Public open space policy, supply and population health: a study of metropolitan Adelaide.

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ABSTRACT.

This thesis contributes to the discussion about how open space is defined, measured, and the current supply guidelines, and if proximity to open space is associated with self-rated health. Within the urban planning and health literature, there has been a refocusing on human health and planning outcomes, especially localised effects. Within this refocusing of human health and urban planning, open spaces are increasingly recognised as fundamental in promoting healthier communities.

The research design for this study employed mixed methods, involving qualitative and quantitative analysis to determine the origins of open space policy and supply standards and test for associations with population health within the study area of metropolitan Adelaide.

Semi-structured interviews were undertaken with urban planners from local and state government and the private sector, to determine how they and their organisations interpreted open space supply legislation and their knowledge of associations between open space supply and population health. The interviews revealed the absence of a clear definition of what is open space and how ineffective legislation has contributed to shortfalls in open space supply in residential areas.

The lack of a clear definition raised the question of how open space distribution is best represented spatially, and the necessity for a quality validated public open space spatial dataset representing partially or wholly vegetated open space that could be the single point of truth for urban planning and research. To develop a quality open dataset, four datasets representing open space were examined: the author's 2011 validated public open space (VPOS 2011) dataset; the Department of Planning Transport and Infrastructure (DPTI) digital cadastre database (DCDB) 2016; the Australian Bureau of Statistics (ABS) Meshblocks 2016; and the Public Sector Mapping Agencies (PSMA) Greenspace 2016. A desktop validation of the selected datasets utilised geographical information systems (GIS) software and high-resolution aerial imagery to develop a public open space dataset. Site visits of a representative 2016 sample confirmed the desk-top process accurately identified open space. This process generated the metropolitan Adelaide open space dataset used for this research (POS).

The POS distribution across the study area was investigated, and two open space supply standards, the percentage of area, and hectares per 1,000 population, were applied to three spatial units, the local government area (LGA), ABS postal area (POA) and ABS state

suburb (SSC). When applying the South Australian legislated 12.5% land area open space standard, 16% of the LGAs, 28% of the POAs and 41% of the SSCs were below the open space supply requirement. This demonstrates that larger spatial units can mask the variation in the spatial distribution of POS supply as the percentage meeting the supply standard decreases as the spatial unit decreases in size, highlights the influence of the modifiable areal unit problem (MAUP).

A 400 m walkability distance as outlined in a South Australian strategic urban planning policy was applied to determine the percentage of dwellings within the study area that had access to POS. The distances from residential dwellings to the nearest POS were calculated based on a 400 m Euclidean distance (straight line) and 400 m street network distance with and without barriers. With barriers, 85% of dwellings were within a 400 m walking distance, and without barriers, this increased to 87% and 96% of dwellings with the Euclidean buffer. It is important to recognise that Euclidean distance may not accurately reflect the availability of POS as people may not travel by this method within urban environments.

The POS count and area, plus the street network access measures were analysed by POA and SSC using population health data South Australian Monitoring and Surveillance Systems (SAMSS) longitudinal survey (2014–2016). The SAMSS data had a sample of 12,892 persons aged 16 years of age or older who were asked to rate their health on a Likert scores with 1 representing poor health to 5 representing excellent health (SF1). Two bivariate correlation analyses (POA & SSC) were used to determine statistical significance when SF1 scores were applied to POS count, area and accessibility, while controlling for the individual age and gender and area-level dwelling density and ABS Socio-Economic Indexes for Areas (SEIFA)–Index of Relative Socio-economic Advantage and Disadvantage (IRSAD). Two multi-level ordinal regression analysis (POA & SSC) compared the SF1 with the POS (500 m buffer) area. The p-value denoted significance within a 5% likelihood, but as the coefficient was 1, it had no impact on the odds ratio, for both spatial units. When all the variables were included in the POA and SSC models, POS area (500 m buffer) was not statistically associated with SF1 self-rated health.

This study demonstrated the requirement for considering the quality and accuracy in both dataset and spatial unit selection and analysis when examining the effectiveness of strategic urban planning policies. Decisions based on outdated and non-empirical open space standards and guidelines, including the mandated South Australian 12.5% open space supply

standard, requires a thorough review of how open space is defined, measured and implemented. With increasing urban population densities, it is important to recognise that an appropriate quantity of good-quality, well-positioned and connected public open space could have a positive influence on population health. Although this research found no statistical association of POS with self-rated health, these results may be influenced by the Modifiable Areal Unit Problem whereby data is aggregated, for example, ABS postcodes and suburbs. These outcomes could be potentially addressed with georeferenced and clinically based health data instead of self-assessed data.

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TABLE OF ABBREVIATIONS.

ABS	Australian Bureau of Statistics
AIC	Akaike's Information Criteria
ASD	Adelaide Statistical Division
ASGS	Australian Statistical Geography Standard
BCE	Before Common Era
BIC	Bayesian Information Criteria
CABE	Commission for Architecture and the Built Environment
CBD	Central business district
CI	Confidence interval
CORINE	Coordination of Information on the Environment
CSV	Comma separated file
DCDB	Digital Cadastre Database
DPTI	Department of Planning Transport and Infrastructure
ESRI	Environmental Systems Research Institute (California, USA)
GIS	Geographical information systems
IRSAD	Index of Relative Socio-economic Advantage and Disadvantage
LG	Local government
LGA	Local government area
MAUP	Modifiable areal unit problem
MOE	Margin of error
MOS	Medical Outcomes Study
MOSS	Metropolitan Open Space Scheme
NDVI	Normalized Difference Vegetation Index
NPFA	National Playing Field Association (UK)
NRPA	National Recreation and Parks Association (USA)
NSW	New South Wales
OR	Odds ratio
OSDF	Open Space Development Fund
OSMM	Ordnance Survey Master Map
POA	Postcode Area (ABS)

POS	Public open space (encompasses all associated terms such as parks, public open space, open space, green infrastructure; for consistency, throughout this thesis these are all referred to as POS)
PROS	Population Research and Outcomes Studies (University of Adelaide until 2016)
PSMA	Public Sector Mapping Agencies Australia Ltd
SA1	Statistical Area Level 1 (ABS)
SA Health	Department for Health and Wellbeing, Government of South Australia
SAHT	South Australian Housing Trust
SAMSS	South Australian Monitoring and Surveillance System (PROS until 2016, currently SA Health)
SAPHS	South Australian Population Health Survey (succeeded SAMSS) (SA Health)
SEIFA	Socio-Economic Indexes for Areas (ABS)
SF1	Short Form-1
SLOAP	Space left over after planning
SSC	State Suburb (ABS)
UK	United Kingdom
USA	United States of America
VIF	Variance inflation factor
vPOS	Public Open Space dataset to be validated
VPOS	Validated Public Open Space dataset
VPP	Victorian Planning Provisions
WHO	World Health Organisation

DECLARATION.

I declare that:

This thesis presents work carried out by myself and does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; to the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text; and all substantive contributions by others to the work presented, including jointly authored publications, is clearly acknowledged.

Signature: 

Date: 10th December 2019

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A special thank you to Professor Ann Taylor and Dr Eleonora Dal Grande, who authorised the release of the self-rated health data from within the South Australian Monitoring and Surveillance System. Likewise AEROmetrex Pty Ltd and George Sioutis, who kindly granted me access to their Metromap aerial imagery for metropolitan Adelaide.

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Chapter 1: Introduction.

Within built environments, open spaces are represented by multiple terms, many of which lack definition, particularly when applied to strategic urban planning policies and population health research. Examples of common terminologies include; a park which can be represented as small urban parks through to a large national park located on the urban fringe: woodlands, roadside vegetation. Without a precise definition, the definition of open space can be subjective (Taylor & Hochuli 2017). The lack of definition generates a disconnect within urban planning, geospatial and health research and without a clear definition, the research outcomes could be biased (Lamb et al. 2019).

There is a disconnect within urban planning policies, where planners views are based on cadastral land use classifications; vacant land, undeveloped or developed reserve and recreation activities (Department of Planning, Transport and Infrastructure 2015).

Historically, open spaces have been a component of the built environment; however, since the 19th century, open spaces have been the result of urban planning legislation and design standards. This thesis explored the development and evidence for open space supply standards, the spatial distribution of and access to open space, and associations with population health. The issue of multiple open space definitions, size and quality is important in population health and continues to attract attention from urban planning and population health researchers (Bryan 2013; Kondo et al. 2018; Lamb et al. 2019; Thompson & Jennifer 2013).

This thesis contributes to the debate about how open space supply is measured, current practice and guidelines relating to open space and to undertake research regarding links between open space supply and population health. To address these variances and to procure reproducibility, open space have been defined in this thesis as public open space (POS), and identified as partially or wholly vegetated land areas which are publicly accessible and available for use by all age groups and suitable for passive and active recreation (Daker 2014a; Daker, Pieters & Coffee 2016). This study focused on POS supply and distribution in metropolitan Adelaide, and the South Australian legislated open space supply standard applied to a range of spatial units. Could the current open space supply standards be out of date? Do they deliver sufficient POS for 21st-century residential developments advocating higher densities? Is there a requirement to examine what is quality versus quantity? Is

population health associated with POS supply and accessibility to POS? These questions require exploration and this research builds on previous research that developed, validated and analysed a POS spatial dataset for metropolitan Adelaide (Daker 2014a; Daker, Pieters & Coffee 2016).

1.1 The foundations of planning legislation related to public open space in South Australia.

The first European settlement of South Australia was recorded in 1836 (Bunker 2007), the British government engaged Englishman Colonel William Light to survey the future State of South Australia to establish a capital city (Adelaide) and open the area for settlement, commerce and primary production. By the 1870s, Adelaide formed the central core ringed by parkland, with a further ring of suburbs interspersed with small farms, orchards and market gardens. These new suburbs were typically low density, single-storey dwellings built on large land parcels. By the late 19th-century, the garden city movement in the United Kingdom (UK) started to influence urban development in metropolitan Adelaide, which included sizeable residential lots, tree-lined footpaths and POS for recreation. From the 1950s to the 1970s, residential developments transitioned from the traditional grid-style layout into a more curvilinear style with no-through roads branching off and cars substituting for walking as the predominant mode of movement (Bird 2012). These changes in urban development and rapid population growth were the catalyst for the 1962 *Report on the Metropolitan Development of Adelaide* (Department of Housing and Urban Development 1962), which resulted in a review of planning policy and a subsequent boom in low-density greenfield residential developments.

The report was the stimulus to review the 10% set in the *Town Planning Act (1963)* with a proposal to increase it to 15%. During the review, a compromise was struck of 12.5% (halfway between the 10% and 15%), and this was legislated in the *Planning and Development Act (1967)* (South Australia Government 1967, pp.3265-3267; South Australian Parliament 1965-1966, pp.1273-1275, 1398-1401, 1513-1516-1966; 1966-67, p.2810). The *Planning and Development Act (1967)* mandated an open space supply standard of up to 12.5% of the developable area for subdivisions with 20 or more individual allotments (not as

a community title [1]) or, in lieu of open space provision, a monetary contribution to the Open Space Development Fund. The justification for this 12.5% open space supply continues to be unchallenged, and it remains in the 30-Year Plan for Greater Adelaide 2017 Update Department of Planning Transport and Infrastructure (2017b) and the current planning legislation, the *Development Act (1993)*. Additionally, despite the lack of justification, it will be included in the *Planning, Development and Infrastructure Act (2016)* which is still to be gazetted in 2019.

The *Planning, Development and Infrastructure Act (2016)* does not acknowledge the *South Australian Public Health Act (2011)*, which stipulates in Div. 4, Sec. 37 (g) that current and future developments should not adversely affect public health. Other South Australian legislation, including the *Local Government Act (1999)* recognises that the design, implementation and maintenance of public infrastructure and open spaces continue to be a core function of local government (LG).

Recently the South Australian state government recognised vital primary production areas on the urban fringes were being lost to lower density residential developments, and many existing lower density developments had, higher levels of car dependency, limited access to public transportation and reduced social connectivity (DPTI 2017a). Subsequently, the *30-year plan for Greater Adelaide 2017 Update*, strives through policy directives to enhance urban liveability and the promotion of population health. To address these objectives, targets include increased dwelling densities within existing urban boundaries through increased residential infill of existing lots and the redevelopment of brownfield sites (DPTI 2017a).

The South Australia planning system is under review and in the near future will gazette the *Planning, Development and Infrastructure Act* (*2016)* (to be gazetted in SA) which includes establishing a new *Planning and Design Code* to amalgamate current council-specific development plans into an overarching planning directive and standard. The aim is for the *Planning and Design Code* and the *Planning, Development and Infrastructure Act* (*2016)* to be gazetted by July 2020 (DPTI 2019).

1 Community Title: whereby land is divided into at least two lots and an area of common property. Common property is shared between residents, such as service infrastructure and driveways (*Community Titles Act 1996 SA)*.

1.2 Spatial representation of open space.

A study in Perth identified the issue of disparity within spatial data at the scale of LGA's, where open space data quality between the LGA's was variable, and this made it impossible to merge at a larger scale (LGA) (Bull et al. 2013). Consequently, the authors were forced to develop and validate a new open space dataset for metropolitan Perth linked to the LGA data. An additional outcome of the research design was an open space dataset template to promote standardisation and replicability for new open space datasets. Similar to the study by Bull et al. (2013), the variability of spatial datasets was explored within metropolitan Adelaide, with four datasets representing open space and their spatial distribution were investigated alongside two open space supply standards, per capita and percent of area (Daker, Pieters & Coffee 2016). There was a significant disparity between the four datasets, especially with the dataset design purpose and definitions. The four datasets included; ABS Meshblocks, DPTI property cadastre, Pitney Bowes SA Parks and the principal authors own POS dataset. The property cadastre is administrative for land tax purposes, land use codes attributed to public open space and recreation activities (Table 6-1) and do not make any claim to defining open space. Pitney Bowes SA Parks utilised as a base/topographical map and a generalised representation of accessible open spaces. The authors own POS dataset was developed through merging two government and one commercial dataset with a desktop validation utilising high resolution aerial imagery, and selected spaces identified as POS. Figure 1-1 presents the differences by count and area of open space representation within the four datasets (Daker, Pieters & Coffee 2016).

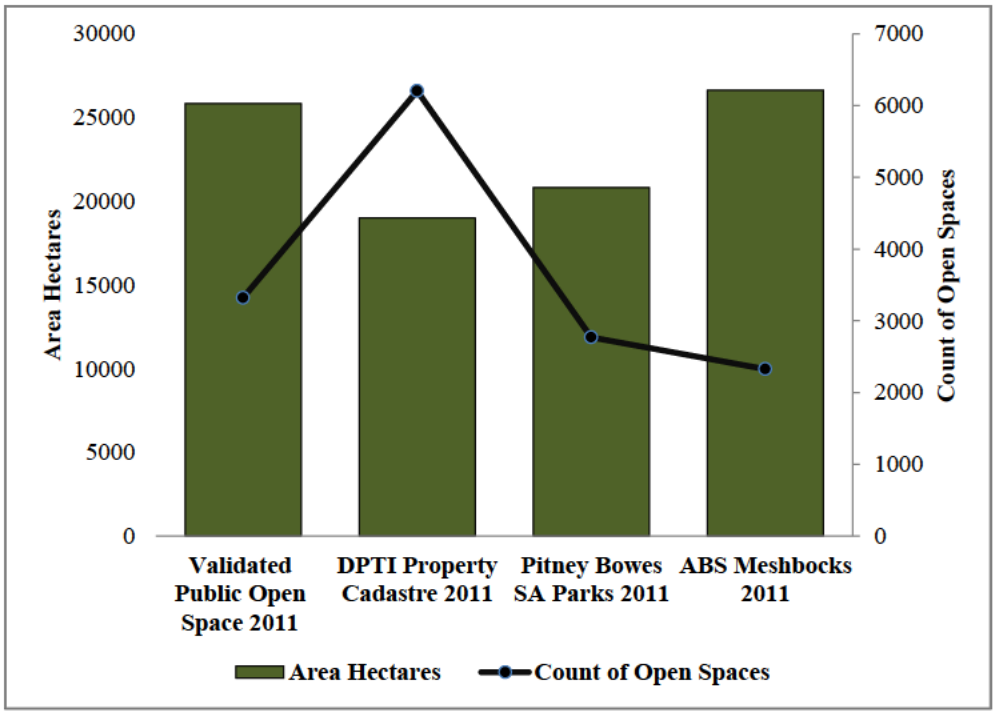


Figure 1-1: Datasets representing open space by total count and area hectares. (Adapted from; Daker, Pieters & Coffee 2016).

A study by Coleman (2016) applied Public Sector Mapping Agencies (PSMA) Greenspace 2011, a national digital dataset, to demonstrate the variability of greenspace supply and access within eight Australian state capital cities. The area of greenspace per capita and the Euclidean distance from each dwelling to the nearest greenspace were measured to calculate the percentage of persons with access to greenspace (Figure 1-2) Adelaide was ranked second last, with Canberra (Australian Capital Territory) and Perth (Western Australia) providing the largest area per capita of greenspace. For the distance to greenspace, Adelaide had the second-highest proportion of persons within 400 m (94%), surpassed only by Canberra (98%) (Figure 1-2). The report did not disclose how greenspace was classified, nor whether validation of the greenspace data took place. As a result, it is unclear whether access to greenspace is visual (able to view) or actual access of public greenspace. Although the 400 m distance was acknowledged as a regularly used walking distance definition, the report provided no citations to support this distance. The author acknowledged that national datasets purported to represent greenspace were of variable quality and accuracy (Astell-Burt, Feng & Kolt 2013, 2014a; Astell-Burt, Feng & Kolt 2014b; Astell-Burt, Feng & Kolt 2014c; Astell-Burt et al. 2014a; Astell-Burt et al. 2014b). The appropriate selection of datasets to answer research objectives was supported by Lamb et al. (2019).

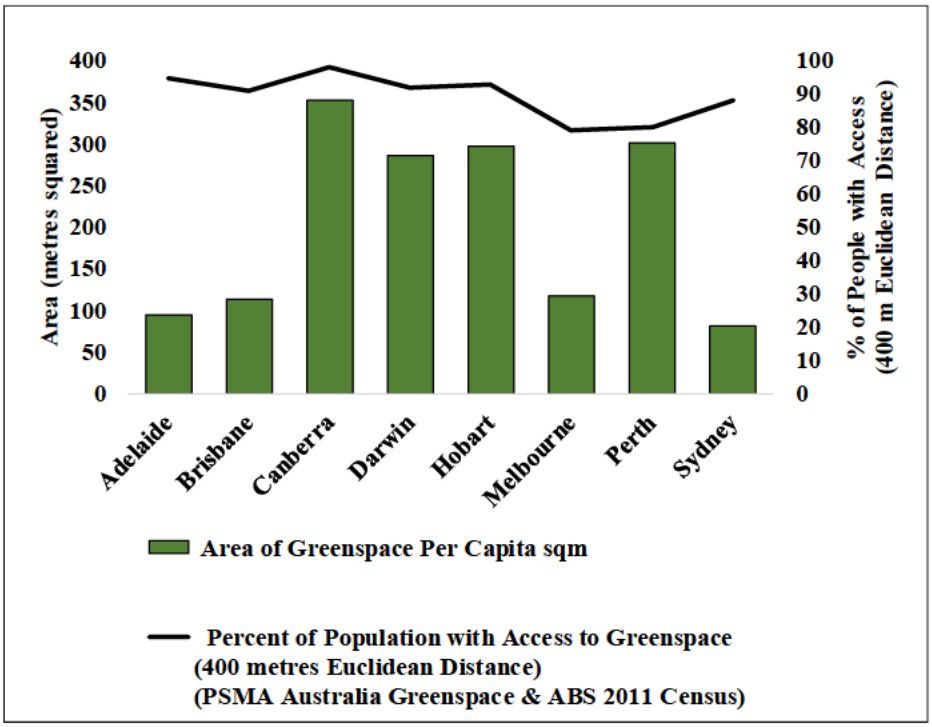


Figure 1-2: Supply of green space and Euclidean distance green space access for Australian state capital cities.
As per the report, Coleman (2016).

Hooper et al. (2018) reported that data quality in Australia continues to have limited consistency in datasets representing open space and supply standards. The study highlighted a fundamental problem regarding the variability and quality of open space datasets available in Australia and the potential to mislead urban planners and population health professionals. This data variation for open space may result in different researchers making inappropriate comparisons, yet these study results are submitted as the body of evidence that supports the necessity for open space associated with population health. The implications of these studies with regard to data quality and standards support this research into the development of a POS dataset that is clearly defined, validated and could be replicated if similar data were available.

1.3 Open space supply and population health.

There is evidence which suggests that good access to open space can improve population health outcomes (Kondo et al. 2018; Maas et al. 2006; WHO 2017). Using this evidence, urban planners progressively recognise the links between urban environments, population health and the increase in levels of chronic disease. Urban environments with good pedestrian accessibility and attractive destinations, which include open space, have been

reported as encouraging human populations to be more physically active (Davern et al. 2017; Handy et al. 2002). However, Lee and Maheswaran (2011) argued that the relationships between urban green spaces and public health were tenuous, alluding to insufficient research and unsupported associations. Some inconsistency to which Lee and Maheswaran (2011) refer might originate from the lack of a definition of open space or quality open space datasets; what is included and what is excluded? Excluded open spaces might be, for example, beaches and semi-restricted public spaces like school grounds, reducing apparent open space supply and affecting research findings (Koohsari et al. 2015). Researchers should consider the design purpose for the open space dataset and whether it provides a sound basis for their research? Open space data established to levy tax or define land use may not provide a sound basis for research on open space supply. The issues raised by Koohsari et al. (2015) were highlighted in research undertaken by Daker (2014b) and Daker, Pieters and Coffee (2016) and a review by Lamb et al. (2019) which emphasised how the lack of an open space definition and spatial dataset selection could influence research objectives and subsequent results. Lamb et al. (2019) proposed a checklist which included defining open space and associated subtypes of POS and the types of open space that are included and excluded when considering the definition of POS relative to the intended research outcomes.

Reports by the Planning Institute of Australia (2009) and National Heart Foundation of Australia (2012) recognised that increasing urbanisation continues to define population health issues and increased levels of chronic disease resulting from inadequate levels of physical activity, in part because of poor accessibility to amenities including POS. They supported the implementation of sound urban design and supply of quality POS to motivate human populations to connect with their urban environments, to support active living and improve health and wellbeing (National Heart Foundation of Australia 2012). The report by the National Heart Foundation supported the new *South Australian Public Health Act (2011)* as a tool to promote public health planning at the local government level. The Planning Institute of Australia (2009) report identified population health outcomes as a core business activity of local government, involving the provision and maintenance of open space and recreation facilities, footpaths and streetscapes and the enforcement of land use planning and building controls to uphold development zoning controls. These reports indicate the lack of an overarching definition of open space and open space supply metrics when applied to urban planning and population health research and strategic policies. Therefore, there is a strong argument to implement greater clarity of open space types, supply, and to define quality and levels of access. Defining open space supports urban planners and population health

researchers in the appropriate selection and validation of data to develop a replicable body of evidence to support urban planning strategic policies for the promotion of health and welling.

1.4 Study area selection.

The setting for this study was metropolitan Adelaide, South Australia, chosen because it is typical of Australian cities first established in the early 1800s, planned on the experiences of urban planners from Britain (Thompson 2010) and;

1) the study expands previous open space research undertaken in metropolitan Adelaide (Daker 2014a; Daker, Pieters & Coffee 2016; Howard 2011; Marriott 1979; Paquet et al. 2013);
2) the availability of longitudinal health outcomes data from the South Australian Monitoring and Surveillance Systems (SAMSS), which investigates population health in metropolitan Adelaide and South Australia;
3) within metropolitan Adelaide, there is good access to quality data on land use, dwelling locations, population statistics and socio-demographics to support a robust GIS analysis with subsequent statistical modelling and thematic mapping;although open space datasets are available for other Australian cities, they might not have been validated or defined to address the objectives of this research. The secondary validation of a POS dataset outside metropolitan Adelaide would involve a considerable timeline, expense and complex logistics; and
4) the South Australian government's strategic 30-year plan (DPTI 2017a) envisions a more walkable and liveable built environment, with an emphasis on transitioning away from urban sprawl and lower density residential developments and towards higher residential densities and mixed-use developments within existing urban boundaries. A key focus of the plan is to guarantee within residential areas access to quality POS. Adelaide represents a sound location to explore how urban densification influences the supply of quality POS and population health.

1.5 Research objectives.

The aims of this research were to:

1) explore the origins and the appropriateness of legislated open space supply standards and policies within 21st-century urban environments;
2) develop and validate a 2016 POS spatial dataset representing supply within the study area;
3) investigate the distribution of POS and accessibility across the study area; and
4) explore associations between population health and POS area, count, accessibility and dwelling density.

1.6 Research outcomes.

The outcome of this research provided evidence regarding the suitability and appropriateness of open space supply standards in modern urban environments as regulated through development control and related measures. The results presented new evidence using geographic information systems (GIS) spatial representations of open space and its distribution within the context of the selected study area to provide metropolitan Adelaide strategic urban planners with evidence to inform a review of open space policy and related legislation. The results-focused particularly on the suitability of the 12.5% land area supply (*Development Act* 1993; *Planning, Development & Infrastructure Act* 2016) and the potential to incorporate quality; defined as well maintained (Cummins & Fagg 2011), user appeal (Morris 2003), personal security (Lachowycz et al. 2012) and not merely quantity (Wilkinson 1985) and also connectivity measures to improve useability and pedestrian accessibility (Sugiyama et al. 2014).

Further, the thesis tested self-rated health data (SF1) and explored whether excellent health (on the 5 -point scale) was statistically associated with POS supply and proximity. Despite no correlation or statistical association between SF1 health data and POS supply, the evidence still indicates the need for renewed collaboration between urban planners and health specialists to inform strategic policies in open space supply and population health promotion. To facilitate improvements to current and future urban design frameworks, development legislation and standards and the promotion of human population health and wellbeing.

Chapter 2: Origins of urban planning within metropolitan Adelaide.

This chapter begins with an outline of the development and future direction of urban planning in South Australia to frame the research objectives and understanding of open space provision within the study area. When compared with urban development in the northern hemisphere, the planning history of metropolitan Adelaide is recent (Freestone 2010).

The first European settlement of South Australia was in 1836 (Bunker 2007), during a period of significant global change: the Industrial Revolution was underway, along with the European colonisation of the Americas, Asia and southern Africa. These significant changes increased commercialisation and militarism and led to mounting tensions within societal structures (Hutchings 2007; Thompson 2010). An outcome of the industrial revolution were dirty industries mixed with poor quality housing, leading to high levels of poor health. To ease societal pressures, prominent industrialists developed new theories and designs for utopian cities and settlements. The British government selected Australia as a location to transport convicted felons; however, the State of South Australia was designated a free and planned settlement. The British government engaged Englishman Colonel William Light to survey the future State of South Australia to establish a capital city and open the area for settlement, commerce and primary production. After numerous expeditions, he selected a site for a capital city, the present City of Adelaide. This selection was based on sufficient supplies of fresh water from the River Torrens, accessibility to resources for construction and good drainage.

Figure 2-1 reproduces the map drawn by Colonel Light to illustrate the layout of the City of Adelaide. The city design was presented as a grid pattern with a north–south orientation (Proudfoot 2000). The present-day street layout is comparable to the original plan, although some adjustments have been made. The distinctive designs drawn by Colonel Light for the new city included a ring of parklands to provide a ‘green’ buffer around the city (Bunker 2007). However, the newly designated parklands would later be stripped of much of their native vegetation cover as the city utilised the land for livestock agistment, a racecourse, quarrying, waste disposal, an abattoir and a prison (Sumerling 2011).

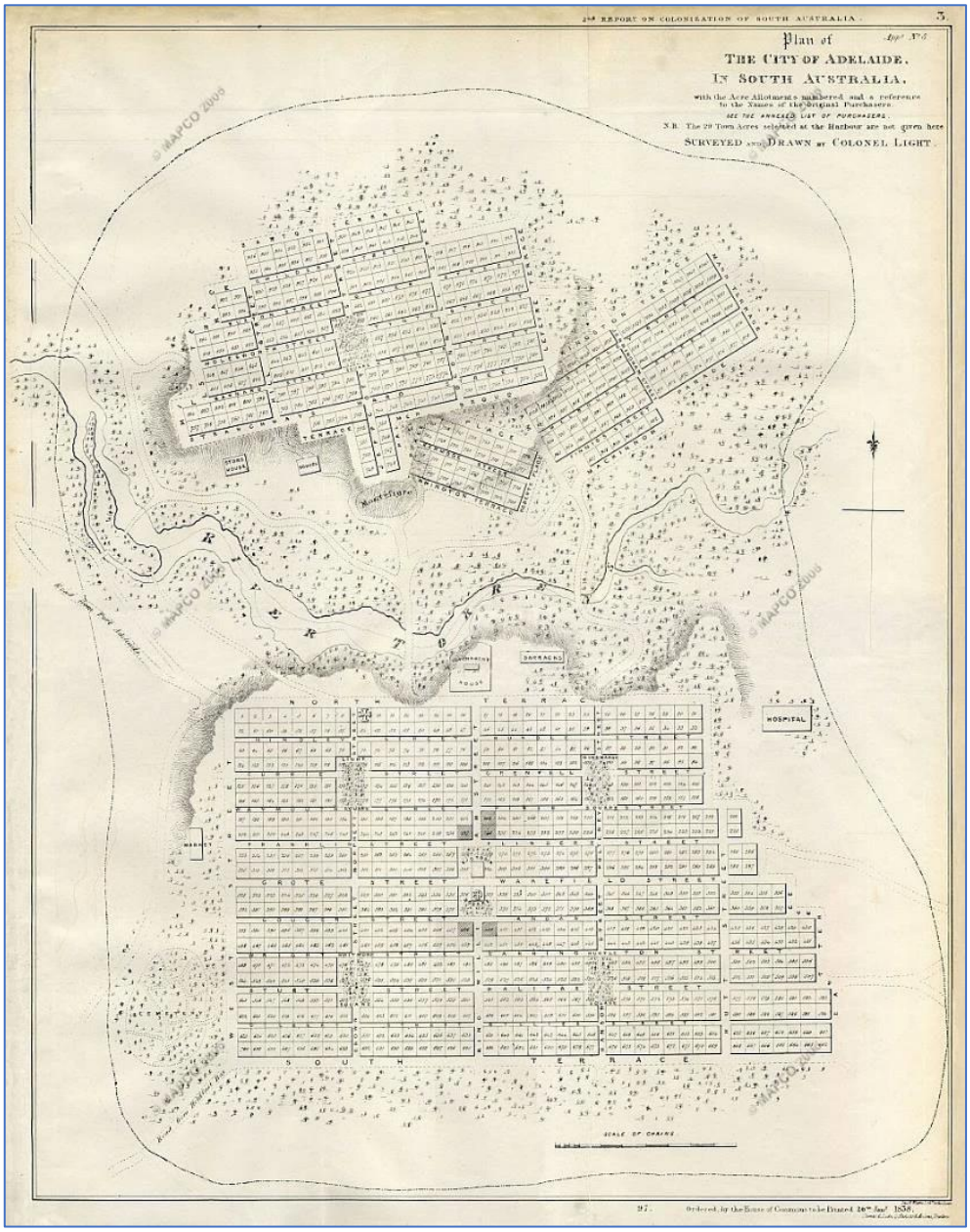


Figure 2-1: Plan of the City of Adelaide in South Australia (1837).
Source: (South Australian Colonization Commission 1837).

After completion of the plan for Adelaide, Colonel Light surveyed the country sections and continued the grid pattern where possible to delineate land parcels and street networks, which are still evident in the present arrangement of metropolitan Adelaide and many country towns. By the 1870s, Adelaide formed the central core ringed by parkland, with a further ring of suburbs interspersed with small farms, orchards and market gardens. Many of these new suburbs comprised low-density, single-storey dwellings built on large land parcels. However, it was not all utopian for the new residents, albeit at a smaller scale than cities in the northern hemisphere; a few inner core suburbs were characterised by diverse industrial activities alongside often substandard dwellings for the workforce.

In the late 19th century, the garden city movement in Britain was influencing urban design practices within British cities, and these designs also shaped the development of parts of metropolitan Adelaide (Batchelor 1969; Howard 1902). Many new suburbs adopted elements of the garden city concept, which included varying street widths signifying residential and principal roads, dwellings on sizeable lots up to a quarter acre (0.1 ha) and open space for recreation. Notably, in 1917, a model garden city suburb, Colonel Light Gardens, was designed and developed. Key features of the new suburb included land-use zoning to ensure residential areas were separated from undesirable activities, for example, smelly and noisy industrial activities, open space for passive and active recreation, tree-lined footpaths and a street hierarchy that promoted safety (Figure 2-2) (Garnaut 1998).



Figure 2-2: An example of the 'garden city concept' applied to a street in Colonel Light Gardens, South Australia.
Photograph by author.

These garden city concepts were incorporated into the first development legislation enacted in South Australia, the *Town Planning and Development Act (1920).* This act was criticised by developers as overbearing, repealed in 1930 and replaced with a statute that reduced urban planning to simple land division. Suburban residential development waned through the 1930s, only to be revived in the late 1940s because of an influx of military personnel returning from service in World War II, and to support the subsequent population and economic expansion. In 1949, the South Australian Housing Trust (SAHT), which managed the construction and upkeep of social housing, began a significant urban

development. It selected a 2,000 ha greenfield site, 24 km north of Adelaide, to be the new suburb of Elizabeth. The South Australian Housing Trust developed the suburb on the philosophies of the emerging 'new town movement', which had planned and constructed new towns outside the blighted and congested industrialised centres in Britain. The suburb of Elizabeth developed as large residential neighbourhood units serviced by centrally located shopping malls and schools. POS was often relegated to buffer zones alongside main roads. From the 1950s to the 1970s, residential developments transitioned from the traditional grid-style layout into a more curvilinear style with no-through roads branching off and cars substituting for walking as the predominant mode of movement (Bird 2012). Large areas of open spaces continued to be undervalued and acted as 'filler' on land unsuitable for development (Hutchings 2007; Hutchings & Garnaut 2007; Kellett 2011).

The transition in urban development styles was the catalyst for the 1962 *Report on the Metropolitan Development of Adelaide* (Department of Housing and Urban Development 1962). The report was responsible for an update on planning policy and the new *Planning and Development Act 1967*. This revised planning legislation directed residential developments to provide a percentage area provision for open space, or for the developer to contribute a financial contribution to the Open Space Development Fund (*Planning and Development Act 1967)*. In the 1990s, driven by market economics, a significant review of the South Australian planning system occurred, resulting in the proposal for greater flexibility for implementing residential developments, with the aim of accommodating an expected population of up to 1.38 million by 2021 (Kellett & Hamnett 2018).

A consequence of the many years of suburban expansion based policy coupled with urban design strategies have resulted in lower-density residential developments and urban sprawl. As planning policy had resulted in urban sprawl and to change direction and provide a more compact higher density urban form, new policy directions were needed. This led to strategies to enhance urban liveability and to protect vital primary production areas from urban encroachment and also to mitigate potential climate change impacts. The *30-Year Plan for Greater Adelaide 2017 Update* ('*the 30-year plan'*) proposed higher residential density within existing urban boundaries with a target of 85% infill housing through subdivisions of current residential lots and redevelopment of brownfield sites by 2045 (Department of Planning Transport and Infrastructure 2017b). The *30-year plan* allocated the remaining 15%

of new dwellings on previously designated greenfield sites within the peri-urban region ([2]) and rural townships to sustain population growth and the economic viability of these regions. The report's emphasis was on advocating greater urban compactness and improved liveability within existing urban boundaries, through targets to reduce car dependency and promote greater walkability and access to services and improved population health outcomes. A principal target of the report was to facilitate good urban design which enhanced and supported neighbourhood infrastructures such as open space and streetscapes, which in turn promoted social connectivity and economic development. Good design practices envisage the creation of neighbourhoods, which are walkable and that open space should be present within 400 m of all dwellings. Although, the report omitted to define metrics for open space, minimum sizes and level of amenities to be incorporated into these higher-density neighbourhoods, and how to address any identified shortfalls in open space supply in existing residential areas undergoing an increase in infill development. The issue of insufficient provision of open space was previously identified in the 1962 *Report on the Metropolitan Development of Adelaide,* whereby recommendations for open space supply should be preempted to ensure adequate provision for future populations *(DHUD 1962).*

2.1 Planning development process in metropolitan Adelaide.

As previously described (Section 1.1), planning controls in metropolitan Adelaide in the late 19th century were not well regulated. Within metropolitan Adelaide, many inner suburbs were developed before 1929 when land use controls mandated no requirement to supply open space within residential areas. This is most evident in the semi-industrialised inner–suburbs, such as Hindmarsh, Bowden and Norwood, (Figure 2-3), where many residences were on small allotments providing limited private open space (gardens and yards) and surrounded with a variety of commercial and industrial land uses. It was not until the *Town Planning Act (1929–1965)* that open space provision was considered along with a minimum lot size for a detached dwelling. These changes resulted in the supply of residential land parcels with a larger area of private open space. It was not until the late 1960s that urban development came under the *Planning and Development Act* (*1967)* and tighter planning controls ensued.

2 Peri-urban, typically areas surrounding metropolitan centres and between rural townships

Within the study area, development approvals are administered by local governments, each with a *Development Plan* aligned with a local government area. Directives from the *Development Act* (*1993)* stipulate the State Planning Commission as the development umpire, providing an advisory role, mediation for third parties challenging non-complying applications approved by a council, and approval for federal government infrastructure projects. The State Planning Commission is also the lodgement body for all land subdivision applications in South Australia.

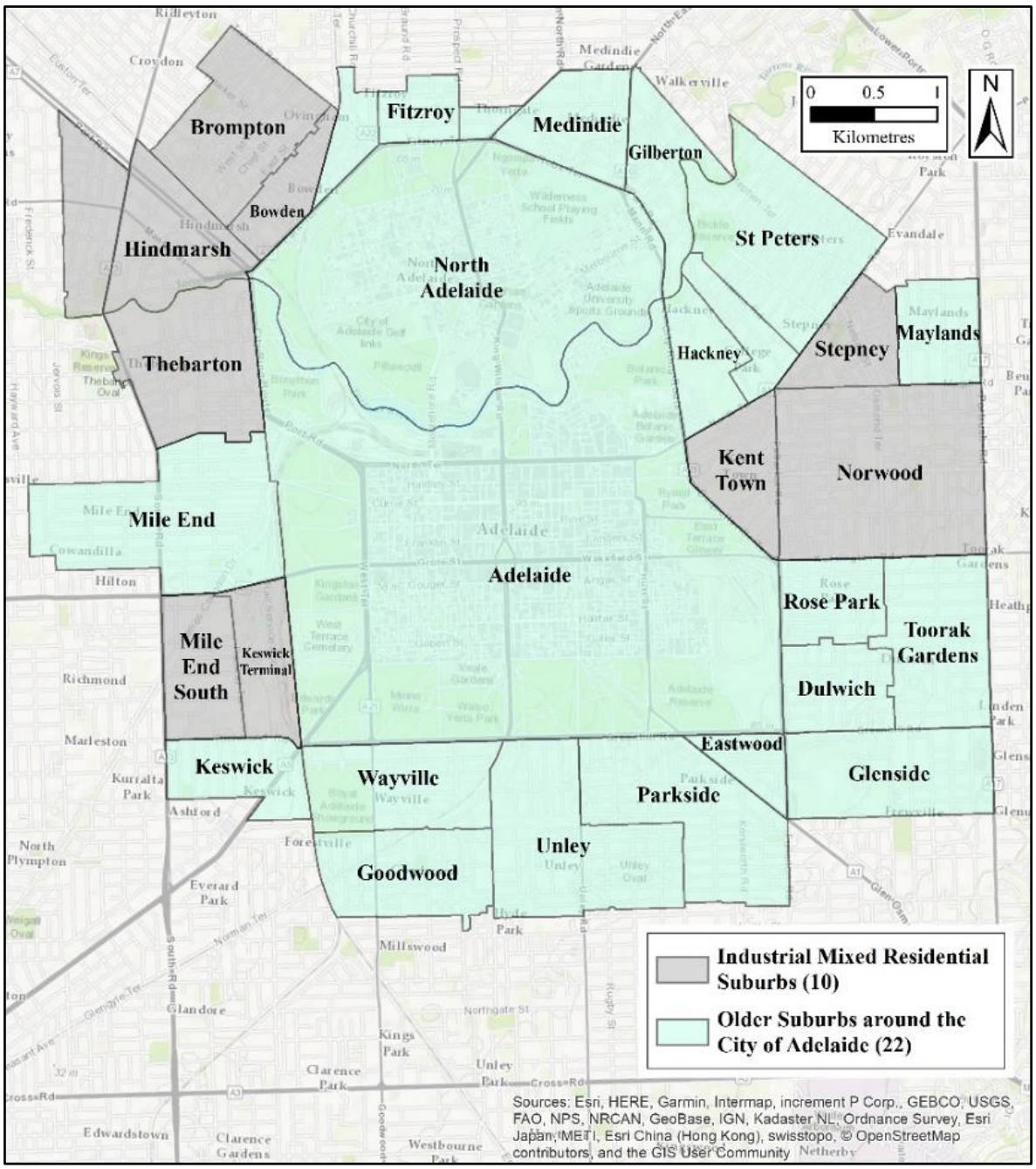


Figure 2-3: Mixed use suburbs around the 19th-century City of Adelaide.
Source: (ABS 2016a).

Changing political and social attitudes in the 21st-century and the push for higher density based on urban planning policy changes have resulted in older dwellings on large residential lots being demolished, subdivided and infilled with semi-detached dwellings, townhouses and multilevel apartments. As a consequence of infill, private open space has reduced in area or disappeared altogether (Haaland & van den Bosch 2015); the cumulative effect is an increased demand on existing open space. There is a concern for health and wellbeing in neighbourhoods that historically have a recognised open space deficit (Hall 2007; Sivam, Karuppannan & Mobbs 2012). In light of these changes in urban design and planning strategies, there is a renewed requirement to investigate the influences of urban densification on population health, in particular, the application of current open space supply standards, and the spatial distribution and representation of open space within urban settings. Therefore, within existing residential areas, the supply of open space and proximity to open space needs to be identified, and new approaches proposed to safeguard and increase the supply of quality open space.

Chapter 3: Review of Literature on Open Space and Links with Population Health.

This chapter reports on the analysis of links between open space and population health in four main sections. The first section investigated the origins of open space and subsequent attempts to standardise provision through legislation and policy. The second section examined the effect of multiple definitions of open space on the interpretation and application of open space supply standards and the progression of urbanisation. The third section investigates the association between open space supply, health outcomes and chronic diseases. The final section investigated the application and limitations of geographic information systems (GIS) as a tool to evaluate and visualise spatial data associated with open space.

3.1 Everything old is new again.

For over 4,000 years, open space has been recognised as an integral component of the urban environment. This section narrative provides the historical context of contemporary open space. One of the earliest open space was recorded on cuneiform clay tablets from a region now identified as central Iran. These open spaces comprised vineyards, orchards and ponds to provide food and the trees offered shelter from the heat and glare of the sun (Dalley 1993). Two thousand five hundred years ago, agoras became a feature of Greek culture as multifunctional spaces for entertainment, retail markets and social assemblies (Stanley et al. 2012). The Roman civilisation maintained open spaces as attractive civic plazas and promenades to facilitate social gatherings, and as arenas for entertainment. Throughout Europe and the Middle East, early urban settlements included semi-public gardens for the cultivation of culinary and medicinal plants and recreational activities (Thacker 1979; Ward Thompson 2011). Early parks, gardens and plazas were not limited to Europe and the Middle East. Accounts from 400 BCE reported that China and Japan constructed formalised walled gardens intended for religious societies and privileged persons to stroll and meditate in relative security (Thacker 1979).

The Roman Empire in Europe continued into the 5th century, after which it collapsed, resulting in significant changes in social and political structures and the decline in open space for recreational activities (Turner 2005). For the next 1,000 years (5th–15th century), the

Middle Ages was recognised as a period of hard living conditions for much of the population, and human survival became the priority.

During this period, in England, common land located outside settlements was allocated by the lord of the manor to the peasants to tend their livestock and cultivate crops for personal consumption or trade. However, much of this land was unfenced and often of poor quality (Fairlie 2009), while the privileged classes such as the nobility, gentry and religious orders enjoyed safe settlements, that included gardens and orchards established for the cultivation of edible and ornamental produce and to provide restorative and preventative medical interventions (Ward Thompson 2011). In England during the late Renaissance (1760–1870), government legislation gave landowners rights to enclose 7,000,000 acres (2,832,800 ha) of common land and revoke rights to free access. These enclosures enabled landowners to build sizeable private country estates that supported intensive primary production and the construction of stately homes surrounded by elaborately themed landscaped parklands (Fairlie 2009; Hunt 1992). The privatisation of common land was not without its critics: as debated in the British House of Commons, the enclosure would 'deprive the poorer classes of society of that 'healthful recreation and innocent enjoyment'. Consequently, the first Common Field Enclosure Bill was not passed (United Kingdom House of Commons 1834). However, the bill passed in 1836 with clauses attached, which exempted common fields from enclosure within 10 miles (16 km) around London and 2 miles (3.2 km) around every English town or city with a population greater than 500 persons (United Kingdom House of Commons 1836).

Throughout the 17th–19th centuries in Britain, the industrialisation of urban centres resulted in unprecedented population growth, with many of the working classes living in substandard and overcrowded dwellings with inadequate amenities including limited or no access to open spaces for recreation. These poor living standards contributed to a significant increase in infectious diseases and high rates of death, which forced the British government to enact new health regulations to improve sanitation and supplies of drinking water. The enactment of the *Public Health Act 1848* (UK) provided the stimulus to improve urban design and development practices, from which town planning emerged as a professional organisation (Cullingworth & Nadin 2003). From then on, town (urban) planners developed design standards that involved land use and zoning regulations that segregated residential areas from undesirable activities (Johnson & Marko 2008; McMichael 2007; Schilling & Linton 2005). A negative consequence of this was the proliferation of urban sprawl (Fox 2010; Frumkin 2002; Oueslati, Alvanides & Garrod 2015).

A consequence of rapid industrialisation and population growth was significant changes to societal structures and increasing tensions for reform to give the working classes improved living conditions. In recognition that intensive industrial activities contributed towards substandard living conditions, several socially progressive British industrialists, including Cadbury, Lever and Salt initiated the construction of model townships (Bourneville, Sunlight and Saltaire). These townships incorporated many modern conveniences, including formally designed parks and gardens to provide the workers with opportunities for socialisation and recreation (Ashworth 1951; Bryony, Lintonbon & Jackson 2010; Machett 2010). It was not just industrialists driving social reform; women also worked to improve living standards and the provision of public parks and gardens in the growing towns and cities (Wohl (1971). Notably, one woman, the English social reformer Octavia Hill, devoted her time to protect many large open spaces within London from development, including Hampstead Heath and Parliament Hill (Malchow 1985).

Aside from political interests and private philanthropy to implement open space, many early 19th-century medical practitioners continued to maintain the belief that miasmas transmitted diseases. According to the Phytogenic Theory, miasmas or bad air were responsible for diseases such as cholera that were prevalent in the filthy and foul-smelling industrialised towns and cities. To improve air quality, city planners implemented open areas, often as city squares, in a belief they performed as the city's lungs to remove the bad air and draw in the fresh air, reducing the incidence of disease. Although the Germ Theory would later disprove the Phytogenic Theory, it elevated the importance of open space and contact with nature to mitigate population health issues (Cartwright 1986; Jones 2018).

Contact with nature was a principle concept of the 'garden city movement' initiated and promoted by the prominent late 19th-century British social reformer Ebenezer Howard. His utopian designs for garden cities were planned on a concentric pattern that extended from a central core, with the objective to house up to 32,000 people in self-contained communities surrounded by greenbelts of public parks and boulevards that provided a buffer from industrial activities. Although Howard's utopian designs were never wholly implemented, future urban planners adapted the concepts to ensure residential areas were close to parks, included attractive streetscapes and were buffered from undesirable industrial and commercial activities. Early examples of garden cities included the City of Letchworth and Welwyn Garden City outside the City of London (Batchelor 1969; Buder 1990), and Colonel Light Gardens in South Australia (Garnaut 1998). The principles of the movement reached the United States of America where the prominent landscape architect Frederick Law Olmsted

recognised the public health benefits of contact with nature and in 1858 designed Central Park for the residents of New York (Cohen et al. 2007; Frumkin 2003; Ward Thompson 2011). In recognition of the separation of land uses advocated by Howard and increased jurisdiction held by urban planning authorities, a landmark case in the United States Supreme Court, *Village of Euclid v. Ambler Realty Co* (1926), established that local governments held a legal mandate to restrict or control undesirable land-use zoning and developments with an objective to protect public health.

In the early 20th century, previous close collaborations between urban planners and health professionals waned because of shifts in societal outlooks and advances in medicine (Duhl & Sanchez 1999). Increasingly, health professionals understood the cause of infectious diseases and prevention strategies, resulting in a public health focus on medical solutions and less emphasis on urban environmental influences. Urban planners had new issues to address ensuing from the industrialisation of towns and cities, including the clearance of 19th-century slum dwellings and relocation of residents into the new master-planned suburban developments located beyond the old degraded urban cores. Another factor was a shortage of housing to support the post-World War II population boom (Garnaut 1998; Merlin 1980). Many of the master-planned suburbs were based on 'new town movement' concepts and aligned with Howard's design philosophies (Merlin 1980). During this period, zoning regulations were enforced, one outcome of which was 'leapfrogging' where residential areas bypassed undesirable areas and contributed to increased urban sprawl. The rigidity of planning regulations contributed to the development of significant areas of low-density residential developments often with limited amenities. New health issues emerged linked to increased car dependency and diminished pedestrian walkability to open space, public transport, schools and shops (Frumkin 2002).

Population health impacts linked to poor urban designs have renewed the alliance between urban planners and health professionals (Royal Town Planning Institute 2014). This re-emerged professional alliance has recognised public health issues such as preventable chronic diseases including heart disease, hypertension, type II diabetes, depression and some forms of cancer and obesity. These chronic diseases have been linked to inadequate levels of physical activity associated with poor urban design, which has encouraged collaboration between urban and health professionals to reform urban design principles and develop planning policies that promote higher residential densities and mixed-use developments, improved liveability, walkability and health outcomes (Frumkin 2002; Ståhle 2008). In the 1960s, during the rapid expansion of low-density development in the United Kingdom, North

America and Australia, the US American urban activist, Jacobs (1961) claimed that the growth of low-density residential developments contributed to characterless streetscapes. Jacobs (1961) advocated for mixed-use higher-density developments within existing urban areas, intending to promote house frontages and streets as public domains to enhance social interactions and security. The effects of urban sprawl were reported in the cities of Vancouver and Seattle by Fox (2010), as contributing to overstretched infrastructure and utilities and influencing the quality of life for residents. In South Australia, the state government recognised that metropolitan Adelaide urban sprawl could not continue unabated planning policies were implemented to define an urban growth boundary and to increase residential density through suburban infill and redevelopment of brownfield sites (Department of Planning Transport and Infrastructure 2017a; Giannakodakis 2016).

The research concluded that higher-density developments could compromise open space supply as developers struggle with legislative pressures and safeguarding economic margins and property values (Giles-Corti 2006). A report by the Commission for Architecture and the Built Environment (CABE) in 2006 emphasised that higher-density development created a need to ensure that the implementation of quality public open space supply was an integral component of master plans. This was proposed to ensure open space does not become 'space left over after planning' (SLOAP), and to address the requirements of current and future residents (CABE Space 2006).

3.1.1 Summary of open space development within urban environments

The inclusion and application of open spaces within the urban environment have varied over time. In earlier periods they provided opportunities for food production, shelter and meeting spaces, the 17th century resulted in significant changes, with the industrialisation of urban centres and unprecedented population growth with issues arising from poor living conditions including a significant increase in infectious diseases and high death rates. Many of these new urban centres developed ad hoc, and with minimal concepts of urban design and planning, frequently the inclusion of open spaces was not considered. In response to poor population health outcomes, in the United Kingdom, the *Public Health Act 1848* (UK) provided a catalyst for new urban design standards and planning codes to mitigate the impacts of the built environment on human health and wellbeing. The implementation of open spaces re-emerged as an important component of urban infrastructure to provide opportunities for active and passive recreation.

Over time, how open spaces have been defined varied considerably, linked to different geographical, cultural and social settings, recurring terms include parks, gardens and greenspace. Consequently, these terms are frequently utilised in research and urban planning policies without recognition of whether these space have full or limited or no access public. Since the late 19th century, urban planners developed open space supply standards in an attempt to provide uniform and replicable open space measures within urban environments; these developments are discussed in Section 3.2.

3.2 Provision of open space supply standards.

The changing perceptions of open space over time have resulted in different levels of open space provision in Britain and US America compared with Australia. The development of open space supply standards within these countries are reviewed in the following sections.

3.2.1 Development of open space standards in Britain.

In the early 19th century, British urban planners recognised the value of open space to promote public health outcomes in the expanding towns and cities. One consequence of rapid urbanisation was a standardised approach that ensured future open space supply for growing populations.

In 1833, Richard Slaney MP for Shrewsbury submitted to the British House of Commons a proposal that there should be measures to secure open spaces as public walks within the proximity of populated towns, to encourage ‘healthful exercise of the population’. He recognised that before extensive industrialisation, many workers were engaged in outdoor occupations and therefore had access to cleaner air and sunlight. An ulterior motive for his call for open spaces was to encourage the working classes to partake in exercise and recreation on their days off instead of frequenting drinking and gambling establishments (United Kingdom House of Commons 1833).

