

# Supplementary File - Flood risk assessment at the neighbourhood level using Spatially Adaptive Weighting Melbourne

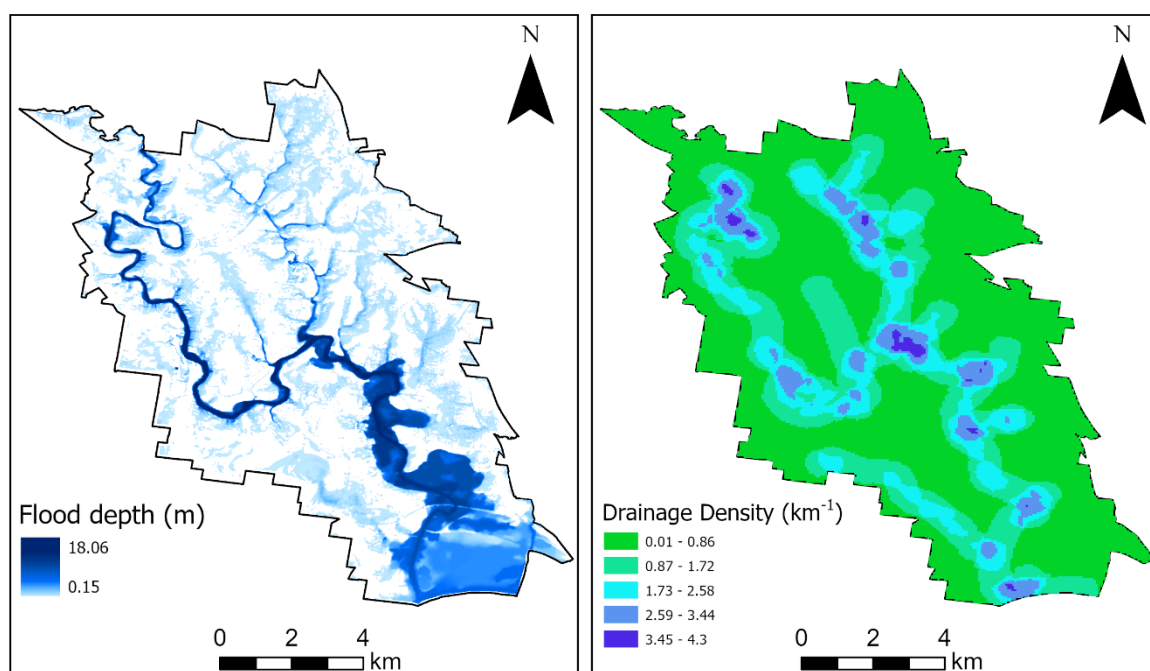
## 1 Datasets used

### Supplementary S1. Datasets used

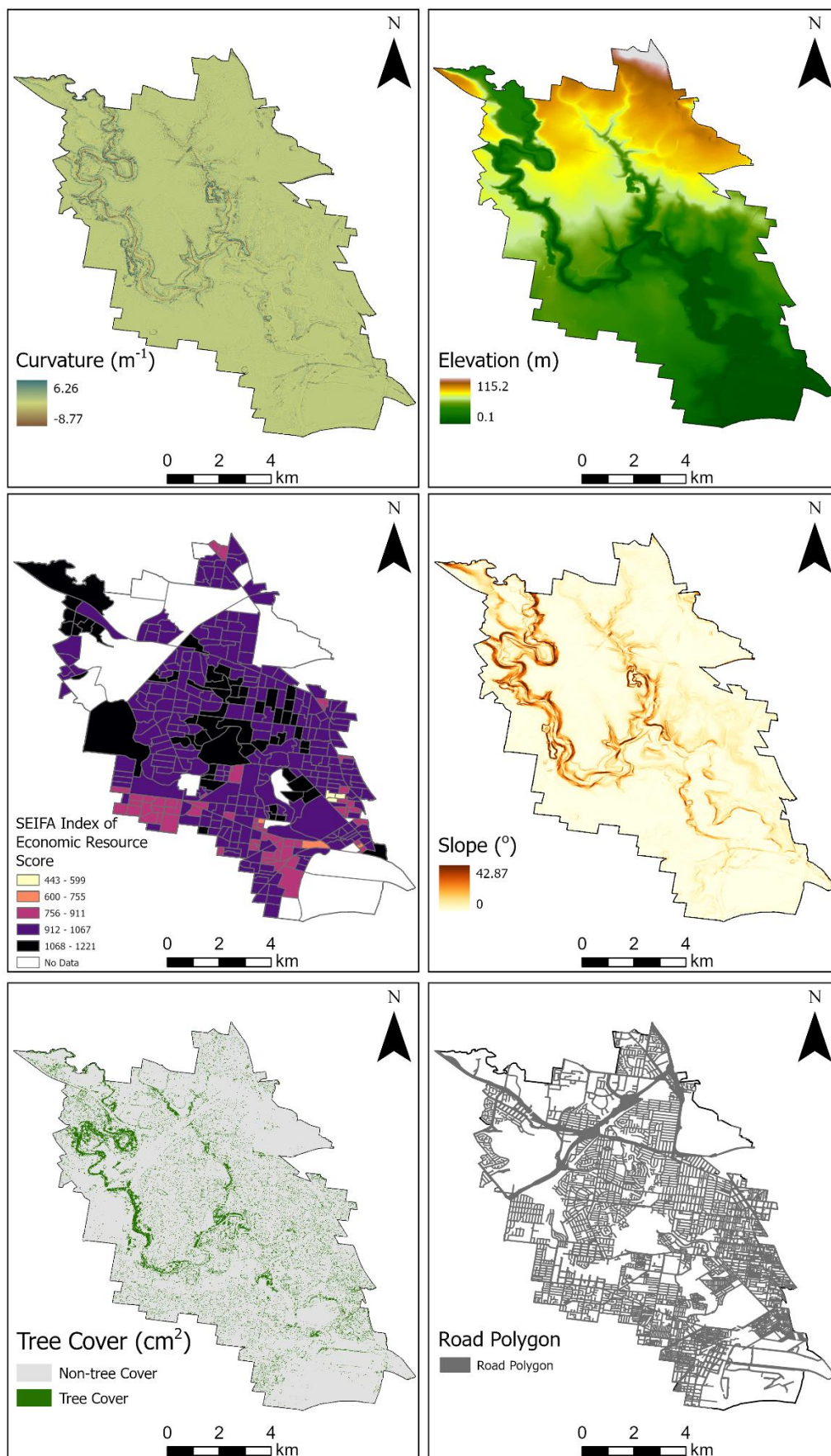
| Dataset                                                       | Format                   | Description                                                                                                                                                                           | Source             |
|---------------------------------------------------------------|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| DEM                                                           | Raster (10m resolution)  | Digital Elevation Model of the study area at a 10m resolution.                                                                                                                        | (DELWP 2025)       |
| Tree Extent                                                   | Raster (20cm resolution) | Binary raster that indicates the presence or absence of woody vegetation.                                                                                                             | (DELWP 2021)       |
| Maribyrnong and Moonee Valley Buildings                       | Polygon Shapefile        | Shapefiles of buildings within the Maribyrnong and Moonee Valley neighbourhoods.                                                                                                      | (Council n.d.)     |
| Road Casement                                                 |                          | Length and width of the roads.                                                                                                                                                        | (DTP 2022)         |
| Waterways                                                     |                          | Length and width of the river streams.                                                                                                                                                | (DTP 2024)         |
| Statistical Area Level 1 and Level 2 (SA1 and SA2) Boundaries |                          | Neighbourhood boundaries of the study area.                                                                                                                                           | (ABS 2021c, 2021d) |
| Global Building Shapefiles                                    |                          | Shapefiles of buildings outside the Maribyrnong and Moonee Valley study region.                                                                                                       | (Microsoft 2023)   |
| Rainfall (mm)*                                                | Excel Spreadsheet        | Hourly rainfall of the study area region obtained from the Maribyrnong River sensor.                                                                                                  | (Water n.d.)       |
| River Level (m)*                                              |                          | Hourly river level readings from the following sensors: Flemington, Southbank and Maribyrnong.                                                                                        | (Water n.d.)       |
| Flow Velocity (m <sup>3</sup> /s)*                            |                          | Hourly flow velocity readings from the following sensors: Flemington, Maribyrnong, Keilor East and Keilor.                                                                            | (Water n.d.)       |
| Index of Education and Occupation (SEIFA)                     |                          | Education, occupational, skills and qualification level of a community at an SA1 level.                                                                                               | (ABS 2023)         |
| Index of Economic Resources (SEIFA)                           |                          | Socioeconomic status related to income, housing and access to economic resources at an SA1 level.                                                                                     | (ABS 2023)         |
| AGE10P Age in Ten Year Groups (ABS)                           |                          | Population by person's age in 10-year age groups.                                                                                                                                     | (ABS 2021a)        |
| ASSNP Core Activity Need for Assistance (ABS)                 |                          | Population of people who need assistance with their day to day lives. What qualifies a person under this need is if they have a long-term health condition, disability or of old age. | (ABS 2021b)        |

\* Denotes data obtained from sensors. The data is hourly intervals using a temporal scale of 13<sup>th</sup> of October 2022 12AM until 15<sup>th</sup> of October 2022 11PM.

