100 200 300 m
Scale: 1:10,000

LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 7.17 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- Project Boundary
- BC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- BC Q01 Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary
- D1 Dwelling Location and Identifier

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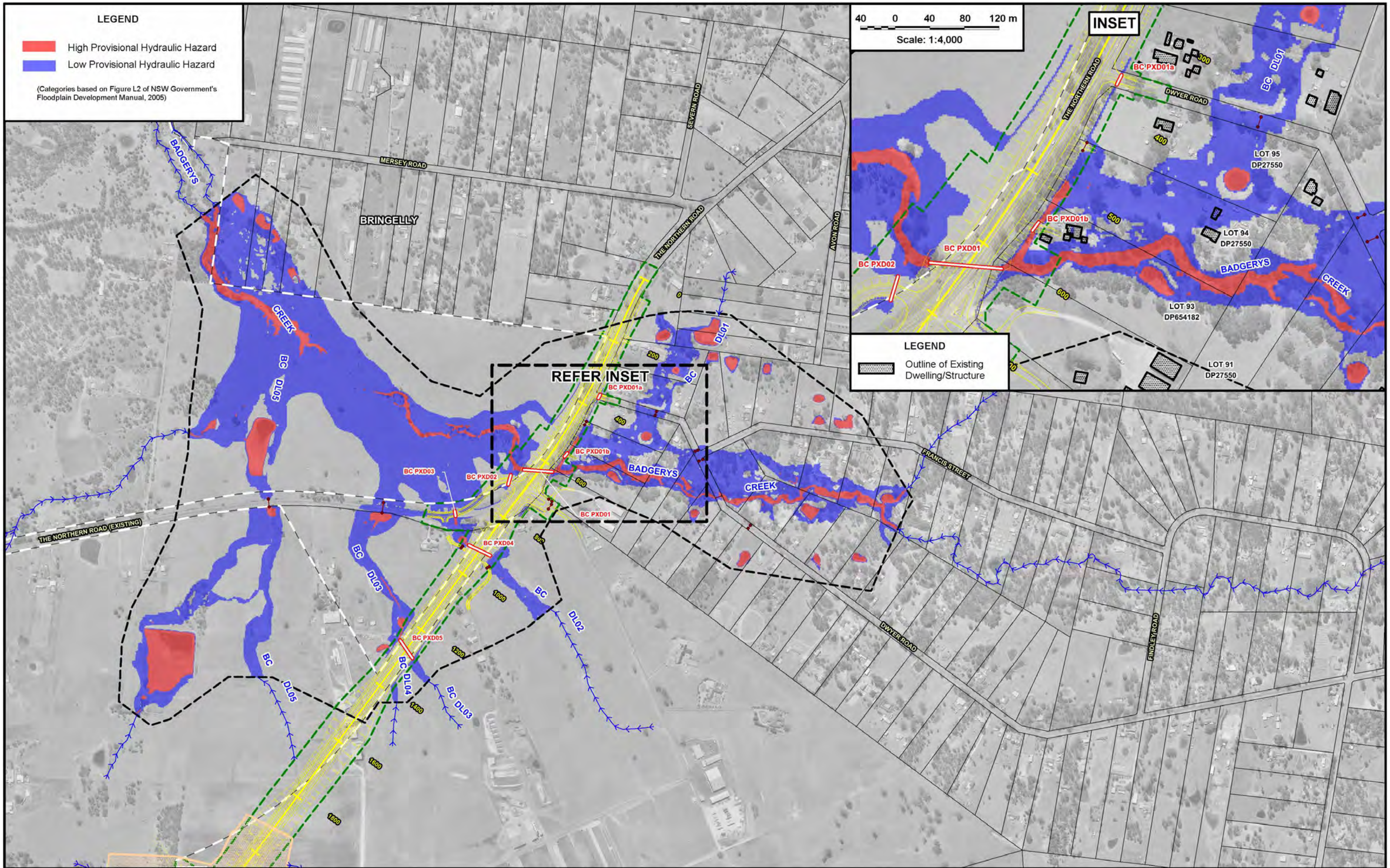
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.27

IMPACT OF PROJECT ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
BADGERYS CREEK CATCHMENT - PMF



LEGEND

100 0 100 200 300 m

Scale: 1:10,000

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.18 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

Project Boundary

BC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

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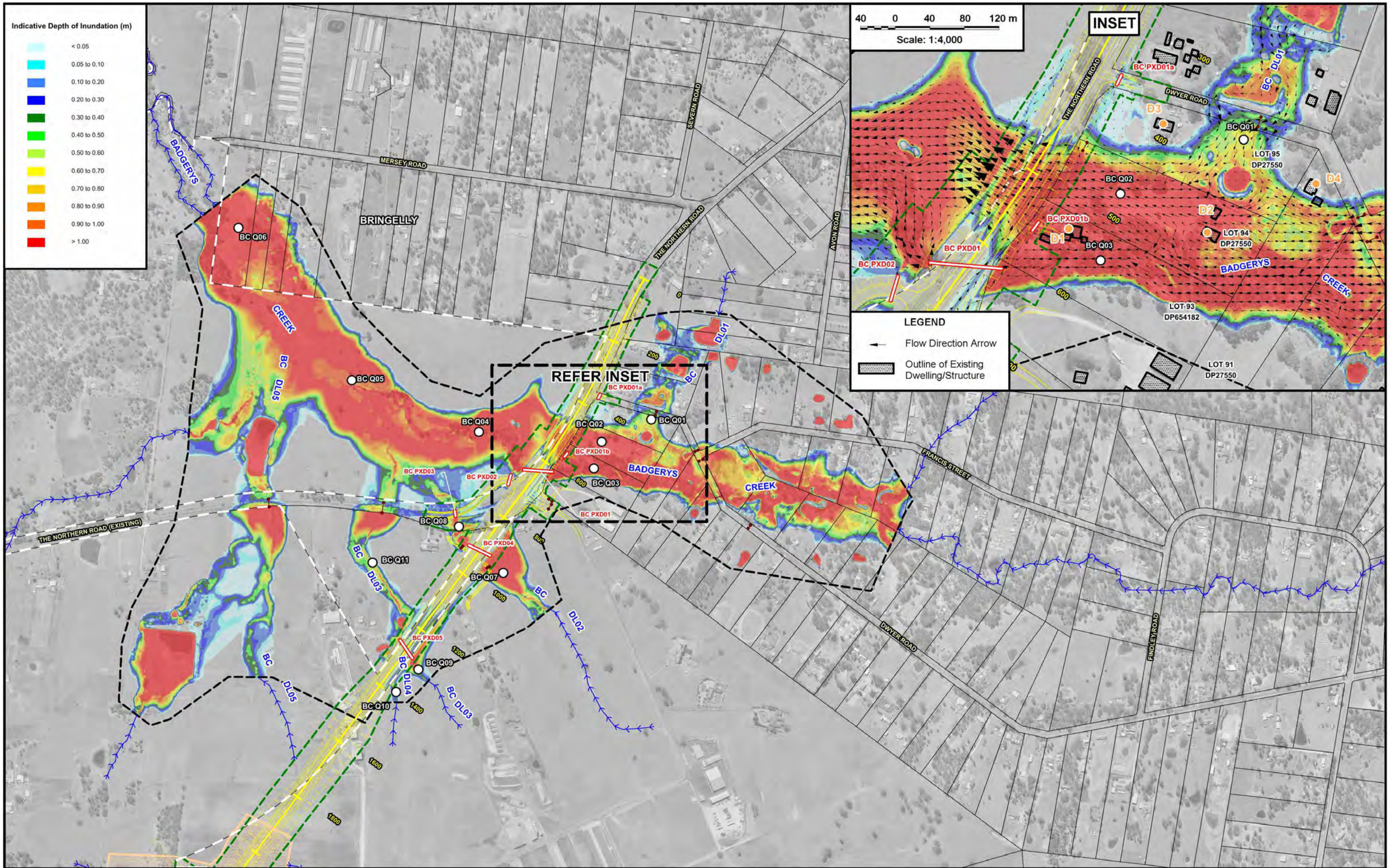
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.28

PROVISIONAL FLOOD HAZARD IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT
POST-PROJECT CONDITIONS - 100 YEAR ARI



100 0 100 200 300 m
Scale: 1:10,000

LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 7.17 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- Project Boundary
- BC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- BC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary
- D1 — Dwelling Location and Identifier

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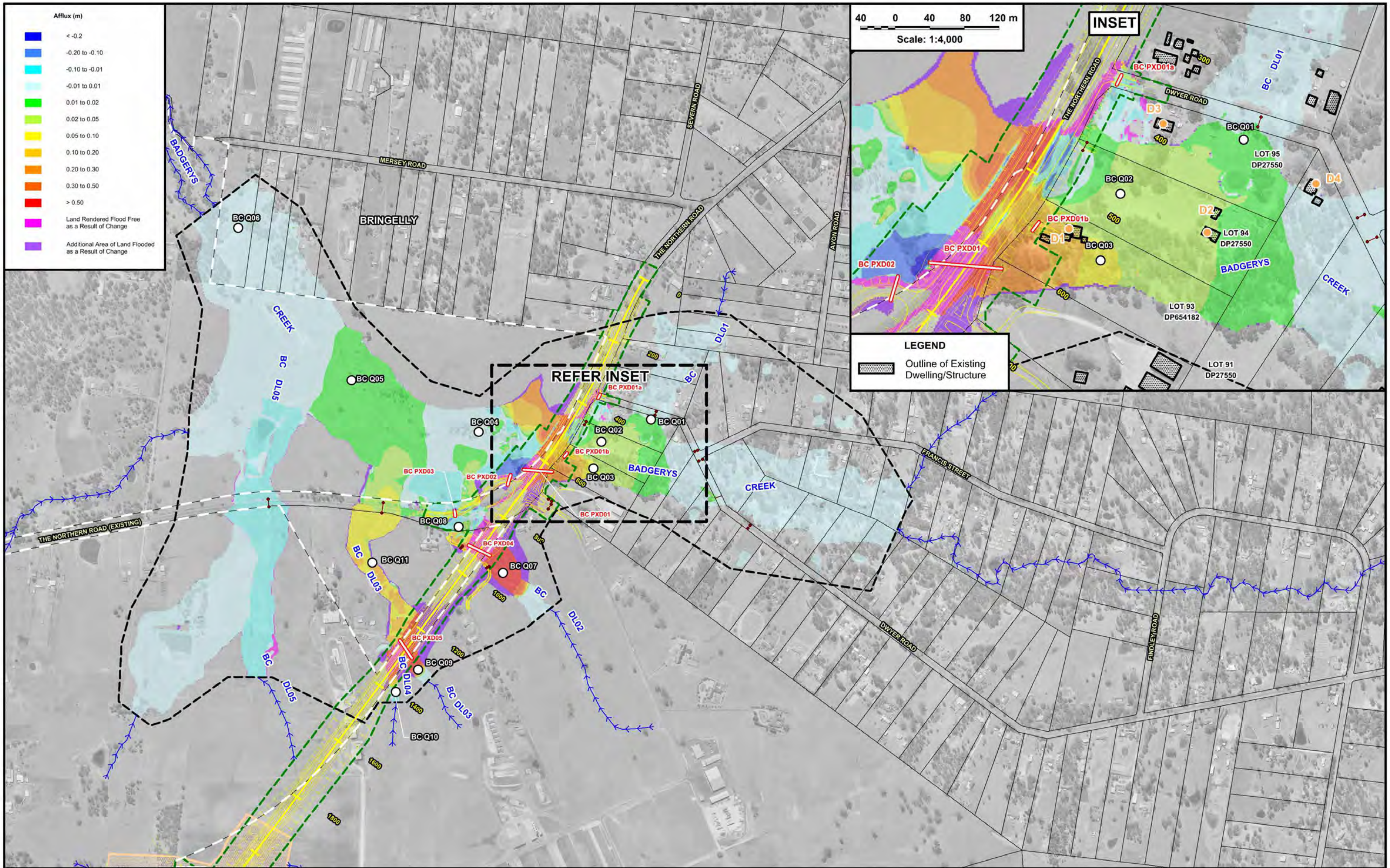
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.29

FLOODING BEHAVIOUR IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT
POST-LOWERED ROAD CONDITIONS - PMF



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 7.17 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- Project Boundary
- BC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- BC Q01 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D for Peak Flow in Receiving Drainage Lines)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary
- D1 — Dwelling Location and Identifier

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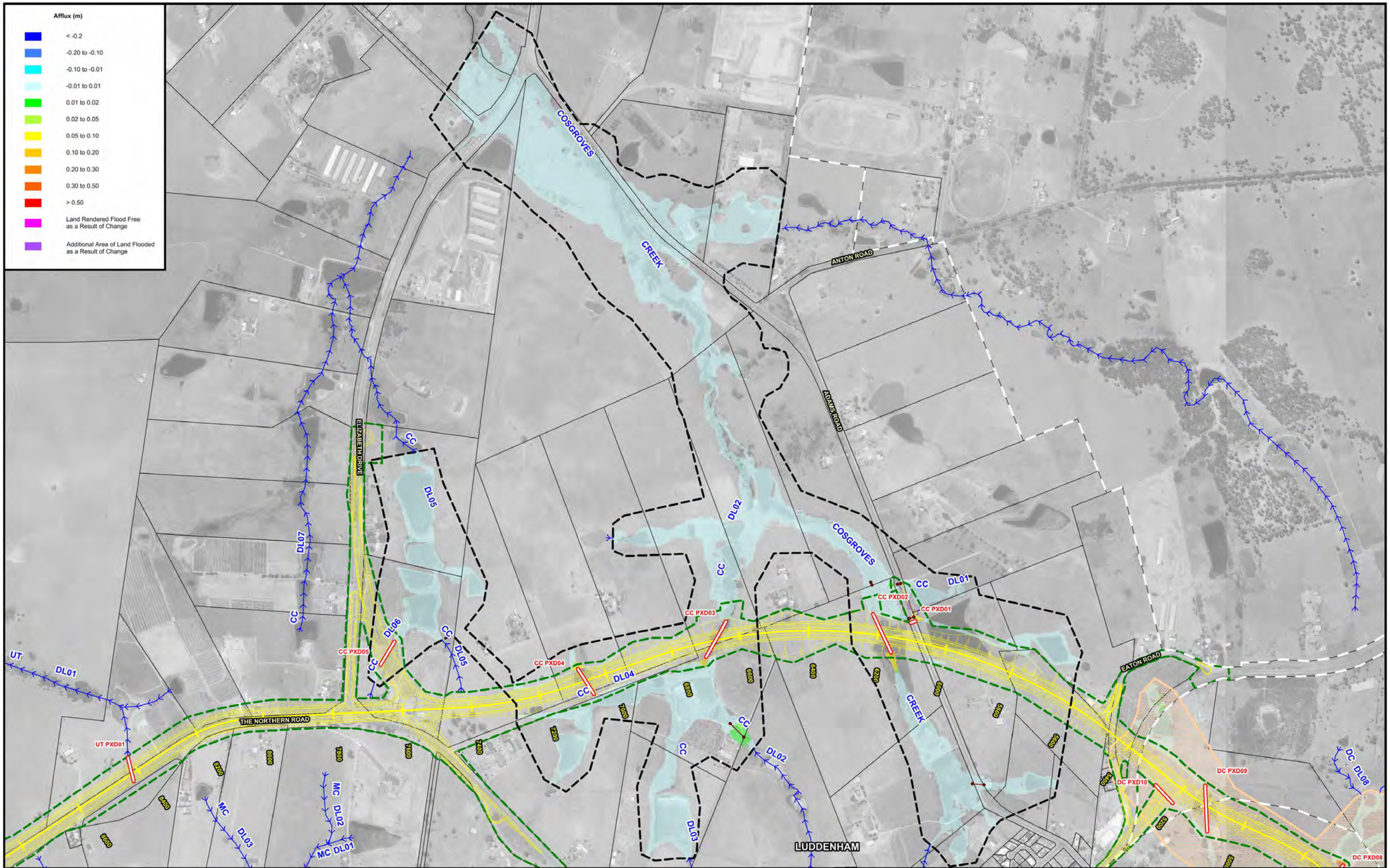
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.30

IMPACT OF LOWERED ROAD ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
BADGERYS CREEK CATCHMENT - PMF



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 7.30 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- CC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary
- Project Boundary

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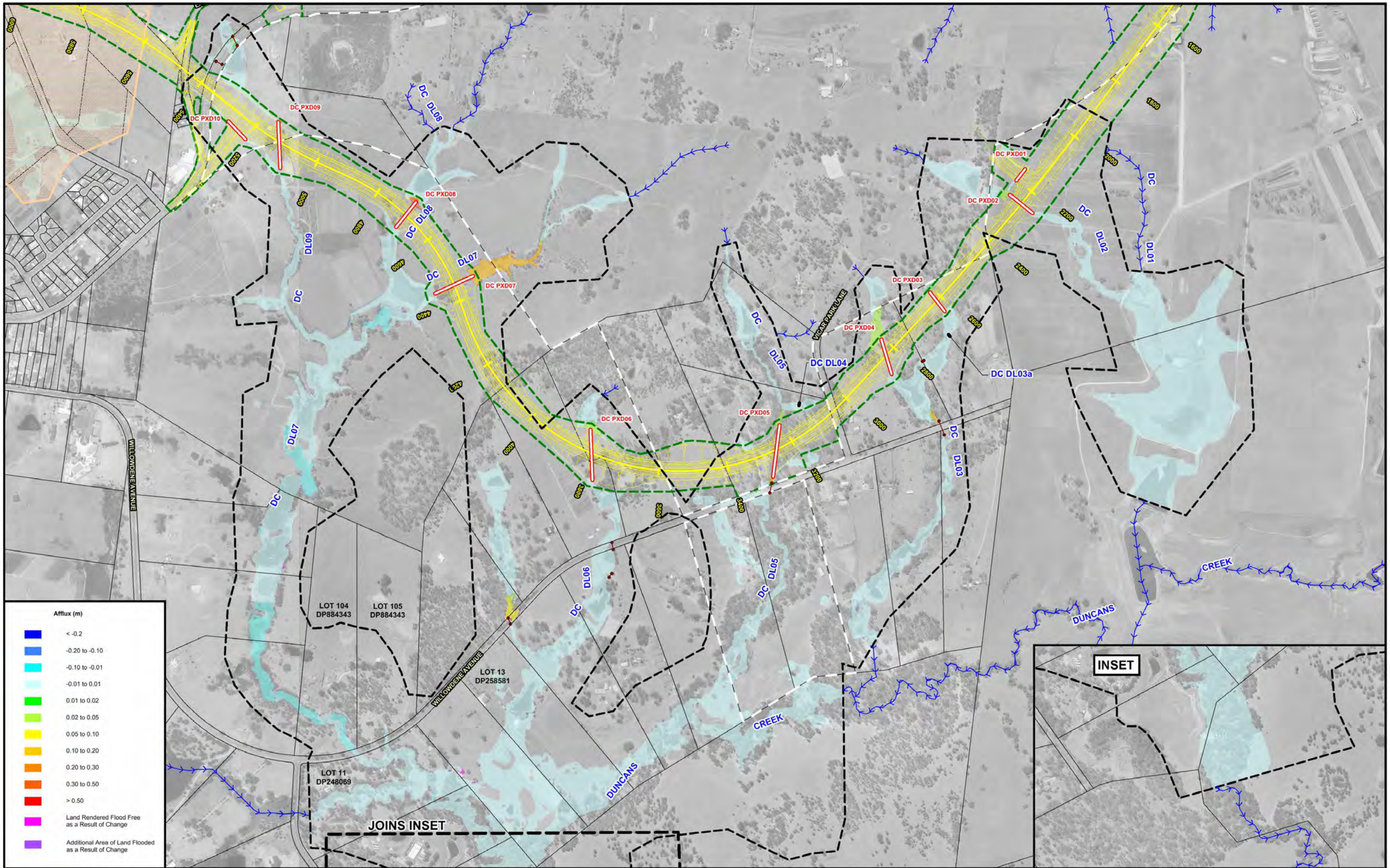
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.31

