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Groundwater Balance Research to Improve the Accuracy of Drawdown Predictions in the Surat Basin, Queensland

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Abstract

Groundwater modelling studies rely on an accurate determination of inputs and outputs that make up the water balance. Often there is large uncertainty associated with estimates of recharge and unmetered groundwater use. This can translate to equivalent uncertainty in the forecasting of sustainable yields, impacts of extractive industries, and susceptibility of groundwater dependent ecosystems. In the case of coal seam gas (CSG), it is important to characterise the temporal and spatial distribution of depressurisation in the reservoir and to what degree and over what time-scale this may extend to the adjacent aquifers.

A regional groundwater flow model has been developed by the Queensland Government to predict drawdown impacts due to projected CSG activities in the Surat basin. This groundwater model is undergoing continued refinement and there is currently scope to address some of the key areas of uncertainty including better quantification of groundwater recharge and unmetered non-CSG groundwater abstractions. Research is currently underway to improve the accuracy of estimates of both of these components of the groundwater balance in order to reduce uncertainty in predicted groundwater drawdowns due to CSG activities, as discussed in the following.

Improved Recharge Estimation

This 3.5 year research project aims to improve our understanding of spatial and temporal distributions of groundwater recharge in the Surat basin. Work completed to date has brought together existing relevant data sets and knowledge, developed new recharge estimates particularly for the Surat basin, provided a short-list of possible experimental sites and conceptual models, and produced an outline of designs for potential field experiments at those sites. These outcomes have been guided by industry partners and external experts at a series of six project workshops and numerous separate meetings. Here, we briefly discuss some of the themes involved in this research.

A number of recharge estimation methods have been applied in the Surat basin prior to this study, e.g. groundwater hydrograph analyses, groundwater chloride mass balance, unsaturated zone chloride mass balance and soil water balance modelling. These previous recharge estimates included a range of spatial scales but were typically limited to long term averages with limited information about temporal variation.

Analysis and interpretation of available data provided here examines this gap and has resulted in new estimates of the spatial and temporal distribution of groundwater recharge in the Surat basin. Regional groundwater flow directions in different aquifers were plotted by fitting potentiometric surfaces to available borehole data. However due to various data limitations, the potentiometric surfaces are only broadly indicative of regional groundwater flow paths and require improvement. Higher quality and quantity of water level data is necessary with better characterisation of source aquifers and borehole location. The water table fluctuation method was applied to selected groundwater hydrographs producing new estimates of groundwater recharge. Calculated annual average recharge rates varied between 4 and 37 mm/year depending on location, but were restricted to a limited number of bores with sufficient data and where aquifers are unconfined, water tables are shallow, and pumping impacts are limited. If suitable locations are targeted for additional groundwater monitoring, this method could easily be used to extend recharge rate estimation further throughout the unconfined Main Range Volcanics and Walloon Coal Measures.

Analysis of surface water data was also used to quantify groundwater recharge. This is a powerful method because it only requires stream flow records; however, it has important assumptions, including the need to assume that recharge appears as stream base flow at the outlet of the surface catchment. Annual average recharge rates using this method varied between 0 and 3.2 mm/year. There are a number of potential ways forward for the surface water analyses including extending it to other parts of the Surat basin, examining recharge on larger time scales such as annual or seasonal, and applying alternative base flow separation and recession analysis methods.

Deep drainage estimation also forms a significant part of the research. The combined remote sensing and modelling product from CSIRO (the Australian Water Availability Project) gives regional deep drainage estimates at a 5 km grid resolution at monthly and annual timescales. The CSIRO data, supplemented with additional remote sensed soil moisture data, were used to investigate the spatial and temporal variability of recharge throughout the whole Surat and for separate geological units. For example, over the Walloon-Injune units, the annual average deep drainage rate ranged Recharge Estimation in the Surat basin between 2 and 34 mm/year; while across the Main Range Volcanics the rate varied between 1 and 105 mm/year. Averaging deep drainage over the whole of the Surat, the range changed from 3 to 64 mm/year when moving from a particularly dry to a particularly wet year. Although they provide the sought spatial and temporal resolutions, the CSIRO deep drainage estimates are based on national scale water balance generalisations, only partially use the available remote sensed data, and provide deep drainage rather than actual recharge rates. Hence, these data should not yet be assumed suitable for groundwater impacts assessment in the Surat basin, and further analysis and development is recommended.

Deep drainage within the Surat basin as a whole was found to exhibit a high degree of spatial variability, and areas of higher deep drainage are driven by a combination of higher precipitation and /or soil and landscape properties. The temporal distribution of deep drainage shows large variability around the long-term mean values. These results show the potential importance of including recharge as a time varying input (at least annually varying) to groundwater models.

