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INCREASING GROUNDWATER SALINITY IN THE NORTHERN WHEATBELT

By R. J. McGowan, Hydrogeologist, Geological Survey

Every farmer in Western Australia's northern wheatbelt will know of a groundwater supply, be it bore, well or soak, that has become increasingly saline. The groundwater may have become more saline over a period of 15 years or more, or have been noticed only recently. Inevitably, the bore will lie within an area cleared for agriculture. This increase in groundwater salinity may be associated with soil salinisation.

Although researchers have some understanding of the processes causing salinisation of groundwater in the wheatbelt and the extent of the problem, little is known about the rates of salinisation and groundwater rise.

A preliminary survey by the Department of Agriculture showed that average bore water salinity in the northern wheatbelt had increased during an eight-year period. In 1983, the Geological Survey and the Department started a more detailed joint project to monitor changes in groundwater levels and salinities in the Winchester Catchment in the northern wheatbelt. The aim is to measure trends in groundwater salinity and to investigate the causes of salinity increases. These analyses could help to identify susceptible areas elsewhere.

This article discusses the causes of saline groundwater, the purpose of the Winchester Catchment study and some of the early results.

Salinity and water levels
Saline groundwater poses problems for domestic and stock water supplies, and increasing salinities may force farmers to abandon expensive and important groundwater supplies. More insidious though is the ultimate effect of increasing salinities on the soil and agriculture.

Increasing salinities are usually associated with rising water levels. When water levels rise to what is called the 'capillary fringe', two metres or less below the soil surface, direct evaporation acting on the watertable may cause salt from the groundwater to be deposited in the topsoil. This results in degradation of the soil structure and prevents growth of all but highly salt-tolerant plants.

Origin of groundwater salts
Dissolved solids, usually salts, are present in all groundwater. In wheatbelt groundwaters they are mainly sodium chloride and calcium sulphate. These salts enter groundwater in rainfall which, directly or indirectly, is the only source of recharge.

Rain may contain up to 150 milligrams per litre total dissolved solids (T.D.S.) which originate from sea spray or in inland areas from dust particles. In the Western Australian wheatbelt, however, average salt concentrations are between 5 and 15 mg/L T.D.S. The salinity of the rainfall represents the minimum salinity that may be expected in the groundwater of an area. A small percentage of rain may become groundwater as recharge, but in between reaching the ground and infiltrating to the watertable there are many processes tending to concentrate and add salt to the water.

Ninety per cent or more of rainwater volume may be removed by evaporation and use by plants, leaving behind the salts and thus producing a ten-fold increase in the dissolved solids concentration of the remaining water. Where this water moves through the soil, plant roots may extract the fresh water and leave the dissolved salts behind. If this takes place within the capillary fringe the salts may crystallise and remain in the soil matrix.
The situation becomes more complex as further infiltrating water may tend to dissolve salts stored in the soil and carry these to the watertable. Deep-rooted plants, usually trees, often draw water from well below the watertable and similarly tend to concentrate salts.

Variation in groundwater salinity

Wheatbelt groundwater shows an extreme range in salinity caused by the processes described and one other very significant process.

Groundwater salinities tend to be higher in lower-lying areas and this can cause problems in locating bores. Where the water salinity is low, the prospects for obtaining a significant water yield are often poor due to a lack of thick groundwater-bearing zones in the upslope areas.

In the slope, soil and strata conditions typical of the wheatbelt, groundwater tends to move in the direction of downward surface slope. Recharge may be occurring over most of the area under which the groundwater is present and moving. This recharge dissolves the stored salt that is more concentrated in the lower slope areas. Groundwater also tends to accumulate salt from the strata through which it flows, and hence groundwater salinity increases during the course of its movement. The depth to water also tends to decrease due to the increasing volume of water passing through the limited soil and strata profile.

In lower-lying areas, groundwater may be less than two metres below the soil surface and be subject to direct evaporation. When this happens, water is drawn up through the soil matrix by capillary action. As the water evaporates, salt is concentrated, the groundwater becomes very saline and, frequently, salt-scalding and even salt crusting can develop.

The concentration of sodium salts causes a breakdown of the soil structure by inducing defloculation (instability) in the soil crumbs or aggregates. Such processes can cause the development of clay-pans or salt-pans.

Agriculture and the groundwater balance

The introduction of agriculture into the wheatbelt, especially the lower rainfall and more fragile northern wheatbelt, has significantly disturbed the balance or equilibrium in the groundwater system. The groundwater salinising processes described may have operated before agricultural development, but they have been greatly accelerated by the widespread clearing of native vegetation.