IMPACT OF PARTIAL BLOCKAGE OF PROPOSED TRANSVERSE DRAINAGE STRUCTURES ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT - COSGROVES CREEK CATCHMENT - POST PROJECT CONDITIONS - 100 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

Lyall & Associates

LEGEND

Design Road Control String and Chainage

Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.29 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

DC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

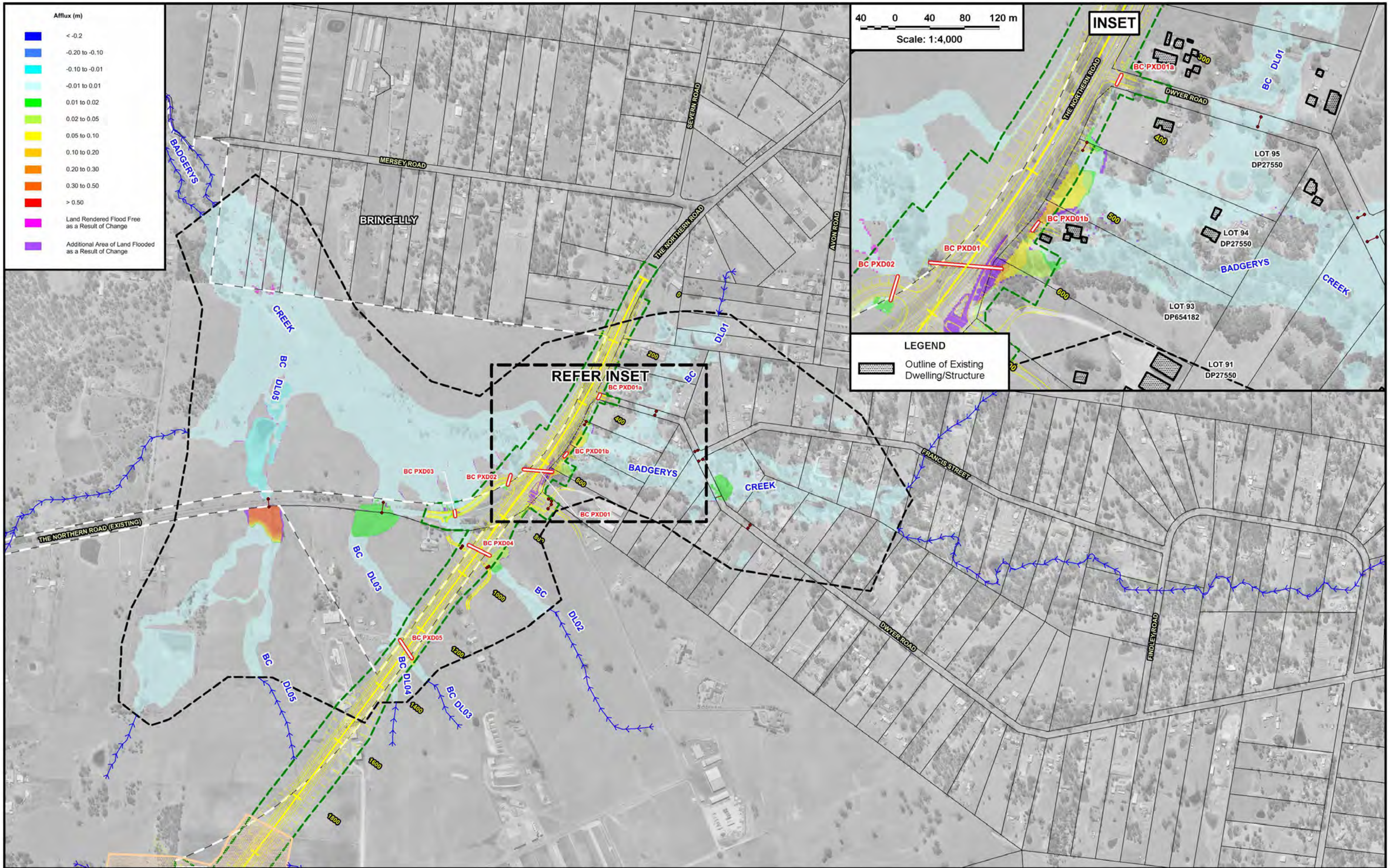
Proposed Western Sydney Airport Boundary

Project Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.32

IMPACT OF PARTIAL BLOCKAGE OF PROPOSED TRANSVERSE DRAINAGE STRUCTURES ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT - DUNCANS CREEK CATCHMENT - POST PROJECT CONDITIONS - 100 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.30 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

BC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

Project Boundary

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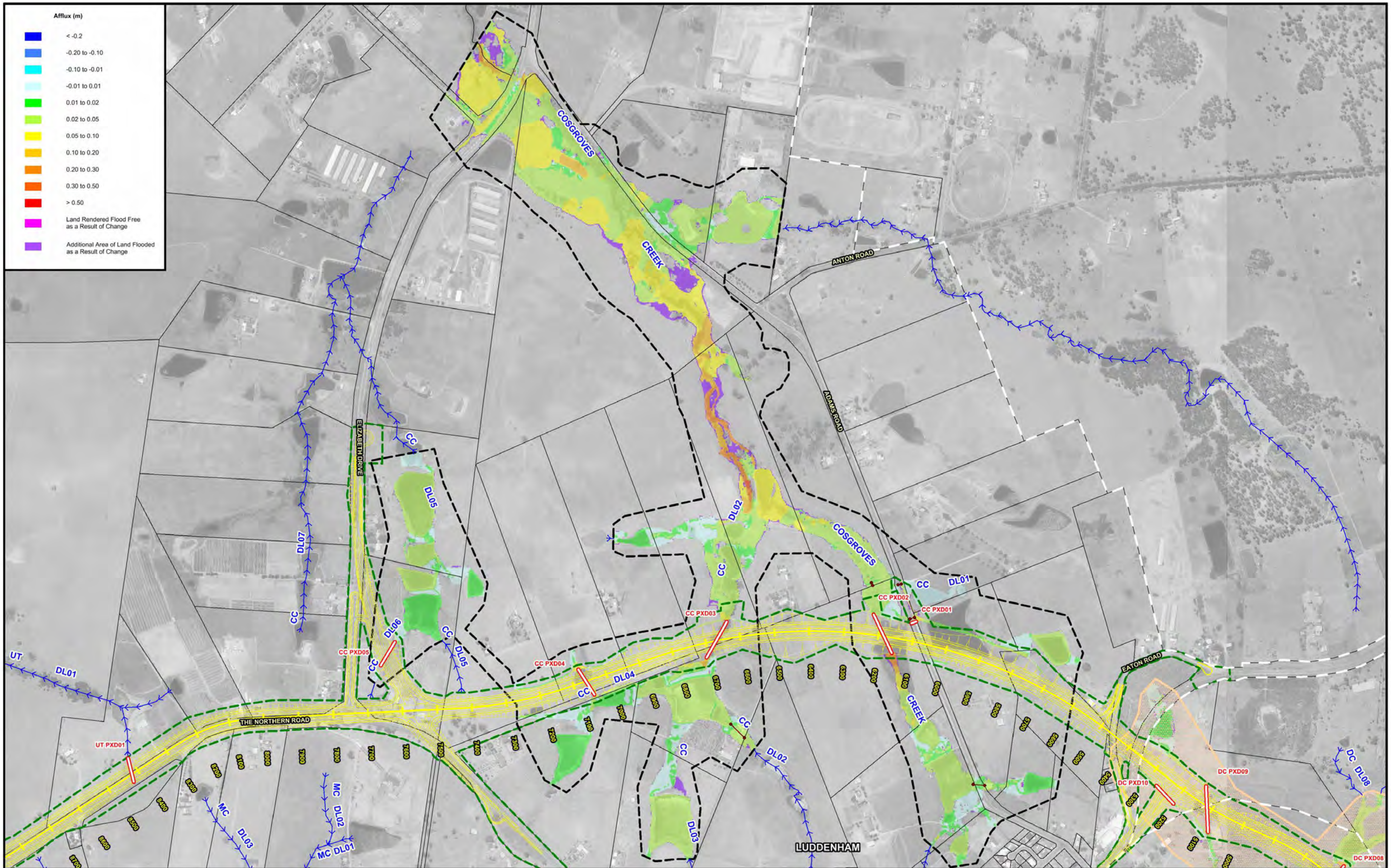
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.33

IMPACT OF PARTIAL BLOCKAGE OF PROPOSED TRANSVERSE DRAINAGE STRUCTURES ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT - BADGERYS CREEK CATCHMENT - POST PROJECT CONDITIONS - 100 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

- Design Road Control String and Chainage
- Extent of Duncans Creek TUFLOW Model (Refer Figure 7.33 for TUFLOW Model Results)
- Modelled Stormwater Drainage Network
- Design Strings
- CC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
- Two-Dimensional Model Extent
- Proposed Western Sydney Airport Boundary
- Project Boundary

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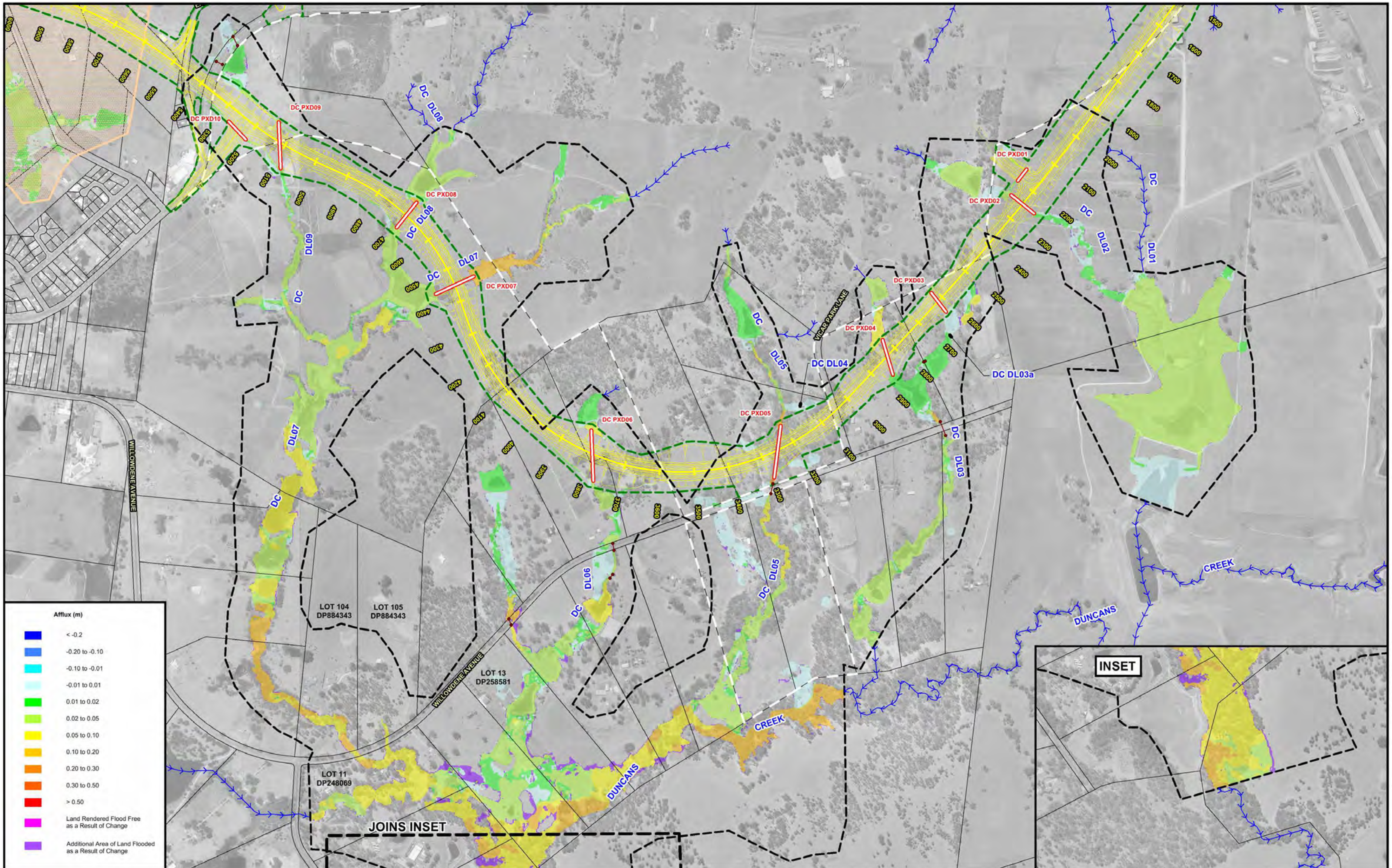
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.34

IMPACT OF 10% INCREASE IN DESIGN RAINFALL INTENSITIES ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
COSGROVES CREEK CATCHMENT - POST PROJECT CONDITIONS - 100 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.32 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

DC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

Project Boundary

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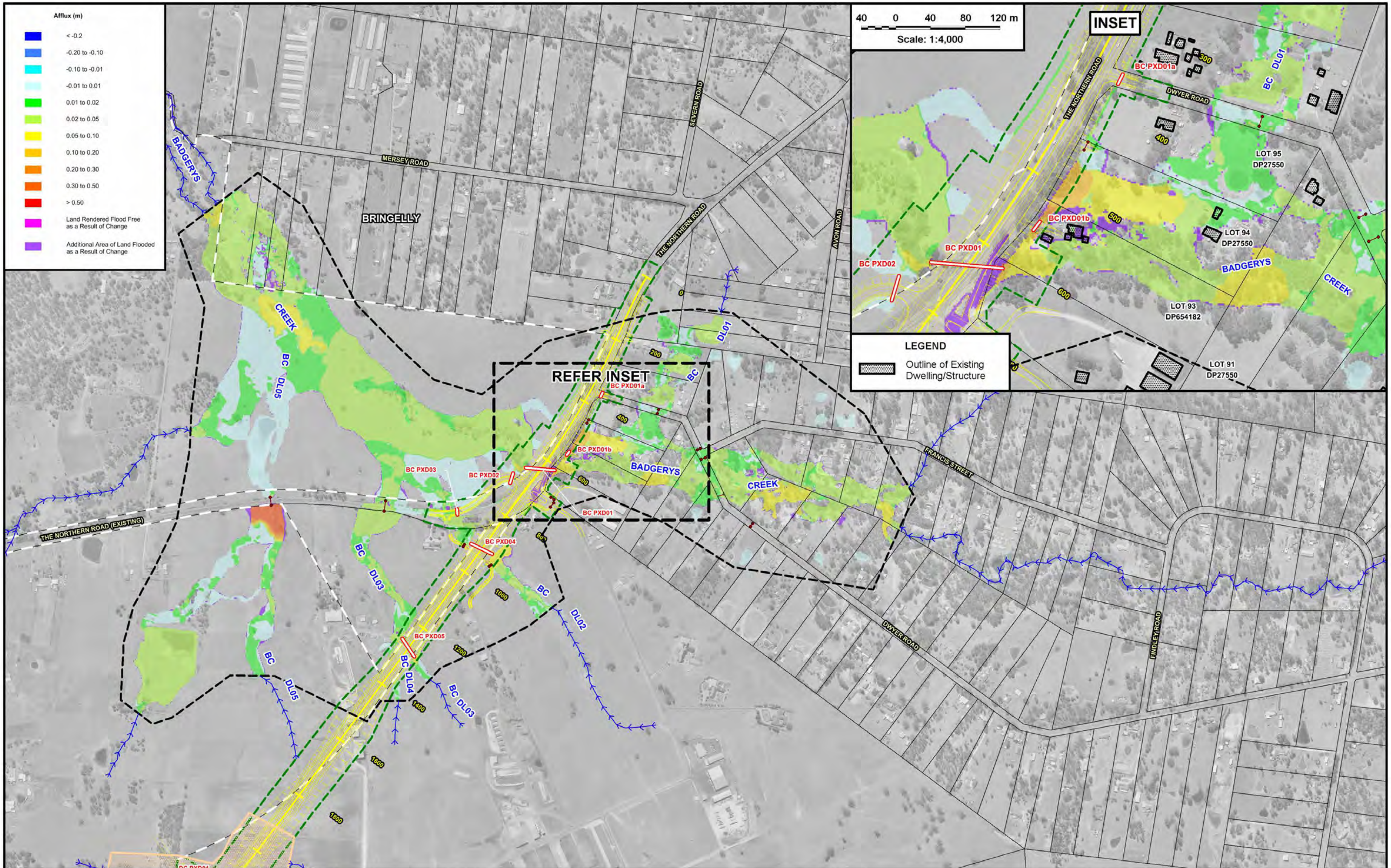
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.35

IMPACT OF 10% INCREASE IN DESIGN RAINFALL INTENSITIES ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
DUNCANS CREEK CATCHMENT - POST PROJECT CONDITIONS - 100 YEAR ARI



Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.33 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

