Government of **Western Australia**
Department of **Water**

Introduction to acidic saline groundwater in the WA Wheatbelt —

characteristics, distribution, risks and management

Background

Extensive areas of the valley floors in the Western Australian Wheatbelt are already affected by shallow saline groundwaters and these areas are likely to grow for decades as groundwater levels are still rising. The use of engineering methods such as deep (2–3 m) drains and pumping to control shallow groundwater is increasing. More than 5000 km of deep drains are estimated to have been constructed to protect low-lying land from salinisation and to help rehabilitate marginally saline lands.

Many drains discharge into already saline sites, principally playas and floodways in the main palaeodrainage systems, although some discharge to purpose-built containment areas such as evaporation basins. There is increasing interest in expanding the salt-affected areas managed by deep drainage, and using a series of interconnected conveyance channels and lakes to manage the salt loads and water volumes discharged by drains. In parallel, there is increasing interest in using groundwater pumping to protect high value land or infrastructure such as buildings and roads.

Until recently, concerns about the risks of rising groundwaters were mainly on the increased quantities of salt brought to the soil surface by discharge and on salt loads and water volumes in waterways and lakes. It is now clear that much shallow saline groundwater may also be acidic, often with high concentrations of dissolved trace metals.

This information sheet is an introduction to the acidic saline groundwaters of the Wheatbelt: where they occur, the origins of their acidity, aspects and methods to manage or treat these.

What are acidic saline groundwaters?

Groundwaters in some parts of the WA Wheatbelt are very saline (saltier than seawater), very acidic with pH commonly between 3–4 (like weak vinegar), and, more critically, contain high concentrations of dissolved aluminium, iron and trace metals like lead, nickel, copper and zinc (see Shand & Degens 2008).
The trace metals have mostly been leached from local geological materials by the acidic waters.

While acidity is commonly measured as pH, this is only part of the story when considering acidic groundwaters. Acidity is chemically described as the quantity of alkaline materials (e.g. caustic soda or limesand) that a solution will consume before reaching a neutral state. When acidic waters are neutralised by alkaline materials, dissolved metals like iron and aluminium consume large quantities while pH, (a measure of hydrogen ion concentration), consumes comparatively small quantities. In effect, the dissolved iron and aluminium represent a major 'store' of 'hidden' acidity not measured by pH alone.

Where do acidic groundwaters occur?

Sampling from bores, seeps and deep drains indicates that acidic (grouped as pH<5.5) saline groundwaters occur in all parts of the Wheatbelt but are more common and shallowest in the broad valley floors, and more often in the eastern (mainly Avon) and south-eastern (Esperance coastal) zones (see Fig. 1).

More than 50 per cent of groundwater observation sites in the Avon basin and about 46 per cent in the Esperance Coastal basin are acidic. In these basins, wide areas of the broad valleys are expected to have acidic groundwaters interspersed with pockets of alkaline groundwaters. There is an east-west pattern with acidic waters most likely to be found east of the Meckering Line (see Fig. 1). Towards higher rainfall zones, west of the Meckering Line, fewer observation sites have acidic groundwater and the aquifers with acidic groundwater are more likely to be localised (see Lillicrap & George 2008). There is also a north-south pattern with a lower incidence of acidic groundwater sites in the northern Wheatbelt, particularly north of a line from Carnamah to Perenjori which broadly corresponds with the western end of the Menzies Line.

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What is the origin of these acidic groundwaters?

The groundwaters in the eastern Wheatbelt were known to be acidic before active management of groundwater, like tree planting, drainage and pumping, and were probably acidic before the landscape was cleared. In some Wheatbelt valleys, the groundwater has pH = 3.5 from the watertable to bedrock (often >20 m).

The low pH is mainly due to oxygen in infiltrating waters reacting with high concentrations of dissolved iron. In aquifers with no neutralising minerals like carbonates this results in pH remaining low. However, where neutralising minerals occur these often react to dampen the effect on pH. The iron from the reaction with oxygen can sometimes be observed to precipitate as iron oxides (Fig. 2).

Despite the low pH, most acidic groundwaters still contain high concentrations of dissolved iron and so have the potential to become even more acidic (i.e. lower pH even more) on exposure to the air if they seep into lakes and creek-lines or are drained or pumped to the surface.

The origins of these high iron concentrations are not clear. Iron oxides in soils and deep within aquifers can be dissolved by microbial attack when waters are depleted of oxygen (especially under waterlogged conditions). However, this also results in the production of alkalinity (often as dissolved bicarbonate) that would offset any acidity if the waters came in contact with air and the iron reacted to re-form the iron oxides.

