Australia's National
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Response to the Draft NSW Groundwater Strategy

CSIRO Groundwater Management Group

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Introduction

CSIRO welcomes the opportunity to provide input to the consultation process in relation to the draft NSW Groundwater Strategy available at: https://water.dpie.nsw.gov.au/plans-and-programs/nsw-groundwater-strategy. Our submission attached follows recent engagements with the NSW Government in relation to groundwater characterisation and management, recharge estimation and groundwater trend analysis, groundwater modelling, impacts from development on groundwater dependent ecosystems, Managed Aquifer Recharge (MAR), water banking and related topics such as brackish groundwater desalinisation, regional water security and drought resilience.

Over many decades CSIRO has supported Australia's groundwater knowledge requirements through projects involving aquifer and groundwater resource characterisation, groundwater and the environment, surface water – groundwater interactions, groundwater modelling, MAR, groundwater in the resources and energy sectors, groundwater quality and adaptive water management. An overview of CSIRO's research is available here: https://www.csiro.au/en/research/natural-environment/water/groundwater-resources.

In our submission we seek to provide an overview of groundwater research, including the potential opportunities that this research offers to address water security needs in NSW. Some of this information was also previously provided as input to the NSW Government's public consultation process in relation to the draft NSW Regional Water Strategies.

We would like to reaffirm our interest in continuing to explore opportunities for CSIRO to collaborate on the implementation of the NSW Groundwater Strategy.

Should you require any further information from CSIRO or wish to discuss any aspect of our submission please contact [redacted]

CSIRO response to the Draft NSW Groundwater Strategy

1 Response to actions

Action 1.1 - Refresh and expand our approach to sustainable groundwater management

We welcome the intended move towards adaptive and sustainable groundwater resource management through reviewing and updating groundwater policy. The ongoing adaptation of policy to incorporate new knowledge and stakeholder values is likely to be central to the achievement of other actions described in the Draft NSW Groundwater Strategy. We look forward to the development of a policy implementation strategy that will capture a definition of sustainable groundwater use and adaptive management, metrics for measuring success sustainability targets and benchmarks.

Action 1.2 - Better integrate groundwater management with other land and water management processes

Groundwater and surface water resources are mutually dependent, where groundwater can provide essential baseflow to surface water systems and support flows to surface water ecosystems, and surface water in rivers and lakes can locally recharge groundwater systems, supporting groundwater dependent industries and ecosystems. Although the time scales at which they are managed can be different (groundwater generally from months to decades, compared with surface water from sub-daily to monthly), both surface water and groundwater systems may be better supported by combined management of the one water resource.

CSIRO research into the effects of climate change on groundwater recharge has estimated substantial decline in natural groundwater recharge will occur in the future (Barron et al., 2011, Crosbie et al., 2010, Crosbie et al., 2021). In some areas of southern Australia where groundwater demand is already near the sustainable yield, the decline in groundwater recharge is estimated to be between 14% and 55%. Recent research in the Murray Darling Basin has also indicated that groundwater levels in many of the alluvial aquifers are decreasing (Fu et al., 2022), most likely as a result from a combination of climate change and groundwater extraction.

Baseflow to rivers is dependent on groundwater levels being higher than the river stage, and where groundwater levels have decreased there is potential for a decrease in baseflow to follow. This is a potential challenge for the Murray Darling Basin, particularly in NSW (Walker, 2022; Walker et al., 2021). Where baseflow to rivers decreases, or rivers change from gaining groundwater as baseflow to losing water to groundwater systems, management of groundwater systems will have an impact on surface water resources and the way that they are managed.

Research on improving the understanding and quantification of the fluxes between groundwater and surface water systems is important, and monitoring of these fluxes through conventional (programs for groundwater and surface water data acquisition) and novel (remote sensing, subsidence etc.) methods will support this. There is opportunity for integrated modelling of groundwater and surface water through coupled or semi-coupled models, and/or emulation of model behaviour to align the timescales of surface water and groundwater, to better support management decision making.

This action will support the challenges associated with managing impacts on groundwater from large developments during the transition from coal to gas, renewable and hydrogen energy sources. CSIRO has a long history working with stakeholders to address knowledge gaps around the potential impacts on groundwater resources from the coal industry (for example in the Hunter Valley) mineral extraction and gas development (including the Bioregional Assessments Program), particularly through groundwater modelling (Janardharnan et al., 2018, Peeters et al., 2018 and Herron et al., 2018). Recent work to improve the process of risk assessment in Queensland, South Australia and the Northern Territory in the Geological and Bioregional Assessments (GBA) Program provided a systematic and spatially explicit framework for assessing the impacts of coal seam gas on groundwater and surface water related assets.