BC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

Project Boundary

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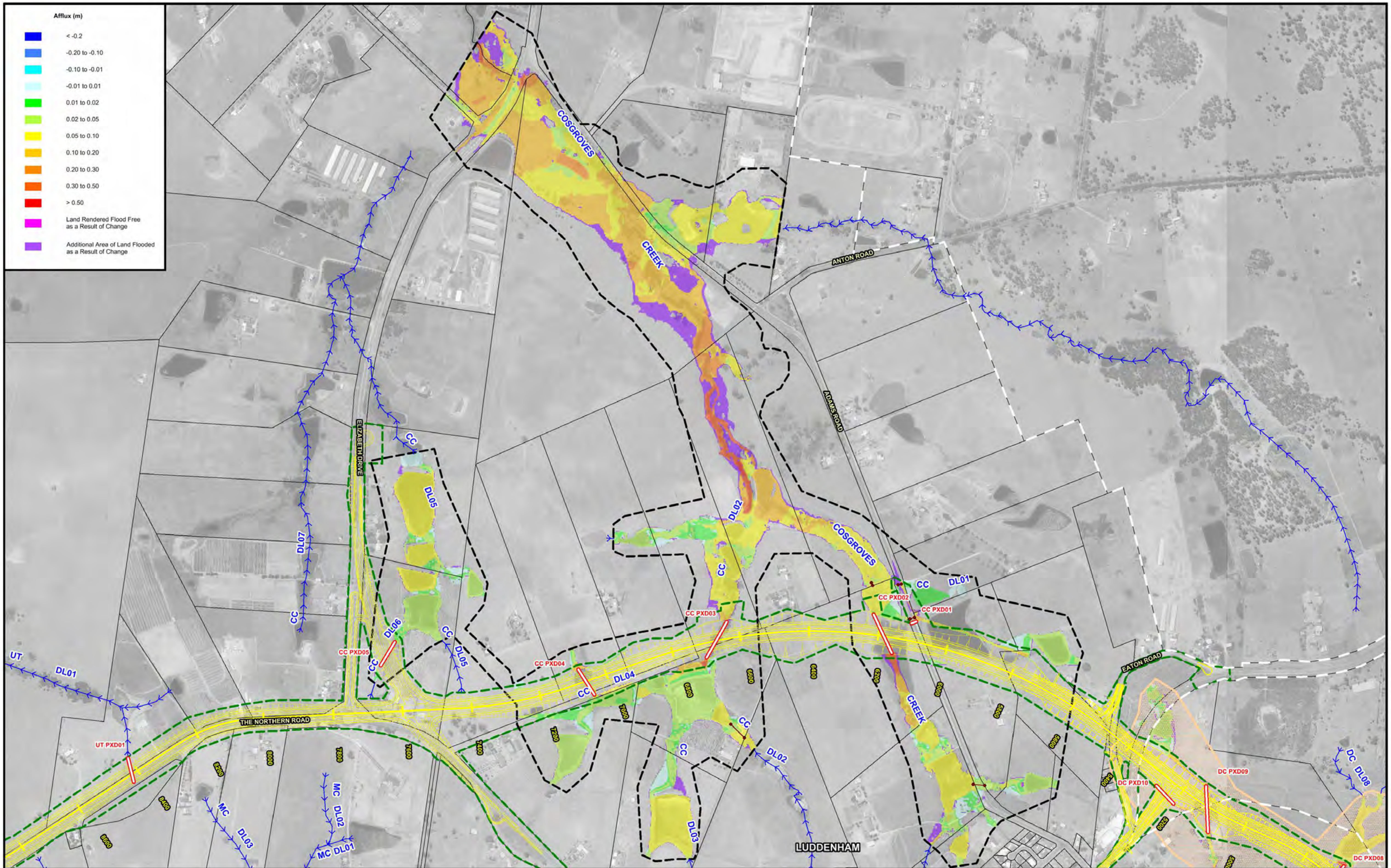
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.36

IMPACT OF 10% INCREASE IN DESIGN RAINFALL INTENSITIES ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
BADGERYS CREEK CATCHMENT - POST PROJECT CONDITIONS - 100 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

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LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.36 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

CC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

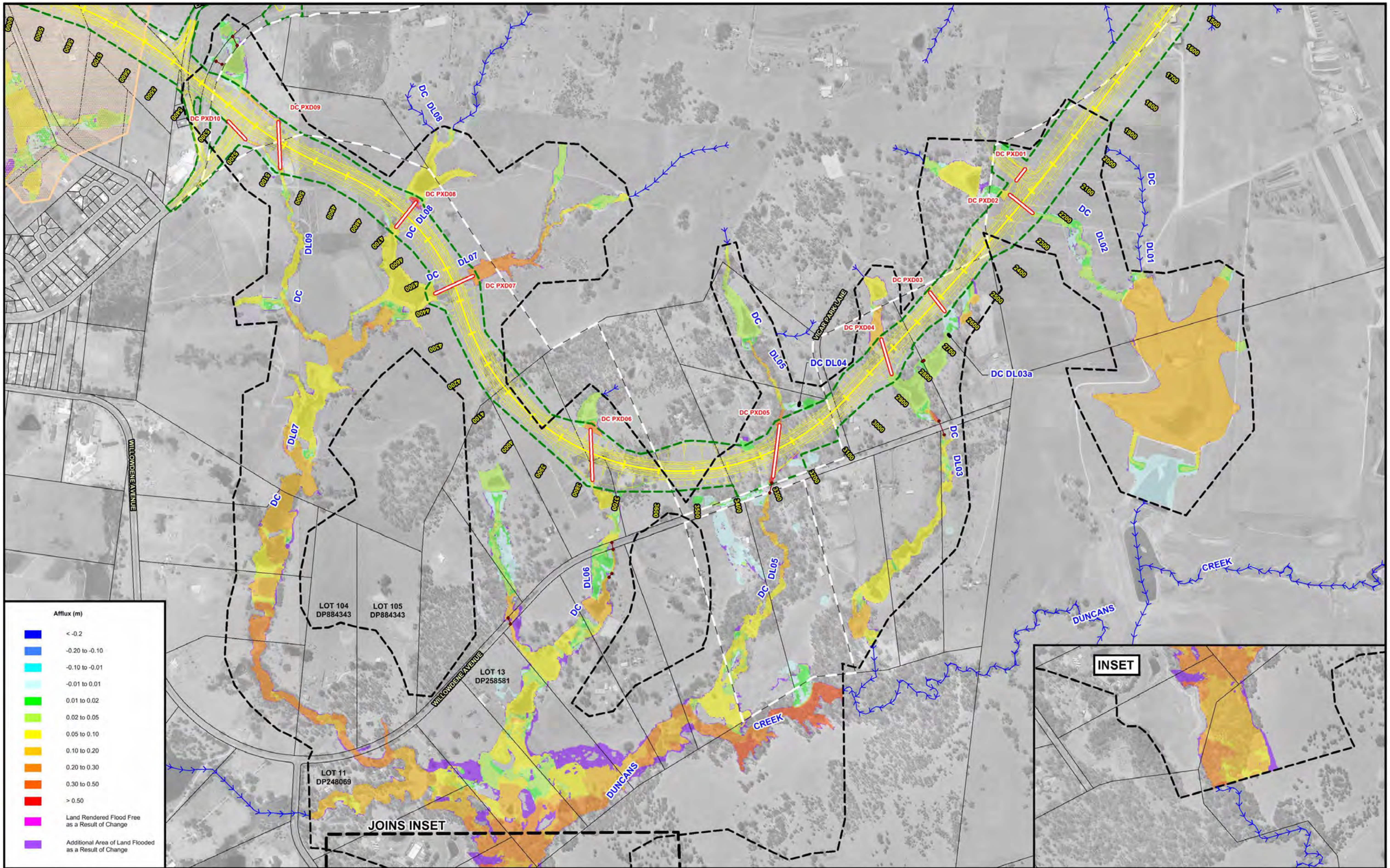
Proposed Western Sydney Airport Boundary

Project Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.37

IMPACT OF 30% INCREASE IN DESIGN RAINFALL INTENSITIES ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
COSGROVES CREEK CATCHMENT - POST PROJECT CONDITIONS - 100 YEAR ARI



LEGEND

Scale: 1:10,000

100 0 100 200 300 m

Design Road Control String and Chainage

Extent of Cosgroves Creek TUFLOW Model (Refer Figure 7.35 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

DC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

Project Boundary

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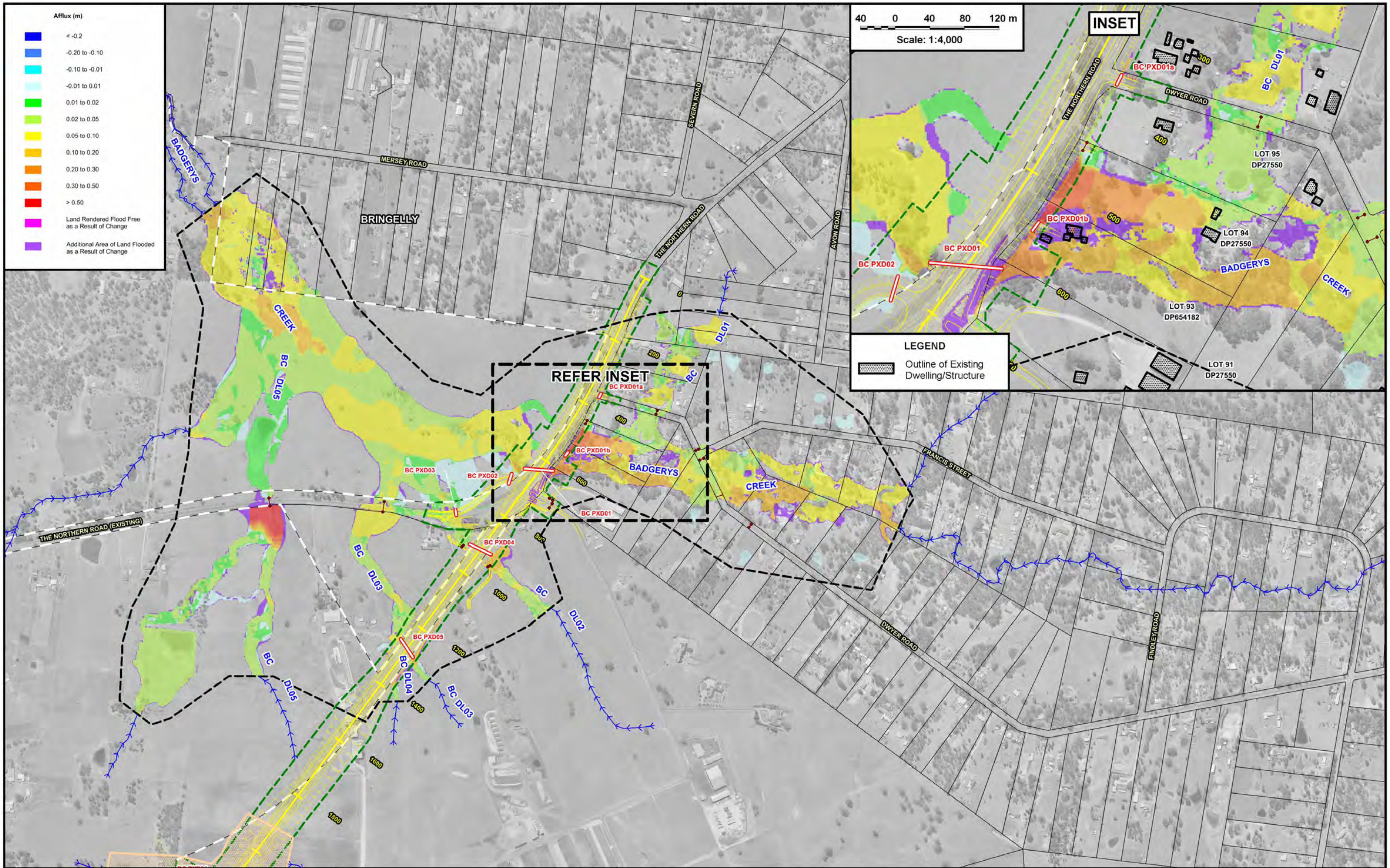
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.38

IMPACT OF 30% INCREASE IN DESIGN RAINFALL INTENSITIES ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
DUNCANS CREEK CATCHMENT - POST PROJECT CONDITIONS - 100 YEAR ARI



LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure 7.36 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

BC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

Project Boundary

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THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure 7.39

IMPACT OF 30% INCREASE IN DESIGN RAINFALL INTENSITIES ON FLOODING BEHAVIOUR IN VICINITY OF PROJECT
BADGERYS CREEK CATCHMENT - POST PROJECT CONDITIONS - 100 YEAR ARI

APPENDIX A
BACKGROUND TO DEVELOPMENT OF FLOOD MODELS

TABLE OF CONTENTS

Page No.

FIGURES
(BOUND AT THE END OF THIS APPENDIX)

A1. SYNOPSIS

This Appendix provides background to the development of the hydrologic (RAFTS/ILSAX) and hydraulic (TUFLOW) computer models that were developed to define flooding behaviour in the vicinity of the project.

A2. HYDROLOGIC MODEL DEVELOPMENT

A2.1 General

This chapter of the Appendix provides a brief description of the ILSAX and RAFTS rainfall-runoff models that were developed as part the present investigation using the DRAINS software.

DRAINS is a simulation program which converts rainfall patterns to stormwater runoff and generates discharge hydrographs. These hydrographs are then routed through networks of piped drainage systems, culverts, storages and open channels to calculate hydraulic grade lines and analyse the magnitude of overflows. Alternatively, discharge hydrographs generated by DRAINS can be used as inflows to hydraulic models (such as the TUFLOW two-dimensional hydraulic modelling software) to determine flooding patterns. The latter approach is particularly appropriate for modelling complex flood behaviour involving multiple flow paths and has been used in the present study.

A number of hydrologic sub-models are available within the DRAINS software to simulate the conversion of rainfall to runoff. The RAFTS sub-model was used to assess the runoff characteristics of the semi-rural catchment which contributes to flow in the drainage system in the vicinity of the project, while the ILSAX sub-model was used to assess the runoff characteristics of the upgraded section of The Northern Road.

A2.2 DRAINS model layout

Figures A2.1 and **A2.2** show the layout of the sub-catchments which comprise the hydrologic models which represent pre- and post-project conditions, respectively. Sub-catchment boundaries were digitised based on contour information derived from the available LiDAR survey data. Sub-catchment slopes used as input data to the DRAINS model were derived using the average sub-catchment slope and equal area method for the ILSAX and RAFTS sub-models, respectively. Aerial photography was used to assess the degree of urbanisation present in the sub-catchments which comprise the DRAINS model.

A2.3 Design Storms

A2.3.1 Up to 500 year ARI

Rainfall intensities for the 2, 10, 100, 200 and 500 year ARI events were derived using procedures outlined in Australian Rainfall and Runoff (**ARR**) (IEAust, 1998) for storm durations ranging between 25 minutes and 12 hours. The design rainfalls were converted into rainfall hyetographs using the temporal patterns presented in ARR.

No Areal Reduction Factor (**ARF**) was applied to the design rainfall intensities obtained from ARR due to the relatively small size of the catchments which drain to the project corridor.

A2.3.2 Probable Maximum Flood

Estimates of Probable Maximum Precipitation (**PMP**) were made using the Generalised Short Duration Method (**GSDM**) as described in the BoM's update of *Bulletin 53* (BoM, 2003). This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 km^2 in area and storm durations up to 6 hours.

Given the relatively small size of the catchment that contributes to flow in the drainage system in the vicinity of the project (the largest being the 3 km^2 Badgerys Creek catchment), PMP rainfall applicable to the smallest ellipse shown on Figure 6 of BoM, 2003 (i.e. Ellipse A) was used as input to the model.

A2.4 Model parameters

Adopted RAFTS sub-model parameters comprised initial losses of 2 and 15 mm for paved and grassed areas, respectively, while continuing loss rates of 0 and 2.5 mm/h were adopted for paved and grassed areas, respectively.

A storage routing coefficient multiplier (Bx factor) of 1.0 was adopted after comparison of peak discharges from a range of sub-catchments with those derived from the PRM approach.

Lagging was used to model the translation of the discharge hydrographs between sub-catchment outlets within the ILSAX and RAFTS sub-models (referred to as links). This approach required a flow velocity to be assumed in each link. The sensitivity of the results to assumed flow velocities ranging between 1 and 2 m/s was tested for the 100 year ARI critical storm. After consideration of flow path slopes and comparison of results with those derived from the PRM approach, a flow velocity of 1 m/s was adopted for vegetated flowpaths while a flow velocity of 2 m/s was adopted for pipes and concrete lined flow paths.

Adopted ILSAX sub-model parameters comprised initial losses of 2 and 10 mm for paved and grassed areas, respectively. ILSAX uses the Hortonian loss modelling approach which does not require the user to input a continuing loss rate. Instead, a soil type and antecedent moisture condition (**AMC**) are used to define the continuing loss over time. The soil type was set equal to 3, which corresponds with a soil of comparatively high runoff potential while an AMC of 3 was adopted reflecting rather wet conditions prior to the onset of runoff producing rainfall.

A2.5 Comparison of peak flows

As the streams which drain across the project corridor are ungauged in their upper reaches, it was not possible to calibrate model parameters to reproduce recorded flows. A comparison of the peak flows generated by the hydrologic model representing pre-project conditions was therefore made with the Probabilistic Rational Method (PRM) of flood estimation as described in IEAust, 1998.

The peak flows derived by DRAINS were found to be higher than those derived using the PRM for design storms ranging between 2 and 100 year ARI. The adoption of the model parameters set out above will therefore result in the hydraulic model generating conservatively high peak flood levels and lead to the adoption of transverse drainage structures which are slightly larger than would be assessed should the designers rely on peak flows derived using the PRM for sizing the individual structures.

A3. HYDRAULIC MODEL DEVELOPMENT

A3.1 General

Detailed two-dimensional hydraulic modelling was undertaken using the TUFLOW software to define flooding behaviour in the vicinity of the project.

TUFLOW is a true two-dimensional (in plan), fully dynamic hydraulic modelling system which does not rely on a prior knowledge of the pattern of flood flows in order to set up the various fluvial and weir type linkages which describe the passage of a flood wave in a drainage system.

The basic equations of TUFLOW involve all of the terms of the St Venant equations of unsteady flow. TUFLOW solves the equations of flow at each point of a rectangular grid system which represent ground surface elevations throughout the model domain. TUFLOW allows for a dynamic linkage between the floodplain which is modelled by a two-dimensional grid and the creek and stormwater channels which may be modelled in a one-dimensional sense by cross sections normal to the direction of flow. Pipe networks can also be modelled using the software as one-dimensional elements which are linked dynamically to the two-dimensional domain at the location of surface inlet pits and headwalls.

The structure of a TUFLOW model can be adjusted to assess the impact works on the floodplain will have on flooding behaviour. It can also be adjusted to assess the benefits of various flood mitigation measures such as channel improvement works, levees and flood retarding basins.

A3.2 TUFLOW model structure

The layout of the TUFLOW models which were developed as part of the present investigation for the Cosgrove Creek, Duncan Creek and Badgerys Creek drainage systems are shown on **Figures A3.1**, **A3.2** and **A3.3**, respectively.

Data provided by Roads and Maritime were used to describe the key features of the local stormwater drainage system in the vicinity of the project corridor. These data were input to the TUFLOW model and included: internal dimensions of pipes and box culverts; number of conduits; and where available, invert levels.

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

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

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

A3.3 Model boundary conditions

Discharge hydrographs generated by DRAINS were applied at the inflow boundaries of the TUFLOW models. These comprised both inflows applied at the external TUFLOW model boundary and internal point source and region inflows[1] as shown on **Figures A3.1**, **A3.2** and **A3.3**.

