

Groundwater extraction

Groundwater: an important resource

Groundwater is a valuable resource in the Basin. As discussed in the first report in this two part series, groundwater extraction has increased in recent years. In some parts of the Basin, groundwater stores are declining at alarming rates and this may jeopardise its future use locally.

Groundwater pumping can also threaten water security downstream. A number of studies highlight the potential impact on increasing groundwater use on stream flow and on Murray-Darling Basin Ministerial Council strategies such as the Cap on diversions and, indirectly, The Living Murray.



Figure 16. Windmills pumping groundwater in SA.

In connected groundwater-surface water systems, there is normally a time lag of years or decades between the start of groundwater extraction and the moment the full impact of that pumping is felt in the streams. This also means that even if all groundwater pumping were to cease immediately, there will be an ongoing impact in streams due to historical pumping. Management of this legacy of pumping will be a complex task (Figure 16). Furthermore, it is difficult to establish

what exactly constitutes a 'sustainable groundwater yield' (see box) ²⁴.

Defining sustainable yields

The water budget for a region or catchment is the balance between all inputs and outputs of water: water is exchanged with the atmosphere (rainfall and evaporation) and gained from or lost to adjacent areas as surface and groundwater flows. A natural water budget can be assumed to be approximately neutral over the long term, with equal inputs and outputs.

When the groundwater system is pumped, an extra output term is added to the water budget. The only way for the budget to become neutral again, is by increasing inputs (such as greater recharge from rivers) or reducing other outputs (such as discharge to the surface or streams, or groundwater outflows). This change is inevitable but may come about only slowly if the groundwater storage is large.

This means that the natural, pre-development water budget by itself is of limited value in determining the amount of groundwater that can be withdrawn on a sustainable basis ^{Error!} Bookmark not defined. Ignoring this fact will lead to unsustainable groundwater management.

Several studies have attempted to predict future groundwater extraction within the Basin. All studies assume that ultimately, the sustainable yield for the Basin will be the effective upper limit to extraction. The major difference is in how fast this limit will be achieved. One recent study used simple linear models based on long term average rates of increase²⁵, while another highlighted the increased extraction rate and assumed a more rapid increase²⁶. What

all studies have in common is that further groundwater will be extracted from the Basin's groundwater systems, and that this extraction will continue to erode surface water flows.

How is stream flow lost to groundwater pumping?

A geological formation that contains extractable and economic quantities of water is referred to as an aquifer. The aquifer is called unconfined if the watertable is within the aquifer, and water pumping will lower it. If the aquifer is capped by a low permeability layer (an aquitard) and the saturated water is under pressure, the aquifer is said to be confined. A well or bore drilled through the aquitard will allow the water to rise up to the water pressure or hydraulic head in the aquifer. Where a confined aquifer is capped by a leaky aquitard, a semi-confined aquifer will result.

As a groundwater body is pumped, the water level (or hydraulic head) around the pumping bore will be drawn down in the shape of a so-called pumping cone. Over time, this cone will expand and deepen at a rate that depends on the characteristics of the aquifer.

After a longer period of pumping a balance can be achieved in which the cone does not expand, but extractions are compensated by inflows of groundwater further away, or outside the aquifer altogether. The sources of this water can be surface water bodies such as rivers, groundwater that would otherwise discharge into the stream, or other saturated layers. There are several ways groundwater extraction can lead to reduced stream flows. Three common processes are described below.

Induced recharge

When the influence of a pumping bore, or area of pumping, is close enough to a river or stream, the hydraulic gradient between the area of pumping and the stream can be increased, or even reversed, such that water

flows from the stream to the aquifer. In both these cases, the volume of water moving to the aquifer from surface water is greater than when there is no pumping. This increase in the water flux is called induced recharge. This type of leakage from streams is effectively a form of groundwater recharge. Sometimes it is apparent as transmission losses: a volume of water that goes missing between two stream gauging stations. In other cases it is not identified at all. It can occur under natural conditions, but groundwater extraction can exacerbate it by increasing the difference in water pressure between the stream and the groundwater system.

In general, the time frame for the onset of induced recharge will be short, but the time to full impact depends on a range of factors including the volumes of water pumped and the volumes of water in the river, how much the hydraulic gradient is changed and the properties of the aquifer material. In some circumstances where the aquifer is pumped at high rates, the water level can be drawn below the river bed. In these cases, the aquifer-stream relationship becomes disconnected. Induced recharge will not occur in a stream-aquifer system that is already disconnected under natural conditions, as in that case leakage to the aquifer will already be at maximum.

