Towards development of a risk management tool for roads affected by dryland salinity.

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SUMMARY

There is a popular assumption that damage to roads due to high soil salinity is one of the greatest economic effects of dryland salinity. There is little scientific evidence to back up these claims. The effect of salt on road materials is not documented or understood. This study started as an attempt to develop a risk management tool for roads in saline areas using geophysical techniques. EM38 and EM31 surveys were carried out effectively and safely on major and minor rural roads. They relate to changes in salt content in the road basecourse and underlying subgrade. The lack of scientific understanding of the effects of salt on road material has resulted in a focus on understanding how the road is affected. Mineralogical and geochemical changes are indicated that may result in volumetric and strength changes to the road pavement but more work is needed.

Key words: Roads, Salinity, EM, Risk management, Geochmistry.

INTRODUCTION

There are currently around two million hectares of salt affected land in Western Australia and significantly larger areas with existing high watertables are considered at risk of salinisation sometime in the future.

A search of unrefereed websites shows salinity damage to roads estimates at between $10 and $100 million in year the late 1990s, increasing to up to $380 million by the year 2050. The wide disparity in figures is indicative of the lack of knowledge of effects and extent of salinity.

Problems with the road pavements attributed to shallow saline water tables, have been recognised in salt-affected catchments across the south of Australia for some time. Road pavements often deteriorate soon after roadside vegetation is affected by salinity. The assumption is usually made that the salt attacks the road base but the mechanisms for this road damage and its relationship to soil salinity, acidity and sodicity are poorly understood. This lack of scientific underst6anding means that at present, it is not possible to carry out effective risk management for roads in saline areas nor is it possible to verify the long term extra expenditure on roads due to effects of salinity.

Inspection of roads in rural Western Australia showed evidence of road pavement damage consistent with that seen elsewhere (Street and Petrusma, 2004). Bubbles in the road seal can be seen on little used country roads often with evidence of salt crystals on surrounding pavement. Rutting, shoving and other effects were seen and measurement of conductivity using EM meters suggested high salinity in eth underlying formation.

The objective of this project was to conduct some basic research to identify salt distribution in road pavements. Correlations between the presence of a saline water-table indicated by geophysics and pavement deterioration at the surface as well as correlation with physical measurements of pavement condition and age were attempted.

It became clear within the project however that the lack of scientific explanation for road failure due to increased salt concentrations compromised the study and the project expanded to consider ways of investigating the mechanisms for road failure.

METHOD AND RESULTS

Shallow penetrating EM instruments such as the Geonics EM38 and EM31 (McNeil, 1980) have the potential to map conductivity distribution within the road pavement and within the underlying subgrade. These instruments can be towed behind a vehicle (Figure 1) and profiles of road conductivity can be measured at speeds up to 30 km per hour allowing long sections of roads to be traversed. The relationships between EM conductivity and salinity have been explored elsewhere (McNeil, 1980: Broadfoot et al., 2002). Local tests around areas of distorted pavement (Figure 2) also indicated there were lateral difference in conductivity across the road (Street and Petrusma, 2004).

In this study the use of a towed array of electromagnetic instruments was trialled to measure salt concentration beneath the bitumen surface of main roads.

First trials were carried out on a 10 km section of the Great Eastern Highway. These tests indicated the procedure could be quickly and safely carried out and that the results could be used to focus attention of the most likely areas that might be impacted by salinity (Figure 3). Further widespread trials were conducted over around 500 km of main roads and then 2000 km of rural paved roads in the southwest of Western Australia. However, analysis of these data was not conclusive due to the lack of data on road construction and age. Direct correlation between conductivity and road condition could not be established and the method still needed some subjective assessment of the results.

In order to use the method more objectively an understanding of how the road pavement is affected by shallow saline watertables was considered essential. A detailed literature search found little information was available on the mechanisms of salt damage to roads in general, and particularly on the effects of a shallow saline groundwater table on roads. It appears little work has been carried out on the problem in Australia in the past two decades and the most recent research has been conducted by the Transport Research Laboratories of UK in Botswana (e.g. Obika et al, 1989).

Figure 1. EM equipment towed behind a vehicle on a country road in Western Australia.

Figure 2. An EM38 meter sitting on a severely rutted rural road.

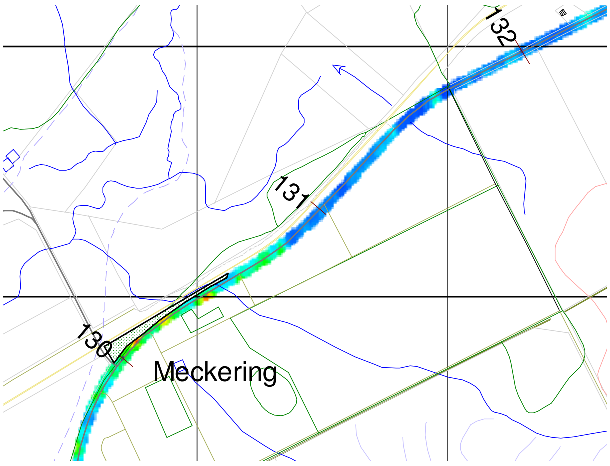

Figure 3. EM-38 conductivity from SLK130 to 132 through the town of Meckering. Conductivity is low in blue areas, moderate in green and high in yellow to red.