The downstream boundary of the TUFLOW models comprised a tailwater level based on normal depth flow conditions. The model extents were selected to ensure the downstream boundary was located a sufficient distance downstream of the project to prevent any influence on flow behaviour within the vicinity of the proposed road works.

A3.4 Model parameters

The main physical parameter represented in TUFLOW is hydraulic roughness, which is required for each of the various types of surfaces comprising the overland flow paths in the two-dimensional domain, as well as for the culverts and pipes which were incorporated in the model as one-dimensional elements. In addition to the energy lost by bed friction, obstructions to flow also dissipate energy by forcing water to change direction and velocity, and by forming eddies. Hydraulic modelling traditionally represents all of these effects via the surface roughness parameter known as “Manning’s n”.

Hydraulic roughness values adopted for design purposes were selected based on site inspection, past experience and values contained in the engineering literature (refer **Table A3.1** over the page).

A3.5 Sensitivity of flood behaviour to increase in hydraulic roughness

Figures A3.4, **A3.5** and **A3.6** show the difference in peak flood levels (i.e. the “afflux”) for the 100 year ARI storm resulting from an assumed 20 per cent increase in hydraulic roughness compared to the “best estimate” values given in **Table A3.1** over the page for the Cosgrove Creek, Duncans Creek and Badgerys Creek drainage systems, respectively. The afflux is given in colour coded increments in metres. The figure also identifies areas where land is rendered flood free, or where additional areas of land are flooded.

[1] In parts of the model area, inflow hydrographs were applied over individual regions called “Rain Boundaries”. The Rain Boundaries act to “inject” flow into the one and two-dimensional domains of the TUFLOW model, firstly at a point which has the lowest elevation, and then progressively over the extent of the Rain Boundary as the grid in the two-dimensional model domain becomes wet as a result of overland flow.

The investigation found that there would only be a minor increase in peak 100 year ARI flood levels in the vicinity of the project as a result of a 20 per cent increase in the best estimate hydraulic roughness values set out in **Table A3.1**.

TABLE A3.1
"BEST ESTIMATE" OF HYDRAULIC ROUGHNESS VALUES
ADOPTED FOR TUFLOW MODELLING

Surface Treatment	Manning's n Value
Reinforced concrete pipes and box culverts	0.015
Roads	0.02
Concrete channel	0.03
Grassed channels and reserves	0.045
Remnant cleared pasture land	0.045
Stands of trees and macrophytes	0.06
Buildings	10

A3.6 Adjustments made to TUFLOW model to reflect post-project conditions

The concept road design model for the project, as well as details of the transverse drainage and flood mitigation strategy were incorporated in the model. The design discharge hydrographs generated by the hydrologic model representing post-project conditions were also applied to the adjusted model in order to:

- assess the impact the project would have on flooding behaviour; and
- assess the flood risks to the project.

Figure 6.2 (12 sheets) of the Technical Working Paper shows the key features of the proposed transverse drainage and flood mitigation strategy for the project, while **Table 6.1** in **Chapter 6** of the Technical Working Paper provides details of the upgraded transverse drainage.

A4. REFERENCES

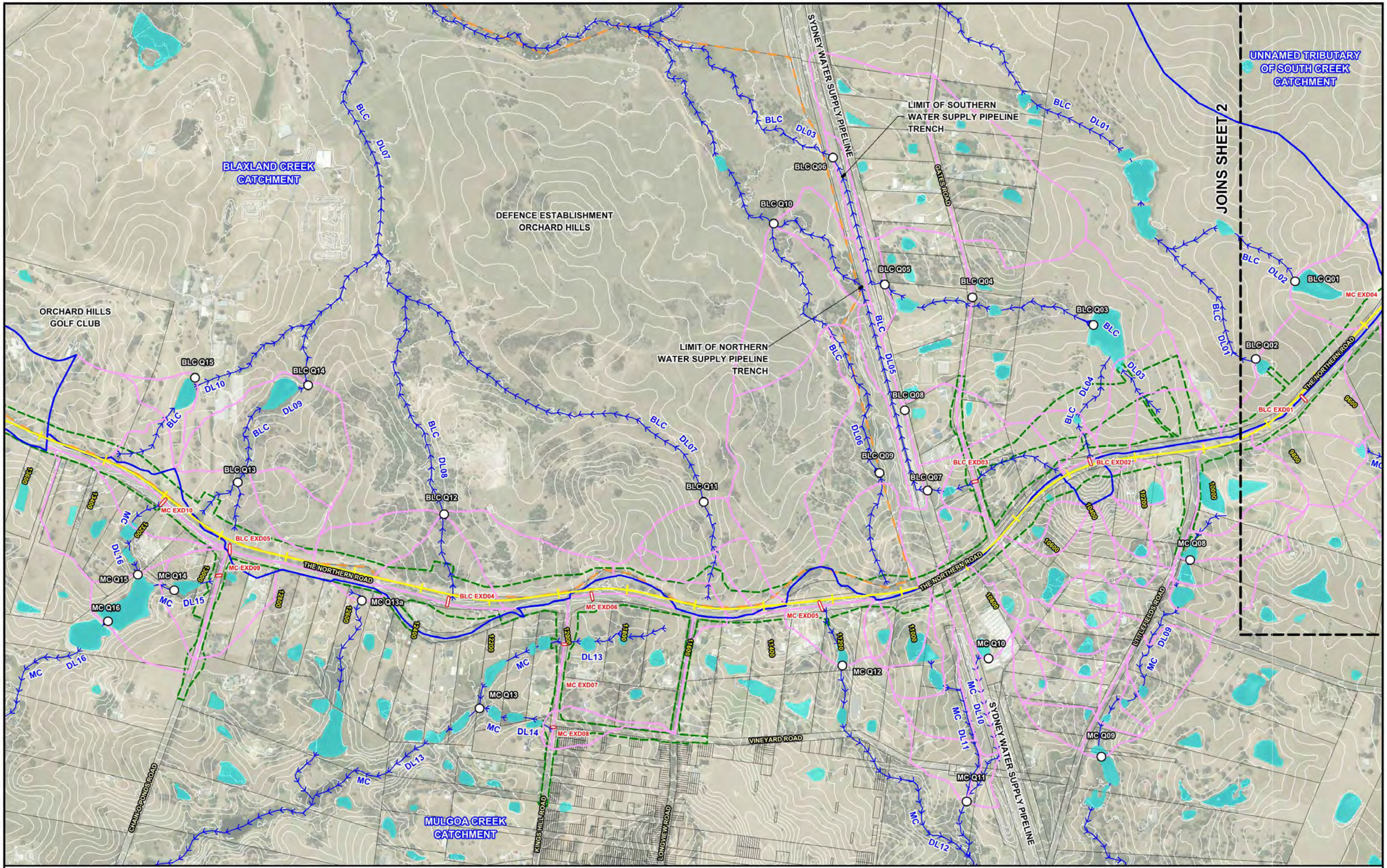
Bureau of Meteorology, 2003. *"The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method"*.

The Institution of Engineers, Australia, 1998. *"Australian Rainfall and Runoff – A Guide to Flood Estimation"*.

Von Thun J. L. and Gillette D. R. (1990), "*Guidance on Breach Parameters – A Needs Assessment." Un-published U.S. Bureau of Reclamation document, Denver Colorado, 17 p.*

Wahl T. L. (1998), *"Prediction of Embankment Breach Parameters." DSO-98-044, U.S. Department of the Interior, Bureau of Reclamation – Dam Safety Office.*

FIGURES



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

- MC EXD05 — Existing Transverse Drainage Structure and Identifier
- Design Road Control String and Chainage
- Existing Dam
- Existing Drainage Lines
- Catchment Boundary
- BLC Q12 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
- Sub-Catchment Boundary
- Defence Establishment Orchard Hills Boundary
- Project Boundary

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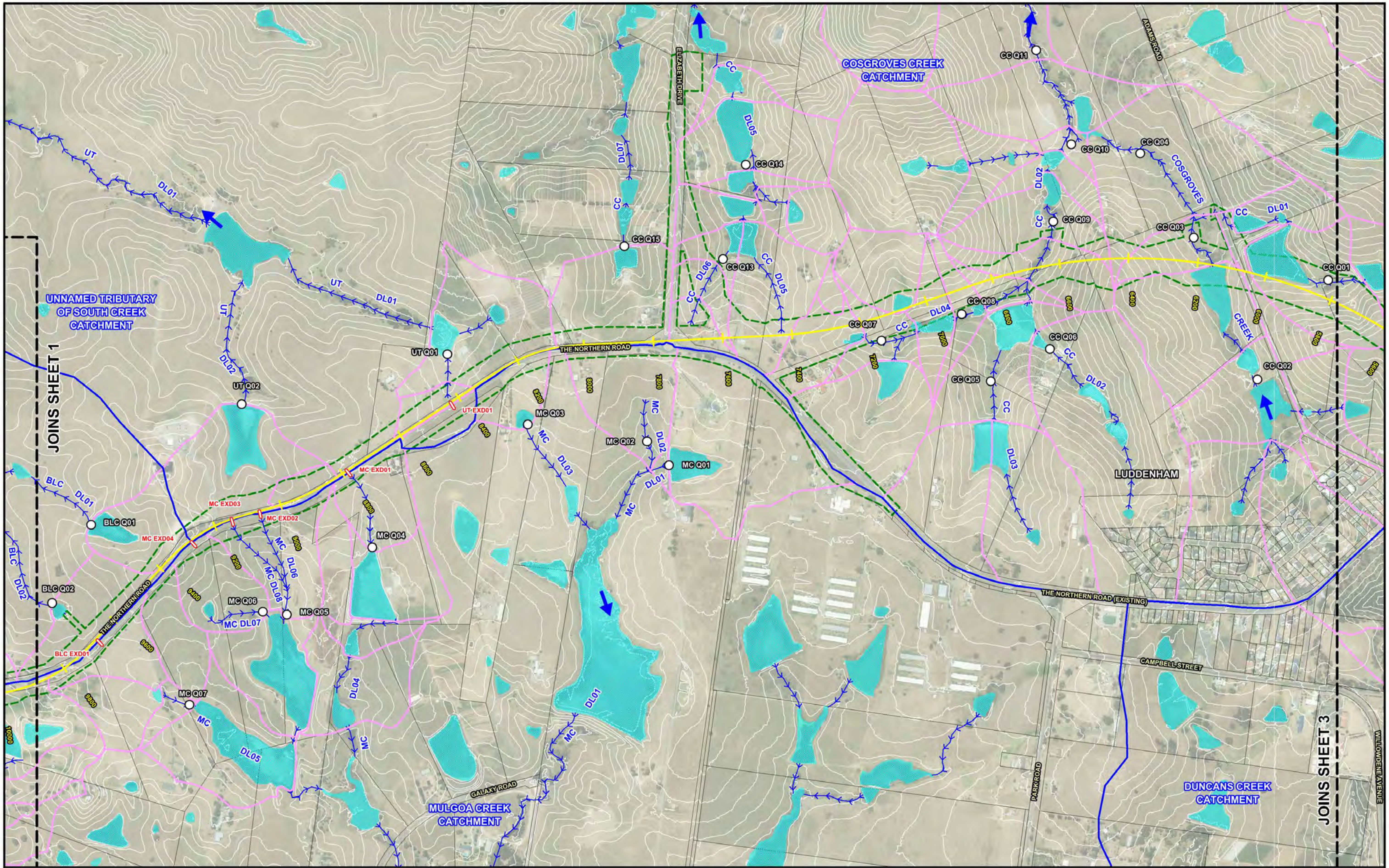
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A2.1
Sheet 1 of 4

SUB-CATCHMENTS COMPRISING HYDROLOGIC MODEL
PRE-PROJECT CONDITIONS



MC EXD01	Existing Transverse Drainage Structure and Identifier
	Design Road Control String and Chainage
	Existing Dam
	Existing Drainage Lines

LEGEND

	Catchment Boundary
MC Q04	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Sub-Catchment Boundary
	Proposed Western Sydney Airport Boundary
	Project Boundary

100 0 100 200 300 m

Scale: 1:10,000

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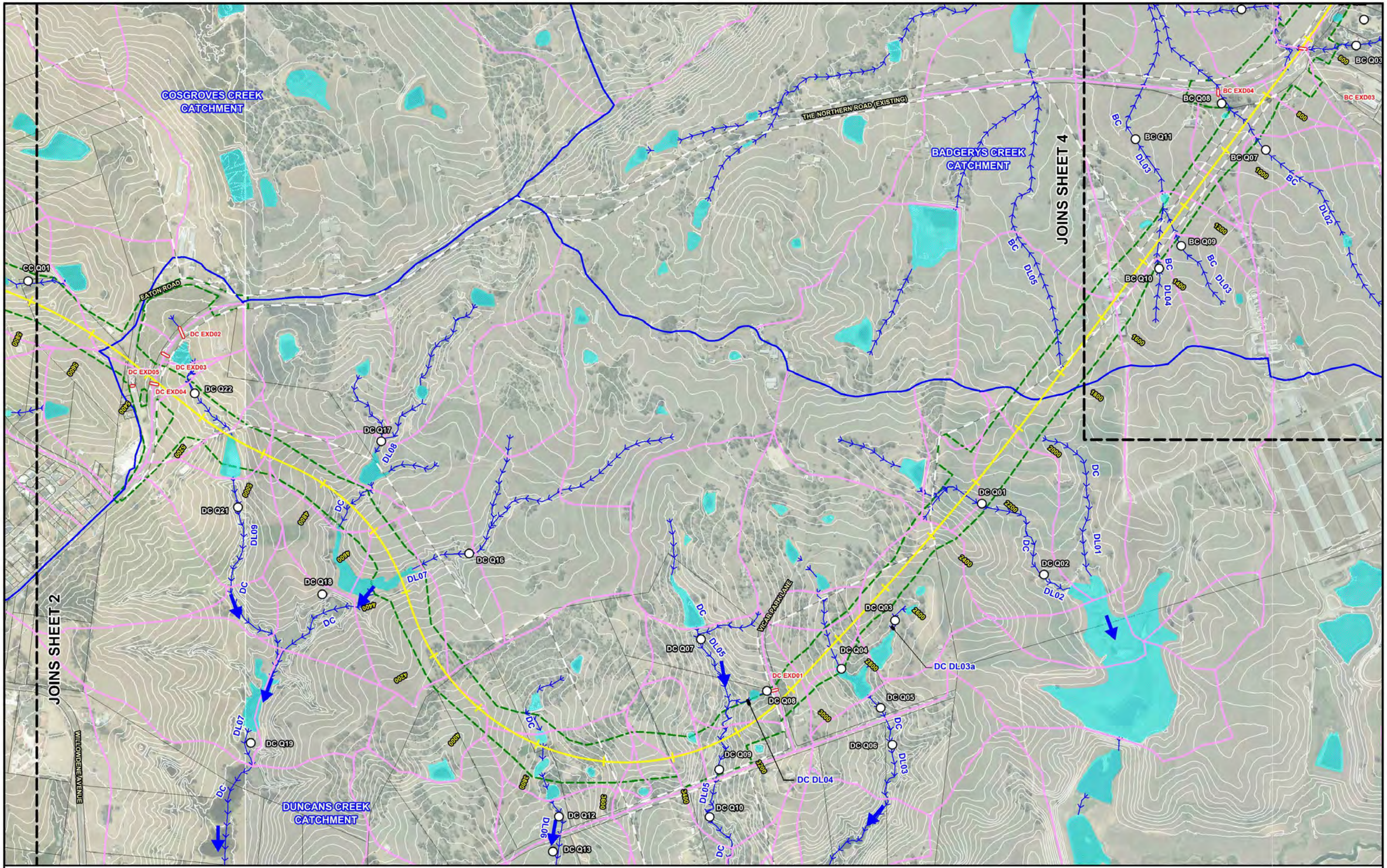
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A2.1
Sheet 2 of 4

SUB-CATCHMENTS COMPRISING HYDROLOGIC MODEL
PRE-PROJECT CONDITIONS



100 0 100 200 300 m
Scale: 1:10,000

LEGEND

- DC EXD03 — Existing Transverse Drainage Structure and Identifier
- Design Road Control String and Chainage
- Existing Dam
- Existing Drainage Lines
- Catchment Boundary
- DC Q02 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
- Sub-Catchment Boundary
- Proposed Western Sydney Airport Boundary
- Project Boundary

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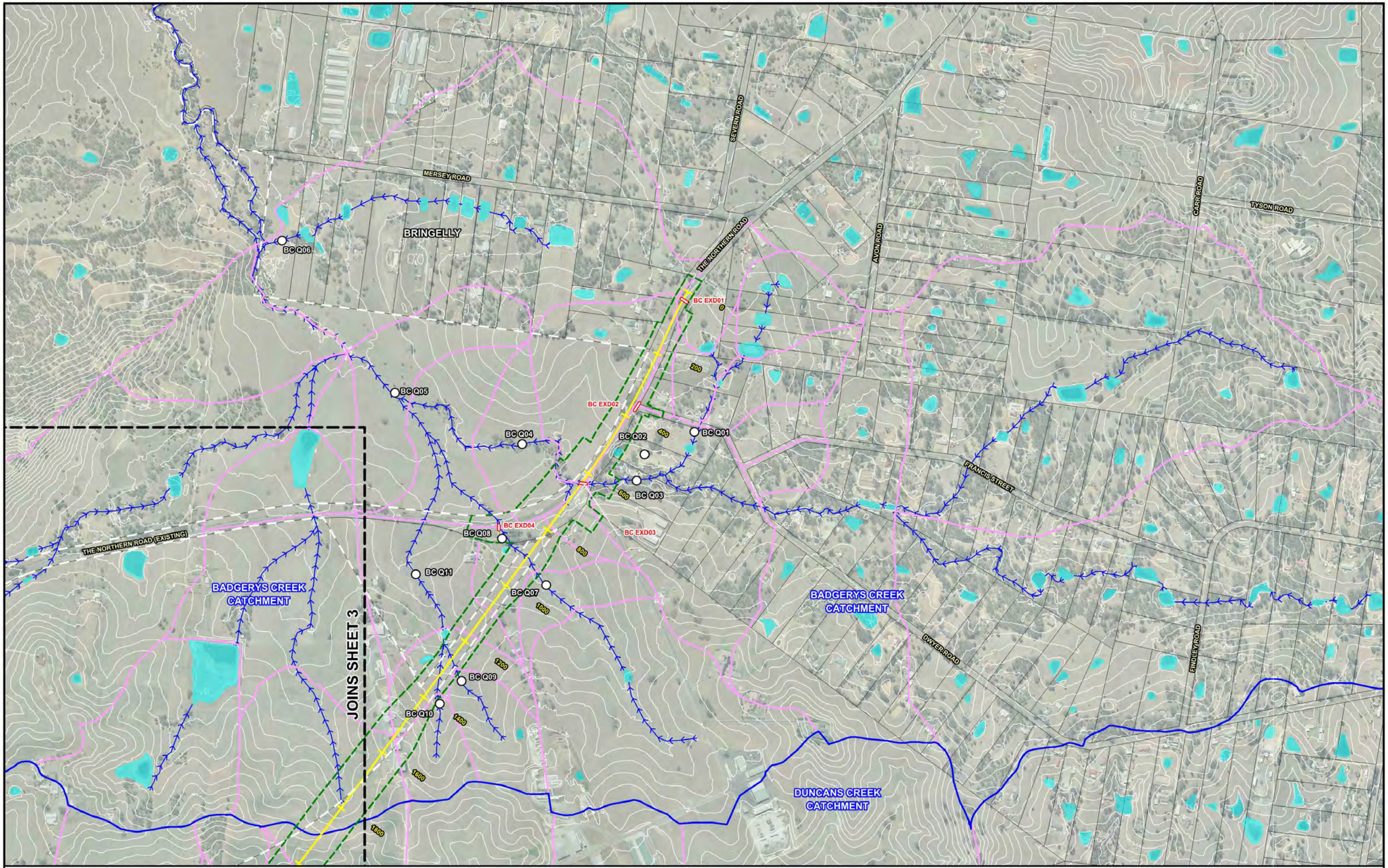
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A2.1
Sheet 3 of 4