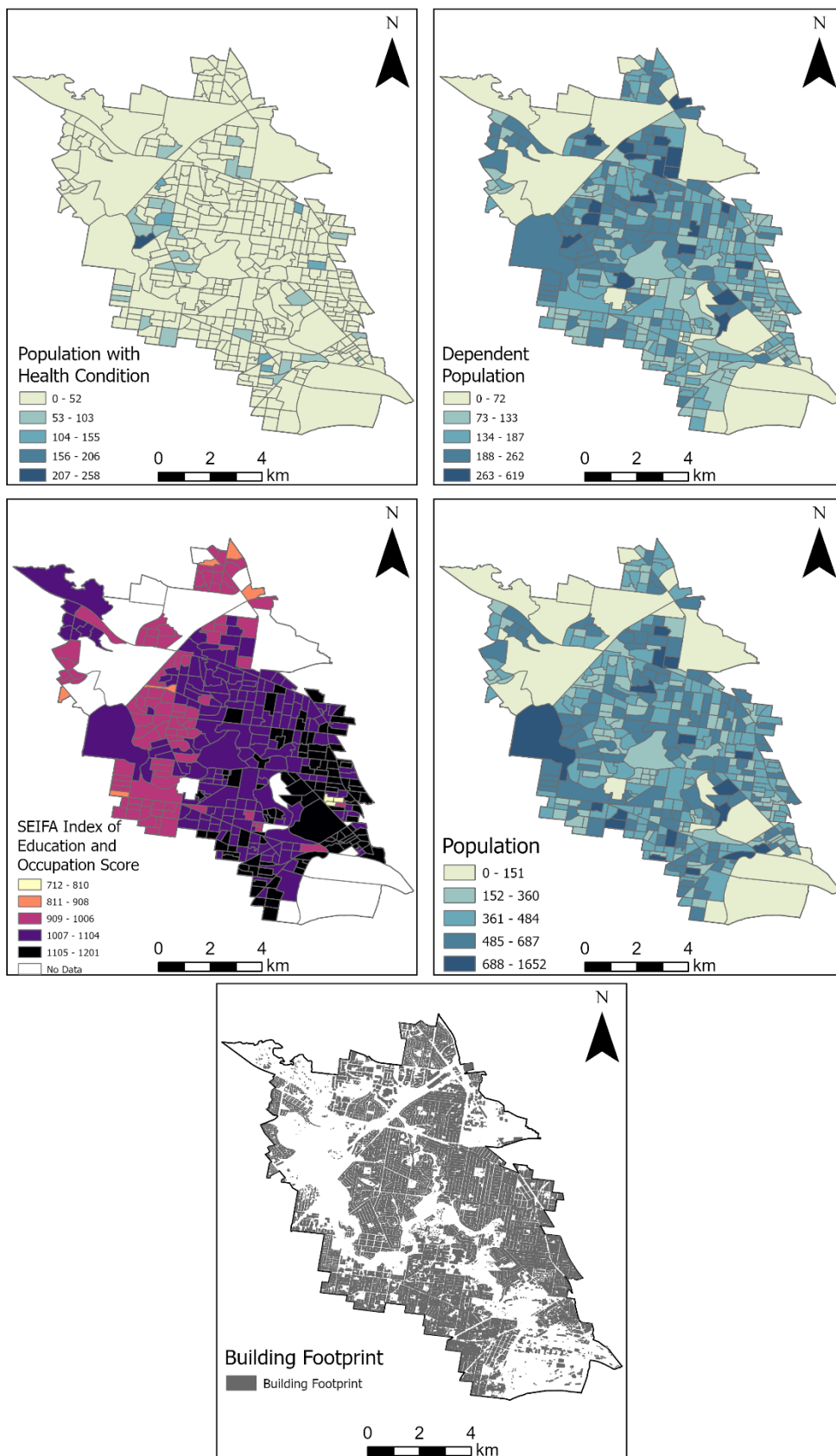
## 2 Raw Indicator data maps



**Supplementary S2** Raw hazard indicator maps.

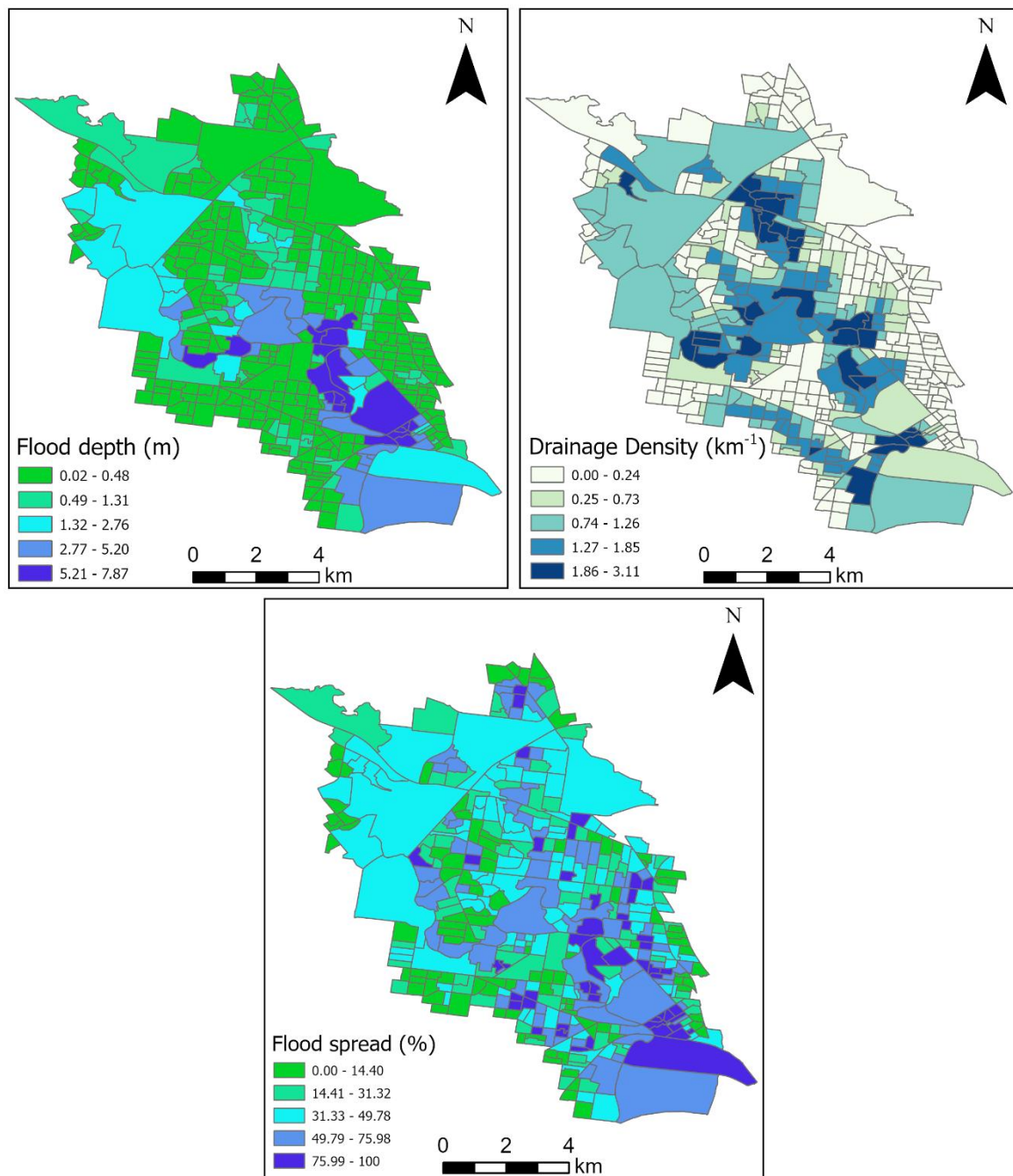


**Supplementary S3** Raw vulnerability indicator maps.

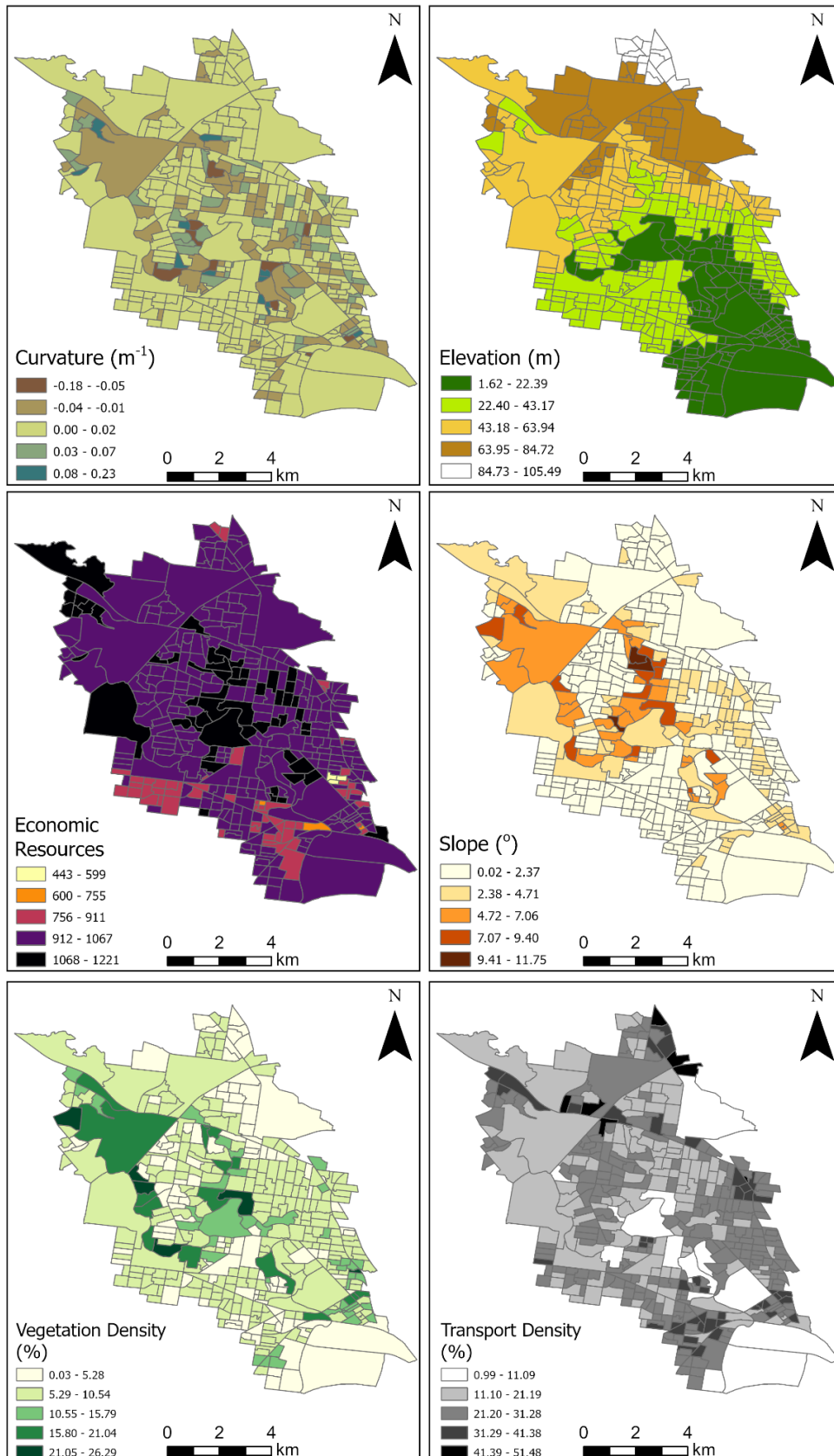


**Supplementary S4** Raw exposure indicator maps.

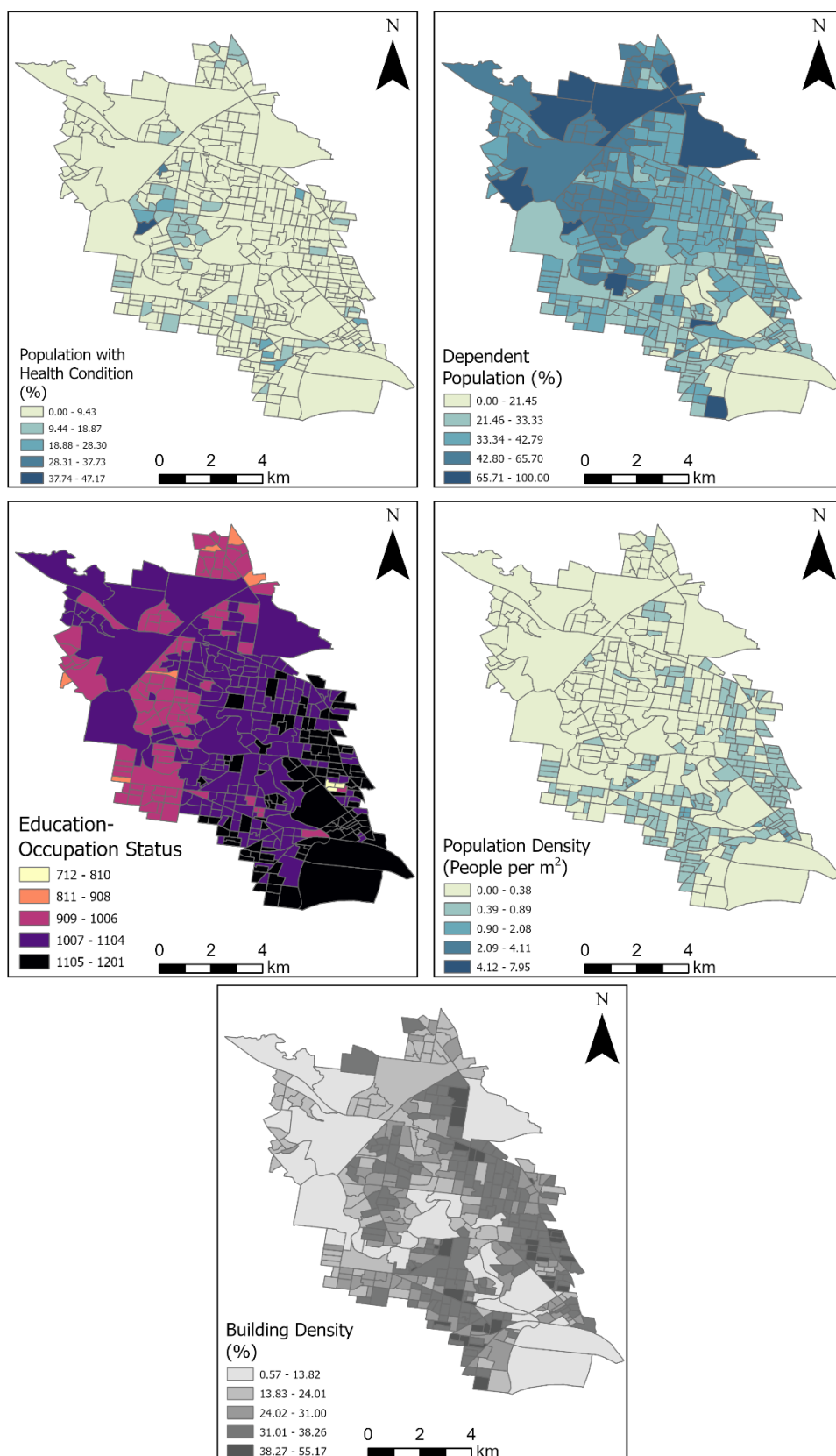
### 3 Processed Indicator data maps



**Supplementary S5** Processed hazard indicator data where both maps are measured in mean per SA1.

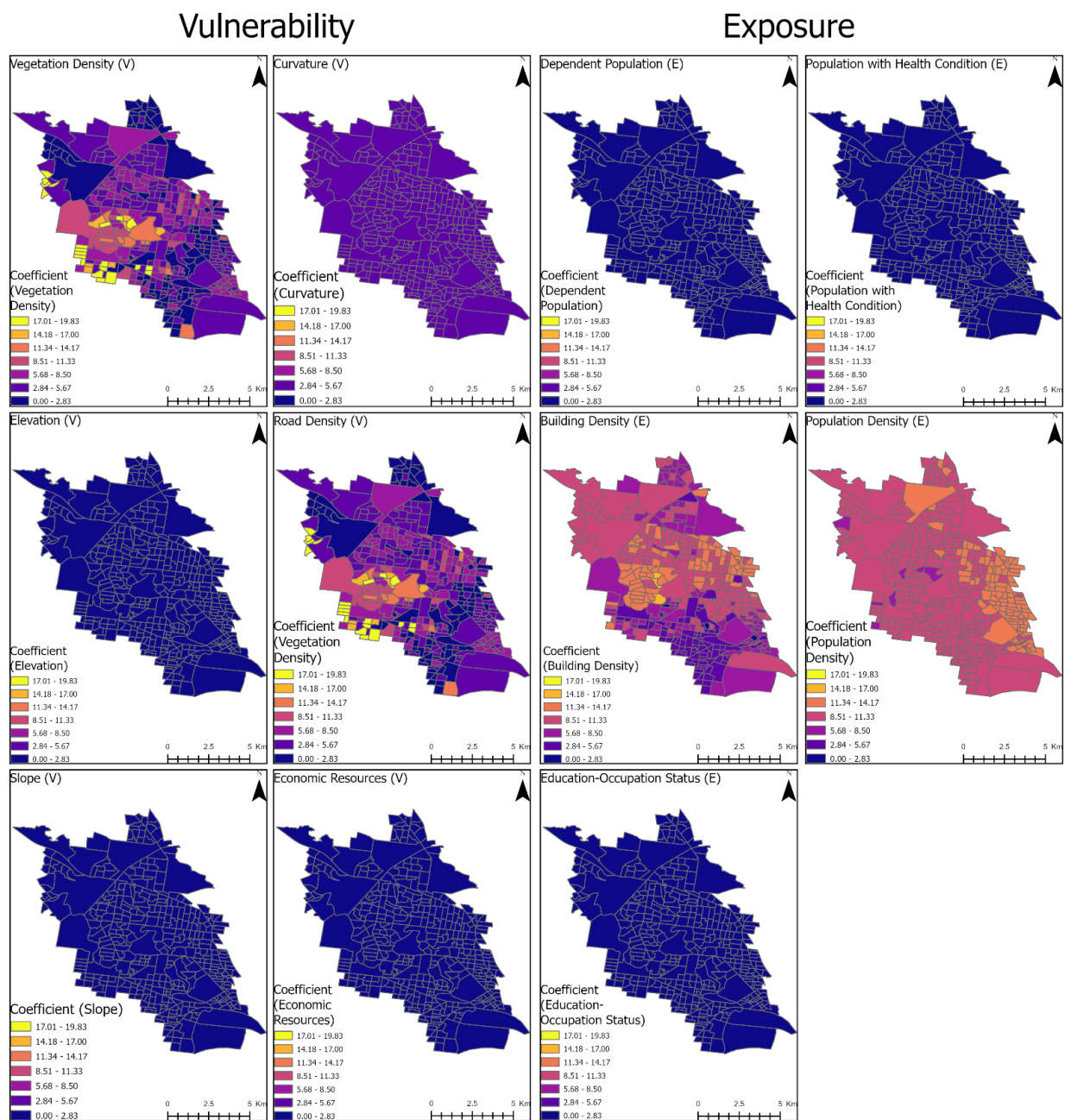


**Supplementary S6** Processed vulnerability index data. Slope, elevation and curvature are mean scores. Vegetation density and transport density are percentages per SA1. Economic Resources are SEIFA index scores.



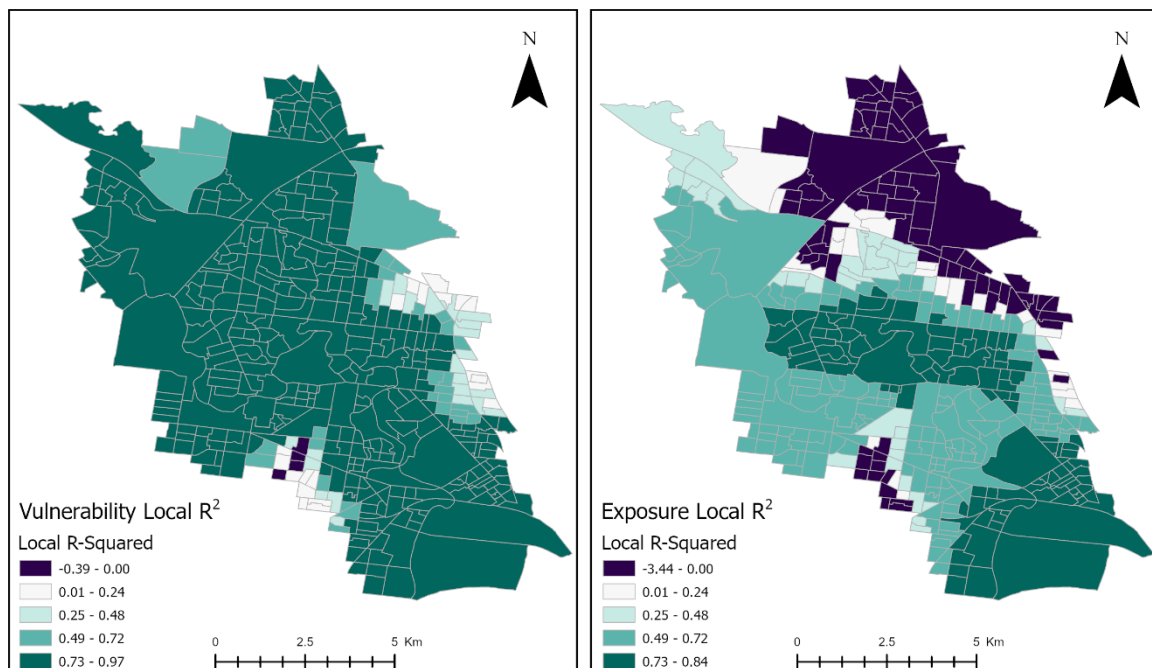
**Supplementary S7** Processed exposure index data. Population density are people per m<sup>2</sup>. Building density, dependent population and population with health condition are percentages per SA1. Education-Occupation Status are SEIFA index scores.

## 4 Map of MGWR-derived indicator coefficients



**Supplementary S8** Local coefficients of vulnerability and exposure indicators obtained from MGWR. The higher the coefficient values are, the stronger the relationship between flood spread and the independent variable is.

## 5 Local R-squared MGWR Maps



**Supplementary S9** Exposure and Vulnerability local R<sup>2</sup> maps.