LABORATORY TESTS

Interviews with a number of road management engineers suggested that road basecourse is converted to a "red paste" in areas of very high salinity. The effects appeared geochemical but field investigations of sites where these effects had occurred found the roads were already realigned and affected areas were already ripped and rehabilitated with vegetation.

In attempt to replicate these effects in the laboratory samples of roadbase material compressed to similar specifications as road basecourse were prepared in cubes. These were subjected to water with varying levels of NaCl and Na_2SO_4 salt concentration from distilled to 60,000 mg/L as well as solutions of low pH.

In trials of capillary rise over a period of three weeks, higher NaCl concentration was found to correspond to increased strength of basecourse material, as did the presence of acid. The presence of Na_2SO_4 weakened the strength of the basecourse. Immersing the cubes in distilled water caused rapid collapse within an hour.

In the road pavement an increase in road strength may compromise the ability of the road to recover from heavy traffic resulting in cracking of the seal. Ingress of rainwater under the edge of the road seal may strip more mobile minerals and elements form the road pavement resulting in a potential volume loss.

GEOCHEMISTRY AND MINERALOGY

Further work looked at changes in the road chemistry and mineralogy. Road subgrade samples from stockpiles and damaged roads were analysed by spectral infrared analysis and for pH and electrical conductivity. A subset of 8 samples (two unused samples and six from damaged roads) was then selected for X-Ray Diffraction analysis and major ion and trace element soil chemistry.

For the eight samples where full soil chemistry was analysed, there was a significant decrease in Ca where the pH dropped below 8 to 9. This suggests that the initial lime demand of soils in some areas may not be met by the addition of lime in road construction.. This may be due to the subgrade having a low clay mineral (alumino-silicate component), and a high clay *sized* material component; e.g. quartz and gibbsite, the former showing limited reaction with lime and the latter having a very high lime requirement.

For damaged road subgrade the spectral analysis suggested that gibbsite dissolution is taking place, with kaolinite forming in the presence of free silica (Furian et al., 2002). This is common where the volume of fine pores, with an equivalent diameter around 0.3 μm, is high, which is likely where pozzolanic reactions, accompanied by flocculation, have been induced. Such reactions may result in volumetric changes in the road basecourse.

EC data from the soil chemistry dataset were compared with ECa measurements acquired using an EM38 instrument across selected transects on road H006. The EM38 was operated in the vertical dipole position giving a penetration of around 0.75 to 1.5 metres (McNeil, 1980). ECa measurements for a total of 21 samples were examined, 15 producing a correlation and 6 samples from one transect in the lower landscape showing as outliers (red dots in Figure 3). These samples were collected close to the road seal in a saline area in the lower landscape. It is likely that the slightly higher EM38 measurements in this area are due to the instrument measuring salt below the level of the subgrade soil sample. An EM meter that takes a measurement of conductivity within the basecourse or top 20cm as well as deeper measurements might be a more useful instrument for studies such as these.

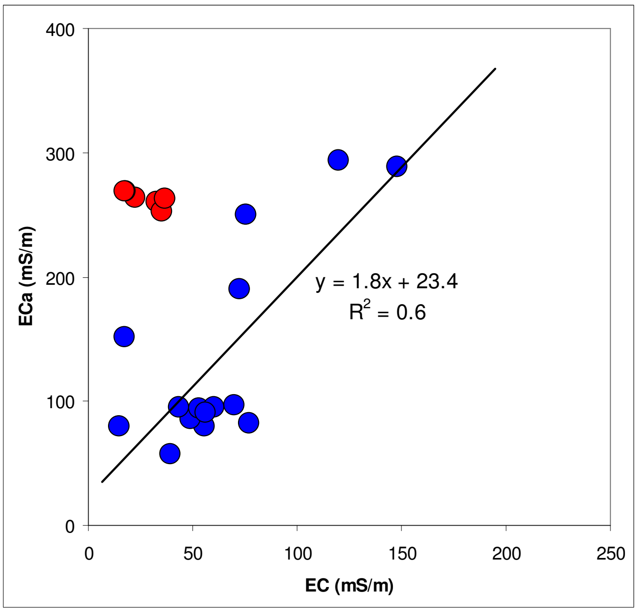

Figure Error! No text of specified style in document.**-1. Graph of soil electrical conductivity and EM38 apparent electrical conductivity (ECa) (n=15, outliers (n=6) are coloured red).**

CONCLUSIONS

It is clear from the work conducted to date that salt concentrates in the roadbase of paved roads above a saline watertable. Empirical evidence suggest that the seal map become detached, bubbles may form and road may become rutted.

EM data suggest that salt concentrations vary across the road with highest concentration usually towards the centre. Lower salinity is present at the edge of eth seal and laboratory tests indicate that very fresh water such as would result from rainfall may strip material from the basecourse and cause it to collapse. In the centre of the road salt may increase the strength leading to brittle failure of the road and cracking of the pavement.

If EM measurements are to be used in salinity effects to roads then an instrument that measures at a range of depths from 0-20cm and then deeper depths may be more appropriate.

Geochemical and hyperspectal tests indicate that in areas of damaged roads in saline areas there is some dissolution of gibbsite which may change the structure of the basecourse making in vulnerable to distortion by heavy vehicles.

Further work is needed to properly understand the effects of road basecourse on salinity but from these studies it appears mineralogical changes and stripping of some components of the road base may be occurring.

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