

## Dryland salinity associated with primary groundwater discharge zones in south west Victoria

**Jon Fawcett<sup>1,2</sup>, Rob Norton<sup>1</sup>, Peter Dahlhaus<sup>3</sup>, Rob Fitzpatrick<sup>4</sup>, Bill Gardner<sup>5</sup>**

<sup>1</sup>The School of Agriculture and Food Systems, The University of Melbourne. Horsham Victoria

<sup>2</sup>Future Farming Systems Research Victoria, Bendigo, Victoria

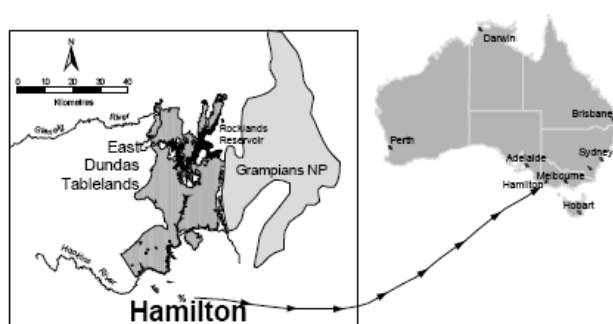
<sup>3</sup>University of Ballarat, Ballarat Victoria

<sup>4</sup>CSIRO Land and Water, Glen Osmond, SA

<sup>5</sup>RMB 7399 Horsham, Australia

### Introduction

Dryland salinity and its associated land and water degradation affects an estimated 13,298 hectares of the Glenelg Hopkins Catchment in southern Victoria, Australia (Figure 1). Rising groundwater levels and discharge of saline groundwater caused by an increase in recharge since European land clearing has been the favoured explanation for this occurrence of salinity. Research (Fawcett 2004) into the salinity of the Eastern Dundas Tablelands (EDT, Figure 1) developed an alternative model for the cause of dryland salinity.



**Figure 1. Location of eastern Dundas Tablelands**

### Method

Detailed groundwater, soil and chemical measurement occurred at the Merrifield's research site, located 45km north of Hamilton, with regional parameters regarding groundwater and saline discharge distribution occurring across the entire EDT.

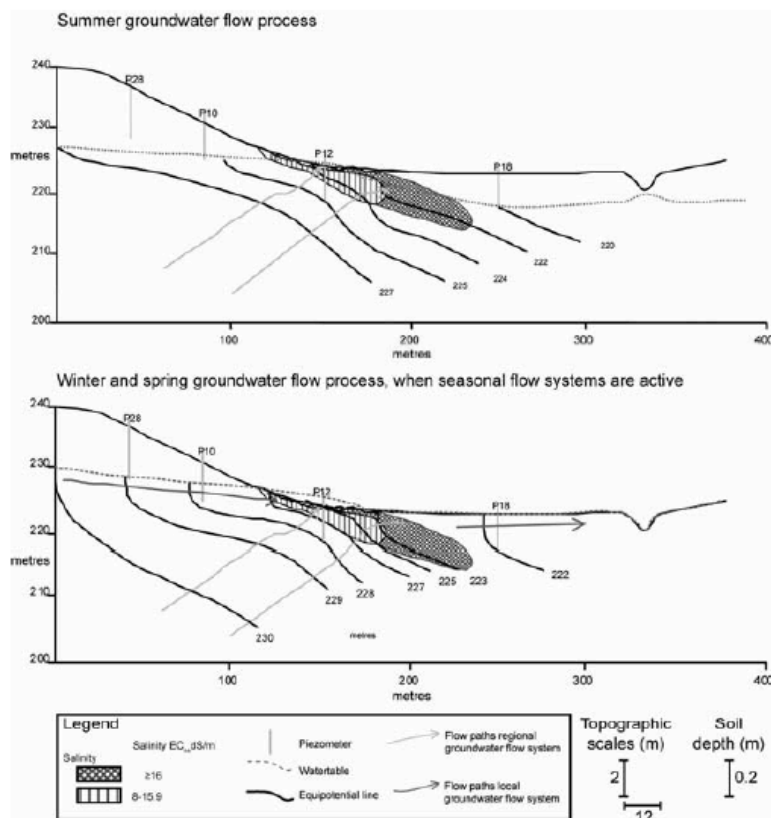
Groundwater levels and pressures were monitored in 128 piezometers across the EDT over the period from 1980 to 2004. A seismic survey was used to identify any sub surface structures that exist below discharge zones. The location of springs was determined by field mapping and conducting a land holder survey. Hydraulic conductivity of shallow piezometers was determined by field assessment using Hvorslev's equation. Analysis of the chemical properties was undertaken on 42 water samples in 1998, with 15 samples sourced from spring discharge, 13 from bores (0.5 to 15 metres deep) in the regolith directly within and around discharge zones at the Merrifields research site, and 15 from bores (15 to 149 metres deep) within the unweathered fractured rock. Carbon dating of groundwaters was performed at nested piezometers (149 m and 27 deep) representing recharge zones, and also at 6 m deep piezometer located directly in a discharge zone. In order to describe the soil-water environment in which the degradation takes place, nine landscape toposequences along three transects that run through three degraded discharge zones were created. The toposequence models display and interpret various soil characteristics: soil macromorphological features, soil EC and sodicity; and soil pH. Water discharge from saline scalds at the Merrifield's research site was monitored via a series of U shaped drains that surrounded scalds and a series of piezometers. The surface EC, pH and redox of the discharge waters was measured on three occasions, June 1997, July 1997, and June 1998. Measurements were made downslope from a permanently flowing discharge across areas of iron scalding, downslope from the same discharge zone along an area that remained saturated all year round.

