CHAPTER SIX: DISCUSSION

6.1 Saline/alkaline Scalds in the Uralla/Walcha district

The results from this study support the hypothesis that saline/alkaline scalds found in the Uralla/Walcha district of the Northern Tablelands of New South Wales are different from scalds which occur in Western Australia and Victoria. Firstly, the scalds in the Uralla-Walcha district appear not to occur as a direct result of vegetation clearing, since they were found in areas which have not been cleared. The results also showed that the soluble salts occurring on scalds in the Uralla-Walcha district are mostly sodium carbonates and/or bicarbonates whereas the soluble salts responsible for scalds in the above places predominantly consist of sodium chloride (Peck 1977; Bresler *et al.* 1982).

Scald development in the Uralla-Walcha district appears to be related to alternating wet and dry periods and scalds are mostly associated with small confined aquifers which have a rapid response to rainfall patterns. Broad unconfined watertables such as occur in Western Australia and Victoria are not common in the Uralla-Walcha district. During high rainfall the soil profile is saturated and these confined aquifers are filled with CO_2 enriched water which bring carbonates and/or bicarbonates (usually of sodium) to the surface at the aquifer outlet. The soils in the Uralla-Walcha district are shallow with low water holding capacity so a period of high rainfall will saturate the profile irrespective of the number of trees present. Dry spells after high rainfall cause soluble salts to accumulate on the soil surface through drying and capillary action. Moderate rainfall which does not fill the profile will dissolve and dilute the soluble salts and the scalds heal. Dry periods after moderate rain can lead to scald expansion because of stock trampling and licking but the salt crystals on the surface do not necessarily reappear.

The surveys indicated great variations among the characteristics of individual scalds in terms of pH, electrical conductivity and the relative proportions of different cations and anions. Position in the landscape was also very variable as were the differences in soil chemistry in different parts of the soil profile of different scalds. Some of the scalds exhibited unusual characteristics and most of the unusual ones were not included in the second survey. This variability in scald characteristics within a relatively small area (30,000 hectares) has not been recorded before in the Australian literature.

Some landholders commented that the severity and size of scalds varied over time:

(i) possibly resulting from land management changes (e.g. variations in stocking rates and grazing management)

(ii) possibly resulting from sequences of wet and dry years causing some patches to expand - especially evident after the three wet winters of 1989, 1990 &1991 - and others to contract.

Information on how long these scald sites have existed is based entirely on subjective landholder information. According to landholders in the district some scalds have existed for many years and expanded and contracted with changing weather patterns (pers. comm A. Burgess; J. Street 1992).

Most of the literature in higher rainfall temperate Australia indicates that scalds occur in valley positions or low lying areas where soluble salts accumulate (Peck 1971; Bettenay 1978; Bresler 1981; Wagner 1987). The majority of scalds in the Uralla-Walcha district occurred in lower to mid-slope positions in the landscape on slopes between 2 and 3%.

Scalds in the Uralla-Walcha district (70%) were found to be relatively small, each covering an area of between 5-50 m^2. Only 22% of the scalds had areas greater than 50 m^2 with a small percentage (8%) ranged from 1-4 m^2. The number of scalds varied from three to as many as six per property.

Scalds in general were found to have smaller surface water catchments than adjacent sites without scalds. The implication is that water and chemicals are not travelling long distances in the development of scalds and that vertical water movement is also an important aspect. The literature stated that the water carrying soluble salts to scalds in other parts of Australia generally travels large distances in extensive regional catchments while most scalds in the Uralla/Walcha district are in relatively small local catchments often close to the top of the watershed (eg. Kreeb *et al.* 1995).

Very sharp pH gradients were recorded between scalds and adjacent pasture areas. Kreeb *et al.* (1995) reported similar sharp pH gradients at "Miramoona" Walcha, which is within the study area. Two dominant grass species occurred on scalds; *Cynodon dactylon* (couch) *and Hordeum marinum* (sea barley grass) with *Pennisetum alopecuroides* (swamp foxtail grass) occurring on the perimeters.

