Strategic Bushfire Study – Greater Macarthur Growth Area: Land Release Area

NSW Department of Planning, Industry & Environment

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Template 2.8.1

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Abbreviations

Abbreviation	Description
APZ	Asset Protection Zone
BPMs	Bushfire Protection Measures
BFMC	Bush Fire Risk Management Committee
DPE	NSW Department of Planning & Environment
DPIE	NSW Department of Planning, Industry & Environment
ELA	Eco Logical Australia
FFDI	Forest Fire Danger Index
GEV	Generalised Extreme Value
NSP	Neighbourhood Safer Places
NSW	New South Wales
PBP	Planning for Bush Fire Protection
RFS	Rural Fire Service
SA	Standards Australia
SBS	Strategic Bushfire Study

Executive Summary

The aim of this Study was to evaluate the Indicative Land Use Plan for the Land Release Area of the Greater Macarthur Growth Area under the strategic planning requirements of 'Planning for Bushfire Protection' (PBP). This 'Strategic Bushfire Study' undertakes an evaluation against the strategic planning principles outlined in Chapter 4 of PBP in light of the bushfire risk context for the Study Area. The Strategic Bushfire Study examines whether the Greater Macarthur Growth Area is appropriate in the bushfire risk context or whether it represents 'inappropriate development' as per PBP, and the strategic implications of future development for bushfire mitigation and management.

The Study identifies that the Growth Area is not exposed to a significantly high bushfire risk. This finding is on the basis of: the bushfire risk in areas immediately adjoining the Growth Area is moderated by the partial 'sheltering' of the Growth Area from bushfires by existing and increasing development; lesser hazard types that adjoin much of the Growth Area; discontinuity of fuel and significant impedances to fire spread to the Growth Area; lack of historical precedence of fire spread to the Growth Area indicating low likelihood; bushfire weather analysis indicating that there is significantly reduced risk from the south and east; and bushfire spread and bushfire intensity modelling not indicating a significant risk to the Growth Area at a level beyond which the bushfire protection measures within PBP are founded.

In addition, the bushfire hazards that will be retained, rehabilitated or introduced into the Growth Area are generally: convoluted, which moderates the length of potential head fire spread in many areas; narrow in areas, limiting the potential bushfire development, severity and extent of attack; disconnected thus limiting fire development; and have limited connectivity to external bushfire hazards, further reducing the likelihood of an external bushfire spreading to and penetrating into the Growth Area.

A key finding of the study is that there is ample capacity within the precincts to afford future development with bushfire protection measures that meet the requirements of PBP. In addition, due to the size of the precincts, there is a significant proportion of the precincts located outside the 'Bushfire Planning Focus Area', which is the land within 100 m from the hazard, where bushfire protection measures are formally prescribed by PBP, indicating extensive areas of lower risk within the precincts.

Off-site evacuation is a threshold issue and will need to be carefully evaluated for each precinct once further information comes to hand during precinct planning. In addition, on-site community refuges are encouraged for precinct designs, as an additional bushfire protection 'redundancy'.

Precincts with elevated (but not significantly high) bushfire risk exposure include Gilead (C) and (D), North Appin and Appin (A) and (B). This finding is primarily in relation to the potential for reduced off-site evacuation capacity, due to the potential fire impact on evacuation routes (albeit lower likelihood). As such, evacuation route, timing and capacity needs to be planned carefully for these precincts, along with on-site refuge capacity, for redundancy. However, all precincts have multiple options for off-site evacuation, on-site refuge, and in-situ sheltering capacity.

Given the Greater Macarthur Growth Area is not considered to have a significantly high bushfire risk context; good capacity for the provision of bushfire protection measures; will provide a low risk setting for a large proportion of the future development; multiple off-site evacuation options; and capacity for on-site community refuge; the findings of this Study at a regional planning scale are:

- The Indicative Land Use Plan complies with the strategic planning principles of PBP;
- The Indicative Land Use Plan does not trigger the "inappropriate development" exclusion requirements of PBP;
- That the Acceptable Solution bushfire protection measures within PBP can be met by the future development envisaged by the Indicative Land Use Plan and it offers opportunity for protection measures beyond the minimum compliance under PBP;
- Compliance with PBP is not reliant on the intervention/response by emergency services or hazard management on adjoining land;
- The development contemplated by the Indicative Land Use Plan will not adversely impact the bushfire safety of occupants of nearby existing development and wherever possible, actually lower the risk.

These findings conclude that the level of residual risk after inclusion of the bushfire protection measures typically applied under PBP, is appropriate and the development contemplated by the Indicative Land Use Plan can meet the PBP strategic planning principles and requirements. Specifically, that the aims and objectives, acceptable solutions and performance requirements of PBP pertaining to risk to life and risk to property can be met or exceeded. Further, there is not a reliance on emergency service response / intervention, nor a reliance on fuel management on adjoining lands to provide the level of bushfire protection and residual risk.

1. Introduction

This Strategic Bushfire Study (SBS) has been prepared to assess the Greater Macarthur 2040 Interim Plan (DPE 2018), recent information made available regarding the precincts within the Greater Macarthur Growth Area and retained land, as well as in response to the 'What we heard' report (DPIE 2019). This study provides a bushfire assessment of the Indicative Land Use Plan for the Greater Macarthur Growth Area in regard to the strategic planning requirements outlined in '*Planning for Bushfire Protection*' (PBP) (RFS 2019). This is one of the first steps in the strategic planning pathway for the Growth Area in relation to bushfire protection, and PBP prescribes further assessment at subsequent stages of the planning process (i.e. at precinct planning, neighbourhood planning, subdivision and down to individual allotment development).

The Greater Macarthur 2040 Interim Plan contains two distinct areas (Figure 1), the Greater Macarthur Land Release Area (Figure 2) in the south and the Glenfield to Macarthur Urban Renewal Corridor to the north (Figure 3). The Urban Renewal Corridor predominately concerns brownfield development within existing urban areas and away from bushfire prone land, so the Greater Macarthur Land Release Area is the focus of this study and is referred to as the 'Growth Area' for the purposes of this study.

1.1 Background

The Greater Macarthur Growth Area is located parallel to the Hume Motorway at the southern end of the Cumberland Plain, south of Campbelltown (Figure 4). It is situated within the Local Government Areas (LGAs) of Campbelltown City, Wollondilly Shire and Camden.

The Greater Macarthur 2040 Interim Plan seeks to enhance and develop the area in order to boost the economy, bring investment in local jobs and provide high quality education, recreation and housing opportunities as well as provide a koala reserve that will secure habitat and movement corridors making the region a koala friendly community.

The Greater Macarthur Growth Area contains five precincts (Figure 5) that are contemplated to be the subject of land development, primarily residential develop and town/local centres. The precincts are as follows (and mapped in Figure 6 to Figure 14):

- Glenlee
- Menangle Park – precinct already rezoned
- Gilead, which for the purposes of this study have been split into the following sub-precincts: Gilead A; Gilead B (sub-precinct already rezoned); Gilead C; and Gilead D.
- North Appin
- Appin, which for the purposes of this study have been split into the following sub-precincts: Appin A (part already developed in the existing township of Appin); and Appin B.

The Growth Area is currently zoned as IN1 General Industrial, RU2 Rural Landscape, E2 Environmental Conservation, E3 Environmental Management, SP2 Infrastructure, RE1 Public Recreation, R5 Large Lot Residential with some Precincts previously rezoned B2 Local Centre and R2 Low Density Residential.

This study considers the Indicative Land Use Plan that contemplates development of the area with low to medium density homes, local centres, schools, parks and community facilities, in addition to lands retained for biodiversity and other open space.

1.2 Aims and Objectives

The aim of this study is to assess the bushfire risk context of the Greater Macarthur Growth Area (Figure 4) and evaluate the appropriateness of the development contemplated by the Indicative Land Use Plan against the strategic planning principles, 'inappropriate development' requirements and assessment considerations detailed in PBP. The purpose is to evaluate that the development contemplated is appropriate and to further inform planning and development control, both across the Greater Macarthur Growth Area and for the individual precincts comprising it.

1.3 Study Area

The Greater Macarthur Growth Area (Figure 4) is located approximately 56 km south-west of Sydney CBD. It adjoins existing urban development to the north (suburbs of Campbelltown); the Nepean River valley, the Hume Motorway, existing developed areas in Menangle and Douglas Park, along with rural lands to the west; the Georges River, rural residential lands in Wedderburn and Dharawal National Park to the east; with the Wilton Growth Area, rural lands and water catchment in the south. The study area has been extended to 5 km (Figure 4) in order to allow bushfire assessment of the landscape context.

Currently, the subject land is primarily comprised of rural grassland used for agriculture, small pockets of existing urban development (previously rezoned) and areas of existing woodland and forest, much of which is earmarked for retention as part of the Cumberland Plain Conservation Plan (CPCP). The draft CPCP was on exhibition between 26 August and 2 November 2020. When finalised, the CPCP will apply to a large portion of the Greater Macarthur Growth Area and will support the delivery of development and conservation objectives. The final CPCP will also consider the Chief Scientist and Engineer's advice on koala corridors. It is understood that the Department of Planning Industry and Environment will include the CPCP mapping in the final Greater Macarthur 2040 plan.

The Greater Macarthur 2040 Interim Plan identifies indicative areas proposed for development, as well as areas proposed for vegetation retention or rehabilitation. This high level identification of potential future land use forms the basis for the assessments within this study. As a starting point, a 'Bushfire Planning Focus Area' has been mapped (see Figure 6 to Figure 14) by applying a 100 m buffer to all areas identified for retention/rehabilitation. The logic for this is that PBP only formally prescribes the application of bushfire protection measures (i.e. asset protection zones and construction standards etc.) for up to 100 m from the hazard interface. As such, the Bushfire Planning Focus Area provides a high level identification of interface areas where bushfire protection measures must be applied. It also provides a high level understanding of bushfire risk exposure, whereby precincts that have large amounts of their land outside the focus area, will place more future development at lower risk.

A number of transport connections are also proposed for the region in collaboration with the proposed development of the Growth Area and are shown on Figure 4. This includes indicative east to west and north to south connections / corridors as well as the Outer Sydney Orbital. The Outer Sydney Orbital alignment used within this study is from The Greater Macarthur 2040 Interim Plan and is indicative only. Transport for NSW announced on the 31 August 2021 that the current alignment is under investigation,

and it is understood that the final alignment of the transport corridor will be presented in the final Greater Macarthur 2040 Plan.

The subject land is mapped as bushfire prone land (BFPL) (Figure 15) on the Bushfire Prone Land layer within the ePlanning Spatial Viewer[1] thus bushfire assessment at this regional planning stage is appropriate.

[1] https://www.planningportal.nsw.gov.au/spatialviewer/#/find-a-property/address

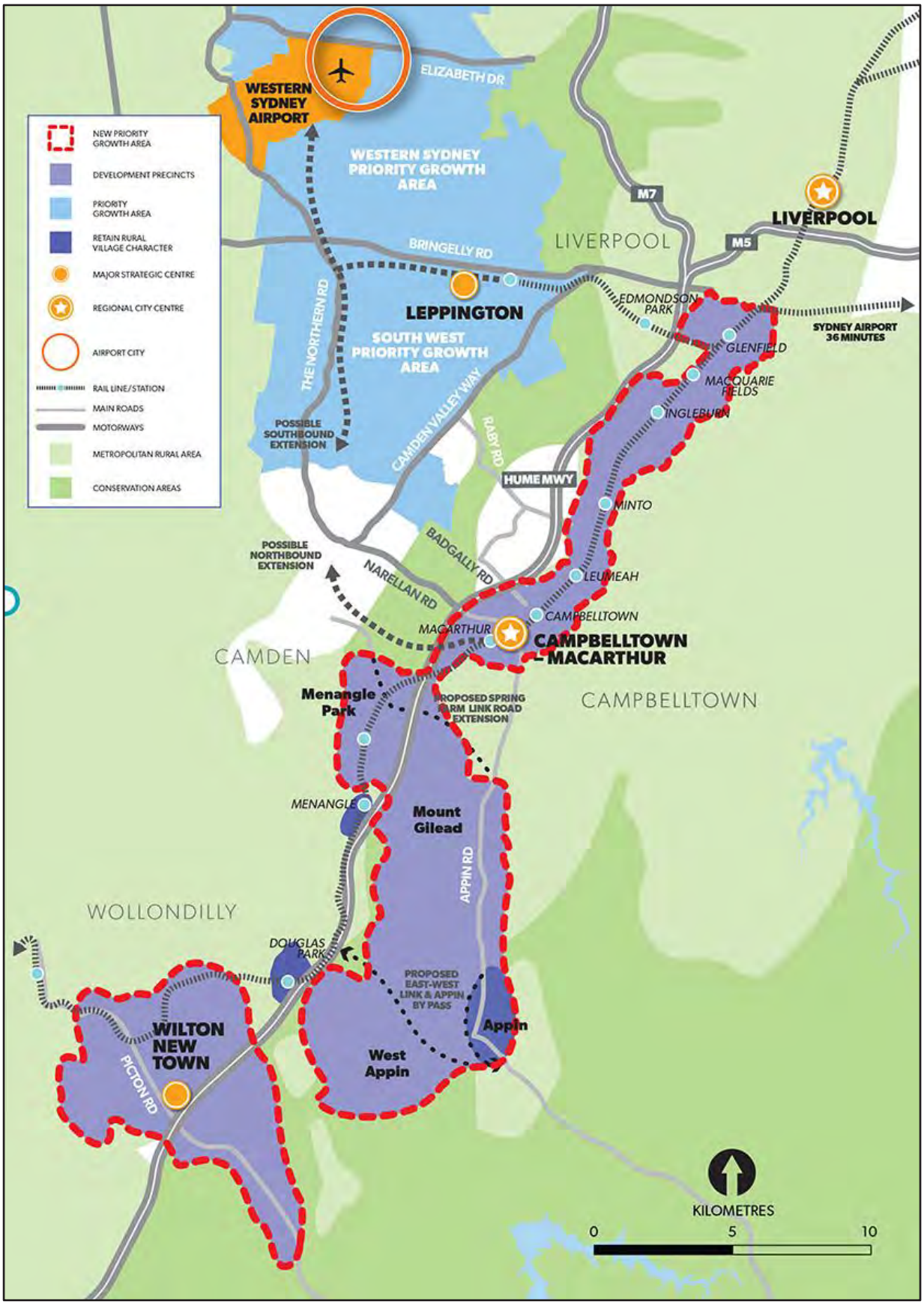

Figure 1: Greater Macarthur Growth Area and Wilton GA (the latter is not a subject of this study)

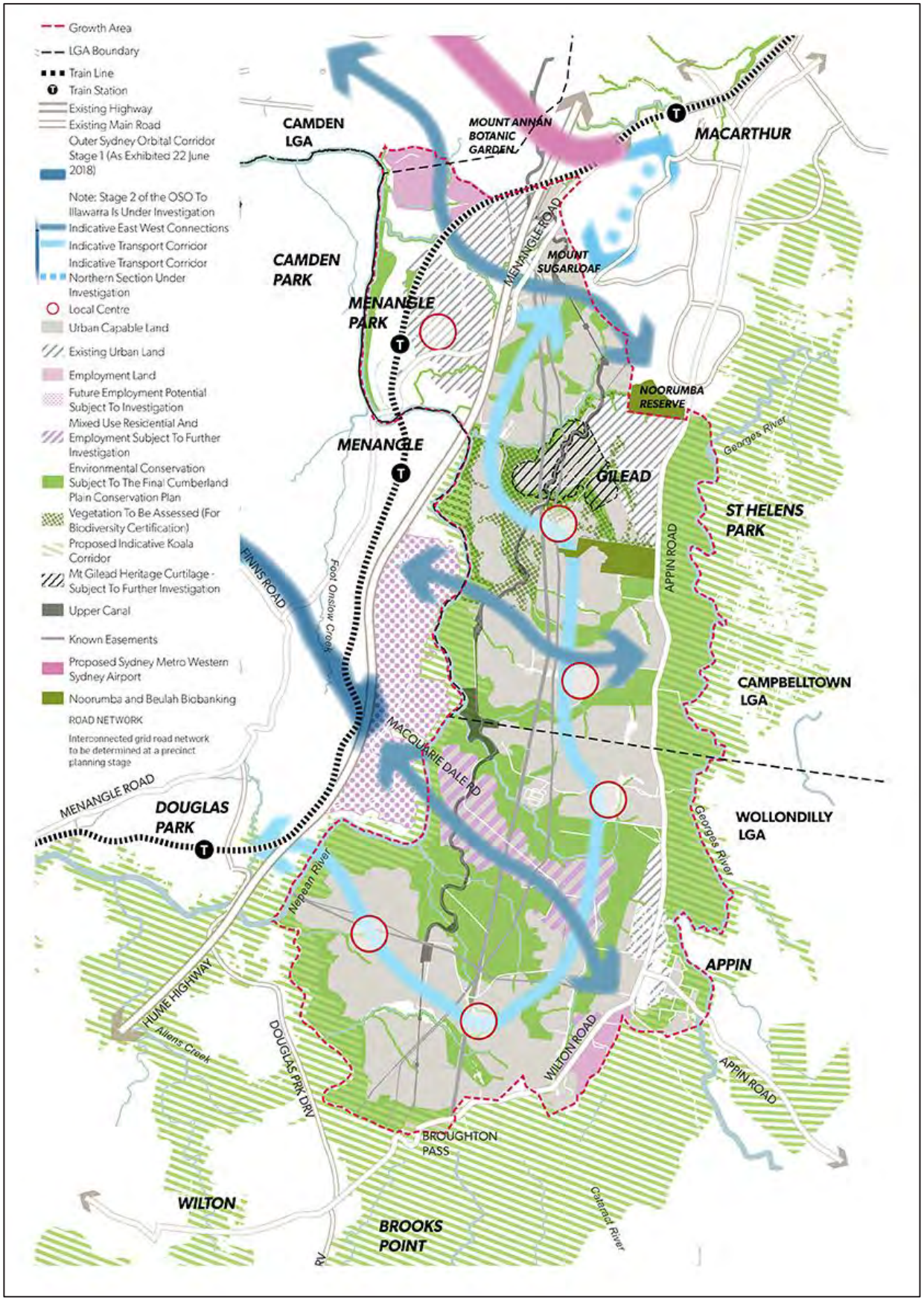

Figure 2: Greater Macarthur Land Release Area (source: The Greater Macarthur 2040 Interim Plan)

