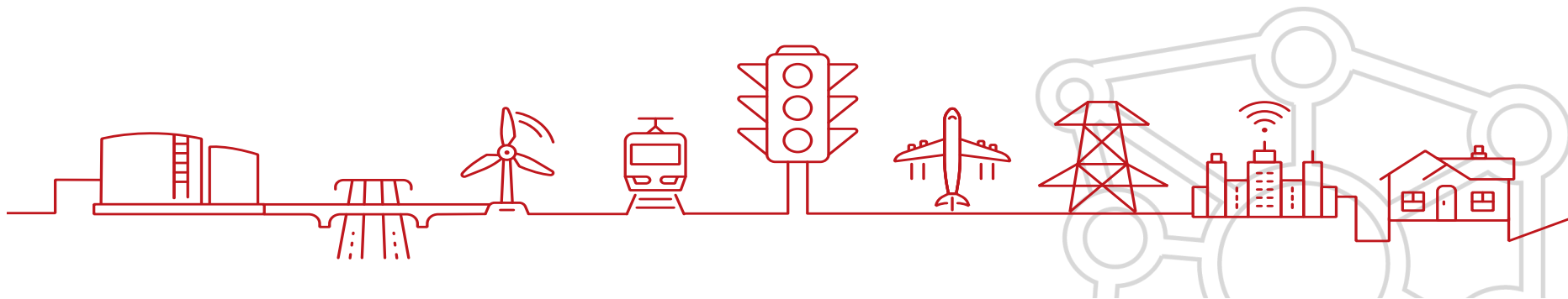


# Climate risk assessment: Western Sydney Aerotropolis Growth Area





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# Glossary

## Key indicators

The following indicators are used for quantifying the extreme weather and climate change impacts to the built environment in each specific area:

1. Technical Insurance Premium (TIP, \$), which is the annual cost of damage in dollars and assumes all hazards are insured.
2. Percentage of Value-at-Risk (VAR%), which is the TIP as a percentage of the replacement cost of the asset.
3. Failure Probability (FP%): Annual probability that an asset will stop working with or without damage.

## Archetype

An archetype is a synthetic representation of an asset that is based on nominal industry standard building codes and designs.

This XDI Land Use Planning Report uses two archetypes for the analysis; (1) council building and, (2) flexible pavement. The council building represents a standard complex building, meaning it has multiple components e.g. electrical and mechanical. The flexible pavement represents a non-complex road, meaning it only has basic civil construction.

Further detail is in appendix 2.

## Extreme weather

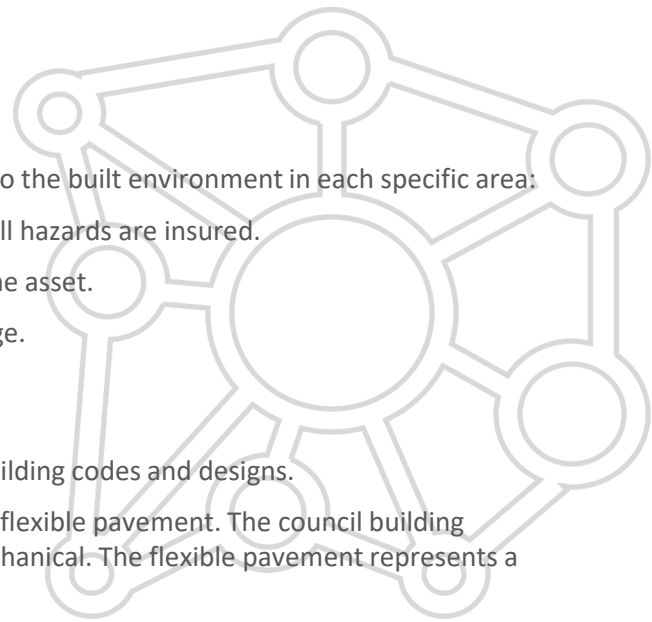
An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations.

## Inundation

Inundation is from seawater flooding due to high tides, wind and waves that can damage land and property. Its likelihood is increased due to higher sea levels. It causes damage to materials in a building, and causes damage to road sub-base.

## Soil movement

These are sinking, swelling or contracting soils that can result in cracking and shifting foundations, walls and roads during drought.



## **Flood**

Riverine or other inland fresh water flooding can damage buildings. Increased frequency of extreme rainfall may increase frequency of floods. It causes damage to materials in a building, and causes damage to road sub-base.

## **Wind**

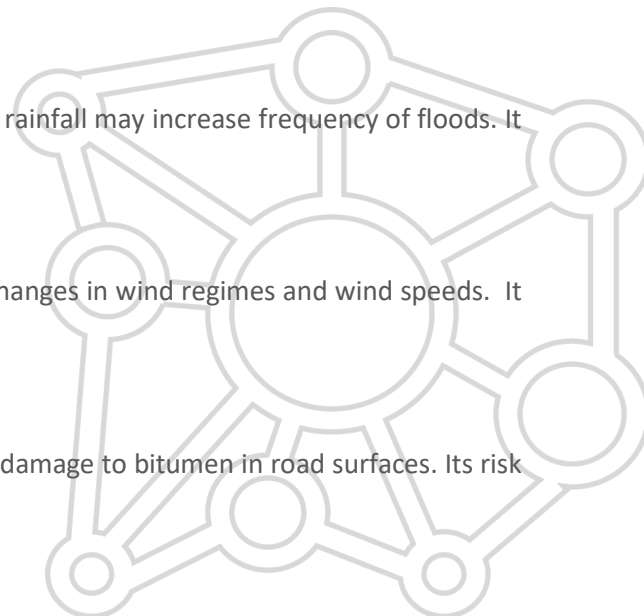
Extreme windstorms can damage structures and facilitate water damage. Wind has altered due to changes in wind regimes and wind speeds. It causes damage to roofs, but no damage to roads.

## **Forest fire (or bushfire)**

Burning vegetation can damage or destroy buildings through direct flame or intense heat and cause damage to bitumen in road surfaces. Its risk is increased due to increased vegetation growth, increased temperatures, increased dryness.

## **Heatwave**

Electrical and mechanical components can fail or send spurious signals when their temperate design is exceeded during extreme heat events.



# Executive summary

## Objectives

The purpose of the project is to establish whether extreme weather events and climate change present risks to urban development within the boundary of the Place-based Infrastructure Compact for the Western Sydney Aerotropolis Growth Area (WSAGA).

Where risks are identified, the project sought to:

- understand what hazards pose a material risk;
- specify the locations at risk; and
- quantify the scale of the problem both today and in the future.

## Methodology

The WSAGA was divided into a map of 'risk tiles', each of which was analysed using the Climate Risk Engines software to quantify risks from 2020 to 2100. Each tile presents an output of generalised risk for the area that it represents. Each tile covers approximately 500m<sup>2</sup> and approximately 25 asset points are placed in each tile.

The analysis takes established datasets on riverine flooding, forest cover, soils and topology and combines these with meteorological datasets from the Bureau of Meteorology (BoM), forward-looking climate change models from UNSW (NARClIM) and engineering design specifications to calculate the risk of damage and disruptive failure. For each hazard, the outcome of the analysis is then presented for each risk tile to show the areas of highest concern in WSAGA.

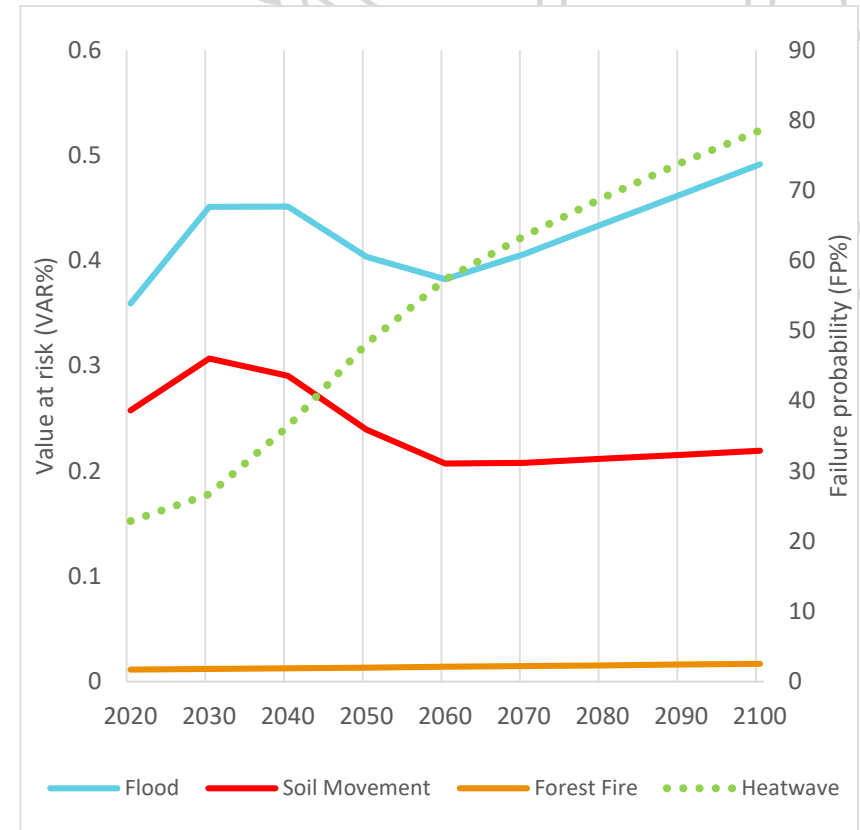


FIGURE 1 Value at risk percentage (VAR%) and Failure probability (FP%) over time for all hazards for buildings

## Risks will increase due to climate change

The analysis found that the risks from climate change and extreme weather increase by approximately 20% over time to 2100. Key findings include:

- Climate change increases the risk of flooding in WSAGA by approximately 40% over time to 2100. The area classified as acute risk increases from 0 hectares to 773 hectares in 2100.
- Heat is the most widespread hazard across WSAGA and climate change increases the probability of disruptive heatwave events by 245%. These events could disrupt critical infrastructure, make buildings uncomfortable or place people at significant risk of heat stress.
- The annual cost of damage (as a percentage of the replacement cost) for soil movement may increase by 20% in the short term and decrease towards 2100.
- The annual cost of damage from forest fire is projected to increase by 50% at end of the century due to climate change.

Flood, forest fire, heatwave and soil movement damage and disruptive failure risks are projected to increase under at least one of the NARClIM downscaled scenarios, though soil movement may also decrease for a period. The data on wind related risks are less conclusive as trends towards reduction in mean wind speeds may be outweighed by small storm cell behaviour, which is not yet modelled by UNSW.

## Adaptation measures are effective

The project also considered how adaptations can change the risk to infrastructure. The analysis shows that readily available adaptation measures can be highly effective in bringing risks down to, or even below, current levels. The analysis shows that even a modest adjustment to electronic, electrical and mechanical systems in buildings and infrastructure to withstand an additional 3°C would be sufficient to offset the climate change impacts. Urban cooling techniques, including green infrastructure, can significantly reduce ambient temperatures.

The adaptation analysis also shows that modifying the elevation of buildings at or above 0.5m would effectively reduce the impact of flooding in high risk areas.

Although sensitivity testing was not undertaken through this assessment, a similar reduction in risk is also expected for the use of high-strength rigid foundations to address soil movement, while appropriate design and materials combined with adequate local fire-fighting capability would also have strong benefits in reducing the effects of forest fire.

Adaptations to buildings and infrastructure, including those identified above, can increase resilience to extreme weather and climate change.

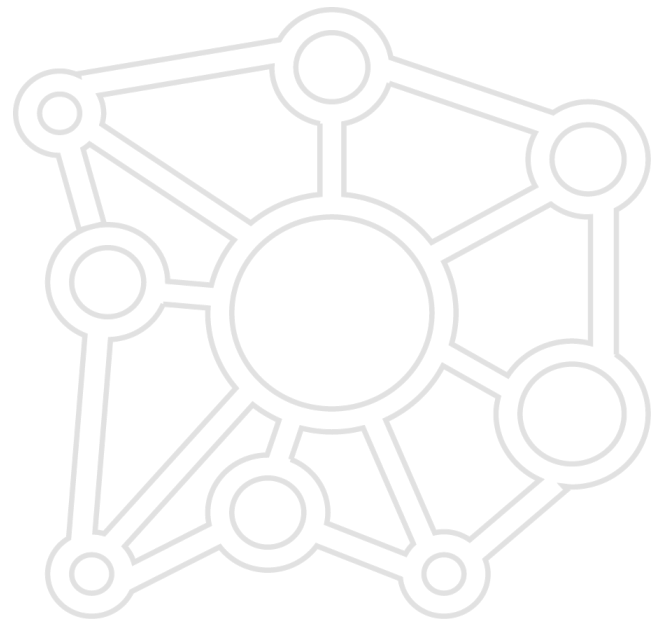
## Conclusions

Key conclusions include:

1. Consider location-specific weather and climate change risks at the planning stage.
2. Specify performance thresholds that ensure a high resilience for critical infrastructure.
3. Apply performance-based planning requirements to ensure safe and insurable buildings and infrastructure.
4. Avoid locating essential and community infrastructure in areas that may become inaccessible or at high risk from flooding or forest fire.
5. Ensure building code and planning requirements consider soil and forest fire standards.
6. Map the cross-dependent risks between planned development and critical infrastructure to understand risks across sectors.

The conclusions are further detailed in the body of the report that follows.





# Project introduction and methodology



# Introduction

The Place-based Infrastructure Compact (PIC) is a new collaborative model that looks holistically at a place to identify the most cost-effective sequencing for growth in jobs and homes by providing infrastructure and services in the right place and at the right time. By better aligning growth with infrastructure and services, governments can deliver quality outcomes for people and the environment.

The PIC model brings together government agencies, local councils and utility providers to consider holistically what infrastructure and services are needed to create places where people can live, work, play and do business. As a commitment of the Western Sydney City Deal, two PICs are being undertaken concurrently in the Western Parkland City: PIC #1 – Western Sydney Aerotropolis Growth Area (WSAGA); and PIC #2 – Greater Penrith to Eastern Creek (GPEC).

**This report considered the current and future exposure and vulnerability** of infrastructure to extreme weather hazards and climate change within WSAGA. The early identification of these hazards can help to understand and mitigate risk, and inform infrastructure decisions. The objective of the climate risk assessment is to:

- establish areas within the study where assets are at potential risk from extreme weather events and a changing climate;
- expose the hazards that are contributing to damage and failure risk within the area, along with where and what assets types are vulnerable (e.g. complex versus non-complex assets);
- establish whether planning guidelines could be effective in reducing the identified extreme weather and climate change related risks.

The XDI Land Use Planning approach identifies areas of high risk from extreme weather, based on a standard grid of assets, this does not include specific, or individual assets, current or future planning zones or infrastructure types.

Adaptation and stress testing is essential to future planning. Different adaptation approaches are used to assist in minimising risk to assets from climate change exacerbated, extreme weather events such as flooding. If adaptation is overlooked in the design and planning process through measures such as planning guidelines or building standards, the demand and costs associated with infrastructure repair and rehabilitation will increase.

# WSAGA Area

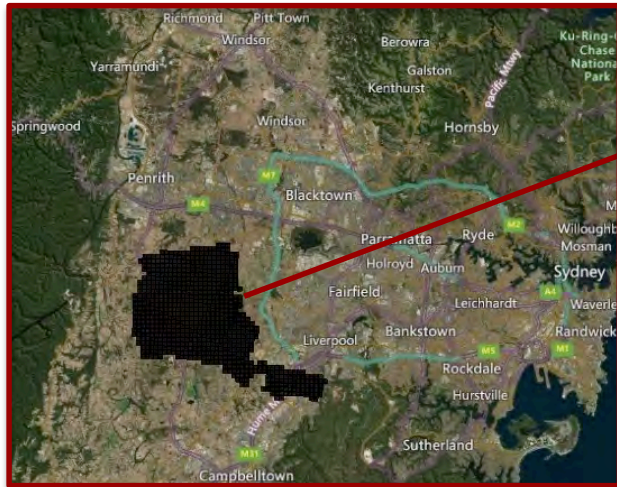


Figure 2 Western Sydney Aerotropolis Growth Area

# Methodology

Climate Risk Pty Ltd undertook an analysis using Climate Risk Engines software for WSAGA. The assessment used a gridded analysis of a large number of artificial structures (building and road archetypes) placed throughout the study area. The assessment seeks to quantify risks between 2020 and 2100.

WSAGA was divided into a map of 'risk tiles', each of which presents an output of quantified risk for the area that it represents, which for WSAGA, is approximately 500m<sup>2</sup> per tile with approximately 25 artificial structures in each tile.

The analysis takes established datasets on riverine flooding, forest cover, soils and topology and combines these with meteorological datasets from the Bureau of Meteorology (BoM), forward-looking climate change models from UNSW (NARClIM), and engineering design specifications to calculate the risk of damage and disruptive failure. For each hazard, the outcome of our analysis is then presented for each risk tile to show the areas of highest concern. Climate Risk then undertook sensitivity testing to understand how the adaptation of infrastructure assets would reduce the risk of damage or failure. This testing included:

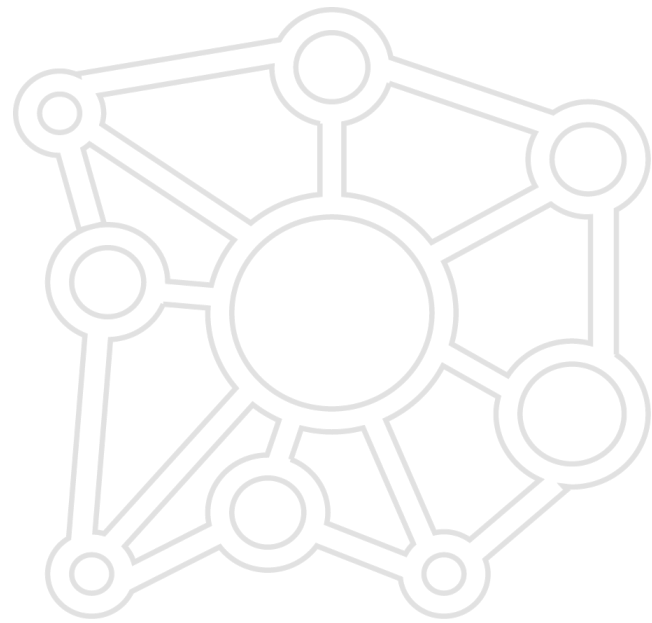
- increasing the performance threshold for the hypothetical infrastructure assets to withstand heat from 42°C to 45°C;
- raising the floor height of the infrastructure from 0 to 0.5 metres to better withstand flooding; and
- raising the elevation of hypothetical road infrastructure from 0 metres to 0.5 metres to better withstand flooding.

Using the VAR%, risk tiles were classified into areas of acute risk (greater than 5%), high risk (1 - 5%), moderate risk (0.2 – 1%) and low risk (less than 0.2%).

## Assumptions and limitations

There are several limitations of the analysis, including:

- XDI Land Use Planning approach does not look at the current or planned assets but analyses the same generic asset at gridded intervals. This creates a standard set of data for comparison of adaptation options which may be interpreted as changes to design guides, building codes, planning levels etc.
- The projects scope was limited to two asset types, buildings and roads, and included two adaptations.
- Flood data from PIC area Councils and the Department of Planning, Industry and Environment was used for the study. There may be some gaps in the data which may cause inaccurate results.
- Climate data sources, both CORDEX and NARClIM, are not at a resolution for extreme storms such as East Coast Lows.
- The assessment only considers the hazards specified. It does not include fluvial (surface) flooding, erosion, landslip, small scale wind-storms or co-incident events.



# Results

Risks to buildings

# Risk to buildings – all hazards

The value at risk metric (VAR%) can be used to represent the level of risk that will be experienced by any buildings located in each risk tile across each time period. The building archetype, which includes electrical and mechanical components, can be used as a proxy for different types of infrastructure, including stations, utility assets or other buildings.

The total average VAR% from all hazards in 2020 is 0.63% and increases to 0.73% in 2100, a 15.8% increase. VAR% from flood contributes the most to the overall risk, in 2020 contributing 1.5 times more than soil movement and more than 33 times forest fire.

Figure 3 shows riverine flooding, soil movement and forest fire projected average VAR% per year for non-adapted buildings within the study. The figure also shows the projected average failure probability (FP%) for heatwave across all commercial buildings within the study. A continual increase in FP% from 23% in 2020 to 79% in 2100 is shown.

Figures 4, 5 and 6 show the category of risk in WSAGA over time and Table 1 shows the amount of land in each risk category over time.