Captured discharge

When pumping occurs further from the stream and the hydraulic gradients are not changed, the major impact will be that groundwater will be extracted that otherwise would have flowed into the river at a downstream point. Discharge capture can be felt in the river itself as diminished stream flow. It can also be manifested away from the river, for example as reduced water supply to groundwater dependent ecosystems in lakes or billabongs (Figure 17).



Figure 17. Groundwater pumping changes the balance of water exchange between the river and the groundwater system, and can also affect groundwater dependent water ecosystems.

Captured groundwater discharge will take longer than induced recharge to be felt. Again, much depends on the distance of the pumping from the stream, the water volumes pumped and water volumes in the river, the change in hydraulic gradient and aquifer properties. In some cases where pumping is close to the stream and the change in the hydraulic gradient is large, the impacts may be felt almost immediately (Figure 18).



Figure 18. A pumping station designed to intercept saline groundwater flowing into the river and provides an example of captured discharge.

Induced leakage

A more complex form of water loss can occur in semi-confined aquifers. Pumping the aquifer can cause water to leak out of the semi-confining layer above. This leakage is a one-off component of the water

budget, unless the leakage is matched by water being added at the top of the semi-confining layer, which may be from irrigation or from a river. If there is no addition to the semi-confining layer that compensates for the leakage, then this layer will dewater and this may cause land subsidence. The response of the aquifer to induced leakage from the semi-confining layer is usually indistinguishable from that of induced recharge. This can be a problem when trying to establish the sustainability of a developed water budget.

Impacts differ between regions

The major groundwater systems with linkages to surface water in the Basin differ in the way they behave, and in the processes by which they are recharged and discharge. This has important consequences for the impact of groundwater extraction on surface water resources.

Generally, the connected aquifer-stream systems occur in the south-eastern parts of the Basin, and disconnected systems occur in the north. Aquifers in South Australia are connected at the discharge end with the River Murray, but the timing of the onset of impacts is extremely long, and in fact the salinity of the Mallee Limestone system means that a reduction in discharge will provide a salinity benefit.

The regions at highest risk will be those where the current and potential future extraction of groundwater is high and where the aquifer and stream are strongly connected. This situation occurs in the alluvial valleys of New South Wales. A good example is the Mid-Murrumbidgee River valley.

Other areas where extraction rates are high at present, such as the Shepparton-Katunga and Lower Murrumbidgee regions, have a similarly high level of risk. However, the situation here is complicated by the presence of a semi-confining layer. In the Shepparton-Katunga region, high levels of extraction contribute to salinity mitigation.

What will happen to our water resources?

A number of studies have estimated the impact of groundwater pumping across the Basin on total surface water resources. One study estimated that increased groundwater extraction from aquifers that are connected to streams could range from a reduction of 275 GL to a worst case scenario of reduced annual stream flow of 550 GL in 20 years, with a likely estimate was 330 GL^{1,26}. A later study has estimated that 327 GL of annual stream flow is already lost because of groundwater pumping, and predicts a total reduction of 580 GL by 2012/13, that is, a further reduction of 253 GL²⁷.

Time lag between pumping and changes in stream flow

The timing of the impact of pumping on surface water is difficult to predict. A recent modelling study estimated the timing of the response of surface water systems to groundwater extraction²⁸. The results suggest that the onset of the initial impact on stream flow from groundwater extraction is rapid, but it takes several decades for the full impact to be realised. The major factor that determines response time is the volume of groundwater abstracted compared to the size of the groundwater system. The distance of pumping from the river is less important.

The lag between the onset and the ultimate stabilisation of impacts means that at any one time there is a legacy of impacts due to past development. This legacy of previous pumping slows the rate of stream flow change: large changes in short term pumping do not have a correspondingly large change on river impacts. Aquifer management plans need to take this slow response into account.

River health and water quality

Groundwater extraction can reduce stream flow quantity in the Basin's rivers. However, groundwater pumping can also change stream flow quality and river health in direct and indirect ways.

Groundwater is generally more saline than soil water or rainfall. Clearing of native vegetation and irrigation has led to raised water levels in many parts of the Basin, forcing saline groundwater out into the streams, where it has deleterious effects on river health. Groundwater pumping can in some cases reduce this discharge by reducing the height of the watertable.

Partially or wholly groundwater dependent ecosystems can be severely impacted by local watertable lowering. Others, like the Chowilla floodplains (Figure 19), are threatened by saline groundwater and here pumping again can have a favourable effect.



Figure 19. The Chowilla forests suffer from a long-term lack of flooding and salt accumulation.