Figure 2 Iron oxide minerals cover a sandy creek bed as iron rich water from a groundwater drain reacts with oxygen in the air

Recently, a new explanation has been proposed. Iron-rich waters may form in the topsoil horizons of landscapes during conditions such as waterlogging and

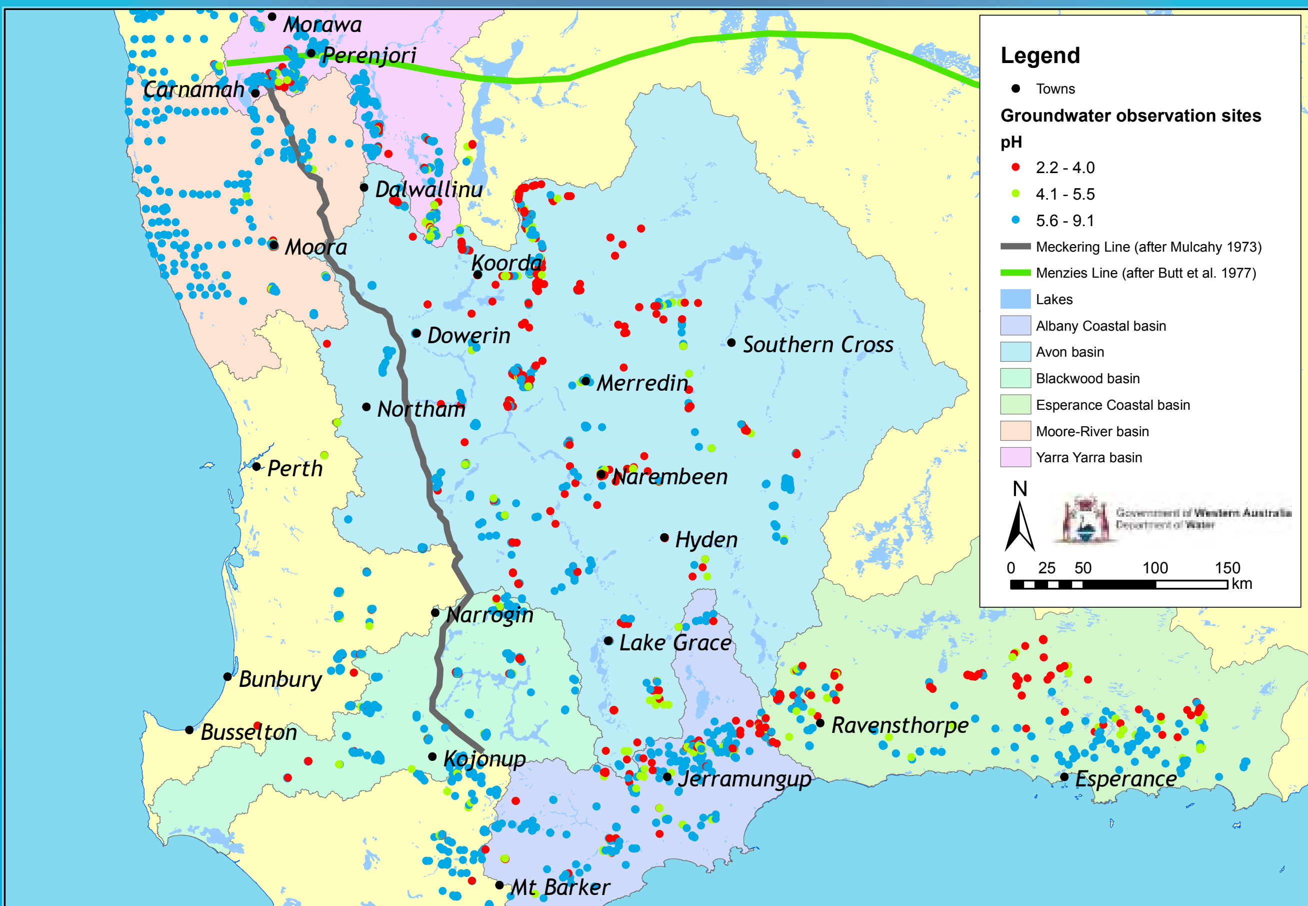

Figure 1 pH of groundwater in bores and seepage sites (lakes and drains) in the Wheatbelt

Figure 3 A lake near Dalwallinu with lake-bed soils acidified by localised acidic groundwater discharge

then percolate to the groundwater with the alkalinity left behind as carbonate minerals (i.e. nodules of calcium carbonate or limestone) in the soils. This process is greatly aided by trees and shrubs growing in these soils and is thought to have occurred over tens of thousands of years. How this occurs is the subject of ongoing research, but may explain observations that alkaline (calcareous or carbonate-rich) soils often overlie areas with low pH groundwater (Lillicrap & George 2008).