Table 1 Hectares in each risk category over time – all hazards

Hectares in each risk category			
Risk level	2020	2050	2100
Acute	0	29	818
High	1980	1951	1013
Moderate	13418	12390	7551
Low	133	1161	6149

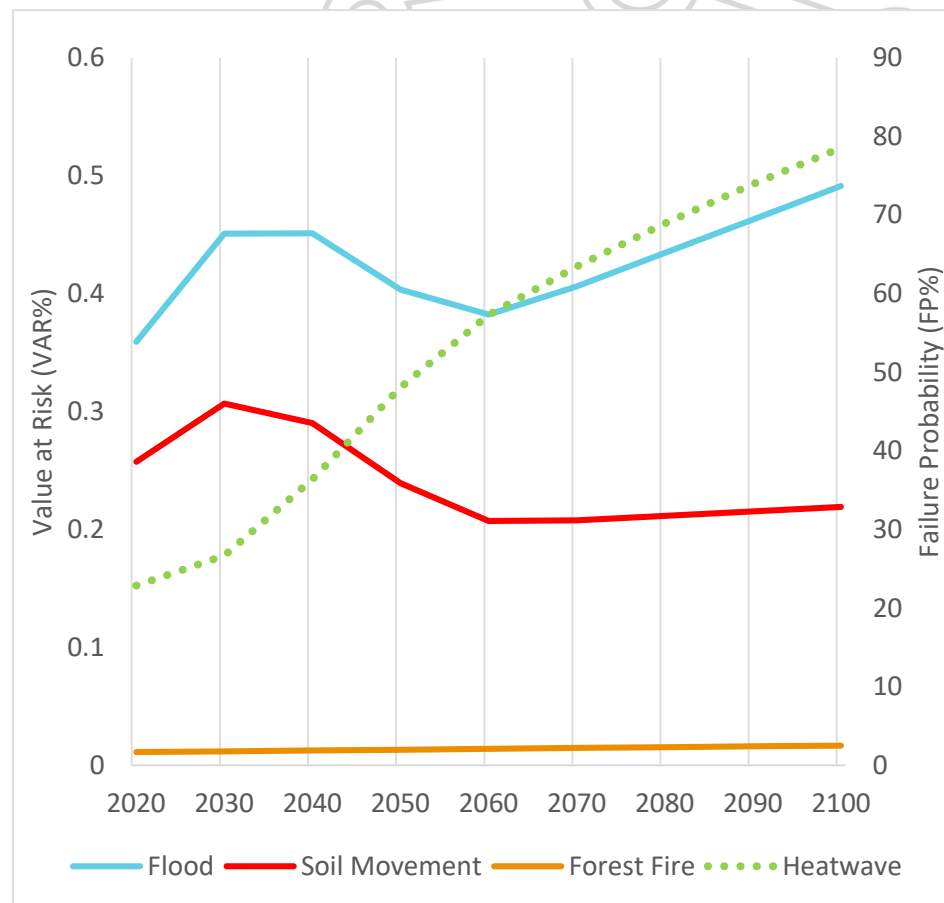


Figure 3 Average VAR% & FP% over time for all hazards for buildings



Figure 4 - 2020

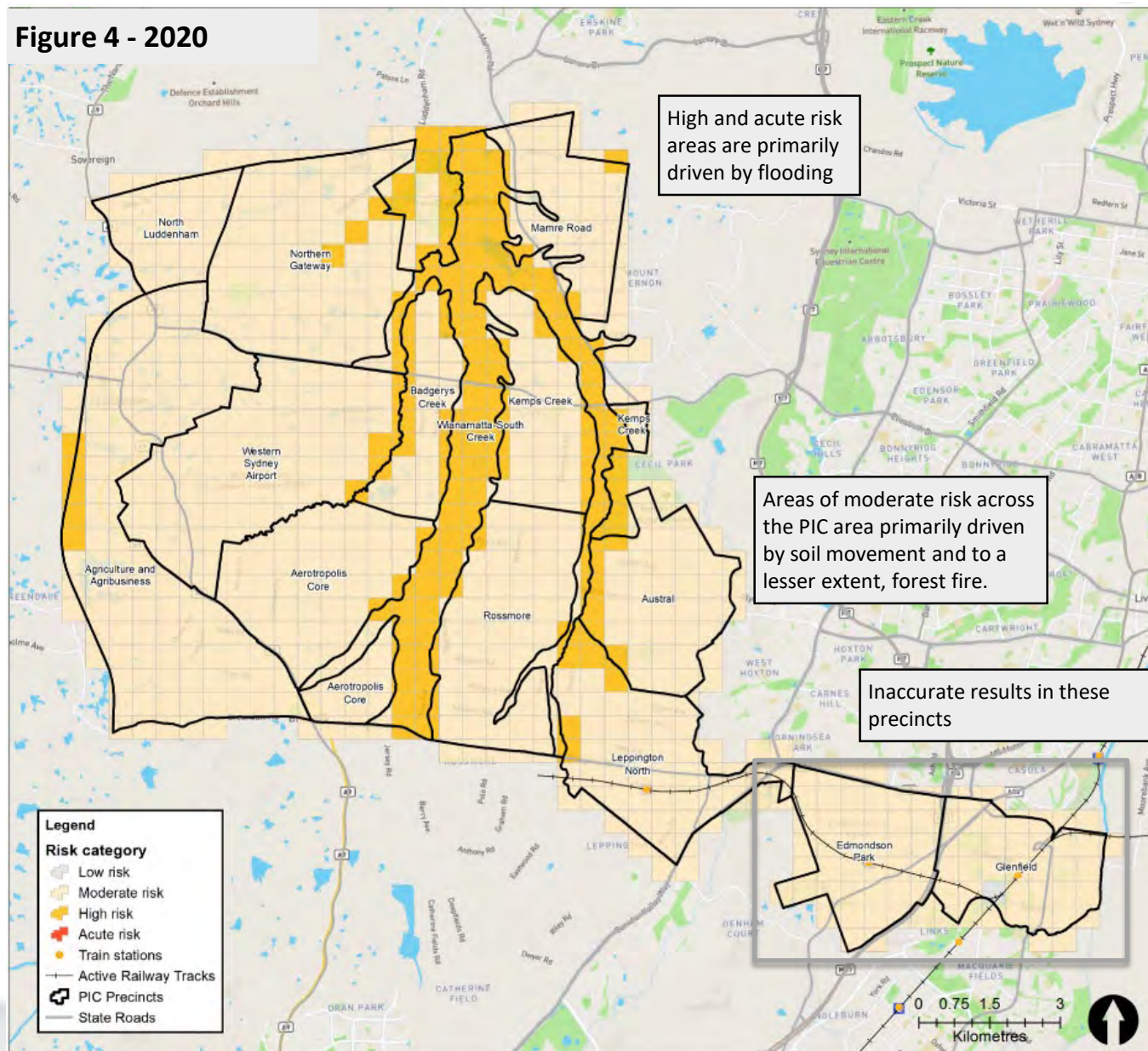


Figure 5 - 2050

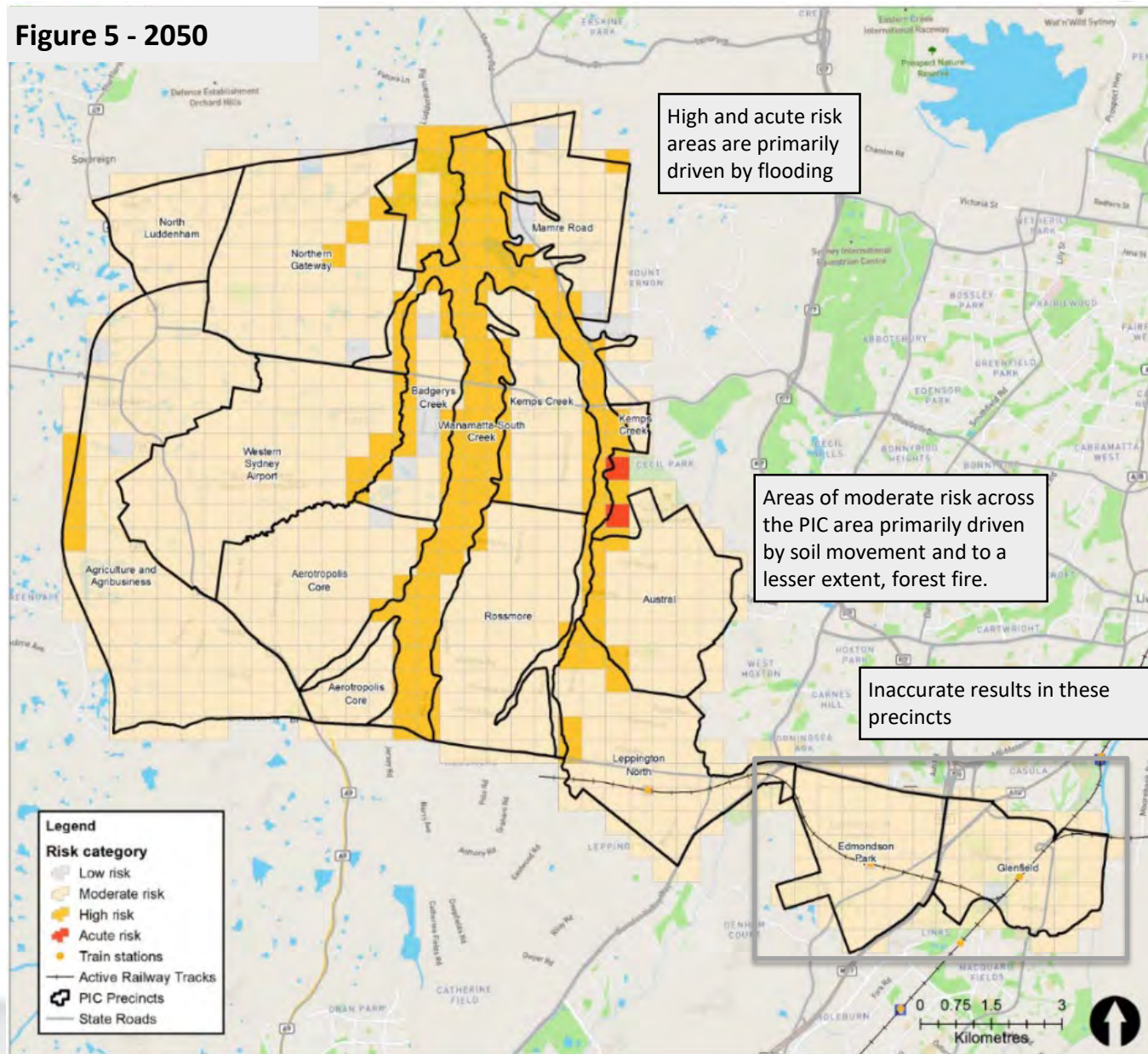
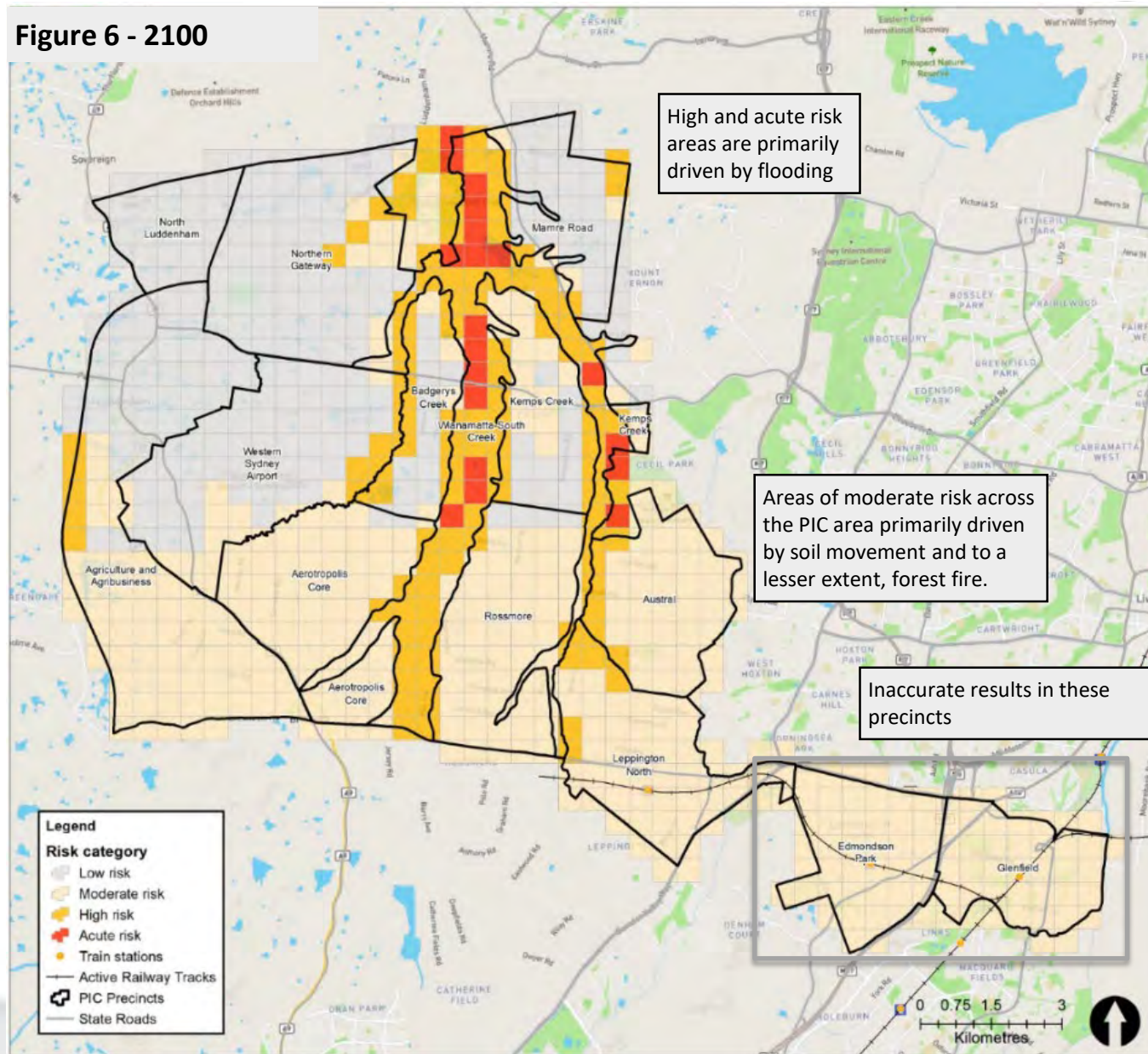




Figure 6 - 2100



# Risk to buildings – forest fire

Figure 7 shows the projected average value at risk (VAR%) for forest fire across all WSAGA over time. The lowest VAR% for forest fire in 2020 is 0% and the highest is 0.28% for the area level assessment.

The average forest fire VAR% in 2020 is 0.011%, increasing by 18% to 0.013% in 2050. This increases to 0.017% in 2100, representing a 55% increase on the risk level in 2020.

Table 2 shows the number of hectares for each risk category over time. These figures reflect the climate becoming hotter and drier over time, increasing the probability of damage from fires. Areas of higher risk are primarily located in areas that are currently vegetated. As the PIC area becomes more urbanised over time, this risk may be reduced. Where vegetation corridors will be preserved, this risk may remain. It will be important to balance the need for bushfire mitigation with maintaining biodiversity value in these areas.

The model of risk of damage from forest fire is based on actuarial data. Where assets are exposed to fire, there a number of factors that can help to reduce risk. Therefore probabilities of loss are lower than the probability of a bushfire occurring.

Figures 8, 9 and 10 show the risk rating across WSAGA over time. As the area is predominantly at a low risk, the category has been further broken down to show variation across the area.

Table 2 Hectares in each risk category over time – forest fire

Hectares in each risk category			
Risk level	2020	2050	2100
Acute	0	0	0
High	0	0	0
Moderate	33	63	149
Low	15498	15468	15382

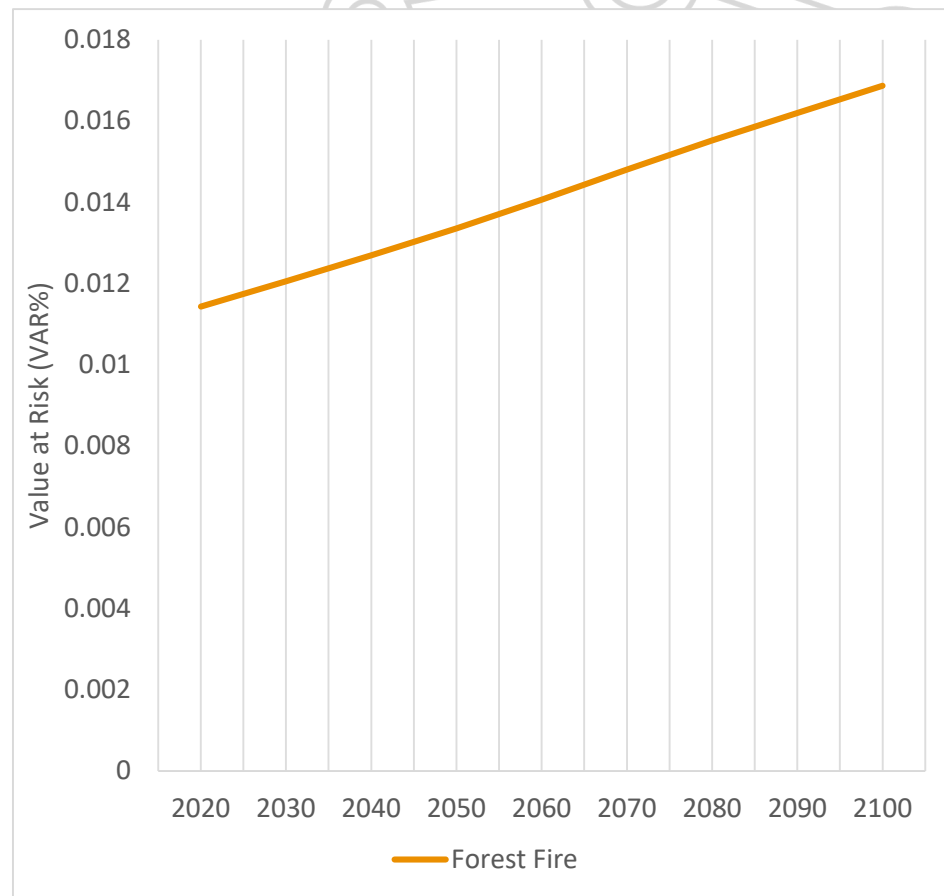
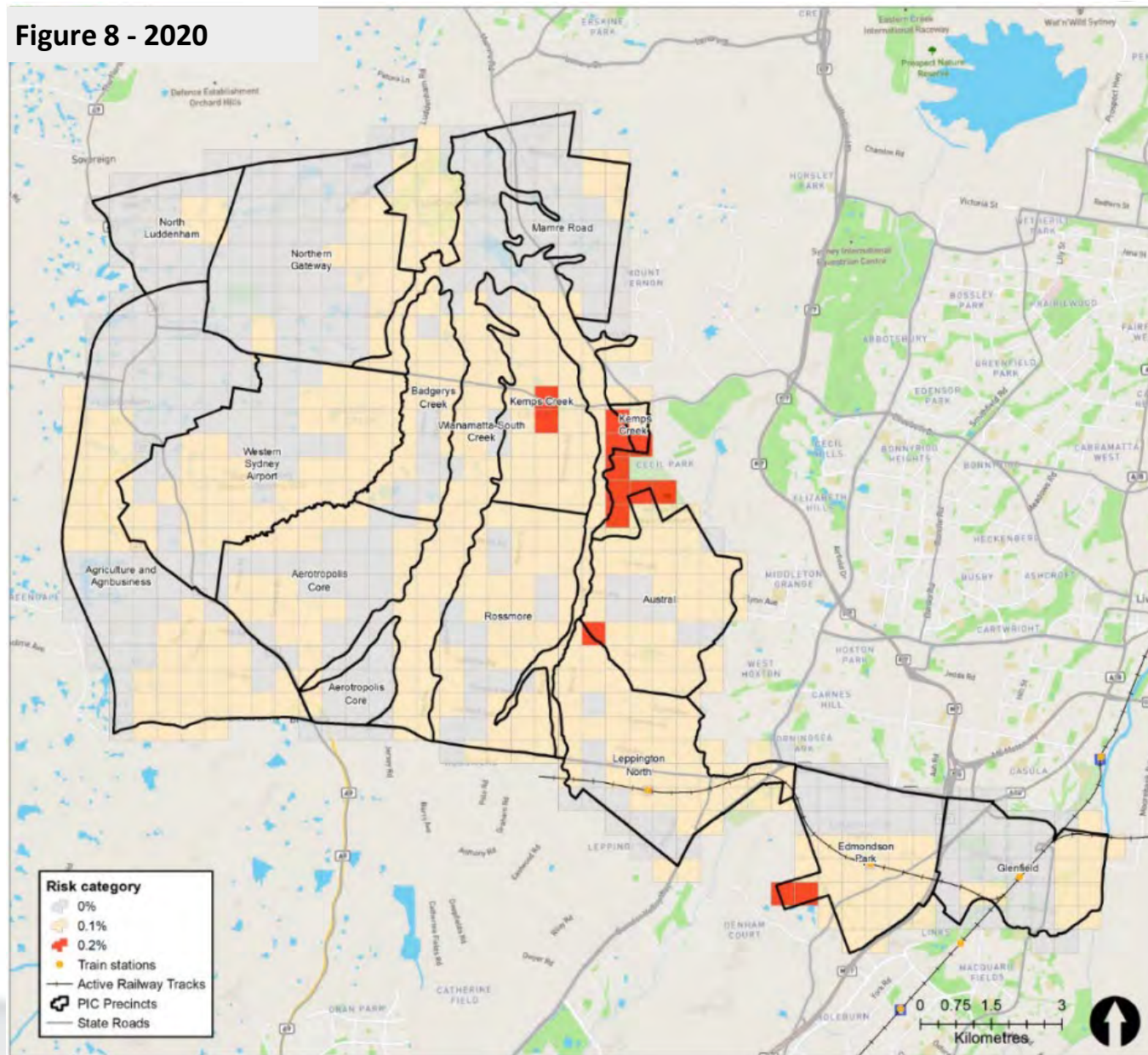


Figure 7 Average VAR% over time for forest fire for buildings



Figure 8 - 2020



### Figure 9 - 2050

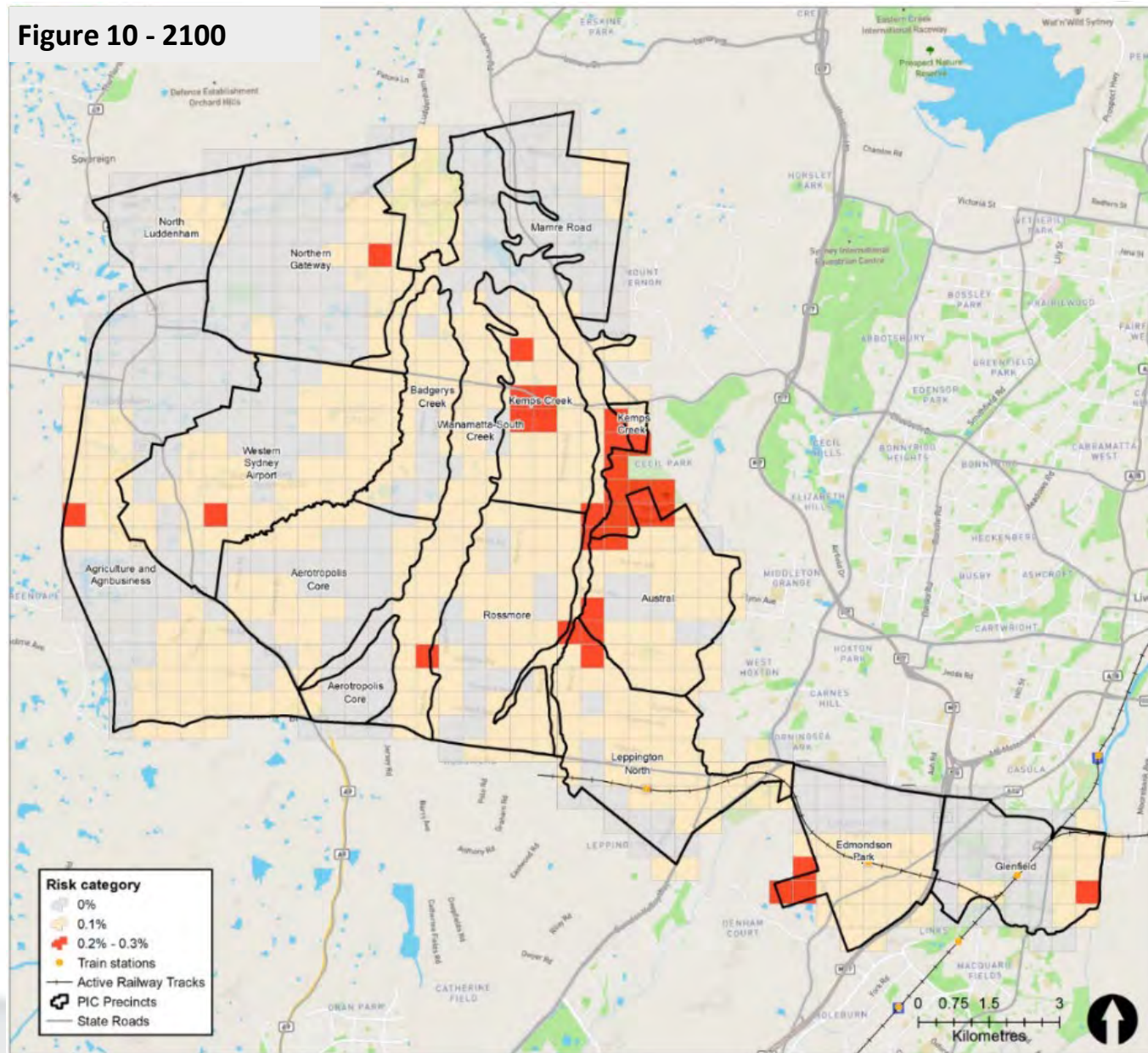
**Risk category**

- 0%
- 0.1%
- 0.2% - 0.3%
- Train stations
- Active Railway Tracks
- PIC Precincts
- State Roads

0 0.75 1.5 3  
Kilometres



Figure 10 - 2100



# Risk to buildings – flooding

Figure 11 shows the projected average value at risk (VAR%) for flooding across WSAGA for the building archetype over time.

