



SOUTHERN NSW
Innovation Hub

SUSTAINABLE AGRICULTURE,
LANDSCAPES AND COMMUNITIES

SHARING EARLY INSIGHTS FOR MORE RESILIENT COMMUNITIES

STAGE 1 REPORT | JUNE 2023



UNIVERSITY OF
CANBERRA

This report presents key findings from the first stage of the Sharing Early Insights for More Resilient Communities project, an initiative led by the University of Canberra and part of the Australian Government's Agricultural Innovation Hubs Program. These findings will inform the development of an early warning tool for communities in Southern NSW.

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EXECUTIVE SUMMARY

INTRODUCTION

This report presents the key findings from the first stage of the *Sharing Early Insights for More Resilient Communities* project. Many NSW communities have experienced different types of extreme weather events over recent years and are in differing stages of disaster preparation, response and recovery (and often all three at the same time). This project aims to identify measures that can act as 'early indicators' that resilience loss is occurring, or accelerating, in a community, allowing for earlier intervention that reduces the extent of loss, hardship and mental health damage that occurs. The project will then use these measures to develop and test tools that can be used by services and organisations at various stages of the disaster preparation and recovery cycle to help identify communities and/or groups experiencing resilience loss at earlier, rather than later, stages of change.

This report presents findings from the first stage of the project. The aim of this stage is to inform the development of an early warning tool that can be used by communities in Southern NSW to monitor changes in resilience in ways that enable identification of earlier change (as well as, in many cases, later stage changes).

There are three main outcomes of this stage of the project:

1. A list of priority resilience indicators for which it is likely to be possible to measure change over times in ways that not only identify what level of resilience is present, but how rapidly and to what extent that levels is changing (thus enabling identification of 'early warning indicators' of resilience loss, as well as of positive change in resilience levels).
2. A list of potential data sources for priority resilience indicators.
3. Specifications for the development of a tool which can rapidly communicate changes in resilience to service providers working in Southern NSW.

This project is a joint initiative with the Southern NSW Drought Resilience Adoption and Innovation Hub (from this point forward referred to as the Southern NSW Innovation Hub) and forms part of the Australian Government's Agricultural Innovation Hubs Program. The project is being conducted by the University of Canberra, Australian National University, Charles Sturt University, and University of Wollongong.

METHODS

To inform the outcomes of this stage of the project, the following activities were undertaken:

- i. A rapid literature review to identify indicators used in previous resilience frameworks and studies and assess the appropriateness of these indicators to actively track changing levels of resilience over time.
- ii. A series of stakeholder workshops with people actively working across regions in NSW that have experienced cumulative extreme events; workshop participants helped prioritise which indicators will be examined in subsequent stages of the project.
- iii. Synthesis of findings of (i) and (ii) by the project team to finalise the outcomes of this stage of the project.

Throughout this phase of the project, it was important to examine the differing definitions of resilience in the literature and consider which definition of resilience will be used for the purpose of this project. Reviewing these definitions was completed as part of the literature review. The following definition of resilience was identified for use in this project:

The capacity of individuals and communities to prepare for, respond to, recover from, and adapt to natural hazard events, with this capacity supporting a reduction in negative impacts and more rapid recovery from those negative impacts that do occur.

OUTCOME 1: PRIORITISING RESILIENCE INDICATORS

Background

The rapid literature review identified over 500 indicators used to assess natural disaster resilience, however many of these indicators were not suitable for use as measures of changes in resilience, or more specifically as early warning indicators of resilience loss. Most current resilience indexes (and indicators) have been developed for the specific purpose of assessing the capacity and vulnerability of communities to withstand and/or mitigate the impact of natural disasters or crises before they occur. This means many are not suitable for use as early warning indicators of resilience loss as they (i) can be limited in their ability to measure *change* in levels of community resilience, and (ii) often focus on a particular phase of the disaster cycle (e.g. preparation phases) or on a specific point in time (for example by using a score card system).

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To help prioritise which existing and newly proposed indicators identified from the literature review and stakeholder workshops may be appropriate for use as early warning indicators of resilience loss the following criteria were developed for selecting indicators:

- **Interpretability.** The indicator should be measurable in ways that have clear, consistent interpretation.
- **Ability to measure level of resilience.** Measures should have clearly defined thresholds to indicate the level of resilience an individual/community has, for example indicating low, moderate or high resilience.
- **Sensitivity to change.** Change in the indicator is able to, or potentially be measured in a way that is sensitive to relatively small changes in resilience levels.
- **Timeliness.** Indicators needed to be able to be measured early in the process of resilience loss to be suitable as an early warning signal, and able to be measured regularly – at least once a year.
- **Ability to measure change over time.** Change over time must be measurable in meaningful increments.
- **Validity.** There must be evidence demonstrating that change in the indicator was an indicator of change in capacity to successfully navigate challenging times (i.e., resilience).
- **Relevance to study region.**
- **End user prioritisation.** Feedback from the stakeholder workshops was used to assess end user prioritisation.

Findings

The following indicators were selected as a high priority to examine in the second stage of this project if they met the criteria outlined above. They have been grouped according to commonly used themes or domains of resilience described in the literature.

Financial resources – individual household

The financial resources of an individual/household contribute to resilience in many ways. Broadly speaking, having access to financial resources enables a person/household to implement a range of actions that can support preparation for, response to, or recovery from a natural hazard event. In workshops with key stakeholders, indicators of financial distress were identified as an important sign of resilience loss.

Priority indicators for financial resources at the individual level were possession of financial assets, employment, financial stress, income/prosperity, standard of living/affordability of living costs and access to insurance.

Financial resources – community

'Community' financial resources are those indicators of financial resilience which are not measured at the scale of the individual or household which can be used to indicate overall community economic performance. Stakeholders raised issues related to funding of critical services and availability and affordability of housing as important financial resources at the community level.

Priority indicators for financial resources at the community level identified include income distribution and average, real estate availability and affordability, revenue per capita, economic activity and economic diversity.

Health and wellbeing – individuals and communities

Good health and wellbeing are strongly associated with resilience, making them appropriate for use as an early warning signal of resilience loss, rather than relying solely on indicators of physical and mental illness alone. Participants in the workshops regularly identified declining mental health (including increasing incidences of mental illness) as a warning signal of resilience loss.

Priority indicators for health and wellbeing identified included mental health, healthy behaviours, overall health and life expectancy.

Human resources and functioning – skills and capacity of individuals

Indicators relevant to this domain of resilience refer to aspects related to a person's skills and psychological resources. It includes not only formally attained qualifications, but also psychological resources such as a sense of optimism and coping skills. Personal skills and capacity were frequently discussed in stakeholder workshops, and often rated as more important than commonly used indicators from the literature such as attainment of formal education.

Priority indicators identified included personal psychological resources, confidence in the future, personal skills and educational attendance and performance.

Social resources – individual/household

Social resources – often referred to as social capital – are resources people access via social interaction with others. Mirroring findings from the literature review, changes in social resources were identified as a key indicator of resilience loss at stakeholder workshops. In particular, workshop participants discussed changes in social cohesion and incidence of conflict among community members as important signs of change in resilience.

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Priority indicators for social resources at the individual/household level identified include engagement with social groups/organisations, volunteering, self-rated access to social support, support networks and social cohesion.

Social resources – community

Social resources at the community level are closely related to social resources at the individual level, and indicators present in the literature are heavily focused on indicators such as the number of services/organisations present in a community, rates of volunteering, and length of residence rather than more difficult to measure indicators of social cohesion. The concept of community cohesion was identified as a very important resilience resource by workshop participants, especially when reflecting on examples of when recovery went well. Lack of social resources, or indicators of community disengagement were also identified as important challenges being faced by participants in the workshop as early indicators of resilience loss experienced by communities following climate-change related disasters.

Priority indicators for social resources – community identified from the literature and workshops include the presence of functioning community organisations, participation in community activities, inter-community social resources, intra-community social resources, community gathering places, community cohesion and length of residence.

Infrastructure and services

Having good access to a range of types of infrastructure and services is widely recognised as important to maintaining resilience. The types of infrastructure and services identified in the literature and workshops range widely. While indicators in the literature tended to focus on (i) changes in the availability of key infrastructure as a result of climate-change disasters, and (ii) efficient and effective restoration following events, workshop participants discussed issues related to access and quality of infrastructure and services over the medium to longer term.

Priority indicators for this domain include ability to access health services, social service and care sectors, grocery/domestic goods supply, transport infrastructure, telecommunications infrastructure, residential housing infrastructure, emergency services infrastructure, water sanitation, energy, education services, community infrastructure and financial/professional services.

Institutional resilience

Living in a community in which there is effective, transparent, and accountable governance that treats all people fairly and equitably make an important contribution to resilience. This can be directly through the fair allocation of funding, strong local leadership and equitable treatment of those people and groups living in a community. Institutional resources can also impact indirectly on overall resilience through limiting the functioning of services, businesses and systems within a community that allow them to effectively prepare, respond and recover from climate change related disasters. There are relatively few indicators of institutional resilience available in the resilience literature. Issues related to burnout of leadership, financial health of local government and funding were raised by workshop participants.

Priority indicators of institutional resilience identified in this report include leadership and participation in local government.

Ecosystem service provision

Changes in health of the natural environment are important indicators of resilience. Decline in environmental health has many implications for human resilience, through changing availability of the ecosystem services humans often rely on. While vital for the long-term sustainability of the planet and human health, changes in environmental health occurring over the long-term are not the focus of this project. Instead in this report we seek to identify indicators related to ecosystem health that provide insight into shorter-term change in human resilience. Specifically, those that focus on change in the quality and quantity of ecosystem services available to humans. Indicators of ecosystem service provision in the literature often focused on coverage and health of natural resources such as soil, water, vegetation and land; and the integration of these resources within population centres. In workshops, ecosystem resources were often discussed in terms of peoples emotional and psychological responses to the loss of environmental health during and following a climate-change related event.

Priority indicators for ecosystem service provision include overall ecosystem health, extreme weather absorptive capacity, soil health, water quality, air quality and perceived environmental health.

Other aspects of liveability

'Liveability' refers to the extent to which a community provides a physical, economic and social environment that supports a high quality of life. While many indicators related to 'liveability' can be included as part of other resilience domains, others were raised in workshops, and included in resilience frameworks found as part of the literature. These include indicators related to local physical environment (natural and built), crime and safety, and culture and identity.

Priority indicators for these aspects of liveability include amenity, crime and safety, and culture and identity.

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Natural hazard resources – individual/household

When resilience to natural hazards such as disasters and drought is discussed, one of the first things often discussed are the level of specific skills, resources and infrastructure in place that help people and communities reduce the impact and damage that occurs from natural hazards. Many natural disaster resilience indicators found in the literature are focused on natural hazard resources, and many were raised by workshop participants.

Priority indicators identified in this domain include awareness of community emergency resources, hazard risk perceptions, preparedness and past natural hazard experience.

Natural hazard resources – community

In addition to natural hazard resources at the individual/household scale, a large number of community-scale natural hazard resources can contribute to building resilience to natural hazards. These are extensively discussed in the literature, and were raised in the stakeholder workshops. While many of these indicators will cross-over with other resilience domains (such institutional and social resources) they are specific to resources required for effectively preparing, responding and recovering to natural hazards/disasters and therefore warrant a specific domain.

Priority indicators for natural hazard resources at a community scale include training of disaster preparation, response and recovery personnel, population risk vulnerability identification, disaster planning, disaster coordination, institutional conflict related to disaster management, funding availability, burnout of staff and volunteers, information dissemination and equity of access.

Exposure to natural hazards

Indicators relevant to exposure to natural hazards feature heavily in the natural disaster resilience literature. While exposure to natural hazards is not a type of resilience resource, the frequency, intensity, and duration of events a person, household or community experiences directly affects their capacity to prepare, respond and recover. Whereas indicators in the literature typically focus on identifying risk of a single hazard occurring, workshop discussions emphasised the importance of developing indicators to identify the *cumulative* exposure and individual, household or community experiences.

Priority indicators for exposure to natural hazards include natural hazard occurrence and natural hazard risk.

Socio-demographic and geographic variables

A decision was made not to use socio-demographic characteristics as indicators of resilience in this project. While it is relatively common for resilience frameworks to use these indicators (especially as measures of social resilience), such measures are limited in their capability to act as early warning signals as they (i) either cannot be changed or infrequently change and (ii) are not on their own a reliable indicator of high/low resilience. For example, age is often used as an indicator of social resilience, with a high percentage of elderly population indicating lower levels of community resilience. As an indicator, the percentage of a community over a certain age would be unlikely to change at rate frequent enough for it to be used as an early warning indicator. Further, it is difficult to ascertain a person's level of resilience based on their belonging to a particular age category alone. Finally, there is a significant ethical concern with labelling entire groups as having low resilience simply by virtue of their membership of that group, an approach which risks stigmatising that group and is not consistent with strength-based perspectives. For example, an older person has sufficient financial and social resources, and good access to services, their level of resilience may be considerably higher than a younger person lacking these resources. Given this, our approach focuses on measuring indicators that are more directly related to high/low resilience rather than using membership of a particular group as a 'proxy' for resilience.

OUTCOME 2: DATA SOURCES TO BE EXPLORED

A large number of potential indicators of change in resilience were identified. Potential data sources that can be used to measure these indicators were also identified. These potential data sources were identified by members of the expert project team, and also informed by stakeholder workshops. The main sources of data identified in this report include:

- **Regional Wellbeing Survey:** Run by the University of Canberra since 2013, the Regional Wellbeing Survey (RWS) will be used for this project in two ways. First, past data from the survey will be analysed to produce time series information for indicators, and to identify potential recommendations for thresholds and confirmation of the usefulness of some indicators. Any indicators for which 'existing' is noted in this column are indicators where historic data is available from the Regional Wellbeing Survey, usually collected multiple times since 2013.
- **Special RWS data collection:** Collection of survey data will be undertaken in southern NSW for this project using the RWS. This will include both previously measured indicators and new indicators designed for this project to enable testing and development of a number of the indicators identified in Stage 1, particularly where no other data sources exist.
- **Other survey data:** This indicates that data for an indicator are available from other surveys known to have included the measure proposed. These include ABS surveys, the HILDA survey, and others.
- **Administrative data:** This refers to data held by government, at local, state or federal level.

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- **Social media analysis:** This refers to production of indicators through systematic analysis of social media content.
- **Online search analysis:** This refers to production of indicators that use data about the types of terms people have searched for online using search engines such as Google.
- **Other organisation data:** A range of other organisations may hold data that enables population of a measure. These include insurance companies, banks, the health sector and organisations providing a range of other types of services.

OUTCOME 3: DEVELOPING A DATA TOOL THAT WORKS FOR END USERS

The first stage of the project identified key insights into the type of data ‘tool’ needed by those intended to be end-users of the indicators measured in this project – the wide range of organisations, from local to national, working in the areas of drought and natural hazard preparation, response and recovery. These end users are typically very busy, and not always highly data literate. This means that any data tool needs to make data for multiple indicators easily accessible in one place, and provide plain language interpretation that enables users to understand what each indicator means, and what change in it means. A set of key characteristics needed in a data interface was identified and is documented in this report. Data interface here means a tool such as a website or app developed to enable users to interact with resilience indicator data.

Conclusions and next steps

The findings presented in this report will guide the second and final stage of the project, ensuring that project outcomes are evidence-based and relevant to the needs of the service providers. While it is not expected all indicators and data sources included in this report will form part of the early warning tool developed, the findings presented in this report allow for the progression of objectives relevant to the final stage of the project. These include:

1. Systematically testing and finalising a set of early warning indicators that can provide timely, geographically relevant and accurate information on levels of resilience loss experienced by communities in the project region.
2. Development of an early resilience warning tool that can present this information to service providers and community groups in a way that is useful to their needs.

The final report from the project will report on these objectives, and identify further opportunities for future work in this area. This may include expanding the tool developed to include indicators for which data could not be sourced in this initial pilot project, and further work to improve the accessibility, useability and relevance of the data platform.



1. INTRODUCTION

Extreme climate events such as droughts, bushfires and floods are becoming more common. Across Australia, the frequency and intensity of extreme weather events including droughts, floods, severe storms, and bushfire, has increased in recent years, and is projected to increase further due to the effects of human-induced climate change (Binskin et al., 2020).

This increased frequency of extreme weather events – sometimes referred to as disasters, or as natural hazards – has many impacts. Amongst them is that communities across Australia are increasingly experiencing cumulative natural hazard events, with little time between events to recover from the previous event or prepare for the next one (Binskin et al., 2020; Dare et al., 2021). This creates a situation in which many households and communities are simultaneously attempting to respond to an extreme weather event such as a drought, flood or fire, while also experiencing ongoing impacts of previous extreme events, and seeking to invest in reducing the potential impacts of future events. All three of these things – preparing for future events, responding to current events, and managing the impacts of past events – require people and communities to draw on a wide range of resources. These can include financial resources, social support, government and community organisations, personal skills and resources, and local infrastructure. Together, these resources provide resilience – the resource and capability drawn on to support community and individual capacity navigate all stages of challenges, from preparation to recovering from impacts.

Resilience resources are, of course, drawn on to navigate any type of challenge, not just those presented by extreme weather events. At the same time they experience extreme weather events, many people are navigating other challenges in life, such as divorce, illness, economic downturn, difficulty meeting cost of living, or other challenges. These other stressors may exacerbate or be exacerbated by extreme weather events. The same resources that people draw on to help prepare for, respond to, and recover from the impacts of extreme weather events are also drawn on to help navigate the many other challenges people may be experiencing.

There is growing interest in how local communities can navigate ongoing extreme weather events while maintaining household and community resilience resources at sufficient levels to enable these households and communities to be able to maintain their quality of life over time. This is particularly important as it is likely that many communities will face multiple events and challenges over a period of years, as the frequency of climate-change related hazard events increases (Binskin et al., 2020).

As communities experience growing numbers and intensity of extreme weather events, it is becoming increasingly important to be able to monitor overall capacity of people in those communities, and the community as a whole, to maintain their quality of life. This capacity to achieve a good quality of life depends in large part on whether people and communities are able to maintain the resilience resources that are so central to responding to challenging times – including preparing for, responding to, and recovering from challenges.

The aim of the Resilient Communities Southern NSW Innovation Hub project, *Sharing Early Insights for More Resilient Communities project* (from this point referred to as 'the project') is to develop and test 'early warning' indicators for loss of resilience following challenging climate-related events. These indicators will be used to develop a resource that can be used to by the wide range of organisations and services to identify communities in the early stages of resilience loss and provide targeted support to agricultural communities.

This project is a joint initiative with the Southern NSW Drought Resilience Adoption and Innovation Hub (Southern NSW Innovation Hub) and forms part of the Australian Government's Agricultural Innovation Hubs Program.

The project is being conducted by the University of Canberra, Australian National University, Charles Sturt University, and University of Wollongong.

Through understanding early warning signs that individuals and communities are at risk of resilience loss, we could inform policy and support service interventions earlier. This would provide communities with the necessary support to mitigate wider and longer lasting resilience loss related to the impacts of a climate events, which in turn, would reduce the overall harm to lives and livelihoods and facilitate resilience building across physical, psychological, social, economic, domains.

This report presents findings from the first stage of the project, which sought to identify indicators that can be used to monitor changes in resilience in ways that enable identification of earlier change (as well as, in many cases, later stage changes). To do this, a review of indicators used in previous resilience frameworks and studies was conducted, focusing on identifying the extent to which indicators could be used to actively track changing levels of resilience over time. This was followed by conducting stakeholder workshops with those actively working in a number of NSW regions that have experienced cumulative extreme events. In those workshops, stakeholders discussed the signs they saw when resilience was changing in the communities they worked in. This was used to identify additional indicators beyond those identified in the literature review, as well as to assist in prioritising which indicators would be examined in subsequent stages of the project.

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The findings presented in this report will guide subsequent stages of the project, which will seek to access data for the indicators identified as high priority, and to collect data for some via a survey of communities. Parallel to this data collection, a data platform will be developed that enables stakeholders working in communities that are experiencing cumulative extreme weather events over time to easily access relevant data as a proof of concept on how resilience is changing in their community. This platform will be populated with data for those indicators that are successfully measured in the second stage of the project, and provide a pilot platform of the concept of more actively monitoring change in resilience over time. The final report from the project will identify further work to be done, including types of indicators for which data could not be sourced in this initial pilot project, and further work to improve the accessibility, useability and relevance of the data platform.

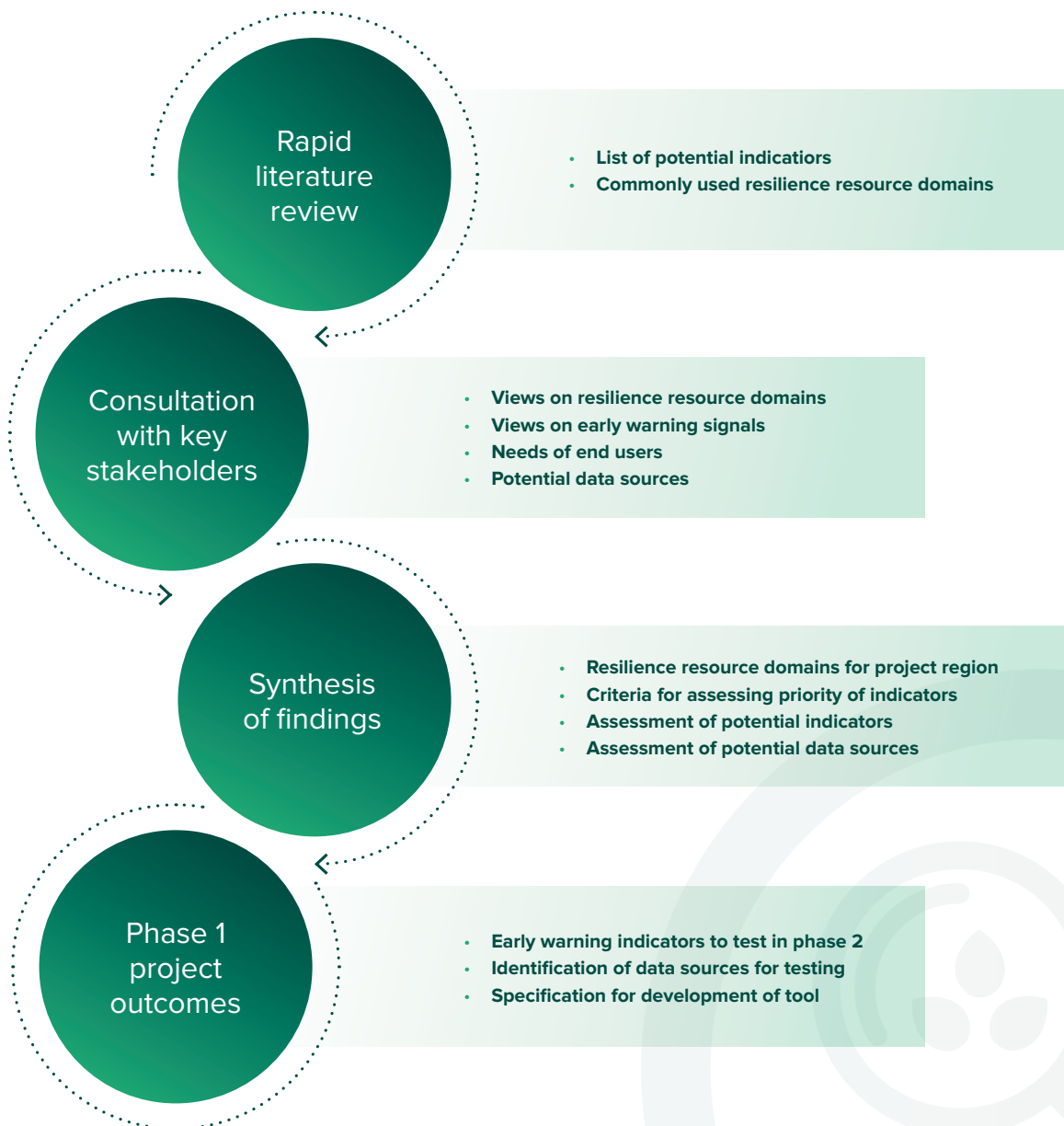
The overall aim of this project is to develop indicators, methods for rapidly collecting and processing data for some of these indicators, and a prototype of a data platform that could enable rapid dissemination of information about how resilience is changing in different communities. Through this, we aim to provide information that can be used by those working in southern NSW communities that are preparing for, responding to and recovering from cumulative extreme weather events to help support and enable work to build and maintain resilience in those communities.



2. METHODS

In order to achieve the objectives of the first stage of this project, there were two key components of data collection – a rapid review of natural disaster resilience indicator literature and semi-structure workshops with key stakeholders. As outlined in Figure 1, the findings from each of these components were synthesised to produce the findings in this report.

Figure 1 Summary of methods used in Stage 1



RAPID LITERATURE REVIEW

The rapid literature review examined the resilience indicators found in the natural disaster literature, and from these identify which indicators and measures could serve as early warning indicators of resilience loss in communities impacted by climate-change related disasters. The rapid literature review process involved a systematic search of the published literature, followed by a screening process to exclude literature not relevant to the aims of the project. Full details of the search strategy and the study inclusion and exclusion criteria can be found in Appendix 1. Members of the research project team were also invited to add eligible papers not identified in database searches. A total of 113 papers were included in the literature review. Each paper was assessed individually by members of the project team, and details relating to the use of specific resilience indicators/measures, and approaches adopted in the literature in relation to the categorising/conceptualising domains of resilience resources was recorded and summarised.

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STAKEHOLDER WORKSHOPS

Nine stakeholder workshops were held online over two weeks in March 2023, using Webex. The stakeholder workshops sought the views of a wide range of stakeholders working with communities across the Southern NSW Innovation Hub project region. These stakeholders were asked to discuss the signs they had observed when resilience was changing – in particular, when it was declining – in the communities they worked in. They were also asked to discuss their views about the different types of resilience indicators identified in the literature review as having potential relevance as ‘early warning signals’.

Workshop participants

A total of 40 participants attended the workshops with a maximum of seven people attending any one workshop. The people invited to the workshops were chosen as they were either existing contacts provided by the Southern NSW Innovation Hub or identified as working with communities in southern (or in some cases, northern) NSW in a range of roles related to community development, social service provision, and/or to support preparation for, response to, or recovery from natural hazard events. Participants were selected based on their work with communities that have experience with one or more natural hazard events and knowledge of community recovery processes. The workshops aimed to include a range of people with diverse experiences and perspectives. Snowball sampling was also used with participants being asked to forward the workshop invite to people who may be interested in the project and have experience working with communities impacted by natural hazard events. The aim of the sampling was to achieve a diversity of views through ensuring participation of stakeholders working in a range of different communities, and with a range of different types of organisation. Of the 40 participants, 19 had roles that involved state-wide activities (16) or nation-wide activities (3), rather than focusing on a specific community. The remaining 21 worked in a diverse range of communities, including the local government areas of Queanbeyan-Palerang (2), Eurobodalla (3), Hawkesbury/Sydney (3), Blue Mountains (4), Snowy Monaro (1), Forbes (2), Wollongong (1) and northern NSW areas (2). Participants included people working with local governments, with a range of NSW and Australian government agencies, non-governmental organisations (NGOs) in a number of areas, and also included some individuals who provided leadership in an ‘informal’ capacity such as through managing a grassroots campaign (Table 1). Several participants had multiple roles: for example, many NGOs deliver services under contract by government, meaning that organisational roles have complex inter-relationships not reflected in Table 1. Similarly, it is common for some disaster recover roles to be funded by one level of government and appointed and acting in another (e.g. Local disaster recovery organisation or project funded by federal government). Government staff were classified based on where they worked rather than by who funded their role.

Table 1 Workshop participants by organisation type

ORGANISATION TYPE	WORKSHOP PARTICIPANTS
Local government	8
State/Australian government	10
NGO – formal	15
NGO – informal	2
Individual leader/coordinator (informal)	3
Other	2
Total	40

Workshop structure

The workshops were semi-structured, with a set of resources and discussion topics designed that were used to guide discussion about participant’s experiences and observations of when communities recovered well or not well from natural hazard events. These broader questions aimed to prompt participants to think about the signs that their communities were losing resilience and what were the earlier indicators that they were at risk of resilience loss. Subsequent workshop activities presented existing indicators in the literature and ideas from the project team and participants validating whether they apply to their community and whether information would be useful them in measuring resilience. Although we aimed to identify how participants would like indicators to be presented in a data communication tool, as the workshops were held online and time was limited, the facilitators prioritised identifying resilience indicators, with the discussions held revealing the ways stakeholders thought about, and preferred to communicate, data of this type.

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Ethics and confidentiality

All workshop participants were provided with an information sheet and informed about the workshop beforehand. Participants consented to the workshop being audio and video recorded and transcribed and they were able to ask for the recording to be turned off at any time. As the workshops were conducted in groups, participant anonymity was not guaranteed however, any information disclosed during the workshop remained within the research team. Any names or identifying information were also excluded from any publications. Ethics approval was granted by the University of Canberra Human Research Ethics Committee (protocol number 12-186).

Thematic analysis to identify indicators

Workshops were transcribed using an online transcription service and then analysed using Nvivo 12 to extract indicators suggested by participants. The groups of indicators and number of codes identified can be found in Appendix 2.

SYNTHESIS OF FINDINGS FROM THE RAPID LITERATURE REVIEW AND STAKEHOLDER WORKSHOPS

Findings of both the literature review and stakeholder workshops were brought together and synthesised to present the key outcomes of this report. Bringing together findings from both these data sources helped ensure that the priority indicators selected for the second phase of this project were both informed by the resilience literature, and relevant to the specific needs of communities in the project region.

Bringing together the data from both the literature review and stakeholder workshops involved the following:

1. Presenting a summary of the key themes/domains of resilience resources identified in the literature to stakeholders in the workshop and assessing participant support of these themes.
2. Compiling a comprehensive list of potential early warning resilience indicators/measures relevant to climate change related events using data from both the literature review and stakeholder workshops
3. Development of a criterion to assess the appropriateness of each potential indicator/measure identified above to help inform the selection of a small number of indicators/measures to be tested in phase two of the project. The development of this criteria is based on expert advice from the project team, data from stakeholder workshops and relevant published and grey literature.
4. Using this criterion, members of the project engaged in a collaborative process by which each indicator/measure was assessed, and recommendations were made as to which indicators/measures and data sources would be used to test an early warning resilience tool in stage 2 of the project.



3. DEFINING RESILIENCE, RESILIENCE LOSS, AND EARLY WARNING SIGNALS

Resilience is defined in many ways depending on the specific context, the way resilience is understood to function, and views about its purpose. In any given project, the definition of resilience adopted will almost inevitably represent only one of many possible definitions, guiding what is and is not focused on. This section describes how resilience is defined for this project.

Resilience is not something that can be easily measured. While there has been extensive research devoted to defining, measuring, and modelling disaster resilience, there is currently no consensus about what resilience is or the best way it can be measured (Holling, 1973; Klein et al., 2003; Manyena, 2006). Resilience can operate at multiple scales and is sometimes examined only at one of these in a given study, such as at the individual or household scale (Bonnano, 2004; Bonnano et al., 2010), the community scale (Norris, 2008; Cutter et al., 2008; Emery & Flora, 2006) or at the socioecological system scale – which itself may be defined in many ways that may encompass a range of scales within it (Gunderson & Holling, 2002; Folke, 2006; Folke et al. 2004). Resilience is also often defined differently across different disciplines including engineering, environmental science, health and social sciences. When the focus of resilience is on resilience to natural hazards/disasters /extreme weather events, it is often defined in relation to specific stages of the disaster cycle, types of natural hazard, or in specific geographic contexts such as countries, coastal communities, cities, islands, or suburbs (Djalante & Thomalla, 2010; Norris, 2008).