Three dimensional baseline soil sampling of a scald at "Adgin Green" indicated substantial differences in both amounts and proportions of different cations and anions both a different depths at the one location and different locations at the one depth. This spatial variability in the soil chemistry was related to the location of the scald at the surface, but high levels of soluble salts also occurred beneath intact pastures. The lack of a relationship between surface scalds and below ground soil chemistry is further discussed below.

The 20 scalds selected for the experimental treatments occurred in pastures with relatively low salt content and low surface pH. All 20 scalds exhibited poor surface structure associated with high pH levels and/or ion imbalances. Soils were generally medium in texture and duplex in nature. High proportions of exchangeable sodium occurred in the soil profile from the surface to 400 mm depth at all 20 sites and all sites possessed carbonates/bicarbonates which were associated with the high pH. Black colouration commonly occurred on the surface of the soil, possibly due to organic matter being dissolved as a result of the high pH levels. The surface soil at the 20 experimental sites was highly dispersive becoming boggy and sticky in wet conditions and hard and crusty when dry. After rain, surface water tended to persist even though the underlying ground was dry.

Walcha generally receives slightly higher rainfall than Uralla, but these differences did not relate to the differences in the EC and pH values of the piezometer water samples. Low EC values occurred in the higher rainfall area at Walcha and also at Uralla. Therefore it would appear that rainfall is not the sole factor influencing EC and pH and other characteristics including the chemistry of the underlying rock strata, but that lateral movement of waters and position in the landscape are important (Jenkin 1981). The soluble products of weathering from CO_2 charged water percolating through the profile contributed to the salt content of the groundwater systems.

Piezometer water samples generally had lower EC and pH levels in comparison with the soil results (Tables 5.3 and 5.4), but no direct relationship appears evident between or within individual scalds. High piezometer EC results were not always associated with high soil EC and the same trend was evident for pH. For example, the highest soil EC value was 6.35 dS/m at "Church Gully", Uralla while the highest reading for water samples was 3.7 dS/m at "Buri West", Walcha. The highest pH for soil samples was 10.2 at "Wollun Station", while the highest pH for piezometer water was 8.9 at "Adgin Green". The differences in soil and water sample values possibly resulted from scalds differing in position in the landscape (Jenkin 1981). For example at "Wollun Station" the EC value of the soil sample was 3.56 dS/m while at "Church Gully" the EC was 6.35 dS/m. "Church Gully" is positioned on a slighter lower position on the slope but also adjoins a creek system which may influence the groundwater. Another factors which possibly affected the results is the positioning of piezometers in the field.

The piezometers were placed in the middle of the bare scalds, but Kreeb *et al.* (1995) showed that piezometers close together could tap completely different aquifers with different chemistry. Positioning a piezometer directly in the middle of a scald does not guarantee that the groundwater contributing to the salinity/alkalinity is sampled and the assumption that the groundwater contributing to a scald comes from directly beneath it, is not necessarily correct.

The results of the electromagnetic surveys must be treated with caution because the readings produced by the survey units can be affected by factors other than the amount of salt. Soil EC readings may increase with increasing soil water content, clay content and temperature but decrease with increasing bulk density (Slavich 1990). The electromagnetic survey results supported the conclusion from the "Adgin Green" data that the surface scald and the underground salt distribution may not coincide. The result is that one soil core located in the middle of a scald may give a misleading impression of the distribution of soluble salts underground. To illustrate this point two hypothetical cores were located on the computer generated maps, identified as H1 and H2 on figures 5.8 through to 5.11 and the EC values estimated from the maps (Table 6.1).

Table 6.1 Comparisons between soil core EC values and the EM38 electromagnetic survey including two hypothetical soil cores at H1 and H2 (Fig. 3.9, 3.10, 3.11 and 3.12).