Implementation of this action could also consider the potential impacts of developing industries such as the hydrogen industry and carbon capture and storage on groundwater systems, and associated issues such as management of waste brines. There is potential for development of research through CSIRO to address some of these knowledge gaps.

Characterisation and management of cross-border groundwater systems is a challenge for many states and territories. Areas where cross-border groundwater management could be strengthened for NSW includes the Great Artesian Basin (GAB) and Murray Darling Basin (MDB). Recent work conducted by Geoscience Australia and CSIRO (including work conducted jointly by both agencies as part of the Geoscience Australia project 'Assessing the Status of Groundwater in the Great Artesian Basin') suggests that springs within the Surat Basin and south-eastern Eromanga Basin in NSW may be discharge points of long flow paths originating in Queensland. Nevertheless, many knowledge gaps remain, some of which may only be closed by cross-border studies.

Cross-border studies could be made simpler by a national resolution of aquifer conceptualisations, aquifer hydraulic properties and groundwater properties (e.g. quality, heads, flow directions) to ensure a smooth rather than stepped transition across state borders. An example of this is improving the understanding of the stratigraphy of cross-border basins such as the Surat and Eromanga basins in NSW. At present, the detail in 3D geological models available in Qld and NSW for aquifer systems of the GAB is very different. Having an accurate understanding of the geometry of the GAB and overlying aquifers is essential to understand connectivity, and the combination of 3D geological models of the Surat Basin in Qld and NSW could be beneficial for both states.

Conceptualisation of groundwater dependent ecosystems (springs and groundwater-fed streams) in cross-border groundwater management areas may also contribute to improvements in cross-border groundwater management. Recent studies conducted or commissioned by NSW Department of Planning and Environment (e.g. Golder Associates, 2021) that have involved hydrochemistry and environmental isotope sampling of springs and groundwater bores (including GAB bores) have been extremely useful for characterisation of the GAB. Further expansion of this work and integrating it with other lines of evidence (geophysics, 3D geological models, remote sensing etc.) to identify the origin of water supporting groundwater dependent ecosystems could add confidence to estimates of cross-border groundwater flows of high environmental value.

Improving the availability and sharing of groundwater model outputs for the GAB and other large-scale, cross-border groundwater storage assessments with researchers could further simplify further cross-border studies.

Action 1.3 - Improve management and protection of groundwater dependent ecosystems and baseflows to streams

Knowledge available for identifying, assessing and characterising groundwater dependent ecosystems (GDEs) is fairly well established. The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) Explanatory Note on Assessing groundwater dependent ecosystems provides a guidance around developing frameworks and presenting methods for assessing GDEs in an environmental impact assessment (Doody et al. 2019). The NSW Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Serov et al., 2012) also provides a conceptual framework to define GDEs and their ecological value, define the potential risk from an activity to aquifers and associated GDEs and develop management strategies for aquifers and identified GDEs.

A recent detailed mapping effort for terrestrial GDE vegetation across NSW has been updated in the National Atlas of Groundwater Dependent Ecosystems (GDE Atlas; Doody et al., 2017). Future development of this data could consider a finer scale mapping resolution. Additional mapping of aquatic GDEs (rivers, springs, wetlands) in the GDE Atlas could also simplify the assessment of mapping of a larger range of GDEs. The GDE Atlas also collated all field studies identifying GDEs up to 2010 (including those within NSW). There may be value in making this collation of information publicly available and build upon them by adding studies published from 2010 onward. This could help to prevent duplication in measuring ecosystem responses to groundwater regimes and prioritise funding on areas which have not yet been studied.

The High Ecological Values Aquatic Ecosystems (HEVAE) national framework includes measures of ecosystem diversity, distinctiveness, vital habitat, naturalness and representativeness to characterise and map high value aquatic ecosystems in NSW. It may be useful to expand this framework to include terrestrial groundwater dependent ecosystems in the same way.