SUB-CATCHMENTS COMPRISING HYDROLOGIC MODEL
PRE-PROJECT CONDITIONS



N

100 0 100 200 300 m

Scale: 1:10,000

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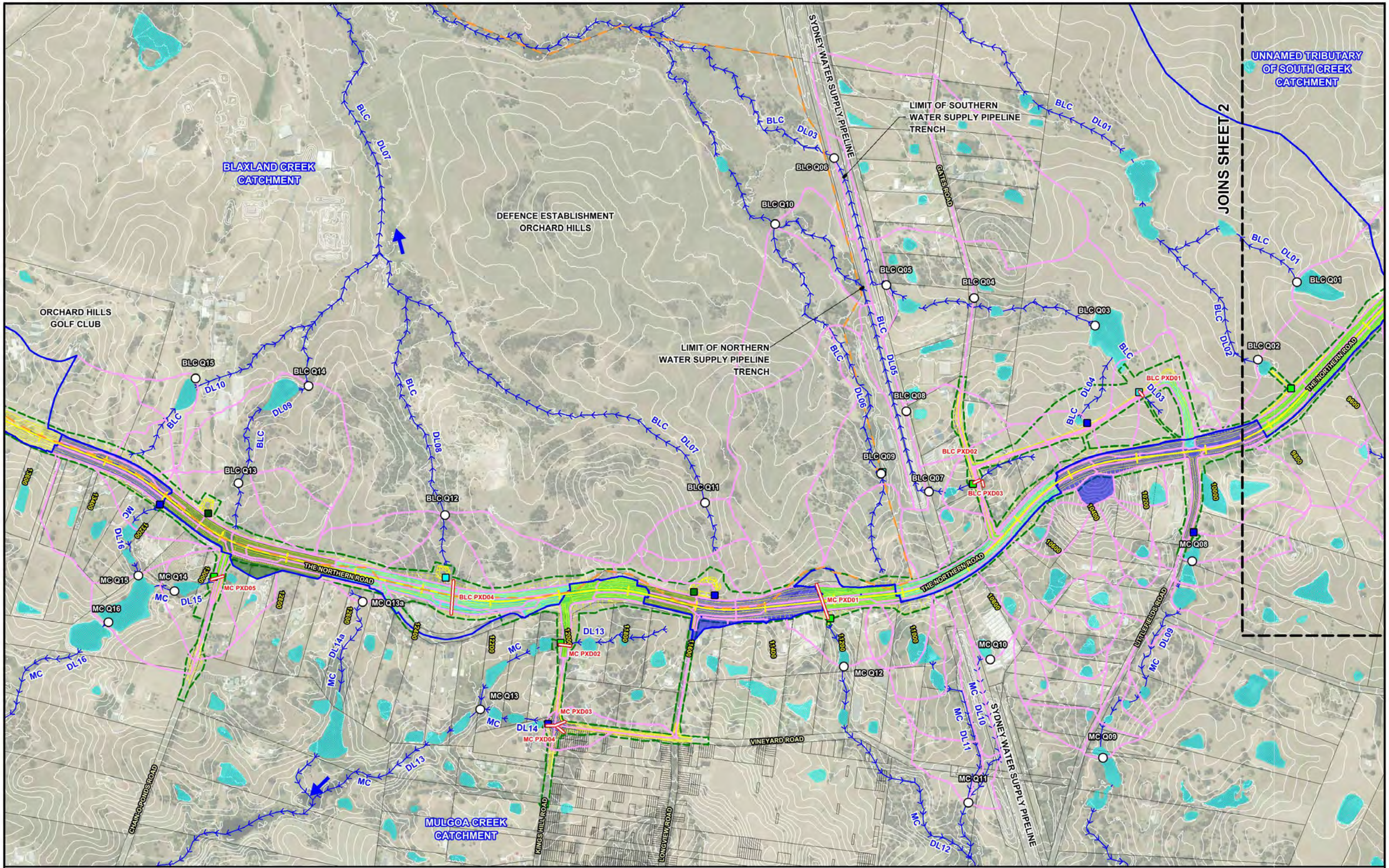
LEGEND

BC EXD03	Existing Transverse Drainage Structure and Identifier		Catchment Boundary		Project Boundary
1800 1900	Design Road Control String and Chainage	BC Q07	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)		
	Existing Dam		Sub-Catchment Boundary		
	Existing Drainage Lines		Proposed Western Sydney Airport Boundary		

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A2.1
Sheet 4 of 4

SUB-CATCHMENTS COMPRISING HYDROLOGIC MODEL
PRE-PROJECT CONDITIONS



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

MC PXD05	Proposed Transverse Drainage Structure and Identifier
	Design Road Control String and Chainage
	Existing Dam
	Existing Drainage Lines
	Sub-Catchment Boundary
BLC Q12	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Project Boundary
	Defence Establishment Orchard Hills Boundary
	Design Strings
	Pavement Drainage Outlet Location
	Extent of Catchment Controlled by Proposed Pavement Drainage
	Catchment Boundary

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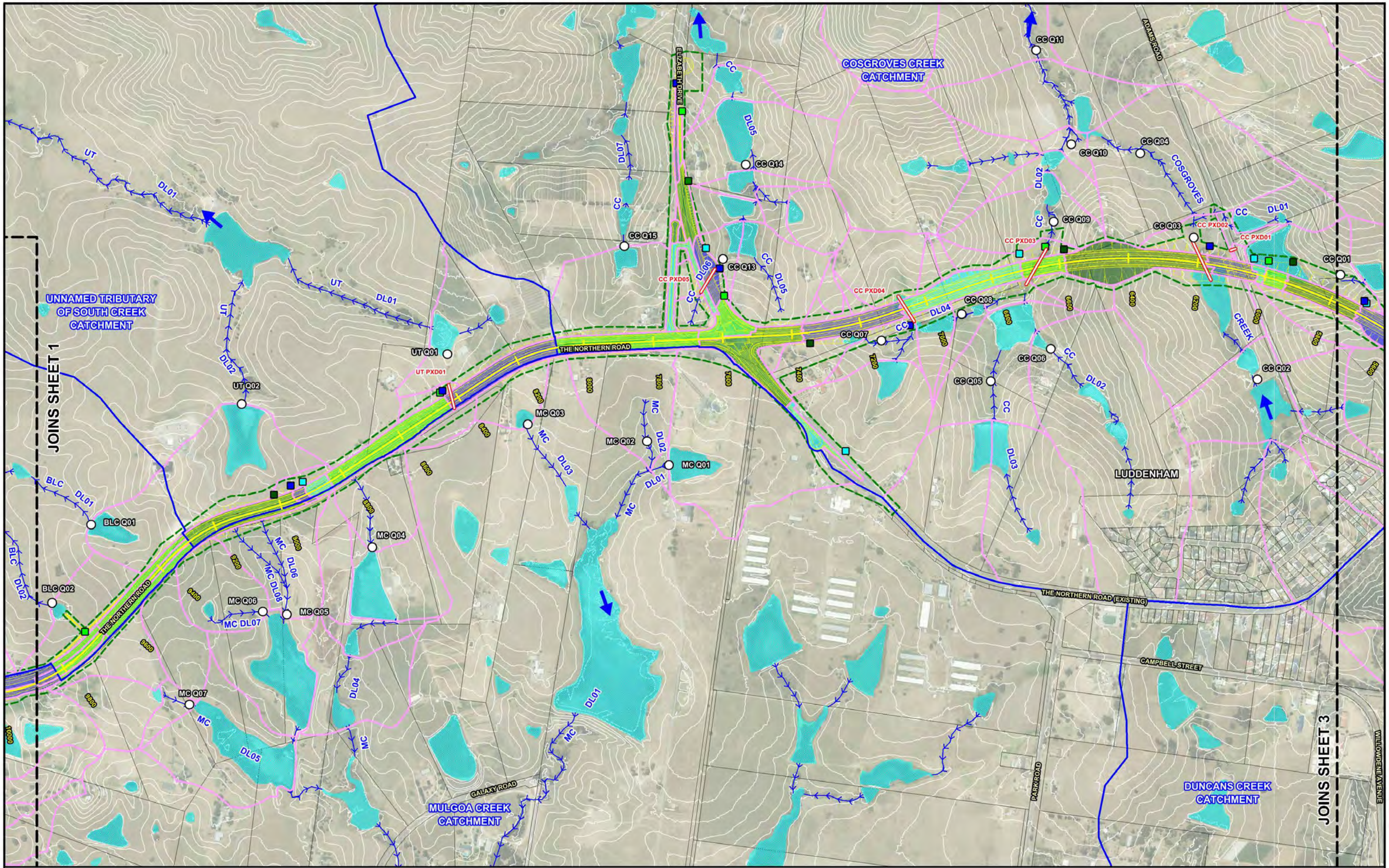
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A2.2
Sheet 1 of 4

SUB-CATCHMENTS COMPRISING HYDROLOGIC MODEL
POST-PROJECT CONDITIONS



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

MC PXD01	Proposed Transverse Drainage Structure and Identifier		Sub-Catchment Boundary
	Design Road Control String and Chainage	MC Q04	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Proposed Western Sydney Airport Boundary		Project Boundary
	Existing Dam		Design Strings
	Existing Drainage Lines		Pavement Drainage Outlet Location
			Extent of Catchment Controlled by Proposed Pavement Drainage
			Catchment Boundary

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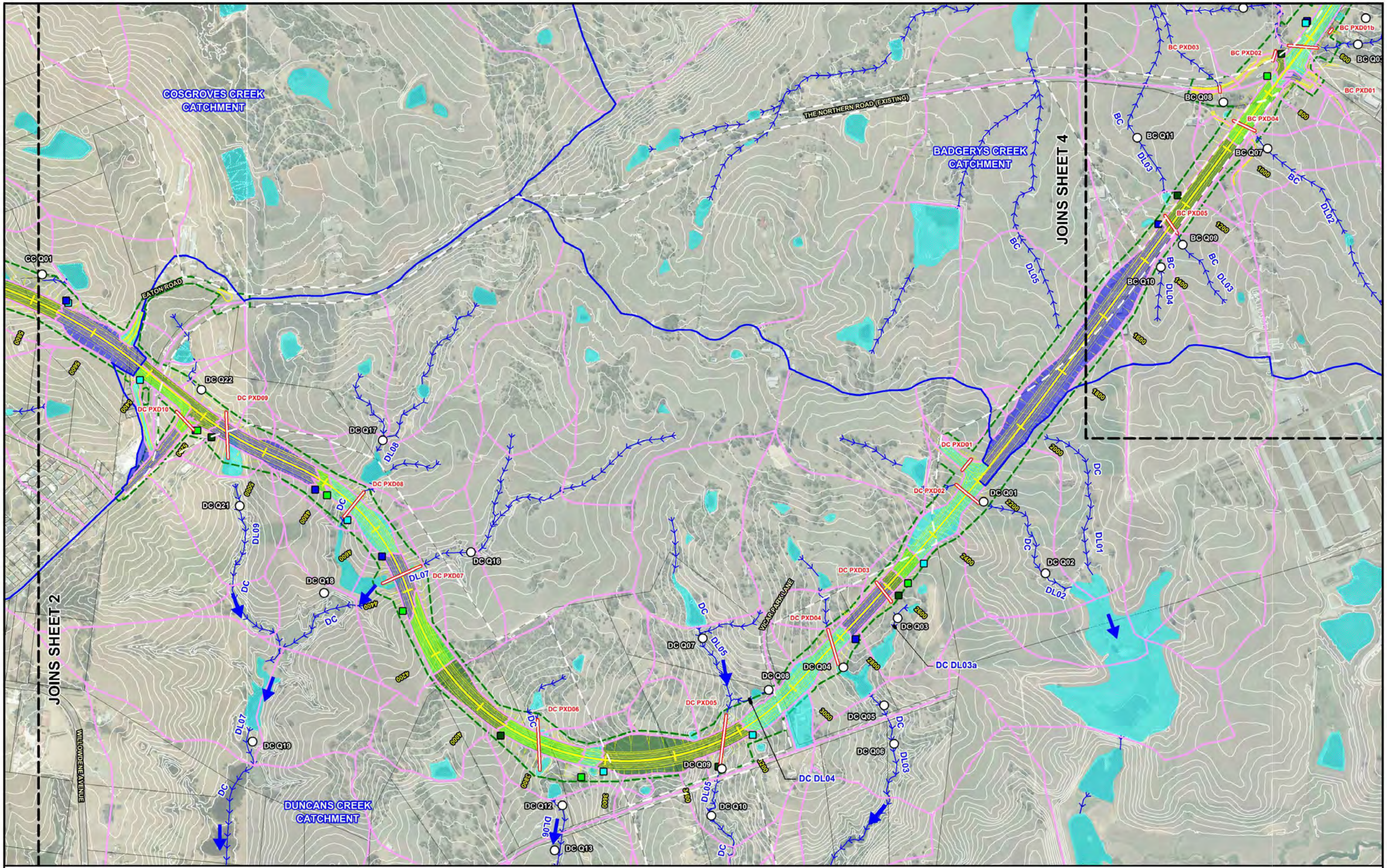
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A2.2
Sheet 2 of 4

SUB-CATCHMENTS COMPRISING HYDROLOGIC MODEL
POST-PROJECT CONDITIONS



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Scale: 1:10,000

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LEGEND

DC PXD03 — Proposed Transverse Drainage Structure and Identifier

Design Road Control String and Chainage

Proposed Western Sydney Airport Boundary

Existing Dam

Existing Drainage Lines

Sub-Catchment Boundary

DC Q02 — Peak Flow Location and Identifier (Refer Table D1 of Appendix D)

Project Boundary

Design Strings

Pavement Drainage Outlet Location

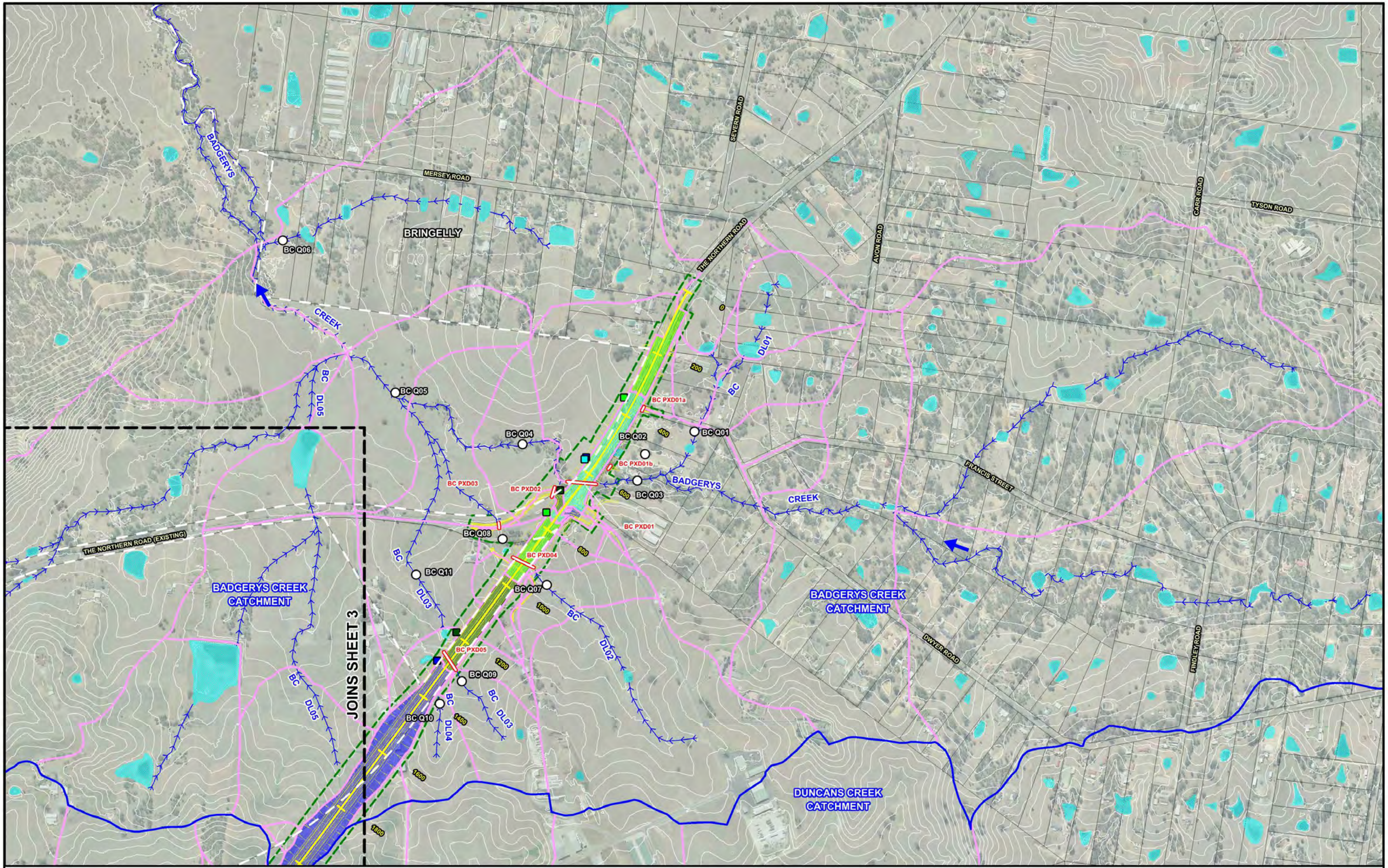
Extent of Catchment Controlled by Proposed Pavement Drainage