This project defines resilience in a way that is not based on specific stages of natural hazard cycles as we are focused on resilience change in communities that have experienced a range of natural hazards, often over a relative short period of time. This can result in communities being simultaneously engaged in disaster preparation, response and recovery, and therefore requires an approach to defining resilience that encompasses factors across all stages of the natural hazard cycle. For this reason, we have chosen a definition relevant to aspects of resilience that facilitate or inhibit the individual, household or community's capacity to prepare for natural hazards before they occur, respond to natural hazards when they are occurring, and recover and adapt following impact.

We define resilience as:

The capacity of individuals and communities to prepare for, respond to, recover from, and adapt to natural hazard events, with this capacity supporting a reduction in negative impacts and more rapid recovery from those negative impacts that do occur.

This definition is based on those commonly found in studies examining climate change resilience, disaster resilience and socioecological resilience.

Given the purpose of this project is to develop and test 'early warning' indicators for loss of resilience following challenging climate-related, it is also important to also define what we mean by 'resilience loss'. Our definition of **resilience loss** is closely related to our definition of **resilience** and is defined as:

The loss of capacity and resources that individuals and communities can draw on in preparing, responding, recovering, and adapting to natural hazard events.

This definition deliberately focuses on resilience resources that can be drawn on when preparing for, responding to, or recovering from natural hazard events, as this is the specific focus of this project. It is however important to clarify that this does not mean that natural hazard events are the only factors influencing the rate of change in these resilience resources. Many factors will affect the types of resilience resources a person, household, or community has available to draw on to prepare for, respond to and recover from natural hazard events. For example, a household affected by job loss unrelated to a natural hazard event may have fewer financial resources it can draw on to mitigate or recover from the impacts of a natural hazard event. This project seeks to measure levels of and change in capacity and resources, irrespective of what has caused that change or how they have been built or lost over time, that affects ability to prepare for, respond to and recover from natural hazard events.

The definition of resilience is deliberately broad, while being somewhat more specific than some other examples of resilience definitions in that it is focused on the resources and capacity in the context of natural hazard events. We believe striking this balance is important for measuring early indicators of resilience loss as it allows us to consider a diverse range of indicators related to resilience to natural hazards while being specific enough to allow for quantitative measurement. Specifically, it is important for this project to identify the types of indicators that can give insight into not only the presence or absence of resilience, but more importantly provide insight into smaller changes in levels of resilience resources over time, rather than focusing on long-term catastrophic change in resilience.

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Our definition allows for the consideration of a diverse range of factors that contribute to resilience across individual, household, community scales. This enables recognition of the complex interactions across scales that affect capacity and resources. For example, an individual's ability to prepare/respond/recover will depend in part on whether they have access to community scale resources such as effective emergency response capacity, evacuation centres, qualified tradespeople, and people able to contribute their time and skills to support that individual. It is important to highlight that a person, household or community with high resilience will still experience some negative impacts of natural hazard events, including negative psychological, social and physical impacts. Our definition of resilience recognises this, rather than suggesting that resilience confers some type of 'imperviousness' to being impacted, it highlights that resilience resources enable more rapid recovery of the things important to a person when negative impacts occur, as well as in some cases reducing the extent of those negative impacts in the first place.

Generalised versus specified resilience: which are we focusing on in this project?

The way this project defines and measures resilience includes elements of both generalised and specific resilience related to natural hazard events. Some projects measure the overall or 'generalised' resilience of a person, household, business or community, meaning their overall resilience to cope with and adapt to adversity irrespective of the specific context in which that resilience is operating. Others develop specific measures of resilience in particular contexts – for example, measures of resilience to a specific type of event such as bushfire, or market downturn, or outbreak of a pest or disease in agriculture. Moreover, some measure resilience of ecosystems, humans, natural and built environments, or of specific groups of people such as those engaged in a particular occupation such as farming. These represent measures of specified resilience. While for some time there was a focus on building resilience to specific challenges or events, sometimes in preference to generalised resilience to multiple types of challenge, there is now growing recognition that both generalised and specific resilience are important (Carmen et al., 2022; Carpenter et al., 2012).

Our definition incorporates elements of generalised resilience, in that it focuses on overall capacity of people and communities to prepare, adapt, and recover, rather than focusing solely on the presence of capacity, actions or resources specific to a given type of natural hazard event such as drought, bushfire or flood. It incorporates some elements of specificity in that it is focused on resilience in relation to natural hazard events however, it can be applied across a range of natural hazards including droughts, bushfires, floods, and storms.

Bouncing back, coping, adapting, or risk and vulnerability: which are we focusing on in this project?

Across the literature and existing frameworks and measures of disaster resilience, the conceptual approaches to resilience differ. Disaster resilience has been defined as a capacity of a system to bounce back or resist the impacts of disaster to experience fewer or no negative disaster impacts (Timmerman, 1981). However, critics of the bounce-back approach suggest that it maintains existing vulnerabilities and limits the potential for transformation to increase resilience. Other approaches view resilience as an outcome associated with successful recovery from a challenging time, such as the time taken to restore functioning after a disaster (Pfefferbaum et al., 2013).

As individuals and communities are complex, dynamic systems that are constantly changing, rather than simply bouncing back or resisting impacts, we recognize the potential for adaptive capacity building, the ability to use resources cope, adapt and learn to respond and recover to future natural hazard events (Buergelt & Paton, 2014; Paton, 2013; Paton & Buergelt, 2019). This is particularly important in the context of increasing frequency and intensity of natural hazards due to climate change. For this reason, although not the central focus of this project, we are interested in when individuals and communities are starting to lose their capacity or resources to cope, adapt and transform to increase resilience.

In the social-ecological systems literature, and more broadly the climate change resilience literature, resilience is often defined as being a function of the extent to which an entity (person, household, community) is (i) exposed to a threat or challenge such as climate change or natural hazards, and (ii) vulnerable to the effects of that challenge. Vulnerability is therefore considered to be a function of the level of sensitivity or susceptibility to the threat, and their level of adaptive capacity – meaning access to resources that enable them to respond, recovery and adapt successfully to the challenge (see for example Adger, 2006; Adger et al., 2005; Gallopin, 2006; Smit and Wandel, 2006; Mumby et al., 2014; Jacobs et al., 2015). This approach tends to associate particular individual, community, or environmental characteristics as an indicator of low resilience or susceptibility to disaster. Due to this, vulnerability-based frameworks tend to focus on measures that examine the extent to which actions have been implemented to reduce the risk and severity of natural hazards, through prevention, mitigation, and preparation prior to natural hazard events.

While this approach recognises the importance of investing in preparation, response and recovery, critics argue that many using it focus on risk reduction to specific individual natural hazard events at the expense of broader measures of resilience. More broadly, this approach has increasingly come under scrutiny as it does not always recognize or enable measures of the potential for positive outcomes such as post-traumatic growth and building of skills in response to experience of natural hazards or other challenges (Bonanno et al., 2010; Bonanno, 2004; Paton, Smith, & Violanti, 2000).

As this project is focused on understanding overall ability to live well while experiencing multiple natural hazards over a period of time, and change in resilience over time, it is not appropriate to focus on specific risk reduction. Rather, the

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definition selected focuses on measuring the ‘capacity’ aspect of resilience, with our argument being that this capacity is what drives ability to invest in activities such as risk reduction, but also disaster response, and recovery from the impacts of natural hazards. This focus on capacity relates to the idea of adaptive capacity in climate change and social ecological systems literature. This approach also directs consideration to the environmental, social, and institutional context that influences individual and community capacity to cope, adapt, and live with natural hazard events (Paton, 2006, 2013).

Resilience resources: our approach to measuring resilience

As this project takes a capacity-based approach to resilience, there is a strong focus on access to resources. There is substantial empirical evidence that access to resources such as psychological, social, community, and societal resources influences how individuals prepare, respond, and recover from natural hazard events (Hillig & Connell, 2018; Kaniasty & Norris, 1996; Kulig et al., 2013; Link et al., 2018; Norris et al., 2008; Paton, 2008). People’s access to and use of resources impacts how well they cope in response to a natural hazard, how well they recover and prepare for other natural hazard events and how severely a natural hazard impacts their life. Resources interact to facilitate access to other resources. For example, having access to social resources such as emotional and practical support from a network of close friends and family supports both psychological resources such as self-efficacy and wellbeing, and also often increases access to practical resources that facilitate preparing for and recovering from natural hazards, such as access to practical things like equipment, places to stay when a property is damaged, and many other practical resources. The level of particular resources a person has access to changes over time based on changes in their resource requirements, resource availability, and resource loss (Hobfoll, 1989, 2004).

In this project, we are focused on identifying resources across various domains that can be used to measure resilience loss. These resources exist across various domains at the individual and community level:

- **Financial resources (individual/household)** – monetary and non-monetary resources that enable individual or households to maintain or improve their standard of living such as home ownership, household income, level of diversity of economic resources, and insurance coverage.
- **Financial resources (community)** – monetary and non-monetary resources at the community level such as access to financial services, unemployment rate, affordability of housing, and local government financial health
- **Health and wellbeing (individual and community)** – individual health resources measured at the individual or community scale that enable people to prepare for, cope with and adapt to natural hazard events.
- **Human resources and functioning** – skills and capacity of individuals that enable them to prepare for, cope with and adapt to natural hazard events.
- **Social resources (individual and community)** – also referred to as social capital. This includes networks of friends and family who can provide support and resources such as knowledge, skills, peoples sense of belonging, along with social resources at the community level such as community cohesion and participation.
- **Infrastructure and services (community)** – having access to infrastructure and services that enable people to maintain or increase their resilience such as physical infrastructure such as roads, housing, health and social services.
- **Institutional resilience (community)** – access to effective, transparent, and accountable governance that enables communities to prepare for, cope with and adapt to natural hazard events
- **Ecosystem service provision** – health of the natural environment that effect the ecosystem services available to people such as quality of drinking water.
- **Liveability of community** – physical, economic and social environment that supports a high quality of life that do not fit into other resources categories.
- **Natural hazard resources (individual/household)** – tangible and non-tangible resources including skills, knowledge and physical resources that enable individuals to prepare for, respond to, and reduce the impact of natural hazard events.
- **Natural hazard resources (community)** – resources at the community level that enable individuals to prepare for, respond to, and reduce the impact of natural hazard events.
- **Exposure to natural hazards** – individual or community exposure or risk of exposure to natural hazards.
- **Socio-demographic and geographic variables** – characteristics of individuals and geographic regions that can impact their resilience to natural hazards.

4. COMMON INDICATORS OF RESILIENCE: OPPORTUNITIES AND CHALLENGES FOR IDENTIFYING CHANGE IN RESILIENCE LEVELS OVER TIME

4.1 INTRODUCTION

In this project we are interested in identifying indicators that enable tracking of change in capacity and resources to prepare for, respond to and recover from natural hazard events. This focus on indicators that track change reflects the overall goal of being able to identify 'early warning indicators' of resilience loss, enabling intervention before a significant amount of resilience is lost. This project does not assume that a person, household, or community has a pre-set level of resilience that is sufficient, but rather seeks to identify indicators that show whether they are experiencing loss of whatever level of capacity and resources they had at the start of monitoring. Regardless of whether they began with very low levels of resilience, or very high levels, identifying indicators that are sensitive to small changes can enable more rapid intervention if resilience loss occurs. This requires measures that are sensitive to small changes in resilience across different levels of analysis, rather than focusing on long-term catastrophic outcomes of resilience loss such as homelessness, bankruptcy, or suicide.

Focusing on indicators for which change can be measured means this project does not focus on indicators that are based on risk profiles. For example, some resilience frameworks suggest that people who have particular lifelong or long-term characteristics, such as having a disability, automatically have lower resilience. We reject this approach, consistent with its rejection in many other settings, as it conflates resilience with risk, and can reinforce disadvantage and discrimination through implying some groups are inherently less resilient than others. A better approach is to recognise that some groups have greater or lesser opportunity to build and maintain some types of resilience resources – but that this should be addressed by investing in changing the factors that mean these groups have less opportunity, something that is less likely to happen if that group is simply labelled as 'not resilient'. Our approach involves measuring the factors that may be causing differences in resilience amongst groups, and being able to monitor change in these.

The first step to identifying potential resilience indicators that can be used as early warning signals of resilience loss was to conduct a rapid review of the natural disaster literature and bring together the common approaches and themes related to measuring resilience resources and capacity. As part of this review, over 400 research papers were assessed, and from this over 500 resilience indicators were identified from the literature. The purpose of this literature review was not to provide an exhaustive list of resilience indicators used in the literature. Rather, it was to identify common approaches used to operationalise resilience indicators and use this as a starting point to assess the suitability of particular resilience indicators as early warning signals of change in levels of resilience.

Key findings from this rapid review are summarised in this section.

4.2 COMMON APPROACHES TO MEASURING COMMUNITY RESILIENCE

There are many existing tools, models and methods which can be used to evaluate and measure aspects of community disaster resilience. These tools differ widely in their scope and focus. For example, some focus on specific geographical regions, or on particular disaster events, while others adopt different methodologies or are based on differing understandings of the factors that influence resilience. Different approaches to assessing and measuring community disaster resilience have been reviewed in the literature (see Asadzadeh et al., 2017; Cutter, 2016; Nguyen & Akerkar, 2020; Ostadtaghizadeh et al., 2015; Saja et al. 2019; Talubo et al., 2022; Tariq et al., 2021 for example). The focus of these reviews has generally been to describe key features and identify commonalities and differences across the different approaches. In our rapid review, measures/indicators of community resilience found in the literature were examined in terms of their appropriateness, potential and suitability to (i) monitor resilience change over time, and (ii) to act as an early warning signal for resilience loss.

Key finding 1) Measuring resilience requires indicators examining multiple domains.

Community resilience is multi-dimensional, and for this reason most of the approaches to measuring resilience comprise of measurements/indicators across several different dimensions/components forming part of an index, scorecard or tool (Cutter, 2016). There was some variation in how the different dimensions were described, however most studies reviewed included at a minimum measures/indicators from these broad five dimensions of resilience (Saja et al., 2019):

- Social
- Economic
- Infrastructure

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- Institutional
- Environmental

Measuring early warning signals of community resilience should also include indicators across these broad domains.

Key finding 2) There are a range of approaches to measuring community resilience and the approach adopted should be relevant to the aims of the project and needs of the community.

Most approaches to measuring community resilience involve bringing together information and data across all dimensions of resilience, and then summarising these measures into a single value by which the resilience of a region/location or group can be evaluated and assessed. Information and data used for these tools can be qualitative -for example many score-card methods use groups of 'experts' or community informants to provide a qualitative assessment in the form of a score against domains of resilience (See Mason et al., 2016; Ramsey et al., 2016 and Singh-Peterson et al., 2015 for examples). Alternatively, indicators can be quantitatively measured and combined into the form of indices as is the case for the Australian Disaster Resilience Index (Parsons et al., 2016). For the majority of quantitative measures of resilience found in the literature, data is usually obtained from government sources such as Census data.

The approach adopted is usually determined by the reason/purpose for assessing resilience (Cutter, 2016). As in the case here – the purpose of assessing resilience is to provide communities in the project area with an early warning signal (EWS) that resilience loss may be occurring, allowing them to advocate for the required resources needed to intervene and prevent the onset of significant levels of resilience loss. For this reason, community experts and stakeholders should be involved in the process of identifying suitable early warning indicators, and only indicators where timely data is available should be considered. This means that many of indicators/measures included in current resilience measures would be inappropriate as early warning indicators as they rely on census data which is only collected every four years. Alternative sources of data for resilience measures are required to ensure changes in the levels of community resilience can be communicated within a timeframe that allows for intervention to occur shortly after levels of resilience begin to change.

Key finding 3) Current approaches to measuring resilience often focus on measuring community resilience at particular stages of the disaster cycle.

For example, the purpose/aim of many resilience measures are to measure resilience in anticipation of a natural disaster occurring, with the aim of predicting a community's ability to withstand, recover and adapt. While this is extremely important to reduce the impact of natural disasters, for resilience measures to be used as EWS, levels of resilience need to be tracked over time, especially following a natural disaster event. Many of the current approaches to measuring resilience aim to assess the resilience of regions/groups so that resources can be directed to the areas that are either at higher risk of exposure to natural disasters or may be lacking the capacity and resources required to withstand and recover if such an event occurred in the future. This approach can also be problematic for communities who are experiencing an increase in the frequency of climate-change related events, where they are required to simultaneously engage in preparation actions while still recovering from recent natural disaster events. While these approaches can still help inform communities about their levels of resilience, it is important to consider which approaches/measures of resilience may be more suitable to tracking community resilience over time, regardless of which stage/s of the disaster cycle a community is grappling with.

Measures relevant to general community functioning may be more suitable for measuring level of resilience over time following a disaster (Link et al., 2018). As these measures are not tied to any particular phase of the disaster cycle, it is easier to interpret whether or not changes are reflecting an increase or decline in resilience levels. For example, an increase in unemployment would be interpreted as a signal of declining resilience regardless of the stage of the disaster cycle the decline occurred – or is observed as a measure of community functioning. Alternatively, an increase in the number of people accessing mental health treatment may be considered a positive signal for resilience when it occurs in the months following a disaster event, but a negative signal for resilience if measured during a time where a community is functioning 'as normal'. In the rapid review, many measures/indicators used were important to only the preparation or early recovery stages of the disaster cycle (for example existence of disaster planning, number of fire stations, % of buildings in flood zone etc). These types of measures, while important, would not necessarily act as useful EWS. Instead, those resilience measures related to general community functioning (such as access to services, financial distress etc) are much easier to interpret regardless of what stage of the disaster cycle a community is in.

For these reasons, it is important for indicators of EWS to be relevant to all phases of the disaster cycle so changes in resilience can be tracked over time. This is vitally important as community resilience is dynamic and continually changing, and while finding quantitative measures that can be used to represent resilience over time is difficult – it is a necessary and often overlooked component of improving the resilience of communities faced with climate-change related events (McConkey & Larson 2022).

Key finding 4) Existing measures of resilience found in the literature often conflate socio-demographic characteristics with resilience.

While some community resilience measures include a wide range of social and community indicators to provide a more comprehensive assessment of these dimensions (see Parsons et al., 2021 for example), many resilience indexes rely on social and demographic measures as indicators of social and community resilience. Common factors used include household and family composition, age, gender, education, employment, disability, language and length of residence. Further, for most studies no evidence supporting the relationship between these factors and higher/lower resilience is provided, and it is often difficult to find any studies which have examined the relationship between these factors and resilience outcomes. It is likely that these measures are selected as in the broader literature they are often used as indicators of socio-demographic disadvantage. Further, some of these characteristics – for example age and disability – may represent (at least in part) specific challenges related to some of the physical aspects of disaster response such as evacuation and removal of debris etc. For example, many studies include age as an indicator, with older age considered to indicate low resilience (Ostadtaghizadeh et al 2015). However, recent approaches in fields other than resilience research have moved away from using such measures as indicators of disadvantage/vulnerability, and instead recognise that holding such characteristics does not automatically mean a person is disadvantaged in some way. Rather there is increasing recognition that the disadvantage experienced by people in these groups is a reflection on the social environment in which they live.

Specifically, in most fields it is recognised that labelling a group as vulnerable also risks that group being viewed as victims, helpless or stigmatised, and reduces recognition of the many strategies this group may have put in place to cope successfully with their higher level of vulnerability (Hooegeven et al. 2004) – strategies that may increase key resilience resources. Rather than assuming an entire group of people known to have higher risk of lacking accessing to resilience resources has low resilience, their actual level of access to those resources should instead be measured. This enables identification of the areas in which access to resources could be better enabled, as well as areas of strength. This is consistent with strengths-based approaches which emphasise that assuming membership of a group equates to disadvantage is, in and of itself, a labelling that stigmatises that group and may label them as ‘other’ (Sumner and Mallett 2013, Pulla 2012).

Given this, and the lack of evidence that such characteristics are in fact related to poorer resilience outcomes, EWS indicators of social and community resilience should not be limited to socio-demographic factors, and instead incorporate measures which have a more direct relationship with resilience outcomes (for example, financial stress).

Key finding 5) Many resilience measures/indicators do not have a clear ‘goal’ or threshold, and data science based systems for setting such parameters are lacking

One of the key limitations of current approaches to measuring community resilience is the lack of an articulated ‘goal’ or threshold by which resilience can be assessed on. Instead, many approaches rely on comparisons across geographical regions/groups as a way of quantifying whether resilience is low or high. This can be problematic for several reasons, but most obviously it can limit progress on improving the resilience of communities and make evaluation of resilience-based interventions difficult (McConkey & Larson, 2022). For example, if a community is using the number of hospital beds as an indicator of resilience, and there is no benchmark or goal for how many hospital beds are required for that community to adequately resource them, there is no way of understanding whether or not the number of hospital beds that community has indicates a high or low level of resilience. Often, to overcome the lack of a goal, many resilience measures compare indicators across regions/groups. This may provide some sense of where a particular community sits in terms of the number of hospital beds, but if all the communities in a region have an insufficient number of hospital beds, comparing this measure may not adequately indicate a lack of resources. For this reason, it is important for EWS to have evidence to support a goal or threshold by which the measure can be assessed against – rather than relying on comparisons between communities to assess the need for resilience resources. A way forward to addressing this issue would be the development of technological/data science based systems that can provide continual and up to date parameters that can be used to articulate goals and thresholds.

5. INDICATORS

This section presents the main findings of the first stage of the project – the indicators identified as having potential to be used to identify change in levels of resilience, and in particular those sensitive enough to change to have potential to provide early warning signals of resilience loss. These are presented in several sections, each examining a different type of resilience resource. Each section identifies those indicators selected to be examined in more depth in subsequent stages of this project, and also identifies other commonly measured resilience indicators related to that resource and why they were not selected for further examination.

For each indicator identified as a priority, potential data sources will be explored and, where feasible, accessed to produce information on the indicator. Where no existing data sources can provide information, data will be produced for the indicator through direct survey of communities in southern NSW, and examination of whether the proposed indicator is suitably sensitive to differences in circumstances to provide early information on change in resilience.

The indicators presented in this section were identified through:

- Review of previous studies examining resilience, which critically examined the indicators used to measure resilience and change in resilience for their suitability in identifying the early warning signals of resilience loss
- Stakeholder workshops, in which participants were asked to identify what signs they saw when recovery from an extreme weather event or other challenging event was not going well, or when in general some aspect of capacity to cope with challenges was declining
- Discussions amongst experts in the field of disaster resilience involved in the project.

These processes were used to both identify a list of potential indicators, and to prioritise which were most likely to provide measures of change in the level of a resilience resource that, when measured over time, would likely produce ‘early warning’ signs of resilience loss. In many cases, the same indicator may also be used to measure later stages of resilience loss: ideally, resilience indicators should be able to measure change in levels of resilience with sufficient sensitivity that early small changes can be identified, as well as larger, later changes that suggest significant loss has occurred.

Indicators were selected as a high priority to examine in the second stage of this project if they met the criteria outlined in Table 2. These criteria have been developed based on those used in some other projects (e.g. McConkey & Larson 2022), however have been adapted for the specific objectives of this project.

Table 2 *Criteria used to select indicators*

CRITERIA	DESCRIPTION
Interpretability	The indicator should be measurable in ways that have clear, consistent interpretation. For example, a measure that can be easily interpreted is one where an increase in levels of a resource is an unambiguous sign of growth in resilience, and vice versa. Some resilience indicators were rejected due to evidence of inconsistent interpretation. For example, the proportion of people who are part-time residents in a community was sometimes suggested as an indicator of resilience. However, some felt large numbers of part-time residents indicated lower community resilience, due to those people not always being present or lacking meaningful engagement in local community social networks and groups. Others felt that it may indicate higher resilience for some, as these residents had alternative residences that could be used and could provide links to other communities who can provide support in times of challenge.
Ability to measure level of resilience	Indicators should ideally go beyond measuring the presence or absence of a type of resilience resource and measure levels of that resource in some way. Ideally this would be associated with having clearly defined thresholds defining whether the level of resilience a person had indicated low, moderate, or high resilience. As noted in Section 4, there are few indicators for which clear evidence-based thresholds have been established. Establishing these thresholds will require data science systems that allow parameters to be automatically updated.
Sensitivity to change in level of resilience	Change in the indicator is, or could potentially be, measured in a way that is sensitive to relatively small changes in resilience levels. For example, when measuring financial stress, the literature suggested rate of bankruptcy as a potential resilience indicator. However, bankruptcy is not a highly sensitive indicator in that rising rates of bankruptcy are likely to occur after financial stress has been occurring for some time. If bankruptcy is to be used as an indicator, it would need to be combined with other, more sensitive measures of financial stress that capture earlier signs of stress, such as lower business profitability, or a greater number of businesses reporting making a loss.

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CRITERIA	DESCRIPTION
Timeliness (in general, and specifically in relation to resilience loss)	Indicators needed to be able to be measured early in the process of resilience loss to be suitable as an early warning signal. Indicators were rejected if they would only show evidence of resilience decline once a significant amount of capacity had been lost – in other words, if the measure meant only late stages of resilience loss would be observed. Additionally, if the indicator could be measured relatively regularly – at least once a year, or ideally more frequently – it was considered to have potential to be an ‘early warning signal’. If the indicator can only be measured over longer timeframes (e.g. longer than a year, for example there is a 5 year gap between measurement), it was not considered suitable for inclusion. It should be noted that longer-term measures are suitable for measuring longer-term resilience change. In this study, which focuses on identifying indicators that change earlier and more rapidly, longer-term indicators are not suitable.
Ability to measure change over time	This criterion overlaps with both sensitivity and timeliness. To be suitable as early warning signals, change over time must be measurable in meaningful increments. Some commonly identified resilience indicators do not achieve this. In particular, those that rely on the attributes of a person to infer resilience – such as gender, or age – are not suitable as early warning indicators, as no meaningful change in them over time can be measured. Further, measuring change over time also requires data science systems that allow for the continual update of parameters to ensure change signals are relevant and timely.
Validity	To be included, there needed to be evidence demonstrating that change in the indicator was an indicator of change in capacity to successfully navigate challenging times – which may include preparing for, responding to, or recovering quality of life after experiencing challenging times.
Relevance to study region	Relevance to study region (based on both workshops and general Australian conditions)
End user prioritisation	Feedback from the stakeholder workshops was used to assess end user prioritisation.

Importantly, the criteria used to select early warning indicators were not based on how commonly an indicator is used in existing resilience frameworks or tools, or in previous studies of resilience. This is because most existing frameworks do not explicitly seek to include only indicators that are sensitive to relatively small levels of change in different types of resilience resource.

Indicators of community resilience exist at both the individual/household level, and the community level. Assessing resilience at both levels is important to gain a comprehensive understanding of how resilient a community is. Indicators at the individual/household level include measures that indicate the level of a particular resilience resource individual people, or a household as a whole, have. Often this information is collected at the individual level. For example, survey data asking about symptoms of depression would be classified as a mental health indicator at an individual level. This data is often aggregated across a community to provide a community-wide perspective – but it still is indicating the level of a resilience resource (mental health) available to individual in the community.

In addition to the same indicator sometimes providing information about both level of resilience of an individual or household and, when aggregated, levels of resilience across a community, individual and community resilience are highly interdependent. For example, the resilience of an individual depends on part on the types of resilience resources their community has available, in the form of access to things like health services, effective and fair governance and distribution of funds, and high speed internet, to name just a few. Similarly, the resilience of a community depends on the ability of the many people living in it to contribute to the future of that community.

Given the interaction between individual, household and community resilience, and unclear boundaries between indicators of each in many cases, all three are considered in this report. We define these indicators as follows:

- **Individual resilience indicators:** Defined as any indicator that is measured at the scale of individuals. These indicators, when aggregated, also provide insight into household resilience and community resilience. For example, the amount of income an individual earns is an important indicator of their individual resilience. It may also support their household, and thus when combined with information on the household that person lives in, provides part of the information needed for some measures of household resilience. At the community scale, understanding things like the level of income inequality across a community, and proportion of a community earning income that provides a good standard of living, provides insight into the resilience of the community as a whole and its access to financial resources.
- **Household resilience indicators:** Defined as any indicator that is measured at the scale of a household. For example, the total income a household earns in a year is an example of a household scale indicator. That household income may be earned by one individual or more than one living in the household and be used to support all household members.

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- **Community resilience indicators:** Defined as any indicator that is measured at the scale of a community, rather than aggregated from individual or household level. For example, this might include the availability of specific services or infrastructure in that community, or crime rates. Community resilience resources are available across a community, but may not be equally available to everybody in that community. For example, a health services may be present in a community, and hence be a community resilience resource, but may be expensive and hence not easily accessed by those living in that community who have low incomes.

The indicators discussed in the next sections are described by the scale at which they are measured, and also by whether they are a 'change' or 'step change' indicator. A change indicator is one that can be measured in increments that, if measured sufficiently frequently, would enable identification of relatively small changes in resilience and measurement of magnitude of change over time. For example, measures of household income are an example of a change indicator, which can measure change over time in increments theoretically as small as a single dollar.

Step-change indicators, in contrast, are indicators that provide important information about resilience, but for which incremental change cannot be measured. By their nature, they are 'present' or 'absent', rarely change, or when they change do so in large increments only. For example, the presence or absence of infrastructure such as a community meeting place is an example of a step-change indicator. This meeting place may be a pub, café, or community centre. Its presence may be important to providing a place where people can meet, and share knowledge, skills, ideas, and emotional support. This type of place will typically be either 'present' – available for use – or 'absent', with sudden change in ability to gather socially if the building is destroyed in a fire, or closes suddenly in a pandemic. While this project is not focused on step-change indicators, some were identified as important indicators of resilience change and are listed in Section 5. However, the primary focus of this project is on change indicators.

5.1 FINANCIAL RESOURCES – INDIVIDUAL/HOUSEHOLD

5.1.1 Introduction

The financial resources an individual/household have contribute to resilience in many ways. Broadly speaking, having access to financial resources enables a person/household to implement a range of actions that can support preparation for, response to, or recovery from a natural hazard event.

The term financial resources means any monetary resources the household can access. While often narrowly defined in terms of income earned or direct savings, in reality a household's financial resources are often more complex than this. Financial resources can be in the form of both tangible, directly owned assets – such as income earned, savings held in the bank, or assets a household owns that can be borrowed against. However, the financial resources a household has access to also includes finance the household does not directly own – such as ability to access credit, to access insurance products that will provide financial support if a natural hazard event occurs, and access to financial support/loans from others such as family and friends.

5.1.2 Brief review of indicators

Resilience indicators commonly include measures of financial resources. For example, the Australian Disaster Resilience index includes the following, drawing on data from the *ABS Census of Population and Housing* and *Social Health Atlas of Australia* (Parsons et al. 2021):

- % (i) owning their home outright, (ii) owning with a mortgage, (iii) renting their home
- Median weekly rent or median monthly mortgage repayment
- Median weekly personal income, median weekly family income
- % family with < \$600 per week income, % families with > \$3000 per week income
- Age standardised number of people per 100 population whose household could raise \$2000 in a week.

Other indicators also examined some aspects of financial resources, while also providing insight into other resources such as access to transport, including indicators of employment, and motor vehicle access (Parsons et al 2021).