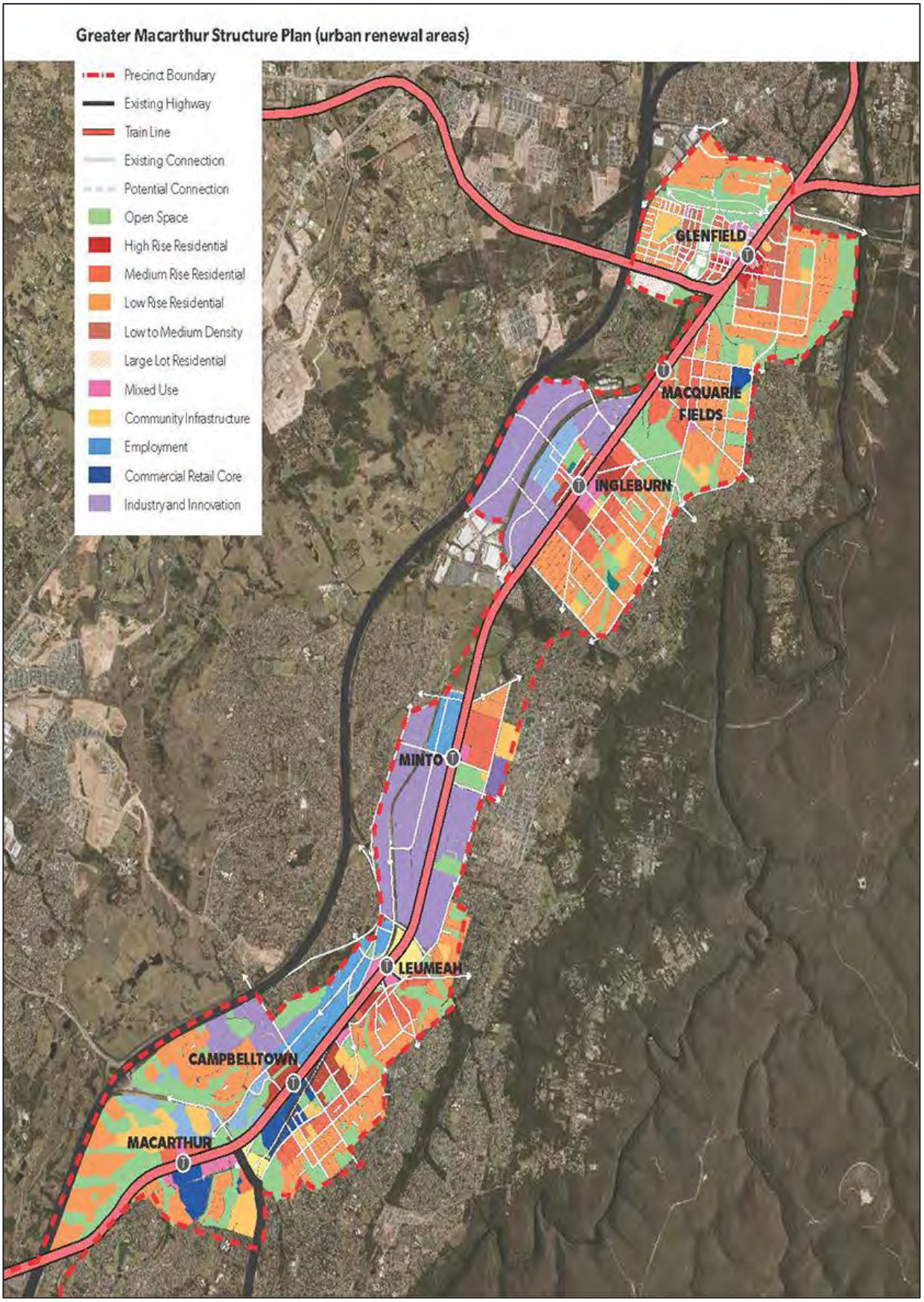

Figure 3: Glenfield to Macarthur Urban Renewal Corridor

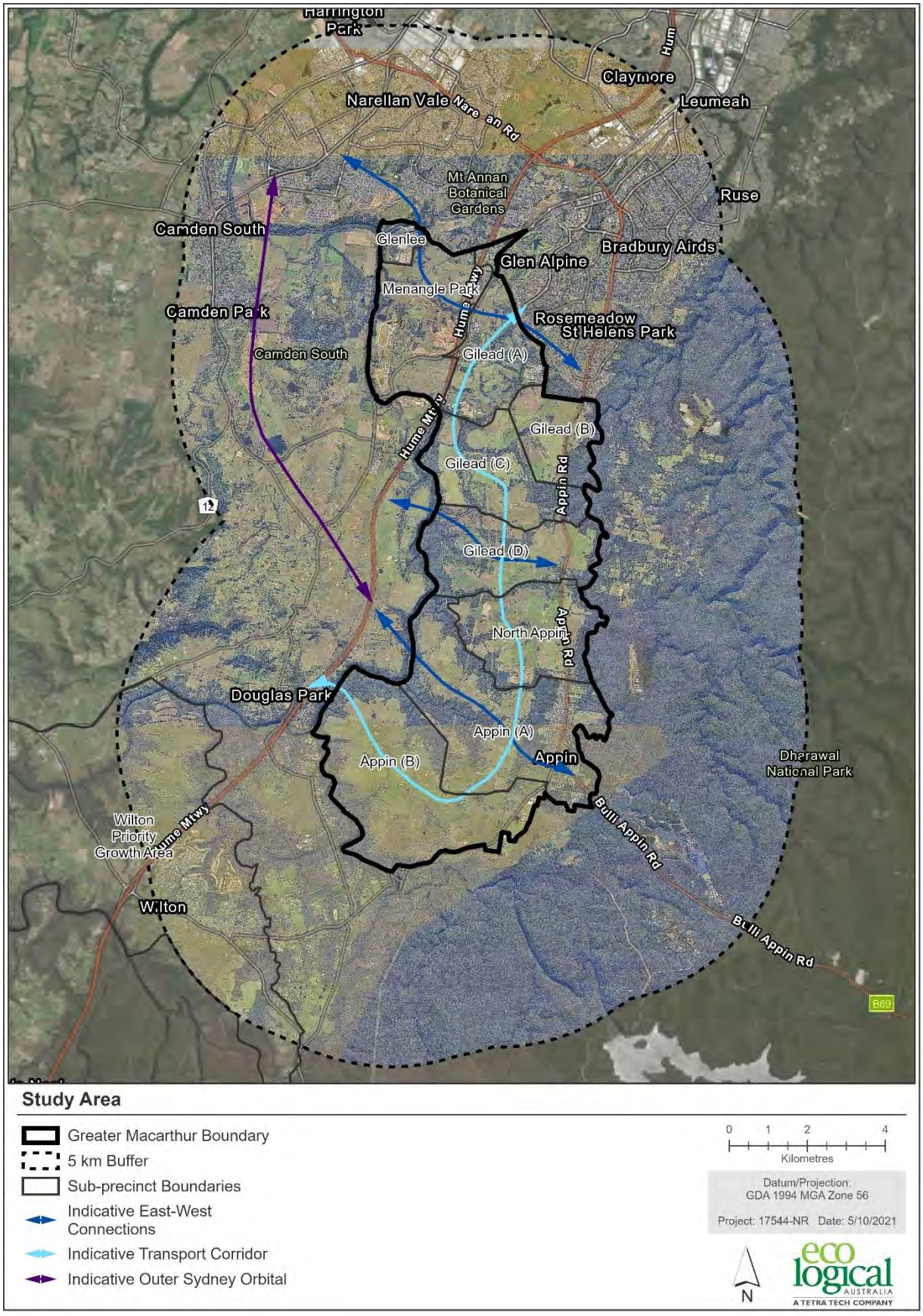

Figure 4: Extent of Study Area

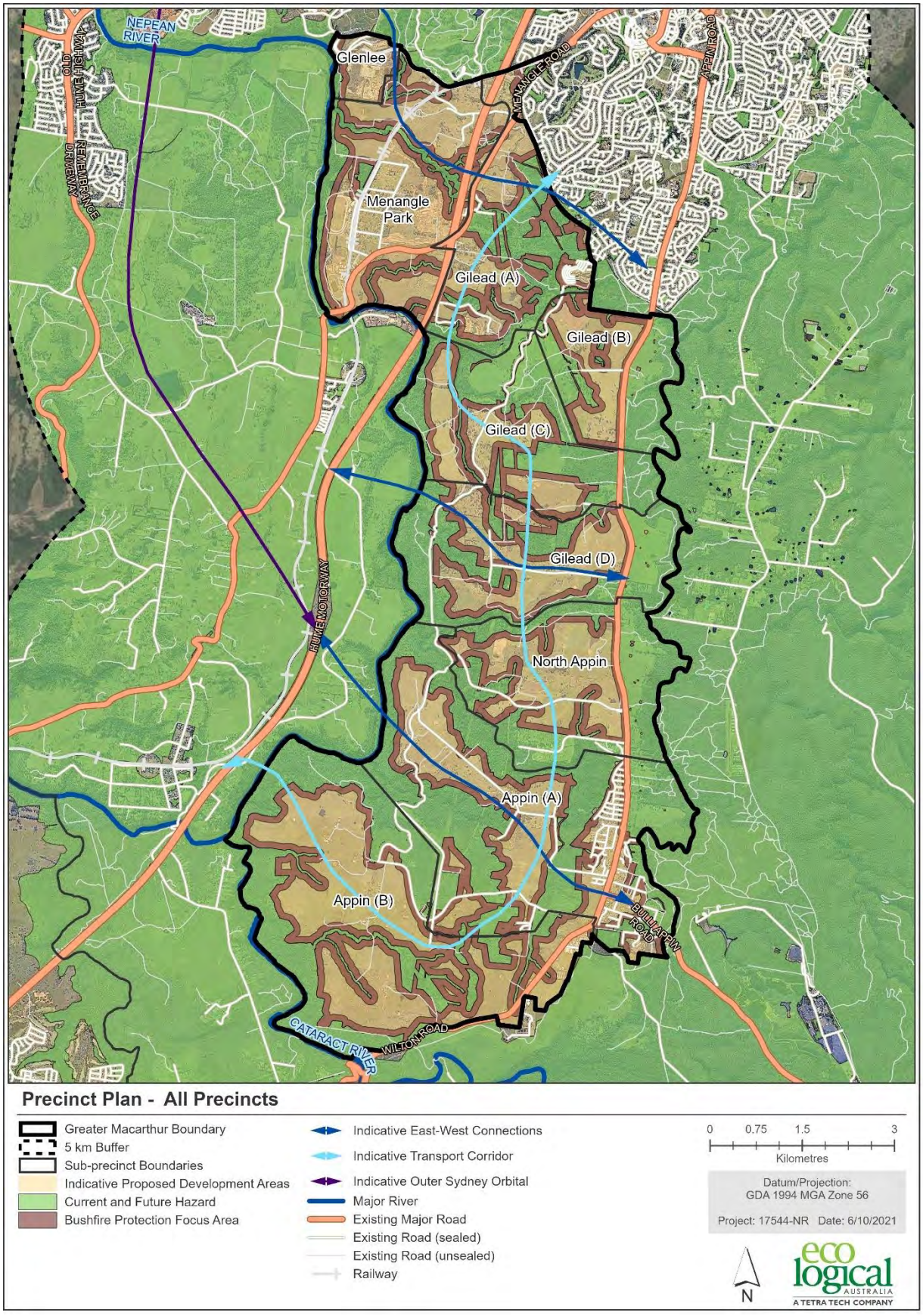

Figure 5: Greater Macarthur Precincts

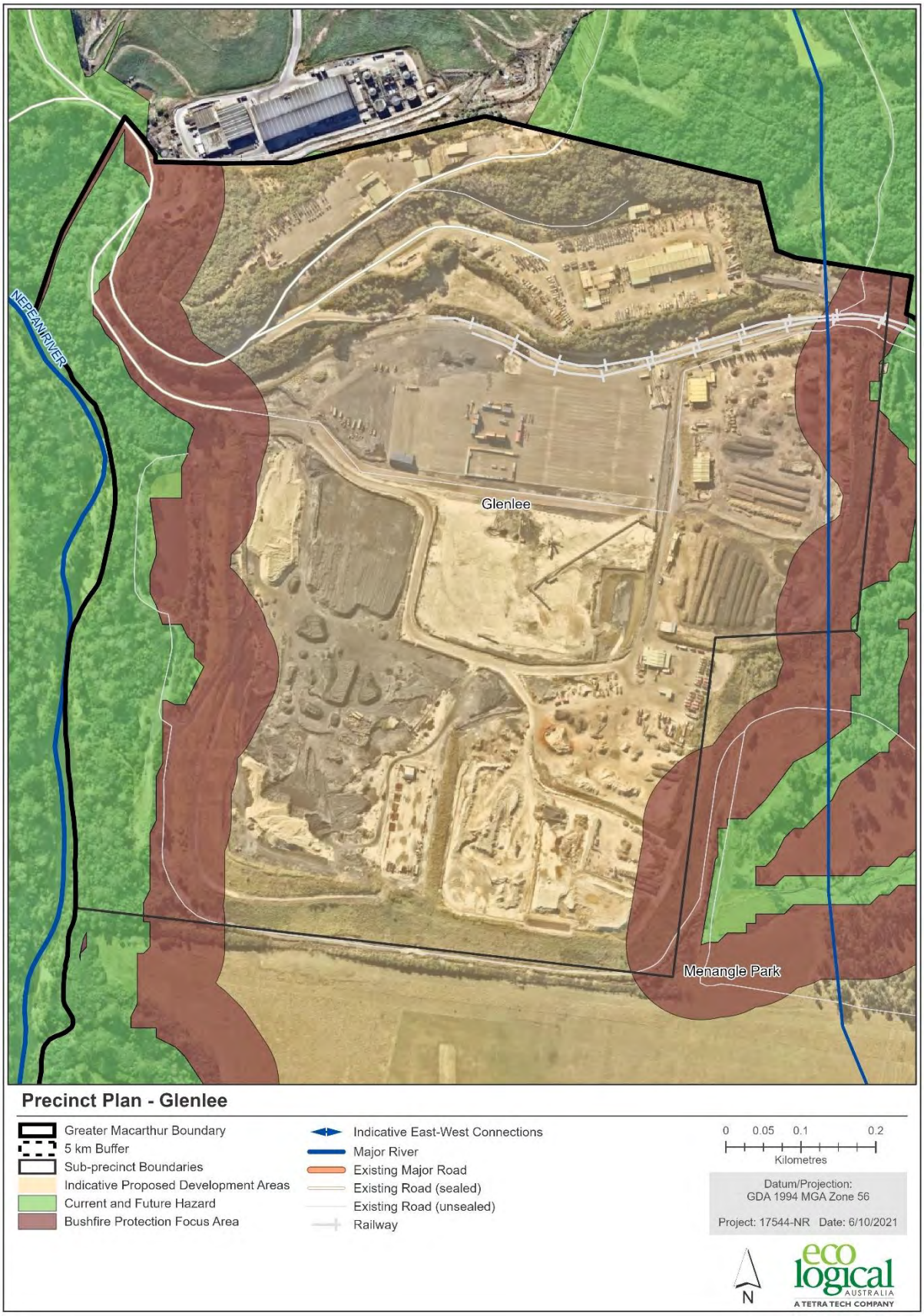

Figure 6: Glenlee Precinct

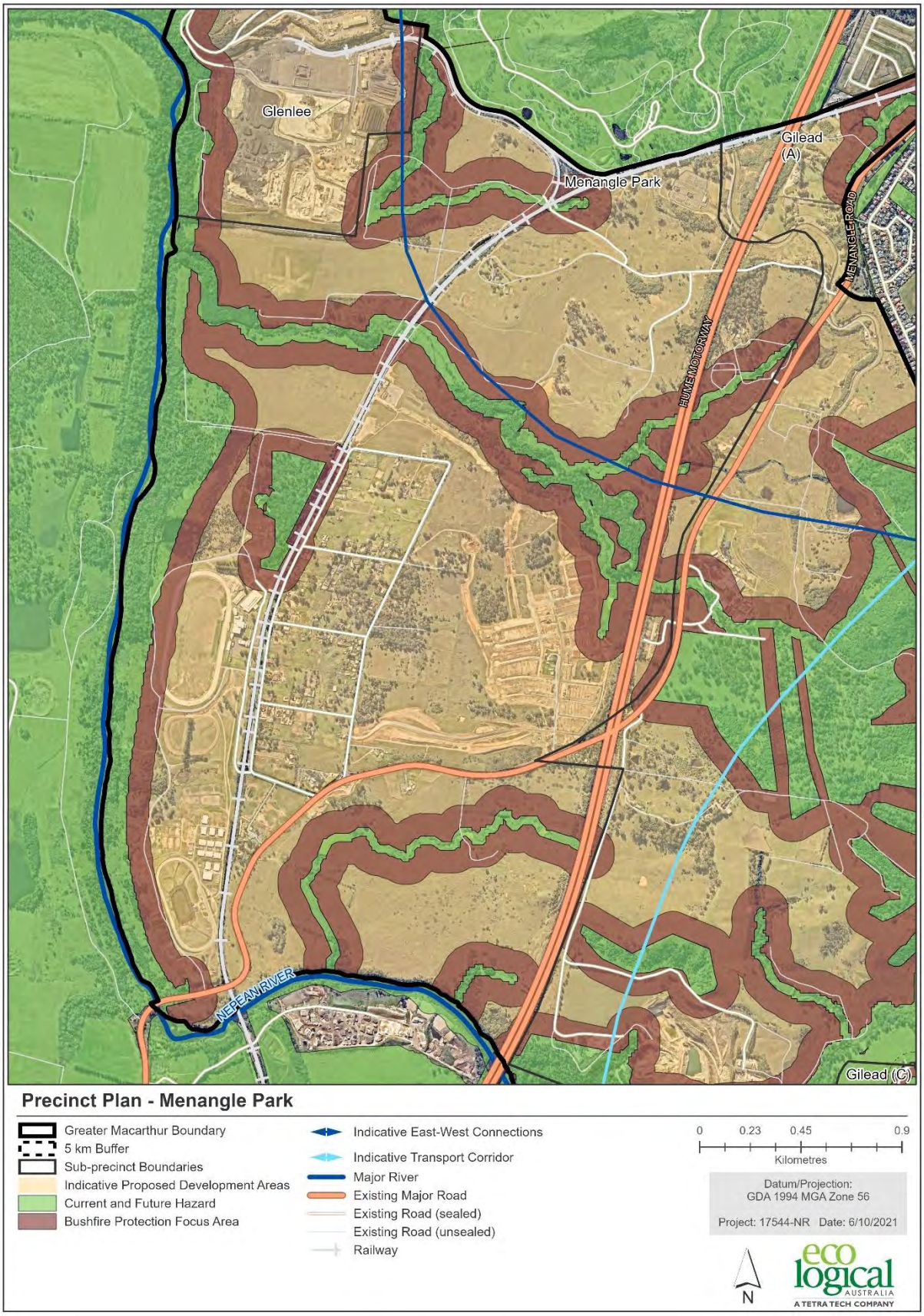

Figure 7: Menangle Park Precinct

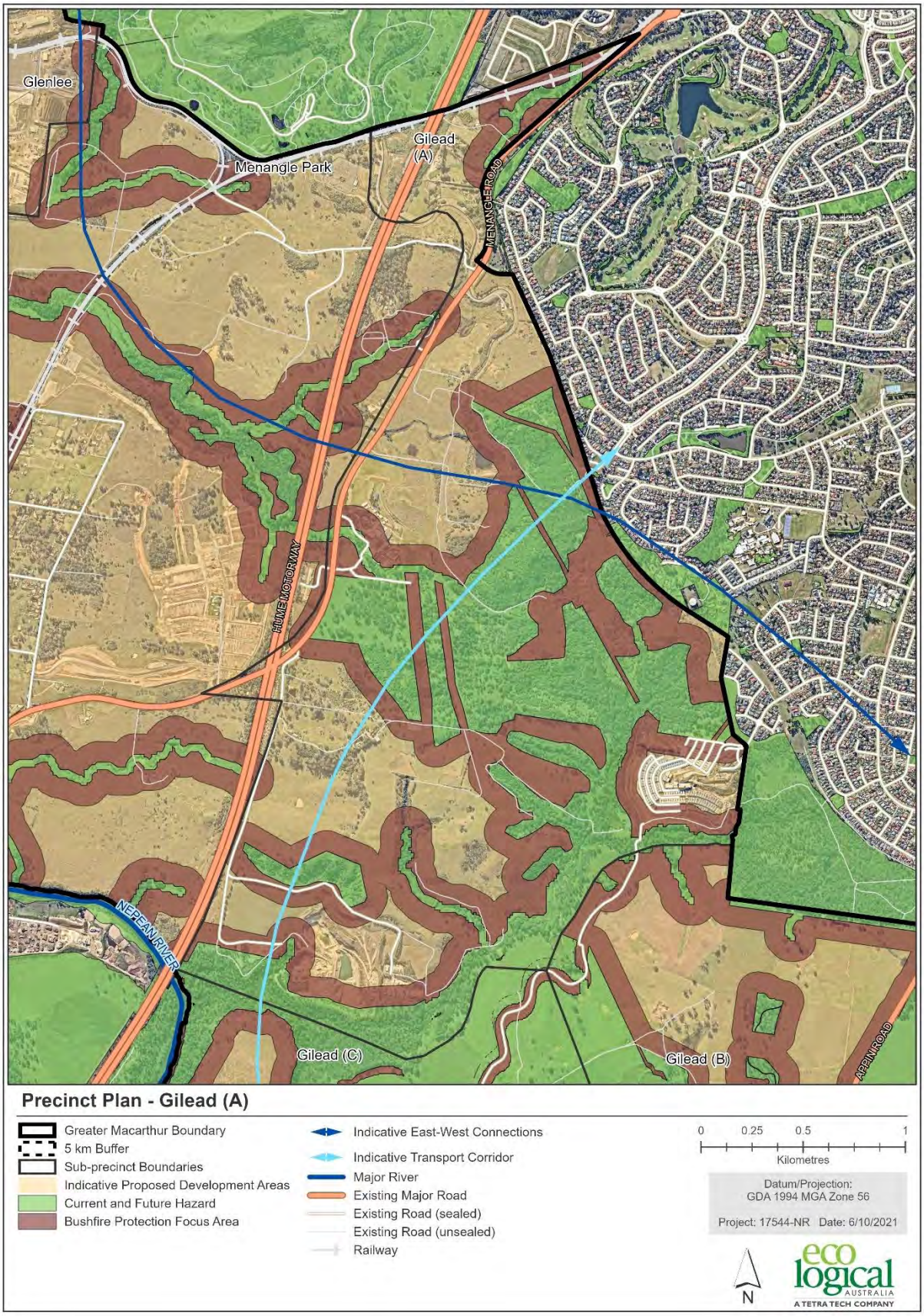

Figure 8: Gilead Precinct (A)

Figure 9: Gilead Precinct (B)

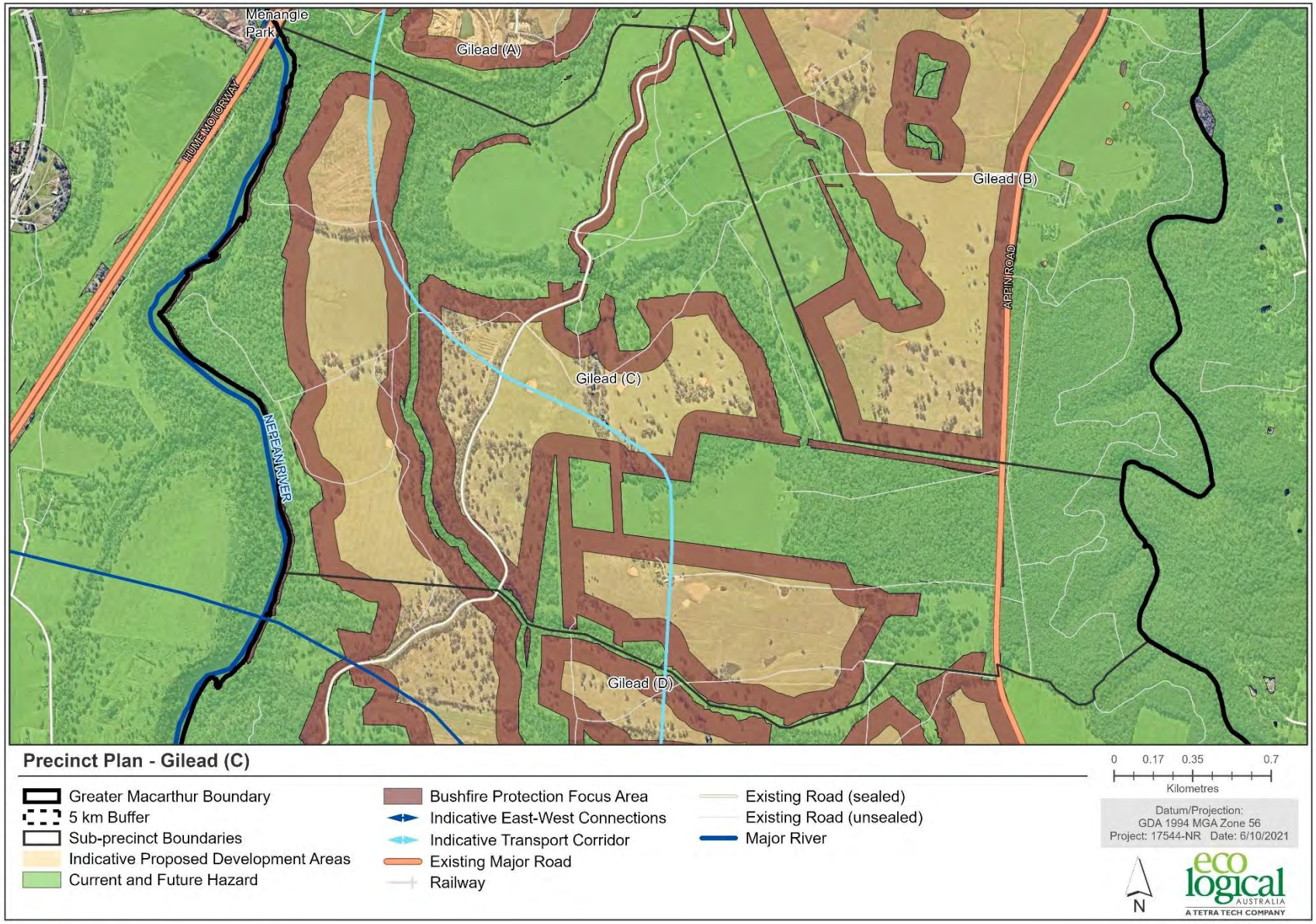

Figure 10: Gilead Precinct (C)