Methods for incorporating the behaviour of GDEs into conceptual and numerical models used for groundwater management are less defined. The conceptual models of GDEs developed in the Queensland WetlandInfo site are an excellent start. Incorporating them into groundwater models could be improved by better understanding the response of GDEs (vegetation, surface water and aquatic species) to groundwater lowering or raising. Not only does lowering of groundwater reduce the flow of water to wetlands and rivers, but also reduces the access groundwater dependent terrestrial vegetation to shallow groundwater by lowering the water table below the plant root zone. If the decline in groundwater level is too rapid, the vegetation has no time to adapt and will decline and decrease in condition over time, and groundwater decline in dry seasons (summer) is more likely to impact GDSs than in wet seasons (winter; Doody et al. 2021). Characterising of the timing and speed of groundwater decline as well as the magnitude is important for predicting potential impacts on GDEs.

One of the key challenges in detecting the response of GDEs to lowering of groundwater levels is the relatively long delay between changes to the groundwater system and the resulting vegetation response. Remote sensing information has been shown to be useful for the monitoring of GDEs, including the use of SAR imagery (Castellazzi et al., 2019). Solar-induced chlorophyll fluorescence (SIF) from LiDAR measurements can also provide a means to estimate plant photosynthetic activities and to detect early plant stress, and therefore provide rapid feedback for groundwater managers (Gao et al. 2022).

Inversely, groundwater dependent vegetation, particularly in forestry plantations can also have an impact on groundwater levels (Benyon et al., 2006), and accounting for forestry water use in water accounting is included in Water Allocation Plans in areas such as the Lower Limestone Coast of South Australia (Simmons et al. 2019).

Some GDEs, such as stygofauna, may be hidden from sight, but could provide information about aquifer characteristics and connections. Ongoing work by CSIRO's Gas Industry Social and Environmental Research

Alliance (GISERA) includes research in the Beetaloo Sub-basin to characterise stygofauna found in the Tindall Limestone (GISERA, 2020).

Action 1.4 - Review and update approaches to sustainable groundwater extraction

Previous research, particularly in the Murray Darling Basin and southern Australia suggests that there is often a mismatch between the scale of the groundwater source extraction limits (SELs) for a groundwater management zone and the impacts on ecosystems of value (Walker et al., 2021). Groundwater extraction may be within the limits of an SEL but may be spatially distributed in such a way that groundwater dependent ecosystems are not afforded the protection that the SEL intended. We agree that a multi-level groundwater management approach is sound, if spatial discretisation and conceptualisation was suitable for the assets being managed.

The proposed two levels of management, at resources scale (total extraction limit) and local scale (rate extraction) would likely include a conventional water balance management at regional scale in addition to a risk-based approach that accounts for the cumulative, localised spatial effects of groundwater extraction on groundwater dependent ecosystems and assets such as water bores. Research has indicated that to ensure reliability of results, groundwater models used for risk assessment at a local scale need to be developed specifically for the management question being asked to be fit for purpose. More reliable results are obtained when models are developed at an appropriate level of discretisation for the system being modelled and the risk being assessed, and not necessarily be the same model that is used for regional groundwater accounting. Best practice is for groundwater models to include uncertainty around hydrologic parameters, model drivers (such as recharge and evapotranspiration) and preferably model conceptualisation (for example, accounting for presence or absence of geologic structures that might influence the direction of groundwater flow) (Enemark et.al., 2019, Enemark et al, 2020).

We agree that a better understanding of the response of groundwater dependent ecosystems to changes in groundwater level, including the magnitude and rate of change is essential in better managing the risks to ecosystems (see response to Action 1.3). We also agree that the process of developing more robust and drought resilient groundwater source extraction limits might account for long-term changes in groundwater recharge through climate change, both diffuse recharge from rainfall and localised recharge through river losses and overbank floods (Crosbie et al., 2021).

To support the uptake of MAR pilot schemes, it would be beneficial to consider how MAR fits within the groundwater policy context. In the current policy framework, there is no distinction between water that is part of the natural groundwater resource, and therefore subject to SELs and groundwater that originated through recharged surface water or treated wastewater. Having an enabling policy framework to support the operation of MAR is likely to assist in with the development and trialling of this system supporting water security and drought resilience.

Improvements in the accuracy of estimated components of the water balance, through improving groundwater use metering and estimates of basic landholder rights (stock and domestic) consumption, groundwater recharge estimates, baseflow to rivers and evapotranspiration could also lead to the improvements calculating SELs in alluvial aquifers.

