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Assessing the potential impacts of well integrity failure on groundwater resources in Australia

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Abstract: Groundwater resources are crucial for supporting ecosystems and providing water for consumption, industry and agricultural activities. However, resource developments involving deep wellbores have the potential for enhancing inter-aquifer connectivity owing to wellbore failure after decommissioning (Mallants et al., 2018). The integrity of wellbores may become compromised through corrosion or separation of well steel and cement components, creating pathways for the migration of fluids between a deep resource (e.g. gas reservoir or for energy storage) and overlying aquifers (Huddlestone-Holmes et al., 2017). This can result in the degradation of groundwater quality and quantity. This study employed a multi-stage screening method to assess the likelihood and consequence of inter-aquifer leakage from compromised wells, including decommissioned coal seam gas (CSG) wells, deep water bores and legacy coal exploration drillholes. It involved a semi-quantitative risk prioritisation of potential pathways, an analytical model to assess the consequences of each pathway, and numerical groundwater modelling of single and multiple leaky wells. The study only considered the flow of water and used single-phase modelling as a conservative representation of the fluid-driven contamination process. The screening method for this assessment was applied to a proposed CSG development near Narrabri, Australia.

All three approaches indicated that high flow leaky gas wells (effective well conductivity, K_w $<10^{-1}$ m/d) are not likely to cause significant increases in inter-aquifer leakage or drawdown in upper aquifers based on conditions reported in previous studies and for the case study. However, extremely high flow leaky wells (K_w $>10^{2}$ m/d) could have an impact where aquitard conductivity is 10^{-4} m/d or less, or well failure density is higher than 1 well per km^2 (Doble et al., 2023). Nonetheless, compromised gas wells with K_w values >1 m/d have not been identified in previous studies. The most extreme case tested, i.e. open legacy coal exploration drillholes or petroleum bores repurposed into water bores across an aquitard, has the potential to deplete or contaminate groundwater resources in connected aquifers, depending on aquifer and production zone transmissivity. The residual risk of such contamination, however, is relatively small as multiple avoidance and mitigation strategies are imposed by the Australian regulation for petroleum exploration. Additional effort is needed to determine K_w and failure rates of gas wells, water bores and exploration drillholes in Australian conditions to better quantify the potential risks associated with leaking infrastructure.

The study highlighted the potential risks associated with gas resources on groundwater resources and provided insights into the likelihood and consequence of such risks. These findings are useful for informing regulatory decisions on the development and decommissioning of gas and other resources, including gas used in the production of blue or green hydrogen, carbon capture and storage or accessing deep water resources.

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