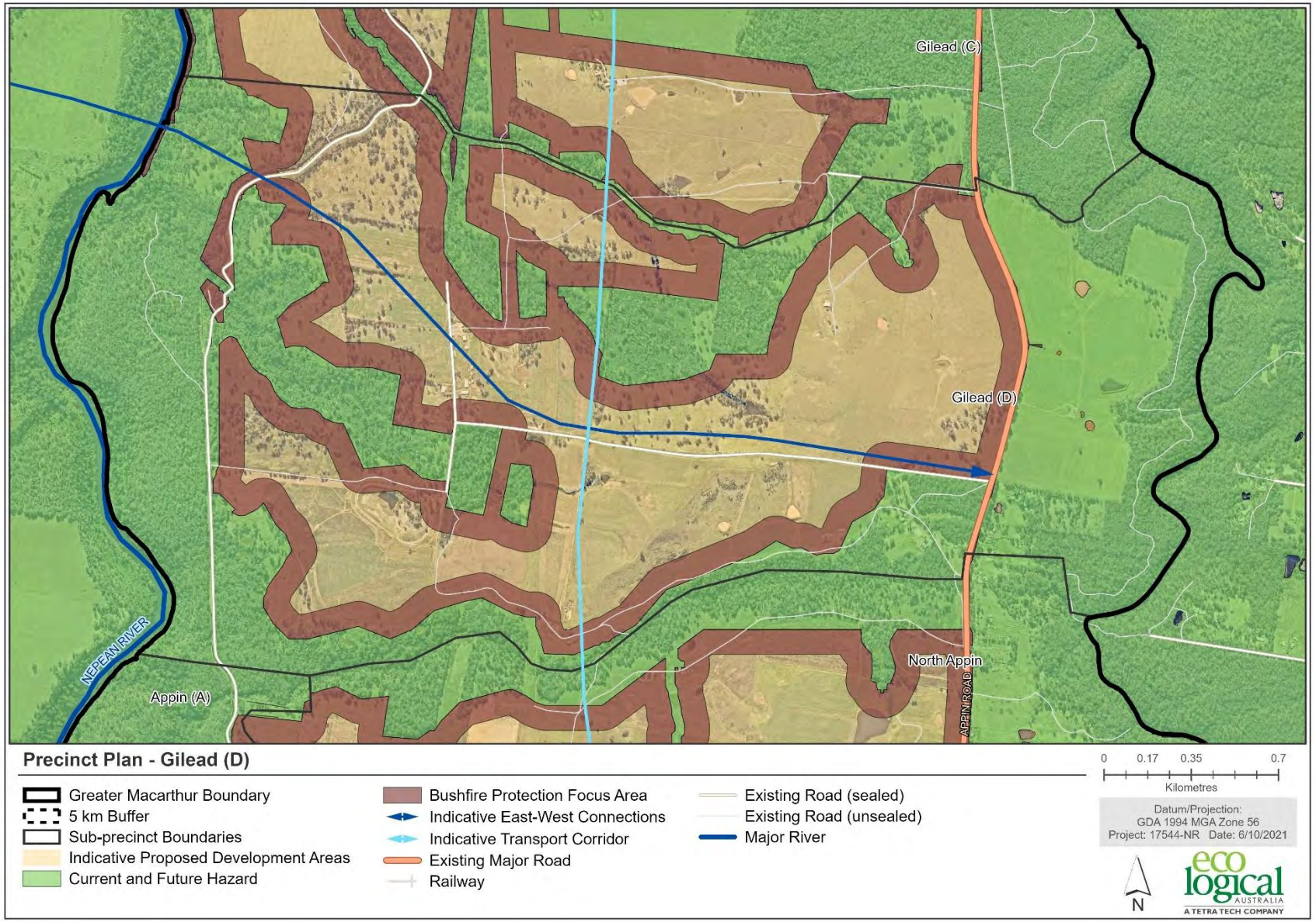

Figure 11: Gilead Precinct (D)

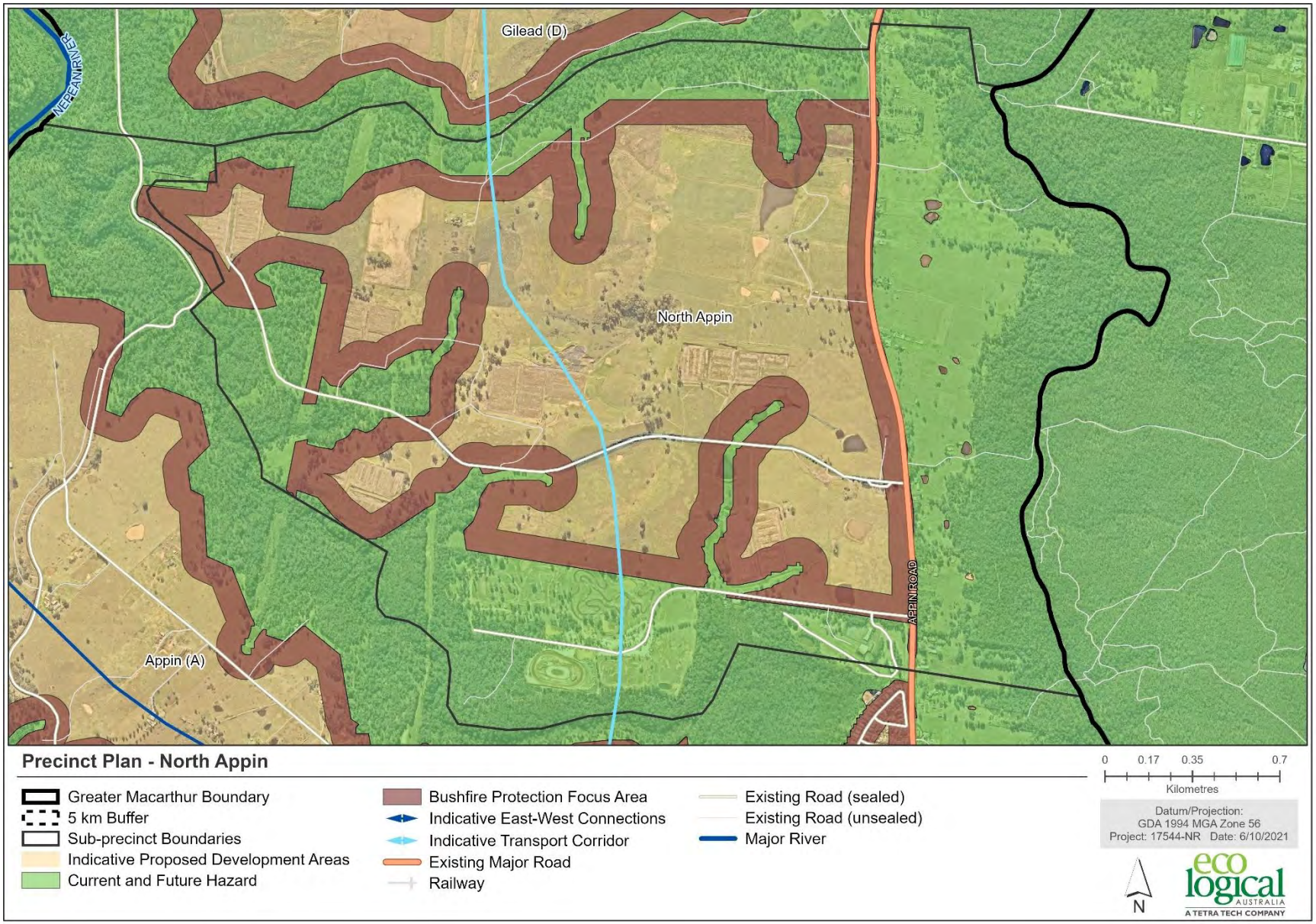

Figure 12: North Appin Precinct

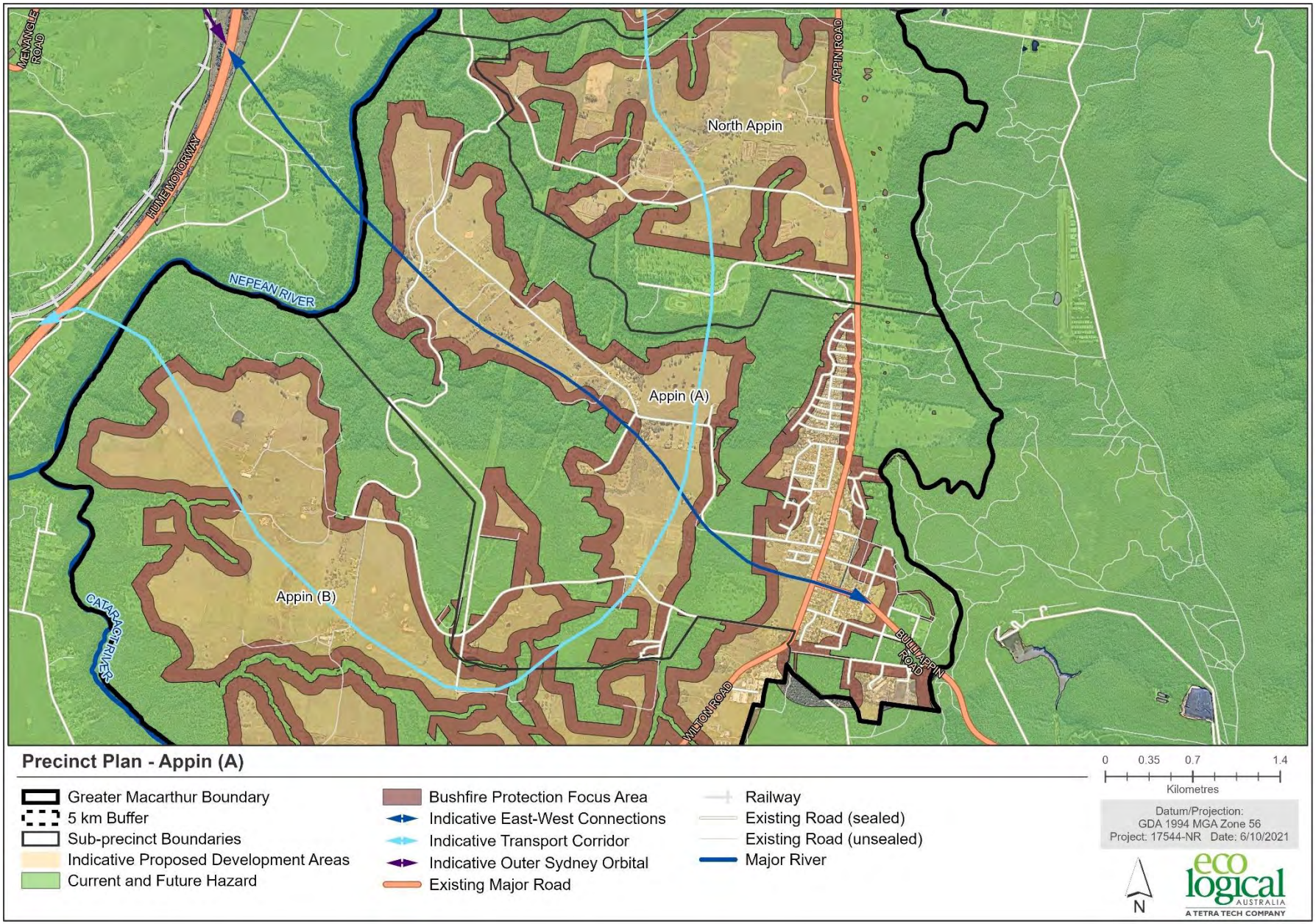

Figure 13: Appin Precinct (A)

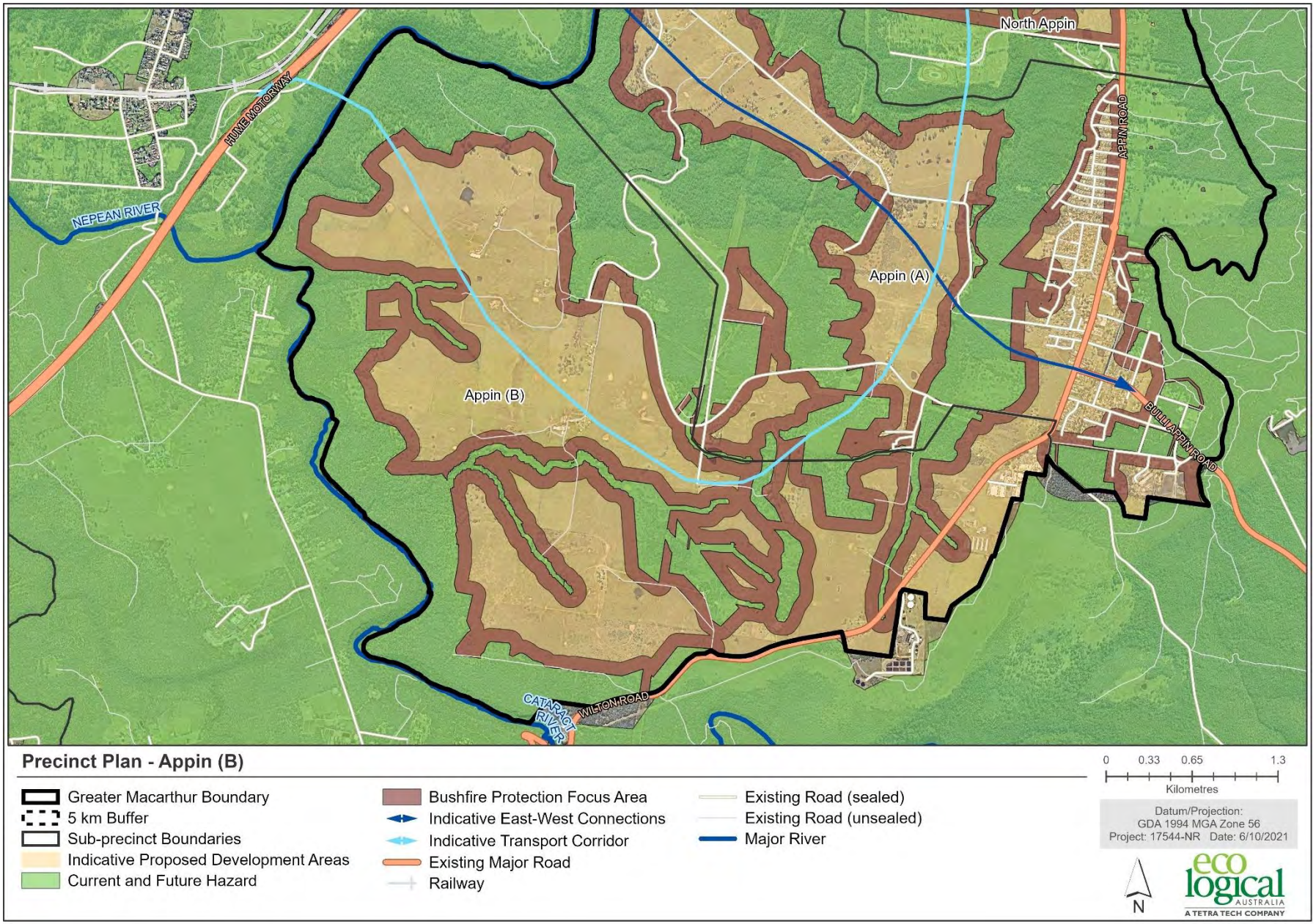

Figure 14: Appin Precinct (B)

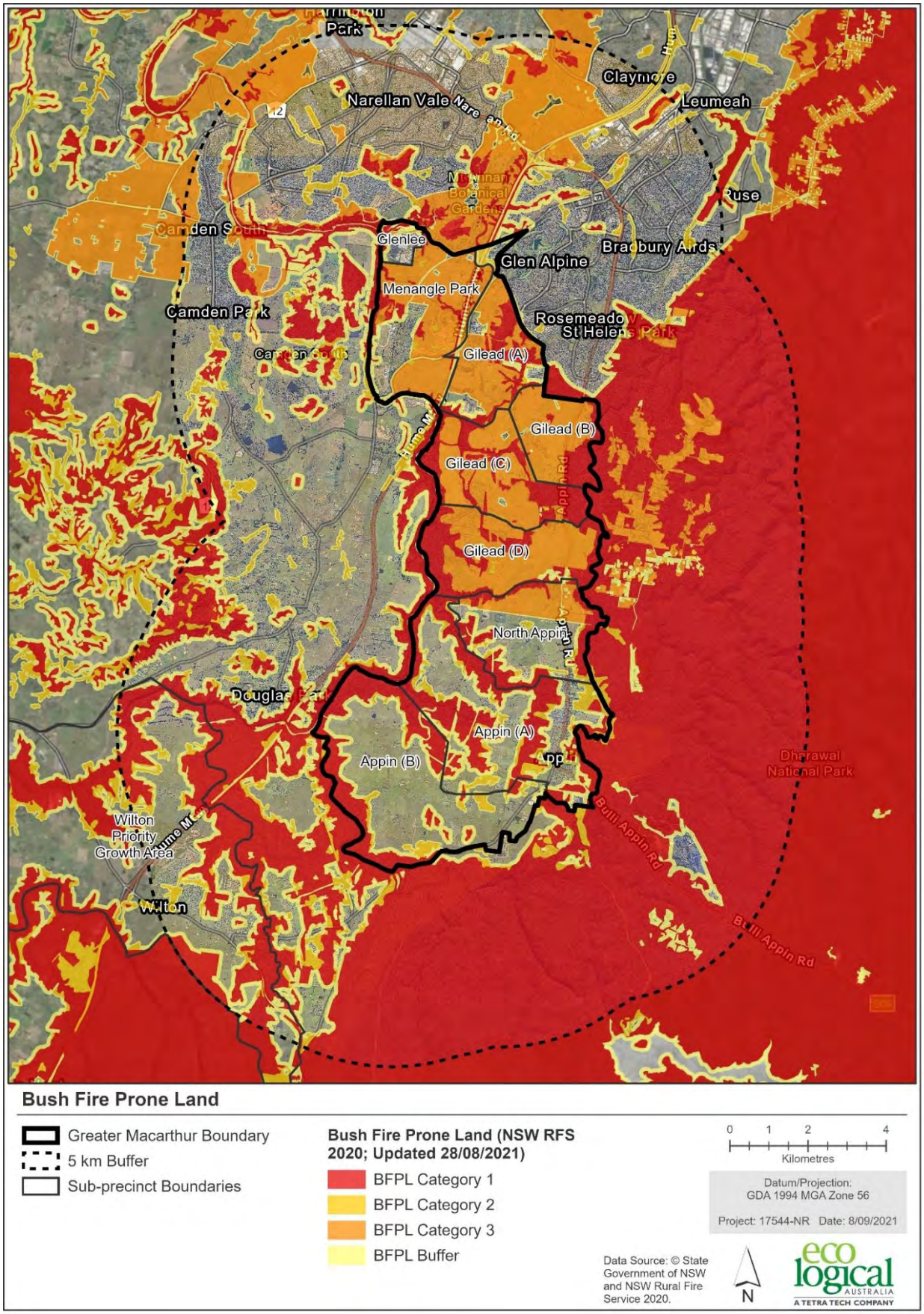

Figure 15: Bushfire Prone Land Mapping (RFS 2021)

1.4 Legislative Framework

The Greater Macarthur 2040 Interim Plan is considered a regional strategy. Section 4.3 of PBP (RFS 2019) prescribes the following expectations for regional strategies, which essentially involve preparation of a strategic bushfire study (this report) and consultation with the Rural Fire Service (RFS):

> *These strategies and plans should incorporate the bush fire strategic planning principles set out in section 4.1 while having regard for the priorities of state and local governments in identifying appropriate areas for growth.*
>
> *The NSW RFS is a key stakeholder and should be consulted in the development of regional strategies and plans to ensure that appropriate strategies are developed and future conflicts do not occur.*

The legislative framework guiding the assessment of bushfire risk and the application of bushfire protection measures at the strategic level, includes the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and the *Rural Fires Act 1997* (RF Act). Key aspects of these instruments are outlined below.

1.4.1 NSW Environmental Planning and Assessment Act (1979)

The NSW *EP&A* Act is the principal planning legislation for the state, providing a framework for the overall environmental planning and assessment of development proposals. Various legislation and instruments are integrated with the *EP&A Act*, including the *RF Act*.

Section 10.3 of the *EP&A Act* requires the identification of BFPL and development of BFPL maps, which act as a trigger for bushfire assessment provisions for strategic planning and development.

When investigating the capability of BFPL in relation to a regional plan, consent authorities should have regard to s.9.1 (2) Direction 4.4 – 'Planning for Bushfire Protection' of the *EP&A Act*. The objectives of Direction 4.4 are:

- To protect life, property and the environment from bushfire hazards, by discouraging the establishment of incompatible land uses in bushfire prone areas; and
- To encourage sound management of bushfire prone areas.

Direction 4.4 instructs the consent authority on the bushfire matters which need to be addressed when a relevant planning authority prepares a planning proposal that will affect or is in proximity to land mapped as bushfire prone land. This includes:

- Consultation with the Commissioner of the NSW RFS and consideration to any comments made;
- Regard to requirements of PBP*;* and
- Compliance with numerous bushfire protection provisions where development is proposed.

Further, there are various provisions within the *EP&A Act* that may be applicable to proposals on BFPL, as outlined below:

- Section 3.29 of the *EP&A Act* relates to the development of State Environmental Planning Policies (SEPPs) and within these policies, bushfire considerations may apply for example:
  - Codes SEPP (Exempt and Complying Development Codes)

        - Clause 34 specifies complying development standards that prescribe compliance with PBP and AS3959, with development on BFPL not permitted within BAL-40 and BAL-FZ.
    - Seniors Housing SEPP (Housing for Seniors or People with a Disability)
        - Clause 27 of the SEPP requires PBP compliance and RFS consultation for development on BFPL.
    - Infrastructure SEPP
        - Clause 16 of the SEPP requires RFS consultation for residential or Special Fire Protection Purpose (SFPP) development on BFPL; and
- Section 4.14 relates to infill and other development.
    - Requires that all development on BFPL conforms to the specifications and requirements outlined in PBP, i.e. the specific requirements for residential infill in Chapter 7; and
    - The consent authority should be satisfied that the development conforms to PBP, or otherwise consult with the RFS Commissioner.
- Section 4.46 relates to integrated development and triggers Section 100B of the *RF Act* and Clause 44 of the *Rural Fires Regulation 2013* (RF Reg):
    - Applicable to subdivision, with specific requirements in Chapter 5 of PBP.
    - Applicable to SFPP developments, with specific requirements in Chapter 6 of PBP; and
    - Requires a bushfire safety authority under Section 100b of the *RF Act*.
- Section 9.1 relates to strategic or local planning.
    - Applicable to land use planning that covers large areas and may include a variety of land uses and longer-term development objectives. Specific requirements are outlined in chapter 4 of PBP.