## 6 MGWR Tables

**Supplementary S10** MGWR comparison for Exposure and Vulnerability.

| Statistics                                    | MGWR (Exposure)                                                                                                                   | MGWR (Vulnerability)                                                                             |
|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| R-Squared                                     | 0.7382                                                                                                                            | 0.8982                                                                                           |
| Adjusted R-Squared                            | 0.6885                                                                                                                            | 0.8676                                                                                           |
| AICc                                          | 1144.5038                                                                                                                         | 847.3039                                                                                         |
| Sigma-Squared                                 | 0.7611                                                                                                                            | 0.3235                                                                                           |
| Sigma-Squared MLE                             | 0.6400                                                                                                                            | 0.2490                                                                                           |
| Effective Degrees of Freedom                  | 346.4596                                                                                                                          | 317.0434                                                                                         |
| Optimal GWR Bandwidth: (K nearest neighbours) | 69                                                                                                                                | 57                                                                                               |
| Dependent Variable                            | Flood Spread                                                                                                                      |                                                                                                  |
| Explanatory Variable                          | Education-Occupation Status<br>Building Density<br>Population Density<br>Dependent Population<br>Population with Health Condition | Curvature<br>Economic Resources<br>Elevation<br>Slope<br>Transport Density<br>Vegetation Density |