In 1835 then, the Member for Sheffield, James Buckingham MP, proposed a bill to establish gardens and spaces for recreation within the towns and cities, to be funded through taxation of the most affluent residents. Because of a lack of interest and political motivation from the other members of parliament, the bill did not reach a second reading (United Kingdom House of Commons 1835). It was not until the 1840s that apathetic industrialists and politicians switched to active patronage for the implementation of open spaces within

urban areas as a consequence of multiple factors, including reports highlighting the miserable conditions endured by the working class in urban areas and the necessity to improve living standards. Local authorities took on the challenge to improve urban environments and increase civic pride, and a competitive spirit between town and cities provided the momentum for change. Local authorities recognised their finances were finite, and they encouraged private philanthropists to collect publicly funded subscriptions to facilitate the design and construction of grandiose parks. Later these parks were bestowed to local authorities, for their upkeep and to promote civic pride (Morris 1979; Walker & Duffield 1983).

The *Town Improvement Act* 1847 *(UK)* authorised local authorities with the power to utilise property taxation to fund the development of new parks. Many of these new parks were built on the edges of existing urban areas, resulting in a continuing shortfall of larger open spaces within the older urban cores. Subsequent legislation empowered local authorities to hold land for open space for children's playgrounds and adult recreation (Walker & Duffield 1983). It was not until the late 19th century that legislation directed the provision of open space with the consolidated *Open Spaces Act 1906* (UK). This act authorised the transfer of open spaces to local authority control to promote public recreation and established 'open space' as the generic term governing parks, walks and gardens.

Although numerous laws recommended the provision of open spaces within urban developments, they failed to establish open space supply standards that would meet the requirements of the diverse urban population. An open space supply standard was proposed in 1883 by the British Metropolitan Public Gardens Association recommending that parks should be within 0.25 miles (400 m) of every dwelling. Also, in 1891 Robert Hunter, a principal member of the Commons Preservation Society, argued new towns should secure up to 5% land area for open space. There was limited political enthusiasm for Hunter's proposal, and it was not implemented (Theobald 1984). The first open space standard in Great Britain to include area was established in 1925 by the National Playing Field Association. The National Playing Field Association suggested 6 acres (2.43 ha) per 1,000 population as a minimum standard for playing fields and children's playgrounds based on generalised population participation rates for recreation and sports activities (Veal 2012; Wilkinson 1985). The British open space supply standard underwent limited testing and evaluation of residents' requirements, with the standard excluding gardens, woodlands, commons, full golf courses and areas where the playing of organised games by the general public was discouraged or forbidden (Veal 2012). Pepler (1923) argued that recreation areas might not be as beneficial because their locations were not accessible for the intended users. The National Playing Field

Association standard continues to be applied by local governments in Britain, with 4 acres (1.6 ha) for outdoor sport and 2 acres (0.8 ha) for children's play spaces. The limitations of a fixed standard in new residential developments have been recognised in Scotland, whereby developers have to outline the open space form, quality and functionality to ensure they meet the requirements of the community (The Scottish Government 2007).

In the 1990s, British open space planners started to question the existing qualitative greenspace standards, and research was undertaken to determine minimum distances a person would travel to greenspace, the result was the 'Access to Natural Greenspace Standard (ANGSt)'. Three key principles defined the standard: (1) access to greenspaces, (2) improved the attractiveness of greenspaces and (3) enhanced connectivity. A key number of recommendations included persons should have access to at least two hectares of greenspace, which included natural and semi-natural areas no more than 300 m from their home (Natural England 2010).

3.2.2 Development of open space standards in North America.

Following the developments in Britain to recognise and implement open spaces in urban environments, a prominent US American organisation, the American Park and Outdoor Association in 1901, proposed 1 acre (0.4 ha) of park for every 200 people as appropriate for the average population density of US American cities, providing developers and local authorities were not economically disadvantaged. The prominent US American landscape architect Frederic Olmstead suggested parks and squares should make up 8% to 10% of a city's area. This open space provision was to comprise one 20 acres (ha) park to every square mile (2.6 km^2), with the balance made up of playgrounds and squares. Other US American town planner and engineer provisions varied from 115 to 250 persons per acre of park, depending on the population and demography, where younger people required spaces for games and to escape the city's noise and activity and to reconnect with nature (Pepler 1923). The consensus was 1 acre (0.4 ha) of permanent open space per 200–250 persons (Pepler 1923).

The North American Playground Association was concerned that schoolchildren were not undertaking sufficient non-structured physical activity and in 1906, developed provisions in Washington DC that every school district should have 1 acre (0.4 ha) of playgrounds per 2,000 children (Mertes & Hall 1995). This was supported by Olmstead (1925), who stated that urban planners needed to develop parks that addressed the needs of the current and

prospective population while operating within reasonable economic limits. By the 1930s, the National Recreation and Parks Association augmented the earlier North American Playground Association provision and proposed 10 acres (4 ha) of parks per 1,000 population in urban areas with an equal area set aside for large parks and parkways bordering the city limits (NRPA 1971)

3.2.3 Development of Australian open space legislation and standards.

Legislation and standards for open space provision in Australia were aligned with British open space legislation and standards, principally the percent of a residential developable area. However, unlike in Britain in the mid-19th century, Australian cities had minimal planning controls, resulting in a laissez-faire approach to urban development and a minimal recognition of open space supply (Sandercock 1990). Table 3-2 presents a chronological timeframe for urban planning legislation and open space supply in Australia.

Table 3-1: Australian public open space legislation and standards.

	Historical policy/legislation	Current policy/legislation	Reference
South Australia	*Town Planning Act 1929–1963* advised 5% POS in a new development (advisory) report on the metropolitan area of Adelaide 1962 recommended 12.5 acres (5 ha) per 1,000 population *Planning and Development Act 1967*—origins of the current open space standard *Planning Act 1982*—no directives for open space *Planning Development and Infrastructure Bill 2015* Sec. 186	*Development Act 1993* Div. 4 (50: 1c) *Planning Development and Infrastructure Act 2016* Sec. 198 (to be gazetted) Developments over 20 dwellings may require up to 12.5% open space or payment in lieu to Open Space Development Fund	*(Development Act 1993; Planning, Development & Infrastructure Act 2016)*
Victoria	Victorian Planning Provisions 2016 directed individual councils to determine open space contribution according to Clause 52.01 'Public open space contribution and subdivision'	*Planning and Environment Act 1987*, Part 3B Final figure negotiated by a council with the developer on remuneration as a percentage of the site value Subdivision Act 1988 (Vic) Sec. 18 Open space not to exceed 5% within a subdivision	(*Planning & Development Act 2007)*
New South Wales (NSW)	Cumberland Plan 1948 2.43 ha per 1,000 persons	NSW Recreation and Open Space Planning Guidelines for Local Government 9% share of non-industrialised land for local and district open space Urban renewal 9–15%; higher-density developments to be 15% *Environmental Planning and Assessment Act 1979*, Section 94 Land allocation or payment of a monetary contribution or both	(Abercrombie 2008; City of Sydney 2016; Department of Planning 2010; *Environmental Planning & Assessment Act 1979*)
Western Australia	Plan for the Metropolitan Region Perth and Fremantle 1955 Report 3.5–10.2 acres per 1,000 persons depending on residential density	*Planning and Development Act 2005* Development Control Policy 2.3 Public Open Space in Residential Areas 10% gross of the development area In practice, developers opt for 8% of open space and 2% cash in lieu	(Grose 2007; *Planning & Development Act 2005*)
Queensland		*Local Government (Planning and Environment) Act 1990* Sec. 5.6 An area that is 10% of the area of the land to be subdivided; alternatively, a contribution to the local authority—can be a combination of land and money	*Planning and Environment Act 1990)*
Tasmania		*Local Government (Building and Miscellaneous) Act 1993* (Tas) Sec. 117 5% of a subdivision or financial contribution to the council in lieu of land	(*Local Government Building & Miscellaneous Provisions Act 1993*)
Northern Territory		*Planning Act 2009* (NT) Part 6 Contribution plan between the developer and council	(*Planning Act 2009*)
Australian Capital Territory	National Capital Development Commission 4 ha per 1,000 persons	*Planning & Development Act 2007* (ACT) Part 10.3 Public land may be reserved for open space	(*Planning & Development Act 2007)*

It was not until the 1940s that open space standards were recognised in all Australian states when a hybrid of the British and US American standards was included that mandated a minimum of 7 acres (2.83 ha) per 1,000 population (Veal 2013). While in 1958, the National Capital Development Commission (NCDC), Canberra, established the open space supply standard of 4 ha of open space per 1,000 population with five subclassifications to recognise different open space types, land area and recreation activities (Table 3-2) (Gray & Cullen 1976; National Capital Development Commission 1981).

Table 3-2: Open space classification (National Capital Development Commission) Canberra.

Open Space Hierarchy	Per capita	Description of Hierarchy
Playing fields	1.8 ha per 1000 persons	
Local and neighbourhood parks	1.2 ha per 1000 persons	Excludes playing fields and demand spaces
Town and district parks	0.4 hectares per 1000 persons	A town park should not be less than 12 ha A district park should not be less than 4 ha
Ancillary space	0.4 hectares per 1000 persons	Screening and shelterbelts, stormwater management
Demand space	0.2 hectares per 1000 persons	Land set aside for recreation purposes to be developed after the initial development

Source: (National Capital Development Commission 1981).

In 1955, the progressive Western Australian state government delivered the 'Stephenson–Hepburn plan', the first regional plan for Perth and Fremantle, proposing open space supply for children's play areas and sports fields be based on population density and set at 0.5 acres (0.2 ha) per 1,000 persons. This proposal contradicted a previous recommendation of 1 acre (0.4 ha) per 1,000 persons because Western Australian house lots were considered significant and provided ample private open space (Grose 2007). Parks and Leisure Australia (2011) reviewed the Stephenson–Hepburn plan and concluded that the original open space supply standard had since been revised to 10% of the total sub-dividable land within a residential development. This open space supply standard assumed a population density of 10 dwellings per hectare with three occupants per dwelling, equating to 3.36 ha of open space per 1,000 population.

3.2.4 Development of South Australian open space legislation and standards

South Australia was the first state in Australia to introduce planning legislation that supported open space supply standards. In 1920, the South Australian state government enacted the *Town Planning and Development Act (1920),* which empowered government planners to obtain the best economic and social outcomes for land uses, which included the supply of open space. Approval for a subdivision could be withheld when there was an insufficient supply of open space in a submitted design. The act recommended that subdivisions with over 20 dwellings should provide 5% of the total area as open space. An exception to the new public space supply guidelines were the Adelaide Parklands surrounding the City of Adelaide (Mobbs 1996). Earlier legislation, the *National Parks Act (1891)* had led to the formation of the Belair National Park, the first national park in South Australia, eight km south-east of the City of Adelaide, to provide for leisure and recreation in a naturalised setting.

Significant population growth in the 1950-60s occasioned the Department of Housing and Urban Design in 1962 to establish the South Australian *Metropolitan Development Plan*. The plan acknowledged populations would continue to expand and the need to identify potential shortfalls in infrastructure and amenities within metropolitan Adelaide, The plan identified that the future supply of open space within metropolitan Adelaide would be insufficient when aligned with projected population growth (DHUD 1962). The plan proposed that all open space should meet the needs of all age groups, with the requirement for orderly planning and procurement of open space ahead of demand. An impetus for the plan was an amendment of the *Town Planning Act (1929–1965)* here the recommended open space supply standard of 5% land area within new subdivisions was increased to 10% (Sandercock 1990). The 1962 *Metropolitan Development Plan* provided the foundation for the new *Planning and Development Act (1967*) Part VI, Sec. 52 (b), which stipulated up to 12.5% open space of the total development area for developments with more than 20 dwellings and when one or more dwellings were constructed on less than one hectare (*Planning & Development Act* 1967). The 12.5% allocation resulted from political differences. The then Liberal opposition supported the prevailing 10%, while Labor proposed 15%. The Liberal members argued it would impose a financial burden on property developers and in smaller developments open space would be out of proportion. To break the impasse, a compromise of 12.5% was reached in the Legislative Council (South Australia Government 1967, pp.3265-3267; South Australian Parliament 1965-1966, pp.1273-1275, 1398-1401, 1513-1516; 1966-67, p.2810). This open space supply allocation was an arbitrary land area metric not established on population or

residential densities. Developers, however, could elect to contribute financially in lieu of providing open space into the Open Space Development Fund managed by the state government. Where a local government recognised a shortfall in quality open space within a particular area, they could submit a grant application to the state government to obtain up to 50% of the total costs to either purchase land for new or to upgrade an existing open space (Department of Planning Transport & Infrastructure 2016a; InfraPlan 2014). The *Development Act* (*1993)* continued to uphold the original 1967 open space supply standard of 12.5%, and the figure remains unchallenged in the to-be-gazetted *Planning, Development and Infrastructure Act (2016)*.

The ongoing issue of a shortfall of open space supply was recognised in South Australia in 1994, with the implementation of the *Metropolitan Open Space Scheme* (MOSS) (DPTI 2013). The intention was to increase connectivity for communities with limited or zero access to open space. Significant areas of vegetated open space were protected from future urban development and included the Adelaide Parklands, River Torrens Linear Park and Adelaide Hills Face Zone (DPTI 2013). However, significant land areas under the MOSS are in private ownership and have restricted public access, including the Adelaide Hills Face Zone and Torrens Island.

In 2014, InfraPlan, a leading planning infrastructure consultancy in Adelaide, prepared a report for the Local Government Association of South Australia to explore the viability of the 12.5% open space supply standard and the Open Space Development Fund. The report outlined that within a low-density development of 10–22 dwellings per hectare, the 12.5% open space supply within a subdivision represented approximately 4 ha per 1,000 people. When the 12.5% open space supply standard was applied to higher-density developments, for example, 45–100 dwellings per hectare, it would deliver as little as 0.9 ha of open space per 1,000 population. They were also critical of the equitability of Open Space Development Fund contributions from land subdivisions into the state government Planning and Development Fund, with regard the level of contributions and the complexity to apply for grants to contribute towards new open space projects (InfraPlan 2014).

The report prepared by the City of Charles Sturt Council (2011) suggested that the percent of a developable area might be an out-of-date method to implement open spaces in light of current planning policies, which promote medium and higher-density infill developments within existing urban boundaries. These infill policies will result in more people living within an area, often with less open space. InfraPlan (2014) suggested applying both the percentage of developable area and the hectares per 1,000 population, adopted from

the British 6 acres (2.4 ha) per 1,000 persons (Veal 2012), to decide the amount of open space that would be suitable for anyone development. Higher-density developments and the risk of under-supply of open space have been highlighted by CABE Space (2006) & (2009), with poor design decisions, the potential for open space to become 'Space Left Over After Planning 'SLOAP or constructed on land unsuitable or not viable for residential developments.

In South Australia, the *Planning, Development & Infrastructure Act (2016)* and the supply of open space, is disconnected from other state legislation, including the *South Australian Public Health Act* (*2011),* which stipulates in Div. 4, Sec. 37 (g) that current and future developments should not adversely affect public health. Moreover, the *Local Government Act (1999),* which defined the design, implementation and maintenance of public infrastructure and open spaces as a core function of local government.

3.2.5 The validity of open space supply standards.

The original British and US American open space standards were based on professional opinions of urban and open space planners with limited or no social science evidence to support them (Veal 2012). Research undertaken by Marriott (1979) recognised that the reliance on set standards resulted in quantitative assessment rather than an approach using mixed methods assessments, resulting in the assumption that both users' and non-users' needs were met once the accepted standards were implemented.

Consequently, open space planners overlooked or failed to recognise the requirement to assess whether the open spaces were adequate. Maintaining rigid attention to open space standards diverts attention from other issues such as area, shape, distribution, amenity, accessibility, quality and useability with no consideration of age, gender, socio-demographics and ethnic diversity within the community. Marriott in 1979 recognised that previous planning approaches were continuing to be applied as they had been decades before, and with limited consideration of emerging new attitudes to open space planning procedures (Marriott 1979).

In 2005 the United Nations recognised a majority of the world's population was living in urban environments, and this figure would continue to grow. To improve sustainability, the *Urban Environmental Accords* (United Nations 2005) established targets to improve the health and wellbeing of urban residents through the implementation of open spaces. Twenty-one actions were identified, including Action 10, which proposed a benchmark:

> Action 10: Ensure that there is an accessible public park or recreation open space within half a kilometre of every city resident by 2015 (United Nations 2005, Action 10).

The United Nations 2005, Action 10, provided no details around the open space area or definition of quality metrics.

At the European level, open space supply varies. A report produced by Kabisch, Strohbach and Haasedja (2015) analysed six European cities (Berlin, Malmo, Ljubljana, Edinburgh, Bari and Lodz) to define the total area of open space supply per capita. The reports' definition of green spaces encompassed gardens, parks, forests, residential gardens and street trees; therefore, not all green space was publicly accessible. They identified that the City of Berlin aimed to provide 6 m^2 urban green space per person, with access to a minimum of 0.5 ha within 500 m of their residence. The report highlighted that Berlin's total area of green space, which included forests and urban green spaces, provided each resident 60 m^2 of green space. The report identified that in Southern Europe, green space was often limited because of the hot and dry summer conditions. This was identified in Bari in Italy, the smallest city in the analysis, with 182 ha of green space, equating to 6 m^2 per inhabitant. The report highlighted that as a result of localised settings, the supply and distribution of green space is not homogenous (Kabisch, Strohbach & Haasedja 2015).

There is considerable variation around the world in the determination of an objective open space supply provision within urban environments. Moreover, no definitive consensus has been proposed, and these supply standards were adopted by Australia and continue to be applied. Subsequently, with increasing urban population densities, it is important to recognise that an appropriate quantity of good-quality, well-positioned and connected open space could have a positive influence on population health. Therefore, decisions based on outdated and non-proven open space standards and guidelines, including the mandated South Australian 12.5% open space standard, require a thorough review of how open space is defined, measured and implemented. Additionally, this lack of agreement may be attributed to how open space is defined as demonstrated in Table 3-3.

Table 3-3: Continuing the confusion: open space definitions

Open space term	Definition	Reference
Botanical garden	Garden dedicated to the cultivation and presentation of global plant collections	(Thacker 1979)
Civic space	The public realm, urban squares, plazas, tree-lined streets	(Kellett & Rofe 2009)
Conservation / national / regional park	Larger expanse of terrain representing a natural or semi-natural landscape with recreation opportunities (walking, cycling)	(Washington State Department of Community Trade and Economic Development 2005)
Community garden	Community space designed for the cultivation of edible and ornamental produce; access restricted through membership	(Harris 2009)
Garden	Land to cultivate produce and formally present flowers, shrubs, trees; can either have public or restricted access	(Thacker 1979)
Greenbelt	Areas of undeveloped land to provide networks of open space around built-up areas and a buffer from industrial activities; land with a legal encumbrance to safeguard against future urban development	(Abercrombie 2008; Pacione 2013)
Green infrastructure	Green open space networks providing support for urban ecosystems	(Ely & Pitman 2012)
Green roof	A roof area partially or wholly covered with vegetation with full or limited public access	(Dunnett & Kingsbury 2008)
Greenspace	Park, garden, wetland, waterway, cemetery, open space, transport corridor or derelict land awaiting redevelopment	(Harrison et al. 1995)
Neighbourhood park	Larger area to support informal, active and passive activities; could provide picnic and barbeque facilities, children's play equipment, toilet	(Sarkissian, Bateman & Hurley 2013)
Open space	Undeveloped land with no built structures and accessible to the public	(*Open Spaces Act* 1906)
Park	Ornamental open space within an urban setting for passive and active pastimes	(Mertes & Hall 1995)
Plazas and squares	Formal areas of pavement to allow a congregation of persons for passive or active pursuits; could be partially vegetated	(Byrne & Sipe 2010)
Pocket park	Small space typically only with seating and children's play equipment	(Sarkissian, Bateman & Hurley 2013)
Public open space	Land that has been developed for leisure and sporting activities and with access to the public	(Daker, Pieters & Coffee 2016; Parks and Leisure Australia 2013)
Reserve	Community land reserved or designated by a council	(*Local Government Act* 1999)
Semi-restricted spaces	Golf courses, tennis courts, other semi-private sporting grounds; access restricted through membership	(Brown, Sherrard & Shaw 1969)
Social spaces	Areas designated for public assembly	(Law 2002)
Spaces between buildings	Alleys, laneways, footpaths and landscaped areas adjacent to a building's perimeter	(Ford 2000)
Undeveloped outdoor landscape	Naturalised areas accessible to the public	(Rietveld & Wagtendonk 2004)
Urban forest	A significant area of trees located and managed within an urban setting	(Tyrväinen et al. 2005)
Wetland	A body of water combined with hard surface/vegetated areas with public access	(Scottish Executive 2005)

3.2.6 Continuing confusion around defining open space.

The absence of clarity regarding an open space definition could further complicate the implementation and revision of open space supply standards. Griffith (2010) highlighted that traditional definitions vary within modern urban environments and now include more diverse land uses such as bodies of water and shared open spaces. As a result, open space continues to have multiple interpretations: for example, civic squares, parks and gardens, national parks, green spaces, open spaces, (Kellett & Rofe 2009; Mitchell & Popham 2007). The term 'green space' as defined by Harrison et al. (1995) could include open spaces with restricted public access; for example, vacant land awaiting redevelopment. Conversely, in US America, a 'park' is the recognised classification of open space and applies to anything from a small suburban park too including a large national park outside the urban boundaries (Washington State Department of Community Trade and Economic Development 2005).

The measurement of open space is challenging from both a spatial and classification perspective because of different geographical, cultural and social settings. This influences how questions will be answered; however, to provide a single open space definition with an international application could be problematic and might not be appropriate as open space definitions have developed over an extended period. Table 3-3 illustrated the diversity of open space definitions.

For the current research, to develop a point of clarity, reproducibility and to reflect the intention of this research, open space has been defined as public open space (POS):

> Public open space is land partially or wholly vegetated, accessible and available for use by the public and all age groups. It may comprise an active space (sporting facilities and children's playgrounds) or passive recreation space (walking, sitting and social functions) or a linear linkage, a longer and narrower POS for informal recreation (walking, running and cycling) (adapted from Daker 2014a; Daker, Pieters & Coffee 2016).

3.3 Open space and associations with population health.

Despite mixed evidence regarding between open space supply and population health benefits, the evidence continues to implicate poor urban design and sedentary lifestyles may lead to increased chronic health-related problems. These include cardiovascular disease (Paquet et al. 2013), obesity (Blanck et al. 2012), adult-onset type II diabetes (Jackson & Kochtitzky 2010) and reduced levels of perceived health and wellbeing (Reklaitiene et al. 2014). Contact with nature may lead to a stronger immune system (Kuo 2015). Tolhurst et al. (2016) reported that one in two Australians has a chronic disease, with one-third of these being preventable through changes to lifestyle, including increasing daily physical activity. Research has shown that urban environments with good accessibility and attractive destinations, which can include open green space, could encourage human populations to be more physically active (Dadvand et al. 2016; Gavin 2017; Larson, Jennings & Cloutier 2017; Triguero-Mas et al. 2015). However, Lee and Maheswaran (2011) argued that the relationships between urban green spaces and public health were tenuous, alluding to insufficient research and unsupported associations. Some inconsistencies to which Lee and Maheswaran (2011) refer might result from spatial issues and the lack of a consistent definition of open space and environmental aspect being studied, (Lamb et al. 2019), specifically, what is included and what is excluded. Types of open spaces excluded from the definition could be, for example, beaches and semi-restricted public spaces such as school grounds, which reduce apparent open space supply and influencing research findings (Koohsari et al. 2015). Based on public health studies, it has been proposed that access to open space can provide health benefits across a broad sector of the population, although there are still concerns about whether the distribution of parks and their attributes exacerbate or moderate population health (Cutts et al. 2009; Peschardt & Stigsdotter 2013; Villanueva et al. 2015). Abraham, Sommerhalder and Abel (2010) questioned how diverse communities identified and interacted with appealing landscapes, and acknowledged they could promote healthier lifestyles through increased physical, mental and social activity. Although many Australians experience good health, current lifestyles are increasingly influenced by modern urban designs that have seen a decrease in physical activity, reduced social connectivity which could be attributed to a corresponding increase in chronic illnesses including obesity, cardiovascular and mental health (Thompson 2007; Thompson & Kent 2016).

Reports by the Planning Institute of Australia (2009) and National Heart Foundation of Australia (2012) recognised that urbanisation continues to influence population health issues, in particular, increased levels of chronic diseases resulting from inadequate levels of

physical activity. They supported the implementation of urban design to increase the supply of quality open space to motivate human populations to connect and interact with their urban environments, to support active living for improved health and wellbeing. The 2012 report by the National Heart Foundation supported the new *South Australian Public Health Act (2011)* as a tool to promote public health planning at the local government level.

There is a strong recognition of how socio-economic status could influence health, particularly in disadvantaged communities that might not have safe access to green space (Gidlow & Ellis 2011; Timperio et al. 2007) or quality amenities within a POS (Crawford et al. 2008); also, lower-income households may have less green space available (Astell-Burt et al. 2014a). Mavoa et al. (2015) investigated whether there was an equitable distribution of POS across metropolitan Melbourne (Victoria) and if this supply adhered to the *Victorian Planning Provisions* (VPP) for a 400 m distance of POS from a residence. The results demonstrated that socio-economically disadvantaged areas had better access to POS compared with advantaged socio-economic areas. The authors attributed this to disadvantaged populations being located in middle and outer suburbs with opportunities to access large semi-natural areas on the urban fringes (e.g., National Parks). The research concluded further studies were required that utilise different measures, which could include facilities within a POS, to provide new evidence to support accessibility by a diverse population and the development of sturdier POS regulations and policies.

3.3.1 Open space as a landscape for mental stimulus.

The relationship between open space and mental wellbeing has been associated with Edward O. Wilson's hypothesis of 'Biophilia', which is that humans have an essential requirement to connect with other living things and life processes (Kellert 1984). The connection with nature has been linked to an individual's familiarity with natural places, especially childhood experiences (Chawla 1992, 2015). Naturalised spaces have been recognised as places of refuge and seclusion from stressful stimuli, overcrowding and noise associated with urban environments (Windhorst & Williams 2015). Additional studies have established that perceived nearness to open space is associated with improved mental wellbeing through exposure to natural environments (Beyer et al. 2014; Bordier Høj 2016; de Vries et al. 2003; Houlden et al. 2018; Nielsen & Hansen 2007). The proportion of parks or green space in urban environments has been described as a measure of nature (Maas et al. 2006). The presence of natural environments has been acknowledged to enhance an

individual's mental health; studies indicated persons with more green areas were positively related to improved mental health than persons with less green areas (Groenewegen et al. 2012; Mitchell & Popham 2008).

Subsequent studies have shown that well-maintained and attractive open space and streetscapes encourage residents to be more active and are associated with increased mental wellbeing. The connection between open space and mental wellbeing is widely recognised. Francis et al. (2012) suggested that further analysis was required to understand how POS quality, amenity and accessibility could influence mental health outcomes. Similarly, neighbourhoods that had a higher perceived sense of security had higher open space patronage, strengthening social and community interactions (Cohen et al. 2010; de Jong et al. 2012; Kuo & Sullivan 2001). There is renewed interest in testing current Australian open space quality and quantity guidelines (Davern et al. 2017). These outcomes should strengthen social and health science knowledge to provide enhanced context to question and propose revised open space supply standards to not only improve mental health but physical health and general wellbeing.

3.3.2 Self-rated health and associations with open space.

The evidence suggests open space can contribute towards improved health and wellbeing, to test these assumptions, numerous studies have analysed associations between contact with open space and self-rated health on a five-point Likert scale (poor, fair, good, very good and excellent).

The self-rated health (short-form one, SF1) question has been applied in health research for more than 50 years (Palmore & Luikart 1972; Suchman, Phillips & Streib 1958), an adaptation from the Medical Outcomes Study (MOS) 36-item short-form health survey (SF36) developed in the United States. The MOS survey first presented respondents with a generalised question: 'In general, would you say your health is 'very poor, poor, good, very good and excellent' (Larson 1997; Ware et al. 1995). The Medical Outcomes Study survey was validated against the Nottingham (UK) health profile, a postal survey of 1,980 patients aged 16–74 years randomly selected from two general practices in Sheffield. The study concluded the SF1 general health question provided a robust instrument for measuring health perceptions The evaluation and delivery of health care have involved health surveys with multi-item scaled questions, which have been applied to record respondents' physical and mental health scores (Bowling 2005; Stewart, Hays & Ware 1988).

This single-item measurement of self-rated health has been expressed in multiple formats; where individuals are asked to assess their health on a globally recognised scale, typically a range from excellent to poor (Mackenbach et al. 1994; Simon 2002). This further acknowledges that general health ratings are subjective and therefore, do not specify the person's actual medical status (Davis & Ware 1981; Ware, Davis-Avery & Donald 1978). Numerous studies have reported individuals with a lower socio-economic status report a higher prevalence of health issues and a lower self-rated health status (Delpierre et al. 2009; Demakakos et al. 2008; Lahelma et al. 2004; Nobles, Weintraub & Adler 2013; Präg, Mills & Wittek 2016). The self-rated general health scores do not focus on specific health outcomes and indicate subjective information on a respondent's physical and mental wellbeing at a given time (Davis & Ware 1981).

At a national level, the Australian Bureau of Statistics (ABS) has utilised the SF1 in its *Australian Health Survey* since 1989. Since 2002, the SF1 question has been a component of South Australian Monitoring and Surveillance System (SAMSS), and since 2018 as the South Australian Population Health Survey (SAPHS) (SA Health 2004, 2016b, 2018b). The SF1 question has been recognised as a valid assessment tool for the health status of South Australian populations because of consistency in results. The Government of South Australia's Department for Health and Wellbeing (SA Health 2004) reported that the South Australian Monitoring and Surveillance System SF1 question had a greater occurrence of respondents reporting very good health; however, older respondents were more likely to report either fair or poor health. In recognition of the difficulties in interpreting and scoring multiple health status measures, the SF1 question provides a straightforward insight into overall health (Avery et al. 2006; SA Health 2013).

The South Australian Monitoring and Surveillance System data are collected via a phone survey and achieving a representative sample might be compromised because households with no landline connected or those with a silent number will be excluded from telephone interviews. A significant proportion of the population may thus be missed; these are identified as younger persons, single, unemployed and those with lower socio-demographics or residing in rental accommodation. Subsequently, clinical medical issues, for example, mental health, maybe under-reported. The research also recognised changes in communication preferences from landlines to mobile phones, influencing how people are contacted (Dal Grande et al. 2015; Dal Grande, Taylor & Wilson 2005). More recently, the South Australian Population Health Survey administered by SA Health access mobile phone number data; subsequently, a broader population cohort can be attained (SA Health 2018a).

Several social planning and health studies have utilised SF1 data to determine whether there are associations between access and contact with open space and better health outcomes. An exploratory analysis in the Netherlands (de Vries et al. 2003) based on health data obtained from the Netherlands Institute for Health Services Research with 10,179 respondents in 1,155 neighbourhoods determined whether people residing in greener areas were healthier than people living in less green areas. Health data included a five-point general health indicator scale from very good (1) to very bad (5). Greenness was calculated from the National Land Cover Classification database as the percentage of greenspace (urban green, agricultural green, forests and nature areas), whereas the percentage of blue space, both fresh and saltwater was calculated separately. An additional question included if they had access to a garden (yes or no). The results showed that health improved for residents in proximity to greener residential environments. The presence of a private garden was associated with improved health outcomes (de Vries et al. 2003).

A subsequent study in the Netherlands investigated the extent of green space to buffer the adverse influences of stressful events on perceived health. Green roadsides were not included in the green space data. The hypothesis proposed the experience of stress to be less severe in urban environments with more green space and was based on a spatially representative sample of 4,529 respondents 18 years and older, selected from 104 general medical practices. The respondents were asked an overall health question with 1 = excellent and 5 = poor. Percentage of green space was determined from the National Land Cover Classification database within a 1 km and 3 km radius of a respondent's geocoded address. The association between the area of green space and health outcomes was estimated in a multilevel regression model with demographic data (gender, age, level of education and household income) as covariates. The results reported stronger associations between self-rated general health and the amount of greenspace within a 3 km radius of residents home and to a lesser degree within 1 km. Possibly attributed to larger expanses of green spaces, including, forest and primary production areas are located outside residential areas (van den Berg et al. 2010).

A study of four suburbs in metropolitan Perth investigated the relationship between self-rated health and access to green spaces (Carter & Horwitz 2014). Within the selected suburbs, the parks and green spaces were distinctly diverse, green spaces. The older suburbs were identified as having mature and established trees and expanses of turf, while the new greenfield developments were landscape designed and manicured. The qualitative results showed that residents who perceived their green space as accessible and included quality

amenities were twice as likely to report better health outcomes as those who did not. In newer neighbourhoods, respondents provided fewer positive responses, which were linked to there being insufficient green spaces (Carter & Horwitz 2014).

A Finnish study investigated the relationship between exposure to green spaces and self-rated health within urban and suburban areas. It determined the area of green space for recreation from satellite imagery and included forests, semi-natural areas and wetlands. The proportions of green space, roads and paths and built-up areas were calculated within a 1 km radius of participants' geocoded addresses. A cohort of 3,108 respondents recorded self-rated health based on a five-point Likert scale from 1 = poor to 5 = good. The primary analysis reported that there might be an association between exposure to green space and perceived health, but this could occur indirectly through direct exposure rather than physically visiting a green space. The correlation analysis describing the respondent's residential environment and self-rated health showed that the quality of the road and footpaths was related to other variables; respondents age, gender and level of education. The study acknowledged that there were complex individual factors at play, for example, housing choices, personal lifestyles, access and availability of green spaces (Pietilä et al. 2015).

A study in Washington State, USA, utilised 532 zip-code areas, ranging from those with populations of 38 persons to 64,214 persons, to establish whether the general health question (1 = excellent to 5 = poor) was associated with green space provision. The green space data were grouped into five categories of urban green space, forest, rangeland, agricultural and wetland, similar to the Dutch study undertaken by Maas et al. (2006). Bivariate and multilevel linear regression modelling reported when the five categories of green space were aggregated as simply green it was not significantly associated with general health, although when the analysis applied socio-demographic data, people with a higher socio-demographic score reported better general health outcomes (Akpinar, Barbosa-Leiker & Brooks 2016).

The association between green neighbourhoods and self-rated health outcomes was investigated in a German study, with a sample of 4,480 participants in three adjacent cities (Bochum, Essen and Mulheim/Ruhr) (Orban et al. 2017). The level of greenness was calculated using the Normalised Difference Vegetation Index (NDVI). The Normalised Difference Vegetation Index comprised private gardens and public green spaces, and also areas with no vegetation and blue spaces. The authors calculated a mean Normalised Difference Vegetation Index within 100 m and 1,000 m of each participant's geocoded address. The health data was presented as a five-point scale (very good, good, fair, poor or

very poor). The study found that a 0.1 increase in residential Normalised Difference Vegetation Index reduced the odds of poor self-rated health by nearly 10% and that access to green space was not equitably distributed with different socio-economic classes. Further research is required to address causal factors, including the aesthetics of greener neighbourhoods' contributions to improved health and wellbeing (Orban et al. 2017).

Of these studies, the outcome has been mixed; various studies indicate persons with good access to green areas increased the odds statistically of better health outcomes (Carter & Horwitz 2014; Maas et al. 2006; Orban et al. 2017; Pietilä et al. 2015; Reklaitiene et al. 2014). However, such results might be linked to how open space was defined and measured (Maas et al. 2006), the number and distribution of respondents and the geographic region of the study (Richardson et al. 2013; Stronegger, Titze & Oja 2010). Other studies have indicated stronger correlations exist between health measures and socio-demographics (age, sex, education and income): for example, persons reported as having higher education and income levels tend to have better health (Bowling 2005; Stewart, Hays & Ware 1988). A literature review by Twohig-Bennett and Jones (2018) established the association between access to greenspace, and self-rated health was often not strongly established because studies involved cross-sectional data analyses from a population at a specific point in time.

To question the evidence, do people have better health outcomes residing in areas with a greater area and count of open space? To test this hypothesis on a study area of metropolitan Adelaide, and to date has not been associated with SF1 data analysis.

3.3.3 Environmental influences of the built environment on population health.

The climate and environmental factors influence the liveability of our urban centres and can be a significant contributing factor to adverse population health outcomes. These environmental factors can be attributed to changes in urban planning policies, for example, those that promote higher densities of infrastructure within existing urban boundaries. An outcome of increased urbanisation often results in a reduction of vegetated land areas (Jackson & Kochtitzky 2010; van den Bosch & Kabisch 2017), which can initiate anthropogenic environmental hazards that affect human health and wellbeing through exposure to, for example, reduced air and water quality, excessive noise and extreme heat events (Jackson & Kochtitzky 2010). Significant areas of impervious surfaces, both horizontal and vertical, within built environments absorb, retain and reflect heat, creating higher ambient air temperatures and potential impacts for population health (Gunawardena, Wells & Kershaw

2017). Other factors include continuous noise within the urban environment from vehicles and people (Gidlöf-Gunnarsson & Öhrström 2007) and air pollutants emitted from vehicles and industrial activities: carbon monoxide (CO), sulphur dioxide (SO_2), heavy metals and respirable particles (PM2.5 and PM10) (Kampa & Castanas 2008).

An increased supply of vegetated open spaces and water systems within urban environments have been associated with mitigating the negative environmental impacts of excessive heat exposure, noise and poor air quality on population health (Braubach et al. 2017; Ely & Pitman 2012). Increasing the levels of green infrastructure by 10% could result in evapotranspiration cooling of urban environments by up to 2.5 ^{o}C. (Forest Research 2010). Which could be achieved with the incorporation of blocks of multi-tiered vegetation to mitigate the effects of heat absorption and reflection from large areas of impervious surfaces, both horizontal and vertical (Bowler et al. 2010a). Reductions in extreme urban air temperatures, especially in summer, have been linked to reduced rates of morbidity and mortality among individuals identified as vulnerable, including young children, the elderly and those with acute health conditions (Nitschke et al. 2011). Additionally, green infrastructure can deaden excessive noise levels (Ely & Pitman 2012) and absorb or trap particulate air pollution (Abhijith et al. 2017). Furthermore, urban green infrastructure could mitigate the effects of the urban heat island effect initiated by higher air and surface temperatures within built environments compared to surrounding rural areas (Villanueva et al. 2015).

The evidence suggests open spaces can provide natural ecosystems that reduce exposure to noise, air pollution and excessive heat. Overall, population health benefits depend on the supply of quality open spaces within residential areas, which can be delivered by strong urban planning policies that recognise the importance of open space to support social and environmental systems.

3.4 Geographic information systems application to land use planning and population health analysis.

The application of geographic information systems (GIS) in urban planning continues to increase. GIS is a tool that can be used to measure and determine relationships between features in the urban environment, providing spatial statistics and visual opportunities to identify how built environment characteristics can influence health outcomes (Higgs, Fry & Langford 2012; La Rosa 2014; Nicholls 2001; Nicholls & Shafer 2001). GIS should not be

considered just as a mapping tool but a valuable analytical tool (Ricketts 2003). Therefore, GIS provides the tools to develop and validate a quality POS dataset and to address the research objectives.

The utilisation of GIS to investigate the availability of green space was trialled in a Dutch study (de Vries et al. 2003). Environmental data were obtained from the National Land Cover Classification database, which classified distinct land use types across the whole of the Netherlands. The study calculated the percentage of green space within 1 and 3 km radius around each respondent's dwelling (de Vries et al. 2003). A Melbourne study investigating POS and socio-economic status utilised the Open Space 2002 spatial dataset from the Australian Research Centre for Urban Ecology to identify open (green) space and concluded additional research was necessary to identify POS quality and accessibility, and that this might vary between geographic units (Timperio et al. 2007).

Mitchell, Astell-Burt and Richardson (2011) highlighted variability among datasets representing green space coverage in Britain and compared two major data sources, the Coordination of Information on the Environment (CORINE) and the British Ordnance Survey Master Map (OSMM), to document the differences. CORINE classified 46 land cover categories obtained from satellite imagery, while the OSMM data were captured from aerial photography. Testing identified the CORINE data missed small open spaces, thus underestimating total available green spaces, while the OSMM data included these smaller spaces but incorrectly identified some of the larger green spaces as public open spaces. To provide an accurate representation of all green space within Britain, Mitchell, Astell-Burt and Richardson (2011) combined these two datasets to develop a hybrid representation.

Variation in the representation of open space supply was identified in a study in Perth (Bull et al. 2013). The authors recognised that many local government authorities held data on their open spaces; however, the quality and form of the data varied between local governments. The lack of consistency in terminology and open space descriptions made merging data sources impossible at a larger scale. In response to the inconsistent data, Bull et al. (2013) developed over two years a web-based POS tool from a manual audit of 7,264 polygons identified as POS, to enable the visualisation and spatially analysis of the distribution of POS across metropolitan Perth. The GIS POS tool produced a consistent dataset that represented POS supply across metropolitan Perth (Hooper et al. 2018). A study in the northern and western regions of metropolitan Adelaide by Paquet et al. (2013) identified POS from cadastral data based on land use codes that classified sporting activities, reserves, national parks and gardens on parcels greater than 700 m^2, to investigate the

associations between accessibility to POS, size and type with population health risks, in particular, cardiometabolic disease. Aerial imagery was utilised to confirm the attributes of the cadastral/land use data (Paquet et al. 2013).

Australian Bureau of Statistics (ABS) data with Meshblocks 'parkland' classification, representing green space, were explored by Astell-Burt, Feng and Kolt (2013). They investigated the association between green space and psychological stress in 260,061 residents in New South Wales (NSW). A Meshblock is the smallest census unit available in Australia and is designed to represent the dominant land use; for example, residential. Meshblocks also use broad classes of land use, including parkland. The ABS parkland classification represents open spaces, parks and woodlands but excludes primary production areas and private gardens. The ABS does not recommend Meshblocks to be utilised for identifying land use because they are based on the majority rule and may not be an accurate land-use dataset (ABS 2016d). A subsequent cross-sectional study of Australian capital cities utilised ABS Meshblocks classified as 'parkland' in association with socio-economic data (ABS Socio-Economic Indexes for Areas [SEIFA]). and reported that Adelaide had the least equitable distribution of green space between low and high socio-economic Statistical Area 1 (SA1) census areas (Astell-Burt et al. 2014b).

A recent investigation tested the spatial measures of POS planning standards in Australia (Hooper et al. 2018) and reported there was limited uniformity in POS planning standards and spatial datasets representing POS between the state and territories (South Australia was not included in the study). The ABS Meshblocks parkland classification as applied by Astell-Burt et al. (2014a) was evaluated against a state POS dataset from Perth. The results identified that the Meshblocks did not align with POS as defined in a state-based POS dataset or provide an accurate representation of open spaces with public accessibility due to the generalised approach of how ABS Meshblocks 'Parklands' were determined. This study highlighted that caution is required when employing datasets for research (Hooper et al. 2018).

An outcome of these studies highlights the variability and quality of datasets available in overseas and within Australia, which can mislead urban planners and population health professionals as they may not be comparing like with like, yet this is submitted as the body of evidence that supports the necessity for open space within urban settings associated with population health. The implications of these studies support additional study in the development of a POS dataset that is clearly defined, validated and could be replicated if similar data source data were available.

3.4.1 Modifiable areal unit problem.

Spatial analyses are sensitive to variations in geographical spatial units to collate data and the scale at which the data are reported. Early empirical work in the 1930s recognised statistical correlations increased in size when census tracts were aggregated (Gehlke & Biehl 1934). The issue of aggregated spatial analysis was revisited by Openshaw, Taylor and Wrigley (1979) and Openshaw (1983), who described this phenomenon as the Modifiable Areal Unit Problem, with two categories: scale and zonation.

Geographical data are frequently aggregated to enable the presentation of results in a practical context, and spatial units, for example, census tracts, suburbs or postcode boundaries, are examples of scale to illustrate spatial variations within aggregated data. Zonation is observed when the scale is fixed, but the shape of the aggregation unit changes (Jelinski & Wu 1996; Unwin 1996). Nakaya (2000) acknowledged that there is a potential source of error when aggregated data are applied to an arbitrary spatial unit: utilising smaller areal units could create a bias in an analysis because the representative data are often too small to provide a meaningful outcome; whereas larger areal units could conceal significant data variations in an analysis. In research, the Modifiable Areal Unit Problem is consistently not acknowledged in health research and omitted as a limitation (Root 2012).

3.5 Conclusion.

From the review of the open space standards, it is clear that there was little if no empirical basis for the supply standards. Additionally, since their development close to a hundred years ago, little effort by urban planners to review and develop rigorous evidence-based standards. While there have been isolated examples of work to explore the supply standards, these were for small geographical extents and not followed up with larger-scale research.

One small scale project was a study undertaken in Colchester, United Kingdom, in 1967 which investigated the patronage of parks and playing fields in both winter and summer to determine the open space needs of the population, and the relevance of the British standard of 6 acres per 1,000 population. The study concluded that 2.5 acres (1.01 ha) of playing fields were utilised in winter, but only 1.8 acres (0.7 ha) of playing fields in summer, per 1,000 population (Winterbottom 1967). Similarly, a local government research project in South Australia investigated the effects on open space supply when residential densities increased reporting the 12.5% open space supply standard could deliver an insufficient supply of quality open space within new residential developments. Therefore, unless there is enough open space in the adjoining areas, there could be a potential deficit of supply to service the local community (City of Charles Sturt Council 2011).

Open space supply standards continue to be controversial and challenging to apply, especially in areas with higher residential densities (Byrne, J, Sipe & Searle 2010). There has been a focus on providing quality POS and improved accessibility rather than relying on standards advocating only quantity (Ståhle 2008). To improve the provision of POS, supply standards and legislation must include quality and access metrics. In the United Kingdom, the 'Natural Greenspace Standard (ANGSt) was developed to provide recommendations for access, size and connectivity to greenspaces; the minimum recommendation was at least 2 ha in size of green space no more than 300 m from home (Natural England 2010). Without considering the quality and access metrics, the application of purely quantity standards at an urban scale might be meaningless. Of particular relevance is that the urban green space area per resident might be high for a larger residential area, but when applied at a street or neighbourhood level there could be an inadequate supply of accessible urban green space (Haaland & van den Bosch 2015). Urban design practices are frequently focused on economic, environmental and social factors, although commercial concerns increasingly influence planning practices to the detriment of social and ecological systems (Hofstad 2012).

Despite limited political motivation and resources, change is occurring slowly; urban planning policies advocating open space standards have an increased emphasis on the supply of quality open space to meet the requirements of 21st-century urban environments. Although more work is required, there are opportunities for urban planners to develop on-demand and value-based guidelines to address the requirements of local communities and promoting population health (Byrne 2013; Cranz 1982; Fields in Trust 2015; Parks and Leisure Australia 2013).

Research has shown that poor general health and wellbeing can be associated with adverse environmental factors, including poor air quality, excessive noise and extremes of heat and has linked the inclusion of green infrastructure and increased biodiversity to mitigate these environmental factors (Lõhmus & Balbus 2015). Although such research recognises environmental factors as causal in relation to population health, these factors are not included in the current study as the investigation involves only social planning aspects.

Hooper et al. (2018) revealed that representations of POS in spatial datasets are not uniform, and caution is necessary when applying them to a research objective. Therefore, geographic information software provides robust tools to validate and analyse data. However, the data must be well defined, and sufficient justification provided for the spatial units selected. The literature emphasises the need for quality validation and analysis of spatial data, including the use of aerial imagery and field validation to ensure accurate data representation to fulfil research objectives.

3.6 Research questions.

This literature review identified that a more in-depth analysis is required to understand open space supply legislation and standards in current planning policies and for higher-density 21st century urban environments. How open space is defined and represented spatially can contribute to the development of new open space standards that advocate for increased equitability of open space supply and promotion of population health through improved physical activity and mental health. The flow-on benefits of improved population health can reduce the economic burden on health and wellbeing programmes managed by the private sector and governments. To address the outcomes of the literature review, the following questions are posed as a study of metropolitan Adelaide, in a broader context, these questions could be applied to other cities:

1) are South Australian open supply standards equitably implemented?
2) does the supply of public open space vary across metropolitan Adelaide?
3) how accessible is public open space across metropolitan Adelaide?
4) are there significant statistical associations between population health and public open space count and area across metropolitan Adelaide? And
5) what are the urban planning policy implications of this research?

Chapter 4: Research Design.

This research applied mixed methods and a multidisciplinary approach to broaden knowledge about the complexities of open space and associations with population health. This chapter describes the research design applied to accomplish the objectives stated in Section 1.5, which were to:

1) explore the origins and the appropriateness of legislated open space supply standards and policies within 21st-century urban environments;
2) develop and validate a 2016 POS spatial dataset representing supply within the study area;
3) investigate the distribution of POS and accessibility across the study area; and
4) explore associations between population health and POS area, count, accessibility and dwelling density.

This chapter addresses the above objectives in the following sections:

- Section 4.1 presents the research designs that have been applied in the research;
- Section 4.2 outlines the research paradigm underlying the research;
- Section 4.3 considers the ethical considerations in undertaking the research;
- Section 4.4 provides an overview of the metropolitan Adelaide study area;
- Section 4.5 reviews the qualitative data analysis associated with the semi-structured interviews (Chapter 5:);
- Section 4.6 outlines the secondary data sources used to undertake quantitative analyses in Chapter 6:–Chapter 8:;
- Section 4.7 describes the software utilised to interpret, validate and visualise the qualitative and quantitative data; and
- Section 4.8 details the analytical methods applied to answer the research aims.

4.1 Research design.

Mixed method research involves the collection, analysis and interpretation of data via quantitative and qualitative techniques and concepts to examine underlying phenomena (Castro et al. 2010; Clark & Ivankova 2016; Leech & Onwuegbuzie 2009). The mixed-methods approach, however, is not without critics, who imply that qualitative and quantitative are distinct and should not be combined because of their different assumptions (Fielding & Schreier 2001). Conversely, Fakis et al. (2014) argued that mixed methods research enables a researcher to answer one or more questions from different viewpoints. Fetters, Curry and Creswell (2013) maintained that mixed methods research facilitates the collation of qualitative data which can be applied to assess the validity of quantitative data. Likewise, quantitative data can be utilised to generate qualitative samples, or to explain the results from the qualitative data analysis. The increasing application of digital technologies has cemented mixed methods as a recognised research design and process, as technology enables researchers to manage large and diverse data, facilitating data mining and integration, statistical analyses and visualisations (O'Halloran et al. 2018).

4.2 Research paradigm.

Creswell and Plano Clark (2011) proposed that mixed methods research aligned with four categories of inquiry: embedded, exploratory, triangulated and explanatory. This research is aligned with triangulation, which recognises the insufficiency of a single data source and the requirement to obtain multiple viewpoints to understand the complexity of social events (Webb et al. 1966). Triangulation, as utilised in the social sciences, is further divided into two categories: simultaneous and sequential. Simultaneous triangulation involves multiple methods applied independently in data collection, analysis, results and discussion; whereas, in sequential triangulation, the results from one method are required to guide the next method (Creswell 2015; Johnson, Onwuegbuzie & Turner 2007).

The sequential triangulation approach was applied in this study. A first, qualitative phase identified strategies that focus on how people think, apply and resolve social measures. This fed into a quantitative approach employing numerical geography using identified social measures, with the objective of interpreting and visualising evidence at different spatial scales. The research design comprised five sections.

1) semi-structured interviews with urban/open space planners to determine the implementation of open space within current state government urban planning policies and guidelines;
2) the use of GIS to develop and validate an open space spatial dataset within the study area;
3) to determine whether the current open space supply standards are equitable across the study area
4) the application of GIS to calculate the distance metrics from dwelling points to open space within the study area; and
5) statistical analyses to investigate associations between population health and open space count and area, access, dwelling density and socio-demographic data.

An overview of the research design is presented in Section 4.8.

4.3 Ethical integrity.

Human ethics approval for the study was granted by the University of South Australia Ethics Committee to undertake semi-structured interviews with selected persons (Appendix 1). on the basis the semi-structured interviews:

1) upheld complete confidentiality and anonymity;
2) requested informed consent from respondents;
3) informed respondents that participation was voluntary;
4) informed the respondent they could withdraw at any time from the research process;
5) protected the data collected, according to the University of South Australia guidelines;
6) offered respondents notes of the interview outcomes; and
7) respected respondents' expertise and opinions and emphasised as impartial and nonjudgmental.

Additional human ethics approval to acquire and utilise data from the South Australian Monitoring and Surveillance System was obtained from SA Health (Appendix 2). The

University of South Australia Ethics Committee endorsed the SA Health ethical approval (Appendix 3).

As defined by the University of South Australia *Ownership and Retention of Data, Policy No: RES-17.0,* general research data and records will be retained for a minimum of five years and stored in a secure location to prevent unauthorised access, destruction or alterations.

A field study to validate a sample representation of the POS dataset involved only visual observation recorded on an Apple iPad and as photographic imagery. Physical and oral contact was avoided with those identified as vulnerable persons, for example, children. Documents providing evidence of approval for the field study were carried during the investigation, for presentation if requested by a recognised official (council ranger or police officer).

4.4 Study area.

The South Australian *Development Act* (*1993)* defined the study area of metropolitan Adelaide, which corresponded with the Australian Bureau of Statistics (ABS) Adelaide Statistical Division (ASD) 2006 boundary (Australian Bureau of Statistics 2006). In 2011, the ABS reclassified the ASD as the Greater Capital City Statistical Area (Adelaide) (ABS 2016d). The area added was outside the scope of this research as it was predominantly low-density rural, intermingled with small townships (Figure 4-1).