The analysis used 20-year, 50-year, 100-year, 200-year, 500-year and the probable maximum flood return frequencies. Some lower-order streams may not be highlighted on the figures as a risk due to a lower return frequency or a lower risk of damage occurring from these floods.

In 2020, the average VAR% for flooding across WSAGA is 0.36%. In 2050, the average VAR% for flooding increased to 0.40% across WSAGA, representing a 11% increase in flooding risk. In 2100, the average VAR% increased to 0.50%, representing a 39% increase from 2020. The variation in risk levels also reflect a reduction in rainfall by mid-century which occurs in the NARClIM data for parts of NSW.

Table 3 shows the amount of land in each category over time. The risk of flooding in WSAGA increases significantly over time, with a large increase in areas of high and acute flood risk.

Table 3 Hectares in each risk category over time – flooding

Hectares in each risk category			
Risk level	2020	2050	2100
Acute	0	0	773
High	1980	1837	1022
Moderate	0	143	185
Low	13551	13551	13551

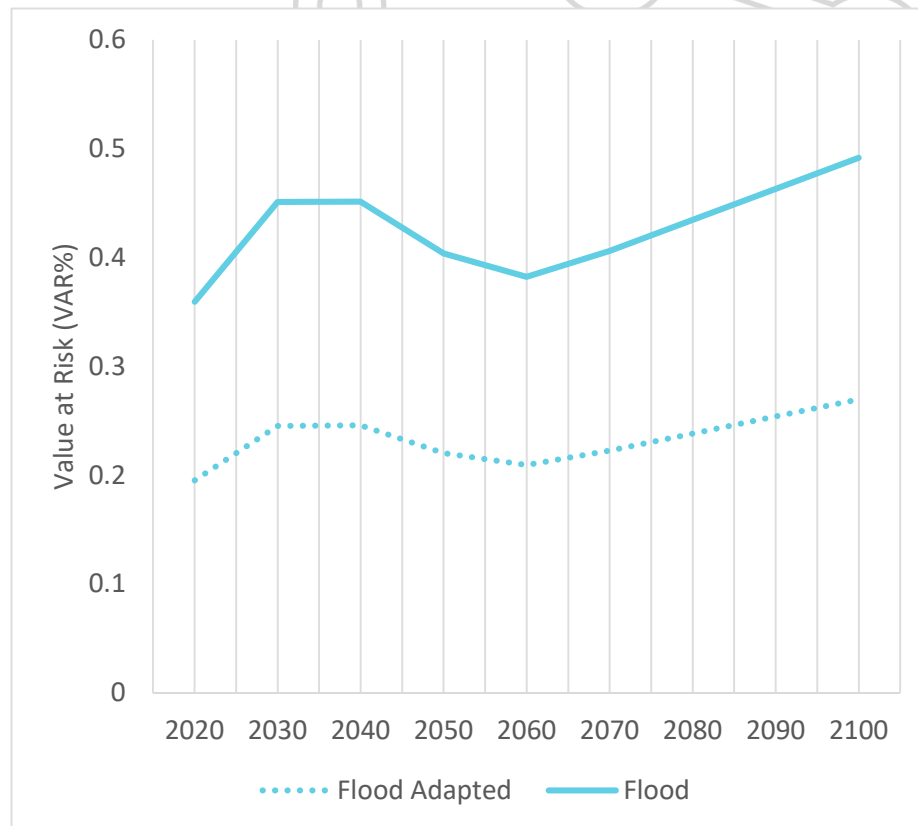


Figure 11 Average VAR% for flooding for adapted and non-adapted buildings

The analysis also considered how raising the height of theoretical buildings would reduce the risk across the PIC area. By raising the building height by 0.5 metres, the average VAR was 0.20% in 2020, 0.22% in 2050 and 0.27% in 2100. This corresponds with 934 hectares being classified at high risk in 2020, 920 hectares at high risk in 2050 and 431 hectares at high risk and 490 hectares at acute risk in 2100. Figures 12, 13 and 14 show the risk across WSAGA.

This demonstrates that adaptation of any infrastructure located in flood affected areas would have a significant impact in reducing the overall risk.

**Note:** This assessment includes flood data from a number of different sources. These data are the best available at the time of analysis and will be updated as new data become available from local governments and the Department of Planning, Industry and Environment. The XDI analysis for the Western Sydney PIC areas also has some spatial gaps in the flood data – these gaps will be filled over time as the data becomes available. Comprehensive flood information will soon be available through the Hawkesbury Nepean Flood Taskforce; the taskforce flood information is considered the most up to date and comprehensive set of data and is endorsed by the Department of Planning, Industry and Environment.

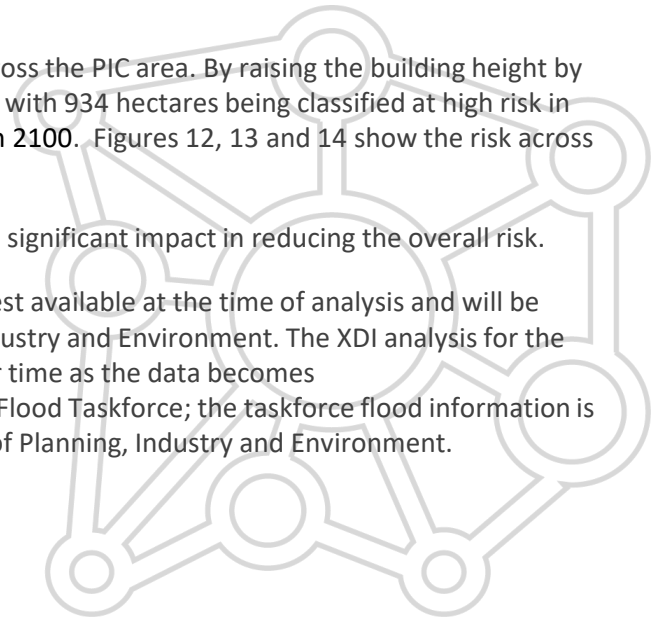




Figure 12 - 2020

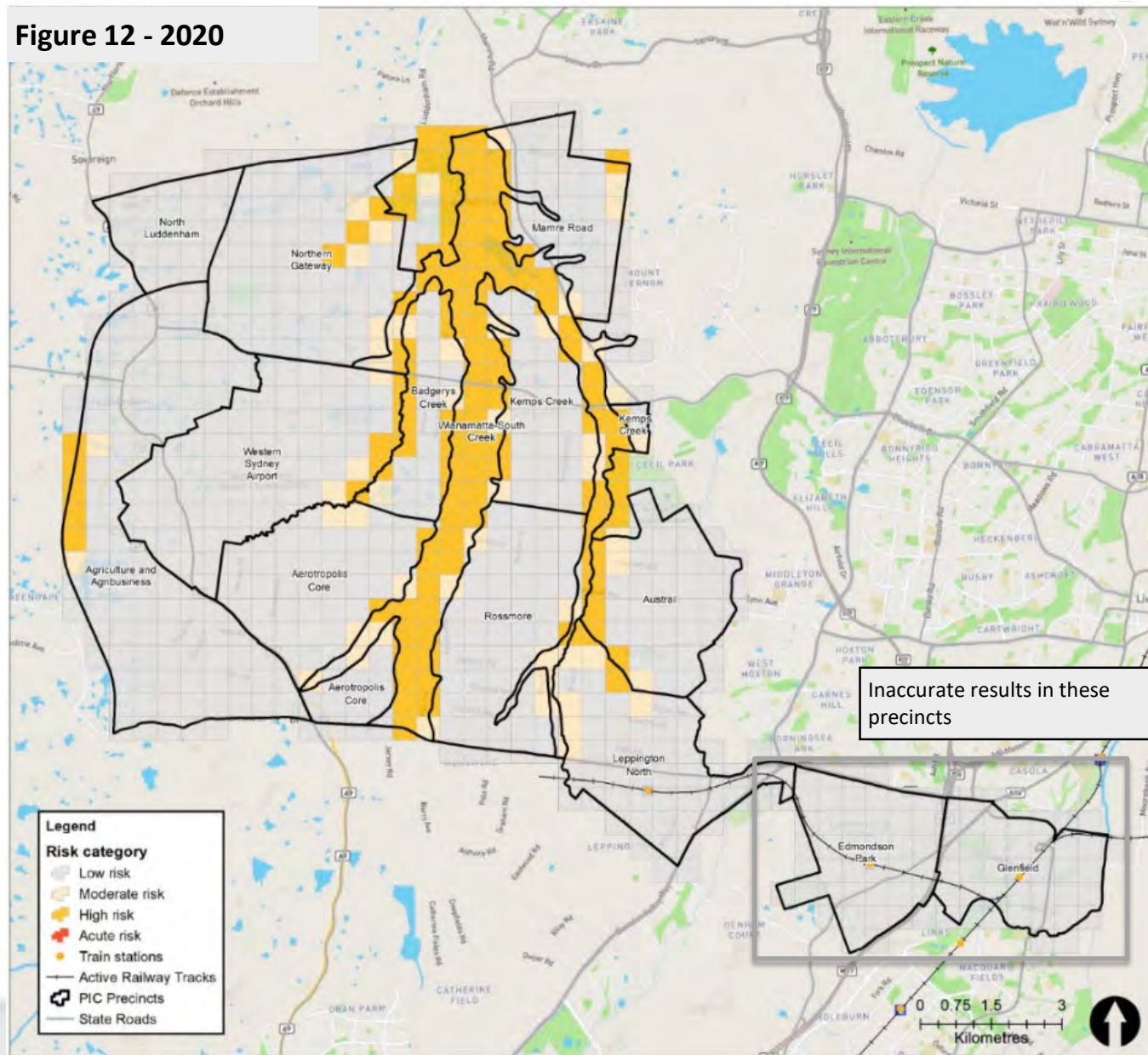




Figure 13 - 2050

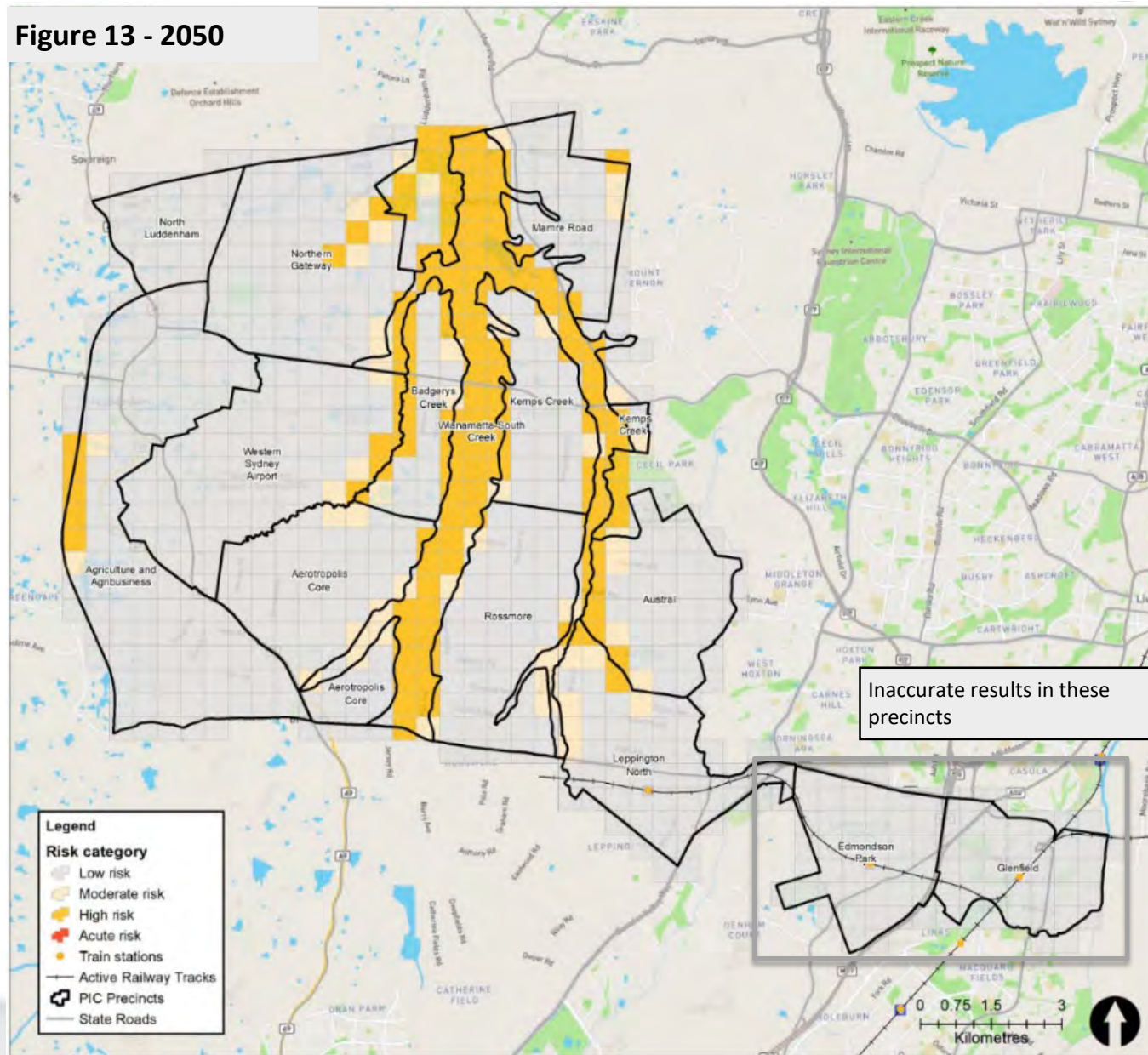
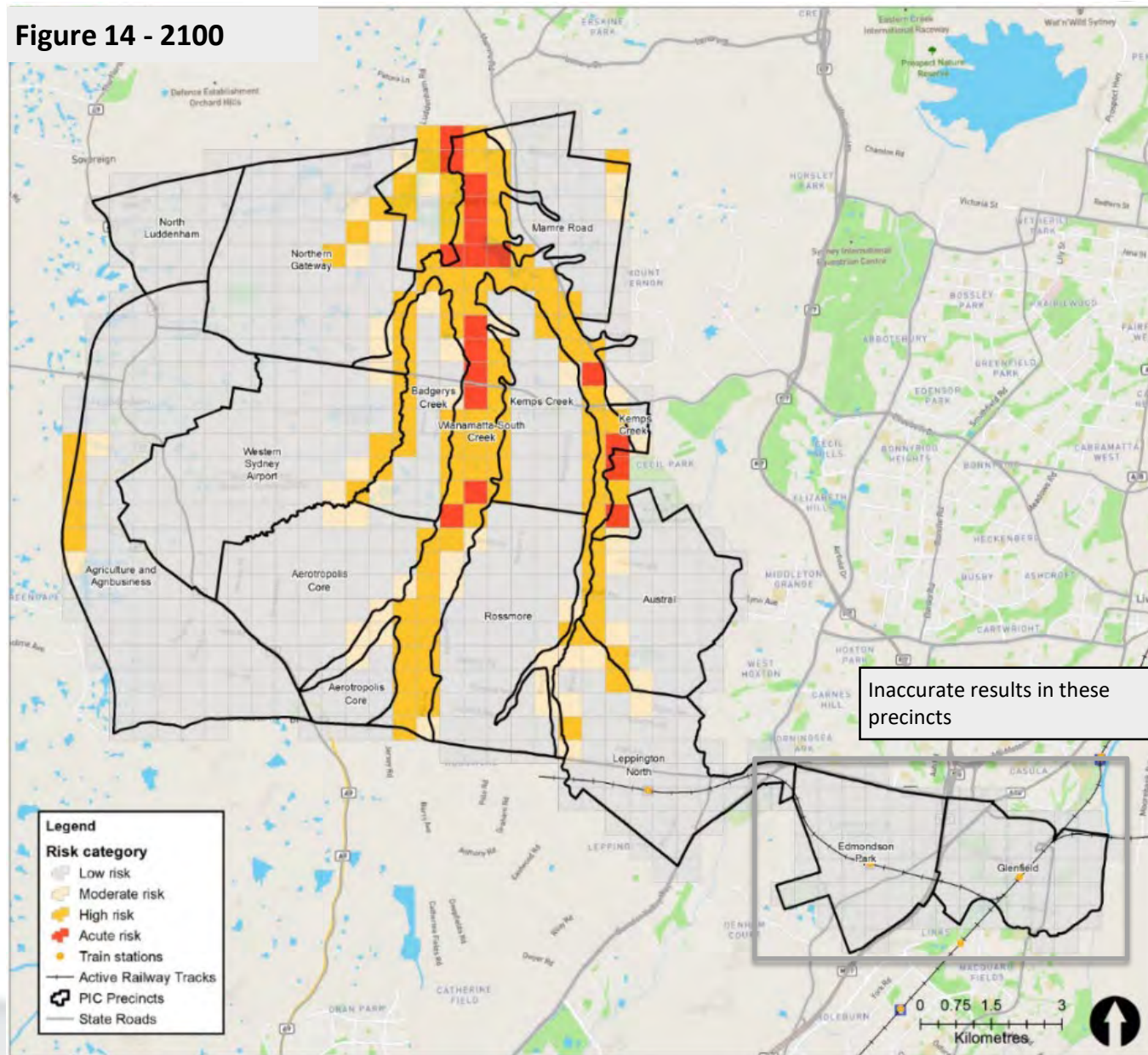


Figure 14 - 2100





# Risk to buildings – soil movement

Figure 15 shows the projected average value at risk (VAR%) across all non-adapted buildings within the study area. This is an indicator for insurance costs. The lowest VAR% for soil movement in 2020 is 0% and the highest is 0.29%.

In the short term, the average VAR% increases from 2020 to 2030, then decreases yearly to 2100. This trend in soil movement is sometimes seen in the NARClIM data for parts of NSW. Although the driest models for the area are used for the assessment, some grid cells can go against the trends. In the long term, average VAR% from soil movement decreases from 0.26% in 2020 to 0.22% in 2100, a 15% decrease.

WSAGA has some component of clay soils. The overall VAR% for soil movement remains low, at or below a VAR% of 0.29% and unlikely to cause unaffordable insurance premiums. However, it is recommended that there is diligent enforcement of building codes or implementation of building codes that require foundations that are impervious to soil movement to ensure the risk is mitigated. Figures 16, 17 and 18 show the risk across WSAGA. Table 4 shows land area at risk.

For a default replacement cost of \$2 million for a generic commercial building, the average technical insurance premium for soil movement risk is \$5,000 in 2020, decreasing to \$4,400 in 2100. The impact varies by area as seen in the following maps.