Catchment Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A2.2
Sheet 3 of 4

SUB-CATCHMENTS COMPRISING HYDROLOGIC MODEL
POST-PROJECT CONDITIONS



N

100 0 100 200 300 m

Scale: 1:10,000

Lyall & Associates

LEGEND

BC PXD03	Proposed Transverse Drainage Structure and Identifier		Sub-Catchment Boundary
1800	Design Road Control String and Chainage	BC Q07	Peak Flow Location and Identifier (Refer Table D1 of Appendix D)
	Proposed Western Sydney Airport Boundary		Project Boundary
	Existing Dam		
	Existing Drainage Lines		

Design Strings

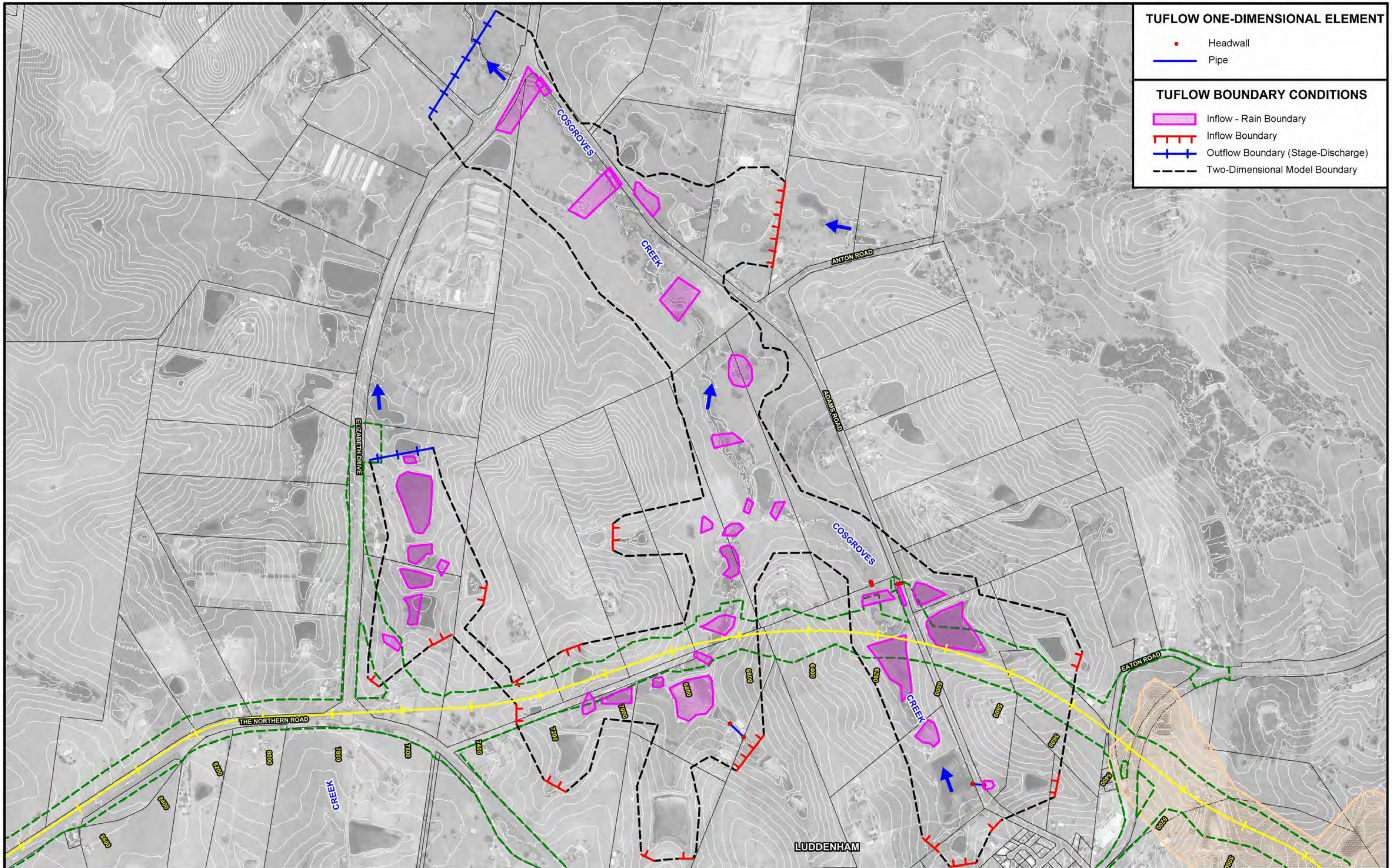
Pavement Drainage Outlet Location

Extent of Catchment Controlled by Proposed Pavement Drainage

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A2.2
Sheet 4 of 4

SUB-CATCHMENTS COMPRISING HYDROLOGIC MODEL
POST-PROJECT CONDITIONS



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Scale: 1:10,000

Lyall & Associates

LEGEND

Design Road Control String and Chainage

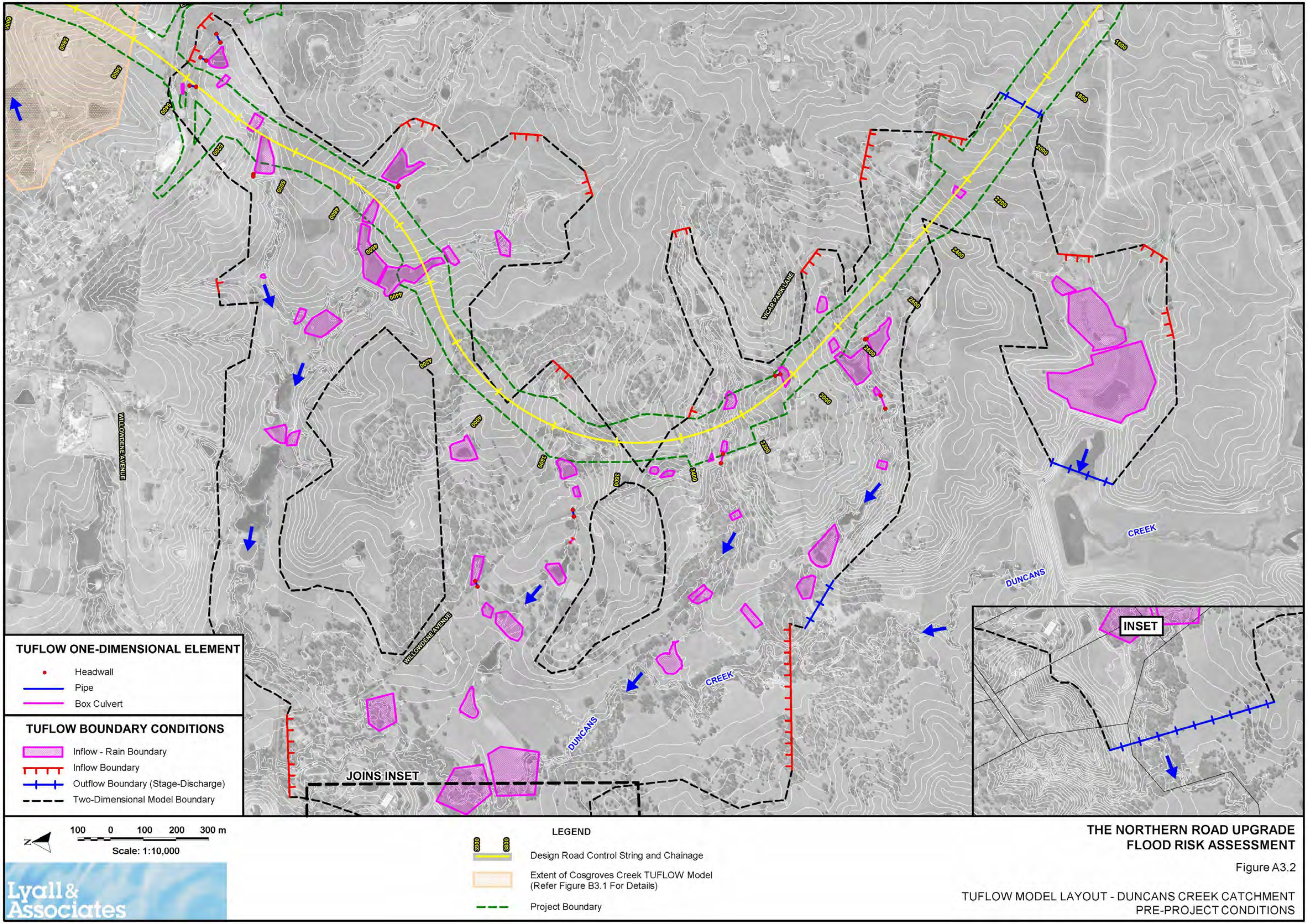
Extent of Duncans Creek TUFLOW Model (Refer Figure B3.2 For Details)

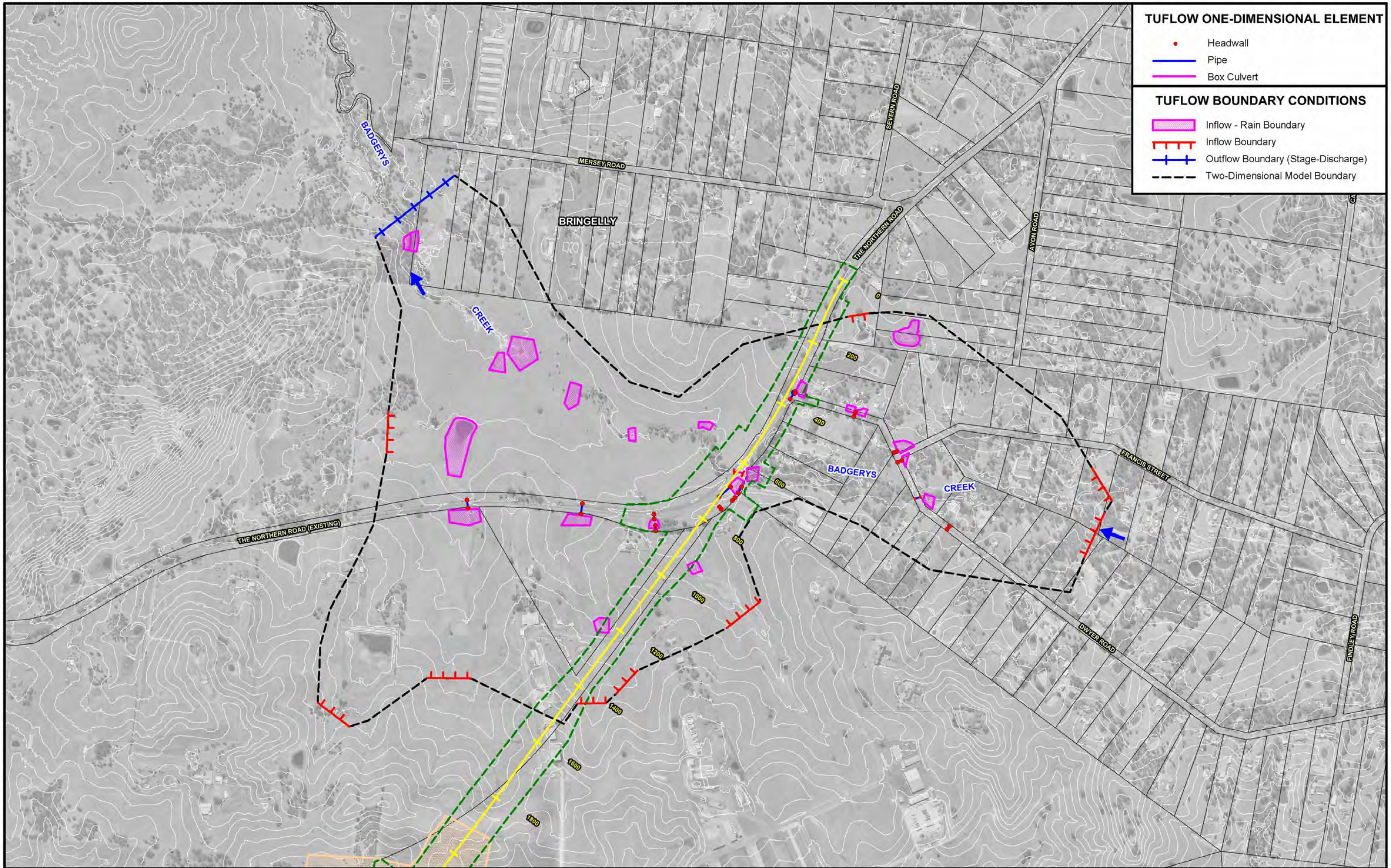
Project Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A3.1

TUFLOW MODEL LAYOUT - COSGROVES CREEK CATCHMENT
PRE-PROJECT CONDITIONS


TUFLOW ONE-DIMENSIONAL ELEMENT
Headwall
Pipe
Box Culvert
TUFLOW BOUNDARY CONDITIONS
Inflow - Rain Boundary
Inflow Boundary
Outflow Boundary (Stage-Discharge)
Two-Dimensional Model Boundary
JOINS INSET
INSET
DUNCANS CREEK
WILLOWDENE AVENUE
VICAR PARK LANE
100 0 100 200 300 m
Scale: 1:10,000
LEGEND
Design Road Control String and Chainage
Extent of Cosgroves Creek TUFLOW Model
(Refer Figure B3.1 For Details)
Project Boundary
Lyall & Associates
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT
Figure A3.2
TUFLOW MODEL LAYOUT - DUNCANS CREEK CATCHMENT
PRE-PROJECT CONDITIONS



100 0 100 200 300 m

Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure B3.2 For Details)

Project Boundary

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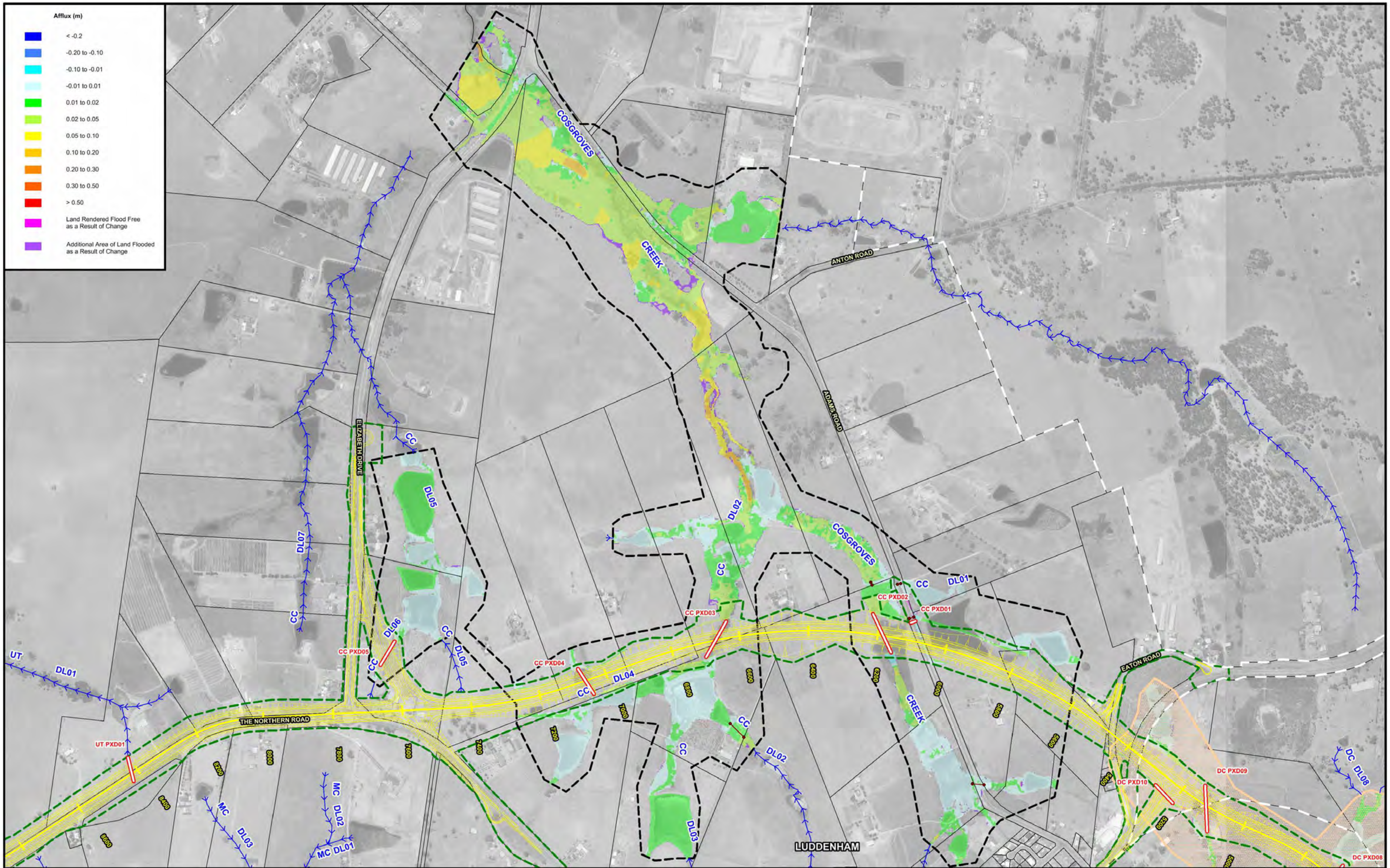
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A3.3

TUFLOW MODEL LAYOUT - BADGERYS CREEK CATCHMENT
PRE-PROJECT CONDITIONS



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Scale: 1:10,000

LEGEND

Design Road Control String and Chainage

Extent of Duncans Creek TUFLOW Model (Refer Figure B3.5 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