1.4.2 Rural Fires Act 1997 (RF Act)

The *RF Act* is integrated into the *EP&A Act* and triggered by Section 4.46 as outlined above. The key objectives of the RF Act are to provide for the:

- Prevention, mitigation and suppression of bushfires;
- Co-ordination of bush fire fighting and bush fire prevention;
- Protection of persons from injury or death, and property from damage, arising from fires;
- Protection of infrastructure and environmental, economic, cultural, agricultural and community assets from damage arising from fires; and
- Protection of the environment by requiring certain activities have regard to the principles of ecologically sustainable development.

1.5 Assessment Framework

1.5.1 Strategic Planning for Bushfire Protection

A SBS provides the opportunity to assess whether development proposed by a strategic plan is appropriate in the bushfire risk context. It also provides the ability to assess the strategic implications of future development for bushfire mitigation and management. Section 9.1 (2) of the *EP&A Act* triggers consideration of PBP for strategic planning. Chapter 4 of PBP contains the broad strategic planning principles and assessment considerations. The strategic planning principles for bushfire protection stated in PBP are:

- ensuring land is suitable for development in the context of bush fire risk;
- ensuring new development on BFPL will comply with PBP;
- minimising reliance on performance-based solutions;
- providing adequate infrastructure associated with emergency evacuation and firefighting operations; and
- facilitating appropriate ongoing land management practices.

These principles require consideration of bushfire protection measures for development subsequent to the strategic planning stage, and to consider the suitability of future land uses within the broader bushfire hazard setting and that future land uses can meet the aim and objectives of PBP outlined below:

> *The aim of PBP is to provide for the protection of human life and minimise impacts on property from the threat of bush fire, while having due regard to development potential, site characteristics and protection of the environment.*
>
> *The objectives are to:*
>
> - *afford buildings and their occupants protection from exposure to a bush fire;*
> - *provide for a defendable space to be located around buildings;*
> - *provide appropriate separation between a hazard and buildings which, in combination with other measures, minimises material ignition;*
> - *ensure that appropriate operational access and egress for emergency service personnel and residents is available;*
> - *provide for ongoing management and maintenance of bush fire protection measures; and*
> - *ensure that utility services are adequate to meet the needs of firefighters.*

In addition, Chapter 4 of PBP prescribes that strategic planning should exclude "inappropriate development" in bush fire prone areas, where:

- the development area is exposed to a high bush fire risk and should be avoided;
- the development is likely to be difficult to evacuate during a bush fire due to its siting in the landscape, access limitations, fire history and/or size and scale;
- the development will adversely affect other bush fire protection strategies or place existing development at increased risk;
- the development is within an area of high bush fire risk where density of existing development may cause evacuation issues for both existing and new occupants; and
- the development has environmental constraints to the area which cannot be overcome.

1.5.2 Assessment Approach

The study is focused on the strategic planning principles of PBP and specifically the key principles of: '*ensuring land is suitable for development in the context of bush fire risk*' and '*providing infrastructure associated with emergency evacuation and firefighting operations*'. The assessment therefore seeks to identify the bushfire risk context relevant to the Greater Macarthur Growth Area and how this influences future development being able to meet the strategic planning principles.

The approach taken involves review of bushfire hazards within and affecting the Growth Area, assuming those areas identified for potential development are realised and the proposed retained lands will

comprise a bushfire hazard, along with bushfire hazards within the locality to a 5 km extent. The bushfire risk context is then explored through review of wildfire history and frequency, analysis of bushfire weather, modelling of bushfire intensity and bushfire spread potential, to inform the potential rate of spread, time to arrival and intensity of bushfire attack on the hazard interface, from various bushfire attack scenarios. This is then evaluated against the capacity of the growth area to afford appropriate bushfire protection measures (BPMs) in compliance with PBP, and the evacuation and refuge capacity.

The results of the study are informative and need to be considered in light of the emergency management options available to occupants of the area (either available now or proposed or the potential), as well as the level of protection afforded to them, through the incorporation of BPMs as per the requirements of PBP and building construction standards as per *AS 3959:2018 Construction of buildings in bushfire-prone areas* (SA 2018) or the NASH standard *Steel Framed Construction in Bushfire Areas* (NASH 2014).

1.5.3 Assumptions

There are a range of assumptions adopted in this study, which are relevant to note, including but not limited to the following:

- The areas contemplated for development are approximately as represented in Figure 6 to Figure 14. The assessment assumes full development of these areas, that is they won't present bushfire hazard once developed. Despite this assumption, development staging will need to be appropriately planned.
- The main areas that will be retained / undeveloped will comprise a bushfire hazard to future development; and are approximately as represented in Figure 6 to Figure 14.
- The assessment and evaluation against PBP strategic planning requirements considers the residual risk after implementation of bushfire protection measures, not the unmitigated risk.
- The assessment seeks to align with how risk acceptability is adopted by PBP, that is, greater than zero risk is acceptable.
- The risk to life is the primary consideration. This risk can be mitigated by appropriate setbacks, building construction, access and evacuation options, including on-site refuge where suitable.
- More detailed information may become available as planning of the precincts progresses and this will allow for the refinement and more detailed assessment of bushfire protection capacity for the precincts. Matters that are not yet confirmed include (but are not limited to):
    - Koala habitat protection areas, including any revegetation
    - Land to be protected under the CPCP or other mechanisms for biodiversity conservation
    - Any areas of open space retained within the precinct, can be designed in a way or managed such as to not present a significant hazard (or at all)
    - Tree canopy cover targets (e.g. to mitigate Heat Island effect) can be achieved without adding significant bushfire hazard to the internal areas of the precinct, such as by incorporation of street trees, rather than large patches of unmanaged vegetation
    - The role and function of new road networks
- That more detailed assessment of bushfire protection and evacuation routes will be undertaken for precinct planning, planning proposals and subsequent staged development, when further clarity and information is available.

2. Bushfire Risk Context

2.1 Bushfire Hazard

The Greater Macarthur Growth Area is situated within a broader complex landscape, with increasing residential and commercial development to the north, north-east and north-west, Wilton Growth Area to the south, mostly forest vegetation to the east and south within Dharawal National Park and catchment lands as well as penetrating into retained lands within the Growth Area.

To the west is predominately rural land uses with small urban - rural/residential villages with surrounding rural lands used predominately for livestock grazing. The rural lands to the west are generally undulating with grassland and grassy woodland vegetation predominating, however much of this is not mapped as bushfire prone (Figure 15). The areas containing forest vegetation present a mix of terrain but often steeper slopes, including incised river valleys of the Nepean and Georges Rivers.

Bushfire hazards are expected to be the greatest in areas of higher fuel loads and on steeper slopes, downhill from development, particularly in areas where there is potential for longer fire runs through contiguous hazard vegetation towards the at-risk asset (Figure 16 and Figure 17). Further detail on the bushfire hazard assessment is found in Appendix A

2.2 Bushfire Weather

The Macarthur and Wollondilly Bush Fire Risk Management Committees indicate that elevated bushfire weather is generally when westerly winds are predominant, along with higher daytime temperatures and low relative humidity, particularly during the summer months. Bushfires under milder conditions and different wind directions are possible, however are expected to be slower moving, more predictable and less intense.

Bushfire weather is often described in terms of the Forest Fire Danger Index (FFDI) and this metric has a direct influence on the intensity of a bushfire. FFDI is also one of the key elements used to calculate radiant heat and therefore appropriate Asset Protection Zones (APZ), with PBP applying FFDI 100 to this area of NSW. However, when considering FFDI in a bushfire risk context, it is a common understanding that different weather conditions are experienced from different directions. To better understand this, the bushfire weather relevant to the Study Area was identified by Generalised Extreme Value (GEV) analysis of long-term historical weather records (detailed further in Appendix B). The following was identified from the analysis:

- GEV FFDI for wind directions from the south-west to north was 116;
- GEV FFDI for wind directions from the south-east to south-west was 47; and
- GEV FFDI for wind directions from the north to south-east was 63.

This analysis indicates that there is variation in the bushfire weather conditions and therefore the potential Likelihood and Consequence of bushfire attack on the Growth Area, from different directions (Figure 18). Areas exposed to bushfire attack under higher FFDI are more likely to be impacted by fire as adverse fire weather will occur more often from those directions and a higher fire intensity is more likely as the weather conditions reach higher FFDI values. Conversely, areas only exposed to bushfire attack at lower FFDI have a lower risk profile.

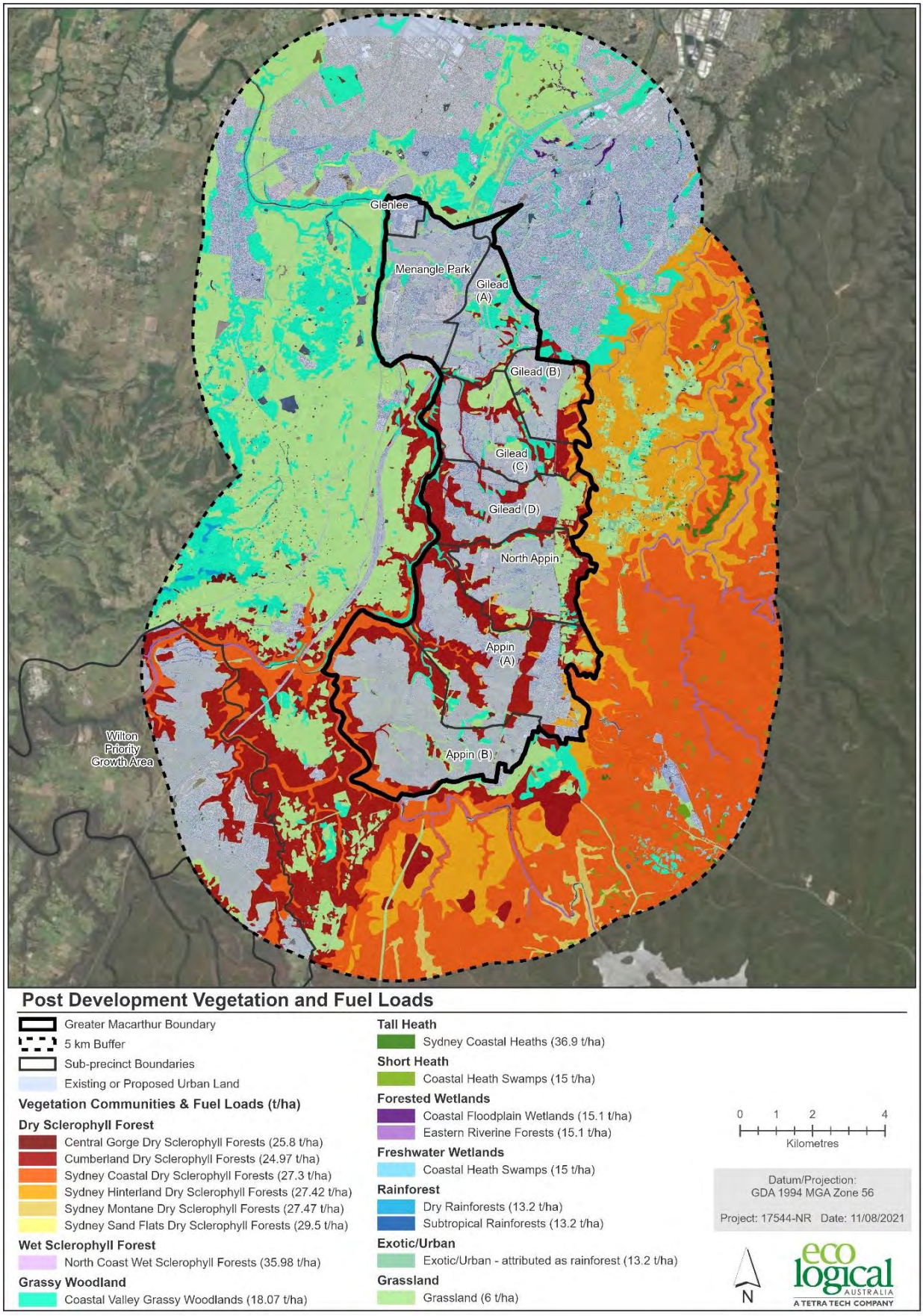

Figure 16: Vegetation Formations and Potential Climax Fuel Loads

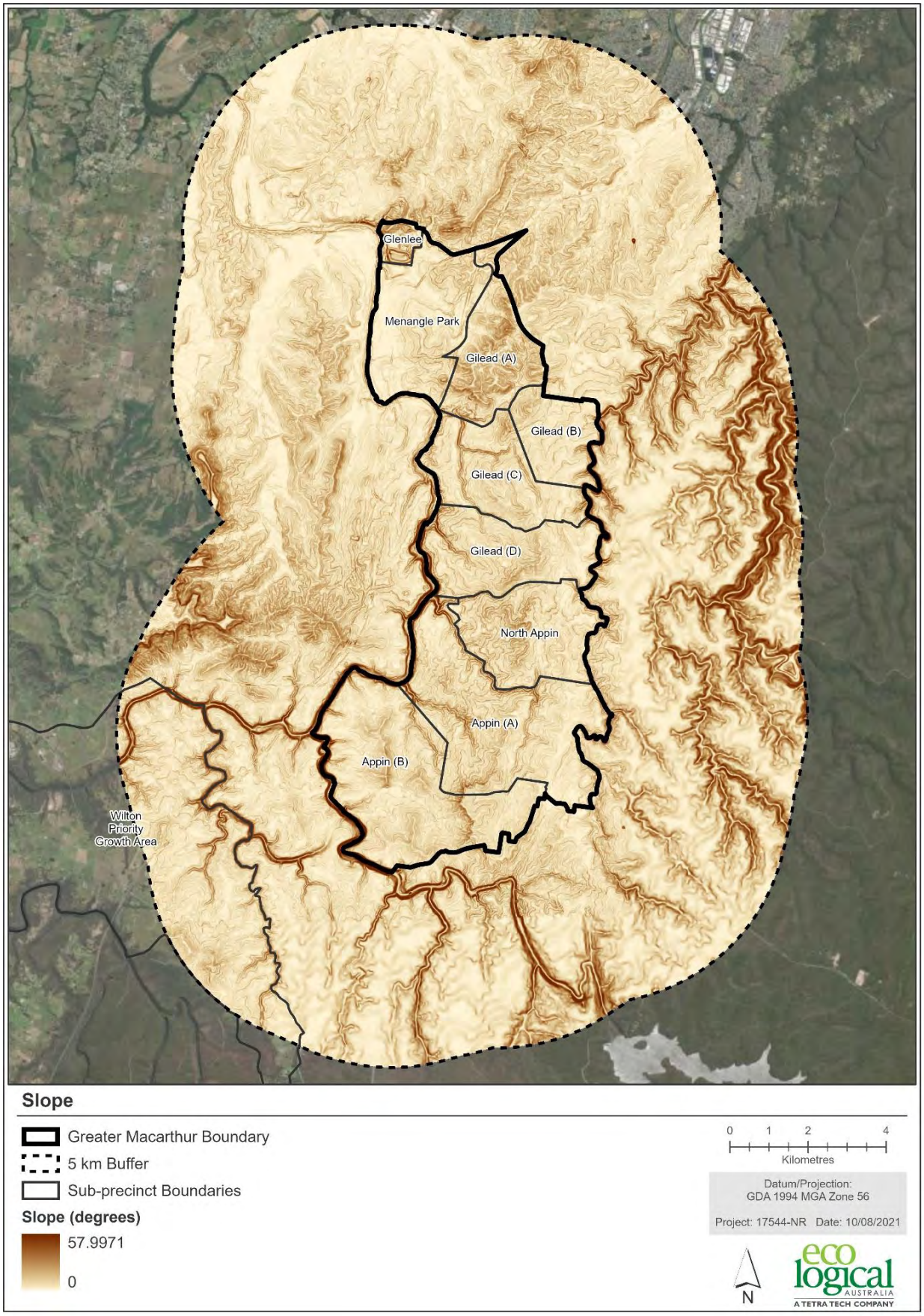

Figure 17: Slope

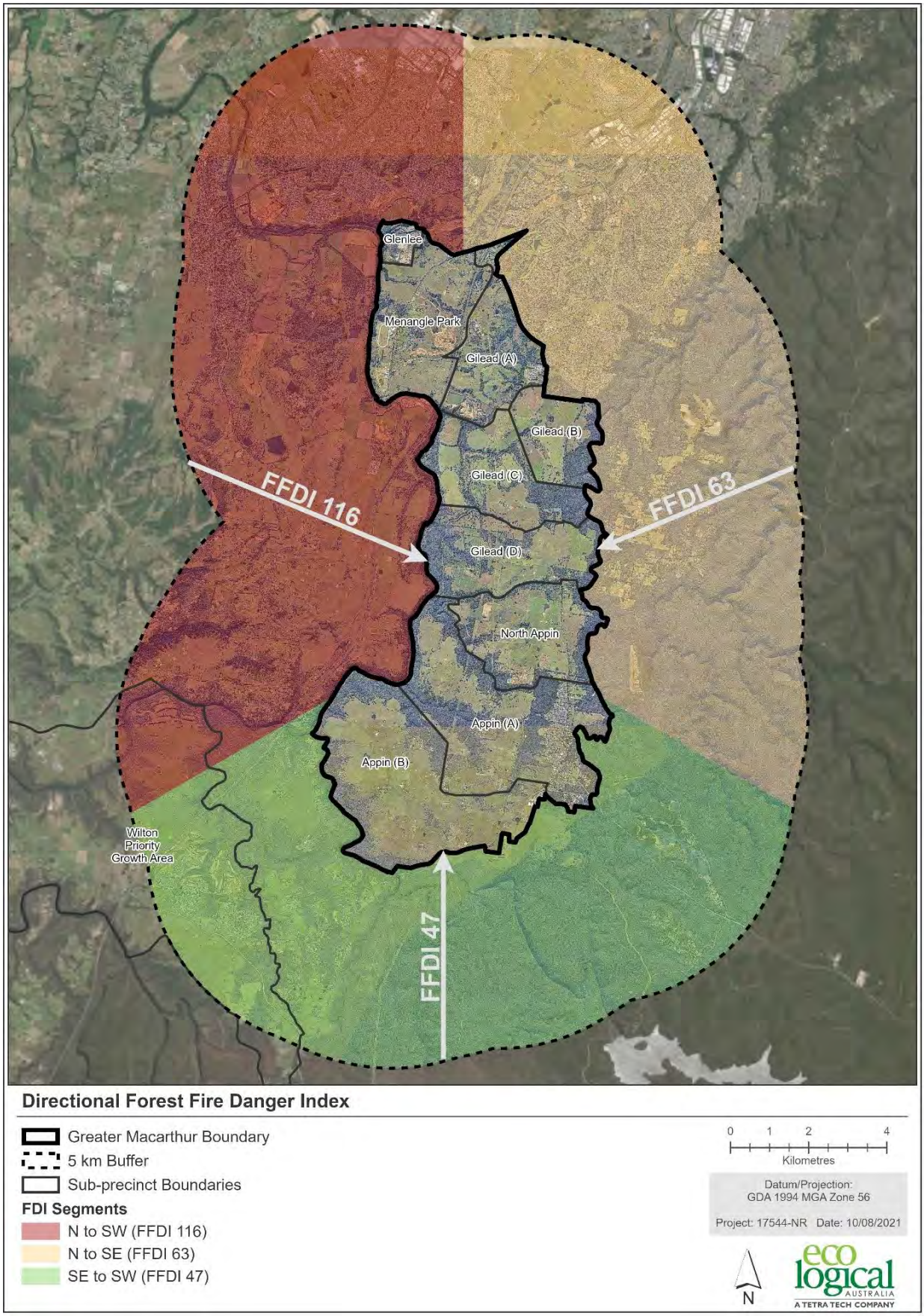

Figure 18: Bushfire Weather Analysis and FFDI Sectors for the Study Area

2.3 Bushfire History

The mapped record of fire history in the region dating back to 1963, as collated by the NSW RFS, National Parks and Wildlife Service, and other fire management agencies, was combined and investigated in order to provide an understanding of patterns in the occurrence of bushfire and also informs the bushfire risk context (i.e. likelihood). Examination of the mapped fire history records shows a low incidence of bushfire within and to the north and west of the Greater Macarthur Growth Area (Figure 19), the more problematic direction for bushfire attack given the bushfire weather analysis revealing that this is the direction for elevated FFDI conditions.

The collated fire history and conversion to a fire frequency analysis (Figure 20) indicates that there has been a moderate to high frequency of bushfires to the east and south of the Growth Area. However, given the bushfire weather analysis indicated that elevated bushfire weather conditions are mostly associated with westerly winds, and the patterns of fire spread observed in the fire history record, it appears that most of these fires burn away from the Growth Area. Further, of the fires started in urbanised or rural areas within or nearby to the Growth Area, most seem to have spread in an easterly/south-easterly direction away from the Growth Area (Figure 19, Figure 20). This observation further informs the bushfire risk context.

Whilst the compiled dataset would not contain all bushfire occurrences, it indicates a lower likelihood of bushfires impacting the Growth Area, especially larger landscape scale events originating from the west and burning under more elevated bushfire weather conditions.

The main source of wildfire ignition within the region as documented by the Macarthur and Wollondilly / Wingecarribee Bush Fire Management Committees (MBFMC 2014, WWBFMC 2017) is deliberate misuse of fire and arson related activities, with a number of major fires started in the inhabited areas and travelling in an easterly direction and impacting on conservation estate and water catchment lands. Most other major fires have ignited in the west associated with storms and have coincided with extensive dry periods coupled with hot westerly winds (WWBMC 2017).

However, as evident from the fire history record (Figure 19) no major landscape fires have developed in the west and spread to reach the Study Area since 1963. It is likely that not all small fires that start within the Cumberland Plain are recorded, as they are generally extinguished quickly and do not develop into larger landscape fires.