Depths	0-0.75 m	0-1.5 m	0-3.0 m	0-6.0 m
Soil Core EC dS/m	3.10	-	-	-
EM38 EC value dS/m	3.50	2.25	3.75	3.75
Hypothetical core 1 (H1)	6.50	3.75	2.25	1.50
Hypothetical core 2 (H2)	6.50	6.50	6.65	5.50

The EC values at both H1 and H2 were the same to 0.75 m but decreased with an increase in depth at H1 while at H2, EC values were more or less the same to 6.0 m (Table 3.9).

Similar differences are likely to occur with respect to the positioning of a piezometer. Positioning a piezometer in the middle of a scald on the assumption that this location is the site of maximum accumulation of soluble salts will not necessarily be correct. For example in Fig. 5.7, suppose a piezometer was placed in the middle of a bare scalded area which was viewed as the worst affected part. However the EM38 maps (Fig 5.7 to 5.11), indicated that high EC areas exist away from the piezometer in the bottom left hand corner of the map (H2) (Table 5.8). A piezometer placed over a hot spot (high EC area) would probably have different water chemistry than a piezometer placed over a cold spot (low EC area). Therefore relying on one piezometer placed in the middle of a scald would not automatically give an indication of the highest EC values. Therefore the one soil core taken in the middle of each of the original 50 scalds (Table 5.3) clearly did not adequately sample them. Variations can occur depending upon where the soil sample was taken, as evident in the soil core sample taken at "Bergen Op Zoom" and the hypothetical cores H1 and H2 (Table 6.1).

Electromagnetic surveys should be carried out prior to any future studies on saline/alkaline scalds to give a better understanding of the individual scalds being studied. However limitations do exist in the interpretation of the EM surveys as the surveys for each depth are taken from the surface to the specified depth.

Saline/alkaline scalds in the Uralla-Walcha district are very variable and possess the following features which make them different from scalds found in other parts of Australia:

1. clearing of woody vegetation is not directly related to the development of scalds
2. soluble salts generally consist of sodium carbonates and/or bicarbonates rather than sodium chloride,
3. low chloride levels generally occur in most soil profiles,
4. high pH values up to 10 are common and which vary down the profile,
5. variable EC values occur at different scald sites,
5. position in the landscape varies with scalds generally occurring on slopes between 2 and 3%,
6. scald development appeared to be related to alternating wet and dry periods,
7. soils affected predominantly consisted of solodics with a duplex nature and
8. scalds were affected by local catchment characteristics rather than regional influences.

The variability among the scalds means that it has not been possible to develop a strategy which can be used universally to control them in the Uralla/Walcha district of the Northern Tablelands of New South Wales. The merits of each amelioration technique is therefore dependent largely on the scald and landscape characteristics.

6.2 Scald Reclamation

The principal task in any reclamation of saline/alkaline soils is to prevent the concentration of soluble salts at the soil surface and/or to disperse salts which are already there. Reclamation activities can be focused on where water enters the soil and include tree planting and the use of deep rooted perennial pastures. These activities are long term and will always have little immediate effect on saline/alkaline scalds. However they should be part of any integrated, long term farm plan for sustainable pasture and animal production. The approach used in this thesis was to apply techniques which were directed at the scalds themselves. These activities were designed to disperse soluble salts already concentrated in saline/alkaline scalds and/or prevent their further accumulation.

The techniques used all produced some amelioration of different features of the scalds including:

- reducing the total salt load,
- alleviating waterlogging,
- revegetation of previously bare patches,
- increasing infiltration and
- reducing SAR & ESP values.

6.2.1 Ponding

The water from the five experimental ponds in the study was pumped out each time they filled but the removable caps on the PVC pipe were not used as they were installed too high in the banks to be effective. Even if they had been placed lower the ponds would still not have drained completely. However, the majority of the water would have been removed and the majority of the soluble salts dispersed. The PVC pipe drainage system could be effectively used by landholders.