Table 4 Hectares in each risk category over time – soil movement

Hectares in each risk category			
Risk level	2020	2050	2100
Acute	0	0	0
High	0	0	0
Moderate	14849	12782	7223
Low	682	2749	8308

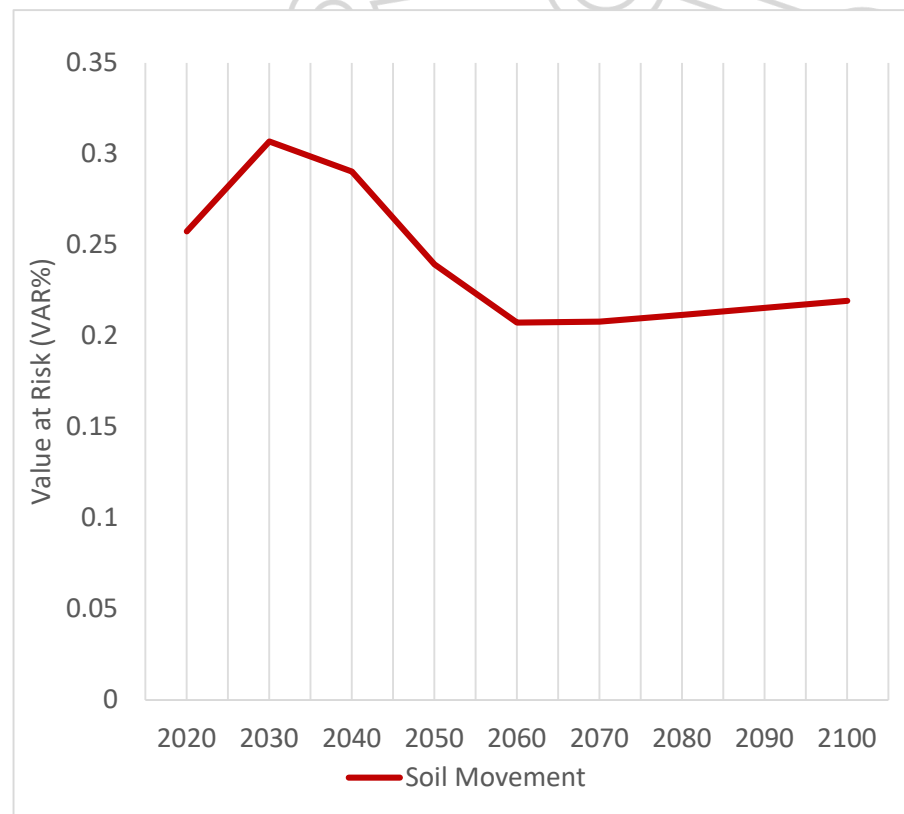


Figure 15 Average VAR% over time for soil movement for buildings

Figure 16 - 2020

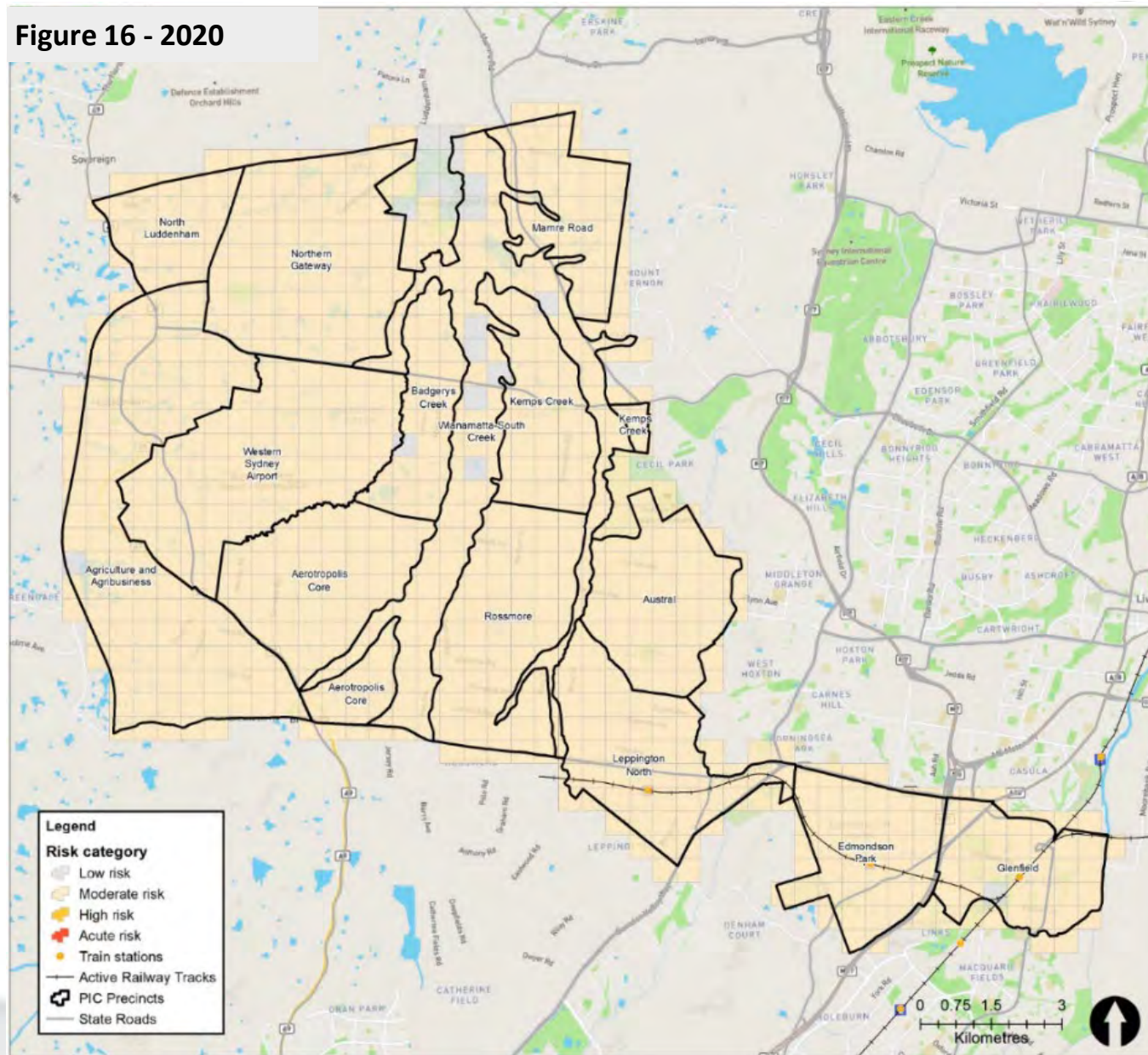




Figure 17 - 2050

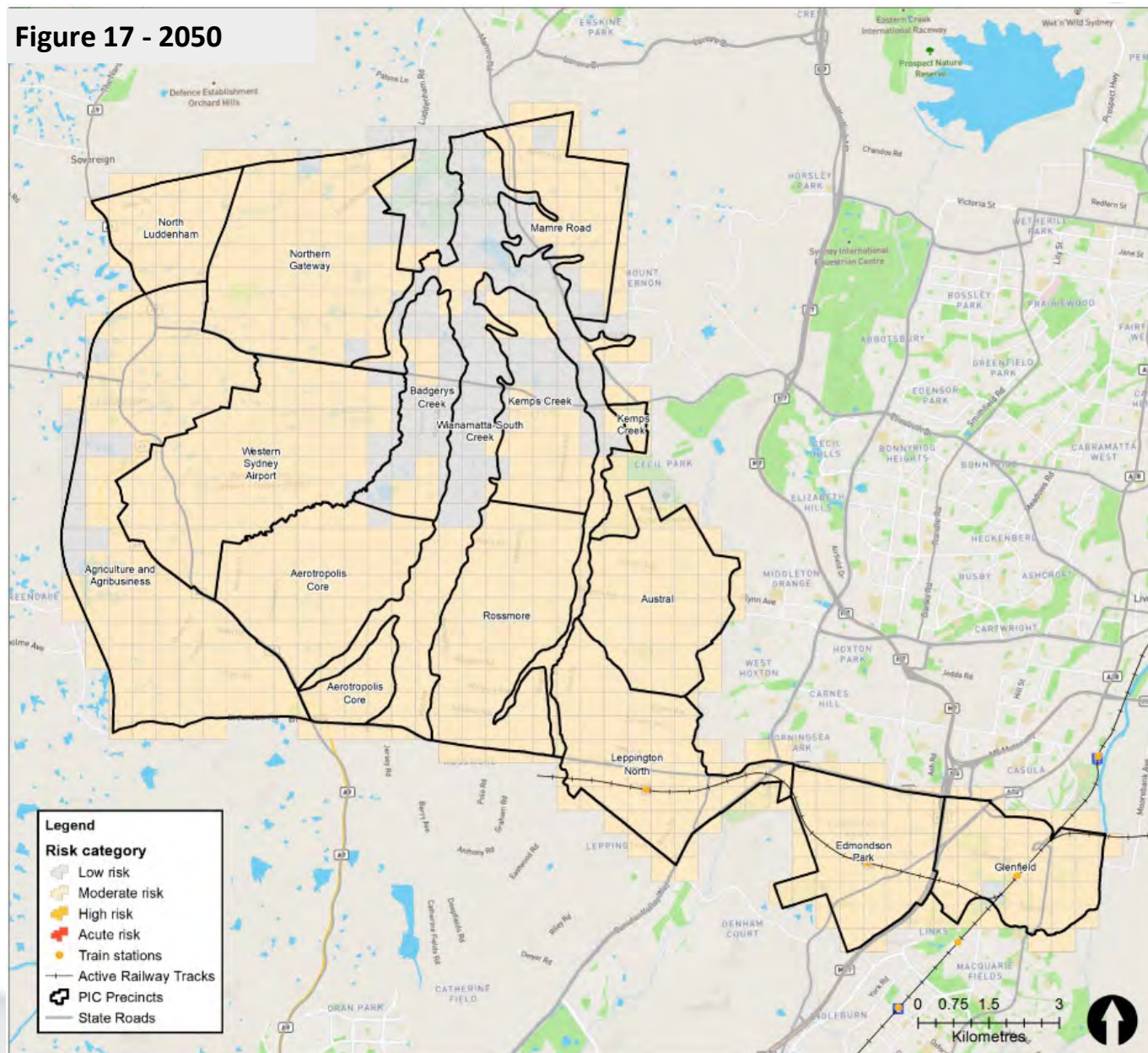
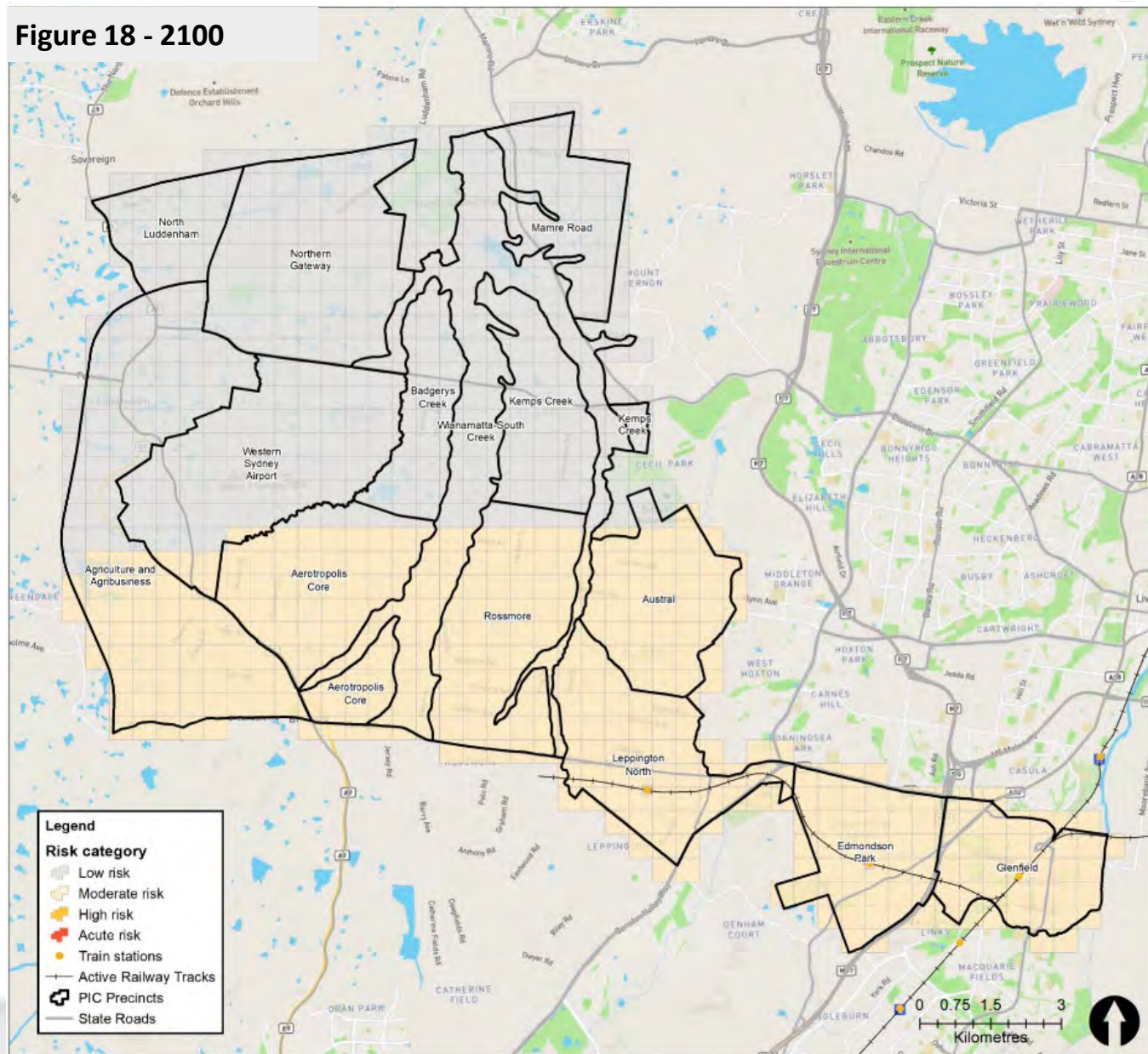


Figure 18 - 2100





## Risk to buildings – heatwave

Figure 19 shows the projected average failure probability (FP%) across all non-adapted and adapted buildings within the study area. In 2020, the FP% ranges across the PIC from 15.7% to 27.1%.

The models predict a continuation of historical global temperature trends, with extreme temperatures increasing into the future. The annual probability of failure events that exceed the 42°C threshold increases 3.5-fold from 23% in 2020 to 79% in 2100.

FP% from heatwave will differ depending on the area, as evident on XDI Globe, with regional modelling calculations visible. Figures 20, 21 and 22 show the difference across WSAGA.

Adaptations were used to assess the change in risk that occurs when the heat design threshold for assets is increased from 42 to 45 degrees Celsius. By modifying the heat threshold of the building to 45 degrees Celsius, we can delay the current risk to the building and the occupants.

Raising the heat threshold to 45 degrees Celsius drastically reduces the FP%, across all years, compared to that of a non-adapted building. A building in 2020 when adapted to heatwave shows a 97% reduction in FP%, and in 2100 FP% is reduced by 87%.