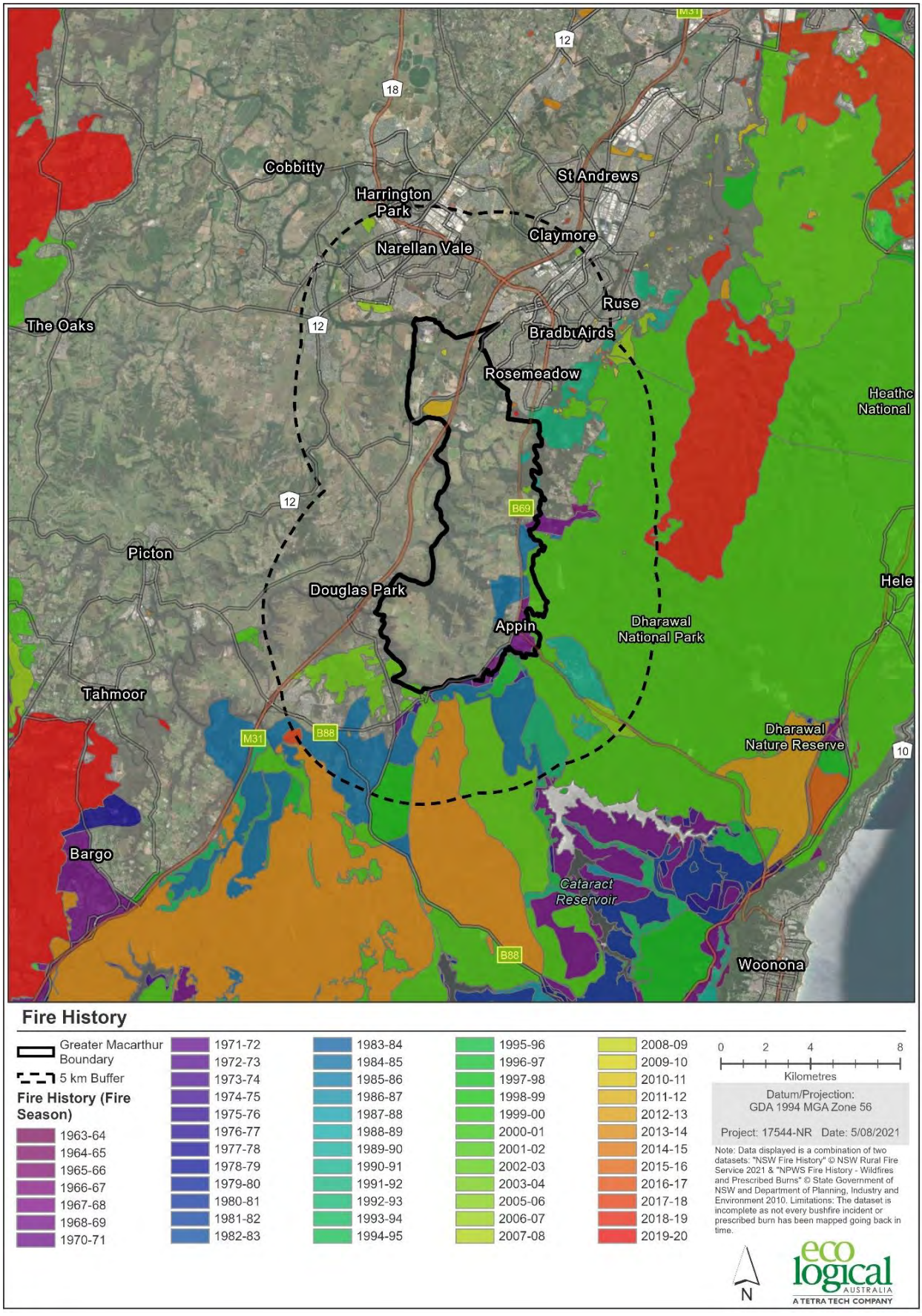

Figure 19: Wildfire History

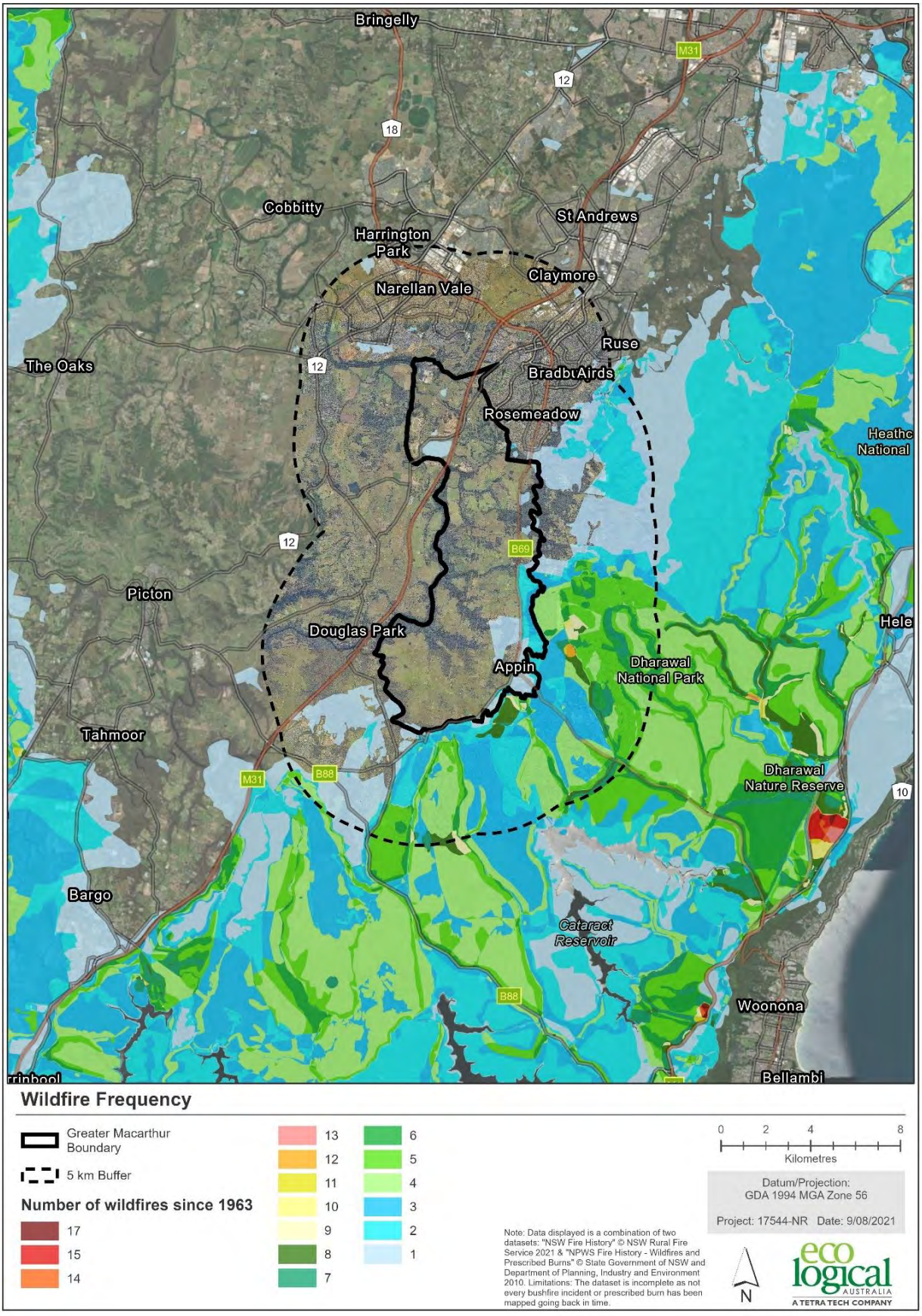

Figure 20: Wildfire Frequency

2.4 Bushfire Spread

2.4.1 Ignition Scenarios

The Macarthur and Wollondilly / Wingecarribee Bush Fire Risk Management Plans (MBFMC 2014, WWBFMC 2017) identify the main sources of ignition in the area, as:

- Arson
- Escapes from legal burning
- Ignition of abandoned/stolen motor vehicles
- Lightning
- Arching of electrical power lines

The above ignition types could be experienced anywhere in the region, however the more common anthropogenic sources are more likely to be experienced in proximity to existing residential areas and in relation to roads and other forms of access.

The chance of an ignition developing into a bushfire and spreading and impacting other areas, is mostly dependant on the fuel type and fuel load at the ignition point, the weather conditions prevailing, the downwind continuity and characteristics of fuel, barriers to fire spread, terrain, and the application of fire suppression activities. The following general observations are made in relation to the Study Area:

- Fuel types – mostly grassland to the west, which may allow for rapid fire spread if cured and not fuel reduced due to grazing or vegetation management. Mostly forest vegetation to the east and south where fire spread would be much slower, but intense and with potential for heavy ember generation.
- Weather conditions – elevated bushfire weather is more likely from the west under hot and dry westerly winds, significantly less from other directions, as per Section 2.2.
- Fuel continuity and barriers – the Hume Motorway, other main roads, larger water bodies and fuel free or fuel reduced land associated with existing (or planned) developed areas, break the fuel continuity and disrupt the fire spread potential. There are numerous interruptions to fuel continuity, particularly to the north, west and south of the Growth Area.
- Terrain – the terrain to the north, west and southwest is generally moderate, including some areas of more extensive downhill fire runs, which would moderate bushfire spread. The terrain in easterly directions is a combination of flatter plateaus with dissected valleys and some uphill fire runs to the Growth Area.
- Fire suppression – the lack of large bushfires recorded to the north and west of the Growth Area (Section 2.3) indicates generally effective fire suppression activities in these areas, in combination with the other factors outlined above.

Given the bushfire hazard within the broader Study Area, the bushfire weather conditions analysed, the bushfire history and the potential ignition sources, the key bushfire scenarios considered most relevant to bushfire attack of Greater Macarthur Growth Area are outlined in Table 1.

Table 1: Analysis of Key Bushfire Ignition and Spread Scenarios to Greater Macarthur

Ignition Source	Probable Locations	Potential Bushfire Spread & Impact Scenarios	Likelihood
Lightning Strike	Razorback Range to the west of the Growth Area	Spread to the east under high FFDI through predominately grassland and grassy woodland fuels, however with the potential to spread into the forested Nepean River valley. Potentially impacting the southern parts of the Growth Area at higher intensity.	Low
	Broad ridgelines within the Metropolitan Catchments area, Holsworthy defence estate, or conservation reserves	Spread to the north and west under low to moderate FFDI through predominately forest fuels with the potential to spread into the forested Georges River valley which forms the eastern boundary of the southern portion of the Growth Area. Potential bushfire attack in the Appin Road area (Gilead to Appin) and Wilton Road area at moderate to high intensity.	Very Low
Arson, Accidental Ignitions (e.g. cigarettes, dumped cars etc) and Fire Escapes (Pile Burns etc)	Eastern outskirts of Douglas Park and along Hume Motorway	Spread to the east under high FFDI through a mix of grassland and grassy woodland fuels on undulating land. Would need to cross over the Hume Motorway and other fuel interruptions to spread into forest fuels within the Nepean River valley, before potentially impacting the southern parts of the Growth Area at high intensity.	Low
	Eastern outskirts of Camden South and Menangle	Spread to the east under high FFDI through mostly grassland and grassy woodland fuels on undulating land. Potential to impact the northern parts of the Growth Area in the Menangle Park area or eastern and southern parts but would need to cross over the Hume Motorway and other fuel interruptions to do so.	Very Low
	St Helens Park	Spread to the west under moderate FFDI through predominately forest fuels within Georges River valley, which forms the eastern boundary of the Growth Area. Potential bushfire attack in the Appin Road area (Gilead to Appin) at moderate intensity.	Low
	Within the Growth Area	Ignition within retained vegetation within or around the Growth Area. Spread influenced by wind and weather conditions at the time. Given more severe bushfire weather is likely to be experienced from the western sectors, ignition in the western parts of the Growth Area and spread to the east carries the highest risk. However, given the narrow, fragmented and restricted nature of retained hazard, the bushfire spread of such an ignition would likely only have a limited extent.	Moderate

2.4.2 Spread Models

Bushfire spread modelling was undertaken to further inform the bushfire risk context of the Greater Macarthur Growth Area. Fire spread modelling for a set of bushfire attack scenarios, informs the potential time to arrival, for bushfires with similar characteristics to those being modelled, as well as inform more generally how bushfire may move through the landscape. The time to arrival, can be used to inform emergency management responses, including the available time to evacuate or refuge onsite. However, they are informative not determinative for this use, as there are countless fire scenarios, each with differing characteristics. Further, the models do not indicate the likelihood or severity of bushfire attack at the hazard interface, and these factors need to be considered to appreciate the risk context. The bushfire hazard (Section 2.1) bushfire weather (Section 2.2) and bushfire history (Section 2.3) inform

likelihood. Severity of attack can be informed by bushfire behaviour models (Section 2.5) as well as the setback that is afforded to development (e.g. by Asset Protection Zones).

Given the assumptions, the models are likely a conservative over-estimate of the fire spread potential. Assumptions include that the weather conditions would be at a consistent maximum for the duration; the fuel load is at climax and fully cured; there is limited fire development time required from ignition; the ignition points are in the locations mapped; that fire spread is not stopped or heavily impacted by fuel interruptions (i.e. roads and rivers); and that no suppression/intervention activities are applied.

The predictive bushfire spread models, for the three bushfire weather scenarios (i.e. SW-N (FFDI 116), N-SE (FFDI 63), and SE-SW (FFDI 47)) are shown in Figure 21, Figure 22 and Figure 23. These three predictions are based on a 4 hour fire spread simulation using the weather conditions (including wind characteristics), the 11 selected ignition locations and other inputs identified in Section 0.

High level observations of the modelling results include:

- There is potential for bushfire spread to the Growth Area under some of the ignition and weather scenarios modelled, particularly locations where rapid spread through grassland vegetation is possible.
- Bushfire spread to the Growth Area from the west, has the potential to be rapid due to the predominately grassland hazard in combination with the potentially elevated bushfire weather conditions, but far less rapid from most other directions given predominately forest vegetation and lesser bushfire weather conditions.
- There are a range of impedances to bushfire spread, particularly to the west (i.e. the Hume Motorway and other main roads, as well as existing or planned developments and other fuel free or fuel reduced areas).
- There is the potential for bushfire penetration into areas within the Growth Area, that are proposed to be retained. However, the risk of this situation eventuating is lower in some areas, particularly where there are narrow fingers of hazard that would have a reduced head fire width and thus lower intensity and where slower spreading bushfire can be expected. Further, bushfire penetration into the narrow valleys that dissect some parts of the Growth Area requires the wind to be blowing at a specific direction, otherwise head fire spread into these areas would not occur, only flanking fire. As such, the likelihood of penetration into the Growth Area is reduced, and thus the models are a very conservative estimate of fire spread in these situations.
- That existing suburbs outside the Growth Area and proposed development areas both within the Greater Macarthur and Wilton Growth Areas, provide a potential benefit of limiting bushfire spread across the landscape.
- There is potential for bushfire spread to and across some of the main off-site evacuation routes, although at longer burn durations than those modelled.
- That it is unlikely that all off-site evacuation routes would be cut by fire at one time, given the location and number of potential off-site evacuation routes, along with the potential benefit that future development may provide in terms of limiting fire spread.
  The potential impact of bushfire spread from the west is the greatest, in terms of the potential time to impact and consequence on evacuation routes.

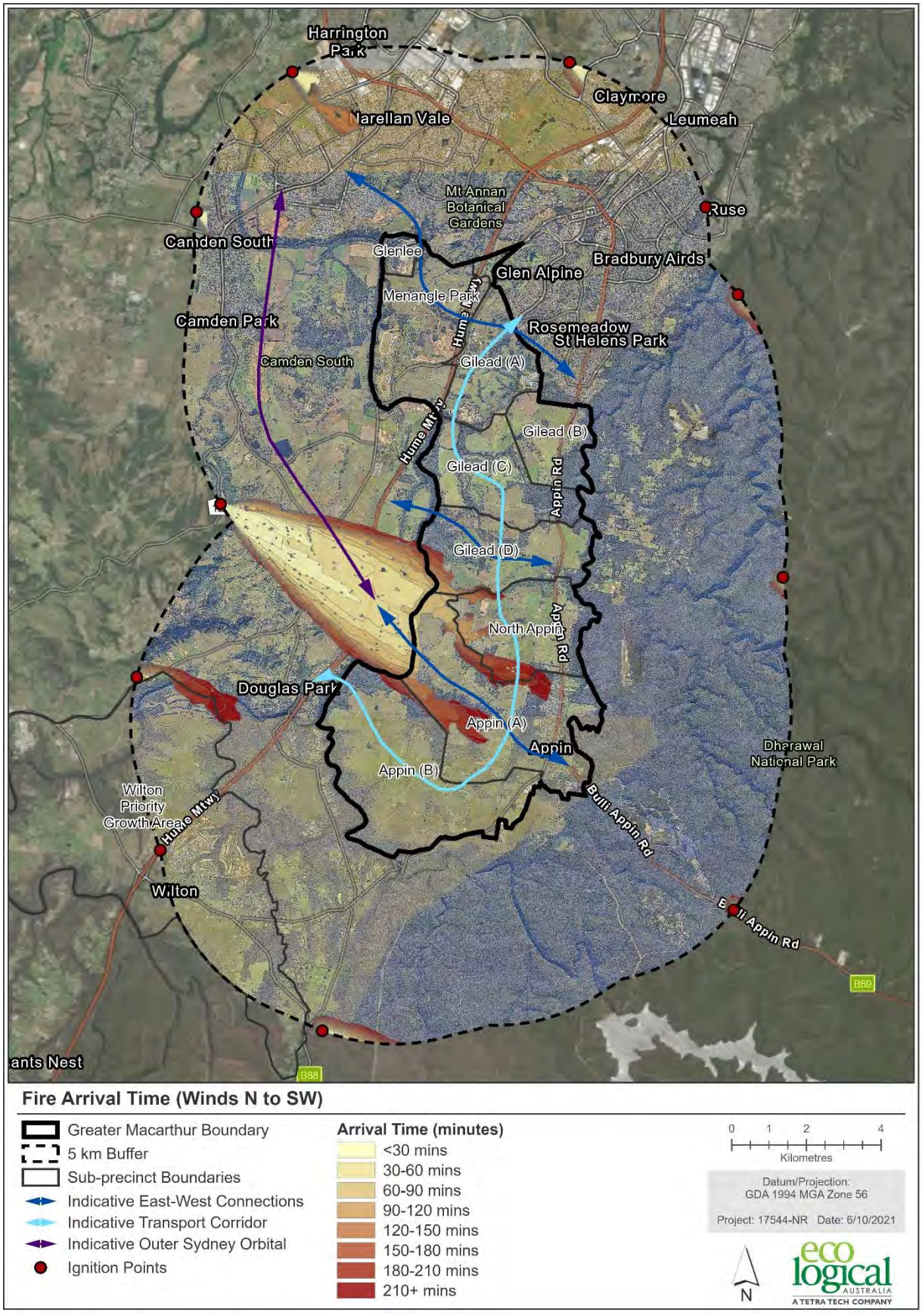

Figure 21: Fire Spread & Arrival Time – Individual Ignition, Westerly Winds (FFDI 116)

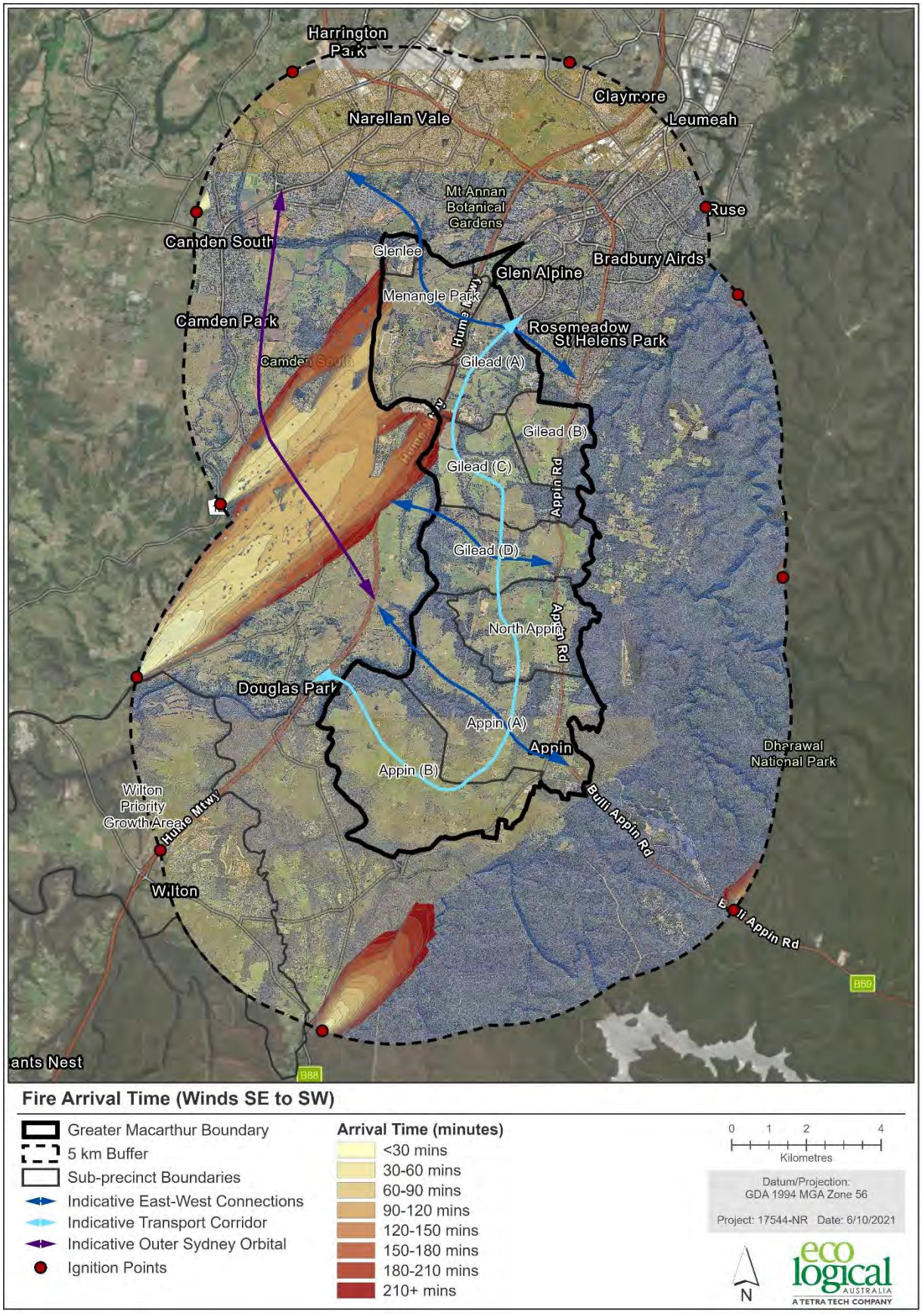

Figure 22: Fire Spread & Arrival Time – Individual Ignition, Southerly Westerly Winds (FFDI 47)

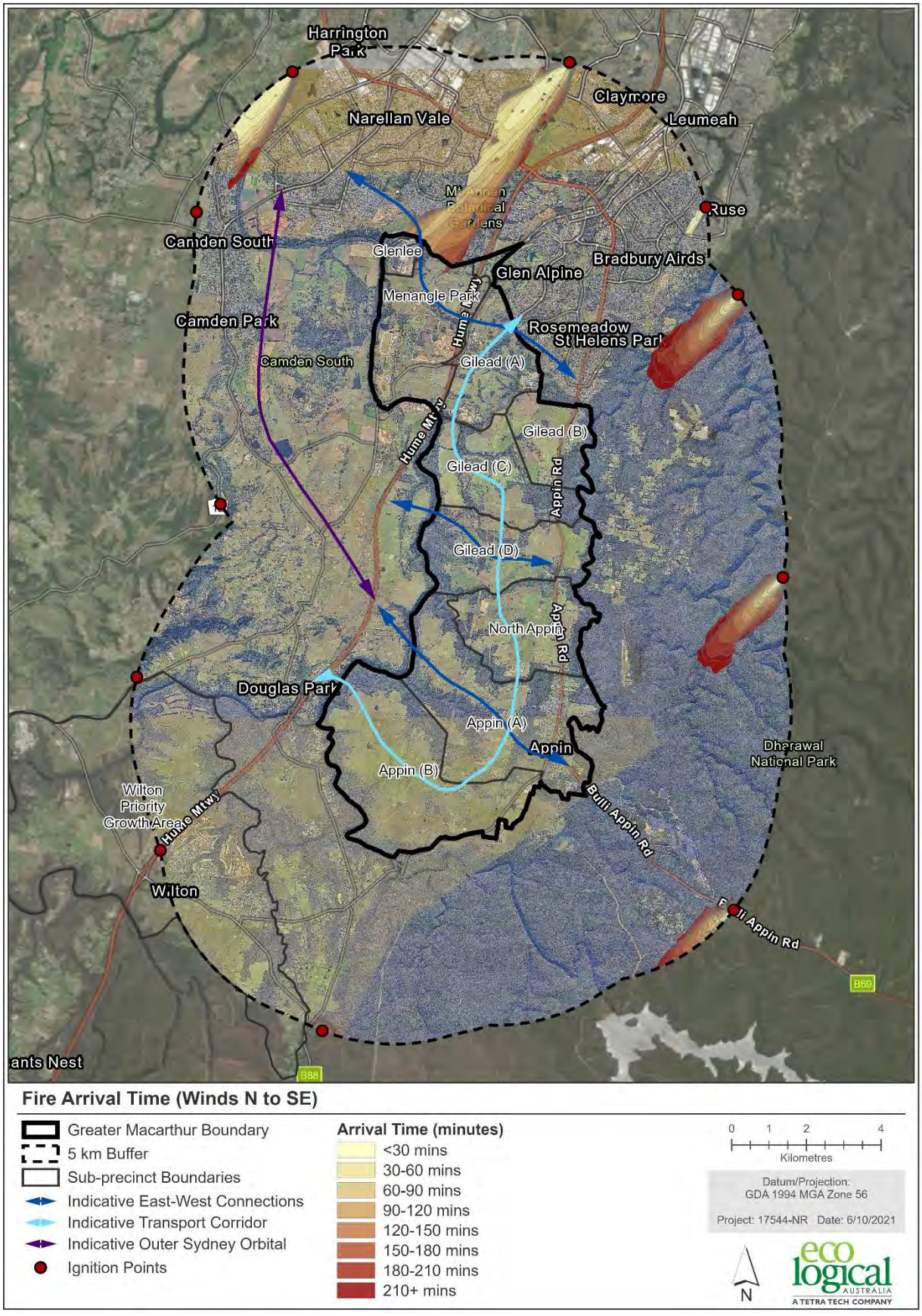

Figure 23: Fire Spread & Arrival Time – Individual Ignition, North Easterly Winds (FFDI 63)

2.5 Bushfire Intensity

Whilst each bushfire event is different, fire spreads by responding to changes in fuel, terrain, and weather conditions. Therefore, based on the bushfire hazard and weather analysis undertaken, the potential bushfire intensity can be modelled.