Trees and other vegetation that use large quantities of soil water and groundwater have been removed and replaced by wheat and other shallow-rooting, low water usage crops.

The northern wheatbelt usually has internal drainage basins where catchments drain to a focal salt-lake or clay-pan area where groundwater may only be discharged via evaporation or evapo-transpiration. There is no major groundwater discharge via flow into...
By drilling and constructing monitoring bores in carefully chosen locations and obtaining detailed information on the local soil and strata, we are now better able to say how quickly and why groundwater levels and salinities may be increasing.

**Typical piezometer construction within a sediment and weathered zone profile**

![Diagram of piezometer construction](image)

**Winchester Catchment Study**

It would be ideal to have groundwater data over the whole of the northern wheatbelt, or even the whole wheatbelt. An early suggestion in the current investigations was the identification of a large number of existing bores, in an approximate grid configuration over the northern wheatbelt, that could be used for monitoring. This method would have been relatively cheap, involving say monthly recording of bore water levels and salinities. However, the data obtained would not have been satisfactory for the following reasons:

- Pumping of the bore or nearby bores would disturb the local groundwater flow and balance.
- The nature of the construction of the bore being used was usually uncertain or unsuitable for monitoring.
- Detailed records are seldom available of the soil and strata penetrated by on-farm bores.
- Information on the variation of water salinities and possible differences in water pressures with depth was required. This could not be obtained from one conventional bore in a given location.

It was decided to select a wheatbelt catchment that showed a variety of conditions in terms of previous and existing agriculture, soils, geology and existing groundwater and soil salinity. The catchment approach allows study of a discrete area without considering groundwater or surface-water inputs from other areas.

The Winchester Catchment, 10 kilometres south of Carnamah, is relatively restricted and well defined in wheatbelt terms but still covers an area of about 43,000 hectares.

The first phase of drilling started in mid-1983. 'Nests' of piezometers were installed at 18 sites within the northern half of the catchment. A piezometer is a small diameter bore designed for monitoring water levels and for sampling groundwater. Drilling was concentrated into sub-catchments in part of the whole catchment to give a suitable bore density and co-ordinated data from the initial work.

The 'nests' of piezometers usually involve two or three bores at one site that are designed to sample the water from different depths within the sediment and weathered bedrock profiles. The piezometer construction is shown in the diagram. The design makes it possible, for instance, to determine whether salinisation of groundwater is initially occurring close to the watertable and having a gradual or rapid effect on the whole of the saturated profile.

**Monitoring and early results**

The piezometers have been monitored monthly for water levels and sampled quarterly for salinity. Results so far have shown predictable responses to rainfall in most piezometers, with annual water level fluctuations of between 0.4 and 1.0 metre. The water level rises from rainfall recharge and appears to be rapid after periods of heavy rain, with a subsequent gradual decline.

With only one full year's data available however, it would be wrong to interpret the hydrographs (graphs of water level fluctuations), and changes in salinity over time, in detail.

- Vertical variations in groundwater salinity are very pronounced at many sites and very significant.
- In areas of sandy surface soils, the shallow, 'watertable', piezometers tend to show lower salinities than the deeper piezometers, while in areas of red clay soils, the reverse may be true or there is little vertical contrast. This may be explained in terms of more rapid salt and groundwater 'flushing' in the more permeable sands. The areas of red clay which occur in lower slopes or valley floors are generally underlain by kaolin clay and grit of a weathered granite profile, together called the pallid zone. Here, the 'watertable' piezometer may show a groundwater salinity of, for instance, 20,000 mg/L T.D.S. and the deep piezometer at the base of the weathered profiles, 3000 mg/L T.D.S.

Again, different groundwater flow rates may be a partial explanation, but salinisation may be occurring at the watertable and the effects have not yet been transmitted through the profile. Hydrographs from shallow and deeper piezometers usually show similar responses but this does not necessarily mean that the whole profile is in good hydraulic connection, or that there is free exchange of shallow and deep groundwater within the whole soil profile. Only continued data collection and assessment will allow the degree of interpretation of conditions and trends that the project set out to achieve.

The Geological Survey with assistance from the Department of Agriculture will continue monitoring groundwater salinity in the Winchester Catchment. The data will be periodically reviewed so that the significance of water level and salinity responses and trends may be determined.

If necessary, more drilling and piezometer construction as well as other testing will be carried out at the Winchester Catchment. This will help remove some of the many 'grey areas' that exist in the complex field of wheatbelt salinity studies.