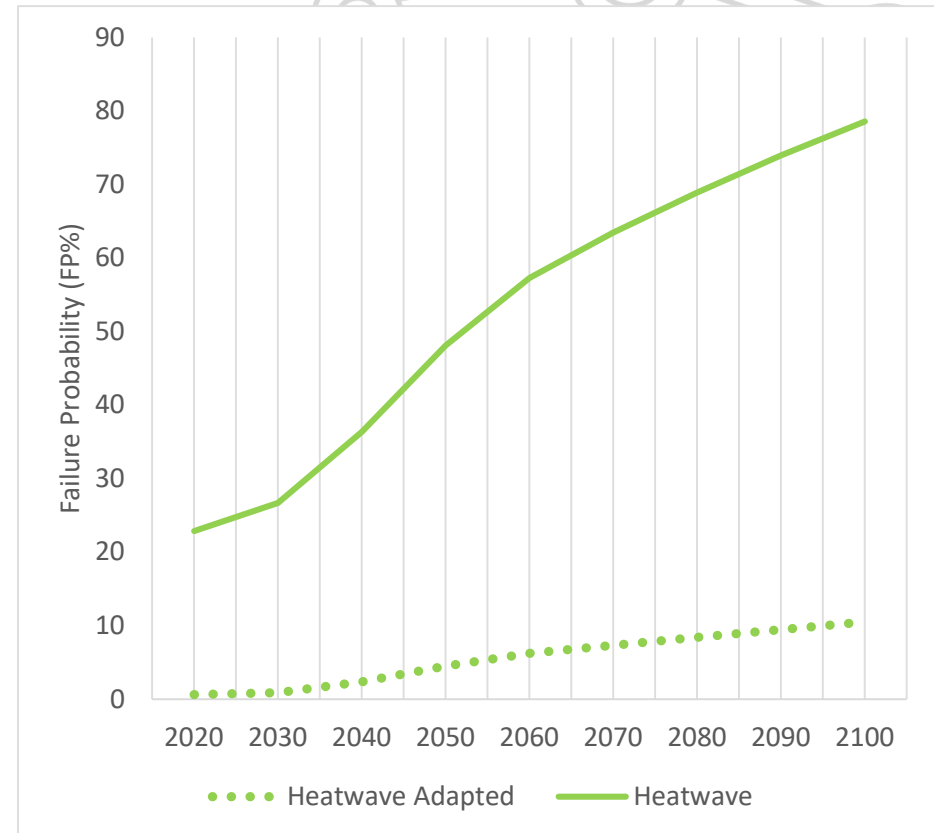


Figure 19 Average FP% from heatwave of all non-adapted and adapted buildings

Figure 20 - 2020

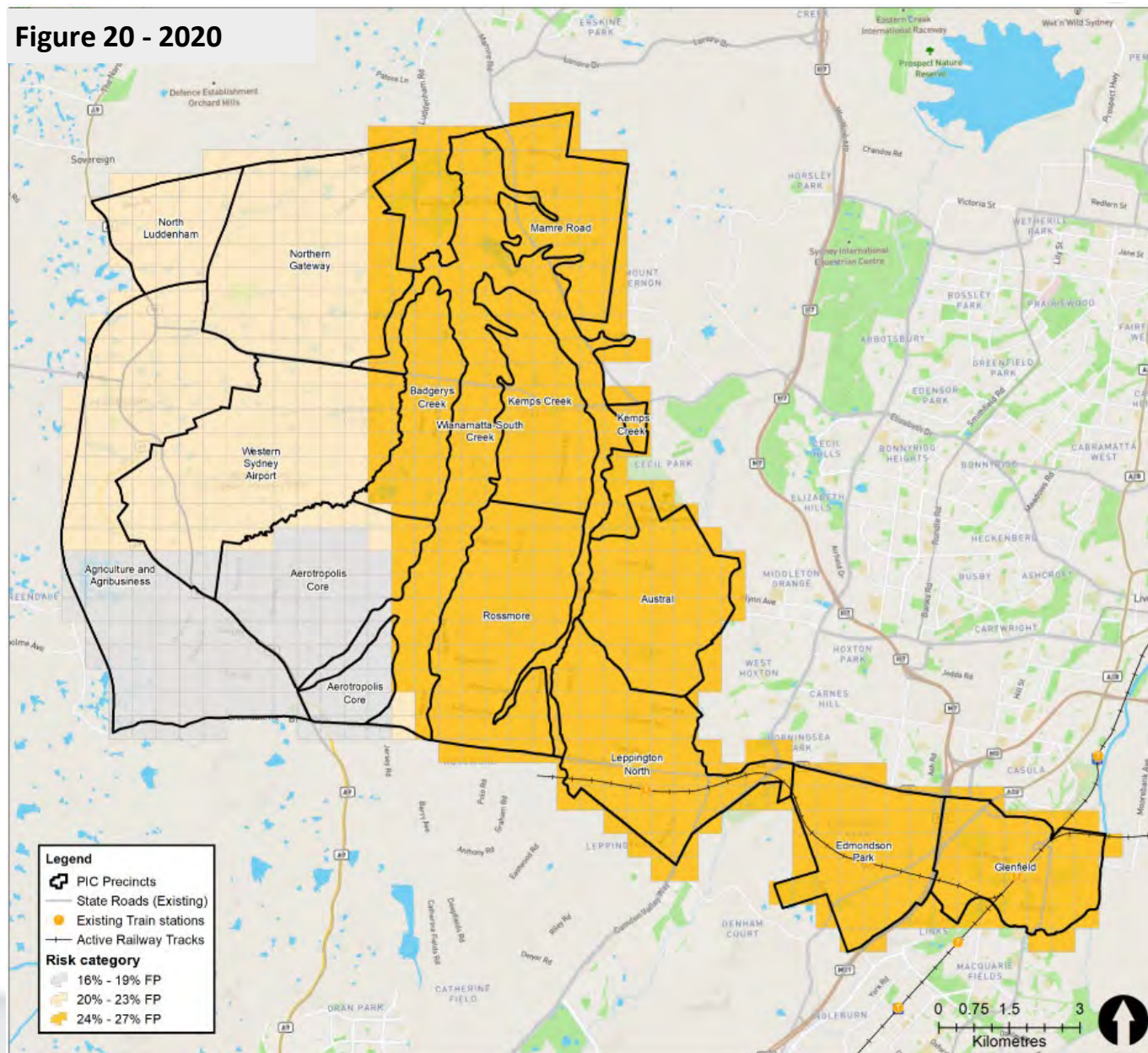




Figure 21 - 2050

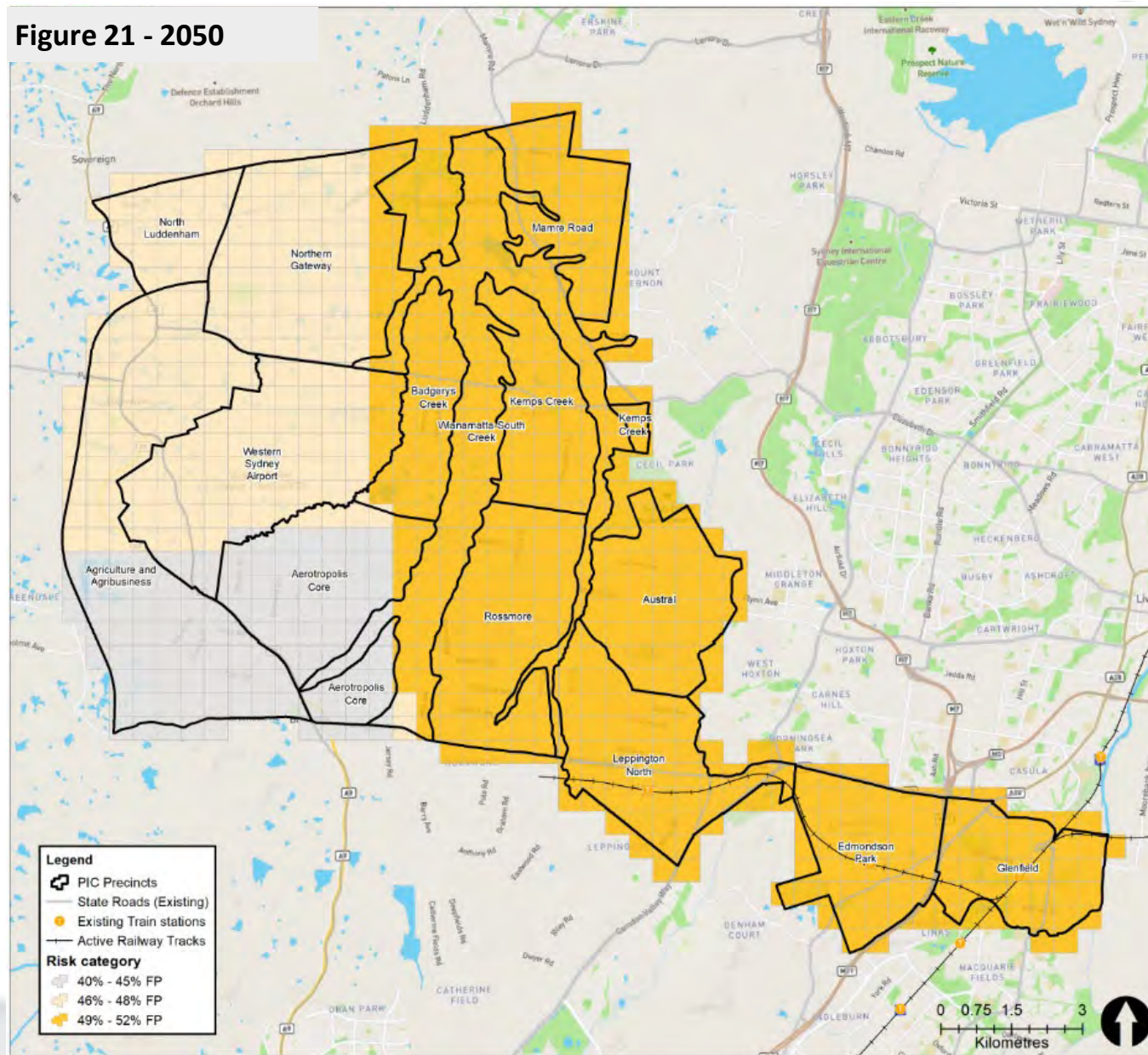
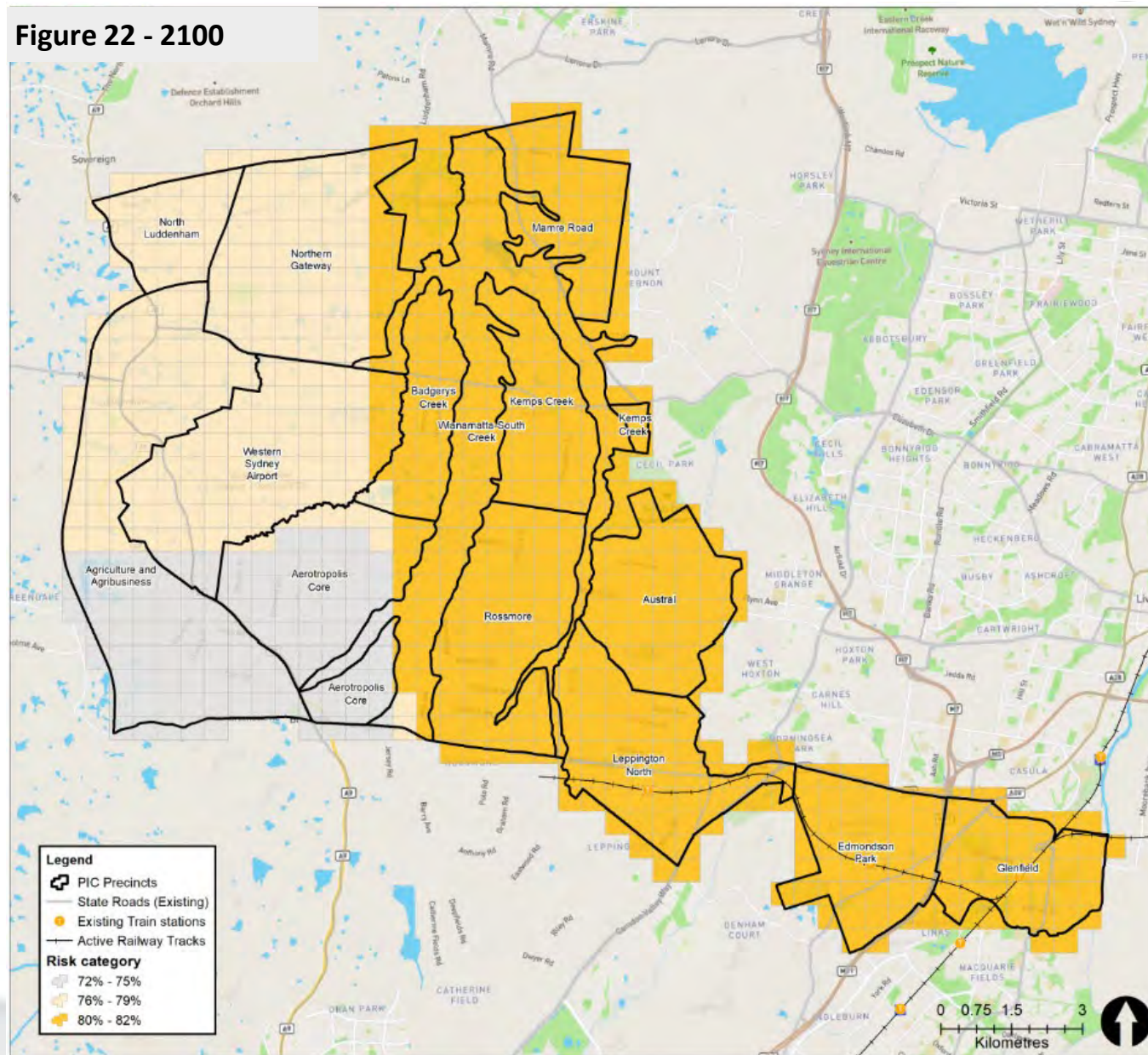
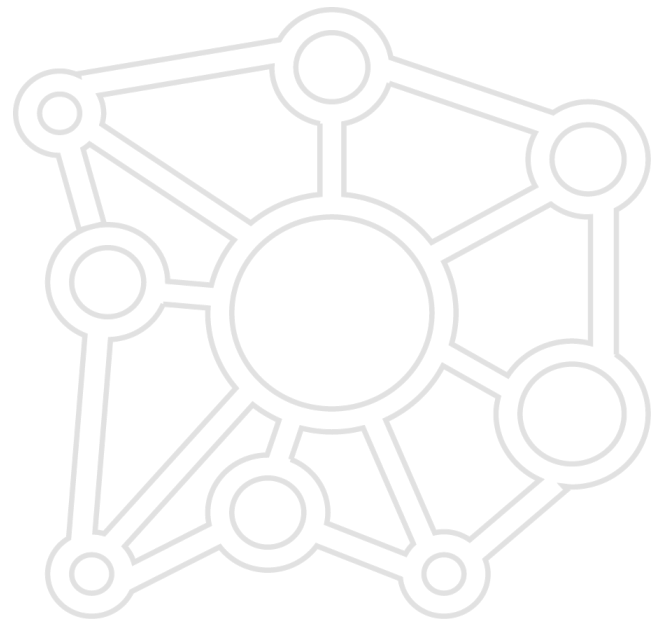


Figure 22 - 2100







# Results

Risks to roads

# Risk to roads – all hazards

The value at risk metric can be used to represent the level of risk that will be experienced by any roads located in each risk tile across time.

Figure 23 shows riverine flooding, soil movement and forest fire projected average value at risk (VAR%) per year across all non-adapted roads within WSAGA. Table 5 shows land area at risk over time.

The average VAR% from all hazards in 2020 is 0.47% increasing to 0.54% in 2100, which is a 15% increase. Figures 24, 25 and 26 show the risk across WSAGA.

VAR% from riverine flooding contributes to the majority of the risk over time, with the average VAR% in 2020 at 0.3%, contributing 2 times more than soil movement (0.16% VAR) and many more times than forest fire (0.0039x10<sup>-5</sup>% VAR).

Table 5 Hectares in each risk category over time – all hazards

Hectares in each risk category			
Risk level	2020	2050	2100
Acute	0	0	678
High	1980	1837	1117
Moderate	0	143	185
Low	13551	13551	13551

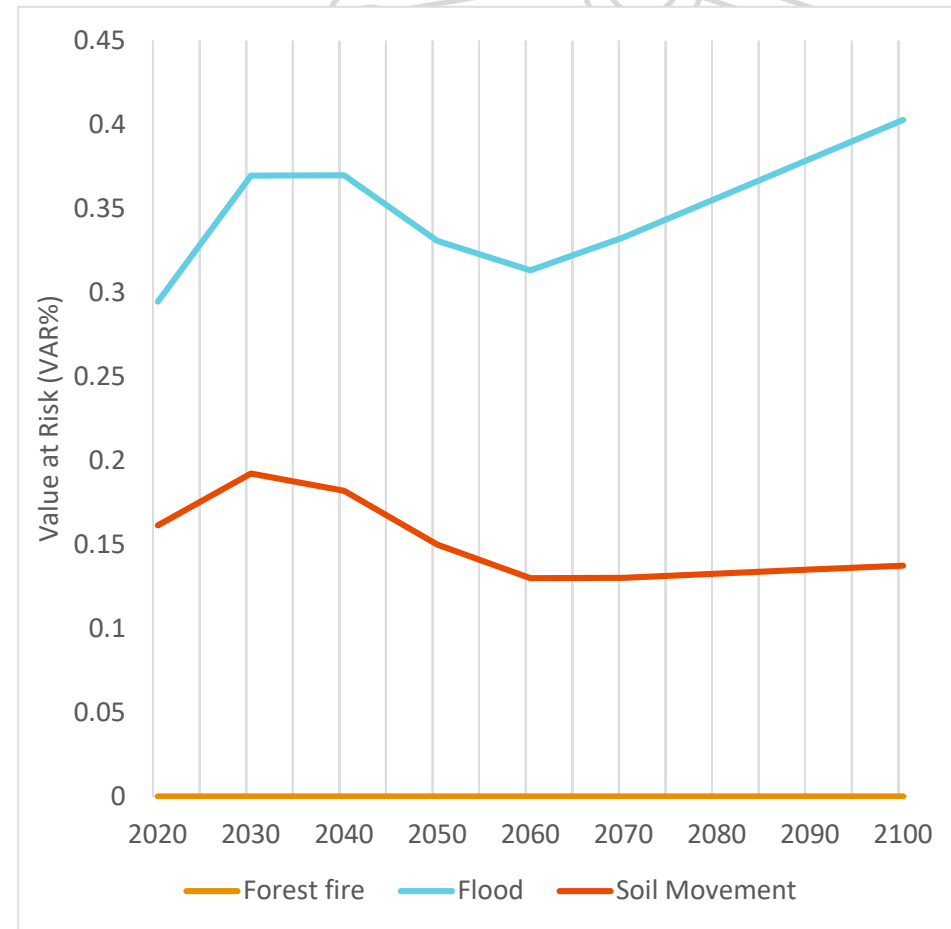


Figure 23 Average VAR% over time for all hazards for roads

Figure 24 - 2020

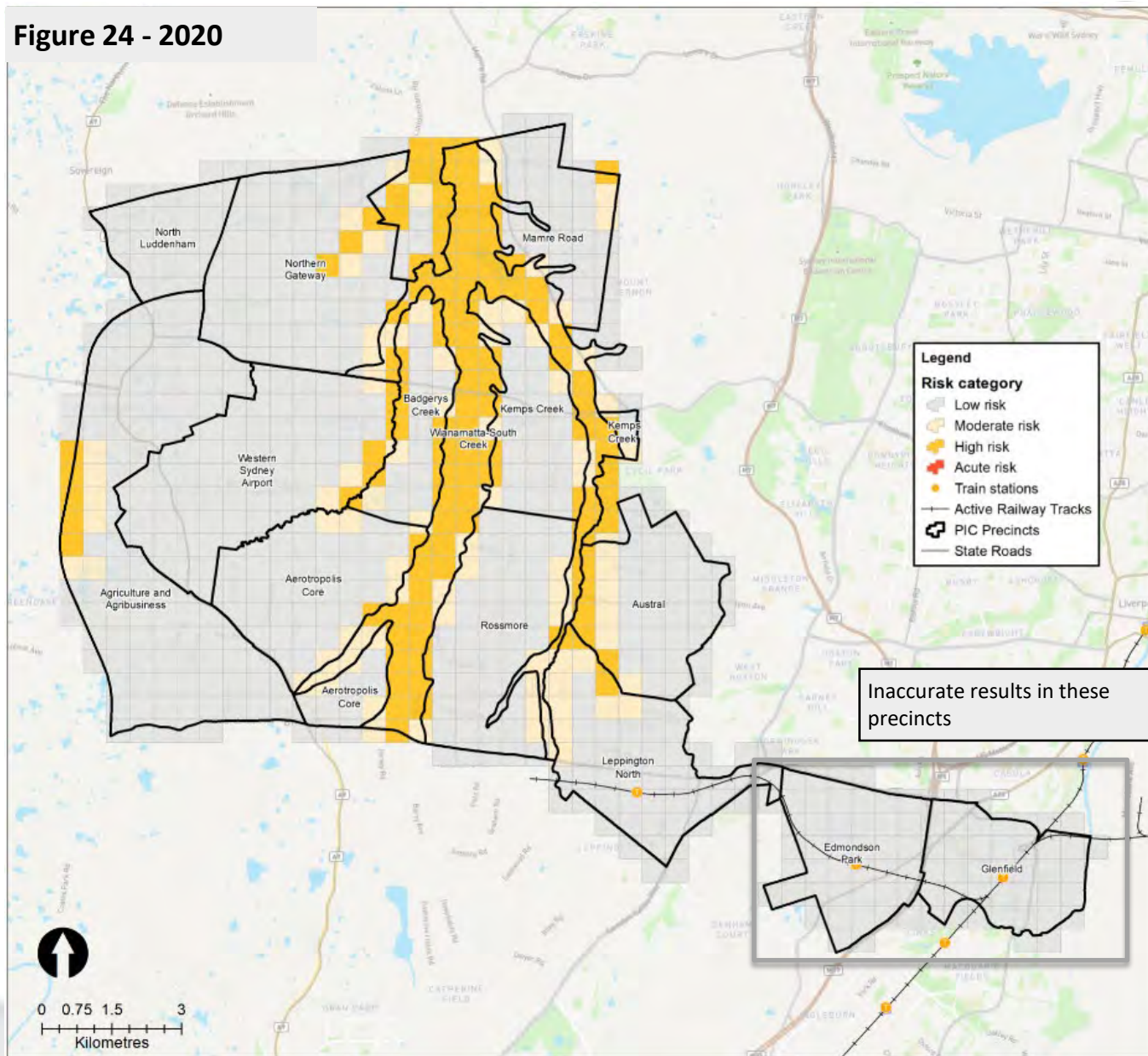


Figure 25 - 2050

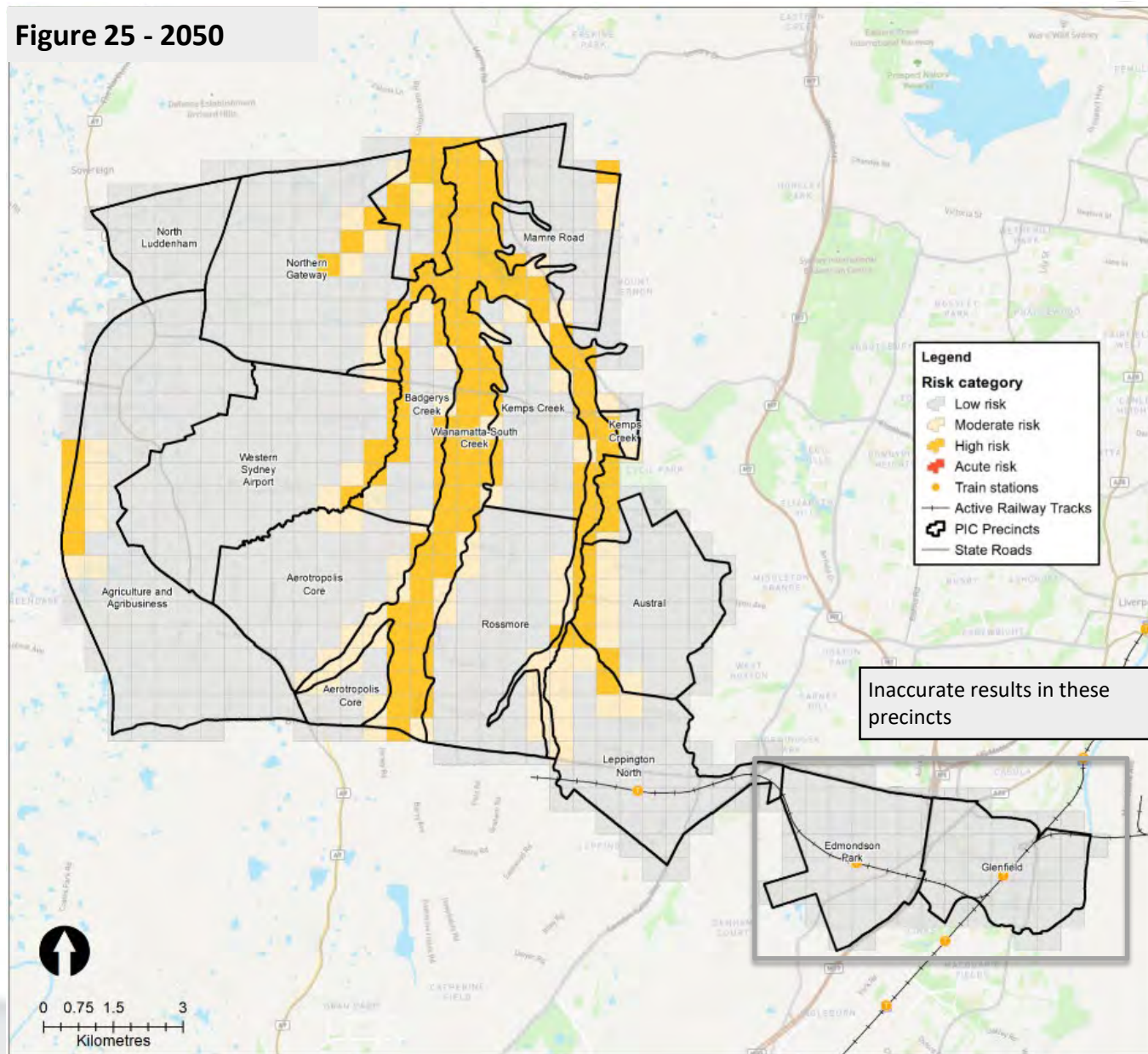
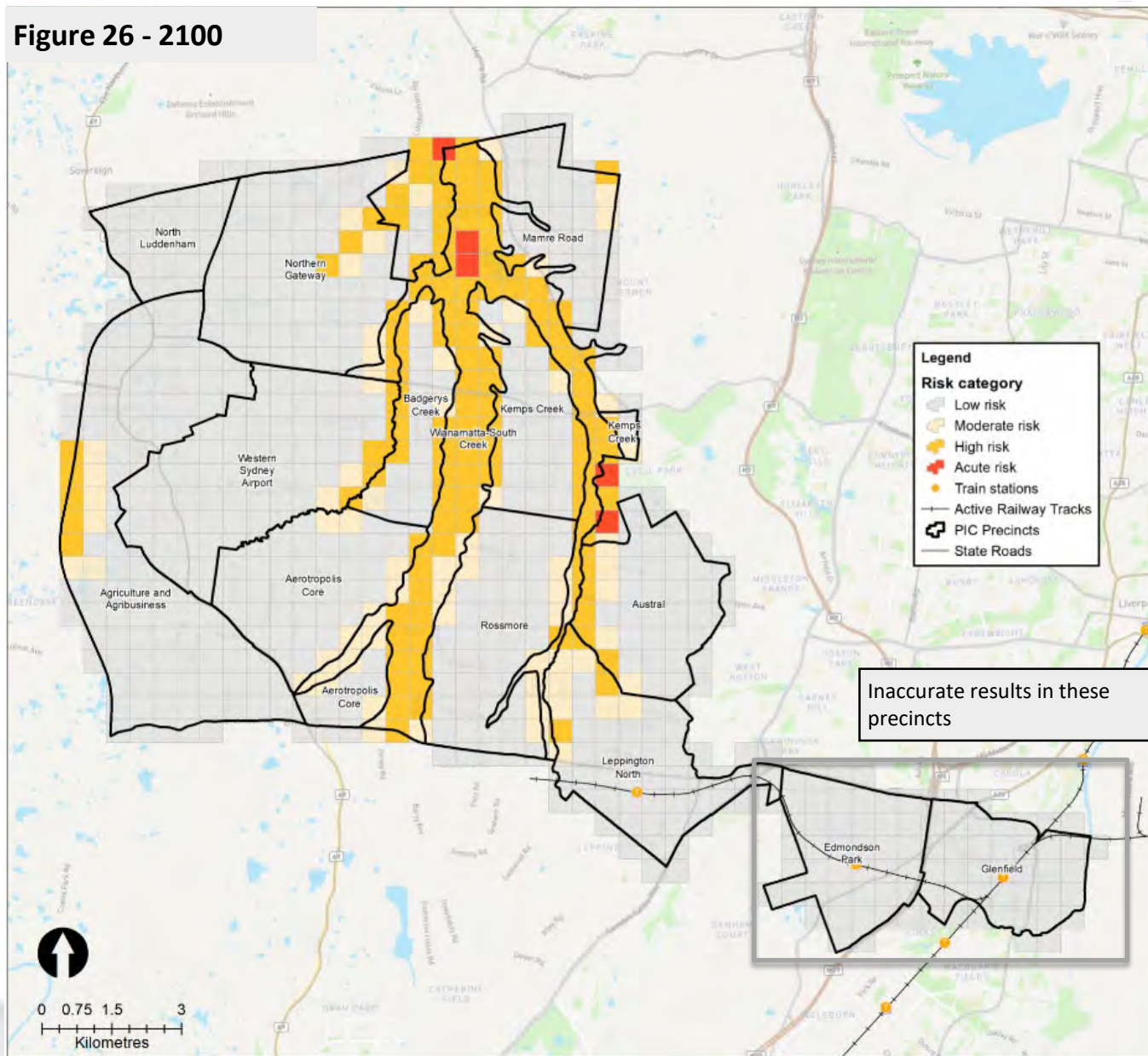




Figure 26 - 2100



# Risk to roads – forest fire

Figure 27 shows the projected average value at risk (VAR%) across all non-adapted roads within the study area. The lowest VAR% in 2020 for forest fire is 0% and the highest is  $0.096 \times 10^{-5}\%$ .

The average VAR% increases over time as the models predict more prevalent hot and dry conditions resulting in higher risk of fires. Average VAR% from forest fires in 2020 is  $0.0039 \times 10^{-5}\%$ , increasing to  $0.0057 \times 10^{-5}\%$  in 2100, a 54% increase. Roads throughout WSAGA were found to have a low risk of damage due to forest fire. Figures 28, 29 and 30 show the risk across WSAGA. As the area is predominantly at a low risk, the category has been further broken down to show variation across the area. Table 6 shows land area at risk in each category over time.

For a default replacement cost of \$2 million for a generic road, the highest average technical insurance premium seen for forest fire risk to a single road would be \$0.0008 in 2020 increasing to \$0.001 in 2100. The impact varies by area as seen in the following maps.