## Results

The groundwater flow system of the EDT is an example of the gravity-driven groundwater flow system within a regionally unconfined aquifer (Fawcett 2004). The groundwater system is described as a series of nested flow systems increasing in flow length with depth. The general chemistry of groundwaters of the EDT describes a groundwater system that has undergone similar wall rock alteration processes within different depths and locations. The lack of any significant difference in the composition of the groundwaters can, in part, be explained by a mixing of waters from different depths along the flow paths (Fawcett 2004). Within discharge zones, groundwater depths of circulation can vary by 80 metres within a year. The carbon age of spring water indicates some discharge water has been in the groundwater flow system for at least 2540 years (Fawcett 2004). Within in any discharge zone water can be sourced from both the regolith and regional flow systems.

Soil toposequences and groundwater monitoring at the Merrifields site detail how severe degradation occurs where regional and seasonally active flow systems discharge concurrently.

Discharge from the regional system is in part controlled by sub surface structures, in such a way that discharge can occur mid slope, with no discharge directly down within the adjacent valley where seasonal high water tables are present. Therefore, the presence of shallow water tables does not always equate to land degradation. The presence of the highest soil salinity directly within permanently flowing discharge zones (Figure 2) suggests that the source of salts will dominantly be the regional groundwater system. The local and seasonal flow systems act to spread soil-salting downslope, creating a tear drop lense of high salinities (Figure 2).



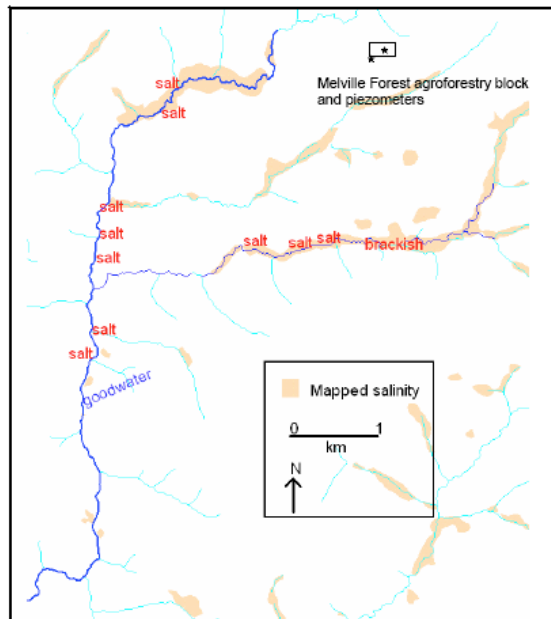
**Figure 2** Groundwater flow processes within a degraded spring on the EDT. Salts that accumulate within the discharge zone of the regional system are spread downslope by the seasonal active flow system.

