Addressing quality & quantity

at catchment scale

Managed Aquifer Recharge is an approach to sustainable groundwater management that is now being used at catchment level in New Zealand. **Robert Bower** and **Brett Sinclair** of Golder Associates outline the pilot scheme now underway in the Hinds Catchment in Canterbury.

The Hinds/Hekeao (Hinds) catchment is located in the Ashburton District on the Canterbury Plains and falls within the management area of the Canterbury Regional Council (CRC). In 2009, CRC initiated the Canterbury Water Management Strategy (CWMS), which is based upon a collaborative and community-based approach to achieving aspirational water management objectives (Canterbury Water, 2009). As part of the CWMS, each of the region's 10 water management zones develops recommendations based on a community-based consultation process. Each zone is led by a Zone Committee consisting of community members appointed to represent the varied interests relative to the current and future management of the resources.

The Ashburton Zone Committee (AZC) been responsible for the development of the Hinds catchment recommendations. Development was guided by AZC's Zone Implementation Programme (ZIP), which prioritised a list of 25 *Desired Outcomes* for the Hinds catchment (Canterbury Water, 2011). This process follows the CWMS *preferred approach* in which water quality and quantity objectives are first determined and then the means by which these objectives can be achieved are identified. A majority of the Hinds *Desired Outcomes* are directly dependent on the condition of the Hinds groundwater system. Prioritising the sustainable management of the groundwater quality and quantity within the catchment is therefore critical to achieving these objectives (Bower, 2014).

Biophysical numerical modelling was done for the catchment's water quality and quantity in order to support the AZC in the consultation process. The water quality modelling was conducted via a mass-balance, spreadsheet-based accounting tool. This tool utilised nutrient inputs from the on-farm modelling conducted in Overseer™ to calculate the nitrate-nitrogen (nitrogen) loading related to various land uses (Scott, 2013). The water quantity modelling was achieved through an integrated MIKE SHE (DHI) surface-groundwater spatial model (Durney, 2014). Other relevant analyses used to support the consultation related to changes in local and regional economics, ecology of groundwater-dependent ecosystems, cultural aspirations and the social wellbeing of the Hinds community.

In 2014, after nearly two years of deliberations, the AZC presented final recommendations to CRC. These recommendations included the implementation of some catchment-scale changes including the use of Managed Aquifer Recharge.

WATER CHALLENGES IN THE HINDS CATCHMENT

The water resource challenges in this catchment are considerable, with the quantity and quality of groundwater being under significant pressure from increasing usage and contaminants derived from land use intensification. The Hinds catchment is bound by the Rangitata River to the south and the Ashburton River/Hakatere to the north (Figure 1). The Hinds/Hekeao River flows through the middle of the catchment. The movement of water in this catchment, and the associated transport of nutrients, is controlled primarily by surface recharge, saturated groundwater transport, river interactions and spring-fed waterways near the coast (Scott, 2013). Water entering the groundwater system (recharge) primarily comes from a combination of rainfall, river leakage, and losses from irrigation (Figure 2). Groundwater leaving the aquifer (discharge) primarily occurs in the form of evapotranspiration, groundwater outflow (to ocean), spring flow back to lowland water bodies and groundwater abstraction for irrigation.

Over the past couple of decades, significant increases in usage have occurred, leading to the issue of overall allocation. At the same time, *accidental* recharge has declined due to leaky races being piped and more efficient irrigation practices becoming common place. Ongoing drought conditions have also acted to reduce the natural recharge.