Table 6 Hectares in each risk category over time – forest fire

Hectares in each risk category			
Risk level	2020	2050	2100
Acute	0	0	0
High	0	0	0
Moderate	0	0	0
Low	15531	15531	15531

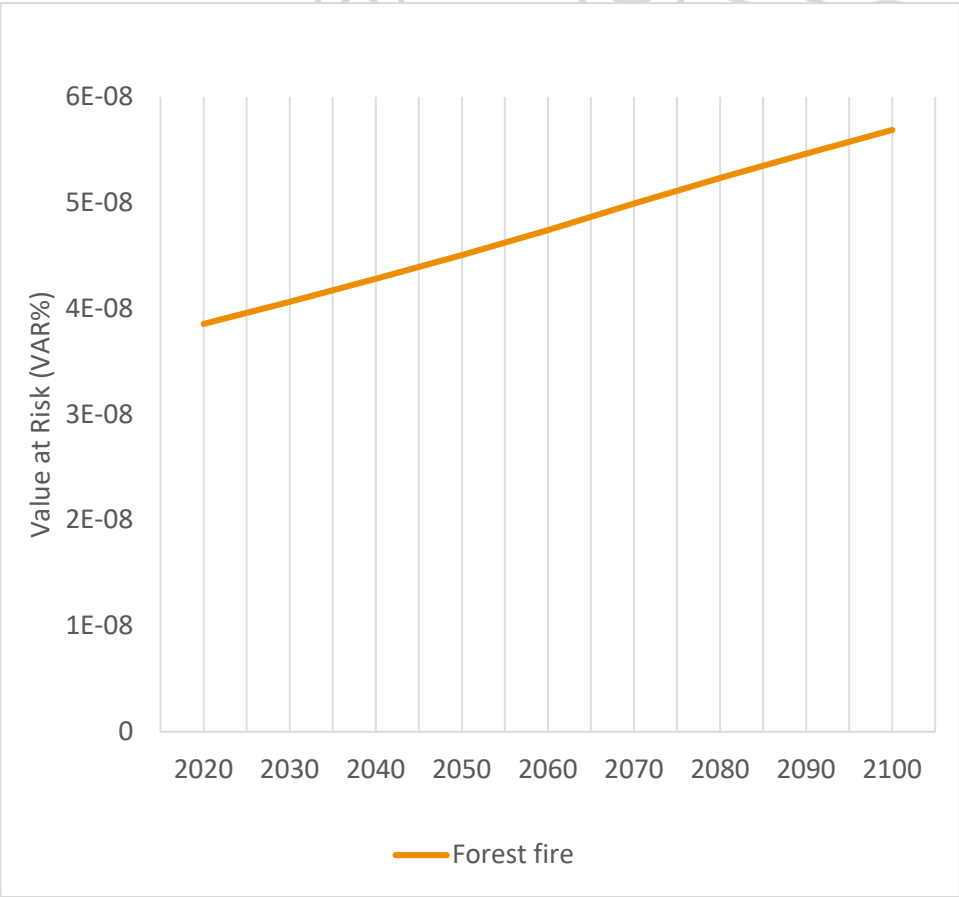


Figure 27 Average VAR% overtime for forest fire for roads



Figure 28 - 2020

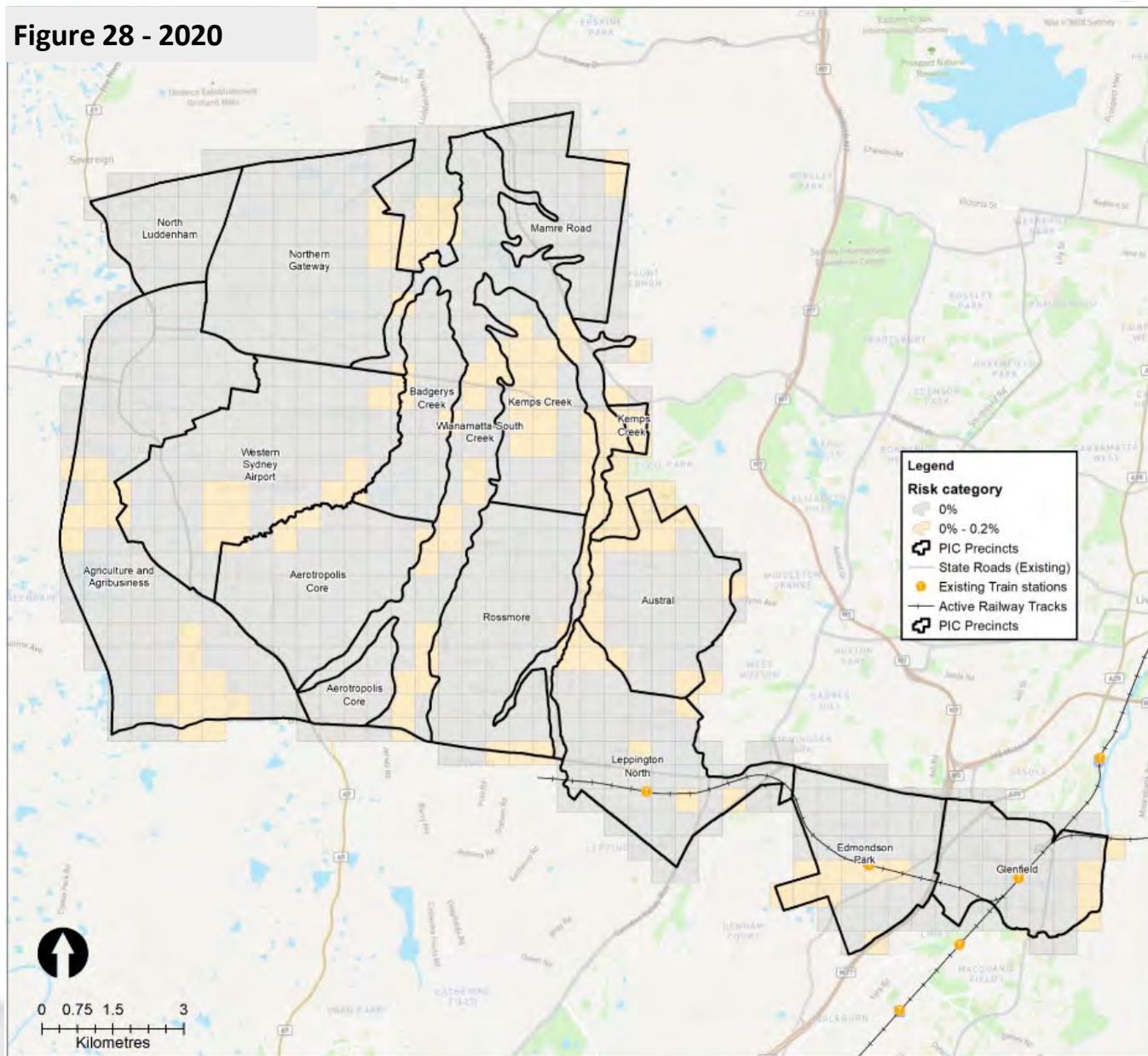


Figure 29 - 2050

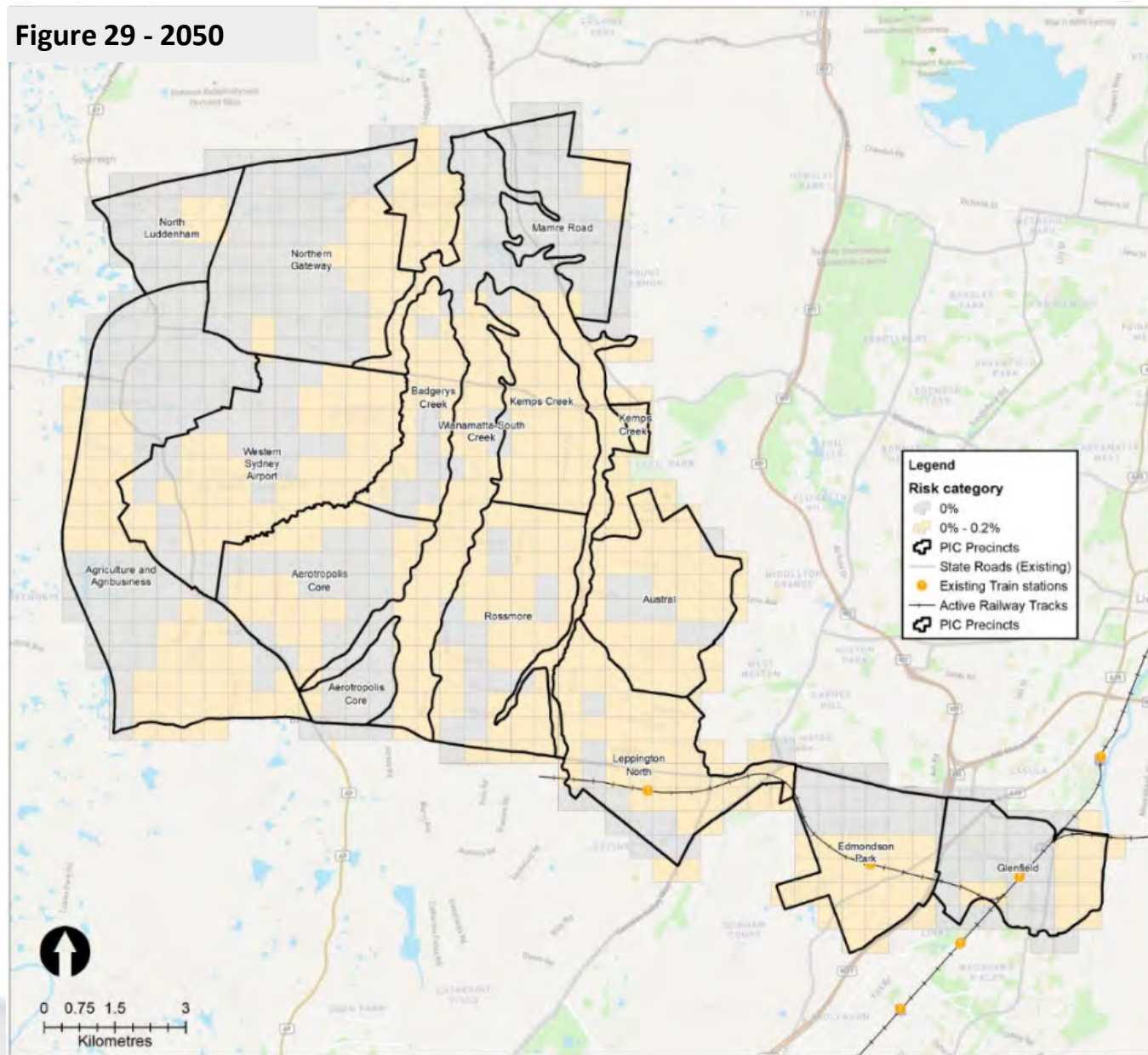
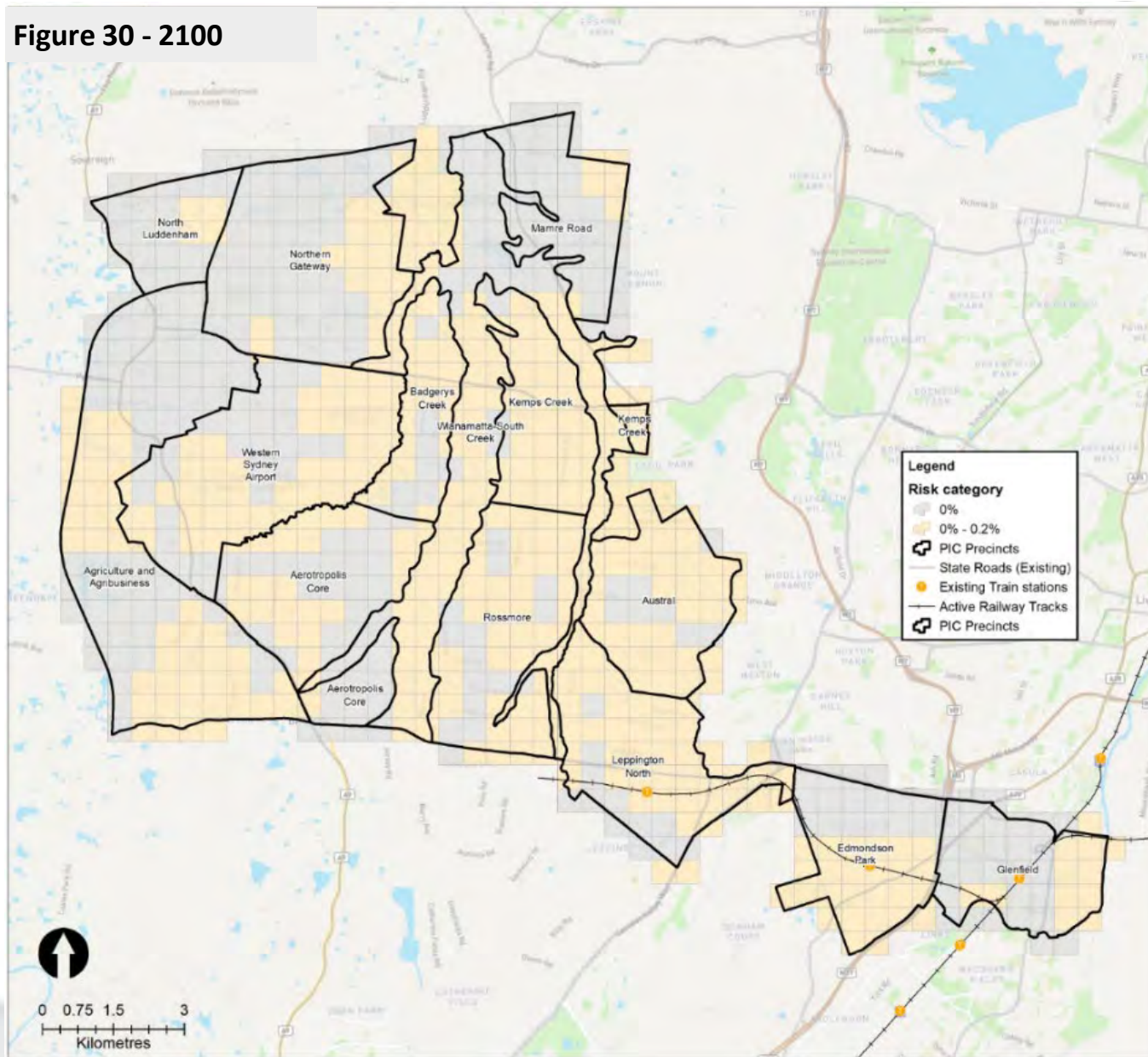




Figure 30 - 2100





# Risk to roads – flooding

Figure 31 shows the projected average value at risk (VAR%) per year across all non-adapted roads within the study. The lowest VAR% for flood in 2020 was 0% and the highest was 3.2%.

Over the first 20 years, the average VAR% increases from 2020 to 2040, decreasing from 2040 to 2060 then increasing steadily to 2100. This dip in rainfall mid-century is sometimes seen in the NARClIM data for parts of NSW. The average VAR% in the long term increases from 0.29% in 2020 to 0.40% in 2100, a 37% increase. Table 7 shows land area at risk in each category over time.

For a default replacement cost of \$2 million for a generic road, the average technical insurance premium for flooding risk would be \$5,800 in 2020, increasing to \$8,000 in 2100.

By modifying the civil height of the road from 0 metres to 0.5 metres we can delay and reduce the current risk. Raising a road's civil height to 0.5 metres reduces the VAR% across all years. In 2020 the adaptation reduces the VAR% by 46%, and in 2100 the VAR% reduces by 45%.

Table 7 Hectares in each risk category over time – flooding

Hectares in each risk category			
Risk level	2020	2050	2100
Acute	0	0	0
High	1839	1795	1783
Moderate	141	185	197
Low	13551	13551	13551