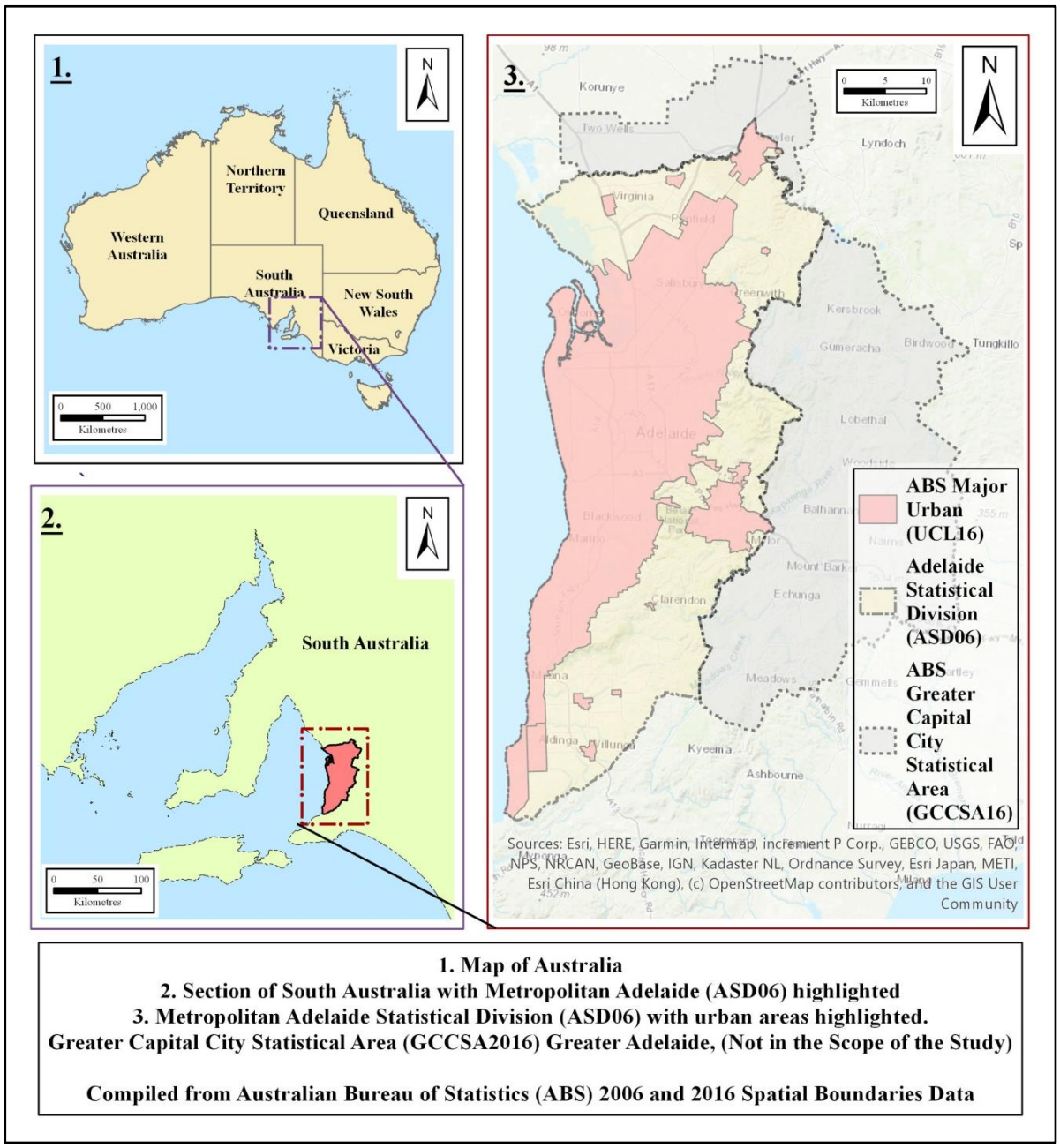


Figure 4-1: Study area: metropolitan Adelaide, South Australia.

The ASD extends approximately 30 km from the coast to the Adelaide Hills in the east, and 90 km from Gawler in the north to Sellicks Beach in the south and covers an area of 1,823 km^2 (Figure 4-1). The 2016 census recorded a population of 1,235,941 persons living within metropolitan Adelaide, an increase of 5% from the 2011 census (ABS 2011b).

Metropolitan Adelaide is regarded as having a Mediterranean climate, receiving an average annual rainfall of 550 mm, mainly in the winter months. Average maximum and minimum temperatures for January are 31°C and 17.5^{o}C respectively and for July, 14.8^{o}C and 7.5^{o}C respectively. Only a few weeks during the year experience extremes of hot and dry or wet and cold weather (ABS 2009).

A representative image of metropolitan Adelaide is provided in Figure 4-2. This shows the central business district (CBD) (top centre-right) with a typical layout of suburbs with tree-lined streets between the camera and the central business district.



Figure 4-2: Photograph of the study area looking north and location in Adelaide, South Australia. Photograph by author.

4.5 Qualitative data sources.

4.5.1 Review of open space legislation and policy.

The review of open space definitions, policies and legislation in Chapter 3: identified open space supply standards and legislation in Britain, US and Australia. Further, the review identified how definitions, legislation and policies have developed over time and are currently applied to current urban planning strategies, particularly in light of the densification of urban areas. This review was supplemented by undertaking semi-structured interviews with urban planners.

4.5.2 Survey of urban planners on the implementation of public open space legislation.

The semi-structured interviews were undertaken to ascertain the attitudes and opinions of urban planners (and open space planners within larger organisations) concerning open space definitions, how decisions were made regarding open space supply within development proposals and the relationship between open space and population health.

The semi-structured interview approach was selected over other interview options as it has been accepted as providing a robust method to gather the opinions of interviewees (Rabionet 2011), through an ordered set of predetermined questions, which encourage additional points to emerge during the interview (DiCicco-Bloom & Crabtree 2006). This style of interview represents a robust method to undertake qualitative research (Bryman 2006). Participant selection is indicative rather than a representative sample with the goal of gaining insights into interviewees' experiences (Gatrell & Elliott 2014).

The selection criteria for the semi-structured interviews in this study required participants to be one of the following:

1) an urban or open space planner involved in the implementation of open space from;
    a. a local government within the study area;
    b. a state government department(urban infrastructure);
    c. a consultant urban planning organisation; and
    d. a construction company involved with large-scale residential developments.

Invitation letters were mailed to the chief executive officer or senior manager to request permission to undertake research with an urban/open space planner within their organisation (correspondence letter templates in Appendix 4). Contact was initiated with organisations identified as employing urban and open space planners; a number did not respond or did not wish to participate and were not available for an interview. No responses were obtained from the construction sector.

In total, 12 local governments, two state government departments and one urban planning consultancy agreed to participate in the research. All participants were sent an approach letter when they made contact via telephone or email; an appointment time and location was confirmed between 9 January and 24 February 2017. Before the meeting, participants were sent an overview of the research questions and a request to sign a written consent to participate proforma (interview questions and authorisation template in Appendix 5 and Appendix 6). No coded details of respondents are presented in view of the small sample size and the potential risk of re-identification of the respondents and their organisations.

The interviews included seven planned questions. The first two questions were related to how the interviewee and their organisation defined open space, with no direction provided regarding how to interpret this question, for example, whether they were being asked their personal or formal position as an employee following their organisation's directives. The next two questions were concerned with the interpretation of the current planning legislation affecting open space and how open space is implemented within new developments. The next two questions focused on investigating the interviewee's and their organisation's understanding of the association between open space supply and population health. The final question allowed the participant to contribute additional observations to support their previous responses (Appendix 5).

The interviews were recorded on a secure smartphone and transcribed utilising NVivo software (QSR International 2017). Transcripts were evaluated and key topics that emerged, for example, defining open space, quality, quantity, legislation and supply, were developed to determine the roles of local and state government provision and management of open space and the promotion of health and wellbeing.

4.6 Quantitative data sources.

4.6.1 Spatial datasets depicting open spaces.

The representation and distribution of open space needed to be determined to facilitate the identification of how open space has been implemented in the urban environment, and testing of the supply of open space within the study area, as described in Chapter 6. Selected datasets for this purpose consisted of two national and two South Australian datasets, including an earlier public open space (POS) dataset developed by the researcher (Table 4-1).

Table 4-1: Summary of the spatial databases representing open spaces.

Data source name	Year	Source	Details
PSMA Greenspace	2016	PSMA Australia Ltd	Sourced through https://portal.aurin.org.au
South Australian Meshblocks digital boundaries	2016	Australian Bureau of Statistics	http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.001July%202016?OpenDocument
South Australian Digital Cadastral Database	2016	Government of SA Department of Planning Transport and Infrastructure (DPTI): Land Services Group	Agreement between DPTI and University of South Australia for teaching and research
VPOS2011 (metropolitan Adelaide)	2011	Researcher's dataset	(Daker 2014a; Daker, Pieters & Coffee 2016)

The PSMA Greenspace dataset represents local larger parks, reserves, national parks and other open space, although it omits botanic gardens and smaller open spaces (PSMA 2016b). The ABS Meshblock is the smallest geographic unit defined in the Australian Statistical Geography Standard (ASGS). The digital polygons within Meshblocks are categorised into broad land use classifications including residential, parkland, agricultural and industrial. For this research, the parkland classification was extracted (ABS 2016c). The third dataset was the South Australian Digital Cadastral Database (DCDB). This dataset provides a spatial representation of land parcel boundaries with attributed land use codes assigned for taxation assessment (Department of Planning Transport and Infrastructure 2016c). Land use codes were extracted that represented potential open space and recreation activities (Department for Transport, Energy and Infrastructure 2015) (see Figure 6-3 for a complete listing of land use codes). The researcher's 2011 POS dataset (Daker, Pieters & Coffee 2016) provided a contextual backdrop to identify changes between 2011 and 2016.

4.6.2 The open space development fund.

South Australian legislation stipulates residential land divisions from a single lot into two or more lots incurs a financial contribution into the Open Space Development Fund. The current Open Space Development Fund contribution, $7,616 per allotment or a community title, (within metropolitan Adelaide) is submitted to the Planning and Development Fund and managed by the Department of Planning, Transport and Infrastructure (DPTI) (*Development Act* 1993; *Development Regulations* 2008). Local and state government departments can apply to the Planning and Development Fund for financial grants up to 50 percent of the project value to either revitalise existing or implement new areas of open space. The collated Open Space Development Fund data is managed by the Department of Planning, Transport and Infrastructure and represents the location, project type and dollar value of open space grants (DPTI 2017c).

4.6.3 Spatial datasets to calculate the distance from dwelling points to any public open space.

A component of exploring potential associations between open space distribution and population health involved the calculation of distance metrics from a dwelling point to any open space. The calculation of a distance between two points requires an origin (dwelling point), a destination (POS dataset) and some means of calculating the distance, either Euclidean distance (straight line) or a street network. For this analysis, both the Euclidean and street network distances were calculated. A list of geographic databases utilised for this investigation is provided in Table 4-2.

For the street network measure, a suitable street network was required and two were assessed, the PSMA Street Network and the Department of Planning, Transport and Infrastructure (DPTI) road data (DPTI 2017b; PSMA 2016a). The PSMA dataset is national, and the methods used in this research could be replicated within other cities in Australia, while the DPTI road data is only applicable for South Australian use. Both datasets were utilised in the research to highlight the variability in street network datasets. The PSMA data represented a more comprehensive network of not only streets but included trails within POS and footpaths from POS and across road dividers, while the DPTI classified only principal roads and streets. Because the trails and footpaths within a POS could influence the subsequent analysis relating to access points from a street, and to extract these footpaths and trails could inadvertently remove desired footpaths, for example, those leading to a POS or

traversing a road divider. Therefore the DPTI road data was utilised to enable the POS data preparation for the access analysis from a POS to the street network. The distance analysis would be undertaken on the more comprehensive PSMA Street Network.

The dwelling point data (DPTI 2016b) are derived from land parcels and valuation data for South Australia. To prevent over-calculation counts associated with a validation that includes more than one parcel were assigned the value of a fraction (i.e. <1) by dividing the number of parcels by the number of dwellings and the fractional result applied to each parcel in the validation. Land use codes attributed to residential dwellings are listed in Appendix 8. The inclusion of the PSMA Railway Lines (PSMA 2017), a national dataset representing railways, tramways and busways and the South Australian government watercourses data (DEWNR 2017) facilitates the option to identify potential barriers within a network walkability analysis (Gelb et al. 2017). The ASD digital boundary for metropolitan Adelaide provides the boundary to define the limits of the street network analysis (ABS 2006).

Table 4-2: Summary of data sources applied to calculate the distance from a dwelling to any POS.

Data source name	Year	Source	Details
Street Network	2016	PSMA Australia Ltd	Sourced through: https://portal.aurin.org.au
Railway Lines	2017	PSMA Australia Ltd	Sourced through: https://portal.aurin.org.au
Roads	2017	Government of SA Department of Planning Transport and Infrastructure (DPTI)	Sourced through: https://data.sa.gov.au/data/dataset/roads
Watercourses	2018	Government of SA Department of Environment and Natural Resources	Sourced through: https://www.waterconnect.sa.gov.au/Pages/Home.aspx
Dwelling Count, South Australia	2016	Government of SA Department of Planning Transport and Infrastructure (DPTI) Land Services Group	Agreement between DPTI and University of South Australia for teaching and research
ASD digital boundary	2006	ABS Australian Bureau of Statistics	Sourced through: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1259.0.30.0022006?OpenDocument

4.6.4 South Australian Monitoring and Surveillance Systems.

The South Australian Monitoring Surveillance System was developed by the Population Research and Outcomes Studies (PROS) Unit, University of Adelaide in conjunction with the South Australian Government Department of Health, which maintains an epidemiological monitoring system to understand the occurrence of chronic conditions and determinants of health within the population of South Australia. Since 2002, all households with a landline telephone number have been eligible for random selection. From 2004, 1,000 South Australian households per month have been randomly selected, with an introductory letter sent to the selected household outlining the survey objectives and informing them to expect a telephone call. Interviews are conducted utilising a 'computer-assisted telephone interview' system (CATI III) to permit interviewer sequencing, recording and cross-checking of the responses with a high degree of accuracy (SA Health 2004). Up to six callbacks are scheduled for the household to complete the survey. The South Australian Monitoring Surveillance System data were imported into SPSS software for analysis, with the data weighted by age, sex and area (metropolitan/rural) to align with the population structure in South Australia and the latest ABS population census data. The overall response rate for the South Australian Monitoring Surveillance System survey has reached nearly 70% (SA Health 2004).

Within the South Australian Monitoring Surveillance System survey there is a self-rated health question titled 'SF1 general health status', in which respondents are asked for an assessment of their overall health from 1 (poor) to 5 (excellent) and not to focus on a single component of health, for example, physical, mental or social health (SA Health 2016b). The SF1 was utilised in this research as it is recognised as a reliable assessment tool for the health status of South Australian populations, and numerous health reports have utilised the SF1 results (Avery et al. 2006; Gill et al. 2009; SA Health 2013, 2016a, 2017). Although a significant limitation of health status measures involves the difficulty of interpretation and scoring, the single-item SF1 has been widely applied in health research and provides an insight into the overall health and an influential predictor of actual population health status (Gill et al. 2009; Mackenbach et al. 1994; Simon 2002).

4.6.5 Australian Bureau of Statistics sources.

Chapters 6 to 8 apply data from the Australian Bureau of Statistics (ABS), which is a national organisation that collects population and business data and delivers the data in

multiple formats. An important role undertaken by the ABS is the national population census held every five years to obtain a snapshot of the Australian population. The ABS also manage the ASGS, which provides the basis for statistical geography to disseminate the population census and other ABS-collated data in Australia.

For this research, three Census Geographic Areas were selected: the LGAs, postcodes (POAs) and state suburbs (SSCs) from the *ASGS Volume 3 Non-ABS Structures* (ABS 2011a). The Socio-Economic Indexes for Areas (SEIFA) and the indices; Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) were also used (Table 4-3).

The three spatial unit boundaries (LGA, POAs and SSCs) were selected to explore the Modifiable Areal Unit Problem when applied to the spatial analysis comparison between datasets representing open spaces. Modifiable Areal Unit Problem is a potential source of bias. The first issue is scale; when the same analysis is applied to the same data but the size of the aggregated unit changes, for example, Postcodes and Suburbs. The second is the zone effect, where the scale is fixed but the shape of the aggregated units is altered (Openshaw 1984).

LGAs approximate officially gazetted local government areas. Within the ASGS, the boundaries are constructed from whole Meshblocks (Figure 4-3).

Table 4-3: Australian Bureau of Statistics data sources.

Data Source Name	Year	Source	Details
Local Government Area (LGA) digital boundaries	2016	Australian Bureau of Statistics	Sourced through: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.003July%202016?OpenDocument
Postcode Area (POA) digital boundaries	2016	Australian Bureau of Statistics	Sourced through: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.003July%202016?OpenDocument
State Suburb (SSC) digital boundaries	2016	Australian Bureau of Statistics	Sourced through: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.003July%202016?OpenDocument
Socio-Economic Indexes for Areas (SEIFA); The Index of Relative Socio-economic Advantage and Disadvantage (IRSAD)	2016	Australian Bureau of Statistics	Sourced through: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/2033.0.55.0012016?OpenDocument

Postcodes are represented by a four-digit number to assist Australia Post mail delivery; however, Australia Post does not define geographic boundaries. Postcodes are a recognised link to an address and are widely applied by businesses and researchers as a method to link data to a geographic area. The ABS has developed geographic boundaries that are a close approximation to Australia Post postcodes. ABS postal areas (POAs) are approximated by Statistical Area Level 1 (SA1) boundaries (Figure 4-4). The SA1 is the second smallest unit after Meshblocks and the smallest spatial unit in which the census data are released. The official postcode delivery boundaries have not been updated since the 1990s, and recent ABS boundary interpretations have not been endorsed by Australia Post (ABS 2011a), which is a potential limitation of using the POA spatial unit.

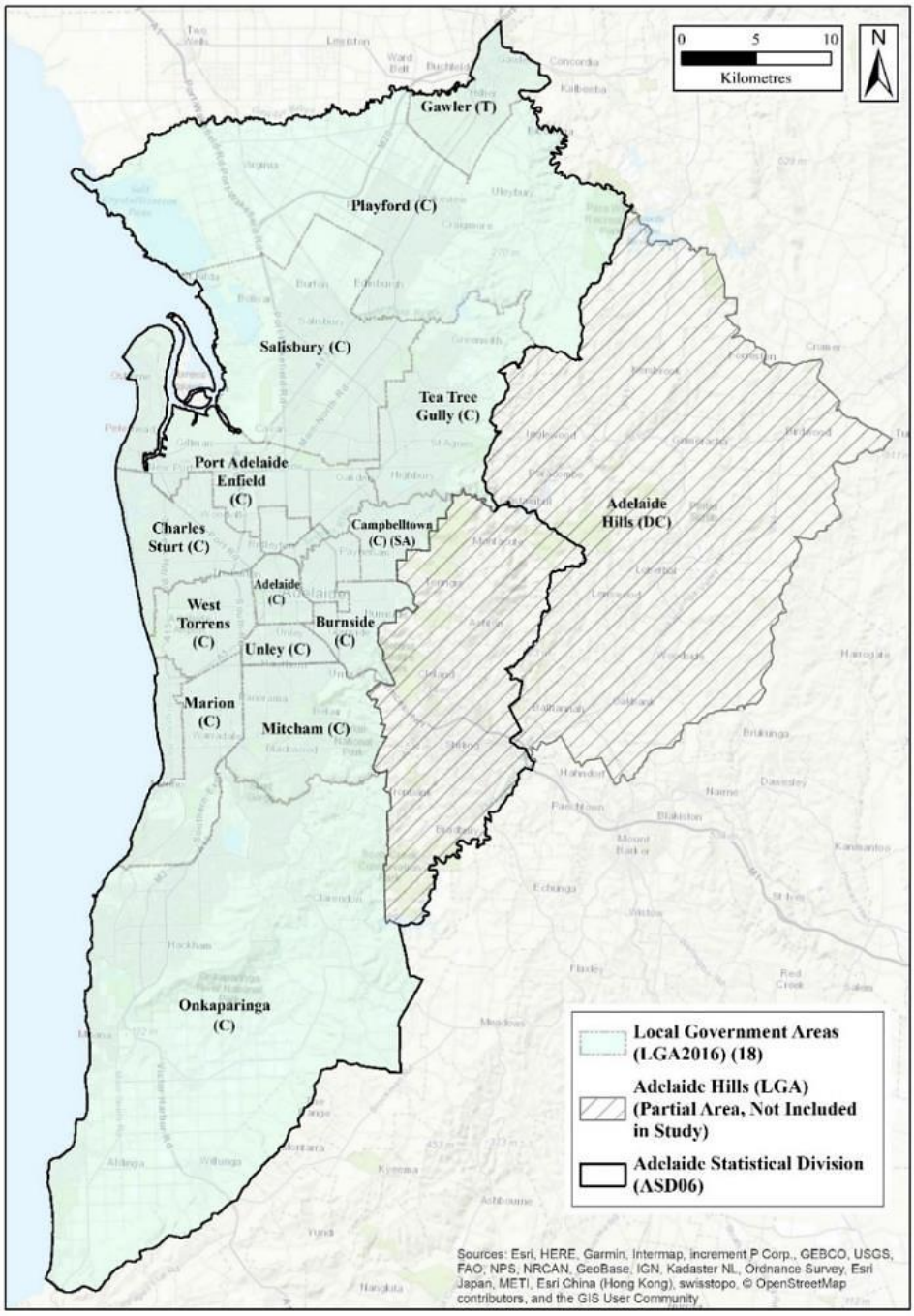


Figure 4-3: ABS Local Government Areas (LGAs).

Data source: (ABS 2016a).

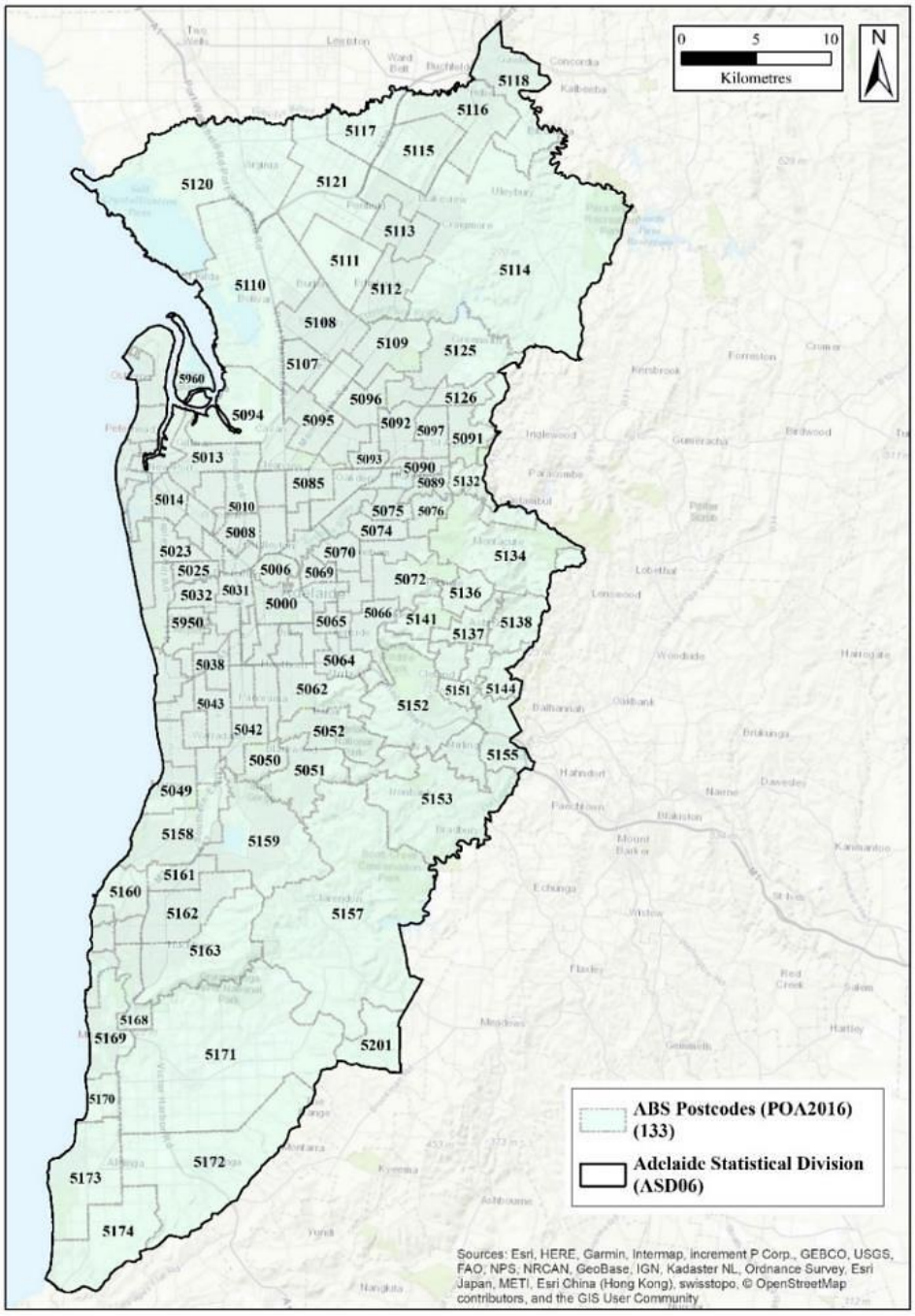


Figure 4-4: ABS Postcode Areas (POAs).
Data source: (ABS 2016a).

ABS State Suburbs (SSC) are based on the state-administrated and gazetted suburbs, and one or more can be located within an LGA and POA area. Previously they were developed from SA1 boundaries, but since 2016 they are created by allocating Meshblocks, thereby delivering greater overall accuracy. The 2016 state suburb names are aligned with gazetted localities provided by PSMA Australia. The SSC boundaries do not precisely match the gazetted suburbs, particularly in rural and remote areas (Figure 4-5).

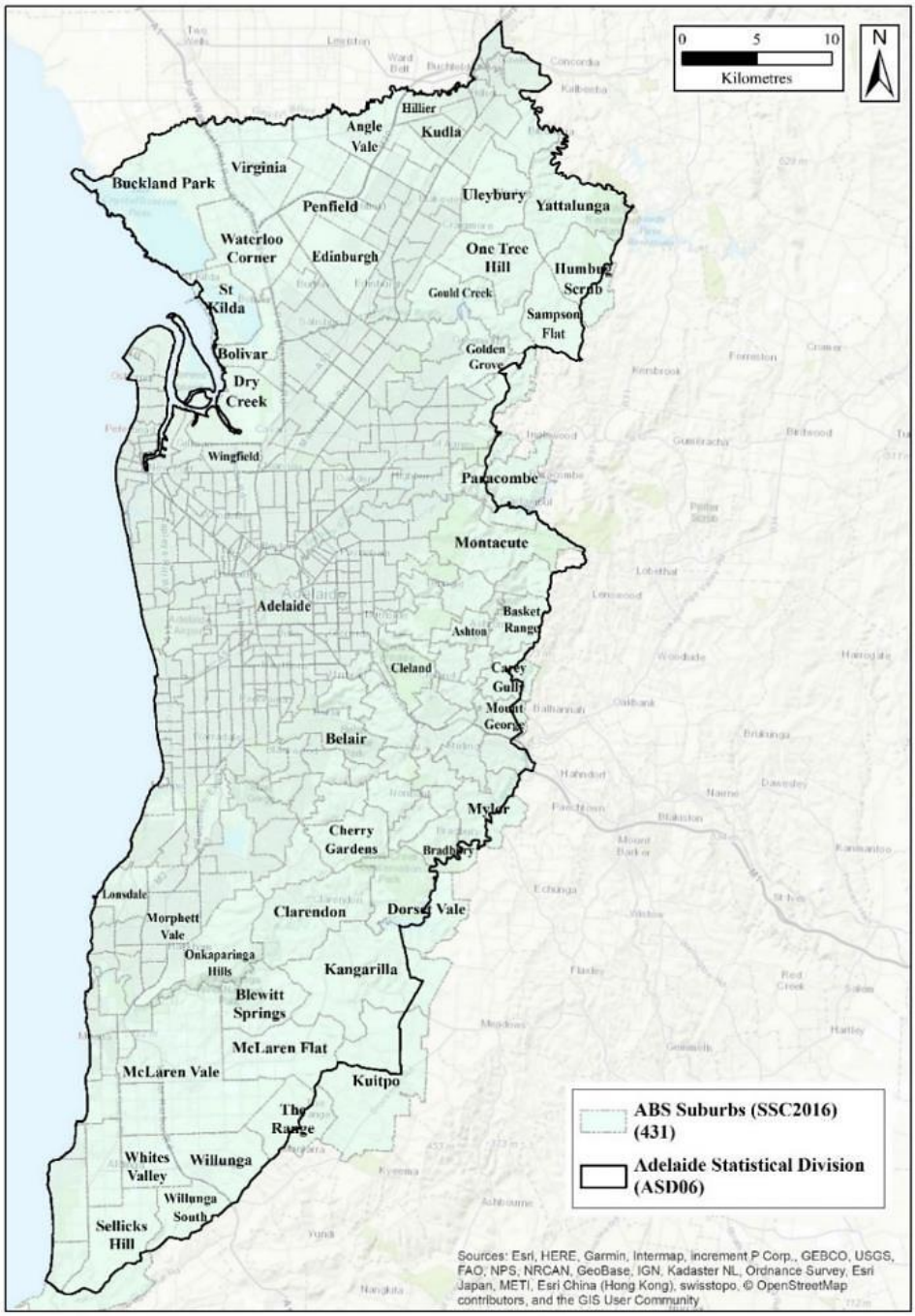


Figure 4-5: ABS State Suburbs (SSCs).
Data source: (ABS 2016a).

The SEIFA has been developed by the ABS and collated from social and economic data collected during a census. SEIFA comprises four indices that rank geographic areas by their comparative socio-economic advantage and disadvantage. Each area receives a score and decile indicating how disadvantaged or advantaged it is compared with the Australian average. The IRSAD was applied in this research because it provides an overview of both advantage and disadvantage representation within the study area. A higher score signifies greater socio-economic advantage. Indicators include completion of an educational

qualification certificate III or a diploma, but not a bachelor degree, and occupied private dwellings with mortgages greater than $2,800 per month. A lower score denotes less socio-economic advantage; for example, a higher incidence of homes with lower weekly incomes and residents often in unskilled occupations (ABS 2016b). The IRSAD decile rank for South Australia can be represented for SSCs or POAs, as shown in Figure 4-6.

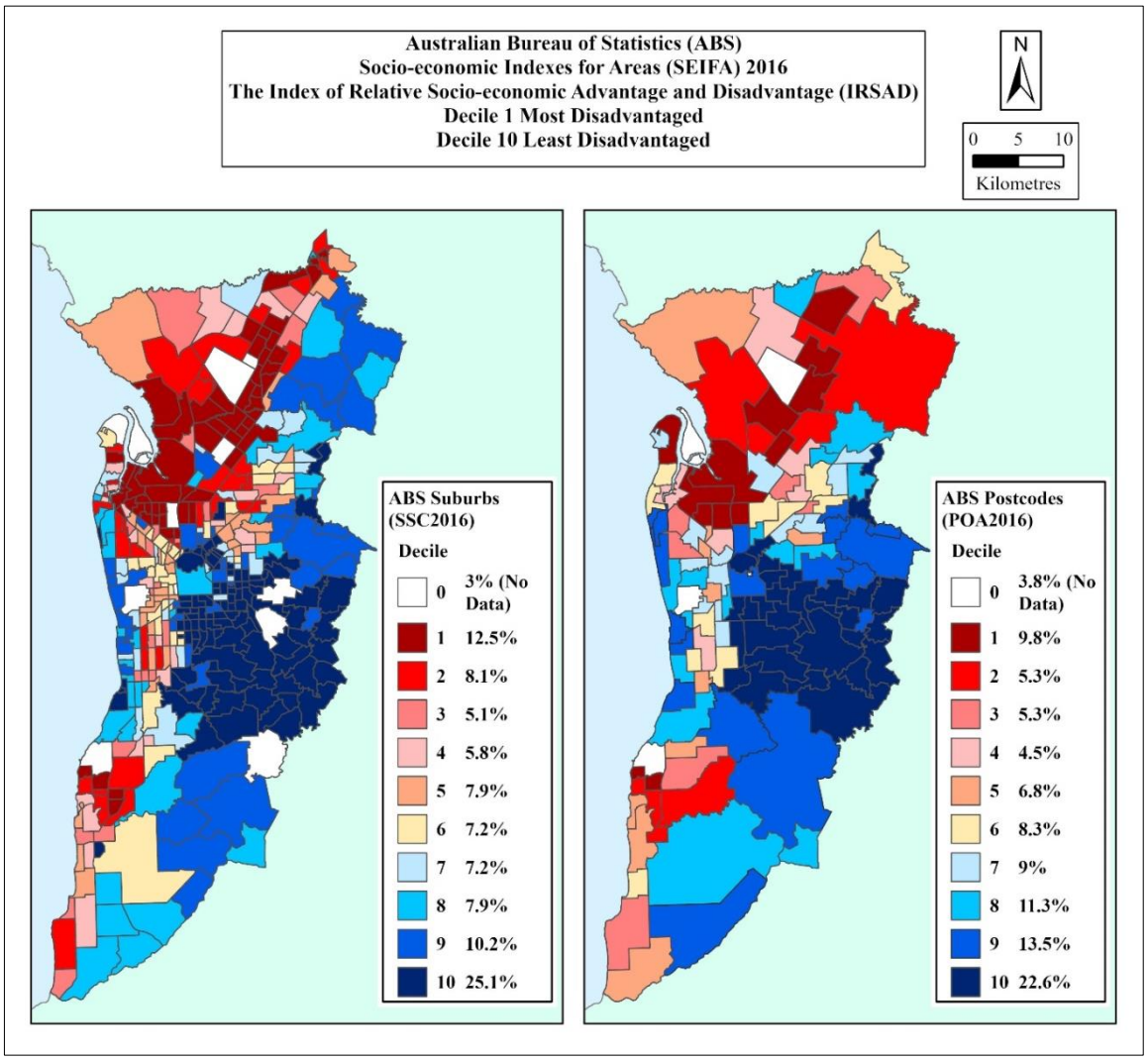


Figure 4-6: ABS Socio-Economic Indexes for Areas: Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) at SSC level (left) and POA level (right). Numbers in brackets show the percent of spatial units within the South Australian State decile. 'No data' indicates areas with no residential dwellings.

Data source: (ABS 2016b).

4.7 Software.

To interpret, validate and visualise the qualitative and quantitative data, the following computer software was utilised:

- ArcMap 10.5 and 10.6 were developed by ESRI to capture, manage, analyse and visualise spatial datasets (Environmental Systems Research Institute 2016b);
- ArcGIS Pro 2.4 developed by ESRI as a desktop and online application to supersede ArcMap (ESRI 2019);
- MapInfo Pro was produced by Pitney Bowes Software to capture, manage, analyse and visualise spatial datasets (Pitney Bowes 2015);
- Metromap was developed by AEROmetrix and presented high-resolution aerial imagery (7.5-cm ground sampling distance). The imagery can be zoomed to a location and maintain clarity. The company undertakes two or more aerial passes per year over metropolitan Adelaide. The imagery contained a timeline from 2004 to 2016 (AEROmetrex 2016);
- Google Earth Streetview (open source data) was used to support the visualisation of locations from a street view when aerial images were inconclusive: for example, tree cover obscuring ground information below the canopy. The date of capture was available (Google Earth© 2016);
- NVivo is qualitative data analysis software that can support qualitative research methods to organise, analyse and locate key insights in written data obtained from interviews, surveys, articles and social media (QSR International 2016);
- SPSS is statistical predictive analytics software that enabled a numerical analysis of POS supply, distribution and association with population health (IBM 2018).

4.8 Analytical techniques.

This research provided a descriptive analysis of the primary and secondary data sources as defined within this chapter and outlines the data sources, aims and analytical methods undertaken to address the research design.

Figure 4-7 illustrates the sequential triangulation approach used in Chapters 5 to Chapter 8.

Table 4-4: Analytical methods to address research design.

Chapter no. and title	Sources of data	Aim	Analytical methods
Chapter 5: Interpretation and Implementation of Open Space Standards	Literature review	Understand the relevance of open space supply standards Analyse implementation of open space supply standards within urban environments Perceptions of associations between open space and population health	Semi-structured interview responses
Chapter 6: Open Space Supply and Distribution	Data from Chapter 5 PSMA Australia Ltd Australian Bureau of Statistics Government of SA Department of Planning Transport and Infrastructure (DPTI)	Highlight variability between datasets representing open space Create a POS dataset (2016) representing passive and active spaces in metropolitan Adelaide Validity of open space standards; percent of area and per capita Equitability of Open Space Development Fund.	Alignment with interview responses Data aggregation Desktop data validation Field validation data sample Spatial scale representations
Chapter 7: Metrics for Access to Public Open Space	Data from Chapter 6 PSMA Australia Ltd Australian Bureau of Statistics Government of SA Department of Planning Transport and Infrastructure (DPTI Department of Environment and Natural Resources	Calculate street network distance from a dwelling to any POS Highlight changes in distances when with and without barriers, and Euclidean distance are applied to a street network	Raster cost distance analysis Vector network service area analysis Spatial distribution
Chapter 8: Public Open Space Supply and Associations with Population Health	Data from Chapters 6 & 7 Australian Bureau of Statistics Government of SA Department of Health	Analyse perceptions of wellbeing Determine associations between POS count and area and health outcomes	Spearman's correlation Binomial regression Ordinal (multi-level) regression

Figure 4-7 illustrates the workflow associated with the research objectives and presents the qualitative and quantitative methods. As discussed, the research was aligned with sequential triangulation. The results from the open space supply legislation and policy literature review fed into the approach utilised for interviewing the urban planners, and the spatial comparison of open space supply and associations with population health.

The quantitative approach applied the outcomes of the qualitative analysis to emphasises the variability within spatial datasets that represent open spaces. Thus, the objective here was to develop a quality POS dataset for the study area that depicted publicly available open space (POS) suitable for passive and active recreation. This quality dataset then enabled the establishment of POS count and area, the percentage of a residential area and the POS area per 1,000 population when applied to two geographical units, POA and SSC. An additional analysis was undertaken to determine the equitability of the distribution of Open Space Development Fund grants to enable open space upgrades and land acquisitions for open space. The results from the POS dataset provided the foundation for an accessibility analysis that compared a raster cost distance and vector network analysis service area tools to measure street network and Euclidean distance from a dwelling point to POS.

The results from the POS analysis and accessibility analysis, in conjunction with dwelling densities, were compared with a recognised population health score to test for statistical associations. Correlation analysis for non-parametric data was applied to explore linear relationships between the dependent health score variable and independent variables, which included count and area of POS, accessibility and dwelling density metrics controlling for socio-economic and demographic variables. The demographics and socio-economic variables included individual age and gender and the area level ABS SEIFA IRSAD by POA and SSC. The final analysis, a multi-level ordinal logistic regression Generalized Linear Models (GLM) and PLUM (Polytomous Universal Model) syntax, were used to determine whether the independent variables might predict self-rated health outcomes. The influence of each variable was independently analysed, and the significance of an independent variable was identified through an odds ratio (Field 2015; Laerd Statistics 2015). The outcomes from the qualitative and quantitative processes are reported in Chapter 9.

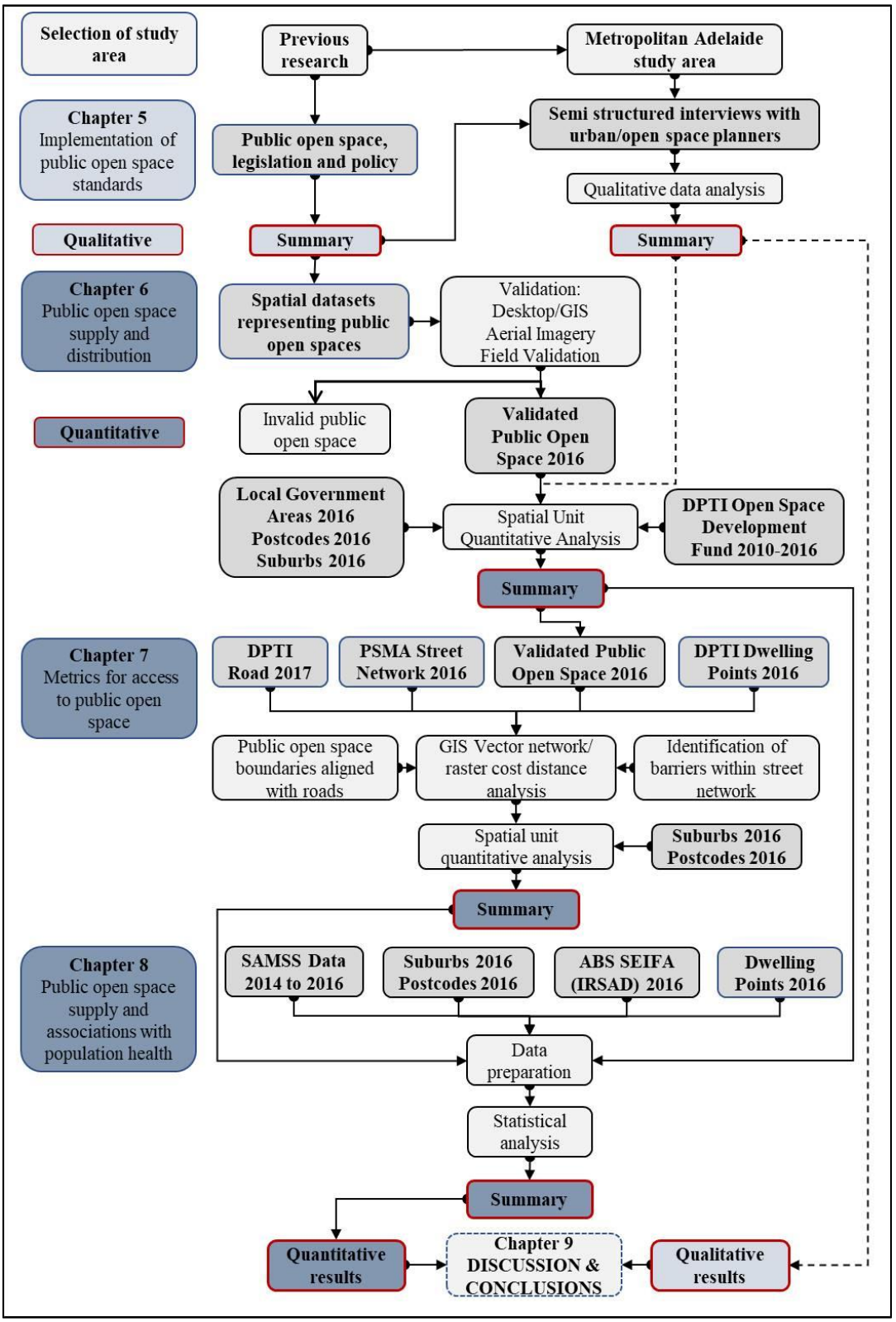


Figure 4-7: Overview of mixed methods research design.

Chapter 5: Interpretation and Implementation of Open Space Supply Standards.

The review in Chapter 2: and Chapter 3: highlighted the international and national differences in open space classifications and the development of open space supply standards and guidelines (Daker 2014a; Daker, Pieters & Coffee 2016; Veal 2013; Wilkinson 1985). This raises the question, within metropolitan Adelaide, how do urban planners define open space and apply the legislated open space supply standard, and is open space distribution equitable? Martin, McCann and Purcell (2003), highlighted that strategic urban planning decisions are increasingly influenced by different goals within government structures and neighbourhood conflicts over current and future developments.

This chapter provides a qualitative analysis of the quantitative data discussed in Section 5.1 to Section 5.3 through the execution of semi-structured interviews with stakeholders from local and state governments and the private sector. The semi-structured interviews were designed to gather organisational and personal opinions of urban planners (and open space planners in larger organisations) concerning how open space was defined, how decisions were made regarding open space supply within the development assessment process and respondents' understanding and opinions about open space and population health.

5.1 Defining public open space.

Participants were asked ‘What is public open space?’ This question aimed to provide data to assess the extent to which there was uniformity regarding the definition of open space. A word cloud analysis of the responses demonstrates consensus regarding several characteristics (Figure 5-1). The prominent response to ‘What is public open spaces?’ was that they were places for recreation and the community and parks was the leading response identified by the respondents to define POS.

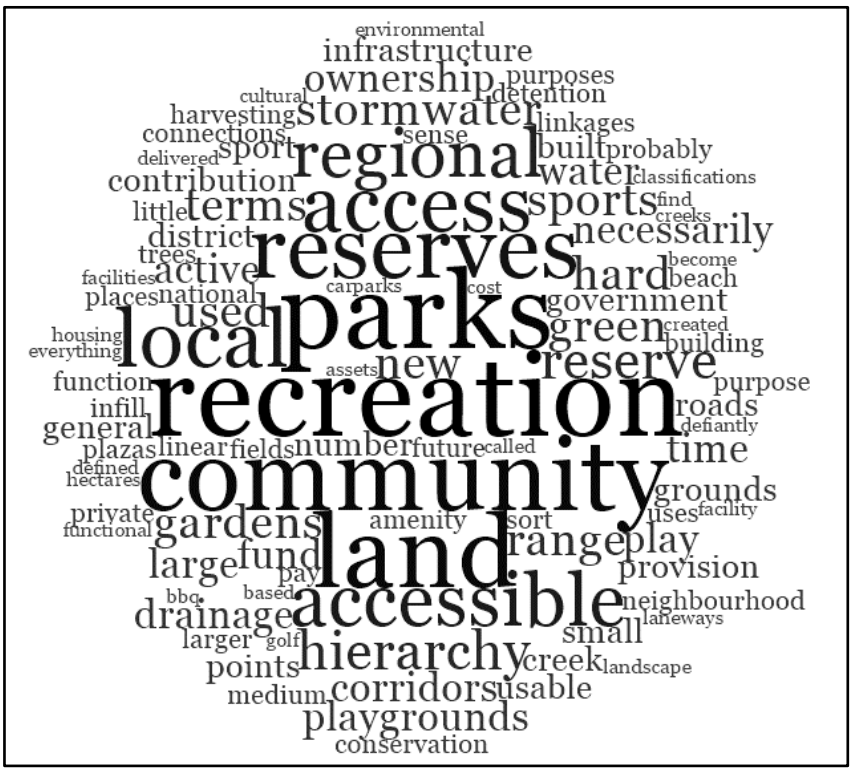


Figure 5-1: Word cloud for participant responses to the question, ‘What is public open space?’

More in-depth thematic analysis showed that planners accepted that POS had multiple definitions that could include reserves and parks that were freely accessible to the community to enjoy unstructured and structured recreation and sport. For example, R4 identified POS as spaces that were:

> Multifunctional and adaptable and encourage community involvement (R4).

R3 highlighted that POS were:

> Anything the public can use in terms of recreation and sport or passively and amenity-based (R3).

Of the15 local government respondents, 10 (67%) did not recognise semi-private areas including bowling greens and golf courses as POS:

> If there is a commercial interest, it's not public open space anymore (R6).

R12 from a local government considered 'public accessibility' to POS involved both public and private ownership; for example, agreements for after-hours access to school ovals. R14 provided a personal view:

> I would look at more of the function of the space rather than who owns it, and if it's publicly accessible and can be used for recreation or perhaps conservation purposes, I would consider that public open space (R14).

Streetscapes re-purposed as occasional POS were discussed. R6 suggested there should be no reason, with the appropriate vehicle management, why they could not be utilised as POS. Three local government respondents (R1, R9 and R12) supported this concept and envisaged that a standard road could be POS when adapted for cultural or sporting events or transformed into a plaza or mall. However, these three respondents recognised that the utilisation of roads for POS involved measures to calm or restrict traffic to ensure pedestrian safety. R9 had investigated redefining larger median strips that ran down the middle of suburban roads, with the objective of making these spaces more of an active space rather than a road divider or an environmental barrier. The outcome of that investigation revealed that to change road layouts to slow traffic and thus ensure pedestrian safety would have been economically impractical.

Roadside verges and median strips were recognised as POS by R2 and R10 as providing interconnectivity to ensure POS was not isolated within a given area. The respondents did not agree on whether detention basins and stormwater infrastructure should be classified as POS even though stormwater infrastructure is written into local government development plans. R10 indicated that their organisation actively encouraged stormwater infrastructure as a component of a POS because this provided additional benefits:

> In a significant recreation reserve, there has been stormwater harvesting, and essentially that stormwater is then used to green that open space (R10).

And:

> We have large areas of floodplain and stormwater harvesting is something that our council generates a certain amount of money (R10).

R7 highlighted the problem with higher-density developments:

Medium to high-level developers will also get bigger yields with less open space, so they push for the basin areas to be included as open space (R7).

R6 highlighted the issue discussed by R7:

A developer coming to us and offering us 12.5% open space as a detention basin we won't normally accept as our standards say we don't receive that as open space as part of the 12.5% and then we have to start talking a monetary contribution to make up that shortfall in the 12.5% (R6).

5.2 Securing public open space

Participants were asked whether they considered the legislated open space supply standard delivered sufficient POS within metropolitan Adelaide. The 15 respondents did not express a consensus, and 7 regarded the amount of POS in metropolitan Adelaide as adequate according to the legislated open space supply standard. Interestingly, three local government respondents suggested the legislated open space supply standard delivered an inadequate open space supply, while the state government and planning consultants responded either yes or answered inconclusively (Table 5-1).

Table 5-1: Enough public open space?

Respondents (*n* = 15)	Yes	No	Inconclusive
Local government (LG)	5	3	4
State government & urban planning consultancies	2	0	1
Total	**7 (47%)**	**3 (10%)**	**5 (33%)**

The respondents discussed the quality of POS and density, followed by infill, Open Space Development Fund, and then legislation and contributions (Figure 5-2).



Figure 5-2: Word cloud for participant responses regarding 'Securing public open space'.

The majority recognised the supply of quality POS was at risk of being compromised through increased infill and higher densities in residential areas:

> From a pure allocation of legislated space yes, it is sufficient, but if that space is poorly maintained and not attractive, then it is not attracting the people it is meant to (R15).

> It is very difficult to put quality into legislation (R14).

And:

> The size is important, but the accessibly and the quality of what is being provided is equally important (R4).

R9, R11 and R14 reported that infill developments often involved fewer than 20 dwellings and therefore the legislated 12.5% open space supply requirement was not applicable. For example:

> Infill is a challenge because we are not getting the open space at all, so the 12.5% becomes meaningless (R14).

R9 highlighted that when developments meet the open space requirements, many are on smaller lots with townhouses or multilevel apartments, and thus:

They do not physically have the 12.5% on the property to vest that to the council for us to use it as a meaningful public open space (R9).

However, one local government respondent indicated they had a potential over-supply of POS combined with predominantly very low residential densities. Therefore, they welcomed increased densification. R9 suggested that rather than just quantity:

The POS allocation should include quality within the legislation and permit smaller percentages of POS in exchange for quality (R9).

R4 supported this comment:

Not always about the size of allocation but the quality (R4).

Responses to this question, however, revealed an apparent belief that rigidity in the policy was unhelpful, for example:

It is black and white at the moment, and that needs to change (R1)

And:

It is too quantitative, it is not flexible, and it does not foster innovation in how we deliver (R1).

And:

The legislation should encourage more diversity than what is being delivered (R1).

Similarly, R12 was critical:

The legislation only describes a land space (R12).

However, R13:

Thought local governments would feel short-changed if a developer offered less than the 12.5% (R13).

R9 considered the provision of POS across metropolitan Adelaide was disjointed and concluded:

I think there is a sufficient allocation of public open space if councils approach it in a more holistic fashion (R9).

R8 stated that the outcome of the push to increase densification could have unexpected consequences:

With increasing densities, it is fairly new, and Adelaide is still learning about it and may not understand all the issues which may come from it yet (R8).

R4 corroborated this and said:

> That with increasing dwelling densities, a POS could get over utilised, which inevitably leads to an increase in wear and tear and higher maintenance expenditure (R4).

The local government respondents were in broad agreement that the implementation of POS in new developments involved complex and time-consuming negotiations between urban planners and property developers because each local government development plan was different. These negotiations could sometimes result in POS not being included because the development had adequate access to existing POS or the local government did not want more POS to maintain. As stated by R7:

> Many local governments have finite financial resources to upkeep POS to a standard the community expects (R7).

As discussed previously, within higher-density developments, the site area might not have sufficient useable quality POS, or have tokenistic POS; for example, an entrance marketing space, roadside verge or roundabout. When POS is not included, the property developer must contribute a significant financial contribution in lieu to the Open Space Development Fund. Local governments that frequently interacted with property developers indicated that contributions to a centralised state government department were contentious from the perspective of the developer. As described by R1 and R6, property developers often perceived the Open Space Development Fund contribution as ‘dead money’ because they did not see the contribution as enhancing the area around their development. R2 and R10 supported attractive and safe streetscapes to encourage communities to connect with POS and other services. However, R14 considered the Open Space Development Fund as an equitable method to distribute monies between local governments for them to purchase land for POS or to upgrade existing POS.

Seven of the respondents reported that most developers want to include quality POS in their master-planned developments because open space becomes a strong marketing tool. R10 emphasised that many new greenfield developments were marketed with a strong aesthetic appeal and POS were increasingly designed as passive spaces or ‘pocket parks’, and with an ecosystem orientation. R6 and R10 indicated an increase in smaller passive spaces had resulted in a shortfall of larger recreation spaces suitable for structured recreation and sporting activities.

Concerning the discussion on the inclusion of stormwater infrastructure as POS, R6 indicated developers sought to include detention basins within the 12.5% open space supply allocation. Although R6 recognised the importance, his organisation refused to include detention basins because they were limited as POS social spaces. However, R10 advocated for detention basins in developments because they mitigated potential flood risks. Additionally, detention basins harvested water, which provided a significant income source through the supply of metered non-potable water to residential properties and businesses for toilets and irrigation.