Bushfire intensity models were generated to provide a representation of the potential bushfire behaviour in the Study Area. They were prepared using scientifically documented formula for bushfire Rate of Spread and intensity calculation (i.e. Cheney *et al* 2012 for Forest and Woodland, Anderson *et al* 2015 for Heath and Shrubland, and Cheney *et al* 1998 for Grassland) and based on the bushfire hazard (Section 2.1) and bushfire weather conditions (Section 2.2).

The models provide an indication of the potential head fire intensity from the direction of attack, for the scenario's being modelled. It should be noted that they model instantaneous maximum intensity for each grid cell for the scenario being modelled, so in some cases they over represent the severity of potential bushfire behaviour, particularly small, isolated or narrow patches of bushfire hazard. They also don't indicate burn duration / residence time, which for grassland, whilst it can burn at high intensity, the residence time is very short.

Bushfire intensity is a significant determinant of risk to life and property, and the controllability of bushfires, and therefore important in the consideration of the bushfire risk context, especially the potential bushfire intensity within the immediate proximity (say 500m) of the development interface. Three bushfire models were generated for this study:

- Bushfire attack from the south-west to north direction (clockwise) at FFDI 116 (Figure 24).
- Bushfire attack from the south-east to south-west direction (clockwise) at FFDI 47 (Figure 25);
- Bushfire attack from the north to south-east direction (clockwise) at FFDI 63 (Figure 26);

High level observations of the bushfire intensity models include:

- The potential for bushfire intensity beyond the generally accepted limit of controllability (i.e. 4,000 kW/m) is modelled for most lands surrounding the Growth Area, under all three scenarios.
- There are some areas of moderate intensity modelled to the west, which is in grassland hazard. Given the increased potential for suppression activities in these locations and for fire runs to be impeded in this hazard type due to fuel interruptions such as roads, the likelihood of bushfire spread to the Growth Area is lessened. This observation is reinforced by there being no mapped record of a fire occurring in the west of the Study Area and spreading to impact the Growth Area (Section 2.3).
- There is a ring of low-very low intensities modelled around much of the Growth Area boundary, seemingly as a result of steep downhill fire runs associated with river valleys. This in combination with other mitigating factors, indicates lower likelihood of bushfire spread into the Growth Area.
- There are some areas within the Growth Area that are modelled with moderate or lower intensity or where the models over represent the potential (i.e. narrow fingers of hazard that would have a reduced head fire width and thus lower intensity can be expected).
- The potential bushfire intensity along parts of the main off-site evacuation routes could be significant, however there are multiple alternate evacuation routes available.
- The models do not indicate any part of the indicative proposed development area within the Growth Area should be excluded as inappropriate.

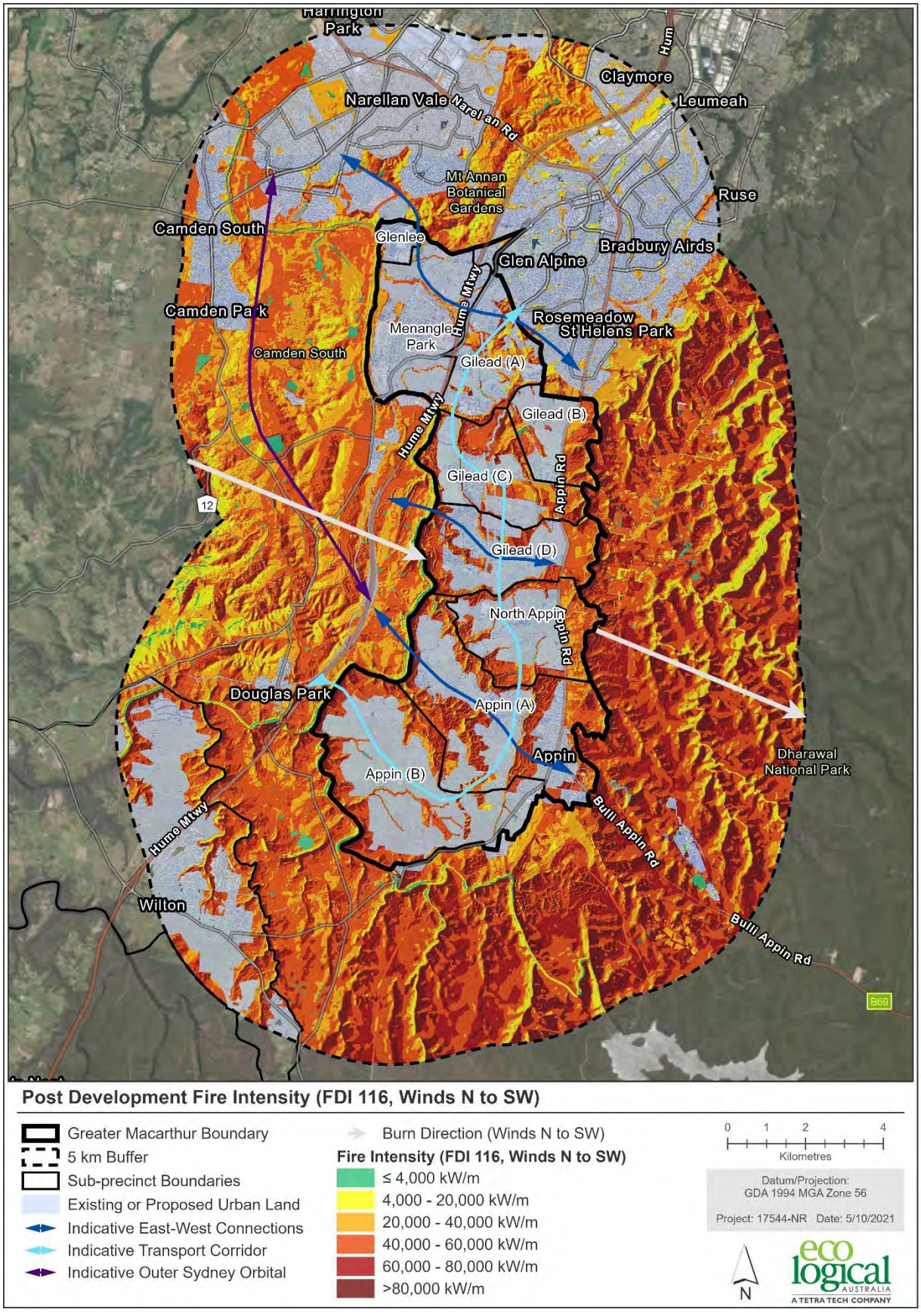

Figure 24: Bushfire Intensity Model – Westerly Winds

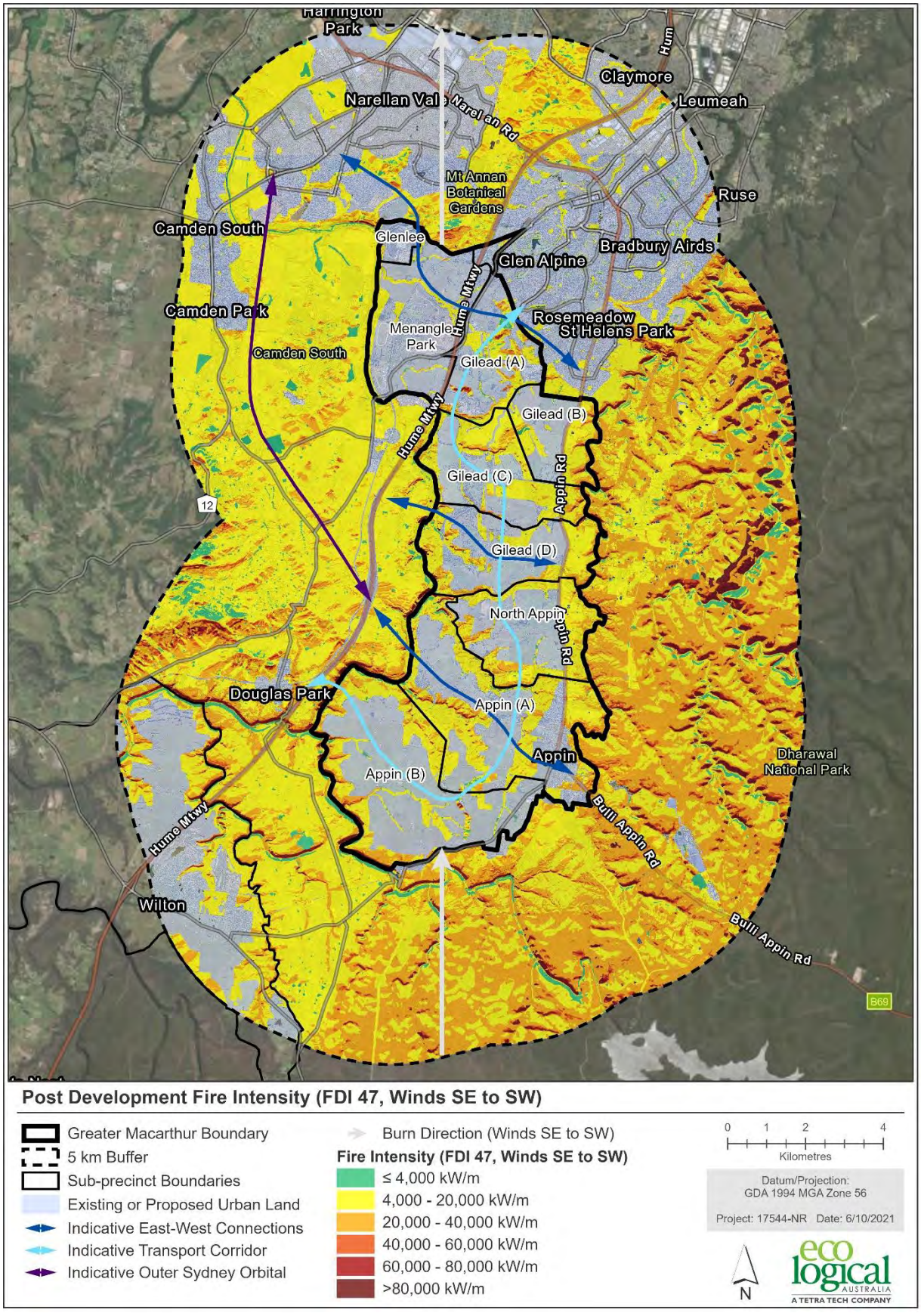

Figure 25: Bushfire Intensity Model – Southerly Winds

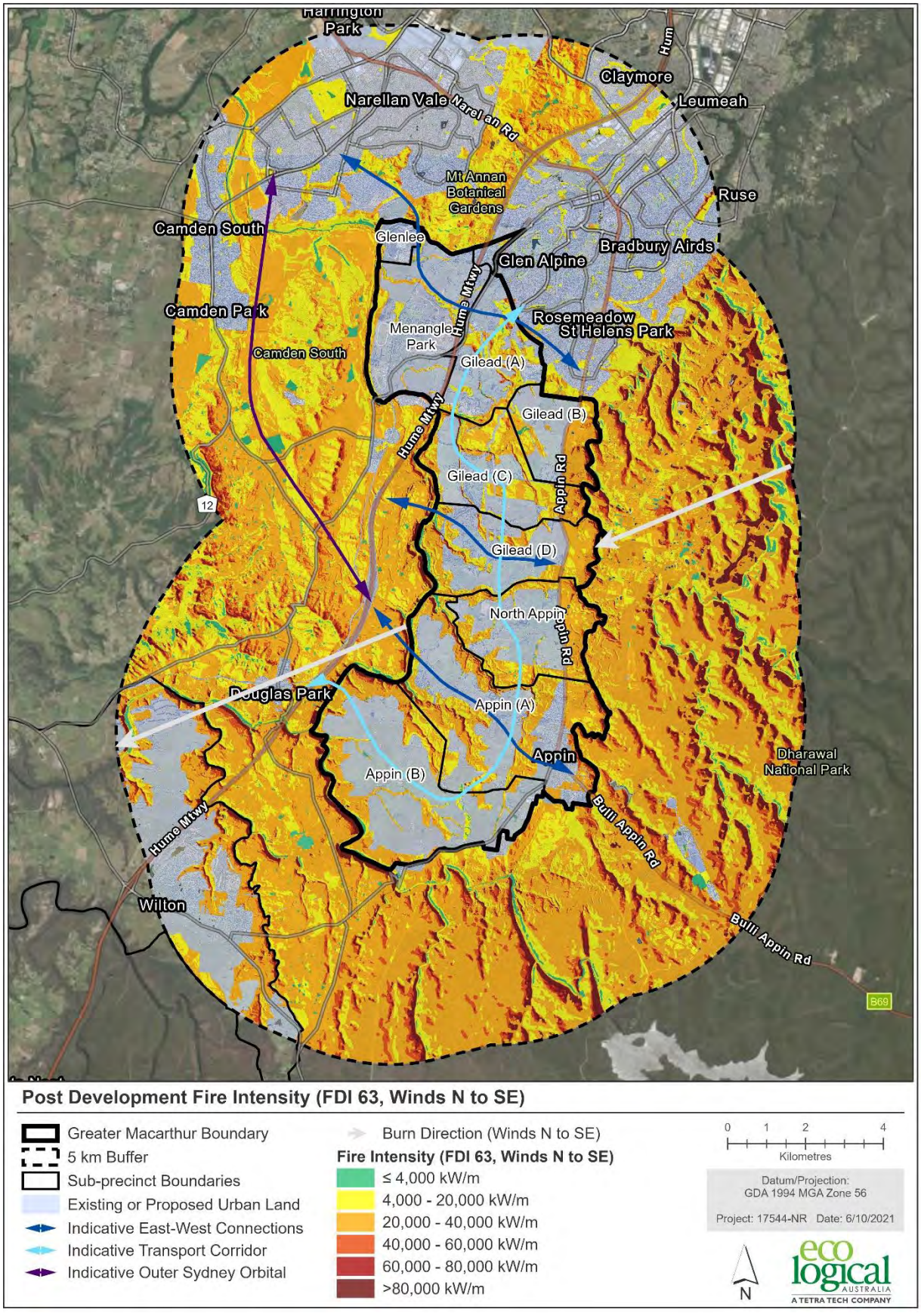

Figure 26: Bushfire Intensity Model – Easterly Winds

2.6 Evacuation Options

The safety of emergency responders and people within the Growth Area exposed to bushfire attack is paramount. Suitable evacuation destinations and safe reliable routes are key, along with alternative evacuation options. Future development proposals should not rely on emergency service assistance during evacuation, as it cannot be guaranteed to be available. Early 'unassisted' off-site evacuation is the policy benchmark of the RFS.

Indicative off-site evacuation destinations have been considered for the Growth Area and include the following locations and adjoining suburbs: Campbelltown; Bulli / Wollongong; Camden / Narellan; Picton; and Wilton (once further developed). An initial review of the potential fire impact on the evacuation routes to these off-site evacuation destinations, is summarised in Table 2 to Table 4 for each precinct. It is also noted that there are risks with off-site evacuation which are elevated when the route adjoins bushfire hazard, is long, or does not provide adequate capacity for the expected demand.

Further analysis of available evacuation options and capacity will be needed for each precinct, in order to determine adequacy at the precinct scale. The results of the bushfire spread models can be used to inform further evacuation analysis, however they should be used conservatively, and it should be noted that the models are based on the inputs and parameters of the scenario being modelled, rather than providing a defined estimate of the required time to safely evacuate from a bushfire. Further, there are many potential bushfire attack scenarios, and it may not be safe, appropriate or even relevant to trigger off-site evacuation for all scenarios.

Safe evacuation is often considered in terms of the Required Safe Egress Time (RSET) and Available Safe Egress Time (ASET) (ABCB 2021). The RSET should be less than the ASET, plus an appropriate factor of safety. The components of RSET can be considered in the following terms: Cue period (i.e. the time to notice or be notified of a cue for action); Response period (i.e. the time from occurrence of a cue to recognition of a need for action); Delay period (i.e. the period following cue recognition to occupant initiation of movement); and Movement period (i.e. the period required to relocate from the origin to destination, noting that increased time may be required due to road closures or other factors) (ABCB 2021). Given this context, additional time beyond the arrival times presented in the bushfire spread modelling, may be required to provide an appropriate timeframe for safe evacuation.

While on-site community refuges are currently not formally recognised in in PBP for the planning of new development, bushfire evacuation patterns (Whittaker *et al.* 2013, Strahan *et al.* 2018, Whittaker 2018, Whittaker 2019) suggest these should be part of best-practice strategic planning consideration, as they add options when early evacuation is not feasible (e.g. rapid on-set bushfires) and potentially increase community safety and resilience in a broader range of bushfire attack scenarios. For these reasons, community refuges are encouraged within the Growth Area as an additional bushfire protection design 'redundancy'. These would ideally be provided in the form of appropriately located and specially designed multi-purpose buildings (e.g. indoor sports stadium or community hall) but could also be provided as open space, provided they are located outside the 2 kW/m^2 setback distance and have minimal fuel. The Neighbourhood Safer Places (NSP) guideline (RFS 2017) has been used to provide a preliminary indication of potentially suitable locations for on-site refuge (Figure 27) either in the form of a Building (>10 kW/m^2) or as Open Space (>2 kW/m^2). This initial assessment could be further refined during Precinct planning, as it is considered a conservative assessment of the bushfire hazard within the Growth Area, particularly the very narrow fingers of vegetation.

Table 2: Initial Evaluation of Precinct Evacuation Routes Against Bushfire Spread Models – Westerly Winds Scenario

Sub-Precinct	Observations regarding offsite evacuation
Glenlee	Egress east on indicative east-west connection and then south on Hume Motorway not impacted. Whilst the model does not demonstrate egress south into Menangle Precinct being impacted, there is potential (albeit very unlikely) given the exposure to the west.
Menangle Park	Egress north on Hume Motorway not impacted. Egress east or west on indicative east-west connection not impacted. Egress south on Hume Motorway potentially impacted, however not the most likely evacuation route to take for this scenario.
Gilead (A)	Egress north on Hume Motorway or Appin Road or indicative Transport Corridor not impacted. Egress east or west on indicative east-west connection not impacted. Egress south on Hume Motorway potentially impacted, however not the most likely evacuation route to take for this scenario. Whilst the model does not demonstrate potential for impact on the indicative north-south transport corridor or on Appin Road, which would affect egress south, there is potential (albeit unlikely), but only after a much longer time duration than the 4 hours of the current modelling. However, this is not the most likely evacuation route to take for this scenario.
Gilead (B)	Egress north on Appin Road not impacted. Also, there is potential for further road connections with St Helens Park to the north. Whilst the model does not demonstrate potential for impact on the indicative north-south transport corridor or on Appin Road, which would affect egress south, there is potential (albeit unlikely), but only after a much longer time duration than the 4 hours of the current modelling. However, this is not the most likely evacuation route to take for this scenario.
Gilead (C) and (D)	Egress north on Appin Road and north-south transport corridor potentially impacted, however lower likelihood given fire history (Section 2.3), narrow hazard connectivity, fuel breaks and convoluted fire path. Further, potential impact is only after a much longer time duration than the 4 hours of the current modelling, particularly for Appin Road. Egress west on indicative east-west connection has potential to be impacted, depending on ignition location, however not the most likely evacuation route to take for this scenario. Potential for egress south on Appin Road to be impacted, however lower likelihood and only after a much longer time duration than the 4 hours of the current modelling. Evacuation route, timing and capacity should be planned carefully for this sub-precinct, along with on-site refuge capacity, for redundancy.
North Appin	Egress north on Appin Road and north-south transport corridor potentially impacted, however lower likelihood given fire history (Section 2.3), narrow hazard connectivity, fuel breaks and convoluted fire path. Further, potential impact is only after a much longer time duration than the 4 hours of the current modelling, particularly for Appin Road. Potential for egress south on Appin Road to be impacted (albeit low likelihood), but only after a much longer time duration than the 4 hours of the current modelling. Evacuation route, timing and capacity needs to be planned very carefully for this sub-precinct, along with on-site refuge capacity, for redundancy.
Appin (A) and (B)	Potential for egress north on Appin Road to be impacted (albeit low likelihood), but only after a much longer time duration than the 4 hours of the current modelling. Egress north and west on north-south transport corridor impacted. Egress west on indicative east-west connection and outer Sydney orbital impacted, however not the most likely evacuation route to take for this scenario. Potential for egress south on Wilton Road to be impacted (albeit low likelihood), but only after a much longer time duration than the 4 hours of the current modelling. Egress east to the coast via Appin Road not impacted due to shielding by future development, although a long travel time and road flanked by bushfire hazard elevates the risk of this route. Evacuation route, timing and capacity should be planned carefully for this sub-precinct, along with on-site refuge capacity, for redundancy.