**Supplementary S11** MGWR output for exposure

| Statistics                                       | GWR                                                                                                                               | MGWR      |
|--------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-----------|
| R-Squared                                        | 0.6551                                                                                                                            | 0.7382    |
| Adjusted R-Squared                               | 0.5485                                                                                                                            | 0.6885    |
| AICc                                             | 1288.7606                                                                                                                         | 1144.5038 |
| Sigma-Squared                                    | 1.1029                                                                                                                            | 0.7611    |
| Sigma-Squared MLE                                | 0.8431                                                                                                                            | 0.6400    |
| Effective Degrees of Freedom                     | 314.9477                                                                                                                          | 346.4596  |
| Optimal GWR Bandwidth: 69 (K nearest neighbours) |                                                                                                                                   |           |
| Dependent Variable                               | Explanatory Variable                                                                                                              |           |
| Flood Spread                                     | Education-Occupation Status<br>Building Density<br>Population Density<br>Dependent Population<br>Population with Health Condition |           |

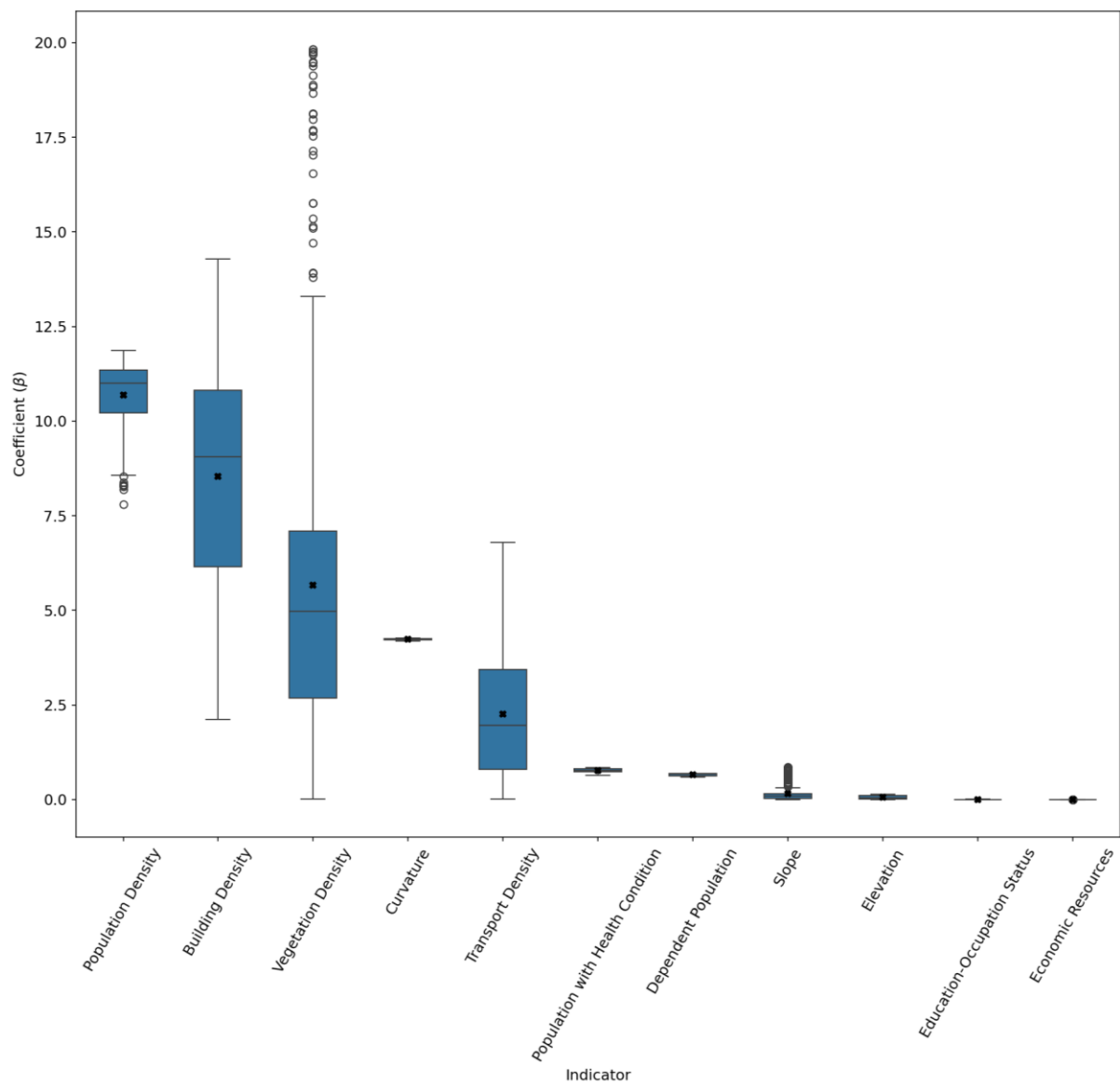
**Supplementary S12** MGWR output for vulnerability

| Statistics                                       | GWR                                                                                              | MGWR     |
|--------------------------------------------------|--------------------------------------------------------------------------------------------------|----------|
| R-Squared                                        | 0.8972                                                                                           | 0.8982   |
| Adjusted R-Squared                               | 0.8498                                                                                           | 0.8676   |
| AICc                                             | 876.3696                                                                                         | 847.3039 |
| Sigma-Squared                                    | 0.3669                                                                                           | 0.3235   |
| Sigma-Squared MLE                                | 0.2513                                                                                           | 0.2490   |
| Effective Degrees of Freedom                     | 282.2541                                                                                         | 317.0434 |
| Optimal GWR Bandwidth: 57 (K nearest neighbours) |                                                                                                  |          |
| Dependent Variable                               | Explanatory Variable                                                                             |          |
| Flood Spread                                     | Curvature<br>Economic Resources<br>Elevation<br>Slope<br>Transport Density<br>Vegetation Density |          |

**Supplementary S13** Optimal bandwidths per individual exposure and vulnerability indicator

| <b>Risk Component</b> | <b>Indicator</b>                 | <b>Optimal Number of Neighbors</b> |
|-----------------------|----------------------------------|------------------------------------|
| Exposure              | Education-Occupation Status      | 30                                 |
|                       | Building Density                 | 30                                 |
|                       | Population Density               | 412                                |
|                       | Dependent Population             | 412                                |
|                       | Population with health condition | 412                                |
| Vulnerability         | Economic Resources               | 30                                 |
|                       | Curvature                        | 412                                |
|                       | Elevation                        | 40                                 |
|                       | Slope                            | 39                                 |
|                       | Transport Density                | 30                                 |
|                       | Vegetation Density               | 32                                 |

## 7 MGWR Model Performance



**Supplementary S14** Boxplot of coefficients of exposure and vulnerability from MGWR. The line indicates the median value, and the 'X' value represents the mean within the dataset.