5.3 What is so good about a walk in the park?

All participants were asked whether they recognised an association between POS supply and population health and whether they could provide evidence to support their personal opinions. As shown in Table 5-2, all respondents recognised associations between the urban environment and access to POS, and population health. However, fewer than half of the interviewees could provide evidence, either in the form of statistical data or government documentation. This included quality metrics and alleviating the urban heat island or biodiversity to support associations between POS and health.

Table 5-2: Respondents recognition of associations between open space and population health.

Respondents (*n* = 15)	Personally recognise	Evidence provided
Local government	12	6
State government & urban planning consultancies	3	1
Total	**15 (100%)**	**7 (47%)**

These factors are highlighted in Figure 5-3, where the respondents recognised population outcomes could be linked to active and quality POS, followed by physical, community and recreation, which was attributed to the quality and level of services provided within a POS. Quality was identified as a key driver; with the respondents describing as attractive those POS that provided good facilities to encourage people to engage and stay longer.



Figure 5-3: Word cloud expressing urban planners' recognition of population health.

Of the respondents who could provide evidence for an association between POS supply and population health, R2, R5 and R12 indicated they had developed strategic health plans aligned with the *South Australian Public Health Act* (*2011)* that related to adjoining local government areas. These respondents' recognised boundaries did not stop people from utilising POS outside their particular local government area. However, only R6 and R12 acknowledged the *South Australian Public Health Act* (*2011)* as a component of their organisation's strategic urban planning procedures.

There was a consensus that improving population health would involve quality urban design that encouraged physical activity and increased interaction with the outdoor environment and encouraged communities to support local facilities. R9 stated:

> The design of the built environment from an urban streetscapes perspective can have a real influence on people's activity levels, though there still is a personal choice, you do not want to put barriers in people's way (R9).

Only half of the respondents recognised the importance of mental health as an ongoing concern. R1 suggested a person who had only visual contact with green infrastructure, for example, from a hospital bed could have enhanced mental health outcomes compared with someone with a view of a blank wall.

Within the health theme, quality was associated with encouraging more people to use POS through attractive, safe and user-friendly open spaces. Depending on the POS size, recognition of community demographics and additional infrastructure, for example, playgrounds, toilets, seating and shelter may encourage people to stay longer and participate in passive or active recreational activities. R7 encapsulated quality thus:

> There is an increase in expected standards of the reserves and in particular from a sporting perspective that playing fields are not boggy mud pits 9 weeks out of 10 (R7).

Linking the previous theme on POS supply to population health was R10:

> It's putting over the health lens rather than just say providing open space for open space sake or biodiversity (R10)

And:

> What is the population health data likely to look like in the next 10 to 20 years as well as the changing demographics and how we are starting to provide open space to accommodate for all that (R10)?

5.4 Summary.

The interview responses demonstrated that urban planners were influenced by key factors regarding development assessment and their interpretation of planning policy increasingly on merit when it came to open space supply. The opinions reflected the planners' obligations to follow government policies and legislation to ensure the economic development of South Australia while acknowledging the tensions and conflicts with property developers around urban densification with regard to population health.

A resounding outcome from the interviewees was the absence of a definition for open space within the development legislation and government documentation which undoubtedly contributes an ongoing confusion of how to define POS and open space supply standards. This lack of a definitive interpretation of POS could be associated with historical perspectives of local governments in older developed areas compared with more local governments with greenfield development sites; and the type, quantity and quality of POS within their local government areas. Alternatively, it could reflect the natural variation of views that exists between individuals and different organisations.

The development of metropolitan Adelaide has occurred over a significant period and with different development legislation and planning policies. In identifying open space supply and distribution, many residential areas built before the *Development Legislation Act* (*1967)* and the mandated 12.5% open space supply standard have a recognised shortfall or inadequate access to POS. Conversely, a northern local government identified they had an over-supply of POS and an issue with providing quality maintenance. Similarly, several local governments recognised that some new greenfield developments had implemented more than the 12.5% open space supply standard because developers wanted to provide an illusion of greenness, with many open spaces not being suitable for social interaction and recreation, instead providing a purely ecosystem function. Within the inner and middle suburbs of metropolitan Adelaide, older residential areas were identified as having a potential POS shortfall that could be further affected by densification, as highlighted by Sivam and Mobbs (2009). Many of these subdivisions with less than 20 dwellings did not initiate the mandatory 12.5% open space supply standard; subsequently, only a limited amount of new POS are being implemented to support higher population densities. The current South Australian development legislation is based on land area and does not address the question of quality versus quantity and connectivity (*Development Act* 1993). To be gazetted *Planning, Development and Infrastructure Act (2016)* would require significant amendments to incorporate quality and connectivity metrics.

Despite the 100% personal consensus regarding an association between the built environment and population health, there was a lower level of theoretical evidence and a reliance on external research and documentation. It would appear that many urban planners have limited experience and knowledge of applying urban planning principles to population health objectives. The outcomes of these interviews indicated that the urban planning discipline might benefit from developing stronger connections with other professionals in health to support greater collaboration to improve social, environmental and economic outcomes.

These results from the respondents provided the impetus to investigate the spatial distribution of open space, the legitimacy of current open space supply standards when applied to different spatial units (LGA, POA and SSC) and accessibility to open space. Another concern identified from the interview analysis was the Open Space Development Fund, viewed by respondents as inflexible and bureaucratic because of the narrow focus of the fund, further analysis will provide an overview of the local governments' Open Space Development Fund grant applications.

Chapter 6: Open Space Supply and Distribution.

The literature review presented in Chapter 3: highlighted the variability in open space nomenclature (Table 3-3) and representations of open space (Astell-Burt et al. 2014a; Bull et al. 2013; Daker, Pieters & Coffee 2016; Paquet et al. 2013), along with the potential of the effect of the modifiable areal unit problem (MAUP) when data are represented at different scales (Nakaya 2000; Openshaw 1983). All these factors contribute to the variability of open space representations and distribution. In addition to the literature review, semi-structured interviews undertaken with local and state government urban planners highlighted the complexity of open space terminology, its provision within urban environments generally and within the study area.

As a result of the literature review and the outcome of the interviews, further investigation was required to identify the distribution and supply of open space. An analysis of the data at three spatial scales, local government area (LGA), ABS suburbs (SSC) and postcodes (POA): identified the distribution of open space against the legislated 12.5% open space supply standard to categorise which areas are and are not meeting the standard and the distribution of successful Open Space Development Fund grants.

As outlined in Chapter 4:, an investigation of datasets representing open space for the study area identified four that were available for further analysis; author's VPOS 2011, DPTI digital cadastre database 2016, ABS Meshblocks 2016 and PSMA Greenspace 2016. GIS comparison of the data highlighted considerable differences in the number and area of POS across the four datasets. Subsequently, a quality public open space (POS) dataset was to be developed and validated to respond to the research objectives. The new POS dataset was aligned with the ABS census collection year 2016 to prevent temporal misalignment.

Two supply metrics, the percentage of the residential land area and area of open space per 1,000 persons were calculated for three spatial units (LGA, POA and SSC).

6.1 Phase 1: Research design to determine public open space supply and distribution.

6.1.1 Phase 1: Desktop validation of public open space dataset.

Two Geographic Information System (GIS) software programs, ArcMap 10.5 (ESRI 2016b) and MapInfo Pro (Pitney Bowes 2016), described in Chapter 4: were utilised to examine the selected input datasets (Figure 6-1) and develop a new POS dataset.

The validated public open space 2011 (VPOS2011) developed by Daker (2014b), was assigned as the principal dataset to be updated to characterise POS supply within metropolitan Adelaide in 2016 (Figure 6-2).

Utilising ArcMap 10.5 (ESRI 2016b), 31 land use codes (Table 6-1) were identified as open space and recreation activities (free access and semi-restricted access, for example, golf courses) and used to extract 8,952 polygons, ranging in area from 11 m^2 to 1069 ha, from the 2016 South Australian DCDB dataset (DPTI 2015, 2016c) (Figure 6-3). The ABS Meshblocks parklands classification extraction comprised 2,276 polygons (Figure 6-4) and the PSMA (2016b) Greenspace, 1,658 polygons (Figure 6-5). All data were reprojected to GDA 1994 datum and the South Australian Lambert Conformal Conic projection, then clipped with the Adelaide statistical boundary (ASD 2006) with a 5-km external buffer. The buffer ensured any open space polygons from the selected datasets that traversed the ASD06 boundary were wholly represented, for example, see the Eastern edge of Figure 6-2 and Figure 6-5.

The VPOS2011 dataset was copied and saved as unvalidated POS 2016 (uPOS2016). The uPOS2016 dataset utilised the DCDB to provide the parcel boundaries for identified POS, with the Meshblocks and Greenspace data overlaid to identify locations and attributes to develop the new layer.

Table 6-1: Land use codes attributed to open space and recreation classifications

LAND USE CODE	DESCRIPTION
4110	Vacant allotment conservation or recreation
4210	Wooded area conservation
4500	Reserve
4510	Undeveloped reserve
4520	Developed reserve
4530	Plantations/Standpipes and undefined land which cannot be sold
5560	Botanical garden and arboretum
7100	Outdoor arenas, sports oval
7105	Outdoor stadium, entertainment area
7110	Athletics
7120	Baseball
7130	Cricket
7140	Football
7141	Australian rules
7142	Soccer
7143	Rugby
7150	Hockey
7160	Lacrosse
7210	Archery
7220	Basketball
7230	Lawn bowls
7240	Croquet
7250	Tennis
7260	Sports ground NEC
7300	Golf course
7310	Golf—pitch and putt
7320	Golf—putt-putt
7330	Golf—driving range
7420	Racing track—bicycle
7530	Parks and gardens including picnicking
7900	Recreation NEC
	NEC = Not Elsewhere Classified

Source: (DPTI 2015)

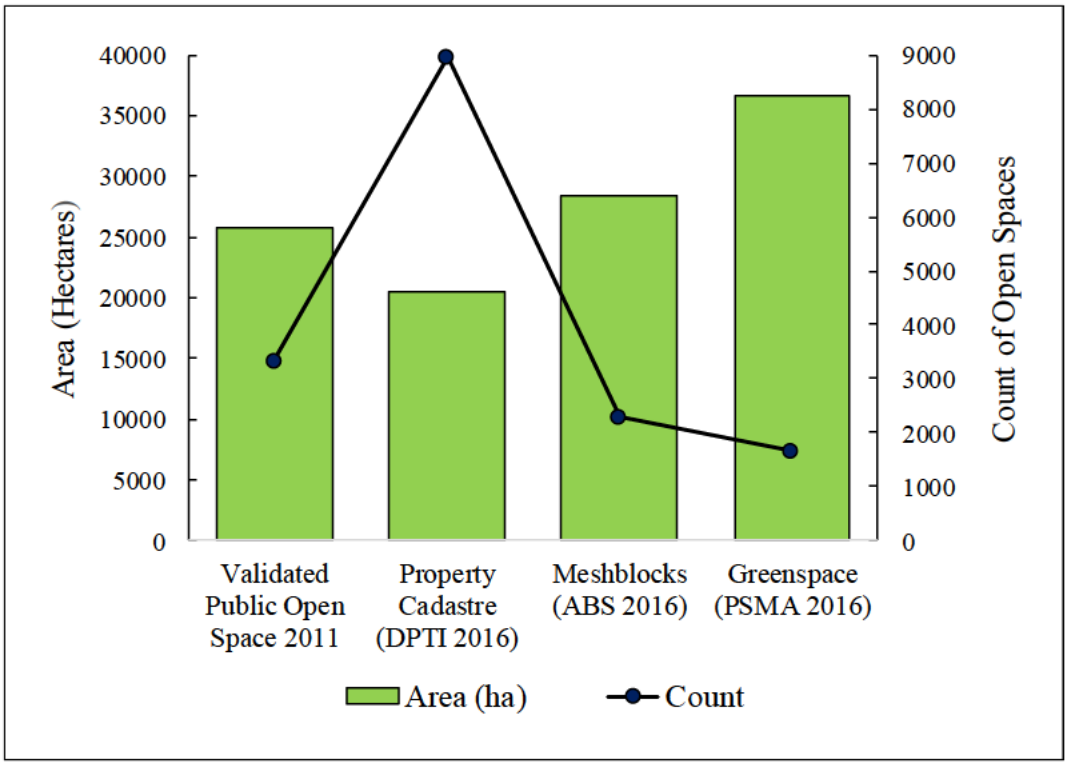


Figure 6-1: Comparison of four open space datasets representing open spaces (VPOS2011, Property Cadastre, Meshblocks and Greenspace) within the study area.

The mean and standard deviation variables in count and area between the four selected open space datasets are quantified in Table 6-2.

Table 6-2: Mean and standard deviations for the four selected POS datasets.

	Count	Total area (ha)	Mean (ha)	Standard deviation (ha)
VPOS2011	3,325	25,783	7.8	91.82
DPTI Property Cadastre 2016	8,952	20,453	2.3	22.35
ABS Meshblocks 2016	2,276	28,381	12.5	59.56
PSMA Greenspace 2016	1,654	36,573	22.1	131.64

Figure 6-2–6-5 illustrate the four datasets selected to represent open spaces within the study area. Each dataset is presented as the individual open space count, mean and total area.

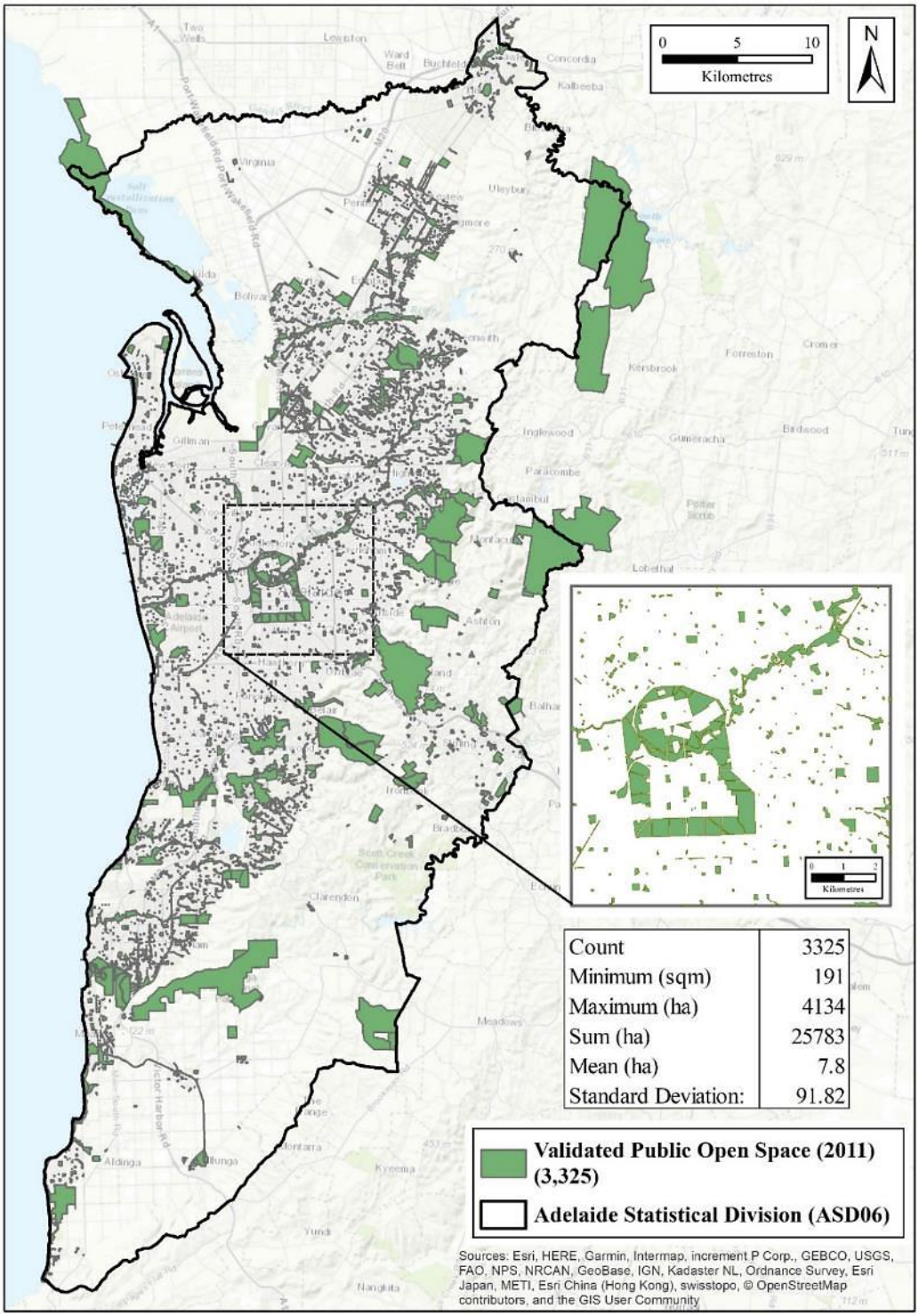


Figure 6-2: Validated POS dataset 2011 (VPOS2011) intersected with the Adelaide Statistical Division (ASD) boundary (ASD 2006).

Data source: (Daker 2014b).

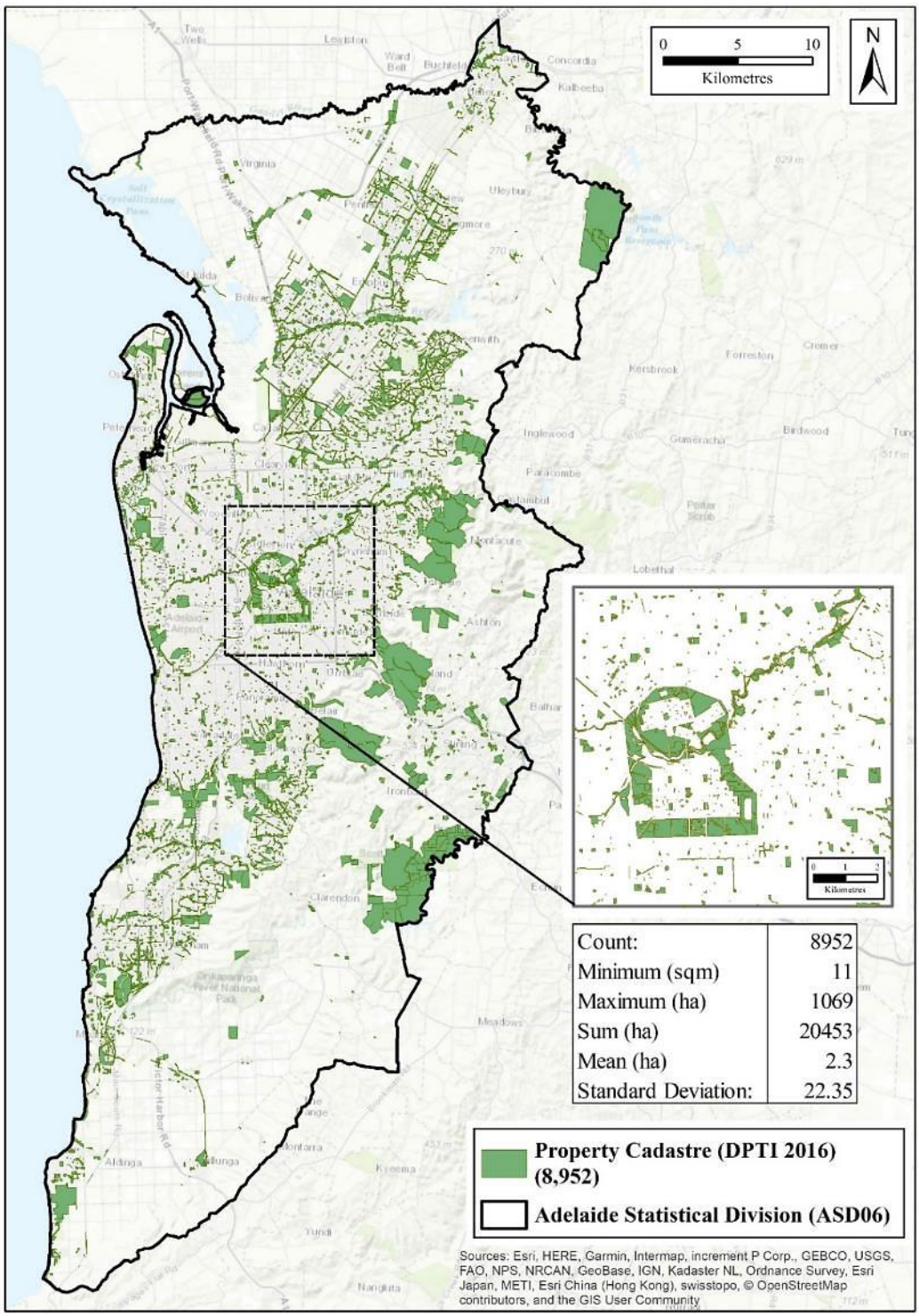


Figure 6-3: Open space and recreation land use codes: South Australian Government digital cadastre boundaries (DCDB) intersected with the ASD boundary (ASD 2006). The data can only be applied to the State of South Australia.

Data source: (DPTI 2016c).

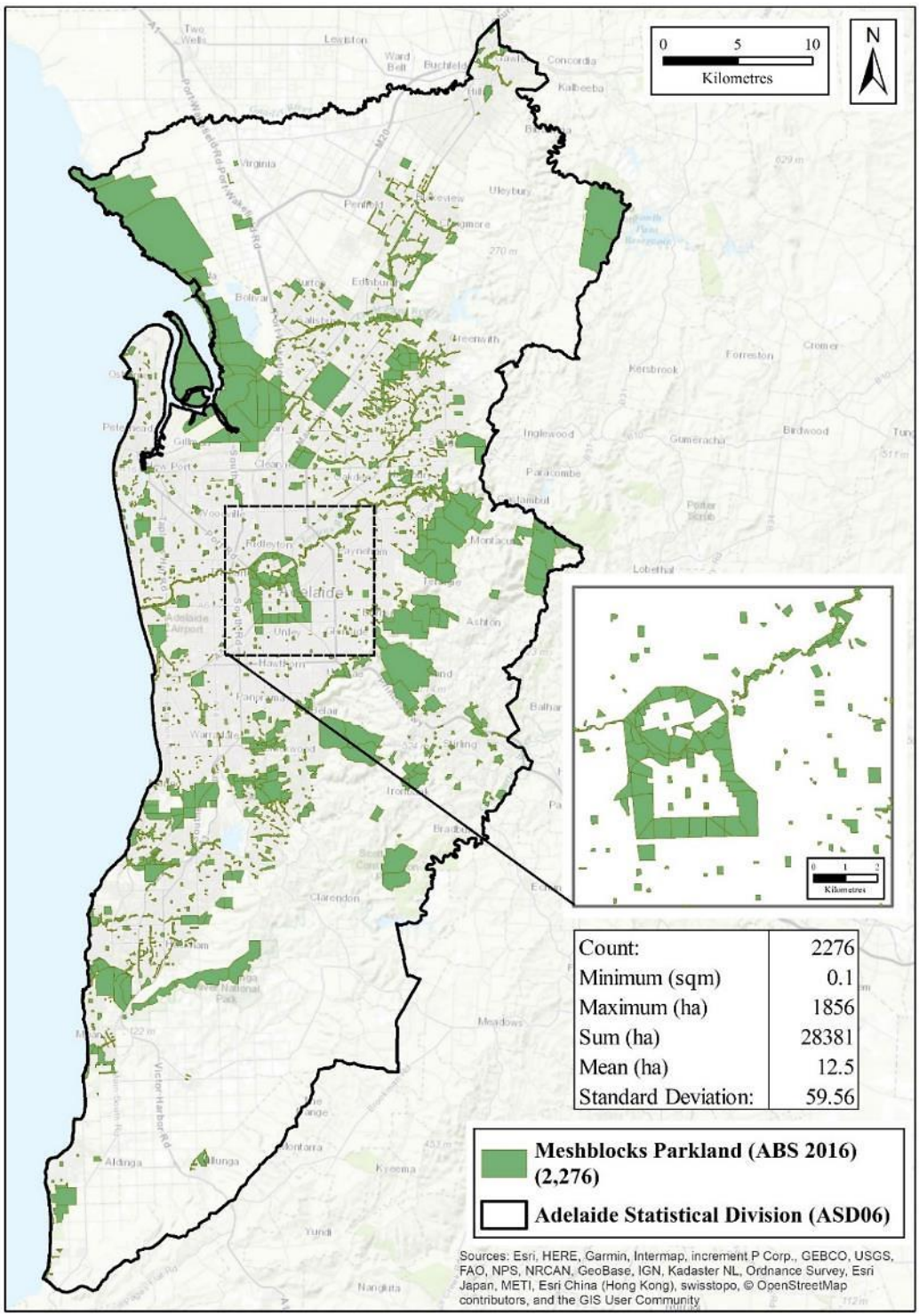


Figure 6-4: ABS Meshblocks 'parklands' intersected with the ASD boundary (ASD 2006). The ABS Meshblocks data can be applied to the whole of Australia.

Data source: (ABS 2016c).

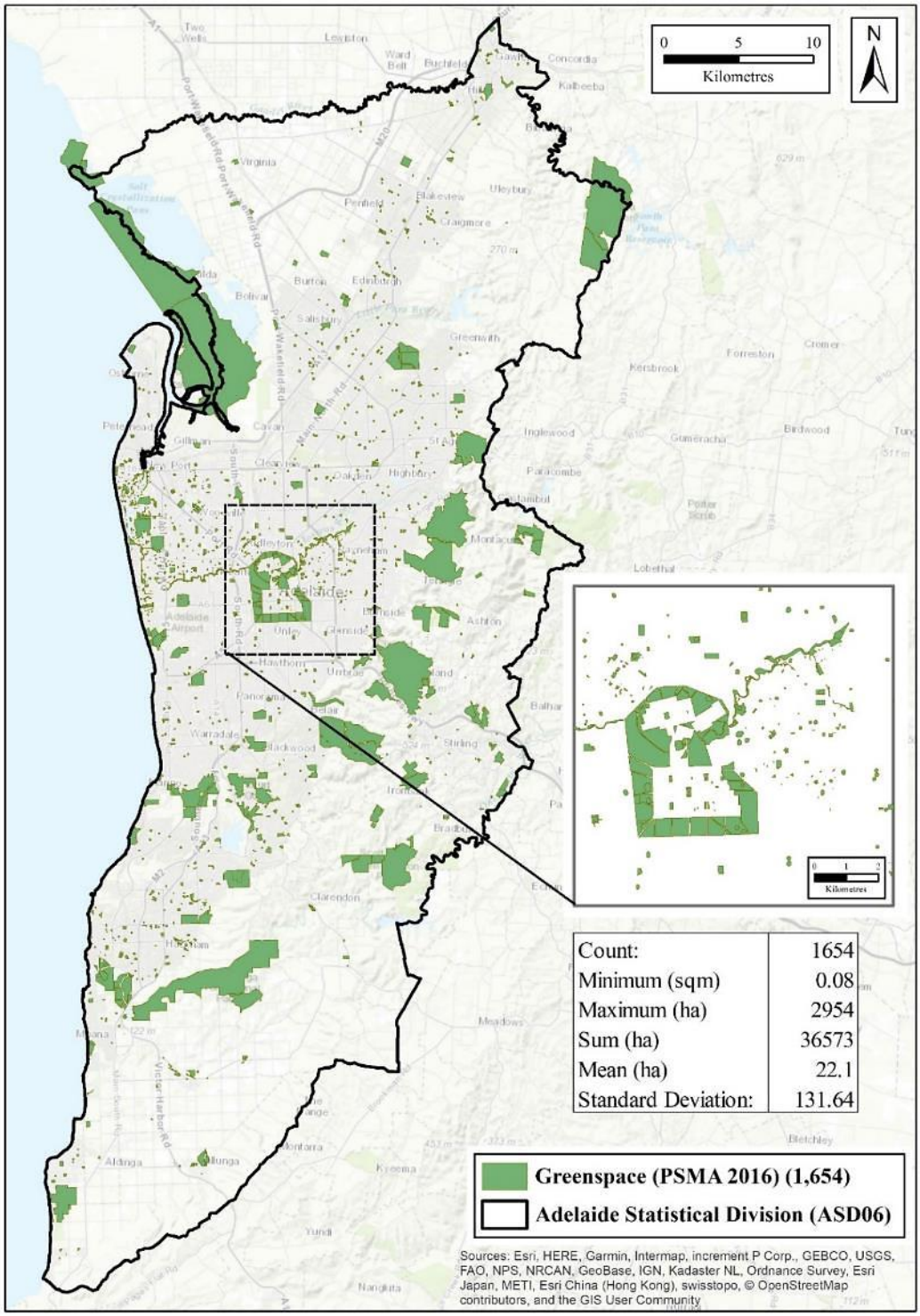


Figure 6-5: Greenspace dataset intersected with the ASD boundary (ASD 2006). The Public Sector Mapping Agencies (PSMA) Greenspace data can be applied to the whole of Australia.

Data source: (PSMA 2016b).

An analysis stacked the open space datasets on top of each other (overlay) and processed a combination of features and attributes to create the preliminary dataset for validated (pvPOS2016) dataset (Figure 6-6).

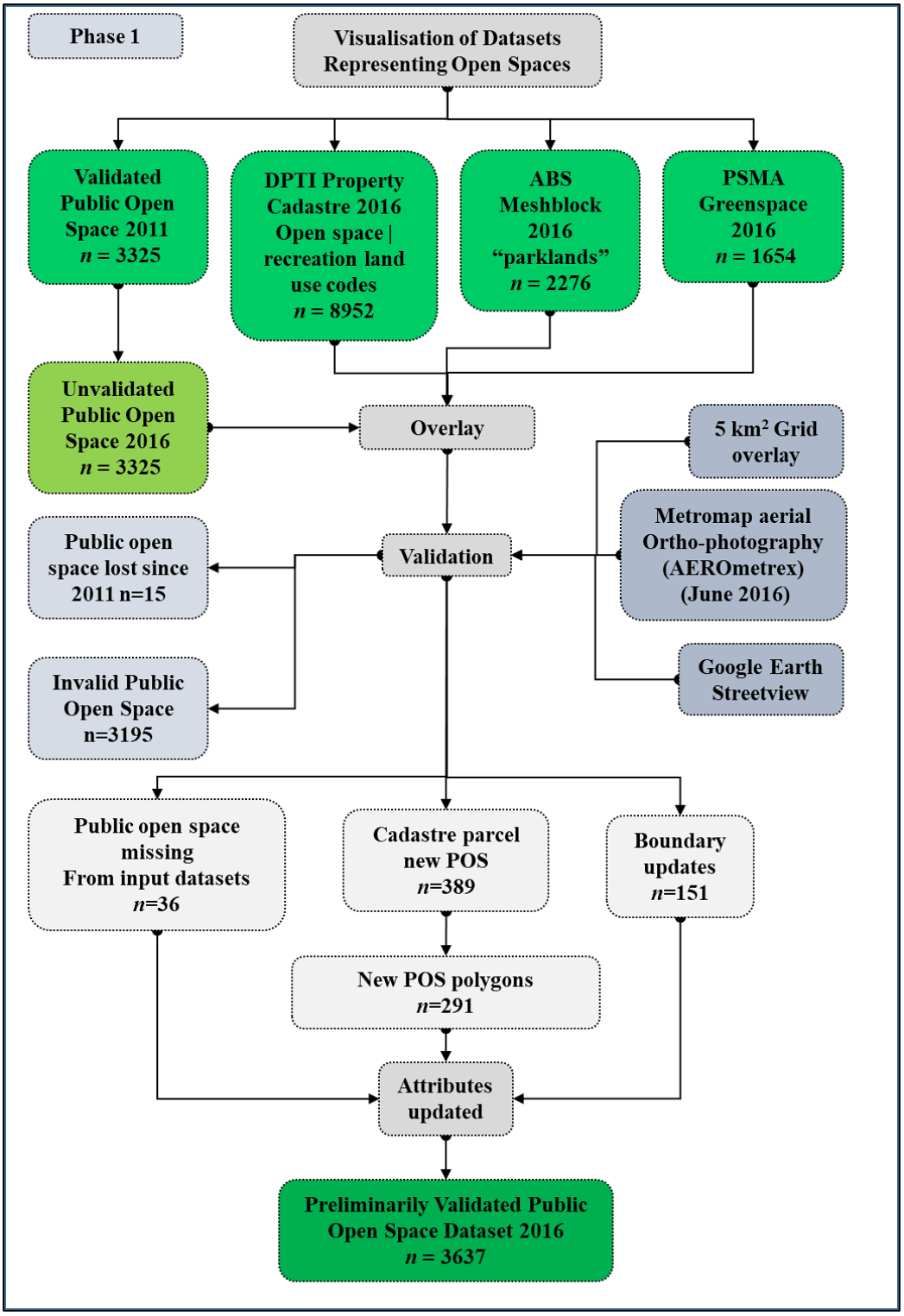


Figure 6-6: Phase 1: Flowchart outlining the validation process for the preliminary validated POS (pvPOS) dataset June 2016.

The identification of POS required careful observations from high-resolution ortho-rectified photographic imagery (see example image with an 8-cm ground sample distance, (Figure 6-7) (AEROmetrex 2016). The validation date was set at 30 June 2016 to align with the collection period for the ABS 2016 population census. To reduce the risk of overlooking a POS, a 5-km grid overlay of 104 cells was used to check the entire study area and checked sequentially.



Figure 6-7: High-resolution aerial imagery of POS at St Clair SA. GPS; 34.869, 138.533. Image captured 13 May 2016.
Source: (AEROmetrex 2016).

To supplement aerial imagery, Streetview (Google Earth© 2016) was viewed for additional confirmation of features, especially when obscured, for example, tree canopies or a roof structure (Figure 6-8). Land uses identified as open space in the Meshblocks, Cadastral and Greenspace data but not confirmed as open space during the validation were retained but listed as invalid attributes (Appendix 9). An area of 300 m^2 was set as the minimum POS size, as defined in the '*open space planning and design guide'* (Parks and Leisure Australia 2013).

Both aerial imagery and Streetview visualisations were essential to record improvements and identify sporting open spaces for the classification between active/passive (Appendix 10). (AEROmetrex 2016; Google Earth© 2016). Google Streetview provided no timestamp when the images were recorded. These attributes were established in an earlier research project (Paquet et al. 2013) and applied to this study to provide data for future social planning and population health research.

The activity list and count were recorded, Passive POS were by default = 1, and then other identified recreation activities were added; for example, playgrounds and cricket, cycling, football and tennis areas (Appendix 11). For ovals and more extensive 'sports' areas, several structured activities may be undertaken over a year. In recognition of changes to field markings, aerial imagery was viewed 13 June 2016 and 17 December 2015 to establish winter and summer sports: for example, Australian rules football and cricket respectively by season.



Figure 6-8: Representation of a Streetview image to enable the identification of POS and attributes for the POS identified in Figure 6-7.
Source: (AEROmetrex 2016; Google Earth© 2016).

The literature suggests defining open spaces according to type and locality (Kellett & Rofe 2009). This assisted with defining POS from the aerial and Streetview imagery to provide 10 subclassifications of POS (Appendix 12).

POS are by nature varied, and in recognition of shape variability and via visual inspection, eight shape profiles were assigned (Appendix 13). The visualisation of POS polygons in GIS enabled the verification of the boundary and potential adjustments of vertices. Similarly, any parcels identified as invalid, for example, roadside vegetation (Appendix 9), were deleted from the primary POS dataset and saved as invalid.

All POS attribute fields were systematically checked and updated where required (Appendix 14 and Appendix 15).

6.1.2 Desktop validation outcomes.

Validation of the 2016 POS dataset revealed 15 POS parcels had been lost from the VPOS2011 because of changes in land uses and losses to construction activity. The process identified 389 new POS parcels from the Property Cadastre. Multiple parcels were adjacent, and the imagery revealed they could be represented as one POS polygon; 291 new digitised polygon boundaries were generated. The new POS polygon attributes tables were completed with relevant land use codes and attributes identified from imagery and then saved as uPOS2016. Review of the aerial imagery identified an additional 36 POS polygons not previously represented because they were not included in the Property Cadastre boundaries. Newly digitised POS boundaries were positioned utilising measurements and coordinates obtained from the aerial imagery. A further 151 POS polygons within the uPOS2016 required their vertices to be repositioned to align with the 2016 Property Cadastre. All attribute fields were updated utilising Property Cadastre data and aerial imagery (see Appendix 15 for an example of a completed POS attribute table).

In the Property Cadastre, Meshblocks and Greenspace data, 3,195 open space polygons were identified as invalid, including vacant land assigned for development, highways and roadside vegetation (Appendix 9).

The uPOS2016 dataset was saved as the preliminary validated POS 2016 dataset (pvPOS2016) with 3,637 POS. The next stage, Phase 2, involved ground truthing of the pvPOS2016 dataset to investigate the accuracy of the desktop validation process.

6.2 Phase 2: Field validation of preliminary validated public open space dataset 2016.

GIS works with large databases that are generated from primary and secondary sources with error introduced by machine or human inputs. Spatial data inherently are not 100% error-free. Error can be associated with three attributes: incomplete data (count error); incorrect classification of features (attribute error); and inaccurate georeferencing (positional error) (Congalton & Green 2009). Studies have reported that count and attribute error are not commonly reviewed (Boone et al. 2008; Foody 2002; Kyriakidis & Dungan 2001). Various validation methods have been implemented to counter input errors, including photographic imagery (Anderson et al. 1976). Remote sensing techniques have their limitations; for example, issues could arise with Google Streetview because of limited viewability and temporal changeability of features within a locality (Rundle et al. 2011), or the resolution of

aerial imagery and inability to distinguish attributes (Daker 2014a). In recognition of issues attributed to dataset validity, a field validation or ground-truthing process can assist with the verification and identification of overlooked or undefined attributes (Caspi & Friebur 2016).

The desktop validation of the POS data was intended to provide the best possible dataset aligned with the research definition of POS. To support the premise that the desktop process provides an accurate POS dataset, a ground truthing validation was proposed (Figure 6-9). However, to undertake direct observations in the field of a large dataset (both number and geographic extent) is a time-consuming and expensive exercise. To overcome the significant time and cost, a representative sample can provide a cost-effective method. To obtain a representative sample size requires consideration of how and what to sample, and recognition that a larger sample size generates a smaller chance of random sampling error (Boone et al. 2008; Kadam & Bhalerao 2010). The minimum sample size must be determined while preserving sample validity and retaining cost-effectiveness of the data validation (Congalton & Green 2009).

To support representative sampling of the pvPOS2016 dataset, the land area representation for each POS could be aligned with an open space hierarchy structure (City of Onkaparinga 2018). An investigation of 18 local government development plans within the study area identified that 12 local governments supported a land area open space hierarchy (Appendix 16). The local government, open space area hierarchies, are presented in Table 6-3. Using ArcMap 10.5, the four open space hierarchy land areas were extracted and saved as CSV files (Table 6-3).

Table 6-3: Local government development plan open space hierarchy calculated for preliminary VPOS dataset.

pvPOS2016	Count	Minimum (ha)	Maximum (ha)	Sum (ha)	Mean (ha)	Standard deviation
Local <0.5 ha	1,784	0.01	0.5	378.7	0.2	0.13
Neighbourhood 0.5–3 ha	1,220	0.50	3.0	1,518.4	1.2	0.67
District 3–20 ha	492	3.00	19.6	3,546.8	7.2	4.12
Regional >20 ha	141	20.10	2,346.9	20,033.2	142.1	341.52
TOTAL	**3,637**			**25,477.1**		

To facilitate field validation efficiencies, representative samples for the four hierarchies were investigated. The first method, demonstrated in Equation 1, applied a simplified stratified sample formula (Yamane 1967) where *n* is the sample size, *N* is the population size, and *e* is the level of precision with a confidence level of 95% and a percentage of error of 5% (*e* = 0.05).

Equation 1: Simplified proportional sample formula (Yamane 1967).

$$n = \frac{N}{1 + N * (e)^2}$$

Based on the simplified stratified sample equation, the sample sizes for each group are presented in Table 6-4. This formula can result in the calculation of a significant sample size, which may be difficult to apply to a field validation exercise.

Table 6-4: Application of a simplified Equation 1 to define a stratified sample.

	Count
Local <0.5 ha	326
Neighbourhood >0.5 <3 ha	301
District >3 <20 ha	220
Regional >20 ha	104
TOTAL	**951**

An alternative to the significant sample size method presented as Equation 1, the percentage of a population has been recognised as a robust approach to determine workable sample size, were a sample size as small as 5% might generate a significant sample. (Congalton & Green 2009). However, applying 5% to the regional data (*n* = 141) could potentially represent an insufficient sample size (*n* = 7). Therefore, 5% was doubled to 10% sampling across all four hierarchies. The representative samples were attained utilising Microsoft Excel's data analysis function: 'sampling'. Within the sampling function, every 10th number was selected from each of the four groups. The calculated sample sizes are shown in Table 6-5.

Table 6-5: Field validation sample data by four classifications of open space hierarchy.

	Count	Minimum (ha)	Maximum (ha)	Sum (ha)	Mean (ha)	Standard Deviation
Local <0.5 ha	178	0.01	0.5	36.3	0.2	0.13
Neighbourhood >0.5 <3 ha	122	0.50	2.9	150.5	1.2	0.65
District >3 <2 0ha	49	3.10	17.7	362.0	7.4	3.94
Regional >20 ha	14	20.90	313.5	1,221.6	87.3	98.63
TOTAL	**363**			**1,770.5**		

The four samples were merged as a CSV file (n = 363) and imported into ArcMap and joined to the pvPOS2016 dataset using 'POS Id' as the join field. The joined data were exported and saved as the Field Validation dataset. The field validation involved two people, 1,362 km of travel and 10 days between 2 and 29 January 2017. Figure 6-9 illustrates the workflow associated with Phase 2.

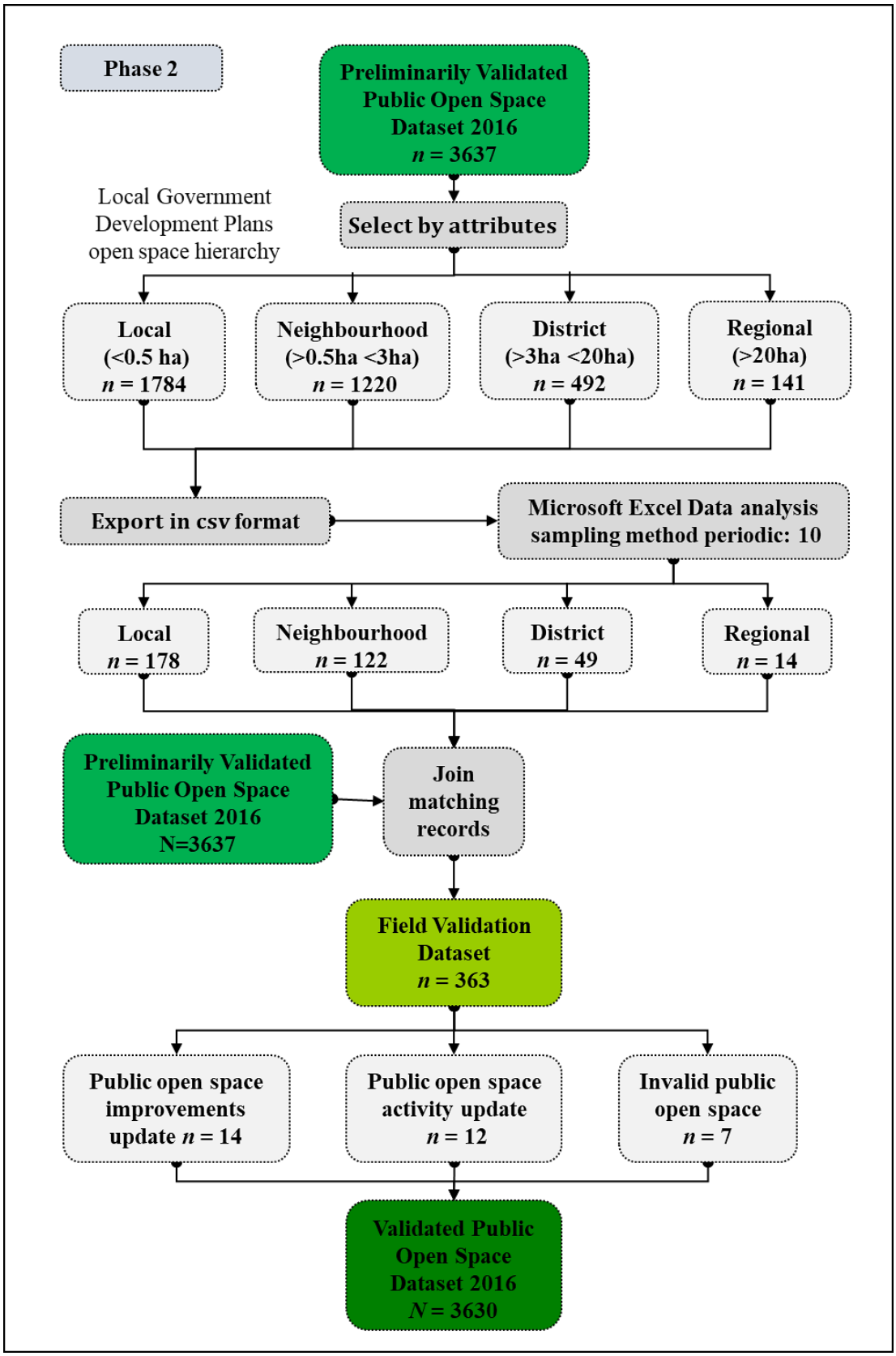


Figure 6-9: Phase 2: Flowchart outlining POS field validation exercise.

The field validation involved the use of an Excel workbook to record updates to the POS attribute fields (if required) (Appendix 17). GPS coordinates were recorded with a handheld Garmin Etrex 20 (Appendix 18) and imported into ArcMap to record the locations where photographs were captured. The photographic points demonstrate the distribution of the sample (see Figure 6-10).

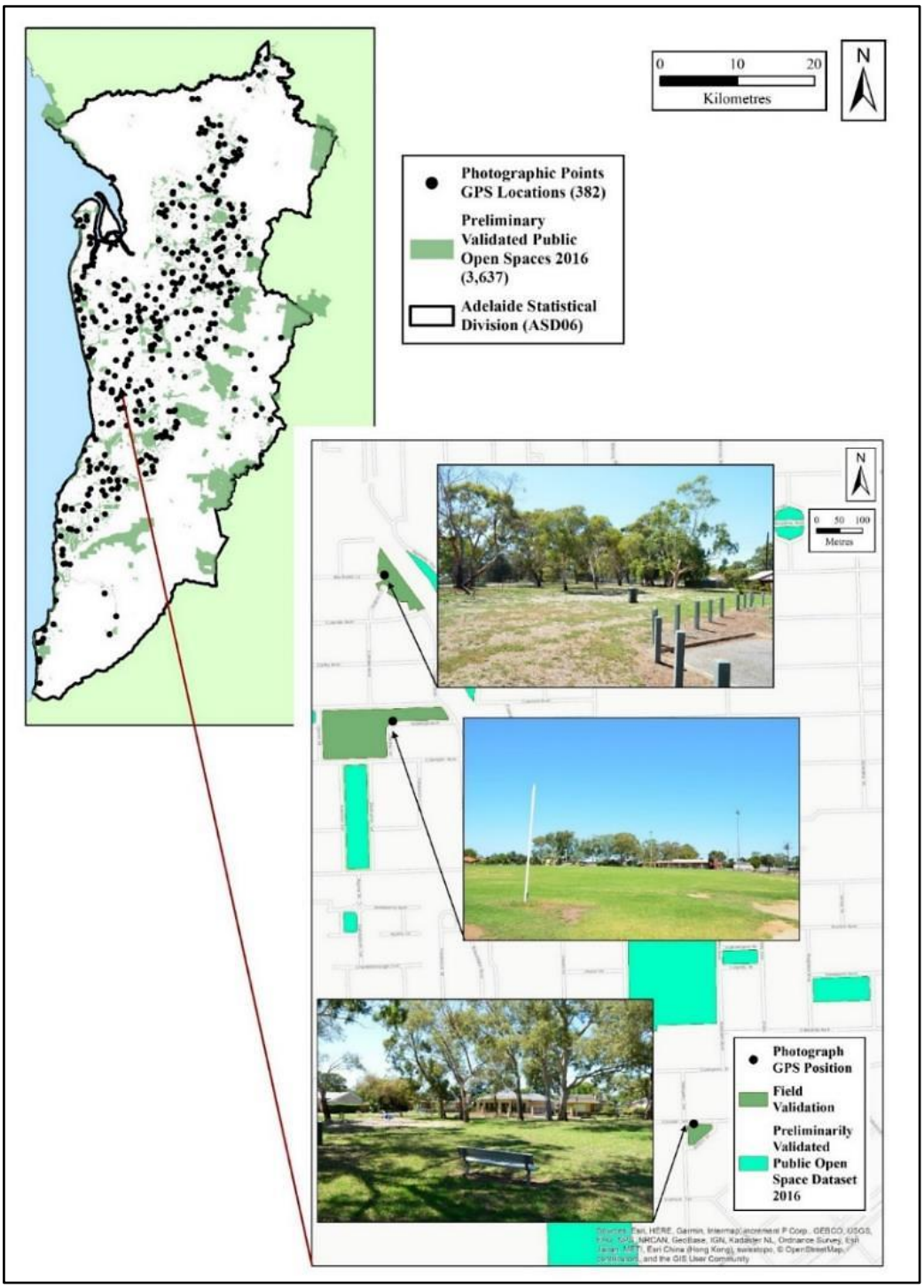


Figure 6-10: Field validation; example photographic points and photographic record of three sites to confirm their attributes.

6.2.1 Phase 2: Field validation outcomes.

The field validation representative sample of 363 from the pvPOS2016 (n = 3,637) identified seven POS as invalid. A margin of error was determined for the representative sample (Equation 2). The outcome of the field validation concluded that the pvPOS2016 desktop validation process achieved 98% accuracy, with a margin of error (MOE) of +/–1.36 (Table 6-6).

Equation 2: The margin of error with a finite population correction (Rumsey 2010).

$$Margin\ of\ Error = Z * \sqrt{p * (1-p)} \,/\, \sqrt{(N-1) * n/(N-n)}$$

where p is the sample proportion, expressed as a decimal (% valid in Table 6-6); Z is the z-score associated with a level of confidence (95% = 1.96); n is sample size (n = 363), and N is population size (N = 3,637).

Table 6-6 Accuracy of field validation with a margin of error (MOE) finite population correction.

Field validation *n* = 363	**Valid**	**% Valid**	**Invalid**	**Confidence level = 95% MOE % points**
Valid	356	0.98	7	+/–1.36
Activities	350	0.96	13	+/–2.7
Improvements	348	0.95	15	+/–3.04

The results attributed to the activity and improvements fields of the pvPOS2016 dataset resulted in updates to 13 of the activity fields and 15 of the improvements fields. The most significant activity update involved half basketball hoops as many were located under or behind trees or other built structures and thus were not visible from aerial or Streetview imagery. Examples of updates made to improvements were a toilet block viewed from aerial imagery that could be mistaken for a shelter, and barbecues that tended to be undercover and challenging to identify from Streetview images. These updates do not detract from the overall level of quality attributed to the pvPOS2016 dataset via the validation process.The results for the pvPOS2016 were updated and saved as the validated POS (VPOS2016)(n=3,630) shown in Figure 6-11. The VPOS2016 dataset is conceptually similar to the legislated definition of open space (Development Act 1993), where the open space supply standard is applied to

residential areas; therefore, these open spaces are publically accessible. On this basis, the VPOS 2016 can be applied to investigate supply, access and population health outcomes.

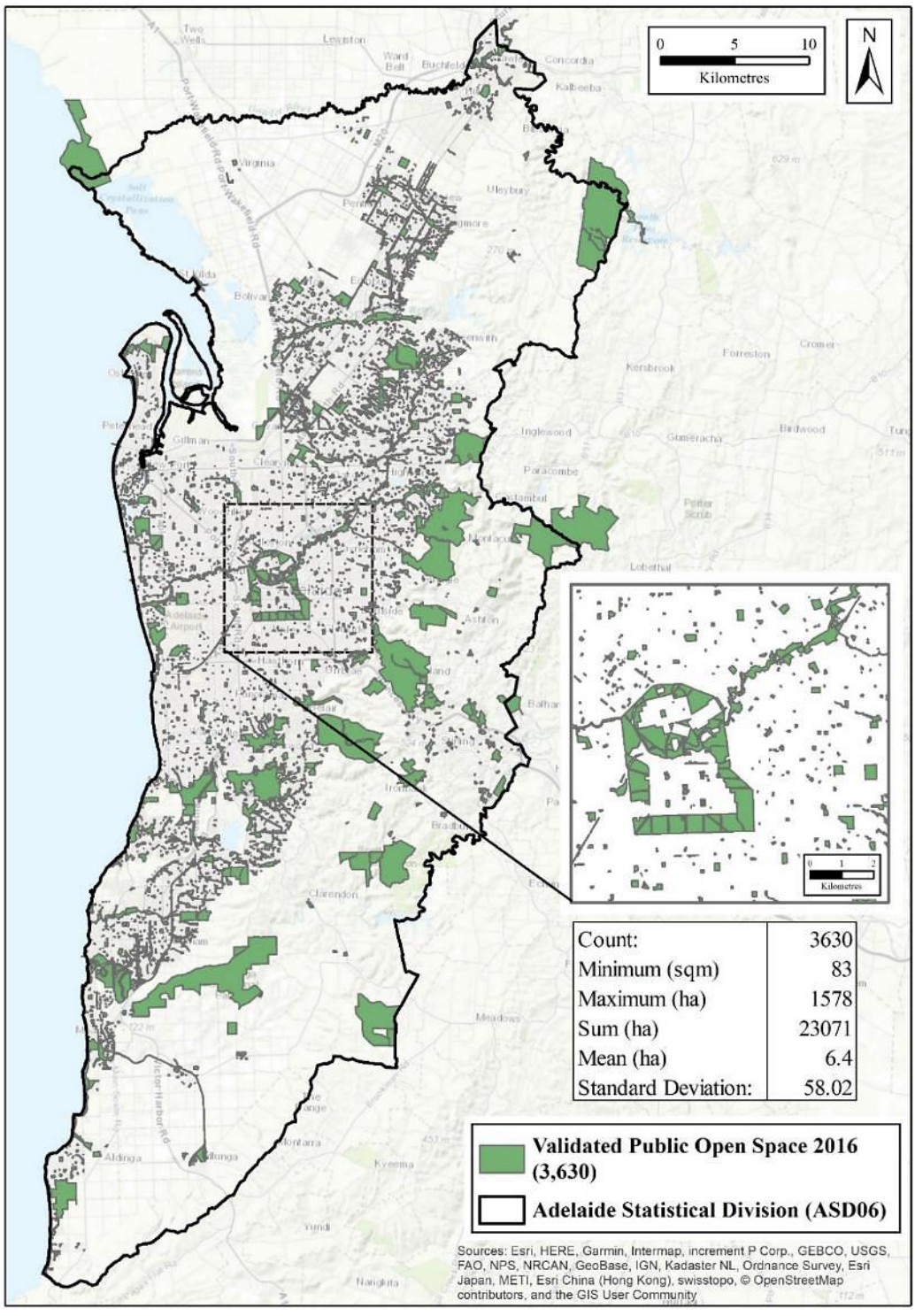


Figure 6-11: POS validated June 2016 intersected with the ASD boundary (ASD 2006).