Table 3: Initial Evaluation of Precinct Evacuation Routes Against Bushfire Spread Models – South Westerly Winds Scenario

Sub-Precinct	Observations regarding offsite evacuation
Glenlee	Egress east along indicative east-west connection not impacted. Potential for egress north into existing urban development (Spring Farm, Mount Annan, Campbelltown), which will not be impacted. Potential for egress north-west along indicative east-west connection to be impacted (albeit low likelihood), but only after a much longer time duration than the 4 hours of the current modelling.
Menangle Park	Egress north-east on Menangle Road and Hume Motorway not impacted. Egress east along indicative east-west connection not impacted. Egress south on Hume Motorway impacted and potential for egress north-west along indicative east-west connection impacted, albeit low likelihood and only after a much longer time duration.
Gilead (A)	Egress north on Hume Motorway not impacted. Egress east and west on indicative east-west connection not impacted. Egress south on Hume Motorway and south on indicative north-south transport corridor potentially impacted, however not the most likely evacuation route to take for this scenario.
Gilead (B)	Egress north on Appin Road not impacted and potential for further road connections with St Helens Park. Egress north on indicative north-south transport corridor potentially impacted, at low likelihood, however not the most likely evacuation route to take for this scenario. Potential for egress south on Appin Road to be impacted (south of Appin) but only after a long time duration and not a likely evacuation route in this scenario.
Gilead (C) and (D)	Egress north on Appin Road not impacted. Egress east on indicative east-west connection (to Appin Road) not impacted. Egress north on indicative north-south transport corridor potentially impacted, at low likelihood. Egress south on Appin Road potentially impacted (south of Appin) but only after a long time duration and not a likely evacuation route in this scenario. Egress north and south on Hume Motorway and west on indicative east-west connection impacted, however not a likely evacuation route in this scenario. Evacuation route, timing and capacity should be planned carefully for this sub-precinct, along with on-site refuge capacity, for redundancy.
North Appin	Egress north on Appin Road not impacted. Egress north on indicative north-south transport corridor potentially impacted, at low likelihood. Egress south on Appin Road potentially impacted (south of Appin) but only after a long time duration and not a likely evacuation route in this scenario. Evacuation route, timing and capacity should be planned carefully for this sub-precinct, along with on-site refuge capacity, for redundancy.
Appin (A) and (B)	Egress north on Appin Road not impacted. Egress east on indicative east-west connection not impacted. Egress north on indicative north-south transport corridor potentially impacted, at low likelihood. Potential for egress west on north-south transport, Hume Motorway and indicative Outer Sydney Orbital to be impacted, however not a likely evacuation route in this scenario. Egress south via Hume Motorway or Wilton Road not likely to be impacted (due to proposed development in Wilton Growth Area) however not likely evacuation routes in this scenario. Evacuation route, timing and capacity should be planned carefully for this sub-precinct, along with on-site refuge capacity, for redundancy.

Table 4: Initial Evaluation of Precinct Evacuation Routes Against Bushfire Spread Models – North Easterly Winds Scenario

Sub-Precinct	Observations regarding offsite evacuation
Glenlee	Egress southeast on indicative east-west connection and Hume Motorway (south) not impacted. Potential for egress north into existing urban development (Spring Farm, Mount Annan) which is not impacted. Potential for Hume Motorway (north) to be impacted, however evacuation via major roads in existing urban areas (Campbelltown) available.
Menangle Park	Egress southeast on indicative east-west connection and Hume Motorway (south) not impacted. Potential for Hume Motorway (north) to be impacted, however evacuation via major roads in existing urban areas (Campbelltown) available.
Gilead (A)	Egress east and west on indicative east-west connection, north and south on indicative north-south transport corridor and Hume Motorway (south) not impacted. Potential for Hume Motorway (north) to be impacted, however evacuation via major roads in existing urban areas (Campbelltown) available.
Gilead (B)	Potential for egress south on Appin Road to be impacted (albeit low likelihood), but only after a much longer time duration than the 4 hours of the current modelling. Potential evacuation routes west through to Gilead (C) providing access to alternate north and south egress on indicative transport corridor and Hume Motorway.
Gilead (C) and (D)	Indicative east-west connection unlikely to be impacted, providing egress west to Hume Motorway and providing unimpacted evacuation routes to the south, north and west. Egress south on Appin Road likely to be impacted, but only after a much longer time duration than the 4 hours of the current modelling. Indicative north-south transport corridor potentially impacted in Precinct (D), but only after a much longer time duration than the 4 hours of the current modelling, and lower likelihood given narrow hazard connectivity, fuel breaks and convoluted fire path. Evacuation routes and alternative options, timing and capacity should be planned carefully for this sub-precinct, along with on-site refuge capacity, for redundancy.
North Appin	Egress south on indicative north-south corridor not impacted, providing access to evacuation routes to the south, west and north-west. Indicative north-south transport corridor potentially impacted to the north, however lower likelihood given narrow hazard connectivity, fuel breaks and convoluted fire path. Further, potential impact is only after a much longer time duration than the 4 hours of the current modelling and this is not a primary evacuation option for this scenario. Egress north and south on Appin Road likely to be impacted, but only after a much longer time duration than the 4 hours of the current modelling. Evacuation routes and alternative options, timing and capacity should be planned carefully for this sub-precinct, along with on-site refuge capacity, for redundancy.
Appin (A) and (B)	Egress south on Wilton Road not impacted. Egress west on indicative east-west connection, north-south transport corridor and outer Sydney orbital not impacted, providing access to evacuation routes to the south, west and north-west Indicative north-south transport corridor potentially impacted to the north, however lower likelihood given narrow hazard connectivity, fuel breaks and convoluted fire path. Further, potential impact is only after a much longer time duration than the 4 hours of the current modelling and this is not a primary evacuation option for this scenario. Egress north and east on Appin Road have potential to be impacted, but only after a much longer time duration than the 4 hours of the current modelling and these are not the primary evacuation routes for this scenario.

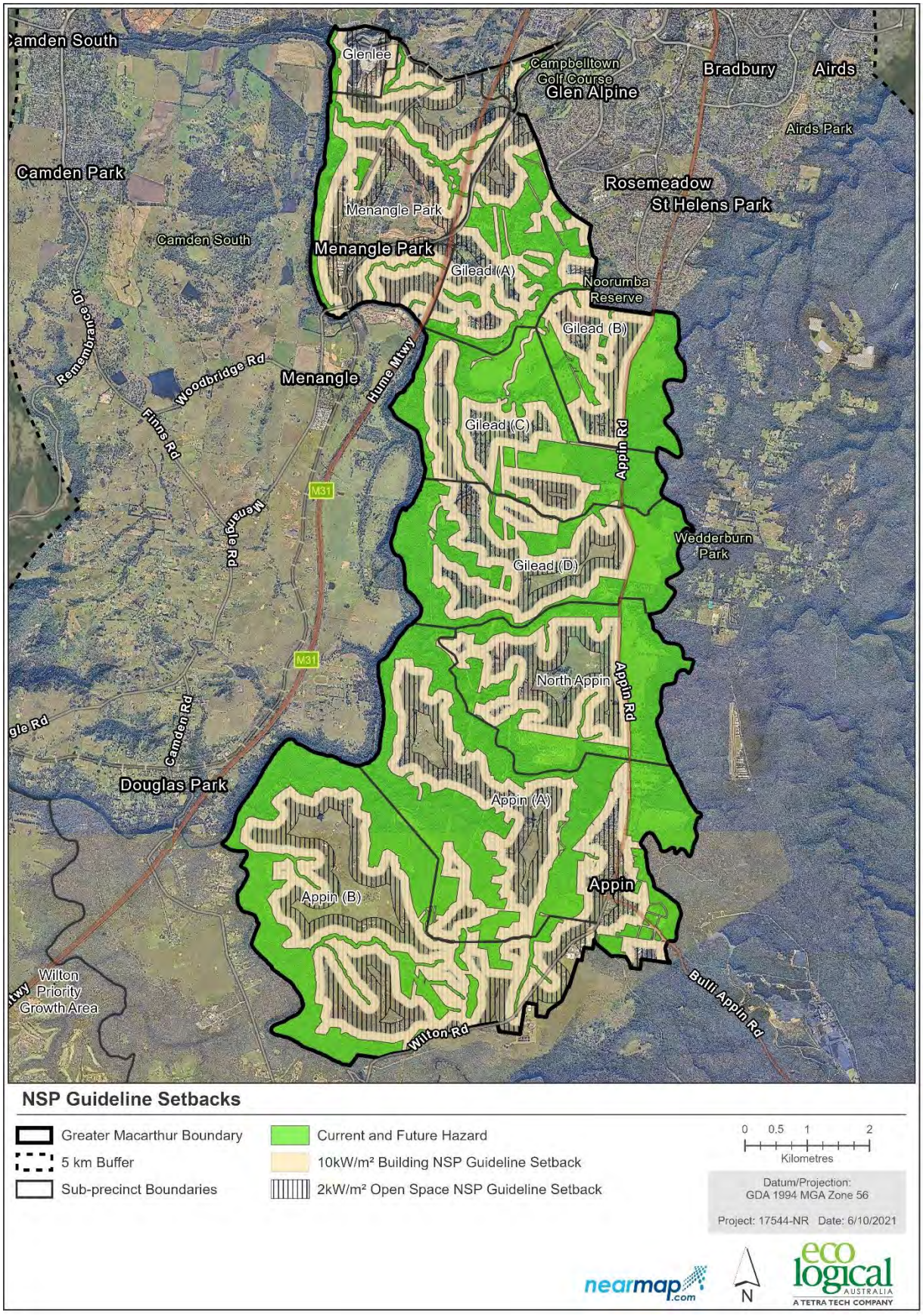

Figure 27: Analysis of Neighbourhood Safer Place Setbacks

2.7 Summary of Bushfire Risk Assessment

In evaluating the bushfire risk overall, whilst there is potential for bushfire attack to occur due to the presence of bushfire prone vegetation within the Growth Area as well as the surrounding Study Area, the residual risk is substantially mitigated by a variety of landscape features, including:

- The 'sheltering' of the Growth Area from wildfires by development in the northwest through to the northeast (i.e. Camden Park through Mount Annan, Campbelltown to St Helens Park) in addition to the increasing 'sheltering' provided by development proposed and occurring in the Wilton Growth Area, Douglas Park and Menangle areas.
- The reduced bushfire hazard to the west, in the form of grassland, often on upslopes, with multiple significant fuel interruptions, and much of which is not mapped as bushfire prone.
- The impedances from bushfire entering the Growth Area and the reduced likelihood of significant fire spread within it due to narrow and convoluted internal hazard.
- The bushfire history not indicating a pattern of large fire development to the west or even any fire spread to the Growth Area from ignitions within the Study Area.
- The weather analysis indicating that the primary bushfire weather is from the west, however the reduced hazard, interruptions, impedances and bushfire history do not indicate a significant risk is present from this direction.
- The remaining directions of landscape bushfire risk from the east and south are also not considered "high bushfire risk" as they have no exposure to the highest FFDI driven bushfires from the west, and the potential maximum FFDI from the east (63) and south (47) is well below the FFDI upon which the PBP 2019 'benchmark protection measures' for the locality are based i.e. FFDI 100.
- The bushfire history, bushfire spread modelling and bushfire intensity modelling do not indicate a significant bushfire risk to the Growth Area from any direction and while nearby vegetation and terrain have the potential to carry higher intensity fires, these fires are not considered likely to be beyond the levels upon which the bushfire protection measures within PBP are founded.
- Preliminary analysis of the off-site evacuation options for each precinct, including destinations, routes and their potential to be impacted by bushfire, has revealed that all precincts/sub-precincts have multiple evacuation options available to them. Notwithstanding this, there are five precincts/sub-precincts (Gilead (C) and (D), North Appin and Appin (A) and (B)) where careful precinct planning is required with regard to evacuation routes, timing and capacity.
- In addition to off-site evacuation, a preliminary assessment in this study indicates that there is also capacity for on-site refuge. The provision of such is recommended as best-practice strategic planning, as an additional bushfire protection design 'redundancy' for Precincts.

3. Risk Assessment and Evaluation

3.1 Precinct Risk Assessment

To better understand the risk profile of each precinct within the Growth Area, a high level bushfire risk assessment has been undertaken, and is presented below. This has been informed by the findings of the bushfire risk context (Section 0). It has been undertaken on the basis that future development within the Growth Area will provide an appropriate suite of bushfire protection measures that address the performance criteria of PBP. Therefore, the risk assessment is of the level of residual risk once standard bushfire mitigation measures are applied (e.g. Asset Protection Zones, access / egress, construction standards, landscaping, utility supply, emergency management capacity).

The assessment provided in this section assesses the risks from bushfire to people and property (infrastructure, assets, private property) within the precincts. The methodology adopted follows the process documented in AS/NZS 31000:2018 'Risk Management – Principles and Guidelines' whereby a risk classification scheme is developed through qualitative scales of likelihood and of consequence.

This assessment adopts a definition of likelihood based on likelihood of occurrence in perpetuity. The scale of likelihood is shown below in Table 5. Values have been allocated to the likelihood descriptors on a scale of 1 to 5 with 1 being extremely rare (extremely unlikely) and 5 being almost certain.

Table 5: Likelihood Description

Likelihood Descriptor	Description
Almost certain (5)	The event is expected to occur
Likely (4)	The event will probably occur
Possibly (3)	The event might occur at some time
Unlikely (2)	The event could occur at some time
Rare (1)	The event may occur in exceptional circumstances

The scale of consequence is shown in Table 6 below. Values have been allocated to the consequence descriptors on a scale of 1 to 5 as outlined below. The assessment considers the most probable consequence which has alignment to the policy setting of PBP.

Table 6: Consequence Description

Consequence Descriptor	Description
Catastrophic (5)	Widespread death and injury, huge financial loss, irreversible widespread environmental damage
Major (4)	Extensive injury or limited death, major financial loss, irreversible local environmental damage
High (3)	Injury requiring medical treatment, high financial loss, Long-term environmental damage
Medium (2)	First aid, medium financial loss, Short-term environmental damage
Low (1)	No injuries, low financial loss, minor environmental impact

Rating codes and the level of risk are then calculated by multiplying likelihood level and consequence level, with the rating determined as per the scale outlined in Table 7 below.

Table 7: Risk Rating

Level of risk	Risk rating
0 - 4	Insignificant
5 - 9	Minor
10 - 14	Moderate
15 - 19	Major
20 - 25	Extreme

The bushfire risk assessment for each of the precincts is presented in Table 8. Precincts with a higher risk rating should not necessarily be precluded from future development, as the risk rating is of the unmitigated risk, not of the residual risk after the application of bushfire protection measures. Rather, those precincts with an elevated rating of unmitigated risk require more careful planning of land use and infrastructure, along with emergency management provision (i.e. off-site evacuation and on-site refuge capacity) in order to reduce the residual risk to an appropriate level.

Table 8: Bushfire Risk Assessment – Greater Macarthur Growth Area Precincts

Precinct	Likelihood (A)	Consequence (B)	Risk Level (A x B)	Risk Rating	Notes
Glenlee	2	2	4	Insignificant	Adjoins urban area of Spring Farm/Mount Annan to the north and Menangle Park to the south (subject to current development proposals and activity), with Camden Park to the west, thus reducing risk. Partially exposed to the west, however limited fire run and predominately adjoined by reduced hazard vegetation (i.e. cultivated agricultural lands). Greater exposure to the south-west including grassland and grassy woodlands, however lower likelihood fire attack direction and with reduced consequence, due to lower intensity and greater suppression opportunities. BPMs, off-site evacuation and on-precinct refuge options should be able to be adequately provided for this precinct. **Conclusion/Recommendation:** Insignificant bushfire risk was identified due to the lack of exposure to high risk hazard, lower likelihood, capacity to provide BPMs and multiple safe off-site evacuation options and on-site refuge capacity. Precinct planning should be able to provide an appropriate combination of BPMs in accordance with PBP.
Menangle Park	3	2	6	Minor	Precinct already rezoned, but subject to proposed amendments. Adjoins urban area of Spring Farm/Mount Annan to the north, with Camden Park to the west. Exposed to the west and south-west, with the west considered a higher risk direction for bushfire attack. The risk from the west is moderated by a discontinuous fire run due to existing development in the Camden Park area and interruptions or lower bushfire hazard areas. The hazard adjoining the precinct is woodland, forested wetland and grassland (predominant) on low to moderate slopes. Precinct has partial connection to landscape risk in the south-west, however large fire impedances provided by existing open space, roads and other fuel disruptions moderate this risk. Narrow areas of hazard within riparian zones protrude into the precinct within the north and south. BPMs, off-site evacuation and on-precinct refuge options should be able to be adequately provided for this precinct. **Conclusion/Recommendation:** Minor bushfire risk rating is based on exposure to higher risk direction although moderated by discontinuous fire run, fire history and multiple off-site evacuation options and on-site refuge capacity. Precinct planning should be able to provide an appropriate combination of BPMs in accordance with PBP.

Precinct	Likelihood (A)	Consequence (B)	Risk Level (A x B)	Risk Rating	Notes
Gilead (A)	1	2	2	Insignificant	Not exposed to the west, the primary direction for elevated bushfire attack. Negligible landscape exposure, with urban development (existing and future) to all directions, significantly reducing the risk. Partially exposed to the south-west by connected hazard on retained lands, however lower likelihood of bushfire spread into the precinct given less likely bushfire attack direction, narrow hazard connectivity, fuel breaks and convoluted fire path. The vegetative hazard leading to bushfire incursion, is mostly grassland on moderate slopes, however with fuel impedances, the risk is reduced. On-precinct hazard is a mix of very narrow riparian zones, corridors and larger patches, but generally of a lower hazard type (i.e. woodland and forested wetland on gentle slopes with fuel discontinuities). BPMs, off-site evacuation and on-precinct refuge options should be able to be adequately provided for this precinct. **Conclusion/Recommendation:** Insignificant bushfire risk identified. Precinct planning should be able to provide an appropriate combination of BPMs in accordance with PBP.
Gilead (B)	3	2	6	Minor	Precinct already rezoned.
Gilead (C) and (D)	4	3	12	Moderate	Exposed to hazard to the east and west, the later considered a higher risk direction for bushfire attack in terms of likelihood and consequence. Vegetation hazard in adjoining areas is a mix of grassland, woodland and forest. In the west it is predominately grassland and woodland hazard, with forest vegetation generally restricted just to the Nepean River valley. The likelihood of fire spread to and penetration into the precinct is moderated by restricted bushfire prone vegetation (Figure 15), fuel discontinuity, increased visibility of ignitions (i.e. from Hume Motorway), and suppression opportunities. In addition, areas to the west of the Growth Area between the Nepean River and the Hume Motorway are identified as potential future employment lands (Figure 2), which if realised will limit the spread of fire into the precinct. In the east, the hazard is predominately forest with moderate slopes directly adjoining the precinct, however there is also grassland and fuel reduced / managed areas on private property adjoining, which mitigate the risk. There are narrow areas of hazard within riparian zones that protrude into the precinct, as well as other vegetation proposed for retention or rehabilitation. However, much of this hazard is narrow, convoluted, and/or disjointed, which partially mitigates the risk that it poses.

Precinct	Likelihood (A)	Consequence (B)	Risk Level (A x B)	Risk Rating	Notes
					BPMs should be able to be adequately provided for this precinct. However, there may be reduced off-site evacuation options in certain bushfire attack scenarios, due to the potential fire impact on evacuation routes, although it is unlikely that all routes would be cut at the same time. There are also potential restrictions to the provision of on-precinct refuge, particularly in the form of Open Space and within Precinct (C) and the west of Precinct (D). **Conclusion/Recommendation:** Moderate bushfire risk rating, based on exposure to both east and west fire attack, as well as from retained vegetation corridors within the Precinct and reduced off-site evacuation and on-site refuge options. However, the risk is not higher as it is unlikely that all off-site evacuation options would be cut at the same time. Further, there is on-precinct refuge capacity, albeit reduced for Open Space. Precinct planning should be able to provide an appropriate combination of BPMs in accordance with PBP. Evacuation route, timing and capacity needs to be planned carefully for these sub-precincts, along with on-site refuge capacity, for redundancy.
North Appin	4	4	16	Major	Exposed to hazard to the east and west, the later considered a higher risk direction for bushfire attack in terms of likelihood and consequence. Moderate amount of direct exposure to larger areas of bushfire hazard in the east and larger areas of retained vegetation along the northern and southern boundaries of this precinct. Narrow areas of hazard within riparian zones protrude into the precinct from the north and south in retained vegetation corridors, however some may conform to 'Low Hazard' in accord with PBP, which moderates the risk. Exposure to landscape fire risk is lessened by the nature of the connections and hazard within the study area, particularly to the higher risk direction of the west. To the west the hazard is predominately grassland and woodland, with forest vegetation generally restricted just to the Nepean River valley. The likelihood of fire spread to and penetration into the precinct is moderated by restricted bushfire prone vegetation (Figure 15), fuel discontinuity, increased visibility of ignitions (i.e. from Hume Motorway), and suppression opportunities. In addition, areas to the west of the Growth Area between the Nepean River and the Hume Motorway are identified as potential future employment lands (Figure 2), which if realised will significantly limit the spread of fire into the precinct and therefore reduce the risk exposure of the North Appin precinct. BPMs should be able to be adequately provided for this precinct. However, there may be reduced off-site evacuation options in some bushfire attack scenarios, due to the potential fire impact on off-site evacuation routes. Impact on all off-site evacuation routes is possible but is considered of low likelihood. There is good capacity for on-site refuge options to be provided.