Characteristics of acidic water relevant for management (risks)

The main risks of acidic groundwaters are defined by the hazards to aquatic environments and the pathways by which they are expressed. Hazards are in two groups: acidity (1) and mobilisation of trace elements (2). The risk depends on how much groundwater reaches the surface environments by the pathways of groundwater rise (3) and/or drain and pump discharge (4).

(1) Acidity hazards

These hazards include the capacity of the waters to acidify lakes, creeks and floodplains and to decrease aquatic life in these saline systems. This risk also applies to soils and sediments.

(2) Trace element mobility hazards

These hazards include the transport and accumulation of trace elements such as lead, cadmium, uranium, arsenic and selenium in surface environments. This carries longer-term risks of accumulation in lakes and waterways, producing toxic effects on aquatic life and possible longer-term bioaccumulation through aquatic food chains.

(3) Groundwater rise risk pathways

Some lakes and waterways in the Wheatbelt already appear to have become acidic due to groundwater rise following the clearing of native vegetation, particularly in the upper reaches of catchments in the Avon basin (Fig. 3). Without interventions on the landscapes to control discharge, these are expected to continue to acidify and accumulate trace metals at a rate determined by groundwater seepage to the sites but countered by the rate of neutralisation by floodwaters.

The ongoing discharge risks acidifying currently alkaline surface soils, waterways and lakes. Though areas at greatest risk have not yet been identified, lakes low in the landscape and on the margins of valleys are likely to be at very high risk over the coming decades. Some are already showing signs of acidification, particularly in the eastern Wheatbelt.

(4) Drain and pump discharge risk pathways

Pumping groundwater and constructing drains increases the surface expression of, and accelerates the mobility of, acidity and trace metals in saline landscapes (Fig. 4). Unplanned and unmanaged disposal of acidic groundwaters to lakes, creeks and floodplains will increase the rate and possibly the extent of damage beyond what has already occurred. Good planning and management should prevent or at least mitigate the damage.

Figure 4 Deep drains, to protect land from salinity, mobilise and redistribute acidity

Figure 5 A lake near Wyalkatchem with waters and sediments acidified by acidic drainage waters

Whether lakes acidified by drainage will stay acidified over the long term depends on the amount of organic matter and neutralising minerals like carbonates in the lake sediments. Organic matter can feed microbial activities that will drive self-remediation.

Management of acidic groundwaters

The management of acidic groundwaters is evolving and currently focuses on managing discharge from deep drains and finding cost-effective practical solutions using local materials and local management.

Existing options for managing acidic waters in drains include:

- **Retain acidity and metals in drains**
  Minerals that retain acidity and trace metals can form in drains. Design drains to minimise flushing of these materials; in particular, by controlling the runoff of water from the surrounding catchment. Place mud and silts removed from drains during cleaning so that they do not wash downstream or back into drains when it rains.

- **Contain and manage waters**
  Acidic waters can be stored and/or evaporated in constructed or natural basins. Treat acidity and trace metals during evaporation or after the site is decommissioned. If using natural basins, consider whether the site is suitable for long-term storage of acidity and trace metals and whether there is a risk of overflow.

- **Treat waters to neutralise acidity and remove trace metals**
  Currently available and cost-effective methods include using neutralising materials (limesand and hydrated lime) and anaerobic microbial treatment in composting wetlands (this will be covered in a future information brochure on treatment of acidic groundwaters).

- **Dispose/discharge into natural disposal sites with remediation capacity**
  Acidic waters might be disposed into lakes with low ecological value where acidity and trace metals are retained and slowly treated with carbonate minerals and microbial processes that occur in lake bed soils. The neutralising capacity of floodwaters may also help.

Further work is underway to understand the extent and impacts of acidic groundwater discharge on valley floor landscapes and to identify options for managing acidic discharge at regional scales.

For further reading on acidic groundwater characteristics and risks
Shand, P & Degens B 2008, Avon catchment acid ground-water: geochemical risk assessment, CRC-LEME Open File Report 191, CSIRO Exploration and Mining, Bentley, WA.

For further information on acid groundwater distribution
Lillicrap, AM & George, R 2008, The distribution and origins of acid groundwaters in the Southwest Agricultural Area, Natural Resource Management Technical Report, Department of Agriculture and Food Western Australia (in press).

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