6.3 Phase 3: Distribution of public open space

Phase 3 involved the analysis of the Open Space Development Fund, and comparisons of the four open space datasets when applied to the mandated 12.5% open space supply standard and 3 ha per 1000 population by spatial unit (LGA, POA and SSC).

6.3.1 Distribution of open space grants.

Several of the interview respondents questioned the Open Space Development Fund distribution of grants to support or upgrade existing POS or the acquisition of land for POS. An analysis of the distribution of open space grants highlighted an inherent inequality in that a significant number of projects were concentrated within the core of metropolitan Adelaide (Figure 6-12).

An evaluation of the grant distribution identified that the distribution of Open Space Development Fund grants varied significantly among local governments. The two local governments securing the highest level of grant support were Charles Sturt ($10,860,000) and Adelaide ($8,571,905). On a population count basis, the two local governments securing the highest value per resident were Adelaide City ($389) and Holdfast Bay ($140). When the total grant value was applied to the total land area of an LGA, Adelaide City achieved the highest value per hectare ($5,517), and this value can be linked to projects to enhance the Adelaide City Parklands. No grant applications were submitted by Burnside or Walkerville (Table 6-7).

These results substantiate two interviewee responses (R1 & R6), where they perceived a limited uniformity in the number of successful grant applications. The variability could be attributed to multiple factors, for example, a local government may have insufficient capital to match the dollar value of a grant application, or they considered their local government area had an adequate supply of quality open space.

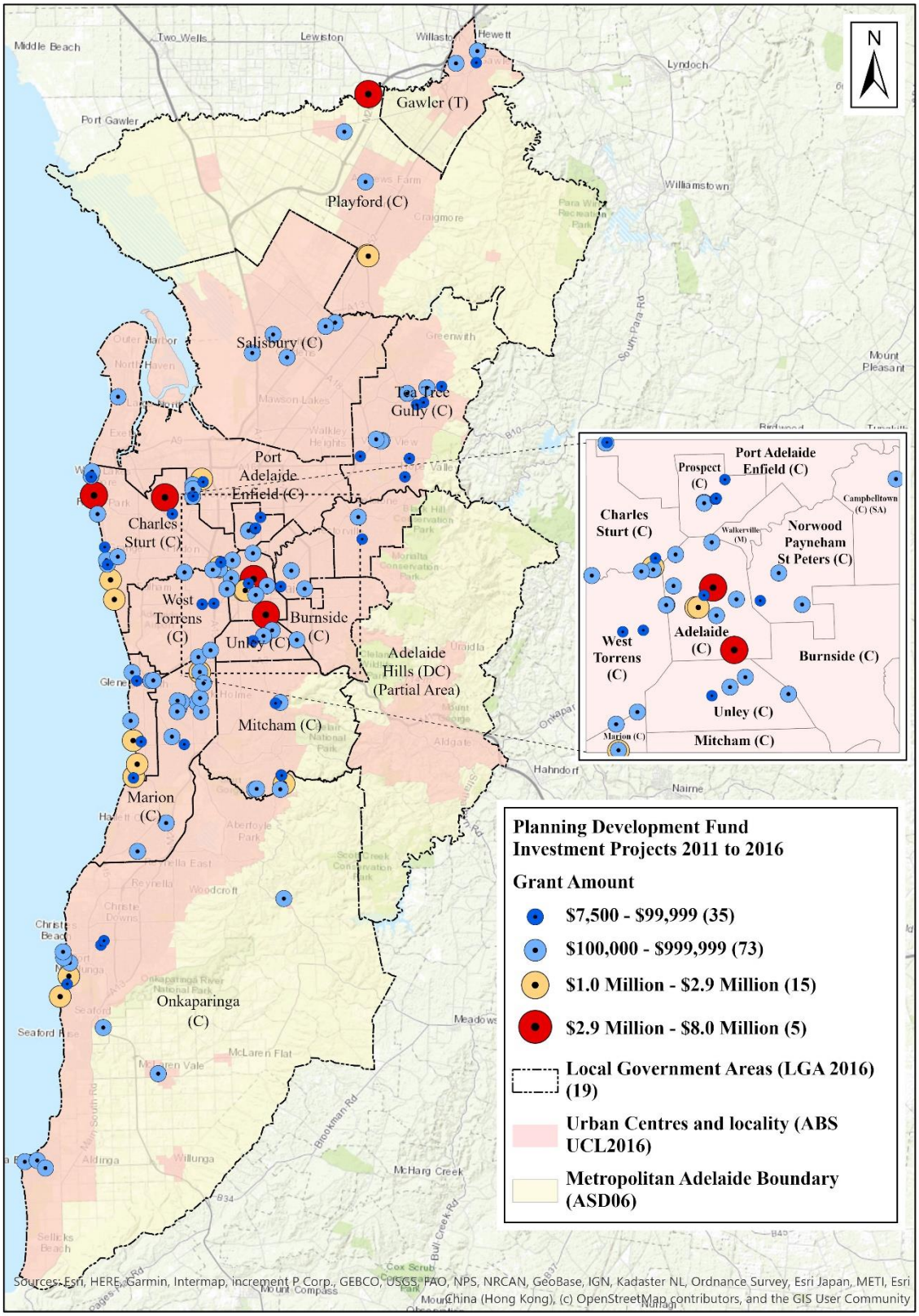


Figure 6-12: Distribution of grants awarded for open space projects from 2011 to 2016.
Data source: (DPTI 2017c).

Table 6-7: Analysis of grant values compared with the total population and POS area.

LGA applicant	No.	Grant min $	Grant max $	Grant mean $	Total grants $	Std Dev	$ per person (ABS census 2016)	$ per LGA area (ha)	$ per POS (ha)
Adelaide	8	100,000	4,500,000	1,033,129	8,571,905	1,568,095	389	5,517	11,861
Burnside	0	0	0	0	0	0	0	0	0
Campbelltown	2	15,000	202,500	108,750	217,500	132,583	4	90	567
Charles Sturt	17	10,000	3,250,000	638,824	10,860,000	863,763	97	1,987	18,007
Gawler	3	50,000	500,000	236,807	710,420	234,523	31	174	2,797
Holdfast Bay	10	35,000	1,031,013	496,213	4,962,127	415,067	140	3,616	63,692
Marion	15	20,000	1,380,000	382,467	5,737,000	344,798	65	1,033	7,180
Mitcham	5	22,000	200,000	101,355	506,775	70,419	8	67	284
Norwood Payneham St Peters	3	45,000	564,211	236,404	709,211	285,218	20	471	7,808
Onkaparinga	13	20,000	2,012,098	551,161	7,165,098	701,739	43	139	1,335
Playford	4	125,000	1,000,000	631,250	2,525,000	440,348	28	73	1,163
Port Adelaide Enfield	5	54,100	779,000	384,321	1,921,606	331,381	16	210	2,934
Prospect	6	7,500	550,000	223,924	1,343,541	254,871	65	1,728	60,151
Salisbury	5	100,000	816,000	442,700	2,213,500	254,553	16	141	1,399
Tea Tree Gully	11	50,000	420,000	143,864	1,582,500	123,801	16	167	1,221
Unley	4	50,000	300,000	154,125	616,500	108,327	16	433	15,749
Walkerville	0	0	0	0	0	0	0	0	0
West Torrens	4	19,000	281,270	126,318	505,270	125,399	9	137	1,283
State Government (various locations)	12	80,000	8,000,000	1,635,603	19,627,237	2,492,244	16		

Data source: (DPTI 2017c).

6.3.2 Provision of public open spaces.

Analysis involving area and population metrics would highlight whether open space provision was meeting the two urban planning guidelines: a percentage of the area of land assigned for open space; or a population ratio, comprising open space area per 1,000 population by LGA, POA and SSC (Hooper et al. 2018; Wilkinson 1985).

Because POS are not necessarily wholly within a spatial unit and also persons might utilise a POS in an adjoining spatial unit, the POS count and total area were calculated utilising three different GIS functions:

1) clip, where only POS within a spatial unit is extracted; any POS outside the spatial boundary was removed;
2) intersect, which includes individual POS within and those intersecting and abutting with the spatial boundary; and
3) a 500 m external buffer around the POA & SSC spatial unit intersected with the POS to account for the fact that persons adjacent to a spatial unit boundary may utilise the nearest POS, which might be in an adjoining POA or SSC (calculation for SCC represented in Figure 6-13). An LGA buffer investigation revealed a limited difference in area and therefore was not considered as providing additional value.

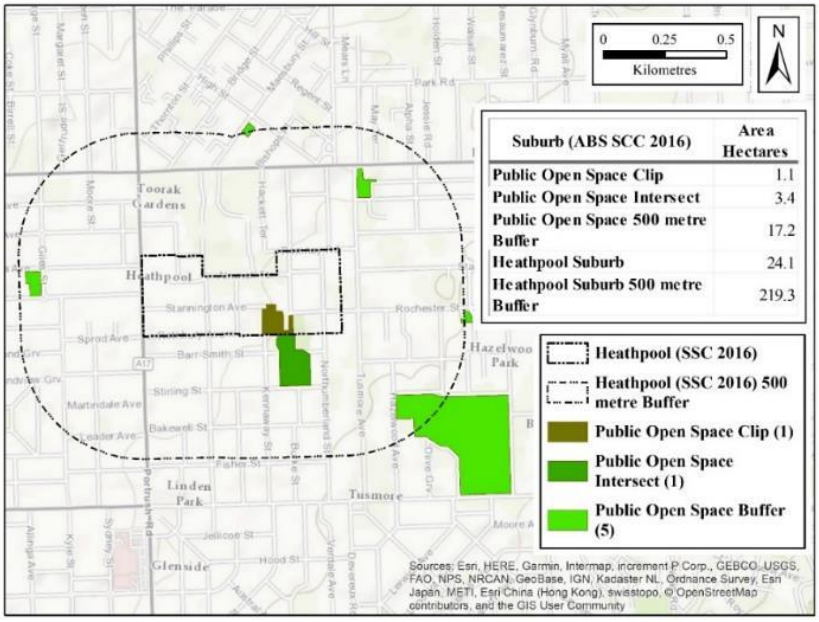


Figure 6-13: An example of the clip, intersect and buffer function when applied to the SSC spatial unit.

In ArcMap, Model Builder facilitates the automation of GIS workflows through the systematic linking of geoprocessing tools, which feed one output into another tool's input. The spatial units (LGA, POA and SSC) were iterated by feature identity, and the clip function sequentially extracted POS features within each spatial unit. The process generated individual geodatabase files for each spatial unit (Figure 6-14).

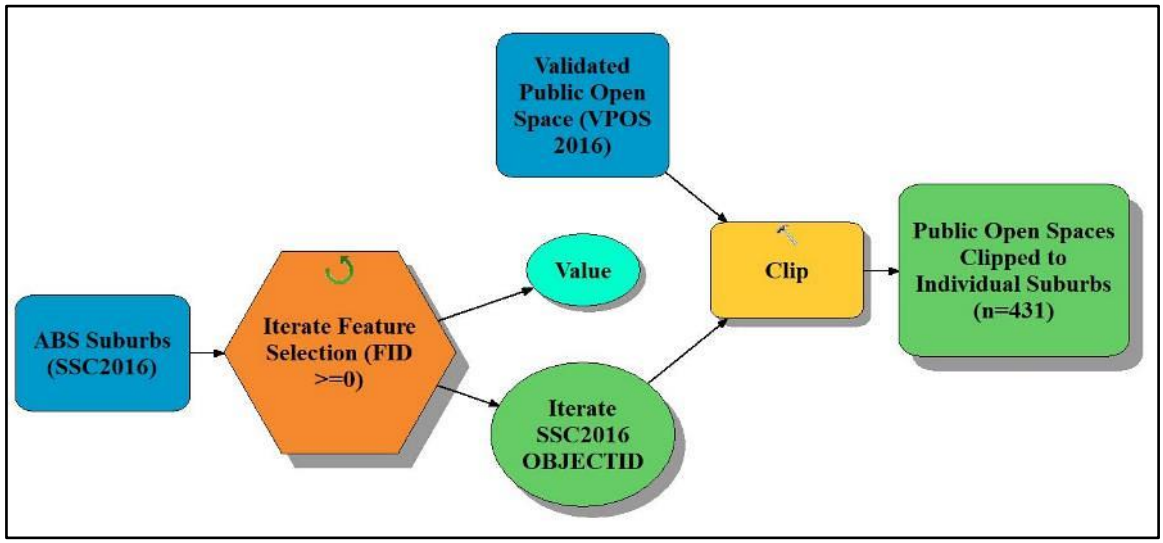


Figure 6-14: Model Builder in ArcMap to complete 'clip' of the VPOS2016 dataset with SSC; repeated for POA and LGA areas. Replicated for the datasets; Property Cadastre, Meshblocks and Greenspace.

In ArcMap, the clipped, intersected and buffer-intersected POS data attributed to a spatial unit were merged into individual geodatabase files, then spatially joined to the LGA, POA or SSC layer to provide the ABS spatial unit codes. Because the clip function split POS polygons, the area within the attributes tables were recalculated, and slivers (less than 10 m2) deleted.

The POS data were extracted into Excel utilising the Table to Excel function, rechecked and inputted into a Microsoft Access database along with the DPTI residential parcel dwelling area and ABS population count by the spatial unit. This allowed determination of the percentage of POS per residential parcel dwelling area (Equation 3) and POS hectares per 1,000 population within a spatial unit (Equation 4).

Equation 3: POS provision by percentage of land.

$$\text{Percentage area of land assigned for POS} = \frac{POS\ (ha) * 100}{Dwelling\ Area\ (ha)}$$

Equation 4: POS provision by population ratio within a spatial unit.

$$\text{POS Hectares per 1000 persons} = \frac{POS\ (ha)}{Population * (1000)}$$

The Access database results were imported into ArcMap to visualise the distribution of POS within the four datasets (DPTI Property Cadastre, ABS Meshblocks, PSMA Greenspace), and the validated POS dataset. The open space provisions applied were the 12.5% standard mandated in the *Development Act 1993* and 3 ha of open space per 1,000 persons (City of Charles Sturt Council 2011).

The issue of scale or Modifiable Areal Unit Problem can be identified with the use of the three selected spatial units (LGA, POA and SSC). The larger LGA unit may mask the more detailed spatial distribution which the smaller POA and SSC units represent with greater clarity (Table 6-8) (Nakaya 2000).

Table 6-8: Count, mean and standard deviations for the selected spatial units.

Spatial unit (2016)	No	Minimum (km^2)	Maximum (km^2)	Mean (km^2)	Standard deviation
LGA	18	3.5	517.2	88.3	130
ABS POA	133	0.2	146	13.7	21.6
ABS SSC	431	0.09	58.4	4.5	7.5

The four open space datasets were spatially joined to the LGA, POA and SSC spatial boundaries, and the percentage of open space area for residential areas was calculated. The analysis defined which spatial units were and were not meeting the 12.5% open space supply standard as mandated in the *Development Act (1993)*. When analysed based on the POS definition applied to this research, the three datasets (Property Cadastre, Meshblocks and Greenspace) contained valid and invalid POS, (invalid are described in Appendix 9).

6.3.3 Representations of open space supply standards when applied to selected open space datasets.

The LGA represented the largest unit, with the 18 local governments within the study area having a mean area of 88.3km^2 (Table 6-8 and Figure 6-15). The majority of the Adelaide Hills local government area lies outside the ASD06 boundary, and it was thus excluded from the analysis. The VPOS dataset had five local government areas not meeting the 12.5% open space supply standard: Prospect, Walkerville, Norwood Payneham St Peters, Holdfast Bay and Unley. In contrast, the Property Cadastre open space data had two, the Meshblocks 'Parklands' data had four, and the Greenspace had seven local government areas not meeting the standard (Figure 6-15).

The POA unit includes 132 POAs with a mean area of 13.7 km^2 (Table 6-8). The results indicated that more POAs were not meeting the 12.5% open space supply standard than was seen with LGA units. The VPOS2016 dataset had 37 POAs not meeting the standard; whereas the Property Cadastre POS data had 33, the Meshblocks POS data had 30, and the Greenspace had twice as many, at 61. Many units with POS below the guideline are within the older urban core of metropolitan Adelaide. (Figure 6-16).

The smallest spatial unit (SSC) in the analysis had 431 SSCs, with a mean area of 4.5 km^2, highlighting the significant difference in size between the largest and smallest spatial units (Table 6-8). In Figure 6-17, applying the 12.5% open space supply standard to the SSC resulted in more SSCs not meeting the standard. The spatial distribution of SSC POS not meeting the standard was more dispersed than was seen with the POAs but was still predominantly within the older urban core.

In the VPOS2016, 210 SSCs (48%) did not provide sufficient POS provision as mandated. The number of Property Cadastre and Meshblocks not meeting the 12.5% open space supply standard were similar, at 138 (32%) and 124 (29%) respectively. Compared with the VPOS2016, the Greenspace under-counted, with 180 (42%) SSCs not meeting the standard (Figure 6-17).

The three open space datasets (Property Cadastre, Meshblocks and Greenspace) included open space areas that were excluded during the validation of the VPOS dataset (invalid POS, Appendix 9), this could exacerbate under/overestimation of open space across all spatial units.

Of significance, among the POA and SSC units, many that did not meet the 12.5% open space supply standard were adjacent to those meeting the standard area. Consequently,

persons residing in a spatial unit not meeting the 12.5% open space supply standard might not be disadvantaged because they could access an adjoining spatial unit that meets the standard (Figure 6-16 and Figure 6-17).

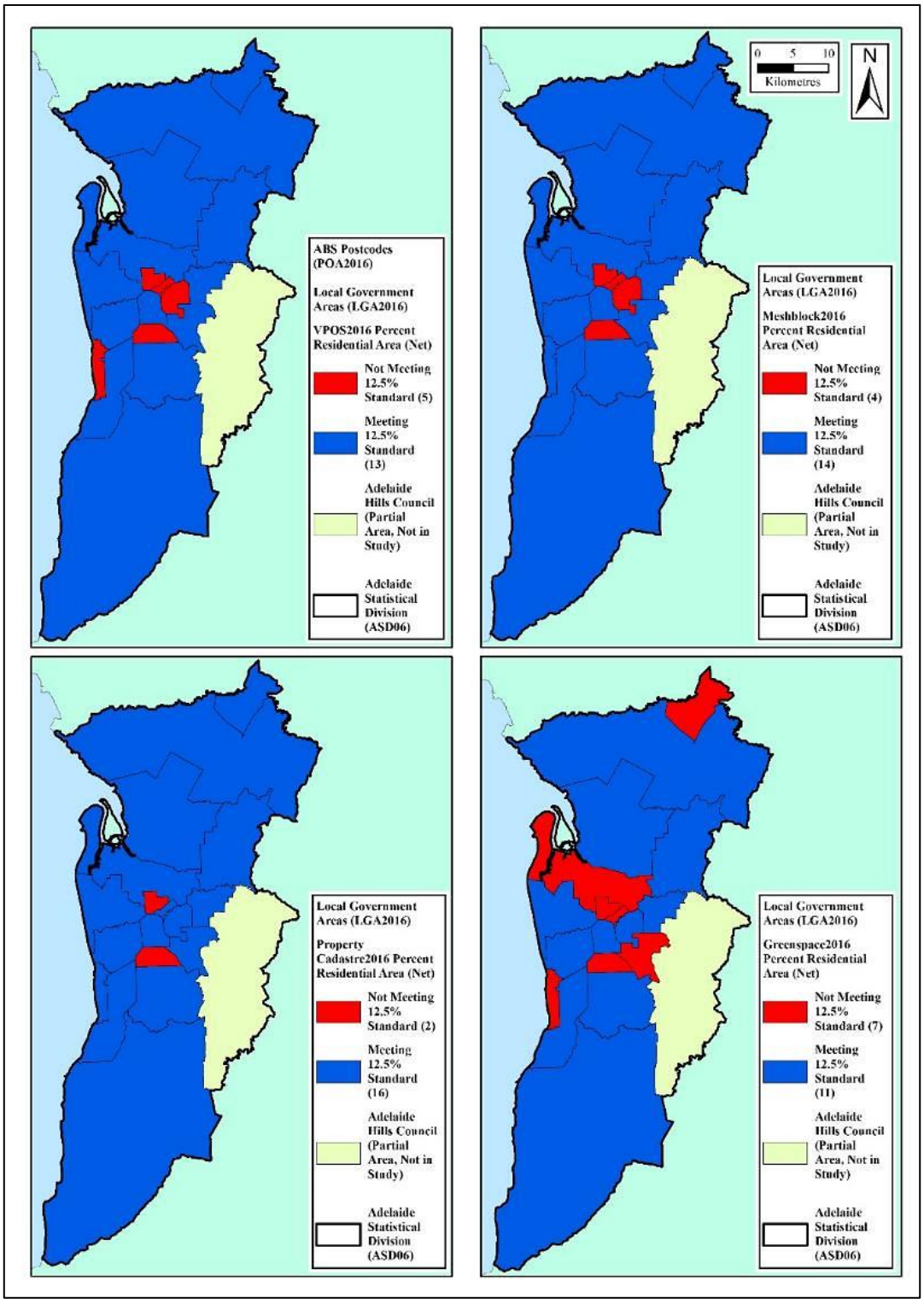


Figure 6-15: Comparison at LGAs between the VPOS2016 and the DPTI Property Cadastre, ABS Meshblocks and PSMA Greenspace (clipped) representing the distribution of open space as a percentage of the residential area.

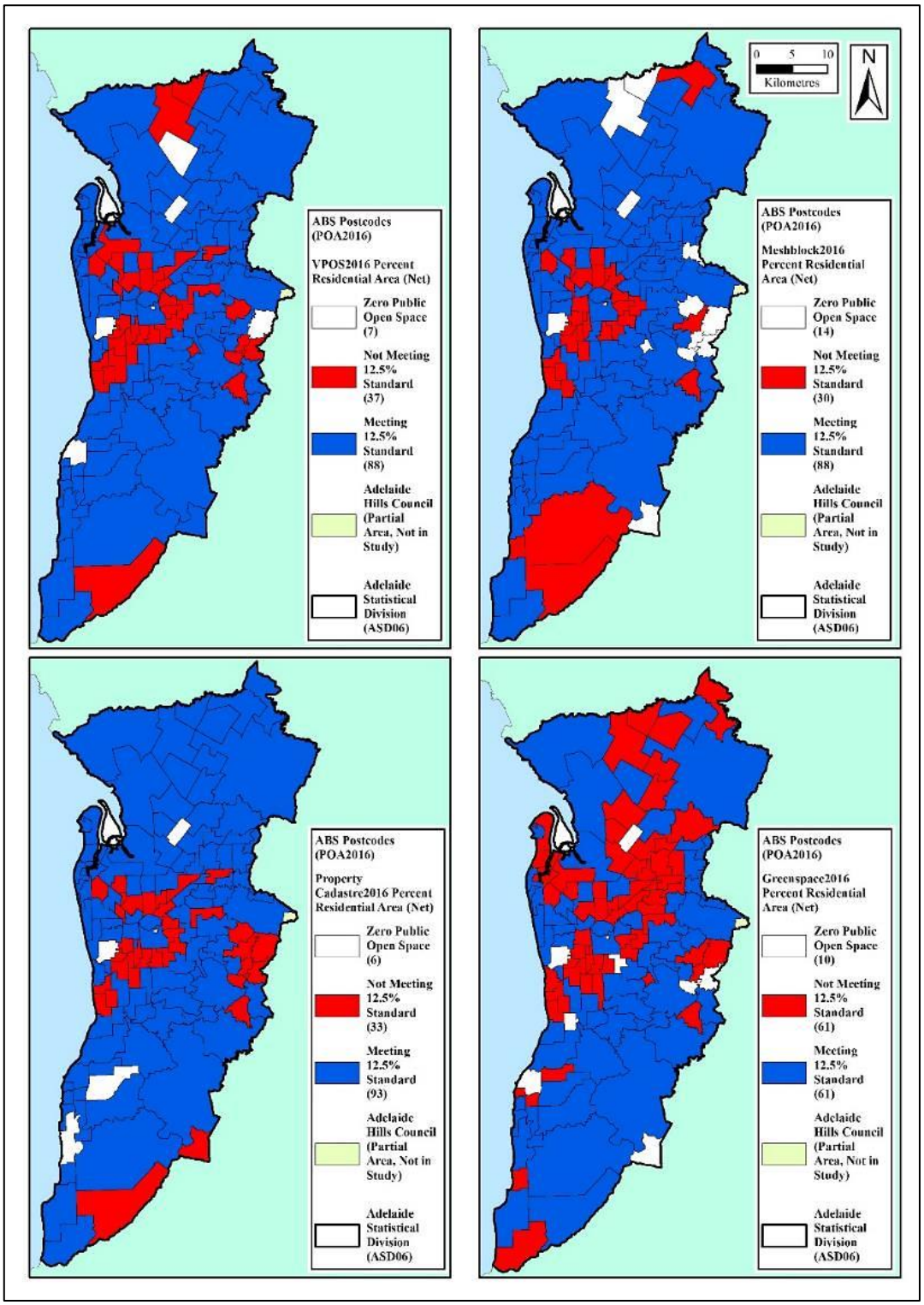


Figure 6-16: Comparison at POAs between the VPOS2016 and the DPTI Property Cadastre, ABS Meshblocks and PSMA Greenspace (clipped) representing the distribution of open space as a percentage of the residential area.

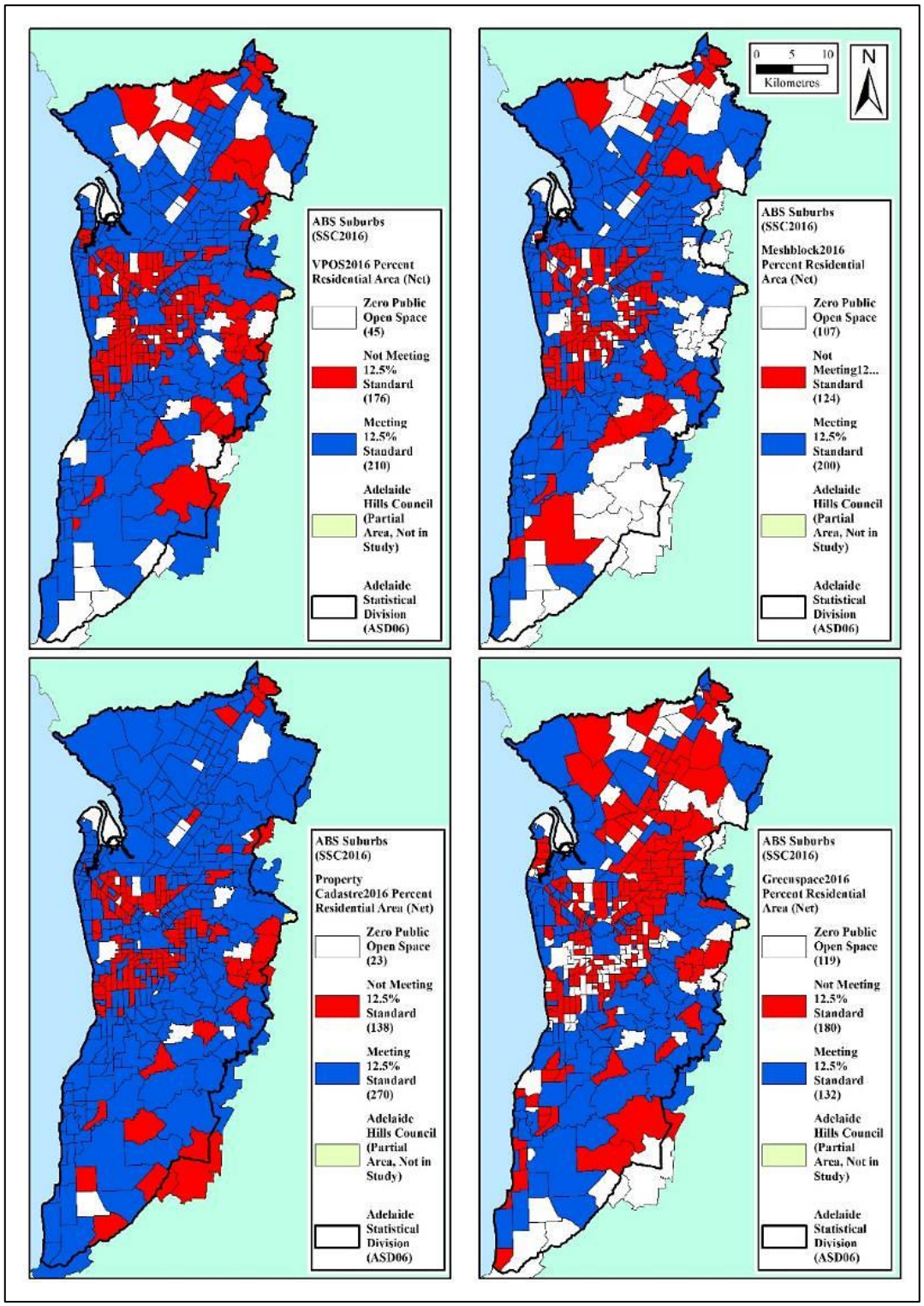


Figure 6-17: Comparison at SSCs between the VPOS2016 and the DPTI Property Cadastre, ABS Meshblocks and PSMA Greenspace (clipped) representing the distribution of open space as a percentage of the residential area.

Table 6-9 reveals the LGA, POA and SSC spatial units (clipped) not meeting the mandated 12.5% open space standard when using the VPOS2016, Property Cadastre 2016, Meshblocks 2016 and Greenspace 2016 datasets.

Table 6-9: Percentage of residential area POS supply standard applied to LGA, POA and SSC.

		VPOS2016		**Property Cadastre (DPTI 2016)**		**Meshblocks (ABS 2016)**		**Greenspace (PSMA 2016)**	
		No.	%	No.	%	No.	%	No.	%
LGAs (*n* = 18)	Zero open space	0	0	0	0	0	0	0	0
	Not meeting 12.5% open space supply standard	5	28	2	11	4	22	7	39
	Meeting 12.5% open space supply standard	13	72	16	89	14	78	11	61
ABS POAs (*n* = 132)	Zero open space	7	5	6	5	14	11	10	8
	Not meeting 12.5% open space supply standard	37	28	33	25	30	23	61	46
	Meeting 12.5% open space supply standard	88	67	93	71	88	67	61	46
ABS SSCs (*n* = 431)	Zero open space	45	10	23	5	107	25	119	28
	Not meeting 12.5% open space supply standard	176	41	138	32	124	29	180	42
	Meeting 12.5% open space supply standard	210	49	270	63	200	46	132	31

Figure 6-18 presents the mandated 12.5% developable area (*Development Act* 1993) when applied to two spatial units (POA and SSC) (clipped), and an Anselin Local Moran's I cluster and outlier analysis based on inverse distance with 999 permutations (pseudo–p-value 0.001). An Anselin Local Moran's I is a spatial autocorrelation tool that is both multi-directional and multi-dimensional that locates patterns within spatial data. A Moran I spatial calculation determines;–1 as perfect clustering of dissimilar values, 0 as no autocorrelation and +1 as perfect clustering of similar values. The analysis operates on a null hypothesis which states the attribute analysed is randomly distributed among the features within a study area. The hypothesis test is calculated of the z-score and associated p-value to identify clustered data, either high or low value with features that have a similar value of magnitude. Additionally, the analysis identifies spatial outliers where non-spatial attributes are markedly different from spatial neighbours (ESRI 2018a; Mitchell 1995).

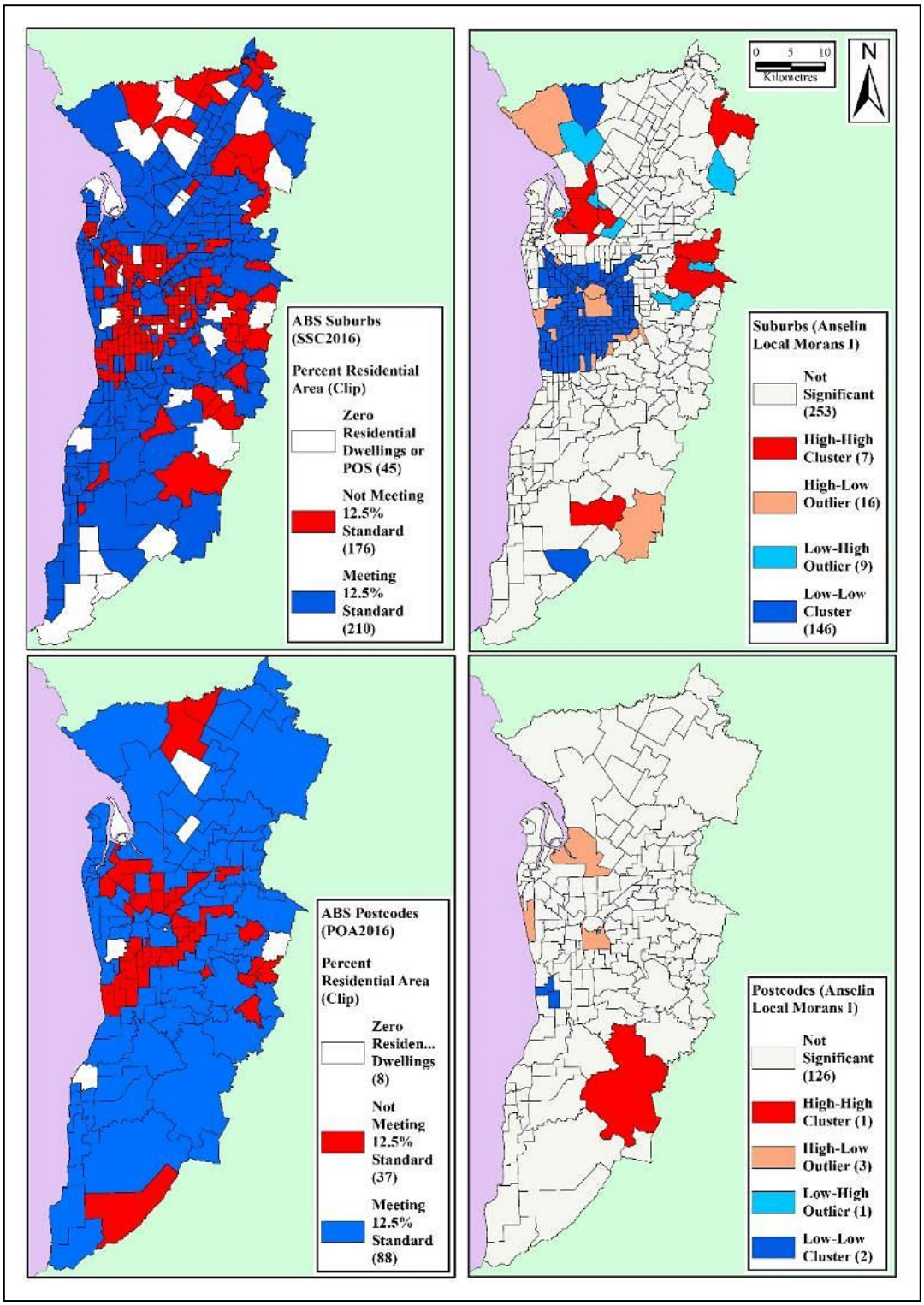


Figure 6-18: Distribution of POS supply (VPOS 2016 clipped); percentage of a residential area and Anselin Local Moran's I at SSC level (top) and POA level (bottom). Numbers in brackets show the count of spatial units within the classifications.

Utilising the 12.5% open space supply standard, a significant proportion of the centralised core of metropolitan Adelaide and the Adelaide Hills on the eastern side of the study area did not meet the open space standard. The POAs and SSCs that did not meet the

12.5% open space supply standard totalled 27% and 40% respectively (Table 6-10). The Anselin Local Moran's I for SSCs presented a low–low cluster of POS in the central urban core. However, these clusters were not replicated in the POA analysis. In both the POAs and SSCs, the Adelaide Parklands was reported as a high–low outlier. 'No data' denotes spatial units either with no POS or residential dwellings or both.

The distribution of the 3 ha per 1,000 persons presented a similar pattern to the 12.5% open space supply standard with the exception of the Adelaide Hills area, which had more spatial units that meet the standard (Figure 6-19). The proportion of POAs and SSCs on the Adelaide plains not meeting the 3 ha standard were 24% and 34% respectively (Table 6-10). The Anselin Local Moran's I, when applied to the hectares per 1,000 persons for the inner core of SSCs, identified them as a low–low cluster; while only the use of POAs identified the Adelaide Parklands as a high–low outlier.

Table 6-10 presents the counts for POAs and SSCs that do and do not meet the two urban planning guidelines, a percentage of the area of land assigned for open space; or a population ratio comprising open space area per 1,000 population when applied to the VPOS2016 dataset.

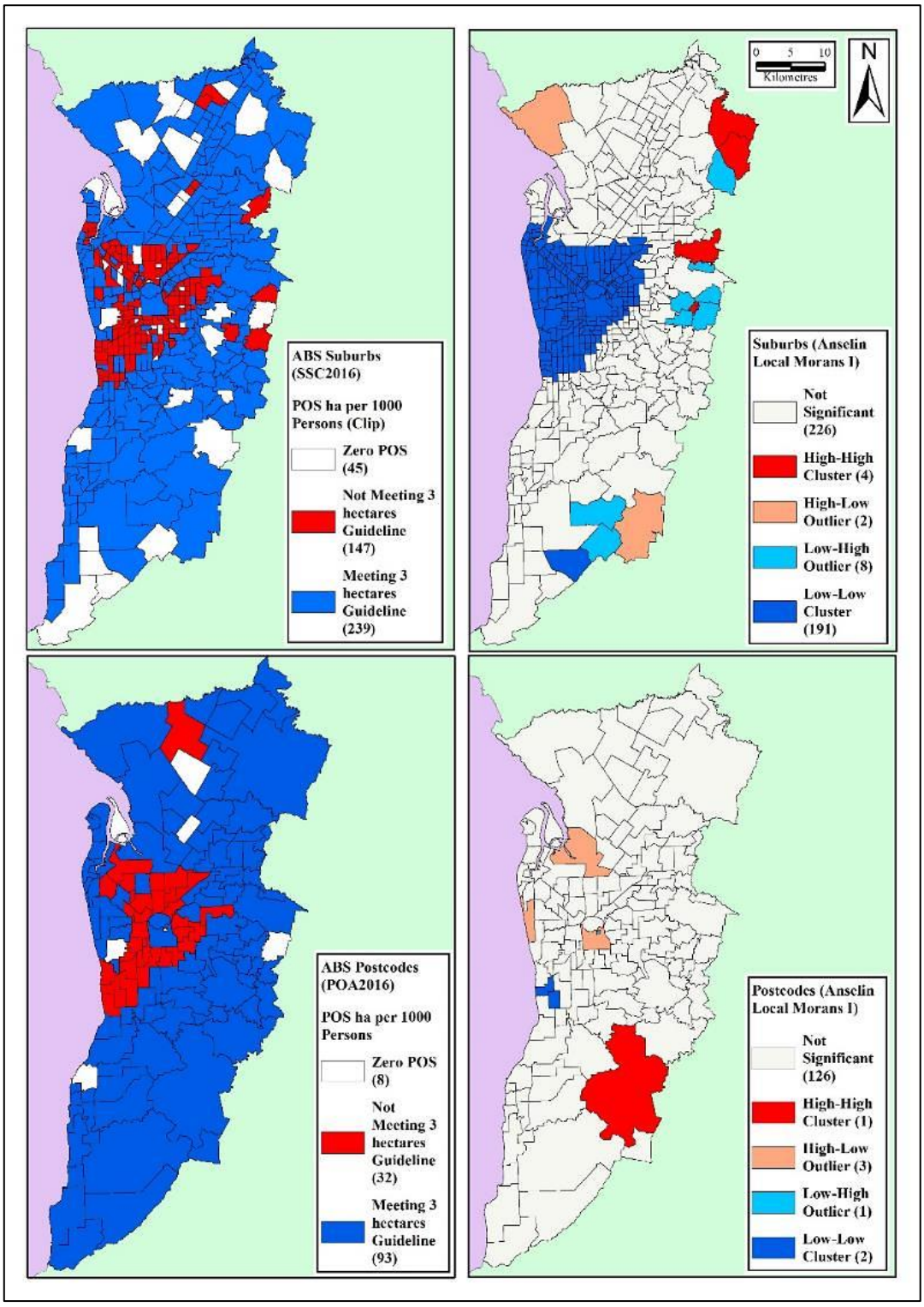


Figure 6-19: Distribution of POS supply (VPOS 2016 clipped); area per 1,000 population and Anselin Local Moran's I at SSC level (top) and POA level (Bottom). Numbers in brackets show the count of spatial units within the classifications.

Table 6-10: POS supply standards applied to POAs and SSCs.

VPOS2016	No data		Not meeting 12.5%		Meeting 12.5%		Not meeting 3 ha per 1,000 persons		Meeting 3 ha per 1,000 persons	
	No.	%	No.	%	No.	%	No.	%	No.	%
ABS POA (2016) (Clip) *n* = 133	7	5	37	28	88	67	32	24	93	70
ABS SSC (2016) (Clip) *n* = 431	45	10	176	41	210	49	147	34	239	56

6.4 Summary

This study built on previous research (Daker 2014a; Daker, Pieters & Coffee 2016) that highlighted the importance of dataset selection to answer research objectives. A previous study had produced a POS dataset (VPOS2011) representing the study area, and this was updated to 2016 for this study. Three additional datasets were selected: the DPTI Property Cadastre, ABS Meshblocks and PSMA Greenspace. The Property Cadastre contained land use codes representing open spaces and recreation activities (Figure 6-1), and these codes provided the base to confirm existing open space with and without recreation activities, the identification of public open space and removal of those lost as a result of land use changes. High-resolution aerial imagery (AEROmetrex 2016) and Streetview (Google Earth© 2016) supported the update, especially with respect to recreation activities and site improvements within individual POS. The imaging also identified POS not previously associated with the VPOS2011, Property Cadastre, Meshblocks or Greenspace datasets.

Dataset validation can involve a degree of error; for example, operator mistakes (Boone et al. 2008) and limitations with Streetview, temporal and image capture. It should be recognised that the utilisation of high-resolution aerial imagery may not enable the identification of all features, especially those under tree canopies or built structures. To overcome these potential problems, a field validation study was undertaken to support the desktop validation. To visit all the 3,637 sites would be time-consuming and involve considerable expense. Therefore, a 10% representative sample was selected from the pvPOS2016 for the field validation.

The outcome of the field validation delivered a 98.06% accuracy with a margin of error e = +/ 1.36%. These results confirmed that the initial validation of the uPOS2016 dataset was achieved to a high standard. Although the dataset may contain errors, these were

random and did not detract from the confirmation that the VPOS2016 dataset embodies an accurate representation of POS for passive and active recreation activities within metropolitan Adelaide (Figure 6-11). The VPOS2016 dataset is conceptually similar to the legislated definition of open space (Development Act 1993), where the open space supply standard is applied to residential areas and publically accessible. On this basis, the VPOS 2016 dataset can be utilised to investigate supply, access and population health outcomes.

The distribution of POS when represented at the spatial scales of POAs and SSCs highlighted the influence of the Modifiable Areal Unit Problem, especially when two POS supply metrics were applied. When comparing the smaller spatial unit of SSCs with the larger spatial unit of POAs, 40% and 27% respectively did not meet the mandated 12.5% open space supply standard (Table 6-10). The uneven distribution of suburbs not meeting the standard suggests that smaller spatial units are more sensitive to data representations. This demonstrates that larger spatial units can mask the spatial distribution of POS and highlights smaller spatial units might be appropriate to represent POS distribution.

The open space area per 1,000 persons for the POAs and SSCs highlighted that those not meeting the 3 ha standard were predominantly within the central zone around the City of Adelaide. This can be attributed to higher residential population densities, particularly in the urbanised areas on the western side of the study area. In contrast, in the peri-urban zone, the percentage area of open space is sensitive to more extensive tracts of open space (national and conservation parks) within these areas, which are also characterised with larger residential land blocks and lower population densities.

When an Anselin Local Moran's I was applied, POS cluster and outliers were highlighted, and when compared with the distribution of POS supply, these highlighted the spatial units that had a smaller count and areas of POS. As discussed in the literature, residential areas with a shortfall in open space were developed before planning legislation mandated open space supply standards. For metropolitan Adelaide, this affected the central core, with the exception of the City of Adelaide bounded by the parklands.

Both local and state government widely report strategic open space planning policies at larger spatial units (e.g., LGA), due to the diverse readership and for ease of information dissemination. However, the distribution of open spaces in relation to connection with residential areas could be masked as well as the issues of under-supply (Delgado 2006; DPTI 2017a; Timperio et al. 2007). When applied to this research, 66% of local government area met/exceeded the 12.5% open space standard and 69% met/exceeded the area per 1,000

persons. In contrast, the smaller SSCs, the results were 49% (12.5% of area). and 55% (area per 1000 persons). Subsequently, the impact of the Modifiable Areal Unit Problem cannot be fully resolved when administrative boundaries as demonstrated by the changing results for the LGA, POA or SSC. The Modifiable Areal Unit Problem needs to be acknowledgment in research projects and government documentation to prevent potentially biased representations of POS supply.

Chapter 7: Metrics for Access to Public Open Space.

With changes in urban design and planning strategies, there is a renewed requirement to investigate the influences of urban design on population health, in particular, the issues of appropriate access to open space. Additionally, the level of access could be attributed to the open space dataset selected; the appropriate selection of datasets was discussed in Chapter 6, and this chapter considers measures of access to public open space.

Extensive research has been undertaken regarding ways to calculate the distance from a destination to a source, for example, a dwelling to an open space (Browning & Lee 2017; Delamater et al. 2012; Ekkel & de Vries 2017; La Rosa 2014). Distances can be computed utilising the shortest straight line (Euclidean), Manhattan network or as a buffer (Annerstedt van den Bosch et al. 2016; Maas et al. 2008; Schipperijn et al. 2013). The simplicity of Euclidean distance and buffers may not reflect the complexity of the urban environment; for example, topography influences human decisions to not travel in straight lines. A Euclidean distance or buffer analysis can deliver oversimplified outcomes (Higgs, Fry & Langford 2012; Sander et al. 2010). Alternatively, more complex vector network or raster analyses can be implemented to measure the distance between points from point A to point B along a street network (Delamater et al. 2012; Koohsari et al. 2018; Paquet et al. 2013; Sallis et al. 2016).

Proximity measures involving a street network are limited by the availability of quality and accurate street network datasets. To deliver uniformity, a majority of street network datasets represent multiple street road widths as single lines delineated to the centre of the road system. In countries where street networks are laid out as a grid pattern, for example, in Australian urban areas, the centre line of the road system mirrors the location of footpath and pedestrian networks (Ellis et al. 2016).

To calculate street network distances, there are two main methods in ArcGIS, the vector network analysis function or the raster cost distance function. A vector network can provide a high degree of accuracy in the calculation of distances, although accuracy can only be achieved when different types of vector data, for example, line, polygon and points to connect have the same level of spatial accuracy (Sander et al. 2010). While the raster cost-distance approach offered an alternative approach that represented a network of uniformly

spaced cells, a raster analysis does not experience issues related to scales of agglomeration or Modifiable Areal Unit Problem (Choi, Um & Park 2014). An important factor in raster analysis is the cell size Mulrooney et al. (2017) highlighted an optimum cell between 10 m and 25 m to ensure good connectivity between features and to minimise over service which can occur with a larger cell size. Delamater et al. (2012) concluded a raster analysis identified more population underserved by health care than a vector network method. Another factor supporting the use of a raster network analysis is the average computer processing time is less than the vector network analysis (Sander et al. 2010).

Both vector and raster network analysis can manage the calculation of street network distances for pedestrian movement. However, potential impedances to pedestrian movements could influence the results; for example, arterial roads, rivers and railways (Gelb et al. 2017; La Rosa 2014). Another issue with measuring distances to a feature, including open space, is the variation in feature size and shape. As described by Boone et al. (2009), for smaller features, a centroid point may be suitable as the destination point, whereas, for larger features, the distance from the centroid to a boundary edge might vary substantially depending on which boundary point you choose and skew results. Instead, improved accuracy could be achieved by defining the boundary edges of the feature as the destination points (Barbosa et al. 2007; Jones, Hillsdon & Coombes 2009).

Health and social planning researchers have applied a range of buffer distances to analysis health outcomes, for example walking from home to an open space along a network or by a radial (buffer). Distances applied to analyses have included 250 m (Ulmer et al. 2016), 400 m (DPTI 2017a; Koohsari et al. 2018), 500 m (Cerin et al. 2017) and 1 km (Astell-Burt, Feng & Kolt 2014a; Paquet et al. 2013). Determining distances can be contentious as multiple factors may be involved; for example, age (child or senior), topography, footpath quality, attractiveness and safety of a neighbourhood (Forsyth et al. 2008; Kaczynski, Potwarka & Saelens 2008).

In health and social planning research, a recurring distance is 400 m (Gong et al. 2014; Koohsari et al. 2018; Ulmer et al. 2016; van Loon et al. 2014). Mavoa et al. (2015) investigated whether POS supply across metropolitan Melbourne adhered to the Victorian Planning Provisions (VPP), which required 95% of dwellings to be within 400 m of a POS (Department of Environment Land Water and Planning 2018). The results showed that one-third of dwellings did not meet the Victorian Planning Provisions distance-to-POS guidelines. However, middle and outer suburbs often had better access as they were more likely to be

closer to larger semi-natural areas (e.g., national parks) on the urban fringe. The research concluded that further study was required to understand which other factors could be involved, including POS useability and facilities provided, population diversity and POS regulations and policies.

The South Australian Government's 30-year plan (DPTI 2017a) includes 400 m as a criterion for walkable neighbourhoods. The South Australian 30-year plan defined walkable neighbourhoods as requiring good access to vegetated open space greater than 4,000 m^2, primary schools, frequent public transport and shops. The report suggested a target of 77% of residents in urbanised areas to have access to vegetated open space, although the report does not address the access issue for the remaining 23% of the population. Additionally, there is no explanation for why 4,000 m2 was selected to represent the minimum open space area.

7.1 Data preparation.

Because the availability of street network data was critical for this analysis, appropriate datasets were sought. Two data sources were selected, the PSMA Street Network and the Department of Planning, Transport and Infrastructure (DPTI) road data (DPTI 2017b; PSMA 2016a). The PSMA dataset is national, and the methods used can be replicated within other cities in Australia. The DPTI road data is only applicable for South Australian use. Both the PSMA Street Network (PSMA 2016a) and the DPTI road (DPTI 2017b) were analysed to determine the suitability to calculate distance from a POS to a dwelling point. The PSMA data represented a more detailed network of not only roads but included trails within POS and footpaths across road dividers, while the DPTI classified only principal roads and streets.

An inspection of both the VPOS2016, the roads (DPTI 2017b) and the Street Network (PSMA 2016a) data revealed that the POS boundaries did not connect with the network, because the road and street network are represented as the centre line of the road. This issue required the investigation of three options to determine the distance from any dwelling to a POS:

1) distance to the geometric centre or the centroid of the POS;
2) distance to the POS boundary buffered to intersect the street network; and
3) distance-to-POS vertices converted to boundary points and positioned along/on to connect with the road or street network. (The selected VPOS

boundary points provided an approximation to POS access. Without improved street network data from both federal and state governments, or extensive validation processes, for example, using aerial imagery (AEROmetrex 2016), Google Streetview (Google Earth© 2016) and physical field validations, the precise entry locations for many of the POS could not be substantiated).

For larger POS, using centroids could result in significant distances from the central point to the boundary: for example, in Figure 7-1, one such distance was 310 m. Thus, the use of distance from a POS centroid to a dwelling point may provide a less accurate representation of the total distance, and the use of the buffered boundary points may result in a potential over-representation (Figure 7-1). Therefore, centroids and the buffered points were excluded as they could both over-represent the distance to a dwelling point. Instead, the POS vertices were selected as boundary points they represent potential entry locations from the DPTI road network to a POS. Figure 7-1 provides an example of the data for the three options in the suburb of Northgate in Adelaide. Validation of the POS vertices method revealed numerous POS had insufficient vertices along the boundaries. This issue was addressed by densifying vertices and adding new vertices to ensure they were no more than 50 m apart.