As is identified further in Table 1, not all these indicators can be used as 'early warning' indicators; and for some there can be difficulty interpreting the indicators. For example, an increase over time in median rent or mortgage repayment may reflect higher financial stress – but can also be an outcome of simultaneous rise in incomes and property prices without any increase in financial stress. High personal or household income may indicate higher financial resources, but this depends on the cost of living in the local area and the number of people being supported by that income.

In workshops held in Stage 1, participants primarily discussed indicators of financial distress as being signs of resilience loss. Common examples of financial distress discussed included things like having to access food pantries, using payday loans to help pay for bills, a reduction in discretionary spending, and being unable to buy essentials.

Table 3 summarises the types of financial resources indicators used in past work measuring resilience. These can be broadly classified into the following categories: possessing financially valuable assets; employment; financial stress; income; standard of living; debt/credit access; access to insurance; income diversity; and household budget management. Brief commentary is provided for each group of indicators, indicating whether and what type of measures can be considered early warning indicators, and why.

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Table 3 Common indicators of resilience used in past studies – financial resources of individuals/households

INDICATOR	MEASURES USED FOR THIS INDICATOR IN PAST STUDIES	COMMENTARY
Possession of financial assets	<ul style="list-style-type: none"> • % households with access to at least one car/vehicle • Home ownership rate • Average level of savings • Change in savings over given period of time (increasing/declining) • Use of savings for everyday living expenses • Liquidity of assets • Ability to access funds if an emergency need arises 	<p>While the indicator overall is useful, many of the measures commonly used are problematic to interpret, as they represent only one of many strategies available to people to build financial resources. For example, a person may have low savings due to low financial resources – or because they have chosen to pay debt off their house early and have a cash-back option on their loan, meaning they can access a significant amount of cash if needed, but that cash is not formally held in savings. Similarly, car ownership is not a good indicator in areas where proximity to public transport and limited parking spaces mean car ownership is not encouraged or a sign of transport access. Rather than attempt to measure all forms of financially valuable assets, a simpler indicator for which change can be measured readily is to examine the outcome of having financial assets – the ability to readily access funds if needed. One existing measure already used in several Australian surveys does this by asking if a person could easily access \$2,000 if needed in an emergency (Australian Bureau of Statistics, 2021). However, this measure focuses on short-term immediate needs only, and not larger sums that may be important for disaster preparation, response and recovery. We propose an amended version that will, via survey data, collect information on whether a household has the ability to access \$2,000 within a week, \$10,000 within a month, \$50,000 within a year (e.g. through loan cashback, savings, selling assets, accessing super).</p>
Employment	<ul style="list-style-type: none"> • Unemployment rate • Employment rate • Underemployment rate • % employed in stable/secure jobs • Participation in labour force • Youth unemployment rate • Elderly unemployment rate • Change in desired work hours (indicator of financial stress in some cases) 	<p>While unemployment is a commonly used indicator of stress, there are limitations to its usefulness. In particular, the Australian definition of unemployment – a person who during a specified period is not employed for one hour or more, actively seeking work and available for work (Parliament of Australia, 2023) - includes some but not all of those experiencing employment insecurity, and does not include many of those experiencing underemployment. In situations of lack of job availability, people may choose to leave the labour force altogether, in which case they will not be identified as unemployed. In workshops, participants discussed the importance of measuring change in quality of employment and working conditions, such as how many people have insecure employment or are underemployed.</p> <p>For individuals, we argue that employment is related to resilience in terms of their access to sufficient employment with good working conditions, which in turn has a direct influence on an individual's overall health, wellbeing and financial resources. Given this, simply tracking unemployment rates is not sufficient to measure resilience, although it is a useful baseline measure. Measures of unemployment should be accompanied by measures examining (i) how many working hours a person does relative to their desired amount of work (underemployment is associated with higher financial stress and lower wellbeing, while overemployment can be associated with poor health and wellbeing [De Moortel et al., 2018], and (ii) a person's satisfaction with their work and working conditions more generally, including level of remuneration, which is well documented to affect overall health and wellbeing (Fragher, Cass, & Cooper, 2005).</p> <p>Note: Indicators such as labour force shortages and job availability are community scale measures and examined in the next section.</p>

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INDICATOR	MEASURES USED FOR THIS INDICATOR IN PAST STUDIES	COMMENTARY
Financial stress	<ul style="list-style-type: none"> • % households experiencing different measures of financial stress • Specific experience of financial stress events in recent period – late payment on bills/rates/loans, going without meals, going without heating/cooling, asking for financial help, delaying purchases • Repossession of assets • Bankruptcy rate 	<p>Experience of financial stress is measured in some existing Australian surveys, namely the HILDA survey, several ABS surveys, and the RWS. The exact types of financial stress measured vary, however. Typically, survey questions will ask about financial stress events such as experiencing difficulty paying bills on time, being unable to heat or cool the home, and asking for financial assistance. The RWS has added in some measures of earlier signs that occur when a household may be in the early stages of financial stress, namely delaying non-essential purchases and activities such as restaurant meals, clothing purchases, or holidays.</p> <p>We recommend measuring a range of financial stress indicators, as workshop participants highlighted these as key signs of changing financial resilience. However, indicators that measure repossession of assets and bankruptcy – used as resilience indicators in some studies - are relatively late warning indicators: they occur after significant financial stress has been occurring for some time. Ideally, earlier warning signs that financial stress is occurring would also be measured, to ensure identification of earlier signs of stress as well as later.</p> <p>We will seek data that tracks change in incidence of different types of financial stress over time, including the following:</p> <ul style="list-style-type: none"> • Difficulty paying bills, delaying non-essential purchases, going without meals, difficulty heating or cooling home • Rate of access to financial helplines/help services; applications for financial support from government and/or charities. This is however considered a problematic indicator due to difficulty in obtaining consistent data over time. • % paying off credit card on time or average % credit card limit used • Frequency of google search terms for terms indicating financial stress • Use of cash converters/pawn shops/payday loans • Repossession of assets, bankruptcy • Level of debt relative to income



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INDICATOR	MEASURES USED FOR THIS INDICATOR IN PAST STUDIES	COMMENTARY
Income level	<ul style="list-style-type: none"> Income at or below poverty line Income at or below living wage % households at risk of poverty Minimum wage level Median income/ % above median household income Income distribution % households above average income level 	<p>Measures of income, and related to income, are commonly recommended as financial resilience indicators. However, some concern was identified in workshops regarding whether changes in income level are an indicator of financial resilience with consistent interpretation. There is also difficulty accessing regular data on income levels at a local level, with small area data typically only available once every five years in the ABS Census of Population and Housing. Some long term changes, such as those associated with retirement, may involve reduced income but not loss of resilience. A higher income in one region may have less purchasing power compared to a lower income in another, due to differences in cost of living across the two regions.</p> <p>Nevertheless, some measures of income are likely to be important to understanding change in resilience. In particular, those measuring change in the <i>distribution</i> of income across a community (a community rather than household indicator), and the proportion of households living at or below (i) the poverty line as defined by (a) the Henderson measure and (b) the OECD relative poverty line measure of having a weekly income less than half of the median income and or (ii) the living wage line, with the preferred measure to be defined.</p> <p>We also recommend use of the <i>self-rated household prosperity measure</i>, a measure used in several Australian surveys (including HILDA, some ABS surveys and the RWS), which asks a person to self-rate whether their household is very poor, poor, just getting along, comfortable, very comfortable or prosperous.</p>



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INDICATOR	MEASURES USED FOR THIS INDICATOR IN PAST STUDIES	COMMENTARY
Standard of living	<ul style="list-style-type: none"> • % income spent on paying rent/mortgage • % households able to afford cost of living • Median rent/mortgage repayment • Mobile homes as % housing stock • Local area affordability (e.g. ratio of median income to median costs of rent/ food/ petrol) • % who own cars • % owning vs renting home • Affordability of housing– median rent, median mortgage repayment, spending on housing as % income • % with access to suitable housing • % relying on social housing/ couch surfing/ living in car/ homeless 	<p>Standard of living refers to having access to a safe, comfortable and healthy standard of living, including a suitable home to live in, ability to afford food, heat and cooling, and to access transport.</p> <p>Measures of standard of living often focus on the specific areas of (i) housing and its affordability, (ii) affordability of common household goods and services, and sometimes (iii) access to transport in the form of owning a motor vehicle.</p> <p>Measures that focus on whether a person owns or rents a home were not considered clear measures of resilience, or of resilience change. This is due to emerging evidence suggesting that renting is not always a sign of lower financial resilience, with some cohorts actively choosing to rent rather than being ‘forced to’ due to lack of finances to purchase a home (e.g. Hulse et al. 2019). Additionally, this is a ‘step change’ indicator – it will not change in small increments or on a regular basis. Similarly, having a larger or smaller mortgage or higher or lower value home is not always an interpretable indicator.</p> <p>However, indicators that can be used as resilience change indicators and have clearer interpretability are:</p> <ul style="list-style-type: none"> • Views about affordability of local community • % of household income spent on housing costs (rent or mortgage repayment) • Ratio of average household income to average cost of a basket of goods • Proportion of people without secure housing – living in temporary accommodation, couch surfing or homeless. This is a late stage resilience change indicator. • Proportion of people at risk of losing access to housing. This is typically measured based on % at risk of mortgage default, however this indicator is only relevant to those with a home loan and excludes renters and those who own their home outright. We argue financial stress indicators are better for identifying those at risk of losing access to housing of any type. <p>Other indicators related to standard of living, such as late repayment of mortgage payments, are included in the financial stress indicators section.</p>
Debt level and access to credit	<ul style="list-style-type: none"> • % with access to credit • Credit card debt (% of limit used) • Debt relative to income 	<p>Some financial resilience indicators focus on a person/household’s level of debt relative to income, or access to credit. However, this indicator can be problematic to interpret, as many people deliberately take on a large amount of debt at key life stages, such as when buying a house, and this does not necessarily indicate a loss of resilience. Debt can be strategically taken on to enable investment in disaster risk reduction activities as well. Given this, level of debt relative to income is not included as an indicator. However, credit card limits, and indicators and making debt repayments on time, are included as potential indicators.</p>

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INDICATOR	MEASURES USED FOR THIS INDICATOR IN PAST STUDIES	COMMENTARY
Access to insurance	<ul style="list-style-type: none"> • % with health insurance • % with life insurance • % with home and contents insurance • % level of insurance coverage relative to likely need (e.g. covered for full replacement, for temporary housing or car for sufficient period of time) • % covered for specific types of event e.g. flood due to rising waters, flood due to storm, etc • % with income insurance • % with crop insurance 	<p>Access to insurance can confer financial resilience. This is discussed in the literature in relation to many forms of insurance, including home and contents, business (and, in the case of agriculture, a range of insurance products specific to the agriculture sector), income insurance, car insurance, health insurance and life insurance. Access to insurance is sometimes discussed as a form of financial resilience; when specific to insurance for natural hazard events, it is also commonly identified as a specific resource enabling disaster resilience.</p> <p>In terms of change in resilience, change in levels of (i) ability to access and (ii) use of different insurance products may be relevant. However, it is important to note that some people actively choose strategies other than insurance, such as having a large savings to draw on in times of emergency, or other investments that are built up and kept as an asset to be drawn on when needed. This means that not choosing insuring will not in all cases indicate low resilience, reducing interpretability of insurance related indicators. In other cases, some may choose not to use insurance products due to lacking access to ability to use services related to them – in particular, some living in rural areas may opt not to have private health insurance due to lack of availability of private health services in the region they live in. However, the following were identified as potential indicators:</p> <ul style="list-style-type: none"> • % households with vehicle/property damage insurance (including % with third party only and % with comprehensive insurance) • Accessibility of natural hazard insurance, defined as affordability relative to income • % households with home and/or contents insurance coverage for natural hazard covering full replacement cost • % businesses with insurance for loss of business income or loss of goods/property damage
Income diversity	<ul style="list-style-type: none"> • Number of income sources per household 	<p>Some studies suggest that households with diversity in their sources of income will be more resilient as they will retain access to some income earning capacity if one of their sources of income is reduced or ceases. However, household income diversity is not consistently able to be interpreted this way, as having diverse household income sources can be an indicator of employment insecurity and low resilience in some cases. For example, a household relying on members having multiple insecure casual jobs that pay low incomes and each offer small numbers of hours may be an indicator of low financial resilience compared to a household with a single secure income source that is well protected by insurance. Given the lack of consistent interpretability, this indicator is not recommended.</p>
Financial skills	<ul style="list-style-type: none"> • Household budget management 	<p>Some resilience studies have assessed household budget management skills as an indicator of financial resilience. This approach argues that the presence of skills will lead to better management of finances and, as a result, higher household financial resilience. However, other studies suggest that even those with high household budget management skills have potential to experience significant loss of financial resilience due to a disaster, as well as loss of ability to apply those skills due to experience of personal stress (see human skills and capacity indicators). Given this, this indicator is not recommended.</p>

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5.1.3 Recommended indicators for measuring change in resilience

Recommended financial resilience indicators at the individual/household scale are summarised below, classified by type of indicator and a summary of what is known about potential 'change' thresholds. Figure 2 shows conceptually which types of household financial indicators are considered more likely to represent early, mid and late stages of resilience change, with a focus on resilience loss processes. Table 4 summarises each indicator and its characteristics.

Figure 2 Understanding early, mid and late warning signs of change in financial resilience of individuals/households



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Table 4 Recommended financial resilience indicators – individual/household

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Possession of financial assets	% able to access \$2,000 within 1-2 weeks in an emergency	Change	▲ % able to access = ▲ resilience.	All (small change = early warning, larger change = late)
	% able to access \$10,000 within a month in an emergency	Change	▲ % able to access = ▲ resilience.	All (small change = early warning, larger changes = late)
	% able to access \$50,000 within a year in an emergency	Change	▲ % able to access = ▲ resilience.	All (small change = early warning, larger changes = late)
Employment	Labour force participation and employment (% in labour force, unemployed, employed part-time, employed full-time, employed and away from work)	Change	▲ unemployment = ▼ resilience. Possible: ▲ part-time work ▼ resilience.	All (small change = early warning, larger changes = late)
Financial stress	% who have experienced any of several types of financial stress event within the past (i) month, and (ii) year	Change	▲ financial stress events = ▼ resilience	All – differing types of stress used as earlier vs later warning signs (see Figure 1 for examples).
	Bankruptcy rate	Change	▲ bankruptcy = ▼ resilience	Late warning indicator only
	Frequency of online search for financial stress keywords	Change	▲ searches = ▼ resilience	All (small change = early warning, larger changes = late)
	Average proportion of credit card limit used each month	Change	▲ % limit used = ▼ resilience	All (small change = early warning, larger changes = late)
	% credit card holders paying off balance monthly		▼ % paying off balance monthly = ▼ resilience	All (small change = early warning, larger changes = late)
	% seeking delayed payment of rates, tax bills, utility bills, loan/mortgage repayments	Change	▲ % with delayed payment = ▼ resilience	All (small change = early warning, larger changes = late)
	% accessing financial support services (phone help lines, food pantries, crisis financial advice)	Change	▲ % accessing support = ▼ resilience	All (small change = early warning, larger changes = late)
	Rate of use of payday loans, pawning of assets	Change	▲ % accessing payday loans/pawning assets = ▼ resilience	All (small change = early warning, larger changes = late)
	% making debt repayments on time	Change	▲ % making repayments on time = ▲ resilience	All (small change = early warning, larger changes = late)
	% households living above and below poverty line (measured using Henderson and relative approaches)	Change	▼ % living below poverty line = ▼ resilience	All (small change = early warning, larger changes = late)

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INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Income/ prosperity	% households earning a living wage	Change	▼ % earning living wage = ▼ resilience	All (small change = early warning, larger changes = late)
	Self-rated household prosperity	Change	▲ reporting being very poor, poor, or just getting along = ▼ resilience	All (small change = early warning, larger changes = late)
Standard of living / affordability of living costs	% household income spent on housing costs	Change	▲ % income spent on housing costs = ▼ resilience	All (small change = early warning, larger changes = late)
	Ratio of average household income to average cost of a basket of goods (living cost affordability)	Change	▲ % cost of goods relative to income = ▼ resilience	All (small change = early warning, larger changes = late)
	% population lacking access to secure housing	Change	▲ % with insecure housing = ▼ resilience	Middle to late warning sign (early warning signs highlight households at risk prior to losing access to housing)
	Rating of affordability of local living costs	Change	▲ % reporting low affordability of living costs = ▼ resilience	All (small change = early warning, larger changes = late)
Access to insurance	% vehicles with vehicle/property damage insurance (including % with third party only and % with comprehensive insurance)	Change	▲ with active insurance = ▲ resilience	All (small change = early warning, larger changes = late)
	Accessibility of natural hazard insurance, defined as affordability relative to income	Change	▲ % income required to afford insurance = ▼ resilience	All (small change = early warning, larger changes = late)
	% households with home and/or contents insurance coverage for natural hazard covering full replacement cost	Change	▲ with active insurance = ▲ resilience	All (small change = early warning, larger changes = late)
	% businesses with insurance for loss of business income or loss of goods/property damage	Change	▲ with active insurance = ▲ resilience	All (small change = early warning, larger changes = late)

5.2 FINANCIAL RESOURCES – COMMUNITY

5.2.1 Introduction

'Community' financial resources are those indicators of financial resilience which are not measured at the scale of the individual or household. For example, they may measure things such as the number of businesses operating in a community. As noted earlier, indicators of individual and household financial resilience also provide insight into community financial resilience when they are aggregated and reported for a particular community. For example, a community in which a high proportion of households are having difficulty paying utility bills likely has lower financial resilience compared to one where almost all households find it easy to pay utility bills.

This section reviews financial resources indicators that are not measured at individual person or household scale, which can be used to indicate overall community economic performance and potentially identify early warning signs of resilience loss.

5.2.2 Brief review of potential indicators

A range of indicators are proposed in the resilience literature to measure the financial resilience of communities – something that is often described as economic capital, financial capital, or in some cases business resilience.

The ADRI, for example, includes indicators that measure the diversity of an economy, such as the largest proportion of employment reliant on a single industry such as agriculture or tourism, the proportion of businesses that are small versus larger employers. It also examines the number of retail and/or commercial establishments per 1,000 people.

In workshops, the majority of indicators discussed in relation to financial resilience were those that are measured at the individual or household level, such as rates of unemployment, underemployment, affordability of living costs and housing. Levels of funding for critical services were also discussed; these are examined further under access to infrastructure and services. They also, however, discussed availability and affordability of housing, which is examined in this section.

Table 5 summarises the indicators commonly identified in the literature for measuring community-scale financial resources, and critically evaluates their suitability for use in this project. Table 6 then summarises which indicators are recommended as potential 'early warning signal' indicators, where there is potential to measure change in resilience in ways that provides early indications of change.

Table 5 Common indicators of resilience used in past studies – financial resources at community scale

INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Income distribution and averages	<ul style="list-style-type: none"> % low income, middle income and high income households 	<p>In some workshops, participants discussed inequitable income distribution as a key issue for resilience, with the view that greater levels of inequality are signs of lower resilience. This was discussed as affecting things known to be important for disaster recovery, including community cohesion and willingness to work together to prepare for, respond to and recover from disasters. Inequality was strongly linked by workshop participants to lower availability of social support for some in the community. Widening income inequality can also suggest that significant cohorts of people are losing resilience if difficulty recovering from disaster is contributing to some having lower income. Change in income equality across a community is therefore considered an important indicator, in addition to the income level measures described in Table 2. Careful consideration of how income distribution and averages are defined and interpreted as these would impact on whether or not early warning signals are detected. For example, low, middle and high income thresholds can be defined differently, and what would be considered a middle income in one area may represent comparable levels of resilience loss in another area characterised by high cost of living.</p>

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INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Real estate availability and affordability	<ul style="list-style-type: none"> • House prices • Rental costs • House price/rental cost relative to income • Rental vacancy rate • House vacancy rate 	<p>A key challenge with real estate indicators is that in some cases, there is no simple linear relationship with resilience. For example: when measuring average time between listing of a home for sale and the home being sold, both a very short and a very long time could indicate low resilience. A short time indicates lack of available housing relative to demand. A long time indicates homeowners are not able to sell houses and shift to new ones, or access financial resources from selling a home, very easily. Real estate prices on their own are not a useful indicator, however prices relative to household incomes are.</p> <p>Given this, it is recommended to measure:</p> <ul style="list-style-type: none"> • Median rental cost as a proportion of (i) median income and (ii) lowest quartile income • Number of years of (i) median income and (ii) lowest quartile income required to pay off the full cost of (i) a freestanding 3 bedroom home or (ii) a 1 or 2 bedroom unit. • Rental vacancy rate (%) • Average length of time residential real estate is on market before sale
Revenue per capita	<ul style="list-style-type: none"> • Tax revenue per capita • Local government finances per capita 	<p>The indicators suggested here were primarily discussed in workshops, and less commonly identified in previous studies on measuring resilience indicators.</p> <p>Tax revenue per capita is an important measure, but likely to be ‘late warning signal’ due to only being measurable some time after change in actual taxable income has occurred.</p> <p>In workshops, some participants emphasised challenges for local government to maintain everyday activities due to the burden of costs resulting from natural hazard events. While many could access some funding for the additional costs incurred to repair damage, or invest in preparation action, not all could do this.</p> <p>This suggests it is useful to explore potential to have an indicator of resilience that examines the amount of funding a local government has for its core everyday activities, and how this changes over time per head of population. Everyday activities here can mean things such as funds per capita for waste collection, roads, local infrastructure, community activities, number of staff in non disaster recovery roles per capita. However, similar to tax revenue, it is likely this can be measured only some time after change has occurred.</p> <p>Local governments rates received per capita may also be a useful indicator, as it indicates whether there is change in the revenue base a local government relies on, and whether a growing proportion of the population is eligible for lower rates.</p>

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INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Economic activity indicators	<ul style="list-style-type: none"> • Retail turnover per capita • Rate of bankruptcies • Gross regional product per capita • Business vacancy rates • Job advertisements • Business numbers/commercial establishments per capita • Business and professional organisations per 1,000 population 	<p>The level of economic activity in a community is a commonly used indicator of financial resilience at community scale. This may be measured based on indicators ranging from gross regional product per capita, to retail turnover per capita, number of job advertisements or rate of business failure and vacant shopfronts or offices.</p> <p>Workshop participants rarely discussed these types of indicators, beyond discussing businesses ‘struggling’ as a sign of resilience loss in a community.</p> <p>Indicators that may change rapidly, and have reasonably consistent interpretation, include:</p> <ul style="list-style-type: none"> • Number of businesses/commercial establishments per capita • Retail turnover per capita OR spending per capita on different aspects of retail trade such as groceries, entertainment, clothing etc. • Possibly job advertisements; however, with jobs advertised in multiple ways and on multiple platforms, it is likely to be difficult to achieve sufficiently consistent data to measure change over time with confidence that the change represents actual change in job vacancies rather than change in method of advertisement. <p>While gross regional product per capita is a potentially useful measure, it is not included due to the known effect of disasters/natural hazard events in which higher rates of damage are often associated with an increase in GRP for some months – or in many cases years – after the event. This increased GRP does not necessarily translate into greater resilience to the next disaster. Retail turnover, meanwhile, provides a better measure of whether households are able to spend on ‘normal’ economic activities.</p>
Economic diversity	<ul style="list-style-type: none"> • Diversity of industries • Level of reliance on industries relative to risk of industry disruption by extreme weather events • Dependence on coastal resources • Dependence on agriculture • Dependence on tourism • Reliance on activities that are publicly funded 	<p>Diversity of employment opportunities was also identified as important: if diversity of available employment declines, that can be an indicator of loss of resilience in the local economy, as there is high reliance on a single industry for a large share of employment. However, this type of indicator is best viewed as a ‘step change’ indicator, not one which changes incrementally and can be used as an early warning indicator. Similarly, reliance on specific industries that are more exposed to impact from natural hazard events is best considered a long-term, step change indicator.</p> <p>Change in the proportion of people employed in industries that rely on public funding – specifically, health care and social services – is also sometimes recommended, as it identifies reliance on government funding for economic activity.</p>
Employment rate	See individual/household	
Business diversity	<ul style="list-style-type: none"> • Ratio of large to small business 	<p>Some studies suggest that the ratio of large to small businesses is a useful indicator of business diversity. However, it is unclear how to interpret change in this indicator: what does change in the indicator mean in terms of resilience change? Given this lack of interpretability, this indicator is not recommended for use.</p>

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Table 6 Recommended financial resilience indicators – community

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Income distribution and average	Income inequality in a community – % low income, middle income and high income households	Change	▲ % income inequality = ▼ resilience	All (small change = early warning, larger changes = late)
Real estate availability and affordability	Median rental costs as a proportion of (i) median income and (ii) lowest quartile income	Change	▲ Rental costs as % income = ▼ resilience	All (small change = early warning, larger changes = late)
	Number of years of (i) median income and (ii) lowest quartile income required to pay off the full cost of (i) a freestanding 3 bedroom home or (ii) a 1 or 2 bedroom unit.	Change	▲ Years of income required to pay off house = ▼ resilience	All (small change = early warning, larger changes = late)
	Rental vacancy rate (%)	Change	Very high and very low rental vacancy rates are both signs of low resilience (for landlords and renters respectively). Thresholds need to be identified indicating where vacancy rate is too low or too high to be considered 'healthy' for tenants and landlords.	This indicator may be a change or step change indicator depending on whether an event causing sudden change in rental vacancy occurs
	Average length of time residential real estate is on market before sale	Change	Very high and very low time on market are both signs of low resilience – high time on market indicates difficulty selling and low resilience for sellers; low time on market indicates difficulty for those seeking housing. Thresholds need to be identified indicating where length of time is too low or too high.	All (small change = early warning, larger changes = late)
Revenue per capita	Local government funding per capita for continuation of core everyday activities (sanitation, waste collection, community activities, infrastructure, planning review and approval, etc)	Change	▼ funding per capita = ▼ resilience	All (small change = early warning, larger changes = late)
	Tax revenue per capita	Change	▼ revenue per capita = ▼ resilience	Late warning signal
	Local government rates per capita	Change	▼ rates per capita = ▼ resilience	Late warning signal

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INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Economic activity	Number of businesses/commercial establishments per capita	Change	▼ establishments per capita = ▼ resilience	All (small change = early warning, larger changes = late)
	Retail turnover per capita OR spending per capita on different aspects of retail trade such as groceries, entertainment, clothing etc	Change	▼ turnover/spending per capita = ▼ resilience	All (small change = early warning, larger changes = late)
	Job advertisements (noting challenges of consistency of location of advertisement for tracking change)	Change	▼ advertisements per capita = ▼ resilience	All (small change = early warning, larger changes = late)
Economic diversity	% employment dependent on activities that rely on public funding	Change	▲ % jobs reliant on public funding = ▼ resilience	Step change indicator
	Share of employment reliant on top 3 employing industries	Change	▲ % jobs reliant on top 3 employing industries = ▼ resilience	Step change indicator

5.3 HEALTH AND WELLBEING – INDIVIDUALS AND COMMUNITIES

5.3.1 Introduction

This section examines indicators related to the health and wellbeing of individual people. By their nature, these indicators are measured at the scale of individuals. They may be then examined at household and community scale through aggregating data about the health and wellbeing of the individuals living in that community. Given that, this section considers all indicators related to health and wellbeing, but identifies where they may be aggregated to provide insight at household and community scale.

Note that access to health services is examined subsequently as part of exploring potential indicators related to access to all types of infrastructure and services.

5.3.2 Brief review of potential indicators

A person's health and wellbeing is often strongly associated with their resilience. However, it is important to note that while poor health and wellbeing is commonly associated with lower resilience, this is not always the case. In particular, many people have health conditions that, as long as they are managed well, do not reduce their overall resilience. Therefore indicators should ensure they do not conflate the presence of a health condition on its own with likely resilience levels. Given this, rates of diagnosis of physical health conditions, and to a lesser extent mental health conditions, are not considered further as indicators of resilience. Indicators that provide insight into the consequences of those conditions for a person's overall health and wellbeing are, however, considered.

This is consistent with the approach of the ADRI, which measures two indicators of health and wellbeing: self-rated overall health, reporting the proportion of people who report having fair or poor health; and global life satisfaction (a common measure of overall wellbeing).

A key challenge with almost all measures of health and wellbeing is that there is little regularly collected data on health and wellbeing outcomes at small scales. Typically, it is difficult to obtain data more than once every two to five years, and then often at small scales. The HILDA survey captures some health and wellbeing data annually, but does not have sufficient sample for small scale regions. Given this, exploration of health and wellbeing indicators needs to consider how to obtain data that measures change more frequently as, while many indicators are well validated, relatively few are measured frequently enough to enable early warning of declining health and wellbeing outcomes.

In workshops, symptoms of mental ill health were regularly identified as being warning signals of resilience loss. Workshop participants suggested several measures that could indicate loss of mental health. This includes the number of people accessing a mental health plan via their GP, waiting times to see mental health professionals such as psychologists, prescription rates of medications for anxiety and depression, and number of calls to mental health support lines.

Table 7 summarises indicators used in previous studies, and critically evaluates their suitability for use in this project. Table 8 then summarises which indicators are recommended as potential 'early warning signal' indicators, where there is potential to measure change in resilience in ways that provides early indications of change.