The main difference between the present study and work carried out by Reeve *et al.* (1955), Jones (1967), Muirhead *et al.* (1969) and Cunningham *et al.* (1974) was that ponded water was not removed from the ponds and either soaked into the soil profile or evaporated. In the present study, a dramatic differences between the initial and final core samples indicated that the treatment reduced sodium, ESP and SAR levels in the soil profile. An average reduction in sodium levels between initial and final soil cores at 0-400 mm depth was 36.4% at the five experimental ponding sites, with reductions in ESP of 54.7% and 31% respectively. Cunningham *et al.*'s (1974) results were similar to those achieved at the five experimental ponding sites with a reduction in the concentration of soluble salts in the top 50 mm of the soil varying from 30 to 70% after 12 months under waterponding. Work by Jones (1967) in the Hay district of New South Wales showed that salt levels in ponded soils at 100 mm depth were reduced to between 10 and 25% of those on an adjacent untreated scald site. The success achieved by Reeve *et al.* (1955) in reducing salinity by as much as 80% could not be duplicated in the five ponding sites in the study region.

The effects of not emptying the ponds is unknown. The present study indicated that pumping had reduced the concentration of sodium, SAR and ESP levels. However, reduction in the concentration of sodium levels was also achieved by other authors where ponded water was left in situ. If ponds in the study region had not been pumped out results similar to those achieved by other researchers may have been achieved and therefore the removal of water may not be necessary. It is postulated that the soluble salts are carried to scalds in the Uralla/Walcha area in intermittently active confined aquifers (Kreeb *et al.* 1995) and are concentrated in and around the scalded areas, and that the B horizons of the solodic soils are generally impervious to water. One would therefore suggest that if the ponds were not emptied, then the soluble carbonates/bicarbonates would continue to accumulate, particularly if the ponds dried out by evaporation between rainfall events. Perhaps future research can investigate the option of not emptying the ponds.

The ponded scalds were randomly chosen from the 20 experimental sites and, by chance, had a much higher mean concentration of EC, sodium, ESP and SAR than the other treatments or the controls. These differences resulted particularly from high values of the scalds at "Adgin Green" and "Wollun Station". Reductions in exchangeable sodium, ESP and SAR between the initial and final soil cores also occurred at the other three scalds where the initial values were much lower. Therefore it is postulated that the ponding technique will be effective for scalds with both high and low EC and other values provided they occur in a suitable position in the landscape.

The catchment area of each pond varied as did the size of the dams. The actual size of the dams had no influence on the different levels of soluble salts removed as each sample from each dam took into account the amount of water pumped out at that time. A single average figure for the removal of sodium via the use of ponds cannot be applied to the region as a whole, as each scald contributed different amounts of salts.

The design of the ponds was such that they can easily be constructed. The ponds cannot be erected on steep slopes as the contour banks would have to be too high. Position of a scald in the landscape and the degree of slope will therefore determine whether a pond is a viable option.

6.2.2 Reverse Interception Drains

The experimental reverse interception drains apparently reduced inflow of both surface and subsurface lateral flow to the scalds. Similar results were obtained by Negus (1983 a,b) in Western Australia where the installation of drains prevented further inflow of soluble salts to scald areas and as a result waterlogged saline/alkaline sites were reclaimed. Crystallisation of sodium carbonate/bicarbonates was found at the interface of the A and B horizon at the inside of all of the reverse interception drains in the present study. The flow of saline/alkaline waters was quite restricted as indicated by the localised patches of white crystals in Plates 5.11 and 5.12. It appears that the B horizon was impermeable and water flowed laterally at the bottom of the A horizon. It is unclear if this lateral flow of salts is responsible for the high pH levels found on saline/alkaline scalds but a dominance of carbonates/bicarbonates was found in the soil profile down to a depth of 400 mm at all 20 experimental scald sites used in the study. Work by Conacher (1975) and Conacher and Murray (1973) tends to support the idea that the accumulation of salts can result from a shallow lateral flow of saline water over an impermeable subsoil.