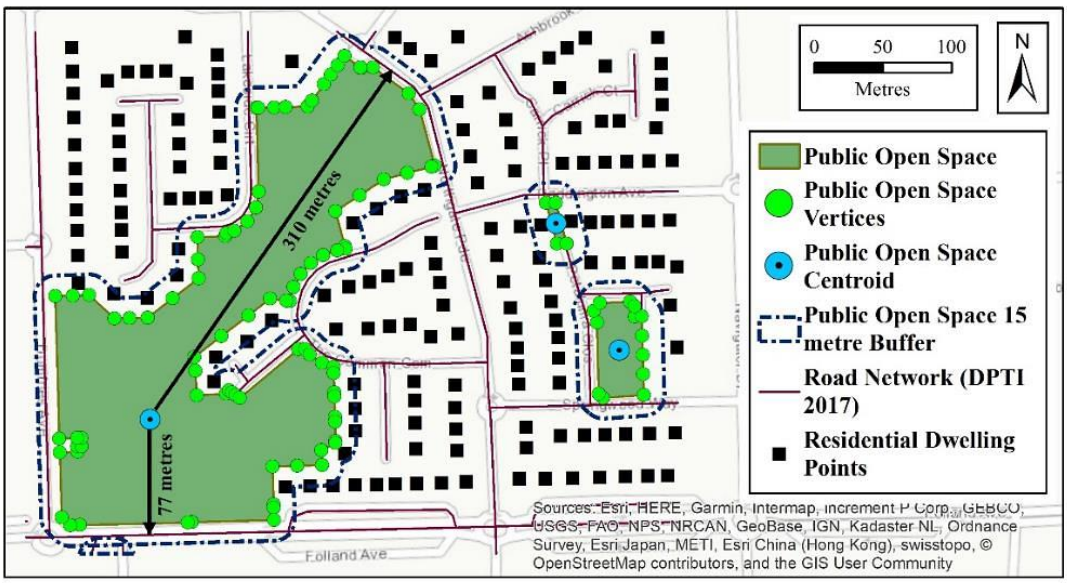


Figure 7-1: Identification of three methods to determine the distance from any POS to a dwelling (centroids, vertices and a 15 m buffer). POS located in Northgate, South Australia.

An analysis of the PSMA data highlighted a significant number of trails and footpaths within POS, which could result in POS points being repositioned inside a POS. To extract these trails and footpaths could inadvertently remove other footpaths, for example, those leading to a POS or traversing a road divider. A visualisation of the DPTI road dataset revealed that the data classified only principal streets, which were thus selected to compute the repositioning of POS boundary points.

A selection of 100 POS were randomly chosen to calculate the distance from the boundary point to the nearest street edge in the DPTI data. Aerial imagery (AERObmetrex 2016) was used to identify barriers; for example, fences along adjoining property boundaries. the results suggested a majority of points within 15 m. The ArcMap 'near' function inputted the 15m distance and calculated the near *x* and *y* coordinates for a POS boundary point to the nearest road. However, a small number of points were just outside the 15 m selection cut-off and required manual adjustment to connect to the street. Additionally, a further validation of the data located invalid points (for example points which traversed a dwelling lot which was less than 15 m deep and duplicated points), these errors were deleted.

The PSMA Street Network was selected for the raster analysis because it supported a more diverse network. Because the POS boundary points were aligned with the DPTI Road, a check had to be undertaken to ensure compatibility with the PSMA data. A visualisation of both the DPTI road and PSMA Street Network datasets identified presented minor differences in the line positioning, particularly on curves and intersections; this was addressed by re-running the 'near' function at ≤3 m thus repositioning the boundary points from the DPTI road to the PSMA Street Network. Figure 7-2 illustrates this process using the ArcMap 10.6 Model Builder application.

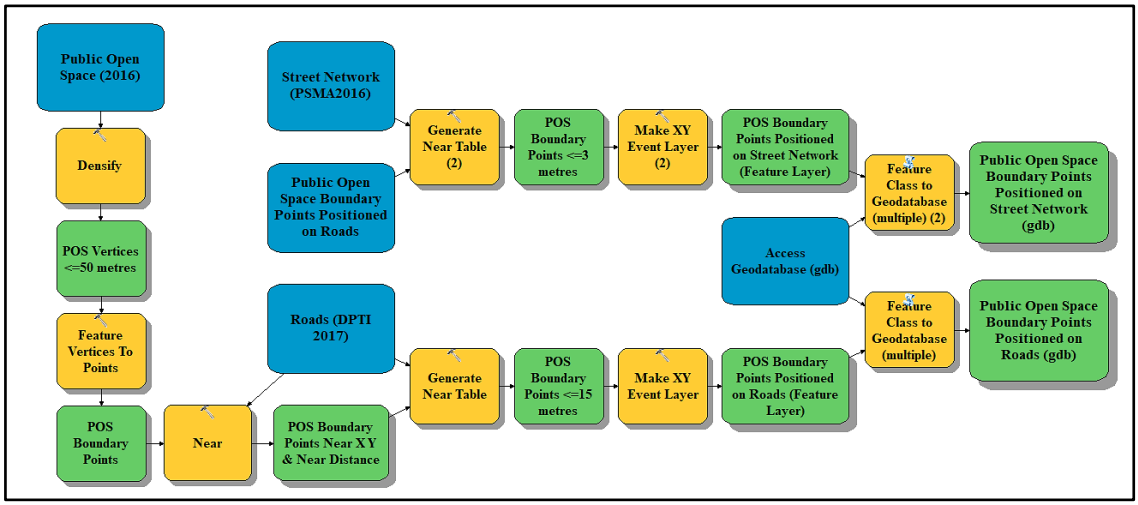


Figure 7-2: Model Builder to manage the selection and repositioning of POS boundary points to join with the DPTI road and PSMA Street Networks.

The representation of VPOS boundary points which provided an approximation to POS access is displayed in Figure 7-3.

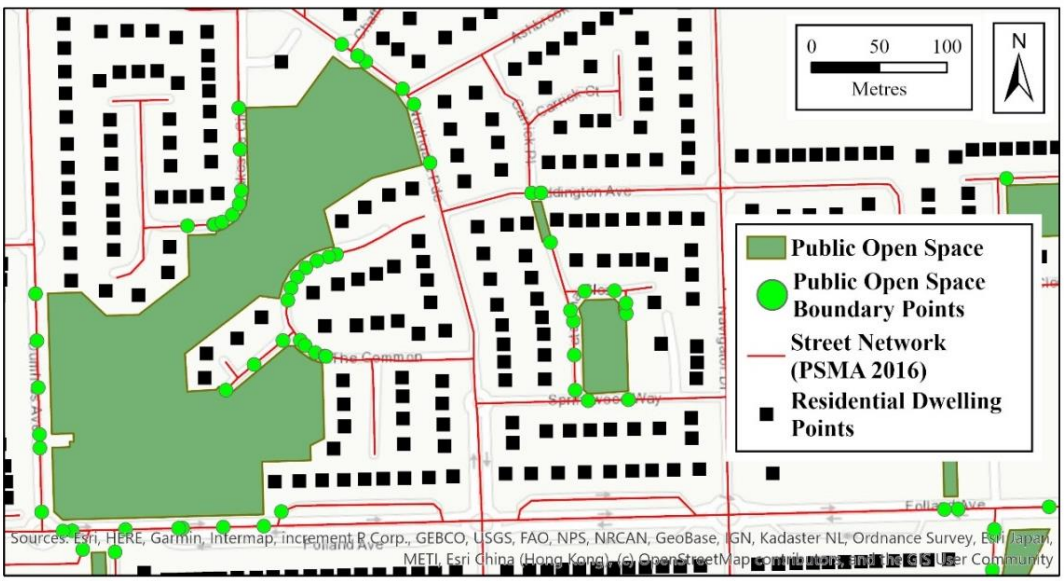


Figure 7-3: POS boundary points repositioned to connect with the PSMA Street Network. (Northgate, South Australia).

As highlighted by Delamater et al. (2012), a vector network analysis could misrepresent connectivity; therefore, a raster cost distance analysis was selected to determine the distance from dwellings to closest POS. Additionally, the study encompassed a sizeable area, a vector network service area analysis was deemed too problematic due to limitations in

software and computer capacity. Therefore a raster analysis was applied in ArcMap 10.6 (ESRI 2018b) to calculate the network distance from dwelling points (n = 430,737) to any POS (n = 3,745), utilising the PSMA Street Network (PSMA 2016a). As the network traversed the ASD boundary and to ensure road connectivity was maintained, a 5-km external buffer was applied to the ASD boundary. Additionally, residents residing near the edge of the ASD might cross the administrative boundary to utilise their nearest POS an additional 115 POS outside the ASD boundary (an extension of the process described in Section 6.1.1) were added to the VPOS2016 dataset. All datasets in this chapter are listed in Table 4-2.

7.2 Network access and identification of limitations.

Gelb et al. (2017) acknowledged that the location of barriers could influence the ease by which people can travel within an urban environment. In recognition barriers could restrict the level of access from a dwelling to an open space, four datasets were utilised to represent potential barriers within the study area:

1) state highways and arterial roads (PSMA 2016a);
2) major named watercourses, for example, River Torrens, Sturt and Gawler Rivers and Dry Creek (DEWNR 2017);
3) railway and tram lines and the O Bahn busway (PSMA 2017); and
4) airports, reservoirs and larger military establishments (DPTI 2016c).

All polygon features (airports, reservoirs and military establishments) were converted to line data (Figure 7-4). In recognition that street networks spanned barriers, small sections of a barrier were manually removed to ensure the raster analysis did not underestimate network accessibility.

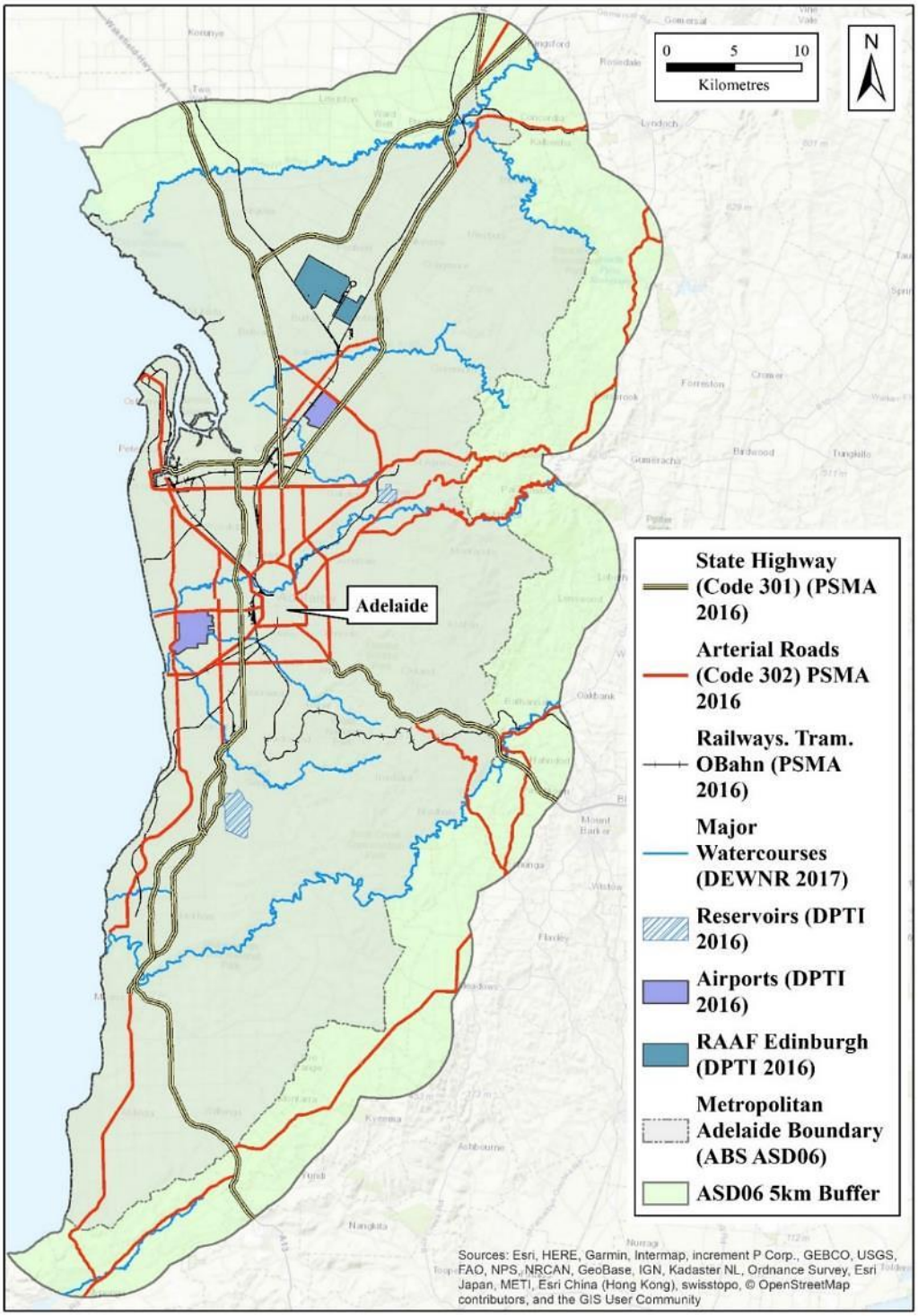


Figure 7-4: Identification of the potential barriers within the ASD06 that could influence distance metrics from a dwelling to any POS.

7.3 Raster network distance analysis

The ASD boundary with the 5-km buffer was assigned as the raster mask in the environment settings. A cell size of 10 m was applied to generate optimal connectivity between the different raster layers. The Model Builder function was utilised to undertake the raster analysis and ensure a systematic workflow (Figure 7-5).

Two street network raster datasets were developed for analysis: one with (A) and one without barriers (B) (Table 7-1). In network A, barriers were reclassified 'NoData', while dataset B included only one barrier classification, national and state highways (Table 7-1), as these were not accessible for pedestrians (Koohsari et al. 2018). Raster cells reclassified 'NoData' were considered a barrier and no values were recorded on any output raster (cost distance and allocation) whereas a zero represents a value in the analysis algorithm (ESRI 2016a).

Table 7-1: Street network raster data, with and without barriers.

Network	Network with barriers (A)	Network without barriers (B)	Data source
National or state highways (Transport Hierarchy Code 301) (no pedestrian access)	NoData	0	(DPTI 2017b; PSMA 2016a)
Arterial roads (Transport Hierarchy Code 302)	NoData	1	
Street Network Transport Hierarchy Code 303–305 (roads) 308 (undetermined), 309 (access roads) and 400 (pedestrian thoroughfares)	1	1	
Watercourses (named rivers and major creeks)	NoData	0	(DEWNR 2017)
Railways, busways, tramways	NoData	0	(PSMA 2017)
Airports (polygon converted to a line)	NoData	0	(DPTI 2016c)
Reservoirs (polygon converted to a line)	NoData	0	
Royal Australian Air Force Edinburgh Base (polygon converted to a line)	NoData	0	

Figure 7-5 presents the ArcMap 10.6 Model Builder workflow developed to run the raster analysis for the three distance analysis (barriers, without barriers and Euclidean distance).

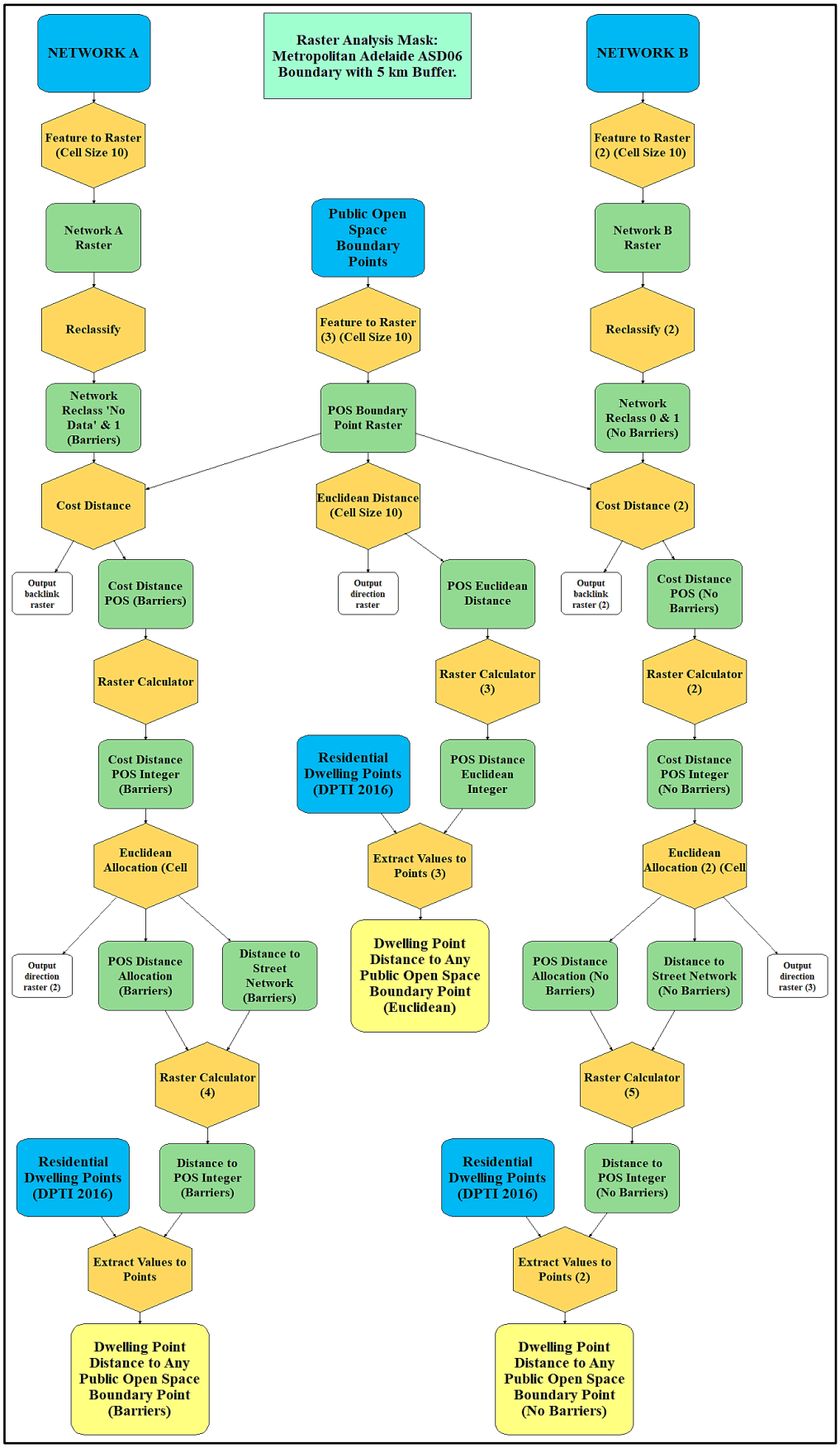
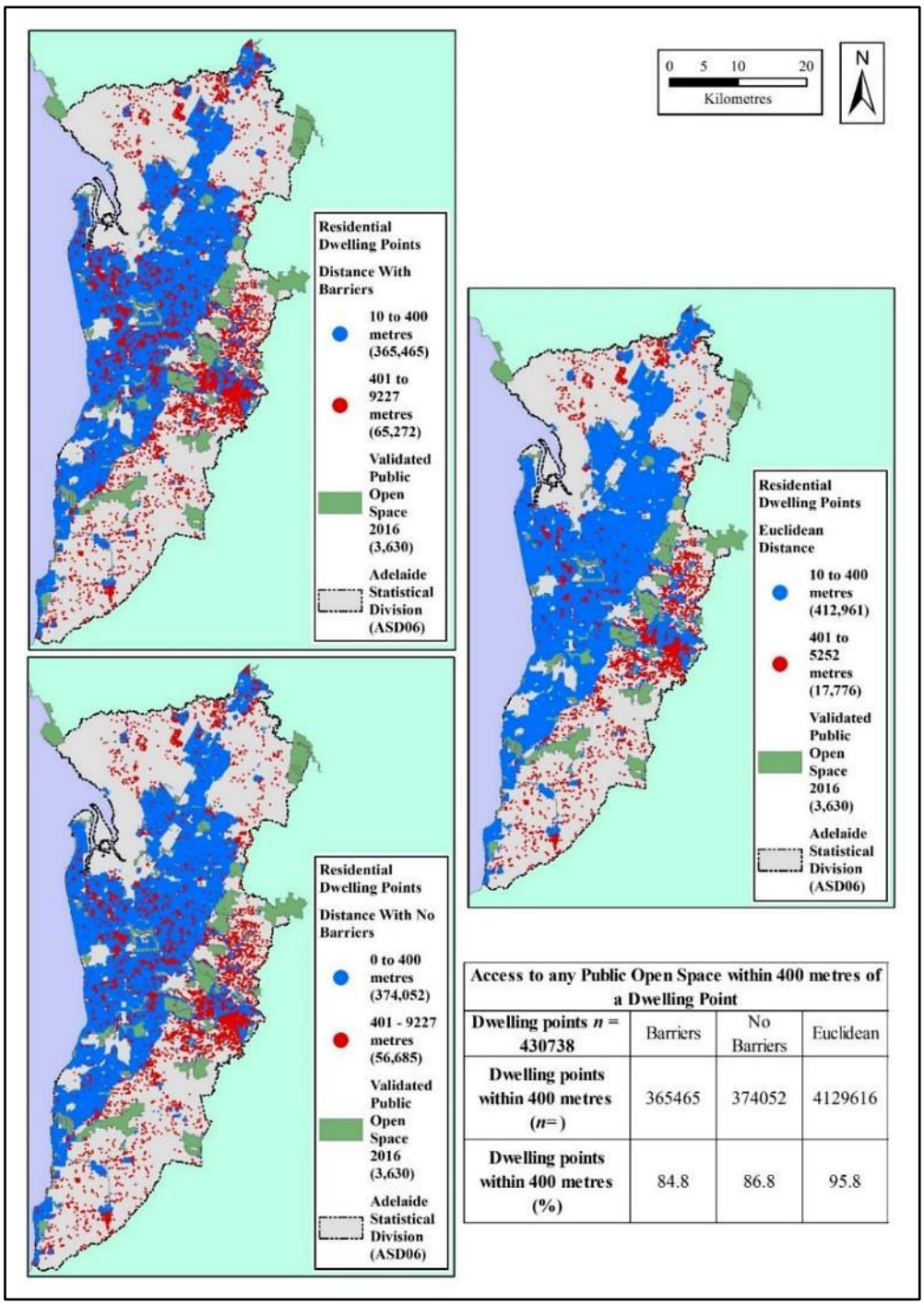


Figure 7-5: ArcMap 10.6 Model Builder to run a raster distance analysis (barriers, without barriers and Euclidean distance) from any POS to dwelling points.

7.4 Results.

With a raster cost-distance analysis, all dwelling points (n = 430,738) had an individual distance computed, and the 400 m distance from a dwelling to POS was selected to calculate the access analytics for the three output metrics (barriers, without barriers and Euclidean) within the ASD (Figure 7-6).



Access to any Public Open Space within 400 metres of a Dwelling Point			
Dwelling points n = 430738	Barriers	No Barriers	Euclidean
Dwelling points within 400 metres (n=)	365465	374052	4129616
Dwelling points within 400 metres (%)	84.8	86.8	95.8

Figure 7-6: Dwelling points with access to any POS within 400 m bounded by the Adelaide Statistical Division (ASD06). Maps show distances with barriers, without barriers and Euclidean distance.

When barriers were applied, 84.8% of all dwellings were within 400 m of a POS, while removing significant barriers increased the percentage to 86.8%. The most significant difference was for Euclidean distance at 95.8%, as previously discussed; this metric is probably unsuitable as people are unable to travel in a straight line in urban environments. For the three analyses, the minimum, maximum, mean and standard deviations of distance are provided in Table 7-2.

Table 7-2: Distances attributed to barriers, without barriers and Euclidean distance for dwellings to any POS within metropolitan Adelaide (ASD06).

	Dwelling points: *n* = 430,737 distance to any POS boundary point (m)		
	Barrier	Without barrier	Euclidean
Minimum distance	10	5	10
Maximum distance	9,927	9,927	5,252
Mean distance	243.2	231.5	153.8
Standard deviation	245.6	224.9	153.9

Figure 7-7 provides a close-up representation of the three access, metrics (with and without barriers and Euclidean) when the 400 m distance was applied.

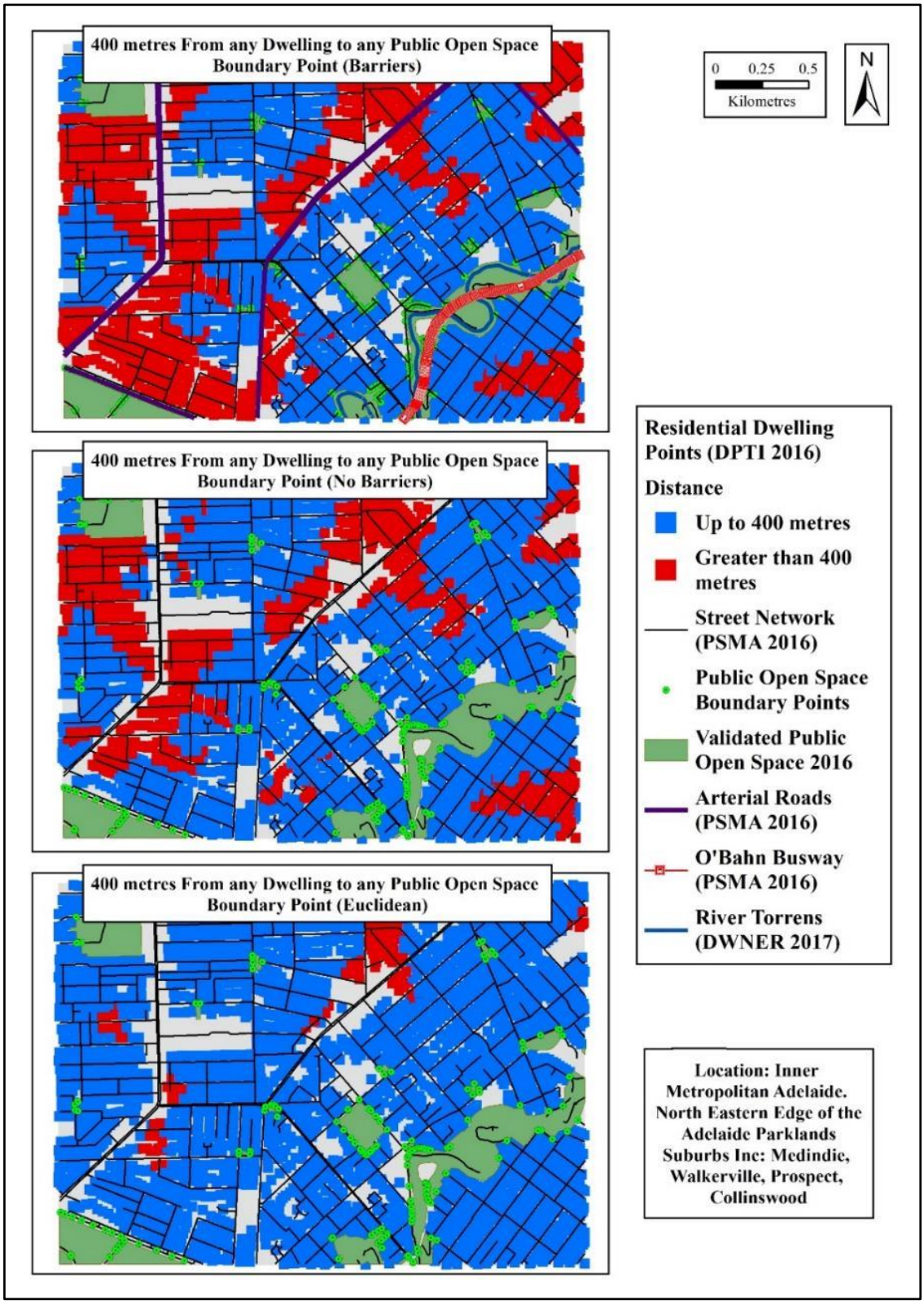


Figure 7-7: Representation of three distance calculations involving a PMSA Street Network with barriers, without barriers and Euclidean distance.

A spatial join of the dwelling points with the two spatial units (POA and SSC) enabled total for the spatial unit to be calculated. The results revealed noticeable differences in the mean percentage with 400 m access (Figure 7-6). For SSCs, the with barriers mean percentage of dwellings with access decreased by 11.1% to 73.5%, compared to POAs, which decreased to 10%. Whereas the Euclidean distance decreased by 7.3% within POAs and SSCs decreased by 7.7% (Table 7-3).

Table 7-3: Percentage of dwellings within 400 m of any POS (ASD, POA and SSC).

Spatial unit	Barrier	Without barriers	Euclidean
ASD (n=1)	84.6	86.8	95.8
POA (*n* = 133): mean (SD)	74.6 (21.9) [1]	78.7 (21.6) [2]	88.5 (19.5) [3]
SSC (*n* = 431): mean (SD)	73.5 (25.5) [4]	78.3 (24.4) [5]	88.1 (22.8) [6]

Note: 1, no access for 7 POAs; 2, no access data for 7 POAs; 3, no access data for 6 POAs, 4 no access data for 29 SSCs; 5, no access data for 25 SSCs; 6, no access data for 23 SSCs.

Figure 7-8 and Figure 7-9 present the differences between POAs and SSCs when computed among the three access metrics. When Euclidean distance was applied to POA and SSC, most of the urbanised area of metropolitan Adelaide had between 94% and 100% access. For all three metrics, the peri-urban area had lower access scores, which could be because of the lower dwelling density, less dense street network and poorer supply of POS.

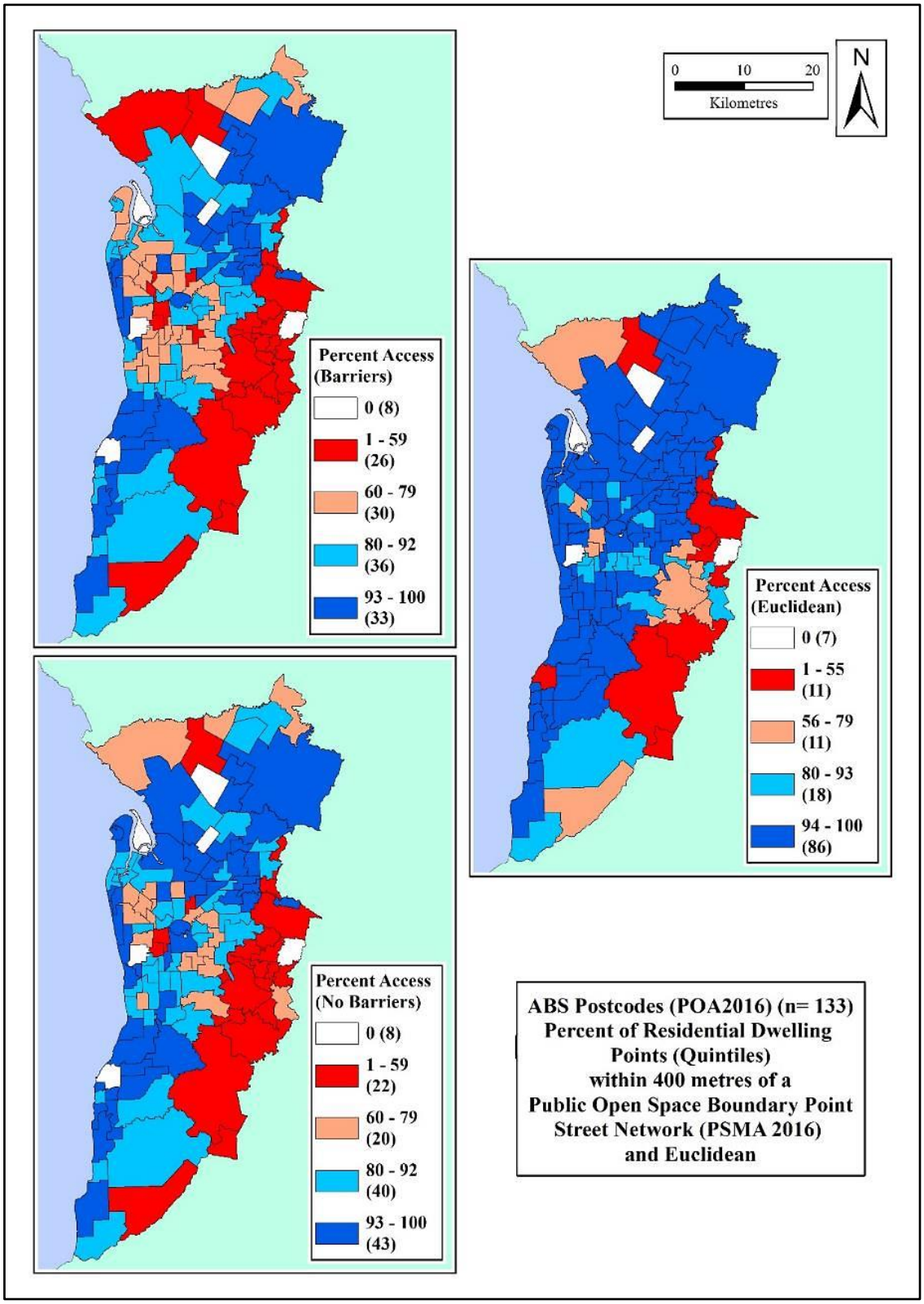


Figure 7-8: ABS POAs: percentage of dwellings with access to any POS within 400 m with barriers, without barriers and Euclidean distance. 'No data' represents areas with no residential dwellings or POS.

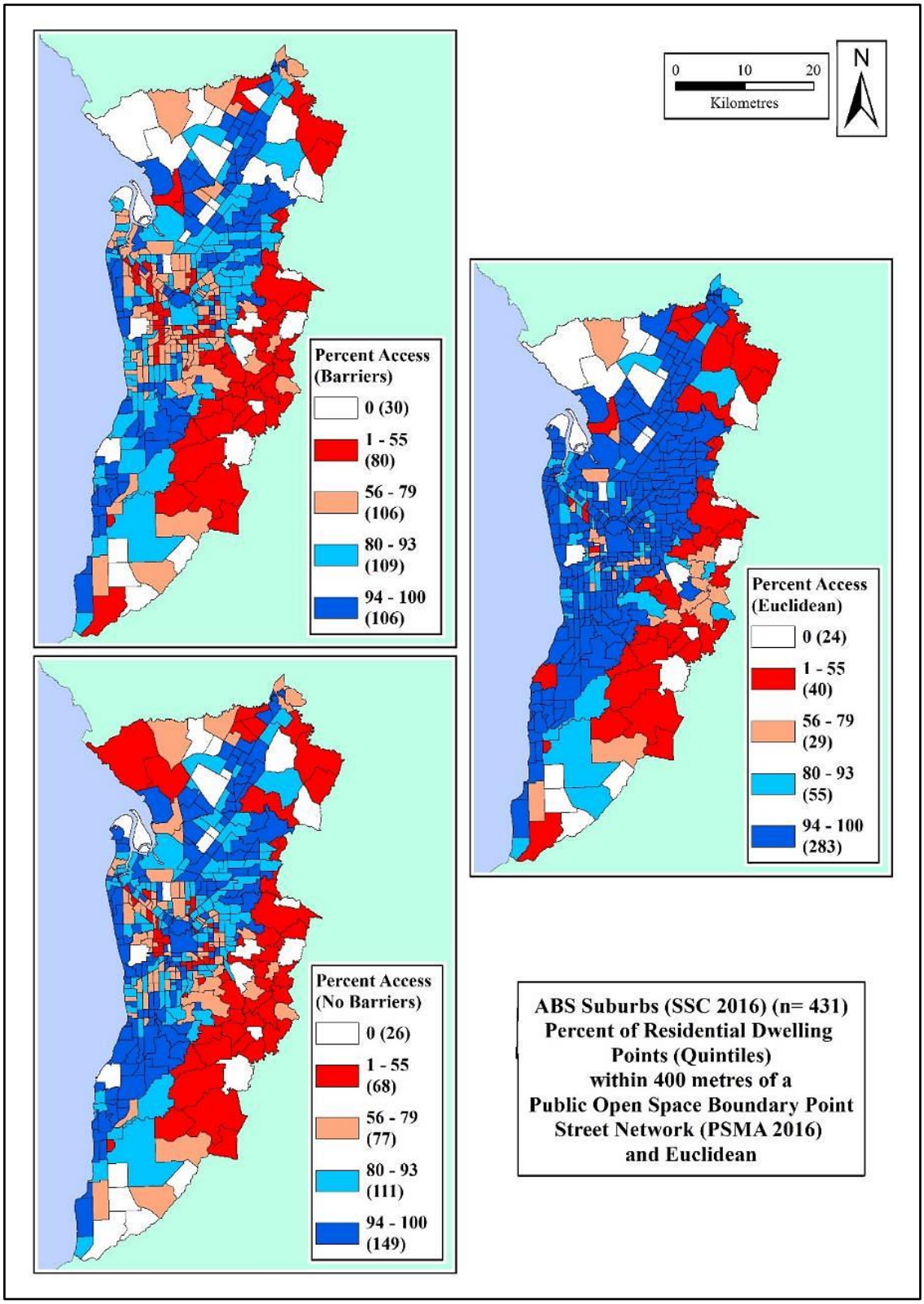


Figure 7-9: ABS SSCs: percentage of dwellings with access to any POS within 400 m with barriers, without barriers and Euclidean distance. 'No data' represents areas with no residential dwellings or POS.

7.5 Discussion and conclusions.

As stated in the previous chapter, robust validation of data is essential to ensure research objectives are met. Therefore, determining the distance from an open space to a dwelling is influenced by the availability of quality data. Also, open space vary in shape and area, and thus the distance from an origin point to a destination was calculated using a variety of methods: distance to centroid (La Rosa 2014), distance to boundary points (Comber, Brunsdon & Green 2008) and distance to nearest access point of any greenspace (Higgs, Fry & Langford 2012).

A centroid of POS for a distance analysis, as illustrated in Figure 7-1, might involve considerable distances from the centroid to the dwelling point and consequently, the final distances could be overestimated. Boone et al. (2009) reported similar results with considerable distances to reach the open space boundary.

The POS boundaries could be points of entry, thereby providing less biased calculations of distance. However, calculating the distance to a POS boundary is not without issues, including the number of boundary vertices that represent points of possible entry locations, and not including boundary points not accessible from the street network (i.e. along rear property boundaries abutting a POS). Without expending considerable time and resources (e.g., aerial imagery, Google Streetview and field validations), the actual entrance locations would be difficult to determine.

Comparing the 'with barriers street' and 'without barriers street networks' within the ASD boundary extent revealed very minor differences (2%) between the two classifications of networks, while via Euclidean distance, up to 96% of dwellings were within 400 m of a POS, similar to the 95% requirement set in the Victoria Planning Provision (Department of Environment Land Water and Planning 2018). Coleman (2016) utilised Euclidean distance to determine the percentage of people with 400 m access to POS in capital cities in Australia. The results for metropolitan Adelaide included that 94% of people had access to POS. Many researchers have applied Euclidean distance to determine the distance between two points along a straight line (Pereira et al. 2013; Picavet et al. 2016; Ulmer et al. 2016); which could be attributed to the simplicity to calculate, or inadequate street network data. It must be recognised that Euclidean distance calculations are not necessarily accurate because people do not or cannot travel in straight lines in the urban environment.

When the raster network results were applied to POAs and SSCs within the ASD, the differences between barriers, without barriers and Euclidean distances for both spatial unit types were limited. When the ASD outcomes in Figure 7-6 were compared with SSCs with barriers, the percentage of dwellings within 400 m decreased to 73.5%, a difference of 11.3% between the large area ASD and smaller area SSC unit. This suggests that a smaller SSC spatial unit may provide an improved understanding of accessibility, although as previously discussed, the results could be influenced by the Modifiable Areal Unit Problem. The ASD results of 86.6% with barriers, when evaluated against the criteria for walkable neighbourhoods (DPTI 2017a) exceed the 77% target. The '30-year plan' defined open space greater than 4000m^2 to be within 400m, which would influence the number of open space and the percentage of dwellings with access. If the open space 4000m^2 criteria were to be applied to the VPOS2016 dataset, it would exclude 1,574 smaller POS or 43% of the dataset, and significantly decrease the number of dwellings within 400 m to a POS; this provides an opportunity for further research.

Forsyth and Musacchio (2005) reported that the recognition and inclusion of small parks were is essential in urban environments because they were are more likely to be closer to people's homes and provide areas for socialisation and relaxation. As shown in Figure 7-8 and Figure 7-9, many of the inner POAs and SSCs within the ASD in both the barrier and without barrier data were assessed as having up to 70% of dwelling with POS access, unlike POS supply distribution in the VPOS2016 data (Figure 6-11), which might be because of insufficient POS supply within these areas. Other issues in inner older residential suburbs are increased dwelling densities through infill of single dwelling lots with higher-density dwelling types (Coffee, Lange & Baker 2016), loss of private open space and often limited supply of open space within these areas (Sivam, Karuppannan & Mobbs 2012).

An analysis of dwelling density in relation to the percentage of access (with barriers) and an open space supply metric highlighted the implications of increased densification. To address the skewness towards low densities within the dwelling density data, a log 10 was applied to the data. Figure 7-10 plots the log^{10} of the POS area (ha) per 1,000 population versus log^{10} dwelling density, which shows that increased dwelling densities could result in a decreased supply of POS within certain SSCs. The dotted line (0.48) represents the value of 3 ha of POS per 1,000 population and is thus an approximation of the mandated 12.5% open space supply standard in South Australia (City of Charles Sturt Council 2011). For example, Kent Town has a residential density of 49 dwellings per hectare and 0.08 ha of open space per

1000 population and has been highlighted in Figure 7-10. Kent Town was also discussed in Chapter 2: (Figure 2-3) as an older inner metropolitan suburb with mixed land uses and experiencing urban renewal. The western edge of the suburb is close to the Adelaide Parklands; however, an arterial road potentially restricts access to this open space.

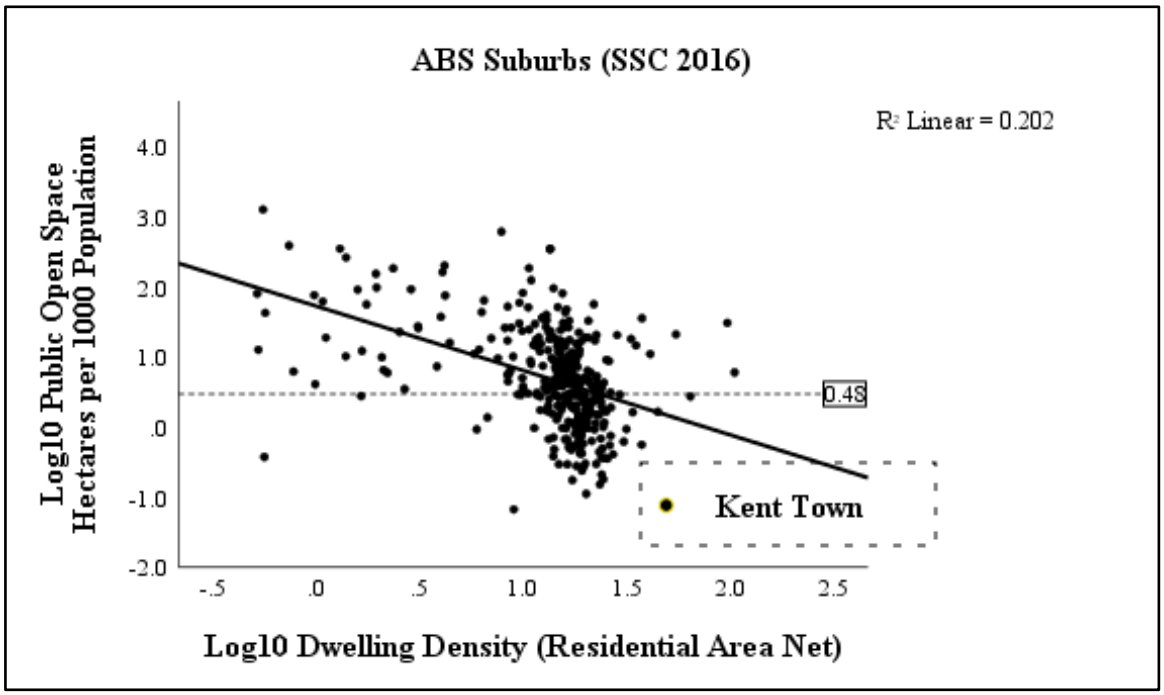


Figure 7-10: Log10 / Log scatter plot of POS area per 1,000 persons *v*. residential dwelling density.

Figure 7-11 plots the $\log^{10}$ percentage POS access against $\log^{10}$ dwelling density and shows that the majority of residential areas are classified as low density: 17–33 dwellings per hectare (net) (DPLG 2011), which is denoted as the area between the vertical lines at 1.2 and 1.5. An outer metropolitan suburb experiencing residential infill, Seaford Heights has currently a residential density of 23 dwellings per hectare and 10.3% access to a POS at 400 m;thus if a higher density development occurs without a provision of quality POS, the issue of access to POS could be exacerbated.

The 30-year plan requires that 85% of all new housing is to be constructed within existing urban neighbourhoods inside the defined urban boundary to prevent further urban sprawl and incursion onto primary production land and naturalised areas (DPTI 2017a). Therefore, as dwelling densities and subsequently population increases, there could be a shortfall in open space supply and levels of access unless additional quality POS suitable for passive and active recreation are implemented within residential areas with identified shortfalls.

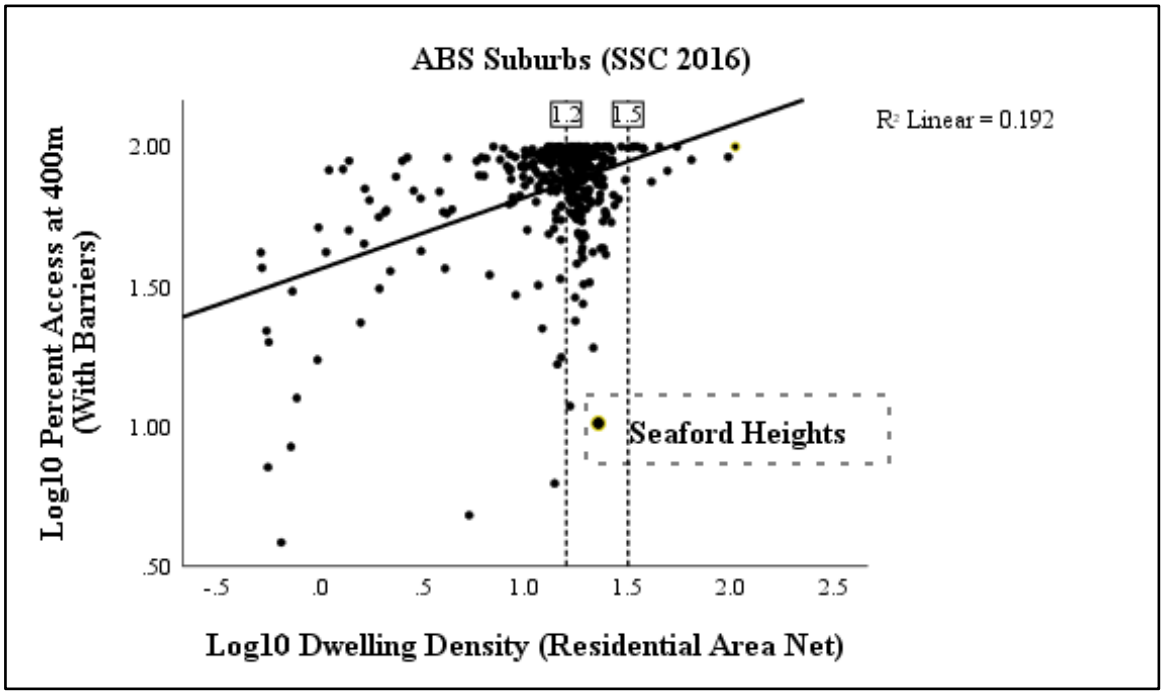


Figure 7-11: Log10 scatter plot representing percentage access at 400 m to POS *v*. residential dwelling density.

The application of an arbitrary distance-to-POS thresholds does not take into consideration the fact that a person may actively seek to travel further or less far to reach a POS. For example, factors in choosing a particular open space can include the level of amenities (Hitchings 2013), the perceived security within the neighbourhood (Loukaitou-Sideris 2006) and route selection based on multiple road intersections or gradients (Forsyth et al. 2008).

A limitation of street networks datasets is that there may be no delineation between how streets and footpaths are represented, where the street is presented as centralised line, which may bias a distance calculation as people can often walk alongside an arterial road. The inclusion of more footpaths in network data would be beneficial when it comes to the analysis of travel by foot rather than a motor vehicle, plus the inclusion of additional data including representations of pedestrian crossing points to allow for the option to navigate barriers, for example, freeways and arterial roads.

Chapter 8: Public Open Space Supply and Associations with Population Health.

The inclusion of open space within the urban environment is increasingly a focus of policymakers, in part, with the intent of promoting population health. Although the literature is divided about whether there are associations between open spaces and population health. Studies have reported that people who reside in areas with more open space, in particular, 'green spaces' including private gardens and views of vegetation, have better health outcomes than those residing in neighbourhoods with limited open space (Bowler et al. 2010b; Frumkin 2003; Gascon et al. 2015; Hartig et al. 2014; Twohig-Bennett & Jones 2018; van den Berg et al. 2015). However, several studies have not detected any association between open space supply and health (Björk et al. 2008; Dunstan et al. 2013; Richardson & Mitchell 2010; Van Herzele & de Vries 2012).

Many of the studies have investigated associations between open space and self-rated health factors and several reported positive associations (Agyemang et al. 2007; Carter & Horwitz 2014; de Vries et al. 2003; Maas et al. 2006; Mitchell & Popham 2007; Orban et al. 2017; van Dillen et al. 2012). Self-rated health surveys developed as multi-item scale questions are generally reliable if designed appropriately and meet psychometric standards.

The associations between open space and health outcomes are inconsistent, which may be because of differences in the health data sample size, open space definition, socio-demographic variables and the size of the selected study area.

8.1 Research questions.

The overarching research objective for this part of the study was to establish whether there are associations between self-rated health outcomes and public open space (POS) supply across metropolitan Adelaide. This was investigated via the following research questions:

1) are POS area and count associated with self-rated health outcomes and does this differ by spatial unit?
2) is accessibility to POS associated with self-rated health?
3) is dwelling density associated with self-rated health? and,
4) are socio-demographic characteristics associated with self-rated health?

8.2 Methods.

8.2.1 Study population dependent variable.

The dependent variable for this study was the Short Form 1 (SF1) self-rated health (Section 3.3.2 and 4.6.4) (Avery et al. 2006). Human ethics approval was granted from SA Health to utilise the South Australian Monitoring and Surveillance System (SAMSS) dataset (Appendix 2). The data selected for this study were responses to the self-rated SF1 question collected between January 2014 and December 2016, when 13,616 persons between the ages of 16 and 100 years were surveyed (SA Health 2016b). To ensure no areas were missed, data were extracted for both Australian Bureau of Statistics (ABS) postcodes (POA) and suburbs (SSC) spatial units to include persons residing within and adjacent to the metropolitan Adelaide study area (n = 13,616 persons). Data cleaning removed persons identified as outside the ASD (n = 724), and for POAs and SSCs with fewer than two respondents and zero residential dwellings (POA, n = 7; SSC, n = 34). The Likert scale; poor (1) to excellent (5) count of the final self-rated health sample (n = 12,892) are presented in Table 8-1.

Table 8-1: SAMSS self-rated health SF1 responses (n=12,892).

(*n* = 12,892)			SF1 'Would you say your health is…?'					Total
			Poor	Fair	Good	Very good	Excellent	
Gender	Male	Count	319	786	1,561	1,684	716	5,066
		% of total	2.5%	6.1%	12.1%	13.1%	5.6%	39.3%
	Female	Count	457	1,193	2,346	2,599	1,231	7,826
		% of total	3.5%	9.3%	18.2%	20.2%	9.5%	60.7%
Total		Count	776	1979	3,907	4,283	1947	12,892
		% of total	6.0%	15.4%	30.3%	33.2%	15.1%	100.0%

Data source: (SA Health 2016a).

The distribution characteristics by gender (male and female) and age (16–100 years) are presented in Figure 8-1.



Figure 8-1: Self rated health distribution of age by gender
Data source: (SA Health 2016a).

Figure 8-2 illustrates the SF1 respondent count (Jenks Natural Break) within POAs and SSCs.