The pH of shallow groundwater within a discharge zone varied from 4.6 to 5.9, which is the general pH range of groundwaters across the EDT. In general discharge waters were more acidic than the groundwater, ranging from very acidic, pH<3.2 to pH 6.2. The highest salt concentrations and the most acidic discharge were measured from diffuse discharge zones

where water flowed at a rate insufficient to maintain surface saturation. In contrast, where water was able to discharge from a pond, or directly from a drill hole and flow freely downslope away from the scalded region, iron scalding did not occur, salinities were lower and waters less acidic. The low pH measurements occurred within a sandy loam soil with high sodicity (>6 % ESP). The pH and Eh data from discharge waters were plotted onto stability diagrams for ferrous and ferric minerals (Fawcett 2004). Along permanently wet regions, the surface environment occurred mainly within the stability field of ferric oxides (e.g. ferrihydrite); this is consistent with observations of the presence of ferrihydrite in SEM images. However, several measurements of the permanently wet area plot were within the stability field of ferric sulfate and ferrous sulfate. It is therefore apparent that the Eh and pH conditions of the discharge zone do support the production of sulfate rich iron minerals. The pH drop measured in surface drains (over 1 pH unit), must be a consequence of the oxidation of the iron sulfide materials. The ranges of pH and redox measured indicate non tidal saline-sulfidic seeps exist within discharge zones of the EDT. It also appears the break down of soil structure and subsequent erosion within the discharge sites can be attributed to the development of sulfidic materials with no or very little soil structure, high salinities, the formation of salt efflorescence, and the production of high acidity.

There exists significant evidence to suggest groundwater discharge occurred prior to European land clearing, and that the degradation observed is a results of the disturbance of the discharge zone, not by an increase in groundwater discharge zone. Groundwater levels in drainage lines remains shallow and artesian across the EDT, in contrast to other saline affected catchments of similar rainfall where groundwater levels have fallen several metres since the mid-1990's across Victoria. The structure control on the location of discharge zones, soil features indicative of long term saturation and carbon age of discharge waters all suggest the discharge zone are a part of the natural landscape of the EDT. Successful remediation of drainage lines has occurred while groundwater springs still discharge and artesian groundwater pressures exist (Fawcett 2004) indicating the presence of shallow water tables and groundwater discharge does not prevent remediation of degraded discharge zones.

There exists palaeogeomorphological studies for western Victoria (Bowler 1977; Wasson and Donnelly 1991) that illustrate variations in rainfall rates, evaporation and groundwater levels, and thus a non steady state relationship between recharge and discharge rates has occurred over the last thousands of years. Dahlhaus et al (2000) detailed a series of accounts describing a landscape where the saline discharge in of waterways was a primary feature. The most significant observation is found in early cartographic surveys of the Koiroite Riverlet (Figure 3), of the Wannon River system (EDT). Prior to the area being cleared for agricultural purposes, the area was surveyed and the resultant map indicates the quality of the water in the streams and springs as ranging from salty to brackish to good water. The map suggests that the water quality improves downstream (towards the bottom) from salty to fresh, which, if true, is the reverse of what might normally be expected. This section of the Koiroite Riverlet was included in statewide salinity mapping in the late 1990s. The comparison of water quality and areas of mapped dryland salinity along the same sections of the Koiroite Riverlet is also shown in Figure 3. Nearly all the current, mapped saline discharge sites were labeled 'salt' or 'brackish' in the 1843 survey. Suggesting saline discharge existed prior to European land clearance.



**Figure 3** The extent of current dryland salinity (Orange area) compared with stream quality determined by taste in the 1843 Koiroite Riverlet survey (text).

## Conclusions

This paper argues there is sufficient data to support variations to the accepted models of the cause of dryland salinity. The main outcome of land clearing has been that many natural discharge zones became exposed and impacted by agriculture. After land clearing, salts that accumulate within the discharge zone along with chemical changes due to the interaction of hydrogen sulfide in groundwater led to the formation of inland acid sulfate soils. The altered and exposed sodic soils were then subjected to erosion due to the increased activity of the local groundwater flow systems. The degradation occurs without any measurable change to the regional groundwater system. The driving cause of the land degradation is the exposure of the discharge zone. This in turn has significant implications for remediation strategies and more importantly, risk assessments. Remediation and management strategies on the EDT must take into account literature regarding the remediation of soils affected by acid sulphate condition that recommend water tables are kept above sub-surface sulfide layers (Indraratna et al 2005 and Rosicky et al 2006). Using depth to water table as a tool to determine risk and assess the effectiveness of remediation strategies is not always appropriate. Successful remediation of degraded discharge zones has been achieved by managing vegetation and stock access onto those areas. These areas still have shallow water tables and artesian groundwater pressures; representative of the pre-clearing state. A more conventional approach would have attempted to apply recharge management methods and would still view the area 'at risk' of becoming salinised.

## References

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