Stock still congregated on the scalds after installation of the drains as the sites were not fenced, but the normally boggy conditions after rain as a result of trampling did not occur. Growth of *Cynodon dactylon, Hordeum marinum* and *Pennisetum alopecuroides* were not affected by the stock and invaded the previously bare scald patches. The increased growth of grasses may have resulted from the alleviation of previously waterlogged conditions as shown by Pessarakli (1991). Doering and Sandoval (1976) and Sommerfeldt and Paziuk (1975) showed that interception drains located on the upslope side of an affected area were effective in reclaiming scalds. The reverse interception drains in this study achieved similar results to Doering and Sandoval (1976 a) and Sommerfeldt *et al.* (1978) in reclaiming bare scalds. Comparison between the control sites and the reverse interception drain sites indicated that the controls showed no visible contraction of the bare scalded areas.

6.2.3 Chemical Ameliorants of Gypsum and Epsomite

The application of gypsum and epsomite at 5 tonnes per hectare significantly altered the balance of exchangeable cations in the soil and improved infiltration capacity. There was an observable difference between the sites where gypsum and epsomite was applied and the controls (those areas which had no chemical ameliorant applied). The addition of gypsum and epsomite substantially reduced sodium levels and the ESP and SAR decreased by approximately 50%. Darab (1985) stated that the decrease in SAR in any amelioration of salt-affected soils results from a reduction in the concentration of sodium ions in the soil solution so that the balance of exchangeable cations is shifted in favour of calcium and magnesium. The reduction in SAR in the soil cores resulted from increases in the exchangeable calcium and magnesium from the gypsum and epsomite treatments respectively with a reduction in the exchangeable sodium creating more favourable soil conditions.

The gypsum application resulted in a four fold decrease in sodium concentration with a four fold increase in calcium levels over the four depths over two and half years. The results are similar to work completed by Shainberg *et al.* (1989) who found that gypsum provided calcium for exchange with sodium. Significant decreases also occurred in exchangeable sodium percentage and sodium adsorption values at all 4 depths. These results are also supported by Prather *et al.* (1978) who showed that concentrated solutions of calcium reduced high ESP values. Potassium and pH levels showed no significant differences between initial and final soil cores. The application of gypsum and epsomite also produced a twelve fold and seven fold increase in infiltration rates respectively after a period of 2 ½ years. The improvements in infiltration rates of the gypsum and epsomite treatments were possibly due to a reduction in exchangeable sodium levels at all 4 depths. Jones (1967) and Muirhead *et al.* (1969) also found that the application of chemical ameliorants increased infiltration rates dramatically.

The effect of epsomite application at 5 tonnes per hectare had similar results to gypsum with a 3 fold decrease in sodium, ESP and SAR and a three fold increase in magnesium from 0-400 mm.

Work by Abbott and McKenzie (1986) showed that soils with high sodicity levels i.e. ESP >5% are most likely to show responses to chemical ameliorants. The soils at the five experimental sites all had high ESP values ranging from 47.0 to 52.6%. After application of the gypsum and epsomite the ESP percentages decreased to 14.9 and 21.7 respectively.

SAR values at the five scalds prior to the application of gypsum and epsomite ranged from 14.7 to 17.0 with significant decreases to 3.0 and 6.2 respectively at the completion of the study. Grass species such as *Bromus brevis* (short brome), *Eleusine tristachya* (goose grass), *Festuca elatior* (fescue), *Paspalum dilatatum*, (paspalum) *Lolium rigidum* (annual ryegrass), *Phalaris aquatica* (phalaris), and *Vulpia bromoides* (squirrel-tailed fescue) invaded the treated areas. The scalded area did not support any of these grass species before the treatments were applied. The species which colonised the bare areas within the gypsum and epsomite rings were mostly weeds and are not considered productive by landholders. However two of the species (*F. elatior* and *P. aquatica*) are valuable pasture species and one could take the view than any grass ground cover is better than no ground cover. Weedy species are generally good colonisers and therefore could perhaps lead to the establishment of more productive species with proper management.

Work by Loveday and Scotter (1966) on the use of ameliorants showed reduction in surface crusting with marked improvements in seedling emergence and establishment. The herbage mass produced on the gypsum treatment tended to be greater than on the epsomite treatment.