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Table 7 Common indicators of resilience used in past studies – health and wellbeing

INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Mental health	<ul style="list-style-type: none"> • Suicide rate • Medication use 	<p>While some resilience work has used suicide rates as a measure of resilience related to mental health, it is not recommended for this project, for several reasons. First, suicide is one of a very wide range of mental health outcomes, and focusing solely on suicide risks ignores the much wider range of signs of mental ill health that may be present. Second, suicide cannot be considered an early warning signal, with a wide range of studies focusing on the importance of identifying risk of suicide early (Azizi et al., 2022). Similarly, medication use can be a problematic measure: not all of those who have mental health challenges seek support and access medication, and some may argue that higher medication use is a sign of better/improved management of symptoms of mental ill health compared to low rates of use. Alternatively, high rates of use of medication such as antidepressants is sometimes criticised as indicating treating symptoms without addressing underlying causes of mental health challenges, something that may mean medication use does not indicate higher resilience. Given this, neither suicide rates, or rates of prescription, are considered appropriate indicators on their own, although both may assist in providing an important picture of a community, if accompanied by additional information.</p> <ul style="list-style-type: none"> • Instead, we recommend use of indicators that are more sensitive to levels of mental ill health and that can better measure change. Specifically, we recommend measures of: • Frequency of experience of symptoms of psychological distress, in the Kessler psychological distress scale, widely used in Australian surveys • Possibly rates of calls to helplines. However, interpretation can be difficult: does an increase in calls reflect higher rates of mental ill health, or success of campaigns encouraging those with mental ill health to seek support? • Possibly online searches for keywords indicative of concerns about mental health of self or others • Prescription rates of antidepressants, anti-anxiety medications and possibly sleeping pills, per head of population
Healthy behaviours	<ul style="list-style-type: none"> • Rates of engagement in unhealthy behaviours including drinking alcohol, smoking, drug misuse • Engagement in healthy behaviours related to diet, exercise • Engagement in preventative health checks such as breast screening participation 	<p>The mental health measures above focused on incidence of mental ill-health. However, prior to signs of ill-health, it may be possible to identify that there is an increasing risk of poor health outcomes by examining rates of engagement in healthy behaviours – those known to protect and enhance good health and wellbeing. It is also possible to examine rates of engagement in unhealthy behaviours, which may increase risk of ill-health. One earlier warning signal of reduced healthy behaviour identified by workshop participants was reduction in regular dentist check-ups, something which may decline for reasons relating to affordability, stress and time pressures.</p> <p>Key indicators to be examined include:</p> <ul style="list-style-type: none"> • Self-reported engagement in healthy and unhealthy behaviours, including preventative health checks and dental check-ups, in surveys • Administrative data on proportion of eligible people who are engaging in recommended preventative health checks, including breast screening, bowel cancer screening, and others <p>A further healthy behaviour related to mental health is having positive social interaction, discussed further as part of social resource access.</p>

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INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Prevalence of specific communicable and non-communicable illnesses	<ul style="list-style-type: none"> • Rate of waterborne diseases • Rates of other communicable diseases that are preventable 	The prevalence of specific diseases is sometimes recommended as an indicator of resilience, particularly in relation to early stages of disaster recovery, as it identifies capacity to prevent spread of preventable communicable diseases in particular. However, as identified earlier, incidence of specific diseases is not always a good indicator of resilience, particularly when discussing non-communicable diseases that may, when well managed, present little barrier to engaging in everyday activities. Given this, it is not proposed to track indicators of these.
Physical health	<ul style="list-style-type: none"> • % healthy population • General health measure 	Measures of overall health have been included in some resilience indexes, including the ADRI. While workshop participants did not specifically discuss physical health, overall health was discussed. The indicator recommended is the same as that used in the ADRI, the General Health measure in which people are asked to self-rate their overall health as poor, fair, good, very good or excellent as part of completing a survey.
Life expectancy	<ul style="list-style-type: none"> • Years of healthy life lost per 1,000 due to preventable illness and disorders • Life expectancy/ life expectancy at birth • Healthy life expectancy 	Life expectancy is an important measure of resilience – but is slow to change and likely to be observed as a late warning indicator, not an early warning of resilience loss. It is recommended that indicators that show the years of healthy life lost due to preventable or treatable illnesses and disorders be examined; while a late indicator of resilience change, this is an important measure of long term resilience change.
Early childhood	<ul style="list-style-type: none"> • % low birth weight babies • Infant mortality rate 	Internationally, some resilience frameworks include indicators related to infant mortality and low birth weight. These were not identified in workshops as high priority indicators.
Physical mobility	<ul style="list-style-type: none"> • % population with capacity for independent physical mobility and transport • % population with differing levels of physical mobility capability 	Understanding the proportion of a population with differing levels of physical mobility is important for managing disaster response processes well, particularly evacuation. For this reason, it is common to see measures of physical mobility forming part of resilience measurement. However, while important for these critical aspects of disaster planning and management, we argue that it is not the physical mobility limitation that represents high or low resilience, but whether systems are in place that enable all people in a community to engage in successful disaster preparation, response and recovery. For this reason, this is not recommended as an indicator. This is discussed further in Section 5.14.
Communication	<ul style="list-style-type: none"> • % population with communication limitations 	Similar to physical mobility, understanding communication differences across a population – such as languages spoken, and those who experience difficulty with some forms of communication – is important to understand when designing disaster response and communication strategies. However, differences in communication do not in and of themselves indicate higher or lower resilience, and are not included as a recommended indicator.

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Table 8 Recommended health and wellbeing indicators

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Mental health	Psychological distress levels (Kessler psychological distress scale)	Change	▲ distress = ▼ resilience	All (small change = early warning, larger changes = late)
	Calls to helplines/support services per head of population	Change	▲ calls per capita = ▼ resilience	All (small change = early warning, larger changes = late)
	Frequency of online searches for keywords indicating concerns about mental health	Change	▲ frequency relative to number of users = ▼ resilience	All (small change = early, large = late)
	Rates of prescription of common medications used to treat anxiety and depression, per head of population	Change	▲ prescription rates = ▼ resilience (however, low confidence in interpretation)	All (small change = early warning, larger changes = late)
Healthy behaviours	% people who had dental check up in last year	Change	▼ % who had check up = ▼ resilience	Early warning
	% population with alcohol intake above healthy levels	Change	▲ % with unhealthy alcohol intake = ▼ resilience	All (small change = early, large = late)
	% population smoking nicotine products (cigarettes, vaping etc)	Change	▲ % smoking/vaping = ▼ resilience	Early warning
	% eligible population engaging in breast screening	Change	▼ % accessing screening = ▼ resilience	Early warning
	% eligible population engaging in bowel cancer screening	Change	▼ % accessing screening = ▼ resilience	Early warning
	% eligible population engaging in other preventative health checks	Change	▼ % accessing screening = ▼ resilience	Early warning
	% population achieving minimum recommended level of physical activity	Change	▲ % with healthy physical activity = ▲ resilience	Early warning
Overall health	Self-rated general health	Change	▲ % reporting fair/poor health = ▼ resilience	All (small change = early, larger = late)
Life expectancy	Average years of healthy life lost due to preventable or treatable illness	Change	▲ years of life lost = ▼ resilience	Late warning signal

5.4 HUMAN RESOURCES AND FUNCTIONING – SKILLS AND CAPACITY OF INDIVIDUALS

5.4.1 Introduction

This section discusses indicators related to the skills and capacity of individuals. ‘Skills and capacity’ refers to any type of resource that relies on a person’s skills and psychological resources. It includes not only formally attained qualifications, but also psychological resources such as a sense of optimism and coping skills.

5.4.2 Brief review of potential indicators

Table 9 summarises common indicators related to skills and capacity of individuals that were identified in previous work. In the resilience literature, it is relatively common to see measures of formal educational attainment used as indicators of resilience. This is due to strong evidence that, over the life course, formal educational attainment is associated with better life outcomes ranging from higher income to greater longevity. However, formal educational attainment is not as well demonstrated to confer benefits in terms of specific resilience to natural hazard events and does not typically change in the short term. Thus it is not an ideal early warning signal, particularly for measuring resilience loss, as a person will not lose educational attainment – while when under stress, they may experience loss of personal psychological resources such as optimism that are better demonstrated to be critical in times of adversity. The extensive literature on personal psychological resilience resources highlights the importance of a wide range of personal psychological resources for resilience, with a large body of evidence demonstrating that those with greater levels of these resources have improved outcomes during and after experiencing adversity compared to those with lower levels.

Personal skills and capacity was discussed fairly frequently in the workshops, and many participants felt that personal skills were more important to understanding resilience in relation to natural hazard events than formal education. Skills mentioned included problem solving ability, self-efficacy and ability to navigate recovery challenges such as knowing where to seek support and how to fill out applications. Having local knowledge of a community was also an important personal skill identified by some workshop participants. School attendance was discussed in several workshops as a measure in which change can indicate a shift in resilience. While not clearly related to personal skills and capacity, school attendance is included as an indicator here, as changes in school attendance may both affect ability of children to build skills and capacity and be an indicator that there has been a change in the skills and capacity of parents.

Table 9 identifies indicators commonly recommended in the literature and critically evaluates their suitability for use in this project. Table 10 then summarises which indicators are recommended as potential ‘early warning signal’ indicators, where there is potential to measure change in resilience in ways that provides early indications of change.

Table 9 Common indicators of resilience used in past studies – human resources, skills and functioning

INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Personal psychological resources	<ul style="list-style-type: none"> • Optimism • Intellectual and reasoning ability • Positive worldview • Self-esteem • Self-efficacy • Hardiness • Emotional reactivity • Coping 	<p>All these psychological resources have a strong body of evidence that links higher levels of resources to better outcomes when a person experiences adversity. Thus, all are considered useful indicators. These types of indicators are traditionally measured using surveys. It may be possible to explore options for analysing social media sentiment to identify changes in prevalence of use of terms that indicate the presence or absence of different types of resources.</p>

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INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Confidence in future		This indicator is not typically included in resilience indexes but was raised in several workshops. In most workshops, some participants identified that lack of confidence about the future, specifically in relation to feeling action was being taken to address human induced climate change and its impacts, was a critical issue affecting resilience. In particular, participants identified that feeling helpless or hopeless about the future due to a sense of powerlessness or lack of confidence in action being taken to address climate change reduced a person's capacity to cope and adapt to natural hazards. Feeling confidence that key institutions were taking action on climate change was, they felt, needed to support individual resilience. This can be measured in surveys, and potentially using social media sentiment measures.
Personal skills	<ul style="list-style-type: none"> • Critical reflection and problem solving skills • Communication capacity • Household self-organisation and learning • Decision making capacity of household heads 	<p>Personal skills differ to personal psychological resources in that they are specific learned skills involving applying particular processes of communication and/or decision making and action.</p> <p>In workshops, several participants identified that those experiencing trauma often experience reduced decision making capacity, something well evidenced in the broader literature (Aupperle et al., 2012; Sailer et al. 2008). This was discussed as making it difficult to engage in regular activities such as lodging tax returns, and navigating administrative systems.</p> <p>Recommended indicators are therefore:</p> <ul style="list-style-type: none"> • Survey measures examining decision making and possibly learning capacity • % individuals lodging tax returns on time • % applications for support begun but not progressed
Educational attendance and performance	<ul style="list-style-type: none"> • School attendance rates • School dropout rate of children • % population 3+ enrolled in school • School performance – NAPLAN 	Educational attendance was discussed in workshops as a warning sign of resilience loss, being an indicator of stress in the household, as well as an indicator that children are having reduced learning and skills building opportunities. Other measures sometimes used as resilience indicators - school performance and dropout from school – were less commonly discussed in workshops, and may act as later warning signals, as they typically occur after a longer period of stress.
Formal educational attainment	<ul style="list-style-type: none"> • Formal educational attainment (% with different types of qualification, or higher level of education attained) • Educational attainment equality 	While formal educational attainment is well demonstrated to improve overall life outcomes, the evidence is less clear regarding ability to navigate specific times of adversity. Given this, and that this indicator is a step change rather than change indicator, it is not recommended for this project.
Literacy and numeracy	<ul style="list-style-type: none"> • Literacy rates • Numeracy rates 	Literacy and numeracy are both well established to be important skills for life long resilience. However, they typically do not change in the short term and while being important factors to understand as part of disaster planning and management, do not change as resilience increases or decreases in response to disaster (although capacity to use these skills effectively may).

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Table 10 Human resources, skills and functioning indicators

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Personal psychological resources	Survey measures of optimism, self-efficacy, hardiness, emotional reactivity, coping, personal resilience	Change	▲ % with healthy levels of resources = ▲ resilience	All (small change = early warning, larger changes = late)
Confidence in future	Survey measures examining confidence in future, specifically in relation to climate change, and overall sense of optimism, helplessness, hopefulness and confidence in future	Change	▲ % with confidence in future = ▲ resilience	All (small change = early warning, larger changes = late)
	Social media sentiment regarding confidence in future	Change	▲ % sentiment indicating confidence in future = ▲ resilience	All (small change = early warning, larger changes = late)
Personal skills	Survey measures examining decision making capacity	Change	▲ % with good decision making capacity = ▲ resilience	All (small change = early warning, larger changes = late)
	% individuals lodging tax returns on time	Change	▲ % lodging tax return on time = ▲ resilience	Early warning signal
	% applications for support begun but not progressed	Change	▲ % not progressing applications = ▼ resilience	Early warning signal
Educational attendance and performance	School attendance rates	Change	▼ school attendance rates = ▼ resilience	Early warning signal
	School performance – NAPLAN and AEDC	Change	▼ school performance = ▼ resilience	Mid warning signal
	% children remaining in school to end of Year 10, 11 and 12	Change	▼ student retention to Yr 10, Yr 11, Yr 12 = ▼ resilience	Late warning signal

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5.5 SOCIAL RESOURCES – INDIVIDUAL/HOUSEHOLD

5.5.1 Introduction

Social resources – often referred to as social capital – are resources people access via social interaction with others. Interacting socially can have many benefits: it supports positive mental health, helps people build knowledge and skills, and is a key way people access practical and financial support from others. This section considers social resources that confer benefits for individuals.

5.5.2 Brief review of potential indicators

When asked what they had observed in their communities when resilience was growing or declining, the most common type of resilience resource discussed by workshop participants were social resources. Many workshop participants discussed changes in support available from social networks, changes in social cohesion of local social networks such as relationships between neighbours, or emergence of conflict in a community, and changes in participation in social and community events, as signs of changing resilience. In general, greater isolation was viewed as a sign of loss of resilience, as was any decline in ability of social networks to provide support – meaning that a person having reduced capacity to provide support to others was a sign of resilience loss not only for that person, but for others in their social network; similarly, a person’s social network having reduced capacity to provide them support was a sign of resilience loss for that person.

While social resources are increasingly recognised as being critical to resilience, this strong evidence comes primarily from one-off studies (quantitative and qualitative), and there is less work available on how to measure indicators of social resources across different communities on a regular basis, something important to being able to measure early warnings of change in availability of social resources. A lot is known about how to measure social networks and interactions in single ‘one-off’ studies, but this does not necessarily translate into readily measurable indicators. Due to this, in Australia there is commonly a ‘default’ to readily available data – in the case of Australia, typically data on participation in volunteering, as this is measured in the ABS Census of Population and Housing, whereas other measures of social participation are not included in the Census.

Table 11 identifies indicators commonly recommended in the literature and critically evaluates their suitability for use in this project. Table 12 then summarises which indicators are recommended as potential ‘early warning signal’ indicators, where there is potential to measure change in resilience in ways that provides early indications of change.

Table 11 Common indicators of resilience used in past studies – social resources at individual/household scale

INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Engagement in groups/ organisations that have potential to provide social support	<ul style="list-style-type: none"> Membership of community/social groups Frequency of engagement in social activities held by community/social groups <p>(The types of groups asked about vary across studies and include sports group, local community groups in general, religious institutions.)</p>	This indicator is often examined using measures that focus on formally constituted community or social groups, such as local sports groups. In workshops, participants did not typically discuss formal membership of groups, but did discuss frequency of engagement with others, whether through formal organisations or in informal gatherings, as being highly important. This suggests that rather than focus on membership of groups, indicators should focus on measuring frequency of engagement in social interaction. This can be measured via survey.

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INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Volunteering	<ul style="list-style-type: none"> % of people engaging in volunteering 	<p>This indicator is relatively commonly included in resilience indicators designed for the Australian context, largely due to its availability from the <i>ABS Census of Population and Housing</i>, which asks if a person volunteered at any point in the last 12 months. At the individual level, it is possible that engaging in volunteering indicates a higher level of resilience, as volunteering likelihood may decline as resilience declines. This was identified as a concern in workshops, in several of which decline in volunteers due to burnout and loss of capacity was identified as a common issue. The decline was not simply about participating in volunteering or not, however, but rather a decline in how frequently a person volunteers. This suggests a need for indicators that move beyond simple binaries measuring whether a person has volunteered over a 12-month period, to measuring change in frequency of engagement in volunteering. Volunteering is also considered critical to community functioning and discussed in the next section.</p>
Self-rated access to social support	<ul style="list-style-type: none"> Ability to access practical, emotional and financial support from personal social network 	<p>People may access many different types of resources via their social networks. In workshops, participants described observing changes in the level of emotional, financial and practical support accessible via social networks when resilience declined. This was often described as people 'running out' of resources after having already accessed as much financial support as friends and family could provide, or friends and family who experienced their own stress having limited capacity to continue providing emotional support to a person. The RWS contains an indicator examining self-rated level of access to these types of support from a person's network of family and friends.</p>
Social networks/ personal social ties	<ul style="list-style-type: none"> Density of social networks Number of social ties (of different types) Engagement with friends, family, neighbours 	<p>Some resilience frameworks measure the size of a person's social network, with a larger network (or larger number of social ties) considered an indicator of higher resilience. It is difficult to interpret the social ties indicator, however, as there is not clear guidance on what number of social ties is considered sufficient for resilience, or whether different people may achieve the same level of resilience with differing numbers of social ties. Given this, social ties are not examined as a resilience indicator in this project.</p> <p>Other examine the frequency with which a person engages in social interaction with their social networks as a measure of resilience, with more frequent engagement considered an indicator of higher resilience. Decreasing frequency of social interactions was mentioned as a sign of loss of resilience in workshops. In particular, social isolation was described as a common sign of loss of resilience, with people described as withdrawing from engagement with others when losing capacity to cope or adapt to change. This suggests it is important to measure indicators of loneliness, and change in frequency of social interaction, as resilience indicators. These are most commonly measured using survey data.</p>

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INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Close social networks	<ul style="list-style-type: none"> Divorce/separation rate 	<p>In several workshops, participants discussed divorce/separation rates as being indicative of loss of resilience. However, this indicator tends to be a 'late warning indicator' and ideally earlier warning signals of difficulty maintaining relationships should also be examined to identify early changes. This can include survey measures asking about satisfaction with personal relationships (asked in some surveys already, including the RWS). It may be possible to identify frequency of use of search terms indicating relationship break down as well. A key challenge is that while the process of relationship breakdown can be associated with loss of resilience, for many people, the act of divorcing or separating can have long term benefits if achieved well. Therefore this indicator should be used with some caution in interpretation. Those who have recently separated are known to have higher likelihood of experiencing financial and psychological stress, however, suggesting that <i>recent</i> divorce/separation is a meaningful indicator of likely resilience loss.</p>
Social cohesion	<ul style="list-style-type: none"> Measures usually focused on participation in social groups/numbers of local community groups per population 	<p>Social cohesion in the form of people getting along well and being able and willing to provide support to each other and work collaboratively was commonly discussed in workshops. This is not typically included as a specific indicator in resilience literature. Indicators that could potentially be used to examine change in social cohesion include:</p> <ul style="list-style-type: none"> Rates of specific types of crime/anti social behaviour Sentiment in social media Sense of belonging (a survey measure already used in some Australian surveys)



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Table 12 Recommended social resilience indicators – individual

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Engagement with social groups/ organisations	Frequency of engagement in social interaction with social networks other than close friends and family	Change	While a decrease in frequency of engagement is a sign of low resilience, it is unclear whether increases above a healthy threshold are signs of increasing resilience	All (small change = early warning, larger changes = late)
Volunteering	% of people engaging in volunteering activities	Change	▲ % volunteers = ▲ resilience	Late warning signal
	Total volunteer availability based on (i) engagement in volunteering and (ii) frequency of volunteering	Change	▲ total volunteer availability = ▲ resilience	Mid warning signal
	% volunteers showing signs of burnout	Change	▲ % with burnout symptoms = ▼ resilience	Early warning signal
Self-rated access to social support	Survey measures examining self-rated access to emotional, financial and practical support from their personal social networks	Change	▲ % with access to support = ▲ resilience	All (small change = early warning, larger changes = late)
Social networks	Frequency of engagement in social interaction with close friends and family	Change	While a decrease in frequency of engagement is a sign of low resilience, it is unclear whether increases above a healthy threshold are signs of increasing resilience	All (small change = early warning, larger changes = late)
	Satisfaction with personal relationships	Change	▼ % satisfied = ▼ resilience	All (small change = early warning, larger changes = late)
	Possibly frequency of search terms related to relationship break down	Change	▲ search term frequency = ▼ resilience	All (small change = early warning, larger changes = late)
	Divorce/separation rate	Change	▲ recent divorce/separation per head of population = ▼ resilience	All (small change = early warning, larger changes = late)
Social cohesion	Social media sentiment measures focused on terms indicating (i) cohesion and (ii) conflict/ disagreement/ anti-social behaviour	Change	▲ % cohesion sentiment relative to conflict/antisocial sentiment = ▲ resilience	All (small change = early warning, larger changes = late)
	Sense of belonging (survey measure)	Change	▲ sense of belonging = ▲ resilience	All (small change = early warning, larger changes = late)

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5.6 SOCIAL RESOURCES – COMMUNITY

5.6.1 Introduction

Closely related to social resources at the individual level is social resources at the community level. The indicators discussed in Section 5.5 are often relevant both to understanding resilience of individuals and of the communities they live in. However, an additional small number of indicators were identified that are measured at community scale, and are examined in this section.

5.6.2 Brief review of potential indicators

The availability of social resources in a community was discussed in most workshops. In particular, discussions talked about availability of places that facilitated social gathering, often informally, as well as the presence of functioning community and social organisations. The concept of community cohesion was identified as very important for recovery and resilience by several participants. While not precisely defined in workshops, it was described as people being willing and able to work together within a community, having a sense of shared purpose, and as enabling people to more readily locate resources and identify who needed resources. Increased disengagement or a rise in community conflict such as anger on social media were identified as signs that a community was losing this community cohesion and hence resilience.

In some workshops, participants described rapid change in population as reducing community cohesion. This was discussed in relation to people relocating after a natural hazard due to lack of available housing, and to situations in which an influx of new residents arrives in a community who need time to develop social ties and ability to contribute to community cohesion.

Table 13 identifies indicators commonly recommended in the literature and critically evaluates their suitability for use in this project. Table 14 then summarises which indicators are recommended as potential ‘early warning signal’ indicators, where there is potential to measure change in resilience in ways that provides early indications of change.

Table 13 Common indicators of resilience used in past studies – social resources at community scale

INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Presence of functioning community organisations	<ul style="list-style-type: none"> Number of community organisations operating in community – sports groups, community service, charity, churches, civic, NGO, etc. 	Several studies measure numbers of active community organisations as a measure of community-scale social resources, with more organisations per head of population considered an indicator of higher resilience. This indicator is included, however, has some limitations in ability to be interpreted consistently. For example, if two organisations merge due to a desire to work closely together, this may be positive for community cohesion – but appear as a decline in community organisations if this indicator was included. This indicator can be monitored through tracking active organisations via online resources, or survey measures that examine how well local residents feel their organisations are functioning.
Participation in community activities	<ul style="list-style-type: none"> Number, type, and attendance at community activities 	The number of community activities held, and attendance at these, is sometimes discussed as an indicator of community cohesion. Workshop participants discussed e.g. community festivals, community activities.
Inter-community social resources - Community capacity to help others/ access support from other/ collaborate	<ul style="list-style-type: none"> Sympathy/empathy Altruism Competition/ conflict over resources Relationship between community and larger region 	Inter-community resources are those involving connection between different communities. In workshops, people discussed sympathy, empathy and altruism towards other communities and people experiencing hardship as a sign of having resilience. Being able to contribute support to other communities was considered a sign of resilience. In workshops participants also discussed a common source of conflict being concern about which communities hit by disaster were getting fair amounts of resources/ support. This links to this area as I suggests prevalence of concerns about ‘getting a fair share’ may be a sign of resilience loss or low resilience due to lower capacity to share resources and help each other. Finally, the ability of a community to access resources from outside the community is considered a sign of resilience. All these aspects are typically measured via self-report surveys.

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INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Intra-community social resources	<ul style="list-style-type: none"> • Social inclusiveness • Social inequality • Social integrity • Social trust • Social cooperation • Communal solidarity • Social division/conflict • Nurturing and care 	<p>Intra-community resources means the social resources used within a community to care for all within it. For example, the COPEWELL resilience index highlights the importance of ‘nurturing and care’ in the form of the “...capacity of a community to provide supportive/assistive care to citizens in need, e.g. child care, elder care, housebound and nursing services.” (Link et al. 2018). Intra-community social resources rely on good cooperation, inclusiveness, and low social inequality. These can be measured in surveys, and potentially through examining community sentiment in social media.</p>
Community gathering places	<ul style="list-style-type: none"> • Presence, accessibility and use of communal gathering places e.g. community centres, halls, others 	<p>In the resilience literature, the presence of absence of community gathering places is discussed primarily in relation to the availability of evacuation centres. Workshop discussions suggests that community gathering places are critical to maintaining resilience through all stages of disaster, particularly in the months and years after a disaster. Several participants identified examples in which either the presence of a common informal gathering place aided recovery through enabling social interaction and ability to share knowledge, ideas and support; or in which loss of a gathering place, for example due to its damage in a disaster, caused loss of social cohesion due to loss of a gathering place. This can be considered a step change indicator that acts as a tipping point in access to social resources. It is likely best measured using survey measures.</p>
Volunteering	<ul style="list-style-type: none"> • Participation in volunteering • Volunteer availability • Volunteer stress 	<p>Many communities rely on the availability of volunteers to maintain many critical activities, ranging from community festivals to disaster response, supporting animal shelters, community sports group, undertaking environmental rehabilitation, and providing social support, amongst many. In many workshops, participants discussed volunteer burnout, or overall difficulty accessing sufficient volunteers, as challenges that reduced the resilience of a community. While relying on volunteering measures on their own as measures of social resources was cautioned against by some workshop participants, availability of volunteers remains an important indicator.</p>
Community cohesion - Working well together	<ul style="list-style-type: none"> • Collective action and decision making • Collective efficacy and empowerment 	<p>This indicator is somewhat unclear but is identified in both the literature and by workshop participants as important to community resilience. In general, community cohesion was described as having the ability to work well as a collective (a community) to achieve positive outcomes for the whole community. This may be able to be explored via social media sentiment and via survey questions.</p>
Length of residence	<ul style="list-style-type: none"> • % living in area 10 years or more • % recently arrived in area • % living in area who were born there 	<p>Length of residence is sometimes considered an indicator of resilience, with a shorter length of residence associated with lower resilience. This is argued to be due to recent residents having fewer social connections and less knowledge of local community processes, disaster preparation needs, and lower ability to contribute to positive community outcomes. However, it should be noted that some argue recent residents can bring new skills, perspectives, and resources into communities, meaning this indicator is not always easily interpretable. In workshops, participants identified that a large influx of new residents was sometimes associated with reduced social cohesion, less knowledge of community resources and processes, and a greater need to support new residents during and after disasters due to both these things.</p>

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INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Weekender/ absent residents	<ul style="list-style-type: none">• % residents living full-time in areas• % homes occupied	<p>In workshops, some participants discussed concerns that 'part-time' residents who have weekender or holiday homes in a region can contribute to lower resilience, for the same reasons new residents are sometimes argued to do this. However, it is also possible that part-time residents bring additional resources, as they typically have access to a primary residence elsewhere, and to social networks located in other communities who can be called on to provide support. Given the lack of consistency of interpretation, this indicator is not recommended. Workshop participants also discussed concerns about impacts of part-time residents on real estate prices; real estate prices are examined as part of financial resources.</p>



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Table 14 Recommended social resilience indicators – community

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Income distribution and average	Income inequality in a community – % low income, middle income and high income households	Change	▲ % income inequality = ▼ resilience	All (small change = early warning, larger changes = late)
Presence of functioning community organisation	Number of active organisations per head of population	Change	▼ active organisations = ▼ resilience	All (small change = early warning, larger changes = late)
	Survey measures examining views about functionality of local community organisations	Change	▼ perceived functionality = ▼ resilience	All (small change = early warning, larger changes = late)
Participation in community activities	Attendance at community activities, per capita	Change	▼ attendance = ▼ resilience	All (small change = early warning, larger changes = late)
Inter-community social resources	Sentiment measures (social media, online) about competition versus collaboration between communities	Change	▼ collaboration relative to collaboration = ▼ resilience	All (small change = early warning, larger changes = late)
	Survey measures rating perceived fairness of access of community to support, compared to others	Change	▼ perceived fairness of access to support = ▼ resilience	All (small change = early warning, larger changes = late)
	Survey measures examining perceptions of relationship to other communities and ability to (i) provide and (ii) access support from other communities	Change	▼ perceived quality of relationship = ▼ resilience	All (small change = early warning, larger changes = late)
Intra-community social resources	Perceived social equality, inclusiveness and cooperation	Change	▼ perceived equality, inclusiveness, cooperation = ▼ resilience	All (small change = early warning, larger changes = late)
	Perceived social conflict	Change	▲ social conflict = ▲ resilience	All (small change = early warning, larger changes = late)
Community gathering places	Presence and accessibility of communal gathering places (survey measure)	Step change	▲ % with burnout symptoms = ▼ resilience	Step change indicator
Volunteering	See social resources – individual			
Community cohesion	Social media/online sentiment about ability of community to work together, versus having issues of competition/conflict	Change	▲ perceived cohesion = ▲ resilience	All (small change = early warning, larger changes = late)
	Survey measures about ability of community to work together to achieve positive outcomes, versus having issues of competition/conflict	Change	▲ perceived cohesion = ▲ resilience	All (small change = early warning, larger changes = late)

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INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Length of residence	% population who have lived in area for less than 1 year, less than 2 years	Change	▲ recent residents = ▼ resilience	All (small change = early warning, larger changes = late)



5.7 INFRASTRUCTURE AND SERVICES – COMMUNITY

5.7.1 Introduction

Having good access to a range of types of infrastructure and services is widely recognised as important to maintaining resilience. These can range from access to mental health services that can provide effective (and ideally early) intervention when a person experiences symptoms of mental ill health, to having good quality roads and bridges, and reliable and high quality mobile phone and internet coverage and access.

The effect of changes in access to services, and of changes in availability of key infrastructure, is commonly identified in the resilience literature, and indicators of access to and quality of infrastructure and services are often considered useful indicators of resilience.

A key challenge when considering indicators of access to infrastructure and services, however, is that simply being present in a community is not generally sufficient to ensure all people in that community have good access to the infrastructure or service. Issues such as affordability of services, waiting times to access services, quality of service or infrastructure, and whether all members of a community are welcomed when they seek to access a service, are also critical to consider when assessing whether a given person has good levels of access to different types of infrastructure or services.

5.7.2 Brief review of potential indicators

The types of infrastructure and services identified in the literature range widely. Each main type is discussed in Table 15, including health services, social services, food and goods supply chains, transport infrastructure, telecommunications, housing, emergency services, water and sanitation, energy, education, community services, and financial/professional services.

In workshops, change in quality of transport infrastructure (roads, bridges, etc), in availability and quality of housing, access to health services, and access to mobile phone, internet, water, sewage and electricity were identified as signs of changing resilience. In addition, access to professional trades services was commonly discussed, with lack of ability to access tradespeople a common barrier to disaster preparation and recovery activities, as well as in day to day life. When discussing access to health services, participants discussed a wide range of services including mental health professionals, general practitioners, nurses, and hospital beds and services, amongst others.

Table 15 identifies indicators commonly recommended in the literature and critically evaluates their suitability for use in this project. Table 16 then summarises which indicators are recommended as potential 'early warning signal' indicators, where there is potential to measure change in resilience in ways that provides early indications of change.