Action 1.5 - Protect groundwater quality within natural limits

Protection of groundwater quality is an important component of valuing groundwater resources. We agree that aquifer vulnerability assessments to different forms of contamination, including from surface spills, seawater intrusion and induction or acceleration of flow between aquifers of different quality, is important for the protection of high-quality, vulnerable aquifers. A baseline assessment of groundwater quality before a development proceeds or is expanded will also assist in identifying where groundwater systems are vulnerable to pollution risks.

CSIRO's Gas Industry Social and Environmental Research Alliance (GISERA) has recently completed research on effective and socially acceptable decommissioning of coal seam gas (CSG) wells in Queensland and NSW (Huddlestone-Holmes et al., 2018) and improved approaches to monitoring decommissioned wells (Huddlestone-Holmes et al., 2022). Development of a program for long-term monitoring of abandoned and decommissioned gas wells, tying in with the NSW review of legacy wells, will minimise the potential risks to groundwater quality due to leakage of groundwater between aquifers associated with gas production and those used for water supply.

Action 2.1 - Support towns and cities using groundwater to improve their urban water planning

Assessment and protection of groundwater sources through increasing water supply efficiency and resolving regulatory issues is likely to help improve the water security for towns and cities using groundwater as a water source, particularly in regional areas. Exploring alternative water sources and storages to improve water security for towns is an option, including the desalination of brackish groundwater, the use of deep or marginal quality groundwater as an emergency supply and the use of MAR for increasing storage of water that can be relied on during drought (see Action 2.2). MAR for town water security is likely to be simpler to implement in terms of regulation, with a single user (the relevant water supply industry), and with limited trade implications compared with MAR for agricultural water security. It generally requires smaller scheme volumes and being for drinking supply is often more economically viable, and a social priority.

Desalination of otherwise unusable brackish groundwater is another potential source of water for regional town water security. Pathways for addressing knowledge gaps in this area include mapping sources of brackish groundwater, and identification of energy sources for desalination, potential storage of treated water in new and existing infrastructure such as dams or through MAR, and the development of technology, capability and policy to support the associated management of waste brines.

Action 2.2 - Support economic growth using groundwater

Among other forms of groundwater management solutions to support economic growth, MAR offers the potential to assist communities with achieving water security. The use of aquifer storage to bolster groundwater resources adds resilience to communities from the negative effects of drought and reduces pressure on surface water supplies.

To date, projects and results have been mostly localised in capital cities, with some more recent investigations across northern Australia as part of the Northern Australia Water Resource Assessment. Substantial progress has been made where local governments or state water utilities have partnered with CSIRO to conduct assessments and determined that the potential benefits to water security outweighed the costs of investment. In some cases, federal government investment has been provided to deliver pioneering research focused on reducing the initial financial and technical risks associated with MAR projects.

Opportunities for NSW regional towns to implement MAR for improved water security during drought still remain to be proven and could be furthered through the establishment of successful, well documented demonstration projects. MAR opportunities could potentially be used as a conjunctive approach to surface and groundwater management to ensure security of water supply for social, economic and environmental outcomes.

Some examples in regional areas in Australia exist where conjunctive use of surface water and groundwater storage projects have been successful. For example, groundwater replenishment by the Burdekin Water boards near Townsville in Queensland that has been in operation since the 1960s to secure irrigation supplies predominantly for sugarcane. Another example of MAR for irrigation support of viticulture is found in the Angas-Bremer region of South Australia which has been in operation since the 1980s. From CSIRO experience with MAR, opportunities for water banking are most favourable in aquifers that contain fresh groundwater (and hence have a high-water recovery efficiency), have low groundwater hydraulic gradients and inter-aquifer leakage (minimising banked water loss), and where MAR can be accommodated within exiting groundwater management plans (e.g. to manage volumes and ensure access to recharged water).

Recent CSIRO investigations in the Murray-Darling Basin region estimated an additional aquifer storage potential of ~4 km3 in surficial aquifers near major watercourses across the Basin (Gonzalez et al. 2020). This represents ~16% of the ~25 km3 total accessible capacity of surface storages across the Basin. For NSW, this equates to a potential 2,000 GL of aquifer storage (with a salinity of <3000 mg/L total dissolved solids) or 1,300 GL (for salinity<1500 mg/L total dissolved solids) for locations < 5 km from a river. There is sufficient storage capacity in many of the river regions that currently have regional water strategies being developed. These storage areas could also be suitable for recovery for irrigated agriculture, town water supplies, stock water, or environmental flows.