Precinct	Likelihood (A)	Consequence (B)	Risk Level (A x B)	Risk Rating	Notes
					Conclusion/Recommendation: The bushfire risk is conservatively assessed as Major, based on exposure to hazard in both the east and west, protrusion of retained vegetation corridors and the potential for impact to off-site evacuation options. The likelihood of all off-site evacuation options being lost simultaneously is considered low, however this should be assessed in further detail at precinct planning stage. Precinct planning should be able to provide an appropriate combination of BPMs in accordance with PBP. However, evacuation route, timing and capacity needs to be planned very carefully for this precinct, along with on-site refuge capacity, for redundancy. Provision of on-site refuge capacity is strongly recommended.
Appin (A)	4	3	12	Moderate	Includes existing urban development to the east in the township of Appin. Exposed to hazard in the east, south and west, the later considered the higher risk direction for bushfire attack in terms of likelihood and consequence. Large fingers of hazard within retained vegetation corridors protrude into the precinct from the west. However, there is reduced bushfire risk context to the west, given limited forest vegetation, mostly grassland, in various states of management and with multiple significant fuel interruptions (e.g. Hume Motorway and other main roads), along with a lack of historical record of fire spread to the Growth Area reinforce the insignificant landscape risk from the west. In addition, areas to the west of the Growth Area between the Nepean River and the Hume Motorway are identified as potential future employment lands (Figure 2), which if realised will limit the spread of fire into the precinct. The vegetative hazard to the east is forest vegetation on moderate slopes (adjoining the precinct), however the precinct benefits from fire breaks provided by existing urban development (Appin) and Appin Road, which partially moderates the risk from the east, in combination with the expected reduced severity of bushfire weather conditions from this direction. BPMs and on-precinct refuge options should be able to be adequately provided for this precinct, however off-site evacuation may be restricted in fire attack from the west, although potential evacuation routes should be available both north along Appin Road, south along Wilton Road and east along Appin Road. **Conclusion/Recommendation:** Moderate bushfire risk is based on exposure to hazard in both the east and west, protrusion of retained vegetation corridors and reduced off-site evacuation options. The risk is moderated by multiple off-site evacuation options and on-site refuge capacity.

Precinct	Likelihood (A)	Consequence (B)	Risk Level (A x B)	Risk Rating	Notes
					Precinct planning should be able to provide an appropriate combination of BPMs in accordance with PBP. Evacuation route, timing and capacity needs to be planned carefully for these sub-precincts, along with on-site refuge capacity, for redundancy.
Appin (B)	4	3	12	Moderate	Exposed to hazard to the east, south and west, the later considered a higher risk direction for bushfire attack in terms of likelihood and consequence. The adjoining bushfire hazard is forest on steeper slopes but there are also large fingers of hazard within riparian zones that protrude into the precinct, which increases the risk. Potential landscape scale exposure is lessened to the west and south-west due to existing and proposed developed areas (Wilton, Douglas Park), which moderates the risk. Further, some of the internal hazards are very narrow and may conform to 'Low Hazard' in accord with PBP, which also moderates the risk. BPMs and on-precinct refuge options should be able to be adequately provided for this precinct, however off-site evacuation may be restricted in fire attack from the west, although potential evacuation routes should be available both north along Appin Road, south along Wilton Road and east along Appin Road. **Conclusion/Recommendation:** Moderate bushfire risk is based on exposure to hazard in both the east and west, protrusion of retained vegetation corridors and reduced off-site evacuation options. The risk is moderated by multiple off-site evacuation options and on-site refuge capacity. Precinct planning should be able to provide an appropriate combination of BPMs in accordance with PBP. Evacuation route, timing and capacity needs to be planned carefully for these sub-precincts, along with on-site refuge capacity, for redundancy.

3.2 Evaluation against PBP Strategic Bushfire Planning Principles

This section evaluates the Indicative Land Use Plan for the Greater Macarthur Growth Area, against the bushfire strategic planning requirements of PBP (detailed in Section 1.5.1) based upon the assessment findings in the preceding sections of this Study, to determine whether:

- the Plan poses an unacceptable risk or will provide for inappropriate development;
- the Plan can adequately respond to the bushfire threat, appropriate to the current stage of planning; and
- adequate bushfire protection measures can be provided to reduce the residual risk to an appropriate level.

The evaluation is based upon PBP Chapter 4 and the Assessment Framework of this Study (Section 1.5) and is summarised in Table 9. In addition to evaluating the Proposal against these matters, the evaluation specifically considers:

- Residual risk - the level of residual risk after the application of bushfire protection measures is a key determinant in the strategic assessment of whether proposed development is appropriate;
- Risk to life - an appropriately low residual risk to human life is fundamental;
- Risk to property – the residual risk to property should meet the Acceptable Solutions within PBP;
- Emergency service response - the acceptability of proposed development should not be reliant on emergency service response / intervention;
- Adjoining lands – the proposed development should not be reliant on fuel management on adjoining lands or effect those landowners ability to undertake such works.

Table 9: Evaluation of the Land Use Plan against the Strategic Planning Principles of PBP (RFS 2019)

PBP Strategic Planning Principle	Evaluation
Ensuring land is suitable for development in the context of bush fire risk	The risk profile of the broader 5 km Study Area is not uniform. Key findings include: • The bushfire risk in areas immediately adjoining the Subject Land is moderated by: o The 'sheltering' of the Growth Area from wildfires by existing development in the northwest through to the northeast, along with the increasing 'sheltering' provided by development proposed and occurring in the Wilton Growth Area, Douglas Park and Menangle areas, in addition to potential development of employment lands directly west of the Growth Area that are subject to investigation. o Lesser hazard types in adjoining areas, such woodland, grassland and managed lands, on mostly flatter terrain or on upslopes, and getting less with development and land management activities, particularly to the northwest to southwest of the Growth Area. o Discontinuity of fuel and significant impedances to fire spread to the Growth Area, such as the Hume Motorway, other infrastructure, development and large expanses of grazed/agricultural land, much of which is not mapped as bushfire prone. o Lack of historical precedence of fire spread to the Growth Area indicating significantly reduced likelihood, with: ▪ No fires recorded as starting in the west having spread to the Growth Area and there has been a general lack of large fires starting to the west and spreading, thus indicating a minimal low likelihood landscape bushfire exposure to the west; ▪ Fires to the east and southeast of the Growth Area have been much larger, but predominately spread in an easterly direction away from Growth Area towards the coast. o Bushfire weather analysis indicating that the primary risk direction is from the west, with significantly reduced risk from the south and east (i.e. lower max FFDI expected, far below the PBP benchmark for protection planning). o Bushfire spread and bushfire intensity modelling not indicating a significant risk to the Growth Area at a level beyond which the bushfire protection measures within PBP are founded. • There are areas of elevated bushfire risk beyond the Growth Area, but these are separated and are generally associated with: o Wooded vegetation (i.e. forest); o Complex terrain including steep slopes containing bushfire prone vegetation (e.g. to the east and southeast of the Subject Land); o Connectivity to a larger fire catchment (e.g. to the east and southeast of the Subject Land); and o Exposure to the most problematic directions of bushfire attack (i.e. from the north to the southwest sector (Section 2.2)). • The bushfire hazards within the Subject Land are generally: o Convoluted, moderating the length of potential head fire spread in many areas; o Narrow in areas, limiting the potential bushfire development, severity and extent of attack; o Have limited connectivity to external bushfire hazards, reducing the likelihood of an external bushfire spreading to and penetrating into the Growth Area; In addition, the following also applies in some cases: o Low hazard vegetation (i.e. very narrow areas set aside for riparian vegetation); o Vegetation that meets the "low threat" prescriptions of PBP and can therefore be excluded as per PBP; or

PBP Strategic Planning Principle	Evaluation
	o Lower threat hazard (i.e. upslope) that can be easily mitigated through the provision of APZs. This Study has identified that the proposed land uses are suitable in accordance with PBP, in light of the bushfire risk context and that none of the 'inappropriate development exclusions' specified in PBP are triggered, however the level of risk varies by precinct based on: • The proximity, type and quantity of external bushfire risk along with the characteristics of the internal bushfire hazards; • The size, shape and location of the precincts along with road connections, which influence the capacity to provide BPMs that meet or exceed the Acceptable Solutions of PBP, as well as the proportion of future development that will require BPMs (i.e. the 'Focus Area'). • The evacuation and emergency management risk: o Precincts in the north generally have a much lower evacuation risk, being better connected to existing development; o Gilead (C) and (D), North Appin, and Appin (A) and (B) have an increased evacuation risk that will require considered planning; o However, all precincts have multiple options for off-site evacuation, on-site refuge, and in-situ sheltering capacity.
Ensuring new development on BFPL will comply with PBP	The Land Use Plan proposes land uses of a type, size and location that can comply with PBP and this can be effectively managed in future development designs, at subsequent stages in the planning and development assessment process.
Minimising reliance on performance-based solutions	The compliance of the indicative Land Use Plan to PBP requirements, does not rely on performance-based solutions, thus reliance on performance approaches can be minimised in detailed development designs.
Providing adequate infrastructure associated with emergency evacuation and firefighting operations	There are multiple egress points from the Growth Area to the existing public road network, providing for off-site evacuation. It is unlikely that all off-site evacuation routes would be cut by fire at one time, given the location and number of potential off-site evacuation routes. However, in addition, on-site refuge options are feasible and would offer useful redundancy to reduce the level of evacuation risk. Infrastructure for firefighting operations will include the road network, including perimeter roads and water supply, to comply with PBP requirements. A number of Rural Fire Service as well as Fire and Rescue NSW Brigades are located within proximity to the Growth Area, however further consultation is recommended to identify any additional infrastructure requirements.
Facilitating appropriate ongoing land management practices	The Land Use Plan does not restrict appropriate ongoing land management practices, nor is it reliant on bushfire management of adjoining lands to support its bushfire protection.

4. Conclusions and Recommendations

This report presents an evaluation of the development proposed for the precincts of the Greater Macarthur Growth Area as contemplated by the Indicative Land Use Plan. The evaluation is discussed in light of the bushfire risk context for each precinct and against the strategic planning principals of PBP. The findings should be used to inform future planning and development control within the Greater Macarthur Growth Area and the individual precincts.

Conclusions and recommendations of the study include:

- The Greater Macarthur Growth Area has not had an extensive history of wildfire, yet there are bushfire hazards surrounding and incurring into the Growth Area at a number of locations and thus there is potential for bushfire attack on future development.
- In a relative and wholistic sense, compared to some areas of existing development in other locations in NSW, the Greater Macarthur Growth Area is not considered to have a significantly high bushfire risk context and not at a level beyond which the bushfire protection measures within PBP are founded. Despite this, future development must be carefully planned.
- Bushfire protection measures that meet the requirements of PBP will need to be afforded to future development within the subject precincts, and there is amble capacity within the precincts to achieve this. In addition, due to the size of the precincts, there is a significant proportion of the land outside the 'Bushfire Planning Focus Area' where bushfire protection measures are not formally prescribed by PBP (i.e. greater than 100 m from the hazard), indicating extensive areas of lower risk within the precincts.
- Off-site evacuation is a threshold issue and will need to be carefully evaluated for each precinct once further information comes to hand during precinct planning. In addition, on-site community refuges are encouraged for precinct designs, as an additional bushfire protection 'redundancy'.
- The results of the study are informative and need to be considered in light of the emergency management options available to current and future occupants of the area, as well as the level of protection that will be afforded to them, through the incorporation of bushfire protection measures as per the requirements of PBP and building constructions standards.
- The results of the bushfire spread models demonstrate potential bushfire spread to the Greater Macarthur Growth Area and surrounds as well as penetration into the retained lands. The 'Arrival Time' presented in the models should be used conservatively, and it should be noted that the model do not provide a defined estimate of the required time to safely refuge or evacuate from bushfire attack.
- Precincts with elevated (but not significantly high) bushfire risk exposure include Gilead (C) and (D), North Appin and Appin (A) and (B). This finding is primarily in relation to the potential for reduced off-site evacuation capacity, due to the potential fire impact on evacuation routes (albeit lower likelihood). As such, evacuation route, timing and capacity needs to be planned carefully for these precincts, along with on-site refuge capacity, for redundancy. Evacuation assessment should be undertaken for each precinct in light of the bushfire spread modelling undertaken herein, and assuming that some evacuation options may become unavailable in some bushfire attack scenarios. However, all precincts have multiple options for off-site evacuation, on-site refuge, and in-situ sheltering capacity.

- Planning and development control should be carefully considered, for future development of these precincts with elevated risk, and others where the provision of adequate bushfire protection measures, on-precinct refuge and off-site evacuation may be restricted.
- The application of bushfire protection measures is a requirement for all development proposed on bushfire prone land. The staging of development also warrants special consideration, especially if infrastructure or bushfire hazard removal is planned or contingent on later stages. Appropriate protection should be afforded each individual development stage. Further, the planning of infrastructure for a precinct needs to consider any dependencies that other precincts may have on the infrastructure within the subject precinct, as well as the staging of that infrastructure, to ensure adequate capacity for all reliant precincts and appropriate timing.
- There are a number of "known unknowns" given the level of information available at the current stage of planning. This includes but is not limited to the nature and location of retained or rehabilitated vegetation within Koala corridors, other areas for biodiversity conservation, and riparian protection areas; as well as vegetation that will need to be managed so as to not present a hazard, such as within open space, landscaping and for urban heat / tree canopy targets. However, the assumptions made within this study are made on the best currently available information and are considered to facilitate fit for purpose outcomes of the study for this stage in the planning process (i.e. regional plan).

These findings conclude that the level of residual risk after inclusion of the bushfire protection measures typically applied under PBP, is appropriate and the development contemplated by Indicative Land Use Plan can meet the PBP strategic planning principles and requirements. Specifically, that the aims and objectives, acceptable solutions and performance requirements of PBP pertaining to risk to life and risk to property can be met or exceeded. Further, there is not a reliance on emergency service response / intervention, nor a reliance on fuel management on adjoining lands to provide the level of bushfire protection and residual risk.

It is lastly recommended that this report is shared with the Technical Assurance Panel and the precinct proponents in order to inform and guide precinct scale investigations, design work and strategic decision making. Planning proposals for individual precincts or sub-precincts will need to be supported by their own Strategic Bushfire Study that evaluates the suitability of precinct plans against the strategic planning requirements of PBP. These studies can be informed by this study, however they will require more detailed assessment as well as be supported by third-party studies pertaining to the adequacy of evacuation capacity; any plans for on-site refuge; provision of infrastructure, resources or funding for emergency services; the supply of services, particularly water supply that meets the requirements of PBP and gas and electricity that minimise life safety issues; and technical studies or plans that relate to the nature of any open space, so that future hazards within the precinct can be fully comprehended.

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Appendix A – Bushfire Hazard Assessment

A landscape bushfire hazard assessment was undertaken for the Growth Area within a 5 km radius. The bushfire hazard assessment has utilised the most recent vegetation community mapping, refined via desktop assessment where relevant. Slope was determined using 2 m contour data from Land and Property Information.

A1 Vegetation

Vegetation types present across the study area have been compiled from best available vegetation mapping, then classified into Keith Formations and Keith Class (Keith 2004) and then assigned a potential total fuel load (tonnes / hectare) using the RFS Comprehensive Vegetation Fuel Loads Guide (RFS 2019b). This classification is presented in Figure 16 noting that extant vegetation in areas earmarked in the Land Use Plan for development were removed and conversely, areas marked as environmental conservation or high constraint were retained / added. That is, the assessment is of the post-development scenario. This includes best available information on areas being considered for Koala corridors, biodiversity conservation and riparian protection. Other vegetation that may be retained or established within the precincts is assumed can be managed to APZ specification (which is generally the case) including street trees, landscaping, open space and tree canopy for urban heat mitigation.

The vegetation dataset generated is a compilation from the following base vegetation mapping projects:

- Cumberland Plain (OEH 2013)
- Sydney Metropolitan Area (OEH 2013b)
- Wollondilly Council (ELA 2010)
- Western Sydney (NPWS 2002)

The allocation of formations, classes and assignment of fuel load is as per Table 10 noting that all vegetation mapped as ‘grassland’ and other locations in currently un-developed rural areas were conservatively allocated a ‘grassland’ fuel load, even though the land use / management practice in some of these areas would be such that they shouldn’t be considered bushfire prone, and many aren’t currently mapped as such (Figure 15).

Table 10: Vegetation Formation, Class and Fuel Allocation for the Study Area

Keith Formation	Keith Class	Overall Fuel (t/ha)*
Rainforest	Dry Rainforests	13.2
	Subtropical Rainforests	
Wet Sclerophyll Forests (Grassy)	Northern Hinterland Wet Sclerophyll Forests	33.1
Wet Sclerophyll Forests (Shrubby)	North Coast Wet Sclerophyll Forests	35.98
Dry Sclerophyll Forests (Shrub/Grass)	Central Gorge Dry Sclerophyll Forests	25.8
	Cumberland Dry Sclerophyll Forests	24.97
Dry Sclerophyll Forests (Shrubby)	Sydney Coastal Dry Sclerophyll Forests	27.3
	Sydney Hinterland Dry Sclerophyll Forests	27.42
	Sydney Montane Dry Sclerophyll Forests	27.47
	Sydney Sand Flats Dry Sclerophyll Forests	29.5

Keith Formation	Keith Class	Overall Fuel (t/ha)*
Woodlands	Coastal Valley Grassy Woodlands	18.07
Forested Wetlands	Eastern Riverine Forests	15.1
	Coastal Swamp Forests	34.1
Heathlands (Tall Heath)	Sydney Coastal Heaths	36.9
Freshwater Wetlands	Coastal Heath Swamps	15.0
	Coastal Freshwater Lagoons	4.4
Grasslands	Grasslands	6.0

*Overall fuel as per Bark and Canopy field (RFS 2019b).

A2 Slope

Slope has been classified from a 10 m grid cell Digital Elevation Model (DEM) into the following slope classes (as per PBP):

- Upslope and flat;
- >0° – 5° downslope;
- >5° – 10° downslope;
- >10° – 15° downslope;
- >15° – 20° downslope;
- >20° downslope.

The slope across the landscape is shown in Figure 17 and provides an overview of the terrain within the study area.

Appendix B – Bushfire Weather Analysis

A bushfire weather analysis was undertaken by ELA (2019) in order to identify the likely bushfire weather conditions that the site could experience from the main bushfire attack sectors.

Weather data developed by Lucas (2010) under the National Historical Fire Weather Dataset (1972-2015) incorporates the daily Forest Fire Danger Index (FFDI), where suitable inputs are available, from over 70 weather stations across Australia. Data from the Sydney Airport and Richmond weather stations (station numbers 66037 and 67033/67105 respectively) was analysed to determine the maximum FFDI for a 1 in 50-year event, which is the accepted recurrence period for land use planning in PBP (RFS 2019).

The dataset for each weather station was split into subsets based on identified directions of potential bushfire attack, including:

- South-west to North (clockwise);
- South-east to South-west (clockwise);
- North to south-east (clockwise); and
- A combination of all directions.

To determine the 1:50 year recurrence value, a Generalised Extreme Value (GEV) analysis method was undertaken to calculate the FFDI value within each data subset (Table 11). Although the GEV model has been used in other disciplines for analysing extreme events (i.e. flooding recurrence values), it is only in recent times to have been considered appropriate for bushfire weather analysis (Douglas 2017). The GEV methodology and its use to analyse bushfire weather data is discussed in a number of papers by Douglas et al (2014; 2016). Further, recent research by Douglas and He (2019) indicates that the values used in this study represent a reasonable estimate of potential future fire weather conditions under near term climate change.

Table 11: FFDI for a 1 in 50-year event

Weather Station	Max FFDI	Recorded	All directions	N to SE	SE to SW	SW to N
Sydney Airport	116		116	63	47	116
Richmond Airport	96		105	52	45	105

The FFDI values for Sydney Airport are worse (higher) than those for Richmond Airport, so the former was considered more appropriate for consideration as ‘worst case’, and thus used in this study. More recent data up to June 2020 was also analysed and yielded similar, but slightly lower results. As such the higher values of the 2019 analysis were adopted in this Study for conservatism.

Appendix C – Bushfire Spread Modelling

Bushfire spread modelling was undertaken to further inform the bushfire risk context of the Greater Macarthur Growth Area. The models were generated utilising the SPARK Wildfire Simulation Toolkit (CSIRO 2018, Miller *et al*. 2015). The SPARK Wildfire Simulation Toolkit (SPARK) allows for bushfire simulations to be run with a high level of configurability. The SPARK software is designed to incorporate a multitude of user inputs, current fire behaviour propagation models and state-of-the-art simulation science. This allows modelling of fire spread across the landscape using specific location and environmental conditions displayed in 2D and 3D.

The primary input into SPARK is the Rate of Spread (RoS) formula that drives the resultant fire spread prediction based on the differing inputs i.e. vegetation types and topography. The latest guide on Rate of Spread modelling for Australian vegetation is A Guide to Rate of Fire Spread Models for Australian Vegetation (Cruz et al. 2015). Different models were used in this study dependent on differing vegetation types, as following:

- Grassland and Grassy Woodlands - formula by Cheney et al. 1998 in Cruz et al. 2015;
- Heath & Temperate Shrublands - formula by Anderson et al. 2015 in Cruz et al. 2015; and
- Eucalypt Forests - formula from Project Vesta and Cheney et al. 2012 in Cruz et al. 2015.

The other modelling inputs utilised for this study included the:

- Bushfire hazard data collated, namely the vegetation type, fuel load and topography (Section 2.1 and Appendix A)
- Bushfire weather scenarios identified (Section 2.2 and Appendix B), namely:
  - Scenario 1 - WNW wind with FFDI of 116;
  - Scenario 2 - SW wind with FFDI of 47; and
  - Scenario 3 - NE wind with FFDI 63.
- Weather parameters that were identified from the detailed weather analysis undertaken on the long term weather records (Section 2.2 and Appendix B) and summarised in Table 12
- Eleven ignition points manually allocated around the perimeter of the 5km Study Area buffer, in locations that could allow for demonstration of bushfire spread towards the Growth Area, for the different weather scenarios modelled
- A 4 hour burn duration
- All other configurations left at SPARK default settings.

Table 12: SPARK Weather Inputs

Input	FFDI 116 (SW to N)	FFDI 63 (N to SE)	FFDI 47 (SE to SW)
Wind direction (°)	292.5	45	225
Wind variation (+/- °)	10	10	10
Wind speed (km/hr)	59.4	35.3	40.7
Temperature (°C)	39.2	42.5	29.7
Relative humidity (%)	9	13	10
Drought factor	8.5	8.3	8.2

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