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Table 15 Common indicators of resilience used in past studies – access to services and infrastructure

INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Health services	<ul style="list-style-type: none"> Number of health workers per head of population. Past work has used various types of health workers, including total health work force, nurses, midwives, general practitioners/ physicians, mental health practitioners, paramedics or others Number of health services/capacity per head of population e.g. number of hospital beds, pharmacies Accessibility of health services (this may be measured by distance, waiting time, or other measures such as average cost, or ability to reach by public transport or other means) Distance to nearest health service (km) Cost of health service appointment relative to income Waiting times to access health services: specific measures include average ambulance response time, and waiting times for services including hospital emergency services (usually measured in hours), doctor appointments (days/ weeks), specialist or allied health appointments (months), and non-urgent surgeries (months). Spending on health services per capita Disease surveillance/ medical intelligence gathering 	<p>Access to health services was identified as an important indicator of resilience in almost every stakeholder workshop. Of the many possible indicators, a preference was expressed for measuring ability to access services, rather than the presence or absence of a service in a community.</p> <p>Given this, indicators of health services to be examined will include:</p> <ul style="list-style-type: none"> Self-rated ability to access a range of health services, measured via survey data collection Average waiting times for different types of health service, including GPs, allied health services, and mental health professionals Number of different types of health professional per head of population Possibly affordability of health services.
Social services and care sectors	<ul style="list-style-type: none"> Number of aged care homes per head of population, or per head of population aged older than a set threshold Disability/psychosocial/community services per capita, sometimes for children vs adults Housing program Social advocacy/ civic/ NGO organisations per capita 	<p>In workshops there was some discussion of lack of availability of social services as a sign of resilience loss. This was mostly discussed in relation to providing services to those in need of specific help, rather than having sufficient aged care places. In some workshops, difficulty accessing sufficient childcare was discussed, however it was not clearly identified as indicating low resilience. Similarly, the presence of social support and advocacy organisations was discussed, however an increase in these organisations and staffing is difficult to interpret, as it may indicate increased need (suggestive of declining resilience) or increased capacity to service existing need (suggestive of increasing resilience).</p> <p>Ability to provide specific social services to different cohorts is important. This indicator will be examined by exploring self-report survey data, and exploring potential to use internet search frequency, related to aged care, child care, and care for those with a disability.</p>

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INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Grocery and domestic goods supply infrastructure	<p>While identified as an indicator of resilience, the literature reviewed did not typically contain specific, measurable indicators beyond broad statements such as ‘number of local food suppliers’ or ‘functioning, secure and equitable food supply systems’.</p> <p>Suggested indicators include:</p> <ul style="list-style-type: none"> • Average price of food staples in local grocery stores • Availability of key groceries in local shops 	<p>Availability and affordability of groceries and domestic goods essential for day to day living were identified in workshops as an indicator of resilience. Some described experiences in which extended shortages of these goods occurred after disaster due to road closures or other factors.</p> <p>Self-rated accessibility and affordability of groceries will be measured via survey indicators.</p> <p>The potential to identify data from major supermarket chains on supply to different local areas will be explored, and if possible indicators developed.</p>
Transport infrastructure	<p>Indicators related to transport vary widely, from generalised statements about ‘accessibility’ or ‘quality’ to more specific indicators. Measurable indicators identified in the literature included:</p> <ul style="list-style-type: none"> • Access to cars e.g. car ownership per head of population, or average number of cars/motorbikes per household • Public transport accessibility, in terms of availability and accessibility to those with disabilities • Number of bridges • Self-rated access to transport • Km of paved roads (often relative to size of population and physical area) • Road width, or other measures of suitability of roads for evaluation • Quality of road 	<p>In workshops, discussion of transport infrastructure focused on issues such as frequency and length of closures of roads and bridges, quality and safety of roads. Long term lack of public transport was also identified as an issue for many.</p> <p>Access to road infrastructure will be measured via survey self-report measures, and exploring data on road closures and access using data from online tools such as Google Maps and Apple Maps.</p>
Telecommunications infrastructure	<p>Telecommunications infrastructure indicators typically focus on either access to a service at all, or access to a service with a minimum threshold of reliability or quality. Common examples include:</p> <ul style="list-style-type: none"> • Average internet speed • % households with access to high speed internet • Rate of outages (internet, mobile phone, radio, television) • % population with access to radio, TV, telephone • Mobile phone network coverage, by quality/level of coverage e.g. 3G, 4G, 5G • Cost of high quality services e.g. mobile phone, high speed internet 	<p>Access to telecommunications, in the form of both mobile phone reception and high speed reliable internet connection, was discussed in almost all workshops. Coverage, speed, quality and frequency of outages were all identified as important issues.</p> <p>Given this, indicators will examine internet and mobile phone coverage, average cost for a given level of coverage/ speed/ bandwidth, rates of outages, and self-rated quality of access. This will be done via both survey data collection, and via data from other sources if possible.</p>

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INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Residential housing infrastructure	<ul style="list-style-type: none"> • Number of bedrooms per head of population • Incidence of overcrowding • New approved building works per head of population • % housing made with high quality materials (materials defined differently depending on study) • % unoccupied or derelict/boarded up buildings • % building in disrepair/poor condition • % households living with at least one of a defined set of housing problems • Affordability of housing • Mobile homes as % housing stock • Affordability of housing (see also financial resources) – median rent, median mortgage repayment, spending on housing as % income • Price of land for residential building 	<p>In workshops, a lack of sufficient housing, as well as concern about high numbers of people living for lengthy periods of time in temporary housing after disasters, high cost of housing, and concern about vacant holiday homes, were all discussed as affecting resilience through influencing ability for a household to have a stable living situation. Housing affordability is included as a financial resources indicator, as are rental vacancy rates. In addition to these existing indicators, it is proposed to measure the proportion of the population living in temporary accommodation or in accommodation requiring repair.</p>
Emergency services infrastructure	<ul style="list-style-type: none"> • Distance to nearest fire station or police station • Average emergency service response time to call out e.g. police, fire • Number of emergency services workers or services per head of population, by type (e.g. police, fire fighters, fire stations, paramedic) • Number of RFS sheds 	<p>Maintaining good emergency services access is important for resilience; in recent years, lengthening ambulance response times have been identified as being of concern in some Australian communities, as has difficulty recruiting sufficient emergency services staff and volunteers.</p> <p>Key indicators to be examined in relation to this include:</p> <ul style="list-style-type: none"> • Ambulance response time • Number of emergency services workers per head of population • Number of active volunteers and paid staff per local branch/brigade of local firefighting and emergency services.
Water and sanitation	<ul style="list-style-type: none"> • % residences or population with access to safe drinking water • % residences/population with access to adequate sanitation facilities • Waste produced relative to waste treated • Sanitation facilities • Waste collection services • Cleanliness of streets/ rubbish levels • Water use per capita 	<p>While not discussed regularly in workshops, access to water fit for domestic use (drinking, washing, cooking), and to adequate sanitation infrastructure and rubbish collection, is important to quality of life.</p> <p>Indicators to be explored in relation to this include:</p> <ul style="list-style-type: none"> • Self-rated quality of drinking water, sanitation and cleanliness of local streets (survey measure) • Drinking water alerts

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INDICATOR	VARIANTS OF INDICATOR IN PAST STUDIES	COMMENTARY
Energy	<ul style="list-style-type: none"> • % households with access to electricity/ gas • Frequency of blackouts/ brownouts e.g. average hours of disruption of electricity supply • Reliability of energy provision • % population with alternative source of electricity in case of disruption • % households using renewable energy sources 	<p>Energy reliability and affordability was discussed in some workshops.</p> <p>Indicators to be explored will include:</p> <ul style="list-style-type: none"> • Number of days in which blackouts, brownouts, or loss of continuity of electricity supply occurred • Energy costs relative to income
Education services	<ul style="list-style-type: none"> • Children per teacher • Functionality of schools after disaster • Spending on education per capita 	<p>Having a healthy, well functioning education system is important for resilience. Indicators recommended in the literature and workshops include:</p> <ul style="list-style-type: none"> • Number of children per teacher: however, there is a lack of clarity regarding interpretation and thresholds for this type of indicator • Educational outcomes for different age groups, using NAPLAN data • Findings of the Australian Early Development Census, every 3 years, provide insight into children's develop as they are in their first year of school <p>Many of these are relatively slow changing indicators, however, so are best understood as mid to late warning signals of resilience change, rather than early warning signals.</p>
Community infrastructure	<ul style="list-style-type: none"> • Libraries • Arts, entertainment and recreation centres 	<p>Community infrastructure refers to things such as presence of libraries, arts/recreation/ entertainment facilities. These are step change indicators, which do not change rapidly. They are not recommended as indicators that provide early warning of resilience change: instead, data on availability of funding for local governments to successfully maintain this type of infrastructure is considered a more relevant indicator than the number of specific sites/ centres/libraries present in a community.</p>
Financial/ professional services	<ul style="list-style-type: none"> • Banks/financial services accessibility • Professional, scientific and technical services per 1,000 population 	<p>Access to financial and professional services is not regularly identified in the resilience literature as an indicator of resilience, although some include the availability of people providing any kind of professional, scientific and technical services. In workshops, participants identified access to professional trades people – e.g. electricians, carpenters, plumbers – as a critical area. This will be examined via self-reported measures collected via survey data.</p>

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Table 16 Recommended resilience indicators – access to services and infrastructure

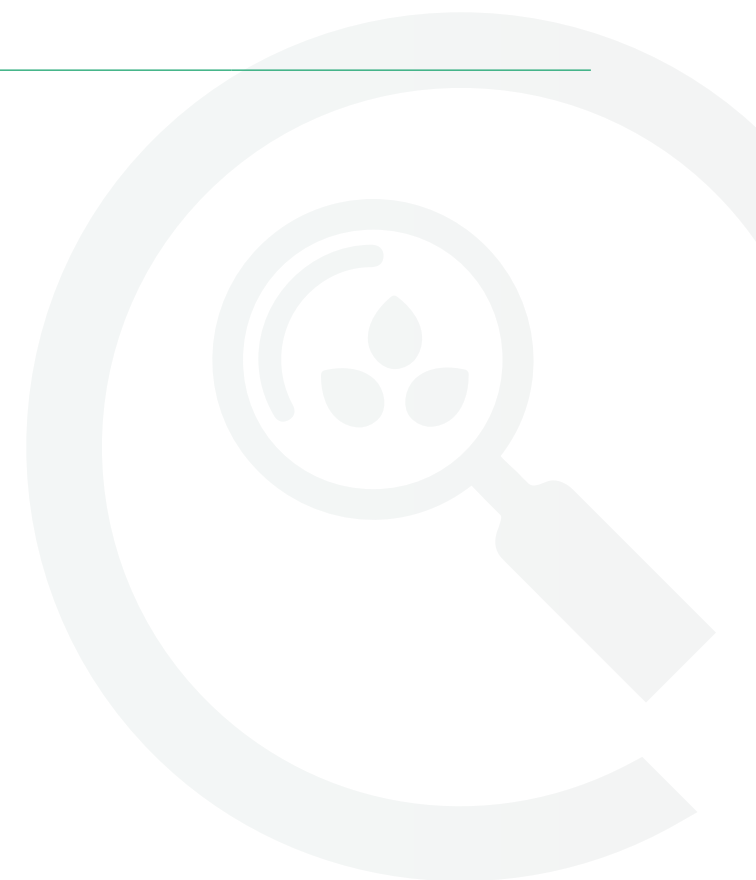
INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Income distribution and average	Income inequality in a community – % low income, middle income and high income households	Change	▲ % income inequality = ▼ resilience	All (small change = early warning, larger changes = late)
Health services	Self-rated ability to access a range of health services	Change	▼ access = ▼ resilience	All (small change = early warning, larger changes = late)
	Average ambulance waiting time	Change	▼ waiting time = ▼ resilience	All (small change = early warning, larger changes = late)
	Average waiting time to see different types of health professional	Change	▼ waiting time = ▼ resilience	All (small change = early warning, larger changes = late)
	Number of different types of health professional per head of population	Change	▼ professionals per capita = ▼ resilience	All (small change = early warning, larger changes = late)
	Affordability of health services	Change	▼ affordability = ▼ resilience	All (small change = early warning, larger changes = late)
Social service and care sectors	Self-rated accessibility of key social services, aged care and child care	Change	▼ accessibility = ▼ resilience	All (small change = early warning, larger changes = late)
Grocery/domestic goods supply	Availability of key groceries and domestic goods	Change	▼ availability = ▼ resilience	All (small change = early warning, larger changes = late)
	Supply chain measures (potential to be explored)	Change	To be explored in Stage 2 of project	All (small change = early warning, larger changes = late)
	Social media posts related to supply of domestic goods	Change	▲ reports of shortages/ difficulties accessing goods = ▼ resilience	All (small change = early warning, larger changes = late)
Transport infrastructure	Proportion of road network affected by road closures over defined period of time	Change	▲ closures = ▼ resilience	All (small change = early warning, larger changes = late)
	Self-rated quality of local road network (survey measure)	Change	▼ perceived quality = ▼ resilience	All (small change = early warning, larger changes = late)
	Social media discussion of road network quality	Change	▲ reports of road network problems = ▼ resilience	All (small change = early warning, larger changes = late)

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INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Telecommunications infrastructure	Average internet speed	Change	▼ % with speeds at or above national average = ▼ resilience	All (small change = early warning, larger changes = late)
	% households with access to high speed internet	Change	▼ % with access = ▼ resilience	All (small change = early warning, larger changes = late)
	Frequency of internet outages	Change	▲ outages = ▼ resilience	All (small change = early warning, larger changes = late)
	% households with high quality mobile phone coverage at residence	Change	▼ % with access = ▼ resilience	All (small change = early warning, larger changes = late)
	Frequency of loss of mobile phone coverage (outages)	Change	▲ outages = ▼ resilience	All (small change = early warning, larger changes = late)
	Affordability of high speed internet	Change	▼ affordability = ▼ resilience	All (small change = early warning, larger changes = late)
	Affordability of mobile phone coverage	Change	▼ affordability = ▼ resilience	All (small change = early warning, larger changes = late)
Residential housing infrastructure	% population living in temporary / non-permanent accommodation	Change	▲ % living in temporary accommodation = ▼ resilience	All (small change = early warning, larger changes = late)
	% population living in accommodation needing significant repairs	Change	▲ % living in substandard accommodation = ▼ resilience	All (small change = early warning, larger changes = late)
Emergency services infrastructure	Number of emergency service workers per head of population	Change	▼ emergency services workers per capita = ▼ resilience	All (small change = early warning, larger changes = late)
	Number of active emergency services volunteers per head of population	Change	▼ emergency services volunteers = ▼ resilience	All (small change = early warning, larger changes = late)
Water and sanitation	Self-rated quality of drinking water, sanitation, cleanliness of community public areas	Change	▼ drinking water quality rating = ▼ resilience	All (small change = early warning, larger changes = late)
	Number of days in which water quality alerts applied to drinking water supply	Change	▲ days of poor drinking water quality = ▼ resilience	All (small change = early warning, larger changes = late)
Energy	Number of days with loss of electricity supply (blackout, brownout)	Change	▲ days with blackouts/brownouts = ▼ resilience	All (small change = early warning, larger changes = late)
	Energy costs relative to income	Change	▲ energy costs relative to income = ▼ resilience	All (small change = early warning, larger changes = late)

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INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Education services	Number of children per teacher	Change	▲ number of children per teacher = ▼ resilience	All (small change = early warning, larger changes = late)
	Educational outcomes	See human resources		
Community infrastructure	See institutional resources and financial resources – community			
Financial/professional services	Self-reported access to professional tradespeople	Change	▼ % with access = ▼ resilience	



5.8 INSTITUTIONAL RESILIENCE - COMMUNITY

5.8.1 Introduction

Living in a community in which there is effective, transparent, and accountable governance that treats all people fairly and equitably make an important contribution to resilience. A person who lives in a community in which local leaders do not listen when they raise problems, or where funds given to governments to promote disaster preparation are misappropriated and not used for community benefit, is likely to have lower resilience to natural hazards compared to one living in a community in which their views are heard and responded to and funds used appropriately.

Institutions operating in communities include government at all levels, and also the range of organisations that contribute to the day to day functioning of a community. These include local not for profit organisations, the range of health, education, social and emergency services operating in a community, community groups, managers of key assets and resources, and private business. Institutional resilience should therefore be broadly understood as including not only having effective government(s), but also systems that enable different institutions to work well together across the public, not for profit and private sector, and effective leaders across all types of community institutions.

5.8.2 Brief review of potential indicators

While recognised as important to achieving positive outcomes, relatively few indicators of institutional resilience are included in resilience frameworks. Table 17 summarises common indicators, and also examines those identified in workshops, where participants discussed issues including burnout of leaders, financial health of local government, and funding. Table 18 then summarises which indicators are recommended as potential 'early warning signal' indicators, where there is potential to measure change in resilience in ways that provides early indications of change.

Table 17 Common indicators of resilience used in past studies – institutional resilience

INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Leadership	<ul style="list-style-type: none"> Trust in officials, leaders, government Views about effectiveness, transparency, accountability of leaders Unfilled leadership positions per head of population Turnover of leadership positions Governance index (political stability, government effectiveness, regulatory quality, rule of law, control of corruption) Corruption levels (lack of clear indicators beyond public perceptions of transparency, accountability) 	The presence of strong and effective leadership and, more generally, governance in a community is well documented to be an important predictor of success of that community in navigating challenges. Strong and effective leadership can be measured in many ways, including levels of trust in leadership, views about effectiveness of leaders, turnover of leadership, and vacancies in leadership positions. With very limited data available from administrative data sets, indicators of leadership will be examined via (i) survey questions and (ii) potentially social media sentiment. Data on known corruption in local governance is relevant, however can be a lagging and incomplete indicator due to variable rates of detection of corruption.
Democratic participation	<ul style="list-style-type: none"> Participation in voting 	In some resilience indexes, voting participation is considered a resilience indicator. In the Australian context of compulsory voting, this is not considered a useful indicator of resilience.
Participation in local governance	<ul style="list-style-type: none"> Confidence in being able to have a voice in decision making Confidence in being listened to by decision makers Participation in local decision making processes 	While not typically discussed in workshops, ability to have a meaningful say in decisions made by local institutions is commonly identified as a sign of a healthy and functioning community. This type of indicator is typically measured using surveys.

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INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Regulation and legislation	<ul style="list-style-type: none"> • ‘Supportive’ regulation/legislation enabling appropriate zoning/use, emergency response, risk reduction, etc • Enforcement of building codes and other relevant regulation/ legislation to reduce disaster risk • Quality of building codes for reducing exposure to hazards 	The presence of absence of regulation or legislation enabling or restricting certain activities is a ‘step change’ indicator. It is considered important, but effectiveness will depend on enforcement/compliance/enactment.
Funding	<ul style="list-style-type: none"> • % budget on social assistance • % budget on disaster response and recovery • % budget on disaster preparation/ mitigation activities • Park maintenance spending per capita • Spending on community services per capita • Spending on other aspects of budget per capita • Spending on community infrastructure per capita 	As discussed in the financial resources – community section, local government budget per capita for everyday activities may be an indicator of change in resilience, and is included as an indicator in that domain.



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Table 18 Recommended institutional resilience indicators

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Leadership	Survey measures examining levels of trust in leaders, views about transparency, accountability and effectiveness	Change	▼ % with positive perceptions = ▼ resilience	All (small change = early warning, larger changes = late)
	Social media analysis of sentiment regarding local leadership	Change	▼ % with positive perceptions = ▼ resilience	All (small change = early warning, larger changes = late)
	Leadership turnover rates	Change	▲ turnover rates = ▼ resilience	All (small change = early warning, larger changes = late)
Participation in local government	Confidence in being able to have a voice in decision making	Change	▼ % with confidence = ▼ resilience	All (small change = early warning, larger changes = late)
	Confidence in being listened to by decision makers	Change	▼ % with confidence = ▼ resilience	All (small change = early warning, larger changes = late)
	Participation in local decision making processes	Change	▼ % actively participating = ▼ resilience	All (small change = early warning, larger changes = late)

5.9 ECOSYSTEM SERVICE PROVISION

5.9.1 Introduction

Changes in health of the natural environment are important indicators of resilience. Decline in environmental health has many implications for human resilience, through changing availability of the ecosystem services human often rely on.

Some changes in environmental health occur over very long periods, or have a long and indirect effect on human resilience. While critical to long-term resilience, these are not examined as part of this project, which focuses on indicators for which shorter-term change in human resilience can be measured. This means that, when examining health of the natural environment, the focus is on change in the quality and quantity of ecosystem services available to humans. It is important to note that these changes are often an outcome of longer term, widespread changes in environmental health, up to and including the effect of global change in greenhouse gas emissions. These larger scale and longer term drivers are not examined here, as the purpose of this project is to identify indicators useable by local community organisations of early signs of human resilience loss, rather than to examine loss of resilience of broader environmental systems.

5.9.2 Brief review of potential indicators

Issues related to ecosystem service provision were sometimes discussed in workshops. In particular, some discussed challenges relating to water and soil quality. Some workshop participants discussed the loss and grief experienced at loss of environmental health and/or changes to local nature areas caused by bushfires or floods. Others discussed frustration of locals when some visitors to their communities confused the return of green vegetation with recovery of environmental health and amenity and this was difficult for local residents who knew recovery was not that progressed. This highlighted the importance of community perceptions of local environmental health, which affect key personal psychological resources such as a person's sense of optimism and confidence in the future.

Table 19 summarises common indicators of ecosystem service provision. Table 20 then summarises which indicators are recommended as potential 'early warning signal' indicators, where there is potential to measure change in resilience in ways that provides early indications of change.

Table 19 Common indicators of resilience used in past studies – ecosystem service provision

INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Ecosystem services – food production	<ul style="list-style-type: none"> • Soil productivity levels (see soil health) • Availability of water for agricultural production • Availability of arable land • Agricultural productivity e.g. average volume of different products produced per hectare 	The indicators listed here are important, but often on very large scales relative to a local community. In the Australian context, it is rare to have high reliance on local food production for sustenance; thus to be relevant to examining change in resilience of humans living in a local community, this type of indicator would need to examine food production at larger scales. Rather than examine environmental health related aspects, instead indicators of access to groceries and domestic goods are examined.
Ecosystem health – general	<ul style="list-style-type: none"> • Environmental/ecosystem health measures • Biodiversity (many measures possible) • % land and water area designated as protected areas • Availability of vegetation corridors for movements of species 	Overall health of ecosystems is critical to resilience. The potential to use existing indicators tracking health will be explored, through consulting organisations who monitor ecosystem health in NSW.

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INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Ecosystem services – extreme weather absorptive capacity	<ul style="list-style-type: none"> • % vegetation or forest cover • Coastal condition • Forest/ vegetation condition • Tree density • % wetlands 	Some resilience indicators focus on measuring factors that affect the absorptive capacity of the natural environment, for example, ability to absorb a storm surge in a mangrove area without the surge flooding the city that is next to the mangrove area. In general, having high levels of vegetation cover, and better soil condition, are considered useful measures. However, within this there are often highly location specific measures of health. The potential to use existing indicators tracking health will be explored, through consulting organisations who monitor ecosystem health in NSW.
Ecosystem services – soil health	<ul style="list-style-type: none"> • Soil productivity • % groundcover or % exposed soil surface • Soil erosion • Health – % organic matter, soil biodiversity, nutrient availability, water retention 	Similar to overall ecosystem health, soil health is critical to resilience, but is important on a large scale relative to a local community when considering ecosystem services supported by soil health such as food production. Local soil health is often a key driver of local water quality. The potential to use existing indicators tracking soil health will be explored, through consulting organisations who monitor ecosystem health in NSW.
Ecosystem services – air quality	<ul style="list-style-type: none"> • % ‘clean air’ days (days per year above/below set threshold of air quality) • Air quality 	The potential to use existing indicators tracking air health will be explored, through consulting organisations who monitor ecosystem health in NSW.
Ecosystem services – water	<ul style="list-style-type: none"> • Volume of clean water available per head of population • Water quality in rivers, streams and lakes 	In addition to drinking water quality measures described elsewhere, the potential to use existing indicators tracking quality of water in waterways and waterbodies within a community will be explored through consulting relevant organisations.
Perceptions of environmental health	<ul style="list-style-type: none"> • Local resident perceptions of quality of access to ecosystem services 	This indicator is, as noted above, something that influences a person’s confidence in the future.



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Table 20 Recommended resilience indicators – ecosystem service provision

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Overall ecosystem health	The potential to use existing indicators tracking health will be explored, through consulting organisations who monitor ecosystem health in NSW.			
Extreme weather absorptive capacity	As above			
Soil health	As above			
Water quality	As above			
Air quality	Indicators of air quality from local monitoring stations, focusing on PM2.5 levels	Change	▲ days with poor air quality = ▼ resilience	All (small change = early warning, larger changes = late)
Perceived environmental health	Survey measures examining perceptions of quality of local ecosystem services	Change	▲ perceived environmental health problems = ▼ resilience	All (small change = early warning, larger changes = late)

5.10 OTHER ASPECTS OF LIVEABILITY – COMMUNITY

5.10.1 Introduction

'Liveability' refers to the extent to which a community provides a physical, economic and social environment that supports a high quality of life. Many indicators of liveability are examined as part of other domains – for example, indicators related to community cohesion are examined in Section 5.6, and those related to infrastructure and services availability in Section 5.9. However, some do not fit into other domains, and are examined in this section. These relate to the overall amenity of the local physical environment (natural and built), crime and safety, and culture and identity. This section only examines those indicators of liveability not examined elsewhere.

5.10.2 Brief review of potential indicators

In workshops, participants discussed issues relating to safety and crime rates, and amenity of the local area, as important things that changed as warning signs of resilience loss. Things like the distance needed to travel for everyday goods such as shops and petrol was an indicator of resilience. Table 21 describes these indicators and examines indicators related to cultural identity, which were identified in some previous studies examining resilience indicators. Table 22 then summarises which indicators are recommended as potential 'early warning signal' indicators, where there is potential to measure change in resilience in ways that provides early indications of change.

Table 21 Common indicators of resilience used in past studies – other aspects of liveability

INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Amenity	<ul style="list-style-type: none"> Pleasantness of environment and surrounds Sentiment about amenity expressed in social media 	<p>The amenity of the physical surrounds a person lives and works in affects overall wellbeing, and reduced amenity – such as buildings in disrepair, local parks or green spaces that are not maintained or have high levels of rubbish, or nature reserves experiencing environmental degradation such as weed invasion – can be a sign of reduced capacity of humans to maintain amenity and hence wellbeing.</p> <p>Amenity of natural areas is sometimes measured using indicators showing the degree of 'greenness' – meaning proportion of land covered by vegetation. This is useful to a degree, but has limitations with high growth of weeds or unwanted vegetation potentially contributing to an increase in greenness while not contributing positively to how pleasant humans find the surrounds they live in. However, overall, the psychological literature suggests that higher greenness is associated with more positive mental health outcomes.</p> <p>Alternatively, residents can be asked to self-rate the amenity of the area they live in, something done in some existing surveys, particularly the RWS.</p>
Crime and safety	<ul style="list-style-type: none"> Self-rated safety when walking alone in community Safety at home Crime rates (various types possible e.g. theft, vandalism, assault, murder) Domestic violence Riots/civil unrest Conflict prevention and mitigation mechanisms 	<p>Increases in different types of crime or anti-social behaviour were identified in several workshops as signs of resilience loss, as was a reduced sense of safety. Increased domestic violence was in particular identified as a sign of resilience loss.</p> <p>These things can be measured by examining both official crime statistics: however, these are limited by reporting rates, with relatively low reporting rates of some types of crime, for example domestic violence.</p> <p>Sense of safety can also be measured by asking survey participants to rate their sense of safety when walking alone in their community, and their sense of personal safety at home.</p>

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INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Culture and identity	<ul style="list-style-type: none">• % population able to practice cultural values and heritage openly	Ability to openly identify with a person’s cultural heritage, and engage in activities important to maintaining cultural identity, are important to long-term resilience. In Australia, this is particularly important, with multiple studies highlighting that ability to safely identify with and engage in practices supporting cultural identity are central to the wellbeing of First Nations people (Bourke et al., 2018; Colquhoun & Dockery, 2012; Dockery, 2010). However, these changes typically occur over long term periods of time. They are critical, but long-term, measures of resilience, rather than something that can be used as a rapidly changing early warning signal of resilience change.



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Table 22 Recommended resilience indicators – other aspects of liveability

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Income distribution and average	Income inequality in a community – % low income, middle income and high income households	Change	▲ % income inequality = ▼ resilience	All (small change = early warning, larger changes = late)
Amenity	Survey measures examining perceptions of amenity of environment and surrounds	Change	▼ perceived amenity = ▼ resilience	All (small change = early warning, larger changes = late)
	Social media/online sentiment regarding local amenity	Change	▼ perceived amenity = ▼ resilience	All (small change = early warning, larger changes = late)
	Greenness of local area	Change	▼ greenness = ▼ resilience	All (small change = early warning, larger changes = late)
Crime and safety	Self-rated sense of safety when walking alone in community	Change	▲ perceived amenity = ▼ resilience	All (small change = early warning, larger changes = late)
	Self-rated personal safety at home	Change	▼ safety = ▼ resilience	All (small change = early warning, larger changes = late)
	Rates of different types of crime per capita, including domestic violence, theft/burglary, assault, and others	Change	▲ rates of crime = ▼ resilience	All (small change = early warning, larger changes = late)
Culture and identity	Survey measures identifying the extent to which a person feels safe to openly express their cultural identity	Change	▼ % able to express culture openly = ▼ resilience	All (small change = early warning, larger changes = late)

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5.11 NATURAL HAZARD RESOURCES – INDIVIDUAL/HOUSEHOLD

5.11.1 Introduction

When resilience to natural hazards such as disasters and drought is discussed, one of the first things often discussed are the level of specific skills, resources and infrastructure in place that help people and communities reduce the impact and damage that occurs from natural hazards. These are ‘natural hazards resources’ – resources that help people and communities minimum harm and damage resulting from natural hazards.

5.11.2 Brief review of potential indicators

In workshops, participants discussed awareness of local community emergency/disaster processes and resources, such as people’s level of awareness of availability of support and information about a particular natural hazard, or location of and existence of evacuation centres. Some discussed level of preparedness, awareness of risk, ability to access insurance, and ability to navigate the recovery process. Table 23 identifies common indicators used to measure natural hazard resources that are held by individuals and households (community scale resources are examined in Section 5.12). Table 9 identifies indicators commonly recommended in the literature and critically evaluates their suitability for use in this project. Table 24 then summarises which indicators are recommended as potential ‘early warning signal’ indicators, where there is potential to measure change in resilience in ways that provides early indications of change.

Table 23 Common indicators of resilience used in past studies – natural hazard resources, individual/household scale

INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Awareness of community emergency resources	<ul style="list-style-type: none"> Awareness of and access to key community emergency resources including: Communications (access to required technology, awareness of where/how to access information in an emergency) Evacuation centres Organisations and processes by which disaster support can be accessed 	These indicators focus on whether individuals and households know how to access information and support provided in their community to those experiencing natural hazards. These range from knowing where and how to access up to date information (for example, radio stations, apps, websites), to knowing where to evacuate to, and how to find out about and apply for support if needed. These indicators can be measured in surveys, or through examining the proportion of people in a community actively using key resources such as specific apps designed to help people access information when a natural hazard is occurring (e.g. the NSW Hazards Near Me app).
Hazard risk perceptions	<ul style="list-style-type: none"> % aware of types of hazards/risks they are at risk of Denial/acceptance of risk 	A key resource that contributes to resilience is having awareness of the level of risk of a natural hazard occurring, and of it having a negative impact on your household. Lack of awareness of risk, or denial of its severity, can be associated with lower likelihood of investing in preparedness actions. Surveys can be used to assist in assessing awareness of risk. However, there are some limitations to ability to measure this, as variance in individual situations may mean there is differing risk of experiencing damage from natural hazards between two neighbouring households.
Preparedness	<ul style="list-style-type: none"> Preparedness attitudes and behaviours Level of preparedness and skills for response Technical skills for household repairs, response to common emergency issues Stage of household preparation 	Investing in disaster preparedness actions, such as preparing an emergency plan, having an emergency kit, good management of vegetation and hazards located near a person’s house, and discussing emergency planning with others, can make a big difference to the risk of experiencing negative impacts when natural hazards occur. Engagement in these can be measured in surveys; however, there are some limitations, with households able to choose different options for preparation that may have similar benefit.
Insurance	See financial resources – individual/household	

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INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Training/ skills building/ education	<ul style="list-style-type: none"> • Engagement in disaster training/ workshops etc • % households who have participated in training/ workshops on disaster preparation, response and recovery • % with first aid training • % with disaster/ risk awareness training 	<p>This type of indicator focuses on accessing training and skills building opportunities that help increase awareness and knowledge, and as a result enable individuals and households to build specific natural hazards resilience resources. However, with individuals and households often having multiple options for building skills and knowledge, including self-directed learning using online resources. Given this variability, engagement in specific forms of training or skills building is not recommended as an indicator.</p>
Past experience	<ul style="list-style-type: none"> • % with past experience of disaster • % with past experience that resulted in positive outcomes in terms of recovery 	<p>In workshops, some participants discussed the role of past disaster experience in helping people build natural hazards skills. Some emphasised that whether or not a person builds resilience through experiencing a natural hazard depends on whether they are able to achieve positive outcomes or otherwise in their prior experiences of natural hazards.</p>



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Table 24 Recommended resilience indicators – natural hazard resources, individual/household scale

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Awareness of community emergency resources	% adult population actively accessing key natural hazards resources, e.g. Hazards Near Me app, natural hazards websites	Change	▲ use of resources = ▲ resilience	All (small change = early warning, larger changes = late)
	Survey measures examining awareness of key community emergency resources (communication and other)	Change	▲ awareness = ▲ resilience	All (small change = early warning, larger changes = late)
Hazard risk perceptions	Survey measures examining hazard risk perception	Change	▲ accurate perception = ▲ resilience	All (small change = early warning, larger changes = late)
Preparedness	Survey measures examining engagement in key hazard preparedness activities including planning, emergency kits, document storage, evacuation plans, and communication with others	Change	▲ engagement in preparedness activities = ▲ resilience	All (small change = early warning, larger changes = late)
Past natural hazard experience	Survey measures examining % of people with past direct experience of natural hazards, and whether they consider themselves to have better or poorer ability to cope with new hazards as a result of that past experience.	Change	▲ past experience of natural hazard associated with positive outcomes in the form of building capacity and resources = ▲ resilience OR ▲ past experience of natural hazard associated with negative outcomes in the form of building capacity and resources = ▼ resilience	All (small change = early warning, larger changes = late)

5.12 NATURAL HAZARD RESOURCES – COMMUNITY

5.12.1 Introduction

In addition to natural hazard resources at the individual/household scale, a large number of community-scale natural hazard resources can contribute to building resilience to natural hazards. This section examines these.