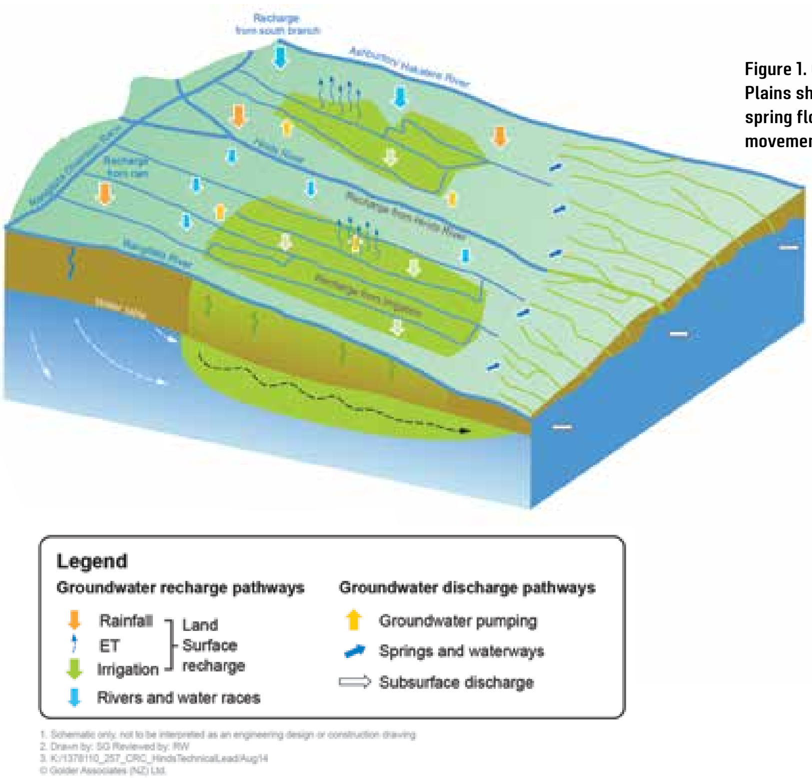

Figure 1. Conceptual block diagram of the groundwater system in the Hinds Plains showing water balance drivers; surface recharge, evapotranspiration, spring flows, groundwater movement and groundwater outflows, includes movement of nutrients into groundwater (Bower, 2014).

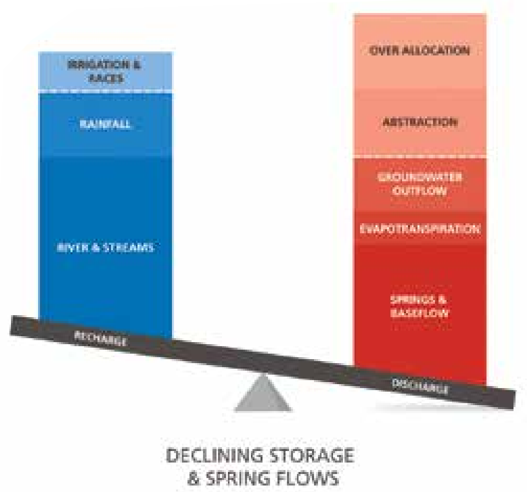

Figure 2. Balancing the drivers of groundwater storage

The combination of reduced recharge and increased abstraction has acted to reduce the overall groundwater stored in the system.

This reduction is expressed in drying of the spring-fed water bodies, loss of ecological habitat and traditional food gathering (kai), and water supplies bores needing to be deepened (Golder 2014). Correlating with these quantity changes, average nitrate-nitrogen (nitrogen) concentrations in the catchment have been steadily increasing in both the groundwater and dependent spring-fed waterbodies. These changes have been primarily driven by the intensification of land use in the agriculture sector combined with these losses in accidental recharge. Groundwater nitrogen concentrations in the catchment have exceeded the national drinking-water standard (11.3 mg/L NO_3-N) and are reported to be some of the highest in the country (Scott, 2013).

AZC's primary recommendations to address these catchment-scale issues were to reduce nitrogen entering groundwater via improved management of on-farm nutrients and implement the use of Managed Aquifer Recharge (MAR) to increase overall clean water recharge. Targets were set for both water quality (6.9 mg/L NO_3-N) and quantity, seeking to restore groundwater storage levels and spring flows by 2035.

Beyond the MAR project for quantity, the AZC also made recommendations to cap the catchment's groundwater allocations, allow the transfer of less reliable surface takes to groundwater, and limit the transfer of water usage consents. The implementation of a Pilot Project to test the application of MAR to help address these issues began shortly after the AZC final recommendations were accepted. Consents for construction and operation of the Pilot Project were secured in early 2016.

COMMUNITY'S EVALUATION OF MAR AS A WATER MANAGEMENT TOOL

The AZC appointed a local community group called the Hinds Drains Working Party (HDWP) (no 1) whose members consisted of local residents and farmers, zone committee members, representatives from Department of Conservation, Fish and Game, and Forest and Bird. Consultation in the form of hui with Te Runanga o Arowhenua, the local iwi representation, was also a key part of the process. One of the primary reasons for the formation of the HDWP was to have the community help to evaluate any risks and help guide the possible implementation of the MAR pilot site based on their local knowledge of the catchment. Their historical perspective on the extensive seasonal use of border-dyke irrigation (accidental recharge), which acted to maintain higher groundwater levels and consistent flows in the spring-fed water bodies, showed that the concept of 'artificial recharge' in the catchment was, in fact, known. However, due to the nature of this seasonal recharge, there were also concerns raised about the risk of un-managed recharge increasing the risk for potential flooding in lowland streams and farms.

During this consultation process, the HDWP helped to finalise the location of the Hinds MAR Pilot site. It was situated specifically as a 'test' of managed recharge to improve groundwater storage and water quality. This site is located in a part of the Hinds catchment that has the highest groundwater nitrogen concentrations and the most depleted stream-flow conditions.