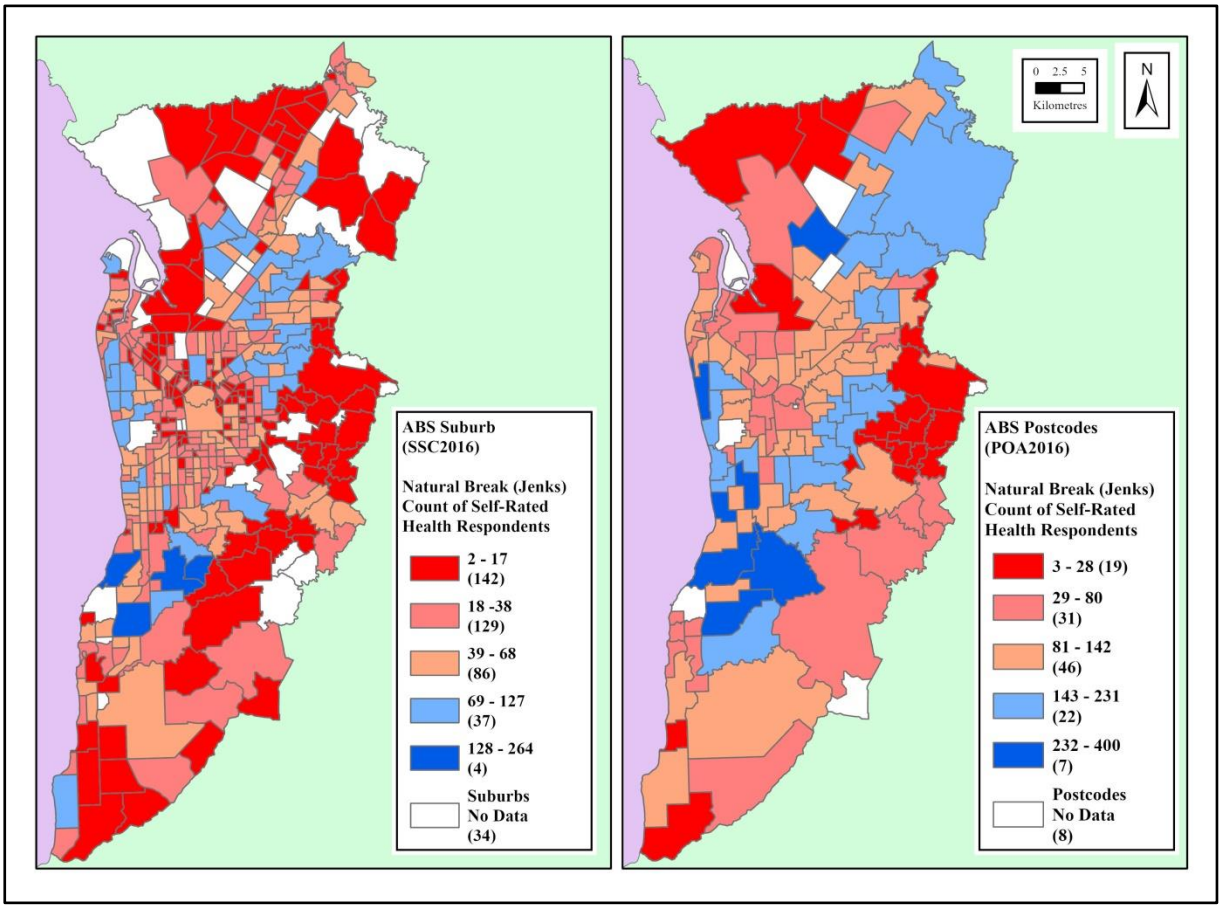


Figure 8-2: SAMSS self-rated health, SF1 response count by SSC (left) and POA (right).
Data source: (SA Health 2016a).

8.3 Independent variables.

8.3.1 Public open space supply and access metrics.

The POS supply metrics for the statistical analysis were calculated from the VPOS2016 dataset for two spatial units, POA and SSC. POS supply was determined by count and area (ha) for three metrics:

1) clip, where only POS within a spatial unit is extracted; any POS outside the spatial boundary was removed;
2) intersect, which includes individual POS within and those intersecting and abutting with the spatial boundary; and
3) a 500 m external buffer around the POA & SSC spatial unit intersected with the POS.

The latter two POS supply metrics were calculated to acknowledge a limitation with administrative spatial boundaries where persons might utilise their nearest POS, which could be in an adjacent POA or SSC area. An additional metric, the percentage of dwelling points with access (without barriers) to a POS within 400 m, was selected to identify if access was associated with better health outcomes. The street network access without barriers data were selected instead of the with barriers data because there was a small percentage difference between the two metrics. Also, when attempting to duplicate the analysis in another location, access to data representing potential barriers might be unsuitable or unavailable.

8.3.2 Dwelling density.

The influence of rapid urbanisation has been linked to population health issues, including mental health (Peen et al. (2010), heat stress and respiratory disease (Giles-Corti et al. 2016b; Godfrey & Julien 2005). Although, increased dwelling densities have been considered a contributing factor to improved health outcomes, in that higher densities might improve urban walkability to connect with services and amenities, which may reduce obesity, type II diabetes and cardiovascular disease (Foster, Giles-Corti & Ryan 2012; Giles-Corti et al. 2016a; Haigh, Ng Chok & Harris 2011). Dwelling count and area of lots were calculated from the 2016 dwelling point dataset (DPTI 2016b). Dwelling density was calculated as the total residential parcel area as hectares within POAs and SSCs divided by the number of dwellings. Figure 8-3 illustrates the dominance of lower densities within the metropolitan area. Which could imply properties may have larger private spaces (gardens), thereby compensating for the absence of POS. Nonetheless, many of these older residential areas are experiencing densification, with an existing lot subdivided into two or more lots, consequently private open space is significantly reduced. As an outcome of residential densification existing open space may become over utilised and degraded (Arberger 2012), or there will there be insufficient open space supply to meet increased demand (Sivam, Karuppannan & Mobbs 2012). Currently, within the study area, residential areas with medium to high densities account for just 2 POAs and 10 SSCs (Figure 8-3).

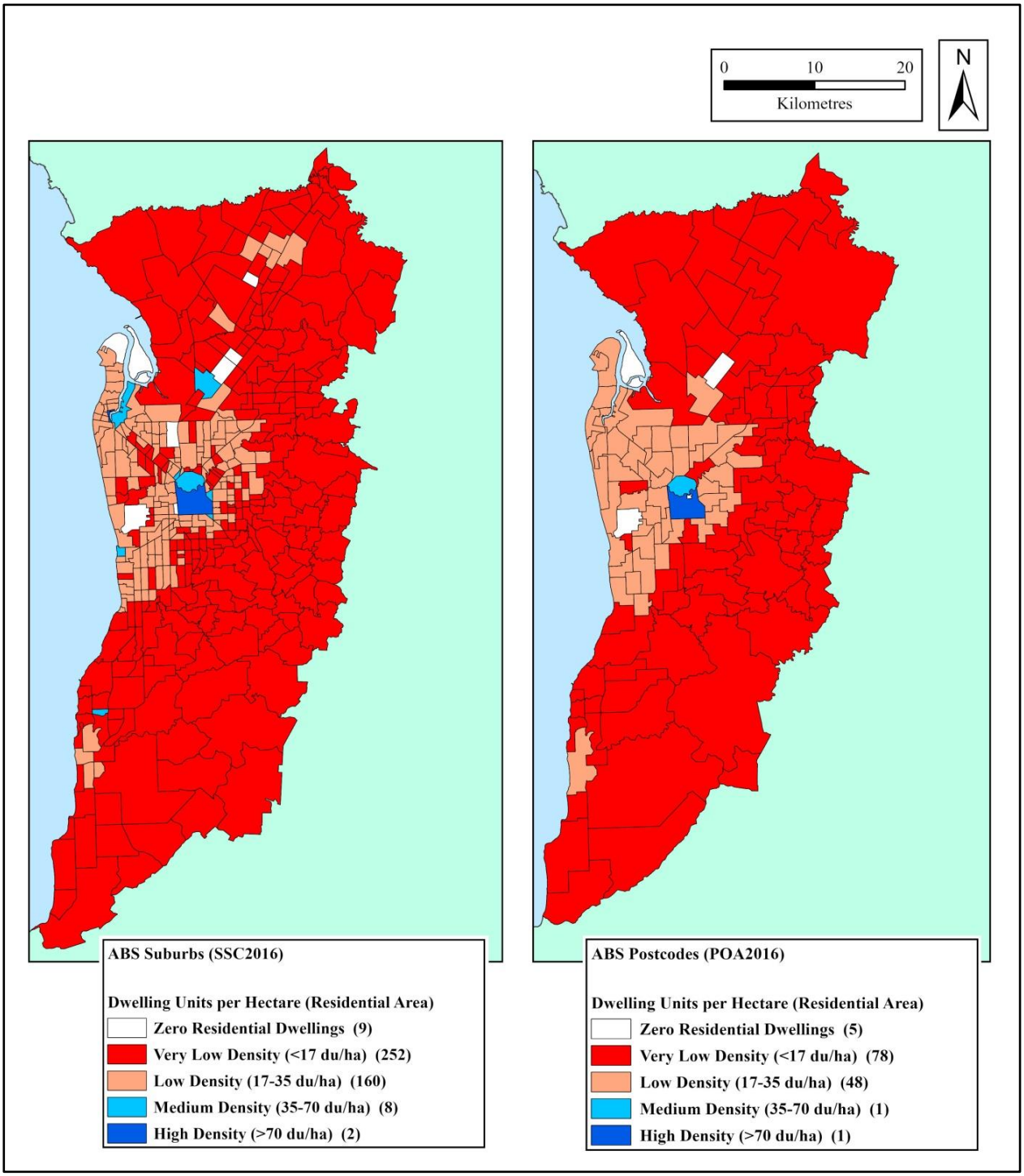


Figure 8-3: Net Dwelling density by SSC (left) and POA (right).
Data source: (DPTI 2016b).

8.3.3 Socio-demographic characteristics.

The ABS Socio-Economic Indexes for Areas (SEIFA) from the 2016 population census collection were used in this research to represent area-level social and economic data (ABS 2016b). Within the SEIFA, there are four indices; however, for this analysis, the Index

of Relative Socio-economic Advantage and Disadvantage (IRSAD) was applied because it provided an indicator of both advantage and disadvantage. The IRSAD data are presented as a decile score where a higher decile implies a greater level of advantage (see Figure 4-6).

8.4 Statistical analysis.

Different statistical methods were investigated to determine whether there are associations between POS count and area and self-rated health outcomes. For the statistical analysis, SPSS Statistics 25 for Windows software was utilised (IBM 2018). Data analyses were undertaken in three steps, starting with a preliminary analysis of the independent variables through the application of histograms. The histograms (Figure 8-4 and Figure 8-5). established that the independent variables did not fit a normal distribution.

Secondly, a bivariate correlation to identify the strength and direction of the linear relationships between the two variables (nonparametric) through a Spearman's correlation two-tailed test. (Field 2015). The values lie between–1.0 and +1.0, and the sign represents the direction of the relationship. A positive correlation indicates that two variables increase or decrease together, while a negative sign indicates an inverse relationship. A 0.0 value indicates no relationship, whereas values of 0.10–0.29, 0.30–0.49 and 0.50–1.0 indicate weak, medium-strength or strong relationships (Pallant 2007).

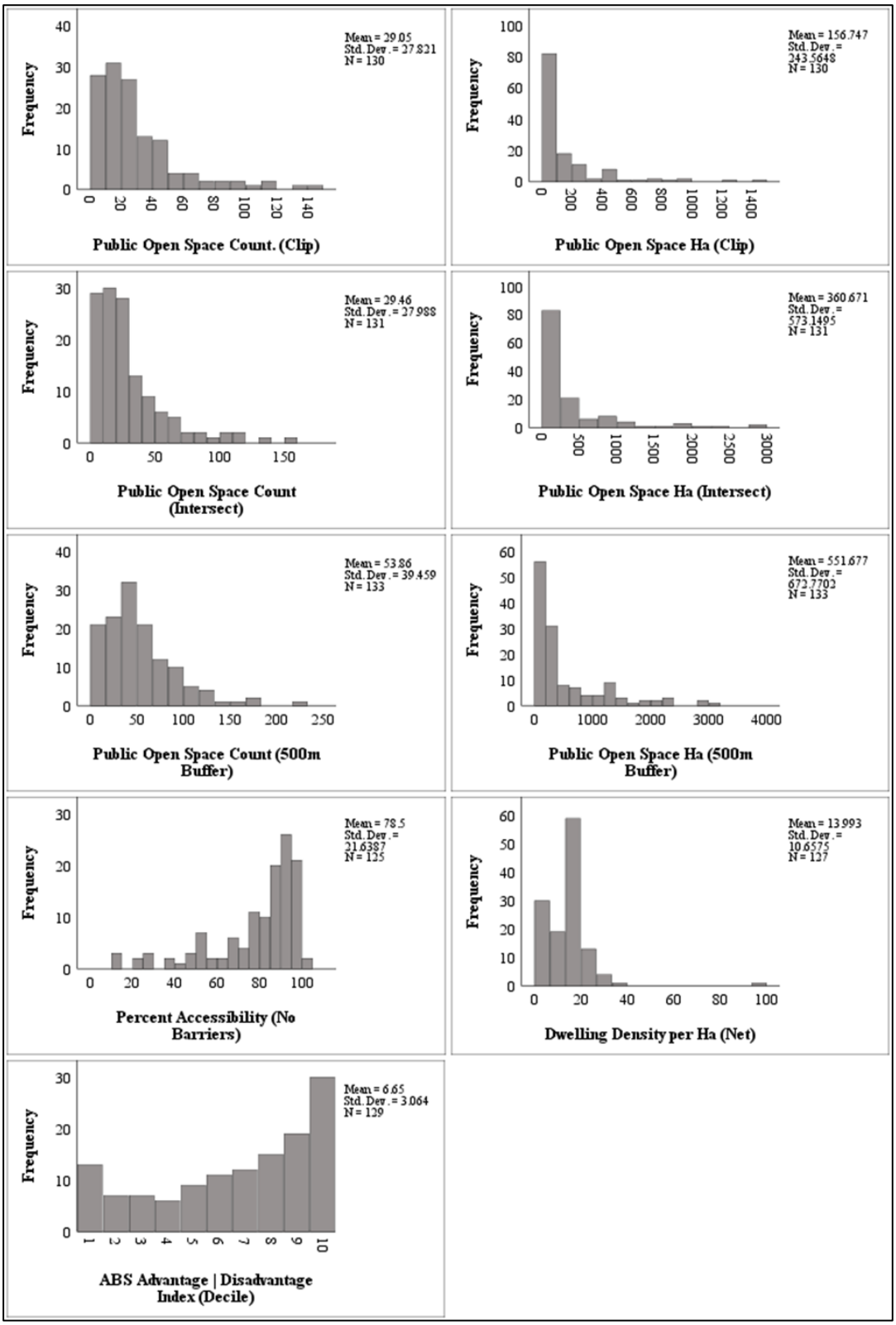


Figure 8-4: Histograms of independent variables (data nested at POAs).

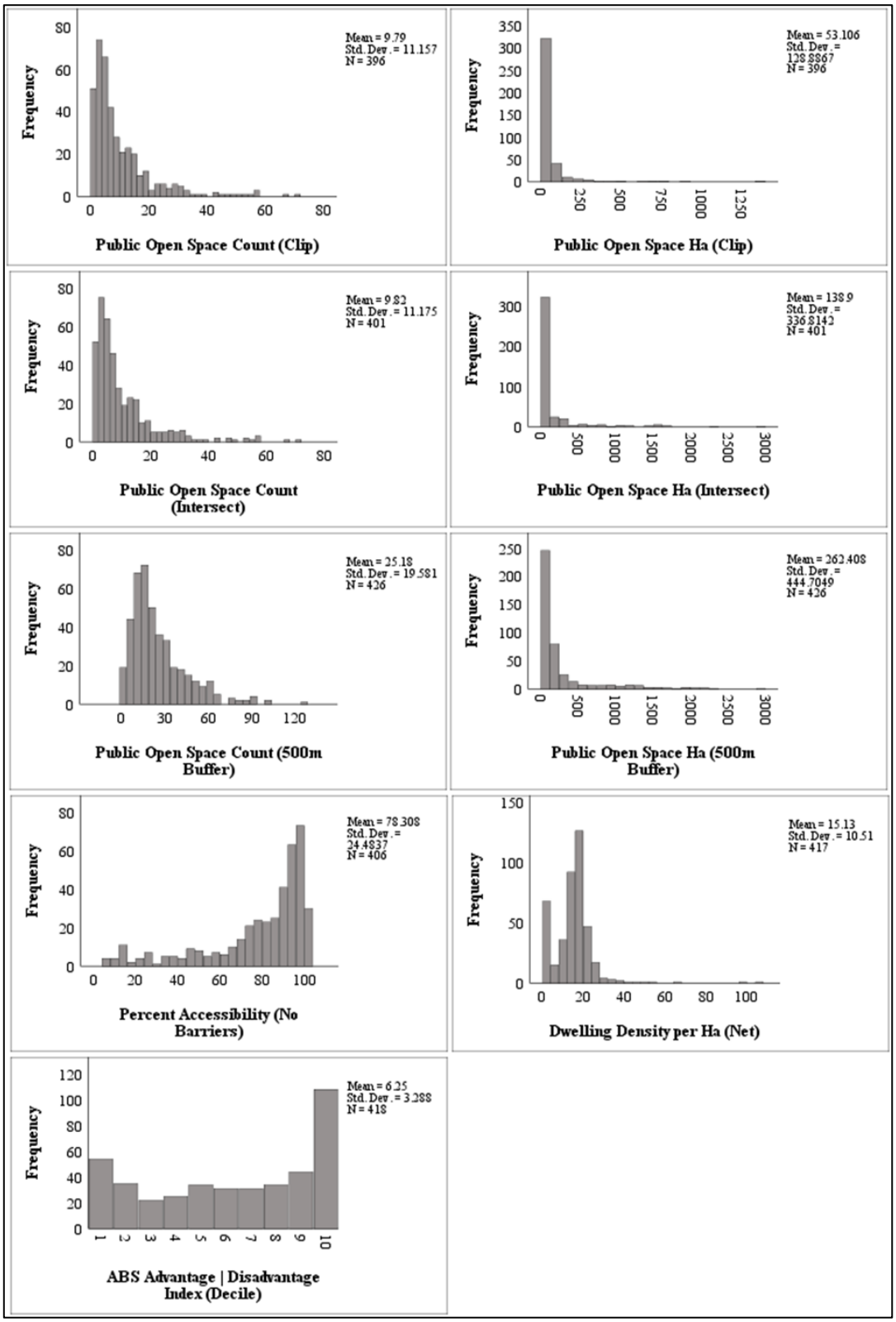


Figure 8-5: Histograms of independent variables (data nested at SSCs).

Table 8-2: Spearman's correlation matrix tested for self-rated health and independent variables for POAs (Independent level).

Spearman's rho ABS Postcodes (POA 2016 n=134)	SF1 "Would you say your health is" (n=12,892)	Gender (Male)	Age (16-100)	POS Count. (Clip)	POS Ha (Clip)	POS Count (Intersect)	POS Ha (Intersect)	POS Count (500m Buffer)	POS Ha (500m Buffer)	Accessibility (Without Barriers)	Dwelling Density (net)	ABS SEIFA (IRSAD) (Decile)
SF1 "Would you say your health is"	1.00											
Gender (Male)	.02*	1.00										
Age (16-100)	-.19**	.04**	1.00									
POS Count. (Clip)	-.05**	-0.01	-.06**	1.00								
POS Ha (Clip)	0.00	-0.02	-.07**	.73**	1.00							
POS Count (Intersect)	-.05**	-0.01	-.06**	1.00**	.72**	1.00						
POS Ha (Intersect)	0.01	-0.02	-.06**	.65**	.90**	.64**	1.00					
POS Count (500m Buffer)	-.06**	-0.01	-.06**	.94**	.61**	.94**	.53**	1.00				
POS Ha (500m Buffer)	.03**	-0.02	-.06**	.59**	.80**	.59**	.88**	.53**	1.00			
Accessibility (without barriers)	-.04**	-0.01	-.03**	.65**	.47**	.66**	.39**	.65**	.35**	1.00		
Dwelling Density (net)	-.04**	.02*	.05**	-.26**	-.59**	-.26**	-.64**	-.15**	-.63**	-0.01	1.00	
ABS SEIFA (IRSAD) (Decile)	.15**	0.00	.05**	-.33**	-.12**	-.32**	-0.01	-.36**	.09**	-.31**	-.09**	1.00

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 8-3: Spearman's correlation matrix tested for self-rated health and independent variables for SSCs (Independent level).

Spearman's rho ABS Suburbs (SSC 2016 n=431)	SF1 "Would you say your health is" (n=12,892)	Gender (Male)	Age (16-100)	POS Count. (Clip)	POS Ha (Clip)	POS Count (Intersect)	POS Ha (Intersect)	POS Count (500m Buffer)	POS Ha (500m Buffer)	Accessibility (Without Barriers)	Dwelling Density (net)	ABS SEIFA (IRSAD) (Decile)
SF1 "Would you say your health is"	1.00											
Gender (Male)	.02*	1.00										
Age (16-100)	-.19**	.04**	1.00									
POS Count. (Clip)	-.04**	-0.01	-.06**	1.00								
POS Ha (Clip)	-.04**	-0.01	-.06**	1.00**	1.00							
POS Count (Intersect)	-.05**	-0.01	-.04**	.92**	.92**	1.00						
POS Ha (Intersect)	0.00	-.03**	-.06**	.76**	.76**	.69**	1.00					
POS Count (500m Buffer)	0.01	-.02*	-.04**	.67**	.68**	.60**	.92**	1.00				
POS Ha (500m Buffer)	.02*	-.02**	-.04**	.63**	.63**	.63**	.76**	.80**	1.00			
Accessibility (without barriers)	-.04**	-0.01	-.03**	.52**	.52**	.51**	.36**	.30**	.28**	1.00		
Dwelling Density (net)	-.05**	.02*	.03**	-.16**	-.16**	-.09**	-.39**	-.43**	-.46**	.11**	1.00	
ABS SEIFA (IRSAD) (Decile)	.16**	0.00	0.02	-.23**	-.23**	-.29**	-.11**	-.03**	.04**	-.16**	-.22**	1.00

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

In both matrices (Table 8-2 and Table 8-3), the SF1 x SF1 = 1.00 (perfect correlation) and this is repeated for each cell in the matrix where the row/column correspond. There were no correlations between SF1 and the POS measures; all the correlation values were below 0.1 (POS clip, intersect and 500 m buffer ranged from 0.01 to 0.06; and accessibility with barriers was -0.04 for both POA and SSC). Dwelling density was not correlated with SF1 (-0.04 and -0.05). The ABS SEIFA (IRSAD), presented a weak correlation with the SF1 score (0.1) for respondents residing in both POA and SSC. There were significant weak to moderate correlations between SEIFA and the POS counts.

The final analysis phase employed a multi-level ordinal logistic regression Generalized Linear Models (GLM) and PLUM (Polytomous Universal Model) syntax, to determine whether the independent variables might predict self-rated health outcomes when applied to POAs and SSCs. With each variable to be independently analysed, variables listed in Table 8-4. The individual values (SF1, age and gender) were nested within POA and SSC.

Table 8-4: Independent variables

Gender (Male)
Age (16-100)
POS Count. (Clip)
POS Ha (Clip)
POS Count (Intersect)
POS Ha (Intersect)
POS Count (500m Buffer)
POS Ha (500m Buffer)
Accessibility (without barriers)
Dwelling density (net)
ABS SEIFA (IRSAD) (Decile)

For an ordinal linear regression to be valid, four assumptions must be met (Laerd Statistics 2015).

1) the dependent variable is measured at the ordinal level (for example, data represented as a Likert scale);
2) one or more independent variables are continuous or categorical. For example, a continuous variable may be a POS metric and a categorical variable, gender;
3) there is no multicollinearity, which occurs when two or more independent variables are highly correlated. This can lead to issues in identifying which independent variable is influencing the dependent SF1 variable; Multicollinearity to be tested through a linear regression with the SF1 dependent variable and all independent variables inputted, and statistical analysis for collinearity diagnostics; and
4) the proportional odds requirement must be met, as shown by the chi-square value, which must be small and not statistically significant ($p > 0.05$). Each independent variable must have a similar effect for each cumulative logit. However, large samples can result in statistically significant results even when the factors are not very different, in which case the proportional odds are not met. This is addressed by dichotomising the ordinal dependent SF1 variable (Table 8-5)

Table 8-5: Dependent variable (SF1) dichotomised.

	Poor	Fair	Good	Very good	Excellent
Poor	1	0	0	0	0
Fair	0	1	0	0	0
Good	0	0	1	0	0
Very good	0	0	0	1	0
Excellent	0	0	0	0	1

and then running a separate binomial logistic regression for each of the dichotomised variables and the independent variables (Table 8-4). Provided that the dichotomous variables present no significant differences between the odds ratio (OR), then the assumption of proportional odds are met.

8.4.1 Ordinal logistic regression test of assumptions.

The first two assumptions for an ordinal linear regression were confirmed; the dependent variable (SF1 self-rated health) was ordinal, and the independent variables were predominately continuous with one being categorical (gender). Multicollinearity was evident, indicated by the variance inflation factor (VIF) between the POS variables at both POA and SSC area levels (Table 8-6). Where the VIF is equal to 1, there is no multicollinearity between the variables, greater than 1 they may be moderately correlated. However, a VIF between 5 and 10 indicates a high correlation which could be problematic. To address, any highly correlated variables should be removed from the modelling (Akinwande, Dikko & Samson 2015). The POS variable with the least multicollinearity was the POS ha (500m buffer) with a VIF =2.30 (SSC).

Table 8-6: Linear regression multicollinearity analysis of independent variables.

Collinearity statistics	**ABS POA**		**ABS SSC**	
	Tolerance	VIF	Tolerance	VIF
Gender (Male)	1.00	1.00	1.00	1.00
Age (16-100)	0.99	1.01	0.99	1.01
POS Count. (Clip)	0.00	1178.98	0.00	1331.24
POS Ha (Clip)	0.23	4.36	0.00	1387.73
POS Count (Intersect)	0.00	1224.30	0.10	9.58
POS Ha (Intersect)	0.13	7.70	0.42	2.39
POS Count (500m Buffer)	0.07	14.45	0.32	3.08
POS Ha (500m Buffer)	0.19	5.21	0.44	2.30
Accessibility (without barriers)	0.62	1.60	0.75	1.33
Dwelling density (net)	0.77	1.29	0.84	1.19
ABS SEIFA (IRSAD) (Decile)	0.76	1.32	0.81	1.23

a. Dependent variable, SF1; 'Would you say your health is…?'
b. VIF; variance inflation factor

As the SF1 sample was large (n=12982), a binary logistic regression was applied to the dichotomised dependent variables to test whether the proportional odds were meet. An examination of the Exp (B) odds ratios in Table 8-7 and Table 8-8 indicated no significant differences between the dichotomised dependent variables, which confirmed the proportional odds assumptions were met.

Table 8-7: Proportional odds analysis of independent variables at the POA level.

ABS Postcodes (POA 2016)	B (parameter estimate)					Exp (B) odds ratio, (OR)				
	Excellent (5)	Very good (4)	Good (3)	Fair (2)	Poor (1)	Excellent (5)	Very good (4)	Good (3)	Fair (2)	Poor (1)
Gender (Male)	-0.16	-0.02	0.05	0.05	0.12	0.852	0.978	1.056	1.049	1.123
Age (16-100)	-0.02	-0.01	0.00	0.02	0.03	0.983	0.988	1.005	1.024	1.028
POS Count. (Clip)	0.00	0.02	-0.02	-0.01	-0.01	1.000	1.018	0.984	0.993	0.988
POS Ha (Clip)	0.00	0.00	0.00	0.00	0.00	1.000	1.000	1.000	1.000	1.000
POS Count (Intersect)	0.00	-0.02	0.01	0.01	0.01	1.003	0.984	1.014	1.005	1.014
POS Ha (Intersect)	0.00	0.00	0.00	0.00	0.00	1.000	1.000	1.000	1.000	1.000
POS Count (500m Buffer)	0.00	0.00	0.00	0.00	0.00	0.996	0.998	1.003	1.003	0.999
POS Ha (500m Buffer)	0.00	0.00	0.00	0.00	0.00	1.000	1.000	1.000	1.000	1.000
Accessibility (without barriers)	0.00	0.00	0.00	0.00	0.00	1.001	1.002	1.001	0.997	1.000
Dwelling density (net)	0.00	0.00	0.00	0.00	0.00	1.001	0.997	1.002	0.998	1.005
ABS SEIFA (IRSAD) (Decile)	0.09	0.04	-0.02	-0.09	-0.09	1.097	1.044	0.981	0.917	0.918
Constant	-1.2	-0.27	-1.25	-2.51	-4.09					

Table 8-8: Proportional odds analysis of independent variables at the SSC level.

ABS Suburbs (SSC 2016)	B (parameter estimate)					Exp (B) odds ratio, (OR)				
	Excellent (5)	Very good (4)	Good (3)	Fair (2)	Poor (1)	Excellent (5)	Very good (4)	Good (3)	Fair (2)	Poor (1)
Gender (Male)	-0.16	-0.02	0.05	0.05	0.13	0.851	0.981	1.053	1.051	1.135
Age (16-100)	-0.02	-0.01	0.00	0.02	0.03	0.984	0.988	1.005	1.023	1.027
POS Count. (Clip)	-0.06	0.04	0.02	0.01	-0.11	0.939	1.042	1.020	1.009	0.893
POS Ha (Clip)	0.06	-0.04	-0.02	-0.01	0.12	1.063	0.962	0.980	0.988	1.127
POS Count (Intersect)	0.00	0.00	0.00	0.00	-0.01	1.001	0.998	1.001	1.004	0.994
POS Ha (Intersect)	0.00	0.00	0.00	0.00	0.00	1.000	1.000	1.000	1.000	1.001
POS Count (500m Buffer)	0.00	0.00	0.00	0.00	0.00	1.000	1.000	1.000	1.000	1.000
POS Ha (500m Buffer)	0.00	0.00	0.00	0.00	0.00	1.000	1.000	1.000	1.000	1.000
Accessibility (without barriers)	0.00	0.00	0.00	0.00	0.00	0.995	1.001	1.003	0.999	1.002
Dwelling density (net)	0.00	0.00	0.00	0.00	0.00	1.001	0.998	1.003	0.996	1.004
ABS SEIFA (IRSAD) (Decile)	0.09	0.05	-0.02	-0.08	-0.11	1.097	1.047	0.978	0.925	0.896
Constant	-0.88	-0.27	-1.35	-2.64	-4.02					

The four assumptions for an ordinal linear regression to be valid were met. A review of the SF1 within the Spearman's correlation tables (Table 8-2 and Table 8-3) identified the

POS ha (500 m buffer) with the highest value even though not correlated (0.03 and 0.02) for both POA and SSC. This POS metric additionally acknowledges persons adjacent to either spatial unit boundary (POA or SSC) who may utilise the nearest POS, which might be in an adjoining postcode or suburb area. Therefore, the multi-level ordinal regression was only applied to this POS metric.

8.5 Ordinal Regression Analyses and Results.

Six model sets for both POA and SSC were run to investigate whether POS ha (500 m buffer) was associated with a higher SF1 score, and to determine the influence of control variables: age in single years, gender (male), access without barriers dwelling density and ABS SEIFA (IRSAD).

8.5.1 Analyses at the postcode level.

A cumulative odds ordinal logistic regression with proportional odds was run to determine the effects of the SF1 on the hypothesis that a greater total area of POS improved self-rated health outcomes. The best fit within the POA group of models was reported for Model 6, which had the highest R-squared value (r = 0.065) and lowest AIC (29,921.77) and BIC (29,921.77) across the six models (Table 8-9). Further, the deviance goodness-of-fit test revealed that Model 6 was a good fit to the observed data $\chi^2(39{,}666) = 30{,}608.85$, although many cells had zero frequencies (70.7% of cells). The likelihood ratio test to assess model fit reported that Model 6 statistically predicted the dependent variable over and above the intercept model $\chi^2(6) = 850.254$ (p = 0.001).

In models 1 to 6, which systematically applied each variable to identify if an increased area of POS was not associated with an increase in the odds of a respondent considering their health was excellent, (odds ratio =1.000; 95% CI, 1.000–1.000; Wald $\chi^2(1) = 16.934$, p = 0.000).

In model 4, higher percentage access to any POS was not associated with an increase in the odds of a respondent considering their health was excellent (odds ratio 0.992; 95% CI, 0.990–0.995; Wald $\chi^2(4) = 37.118$, p = 0.000). Whereas, residing in POAs with higher dwelling densities was very weakly associated but not significant with an increase in the odds of a respondent considering their health was excellent (odds ratio =1.003; 95% CI, 0.998–

1.003; Wald $\chi^2(5) = 1.505$, $p = 0.22$). Areas with higher IRSAD decile scores had significant associations in terms of the odds of residents reporting better health outcomes (odds ratio =1.100; 95% CI, 1.088–1.112; Wald $\chi^2(6) = 276.415$, $p = 0.001$) (Table 8-10).

Table 8-9: Model fit at POA level determined by pseudo-R-Squared Nagelkerke, AIC and BIC.

SF1 "Would you say your health is"	Pseudo R-Square Nagelkerke	Akaike's Information Criterion (AIC)	Bayesian Information Criterion (BIC)
Model 1	0.001	30,713.55	30,750.90
Model 2	0.002	30,710.62	30,755.44
Model 3	0.040	30,231.16	30,283.45
Model 4	0.043	30,195.94	30,255.70
Model 5	0.043	30,196.44	30,263.67
Model 6	0.065	29,921.77	29,921.77

Dependent Variable: SF1 "Would you say your health is" Model: (Threshold), POS Ha (500m Buffer), Gender (Male), Age (16-100), Percent Access (No Barriers), Dwg Density (Net), ABS SEIFA (IRSAD)

a. Information criteria are in smaller-is-better form.

Table 8-10: Ordinal logistic regression of self-rated health variable, POS ha (500 m buffer) and independent variables to determine any significance; at POA level.

ABS Postcodes (POA 2016)		POS Ha (500m Buffer)			95% Wald CI Exp(B)		Gender (male)			95% Wald CI Exp(B)		Age (16-100 yrs)			95% Wald CI Exp(B)		Accessibility (without barriers)			95% Wald CI Exp(B)		Dwelling density (net)			95% Wald CI Exp(B)		ABS SEIFA (IRSAD) (Decile)			95% Wald CI Exp(B)	
		β	Sig. ρ	Exp (B)	Lower	Upper	β	Sig. ρ	Exp (B)	Lower	Upper	β	Sig. ρ	Exp (B)	Lower	Upper	β	Sig. ρ	Exp (B)	Lower	Upper	β	Sig. ρ	Exp (B)	Lower	Upper	β	Sig. ρ	Exp (B)	Lower	Upper
Model 1	Dependent Variable: SF1 "Would you say your health is"	0.000	0.000	1.000	1.000	1.000																									
Model 2		0.000	0.000	1.000	1.000	1.000	-0.072	0.026	0.931	0.874	0.992																				
Model 3		0.000	0.003	1.000	1.000	1.000	-0.110	0.001	0.896	0.841	0.955	-0.020	0.000	0.981	0.979	0.982															
Model 4		0.000	0.002	1.000	1.000	1.000	-0.110	0.001	0.896	0.841	0.955	-0.020	0.000	0.981	0.979	0.982	-0.008	0.000	0.992	0.990	0.995										
Model 5		0.000	0.001	1.000	1.000	1.000	-0.109	0.001	0.896	0.841	0.955	-0.020	0.000	0.981	0.979	0.982	-0.008	0.000	0.992	0.990	0.995	0.003	0.220	1.003	0.998	1.007					
Model 6		0.000	0.332	1.000	1.000	1.000	-0.112	0.001	0.894	0.839	0.9527	-0.021	0.000	0.979	0.978	0.9813	-0.001	0.461	0.999	0.996	1.0016	-0.001	0.516	0.999	0.994	1.003	0.095	0.000	1.100	1.088	1.112

8.5.2 Analyses at the suburb level.

Model 7 to 12 the variables were applied as described for ABS Postcodes in Section 8.5.1. The best fit (but still no association) within the SSC group of models was reported for Model 12, which had the highest R-squared value (r = 0.068) and lowest AIC (33,524.17) and BIC (33,598.77) across the six models (Table 8-11). Further, the deviance goodness-of-fit test revealed that Model 12 was a good fit to the observed data $\chi^2(29{,}386) = 24{,}522$, although many cells had zero frequencies (76% of cells). The likelihood ratio test to assess model fit reported that Model 12 statistically predicted the dependent variable over and above the intercept model $\chi^2(6) = 818.796$ ($p = 0.001$).

Models 7 to 12, an increased area of POS was not associated with an increase in the odds of a respondent considering their health was excellent, (odds ratio =1.000; 95% CI, 1.000–1.000; Wald $\chi^2(1) = 18.042$, $p = 0.000$).

In model 10, a higher percentage of access to any POS was not associated with an increase in the odds of a respondent considering their health was excellent (odds ratio = 0.994; 95% CI, 0.992–0.996; Wald $\chi^2(4) = 37.724$, $p = 0.000$). Residing in SCCs with higher dwelling densities was not associated with an increase in the odds of a respondent considering their health was excellent (odds ratio = 0.994; 95% CI, 0.992–0.996; Wald $\chi^2(5) = 0.012$, $p = 0.914$). Areas with higher IRSAD decile scores had weak associations of the odds of residents reporting better health outcomes (odds ratio = 1.097; 95% CI, 1.085–1.108; Wald $\chi^2(6) = 303.016$, $p = 0.001$) (Table 8-12).

Table 8-11: Model fit at SSC level determined by pseudo-R-Squared Nagelkerke, AIC and BIC

SF1 "Would you say your health is"	Pseudo R-Square Nagelkerke	Akaike's Information Criterion (AIC)	Bayesian Information Criterion (BIC)
Model 7	0.001	34346.26	34383.56
Model 8	0.002	34342.40	34387.16
Model 9	0.041	33859.81	33912.03
Model 10	0.044	33824.30	33883.98
Model 11	0.044	33826.29	33893.43
Model 12	0.068	33524.17	33598.77

Dependent Variable: SF1 "Would you say your health is"
Model: (Threshold), POS Ha (500m Buffer), Gender (Male), Age (16-100), Percent Access (No Barriers), Dwg Density (Net), ABS SEIFA (IRSAD)

a. Information criteria are in smaller-is-better form.

Table 8-12: Ordinal logistic regression of self-rated health variable, POS ha (500 m buffer) and independent variables to determine any significance; at SSC level

ABS Suburbs (SSC 2016)		POS Ha (500m Buffer)			95% Wald CI Exp(B)		Gender (male)			95% Wald CI Exp(B)		Age (16-100 yrs)			95% Wald CI Exp(B)		Accessibility (without barriers)			95% Wald CI Exp(B)		Dwelling density (net)			95% Wald CI Exp(B)		ABS SEIFA (IRSAD) (Decile)			95% Wald CI Exp(B)	
		β	Sig. ρ	Exp (B)	Lower	Upper	β	Sig. ρ	Exp (B)	Lower	Upper	β	Sig. ρ	Exp (B)	Lower	Upper	β	Sig. ρ	Exp (B)	Lower	Upper	β	Sig. ρ	Exp (B)	Lower	Upper	β	Sig. ρ	Exp (B)	Lower	Upper
Model 7	Dependent Variable: SF1 "Would you say your health is"	0.000	0.000	1.000	1.000	1.000																									
Model 8		0.000	0.000	1.000	1.000	1.000	0.016	0.016	0.924	0.867	0.985																				
Model 9		0.000	0.000	1.000	1.000	1.000	0.000	0.000	0.890	0.835	0.9488	-0.020	0.000	0.980	0.979	0.9822															
Model 10		0.000	0.000	1.000	1.000	1.000	-0.117	0.00	0.889	0.834	0.9481	-0.020	0.00	0.980	0.979	0.9822	-0.006	0.00	0.994	0.992	0.996										
Model 11		0.000	0.000	1.000	1.000	1.000	-0.117	0.000	0.889	0.834	0.948	-0.020	0.000	0.980	0.979	0.982	-0.006	0.000	0.994	0.992	0.996	0.000	0.914	1.000	0.996	1.004					
Model 12		0.000	0.648	1.000	1.000	1.000	-0.120	0.000	0.887	0.832	0.9452	-0.020	0.000	0.980	0.978	0.9817	-0.003	0.009	0.997	0.995	0.9993	0.000	0.857	1.000	0.996	1.003	0.092	0.000	1.097	1.085	1.108

8.6 Summary.

The analysis reported in this chapter was exploratory and aimed to recognise and build knowledge on whether persons with higher self-rated health scores were residing in areas with more POS (a higher count or area); alternatively, whether other factors were significant, such as access, dwelling density and socio-demographics. Jylhä et al. (1986) emphasised that self-rated health is a well-utilised indicator of health status.

The Spearman's correlation analysis (Table 8-2 and Table 8-3) reported that three POS supply metrics count and area were not correlated with SF1, which could be attributed to the considerable difference between POS land area and count within the two spatial units (POA and SSC). This could be attributed to the insufficient variation, and most POAs and SSC have a large count and area of POS. The socio-demographic variables; age and SEIFA deciles were weakly correlated with SF1 ($p = 0.01$). In their study on greenspace useability and SF1, Carter and Horwitz (2014) concluded that socio-demographic variables could exhibit a correlative effect. This was further supported when SF1 as the dependent variable was inputted into an ordinal logistic regression and modelled to examine the causal effects of the independent variables on the SF1.

The multi-level ordinal regression reported no statistical significance between the POS area (500 m buffer) and self-rated health (SF1). This could be attributed to multiple causes; the POS areas were high as per the frequency histograms (Figure 8-4 and Figure 8-5), also it could be linked to the modifiable areal unit problem and the aggregation of data within POA and SSC spatial units. Thereby in both scenarios, the actual population distribution is not identifiable as it could be either clustered or dispersed.

As previously discussed, socio-demographics may influence outcomes: a lower age may be associated with a better health outcome, although the odds were weak. Nonetheless, the ABS SEIFA (IRSAD) was associated with a significant odds ratio that was up to 10% higher for better self- rated health in areas with higher SEIFA deciles. These results were supported by Dunstan et al. (2013), who reported that levels of poorer health were linked to lower socio-economic status. In another study, the socio-economic status of older respondents was positively associated with better self-rated health outcomes (Demakakos et al. 2008)

In this study, dwelling density was not a significant predictor of better self-rated health. At the SSC level, there is very little variation in dwelling density as much of the study

area was very low density to low density (n = 412: 95%), with <35 dwelling units per hectare. Of the SSCs, only eight were classified as medium density and two as high density (>70 dwelling units per hectare). The total area of POS in relation to the SSCs dwelling densities indicates that a significant number of SSCs with a very low density of dwellings could have lower open space supply (Figure 8-3). Due to the lack of variation in dwelling density, it is difficult to determine any clear association with better self-rated health and higher density.

Chapter 9: Discussion.

This study sought to investigate whether the provision of public open space (POS) supply in urban environments and access to POS was associated with higher self-rated health. Four research objectives were formulated to investigate these mechanisms.

1) explore the origins and the appropriateness of legislated open space supply standards and policies within 21st-century urban environments;
2) develop and validate a 2016 POS spatial dataset representing supply within the study area;
3) investigate the distribution of POS and accessibility across the study area; and
4) explore associations between population health and POS area, count, accessibility and dwelling density.

The preceding chapters reported the outcomes of a mixed-method sequential triangulation process. The literature review provided the impetus to investigate how industry interpreted the research and urban planning policies to define and implement open space within urban environments. A quantitative analysis sought to emphasise the variability in spatial data representing open space distribution, street network access to POS, and associations between POS area and count and self-rated health.

This chapter begins with a summary of the key findings (Section 9.1); discusses and explores the implications of those findings in relation to the research objectives (Section 9.2); limitations and validity of the research (Section 9.3); and explores the implications for urban planning practice, along with recommendations for future research (Section 9.4).

9.1 Key findings in relation to the research objectives.

Parks and gardens have a long history dating back over 2,000 years and have re-emerged as part of planning healthy urban environments. Despite the renewed interest in healthy cities and the role of open space, there is still no agreed definition or sound foundation for open space supply.

Chapter 3 provided a historical narrative of the development of open space supply within built environments and how this influenced the establishment of open space supply standards. These supply standards continue to be applied despite little evidence to support their presumed validity.

Chapter 4 presented the research design through the application of mixed methods and a multidisciplinary position. The research analysed both primary and secondary data sources to address the objectives.

Chapter 5 reported the outcomes of semi-structured interviews with urban planning professionals'. This provided insights into how the research, legislation and planning policies on open space were defined, interpreted and implemented in relation to the open space supply standard mandated within South Australia's *Development and Infrastructure Act* (*2016).* The interview respondents knew of possible links between open space and population health, despite the limited legislative connectivity between the to-be gazetted *Planning, Development and Infrastructure Act* (*2016)* and the *South Australian Public Health Act (2011).*

Chapter 6 reported differences among the four spatial datasets used to represent open spaces. The different number and area of open space resulting from these four datasets and subsequent concern for data validity was the impetus to develop and validate a new dataset to define the distribution, count and area of POS for this research. Developing the best possible POS dataset involved a desktop audit utilising aerial imagery and Google Streetview. Although the validation process collated information on passive and active counts, infrastructure (shelters, benches, toilets) and types of POS sub-classifications, these built on previous research and to provide new data for additional research. A field validation of a representative 10% sample of the dataset confirmed that the desktop process could be utilised to identify and characterise POS. An analysis of the validated POS dataset against the mandated 12.5% open space supply standard at three different spatial scales, LGA, POA and SSC identified the spatial units that met or did not meet the open space supply standard. This highlights the issue of Modifiable Areal Unit Problem, where large spatial unit does not identify the undersupply problems that were evident with the POA and SSC based on 12.5% open space supply standard.

Chapter 7 Investigated street network distance from a dwelling to a POS, and applied a raster network distance analysis to three POS access measures (400 m street network walking distance with and without barriers; and Euclidean distance), to align with the 30-year

plan, which proposes that 77% of residents in urbanised areas would reside within 400 m of any POS (Department of Planning Transport and Infrastructure 2017a). The results highlighted the way access is measured is critical; the selection of street network data, the impact of barriers and straight line distance (Euclidean), and the influence of Modifiable Areal Unit Problem when different spatial units are applied. Although the difference of the mean between barriers and without barriers was small, however, comparing the smaller spatial units of POA and SSC with the larger (ASD) access (barriers) decreased by 10% and 11.1% respectively. The Euclidean distance returned the least percentages, ranging from 95.8% (ASD) to 88.1 (SSC) which confirms this metric could be perceived as simplistic because the built environment restricts the ability of people to travel in straight lines. Additionally, how open space is defined and what is and is not included, for example, the *30-year plan* walkable neighbourhood target classified open space as greater than 4000 m^2, if applied to VPOS 2016 dataset, 43% of the data would be omitted and significantly different access outcomes.

Chapter 8 reported there was no association between POS supply by area (500 m buffer) and higher self-rated health (SF1 excellent). The inclusion of independent variables, age and gender, provided a no statistical significance of POS area (500 m buffer) when applied to the SF1. As reported in other research POAs and SSCs with a higher socio-demographic status (ABS IRSAD) were associated with a small increased odds of better self-rated health status (higher SF1 score) (Akpinar, Barbosa-Leiker & Brooks 2016; Gill et al. 2009).

9.2 Interpretation of the research.

A review of the historical origins of open space supply standards revealed they were developed with minimal empirical evidence (Veal 2013) and have not been significantly re-evaluated in Australia (Marriott 1979; Wilkinson 1985; Wilkinson 1988). Carmona (2010) reported that open space supply standards were a simplified calculation that may or may not be appropriate at a local level. Within Australia, various open space definitions continue to the uncertainty resulting in different interpretations used to calculate open space supply. Further, the choice of data source can influence findings and potentially provide misguided recommendations.

The provision of open spaces within built environments for food production, recreation and in connection with population health, has a long history. As a result, open spaces have been assigned numerous definitions. Two prominent descriptions, 'parks' and 'greenspace', are widely applied in Europe and the US. Greenspace can include areas with no public access, for example, open spaces between transport infrastructure, private gardens and primary production areas (de Vries et al. 2003). A universal definition of POS may be problematic for research and urban planning policy purposes because of geographic, cultural and historical connections (Daker 2014a; Daker, Pieters & Coffee 2016). Koohsari et al. (2015) proposed that POS definitions should be aligned with the research objectives. Griffith (2010) reported that traditional definitions vary in modern urban environments and now include more diverse land uses such as bodies of water and shared open spaces. For this research, an overarching POS definition with 10 subclassifications was identified in recognition of POS diversity and functionality (Appendix 12).

How open space has been defined can be linked to open space provision and the establishment of open space supply guidelines and standards within urban environments. Early open space guidelines identified that parks and gardens should be developed in industrialised towns and cities to improve public health and provide opportunities for people to engage with naturalised environments (Gould 1888; Stephenson & Hepburn 1955; United Kingdom House of Commons 1836; Wilkinson 1988). From the late 19th century, open space guidelines developed as two supply standard; a percentage of the total residential development area and between 2.4–4 hectares per 1,000 population. However, an extensive literature search found limited or no empirical support for these measures. This lack of an evidence base is demonstrated with the current South Australian 12.5% open space supply standard in the *Planning, Development and Infrastructure Act (2016).* The origins of the 12.5% was the result of a compromise in the 1960s between the state government who wanted 15% and the development sector which wanted 10% (South Australia 1966; South Australia Government 1967; South Australian Parliament 1965-1966, 1966-67). The compromise was 12.5%, and this has been replicated since then in all planning legislation and will be the open space standard in the soon to be gazetted *Planning, Development and Infrastructure Act (2016).*

In the ensuing 50 years, the open space supply standard as a land-only area metric has not been reviewed and may well be inappropriate to meet current planning directives that advocate for increased dwelling densities through infill within existing urban areas and the

containment of urban sprawl within existing growth boundaries. In 2014, an appointed planning reform committee evaluated the South Australian development process through engagement with urban planners, health professionals, academics and the general public. The resulting government report did not question the validity of the mandated open space supply measure in the *Development Act (1993)* (Government of South Australia 2015). An outcome of the review was the *Planning, Development and Infrastructure Act (2016,*) which is still to be gazetted. The mandated 12.5% open space supply standard has remained unchanged, and the review did not address the implications of dwelling/population density increases on open space supply, to define POS and quality metrics, level of access to POS and the necessity to meet communities' current and future requirements. An interview respondent highlighted the recognition of diverse community requirements. While persons of Australian and European ancestry have predominantly utilised open spaces, there has been an increase in the number of persons from the Middle East and Asia, who connect with and utilise open spaces differently, for example, by holding large family and community events.

A component of the South Australian planning process, local government development plans provide planning guidelines on open space supply within residential developments. Related to the review of the interviews, reported that development plans provided advisory support for planning decisions that then often involved negotiations with the development applicant. Marriott (1979) reported that statutory planning policies perpetuated established planning methods, especially those that mandate a minimum open space supply standard because they maintain the status quo. The current local government development plans will be superseded in July 2020 by an overarching *Planning and Design Code* rulebook (Department of Planning, Transport and Infrastructure 2019). The new rulebook is one component of a development application platform that intends to improve planning and design outcomes to meet the needs of people through the simplification and standardisation of the planning process. Carmona (2010) suggested that the generalisation of planning processes could result in urban infrastructure that may or may not be appropriate at a local level.

The potential effect of higher dwelling densities on the 12.5% open space supply standard was highlighted in a report by City of Charles Sturt Council (2011), which identified a high-density development within a 7-hectare site could deliver 0.9 ha per 1,000 persons, whereas a low-density development on 35 ha would contribute 4.4 ha per 1,000 persons. The report concluded that the percentage of land area requirement was outdated and not applicable

when applied to higher-density developments and thus recommended the application of both a percentage of the area and hectares per 1,000 population to deliver open space area linked to population density and not land area or dwelling density. A leading planning consultancy, InfraPlan, supported the 2011 Charles Sturt report and outlined that densification could result in the 12.5% open space standard delivering inadequate supplies of open space (InfraPlan 2014). The revision of the current open space supply standards was supported by the interview respondents, although one suggested there was an abundant allocation of open space if councils approached supply more holistically and disregarded local government administrative boundaries.

Defining open space supply standards linked to population density ratios may be contentious because definitions of dwelling densities vary as does what would constitute density benchmarks. For example, in the United Kingdom, high dwelling density is defined as 60 or more dwellings per ha (Town and Country Planning Association 2003), in the USA this figure is 110 dwellings per hectare (Ellis 2004) and in metropolitan Adelaide, 70 dwellings per hectare (Department of Planning and Local Government 2011). Landcom (2011) recommended caution in step changes between low, medium and high-density classifications, as these are a matter of perception and can depend on individual and community expectations. In Australia, there are no national standards to define dwelling density ratios. Alternatively, legislation could define open space supply standards on the basis of population densities because higher residential dwelling densities do not necessarily result in higher population densities. Whichever approach is adopted, strategies are still required to address shortfalls in open space provision in neighbourhoods undergoing significant infill and have been identified with an existing shortfall of open space. One method to address shortfalls could involve the Open Space Development Fund as a source of funding for local governments to purchase lots in areas identified with shortfalls.

Regardless of the way in which open space supply is operationalised, it does not address how people utilise open space. Within South Australian, the City of Onkaparinga (2018), outlined an open space hierarchy aligned with activity types and facilities applicable to a particular size of open space. Including more facilities within larger spaces was intended to encourage individuals and families to stay for an extended period and engage in passive or active recreation. A report that was part of the revision of the DPTI's 30-year plan (DPTI 2017a), entitled *Healthy Parks Healthy People South Australia 2016-2021* (Government of South Australia 2016) outlined the prerequisite for broader engagement between local

governments and developers, with the goal of agreeing on amenity metrics for quality green open space, particularly in areas targeted for infill development. To date, there is a limited consensus between local governments, state government and property developers.

The provision of open space and recognition of amenity values could be attributed to the increased application of cost-benefit analyses to measure positive and negative aspects of planning policies. One South Australian example is the current strategic direction to contain urban growth within defined growth boundaries and increase residential densities within existing urban areas (DPTI 2017a). A result of these strategic planning policies to restrict the release of large land areas for residential development on the urban fringe is increased subdivisions of existing lots and consequent higher land prices, which has created an issue with how to provide enough quality open space in areas with deficits of open space. The provision of new open space within larger subdivisions can depend on the willingness of future residents to pay higher market values for smaller house lots and increased area of open space. Low-income residents could be priced out of higher-value residential developments (Orr, Paskins & Chaytor 2014; Rouwendal & van der Straaten 2008). There is an inherent flaw in attempting to price what should be priceless, access to naturalised areas and population health: Ackerman and Heinzerling (2002) suggested no market value could be applied as these open spaces should not be for sale.