5.12.2 Brief review of potential indicators

In workshops, participants discussed the need for good availability of information provided by central agencies. This included not only timely and accurate information during the disaster response stage, but also during disaster recovery, such as information about when skip bins for disposing of damaged household goods will be available. Participants also discussed issues such as coordination of action across different community organisations, availability of key infrastructure and services, and long-term access to resources such as temporary accommodation. Table 25 summarises indicators, many of which are recognised as important, but difficult to measure using existing data. Most require collection of specific data via a survey of those involved in community response to natural hazards, rather than a survey of the general population. Table 26 then summarises which indicators are recommended as potential ‘early warning signal’ indicators, where there is potential to measure change in resilience in ways that provides early indications of change.

Table 25 Common indicators of resilience used in past studies – natural hazard resources, community scale

INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Evacuation centre/ shelter availability	<ul style="list-style-type: none"> • Number of buildings/ locations suitable for use as evacuation area or shelter in different types of emergency e.g. religious centres, schools, sports arena, sports fall, universities • Number of dedicated evacuation/ emergency centres • Accessibility of emergency centres for those with disabilities, limited access to transport • Suitability of emergency centres (e.g. availability of kitchen, sleeping, showering, water, toilets) • Capacity of local emergency shelters relative to population size 	This indicator is relatively specific to the disaster response stage of the natural hazard cycle. It is very important as part of that stage, and tends to be a step-change indicator. While recognised as important to disaster management in the response stage, as this type of indicator cannot be readily measured as incremental change and is specified to one point in the disaster cycle, it is not recommended as a priority indicator for this study.
Flood/storm infrastructure	<ul style="list-style-type: none"> • Quality/capacity of street drainage systems • Presence and quality of flood defences e.g. levy banks 	As above
Emergency services availability	See infrastructure and services	
Availability of equipment/ materials for hazard response	<ul style="list-style-type: none"> • Access to material resources and equipment needed for response to different extreme weather events e.g. access to boats, backhoes, sand bags 	As above
Training of disaster response personnel	<ul style="list-style-type: none"> • Existence and/or frequency of conduct of cross-organisation simulation exercises for disaster response and recovery scenarios • Inclusion of all relevant organisations in cross-organisation simulation exercises, including health professionals, educational institutions, community organisations • Inclusion of members of community, including those with different abilities, in simulation exercises 	This indicator would require specific surveys of those actively engaged in organisations involved or likely to be involved in disaster response and recovery.

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INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Population risk and vulnerability identification	<ul style="list-style-type: none"> Regularly updated list of populations with specific risks/vulnerabilities to disaster, e.g. those with limited mobility, need for access to powered equipment, specialist care or medication, those in financial stress Identification of transitory populations who may need to be reached in an emergency e.g. tourists, seasonal workers 	This is a specific type of information important for emergency response agencies to have in the disaster response stage. Measuring this indicator would require specific surveys of those actively engaged in organisations involved or likely to be involved in disaster response and recovery.
Information dissemination	<ul style="list-style-type: none"> Speed of information dissemination in emergencies % population able to readily access and understand emergency information Accuracy of information disseminated in emergencies Availability of emergency information e.g. number of communication mediums carrying information and reach of those mediums into population % population in risk zones who can access appropriate monitoring and alert systems for disasters 	In the resilience literature, indicators relating to information commonly focus on information availability during disaster response stages. In workshops, participants highlighted that having information available on recovery and preparation is equally important. This can be examined using surveys.
Infrastructure and supply chain vulnerability	<ul style="list-style-type: none"> Vulnerability of infrastructure and supply chain links to different types of shocks 	See services and infrastructure section.
Disaster planning – community scale	<ul style="list-style-type: none"> Regularly updated assessments of disaster/hazard risk on specified time period Presence of community disaster plans Quality of disaster planning (e.g. inclusion of all relevant areas e.g. waste management, evacuation, communication, equipment, volunteers) Frequency of review and updating of disaster plans Inclusiveness of disaster planning process, including specific planning for those with different abilities, different languages and cultural needs, pets and livestock Use of participatory risk assessment Inclusion of different forms of knowledge in disaster planning 	This indicator would require specific surveys of those actively engaged in organisations involved or likely to be involved in disaster response and recovery.
Disaster coordination	<ul style="list-style-type: none"> Clear processes for collaborating and coordinating disaster preparation, response and recovery Number of disaster coordinators appointed per head of population 	This indicator would require specific surveys of those actively engaged in organisations involved or likely to be involved in disaster response and recovery.
Institutional conflict related to disaster management	<ul style="list-style-type: none"> Disagreements/disputes related to disaster (within community, between leaders) 	This indicator would require specific surveys of those actively engaged in organisations involved or likely to be involved in disaster response and recovery, as members of the general population may be unaware of this type of conflict.

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INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Equity of access	<ul style="list-style-type: none"> • % of disaster spending reaching those with greatest vulnerability e.g. those on low incomes, with higher financial stress, living with disability or ill health, those experiencing socio-economic disadvantage • Consistency of funding allocation across whole population/ perceived favouritism of funding allocation 	This indicator is potentially important but difficult to measure. The potential to measure equity of access will be explored in Stage 2 of this project.
Volunteers and staff	<ul style="list-style-type: none"> • Burnout rates • Skills – proportion with training and/ or experience in disaster preparation, response, recovery 	Burnout rates can be measured via surveys. However, measuring skills is more challenging, given both the differing types of skills potentially of relevance depending on the community, and the range of ways skill may be built.
Funding availability	<ul style="list-style-type: none"> • Level of funding available to provide assistance to households affected by disaster e.g. for rebuilding 	This indicator is potentially important but difficult to measure across multiple communities and natural hazards due to the wide range of funding of different types that may be provided.



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Table 26 Recommended resilience indicators – natural hazard resources, community scale

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Training of disaster preparation, response and recovery personnel	Survey measures included in survey of those involved in planning and delivering natural hazard preparation, response and recovery.	Change	▲ training = ▲ resilience	All (small change = early warning, larger changes = late)
Population risk and vulnerability identification	As above	Change	▲ frequent updating of risk identification = ▲ resilience	All (small change = early warning, larger changes = late)
Disaster planning	As above	Change	▲ effective planning = ▲ resilience	All (small change = early warning, larger changes = late)
Disaster coordination	As above	Change	▲ coordination = ▲ resilience	All (small change = early warning, larger changes = late)
Institutional conflict related to disaster management	As above	Change	▲ inter-organisational conflict = ▼ resilience	All (small change = early warning, larger changes = late)
Funding availability	As above	Change	▲ funding = ▲ resilience	All (small change = early warning, larger = late)
Burnout of staff and volunteers	Burnout measures included in surveys of those engaged in these roles	Change	▲ burnout = ▼ resilience	All (small change = early warning, larger = late)
Information dissemination	Survey measures included in survey of those involved in planning and delivering natural hazard preparation, response and recovery.	Change	▲ availability of information = ▲ resilience	All (small change = early warning, larger = late)
	Survey measures included in survey of general population, asking about ability to access relevant information.	Change	▲ availability of information = ▲ resilience	All (small = early warning, larger changes = late)
Equity of access	Potential measures to be explored as part of Stage 2 of project.	Change	▲ equity of access = ▲ resilience	All (small = early warning, large = late)

5.13 EXPOSURE TO NATURAL HAZARDS

5.13.1 Introduction

In many workshops, participants discussed how increased frequency and length of natural hazard events was impacting resilience. Many communities are experiencing a higher frequency, intensity and duration of natural hazard events, something increasingly referred to as experiencing cumulative disasters. When this occurs, people may need to draw on resilience resources to prepare for future hazards while at the same time responding to currently occurring hazards, and rebuilding and recovering from past hazards. While exposure to natural hazards is not a type of resilience resource, the frequency, intensity, and duration of events a person, household or community experiences directly affects their capacity to prepare, respond and recover.

5.13.2 Brief review of potential indicators

Table 27 summarises potential indicators, drawn from the resilience literature, and from workshop discussions. Whereas indicators in previous work typically focus on identifying risk of a single hazard occurring, workshop discussions emphasised the importance of developing indicators to identify the cumulative exposure and individual, household or community experiences. Table 28 then summarises which indicators are recommended as potential 'early warning signal' indicators, where there is potential to measure change in resilience in ways that provides early indications of change.

Table 27 Common indicators of resilience used in past studies – exposure to natural hazards

INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Natural hazard occurrence	<ul style="list-style-type: none"> • Frequency/intensity/length of specific types of disaster over given time period • Change in frequency, severity/intensity, and/or length of disaster over time • % population living in areas classified as disaster risk zones e.g. floodplain, other flood risk, bushfire, cyclone, landslide risk, erosion risk • % population at risk of isolation during an emergency event • % living in residences built with specific types of hazard-resistant features • Slope, surface elevation • % of built up areas with permeable surfaces, drainage capacity (see also infrastructure) 	<p>Natural hazard occurrence can be measured in a number of ways, including:</p> <ul style="list-style-type: none"> • Weather, climatic and emergency services data indicating frequency and intensity of occurrence of specific hazards such as low rainfall, flooding, and bushfire. These provide information on what happened, but do not provide insight into the differential impacts of this extreme weather on the different communities, households and individuals who experienced it. • Number and duration of government declarations that an area is significantly affected by a natural hazard event, usually made to enable eligibility for specific types of funding and/or disaster response and recovery activities. These are based on thresholds set by governments regarding what is considered to constitute the level of impact required for a declaration. As these thresholds may be changed, or interpreted differently, by different governments, there is questionable consistency of exposure measured using this indicator. • Statistics on specific types of loss or damage experienced in a given area due to natural hazard events, such as damage to property or human injury. • Survey measures in which individuals are asked to report the specific exposures they have had to natural hazard events and their impacts. This enables assessment of both exposure and how investment in actions such as preparedness changes the nature of the impacts resulting from that exposure.

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INDICATOR	VARIANTS OF INDICATOR	COMMENTARY
Natural hazard risk	<ul style="list-style-type: none">• Frequency of specific types of weather conditions over time, e.g. heatwave, high pollen count, drought• Change in frequency, severity, intensity or typically length of specific types of weather conditions over time• % population living in areas classified as extreme weather risk zones e.g. drought, heatwave	Risk indicators focus on identifying those likely to be at risk from future natural hazard events, and calculating probabilities of exposure. They typically focus on the occurrence of extreme weather, rather than the likelihood of experience negative impacts as a result of that extreme weather. Risk indicators are typically step-change indicators: the level of potential risk does not change rapidly and is likely not to be reassessed on a frequent basis.



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Table 28 Recommended resilience indicators – exposure to natural hazards

INDICATOR TYPE	MEASURE PROPOSED	TYPE OF INDICATOR	DIRECTIONALITY AND INTERPRETATION	INDICATOR OF EARLY/MID/LATE CHANGE IN RESILIENCE?
Natural hazard occurrence	Measures of frequency, intensity and length of occurrence of different natural hazards using weather, climate and emergency services data	Change	▲ frequency, intensity and length of natural hazard events = ▼ capacity due to high level of demand on resilience resources	All (small change = early warning, larger changes = late)
	Government disaster declarations	Change	▲ period of time in which disaster declared for a given area = ▼ capacity due to high level of demand on resilience resources. Note however that care is needed to record changes in criteria used for disaster declarations.	All (small change = early warning, larger changes = late)
	Survey measures asking about exposure to and impacts of natural hazards.	Change	▲ exposure to natural hazard events = higher risk of ▼ capacity due to high level of demand on resilience resources ▲ impacts of natural hazard events = ▼ capacity due to high level of demand on resilience resources	All (small change = early warning, larger changes = late)
Natural hazard risk	% population living in areas classified as being at risk of different natural hazards extreme weather risk zones e.g. drought, heatwave	Step-change	▲ risk = likely ▼ capacity due to high level of demand on resilience resources	All (small change = early warning, larger changes = late)

5.14 SOCIO-DEMOGRAPHIC AND GEOGRAPHIC VARIABLES

5.14.1 Introduction

As discussed in Section 4, it is relatively common for resilience frameworks to suggest that geographic or socio-demographic characteristics should be used as indicators of resilience. However, we will not use socio-demographic characteristics as indicators of resilience in this project, for two reasons.

First, and most importantly, there is growing recognition that this approach can lead to an inaccurate assumption that it is the socio-demographic characteristic that causes high or low resilience or vulnerability, when in reality people with particular characteristics may be at higher risk of low or high resilience due to having differing levels of access to opportunities to build and maintain resilience resources. Using membership of a particular group as an indicator of resilience can thus act to reinforce disadvantage by suggesting that being born with, or developing, particular socio-demographic characteristics in and of itself causes low resilience. Instead, consistent with changing practice recommended by those advocating for groups including people living with disabilities, culturally and linguistically diverse communities, and those experiencing inter-generational disadvantage or trauma, indicators should focus on the underlying causes that result in these groups being more likely to have low resilience. This approach is taken in this work: the indicators recommended focus on causes of high or low resilience. It is then possible to use the information generated to examine the resulting distribution of high or low resilience across groups with differing social and demographic characteristics: this provides insight into the different opportunities and need to provide specific support to assist some groups in building and maintaining resilience.

Second, these characteristics do not typically change or, if they do, change infrequently, often only once or twice in a lifetime. For example, a person's age cannot be changed to make them more or less resilient. What can be changed is their access to different resilience resources, to address inequities in access identified by monitoring the types of indicators recommended in previous sections. Similarly, acquiring a disability occurs infrequently. Again, having the disability may change a person's access to resilience resources – but is not in and of itself an indicator of level of resilience.

As these indicators are regularly recommended in the literature, they are briefly reviewed. However, no indicators are then recommended for measurement in this project. Instead, the characteristics identified in Table 29 are considered important in terms of being types of characteristics that should be measured alongside measuring resilience indicators to enable understanding of differences in equity of access to resilience resources and capacity across different groups.

5.14.2 Brief review of indicators commonly identified in literature

Table 29 summarises the types of socio-demographic and geographic characteristics suggested as indicators of resilience in past studies. In workshops, these were not discussed as causes of resilience loss, but as factors that may mean a person has greater or lower likelihood of having access to resilience resources. For example, some workshop participants discussed single, older women as having lower access to stable housing and higher rates of homelessness.



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Table 29 Socio-demographic and geographic characteristics associated with changed likelihood of having access to resilience resources in previous studies

CHARACTERISTIC	SPECIFIC ASPECTS SOMETIMES USED AS PROXY INDICATORS OF RESILIENCE
Slope, elevation	Note that this type of data informs assessment of risk of natural hazard exposure, and may contribute to that risk assessment (see Section 5.13).
Built-up area	Note that this type of data informs assessment of risk of natural hazard exposure, and may contribute to that risk assessment (see Section 5.13).
Age	<ul style="list-style-type: none"> • % in different age groups • Age dependency ratio (population aged under 15 or 65+ relative to total population aged 15-64) • % population aged under 18 (or under 15, or other threshold) • % population aged 65+ • % population aged <5 years
Gender	<ul style="list-style-type: none"> • Ratio of men to women • % men, women, non-binary gender at risk from disaster
Membership of specific cultural groups	<ul style="list-style-type: none"> • Ethnic diversity
Population growth rate	<ul style="list-style-type: none"> • Birth rate • Death rate • Migration rate • Population growth
Rural/urban population	<ul style="list-style-type: none"> • % population rural vs urban
Locally-born population	<ul style="list-style-type: none"> • % of local population born locally • % born in same country they are living in now
% speaking dominant language	<ul style="list-style-type: none"> • % who have good English language skills
Family structure	<ul style="list-style-type: none"> • Average household size • % sole person households • % female headed households • % non-family households with <18 occupants
Population density	<ul style="list-style-type: none"> • Density of population per geographic area
Disability prevalence	<ul style="list-style-type: none"> • Prevalence of different types of disability
Occupational status	<ul style="list-style-type: none"> • % people working in different types of occupations or industries
Commuting	<ul style="list-style-type: none"> • % employees working in an area but commuting from somewhere else
Land use	<ul style="list-style-type: none"> • % land used for commercial purposes, industrial purposes
Informal settlers	<ul style="list-style-type: none"> • % population who are informal settlers

6. DATA SOURCES TO BE EXPLORED

A large number of potential indicators of change in resilience were identified in Section 5. This section summarises the types of data sources to be explored in Stage 2 of the project to test potential to access sufficient data to measure each indicator. Note that it is not expected all of the potential data sources will eventuate. In many cases, data may be collected too infrequently, inconsistently, or at scales too large for data from a particular source to be used to populate indicators.

Table 30 indicates several potential data sources. A tick (✓) indicates confirmation that data are known to be accessible from this source for this indicator, although it is possible data are collected only infrequently or at large scales that limit ability to use the data to monitor change in resilience in specific communities. The ❖ symbol means data may be available, but it is not yet confirmed whether or at what scales and timeframes data can be accessed.

Table 30 also identifies several potential sources of data:

- **Regional Wellbeing Survey:** Run by the University of Canberra since 2013, the Regional Wellbeing Survey will be used for this project in two ways. First, past data from the survey will be analysed to produce time series information for indicators, and to identify potential recommendations for thresholds and confirmation of the usefulness of some indicators. Any indicators for which 'existing' is noted in this column are indicators where historic data is available from the Regional Wellbeing Survey, usually collected multiple times since 2013. Second, a special data collection will be undertaken in southern NSW for this project using the Regional Wellbeing Survey. This will include both previously measured indicators and new indicators designed for this project, and enable testing and development of a number of the indicators identified in Stage 1, particularly where no other data sources exist.
- **Other survey:** This indicates that data for an indicator are available from other surveys known to have included the measure proposed. These include ABS surveys, the HILDA survey, and others.
- **Administrative data:** This refers to data held by government, at local, state or federal level.
- **Social media analysis:** This refers to production of indicators through systematic analysis of social media content.
- **Online search analysis:** This refers to production of indicators that use data about the types of terms people have searched for online using search engines such as Google.
- **Other organisation data:** A range of other organisations may hold data that enables population of a measure. These include insurance companies, banks, the health sector and organisations providing a range of other types of services.



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Table 30 Data sources identified as potential sources of data to populate different resilience indicators

DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
FINANCIAL RESOURCES – INDIVIDUAL/HOUSEHOLD	Possession of financial assets	% able to access \$2,000 within 1-2 weeks in an emergency	✓ new	✓ not identical				
		% able to access \$10,000 within a month in an emergency	✓ new					
		% able to access \$50,000 within a year in an emergency	✓ new					
	Employment	Labour force participation and employment (% in labour force, unemployed, employed part-time, employed full-time, employed and away from work)	✓ existing	✓ ABS LFS; NSC SALM	❖ JobSeeker			❖ DEWR, NSW RDAN
	Financial stress	% who have experienced any of several types of financial stress event within the past (i) month, and (ii) year	✓ existing and new	✓ not identical				
		Bankruptcy rate			❖ Bankruptcy Register			
		Frequency of online search for key terms indicating financial stress e.g. https://github.com/erdogant/googletrends					❖	
		Average proportion of credit card limit used each month	✓ new					❖ Credit card companies, banks
		% credit card holders paying off balance on time	✓ new					❖ As above
		% seeking delayed payment of rates, tax bills, utility bills, loan/mortgage repayments	✓ new					❖ Utilities, local govt, fed govt, banks
% accessing financial support services (phone help lines, food pantries, crisis financial advice)		✓ existing					❖ Help lines, pantries, financial advisors	
Rate of use of payday loans, pawning of assets	✓ new					❖		

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DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
		Average debt relative to household income	✓ new					❖
		% households living above and below poverty line (measured using Henderson and relative approaches)						
	Income/prosperity	% households earning a living wage		❖ ABS, HILDA				
		Self-rated household prosperity	✓ existing					
	Standard of living	% household income spent on housing costs	✓ new					
		Ratio of average household income to average cost of a basket of goods		❖ ABS				
		% population lacking access to secure housing						❖ AHURI
		Rating of affordability of local living costs	✓ existing					
	Access to insurance	% households with vehicle/property damage insurance (including % with third party only and % with comprehensive insurance)	✓ existing					
		Accessibility of natural hazard insurance, defined as affordability relative to income						
		% households with home and/or contents insurance coverage for natural hazard covering full replacement cost	✓ existing					
		% businesses with insurance for loss of business income or loss of goods/property damage						

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DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
FINANCIAL RESILIENCE - COMMUNITY	Income distribution and average	Income inequality in a community – % low income, middle income and high income households		✓ ABS household income surveys, ABS Household Expenditure Surveys, HILDA Survey, Census and tax records data				
		Real estate availability and affordability	Median rental costs as a proportion of (i) median income and (ii) lowest quartile income					❖ Domain
		Number of years of (i) median income and (ii) lowest quartile income required to pay off the full cost of (i) a freestanding 3 bedroom home or (ii) a 1 or 2 bedroom unit.						
		Rental vacancy rate (%)						❖ REINSW
		Average length of time residential real estate is on market before sale						❖ Domain
	Revenue per capita	Local government funding per capita for continuation of core everyday activities (sanitation, waste collection, community activities, infrastructure, planning review and approval, etc)				❖ Local Council database		
		Tax revenue per capita						
		Local government rates per capita						
	Economic activity	Number of businesses/commercial establishments per capita						
		Retail turnover per capita OR spending per capita on different aspects of retail trade such as groceries, entertainment, clothing etc						

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DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
		Job advertisements (noting challenges of consistency of location of advertisement for tracking change)		ABS job vacancy report	❖ SEEK			
	Economic diversity	% employment dependent on activities that rely on public funding						
		Share of employment reliant on top 3 employing industries						
HEALTH AND WELLBEING	Mental health	Psychological distress levels (Kessler psychological distress scale)	✓ existing					
		Calls to helplines/support services per head of population						❖ Lifeline, Beyond Blue, ReachOut, Head to Health
		Frequency of online searches for keywords indicating concerns about mental health						
		Rates of prescription of common medications used to treat anxiety and depression, per head of population			❖ PBS/RPBS			
	Healthy behaviours	% people who had dental check up in last year	✓ new					
		% population with alcohol intake above healthy levels	✓ new					
		% population smoking nicotine products (cigarettes, vaping etc)	✓ new					
		% eligible population engaging in breast screening	✓ new					
		% eligible population engaging in bowel cancer screening	✓ new					
		% eligible population engaging in other preventative health checks	✓ new					

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DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
		% population achieving minimum recommended level of physical activity	✓ new					
	Overall health	Self-rated general health	✓ existing					
	Life expectancy	Average years of healthy life lost due to preventable or treatable illness						
SKILLS AND CAPACITY	Personal psychological resources	Survey measures of optimism, self-efficacy, hardiness, emotional reactivity, coping, personal resilience	✓ existing and new					
	Confidence in future	Survey measures examining confidence in future, specifically in relation to climate change, and overall sense of optimism, helplessness, hopefulness and confidence in future	✓ new					
		Social media sentiment regarding confidence in future						
	Personal skills	Survey measures examining decision making capacity	✓ new					
		% individuals lodging tax returns on time			❖ ATO tax data			❖ NATSEM
		% applications for support begun but not progressed						
	Educational attendance and performance	School attendance rates						
		School performance – NAPLAN and AEDC						❖ AIHW, ACARA
		% children remaining in school to end of Year 10, 11 and 12						

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DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
SOCIAL RESOURCES – INDIVIDUAL/HOUSEHOLD	Engagement with social groups/organisations	Frequency of engagement in social interaction with social networks other than close friends and family	✓ existing					
	Volunteering	% of people engaging in volunteering	✓ existing					
		Total volunteer availability based on (i) engagement in volunteering and (ii) frequency of volunteering						
		% volunteers showing signs of burnout	✓ existing					
	Self-rated access to social support	Survey measures examining self-rated access to emotional, financial and practical support from their personal social networks	✓ existing					
	Social networks	Frequency of engagement in social interaction with close friends and family	✓ existing					
		Satisfaction with personal relationships	✓ existing					
		Possibly frequency of search terms related to relationship break down						
		Divorce/separation rate			❖ HILDA			❖ AIFS
	Social cohesion	Social media sentiment measures focused on terms indicating (i) cohesion and (ii) conflict/disagreement/ anti-social behaviour						
Sense of belonging (survey measure)		✓ existing						
SOCIAL RESOURCES – COMMUNITY	Presence of functioning community organisation	Number of active organisations per head of population						
		Survey measures examining views about functionality of local community organisations	✓ existing					
	Participation in community activities	Attendance at community activities, per capita						

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DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
	Inter-community social resources	Sentiment measures (social media, online) about competition versus collaboration between communities						
		Survey measures rating perceived fairness of access of community to support, compared to others	✓	new				
		Survey measures examining perceptions of relationship to other communities and ability to (i) provide and (ii) access support from other communities	✓	new				
	Intra-community social resources	Perceived social equality, inclusiveness and cooperation	✓	existing				
		Perceived social conflict	✓	existing				
	Community gathering places	Presence and accessibility of communal gathering places (survey measure)						
Community cohesion	Social media/online sentiment about ability of community to work together, versus having issues of competition/conflict							
	Survey measures about ability of community to work together to achieve positive outcomes, versus having issues of competition/conflict	✓	existing and new					
Length of residence	% population who have lived in area for less than 1 year, less than 2 years							
INFRASTRUCTURE AND SERVICES	Health services	Self-rated ability to access a range of health services	✓	existing				
		Average ambulance waiting time						
	Average waiting time to see different types of health professional				❖ ABS patient experience data		❖ service provider datasets	

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DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
		Number of different types of health professional per head of population						
		Affordability of health services	✓ new					
	Social service and care sectors	Self-rated accessibility of key social services, aged care and child care						
	Grocery/ domestic goods supply	Availability of key groceries and domestic goods						
		Supply chain measures (potential to be explored)						
		Social media posts related to supply of domestic goods						
	Transport infrastructure	Proportion of road network affected by road closures over defined period of time						
		Self-rated quality of local road network (survey measure)	✓ existing					
		Social media discussion of road network quality						
	Telecommunications infrastructure	Average internet speed						❖ ACCC, Speedtest
		% households with access to high speed internet	✓ existing					
		Frequency of internet outages	✓ new					
		% households with high quality mobile phone coverage at residence	✓ existing					
		Frequency of loss of mobile phone coverage (outages)	✓ new					
		Affordability of high speed internet	✓ new					
		Affordability of mobile phone coverage	✓ new					

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DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
	Residential housing infrastructure	% population living in temporary / non-permanent accommodation						
		% population living in accommodation needing significant repairs						
	Emergency services infrastructure	Number of emergency service workers per head of population			❖ Emergency service datasets			
		Number of active emergency services volunteers per head of population						
	Water and sanitation	Self-rated quality of drinking water, sanitation, cleanliness of community public areas	✓ existing and new					
		Number of days in which water quality alerts applied to drinking water supply						❖ Local water bodies data e.g. Riverina water
	Energy	Number of days with loss of electricity supply (blackout, brownout)	✓ new					
		Energy costs relative to income			❖ ABS CPI			
		Self-rated quality of access to sufficient and reliably energy supply	✓ existing					
	Education services	Number of children per teacher						
		Educational outcomes						
	Financial/professional services	Self-reported access to professional tradespeople	✓ existing and new					
INSTITUTIONAL RESILIENCE	Leadership	Survey measures examining levels of trust in leaders, views about transparency, accountability and effectiveness	✓ existing and new					
		Social media analysis of sentiment regarding local leadership						
		Leadership turnover rates			❖ ABS			❖ AHRI

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DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
	Participation in local government	Confidence in being able to have a voice in decision making	✓ existing					
		Confidence in being listened to by decision makers	✓ existing					
		Participation in local decision-making processes	✓ existing					
ECOSYSTEM SERVICE PROVISION	Overall ecosystem health	Specific indicators to be explored in Stage 2						
	Extreme weather absorptive capacity	Specific indicators to be explored in Stage 2						
	Soil health	Specific indicators to be explored in Stage 2						
	Water quality	Specific indicators to be explored in Stage 2						
	Air quality	Indicators of air quality from local monitoring stations, focusing on PM2.5 levels						
	Perceived environmental health	Survey measures examining perceptions of quality of local ecosystem services	✓ existing					
LIVEABILITY	Amenity	Survey measures examining perceptions of amenity of environment and surrounds	✓ existing					
		Social media/online sentiment regarding local amenity						
		Greenness of local area						
	Crime and safety	Self-rated sense of safety when walking alone in community	✓ existing and new					
		Self-rated personal safety at home	✓ existing and new					

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DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
		Rates of different types of crime per capita, including domestic violence, theft/burglary, assault, and others						
	Culture and identity	Survey measures identifying the extent to which a person feels safe to openly express their cultural identity	✓ existing and new					
NATURAL HAZARD RESOURCES – INDIVIDUAL/HOUSEHOLD	Awareness of community emergency resources	% adult population actively accessing key natural hazards resources, e.g. Hazards Near Me app, natural hazards websites	✓ existing and new					
		Survey measures examining awareness of key community emergency resources (communication and other)	✓ existing and new					
	Hazard risk perceptions	Survey measures examining hazard risk perception	✓ existing and new					
	Preparedness	Survey measures examining engagement in key hazard preparedness activities including planning, emergency kits, document storage, evacuation plans, and communication with others	✓ existing					
	Past natural hazard experience	Survey measures examining % of people with past direct experience of natural hazards, and whether they consider themselves to have better or poorer ability to cope with new hazards as a result of that past experience.	✓ existing					
NATURAL HAZARD RESOURCES – COMMUNITY	Training of disaster preparation, response and recovery personnel	Survey measures included in survey of those involved in planning and delivering natural hazard preparation, response and recovery.						
	Population risk and vulnerability identification	As above						

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DOMAIN	INDICATOR TYPE	MEASURE PROPOSED	REGIONAL WELLBEING SURVEY	OTHER SURVEY	ADMINISTRATIVE DATA	SOCIAL MEDIA ANALYSIS	ONLINE SEARCH ANALYSIS	OTHER ORGANISATION DATA
	Disaster planning	As above						
	Disaster coordination	As above						
	Institutional conflict related to disaster management	As above						
	Funding availability	As above						
	Burnout of staff and volunteers	Burnout measures included in surveys of those engaged in these roles	✓ existing					
	Information dissemination	Survey measures included in survey of those involved in planning and delivering natural hazard preparation, response and recovery.						
		Survey measures included in survey of general population, asking about ability to access relevant information.	✓ existing					
	Equity of access	Potential measures to be explored as part of Stage 2 of project.						
EXPOSURE TO NATURAL HAZARDS	Natural hazard occurrence	Measures of frequency, intensity and length of occurrence of different natural hazards using weather, climate and emergency services data						
		Government disaster declarations						
		Survey measures asking about exposure to and impacts of natural hazards.	✓ existing					
	Natural hazard risk	% population living in areas classified as being at risk of different natural hazards extreme weather risk zones e.g. drought, heatwave						

7. DEVELOPING A DATA COMMUNICATION TOOL THAT WORKS FOR END-USERS

This section summarises insights identified in workshops about the characteristics of a data communication tool that can work to help end-users easily identify and understand how resilience is changing in the community or communities they work in. In particular, the data tool should help them identify signs of decline in resilience as early as possible – and ideally also signs of growing resilience, something that can assist in evaluating whether actions being implemented on-ground and supporting a positive change in resilience.