A variety of other factors influenced this site selection including the availably of good quality source water, water delivery infrastructure, access to property for construction and favourable hydrogeologic conditions. These hydrogeological conditions included adequate freeboard (depth) to the water table and reasonably permeable soils to allow the infiltration to occur. Through a consensus decision process, including support from Te Runanga o Arowhenua, the HDWP's final recommendations were accepted by AZC (March 2016) to initiate the commissioning of the site.

PILOT PROJECT DEVELOPMENT

A consortium of groups came together to provide the local leadership, infrastructure, staffing and funding required to implement this project. The Hinds MAR Pilot Working Group was formed through a signed memorandum of understanding (MOU), with the primary members including CRC, Ashburton District Council, and the local irrigation companies: Rangitata Diversion Race Management, Valetta Irrigation, Mayfield-Hinds Irrigation, Eiffelton Community Irrigation Scheme and Barhill Chertsey Irrigation. A secondary group of technical experts was also established to provide input and review during the pilot testing. Members of this group include Canterbury District Health Board, Lincoln-Agritech Limited, New Zealand Forest and Bird and technical staff from CRC and Golder.

The pilot site (Figure 3) is consented to recharge up to 0.5 m^3/s of good quality, alpine-sourced Rangitata River water to ground. The pilot testing process covers a five-year period (2016 to 2021) with two distinct phases.

Phase 1 occurs during the first year (2016 to 2017) and addresses fundamental technical and community questions surrounding MAR (Golder, 2015). Phase 2 (2017 to 2021) proceeds only if the community is satisfied with the Phase 1 results and will focus on further developing an understanding of the physical issues associated with applying MAR specifically to the unique geology and water properties found on the Canterbury Plains (Golder, 2015). The Pilot Project's water quality and quantity monitoring network collects real-time data (15-minute intervals) for groundwater levels, temperatures and surface water flows, coupled with monthly water quality sampling and analysis for parameters including nutrients and faecal bacteria.

On 10 June 2016, recharge operations at the Pilot site commenced. Preliminary results (first 80 days) are already showing groundwater quality improvements around the MAR site and increases in groundwater levels of up to 18 metres being recorded. Based on current operational recharge rates, three to four million cubic metres could be recharged to the aquifer during Phase 1 of the project. This volume represents between three percent and four percent of the capped allocation limit in this groundwater management zone (96.6 million m^3).

[1]*http://ecan.govt.nz/get-involved/canterburywater/committees/ashburton/Pages/drains-party.aspx*

Figure 3. Aerial drone photo of Hinds MAR Pilot site during construction (Lagmhor, Ashburton area, May 2016).

Analysis and reporting of the Phase 1 testing results will be available in August 2017, after a community and independent peer review.

SEEKING GROUNDWATER SUSTAINABILITY THROUGH THE APPLICATION OF MAR

Internationally, thinking in resource science and policy (Jakeman Et. al, 2016) is moving towards a more conjunctive and integrated approach to water management, including groundwater. Viewed at the catchment-scale, we define the application of a systems approach to managing surface and groundwater resources together as integrated water management systems (IWMS). In order to help achieve water quality and quantity goals sought by the community, it is necessary to envisage the use of MAR at the catchment scale.

In the case of the Hinds catchment, this IWMS concept was numerically assessed during the consultation process and a conceptual plan for integrating MAR into existing water management systems was derived. Much like an irrigation scheme, the Hinds Plains Groundwater Replenishment Scheme (GRS) would work with existing and planned surface water infrastructure to capture and deliver water to recharge sites throughout the catchment (Figure 4). Recharge operations would likely be focused on the non-peak demand (irrigation)