## 7 OLS Results

**Supplementary S15** Summary of OLS Results for Vulnerability and Exposure Indicators.

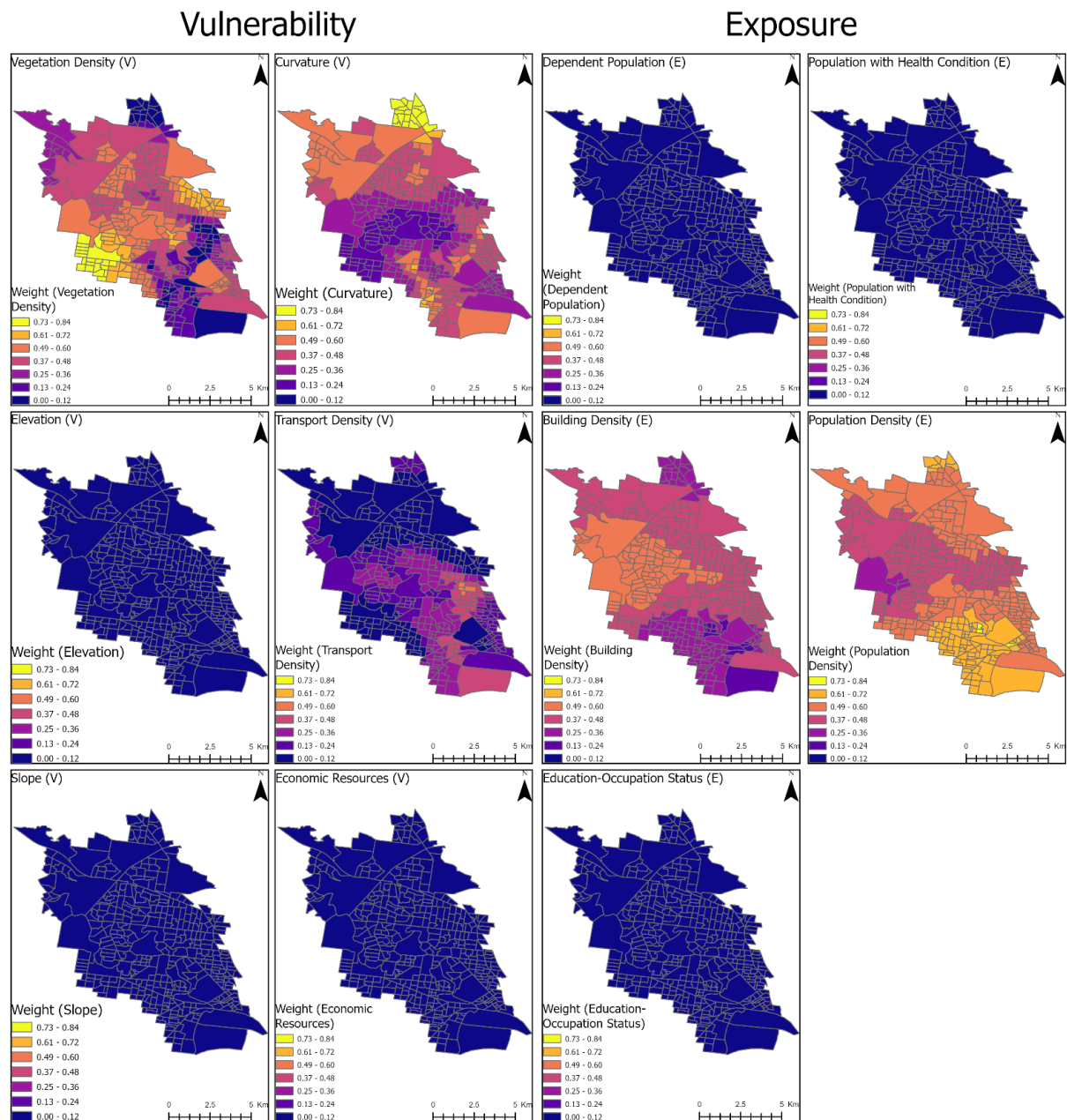
| Variable                                                             | Coefficient | StdError | t-Statistic | Probability | Robust_SE | Robust_t  | Robust_Pr | VIF      |
|----------------------------------------------------------------------|-------------|----------|-------------|-------------|-----------|-----------|-----------|----------|
| <b>Intercept</b>                                                     | 0.088751    | 0.786663 | 0.112819    | 0.910216    | 0.761050  | 0.116616  | 0.907209  | -----    |
| <b>SEIFA Economic Resources</b>                                      | 0.002130    | 0.000777 | 2.742012    | 0.006376*   | 0.000812  | 2.623249  | 0.009032* | 1.209845 |
| <b>Curvature_Mean</b>                                                | -10.511841  | 2.202083 | -4.773590   | 0.000004*   | 2.073241  | -5.070245 | 0.000001* | 1.038168 |
| <b>Elevation_Mean</b>                                                | -0.028856   | 0.002989 | -9.653968   | 0.000000*   | 0.004517  | -6.388071 | 0.000000* | 1.108818 |
| <b>Slope_Mean</b>                                                    | 0.084960    | 0.041170 | 2.063655    | 0.039677*   | 0.048716  | 1.743985  | 0.081928  | 1.780378 |
| <b>Road Density<br/>Decimal Percent<br/>per SA1 Road<br/>Polygon</b> | -2.795871   | 0.893487 | -3.129166   | 0.001892*   | 1.199438  | -2.330984 | 0.020230* | 1.073517 |
| <b>Tree Canopy<br/>Decimal Percent<br/>per SA1</b>                   | 4.076349    | 1.939405 | 2.101855    | 0.036172*   | 2.350895  | 1.733956  | 0.083694  | 1.585206 |

| Variable                                                             | Coefficient | StdError  | t-Statistic | Probability | Robust_SE | Robust_t  | Robust_Pr | VIF      |
|----------------------------------------------------------------------|-------------|-----------|-------------|-------------|-----------|-----------|-----------|----------|
| <b>Intercept</b>                                                     | -4.108449   | 1.217123  | -3.375543   | 0.000822*   | 0.978173  | -4.200124 | 0.000038* | -----    |
| <b>Building Density</b>                                              | -9.930839   | 0.785293  | -12.646033  | 0.000000*   | 1.071838  | -9.265246 | 0.000000* | 1.238819 |
| <b>SEIFA Education<br/>Occupational</b>                              | 0.007509    | 0.001074  | 6.990897    | 0.000000*   | 0.000981  | 7.650780  | 0.000000* | 1.489511 |
| <b>Disabled Population<br/>Decimal Percent</b>                       | 0.110537    | 1.615583  | 0.068419    | 0.945472    | 1.304134  | 0.084759  | 0.932481  | 1.238288 |
| <b>Population density<br/>decimal percent SA1<br/>people per sqm</b> | 22.944148   | 14.168794 | 1.619344    | 0.106162    | 8.939560  | 2.566586  | 0.010620* | 1.222376 |
| <b>Dependent population<br/>decimal percent 2021</b>                 | -0.560045   | 0.539284  | -1.038497   | 0.299647    | 0.509892  | -1.098362 | 0.272692  | 1.324153 |

**Supplementary S16** Moran's I results for exposure and vulnerability indicators.

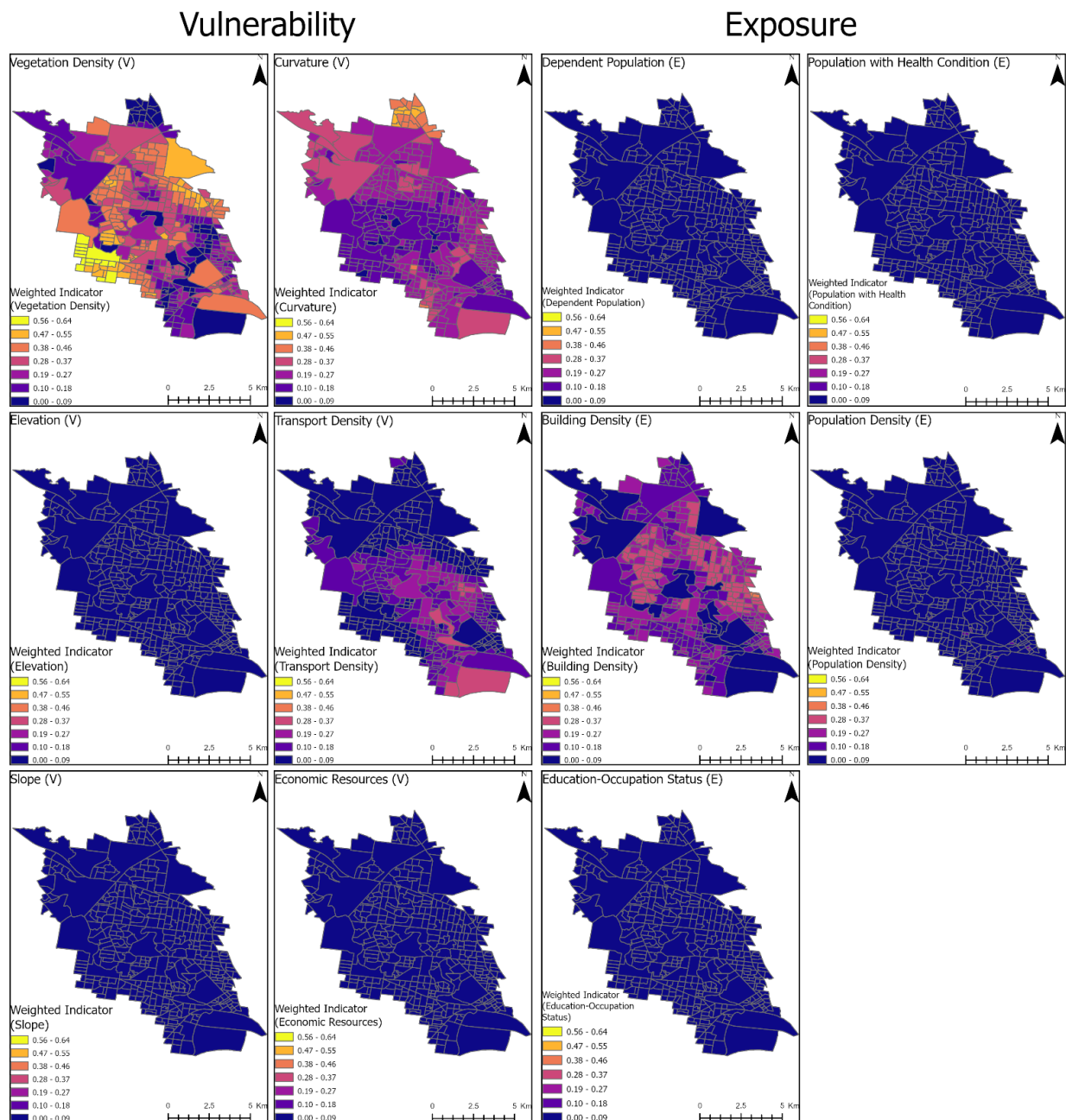
|                       | Exposure  | Vulnerability |
|-----------------------|-----------|---------------|
| <b>Moran's Index</b>  | -0.007689 | -0.027833     |
| <b>Expected Index</b> | -0.002433 | -0.002433     |
| <b>Variance</b>       | 0.000293  | 0.000289      |
| <b>z-score</b>        | -0.307271 | -1.493602     |
| <b>p-value</b>        | 0.758637  | 0.135280      |