The application of gypsum and epsomite at 5 tonnes per hectare proved successful in reducing the exchangeable sodium, ESP and SAR in the soil profile indicating that this rate is sufficient to provide divalent cations. Work by Jones (1967) indicated that approximately 4 tonnes per hectare was sufficient to change the chemical status of the soil favouring the divalent cation of calcium. The success of the treatments can be gauged by a dramatic increase in infiltration capacity, lowering of sodium, ESP and SAR values in combination with the growth of new grass species.

Abbott and McKenzie (1986) indicated that soils will respond to chemical ameliorants if they have ESP greater than 5. Muirhead *et al.* (1969) in the Riverine Plains of New South Wales reported a tenfold increase in infiltration rates 2 years after the application of gypsum at approximately 4 tonnes per hectare. Even though Muirhead *et al.* (1969) reported larger increases in infiltration rates than this study, the drought conditions may have influenced the final results.

Kazman *et al.* (1983) showed that infiltration rates are affected by ESP and that any reduction in ESP will reduce surface crusting of the soil and improve infiltration rates. The ESP and SAR values from the initial and final cores of gypsum and epsomite treatment showed significant decreases which would tend to support the results of Kazman *et al.* (1983).

Significant reductions did not occur in ESP and SAR values in the final soil cores taken from the reverse interception drains, but there were significant increases in infiltration rates. Higher infiltration rates at the reverse interception drain sites could have resulted from the elimination of waterlogged conditions, in combination with the increased grass growth creating friable soil conditions at the soil surface.

6.3 Recommendations

The first step for landholders is to determine whether a particular scald is or is not saline/alkaline. This is easily done by measuring the surface pH and testing for the presence of carbonates/bicarbonates with standard field tests. If the pH is above 7.5 and carbonate/bicarbonate is present then one or more of the treatments used in this thesis will be effective. The specific treatment(s) chosen will depend on the size of the scald and its position in the landscape. The following notes are a general guideline about the appropriate treatment to use in different situations.

a) flat land (not waterlogged) - apply either gypsum or epsomite at 5 tonnes per hectare.
The addition of gypsum or epsomite will only be effective on scalds on flat or almost flat land because the movement of surface water will wash the chemicals away. The epsomite produced more rapid cracking of the soil surface than gypsum whereas the gypsum, after two and a half years, produced a greater change in the water infiltration rate. It may be that a mixture of both chemicals will be the most effective treatment. Use gypsum in preference to epsomite if the calcium to magnesium ratio is low.

b) flat land (waterlogged) - use reverse interception drains.

c) medium slopes 1 to 2% (not waterlogged) - construct ponds or reverse interception drains.
Ponds will only be effective on slopes between 1 and 2% because on steeper slopes, the wall will be too high and too much soil is necessary to build it. It is important to locate the PVC pipe so that most of the water will drain away. The disposal area of the water must not be another scald and must disperse rather than concentrate the dissolved solids.

d) **Steep slopes** - construct reverse interception drains.
Reverse interception drains are perhaps the most versatile of the treatments tested with respect to position in the landscape. They are ideal for scalds near the bank of an easterly flowing water course which provides a means of disposing of the solute laden water. This treatment was effective on slopes up to 3% and could possibly be used on steeper slopes with some modifications. Reverse interception drains on nearly flat land can possibly be combined with chemical ameliorants. A further modification which was not tested in this study is to fill the drains with permeable rubble to reduce the erosion hazard.

e) **Sites not covered above** - require the use of common sense in regard to the local landscape features and slope where the saline/alkaline scald occurs.

The above treatments will produce some reclamation of scalds within a year or two, depending on rainfall events. Simply fencing sites to prevent compaction and erosion from stock trampling, does not appear to be an effective treatment in reclaiming saline/alkaline scalds in the Uralla-Walcha district. However, it may be necessary to exclude livestock from ponded areas to prevent damage to the ponds by livestock.

Whilst tree planting and management of pastures to maintain deep rooted perennial grasses is recommended as part of a whole farm plan, no specific recommendations can be made as to where to plant trees in relation to a scald. Trees would not normally be planted on scalds because of the poor growing conditions.

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