The provision of open space has been associated with reductions in chronic diseases; thus population health costs could also be reduced through increased physical activities and enhanced wellbeing (Reklaitiene et al. 2014; Tolhurst et al. 2016). Orr, Paskins and Chaytor (2014) suggested that urban green spaces should not be an additional requirement or a luxury but an essential component of urban infrastructure. It is essential to recognise that decisions on urban design strategies have become involved and demanding in line with the increased requirement to balance social, environmental and economic outcomes (OECD 2018). The interview respondents identified that property developers were implementing smaller areas of open space primarily as an advertising promotion to persuade people to buy into developments with plentiful areas of green spaces. However, many of these green open spaces are small and possibly unusable for recreation, instead, performing an ecosystem services function, for example, stormwater management. This issue was highlighted by the CABE (2006), who described it as space left over after planning, or open space provided on land deemed unsuitable for development and as spaces intermingled with utility infrastructure, transit corridor buffers, drainage basins and areas with steep slopes (Figure 9-1).



Figure 9-1: Space left over after planning (SLOAP) at Blackwood Park Estate Craigburn Farm (South Australia).
Photograph by author.

A recommendation from this thesis is that politicians and government departments should initiate research on the associations between open space supply and population health and then determine if there are potential savings for the health budget. The current open space supply standards and guidelines should remain in place while research is undertaken to determine a 21st-century, evidence-based solution within changing urban compositions.

Implementing POS at the micro-scale of individual developments does not address a city-scale understanding of the actual distribution of POS and connectivity within residential areas. GIS can provide the tools to report on and analyse these spatial distributions of POS and identify 'POS deserts'. GIS tools when applied to the whole region can reduce the influence of the Modifiable Areal Unit Problem when smaller administrative boundaries are introduced into an analysis. Administrative boundaries, for example, local government areas, maybe an inappropriate scale to represent POS and population characteristics. GIS can

provide a more detailed understanding of POS supply, enable supply standards to be applied and identify areas not meeting the standard.

Previous studies have identified that access to data in Australia can be difficult and that data quality is variable, complicating comparison among data representations (Bull et al. 2013; Daker 2014a; Daker, Pieters & Coffee 2016; Lamb et al. 2019; Paquet et al. 2013). Dataset selection necessitates thoughtful consideration and justification to ensure research outcomes are not biased. Selected data should be audited, and subject to desktop and field validation to ensure the best quality data. This research applied a matched timeline to avoid temporal errors with the POS data in relation to the population census and South Australian Monitoring and Surveillance System data. However, a number of studies selected data sources because they covered the study area and on the assumption that the data representations were valid; they did not undertake supplementary auditing/validation processes, (see, e.g. Astell-Burt, Feng & Kolt 2013, 2014a, 2014b, 2014c, Astell-Burt et al. 2014). This research highlighted the importance of not assuming data sources are suitable or correct and reinforced the requirement for undertaking secondary validation processes, including desktop and field validations. The outcome of the fieldwork supported the desktop capture as an appropriate method to develop and validate a spatial dataset representing POS.

An analysis of whether there is sufficient open space provision can be influenced by the spatial unit applied to inform the research (Brownson et al. 2009; Leal & Chaix 2011). The largest spatial unit (LGA) used in this study showed that a majority of the local government areas met or exceeded the 12.5% open space supply standard. This spatial unit is widely utilised for local government reporting even though it might provide an inaccurate representation of the actual distribution and supply of open space in relation to residential areas and nearby areas across the local government boundary. As the spatial units used reduced in size, the number not meeting the 12.5% open space supply standard increased.

Within the inner areas of metropolitan Adelaide, a significant number of SSCs did not meet the 12.5% open space supply standard, which will be further compounded when these areas are targeted for infill development. The area of public open space per population will decrease as land is consumed for other land uses; therefore, politicians and urban planners need to be proactive before it becomes impossible to secure land parcels due to economic constraints. This is not a new concern; in 1962, the South Australian *Metropolitan*

Development Plan proposed land parcels should be secured for future POS demand (DHUD 1962).

The spatial representation of the validated POS dataset revealed significant variation in area and distribution of POS. When the POS data were classified according to the open space hierarchy within local government development plans, POS less than 5,000 m^2 (local) dominated, accounting for approximately 50% of the total count. However, despite the large count, they represented only 1.5% of the total POS area; if included in an analysis using count and access, this might bias the results relating to dwellings with access to POS suitable for active recreation. The implementation of small areas of POS within many new residential developments raised an additional concern from the interview respondents, in that developers were failing to implement POS of a size suitable for structured active recreation. Several local government respondents revealed they had a waiting list for sporting clubs requiring suitable grounds. However, one respondent highlighted that many residents might object to sports grounds near their properties because of excessive noise, increased traffic and parking issues. A solution suggested for addressing the shortage of sites suitable for structured active recreation was the redevelopment of brownfield sites for POS as this involves minimal deep invasive groundworks and any non-toxic waste materials can be capped (De Sousa 2003).

Sherer (2003) wrote a report for the Trust for Public Land USA that proposed access as a more meaningful measure than total park area. Although many urban environments have intricate street networks, these networks may be associated with limited routes suitable for pedestrians. A few studies have investigated the potential effect of barriers on walkability and acknowledged specific street classifications could prevent pedestrian access, such as freeways (Gelb et al. 2017; La Rosa 2014). Without including potential barriers that restrict passage, the calculation of street network access distance may be misleading. This investigation aligned POS access with the target set out in the 30-year plan (DPTI 2017a), which aimed for 100% of residents to reside within 400 m of three out of four services (open space being one of these). Notably, a walkable neighbourhood in metropolitan Adelaide might have no access to open space. Since open space has been linked to improvements in population health and wellbeing, safe access to open space should be mandatory within this access benchmark.

The raster network analysis for the ASD revealed networks with barriers resulted in 84.8% of dwellings within 400 m of a POS, which increased to 86.8% without barriers, and 95.8% using Euclidean distance. The straight-line or Euclidean distance results in an

overestimation of dwelling access percentage and does not account for actual access. It must be acknowledged that the walking distance a person wishes to travel is subjective and depends on numerous factors, including the topography, mobility problems and age (e.g., the very young and elderly may be more restricted to the distance they can walk). Walking restrictions may also be because of insufficient connectivity of footpaths or their condition. The attractiveness and perceived safety of the neighbourhood are essential factors in whether a person feels secure to utilise their neighbourhood's footpaths and open space (Frank, Engelke & Schmid 2003; Saelens, Sallis & Frank 2003).

To improve access to POS, three local government respondents suggested there was no reason why streets could not be re-purposed to provide greater connectivity between POS, although vehicle management to reduce speeds, restricting access or giving priority to pedestrians or cyclists is a politicised issue. Overseas, many towns and cities have restricted or banned private motorised vehicles from urban centres, including Brussels, Copenhagen, London, Nuremberg, Vienna, demonstrating that changes in perceptions and dependency on motor vehicles can result in more pedestrian and bicycle-friendly urban environments and increased patronage of public transport. As highlighted by the interview respondents, traffic restriction within residential areas and the Adelaide Central Business District could be achieved; despite potential objections, politicians and policymakers need to be brave and make bold decisions for the future. Inadequate pedestrian connectivity results from poor urban design and previous planning policies that encouraged motor vehicle dependency. These issues can be addressed through an increase in the number of shared pedestrian/cyclists pathway networks that link suburbs and the Adelaide central business district. As described in Chapter 2:, the study area has a Mediterranean climate conducive for people to partake in outdoor activities, including walking and cycling for leisure, to work or school. Increasing the number of linear POS comparable to the River Torrens Linear Park trail (Figure 6-11) would ensure POS are not isolated and become part of an extensive network of connected urban infrastructure.

Creating new and connected POS could be addressed through the re-activation of marginal spaces: land deemed underutilised, unnoticed or meaningless by a large portion of society. These left-over spaces include brownfield sites, vacant land, edges of transport infrastructure and space under bridges (Hudson & Panas 2010). Kirkham (2003) defined these areas as problematic as they can be quite small, irregularly shaped, with challenging access or complex ownership rights. Governments and developers regularly overlook these left-over

spaces until an economic value is realised. Instead, policymakers need to free themselves from restrictive perspectives and develop open-minded viewpoints that facilitate different solutions.

A study in Brisbane (Queensland) investigated 100 km^2 of the central area to locate 'informal urban green space', which included vacant lots, brownfield sites and street and railway verges; 6.3% of the study area was identified as informal urban green space (Rupprecht & Byrne 2014). A similar approach could be applied to metropolitan Adelaide to identify areas suitable for linear corridors and to repurpose underutilised land as pocket parks, community gardens, larger recreation areas and urban forests. Providing innovative approaches to supplement and update the mandated open space supply standard could improve open space provision in areas identified with a shortfall. Examples from overseas where re-purposed blighted brownfield sites have been turned into attractive, safe vegetated spaces with shared pedestrian and cycle pathways include the Highline in New York City and the Promenade Plante in Paris (Figure 9-2).



Figure 9-2: Promenade Plante, 12th arrondissement, Paris.
Photograph by author.

A more radical urban regeneration project was undertaken in Seoul, South Korea, which saw the demolition of a two-tier freeway to uncover a river channel. The project revitalised the river channel into open space, with the aim of providing an open vegetated corridor through the city (Landscape Architecture Foundation 2010).

When open space provisions at ground level are unattainable, one solution is to consider vertical migration of open space to develop rooftop gardens, roof terraces and landscaped balconies. Worldwide, rooftop gardens have a long history as a feature of urban environments, although they have been brought to the forefront to address the effects of urban densification and loss of open spaces at ground level. Elevated open spaces provide opportunities for passive and active recreation, community gardens and meeting areas (Ghosh, Giovanageli & Giovanageli 2016). To ensure connectivity between buildings and to facilitate human population movement, sky bridges can be incorporated into the design (Sacha 2014). Increasing the area of green infrastructure by 10% within urban environments can reduce urban air temperatures by 2.5^{o}C (Forest Research 2010). Reductions in extreme urban air temperatures have been linked to reduced morbidity and mortality, particularly of individuals at risk, including children and the elderly (Nitschke et al. 2011).

Despite the inconsistencies regarding evidence for a link between open space supply and population health benefits (Lee & Maheswaran 2011), the evidence is clear that poor urban design and sedentary lifestyles may lead to increased chronic health-related problems. The Australian Institute of Health and Welfare (2018) reported that between 2006 and 2016, growth in health care costs was greater than the growth in population. In the 2006/07 fiscal year, 8.7% of Australia's Gross Domestic Product was spent on health, rising to 10.3% in 2015/16. Community and public health services combined accounted for $12 billion, or 20% of the primary health care budget in 2016. A recent report by Tolhurst et al. (2016) noted that one in two Australians has a chronic disease, with one-third of these being preventable through changes to lifestyle, including increasing daily physical activity. An increased level of physical activity has been linked to the number and area of open space proximal to a residential dwelling (Ambrey 2016; Cohen-Cline, Turkheimer & Duncan 2015; Richardson et al. 2013). Studies have reported relationships between both access and also views of green spaces could be attributed to improved mental health outcomes (Groenewegen et al. 2006; Houlden et al. 2018; Nielsen & Hansen 2007). Paquet et al. (2013) reported that POS was associated with a lower incidence of cardiovascular disease over time, highlighting that a single construct for POS might not apply for all research objectives.

However, many ‘green spaces’ were identified in the development of the VPOS2016 dataset as invalid because they either restricted public access or were unsuitable for passive and active recreation, for example, roadside vegetation, O-Bahn transit corridor and primary production areas. The inclusion of open space for passive and active recreation in urban environments has been perceived as an important aspect of quality urban design and people’s health and wellbeing. Similarly, neighbourhoods that had a higher perceived sense of security had higher open space patronage, strengthening social and community interactions (Cohen et al. 2010; de Jong et al. 2012; Kuo & Sullivan 2001).

Many studies have investigated associations between open space supply and self-rated health (Maas et al. 2006; Picavet et al. 2016; Pietilä et al. 2015). In the current study, statistical analysis of the count and area of POS in relation to responses on an SF1 five-point Likert scale (poor to excellent) from the Australian Monitoring Surveillance System and the independent variables revealed in the multi-level ordinal regression analysis no correlation and no association between SF1 and POS. The area of POS (500m buffer) was not statistically associated with self-rated health. These results may have been influenced by multiple factors, including the aggregated count and area of POS per spatial unit, which highlights the influence of Modifiable Areal Unit Problem when two different sized spatial units were applied. Additionally, the count of Australian Monitoring Surveillance System respondents was not equally distributed across the POAs and SSCs, which may have biased the results. Brownson et al. (2009) reported that the Modifiable Areal Unit Problem and the inappropriate choice of the spatial unit could mask any statistically significant associations. Coffee et al. (2013) made the point that network buffer walkability was statistically associated with lower cardiometabolic risk at the ABS Collection Districts (CD) and SSC were not. Learnihan et al. (2011) also reported in an Australian study that CDs were not statistically associated, they found a strong association between road buffers spatial representations of walkability and more walking for transport, but not with the two predetermined units (the CD and SSC).

9.3 Limitations and validity of the research.

Limitations of this research include the POS dataset: although it defined the count, area and distribution of POS suitable for passive and active recreation, it did not include roadside vegetation, primary production, private gardens and land with no public access. Grey and blue spaces also were omitted, for example, shopping malls and bodies of water not associated with a POS. However, studies have acknowledged that blue spaces and green spaces may be associated with improved mental health (Dempsey et al. 2018; Gascon et al. 2015; Nutsford et al. 2016). Mental health can be recognised as a component of self-rated health but was not investigated here as a standalone theme. Similarly, the analysis in this study could have utilised the Normalized Difference Vegetation Index derived from satellite imagery. Several studies have applied Normalized Difference Vegetation Index data to self-rated health; however, they included open spaces that had no public access, such as private gardens, forestry and primary production (Dadvand et al. 2016; Markevych et al. 2017; Orban et al. 2017; Triguero-Mas et al. 2015). Therefore, the Normalized Difference Vegetation Index only provides an indication of vegetation; it does not provide the basis for building a publicly accessible open space dataset. However, it could be used as one of the datasets, but for a suitable image resolution and for the size of the study area would be very costly and therefore was not possible.

The semi-structured interviews with urban planners did not involve any participants from major residential development companies, despite being invited to participate. Therefore, no data was attained from respondents responsible for interpreting planning development procedures and the implementation of open space within new residential developments.

A significant limitation with Australian health data is the lack of geographic detail. In Australia, data custodians are highly risk-averse regarding potential data re-identification and attribute disclosure (Department of Health 2018; Productivity Commission 2017). This was captured by Ohm (2010), who stated, ‘you can have de-identified data or useful data but not both’. The Australian Monitoring Surveillance System health data were de-identified and supplied for two spatial units, POA and SSC, which prevented the georeferencing of address details. In the absence of information on the respondents’ actual street addresses, it is not known if respondent locations are dispersed or clustered within the spatial unit. As a result, the relationship between proximity to POS and health could not be rigorously explored.

Further, the results of the statistical analysis might be linked to variability in the Australian Monitoring Surveillance System sample data; despite the very large sample size (n = 12,892), the distribution and count of respondents within the study varied considerably. The counts for POAs ranged from 2 to 400 respondents, with 6 POAs having no data. Similarly, data for SSCs ranged from 2 to 264 respondents, and 33 SSCs had no data.

The influence of Modifiable Areal Unit Problem could be reduced if the Australian Monitoring Surveillance System data could be georeferenced: the analysis would then involve the whole study area without having to nest the data within POA and SSC geographic units which are administrative boundaries. The issues attributed to the Modifiable Areal Unit Problem have limited reporting in health research, although it may not be possible to provide a solution to address the Modifiable Areal Unit Problem due to the previously highlighted limitations of the data, it must be reported as a potential limitation and bias of the results.

These results may be influenced by an individual who may not utilise the POS nearest their residence; this could be attributed to the POS area, the perception of security and facilities available, for example, shelter, seating, play equipment. Similarly, people do not recognise nor are they restricted by administrative boundaries and may travel to an adjoining POA or SSC area to access a POS. This is a harder problem to account for, and within the context of this study was a limitation it was not possible to control. Maas et al. (2006) reported that controlling for the variability of human nature is potentially impossible.

9.4 Conclusion and recommendations for future research.

Building on earlier research (Daker 2014a; Daker, Pieters & Coffee 2016), this thesis has contributed to the growing body of research on open space supply and population health. Defining open space is a complex issue, as supported by the literature review, interviewing urban planners and the validation of the POS dataset. In recognition of this complexity, the research applied POS as an overarching description, with 10 subclassifications to highlight the diversity and type of open spaces, although not applied to this research, instead to provide future research opportunities (Appendix 12). However, the definition of POS applied in this research may not be applicable in other locations and may be problematic because of historical, geographic or cultural connections.

Ensuring a sufficient provision of open space provides multiple benefits for people through contact with natural environments and to engage in passive and active recreation to enhance physical and mental health. The open space supply metrics including the South Australian 12.5% open space supply standard of a developable area and the Australian 2.83 ha of open space per 1,000 population guidelines were developed in the early 20th century to provide uniformity and replicability of open space provision within urban environments. These open space supply standards and guidelines were developed without strong empirical evidence, and therefore they need to be challenged. Current open space standards create uncertainty as they may not reflect minimum, maximum or optimal levels of provision. Maintaining a rigid devotion to open space standards aligned with land area and population count diverts the attention from issues regarding metrics that define POS size, shape, distribution, levels of access, useability and quality. Subsequently, comprehensive research and evaluation must be undertaken to deliver recommendations that ensure POS supply meets the requirements of current and future human populations. The existing 12.5% open space supply standard should not be disregarded until a comprehensive review is completed. This review should not solely consider open space per area because this will perpetuate the current open space supply standard. Instead, the review should consider supply measures that meet the needs of changing population demographics within 21st-century urban landscapes. The following issues should be considered in a review of open space supply standards:

1) investigation into what is the optimal area of POS per person. As discussed in the literature, the optimal open space area could range from 9 sqm per person (WHO 2016) to the 1930s North American open space supply standard of 40 sqm per person (4 ha per 1000 persons) (Wilkinson 1985). The issue with defining optimal area is that it may perpetuate a continuation of a simple land area metric. To address this issue, the investigation should consider links between an open space area and the differences in population and dwelling densities. as highlighted in the report by City of Charles Sturt Council (2011),
2) the investigation and development of open space metrics which transition away from simple land area metrics and include quality metrics. To define minimum land areas and dimensions (width and length) aligned with an open space type, for example, pocket park,

sports field) (National Capital Development Commission 1981). Additionally, to incorporate infrastructure metrics, including lighting, toilets, footpaths, playgrounds, shelter, that are classified to a particular type of open space (City of Onkaparinga 2018),

3) the interpretation of population demographics to provide open spaces which are appropriate for different ages, gender and cultural groups, and to acknowledge that those with disabilities require equal opportunities to access open space for passive and active recreation,
4) the investigation of opportunities to reactivate underutilised land as open space, and to improve connectivity between land uses, including open spaces. To undertake spatial analysis to locate and identify transport corridors, vacant land, school grounds and rooftops which might be suitable for further investigation to address shortfalls in open space supply with urban environments, and;
5) revision of the Open Space Development Fund to provide greater equitability. To move from a centralised model to a local government model to enable improvements in existing open space and connecting streetscapes.

There has been limited research on the effects of urban densification on open space supply and population health. This study found no significant relationship between dwelling density and self-rated health, which may be because metropolitan Adelaide is mostly suburban with lower dwelling densities and little variability. Instead, other indicators should be investigated, including access to POS and its amenity value for health outcomes.

This study developed spatial methods that improved the understanding of open space supply, which could be further developed to test access using different networks, with and without barriers and arbitrary spatial boundaries. Identifying priority areas for intervention should begin by identifying areas with shortfalls in open space supply and potential locations of parcels for land purchases to future-proof open space provision. GIS can provide a tool to test different outcomes over time in relation to dwelling and population densities and their effects on open space supply.

An opportunity exists to investigate and develop datasets from government and private stakeholders who manage restricted outdoor recreation areas; for example, school ovals, which could be utilised out of hours by the public to address shortfalls in open space supply.

As higher-density developments are increasingly providing smaller areas of POS or even zero POS supply, there are opportunities to investigate alternative methods to safeguard POS provision; for example, multi-storey buildings with rooftop gardens and sky bridges to link buildings, although this would require revisions to Australian building codes and development and environmental legislation. A significant number of building with flat roof spaces could provide unrestricted access for human populations to participate in passive and active recreation; however, it must be acknowledged that not all rooftops are suitable or provide safe public access. Studies have shown that rooftop gardens also mitigate the urban heat island effect (Cantor 2008; Goodwin & Hopkins 2011; Hopkins 2010), and reductions in urban temperatures are a contributory factor to better human health.

Further research is required to determine whether incorporating amenity into legislation, urban design policies and codes would be an appropriate exchange for POS quantity. The re-activation of underutilised land and brownfield sites as POS and linkages is a possibility; although without adequate economic incentive for private landowners, and legislative changes to address the aversion of risk, many of these sites will continue to be a blight in urban environments.

The spatial analysis of the selected datasets representing open spaces and networks highlighted the variation among data sources and that data might be inaccurate or unsuitable for achieving valid research outcomes. Therefore, it is critical to investigate the sources of data to ensure they are suitable for the research objectives. Further, this research emphasised that spatial data requires secondary validation, including the use of high-resolution aerial imagery, Google Streetview and fieldwork. The field validation of the POS dataset confirmed that the desktop analysis was a valid method to support and strengthen the research being undertaken. The validated POS dataset provided an accurate representation of count, area and distribution of POS supply in metropolitan Adelaide. Although no field validation was undertaken to determine access points for POS, the previous POS dataset validation process supported the utilisation of high resolution imagery to determine access locations; this could be applied in future research.

Although this research found no statistical association between POS and self-rated health, it highlighted the influence of Modifiable Areal Unit Problem and the requirement for health and census data to be georeferenced at the level of a dwelling or the centroid of a street or intersection, which may result in a different conclusion.

This research contributes to new strategic planning approaches in recognising that the current open space supply standards and guidelines are obsolete. The way forward is to undertake research to address the lack of empirical evidence. New evidence-based open space standards and guidelines must ensure the provision and distribution of quality POS which are not in isolation but interconnected to enable people to utilise and enjoy different open spaces with the objective to promote health and wellbeing outcomes. Additionally, open space supply standards need to be adaptive to align with 21st-century urban planning strategies, designs and changing population demographics.

As Mitchell (2015) summarised, ‘rather than ask what makes us sick, we should instead ask what keeps us healthy and can our urban environments contribute?’.

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Appendices.

Appendix 1: Ethics approval from University of South Australia to undertake semi-structured interviews.

Dear Applicant

Re: Ethics protocol "Semi-Structured interviews with urban planners" (Application ID: [redacted])

Thank you for submitting your ethics protocol for consideration. Your protocol has been considered by the E1 Committee Review Group.

I am pleased to advise that your protocol has been granted ethics approval and meets the requirements of the National Statement on Ethical Conduct in Human Research. Please note that the E1 Committee Review Group's decision will be reported to the next meeting of the Human Research Ethics Committee for endorsement.

Please regard this email as formal notification of approval.

Ethics approval is always made on the basis of a number of conditions detailed at http://www.unisa.edu.au/res/forms/docs/humanresearchethics_conditions.doc; it is important that you are familiar with, and abide by, these conditions. It is also essential that you conduct all research according to UniSA guidelines, which can be found at http://www.unisa.edu.au/res/ethics/default.asp

Please note, if your project is a clinical trial you are required to register it in a publicly accessible trials registry prior to enrolment of the first participant (e.g. Australian New Zealand Clinical Trials Registry http://www.anzctr.org.au/) as a condition of ethics approval.

Best wishes for your research.

Executive Officer
UniSA's Human Research Ethics Committee
CRICOS provider number 00121B

This is an automated email and cannot be replied to. Please direct your query to [redacted]

Appendix 2: Ethics approval from SA Health to utilise South Australian Monitoring Surveillance System data (2 pages).

Government of South Australia
SA Health

[redacted]

[redacted]

Dear Mr Daker

HREC reference number: [redacted]

Project title: Across metropolitan Adelaide are there associations between population health and public open spaces

RE: HREC LNR Application – Approval

Thank you for submitting the above Low or Negligible Risk project, which was reviewed by a sub-group of the SA Department for Health and Ageing (DHA HREC).

I am pleased to advise that your application has been granted full ethics approval and appears to meet the requirements of the *National Statement on Ethical Conduct in Human Research*.

The documents reviewed and approved include:

Document	*Version*	*Date*
Cover letter, [redacted]	1.0	25th Nov 2016
LNR Checklist	1.0	8th Nov 2016
LNR Application, [redacted]	1.0	8th Nov 2016
Research proposal	1.0	August 2016
PhD Review Report	1.0	8th Nov 2016
Response to Request for Further Information	1.0	3rd Feb 2017

Sites covered by this approval:

- SA Department for Health and Ageing (SAMSS data)

Please note the following conditions of approval:

- The research must be conducted in accordance with the 'National Statement on Ethical Conduct in Human Research.'
- A progress report, at least annually, must be provided to the HREC. The first progress report is due by 19/02/2018.
- When the project is completed, a final report must be provided to the HREC.
- The HREC must be notified of any complaints by participants or of adverse events involving participants.

- The HREC must be notified immediately of any unforeseen events that might affect ethical acceptability of the project.
- Any proposed changes to the original proposal must be submitted to and approved by the HREC before they are implemented.
- If the project is discontinued before its completion, the HREC must be advised immediately and provided with reasons for discontinuing the project.

HREC approval is valid for 3 years from the date of this letter.

Should you have any queries about the HREC's consideration of your project please contact the Executive Officer of the HREC, on [redacted] or [redacted]

You are reminded that this letter constitutes ethical approval only. You must not commence this research project at a SA Health site until separate authorisation from the Chief Executive or delegate of that site has been obtained via the completion of a Site Specific Assessment form. Please contact [redacted] via email at [redacted] to discuss this process further.

The HREC wishes you every success in your research.

Yours sincerely

[redacted]

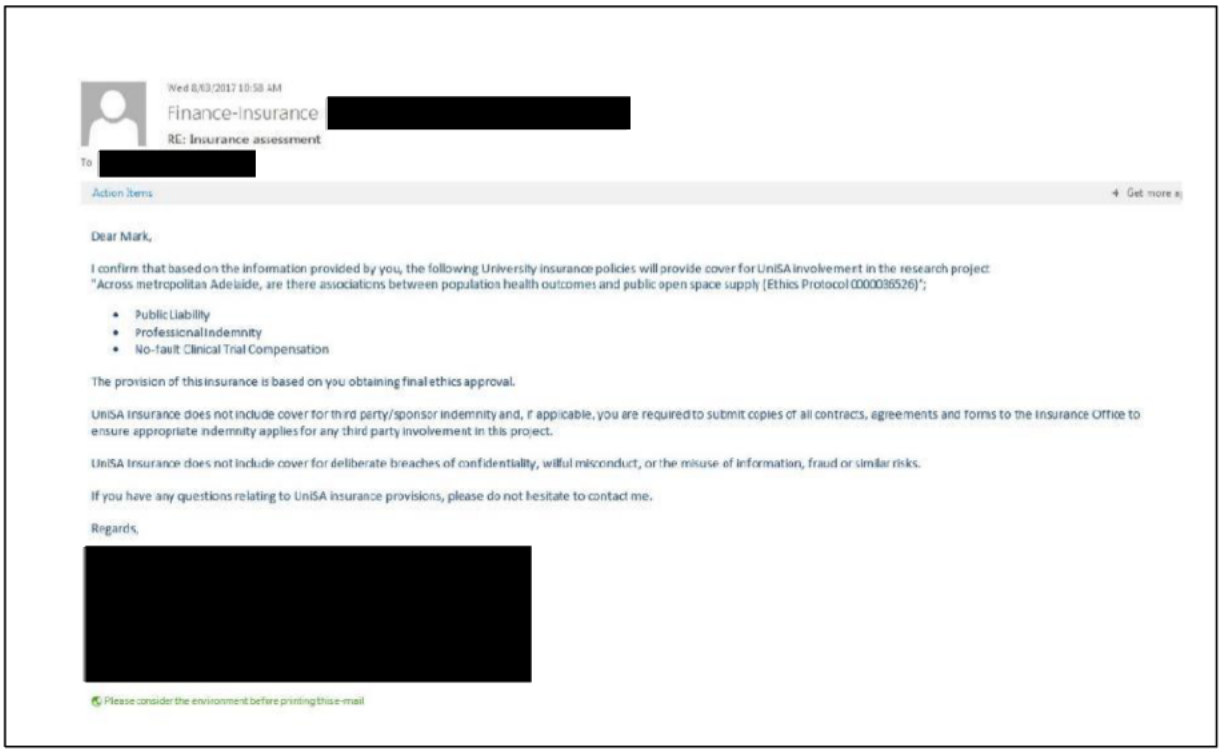
CHAIRPERSON
HUMAN RESEARCH ETHICS COMMITTEE

20/2/2017

[redacted]

Public-I1-A1

Appendix 3: University of South Australia authorisation of SA Health human ethics approval.



Wed 8/03/2017 10:58 AM

Finance-Insurance [redacted]

RE: Insurance assessment

To [redacted]

Action Items

Get more a

Dear Mark,

I confirm that based on the information provided by you, the following University insurance policies will provide cover for UniSA involvement in the research project: "Across metropolitan Adelaide, are there associations between population health outcomes and public open space supply (Ethics Protocol 0000036526)";

- Public Liability
- Professional Indemnity
- No-fault Clinical Trial Compensation

The provision of this insurance is based on you obtaining final ethics approval.

UniSA Insurance does not include cover for third party/sponsor indemnity and, if applicable, you are required to submit copies of all contracts, agreements and forms to the Insurance Office to ensure appropriate indemnity applies for any third party involvement in this project.

UniSA Insurance does not include cover for deliberate breaches of confidentiality, wilful misconduct, or the misuse of information, fraud or similar risks.

If you have any questions relating to UniSA insurance provisions, please do not hesitate to contact me.

Regards,

[redacted]

Please consider the environment before printing this e-mail

Appendix 4: Invitation letter to CEO or senior manager of an organisation to request an interview with an urban/open space planner within their organisation (3 pages).

[redacted]

Date

Organisation Address

Dear ##########

Position

RE: Permission to Conduct Research Study.

I am writing to request permission to conduct research at your organisation. I am a PhD candidate in the School of Natural and Built Environments and the Centre for Population Health Research at the University of South Australia. The title of my research is "Public open space policy, supply and population health: a study of metropolitan Adelaide."

The objectives of my research are to explore

1. Public open space planning standards and their implementation
2. Associations between the characteristics and accessibility of public open space with population health outcomes and
3. The perceptions from urban planners on public open space supply implementation.

I would like to request participation of the principal urban / open space planner within your organisation in one face to face semi-structured interviews; between January / February 2017. All records containing personal information will remain confidential, and no information which could lead to the identification of any individual will be released, unless required by law. All documentation will securely be stored for seven years within the Centre for Population Health, as defined by the University of South Australia's Ownership and Retention of Data Policy.

Should you require any further information, please do not hesitate to contact my supervisor or myself. My contacts details are [redacted]

Principal Supervisor: [redacted]

Your consent is a component of my Human Ethics Application to conduct this study, and your assistance will be greatly appreciated.

Thank you for your time and assistance.

Yours sincerely

Mark Daker
PhD (Geographic Information Science) Candidate

COPY OF THE LETTER WHICH WILL BE SENT TO THE URBAN PLANNER WITHIN YOUR ORGANISATION

[redacted]

Date

Organisation Address

Dear *Name*

Position

I am writing to request your assistance as the principal urban planner for ########. I have obtained authorisation from ########### *CEO* to undertake this research at your organisation.

I am a PhD candidate in the School of Natural and Built Environments and the Centre for Population Health Research at the University of South Australia, and I am researching the following themes:

- Public open space planning standards and their implementation
- Associations between the characteristics and accessibility of public open space with population health outcomes
- The perceptions from urban planners on public open space supply applications.

The title of the research study: Public open space policy, supply and population health: a study of metropolitan Adelaide."

Principal Investigator: Mark Daker

Ethics Approval Number: [redacted]

Principal Supervisor: [redacted]

This project has been approved by the University of South Australia's Human Ethics Committee. If you have any concerns about the project or questions about your rights as participant, please contact the Executive Officer of this Committee, [redacted]

You are being asked to take part in a research study, and your participation is voluntary. If you do not participate, there will be no loss or repercussions for you or your organisation now or in the future.

The purpose of this part of the study is to obtain perceptions from urban planners on the definitions of open space, how public open space is implemented and associated population health outcomes.

The study will take place in January or February 2017. Principal urban planners in Local and State Governments and within the residential development industry are being asked to participate.

Your involvement will comprise one sessions of face-to-face semi-structured interview questions, which will last for up to an hour. This will be undertaken at a time and location convenient to you. You can withdraw from this interview at anytime and your data will be deleted unless you agree to the data being utilised.

The interviews will be audio-recorded (individually identifiable) with your permission and transcribed into a Microsoft Word Document. All records containing personal information will remain confidential, and no information

which could lead to the identification of any individual will be released, unless required by law. All documentation will securely be stored for seven years within the Centre for Population Health, as defined by the University of South Australia's Ownership and Retention of Data Policy.

Written documentation will re-identifiable (coded) and be retained in a locked filing cabinet and shredded after the timeline expires. Upon completion of the project all codes will be destroyed rendering the data non-identifiable. Electronic documentation will be stored on a secure university server and deleted after the seven-year timeline.

It is not anticipated that there are any risks to participation in this study beyond those encountered during everyday life. There are no costs to you or your organisation associated with participating in this study.

A copy of the final research report in a Pdf format will be emailed if requested.

If you agree to participate, please return a signed consent to be audio recorded and the confirmation section at the end of this letter to [redacted]

Your participation will help in the exchange of knowledge about public open space and population health and strengthen interactions between the University of South Australia and the urban planning profession in South Australia.

If you have questions or concerns regarding your participation in this research study, please contact my supervisor or myself; our details are on the first page of this letter.

Thank you for your time and assistance.

Mark Daker

PhD (Geographic Information Science) Candidate
BUrbRgnlPlan (Hons) (SocComm) GradCertProjMgmt

Appendix 5: Semi-structured interview questions.

My name is Mark Daker, and I am a PhD candidate at the University of South Australia. School of Natural and Built Environments and the Centre for Population Health Research.

My principal supervisor is [redacted]

I am undertaking research into ***"Public open space policy and supply and associations with population health: a study of metropolitan Adelaide.'***

During this semi structured interview, I would like to discuss public open space planning legislation, implementation and associations with population health. With this in mind, I would like to obtain your professional observations on the following questions.

Principal Questions	Additional Question
1. What do you personally consider to be public open space	• Can you provide examples
2. How does your organisation define public open space	• Can you provide examples • Can you tell me anything else about public open space
3. Within your organisation, what are the reasons public open space might not be implemented within a new development as defined in Sec 186 (1) a, b, c. Planning Development and Infrastructure Bill 2015	• Can you provide examples • Can you expand a little on this
4. Do you consider the legislated public open space guideline delivers sufficient allocations of public open space within metropolitan Adelaide, particularly within brownfield and infill developments advocating medium to higher densities	• If no, how could the public open space supply standard be improved
5. Do you personally recognise any associations between the built environment and population health	• Are there any policies that promote population health outcomes through public open space supply • Do you have any evidence that you could share about the impact of public open space policy on population health
6. Is your organisation actively promoting population health through the allocation of quality public open spaces E.g.: Sec 37 (2) a, g. South Australian Public Health Act 2011	
Conclusion of Interview	
7. Do you want to add anything regarding public open space supply standards and implementation?	• Can you expand a little on this

Your interviews responses will be analysed through NVivo software to categorise key phrases and words and to assist in identifying any patterns between the interviews to determine if there is any consensus.

All interview data will be kept strictly confidential and securely stored for seven years (UniSA guidelines).

No personal or organisational names will be disclosed in my thesis or other publications without prior written approval from those involved.

If requested, I can provide a copy of the interview notes and the final research outcomes.

I would like to thank you for your time and assistance.

My contact details are: [redacted]

Appendix 6: Signatory approval from the interviewee.

UniSA Research and Innovation Services

Human Research Ethics Committee
CONSENT FORM

Use this consent form when taped materials, photographs or original works are to be retained

This project has been approved by the University of South Australia's Human Research Ethics Committee. If you have any ethical concerns about the project or questions about your rights as a participant please contact the Executive Officer of this Committee, [redacted]

SECTION 1: CONTACT AND PROJECT DETAILS

Researcher's Full Name:	Mark William Daker
Contact Details:	[redacted]
Supervisor's Full Name:	[redacted]
Contact Details:	[redacted]
Protocol Number:	[redacted]
Project Title:	Semi-structured interviews with urban planners

SECTION 2: CERTIFICATION

Participant Certification

In signing this form, I confirm that:

- I have read the Participant Information Sheet, and the nature and purpose of the research project have been explained to me. I understand and agree to take part.
- I understand the purpose of the research project and my involvement in it.
- I understand that I may withdraw from the research project at any stage and that this will not affect my status now or in the future.
- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential unless required by law.
- I understand that I will be audiotaped during the interview
- I understand that the audio recording will be stored on a smartphone / iPad (password protected) and will be erased after the project has been completed
- A copy of the audio recording will be stored on the University of South Australia server (password protected) for seven years

.

Participant Signature	*Printed Name*	*Date*

Researcher Certification

I have explained the study to subject and consider that he/she understands what is involved.

Researcher Signature	*Printed Name*	*Date*

Appendix 7: Land use codes attributed to open space and recreation classifications.

LAND USE CODE	DESCRIPTION
4110	Vacant allotment conservation or recreation
4210	Wooded area conservation
4500	Reserve
4510	Undeveloped reserve
4520	Developed reserve
4530	Plantations/Standpipes and undefined land which cannot be sold
5560	Botanical garden and arboretum
7100	Outdoor arenas, sports oval
7105	Outdoor stadium, entertainment area
7110	Athletics
7120	Baseball
7130	Cricket
7140	Football
7141	Australian rules
7142	Soccer
7143	Rugby
7150	Hockey
7160	Lacrosse
7210	Archery
7220	Basketball
7230	Lawn bowls
7240	Croquet
7250	Tennis
7260	Sports ground NEC
7300	Golf course
7310	Golf—pitch and putt
7320	Golf—putt putt
7330	Golf—driving range
7420	Racing track—bicycle
7530	Parks and gardens including picnicking
7900	Recreation NEC
	NEC = Not Elsewhere Classified

Data Source: (DPTI 2015)

Appendix 8: Land use codes attributed to residential dwelling classifications.

Source: (DPTI 2015)

LAND USE CODE	DESCRIPTION
1100–1119	House
1200–1230	Multiple unit/Maisonette/Row house
1300–1329	Unit, Inc. multi storey
1330–1335	Townhouse
1410–1430	Flats Inc. multi storey
1912	Rural residential
2190	Shop and dwelling

Appendix 9: Invalid POS.

Name	Definition	Count
Aged care	Residential aged care facility	11
Airport	Airport	2
Campsite	Campground	1
Caravan park	Caravan park	19
Carpark	Car park	52
Cemetery	Cemetery	48
Coastal	Below the high tide mark, mangrove swamps	5
Commercial activities	Warehousing, shop, business	57
Community building	Community hall; scouts, girl guides, meals on wheels, cultural group and so forth (with no POS attached)	28
Construction site	Building site	6
Correctional facility	Prison or similar	3
Drainage channel	Stormwater channel with no public access	83
Dwelling	House	458
Emergency service	Country fire service, surf lifesaving, ambulance, State Emergency Service	14
Entertainment centre	Entertainment centre	1
Government house	Government house	1
Highway	Freeway, road, street, lane	365
Indoor sport centre	Indoor sports centre (with no POS attached)	22
Industrial activities	Factory, waste disposal centre	44
Kindergarten	Preschool	15
Link	Narrow path between streets with no vegetation	255
Marina	Marina	10
Military base	Military base	1
Motorsports	Car or motorcycle racing circuit/track	4
Primary production	Farmland, arable or pasture	64
Quarry	Mineral extraction	9
Railway	Railway infrastructure	34
Religious centre	Church, mosque, temple	11
River	River	4
Roadside vegetation	A narrow strip of vegetation (<1.5 m) possibly with footpath	1,117
School	Primary and secondary school	22
School | Private oval	Primary and secondary school oval	235
Stadium	Enclosed sports ground	10
Utilities infrastructure	Electrical substation, fenced transformers	15
Vacant land	Vacant building site	79
Water catchment	Locality around the reservoir, no public access, securely fenced	3
Wetland	No public access, securely fenced	4
Woodland	Private and fenced woodland or impenetrable native vegetation	22
Zoo	Zoo	1

Appendix 10: Description of improvements (2 pages).

Improvement	Definition
Air raid shelter	Air raid shelter (active)
Archery	Archery butts
Baseball	Baseball field
Basketball	Outdoor basketball court
BBQ	Public barbeque
Bench	Bench, seat (wooden or other)
Bicycle safety track	Sealed circuit for bicycle safety training
BMX	BMX dirt track (undulating, mounds, circuit)
Boardwalk	Elevated walkway
Boat ramp	Boat ramp
Bridge	Bridge
Carpark	Car park within a POS
Clubroom	Clubroom with POS (e.g., football club attached to oval)
Community centre	Community centre within POS
Community garden	Community garden
Covered sand-pit	Children's sand play pit
Creek	Natural stream
Cricket nets	Cricket practice nets
Croquet	Croquet court (often with clubroom)
Cycle path	Sealed surface and a paint marked cycle path
Dog park	Fenced area for off-leash dog exercise
Drainage	Drainage channel, artificial (e.g., concrete)
Formal garden	Structured, designed garden, botanical (not scrub like)
Fountain	Water feature
Go-kart track	Typically, sealed track for go-karting (maybe dirt)
Golf course	Golf course/ driving range
Greenhouse	Glass building to grow and protect plants
Half basketball	Single basketball hoop with a small sealed surface area
Handball	Foursquare
Helipad	The landing site for helicopter
Historic building	A building of significance within a POS
Indoor sport	Indoor sports centre with a POS
Kindergarten	Preschool
Kiosk	Small shop within POS
Lacrosse	Lacrosse field
Lake	Lake—water feature, typically larger than pond

Improvement	Definition
Lawn bowls	Lawn bowls (often with clubroom)
Maze	Maze
Memorial	Memorial
Mini golf	Golf putt putt
Model railway	Scaled railway transport system
MTB	Mountain bike track (dirt)
Netball	Netball court
Nursery	Garden centre within POS
Outdoor gym	Outdoor gym equipment
Oval	Oval, such as a field for Australian rules football or cricket
Path	Path (sealed or unsealed)
Petanque	Petanque, bocce, boules
Pier	Platform leading out from shore into a body of water
Playground	Playground
Pond	Pond—water feature, typically smaller than a lake and singular
Pony club	Area for equestrian activities
Rugby	Rugby field
River	A flowing body of water with POS
Running track	Track with clear markings for running (sealed or unsealed)
Sculpture	Artwork
Shade	An artificial structure providing shade (not waterproof)
Shed	Shed
Shelter	An artificial structure providing shelter (waterproof)
Showgrounds	Outdoor arena and associated structures with public access
Skatepark	Concrete (or similar) structure is for skateboarding, roller skating or BMX
Soccer	Soccer field
Stables	Equestrian activities
Steps	Steps (up or down)
Swimming pool	Outdoor pool with POS
Table	Table (e.g., picnic table)
Tennis	Tennis court (any surface, often with clubroom)
Velodrome	Velodrome, outdoor, publicly accessible
Viewing platform	Platform to enjoy a view from
Volleyball	Beach volleyball court
WC	Toilet (public convenience)
Wetland	Flood mitigation area, water retention area may include multiple ponds or lakes and may include naturalised habitat vegetation

Appendix 11: Description of activities (structured and unstructured).

Activity List	Definitions
Archery	Archery
Athletics	Track and field (running, shot putt, hurdles, javelin)
Baseball	Baseball
Basketball	Basketball, including half basketball
Cricket	Cricket
Croquet	Croquet
Cycling	MTB or BMX or road cycling
Equestrian	Equestrian activities (racing, jumping, dressage)
Football	Australian rules football
Go-kart	Go-karting
Golf	Golf course, driving range
Gridiron	Gridiron (American football)
Handball	Foursquare kids' handball
Hockey	Field hockey
Lacrosse	Lacrosse
Lawn bowls	Lawn bowls
Mini golf	Pitch n putt
Netball	Netball
Passive	Sedentary and unstructured physical activities (sitting and walking)
Petanque	Petanque, bocce, boules
Playground	Playground equipment for children's activities
Rowing	Rowing or similar boating activities
Rugby	Rugby league / union
Shooting	Rifle or pistol shooting
Skateboarding	Skate park, including jumps using a skateboard, roller skates or bicycle
Soccer	Soccer (football)
Swimming	Swimming at an outdoor pool
Tennis	Tennis
Volleyball	Volleyball (outdoor or beach)
Work out	Possible activities performed where there is an outdoor gym

Appendix 12: Subclassifications of validated POS.

Type name	Definition
POS	Public open space (reserve or local open space within residential areas)
Botanic garden	Formalised garden (open to the public)
Coastal	POS adjacent to the seafront and above the high tide limit
Conservation park	Natural park (native vegetation, large area, open to the public)
Linear	Narrower vegetated space (cycle path, a pedestrian link between roads)
Linear park	Linear park (e.g., River Torrens)
National park	National park (native vegetation, large land area, open to the public)
Recreation park	Naturalised park supporting outdoor activities (e.g., walking, running cycling)
Sport	Sports ground (e.g., Australian rules football, tennis, golf, lawn bowls)
Wetland	A POS with a significant area of retained water and naturalised vegetation. Alternatively, an area assigned as a stormwater retention system

Appendix 13: POS shape profiles.

Shape description	Definition
Irregular	Uneven in its symmetry and uniformity in contrast to regular shapes
Linear	Notably longer than it is wide, for example, pathway (approx. rectangular)
Linear irregular	Notably longer than it is wide with no continuous straight edge
Ovoid	Approx. oval, egg-shaped
Rectangular	Approx. rectangular shaped
Semi-circle	Approx. semicircular shaped
Square	Approx. square shaped
Triangular	Approx. triangle shaped

Appendix 14: POS 2016 attribute table.

Field name	Definition
POS_ID	Individual identification number 0 to >
Name	Name of POS (identified from Streetview imagery)
Valuation	Valuation code from cadastre (from cadastre layer)
Suburb name	Suburb name (from cadastre layer)
Postcode	Postcode (from cadastre layer)
LGA name	Local Government Area (from cadastre layer)
Area sq. km	Area of POS (*Column Update*)
Perimeter km	Perimeter of POS (*Column Update*)
X	Latitude coordinate (*Column Update*)
Y	Longitude coordinate (*Column Update*)
Land use codes	Land use codes (from cadastre layer)
Improvements	Features on the site (for example path, BBQ, tennis, lawn bowls, river) (identified from aerial and Streetview imagery)
St number	Street number (from cadastre layer)
Street name	Street name (from cadastre layer)
Street type	Street type from cadastre for example road, place, Boulevard (from cadastre layer)
Suburb	Suburb name (from cadastre layer)
Activity count	Passive as default and then a count of individual physical activities (identified from aerial and Streetview imagery)
Activity list	Passive as default then named individual physical activities (identified from aerial and Streetview imagery)
Developed	A maintained space or a naturalised space (identified from aerial and Streetview imagery)
Playground	yes or no (identified from aerial and Streetview imagery)
Shape description	Eight shape profiles: irregular, linear/linear irregular, ovoid, rectangular, triangular, semi-circle, square and triangular (identified from aerial imagery)
Other	Additional type name references for example link defined a footpath (link) (identified from aerial and Streetview imagery)
Type name	Ten definitions: POS, Botanic Gardens, Coastal, Conservation Park, Linear/Linear Park, National Park, Recreation Park, Sport and Wetland (identified from aerial and Streetview imagery)
Status	0 = unchecked, 1 = valid, 2 = new POS, 99 = invalid
Area sqm	Area of POS (*Column Update*)

Appendix 15: Example of completed attribute table from VPOS2016.

Pos_id:	3,403
Name:	
Valuation:	2504813151
Suburb_nam:	St.Clair
Postcode:	5,011
Lga_name:	Charles Sturt
Area_sq_km:	0.02574735059
Perimeter_:	0.95594721821
X:	138.531800794
Y:	-34.8676629239
Land_use_c:	4,500
Improvemen:	playground, shelter, bench, table, BBQ, lake
St_number:	
Street_nam:	St Clair
Street_typ:	Av
Suburb:	St Clair
Address:	
Activity_c:	2
Activity_l:	passive, playground
Developed:	y
Playground:	y
Shape_desc:	irregular
Other:	
Type_name:	POS
Status:	2
Area_sqm:	25,747.35
Category:	

Appendix 16: Local government development plans open space hierarchies.

LGA	Local Government development plan POS hierarchy			
	Regional	***District***	***Neighbourhood***	***Local***
Charles Sturt		District level should be at least 3 ha and within 2 km of all households	Neighbourhood Level should be at least 0.5 ha to 1 ha and 500 m of all households	Local open spaces should be a minimum of 0.2 ha and 300 m of all households
Gawler		District level should be at least 3 ha and within 2 km of all households	Neighbourhood Level should be at least 0.5 ha to 1 ha and 500 m of all households	Local open spaces should be a minimum of 0.2 ha and 300 m of all households
Holdfast Bay		District level should be at least 3 ha and within 2 km of all households	Neighbourhood Level should be at least 0.5 ha to 1 ha and 500 m of all households	Local open spaces should be a minimum of 0.2 ha and 300 m of all households
Marion		District level should be at least 3 ha and within 2 km of all households	Neighbourhood Level should be at least 0.5 ha to 1 ha and 500 m of all households	Local open spaces should be a minimum of 0.2 ha and 300 m of all households
Norwood Payneham And St Peters	Regional should be 200 ha At least 4 ha per 1,000 population	Major district level should be 20 ha and within 5 km of household Minor district level should be 10 ha and 1 km of households		Local open spaces should be at least 0.5 ha to 1 ha and within walking distance of households
Onkaparinga		District level should be at least 3 ha and within 2 km of all households	Neighbourhood Level should be at least 0.5 ha to 1 ha and 500 m of all households	Local open spaces should be a minimum of 0.2 ha and 300 m of all households
Playford		District level should be at least 3 ha and within 2 km of all households	Neighbourhood Level should be at least 0.5 ha to 1 ha and 500 m of all households	Local open spaces should be a minimum of 0.2 ha and 300 m of all households
Port Adelaide Enfield		District level should be at least 3 ha and within 2 km of all households	Neighbourhood Level should be at least 0.5 ha to 1 ha and 500 m of all households	Local open spaces should be a minimum of 0.2 ha and 300 m of all households
Salisbury		District level should be at least 3 ha and within 2 km of all households	Neighbourhood Level should be at least 0.5 ha to 1 ha and 500 m of all households	Local open spaces should be a minimum of 0.2 ha and 300 m of all households
Tea Tree Gully		District level should be at least 3 ha and within 2 km of all households	Neighbourhood Level should be at least 0.5 ha to 1 ha and 500 m of all households	Local open spaces should be a minimum of 0.2 ha and 300 m of all households
Walkerville		District level should be at least 3 ha and within 2 km of all households	Neighbourhood Level should be at least 0.5 ha to 1 ha and 500 m of all households	Local open spaces should be a minimum of 0.2 ha and 300 m of all households
West Torrens		District level should be at least 3 ha and within 2 km of all households	Neighbourhood Level should be at least 0.5 ha to 1 ha and 500 m of all households	Local open spaces should be a minimum of 0.2 ha and 300 m of all households

Sources: (Charles Sturt Council 2016; Gawler Town Council 2016; Holdfast Bay Council 2016; Marion Council 2016; Norwood Payneham and St Peters City Council 2016; Onkaparinga Council 2016; Playford Council 2016; Port Adelaide Enfield Council 2016; Salisbury Council 2016; Tea Tree Gully Council 2016; Walkerville Council 2016; West Torrens Council 2016).

Appendix 17: Excel spreadsheet; representation of field validation workbook.

POS ID	Name	Street name	Street type	Suburb name	Improvement	Activity count	Activity list	Status	Photo no.	Photograph GPS coordinates
273		Crossdale	Dr	Aberfoyle Park	path	1	passive	1	423	3507375 13860355
363		Monaro	Ct	Aberfoyle Park		1	passive	1	422	3506632 13860705
836		Jade	Cres	Aberfoyle Park		1	passive	1	420 421	3506357 13860019
1267		Greenville	Cl	Aberfoyle Park		1	passive	1	424	3507927 13860489
1103		King William	St	Adelaide	path	1	passive	1	81	3493089 13859995
1522		North	Tce	Adelaide	memorial, path, bench	1	passive	1	427	3492117 13860191
1526	Whitmore Square, Ivaritji	Whitmore	Sq.	Adelaide	path, bench, half basketball **WC**	2	passive, basketball	2	82 & 83	3493278 13859499
3043	Walyo Yerta, Veale Gardens	South	Tce	Adelaide	community garden, ~~**greenhouse**~~**(demolished)**, path, creek, clubroom, tennis, netball, bench, WC	6	passive, hockey, cricket, soccer, netball, tennis	2	84, 85, 86 & 87	3493619 1385956 3493742 13859671 3493665 13859712 3493634 13859664
3245	Hurtle Square, Tangkaira	Hurtle	Sq.	Adelaide	path, bench	1	passive	1	77	3496880 13866058

Status	Classification
1	Valid POS
2	Update to improvement / activity List
3	Invalid POS

Appendix 18: Garmin Etrex 20: handheld GPS recorder.