## 8 Weights Maps



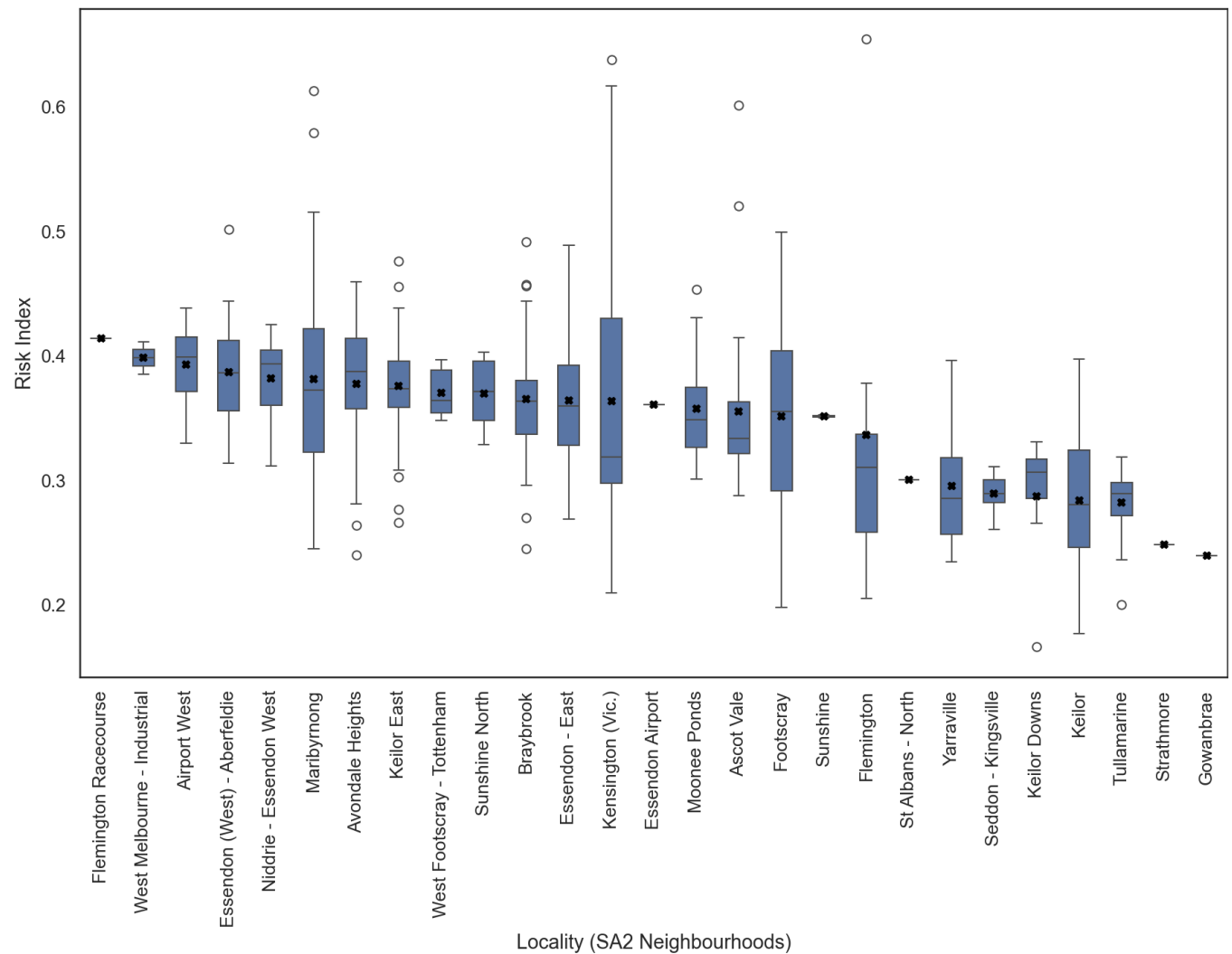
**Supplementary S17** Map of weights (calculated by obtaining coefficient per SA1 divided by sum of coefficients across all SA1 neighbourhoods).

## 9 Weighted Indicator Maps



**Supplementary S18** Maps of weighted indicators for exposure and vulnerability. These maps show the final weighted indicator values (weight  $\times$  normalised indicator) used to derive the exposure and vulnerability indices.

## S.10 Risk values throughout SA2 localities



**Supplementary S19** Boxplot of risk values throughout SA2 neighbourhoods. The X indicates the mean, and the horizontal line represents median value.

## 11 Mean risk and risk component values across SA2 localities

**Supplementary S20** Mean Hazard, Vulnerability, Exposure and Risk values across localities.

| <b>SA2 Neighbourhood</b>     | <b>SA1 Neighbourhoods in SA2</b> | <b>Mean Hazard</b> | <b>Mean Vulnerability</b> | <b>Mean Exposure</b> | <b>Mean Risk</b> |
|------------------------------|----------------------------------|--------------------|---------------------------|----------------------|------------------|
| Airport West                 | 17                               | 0.13               | 0.14                      | 0.44                 | 0.23             |
| Ascot Vale                   | 29                               | 0.14               | 0.22                      | 0.49                 | 0.28             |
| Avondale Heights             | 29                               | 0.16               | 0.30                      | 0.66                 | 0.37             |
| Braybrook                    | 35                               | 0.07               | 0.40                      | 0.51                 | 0.33             |
| Essendon - East              | 17                               | 0.07               | 0.18                      | 0.48                 | 0.24             |
| Essendon (West) – Aberfeldie | 31                               | 0.09               | 0.23                      | 0.52                 | 0.28             |
| Essendon Airport             | 1                                | 0.02               | 0.19                      | 0.35                 | 0.19             |
| Flemington                   | 8                                | 0.03               | 0.50                      | 0.49                 | 0.34             |
| Flemington Racecourse        | 1                                | 0.36               | 0.56                      | 0.00                 | 0.31             |
| Footscray                    | 40                               | 0.16               | 0.46                      | 0.41                 | 0.34             |
| Gowanbrae                    | 1                                | 0.00               | 0.05                      | 0.42                 | 0.16             |
| Keilor                       | 19                               | 0.07               | 0.11                      | 0.37                 | 0.18             |
| Keilor Downs                 | 7                                | 0.04               | 0.12                      | 0.37                 | 0.18             |
| Keilor East                  | 36                               | 0.07               | 0.13                      | 0.54                 | 0.25             |
| Kensington (Vic.)            | 22                               | 0.25               | 0.81                      | 0.32                 | 0.46             |
| Maribyrnong                  | 32                               | 0.20               | 0.47                      | 0.43                 | 0.37             |
| Moonee Ponds                 | 20                               | 0.08               | 0.19                      | 0.53                 | 0.27             |
| Niddrie - Essendon West      | 17                               | 0.17               | 0.14                      | 0.46                 | 0.26             |
| Seddon - Kingsville          | 8                                | 0.05               | 0.27                      | 0.37                 | 0.23             |
| St Albans - North            | 1                                | 0.00               | 0.14                      | 0.43                 | 0.19             |
| Strathmore                   | 1                                | 0.01               | 0.04                      | 0.29                 | 0.11             |
| Sunshine                     | 2                                | 0.01               | 0.42                      | 0.58                 | 0.33             |
| Sunshine North               | 6                                | 0.03               | 0.36                      | 0.60                 | 0.33             |
| Tullamarine                  | 17                               | 0.05               | 0.05                      | 0.34                 | 0.14             |
| West Footscray – Tottenham   | 6                                | 0.06               | 0.76                      | 0.40                 | 0.41             |
| West Melbourne – Industrial  | 2                                | 0.25               | 0.75                      | 0.11                 | 0.37             |
| Yarraville                   | 7                                | 0.02               | 0.30                      | 0.39                 | 0.24             |