CC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

Proposed Western Sydney Airport Boundary

Project Boundary

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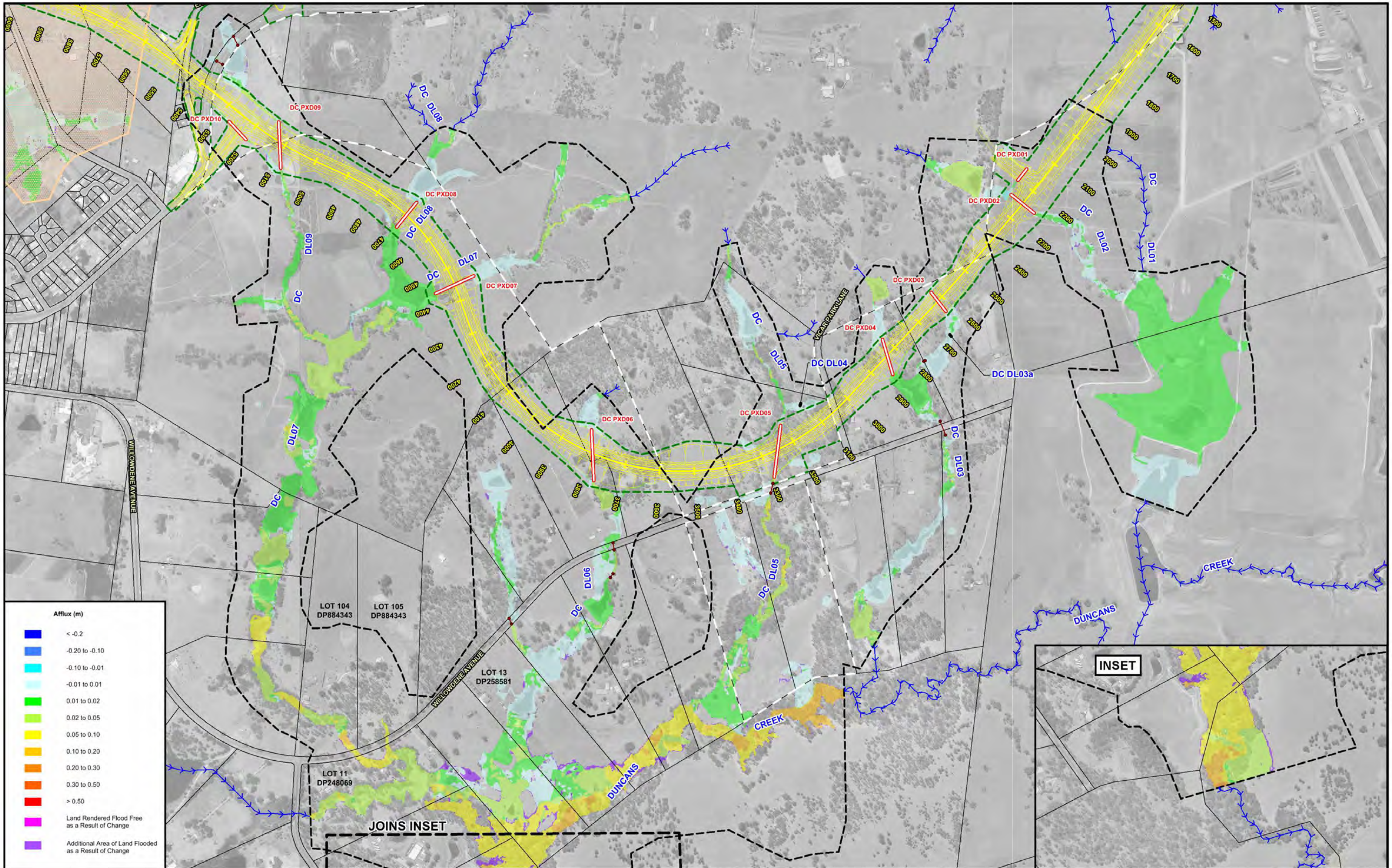
THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A3.4

SENSITIVITY OF FLOOD BEHAVIOUR TO 20% INCREASE IN HYDRAULIC ROUGHNESS VALUES
COSGROVES CREEK CATCHMENT - 100 YEAR ARI



100 0 100 200 300 m

Scale: 1:10,000

Lyall & Associates

LEGEND

Design Road Control String and Chainage

Extent of Cosgroves Creek TUFLOW Model (Refer Figure B3.4 for TUFLOW Model Results)

Modelled Stormwater Drainage Network

Design Strings

DC PXD01 Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)

Two-Dimensional Model Extent

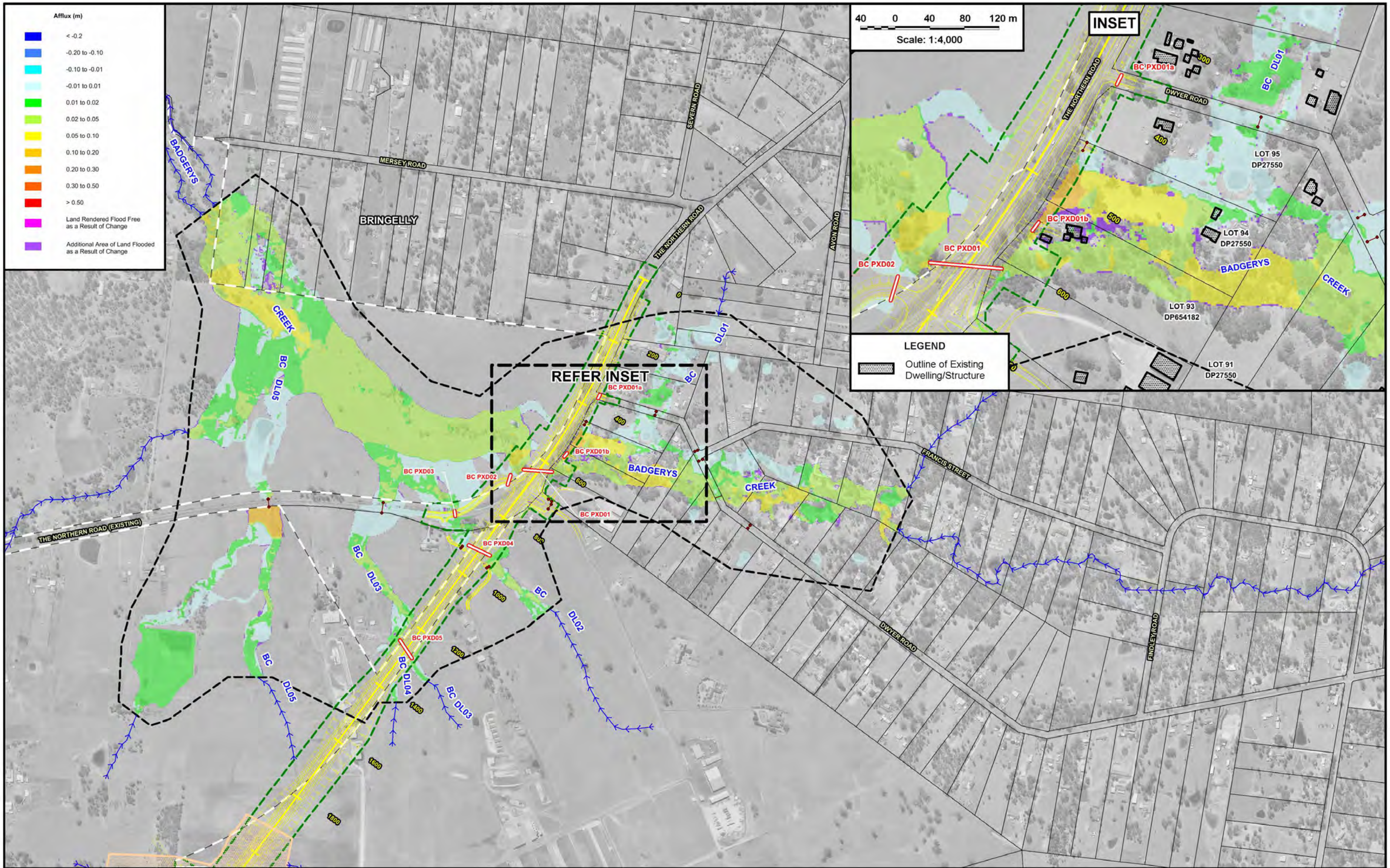
Proposed Western Sydney Airport Boundary

Project Boundary

THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A3.5

SENSITIVITY OF FLOOD BEHAVIOUR TO 20% INCREASE IN HYDRAULIC ROUGHNESS VALUES
DUNCANS CREEK CATCHMENT - 100 YEAR ARI



100 0 100 200 300 m
Scale: 1:10,000

LEGEND

Design Road Control String and Chainage
Extent of Duncans Creek TUFLOW Model (Refer Figure B3.5 for TUFLOW Model Results)
Modelled Stormwater Drainage Network
Design Strings
BC PXD01 — Proposed Transverse Drainage Structure and Identifier (Refer Table 6.1 for Peak Flow in Individual Transverse Drainage Structures)
Two-Dimensional Model Extent
Proposed Western Sydney Airport Boundary
Project Boundary

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THE NORTHERN ROAD UPGRADE
FLOOD RISK ASSESSMENT

Figure A3.6

SENSITIVITY OF FLOOD BEHAVIOUR TO 20% INCREASE IN HYDRAULIC ROUGHNESS VALUES
BADGERYS CREEK CATCHMENT - 100 YEAR ARI

APPENDIX B
SKETCH SHOWING TYPICAL DETAILS
OF PROPOSED SECURITY MEASURE

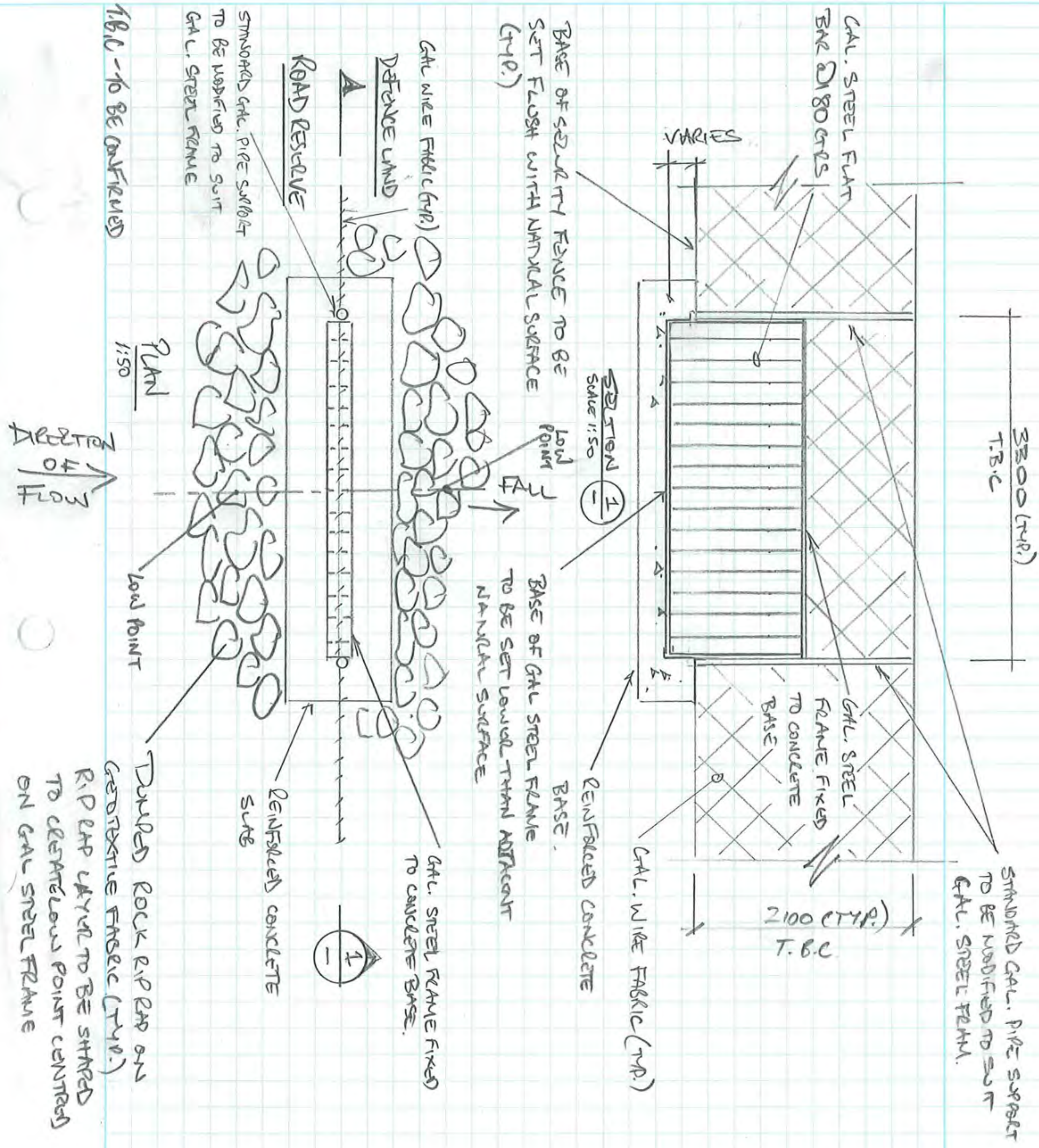
LYALL & ASSOCIATES CONSULTING WATER ENGINEERS

PROJECT: THE NORTHERN ROAD UPGRADE — PAGE No. 1

JOB No. AM399

TITLE: PROPOSED SECURITY MEASURE AT LOCATION OF CONCENTRATED FLOW PATHS. — PREPARED: SAB — DATE: 2/10/16

CHECKED: — DATE:



APPENDIX C
SUMMARY OF PEAK FLOWS
PRE- AND POST-PROJECT CONDITIONS

TABLE C1
COMPARISON OF PEAK FLOWS
(m^3/s)

Catchment	Drainage Line	Length of Carriageway Draining to Receiving Drainage Line		Peak Flow Location	Land Ownership	2 year ARI			10 year ARI			100 year ARI		
		Approximate Start Chainage	Approximate End Chainage			Pre-Project Conditions	Post-Project Conditions	Difference	Pre-Project Conditions	Post-Project Conditions	Difference	Pre-Project Conditions	Post-Project Conditions	Difference
Blaxland Creek	BLC DL01	-	-	BLC Q01	P	0.32	0.30	-0.02 [-6%]	0.80	0.74	-0.06 [-8%]	1.51	1.39	-0.12 [-8%]
	BLC DL02	DRC 9280 (The Northern Road)	DRC 9840 (The Northern Road)	MCPB	P	Minor	0.41	0.41 [>100%]	Minor	0.71	0.71 [>100%]	Minor	1.12	1.12 [>100%]
	BLC DL02	DRC 9280 (The Northern Road)	DRC 9840 (The Northern Road)	BLC Q02	P	0.43	0.55	0.12 [28%]	0.84	1.19	0.35 [42%]	1.61	2.16	0.55 [34%]
	BLC DL03	DRC 10040 (Littlefields Road)	DRC 10440 (Littlefields Road)	LRPB	P	0.29	0.54	0.25 [86%]	0.67	1.19	0.52 [78%]	1.18	2.08	0.9 [76%]
	BLC DL03	DRC 10040 (Littlefields Road)	DRC 10440 (Littlefields Road)	BLC Q03	P	0.84	0.84	0 [0%]	1.96	1.88	-0.08 [-4%]	3.50	3.19	-0.31 [-9%]
	BLC DL03	DRC 10040 (Littlefields Road)	DRC 10440 (Littlefields Road)	BLC Q04	P	1.88	1.64	-0.24 [-13%]	3.87	3.80	-0.07 [-2%]	7.40	7.07	-0.33 [-4%]
	BLC DL03	DRC 10040 (Littlefields Road)	DRC 10440 (Littlefields Road)	BLC Q05	P/WNSW	2.40	1.99	-0.41 [-17%]	4.68	4.59	-0.09 [-2%]	9.31	8.91	-0.4 [-4%]
	BLC DL03	DRC 10040 (Littlefields Road)	DRC 10440 (Littlefields Road)	BLC Q06	WNSW/COM	3.93	3.10	-0.83 [-21%]	7.22	7.11	-0.11 [-2%]	14.00	13.60	-0.4 [-3%]
	BLC DL04	-	-	LRPB	P	0.26	0.10	-0.16 [-62%]	0.55	0.23	-0.32 [-58%]	0.83	0.39	-0.44 [-53%]
	BLC DL05	DRC 10440 (Littlefields Road)	DRC 10680 (Gates Road)	LRPB	P	0.39	0.41	0.02 [5%]	0.78	0.97	0.19 [24%]	1.48	1.71	0.23 [16%]
	BLC DL05	DRC 10440 (Littlefields Road)	DRC 10680 (Gates Road)	BLC Q07	P/WNSW	0.93	0.89	-0.04 [-4%]	2.10	1.99	-0.11 [-5%]	3.70	3.38	-0.32 [-9%]
	BLC DL05	-	-	BLC Q08	P/WNSW	0.33	0.36	0.03 [9%]	0.54	0.56	0.02 [4%]	0.63	0.65	0.02 [3%]
	BLC DL06	DRC 10440 (The Northern Road)	DRC 11020 (The Northern Road)	MCPB	COM	Minor	Minor	0.00 [%]	Minor	Minor	0.00 [%]	Minor	Minor	0.00 [%]
	BLC DL06	DRC 10440 (The Northern Road)	DRC 11020 (The Northern Road)	BLC Q09	COM	0.45	0.67	0.22 [49%]	0.94	1.42	0.48 [51%]	1.74	2.40	0.66 [38%]
	BLC DL06	DRC 10440 (The Northern Road)	DRC 11020 (The Northern Road)	BLC Q10	COM	3.49	3.42	-0.07 [-2%]	6.95	7.29	0.34 [5%]	12.40	12.70	0.3 [2%]
	BLC DL07	DRC 11240 (The Northern Road)	DRC 11740 (The Northern Road)	MCPB	COM	Minor	0.60	0.6 [>100%]	Minor	1.13	1.13 [>100%]	Minor	1.87	1.87 [>100%]
	BLC DL07	DRC 11240 (The Northern Road)	DRC 11740 (The Northern Road)	BLC Q11	COM	0.76	1.02	0.26 [34%]	1.72	2.14	0.42 [24%]	3.10	3.67	0.57 [18%]
	BLC DL08	DRC 11080 (The Northern Road)	DRC 12660 (The Northern Road)	MCPB	COM	0.21	0.62	0.41 [195%]	0.48	1.19	0.73 [159%]	0.79	2.02	1.19 [143%]
	BLC DL08	DRC 11080 (The Northern Road)	DRC 12660 (The Northern Road)	BLC Q12	COM	1.35	1.33	-0.02 [-1%]	2.74	3.00	0.26 [9%]	5.09	5.34	0.25 [5%]

Refer over for footnotes to **Table C1**.