The intended end users of the data collated in this project are those working in the areas of drought and natural hazard preparation, response and recovery. This includes a wide range of organisations, from small local organisations, through to national organisations. Examples of potential end-users include small community groups, local government, local branches of state and nationally based non-government organisations and private sector businesses who provide support related to preparation, response and recovery, and state and national government agencies.

These end users are typically very busy, and not always highly data literate. This means that any data tool needs to:

- Collate data in a central place where they can access information about multiple aspects of resilience in one spot
- Ideally, provide notifications when information has been updated with new data, as busy people are unlikely to actively check a data tool for updated data
- Provide simple, intuitive presentation of data as well as plain language explanation of what different indicators mean, and in particular what change in different indicators means.

In addition to identifying a need for data to be available in one place that made it easy for them to access, understand and interpret, the following were identified as key needs:

- Ability to compare whether a community or group of people are doing well or poorly compared to others
- Ability to identify change over time
- Ideally, information at small geographic scales, with local government area the most commonly mentioned scale desired
- Simple platform for accessing data that is easy to use
- Ability to download data as data tables (preferably in Microsoft Excel compatible formats, as most users had access to this but not to other data platforms) in addition to viewing data visualisations online, due to a common need to use specific figures in reports or generate bespoke visualisations a tool may not provide
- An app was not identified as a preferred way of interacting with data, particularly for government agency staff where apps must meet a range of security requirements before staff are permitted to download them
- The preferred option is a website that users can navigate to easily and has interactive features that enable the user to specify which indicators they wish to view, for what time period, and for what region/group
- Potential end user indicated a need for data in visual formats that can be supported by tools such as Power BI or Tableau. Often their need was for data comparing the region they are working in to regional or national averages. This is often better communicated as graphs rather than geospatial maps, which do not always easily enable these types of comparisons. Thus, the priority in the tool is to have functionality to enable users to generate their own visualisations interactively, by individual indicator. For each indicator, they should be able to easily generate a graph that shows selected geographic regions for a selected period of time, OR compares selected groups (e.g. male, female, those in different age groups) for that indicator and a selected period of time.

Two common types of functionality were not identified by potential end users as of high importance:

- Functionality to visualise an overall resilience index, in which the user can generate a comparison of their region to others and weight individual indicators forming part of the tool. An example of this type of tool can be found at <https://www.oecdbetterlifeindex.org/>
- Ability to view and download data mapped spatially for each indicator, i.e. to generate maps using an interactive tool.

Some workshop participants expressed some concern about the use of the term ‘early warning signal’, as they interpreted this as meaning the indicators measured would only provide insight into loss of resilience amongst those who initially had high resilience. This is not the case, with indicators selected to enable identified of resilience change amongst all cohorts – including those who have experienced low levels of resilience for some time. It is critical that this is clarified. Discussions of this issue highlighted that it is important to be able to interpret each indicator in two ways:

- Level of resilience: do particular communities or groups have relatively low or high resilience compared to an average?
- Change in resilience: is there evidence of change in resilience over time and, if so, what direction is it changing in? For different indicators, it is important to identify whether change in the indicator is likely to be evident after resilience levels have already been changing for some time (a late signal) or evident relatively early in the process of resilience change (an early signal).

CONCLUSIONS AND NEXT STEPS

The main aim of this report has been to identify potential early warning indicators and data sources that can be used to develop a resilience early warning tool relevant to the needs of communities in Southern NSW. This report presents the findings from a rapid review of the natural disaster resilience literature, and together with insights from workshops with key stakeholders from the natural disaster sector in Southern NSW presents a comprehensive list of potential indicators and data sources to be examined and assessed in the final stage of the project. This report also outlines the ideal characteristics for a data tool that could be useful for end users. It is not expected all indicators and data sources included in this report will form part of the early warning tool developed as the main outcome of this project. Instead, information presented in this report will guide the second and final stage of the project, ensuring that main outcome of this project is evidence-based and relevant to the needs of the service providers. Subsequent stages of the project will focus on the following objectives:

1. Systematically testing and finalising a set of early warning indicators that can provide timely, geographically relevant and accurate information on levels of resilience loss experienced by communities in the project region.
2. Development of an early resilience warning tool that can present this information to service providers and community groups in a way that is useful to their needs.

The final report from the project will report on these objectives, and identify further work to be done. This may include the types of indicators for which data could not be sourced in this initial pilot project, and further work to improve the accessibility, useability and relevance of the data platform.



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APPENDIX 1 – LITERATURE REVIEW SUMMARY

ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
1	Abramson, David M.; Grattan, Lynn M.; Mayer, Brian; Colten, Craig E.; Arosemena, Farah A.; Bedimo-Rung, Ariane; Lichtveld, Maureen, 2015. The Resilience Activation Framework: a Conceptual Model of How Access to Social Resources Promotes Adaptation and Rapid Recovery in Post-disaster Settings, JOURNAL OF BEHAVIORAL HEALTH SERVICES & RESEARCH, Issue 42, Volume 1, page 42 - 57	Theoretical	Outlines Resilience Activation Framework based on conservation of resources (COR) theory.	NA
2	Abrash Walton, Abigail; Marr, Janine; Cahillane, Matthew J.; Bush, Kathleen, 2021. Building Community Resilience to Disasters: A Review of Interventions to Improve and Measure Public Health Outcomes in the Northeastern United States, SUSTAINABILITY, Issue 13, Volume 21	Review	Review of peer-reviewed literature on community resilience initiatives in Northeastern United States. Aims to identify evidence based interventions and resilience metrics.	NA
3	Adebimpe, Oluseye Adewale; Proverbs, David G.; Oladokun, Victor Oluwasina, 2021. A fuzzy-analytic hierarchy process approach for measuring flood resilience at the individual property level, INTERNATIONAL JOURNAL OF BUILDING PATHOLOGY AND ADAPTATION, Issue 39, Volume 2, page 197 - 217	Research article	This research sought to develop a quantitative approach for the measurement of property level flood resilience.	Fuzzy-analytic hierarchical
4	Al Rifat, Shaikh Abdullah; Liu, Weibo, 2020. Measuring Community Disaster Resilience in the Conterminous Coastal United States, ISPRS INTERNATIONAL JOURNAL OF GEO-INFORMATION, Issue 9, Volume 8	Research article	Development of the Composite Community Disaster Index (CCDRI) based on five dimensions of community disaster resilience: social, economic, community engagement and capital, housing/infrastructure, and environmental resilience. Relationship between variables and disaster losses in coastal communities in the US was examined.	Index construction using PCA and spatial distribution analysis using ordinary least squares (OLS) and geographically weighted regression (GWR) models
5	Al-Maruf, Abdullah; Jenkins, J. Craig; Bernzen, Amelie; Braun, Boris, 2021. Measuring Household Resilience to Cyclone Disasters in Coastal Bangladesh, CLIMATE, Issue 9, Volume 6	Research article	Measure the level of household resilience to cyclone and storm surges in the coastal area of Bangladesh using a composite indicator.	Principal Components Analysis to develop composite index.
6	Almutairi, Arif; Mourshed, Monjur; Ameen, Raed Fawzi Mohammed, 2020. Coastal community resilience frameworks for disaster risk management, NATURAL HAZARDS, Issue 101, Volume 2, page 595 - 630	Systematic review	Provides a systematic review of coastal community resilience frameworks for disaster risk management, covering their context, structure, and assessment.	NA
7	Alshehri, Saud Ali; Rezgui, Yacine; Li, Haijiang, 2015. Delphi-based consensus study into a framework of community resilience to disaster, NATURAL HAZARDS, Issue 75, Volume 3, page 2221 - 2245	Research paper	Develops a framework of community disaster resilience to disaster in Saudi Arabia using Delphi-based consensus process.	Qualitative -Delphi process
8	Arbon, Paul, 2014. Developing a model and tool to measure community disaster resilience, AUSTRALIAN JOURNAL OF EMERGENCY MANAGEMENT, Issue 29, Volume 4, page 12 - 16	Research paper	To evaluate the usability of a tool to measure community disaster resilience Australia.	Scorecard rating

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
9	Arbon, Paul; Steenkamp, Malinda; Cornell, Victoria; Cusack, Lynette; Gebbie, Kristine, 2016. Measuring disaster resilience in communities and households Pragmatic tools developed in Australia, INTERNATIONAL JOURNAL OF DISASTER RESILIENCE IN THE BUILT ENVIRONMENT, Issue 7, Volume 2, page 201 - 215	Research paper	Research article, literature review and review of resilience toolkit development and testing tool	Scorecard rating
10	Asadzadeh, A.; Koetter, T.; Salehi, P.; Birkmann, J., 2017. Operationalizing a concept: The systematic review of composite indicator building for measuring community disaster resilience, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 25, page 147 - 162	Review paper	A systematic review on developing composite measures of community disaster resilience with the aim to (1) propose an overarching eight-step procedure for composite indicator building and (2) develop a meta-level assessment framework to allow for a systematic review of existing disaster resilience measurement frameworks in application of composite indicator building.	NA
11	Bakkensen, Laura A.; Fox-Lent, Cate; Read, Laura K.; Linkov, Igor, 2017. Validating Resilience and Vulnerability Indices in the Context of Natural Disasters, RISK ANALYSIS, Issue 37, Volume 5, page 982 - 1004	Review	Compare and empirically validate five of the top US disaster indices including three resilience indices and two vulnerability indices.	Regression analysis
12	Beccari, Benjamin, 2016. A Comparative Analysis of Disaster Risk, Vulnerability and Resilience Composite Indicators., PLoS currents, Issue 8	Review	To understand the breadth and depth of composite resilience indicators.	NA
13	Bottazzi, Patrick; Winkler, Mirko S.; Boillat, Sebastien; Diagne, Abdoulaye; Sika, Mashoudou Maman Chabi; Kpangon, Arsene; Faye, Salimata; Speranza, Chinwe Ifejika, 2018. Measuring Subjective Flood Resilience in Suburban Dakar: A Before-After Evaluation of the Live with Water Project, SUSTAINABILITY, Issue 10, Volume 7	Research paper	Aims to assess to what extent the Live with Water (LWW) project improved the resilience of vulnerable populations in Dakar suburbs, Senegal.	Regression analysis
14	Bulti, Dejene Tesema; Girma, Birhanu; Megento, Tebarek Lika, 2019. Community flood resilience assessment frameworks: a review, SN APPLIED SCIENCES, Issue 1, Volume 12.	Review	To analyse existing community flood resilience assessment (CFRA) tools by examining whether the multifaceted nature of resilience has been addressed in their development and implementation processes. More specifically, it is conducted (i) to provide an overview of existing CFRA frameworks; (ii) to define evaluation criteria for CFRA, taking into account the multifaceted nature of resilience; (iii) to evaluate the frameworks against the evaluation criteria.	NA

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
15	Burton, Christopher G., 2015. A Validation of Metrics for Community Resilience to Natural Hazards and Disasters Using the Recovery from Hurricane Katrina as a Case Study, ANNALS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS, Issue 105, Volume 1, page 67 - 86	Research article	The purpose of this article is to provide an externally validated set of metrics that could be considered relevant for measuring disaster resilience at subnational levels of geography.	Correlation to reduce number of variables. Multidimensional scaling analysis assessing internal consistency. Ordinal logistic regression to test associations with recovery.
16	Cai, Heng; Lam, Nina S. N.; Qiang, Yi; Zou, Lei; Correll, Rachel M.; Mihunov, Volodymyr, 2018. A synthesis of disaster resilience measurement methods and indices, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 31, page 844 - 855	Review	To provide an integration of the literature and reflect on the current state of resilience measurement. A synthesis analysis through a systematic review of 174 scholarly articles on disaster resilience measurement from 2005 to 2017.	NA
17	Campbell, Karen A.; Laurien, Finn; Czajkowski, Jeffrey; Keating, Adriana; Hochrainer-Stigler, Stefan; Montgomery, Marilyn, 2019. First insights from the Flood Resilience Measurement Tool: A large-scale community flood resilience analysis, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 40	Research article	A large-scale analysis of systemic and replicable flood resilience baseline data. Findings to inform building an evidence-based approach to building effective flood resilience capacity.	Mixed methods Zurich Flood Resilience Measurement Framework Implementation Process
18	Cerbaro, Mercio; Morse, Stephen; Murphy, Richard; Middlemiss, Sarah; Michelakis, Dimitrios, 2022. Assessing Urban Vulnerability to Flooding: A Framework to Measure Resilience Using Remote Sensing Approaches, SUSTAINABILITY, Issue 14, Volume 4	Research article	To assess the extent to which Google Street View derived information could be reliable in measuring vulnerability and resilience.	Cluster analysis
19	Chen, Xiaobo; Guo, Zupei; Zhou, Hengyu; Qian, Xikun; Zhang, Xuesheng, 2022. Urban Flood Resilience Assessment Based on VIKOR-GRA: A Case Study in Chongqing, China, KSCE JOURNAL OF CIVIL ENGINEERING, Issue 26, Volume 9, page 4178 - 4194		To establish and test an urban flood disaster resilience assessment model using indicators relevant to the Technical, Organizational, Social and Economic (TOSE) framework, and applying the VIKOR-GRA method of ranking.	VIKOR-GRA methodology
20	Chisty, Musabber Ali; Rahman, Md. Mostafizur; Khan, Nesar Ahmed; Dola, Syeda Erena Alam, 2022. Assessing Community Disaster Resilience in Flood-Prone Areas of Bangladesh: From a Gender Lens, WATER, Issue 14, Volume 1, page 40 - 40	Research article	To assess the relationship between gender community disaster resilience.	Descriptive analyses Pearson's Chi-square test
21	Ciccotti, Larissa; Rodrigues, Angela Cassia; Boscov, Maria Eugenia Gimenez; Günther, Wanda Maria Risso, 2020. Building Indicators of Community Resilience to Disasters in Brazil: A Participatory Approach, Ambiente & Sociedade, Issue 23, Volume 2	Research article	To develop a list of community resilience indicators for Brazilian municipalities, resulting from literature review, experts' consulting and application of the Delphi method.	Delphi method

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
22	Clark-Ginsberg, Aaron; McCaul, Bernard; Bremaud, Isabelle; Caceres, Gabriela; Mpanje, Desire; Patel, Sonny; Patel, Ronak, 2020. Practitioner approaches to measuring community resilience: The analysis of the resilience of communities to disasters toolkit, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 50	Review	In this article, we present the Analysis of the Resilience of Communities to Disasters (ARC-D) toolkit, a practical toolkit developed by an international aid organization, GOAL.	NA
23	Cox, Robin S.; Hamlen, Marti, 2015. Community Disaster Resilience and the Rural Resilience Index, AMERICAN BEHAVIORAL SCIENTIST, Issue 59, Volume 2, page 220 - 237	Research article	The goals of the project were to produce resilience assessment and planning tools that could be used by communities to generate locally relevant data on their current resilience and be able to monitor and enhance their resilience over time. This article describes the development and field testing of the RRI, which is designed as a user-friendly, process-based, qualitative resilience assessment tool.	Inductive analysis of interviews
24	Cui, Peng; Li, Dezhi, 2019. Measuring the Disaster Resilience of an Urban Community Using ANP-FCE Method from the Perspective of Capitals, SOCIAL SCIENCE QUARTERLY, Issue 100, Volume 6, page 2059 - 2077	Research article	Three aims of this paper. 1) Identifying the key disaster-adapting capitals of community resilience. (2) Establishing a convenient and quantifiable framework to measure community resilience from the perspective of community capitals. (3) From the results of the case study, some disaster prevention and mitigation implementations and recommendations are proposed for community stakeholders.	ANP method consisting of control and network layers
25	Cutter, Susan L., 2016. The landscape of disaster resilience indicators in the USA, NATURAL HAZARDS, Issue 80, Volume 2, page 741 - 758	Review	Review of existing resilience indices in USA and outlines most commonly used variables to measure different resilience attributes	NA
26	Cutter, Susan L.; Derakhshan, Sahar, 2019. Implementing Disaster Policy: Exploring Scale and Measurement Schemes for Disaster Resilience, JOURNAL OF HOMELAND SECURITY AND EMERGENCY MANAGEMENT, Issue 16, Volume 3	Research article	Comparing the measurements of disaster resilience used in the FEMA and BRIC indexes based on three criteria: original intent (tracking the pre-existing resilience of communities to measure progress over time); spatial scale (counties and/or states); and consistency in input data sources (use of federal data).	Normalised variables based on min-max procedures and compared findings across the two approaches.

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
27	DasGupta, Rajarshi; Shaw, Rajib, 2015. An indicator based approach to assess coastal communities' resilience against climate related disasters in Indian Sundarbans, JOURNAL OF COASTAL CONSERVATION, Issue 19, Volume 1, page 85 - 101	Research article	The article attempts to develop a five dimensional community resilience assessment framework and a composite resilience index against climate related disasters with special applications to the coastal rural communities' in the developing world This article attempts to develop a five dimensional community resilience assessment framework and a composite resilience index against climate related disaster with special applications to coastal rural communities' in the developing world.	Calculation of composite index (weighted mean score of resilience dimensions)
28	Fahad, Shah; Hossain, Mohammad Shakhawat; Nguyen Thi Lan Huong; Nassani, Abdelmohsen A.; Haffar, Mohamed; Naeem, Muhammad Rashid, 2022. An assessment of rural household vulnerability and resilience in natural hazards: evidence from flood prone areas, ENVIRONMENT DEVELOPMENT AND SUSTAINABILITY, Issue 25	Research article	This study develops and assesses the application of a livelihood vulnerability index (LVI), LVI-IPCC and livelihood effect index for the natural and agricultural resources in Northwestern Pakistan	Calculation of composite index
29	Fekete, Alexander, 2018. Societal resilience indicator assessment using demographic and infrastructure data at the case of Germany in context to multiple disaster risks, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 31, Volume , page 203 - 211	Research article	This paper investigates similarities between social vulnerability assessments and societal resilience assessments using spatial indicators.	Interpretation of findings from spatial indicator assessments according to different conceptualisations of resilience.
30	Feofilovs, Maksims; Romagnoli, Francesco, 2021. Dynamic assessment of urban resilience to natural hazards, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 62	Research article	The goal of the study is to develop a quantitative assessment tool that describes the dynamics of urban resilience to natural hazards	Causal Loop Diagrams and probabilistic simulation of system dynamics model.
31	Feofilovs, Maksims; Romagnoli, Francesco, 2020. Assessment of Urban Resilience to Natural Disasters with a System Dynamics Tool: Case Study of Latvian Municipality, ENVIRONMENTAL AND CLIMATE TECHNOLOGIES, Issue 24, Volume 3, page 249 - 264	Research article	Aims to measure urban resilience by developing an assessment tool taking systems dynamics (SD) approach that aims to assess functionality over time	Systems Dynamic approach and Multi Criteria Analysis
32	Feofilovs, Maksims; Romagnoli, Francesco; Campos, Joaquin Ignacio; Gotangco, Charlotte Kendra; Josol, Jairus Carmela; Jardeleza, Jean Meir Perez; Litam, Joseph Emanuel; Abenojar, Katrina, 2020. Assessing resilience against floods with a system dynamics approach: a comparative study of two models, INTERNATIONAL JOURNAL OF DISASTER RESILIENCE IN THE BUILT ENVIRONMENT, Issue 11, Volume 5, page 615 - 629	Research article	Present two different ways of generating dynamic systems to evaluate the resilience of an urban system.	System Dynamics approach and Causal Loop Diagrams

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
33	First, Jennifer M.; Yu, Mansoo; Houston, J. Brian, 2021. The Disaster Adaptation and Resilience Scale: development and validation of an individual-level protection measure, DISASTERS, Issue 45, Volume 4, page 939 - 967	Research article	The objectives of Study 1 were to design and develop an instrument to measure individual disaster resilience and to establish initial evidence of its content validity. Study 2 validated the psychometric properties of the scale on a sample of US adults exposed to disaster.	Calculation of composite index Confirmatory Factor Analysis
34	Gonzalez, Daniela P.; Monsalve, Mauricio; Moris, Roberto; Herrera, Cristobal, 2018. Risk and Resilience Monitor: Development of multiscale and multilevel indicators for disaster risk management for the communes and urban areas of Chile, APPLIED GEOGRAPHY, Issue 94, page 262 - 271	Research article	This work introduces multilevel indicators for measuring dimensions of risk and resilience, to identify and quantify spatial disparities among communes and urban areas in a multiscale perspective.	Calculation of composite index -Principal component analysis Index then computed according to PCA weights
35	Haque, Md Munjurul; Islam, Sabina; Sikder, Md Bahuddin; Islam, Md Saiful, 2022. Community flood resilience assessment in Jamuna floodplain: A case study in Jamalpur District Bangladesh, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 72	Research article	This study aims to assess the community flood resilience of some selected Upazilas of Jamalpur District in Bangladesh by calculating variable resilience index and composite resilience index values.	Calculation of composite index – aggregation and subjective weighting.
36	Hiete, Michael; Merz, Mirjam; Comes, Tina; Schultmann, Frank, 2012. Trapezoidal fuzzy DEMATEL method to analyze and correct for relations between variables in a composite indicator for disaster resilience, OR SPECTRUM, Issue 34, Volume 4, page 971 - 995	Research article	Utilising fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) methodology to calculate a composite indicator – this study assesses the disaster resilience of Germany at a county level. The indicator is based on that developed by Cutter et al 2010.	Trapezoidal fuzzy DEMATEL approach to development of a composite indicator
37	Hofmann, Sahar Zavareh, 2022. Build Back Better and Long-Term Housing Recovery: Assessing Community Housing Resilience and the Role of Insurance Post Disaster, SUSTAINABILITY, Issue 14, Volume 9	Research article	The purpose of this research is to better understand community housing resilience and the role of insurance using a Build Back Better Long-term Recovery Housing framework to analyse approaches and effects on long-term housing rebuilding and recovery.	Multiple case study approach
38	Imani, Moslem; Lo, Shang-Lien; Fakour, Hoda; Kuo, Chung-Yen; Mobasser, Shariat, 2022. Conceptual Framework for Disaster Management in Coastal Cities Using Climate Change Resilience and Coping Ability, ATMOSPHERE, Issue 13, Volume 1	Research article	Assesses the geographic regions of coastal Taiwan using the Climate Disaster Resilience Index	Calculation of composite index. Subjective weights allocated by officials and experts. approach (for each dimension).
39	Jacinto, R.; Reis, E.; Ferrao, J., 2020. Indicators for the assessment of social resilience in flood-affected communities - A text mining-based methodology, SCIENCE OF THE TOTAL ENVIRONMENT, Issue 744	Review	To compile and summarise the dimensions of resilience useful in evaluating the social resilience of flood affected communities	Literature review, Text mining and experts opinion

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40	Ji, Tingting; Wei, Hsi-Hsien; Sim, Timothy; Yang, Liang Emlyn; Scheffran, Juergen, 2021. Disaggregated validation of disaster-resilience indicators using household survey data: A case study of Hong Kong, SUSTAINABLE CITIES AND SOCIETY, Issue 67	Research article	This study performs disaggregated empirical validation of nine disaster-resilience indicators' efficacy at explaining two outcome measures: the resistant capacity and recovery capacity of households in Hong Kong.	Ordinal logistic Regression, Chi-square test of independence
41	Joerin, Jonas; Shaw, Rajib; Takeuchi, Yukiko; Krishnamurthy, Ramasamy, 2014. The adoption of a Climate Disaster Resilience Index in Chennai, India, DISASTERS, Issue 38, Volume 3, page 540 - 561	Research article	Measure to the resilience of 10 administrative zones of Chennai, India using the Climate Disaster Resilience Index (CDRI) Calculation of composite index Subjective weighting of parameters within index.	Pearsons correlation co-efficient to assess differences between dimension of CDRI
42	Johnson, Paul M.; Brady, Corey E.; Philip, Craig; Baroud, Hiba; Camp, Janey V.; Abkowitz, Mark, 2020. A Factor Analysis Approach Toward Reconciling Community Vulnerability and Resilience Indices for Natural Hazards, RISK ANALYSIS, Issue 40, Volume 9, page 1795 - 1810	Research article	Our study attempts to use the results of an FA conducted on a comprehensive set of variables derived from major vulnerability and resilience indices in the field to form an empirical foundation that will aid researchers in attempts to compare and validate indices and their elements.	Exploratory factor analysis
43	Kabir, Md Humayun; Sato, Miharu; Habbiba, Umma; Bin Yousuf, Tariq, 2018. Assessment of Urban Disaster Resilience in Dhaka North City Corporation (DNCC), Bangladesh, Procedia Engineering and - 7TH INTERNATIONAL CONFERENCE ON BUILDING RESILIENCE: USING SCIENTIFIC KNOWLEDGE TO INFORM POLICY AND PRACTICE IN DISASTER RISK REDUCTION, Issue 212, page 1107 - 1114	Research article	Measures urban disaster resilience of Dhaka North City Corporation using Urban Disaster Resilience index (UDRI). Measures overall UDRI across five dimensions: physical, social, economic, institutional and natural.	Calculation of composite index
44	Kadir, Swarna Bintay, 2021. Viewing disaster resilience through gender sensitive lens: A composite indicator based assessment, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 62	Research article	Intends to identify the potential socio-economic indicators of household disaster resilience that are sensitive to gender differences. These indicators are possible sectors of gender discrimination.	Chronbach's alpha reliability analysis , Analytic Hierarchy Process (AHP)
45	Khalili, Sanaz; Harre, Michael; Morley, Philip, 2015. A temporal framework of social resilience indicators of communities to flood, case studies: Wagga wagga and Kempsey, NSW, Australia, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 13, Volume, page 248 - 254	Research article	Using a qualitative, multiple case approach the project aimed to (i) identify the most essential social resilience indicators within communities from previous studies (ii) assess these indicators through interviews with experts (iii) classify these indicators for each phase of the disaster cycle including pre-disaster, response, and recovery.	Qualitative interviews

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
46	Khan, Muhammad Tariq Iqbal; Anwar, Sofia; Sarkodie, Samuel Asumadu; Yaseen, Muhammad Rizwan; Nadeem, Abdul Majeed; Ali, Qamar, 2022. Comprehensive disaster resilience index: Pathway towards risk-informed sustainable development, JOURNAL OF CLEANER PRODUCTION, Issue 366	Research article	Develop and apply a disaster resilience index across 91 countries.	Calculation of composite index. Various methods used including winsorization, principle component analysis and IMF procedures. Descriptive comparisons of index scores across countries.
47	Kontokosta, Constantine E.; Malik, Awais, 2018. The Resilience to Emergencies and Disasters Index: Applying big data to benchmark and validate neighborhood resilience capacity, SUSTAINABLE CITIES AND SOCIETY, Issue 36, Volume, page 272 - 285	Research article	Develop a unified, multi-factor index of local and regional resilience capacity: the Resilience to Emergencies and Disasters Index (REDI).	Calculation of composite index.
48	Kotzee, Ilse; Reyers, Belinda, 2016. Piloting a social-ecological index for measuring flood resilience: A composite index approach, ECOLOGICAL INDICATORS, Issue 60, Volume, page 45 - 53	Research article	Using three flood affected municipalities in South Africa, 24 resilience indicators related to floods and its relevant social, ecological, infrastructural, and economic aspects are selected, and integrated into a composite index using a principal components analysis (PCA)	Calculation of composite index PCA
49	Links, Jonathan M.; Schwartz, Brian S.; Lin, Sen; Kanarek, Norma; Mitrani-Reiser, Judith; Sell, Tara Kirk; Watson, Crystal R.; Ward, Doug; Slep, Cathy; Burhans, Robert; Gill, Kimberly; Igusa, Tak; Zhao, Xilei; Aguirre, Benigno; Trainor, Joseph; Nigg, Joanne; Inglesby, Thomas; Carbone, Eric; Kendra, James M., 2018. COPEWELL: A Conceptual Framework and System Dynamics Model for Predicting Community Functioning and Resilience After Disasters, DISASTER MEDICINE AND PUBLIC HEALTH PREPAREDNESS, Issue 12, Volume 1, page 127 - 137	Research article	To develop a system dynamic model that predict community functioning after disaster - separating community resistance and recovery (as components of resilience).	Systems dynamic modelling
50	Lwin, Ko Ko; Pal, Indrajit; Shrestha, Sangam; Warnitchai, Pennung, 2020. Assessing social resilience of flood-vulnerable communities in Ayeyarwady Delta, Myanmar, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 51	Research article	This study aims to measure the social resilience of communities in flood-prone areas through a case study of Myanmar. This study developed a conceptual indicator-based framework for assessing the social resilience to floods through extensive literature review and identifies the indicators significantly contributing to the social resilience of the community through field investigations and statistical analysis.	Calculation of composite index Weighted average index Pearson's correlation to analyse relationship between resilience, sense of place, flood risk and flood adaptive capacity
51	Manyena, Bernard; Machingura, Fortunato; O'Keefe, Phil, 2019. Disaster Resilience Integrated Framework for Transformation (DRIFT): A new approach to theorising and operationalising resilience, WORLD DEVELOPMENT, Issue 123	Framework development	Review of the literature and outline of the development and operationalisation of the Disaster Resilience Integrated Framework for Transformation (DRIFT)	NA