The research also includes significant field experimentation to better understand recharge processes in the Surat basin. Three field sites have been identified through a series of workshops with industry and government partners and independent experts, and subsequent analysis of data availability. The three sites identified represent different hydrogeological settings within the Surat basin: one representing the Condamine Alluvium, one the Gubberamunda Sandstone, and one the Main Range Volcanics. It is hoped that these three field experiment site will allow researchers to: (i) identify of important recharge mechanisms, (ii) evaluate hypotheses included in conceptual recharge models, (iii) examine spatial and temporal variability in recharge, and (iv) merge field scale data with remote sensing-based estimates to reduce uncertainty in regional scale recharge estimates.

Improved Non-CSG Groundwater Abstraction Estimation

Abstraction of groundwater, primarily for stock and domestic (S&D) usage, occurs via thousands of bores in the Surat basin. Metering of the rate of abstraction from these bores is very rare outside the Condamine Alluvium, and hence there is significant uncertainty in both the amount and spatial distribution of non-CSG groundwater abstraction in these basins. This uncertainty may have significant effects in understanding the response of the regional groundwater system to abstraction, and hence in forecasting the potential impact of CSG operations (either by the use of groundwater / reservoir models developed by CSG operators, or by the use of the Queensland Government's regional groundwater flow model).

This 2.5 year research project aims to better estimate these unmetered abstractions, using both multivariate geostatistical methods and analytical methods to better quantify the amounts and spatial distribution of non-CSG abstraction of groundwater in the Surat and Bowen basins. While historical estimates of unmetered abstractions have been made, these have generally been anecdotal or based on expert opinion, and generally have not attempted to quantify the uncertainty inherent in the estimation process; in particular, the spatial properties of errors in abstraction estimates are usually neglected.

The current research thus aims to develop and apply robust, transparent, and repeatable methods for estimating these unmetered abstraction rates, and explicitly quantify the uncertainty inherent in such estimates. It may also be advantageous to use these estimation techniques to suggest cost effective methods for reducing uncertainty in abstraction rate estimates (e.g. by targeted field data collection). Finally, the research is being undertaken with a view to the possible future use of these estimates in evaluate the effects of uncertainty in abstraction rates on calibration and impact predictions of groundwater flow / reservoir models via numerical sensitivity analysis, and by extension improving our understanding of the regional water balance in the Surat basin. We briefly discuss here some of the issues associated with this research.

In Queensland, metering is not a regulatory requirement for S&D bores, and most small bores (less than 5 ML/year) are unmetered. Approximately 97% of active bores in the Surat basin are unmetered, and with S&D abstraction is thought to make anywhere between approximately 35 – 90% of total abstraction volumes for the Surat and Bowen basins (based on a rudimentary comparison of various studies), it is easy to suppose significant uncertainty exists in regional abstraction volumes. However, water allocations (entitlements) are also issued by the Queensland Government for many unmetered bores, which give legal authority to take a maximum annual volume (in principle determined via hydrological studies) from a specific aquifer or aquifer zone. The combination of these metered abstraction and entitlement volume datasets has been used to produce estimates of regional abstraction volumes in various studies. However, there are considerable variations (in the order of 50%) in the regional estimates from the various sources, both in overall usage as well as in S&D use.

Estimation of unmetered usage other than S&D for most studies is generally made by assuming complete use of entitlement volumes; this assumption is also employed in the Queensland Government regional groundwater flow model. As entitlement volumes are frequently updated (half yearly) to reflect prevailing conditions, this assumption is not entirely unreasonable.

The alternative approach used in the current research extends upon the estimation methods in these studies by employing multivariate spatial statistical methods, examining the correlation between 'actual' abstraction (generally metered, but potentially also based upon detailed local estimates in consultation with landholders), and other more extensive datasets which, in some combination, may be predictors for abstraction rate. These secondary datasets include issued usage entitlements, groundwater depth and quality, climate, stocking rates, demography, topography and others.

An initial feasibility study found that several multivariate spatial statistical techniques were appropriate for this application, including classical geostatistical techniques (such as kriging with external drift, co-kriging etc.), as well as more modern methods (such as generalised linear geostatistical models) which relax some of the assumptions (particularly around normality of the distribution of metered usage volumes) required by classical kriging methods. These statistical methods have inherent advantages in terms of quantifying uncertainty in abstraction rate predictions, such as being able to produce multiple equally likely spatially varying realisations of abstraction rates, which could be used for sensitivity analysis of a regional groundwater flow or reservoir model.

Forthcoming research will finalise the selection of appropriate statistical methods in conjunction with analytical models where appropriate, e.g. cross-referencing with bore casing and construction records to constrain abstraction rate predictions where appropriate. In addition, further feasibility studies are presently being conducted to establish the viability of further field data collection, whether by direct flow metering or landholder survey. By the conclusion of the research project in early 2016, a range of improved spatially referenced estimates of abstraction (and corresponding uncertainty) will be produced and made available to stakeholders in formats suitable for numerical groundwater flow or reservoir modelling applications.