In the same study, simulations of water banking appear very favourable, such as in the Macquarie River catchment near Dubbo, NSW. Water can be purchased from the existing water market when cheap and recovered when expensive, hence it is not likely that any new water extractions would be required. These results indicated that peak aquifer storage could be accessed with a recharge capacity of 6 GL/month supplying water with a market value >AUD$30M which is roughly double the estimated levelised cost of a water bank supply (Gonzalez et al. 2020). Similar opportunities are likely to exist in other regions of NSW.

The economic drivers for water banking are already indicated by significant increases in trading prices during droughts. However, incentives for improving water security would need to include developing clearly defined rights to recover recharged water during drought through policy reform and demonstrating that there is no impediment to the access and use of the recharged volume. Development of demonstration MAR sites that are well designed, monitored, and managed is required to give confidence that water banking is effective, and that it can be managed so that it is fair to all water users, sustains the environment and creates economic benefit.

Action 2.3 - Support Aboriginal rights, values and uses of groundwater

We note the action to support Aboriginal rights, values and uses of groundwater which has been developed in consultation with the input of Traditional Owners in NSW, because co-design and co-development of projects with Aboriginal communities has the potential to improve the way that groundwater systems are managed.

Groundwater rights, more so than surface water, are closely tied to the land from which groundwater is extracted or the waterbodies and ecosystems that are dependent on groundwater. This is where Action 2.3 links closely with Action 1.2 – to better integrate groundwater management with other land and water management processes, to recognise current shortfalls in Aboriginal access to groundwater systems, and land more generally.

Aboriginal knowledge into groundwater management can also be integrated through Aboriginal led scientific evidence into groundwater management, recognising the contributions that Aboriginal people make to scientific research. This could bring together multiple lines of evidence for traditional groundwater knowledge and management. An important aspect of this work would be to ensure that conceptualisation and management of groundwater systems and groundwater dependent ecosystems include both an Aboriginal knowledge and Aboriginal led archaeological/anthropological research outcomes, with an objective of building a strong knowledge base for Aboriginal groundwater systems into the future. This may assist with a better understanding of the cultural value of groundwater dependent ecosystems, and the water conditions required to maintain growth or instigate reproduction of flora or fauna that are significant to Aboriginal communities.

Action 3.1 - Develop a groundwater knowledge plan to improve how we use groundwater information to make decisions

The NSW priority to develop a groundwater knowledge plan to synthesise groundwater knowledge and prioritise how groundwater information is used will support evidence-based decision making. The development of the Groundwater science research priorities research prospectus is a way to clearly define research priorities to guide studies by research providers.

Action 3.2 - Better share and integrate groundwater information

Transparent and easily available groundwater data is a key part of addressing knowledge gaps and improving groundwater management. Opportunities for sharing of NSW groundwater data include the upgrade of the current Water NSW platform to improve its practicality and user interface. Suggestions for improving groundwater data sharing also include:

- Streamlining data requests for groundwater data through an online portal, increasing the simplicity and transparency of data availability and use.
- Developing provisions for batch-downloading of important data from the Water NSW WaterInsights portal, such as water chemistry or stratigraphic records for large numbers of bores. This will become more important with the increasing use of AI/ML for processing large volumes of data.
- Providing data in more user-friendly formats (such as csv) that can easily be read into coding scripts.
- Making stratigraphic records available for bores in NSW, particularly for cross-border systems such as the GAB or MDB.
- Providing hydraulic property data tied to an aquifer framework. This could have benefits for preliminary screening of groundwater systems prior to more detailed modelling, and for probabilistic prospectivity mapping in remote areas, similar to that described in Peeters et al. (2020).
- A method for incorporating additional data into the NSW groundwater repository, such as data from environmental impacts statements which is already in the public domain, or reporting of pumping tests to further constrain hydraulic properties.

Action 3.3 - Improve our understanding of groundwater resources

There is much potential for development of research to support groundwater management using novel methods of combining groundwater and other biophysical models: surface water (Doble et al., 2014), landscape (Doble et al., 2017), ecosystem dynamics, groundwater markets and trade (Gao et al. 2013).