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
52	Marzi, Sepehr; Mysiak, Jaroslav; Essenfelder, Arthur H.; Amadio, Mattia; Giove, Silvio; Fekete, Alexander, 2019. Constructing a comprehensive disaster resilience index: The case of Italy, PLOS ONE, Issue 14, Volume 9	Research article	To develop an innovative composite disaster resilience index (CDRI) and perform a sensitive analysis on this index by applying it at the municipal level in Italy.	Calculation of composite index Compared the use of three different weighting methods including AMP, Topsis and z-score.
53	Mason, Andrew; Crofts, Eleanor; Steenkamp, Malinda; Ramsey, Imogen, 2016. Developing 'Emergency Ready Communities': a tale of two Victorian Councils, AUSTRALIAN JOURNAL OF EMERGENCY MANAGEMENT, Issue 31, Volume 3, page 27 – 32	Research article	To assess the resilience of two towns using a workshop/ score card process with the Torrens Resilience Institute Community Disaster Resilience Scorecard and educate community leaders about disaster resilience through participation in an 'Emergency Ready Communities' forum.	Workshop Scorecard method
54	Mavhura, Emmanuel; Manyangadze, Tawanda; Aryal, Komal Raj, 2021. A composite inherent resilience index for Zimbabwe: An adaptation of the disaster resilience of place model, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 57	Research article	Develops composite resilience indices (CRI) using 26 variables across 5 subdomains of resilience: community capital, economic, infrastructure, social and health.	Calculation of composite index. Factor analysis
55	McConkey, Sally Ann; Larson, Eric R., 2022. Measuring Community Disaster Resilience Over Time, JOURNAL OF HOMELAND SECURITY AND EMERGENCY MANAGEMENT, Issue 19, Volume 3, page 281 - 321	Research article	To examine the suitability of variables in the Baseline Resilience Indicator for Communities (BRIC) resilience measure to be used as longitudinal measures tracking resilience over time.	Case study comparison of resilience data over time using six criteria
56	Moghadas, Mahsa; Asadzadeh, Asad; Vafeidis, Athanasios; Fekete, Alexander; Koetter, Theo, 2019. A multi-criteria approach for assessing urban flood resilience in Tehran, Iran, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 35	Research article	Constructs composite index based on six resilience dimensions social, economic, institutional, infrastructural, community capital and environmental of community flood resilience.	Hybrid multi-criteria decision-making method – combination of the AHP for prioritising selected indicators and TOPSIS tools to get baseline resilience levels.
57	Morelli, Arianna; Taramelli, Andrea; Bozzeda, Fabio; Valentini, Emiliana; Colangelo, Marina Antonia; Cueto, Yandy Rodriguez, 2021. The disaster resilience assessment of coastal areas: A method for improving the stakeholders' participation, OCEAN & COASTAL MANAGEMENT, Issue 214	Research article	The paper aims to provide a new method for the incorporation of multilevel stakeholders' view in the assessment of the inherent resilience of a place and in the design of a metric based Resilience Index (RI).	Integrates the Disaster Resilience of Place (DROP) model and interviews with Grounded Theory Methodology.
58	Nakasu, Tadashi; Bula-Or, Ruttiya; Anantsuksomsri, Sutee; Duangkaew, Sutpratana; Prathumchai, Kullachart; Positimpakul, Korrakot; Kawasaki, Akiyuki, 2022. Measuring capacities and protecting communities: strengthening regional resilience in the flooded industrial area in Thailand, INTERNATIONAL JOURNAL OF DISASTER RESILIENCE IN THE BUILT ENVIRONMENT, Issue 13, Volume 2, page 163 - 179	Research article	Measure capacities and vulnerabilities of communities to contribute to their flood risk management.	Calculation of composite index Survey questionnaire data

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
59	Nasrnia, Fatemeh; Ashktorab, Niloofar, 2021. Sustainable livelihood framework-based assessment of drought resilience patterns of rural households of Bakhtegan basin, Iran, ECOLOGICAL INDICATORS, Issue 128	Research article	Measures household livelihood resilience in Bakhtegan basin by means of a sustainable livelihood approach.	Index calculation and data mining technique to determine resilience patterns
60	Nguyen, Kien V.; James, Helen, 2013. Measuring Household Resilience to Floods: a Case Study in the Vietnamese Mekong River Delta, ECOLOGY AND SOCIETY, Issue 18, Volume 3	Research article	Employ a subjective wellbeing approach to measure households' resilience to floods. Items related to household capacity to cope with, adapt to, and benefit from floods were developed using both a five-point Likert scale and dichotomous responses.	Mixed methods In depth interviews Focus groups Factor analysis with survey data
61	Oladokun, Victor O.; Montz, Burrell E., 2019. Towards measuring resilience of flood-prone communities: a conceptual framework, NATURAL HAZARDS AND EARTH SYSTEM SCIENCES, Issue 19, Volume 6, page 1151 - 1165	Research article	The study examines the challenges, constraints and construct ramifications that have complicated the development of an operational framework for measuring resilience of flood-prone communities. Among others, the study highlights the issues of proliferation of definitions and conceptual frameworks of resilience, challenges of data availability, data variability and data compatibility	Mathematic model developed using dimensions, quantities and relationships established by the definition of resilience adopted. Fuzzy logic equivalent of the model implemented to generate resilience indices.
62	Oladokun, Victor Oluwasina; Proverbs, David G.; Lamond, Jessica, 2017. Measuring flood resilience: a fuzzy logic approach, INTERNATIONAL JOURNAL OF BUILDING PATHOLOGY AND ADAPTATION, Issue 35, Volume 5, page 470 - 487	Research article	The purpose of this paper is to describe the development of a fuzzy logic (FL)-based resilience measuring model, drawing on a synthesis of extant flood resilience and FL literature	Abstraction of flood resilience system, followed by identification and characterisation of systems' variables and parameters. The model was then transferred into a fuzzy inference system using input factors: inherent resilience, supportive facilities and resident capacity
63	Orencio, Pedcris M.; Fujii, Masahiko, 2013. A localized disaster-resilience index to assess coastal communities based on an analytic hierarchy process (AHP), INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 3, page 62 - 75	Research article	This study proposed an index for a disaster-resilient coastal community at the local level, prioritizing national-level components of a risk-management and vulnerability-reduction system.	Delphi technique – 20 decision makers identified criteria to reduce vulnerability of coastal communities using paired comparisons for the Analytic Hierarchy Process (AHP).

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64	Ostadtaghizadeh, Abbas; Ardalan, Ali; Paton, Douglas; Jabbari, Hossain; Khankeh, Hamid Reza, 2015. Community disaster resilience: a systematic review on assessment models and tools., PLoS currents, Issue 7	Review	This study reviews studies conducted using the resilience concept and examines the tools, models, and methods adopted. It examines the domains, indicators, and indices have been considered in the tools	NA
65	Ostadtaghizadeh, Abbas; Ardalan, Ali; Paton, Douglas; Khankeh, Hamidreza; Jabbari, Hossain, 2016. Community disaster resilience: a qualitative study on Iranian concepts and indicators, NATURAL HAZARDS, Issue 83, Volume 3, page 1843 - 1861	Research article	This qualitative study uses content analysis to explore conceptual and working definitions of Community Disaster Resilience (CDR), as well as domains and indicators of CDR in Iranian context	Qualitative content analysis to explore concepts, domains, and indicators of community disaster resilience.
66	O'Sullivan, Tracey L.; Kuziemy, Craig E.; Toal-Sullivan, Darene; Cornell, Wayne, 2013. Unraveling the complexities of disaster management: A framework for critical social infrastructure to promote population health and resilience, SOCIAL SCIENCE & MEDICINE, Issue 93, Volume, page 238 - 246	Research article	This study proposed to build a framework for critical social infrastructure and develop a model to identify potential points of intervention to promote population health and resilience	Community-based participatory research design was used in nine focus group consultations.
67	Parsons, Melissa; Reeve, Ian; McGregor, James; Hastings, Peter; Marshall, Graham R.; McNeill, Judith; Stayner, Richard; Glavac, Sonya, 2021. Disaster resilience in Australia: A geographic assessment using an index of coping and adaptive capacity, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 62	Research article	Assesses disaster resilience using the Australian Disaster Resilience Index which includes indicators of coping and adaptive capacity.	Calculation of composite index including indicator conditioning and aggregation.
68	Pathak, Shefali Dubey; Kulshrestha, Mukul, 2021. ASSESSMENT OF FLOOD RESILIENCE USING RAAAR FRAMEWORK: THE CASE OF NAYYRMADA RIVER BASIN, INDIA, ENVIRONMENTAL ENGINEERING AND MANAGEMENT JOURNAL, Issue 20, Volume 8, page 1263 - 1276	Research article	Proposes the RAAAR framework to assess disaster resilience including the 5 attributes of Resist, Absorb, Accommodate, Adapt and Recover.	Principle Component Analysis
69	Prashar, Sunil; Shaw, Rajib; Takeuchi, Yukiko, 2012. Assessing the resilience of Delhi to climate-related disasters: a comprehensive approach, NATURAL HAZARDS, Issue 64, Volume 2, page 1609 - 1624	Research article	Assesses disaster resilience in Climate Disaster Resilience Index (CDRI) tool	Calculation of composite index Survey questionnaire and data analysis using Weighted Mean Index (WMI) and Aggregate Weighted Mean Index (AWMI)
70	Ramsey, Imogen; Steenkamp, Malinda; Thompson, Andrea; Anikeeva, Olga; Arbon, Paul; Gebbie, Kristine, 2016. Assessing community disaster resilience using a balanced scorecard: lessons learnt from three Australian communities, AUSTRALIAN JOURNAL OF EMERGENCY MANAGEMENT, Issue 31, Volume 2, page 44 - 49	Research article	Reports the findings of three Australian communities that implemented the Torrens Resilience institute Scorecard for addressing disaster resilience.	Scorecard

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
71	Rani, W. N. M. Wan Mohd; Kamarudin, K. H.; Razak, K. A.; Hasan, R. Che; Mohamad, Zakaria, 2018. MEASURING URBAN RESILIENCE USING CLIMATE DISASTER RESILIENCE INDEX (CDRI), INTERNATIONAL CONFERENCE ON GEOMATIC & GEOSPATIAL TECHNOLOGY (GGT 2018): GEOSPATIAL AND DISASTER RISK MANAGEMENT, Issue 42-4, Volume W9, page 237 - 242	Research article	Used the Climate Disaster Resilience Index (CDRI) to assess disaster resilience in Kuala Lumpur, adjusting the index according to type of disaster, local needs and study objectives.	Calculation of composite index Questionnaire survey and data analysis based on mean scores reported by components
72	Razafindrabe, B. H. N.; Cuesta, M. A.; He, B.; Ranola, R. F.; Yaota, K.; Inoue, S.; Saito, S.; Masuda, T.; Concepcion, R. N.; Santos-Borja, A.; Kada, R., 2015. Flood risk and resilience assessment for Santa Rosa-Silang subwatershed in the Laguna Lake region, Philippines, ENVIRONMENTAL HAZARDS-HUMAN AND POLICY DIMENSIONS, Issue 14, Volume 1, page 16 - 35	Research article	This study proposes a measurement and evaluation approach for community resilience to flood disasters using a set of biophysical and socioeconomic indices. Resilience index was based on the Climate Disaster Resilience Index (CDRI)	Calculation of composite score based on measures related to risk, vulnerability and resilience
73	Redshaw, Sarah; Ingham, Valerie; McCutcheon, Marion; Hicks, John; Burmeister, Oliver, 2018. Assessing the impact of vulnerability on perceptions of social cohesion in the context of community resilience to disaster in the Blue Mountains, AUSTRALIAN JOURNAL OF RURAL HEALTH, Issue 26, Volume 1, page 14 - 19	Research article	Assessed the impact of network communications, community participation and elements of vulnerability on the perception of social cohesiveness in the Blue Mountains local government area.	Survey questionnaire and econometric data analysis
74	Rodriguez-Llanes, Jose Manuel; Vos, Femke; Guha-Sapir, Debarati, 2013. Measuring psychological resilience to disasters: are evidence-based indicators an achievable goal?, ENVIRONMENTAL HEALTH, Issue 12	Research article	Summarise evidence on indicators of psychological resilience to disasters and assesses six studies.	Qualitative assessment
75	Roysircar, Gargi; Geisinger, Kurt F.; Thompson, Ashland, 2019. Haitian Children's Disaster Trauma: Validation of Pictorial Assessment of Resilience and Vulnerability, JOURNAL OF BLACK PSYCHOLOGY, Issue 45, Volume 4, page 269 - 305	Research article	Examined the validity of the House-Tree-Person (HTP) drawing test adapted Haitian children and objectively scored for resilience and vulnerability.	Participant interviews and descriptive statistics; internal consistency reliability; interscale correlations; a generalizability, and exploratory factor analysis.
76	Rus, Katarina; Kilar, Vojko; Koren, David, 2018. Resilience assessment of complex urban systems to natural disasters: A new literature review, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 31, Volume, page 311 - 330	Review	Reviewed the existing literature on urban system resilience to disasters to determine how to best assess the resilience of urban systems, including physical and social components and dynamic interactions between them.	NA
77	Sadia, Haleema; Srisatidnarakul, Boonjai; Liaw, Jen-Jiuan, 2020. Exploring the experiences of flood -affected families to develop constructs and themes for family resilience assessment scale, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, 46, 101500	Research article	Designs a tool for family resilience assessment using interviews.	Qualitative data analysis

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
78	Saja, A. M. Aslam; Goonetilleke, Ashantha; Teo, Melissa; Ziyath, Abdul M., 2019. A critical review of social resilience assessment frameworks in disaster management, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, 35, 101096	Review	This paper critically reviews existing frameworks and methods to understand their application in a disaster context, to highlight key challenges and future directions for developing robust social resilience assessment frameworks	NA
79	Saja, A. M. Aslam; Teo, Melissa; Goonetilleke, Ashantha; Ziyath, A. M.; Gunatilake, Jagath, 2020. Selection of surrogates to assess social resilience in disaster management using multi-criteria decision analysis, INTERNATIONAL JOURNAL OF DISASTER RESILIENCE IN THE BUILT ENVIRONMENT, Issue 11, Volume 4, page 453 - 480	Research article	This paper presents a framework for evaluation and ranking of potential surrogates to select the optimum surrogates and test it for five selected social resilience indicators in a disaster context	Survey and ranking using PROMETHEE, a multi-experts multi-criteria group decision analysis technique
80	Saja, A. M. Aslam; Teo, Melissa; Goonetilleke, Ashantha; Ziyath, Abdul M., 2018. An inclusive and adaptive framework for measuring social resilience to disasters, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 28, Volume , page 862 - 873	Research article	This paper presents an inclusive and adaptive '5S' social resilience framework that was developed based on the critical review of existing social resilience frameworks discussed in the literature.	NA
81	Saja, A. M. Aslam; Teo, Melissa; Goonetilleke, Ashantha; Ziyath, Abdul M., 2021. Assessing social resilience in disaster management, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, 52, 101957	Research article	This paper presents a set of potential surrogates for social resilience indicators identified in an exploratory research investigation.	Qualitative interviews and subsequent data analysis using lexical analysis algorithm
82	Schoch-Spana, Monica; Gill, Kimberly; Hosangadi, Divya; Slemp, Cathy; Burhans, Robert; Zeis, Janet; Carbone, Eric G.; Links, Jonathan, 2019. The COPEWELL Rubric: A Self-Assessment Toolkit to Strengthen Community Resilience to Disasters, INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH, Issue 16, Volume 13	Research article	This paper reports on the production of a self-assessment toolkit (or rubric) built on the Composite of Post-Event Well-being (COPEWELL) model that predicts post-disaster community functioning and resilience.	Expert panel review
83	Shahpari Sani, Davoud; Heidari, Mohammad Taghi; Tahmasebi Mogaddam, Hossein; Nadizadeh Shorabeh, Saman; Yousefvand, Saman; Karpour, Anahita; Jokar Arsanjani, Jamal, 2022. An Assessment of Social Resilience against Natural Hazards through Multi-Criteria Decision Making in Geographical Setting: A Case Study of Sarpol-e Zahab, Iran, SUSTAINABILITY, Issue 14, Volume 14, page 8304 - 8304	Research article	Using a city in Iran, the aim of this paper is to propose an approach to assessing the social resilience of citizens.	AHP method followed by Weighted Linear Combination. Weights were informed expert group
84	Sharifi, Ayyoob; Yamagata, Yoshiki, 2016. On the suitability of assessment tools for guiding communities towards disaster resilience, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Issue 18, Volume , page 115 - 124	Review	To provide further insight on the suitability of CRA tools for guiding community resilience.	Review against set criteria

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
85	Sheth, Suraj, 2022. Risk Index Spatial Clustering (RISC): Identifying High Risk Counties Using Local Moran's I and Spatial Statistics for Natural Disaster Risk Management (Leveraging Spatial Tools for Dynamic Risk Assessment, Resilience Planning And Resource Management Across Spatial Scales), 2022 IEEE CONFERENCE ON TECHNOLOGIES FOR SUSTAINABILITY (SUSTECH), Issue , Volume , page 39 - 43	Research article	Using the FEMA Risk Index Database, paper aims to detect high-risk counties in the US	Spatial analysis
86	Shim, Jae Heon; Kim, Chun-Il, 2015. Measuring Resilience to Natural Hazards: Towards Sustainable Hazard Mitigation, SUSTAINABILITY, Issue 7, Volume 10, page 14153 - 14185	Research article	To present an advanced measurement model that operationalises and measures theoretical resilience concepts related to physical build environment and socioeconomic dimensions. Using this model - identify the different sub-groups of jurisdictions in south Korea.	Confirmatory factor analysis and cluster analysis
87	Siebeneck, Laura; Arlikatti, Sudha; Andrew, Simon A., 2015. Using provincial baseline indicators to model geographic variations of disaster resilience in Thailand, NATURAL HAZARDS, Issue 79, Volume 2, page 955 - 975	Research article	Using the Disaster Resilience of Place (DROP) model this paper examines disaster resilience at the provincial level in Thailand.	Principle component analysis for extraction of variables, followed by post-hoc correlation analysis using Pearson's correlation
88	Singh-Peterson, Lila; Salmon, Paul; Goode, Natassia; Gallina, John, 2015. An assessment of community disaster resilience for small, high-risk communities on the Sunshine Coast, Qld, AUSTRALIAN JOURNAL OF EMERGENCY MANAGEMENT, Issue 30, Volume 1, page 35 - 40	Research article	To assess the level of resilience to emergencies and disasters in five small rural communities on the Sunshine Coast QLD using the application of the Community Disaster Resilience Scorecard (developed by Arbon 2014), and also to determine whether their is sufficient information in the public domain to apply the Scorecard appropriately.	Narrative analysis
89	Snyder, Audrey; Matthew, Stephanie; Leahy, Nancy; Gaul, Raiden; Hood, Tiffany Lee; Hijmans, Kyler; Milbrath, Gwyneth, 2022. Island communities and disaster resilience: Applying the EnRICH community resilience framework, PUBLIC HEALTH NURSING, Issue 39, Volume 1, page 62 - 70	Research article	To explore the beliefs, attitudes and perspectives of community resilience in St Kitts and Nevis.	Interpretive Phenomenological Analysis - using the EnRICH framework to categorise and organise data.
90	Song, Jinglu; Huang, Bo; Li, Rongrong, 2018. Assessing local resilience to typhoon disasters: A case study in Nansha, Guangzhou, PLOS ONE, Issue 13, Volume 3	Research article	To develop a composite resilience index to assess disaster resilience by combining factors in different resilience domains	Calculation of composite index Factor analysis AHP method

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
91	Song, Jinglu; Huang, Bo; Li, Rongrong; Pandey, Rishikesh, 2020. Construction of the Scale-Specific Resilience Index to Facilitate Multiscale Decision Making in Disaster Management: A Case Study of the 2015 Nepal Earthquake, SOCIAL INDICATORS RESEARCH, Issue 148, Volume 1, page 189 - 223	Research article	To validate resilience indicators in various dimensions at various spatial scales and over time, and to construct a framework to measure the scale-specific baseline resilience to natural disasters based on the indicators validated on each particular scale.	Validation of constructed resilience index
92	Summers, J. Kevin; Harwell, Linda C.; Smith, Lisa M.; Buck, Kyle D., 2018. Measuring Community Resilience to Natural Hazards: The Natural Hazard Resilience Screening Index (NaHRSI)-Development and Application to the United States, GEOHEALTH, Issue 2, Volume 12, page 372 - 394	Research article	To apply a drought resilience index (NaHRSI) to local counties across USA. Calculation of a composite index. Descriptive analysis.	
93	Talubo, Joan Pauline; Malenab, Roy Alvin; Morse, Stephen; Saroj, Devendra, 2022. Practitioners' Participatory Development of Indicators for Island Community Resilience to Disasters, SUSTAINABILITY, Issue 14, Volume 7	Research article	To develop composite indicators for resilience for island communities using a mixed-methods approach that incorporates practitioner insight and perspective	Mixed methods Principle component analysis Delphi method
94	Tariq, Hisham; Pathirage, Chaminda; Fernando, Terrence, 2021. Measuring community disaster resilience at local levels: An adaptable resilience framework, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Volume 62	Literature review	To review current resilience frameworks and identify and categorised current resilience indicators and measures into a 'library of indicators' that can be used by stakeholders to measure resilience	PRISMA
95	Tong, Peihao, 2021. Characteristics, dimensions and methods of current assessment for urban resilience to climate-related disasters: A systematic review of the literature, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Volume 60	Literature review	Through a systematic review, this study aims to answer the following questions about current urban resilience assessment: 1) what are the most common characteristics of urban resilience; 2) what are the most commonly involved dimensions of urban ecosystems; and 3) what are most frequently applied methods.	PRISMA
96	Torabi, Elnaz; Dedekorkut-Howes, Aysin; Howes, Michael, 2022. A framework for using the concept of urban resilience in responding to climate-related disasters, URBAN RESEARCH & PRACTICE, Issue 15, Volume 4, page 561 - 583	Research article	To identify the dimension of resilience discussed in the literature and explore how they work on the ground using two case study cities in Australia.	Thematic analysis
97	Vazquez-Gonzalez, Cesar; Sophie Avila-Foucat, V; Ortiz-Lozano, Leonardo; Moreno-Casasola, Patricia; Granados-Barba, Alejandro, 2021. Analytical framework for assessing the social-ecological system trajectory considering the resilience-vulnerability dynamic interaction in the context of disasters, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Volume 59	Research article	To present an analytical framework to show the social-ecological resilience-vulnerability interaction by considering the adaptive cycle of SESs and the disaster phases as well as resilience attributes	NA

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
98	Villano, Renato A.; Magcale-Macandog, Damasa B.; Acosta, Lilibeth A.; Tran, Carolyn-Dung Thi Thanh; Eugenio, Elena A.; Macandog, Paula Beatrice M., 2020. Measuring disaster resilience in the Philippines: evidence using network data envelopment analysis, CLIMATE AND DEVELOPMENT, Issue 12, Volume 1, page 67 - 79	Research article	To investigate the link between the real coping capacity and the adaptive capacity of households in a comprehensive manner using a non-conventional approach (network data envelopment analysis NDEA).	EFA followed by a DEA model - and weighting of inputs
99	Wilkin, Joanna; Biggs, Eloise; Tatem, Andrew J., 2019. Measurement of Social Networks for Innovation within Community Disaster Resilience, SUSTAINABILITY, Issue 11, Volume 7	Literature review	To review empirical case studies from the Global South within Disaster Risk Recovery that use social network analysis and connectivity measurement.	Methodology of review based on Rockenbauch and Sakdapolrak's methodology
100	Wu, Feng; Xu, Wanqiang; Tang, Yue; Zhang, Yanwei; Lin, Chaoran, 2022. Gray Measure and Spatial Distribution Exploration of Local Emergency Resilience on Compound Disasters, INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH, Issue 19, Volume 17	Research article	This paper puts forward a framework to calculation of a composite local energy resilience index, including the Projection Pursuit Model based on Real-coded Accelerating Genetic Algorithm and the Moran's Index (Moran's I), to measure the local emergency resilience and analyse its spatial distribution. The proposed index is then applied across case study region of Hubei Province.	Calculation of composite index
101	Xu, Jinwen; Qiang, Yi, 2021. Spatial Assessment of Community Resilience from 2012 Hurricane Sandy Using Nighttime Light, REMOTE SENSING, Issue 13, Volume 20, page 4218	Research article	To explore the utility of night time lights (NTL) remote sensing images in assessing community recovery and resilience in natural disasters.	Spatial analysis to measure change in night time light. Regression analysis was then used to examine the relationship between change in night time light and explanatory variables related to resilience.
102	Xu, Wenping; Xiang, Lingli; Proverbs, David, 2020. Assessing Community Resilience to Urban Flooding in Multiple Types of the Transient Population in China, WATER, Issue 12, Volume 10, page 2784	Research article	To assess the community resilience of the transient population in China, and identify priorities for resilience indicators to help inform the development of an index-based measurement of resilience.	Calculation of composite index
103	Yang, Yuying; Guo, Haixiang; Chen, Linfei; Liu, Xiao; Gu, Mingyun; Pan, Wenwen, 2020. Multiattribute decision making for the assessment of disaster resilience in the Three Gorges Reservoir Area, ECOLOGY AND SOCIETY, Issue 25, Volume 2	Research article	To develop a disaster resilience evaluation index system from societal, economic, infrastructural, and natural environmental perspectives, and explore an integrated approach to produce an accurate evaluation of disaster resilience in the Three Gorges Reservoir Area.	Calculation of composite index
104	Yonson, Rio; Noy, Ilan, 2020. Disaster Risk Management Policies and the Measurement of Resilience for Philippine Regions, RISK ANALYSIS, Issue 40, Volume 2, page 254 - 275	Research article	To assess asset risk, welfare risk and resilience across various regions in the Philippines.	Calculation of composite index Descriptive comparison across regions

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
105	Yoon, D. K.; Kang, Jung Eun; Brody, Samuel D., 2016. A measurement of community disaster resilience in Korea, JOURNAL OF ENVIRONMENTAL PLANNING AND MANAGEMENT, Issue 59, Volume 3, page 436 - 460	Research article	To develop a methodology for constructing a set of indicators measuring Community Disaster Resilience Index (CDRI), and use this to measure the resilience to natural disasters of the 229 local municipalities in Korea.	Calculation of composite index. Followed by cluster analysis, ordinary least square regress and geographically weighted regression analysis to identify the spatial characteristics of CDRI and assess the impact of community resilience on actual losses.
106	Zhang, Hui; Liu, Xiaoqian; Xie, Yingkai; Gou, Qiang; Li, Rongrong; Qiu, Yanqing; Hu, Yueming; Huang, Bo, 2022. Assessment and Improvement of Urban Resilience to Flooding at a Subdistrict Level Using Multi-Source Geospatial Data: Jakarta as a Case Study, REMOTE SENSING, Issue 14, Volume 9	Research article	This paper presents a method to assess the urban resilience to flooding in terms of the recovery rate of different subdistricts in a city using all-weather synthetic aperture radar imagery (i.e., Sentinel-1A imagery).	Correlation analysis between resilience indicators and recovery rates
107	Zhang, Huiming; Yang, Jiayun; Li, Lianshui; Shen, Danyun; Wei, Guo; Khan, Haroon ur Rashid; Dong, Sujiang, 2021. Measuring the resilience to floods: A comparative analysis of key flood control cities in China, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, Volume 59.	Research article	Construction of a comprehensive evaluation model that focused on revising the indicator system and measured resilience to floods across 31 key flood control cities in China.	Entropy-weighting TOPSIS method
108	Zhong, Ming; Lin, Kairong; Tang, Guoping; Zhang, Qian; Hong, Yang; Chen, Xiaohong, 2020. A Framework to Evaluate Community Resilience to Urban Floods: A Case Study in Three Communities, SUSTAINABILITY, Issue 12, Volume 4	Research article	In this study, an advanced index framework for measuring community resilience to urban flooding is proposed.	Calculation of composite index Fuzzy Delphi method (FDM) and the analytic network process (ANP)
109	Zhong, Shuang; Clark, Michele; Hou, Xiang-Yu; Zang, Yuli; FitzGerald, Gerard, 2014. Validation of a Framework for Measuring Hospital Disaster Resilience Using Factor Analysis, INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH, Issue 11, Volume 6, page 6335 - 6353	Research article	This article aims to provide a framework which can be used to comprehensively measure hospital disaster resilience. Eight key domains were identified.	Modified-Delphi consultation
110	Zhong, Shuang; Clark, Michele; Hou, Xiang-Yu; Zang, Yu-Li; Fitzgerald, Gerard, 2014. Development of hospital disaster resilience: conceptual framework and potential measurement, EMERGENCY MEDICINE JOURNAL, Issue 31, Volume 11, page 930 - 938	Review	This article aims to define hospital resilience, build a preliminary conceptual framework and highlight possible approaches to measurement.	NA

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ARTICLE NUMBER	REFERENCE	TYPE OF PAPER	AIM OF PAPER	STATISTICAL ANALYSIS USED
111	Zhu, Huagui; Liu, Fan, 2021. A Group-Decision-Making Framework for Evaluating Urban Flood Resilience: A Case Study in Yangtze River, SUSTAINABILITY, Issue 13, Volume 2	Research article	This paper proposes a group-decision-making framework for measuring urban resilience to flooding and evaluates 41 cities in the Yangtze River basin.	Calculation of composite index Comparison of several Multi-criteria decision making (MCDM) methods. Stochastic multi criteria acceptability analysis is adopted to integrate those results into a composite resilience index
112	Zhu, Shiyao; Li, Dezhi; Huang, Guanying; Chhipi-Shrestha, Gyan; Nahiduzzaman, Kh Md; Hewage, Kasun; Sadiq, Rehan, 2021. Enhancing urban flood resilience: A holistic framework incorporating historic worst flood to Yangtze River Delta, China, INTERNATIONAL JOURNAL OF DISASTER RISK REDUCTION, 61, 102355	Research article	This paper proposes a holistic evaluation framework for evaluating urban flood resilience consisting of indicators of resistance, coping, recovery and adaptation capacity of resilience for three stages of the flood disaster cycle, namely pre, during and post-flood.	VIKOR and Grey Relational Analysis (GRA)

APPENDIX 2 – STAKEHOLDER WORKSHOP METHODS

Financial Resources (individual and community)

INDICATORS	NUMBER OF CODES
Insurance	4
Financial distress	12
Financial resources	4
Unemployment rate and job security	6
Business resilience	3
Tourism	1

Infrastructure and services

INDICATORS	NUMBER OF CODES
Number of tradespeople	7
Services	10
Health services	3
Community event infrastructure	4
Childcare	1
Housing e.g. housing availability and affordability	11

Social resources (individual and community)

INDICATORS	NUMBER OF CODES
Social resources	6
Community cohesion and led recovery	32
Community events and participation	16
Community conflict	6
Community leadership	4
Feeling listened to	5
Relationship breakdowns	2
Social media	2
Volunteerism	8
Sympathy for other communities	1

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Human resources and functioning (individual and community)

INDICATORS	NUMBER OF CODES
Personal skills and capacity e.g. self-efficacy, able to deal with hardship	17
Education level	4
School attendance	5

Health and wellbeing

INDICATORS	NUMBER OF CODES
Physical health	3
Mental health e.g. distress, triggers, help-seeking	25

Institutional resources

INDICATORS	NUMBER OF CODES
Government competence e.g. trust in government, financial health of government	8
Recovery funding period too short	5
Funding distribution unequal	1
Recovery and response support	7

Ecosystem service provision

INDICATORS	NUMBER OF CODES
Perceived environmental health and landscape changes	7
Soil health	1
Water quality	1

Liveability of community

INDICATORS	NUMBER OF CODES
Crime and safety	7

Natural hazard resources and exposure to natural hazards

INDICATORS	NUMBER OF CODES
Resources that assist preparing, responding, recovering	11
Natural hazard exposure	3

Socio-demographic and geographic variables

INDICATORS	NUMBER OF CODES
Homelessness rates	7
Sociodemographic variables e.g. age	7
Temporary population	3
Relocation	2



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