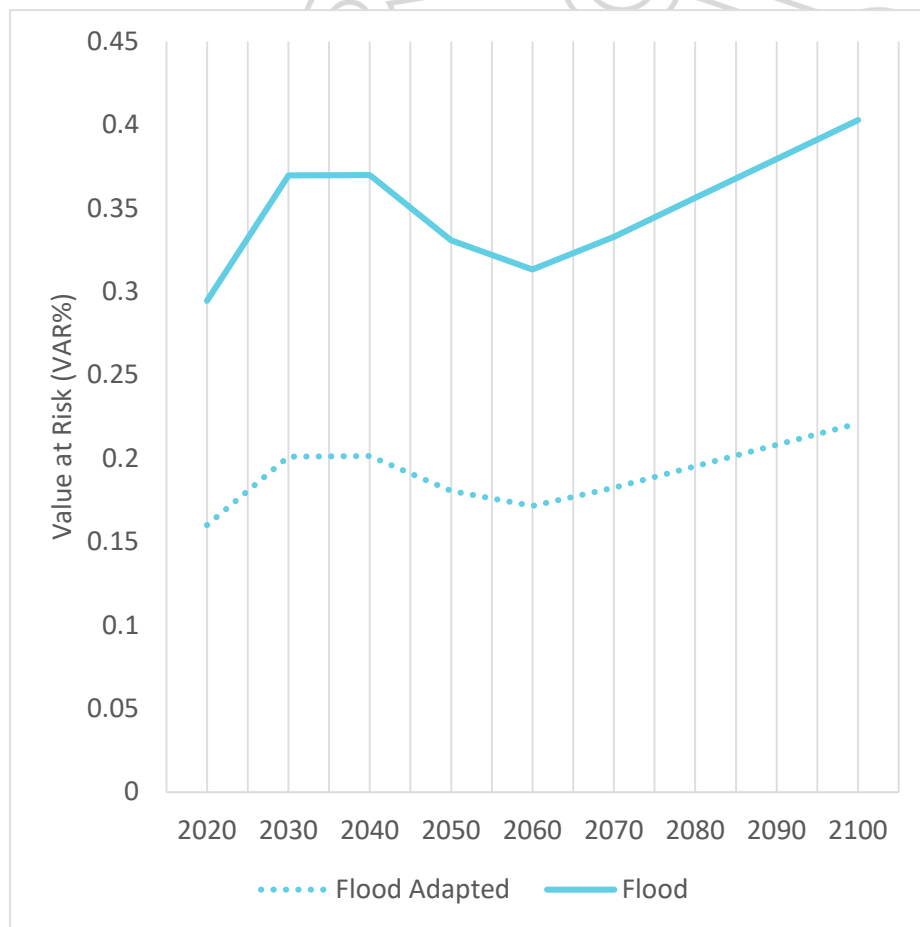


Figure 31 Average VAR% over time for riverine flooding for roads

**Figure 32 - 2020**

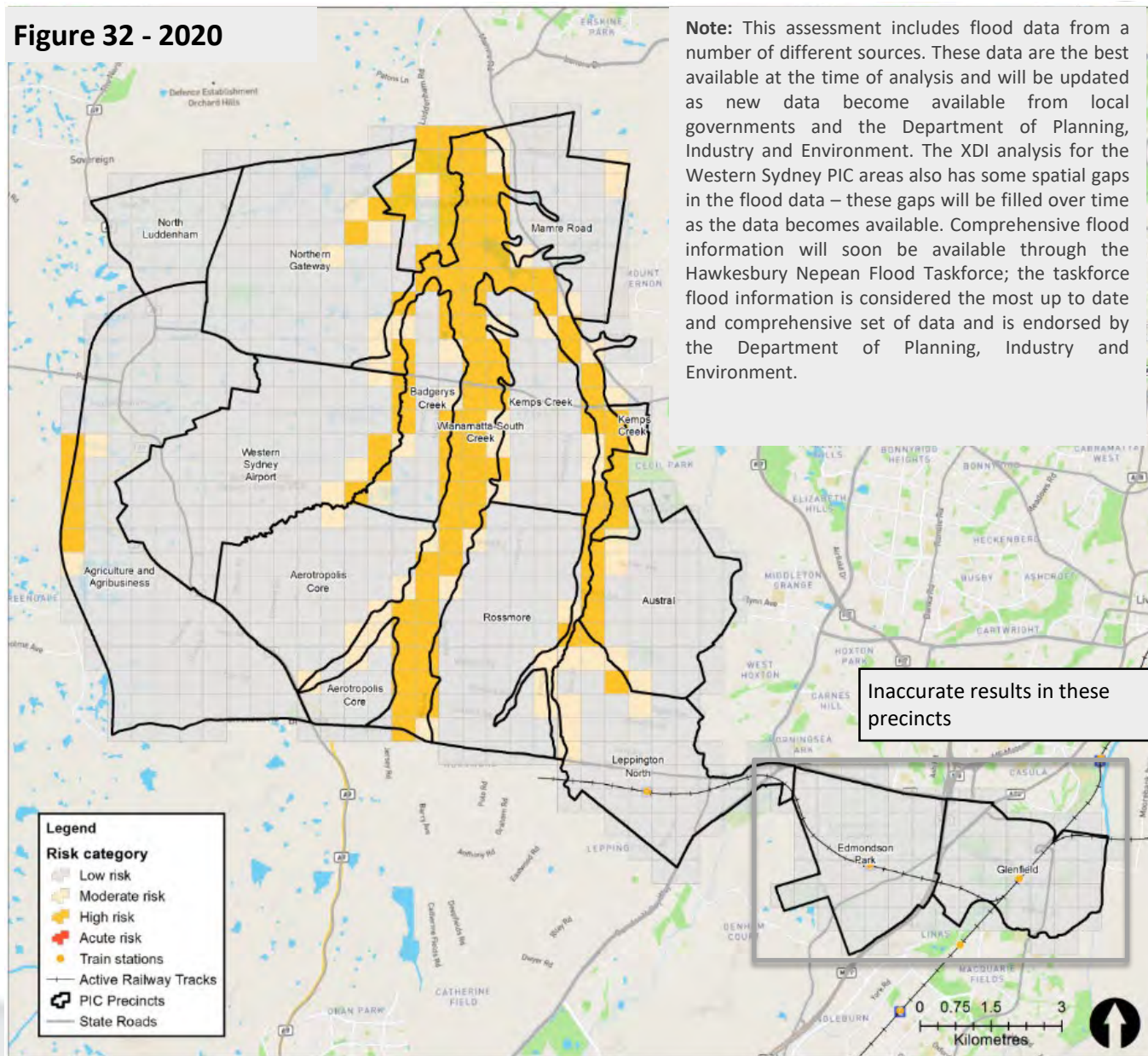


Figure 33 - 2050

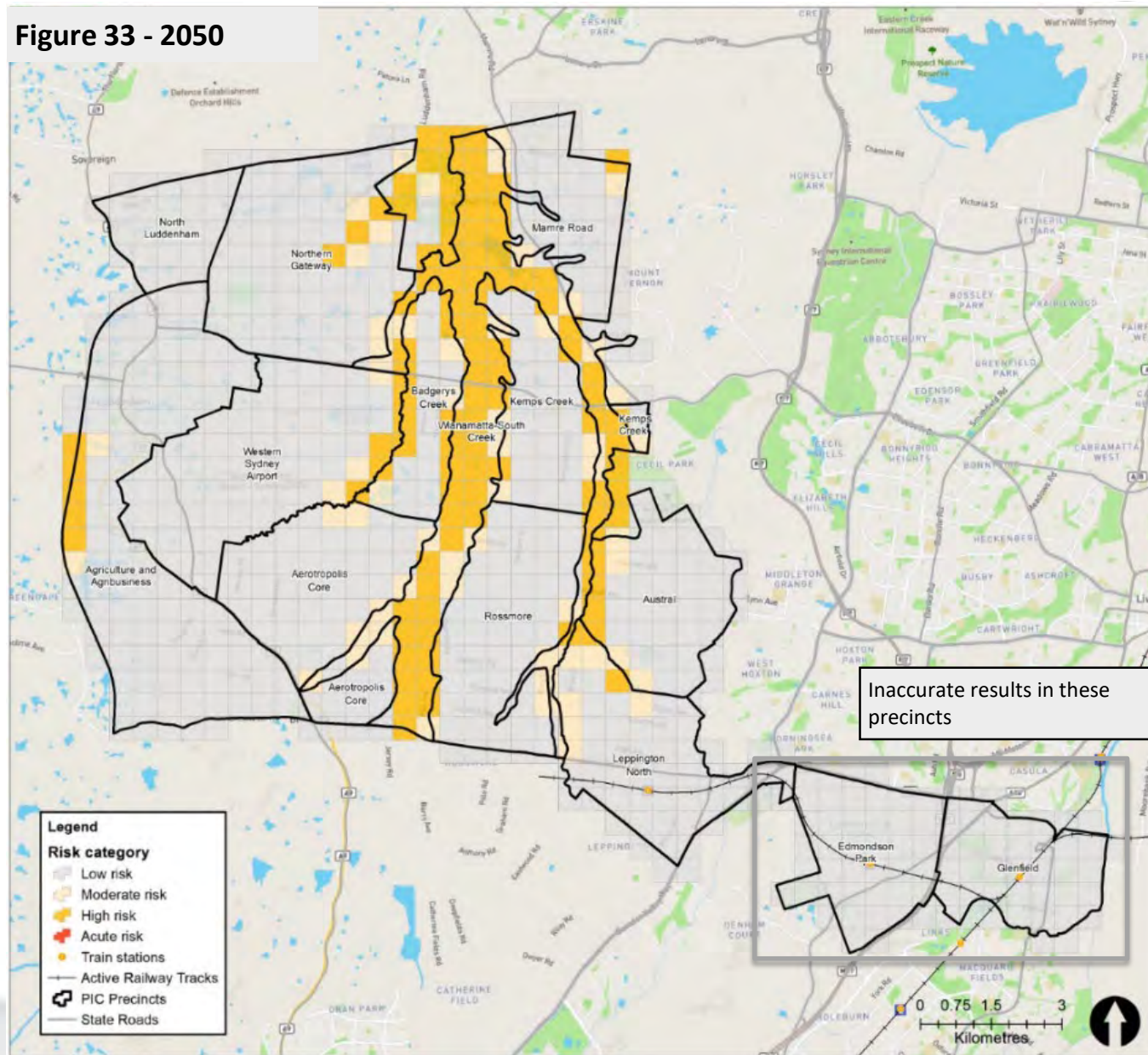
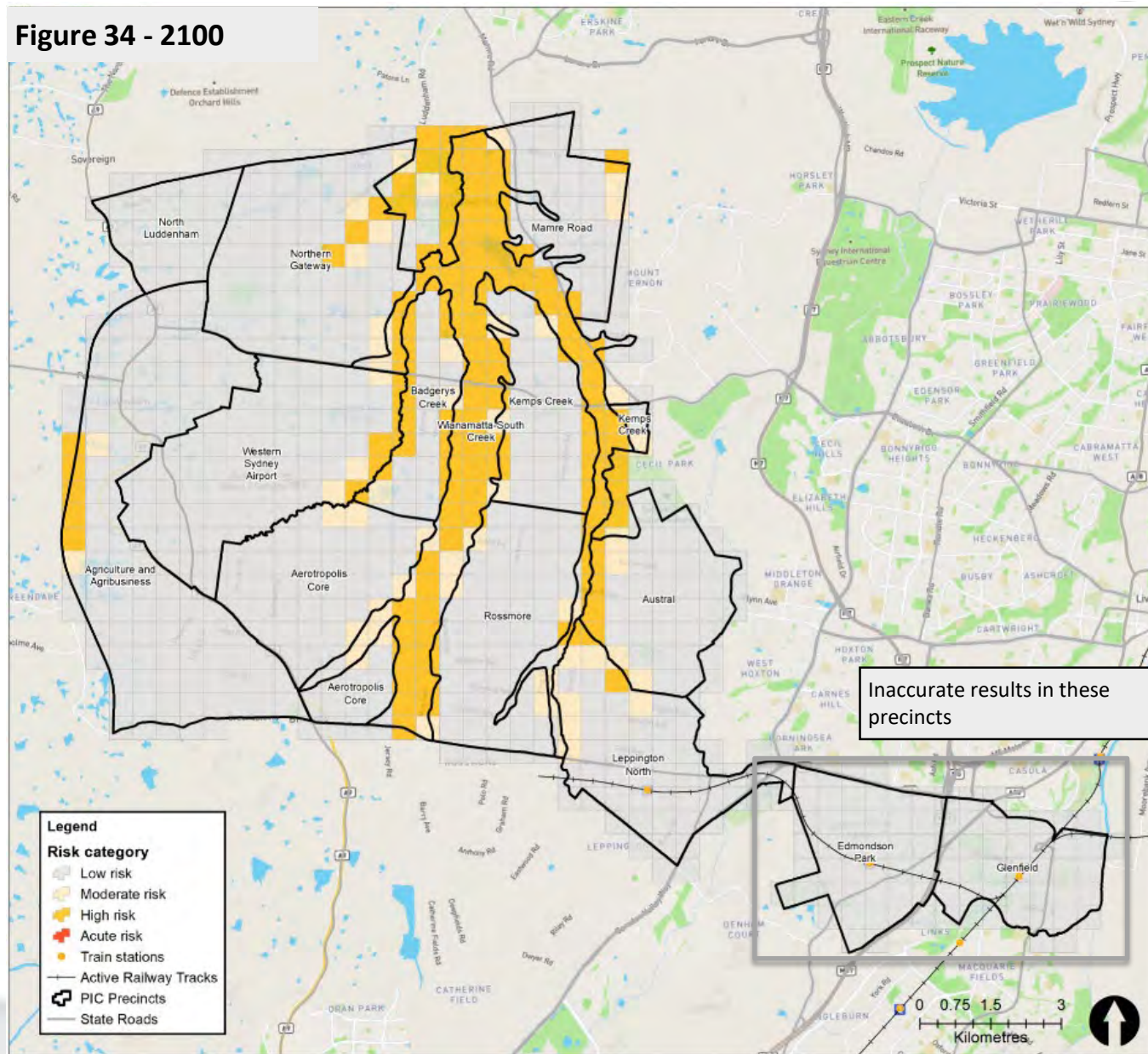




Figure 34 - 2100



# Risk to roads – soil movement

Figure 35 shows the projected average value at risk (VAR%) across all non-adapted roads within the study. The lowest VAR% for soil movement was 0% and the highest was 0.22%.

In the short term, the average VAR% increases from 2020 to 2030, then decreases yearly to 2100. This trend in soil movement is sometimes seen in the NARClIM data for parts of NSW. In the long term, average VAR% from soil movement decreases from 0.16% in 2020 to 0.14% in 2100, a 12.5% decrease. This equates to a low risk for damage to roads from soil movement across WSAGA.

Figures 36, 37 and 38 show the risk rating across the area. As the area is predominantly at a low risk, the category has been further broken down to show variation across the area. Table 8 shows land area at risk in each category over time.

For a default replacement cost of \$2 million for a generic road, the average technical insurance premium for soil movement risk would be \$3,200 in 2020 decreasing to \$2,800 in 2100. The impact varies by area as seen in the following maps.

Table 8 Hectares in each risk category over time – soil movement

Hectares in each risk category			
Risk level	2020	2050	2100
Acute	0	0	0
High	0	0	0
Moderate	0	0	0
Low	15531	15531	15531

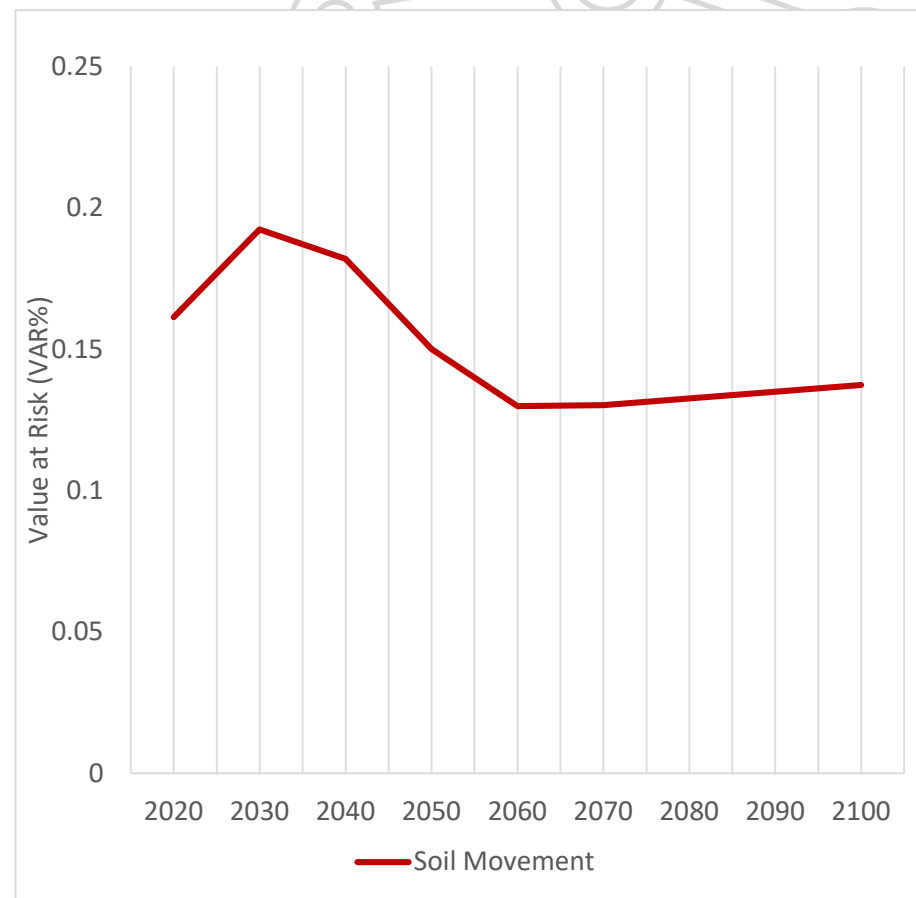


Figure 35 Average VAR% over time for soil movement for roads



Figure 36 - 2020

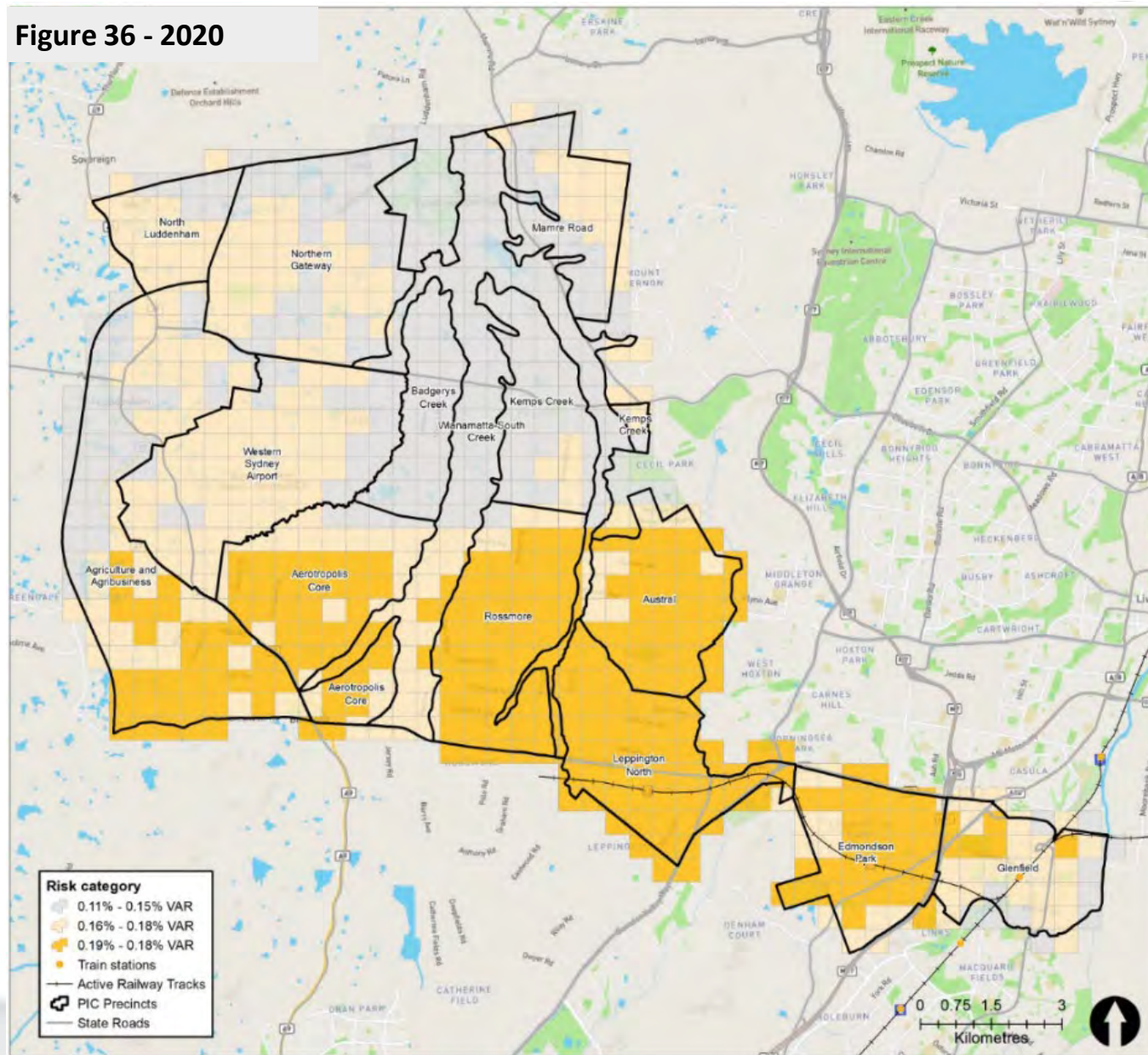




Figure 37 - 2050

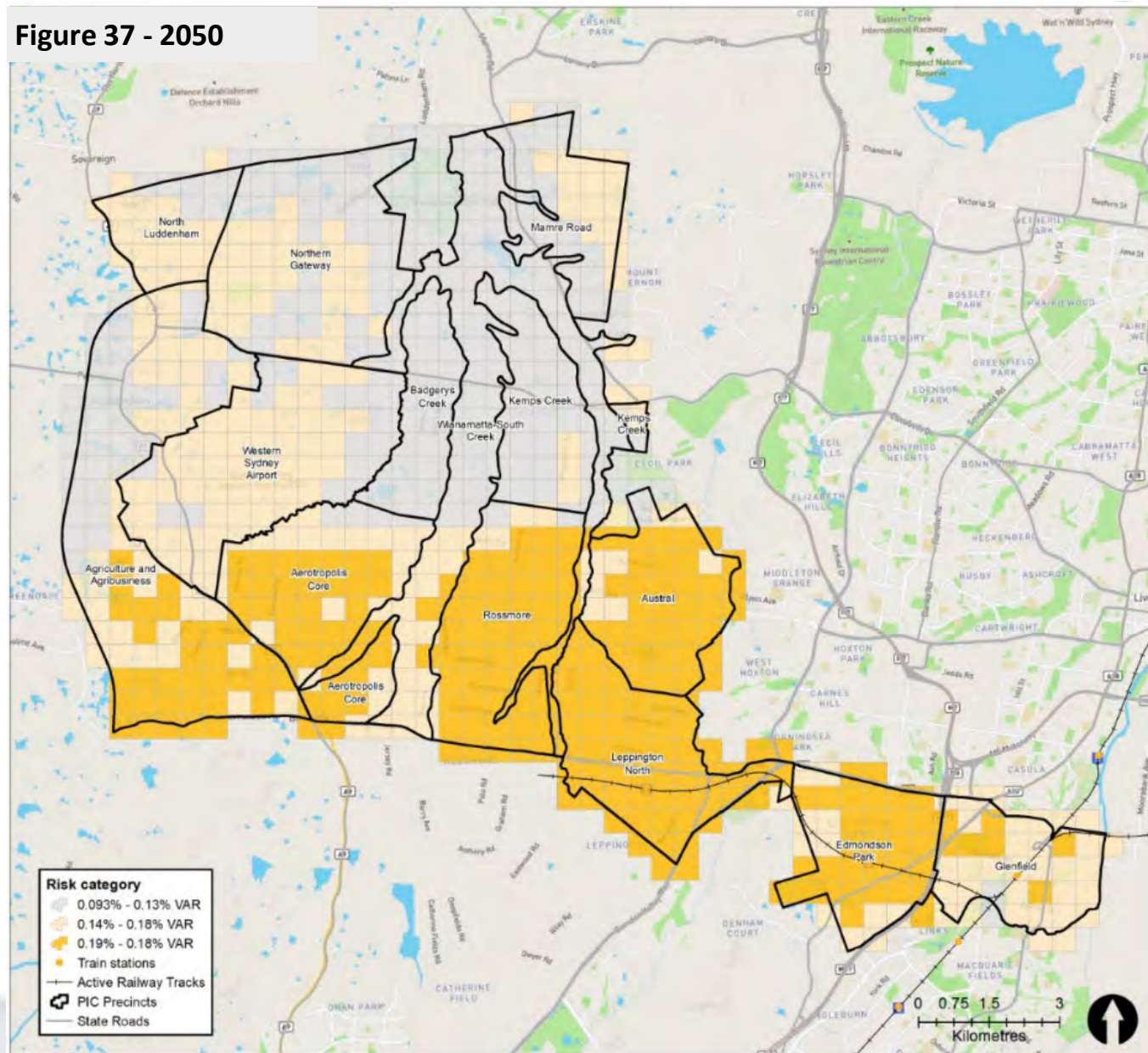
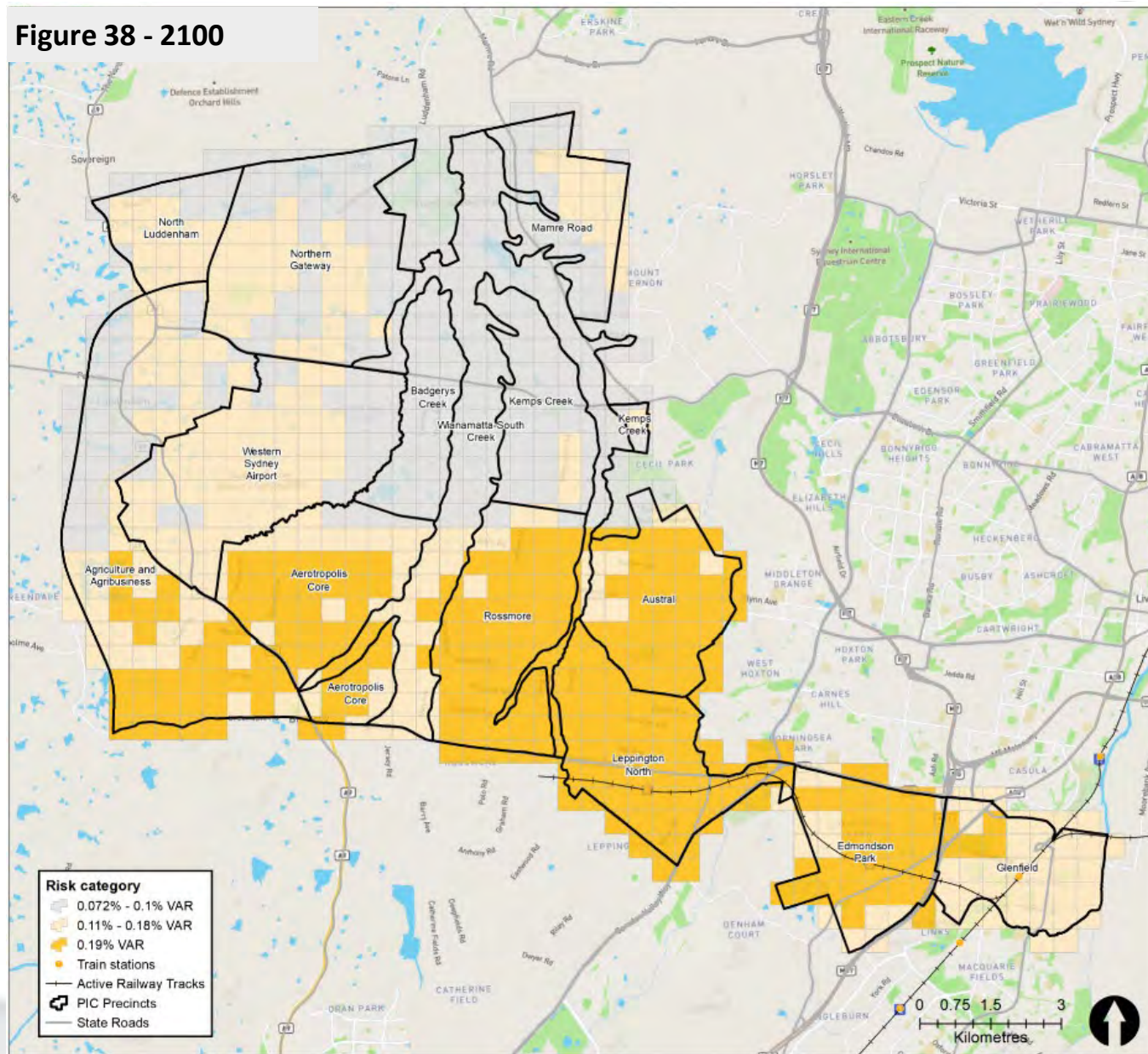


Figure 38 - 2100





# Conclusions

Key conclusions of the project to be considered in future planning include:

1. Consider location-specific extreme weather and climate change risks at the planning stage of all residential, commercial and infrastructure development.
2. Specify performance thresholds for the area that all new development will be required to meet or exceed over its design lifetime (typically 80 years). At a minimum, this should be full insurability for residential properties (i.e. VAR% < 1%) and high resilience for critical infrastructure (FP% < 0.1%).
3. Apply performance-based planning requirements to ensure that any development proposal demonstrates the ability to provide safe and insurable buildings and infrastructure. For example, ensure localised floor heights are sufficient to reduce the risk of flood waters entering the building to less than 1-in-200-year probability over the lifetime of the building.
4. Avoid locating essential and community infrastructure, such as transport hubs, schools or medical facilities in areas which may become difficult to access during events or which will be adversely affected by increasing risk, even if this infrastructure is designed to be resilient. In particular, flood and forest fire risks zones should be avoided.
5. Ensure general building code and planning requirements for active and high clay soils, as well as forest fire standards are stringently applied or exceeded.
6. At the planning stage, map the cross-dependent risks between planned critical supplies in the area to ensure that residents, businesses and other critical infrastructure is not overly dependent or adversely impacted by other infrastructure vulnerabilities (FP% < 0.1% with cross-dependency risk transfer included).