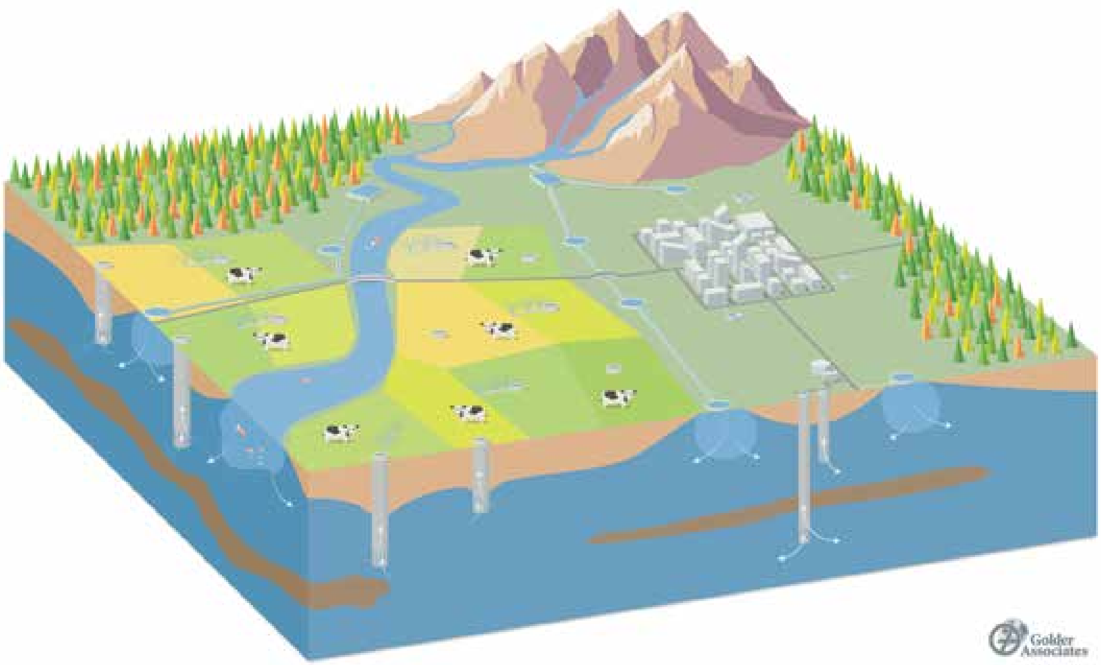

Figure 4. Conceptual illustration of a Groundwater Replenishment Scheme (GRS) using combination of small, off channel capture storage with distributed MAR sites to manage catchment's groundwater storage and water quality rural and municipal objectives. Aquifer's natural ability to spatially distribute water reduces need for costly surface conveyance systems as bores become the primary point of water delivery.

season and seek to replenish groundwater resources with good quality water. Sites would be placed according to specific physical conditions and be operated to maximise the amount of recharge at the appropriate times of year. Coupled with highly efficient irrigation practices and improved on-farm nutrient management practices, the GRS would work toward achieving the desired outcomes established by the AZC.

Governance of this GRS would be conducted in a coordinated approach, taking advantage of strategic partnerships, community goodwill and consensus fostered during the project development phase. A governance structure that recognises and is committed to ongoing stakeholder consultations will be determined by the AZC during phase 1 of the project. Complementing the existing water delivery infrastructure and existing monitoring networks, other potential factors of consideration will be consenting structures, funding mechanisms and ongoing community outreach and education. A catchment-wide, community-led GRS could make the most logistical and economic sense in developing MAR for sustainable groundwater management (Golder, 2016).

Fundamentally, the implementation of a GRS system would work to re-balance the recharge side of the currently declining groundwater storage balance, working first to recover the system to a *sustainable yield* (Figure 5). Most likely, a community defined *sustainable yield* scenario would be set to ensure that reliable groundwater resources for irrigation and drinking water supplies is maintained whilst providing more consistent and improved quality baseflows to the spring-fed water bodies. Once this scenario has been achieved, the possibility of utilising any additional natural aquifer capacity to further increase groundwater resources has also been shown internationally to be feasible (Golder 2016). This *additional yield* could help to protect both water users and ecological habitats from erratic weather patterns driven by climate change, such as prolonged droughts.

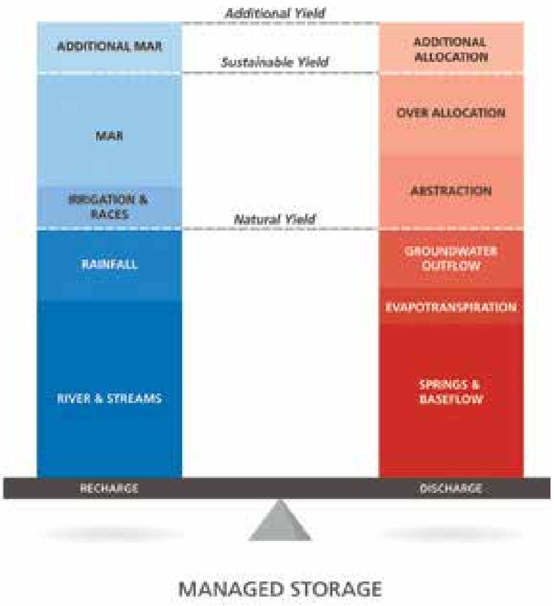

Figure 5. Challenges to managing groundwater storage – balancing catchment-scale recharge and discharges (Golder).

SUMMARY

The Hinds MAR Pilot project represents one community's approach to achieving more sustainable groundwater management, improving water storage, and protecting the environment and cultural values. This project provides an opportunity for New Zealand to re-examine how we not only view the management of groundwater, but how we manage our surface and groundwater supplies in more conjunctive and integrated ways. With the uncertainty of a changing climate driving periods of prolonged droughts and unsettled weather patterns, we suggest that a proactive managed approach to preparing for the future is achievable. We can use collaborative approaches to empower communities to take action and implement change through the establishment of common goals to achieve sustainable and reliable clean water supplies for both the economy and the natural environment. Avoiding a "tragedy of the commons" is in all our best interests. **WNZ**

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