## 12 Detailed explanation of indicator selection and justification

**Supplementary S21** Explanation of indicators. The (+) next to the indicator means higher values or presence increases risk. The (-) means lower values or presence increases risk.

| Flood Risk Components | Indicator (How they are measured locally)          | Justification and Influence on Flood Risk                                                                                                                                                                        | Formulas                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Dataset used                                                                                            |
|-----------------------|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Hazard                | (+) Flood depth (m)<br>(Mean per SA1)              | HEC-RAS-derived depth incorporates terrain, rainfall and flow conditions. Greater depth increases inundation severity, property damage and mortality risk (Ajtai et al. 2023; Huu Duy et al. 2024; Yilmaz 2022). | <p>Mass conservation equation for unsteady flow:</p> $\frac{\partial H}{\partial t} - \nabla \cdot \frac{(R(H))^{\frac{5}{3}}}{n \nabla H ^{\frac{1}{2}}} \nabla H + q = 0$ <p><math>V</math> is the velocity of the vector, <math>R</math> is the hydraulic radius, <math>q</math> is a source/sink flux term, <math>n</math> is the Manning's roughness coefficient, <math>\nabla</math> is the divergence, <math>\nabla H</math> is the surface elevation gradient, <math>\frac{\partial H}{\partial t}</math> is the time rate of change of the water surface elevation.</p> | 10 m DEM (DELWP 2025); hourly rainfall, river level and flow velocity data (Water n.d.)                 |
|                       | (+) Flood spread (Above 15cm depth)<br>(% per SA1) | Represents the proportion of each SA1 affected by potentially hazardous inundation. The 0.15 m threshold reflects the depth at which vehicles may begin to float (SES 2022).                                     | $Spread \text{ per } SA1 = \frac{Flooded \text{ area}_{SA1}}{Total \text{ area}_{SA1}}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                         |
|                       | (+) Drainage Density (km-1)<br>(Mean per SA1)      | Higher drainage density can increase runoff concentration and flood susceptibility (Roy et al. 2021).                                                                                                            | $Drainage \text{ density} = \frac{Stream \text{ length } (km)}{Total \text{ Study Area } (km^2)}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>DEM Raster 10m:</b><br>Processing channels and streams from DEM to compute drainage density per SA1. |

|                      |                                                                       |                                                                                                                                                 |                                                                                                                              |                                                  |
|----------------------|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|
| <b>Vulnerability</b> | (-) Slope (°)<br>(Mean per SA1)                                       | Terrain slope controls runoff direction and velocity; flatter areas are more susceptible to water accumulation (Huu Duy et al. 2024).           | $Slope(^{\circ}) = ATAN \left( \sqrt{\left(\frac{dz}{dx}\right)^2 + \left(\frac{dz}{dy}\right)^2} \right) * \frac{180}{\pi}$ | <b>10m DEM raster:</b><br>DEM-derived slope.     |
|                      | (-) Elevation (m)<br>(Mean per SA1)                                   | Lower-lying areas are more susceptible to water accumulation and prolonged inundation (Yilmaz 2022; Zhang et al. 2020).                         | N/A                                                                                                                          | <b>10m DEM raster:</b><br>DEM-derived elevation  |
|                      | (-) Curvature (°)<br>(Mean per SA1)                                   | Curvature influences runoff convergence, direction and velocity, affecting local flood impacts (Yilmaz 2022; Rashidi Shikhteymour et al. 2023). | $Curvature = -100 * \left( \left(\frac{d^2z}{dx^2}\right) + \left(\frac{d^2z}{dy^2}\right) \right)$                          | <b>10m DEM raster:</b><br>DEM-derived curvature. |
|                      | (-) Economic Resources<br>(SEIFA Index of Economic Resources Ranking) | I Lower access to economic resources reduces the capacity to prepare for, respond to and recover from flooding (ABS 2023; Luu et al. 2020).     | NA                                                                                                                           | <b>SEIFA IER 2021</b>                            |
|                      | (-) Vegetation density (m²) (%)<br>(% per SA1)                        | Greater vegetation cover promotes infiltration and water retention, reducing runoff and accumulation (Yilmaz 2022)..                            | $Vegetation\ density = \frac{Vegetation\ area}{Neighbourhood\ area}$                                                         | <b>20cm Vicmap<br/>Vegetation Tree Extent</b>    |
|                      | (-) Transport Density (m²)<br>(% per SA1)                             | Greater road-network availability provides more potential access and evacuation routes during flooding (Luu et al. 2020).                       | $Transport\ Density = \frac{Road\ area}{Neighbourhood\ area}$                                                                | <b>Vicmap Road<br/>Casements Shapefile</b>       |

|                 |                                                                                        |                                                                                                                                                                                                                                                      |                                                                                                                          |                                                    |
|-----------------|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| <b>Exposure</b> | (+) Population density<br>(Persons per square meter)                                   | Higher population density increases the number of people potentially exposed and places greater pressure on emergency response and recovery systems (Kelly et al. 2023; Ajtai et al. 2023).                                                          | $\text{Population density} = \frac{\text{Population per neighbourhood}}{\text{Area of neighbourhood}}$                   | <b>ABS AGE10P Age in Ten Year Groups</b>           |
|                 | (+) Dependent population (<18 or >65 years old in age)<br>(% per SA1)                  | Younger and older populations may have reduced mobility and require greater assistance during evacuation and emergency response (Ajtai et al. 2023; Feng et al. 2023).                                                                               | $\text{Dependent Population \%} = \frac{\text{Dependent population}}{\text{Total population}}$                           | <b>ABS AGE10P Age in Ten Year Groups</b>           |
|                 | (+) Population with Health Condition<br>(% per SA1)                                    | People requiring assistance because of long-term health conditions, disability or age may have reduced capacity to evacuate during floods (Rana et al. 2023)                                                                                         | $\text{Population with Health Condition (\%)} = \frac{\text{Population with Health Condition}}{\text{Total Population}}$ | <b>ABS ASSNP Core Activity Need for Assistance</b> |
|                 | (-) Education-Occupation Status (SEIFA Index of Education and Occupation 2021 Ranking) | Lower education and occupational status can affect access to information, interpretation of warnings and recovery capacity (Aroca-Jiménez et al. 2023; Armenakis et al. 2017). Population under 18 would be logically found in education facilities. | NA                                                                                                                       | <b>SEIFA IEO</b>                                   |
|                 | (+) Building density (% per SA1)                                                       | Higher building density increases the concentration of exposed structures and impervious surfaces, contributing to runoff and potential flood impacts..                                                                                              | $\text{Building density} = \frac{\text{Building area per neighbourhood}}{\text{Area of neighbourhood}}$                  | Building area / SA1 area.                          |

## References

- ABS (Statistics ABo) (2021a) *AGE10P Age in Ten Year Groups* [Excel Table], TableBuilder website, accessed 8th of August 2025. <https://www.abs.gov.au/statistics/microdata-tablebuilder/tablebuilder>
- ABS (Statistics ABo) (2021b) *ASSNP Core Activity Need for Assistance* [Excel Table], TableBuilder website, accessed 8th of August 2025. <https://www.abs.gov.au/statistics/microdata-tablebuilder/tablebuilder>
- ABS (Statistics ABo) (2021c) *Statistical Areas Level 1 - 2021 - Shapefile* [Shapefile], Digital boundary files: Australian Statistical Geography Standard (ASGS) Edition 3 website, accessed 23rd of January 2025. <https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/access-and-downloads/digital-boundary-files>
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