# APPENDICES

1. Grid mapping
2. Archetypes
3. Methodology
4. XDI tools

# Appendix 1: WSAGA Gridded buildings

15,531 points have been analysed across WSAGA area as the basis for the analysis

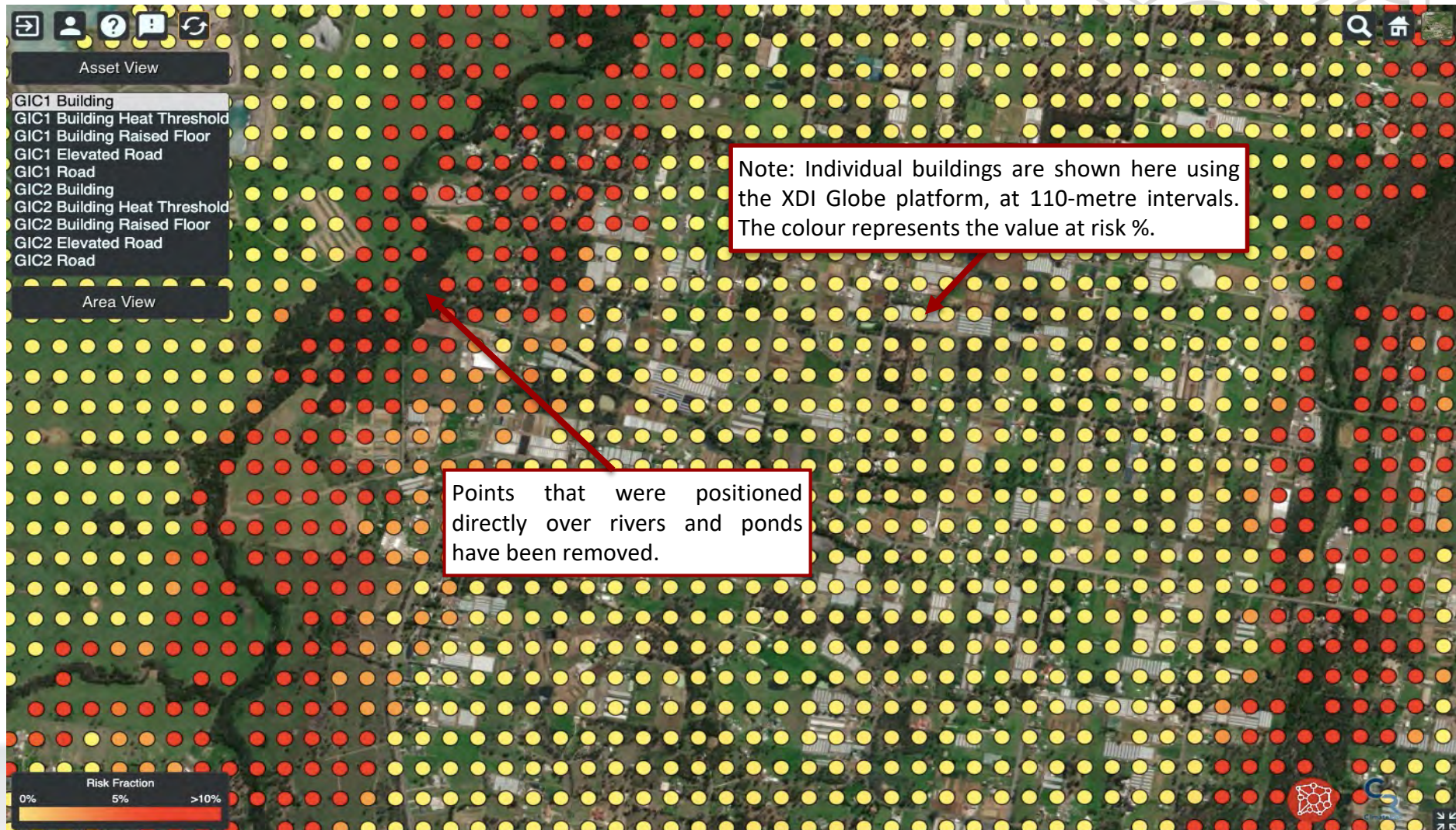


FIGURE 39 XDI Globe artificial asset grid  
xdi.systems



# Appendix 2: Building archetype – council building

The following archetype is a visual representation of a council building used by XDI. The archetype consists of relative information including elements that form the structure of the asset, which can then be analysed. For the following PIC analysis, the failure thresholds will change as part of the adaptation strategy.

## Archetype

Council building

## Replacement cost (no land)

\$2,000,000

## Elements

Civil, electrical, electronic, mechanical, information (telecommunications)

## Civil materials

Reinforced concrete, steel

## Failure thresholds

Floor height - 0 metres

Temperature threshold - 42°C

Wind threshold 1:500

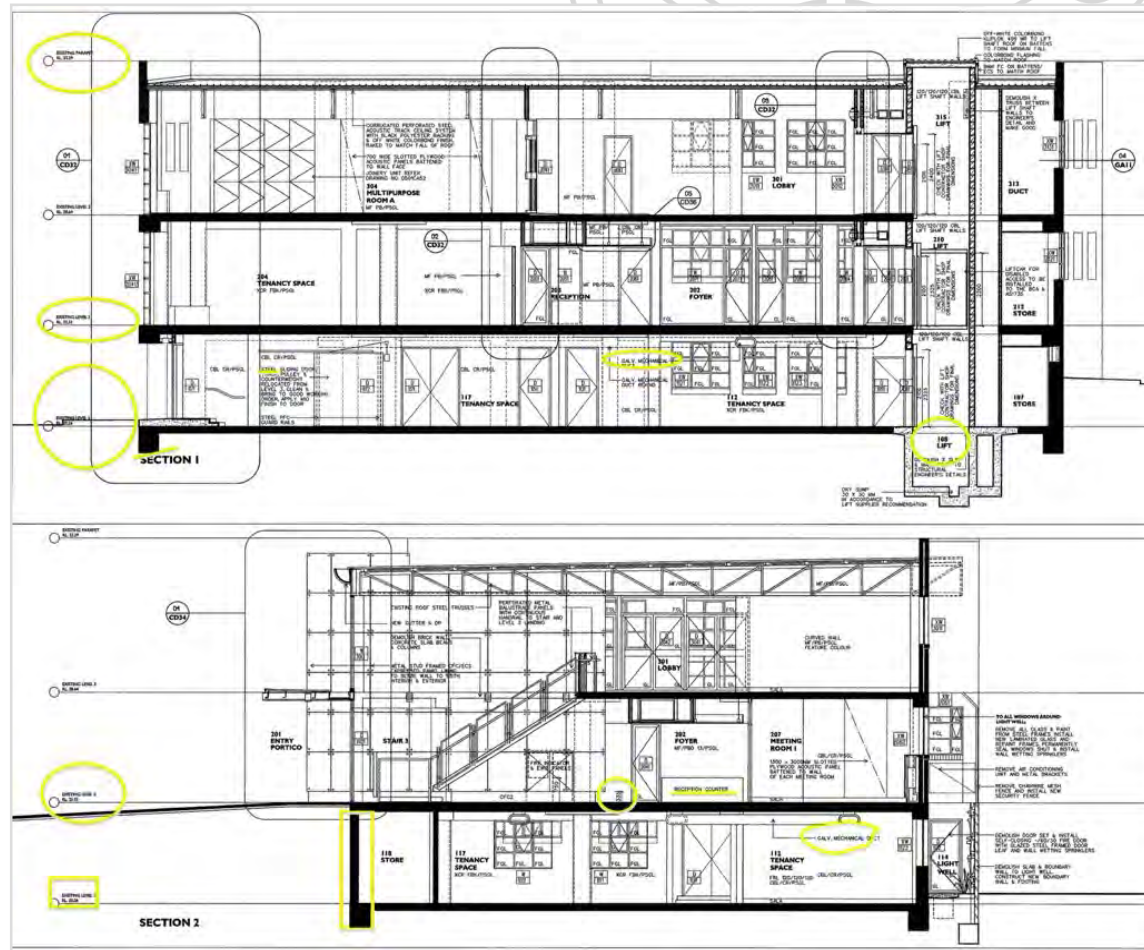


FIGURE 40 Council building archetype as-constructed diagram



# Adapted building archetype – council building

The following archetype is a visual representation of an adapted council building used by XDI. The archetype consists of relative information including elements that form the structure of the asset, which can then be analysed. Council building has a modified civil height of 0.5 metres and the temperature threshold has changed from 42°C to 45°C

## Archetype

Council building

## Replacement cost (no land)

\$2,000,000

## Elements

Civil, electrical, electronic, mechanical, information (telecommunications)

## Civil materials

Reinforced concrete, steel

## Failure thresholds

Floor height – 0.5 metres

Temperature threshold - 45°C

Wind threshold 1:500

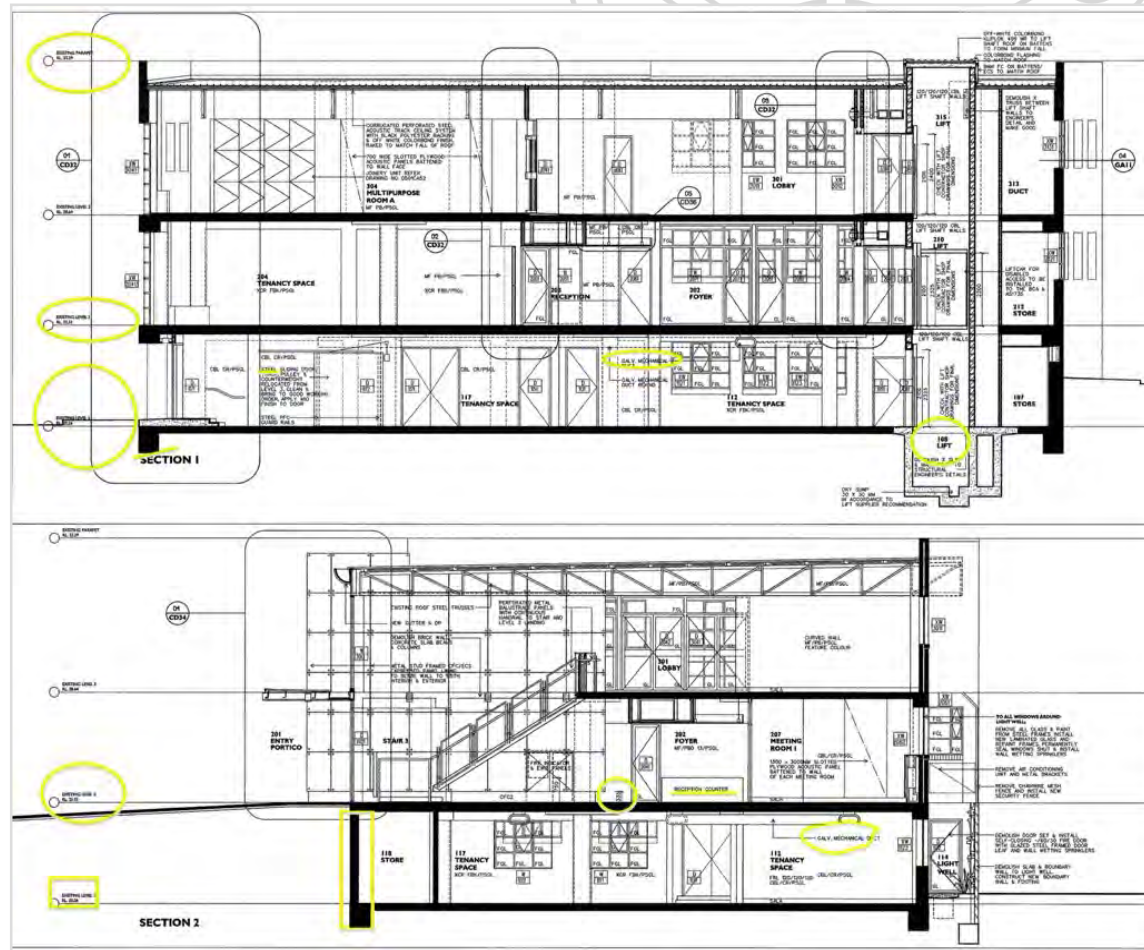


FIGURE 41 Adapted council building archetype as-constructed diagram

# Roads archetype – flexible pavement

The following archetype is a visual representation of the general build for a road used by XDI. The archetype consists of relative information including elements that form the structure of the asset, which can then be analysed. For the following PIC analysis, the failure thresholds will change as part of the adaptation strategy.

## Archetype

Flexible pavement

Replacement cost (no land)

\$2,000,000

## Elements

Civil

## Material

Dense grade asphalt, earth, reinforced concrete

## Failure thresholds

Road base height 0 m

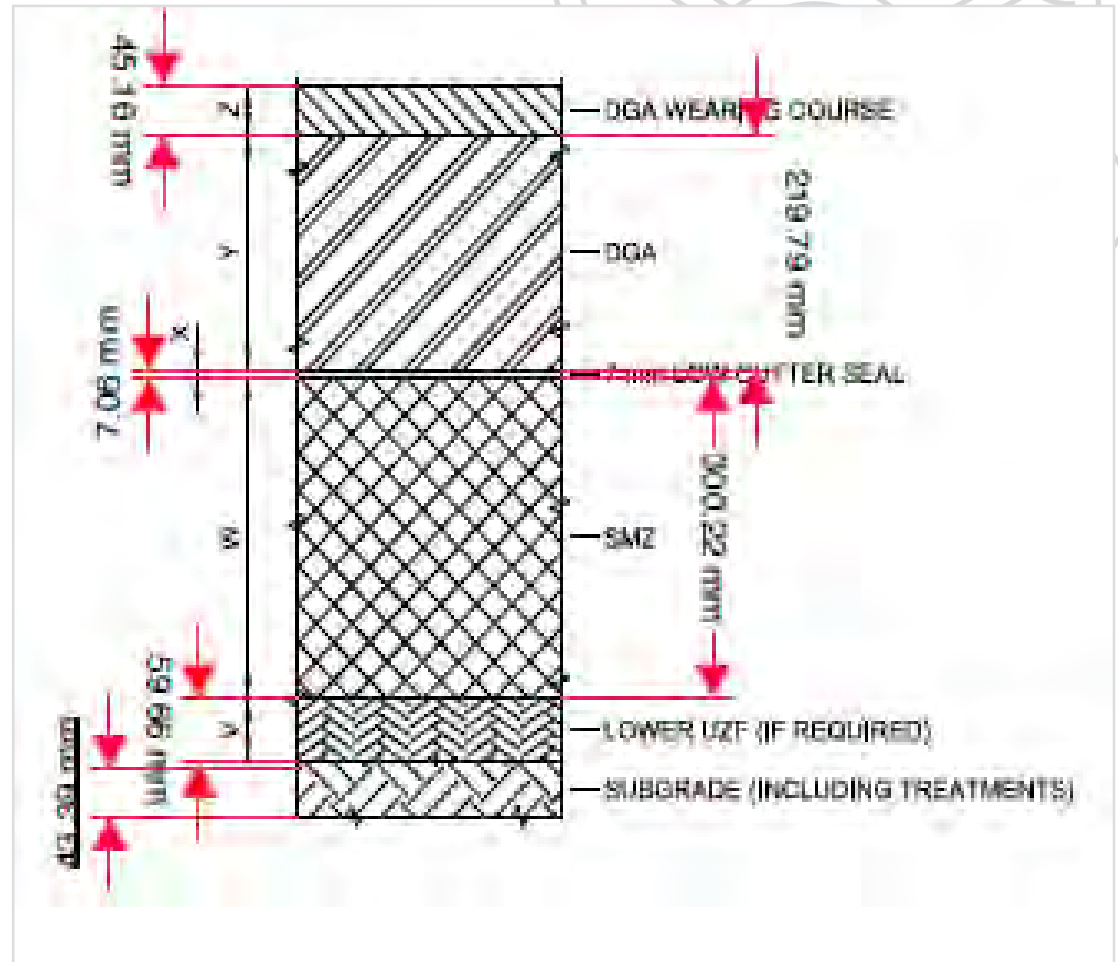


FIGURE 42 Road archetype as-constructed diagram

# Adapted roads archetype – flexible pavement

The following archetype is a visual representation of the specific build for an adapted road with a modified civil height of 0.5 metres compared to a previous general build of 0 metres. The archetype consists of relative information including elements that form the structure of the asset, which can then be analysed. For the following PIC analysis, the failure thresholds have changed for adapting to riverine flooding.

## Archetype

Modified flexible pavement

## Replacement cost (no land)

\$2,000,000

## Elements

Civil

## Material

Dense grade asphalt, earth, reinforced concrete

## Failure thresholds

Road base height 0.5 m

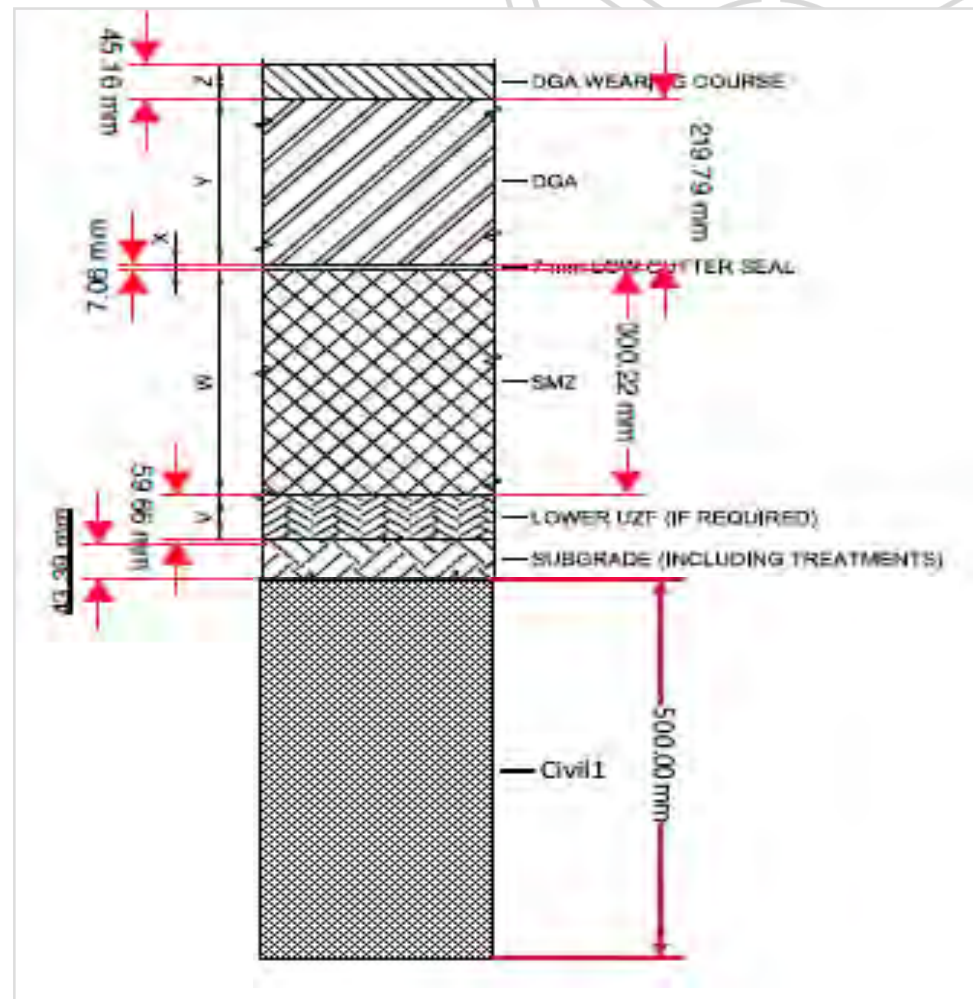


FIGURE 43 Adapted roads archetype as-construction diagram



# Appendix 3: Methodology

## CLIMATE RISK ENGINES

- The Climate Risk Engines are purpose built to compute hypothetical future risks to a modelled asset archetype designed to represent individual property and infrastructure assets. The system enables each such asset to be stress-tested against a wide range of extreme weather and extreme sea events typical of its location. A range of future-looking scenarios can be applied that are consistent with different greenhouse gas emission scenarios, atmospheric sensitivity, adaptation pathways, building standards and planning regimes.
- The Climate Risk Engines combine engineering analysis with statistical analysis of historical weather records and climate projections, and probabilistic methods for financial analysis of risk and value.

## CLIMATE CHANGE MODELS

- Changes in the composition of the atmosphere due to greenhouse gas emissions will change how the atmosphere and oceans behave. Therefore, the historical weather station statistics need to be adjusted to allow for climate change.
- The Climate Risk Engines have access to a large number of datasets from the Coupled Model Inter-comparison Project (CMIP) in which participant organisations model the atmosphere under various representative concentration scenarios (RCP). At a whole-of-atmosphere scale the general circulation models (GCMs) have a resolution of about 100km<sup>3</sup>.
- With downscaling, regional climate models (RCMs) include local topology and land surface information to provide weather parameters at higher spatial resolutions - between 5km<sup>3</sup> and 50km<sup>3</sup>.

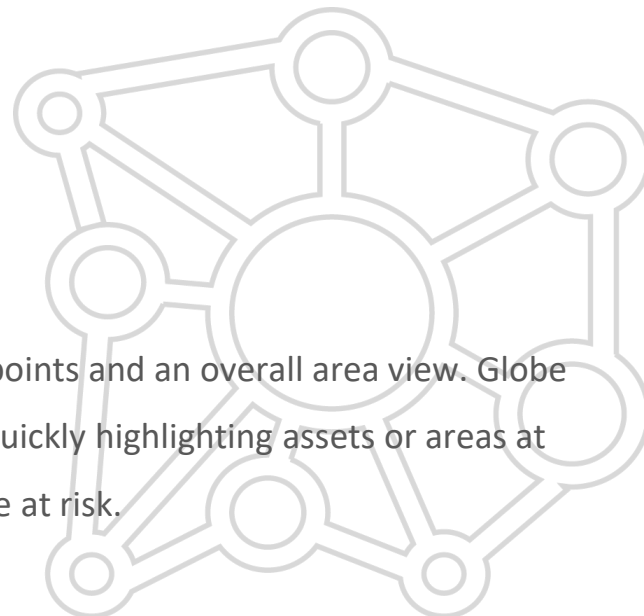
## MATHEMATICAL ANALYSIS

- The extreme weather and climate risks to an asset will depend on its exposure and vulnerability to each hazard, as well as the current and future severity and frequency of the hazard that may alter with climate change.

## A REPRESENTATIVE ASSET ARCHETYPE

- The system uses a synthetic representation of an asset that is based on nominal industry archetypes, but may include some customisation by the user. This representative asset type could be selected and tailored to represent a real asset at the same location or be created as an entirely hypothetical asset being placed in that location.

# Appendix 4: XDI tools



## XDI Globe | [globe.xdi.systems](https://globe.xdi.systems)

XDI Globe allows you to review your assets spatially, both as individual points and an overall area view. Globe assets have been pre-analysed for you. This enables an easy overview, quickly highlighting assets or areas at risk. You can also zoom in on individual assets to understand why they're at risk.

## AdaptInfrastructure | [adaptinfrastructure.com](https://adaptinfrastructure.com)

AdaptInfrastructure is the home of deeper analysis. Here you get to drive the analysis according to the information you need. You can specify inputs for deeper analysis in certain areas, and test adaptation options to help reduce the risk to your assets. You can compare the impact of different adaptation options to arrive at an adaptation pathway that suits your organisation and create a costed business case based on cost-benefit-analysis of the adaptation options.