The issue of cultural values is mostly contained in Action 2.3 in the strategy, however, to advance Action 3.3 a broader perspective could address groundwater user behaviour as part of the modelling chain to embed cultural values/water users' behaviour into groundwater management (Heinrichs and Rojas, 2022). For example, considering risk perception, ability or willingness to comply, physical drivers, and institutional/regulatory constraints enabling or hindering the compliance with mandated water restrictions could assist with better understanding of the potential outcomes of different management scenarios. CSIRO is currently working on a modelling framework unifying all these factors based on coupling Agent-Based Models (ABMs) and biophysical physical models (including groundwater models) with the Natural Resources Access Regulator (NRAR) in NSW. Co-design, co-production and co-delivery is also likely to help to ensure that research and development are aligned with the needs of groundwater stakeholders, and that knowledge is transferred to regulators, industry and communities.

Fit for purpose groundwater models are required to answer the questions pertinent to groundwater characterisation and management. As mentioned previously, quantifying and communicating model prediction uncertainties could assist in groundwater management decision making and improve community confidence in model results. The IESC groundwater modelling uncertainty guidelines (Middlemiss and Peeters, 2018) provides useful information for uncertainty analysis of groundwater models in a risk assessment framework. Some of the latest groundwater modelling, calibration and uncertainty analysis tools provide improved capability to address prediction uncertainties caused by partial or no knowledge about system characteristics and parameters.

Addressing the need for quantifying and managing cumulative impacts to groundwater and groundwater dependent assets could be done through numerical groundwater modelling. Aquifers in NSW have potential cumulative impacts from a variety of stressors including over-extraction, climate change, mining and gas industry uses. Developing improved understanding of cumulative impacts through data and modelling could help to improve management and regulation. The most insightful outcomes from risk-based groundwater modelling have been shown to occur when models are specifically conceptualised to target the specific problem of interest. For example, the Bioregional Assessments Program considered the cumulative impacts to Namoi alluvial and GAB aquifers from coal seam gas and coal mining developments through risk-based groundwater modelling undertaken in the Namoi, Gloucester and Hunter subregions (Janardharnan et al., 2018, Peeters et al., 2018 and Herron et al., 2018).

Action 3.4 - Expand our groundwater data collection

In much of Australia, groundwater monitoring programs have been subject to ageing infrastructure and reduced monitoring programs. In the alluvial aquifers of the Murray Darling Basin, the number of monitored bores for which records were available fell from around 5000 in the early 1990s to less than 500 in 2021 (Fu et al, 2022). In contrast, from the early 1990s to 2010 the total number of observations more than doubled due to the installation of automatic sensors, but from 2011 to 2021 even with this increase in sensors there has been a significant decrease in the total observations. The priority areas for further groundwater data acquisition could be assessed based on aquifer vulnerability and data worth assessments.

The new NSW coal basins groundwater monitoring bore network described in Box 10 is a good example of the value that investments in groundwater bore infrastructure can deliver. CSIRO has used data (stratigraphic, water chemistry and water levels) from these bores in multiple projects to estimate groundwater recharge and to understand connectivity between gas reservoirs and aquifer (e.g. Crosbie et al., 2022 and Raiber et al., 2022). Sample collection for hydrochemistry and environmental tracers from these new bores to understand aquifer connections, groundwater flow patterns and recharge sources will also form a central part in future projects.

Development of a long-term plan for groundwater data collection could also consider the value of novel and/or spatial data sources for aquifer characterisation and monitoring groundwater condition. These data sources may include remote sensing data for the characterisation of evapotranspiration and therefore inferred recharge, geophysics (such as EM and nuclear magnetic resonance) for the detection of the water table or InSAR ground deformation data for large-scale monitoring of ground deformation and investigation of the potential relations with groundwater storage changes. Areas subject to frequent groundwater level decline beyond historical levels are prone to inelastic compaction, decreasing the aquifer porosity and more generally, its value as water source for future generations (Castellazzi and Schmid, 2021). It is expected that this data will provide a means of scaling up point scale groundwater information to increase understanding of groundwater trends at a regional scale.

2 Concluding remarks

We acknowledge the development of a long-term strategy for groundwater in New South Wales as part of the NSW Water Strategy. As expressed above, we can contribute to the efforts of NSW to implement improvements and knowledge gains, particularly in:

- Data acquisition and sharing, particularly for characterisation of aquifers and GDEs in cross-border studies
- Methods of improving water security, including managed aquifer recharge policy and pilot demonstrations, and exploration of alternative sources of water including deep or brackish groundwater
- Linking ecosystem response to the effects of groundwater lowering, changes in surface water systems and environmental watering
- Incorporating economics and social/behavioural modelling into groundwater management models
- Co-design, co-production and co-delivery of research with stakeholders and communities, and including Aboriginal knowledge and science into groundwater management planning.

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