TABLE C1 (Cont'd)
COMPARISON OF PEAK FLOWS
(m^3/s)

Catchment	Drainage Line	Length of Carriageway Draining to Receiving Drainage Line		Peak Flow Location	Land Ownership	2 year ARI			10 year ARI			100 year ARI		
		Approximate Start Chainage	Approximate End Chainage			Pre-Project Conditions	Post-Project Conditions	Difference	Pre-Project Conditions	Post-Project Conditions	Difference	Pre-Project Conditions	Post-Project Conditions	Difference
Blaxland Creek	BLC DL09	DRC 12660 (The Northern Road)	DRC 13200 (The Northern Road)	MCPB	COM	0.09	0.46	0.37 [411%]	0.19	0.85	0.66 [347%]	0.32	1.38	1.06 [331%]
	BLC DL09	DRC 12660 (The Northern Road)	DRC 13200 (The Northern Road)	BLC Q13	COM	0.48	0.67	0.19 [40%]	1.01	1.38	0.37 [37%]	1.85	2.33	0.48 [26%]
	BLC DL09	DRC 12660 (The Northern Road)	DRC 13200 (The Northern Road)	BLC Q14	COM	1.24	1.20	-0.04 [-3%]	2.48	2.83	0.35 [14%]	4.79	5.27	0.48 [10%]
	BLC DL10	-	-	MCPB	COM	Minor	Minor	0.00 [%]	Minor	Minor	0.00 [%]	Minor	Minor	0.00 [%]
	BLC DL10	-	-	BLC Q15	COM	0.63	0.50	-0.13 [-21%]	1.23	1.20	-0.03 [-2%]	2.37	2.31	-0.06 [-3%]
Mulgoa Creek	MC DL01	-	-	MC Q01	P	0.64	0.62	-0.02 [-3%]	1.39	1.36	-0.03 [-2%]	2.59	2.52	-0.07 [-3%]
	MC DL02	-	-	MC Q02	P	0.39	0.37	-0.02 [-5%]	0.80	0.76	-0.04 [-5%]	1.60	1.52	-0.08 [-5%]
	MC DL03	-	-	MC Q03	P	0.37	0.22	-0.15 [-41%]	0.79	0.51	-0.28 [-35%]	1.29	0.93	-0.36 [-28%]
	MC DL04	-	-	MC Q04	P	0.31	0.29	-0.02 [-6%]	0.76	0.70	-0.06 [-8%]	1.42	1.32	-0.1 [-7%]
	MC DL06	-	-	MC Q05	P	0.36	0.33	-0.03 [-8%]	0.75	0.69	-0.06 [-8%]	1.49	1.38	-0.11 [-7%]
	MC DL07	-	-	MC Q06	P	0.28	0.27	-0.01 [-4%]	0.63	0.60	-0.03 [-5%]	1.24	1.19	-0.05 [-4%]
	MC DL05	-	-	MC Q07	P	0.70	0.66	-0.04 [-6%]	1.57	1.51	-0.06 [-4%]	3.09	2.96	-0.13 [-4%]
	MC DL09	DRC 9840 (The Northern Road)	DRC 10440 (The Northern Road)	MC Q08	P	1.13	1.61	0.48 [42%]	2.54	3.34	0.8 [31%]	4.68	5.77	1.09 [23%]
	MC DL09	DRC 9840 (The Northern Road)	DRC 10440 (The Northern Road)	MC Q09	P	3.69	4.04	0.35 [9%]	8.16	8.69	0.53 [6%]	14.20	14.70	0.5 [4%]
	MC DL10	-	-	MC Q10	P/WNSW	0.37	0.30	-0.07 [-19%]	0.80	0.74	-0.06 [-8%]	1.46	1.35	-0.11 [-8%]
	MC DL11	-	-	MC Q11	P/WNSW	1.36	1.12	-0.24 [-18%]	2.86	2.69	-0.17 [-6%]	5.23	4.96	-0.27 [-5%]
	MC DL 12	DRC 11020 (The Northern Road)	DRC 11240 (The Northern Road)	MCPB	P	0.22	0.23	0.01 [5%]	0.47	0.45	-0.02 [-4%]	0.74	0.75	0.01 [1%]
	MC DL 12	DRC 11020 (The Northern Road)	DRC 11240 (The Northern Road)	MC Q12	P	0.59	0.57	-0.02 [-3%]	1.23	1.10	-0.13 [-11%]	1.92	1.76	-0.16 [-8%]
	MC DL13	DRC 11740 (The Northern Road)	DRC 11980 (The Northern Road and Kings Hill Road (West))	LRPB	P	0.78	0.59	-0.19 [-24%]	1.58	1.23	-0.35 [-22%]	3.06	2.49	-0.57 [-19%]
	MC DL13	DRC 11740 (The Northern Road)	DRC 12040 (The Northern Road and Kings Hill Road (West))	MC Q13	P	0.94	0.79	-0.15 [-16%]	1.86	1.73	-0.13 [-7%]	3.63	3.25	-0.38 [-10%]

Refer over for footnotes to **Table C1**.

TABLE C1 (Cont'd)
COMPARISON OF PEAK FLOWS
(m^3/s)

Catchment	Drainage Line	Length of Carriageway Draining to Receiving Drainage Line		Peak Flow Location	Land Ownership	2 year ARI			10 year ARI			100 year ARI		
		Approximate Start Chainage	Approximate End Chainage			Pre-Project Conditions	Post-Project Conditions	Difference	Pre-Project Conditions	Post-Project Conditions	Difference	Pre-Project Conditions	Post-Project Conditions	Difference
Mulgoa Creek	MC DL14a	-	-	MCPB	P	0.02	0.01	-0.01 [-50%]	0.05	0.02	-0.03 [-60%]	0.08	0.04	-0.04 [-50%]
	MC DL14a	-	-	MC Q13a	P	0.06	0.05	-0.01 [-17%]	0.15	0.11	-0.04 [-27%]	0.25	0.21	-0.04 [-16%]
	MC DL14	DRC 11960 (The Northern Road and Kings Hill Road (West))	DRC 12040 (The Northern Road and Kings Hill Road (West))	LRPB	P	0.15	0.31	0.16 [107%]	0.35	0.62	0.27 [77%]	0.63	0.95	0.32 [51%]
	MC DL15	DRC 12980 (Chain of Ponds Road)	DRC 12980 (Chain of Ponds Road)	LRPB	P	0.20	0.19	-0.01 [-5%]	0.40	0.43	0.03 [7%]	0.74	0.85	0.11 [15%]
	MC DL15	DRC 12980 (Chain of Ponds Road)	DRC 12980 (Chain of Ponds Road)	MC Q14	P	0.42	0.37	-0.05 [-12%]	0.83	0.90	0.07 [8%]	1.60	1.73	0.13 [8%]
	MC DL16	DRC 13200 (The Northern Road)	DRC 13540 (The Northern Road)	MCPB	P	0.29	0.25	-0.04 [-14%]	0.57	0.44	-0.13 [-23%]	0.88	0.69	-0.19 [-22%]
	MC DL16	DRC 13200 (The Northern Road)	DRC 13540 (The Northern Road)	MC Q15	P	0.79	0.64	-0.15 [-19%]	1.81	1.48	-0.33 [-18%]	3.25	2.81	-0.44 [-14%]
	MC DL16	DRC 12980 (Chain of Ponds Road)	DRC 13540 (The Northern Road)	MC Q16	P	1.51	1.28	-0.23 [-15%]	3.24	3.01	-0.23 [-7%]	6.06	5.72	-0.34 [-6%]
Unnamed Tributary of South Creek	UT DL01	DRC 8060 (The Northern Road)	DRC 8840 (The Northern Road)	MCPB	P	0.36	0.61	0.25 [69%]	0.77	1.06	0.29 [38%]	1.26	1.84	0.58 [46%]
	UT DL01	DRC 8060 (The Northern Road)	DRC 8840 (The Northern Road)	UT Q01	P	0.80	1.05	0.25 [31%]	1.93	2.18	0.25 [13%]	3.65	3.99	0.34 [9%]
	UT DL02	DRC 8840 (The Northern Road)	DRC 9280 (The Northern Road)	MCPB	P	0.14	0.39	0.25 [179%]	0.34	0.70	0.36 [106%]	0.56	1.17	0.61 [109%]
	UT DL02	DRC 8840 (The Northern Road)	DRC 9280 (The Northern Road)	UT Q02	P	0.57	0.70	0.13 [23%]	1.31	1.55	0.24 [18%]	2.60	2.92	0.32 [12%]
Cosgroves Creek	CC DL01	DRC 5440 (The Northern Road)	DRC 5740 (The Northern Road)	CC Q01	P	0.40	0.50	0.1 [25%]	0.60	0.80	0.2 [33%]	1.20	1.50	0.3 [25%]
	Cosgroves Creek	-	-	CC Q02	P	2.20	2.20	0 [0%]	3.90	3.90	0 [0%]	8.60	8.60	0 [0%]
	Cosgroves Creek	DRC 5440 (The Northern Road)	DRC 6200 (The Northern Road)	CC Q03	P	3.00	4.20	1.2 [40%]	5.30	7.30	2 [38%]	11.40	16.00	4.6 [40%]
	Cosgroves Creek	DRC 5440 (The Northern Road)	DRC 6200 (The Northern Road)	CC Q04	P	3.70	4.60	0.9 [24%]	6.70	7.80	1.1 [16%]	12.90	16.90	4 [31%]
	CC DL03	-	-	CC Q05	P	0.70	0.70	0 [0%]	1.40	1.40	0 [0%]	2.30	2.30	0 [0%]
	CC DL02	-	-	CC Q06	P	1.50	1.50	0 [0%]	2.30	2.30	0 [0%]	5.50	5.50	0 [0%]
	CC DL04	DRC 7400 (The Northern Road)	DRC 7520 (The Northern Road)	CC Q07	P	0.30	0.40	0.1 [33%]	0.80	0.80	0 [0%]	1.50	1.50	0 [0%]
	CC DL04	DRC 7100 (The Northern Road)	DRC 7520 (The Northern Road)	CC Q08	P	1.10	1.30	0.2 [18%]	2.10	2.30	0.2 [10%]	3.50	3.80	0.3 [9%]
	CC DL02	DRC 6200 (The Northern Road)	DRC 7520 (The Northern Road)	CC Q09	P	3.20	3.50	0.3 [9%]	6.60	7.10	0.5 [8%]	10.90	11.70	0.8 [7%]

Refer over for footnotes to **Table C1**.

TABLE C1 (Cont'd)
COMPARISON OF PEAK FLOWS
(m^3/s)

Catchment	Drainage Line	Length of Carriageway Draining to Receiving Drainage Line		Peak Flow Location	Land Ownership	2 year ARI			10 year ARI			100 year ARI		
		Approximate Start Chainage	Approximate End Chainage			Pre-Project Conditions	Post-Project Conditions	Difference	Pre-Project Conditions	Post-Project Conditions	Difference	Pre-Project Conditions	Post-Project Conditions	Difference
Cosgroves Creek	CC DL02	DRC 5440 (The Northern Road)	DRC 7520 (The Northern Road)	CC Q10	P	4.00	4.50	0.5 [13%]	8.40	8.90	0.5 [6%]	13.90	14.70	0.8 [6%]
	Cosgroves Creek	DRC 5440 (The Northern Road)	DRC 7520 (The Northern Road)	CC Q11	P	8.80	10.10	1.3 [15%]	16.50	17.80	1.3 [8%]	27.20	31.90	4.7 [17%]
	Cosgroves Creek	DRC 5440 (The Northern Road)	DRC 7520 (The Northern Road)	CC Q12	P	19.10	20.40	1.3 [7%]	34.20	35.80	1.6 [5%]	55.10	57.50	2.4 [4%]
	CC DL06	DRC 7520 (The Northern Road)	DRC 8100 (The Northern Road)	CC Q13	P	0.40	0.80	0.4 [100%]	0.90	1.40	0.5 [56%]	1.50	2.50	1 [67%]
	CC DL05	DRC 7520 (The Northern Road)	DRC 8100 (The Northern Road)	CC Q14	P	0.80	0.90	0.1 [13%]	1.60	1.70	0.1 [6%]	2.60	2.80	0.2 [8%]
	CC DL07	-	-	CC Q15	P	0.60	0.43	-0.17 [-28%]	1.45	1.02	-0.43 [-30%]	2.72	1.97	-0.75 [-28%]
Duncans Creek	DC DL02	-	-	DC Q01	P	0.70	0.60	-0.1 [-14%]	1.20	1.10	-0.1 [-8%]	1.90	1.70	-0.2 [-11%]
	DC DL02	-	-	DC Q02	P	0.70	0.60	-0.1 [-14%]	1.20	1.00	-0.2 [-17%]	1.90	1.70	-0.2 [-11%]
	DC DL03a	DRC 2180 (The Northern Road)	DRC 2640 (The Northern Road)	DC Q03	P	Minor	0.50	0.5 [>100%]	Minor	0.90	0.9 [>100%]	Minor	1.30	1.3 [>100%]
	DC DL03	DRC 2640 (The Northern Road)	DRC 2800 (The Northern Road)	DC Q04	P	1.00	0.90	-0.1 [-10%]	1.60	1.50	-0.1 [-6%]	2.90	2.40	-0.5 [-17%]
	DC DL03	DRC 2180 (The Northern Road)	DRC 2800 (The Northern Road)	DC Q05	P	1.70	1.70	0 [0%]	2.90	2.90	0 [0%]	5.20	5.00	-0.2 [-4%]
	DC DL03	DRC 2180 (The Northern Road)	DRC 2800 (The Northern Road)	DC Q06	P	1.70	1.80	0.1 [6%]	3.00	3.00	0 [0%]	5.30	5.10	-0.2 [-4%]
	DC DL05	-	-	DC Q07	P	0.80	0.80	0 [0%]	1.40	1.40	0 [0%]	2.70	2.70	0 [0%]
	DC DL04	-	-	DC Q08	P	0.30	0.10	-0.2 [-67%]	0.50	0.20	-0.3 [-60%]	0.90	0.30	-0.6 [-67%]
	DC DL05	DRC 2800 (The Northern Road)	DRC 3620 (The Northern Road)	DC Q09	P	1.70	1.80	0.1 [6%]	2.90	3.40	0.5 [17%]	5.20	5.80	0.6 [12%]
	DC DL05	DRC 2800 (The Northern Road)	DRC 3620 (The Northern Road)	DC Q10	P	1.80	1.90	0.1 [6%]	3.20	3.80	0.6 [19%]	6.00	6.40	0.4 [7%]
	DC DL05	DRC 2800 (The Northern Road)	DRC 3620 (The Northern Road)	DC Q11	P	2.60	2.70	0.1 [4%]	4.60	5.30	0.7 [15%]	9.20	10.10	0.9 [10%]
	DC DL06	DRC 3620 (The Northern Road)	DRC 4180 (The Northern Road)	DC Q12	P	1.00	1.10	0.1 [10%]	1.80	1.90	0.1 [6%]	3.10	3.60	0.5 [16%]
	DC DL06	DRC 3620 (The Northern Road)	DRC 4180 (The Northern Road)	DC Q13	P	1.20	1.40	0.2 [17%]	2.10	2.30	0.2 [10%]	3.60	4.20	0.6 [17%]
	DC DL06	-	-	DC Q14	P	1.10	1.10	0 [0%]	2.30	2.20	-0.1 [-4%]	4.20	4.10	-0.1 [-2%]
	DC DL06	DRC 3620 (The Northern Road)	DRC 4180 (The Northern Road)	DC Q15	P	2.80	3.10	0.3 [11%]	4.90	5.10	0.2 [4%]	9.00	10.10	1.1 [12%]

Refer over for footnotes to **Table C1**.

TABLE C1 (Cont'd)
COMPARISON OF PEAK FLOWS
(m^3/s)

Catchment	Drainage Line	Length of Carriageway Draining to Receiving Drainage Line		Peak Flow Location	Land Ownership	2 year ARI			10 year ARI			100 year ARI		
		Approximate Start Chainage	Approximate End Chainage			Pre-Project Conditions	Post-Project Conditions	Difference	Pre-Project Conditions	Post-Project Conditions	Difference	Pre-Project Conditions	Post-Project Conditions	Difference
Duncans Creek	DC DL07	-	-	DC Q16	P	1.90	1.90	0 [0%]	3.00	3.00	0 [0%]	5.40	5.40	0 [0%]
	DC DL08	-	-	DC Q17	P	1.80	1.80	0 [0%]	3.50	3.50	0 [0%]	6.70	6.70	0 [0%]
	DC DL07	DRC 4180 (The Northern Road)	DRC 5160 (The Northern Road)	DC Q18	P	5.70	6.20	0.5 [9%]	10.00	10.00	0 [0%]	18.20	18.70	0.5 [3%]
	DC DL07	DRC 4180 (The Northern Road)	DRC 5440 (The Northern Road)	DC Q19	P	7.40	8.30	0.9 [12%]	14.10	14.00	-0.1 [-1%]	23.70	24.60	0.9 [4%]
	DC DL07	DRC 4180 (The Northern Road)	DRC 5440 (The Northern Road)	DC Q20	P	7.80	8.90	1.1 [14%]	15.80	15.80	0 [0%]	25.50	25.90	0.4 [2%]
	DC DL09	DRC 5160 (The Northern Road)	DRC 5440 (The Northern Road)	DC Q21	P	1.00	1.30	0.3 [30%]	1.90	2.50	0.6 [32%]	4.20	4.20	0 [0%]
	DC DL09	-	-	DC Q22	P	0.60	0.40	-0.2 [-33%]	1.10	0.70	-0.4 [-36%]	2.40	1.60	-0.8 [-33%]
Badgerys Creek	BC DL01	-	-	BC Q01	P	1.00	1.00	0 [0%]	1.80	1.80	0 [0%]	2.90	2.80	-0.1 [-3%]
	Badgerys Creek	-	-	BC Q02	P	0.90	0.90	0 [0%]	1.80	1.80	0 [0%]	5.10	5.10	0 [0%]
	Badgerys Creek	-	-	BC Q03	P	8.70	8.70	0 [0%]	15.00	15.00	0 [0%]	21.50	21.50	0 [0%]
	Badgerys Creek	DRC 0 (The Northern Road)	DRC 780 (The Northern Road)	BC Q04	P	10.40	10.60	0.2 [2%]	18.30	18.60	0.3 [2%]	29.10	29.60	0.5 [2%]
	Badgerys Creek	DRC 0 (The Northern Road)	DRC 2180 (The Northern Road)	BC Q05	P	14.40	14.80	0.4 [3%]	25.60	26.30	0.7 [3%]	40.50	41.60	1.1 [3%]
	Badgerys Creek	-	-	BC Q06	P	22.50	22.80	0.3 [1%]	40.40	40.90	0.5 [1%]	63.40	64.70	1.3 [2%]
	BC DL02	-	-	BC Q07	P	1.60	1.60	0 [0%]	2.70	2.70	0 [0%]	4.60	4.60	0 [0%]
	BC DL02	-	-	BC Q08	P/SG	1.70	2.00	0.3 [18%]	2.90	3.30	0.4 [14%]	5.20	5.60	0.4 [8%]
	BC DL03	-	-	BC Q09	P	0.40	0.40	0 [0%]	0.70	0.70	0 [0%]	1.30	1.30	0 [0%]
	BC DL04	-	-	BC Q10	P	0.30	0.30	0 [0%]	0.50	0.50	0 [0%]	1.00	1.00	0 [0%]
	BC DL03	DRC 1000 (The Northern Road)	DRC 2180 (The Northern Road)	BC Q11	P/SG	0.90	1.50	0.6 [67%]	1.80	3.00	1.2 [67%]	3.70	6.20	2.5 [68%]

1. A positive difference indicates an increase in peak flow attributable to the project (refer cells highlighted orange). Conversely, a negative difference indicates a decrease in peak flow attributable to the project (refer cells highlighted green).
2. Values in [ ] represent the percentage increase/decrease in peak flow attributable to the project.
3. MCPB = Main Carriageway Project Boundary LRPB = Local Road Project Boundary PFI = Peak Flow Identifier
4. Refer **Figures 4.1** and **6.1** (4 sheets each) for location of Peak Flow Identifiers.
5. P = Private SG = State Government COM = Commonwealth Government